# Summer Fellowship Report

On

## Integrated Circuit Design using Subcircuit feature of eSim

Submitted by

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Under the guidance of

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# Acknowledgment

We take this occasion to offer our heartfelt gratitude to the FOSSEE, IIT Bombay Team for offering us this wonderful opportunity to work on the design and integration of multiple sub-circuits in eSim. Working on eSim has prov ided us with invaluable insights into various open-source EDA tools for circuit simulation and their applications in the practical world.

We extend our sincere regards to Prof. Kannan M. Moudgalya for his valuable guidance and motivation to throughout this fellowship program.

We would like to express our heartfelt appreciation to the entire FOSSEE team including our mentors Mr. Sumanto Kar and Mrs. Usha Vishwanathan, Mrs.Vineeta Ghavri for constantly guiding and mentoring us throughout the duration of our internship.

It is with their support that we have been able to fulfill our project demands successfully. Whenever faced with an issue, our mentors were always accessible to help us assess and debug them. Our learnings from them have been invaluable and shall be of paramount importance to us in the future.

Overall, it was a delightful experience interning at FOSSEE and contributing to its growth and I take away some great insights and knowledge from it. As enthusiastic beginners in the semiconductor industry, this internship is a milestone for us in our pursuit of a successful career.

# Contents

# Chapter 1

# Introduction

FOSSEE which stands for Free/Libre and Open Source Software for Education is an organization, based at IIT Bombay, as a remarkable initiative aimed at promoting the use of open-source software in education and research. It was established with the mission to reduce the dependency on proprietary software and to encourage the adoption of open-source alternatives. FOSSEE offers a wide range of tools and resources that cater to various academic and professional needs.

It provides comprehensive documentation, tutorials, workshops, and hands-on training sessions, for empowering students, educators, and professionals to leverage open-source software for their projects and coursework. The organization's commitment to fostering a collaborative and inclusive environment has significantly contributed to the democratization of technology and has opened up new avenues for innovation and learning.

## 1.1 eSim

eSim, created by the FOSSEE project at IIT Bombay, is a versatile open-source software tool for circuit design and simulation. It combines various open-source software packages into one cohesive platform, making it easier to design, simulate, and analyze electronic circuits. This tool is particularly useful for students, educators, and professionals who need an affordable and accessible alternative to proprietary software.

eSim offers features for schematic creation, circuit simulation, PCB design, and includes an extensive library of components. The Subcircuit feature is a significant enhancement, enabling users to design complex circuits by integrating simpler subcircuits. Through eSim, FOSSEE promotes the use of open-source solutions in engineering education and professional fields, encouraging innovation and collaboration.

## 1.2 NgSpice

NgSpice is the open-source spice simulator for electric and electronic circuits. Such a circuit may comprise JFETs, bipolar and MOS transistors, passive elements like R, L, or C, diodes, transmission lines and other devices, all interconnected in a netlist.

Digital circuits are simulated as well, event-driven and fast, from single gates to complex circuits and the combination of both analog and digital as well as a mixed-signal circuits. NgSpice offers a wealth of device models for active, passive, analog, and digital elements. Model parameters are provided by our collections, by the semiconductor device manufacturers, or from semiconductor foundries. The user adds her circuits as a netlist, and the output is one or more graphs of currents, voltages and other electrical quantities or is saved in a data file.

## 1.3 Makerchip

Makerchip is a platform that offers convenient and accessible access to various tools for digital circuit design. It provides both browser-based and desktop-based environments for coding, compiling, simulating, and debugging Verilog designs. Makerchip supports a combination of open-source tools and proprietary ones, ensuring a comprehensive range of capabilities.

One can simulate Verilog/SystemVerilog/Transaction-Level Verilog code in Makerchip. eSim is interfaced with Makerchip using a Python based application called Makerchip-App which launches the Makerchip IDE. Makerchip aims to make circuit design easy and enjoyable for users of all skill levels. The platform provides a user-friendly interface, intuitive workflows, and a range of helpful features that simplify the design process and enhance the overall user experience.

The main drawback of these open source tools is that they are not comprehensive. Some of them are capable of PCB design (e.g. KiCad) while some of them are capable of performing simulations (e.g. gEDA). To the best of our knowledge, there is no open source software that can perform circuit design, simulation and layout design together. eSim is capable of doing all of the above.

# Chapter 2

# Feautures Of eSim

The objective behind the development of eSim is to provide an open source EDA solution for electronics and electrical engineers. The software should be capable of performing schematic creation, PCB design and circuit simulation (analog, digital and mixed-signal). It should provide facilities to create new models and components. Thus, eSim offers the following features -

**1. Schematic Creation:** eSim provides an easy-to-use graphical interface for drawing circuit schematics, making it accessible for users of all levels. Users can drag and drop components from the library onto the schematic, simplifying the design process. Comprehensive editing tools allow for easy modification of schematics, including moving, rotating, and labeling components.

**2. Circuit Simulation:** eSim supports SPICE (Simulation Program with Integrated Circuit Emphasis), a standard for simulating analog and digital circuits. Users can perform various types of analysis such as transient, AC, and DC, providing insights into circuit behavior over time and frequency.An integrated waveform viewer helps visualize simulation results, aiding in the analysis and debugging of circuit designs.

**3. PCB Design:** The PCB layout editor allows users to place components and route traces with precision. eSim includes DRC capabilities to ensure that the PCB design adheres to manufacturing constraints and electrical rules. Users can generate Gerber files, which are standard for PCB fabrication, directly from their designs.

**4. Subcircuit Feature:** This feature enables users to create complex circuits by integrating smaller, simpler subcircuits, promoting modular and hierarchical design approaches. Subcircuits can be reused in different projects, saving time and effort in redesigning common circuit elements.

**5. Open Source Integration:** eSim integrates several open-source tools like KiCad, Ngspice, and GHDL, providing a comprehensive suite for electronic design automation. Being open-source, eSim is free to use, making advanced circuit design tools accessible without the need for expensive licenses.

# Chapter 3

# Problem Statement

To design and develop various Analog and Digital Integrated Circuit Models in the form of subcircuits using device model files already present in the eSim library. These IC models should be useful in the future for circuit designing purposes by developers and users, once they get successfully integrated into the eSim subcircuit Library.

## 3.1 Approach

Our approach to implementing the problem statement began with examining datasheets from prominent Integrated Circuit (IC) manufacturers such as Texas Instruments, Analog Devices, and NXP Semiconductors. we selected ICs that offer a diverse range of functionalities, including precision amplifiers, comparators, encoders, and audio amplifiers. After building the subcircuits, we tested them to verify basic circuit configurations using NgSpice simulations. The step-by-step roadmap of this process is outlined below :

**1. Analyzing Datasheets :** The primary step is to browse through various analog and digital IC datasheets, and hence find suitable circuits to implement in eSim, that are not previously included into the eSim library. Check for the detailed schematic of the IC's and once the component values and the truth table is ascertained, then finalise the IC to be created.

**2. Subcircuit Creation :** After deciding the IC, we start modeling it as a sub-circuit in eSim, using the model files present in the eSim device model library only. The design is strictly according to the information given in the official data-sheets of the ICs.This step also includes building the Symbol/Pin diagram of the IC according to the packaging and pin description given in the datasheets only.

**3. Test Circuit Design :** Once the component of the IC is ready, now we can build the test circuits, according to the data-sheets. In this step we build the test cases and test circuits using the component IC.

**4. Schematic Testing :** Once the test circuits are ready, now it's time to simulate the test circuits so that the output can be obtained in the form of wave-forms and plots. Here we take help of KiCad to NgSpice conversion and Simulation feature in eSim. If the output of the test circuit is not as per expectation, this implies that the test case has failed, and there is some error in the schematic. In such cases we go back to the design phase of the IC or the test circuits, to look for possible errors and then repeat the testing process again after making required changes.

Once the expected output of the test cases are correct and satisfy the expected results, then in such a case the IC is declared successfully working. The test case has been verified and the designing process is complete.

# Chapter 4

# Analog IC's

## 4.1 LM143 - Single Operational Amplifier

The LM143 is a versatile, high-voltage operational amplifier capable of operating with supply voltages up to ±40V and delivering an output swing up to ±37V. It features an input common-mode range of ±38V, input overvoltage protection up to ±40V, and a slew rate exceeding 2V/µs. With offset null capability and low input bias and offset currents (8 nA and 1 nA, respectively), it ensures minimal errors in both high and low source impedance applications.

The IC's isothermal chip layout symmetry maintains consistent gain for loads of 2 kΩ or more at output levels up to ±37V. These attributes make the LM143 a superior general-purpose op-amp, often serving as a high-performance, drop-in replacement for the LM741 in many applications.

The LM143 IC is used in various applications due to its high voltage capabilities and precision performance. It is commonly utilized in industrial and instrumentation circuits that require wide supply voltage ranges and robust input protection. The IC's high slew rate makes it suitable for fast signal processing tasks. It's also employed in audio amplification, high-impedance sensor interfaces, and precision data acquisition systems.

### 4.1.1 IC Layout

This figure represents the 5-Pin Package Diagram of the LM143 Single Operational Amplifier

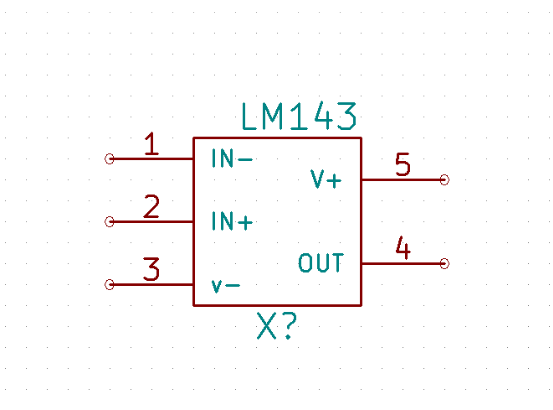


Figure 4.1: LM143 Single Operational Amplifier

### 4.1.2 Subcircuit Schematic Diagram

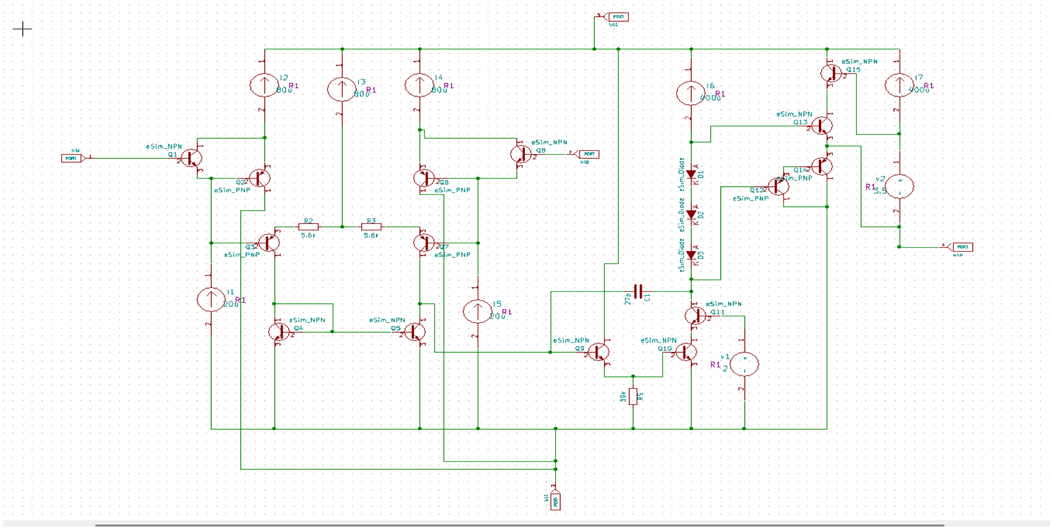

Figure 4.2: Subcircuit Schematic of LM143

### 4.1.3 Test Circuit

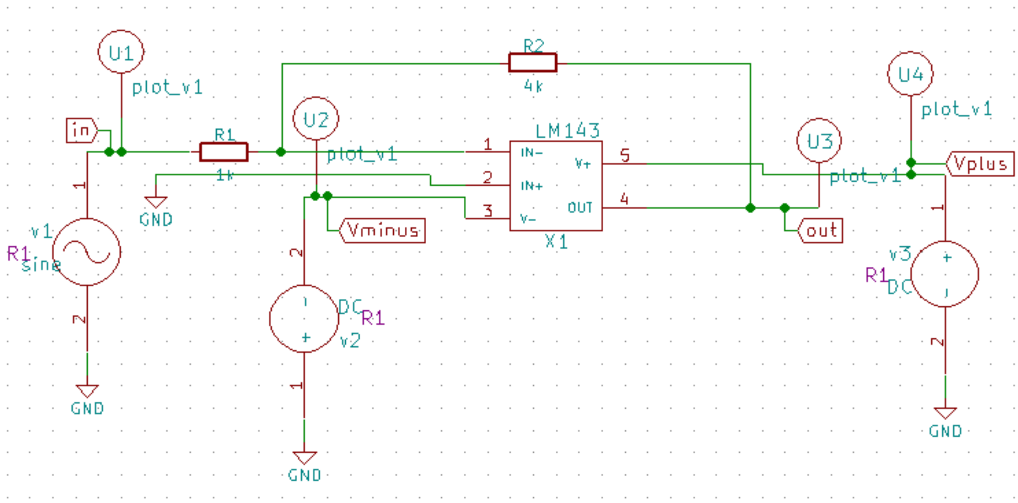


Figure 4.3: Test Circuit of LM143 IC

### 4.1.4 Input Plots

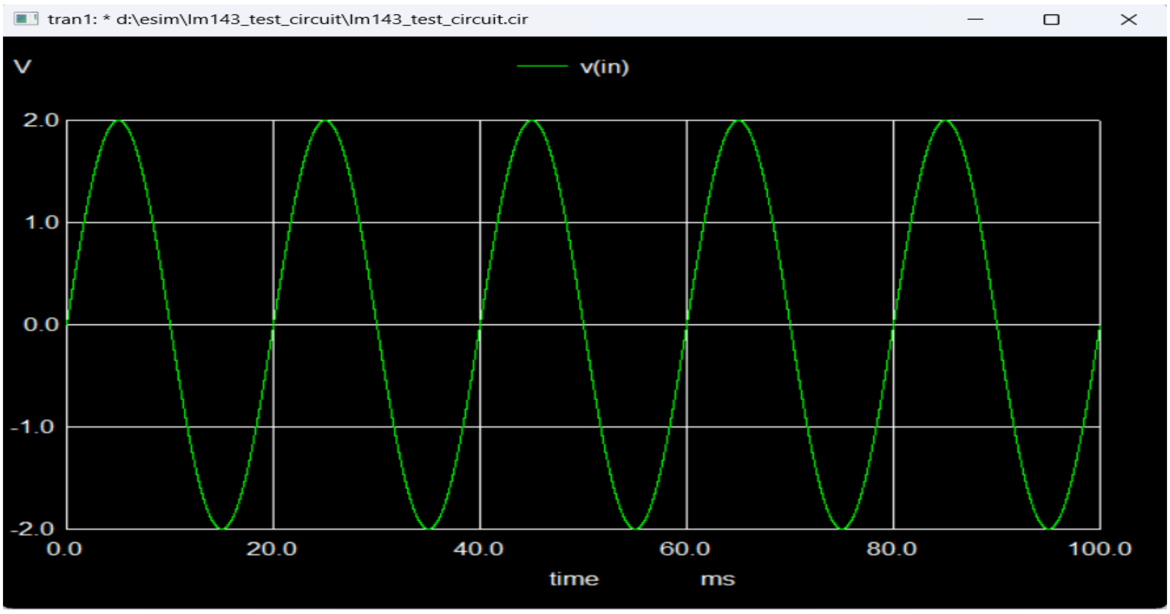


Figure 4.4: Input Voltage Waveform of LM143

### 4.1.5 Output Plots

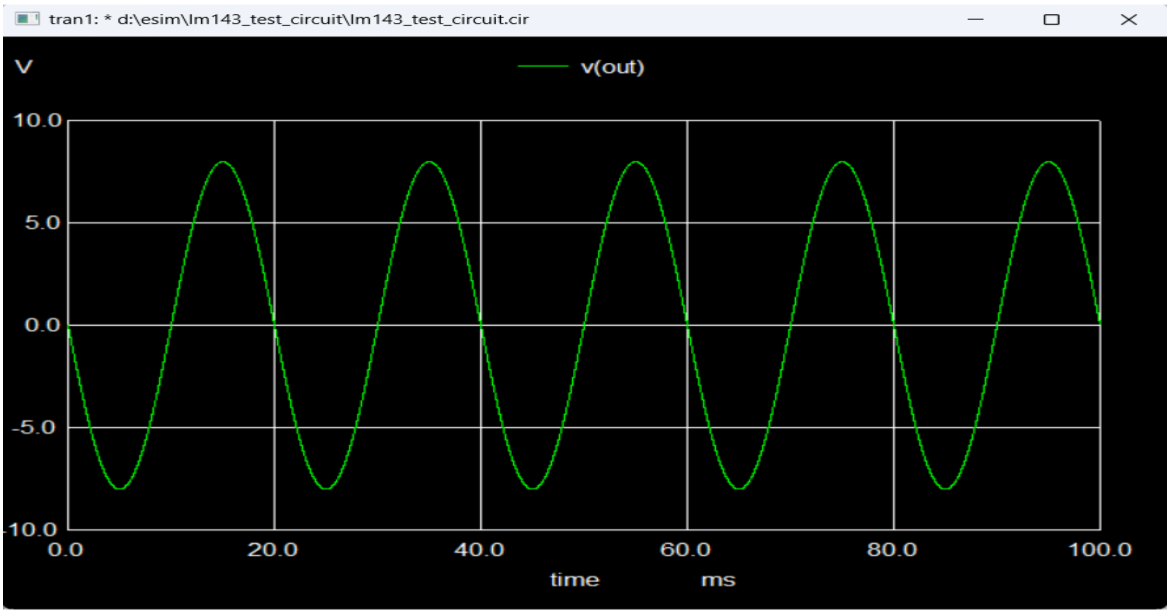


Figure 4.5: Output Voltage Waveform of LM143

## 4.2 TL331 - Single Comparator

The TL331 IC is a single comparator featuring low power consumption and fast response times, making it ideal for precision voltage comparison applications. It operates within a wide supply voltage range of 2V to 36V, ensuring flexibility across different circuit designs. The IC offers an open-collector output, allowing it to interface seamlessly with various logic families and enabling wired-AND configurations.

Applications of the TL331 include zero-crossing detectors, voltage monitoring systems, and signal processing circuits. It is also widely used in pulse-width modulation (PWM) controllers, battery-operated devices, and power management systems due to its low power requirements.

Advantages of the TL331 IC include its low input offset voltage, which enhances accuracy, and its high input impedance, which minimizes loading on the signal source. The IC's fast response time ensures quick and reliable performance in time-sensitive applications. Additionally, its low power consumption makes it suitable for energy-efficient designs, and its wide operating voltage range provides versatility for various applications.

### 4.2.1 IC Layout

This figure represents the 5-Pin Package Diagram of the TL331 Single comparator

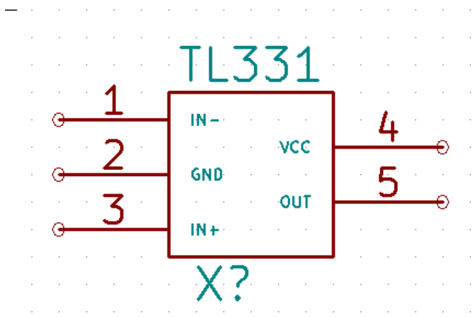


Figure 4.6: TL331 Single Comparator

### 4.2.2 Subcircuit Schematic Diagram

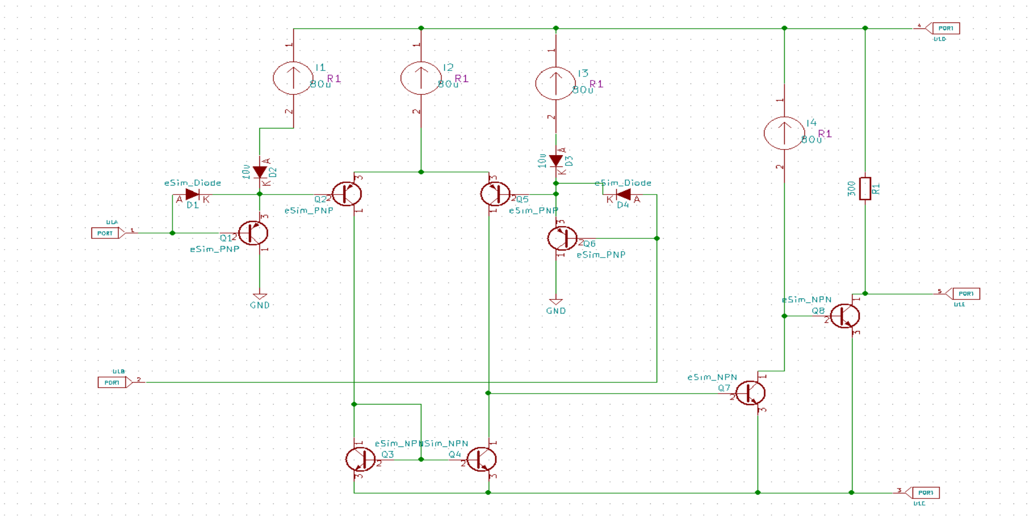


Figure 4.7: Subcircuit Schematic of TL331

### 4.2.3 Test Circuit

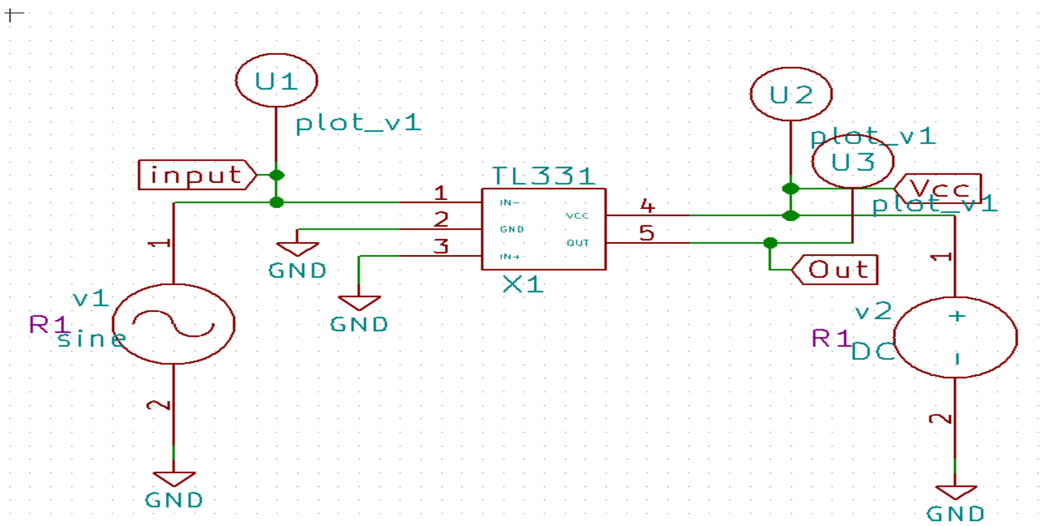


Figure 4.8: Test Circuit of TL331 IC

### 4.2.4 Input Plots

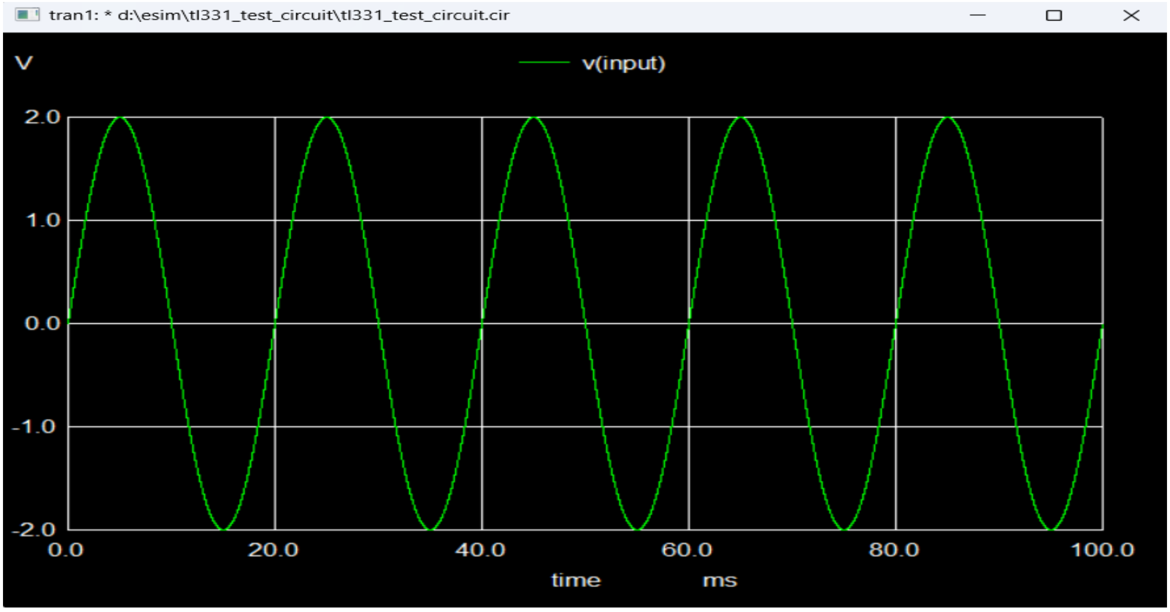


Figure 4.9: Input Voltage Waveform of TL331

### 4.2.5 Output Plots

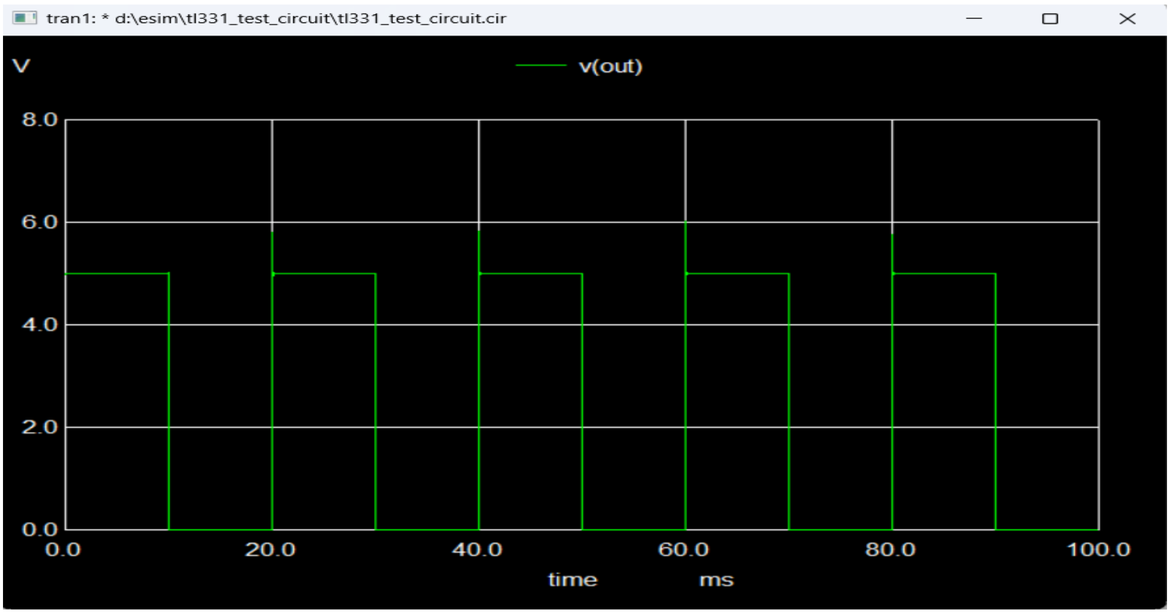


Figure 4.10: Output Voltage Waveform of TL331

## 4.3 RC4559N - Dual Operational Amplifier

The RC4559N IC is a high-performance dual operational amplifier designed for applications requiring wide bandwidth and high slew rates. It operates over a wide voltage range, making it suitable for both single and dual supply operations. The IC features low input bias and offset currents, which enhance its precision in analog signal processing tasks. Additionally, it provides a high gain-bandwidth product, ensuring excellent performance in high-frequency applications.

Applications of the RC4559N include audio amplification, active filters, and instrumentation. It is also used in data acquisition systems, precision rectifiers, and other analog signal processing circuits where accuracy and stability are crucial.

The advantages of the RC4559N IC include its wide operating voltage range, which allows for flexibility in various circuit designs. Its high slew rate and wide bandwidth ensure fast and accurate signal processing. The low input bias and offset currents minimize errors, making it suitable for precision applications. Furthermore, its robust performance across a range of frequencies makes it a reliable choice for high-frequency and high-speed applications.

### 4.3.1 IC Layout

This figure represents the 8-Pin Package Diagram of the RC4559N Dual Operational Amplifier

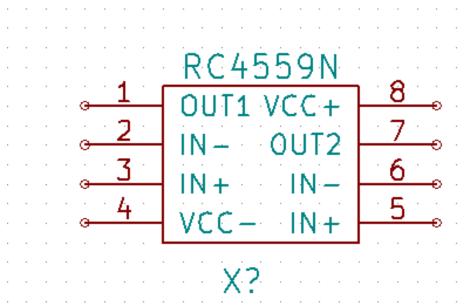


Figure 4.11: RC4559N Dual Operational Amplifier

### 4.3.2 Subcircuit Schematic Diagram

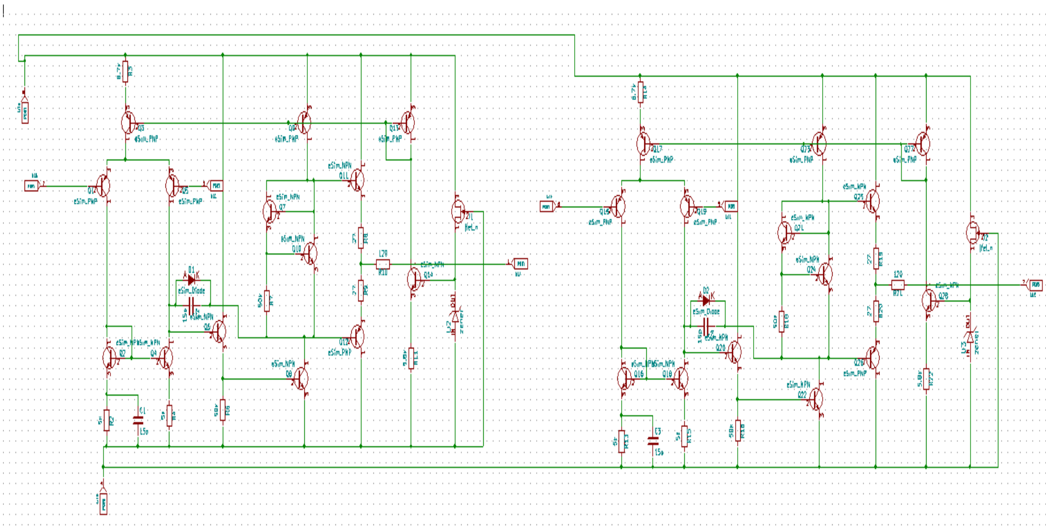

Figure 4.12: Subcircuit Schematic of RC4559N

### 4.3.3 Test Circuit

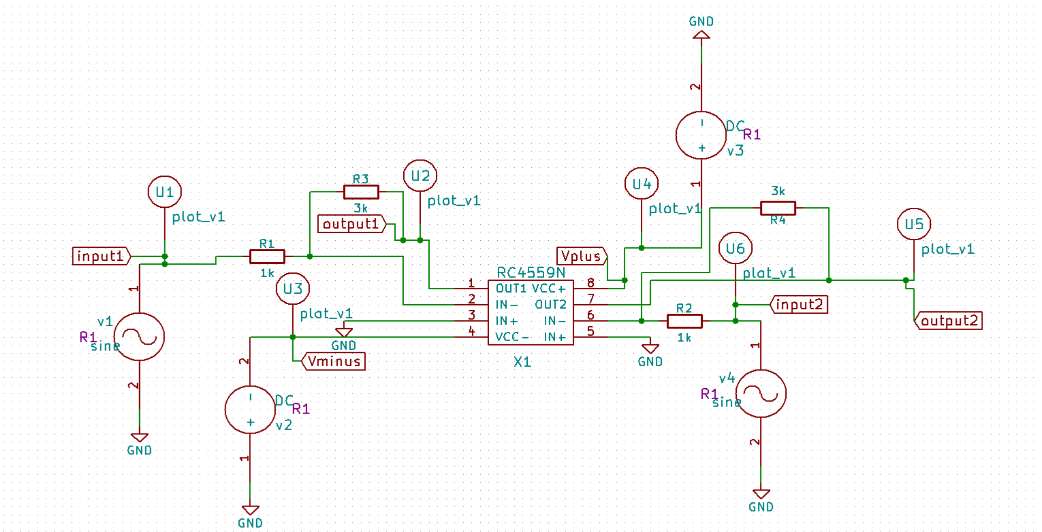


Figure 4.13: Test Circuit of RC4559N IC

### 4.3.4 Input Plots

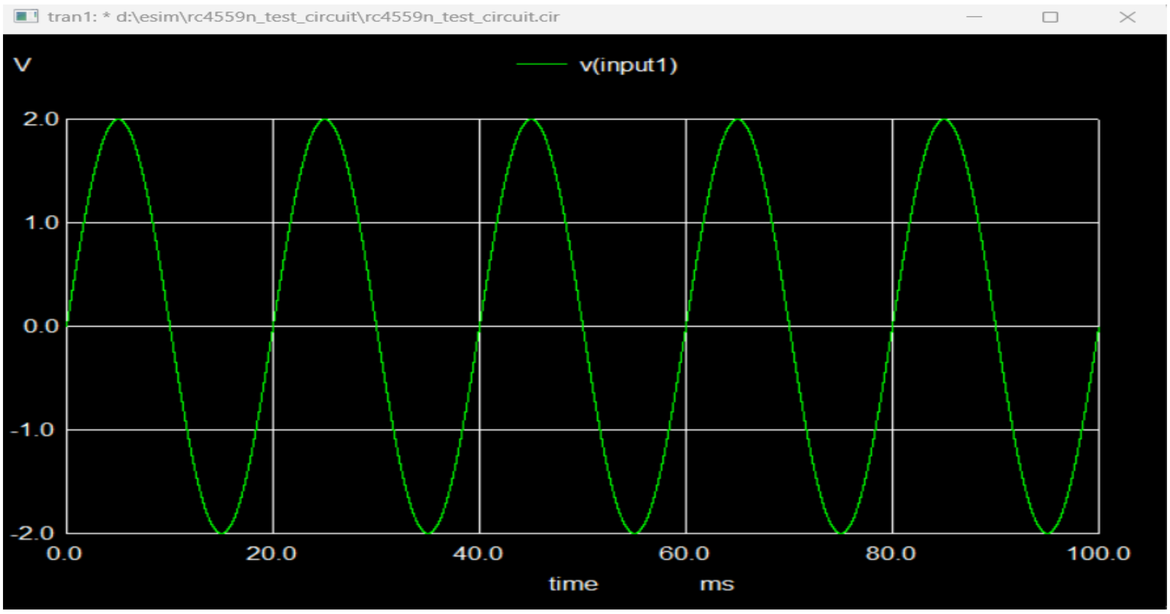


Figure 4.14: Input Voltage Waveform of RC4559N

### 4.3.5 Output Plots

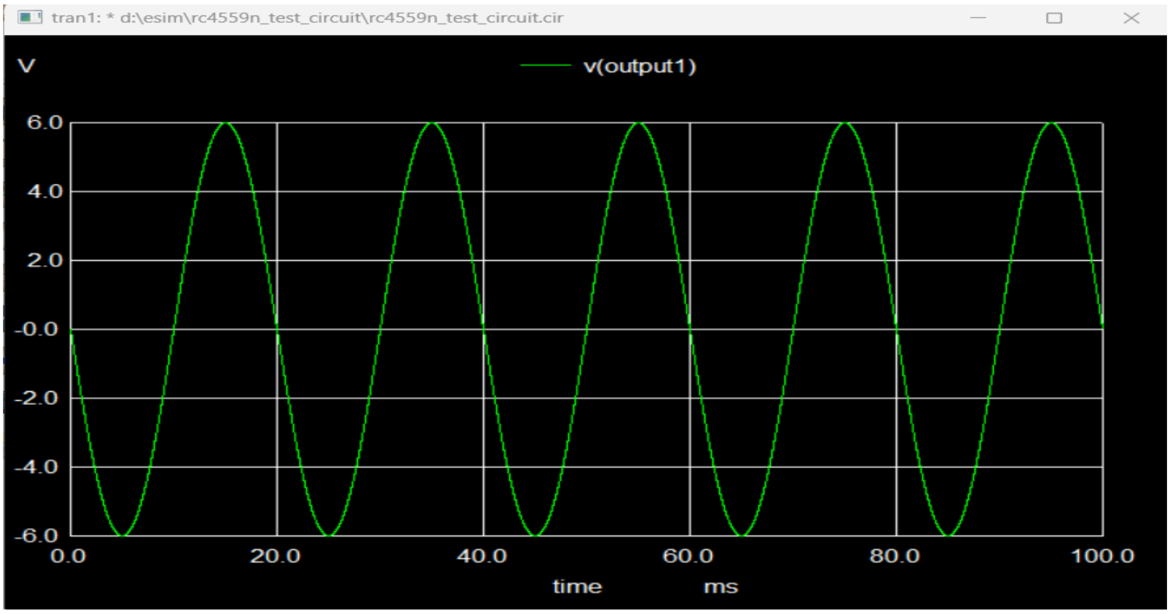


Figure 4.15: Output Voltage Waveform of RC4599N

## 4.4 TS391 - Single Comparator

The TS391 IC is a low-power, single-voltage comparator designed for a variety of applications requiring precise voltage monitoring. It operates with a low supply current, making it ideal for battery-powered devices and energy-efficient systems. The IC features an open-drain output, allowing it to interface easily with different logic levels and enabling wired-AND configurations.

Applications of the TS391 include voltage level detection, battery monitoring, and over-voltage protection circuits. It is also used in pulse-width modulation (PWM) controllers, signal conditioning, and threshold detectors.

Advantages of the TS391 IC include its low power consumption, which extends battery life in portable devices. Its wide operating voltage range enhances versatility across different designs. The open-drain output provides flexibility in interfacing with various digital systems. Additionally, the IC's low input offset voltage ensures high accuracy in voltage comparison tasks, making it suitable for precision monitoring and control applications.

### 4.4.1 IC Layout

This figure represents the 5-Pin Package Diagram of the TS391 Single comparator

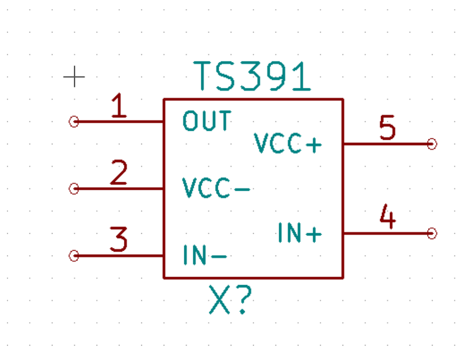


Figure 4.16: TS391 Single Comparator

### 4.4.2 Subcircuit Schematic Diagram

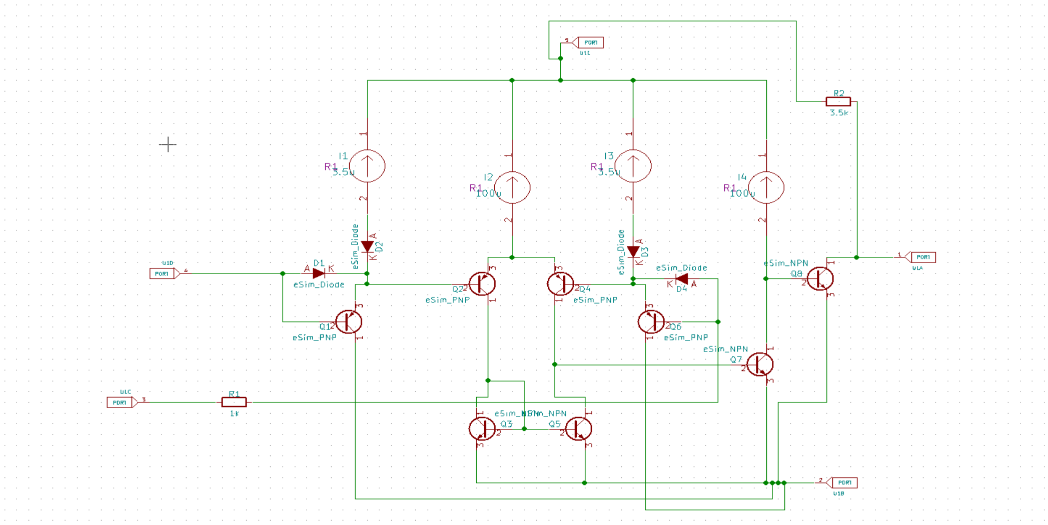

Figure 4.17: Subcircuit Schematic of TS391

### 4.4.3 Test Circuit

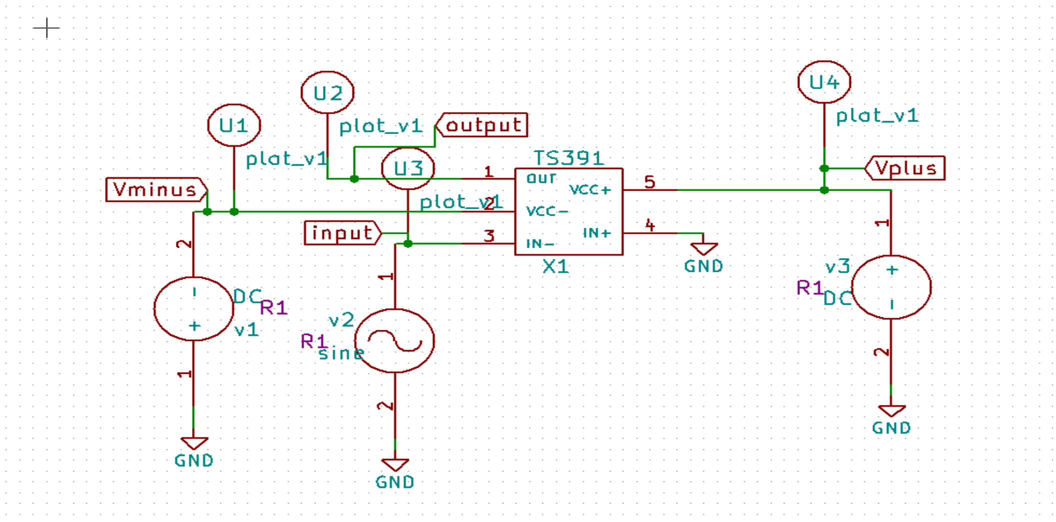


Figure 4.18: Test Circuit of TS391 IC

### 4.4.4 Input Plots

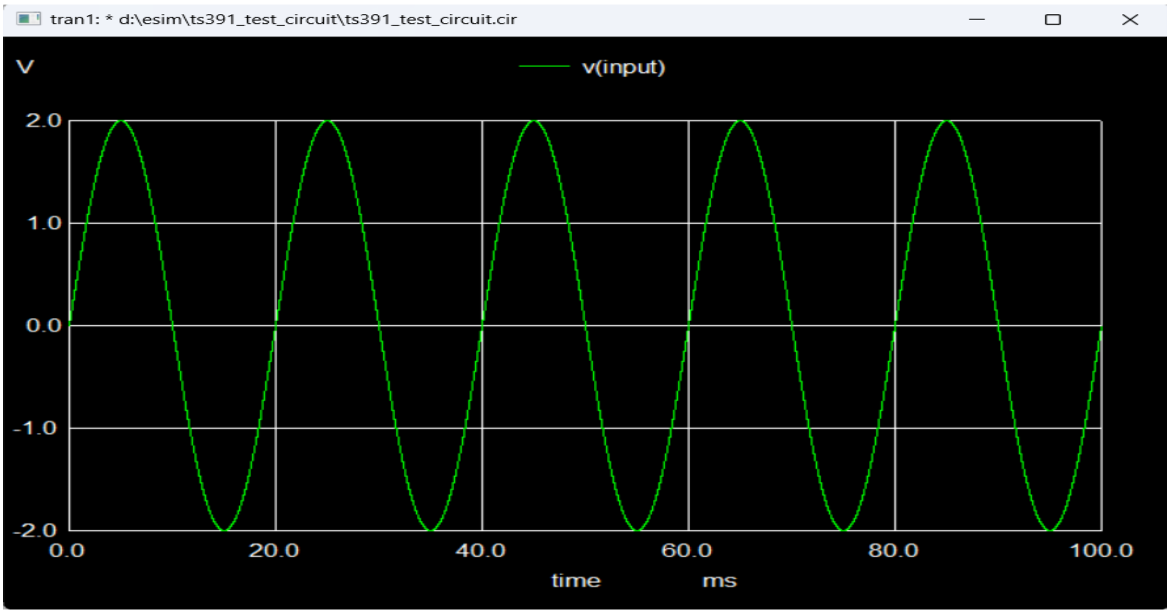


Figure 4.19: Input Voltage Waveform of TS391

### 4.4.5 Output Plots

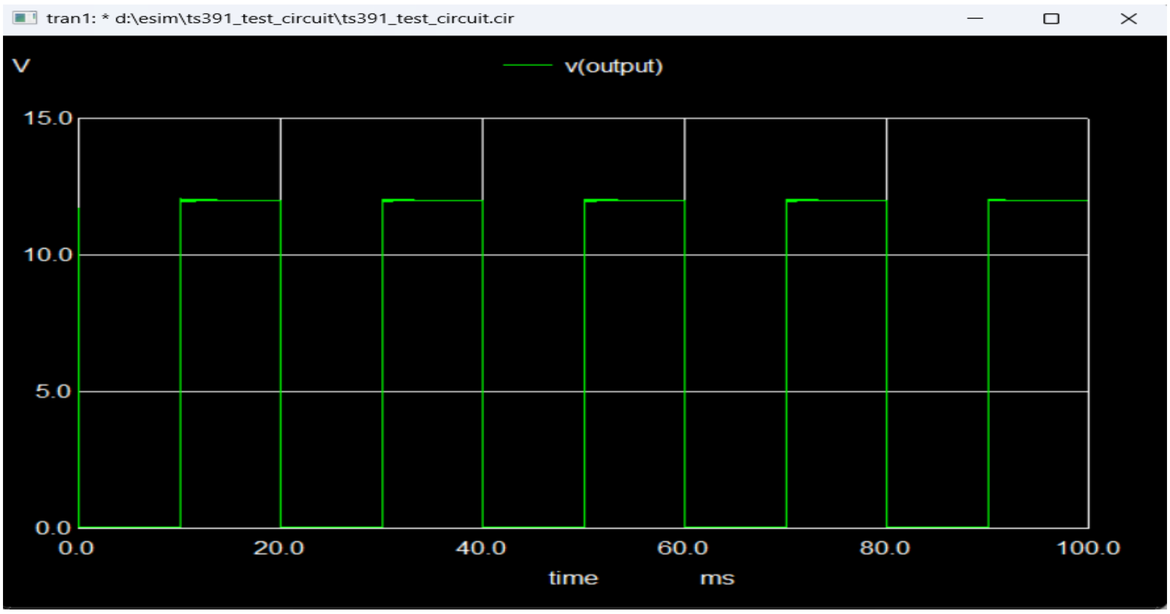


Figure 4.20: Output Voltage Waveform of TS391

## 4.5 MC78L05 - Positive Voltage Regulator

The MC78L05 IC is a three-terminal positive voltage regulator that provides a fixed 5V output with up to 100mA of output current. It is designed for use in a wide range of applications requiring a stable and reliable 5V power supply. The IC features internal current limiting, thermal shutdown, and safe area protection, ensuring robust performance and protection against overloading.

Applications of the MC78L05 include powering microcontrollers, sensors, and other digital circuits in electronic devices. It is also used in battery-powered equipment, portable devices, and general-purpose power supply circuits where a stable 5V output is needed.

Advantages of the MC78L05 IC include its simplicity and ease of use, requiring only two external capacitors for stable operation. Its internal protection mechanisms enhance reliability and safety. The IC's compact size and low cost make it a popular choice for many power regulation tasks. Additionally, its ability to provide a consistent 5V output helps ensure the proper operation of sensitive electronic components.

### 4.5.1 IC Layout

This figure represents the 3-Pin Package Diagram of the MC78L05 Positive Voltage Regulator

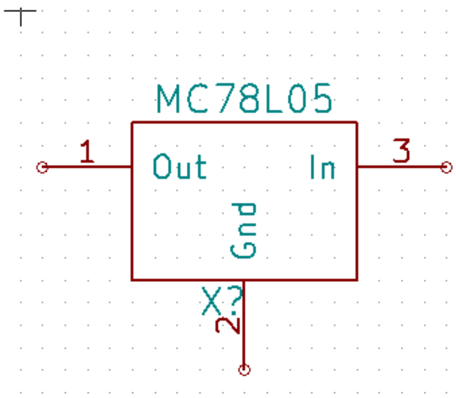


Figure 4.21: MC78L05 Positive Voltage Regulator

### 4.5.2 Subcircuit Schematic Diagram

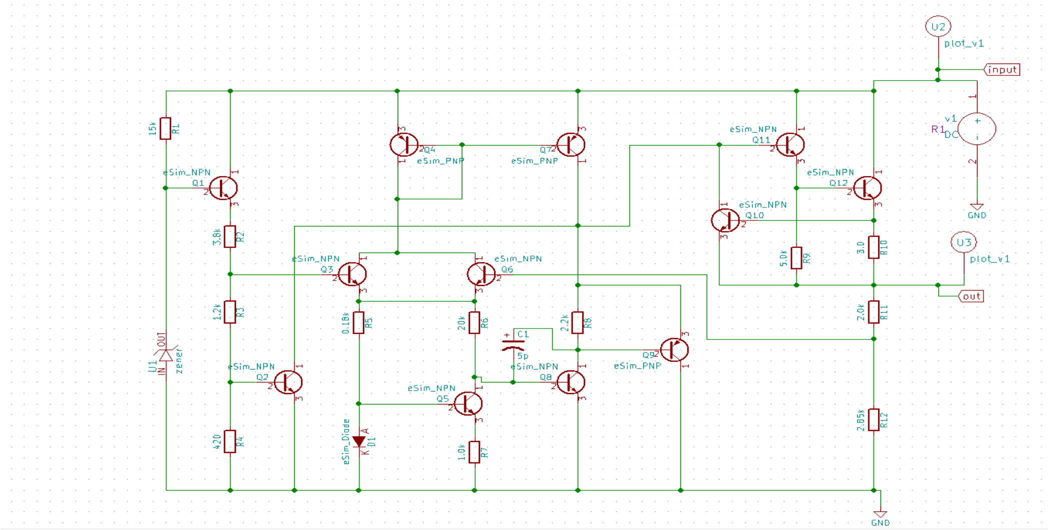


Figure 4.22: Subcircuit Schematic of MC78L05

### 4.5.3 Test Circuit

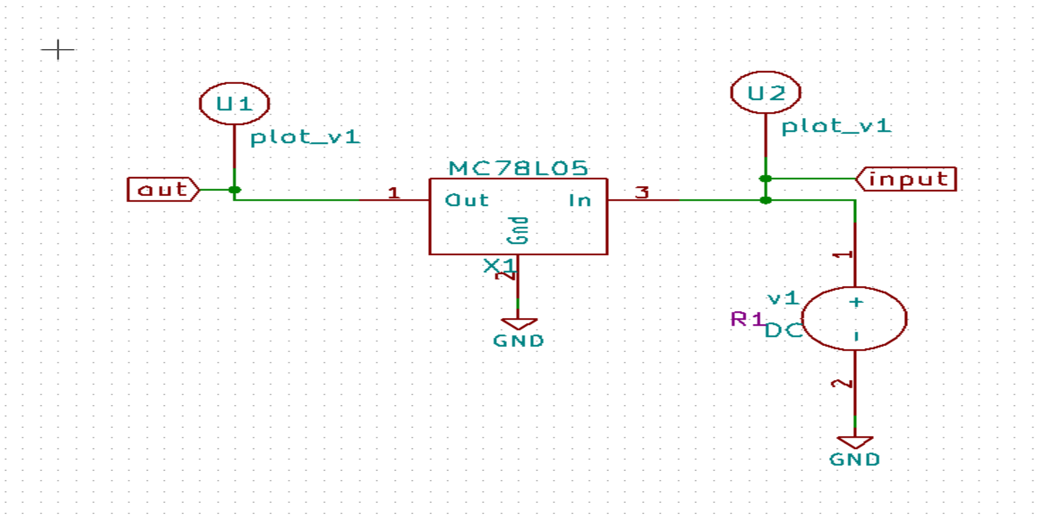


Figure 4.23: Test Circuit of MC78L05 IC

### 4.5.4 Input Plots

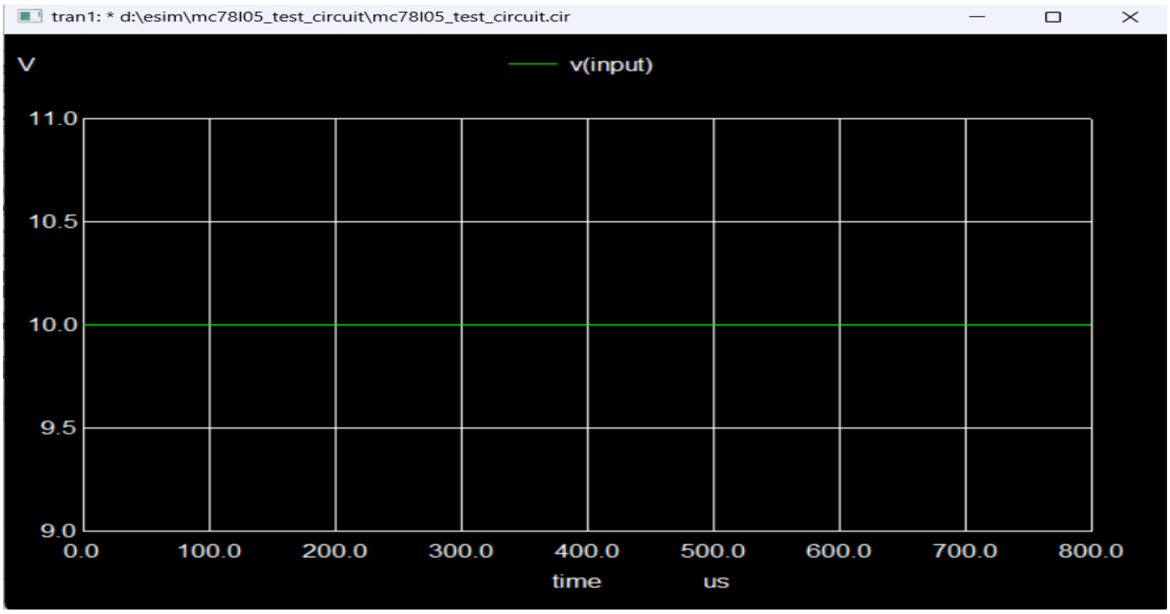


Figure 4.24: Input Voltage Waveform of MC78L05

### 4.5.5 Output Plots

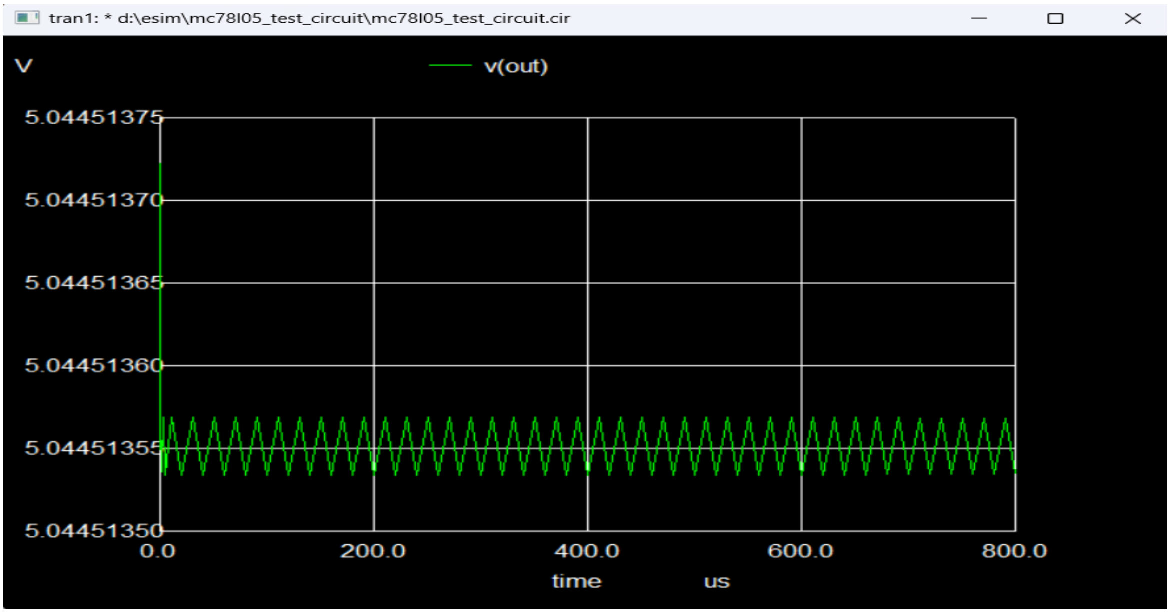


Figure 4.25: Output Voltage Waveform of MC78L05

## 4.6 LM78M05 - Positive Voltage Regulator

The LM78M05 IC is a three-terminal positive voltage regulator that delivers a fixed 5V output with a maximum current of 500mA. It is designed for applications that require a stable and reliable 5V power supply. The IC includes features such as internal current limiting, thermal shutdown, and safe area protection, which ensure safe and consistent performance under various conditions.

Applications of the LM78M05 include providing power to microcontrollers, sensors, and other digital circuits in electronic devices. It is also widely used in power supply circuits for battery chargers, portable devices, and consumer electronics where a stable 5V output is essential.

Advantages of the LM78M05 IC include its straightforward implementation, needing only two external capacitors for stable operation. Its built-in protection features enhance the reliability and durability of the device. The IC's ability to consistently deliver a 5V output ensures the stable operation of connected components, making it a dependable choice for a variety of power regulation tasks. Its moderate current capacity makes it suitable for a wide range of medium-power applications.

### 4.6.1 IC Layout

This figure represents the 3-Pin Package Diagram of the LM78M05 Positive Voltage Regulator

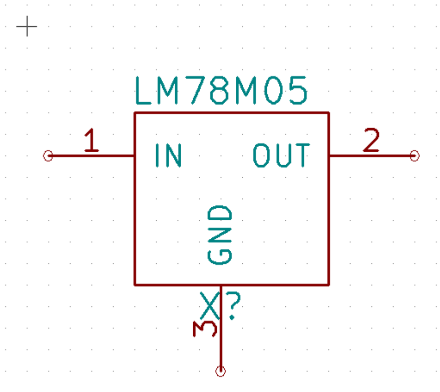


Figure 4.26: LM78M05 Positive Voltage Regulator

### 4.6.2 Subcircuit Schematic Diagram

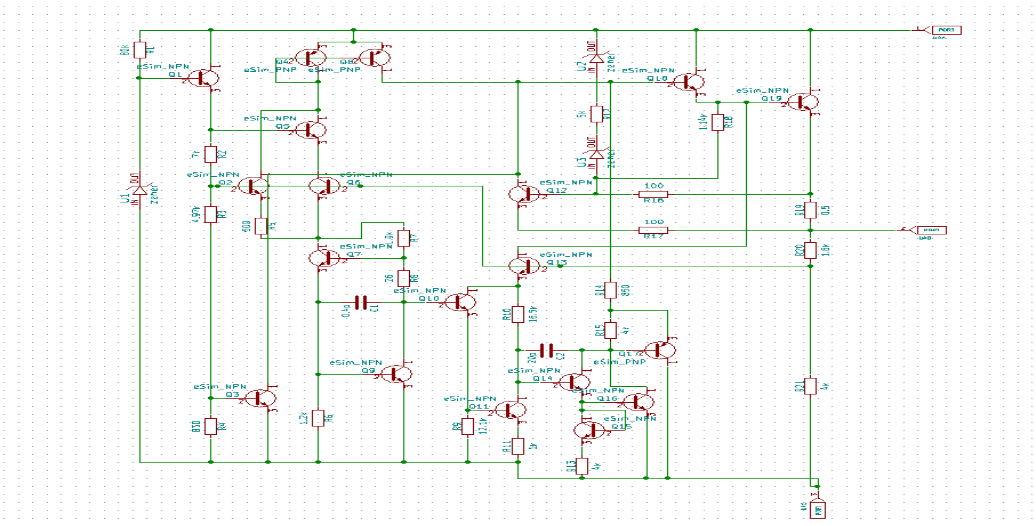

Figure 4.27: Subcircuit Schematic of LM78M05

### 4.6.3 Test Circuit

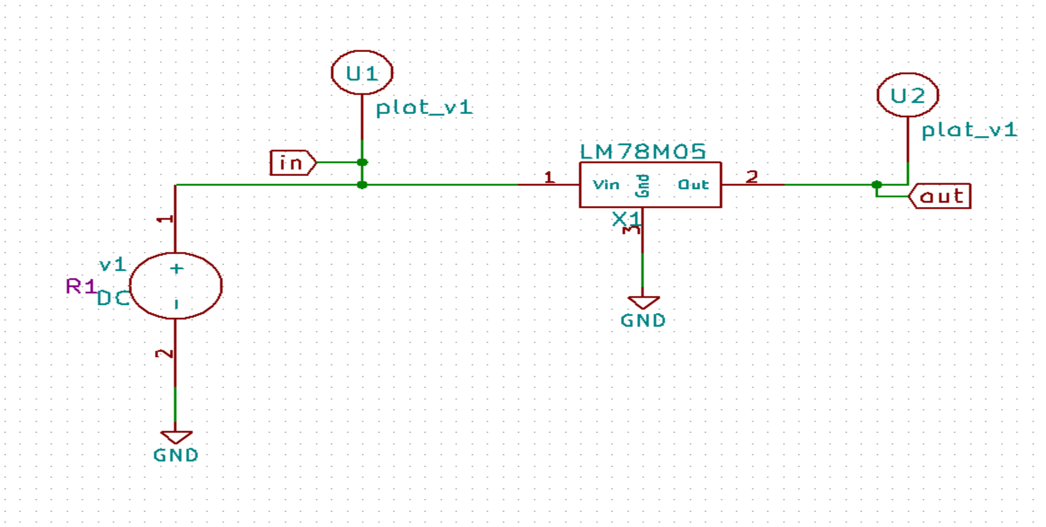


Figure 4.28: Test Circuit of LM78M05 IC

### 4.6.4 Input Plots

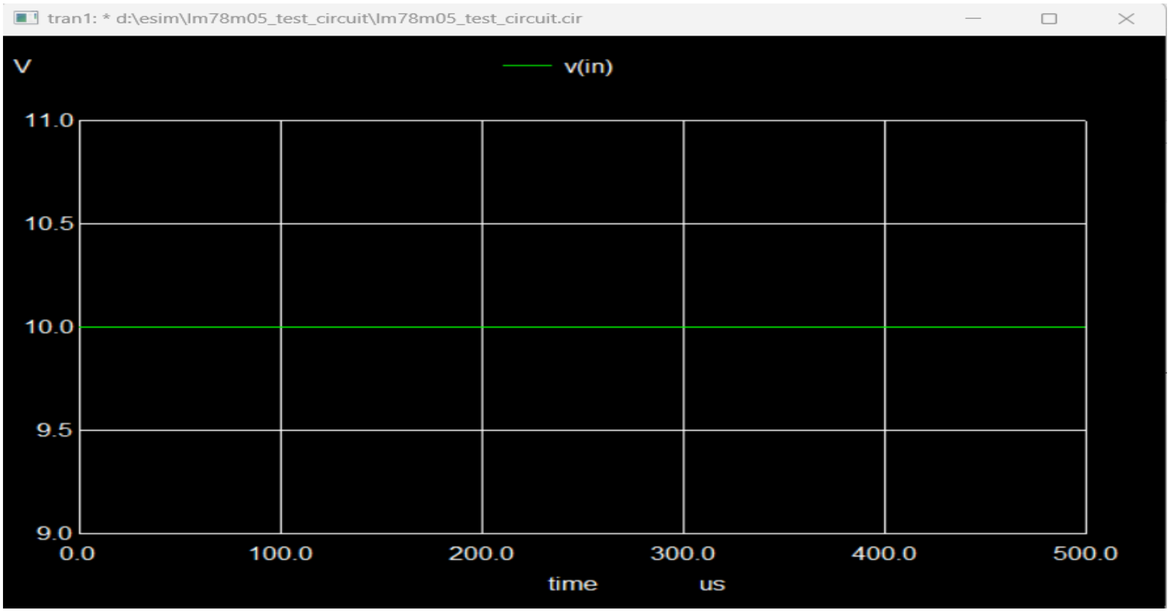


Figure 4.29: Input Voltage Waveform of LM78M05

### 4.6.5 Output Plots

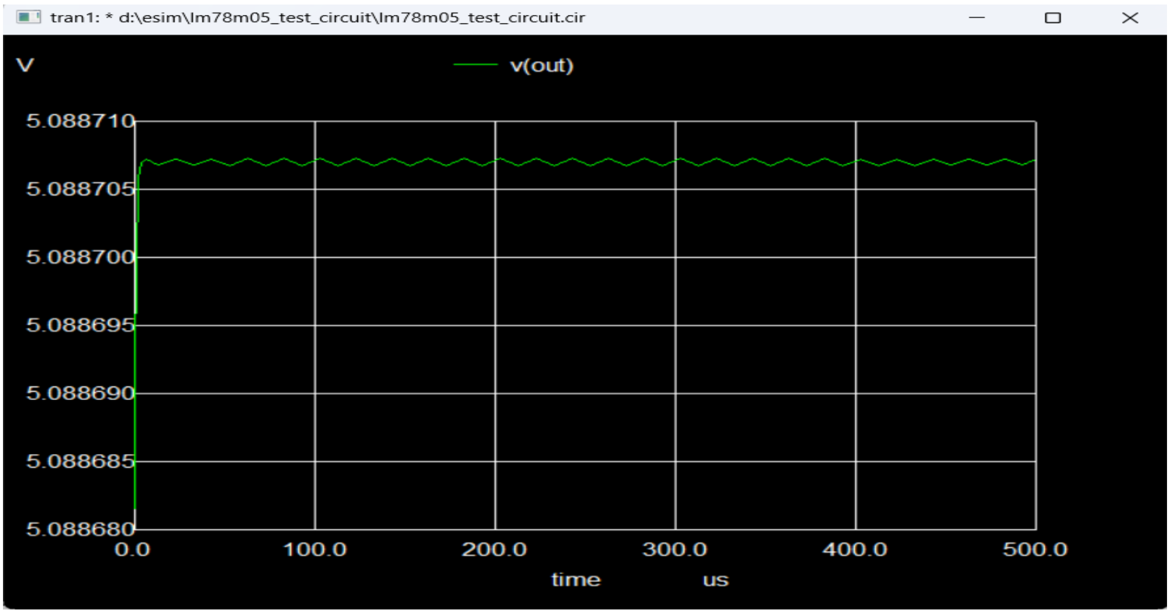


Figure 4.30: Output Voltage Waveform of LM78M05

## 4.7 LM140L - Positive Voltage Regulator

The LM140L IC is a three-terminal positive voltage regulator available in fixed output voltages of 5V, 12V, and 15V. It is designed to provide a stable and precise output with an output current capability of up to 100mA. The IC includes internal current limiting, thermal shutdown, and safe area protection features, ensuring reliable operation and protection against overload and overheating.

Applications of the LM140L include providing regulated power supplies for microcontrollers, sensors, and other electronic circuits in both consumer and industrial devices. It is also used in portable devices, battery chargers, and general-purpose power regulation where a consistent voltage output is required.

Advantages of the LM140L IC include its ease of use, requiring minimal external components for stable operation. The internal protection mechanisms enhance the reliability and longevity of the device. Its ability to deliver a stable output voltage ensures the proper functioning of sensitive electronic components. Additionally, the availability of multiple fixed output voltage options provides flexibility for various design requirements.

### 4.7.1 IC Layout

This figure represents the 3-Pin Package Diagram of the LM140L Positive Voltage Regulator

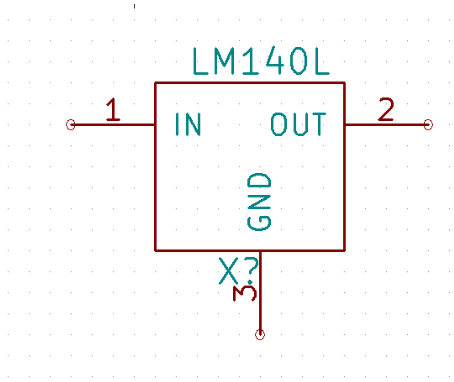


Figure 4.31: LM140L Positive Voltage Regulator

### 4.7.2 Subcircuit Schematic Diagram

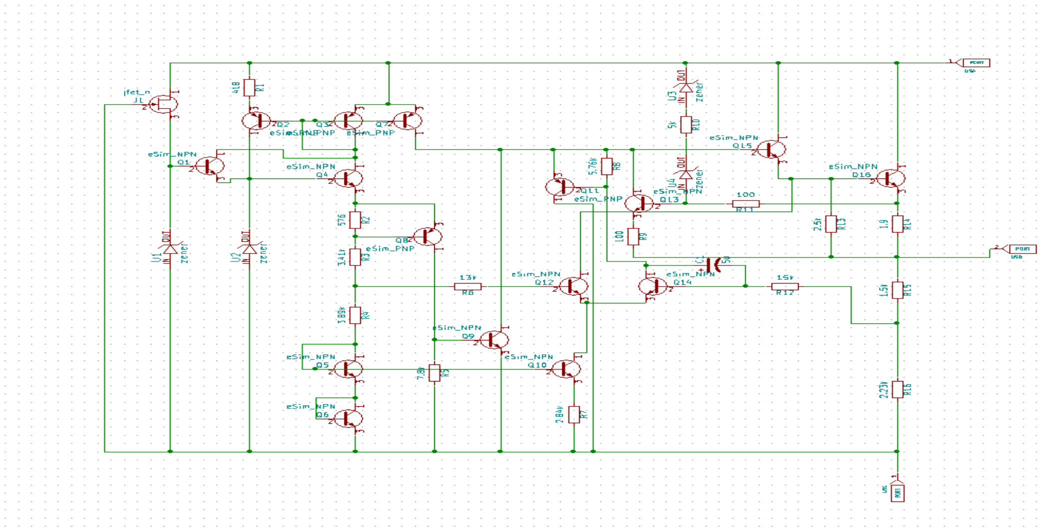

Figure 4.32: Subcircuit Schematic of LM140L

### 4.7.3 Test Circuit

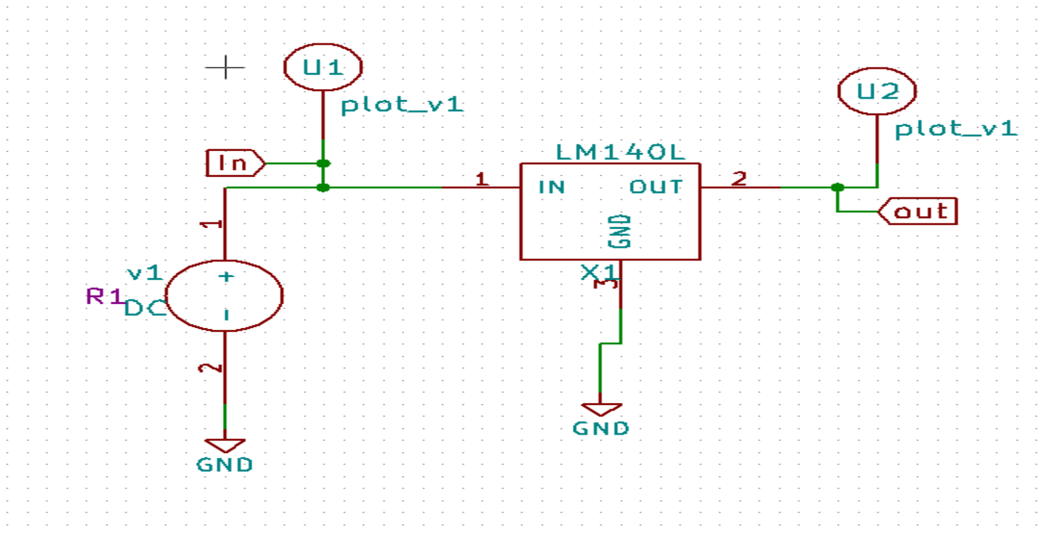


Figure 4.33: Test Circuit of LM140L IC

### 4.7.4 Input Plots

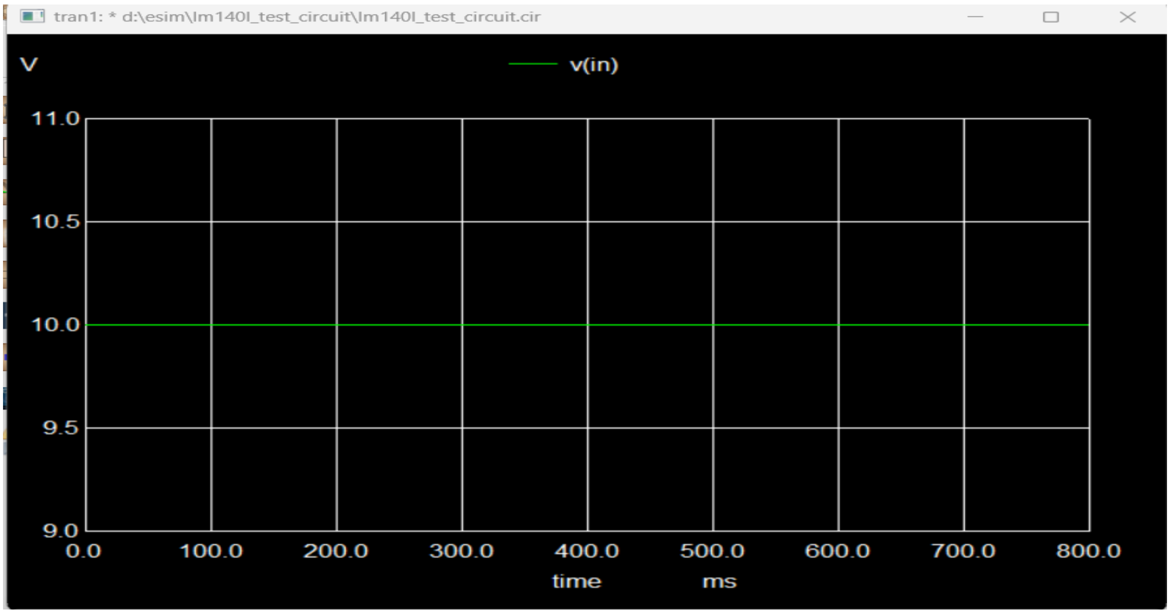


Figure 4.34: Input Voltage Waveform of LM140L

### 4.7.5 Output Plots

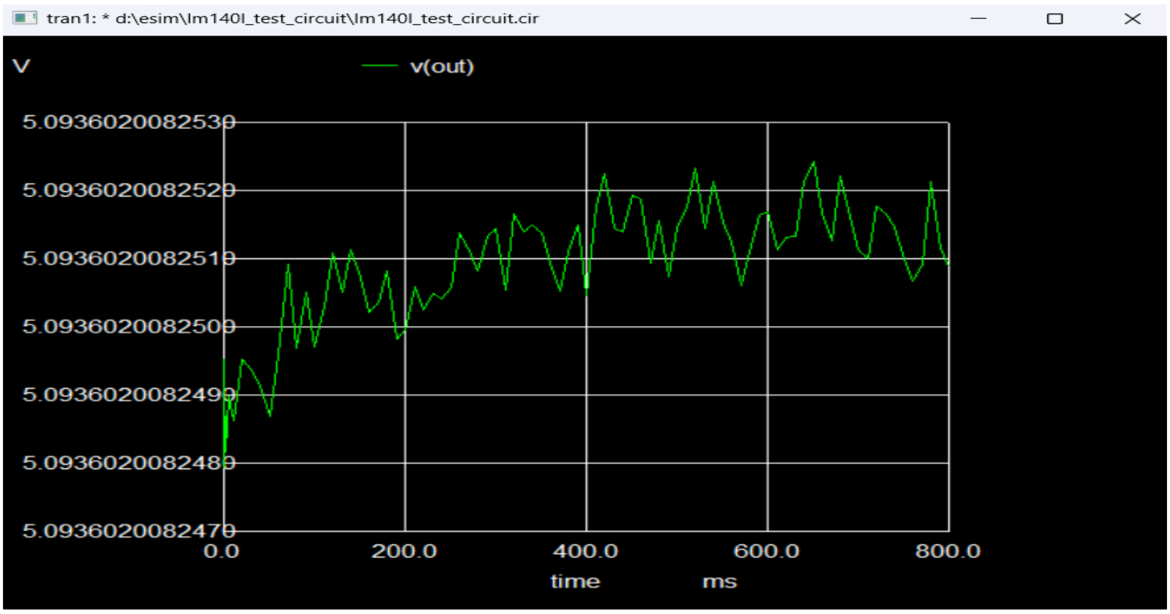


Figure 4.35: Output Voltage Waveform of LM140L

## 4.8 MC3403 - Quad Operational Amplifier

The MC3403 IC is a quad operational amplifier featuring low power consumption, high voltage gain, and wide bandwidth. Each of the four op-amps in the IC can operate independently, making it versatile for various analog signal processing tasks. The IC operates over a wide voltage range, enhancing its flexibility in different applications. It also has low input bias and offset currents, ensuring precision in signal amplification.

Applications of the MC3403 include audio amplification, signal conditioning, and active filtering in both consumer and industrial electronics. It is also used in instrumentation, data acquisition systems, and other analog circuits requiring reliable performance.

Advantages of the MC3403 IC include its low power consumption, which is beneficial for battery-operated devices. The wide bandwidth and high voltage gain provide excellent performance in high-frequency applications. Its low input bias and offset currents minimize errors, making it suitable for precision applications. Additionally, the quad configuration allows for compact and cost-effective designs by integrating four op-amps in a single package.

### 4.8.1 IC Layout

This figure represents the 14-Pin Package Diagram of the MC3403 Quad Operational Amplifier

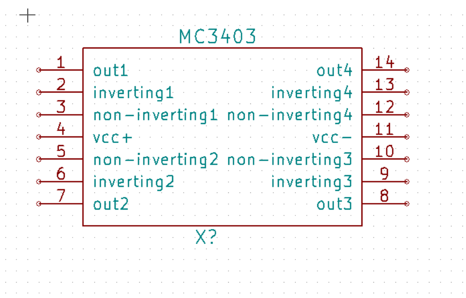


Figure 4.36: MC3403 Quad Operational Amplifier

### 4.8.2 Subcircuit Schematic Diagram

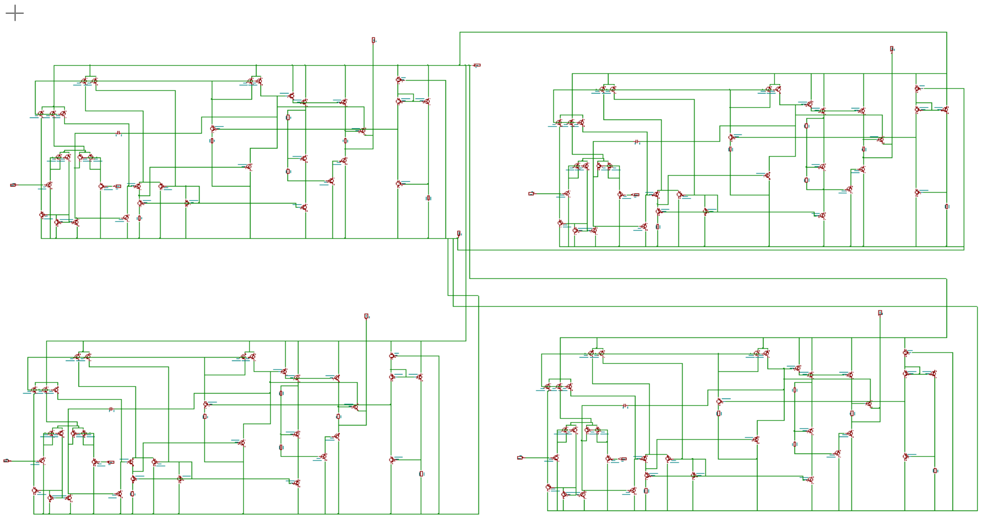

Figure 4.37: Subcircuit Schematic of MC3403

### 4.8.3 Test Circuit

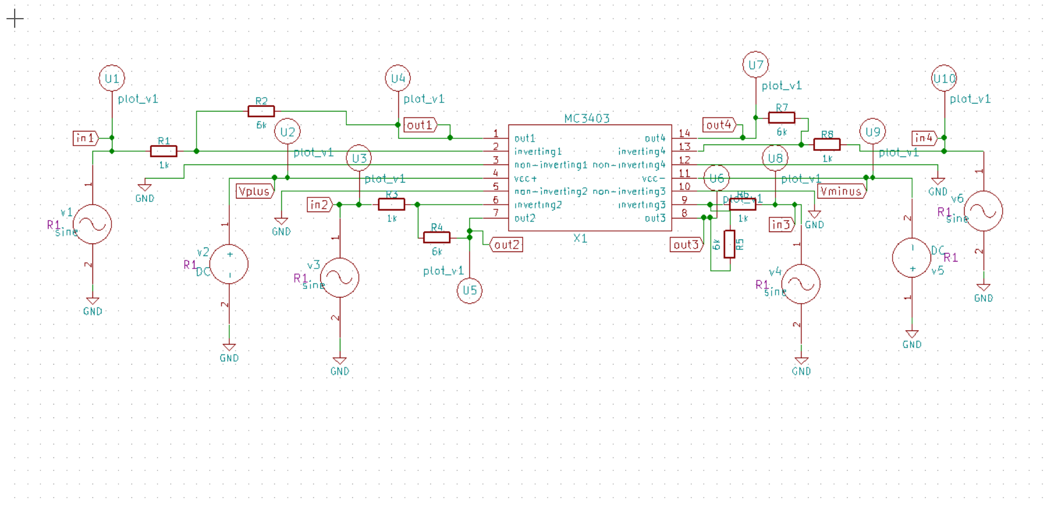


Figure 4.38: Test Circuit of MC3403 IC

### 4.8.4 Input Plots

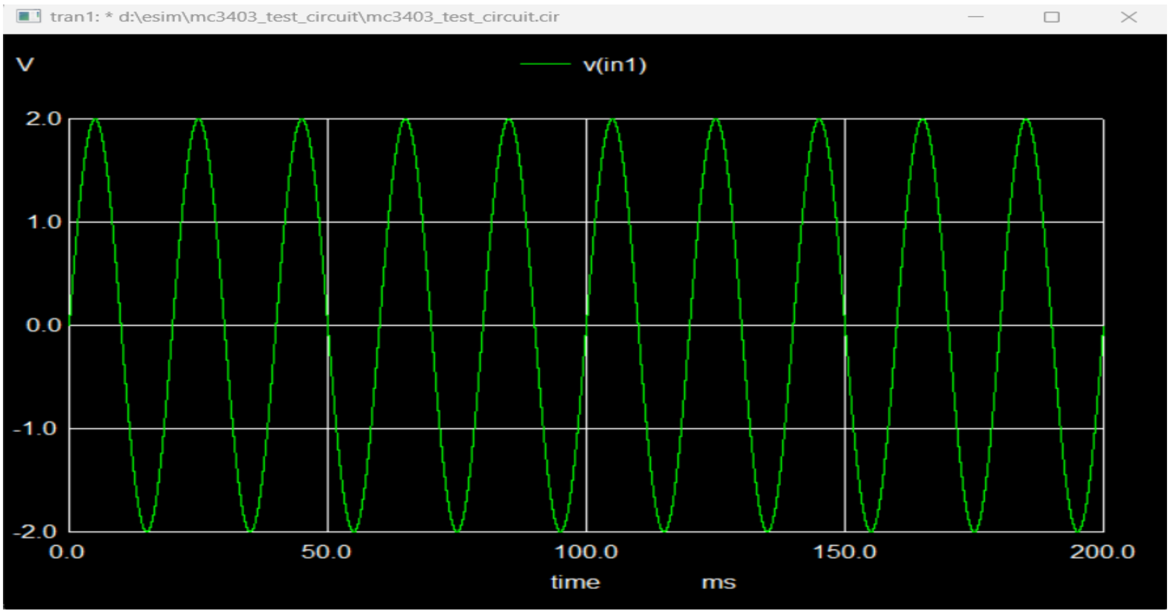


Figure 4.39: Input Voltage Waveform of MC3403

### 4.8.5 Output Plots

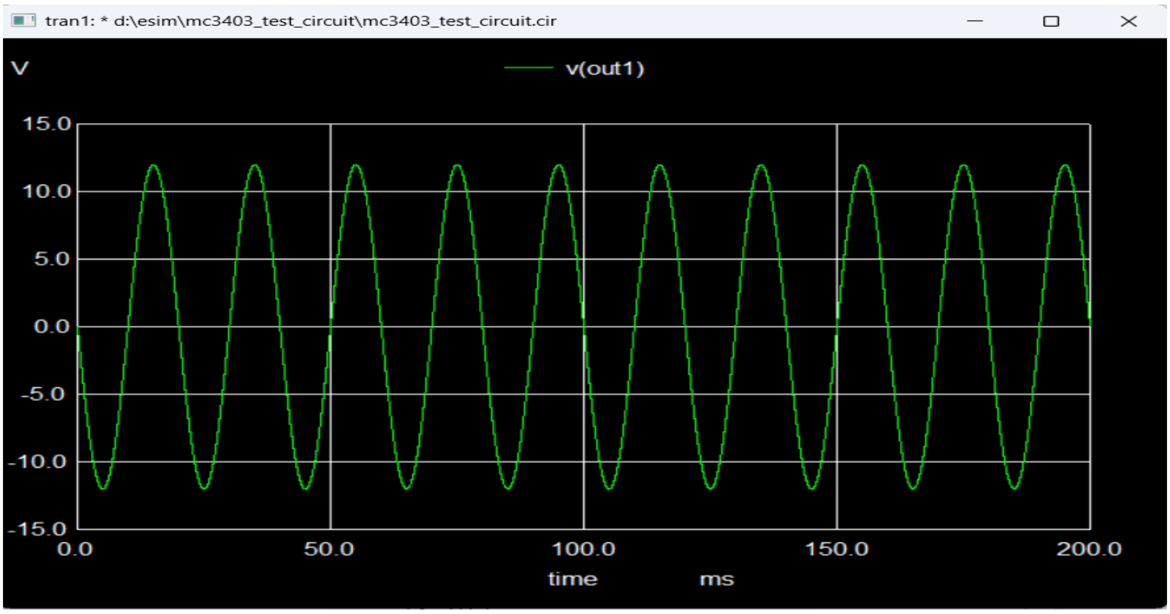


Figure 4.40: Output Voltage Waveform of MC3403

## 4.9 TL064 - Quad Operational Amplifier

The TL064 IC is a quad JFET-input operational amplifier known for its high input impedance and low noise characteristics. It provides four independent op-amps in a single package, each capable of delivering precision amplification and signal conditioning. The IC operates with low power consumption and features a wide bandwidth, making it suitable for various analog applications.

Applications of the TL064 include audio signal processing, active filters, and instrumentation where high fidelity and low noise are crucial. It is also used in data acquisition systems, sensor interfaces, and precision analog circuitry.

Advantages of the TL064 IC include its high input impedance, which minimizes loading effects on signal sources, and its low noise performance, which enhances signal clarity. The low power consumption makes it ideal for battery-powered and portable devices. Additionally, the quad configuration allows for efficient use of space and reduces the need for multiple components in complex circuits. The wide bandwidth ensures accurate performance across a broad range of frequencies.

### 4.9.1 IC Layout

This figure represents the 14-Pin Package Diagram of the TL064 Quad Operational Amplifier

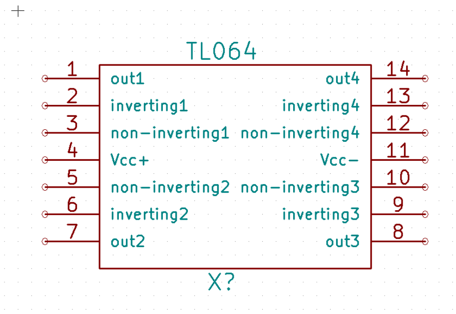


Figure 4.41: TL064 Quad Operational Amplifier

### 4.9.2 Subcircuit Schematic Diagram

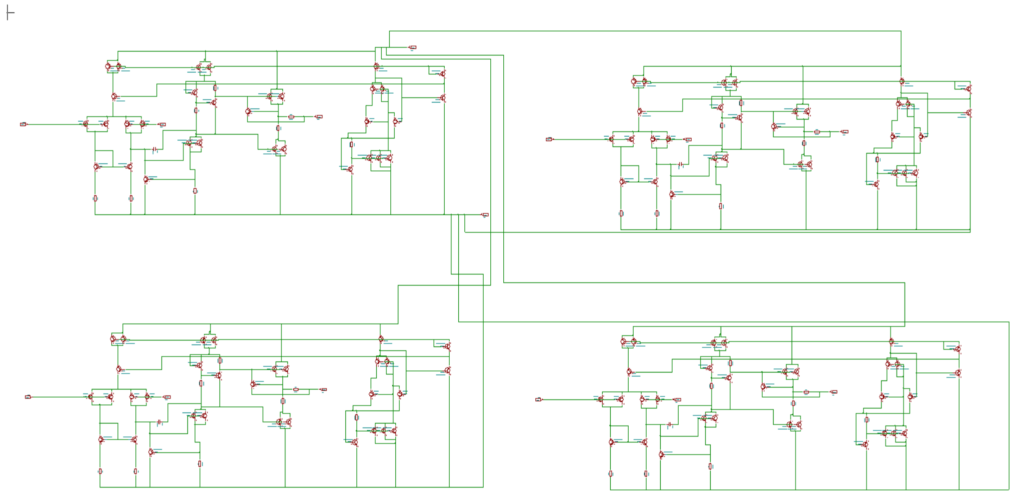

Figure 4.42: Subcircuit Schematic of TL064

### 4.9.3 Test Circuit

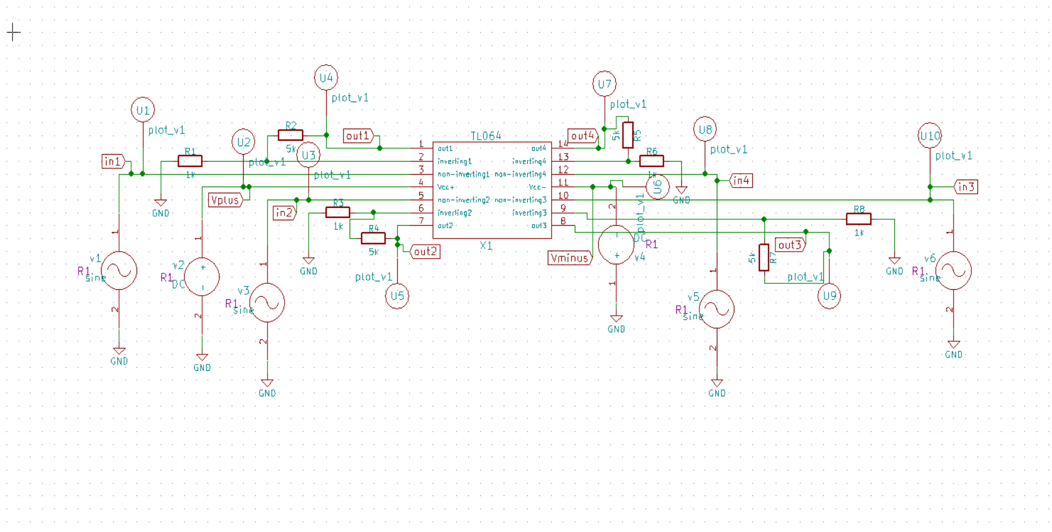


Figure 4.43: Test Circuit of TL064 IC

### 4.9.4 Input Plots

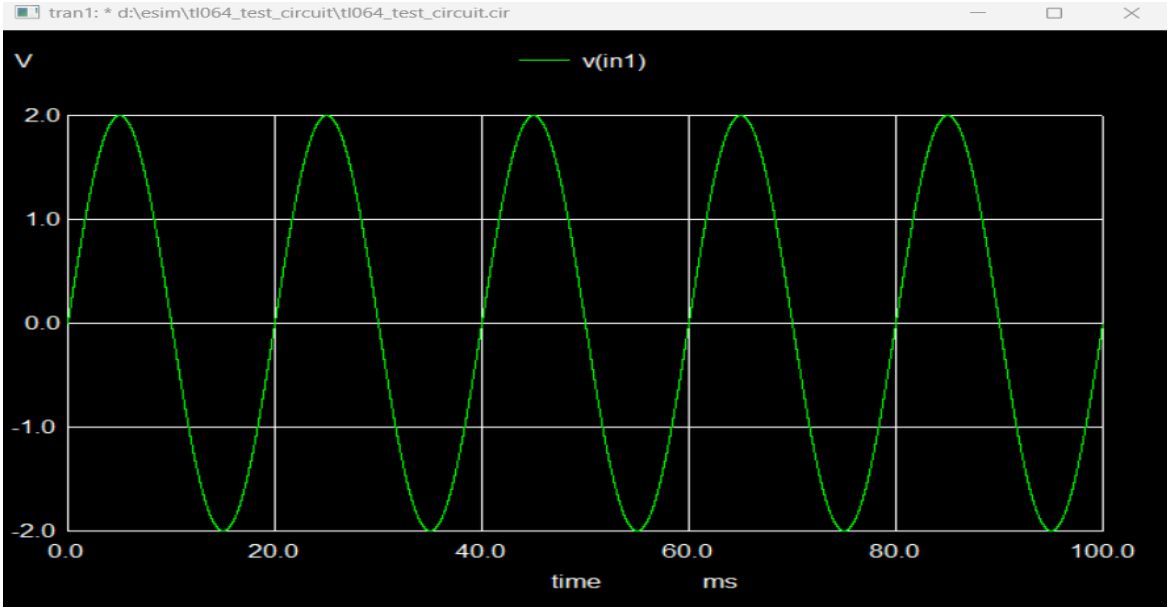


Figure 4.44: Input Voltage Waveform of TL064

### 4.9.5 Output Plots

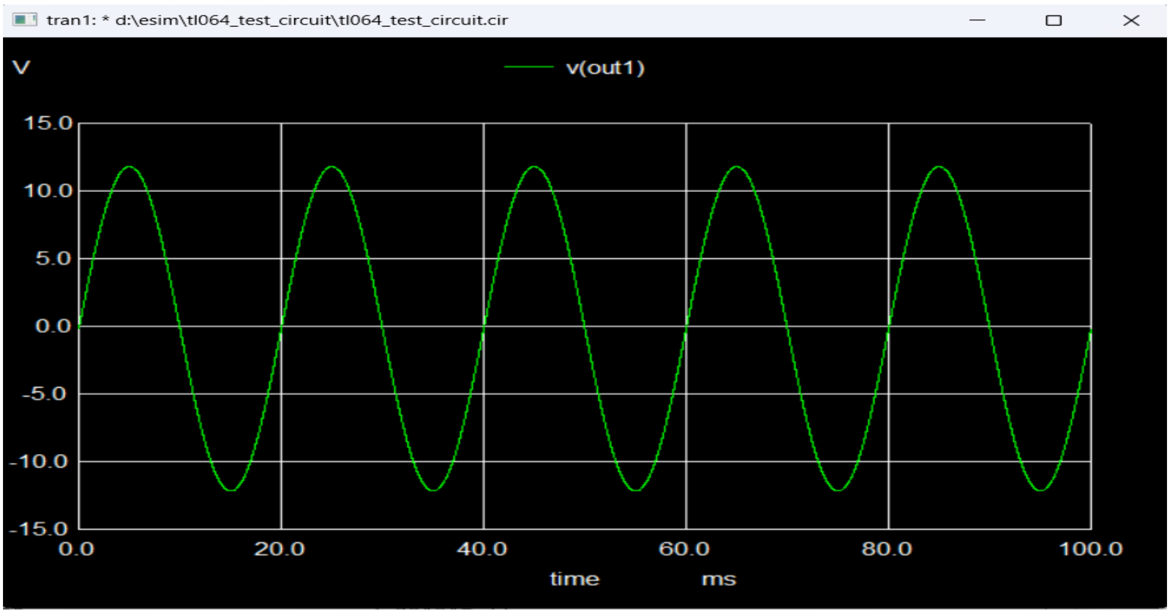


Figure 4.45: Output Voltage Waveform of TL064

## 4.10 LF147 - Quad Operational Amplifier

The LF147 IC is a high-performance, low-noise JFET-input operational amplifier designed for precision analog applications. It offers a wide bandwidth, high slew rate, and low input bias currents, making it suitable for accurate signal processing tasks. The IC operates over a broad voltage range and features a low input offset voltage, enhancing its performance in demanding circuits.

Applications of the LF147 include precision analog signal conditioning, audio amplification, and instrumentation where high accuracy and low noise are required. It is also used in active filters, data acquisition systems, and high-fidelity audio systems.

Advantages of the LF147 IC include its low noise operation, which ensures minimal interference in sensitive applications. The high slew rate and wide bandwidth allow for rapid response and accurate signal processing. Its low input bias currents and offset voltage contribute to precise measurements and stable performance. Additionally, the IC's versatility across various voltage ranges makes it adaptable to different circuit designs.

### 4.10.1 IC Layout

This figure represents the 14-Pin Package Diagram of the LF147 Quad Operational Amplifier

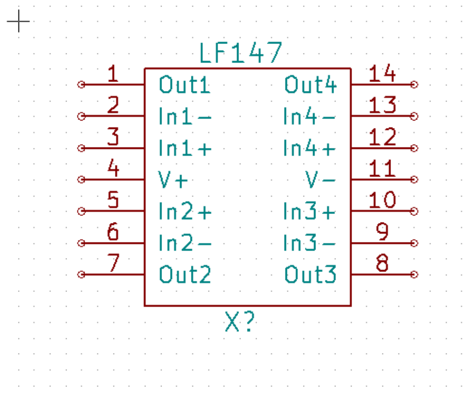


Figure 4.46: LF147 Quad Operational Amplifier

### 4.10.2 Subcircuit Schematic Diagram

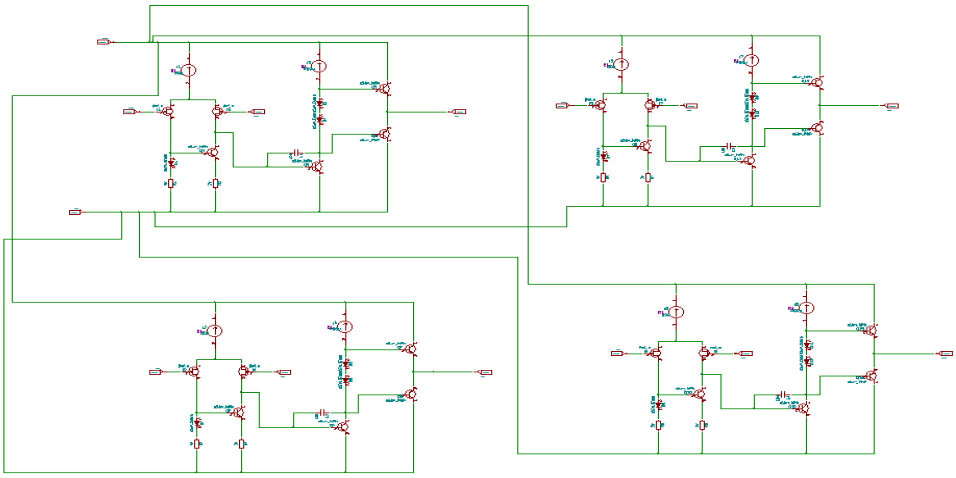

Figure 4.47: Subcircuit Schematic of LF147

### 4.10.3 Test Circuit

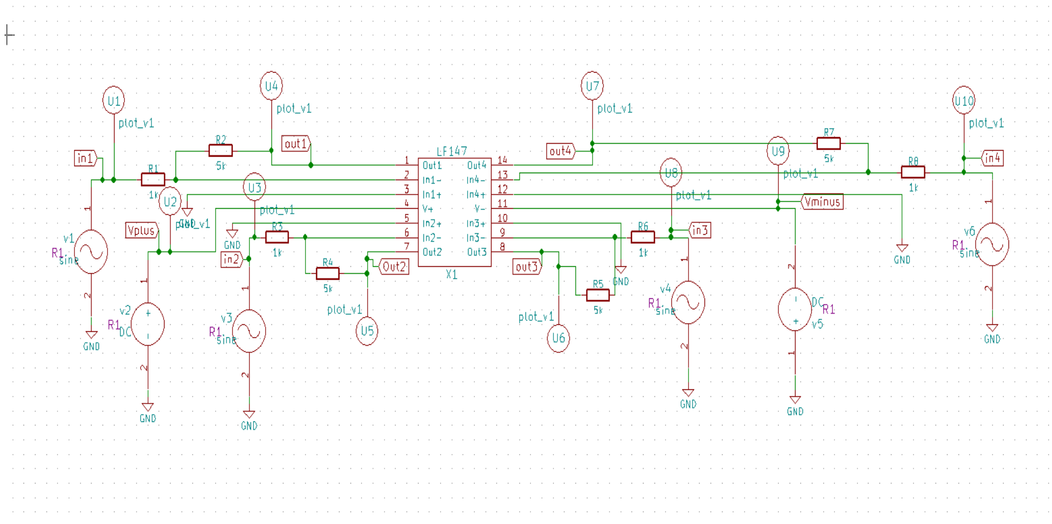


Figure 4.48: Test Circuit of LF147 IC

### 4.10.4 Input Plots

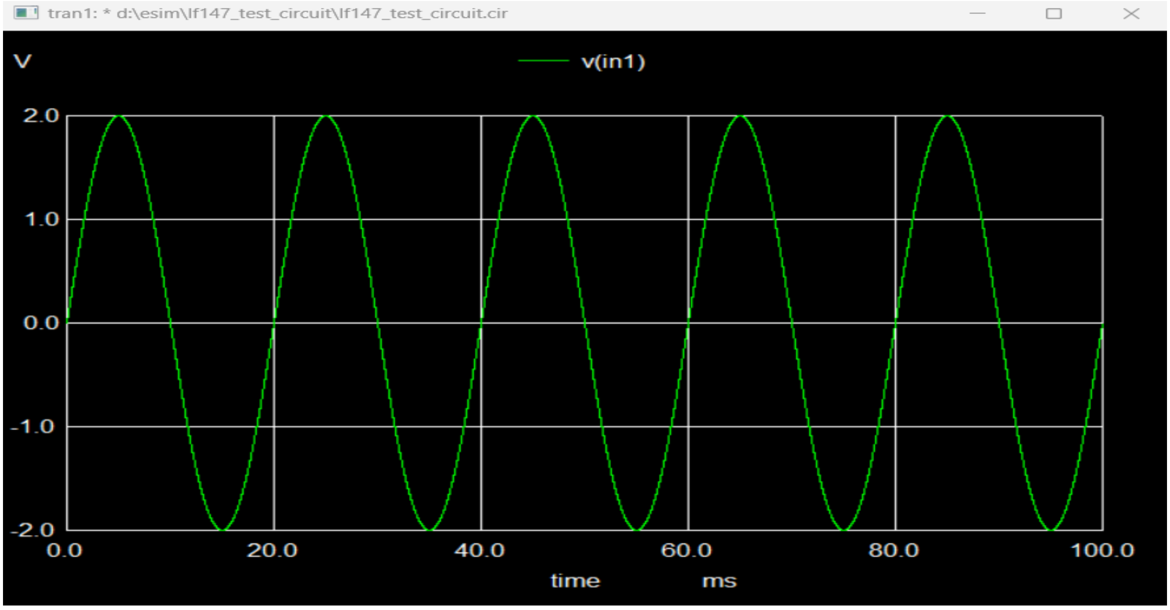


Figure 4.49: Input Voltage Waveform of LF147

### 4.10.5 Output Plots

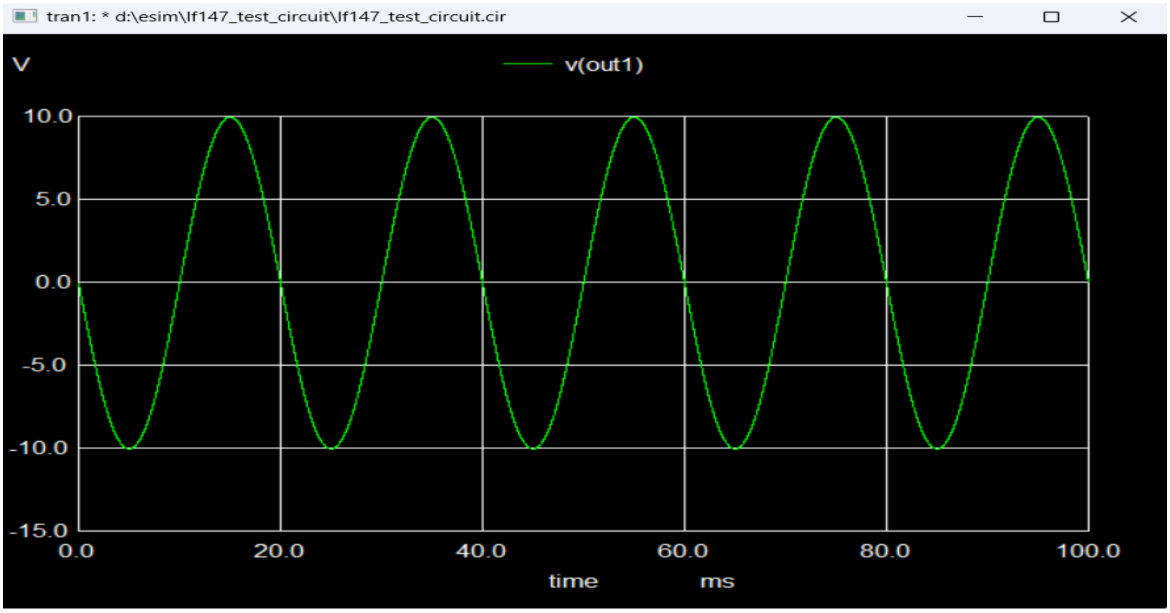


Figure 4.50: Output Voltage Waveform of LF147

# Chapter 5

# Digital IC's

## 5.1 CD4078B

The CD4078B IC is an 8-input NOR/OR gate, providing versatility in digital logic circuit design. It features low power consumption and high noise immunity, typical of CMOS technology. This IC can operate over a wide voltage range, allowing it to integrate seamlessly with various power supply levels. It supports multiple logic configurations, enabling it to function as either an 8-input NOR gate or an 8-input OR gate.

Applications of the CD4078B include digital signal processing, data routing, and complex control logic circuits. It is also used in timing and sequencing operations, as well as various logical operations in consumer and industrial electronics.

Advantages of the CD4078B IC include its flexibility in logic configurations, which simplifies circuit design. Its high noise immunity ensures reliable operation in electrically noisy environments. The low power consumption makes it ideal for battery-operated devices and energy-efficient applications. Furthermore, the wide operating voltage range enhances its compatibility with diverse systems, providing greater design flexibility.

### 5.1.1 IC Layout

This figure represents the 10-Pin Package Diagram of the CD4078B 8-input NOR/OR gate

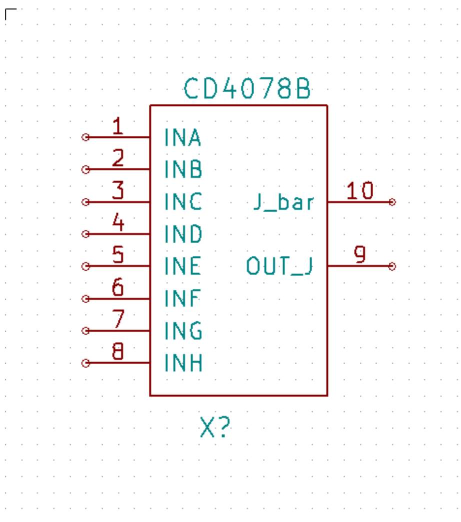


Figure 5.1: CD4078B

### 5.1.2 Sub-circuit Schematic Diagram

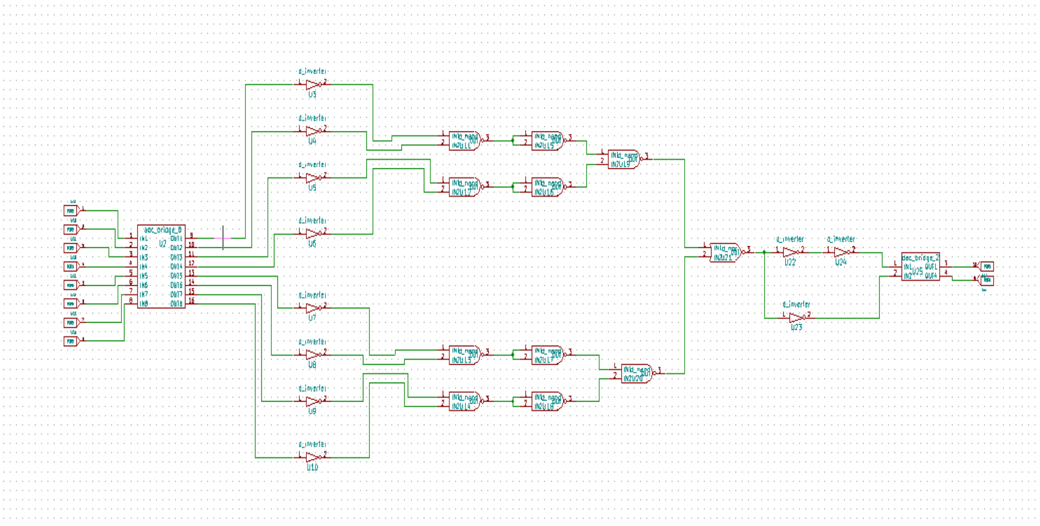

Figure 5.2: Sub-circuit Schematic of CD4078B

### 5.1.3 Test Circuit

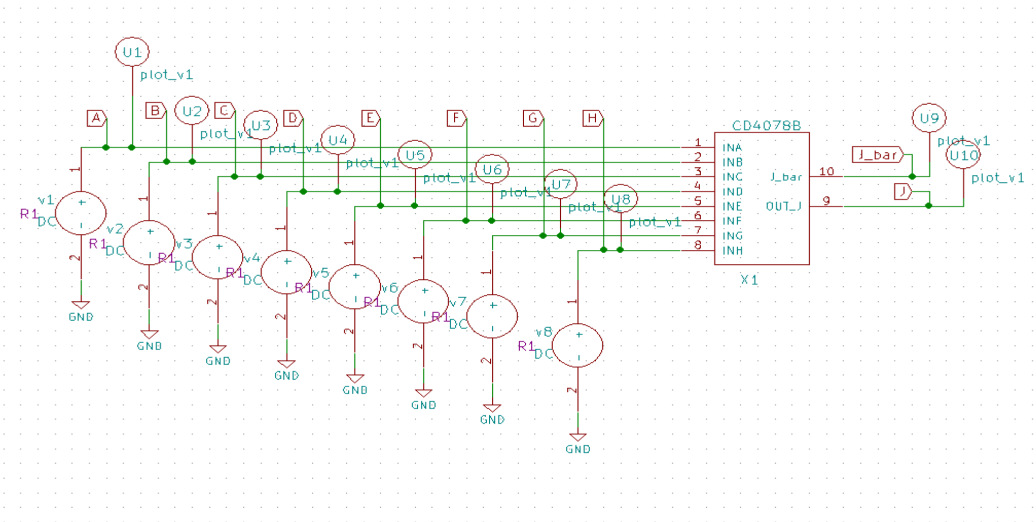


Figure 5.3: Test Circuit of CD4078B IC

### 5.1.4 Input Plots

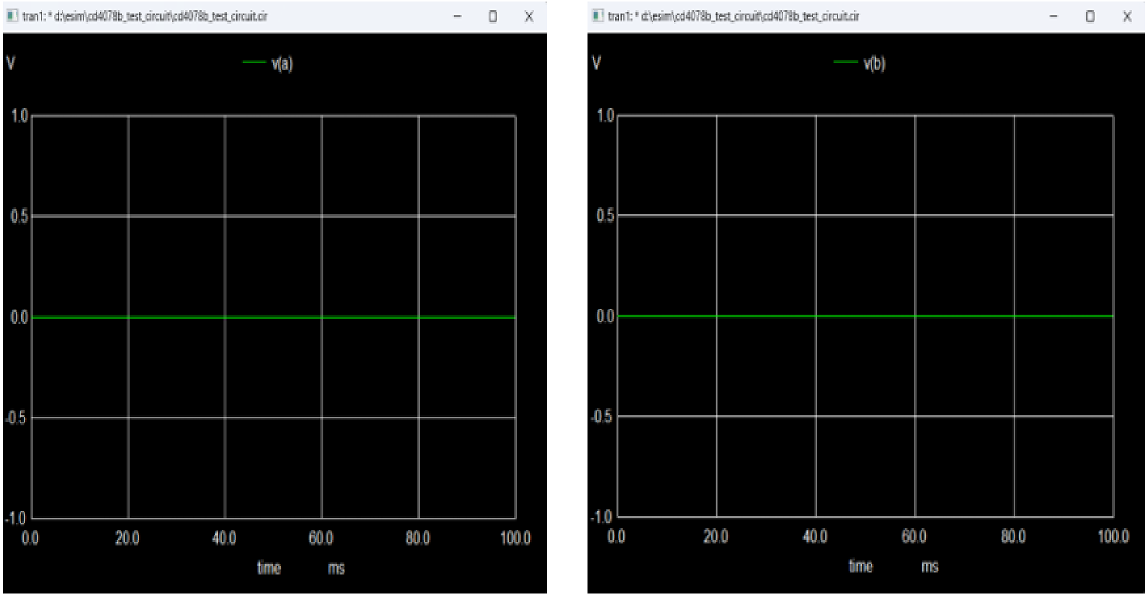


Figure 5.4: Input-1& 2 Voltage Waveform of CD4078B

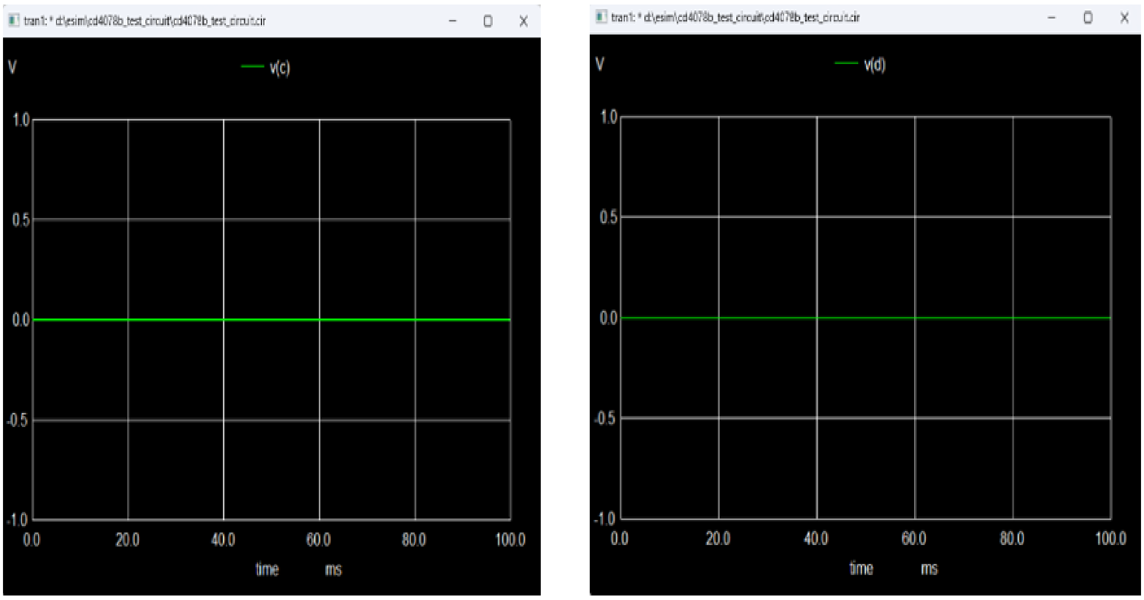


Figure 5.5: Input-3&4 Voltage Waveform of CD4078B

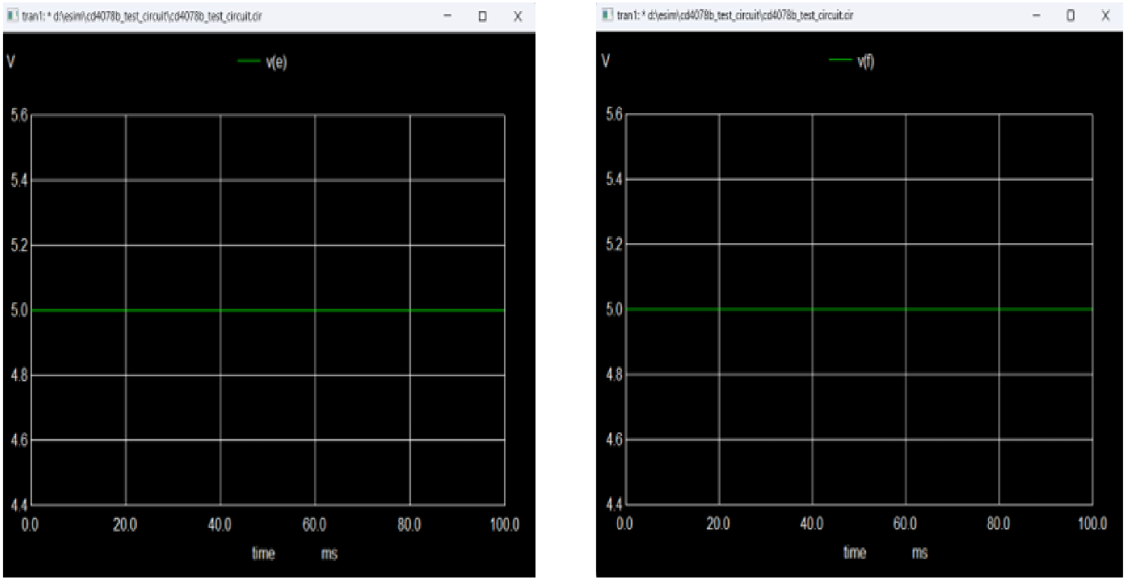


Figure 5.6: Input-5&6 Voltage Waveform of CD4078B

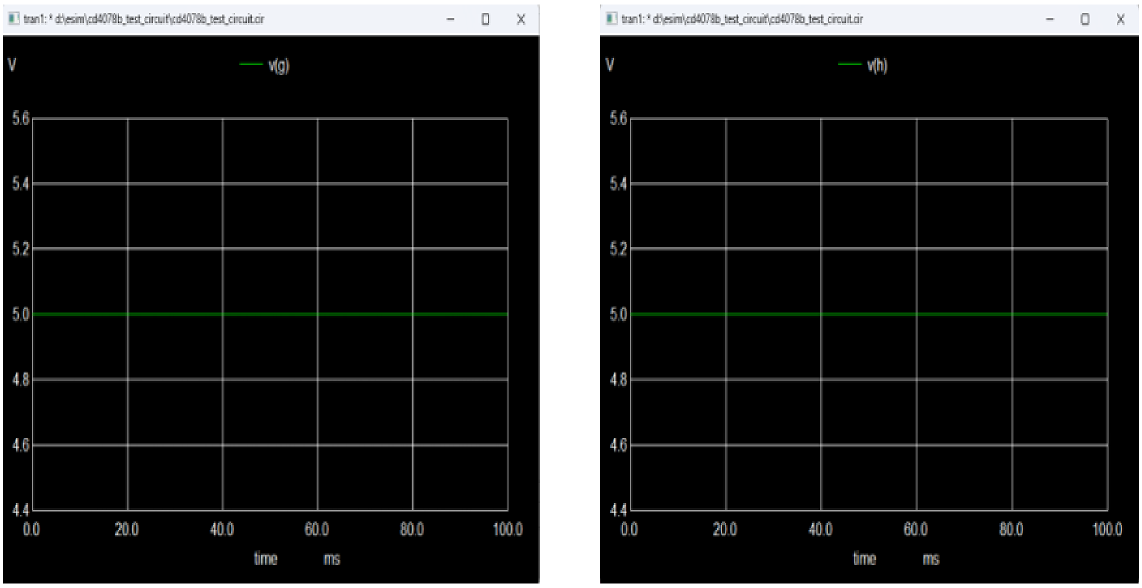


Figure 5.7: Input-7& 8 Voltage Waveform of CD4078B

### 5.1.5 Output Plots

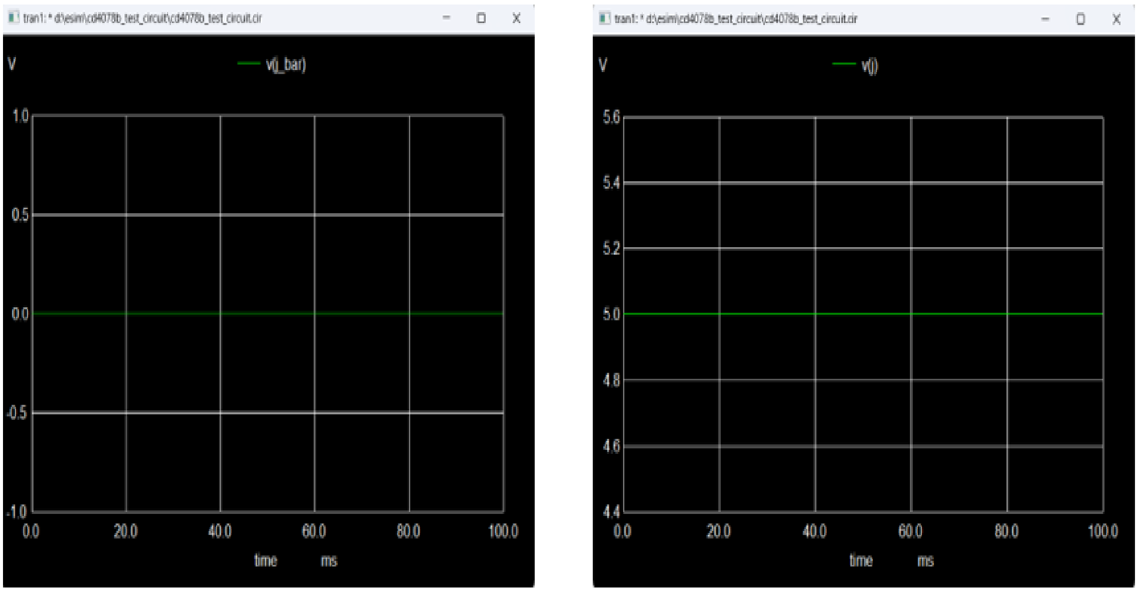


Figure 5.8: Output-1& 2 Voltage Waveform of CD4078B

## 5.2 CD4556BMS

The CD4556BMS IC is a dual 1-of-4 decoder/demultiplexer designed for digital circuit applications. It features two select inputs (A and B), an Enable input (E), and four mutually exclusive outputs for each decoder. The CD4556BMS outputs are low when selected, providing reliable signal routing and control. This IC operates over a wide voltage range, making it compatible with various digital systems.

Applications of the CD4556BMS include data demultiplexing, memory address decoding, and digital signal routing in computers and communication systems. It is also used in control systems where multiple outputs need to be managed by a single input.

Advantages of the CD4556BMS IC include its ability to handle multiple input signals efficiently, reducing the need for additional components in complex digital circuits. The wide operating voltage range enhances its flexibility in different applications. Its low power consumption makes it suitable for energy-efficient designs. Additionally, the IC's robust performance and reliable signal decoding improve the overall efficiency and accuracy of digital systems.

### 5.2.1 IC Layout

This figure represents the 14-Pin Package Diagram of the CD4556BMS dual 1-of-4 decoder

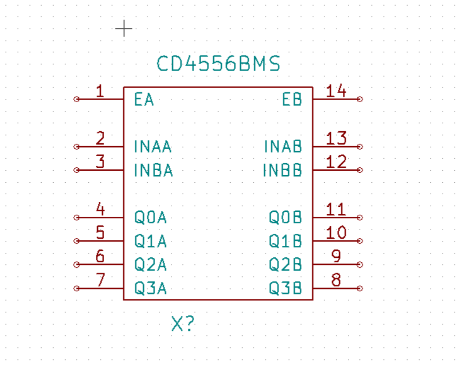


Figure 5.9: CD4556BMS

### 5.2.2 Sub-circuit Schematic Diagram

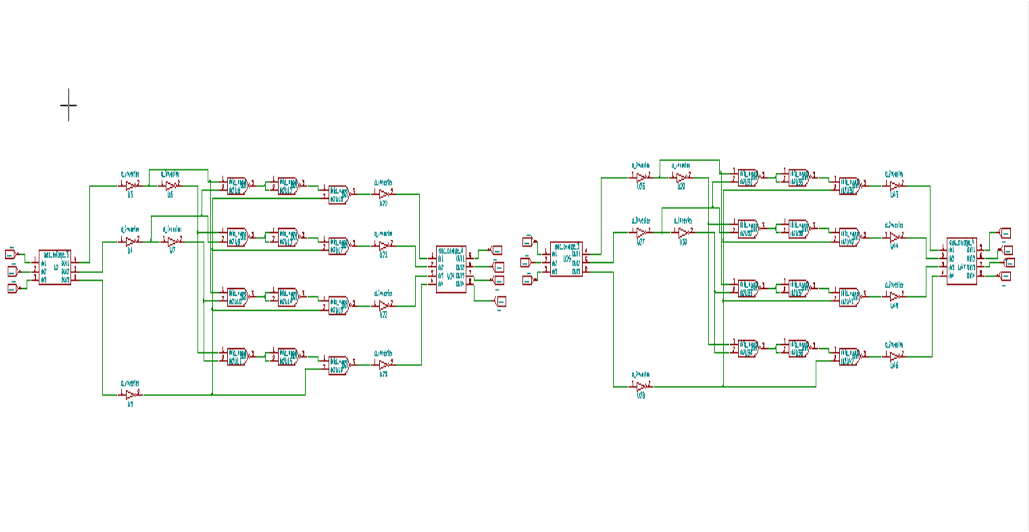

Figure 5.10: Sub-circuit Schematic of CD4556BMS

### 5.2.3 Test Circuit

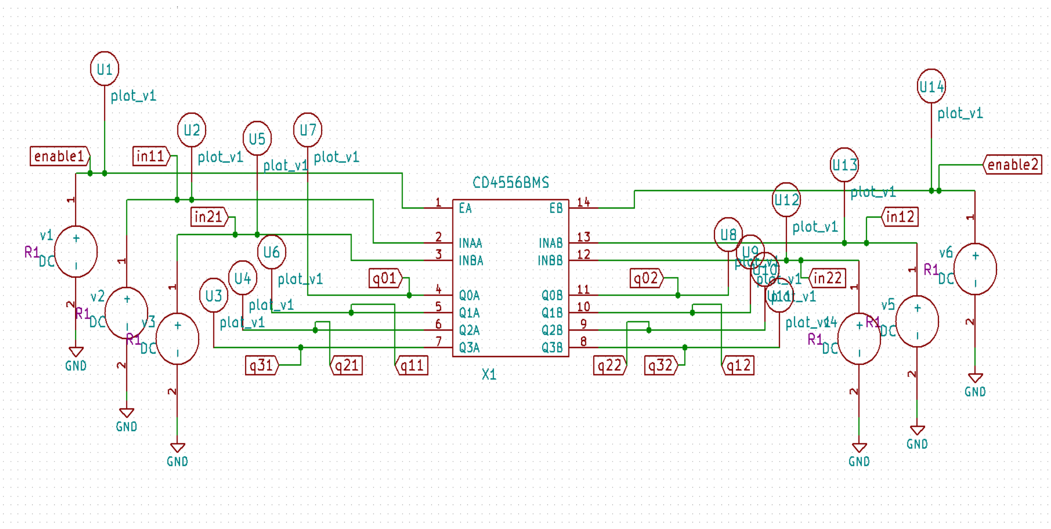


Figure 5.11: Test Circuit of CD4556BMS IC

### 5.2.4 Input Plots

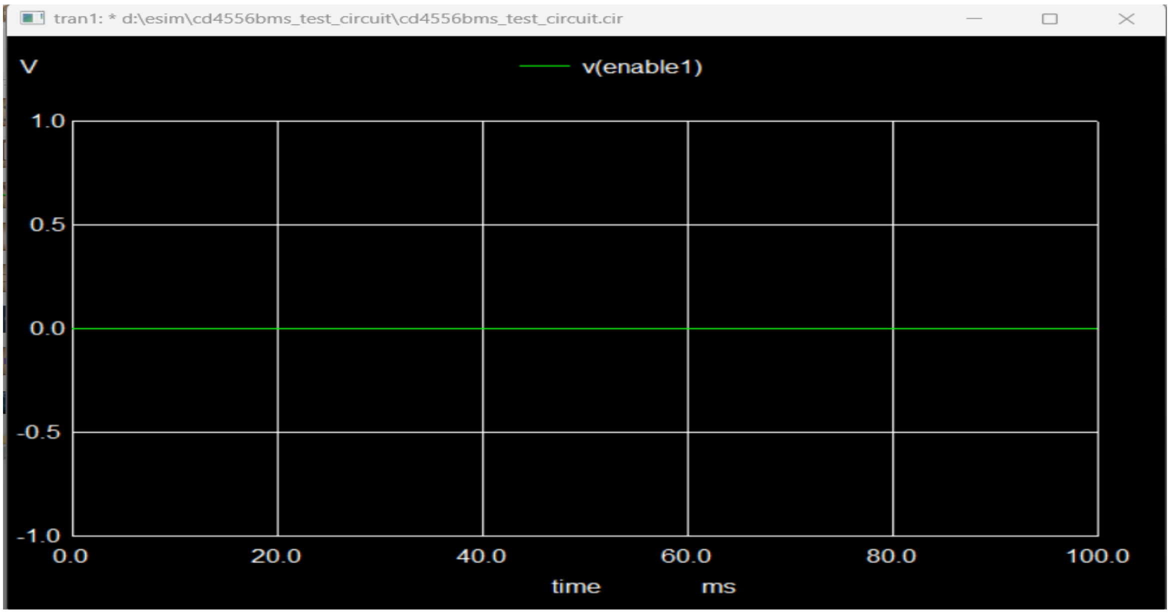


Figure 5.12: Input-1 Voltage Waveform of CD4556BMS

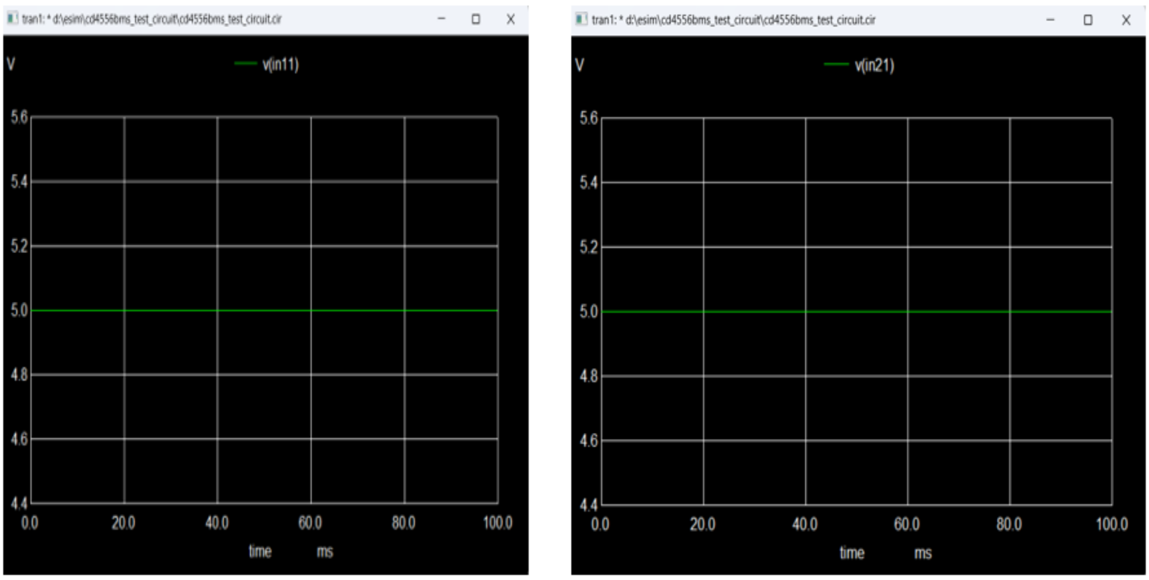


Figure 5.13: Input-2& 3 Voltage Waveform of CD4556BMS

### 5.2.5 Output Plots

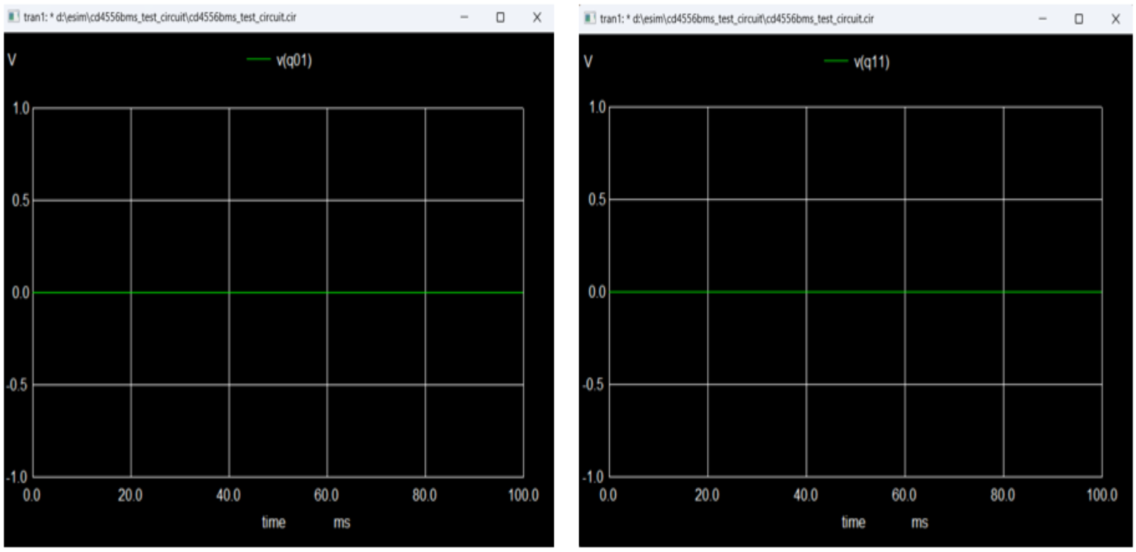


Figure 5.14: Output-1&2 Voltage Waveform of CD4556BMS

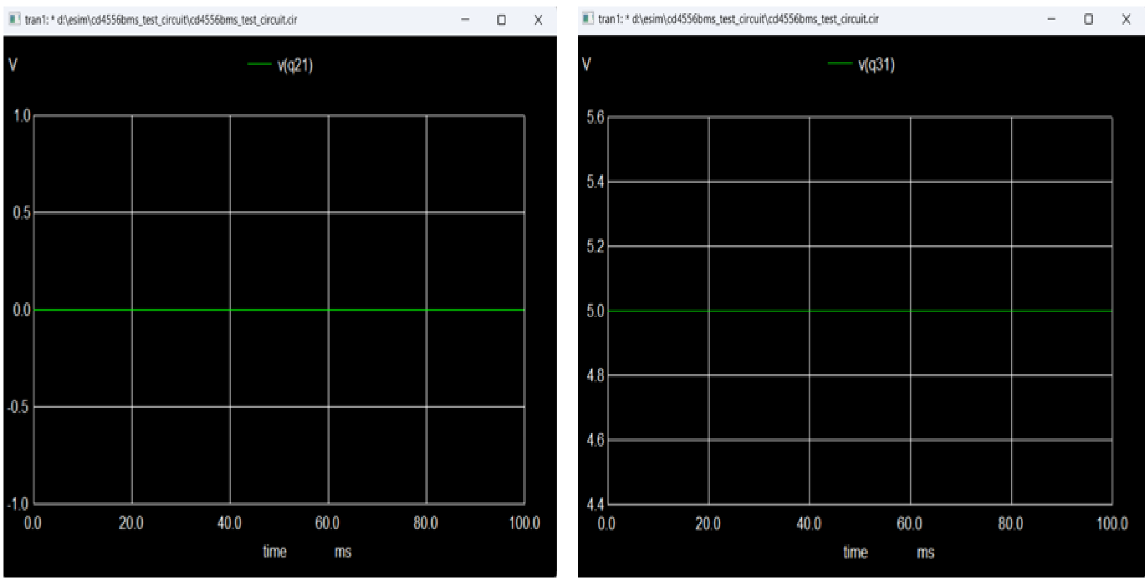


Figure 5.15: Output-3&4 Voltage Waveform of CD4556BMS

## 5.3 SN54147

The SN54147 IC is a priority encoder that converts 10-line decimal inputs into a 4-line BCD (Binary-Coded Decimal) output. It is designed to prioritize inputs, encoding the highest-order active input first, ensuring accurate data conversion. The IC features active-low inputs and outputs, making it compatible with various logic levels and systems.

Applications of the SN54147 include use in digital systems for code conversion, data entry systems, and numerical display devices. It is also commonly used in applications requiring signal prioritization, such as interrupt handling and data routing.

Advantages of the SN54147 IC include its ability to simplify complex input scenarios by encoding multiple input lines into a more manageable binary format. Its priority encoding ensures that the most significant input is always processed first, which is critical in interrupt systems. The active-low inputs and outputs offer flexibility in interfacing with various digital circuits, and its robust design provides reliable performance in diverse applications.

### 5.3.1 IC Layout

This figure represents the 13-Pin Package Diagram of the SN54147 10-line decimal inputs into a 4-line BCD

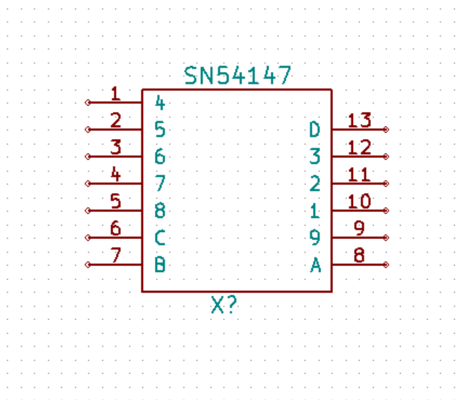


Figure 5.16: SN54147

### 5.3.2 Sub-circuit Schematic Diagram

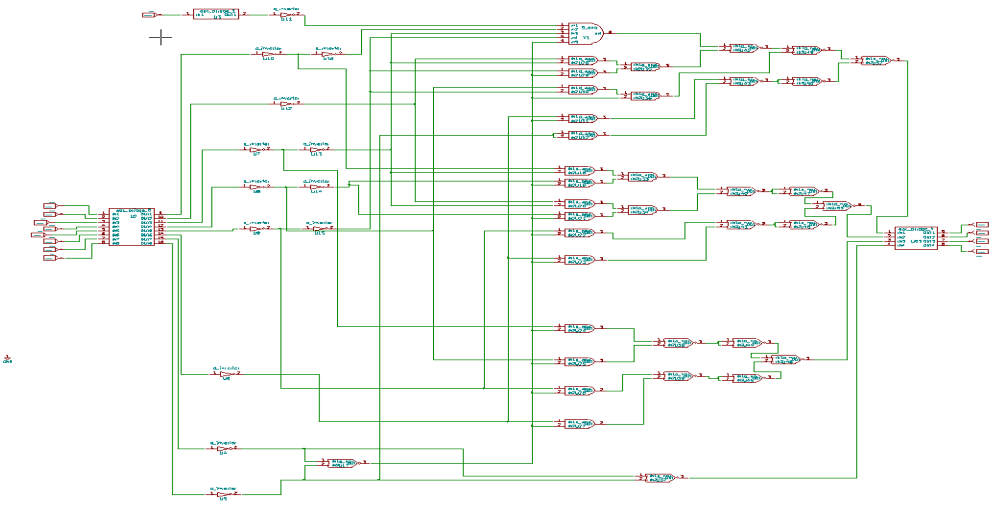

Figure 5.17: Sub-circuit Schematic of SN54147

### 5.3.3 Test Circuit

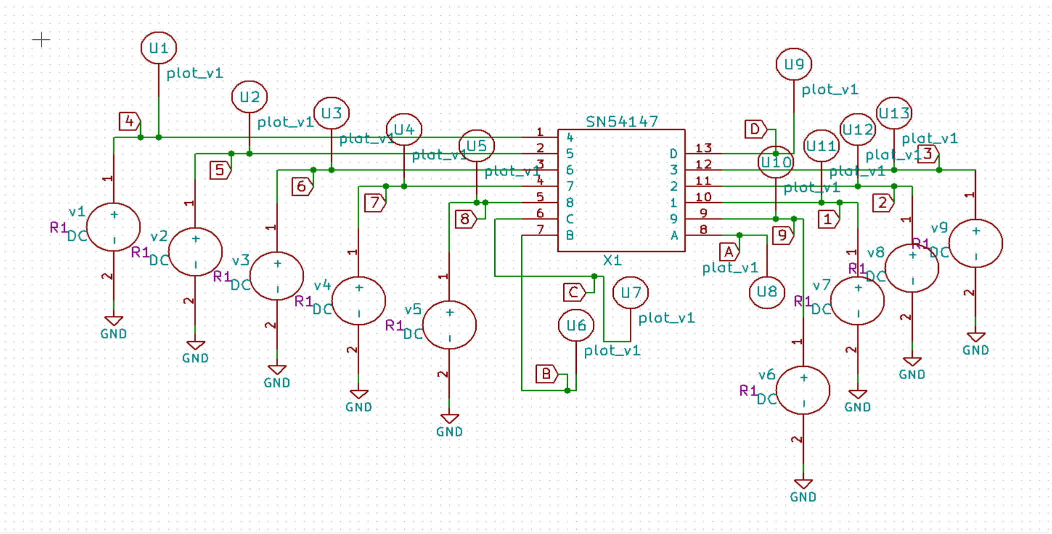


Figure 5.18: Test Circuit of SN54147 IC

### 5.3.4 Input Plots

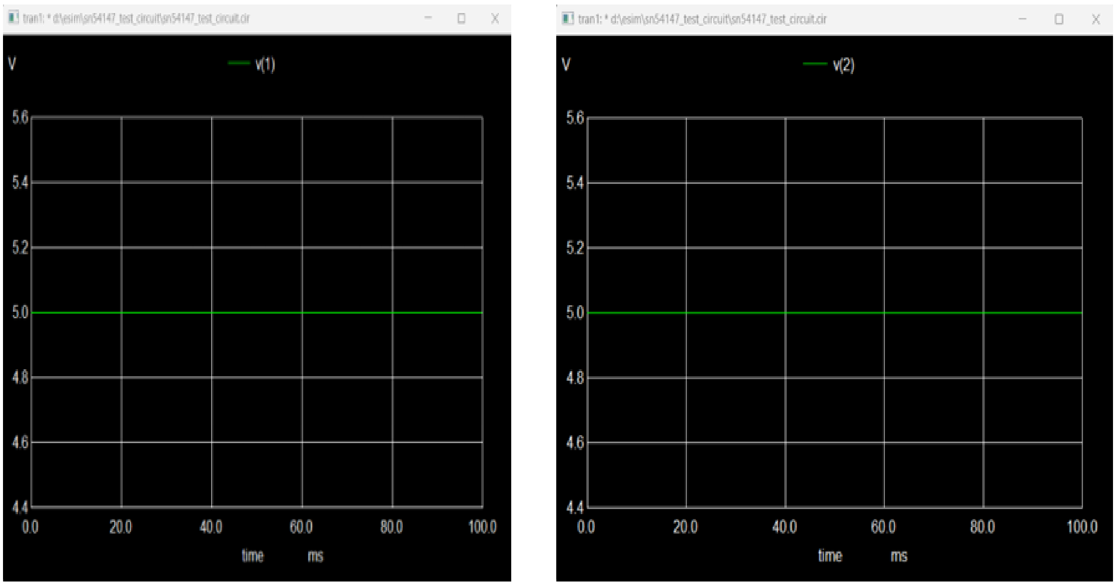


Figure 5.19: Input-1& 2 Voltage Waveform of SN54147

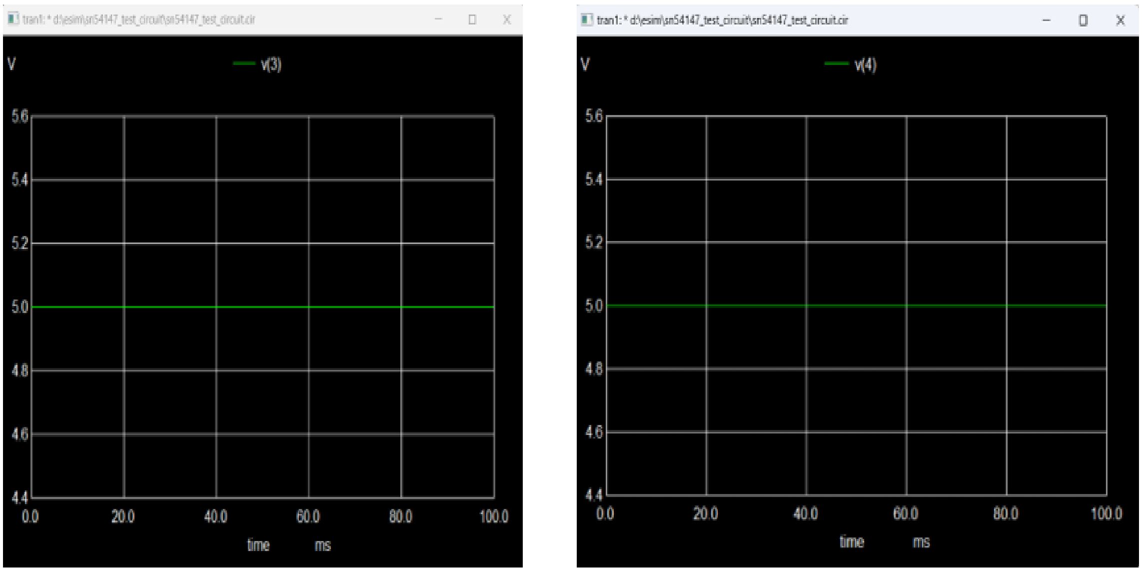


Figure 5.20: Input-3& 4 Voltage Waveform of SN54147

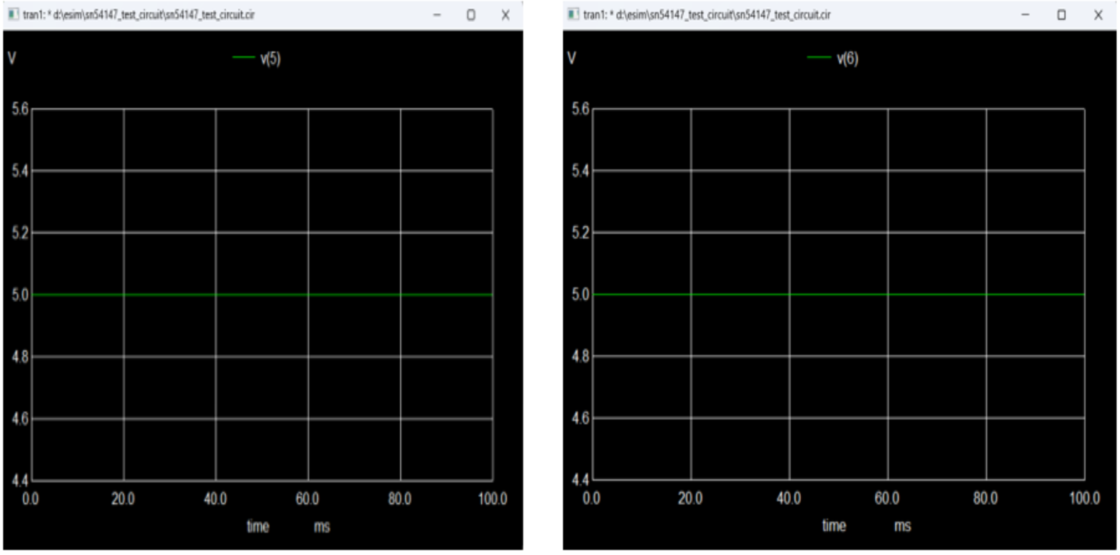


Figure 5.21: Input-5& 6 Voltage Waveform of SN54147

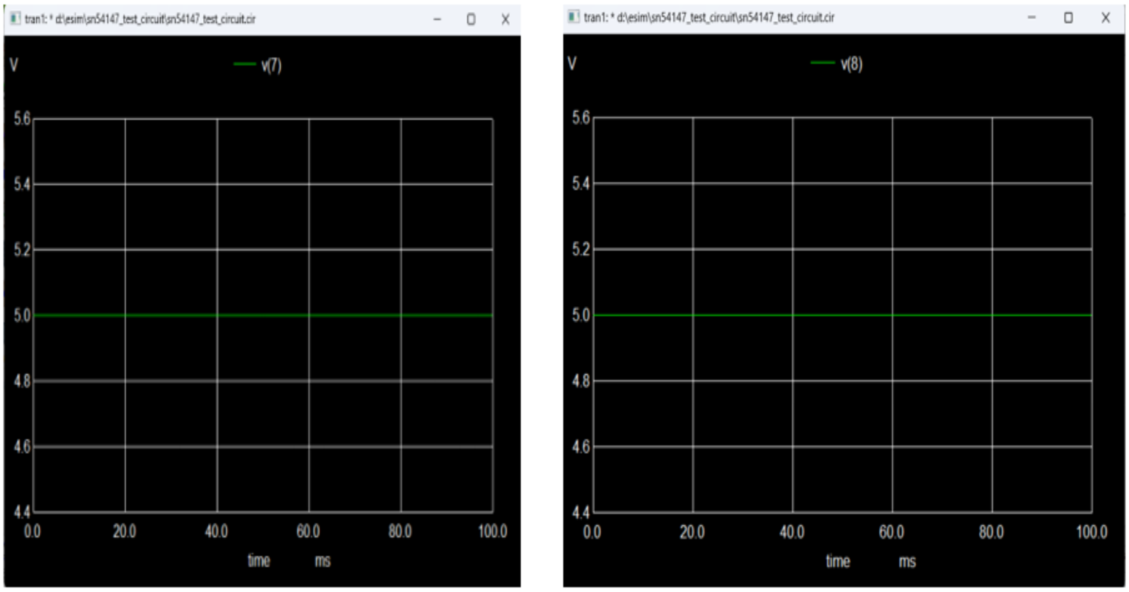


Figure 5.22: Input-7& 8 Voltage Waveform of SN54147

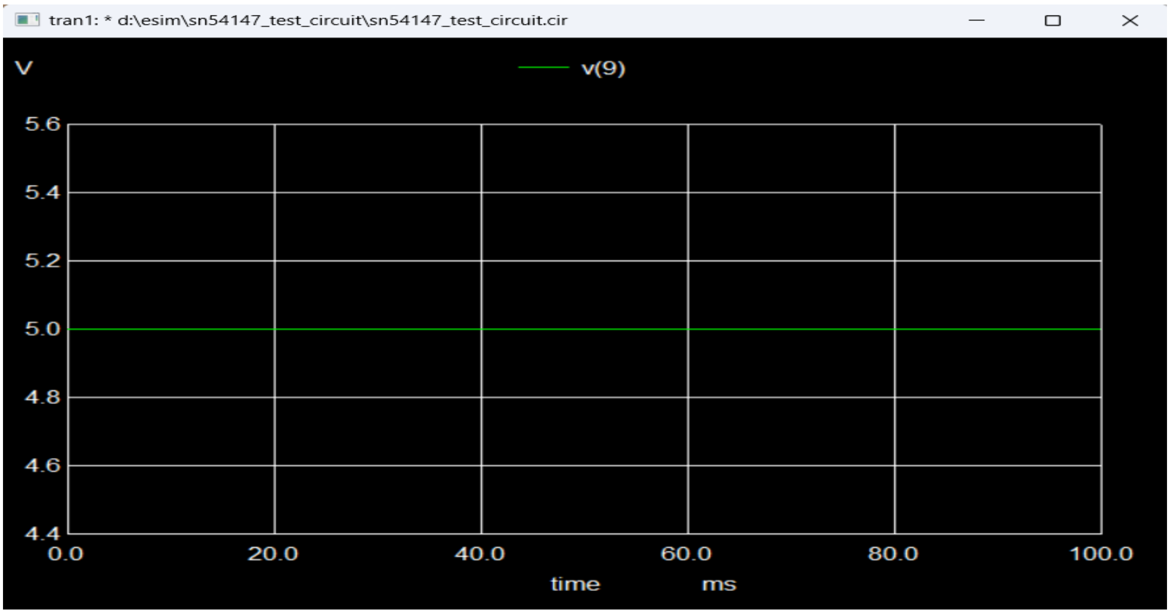


Figure 5.23: Input-9 Voltage Waveform of SN54147

### 5.3.5 Output Plots

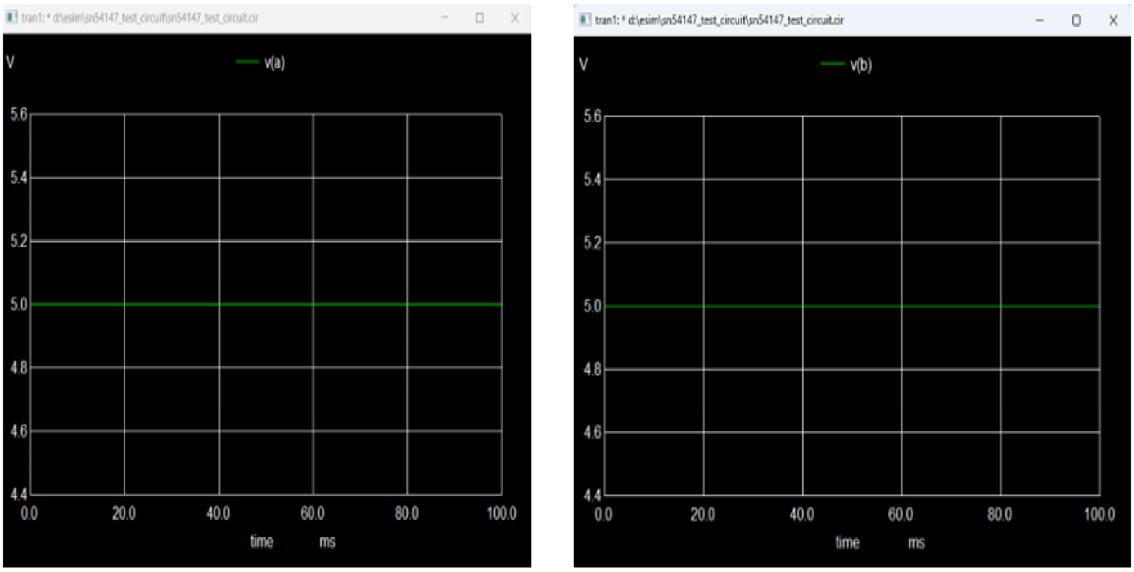


Figure 5.24: Output-1& 2 Voltage Waveform of SN54147

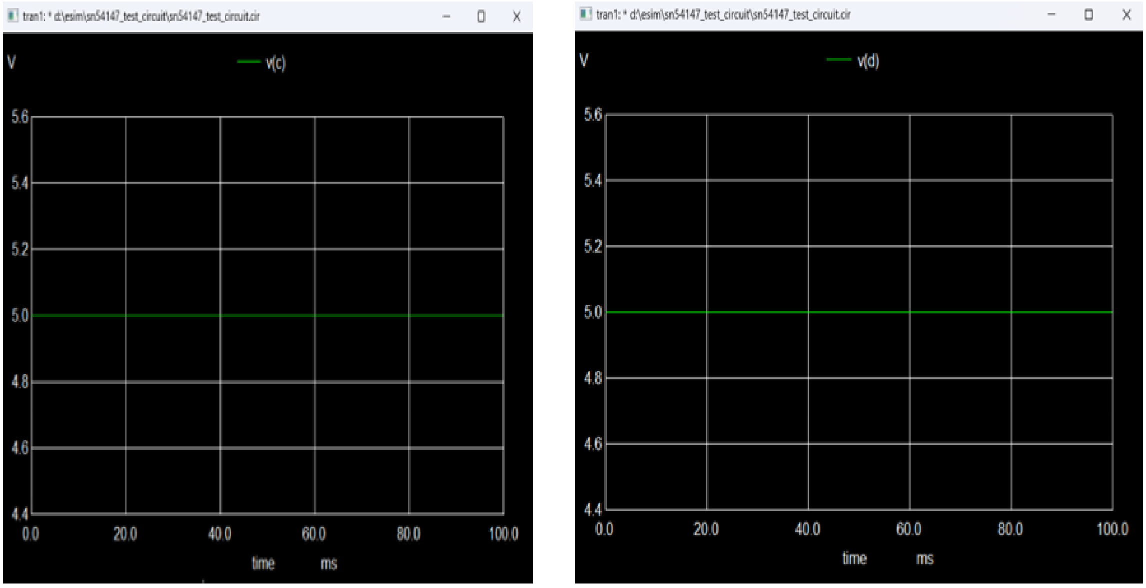


Figure 5.25: Output-3& 4 Voltage Waveform of SN54147

## 5.4 SN74LS148

The SN74LS148 IC is an 8-line to 3-line priority encoder designed to convert eight active-low input signals into a 3-bit binary output. It prioritizes the highest-order active input, ensuring that the most significant signal is encoded first. The IC also features cascading capability, allowing multiple units to be linked for larger encoding tasks, making it versatile for complex digital systems.

Applications of the SN74LS148 include data compression, code conversion, and interrupt handling in microprocessor systems. It is also used in digital circuits requiring input signal prioritization and efficient data routing.

Advantages of the SN74LS148 IC include its ability to prioritize and reduce multiple input lines to a simpler binary output, streamlining data processing. Its active-low inputs and outputs make it compatible with a wide range of logic families. Additionally, the IC's cascading feature allows for scalability in larger systems, enhancing its flexibility and utility in various digital applications.

### 5.4.1 IC Layout

This figure represents the 14-Pin Package Diagram of the SN74LS148 IC is an 8-line to 3-line priority encoder

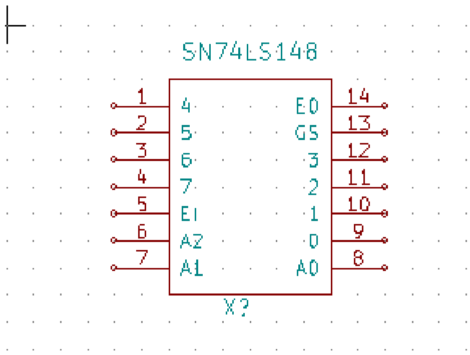


Figure 5.26: SN74LS148

### 5.4.2 Sub-circuit Schematic Diagram

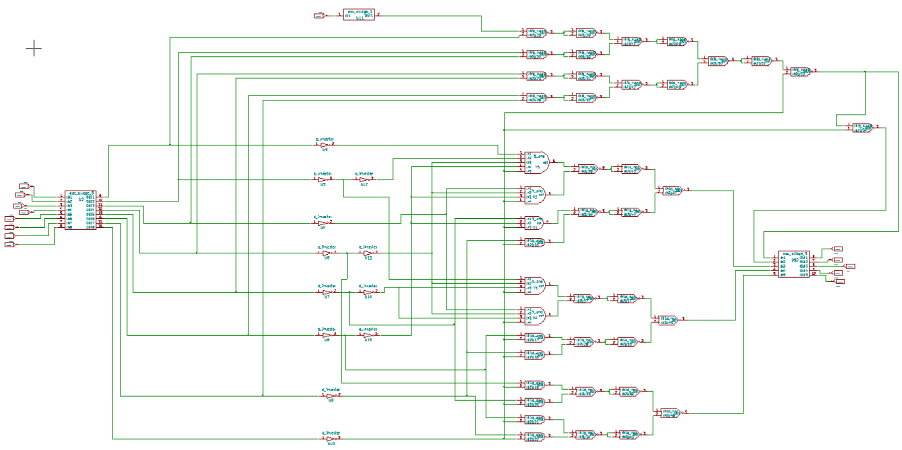

Figure 5.27: Sub-circuit Schematic of SN74LS148

### 5.4.3 Test Circuit

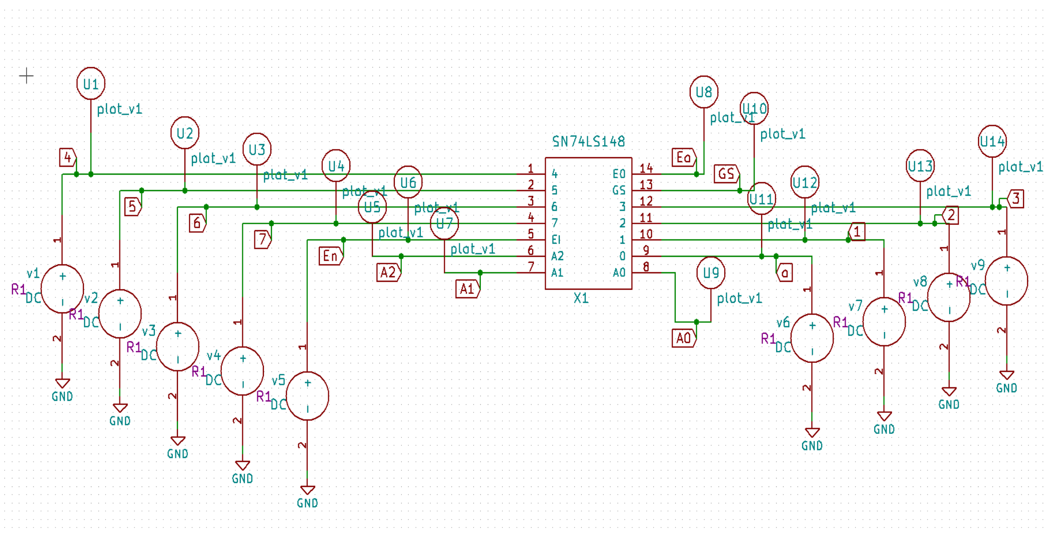


Figure 5.28: Test Circuit of SN74LS148 IC

### 5.4.4 Input Plots

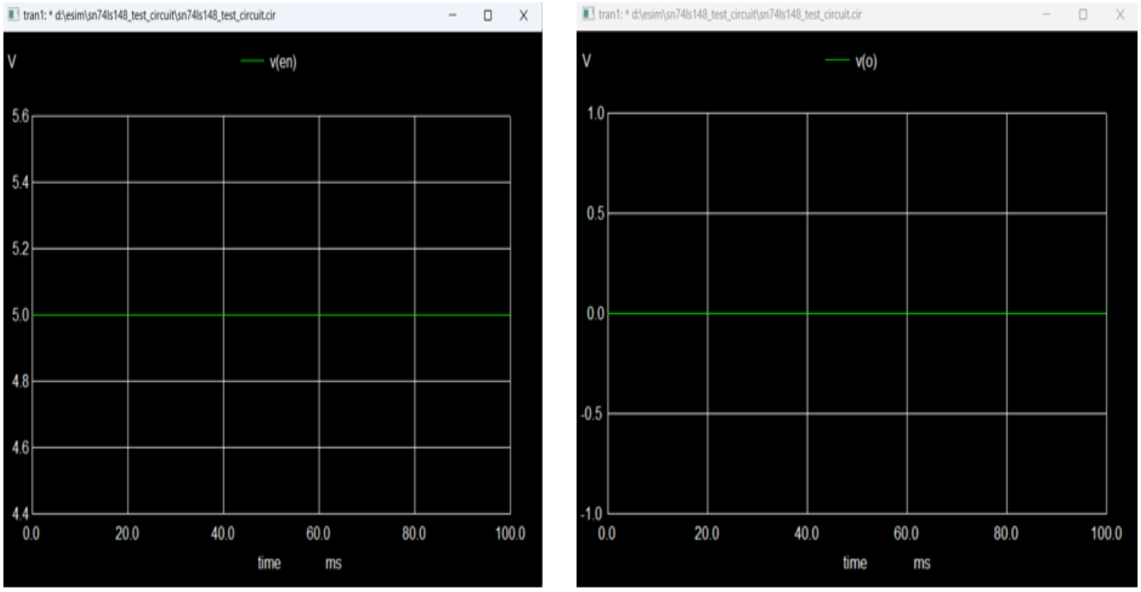


Figure 5.29: Input-1& 2 Voltage Waveform of SN74LS148

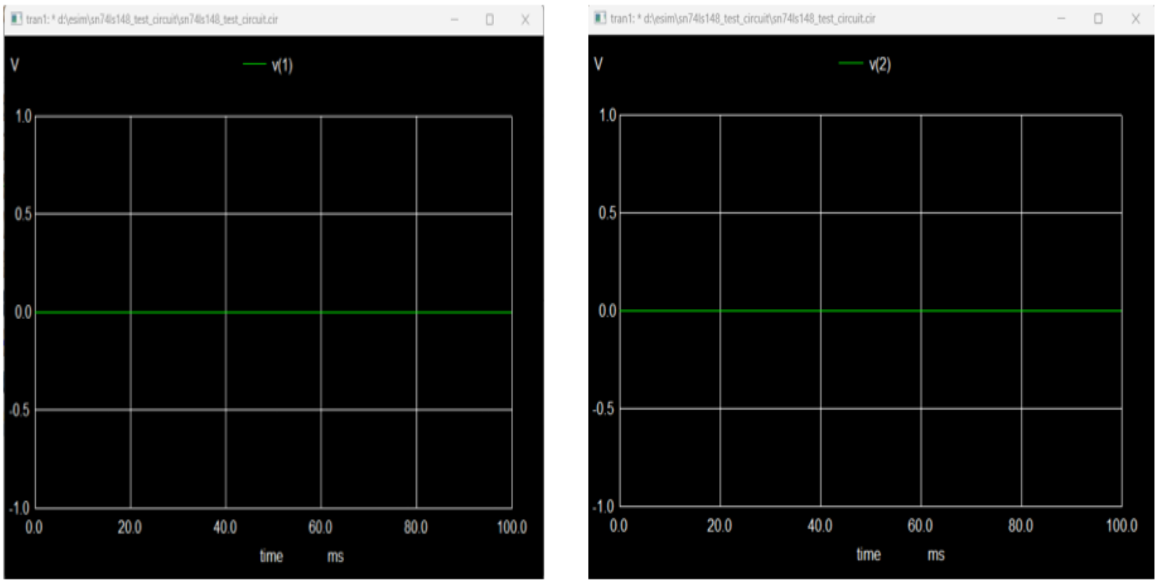


Figure 5.30: Input-3& 4 Voltage Waveform of SN74LS148

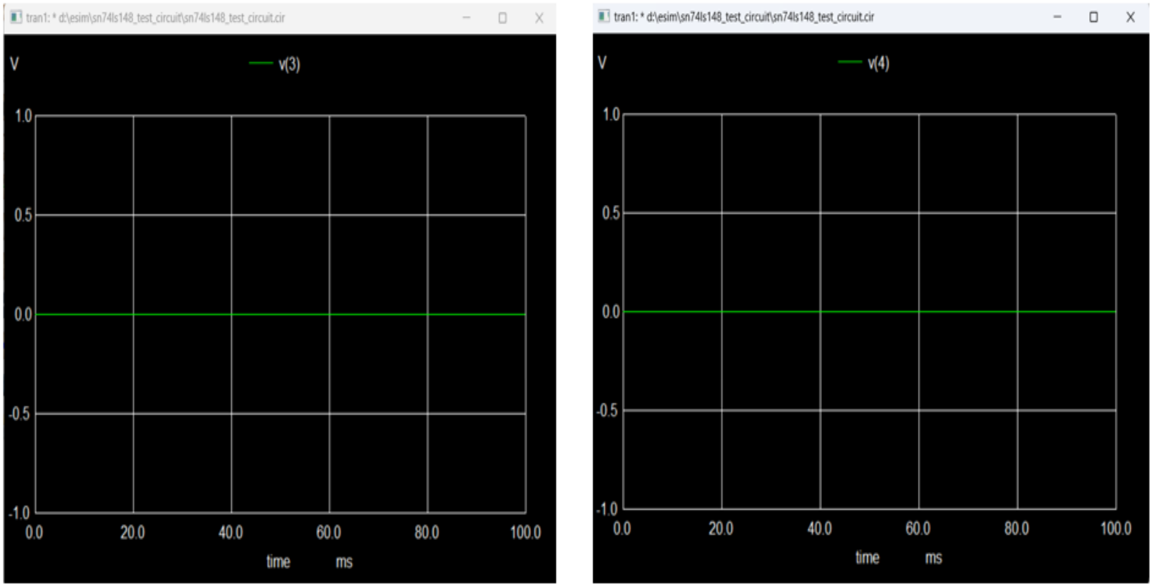


Figure 5.31: Input-5&6 Voltage Waveform of SN74LS148

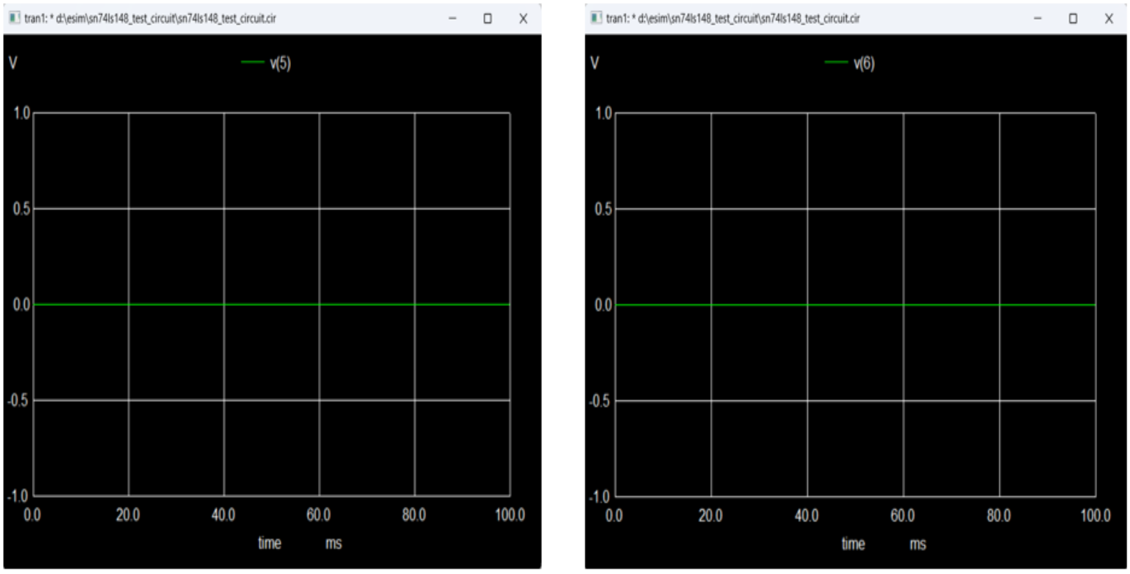


Figure 5.32: Input-7& 8 Voltage Waveform of SN74LS148

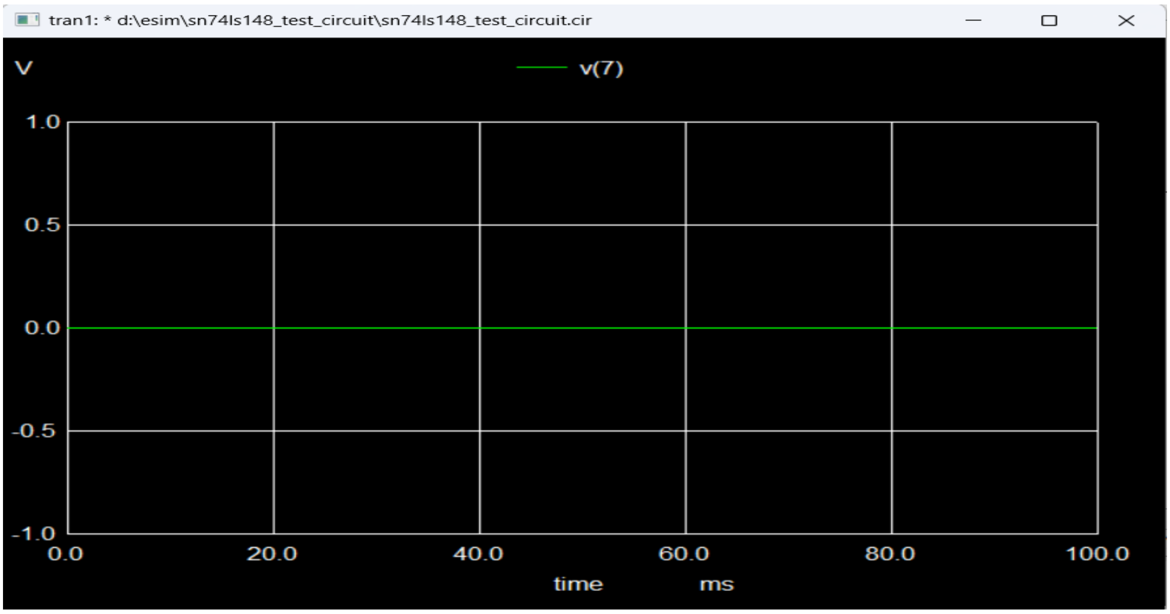


Figure 5.33: Input-9 Voltage Waveform of SN74LS148

### 5.4.5 Output Plots

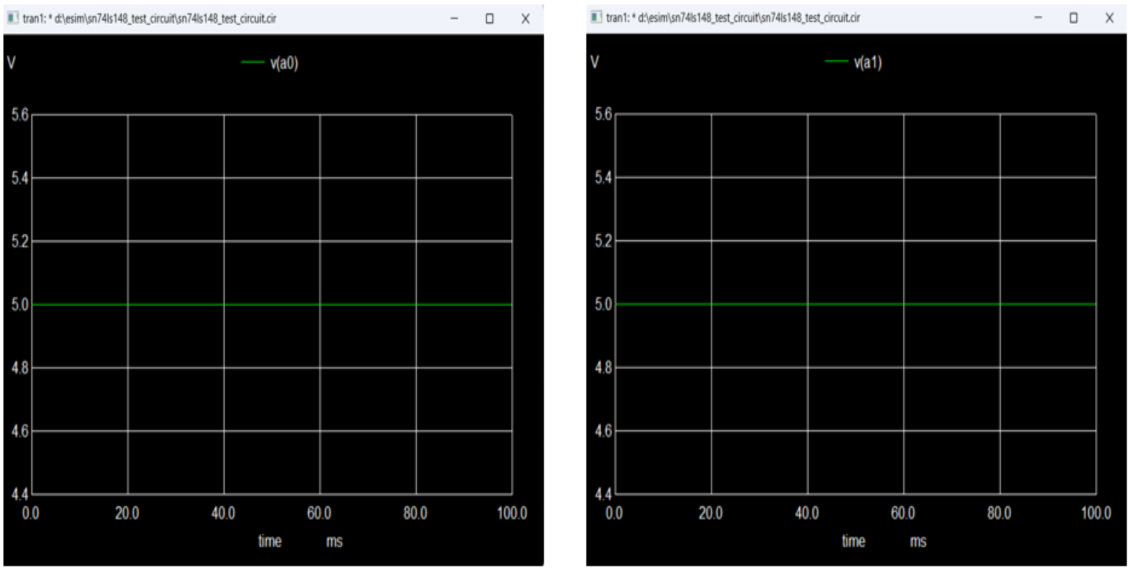


Figure 5.34: Output-1& 2 Voltage Waveform of SN74LS148

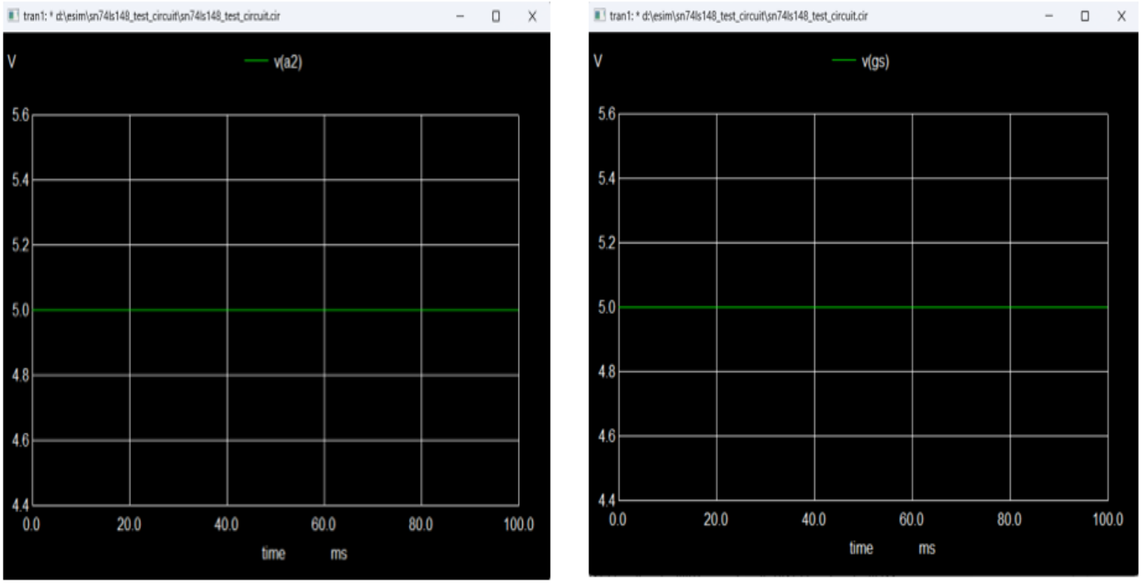


Figure 5.35: Output-3& 4 Voltage Waveform of SN74LS148

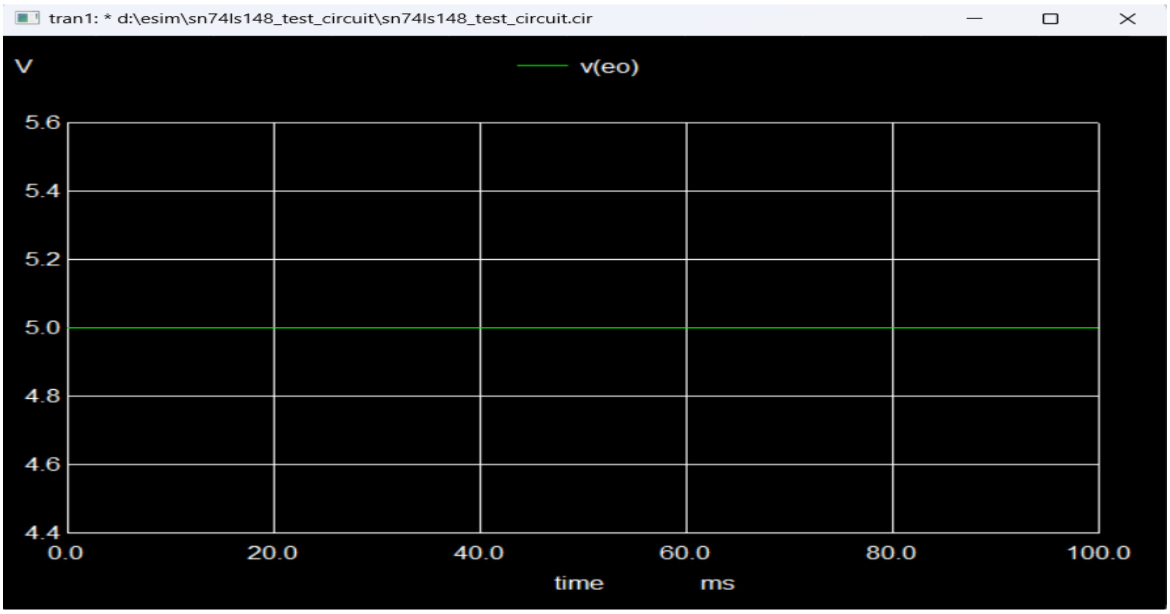


Figure 5.36: Output-5 Voltage Waveform of SN74LS148

## 5.5 SN5442A

The SN5442A IC is a BCD (Binary-Coded Decimal) to 10-line decimal decoder designed to convert a 4-bit binary input into one of ten active-low decimal outputs. This IC is particularly useful in driving numerical displays, such as LED or LCD readouts, by directly translating binary inputs into corresponding decimal digits.

Applications of the SN5442A include digital clocks, calculators, and other numerical display systems where binary data needs to be converted into a readable decimal format. It is also used in data routing and selection circuits within digital systems.

Advantages of the SN5442A IC include its ability to simplify the connection between binary-encoded data and display devices, reducing the need for complex wiring. The active-low outputs are compatible with a wide range of display technologies. Additionally, the IC provides reliable and accurate decoding, making it a valuable component in applications requiring clear and precise numerical representation.

### 5.5.1 IC Layout

This figure represents the 14-Pin Package Diagram of the SN5442A IC 4-line BCD to 10-line decimal decoder.

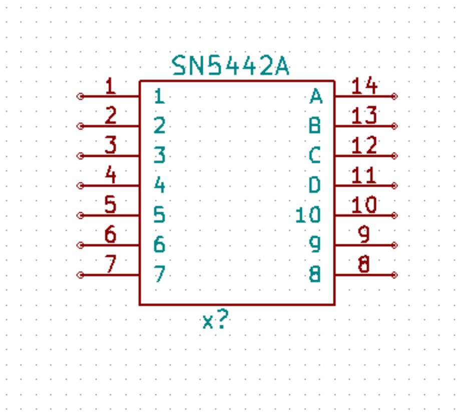


Figure 5.37: SN5442A

### 5.5.2 Sub-circuit Schematic Diagram

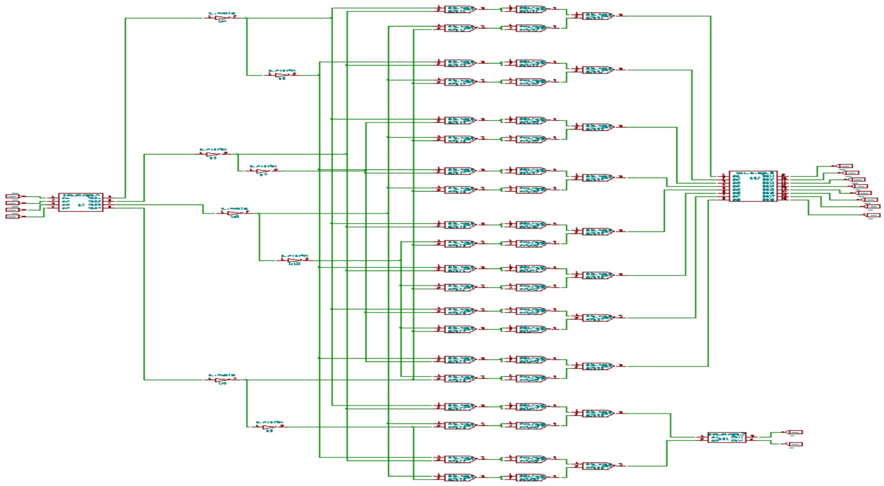

Figure 5.38: Sub-circuit Schematic of SN5442A

### 5.5.3 Test Circuit

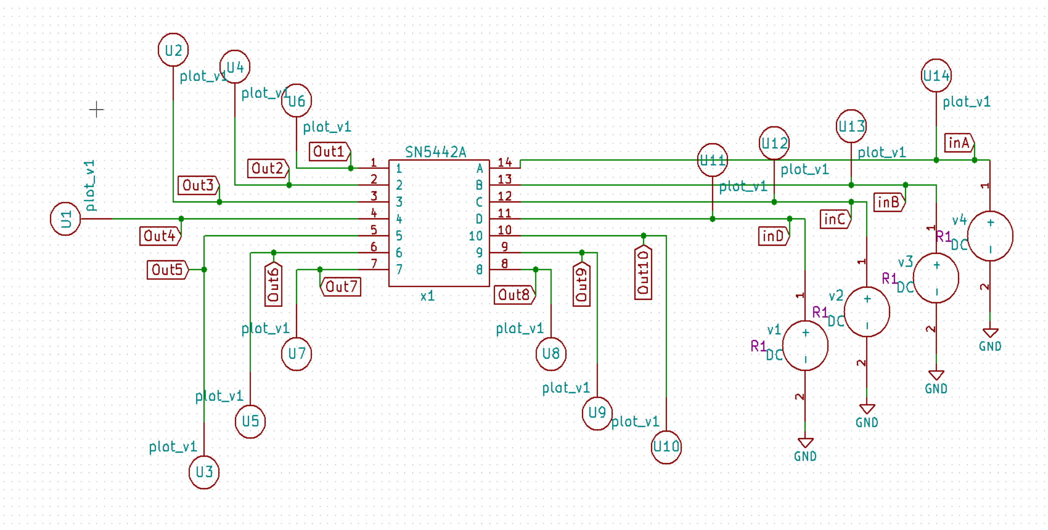


Figure 5.39: Test Circuit of SN5442A I

### 5.5.4 Input Plots

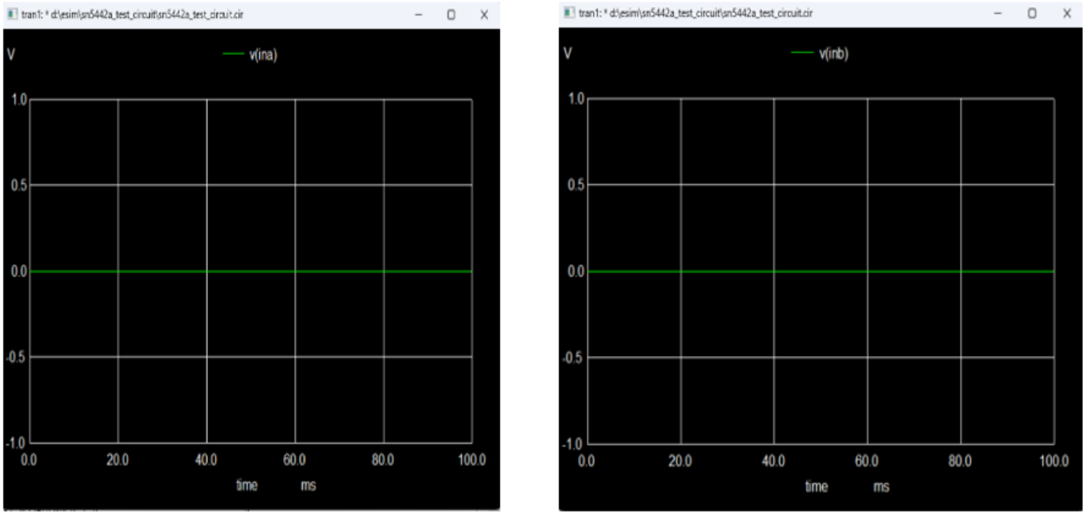


Figure 5.40: Input-1& 2 Voltage Waveform of SN5442A

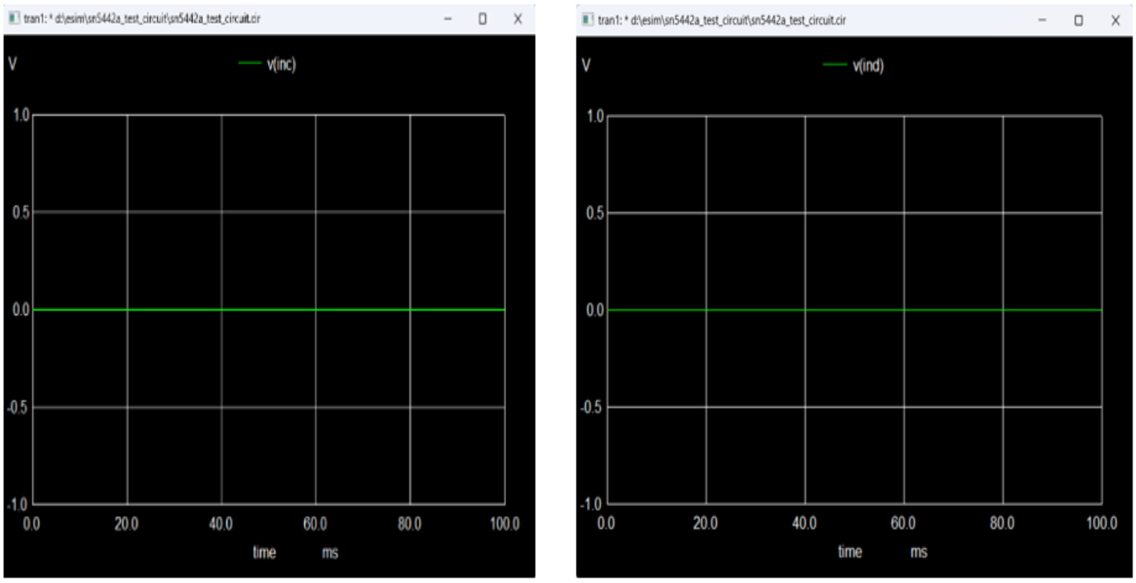


Figure 5.41: Input-3& 4 Voltage Waveform of SN5442A

### 5.5.5 Output Plots

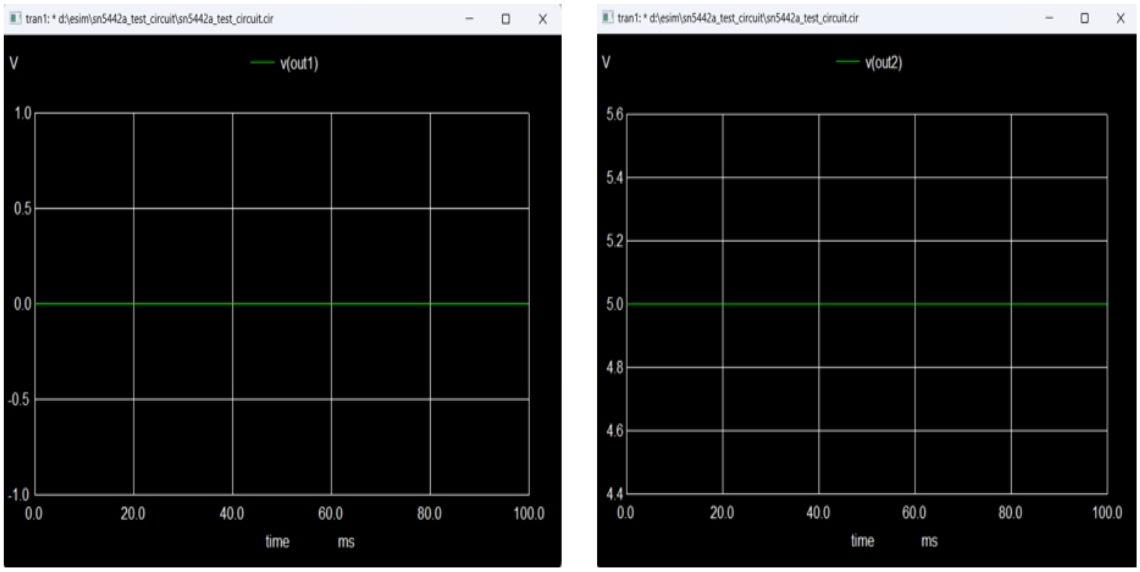


Figure 5.42: Output-1& 2 Voltage Waveform of SN5442A Ic

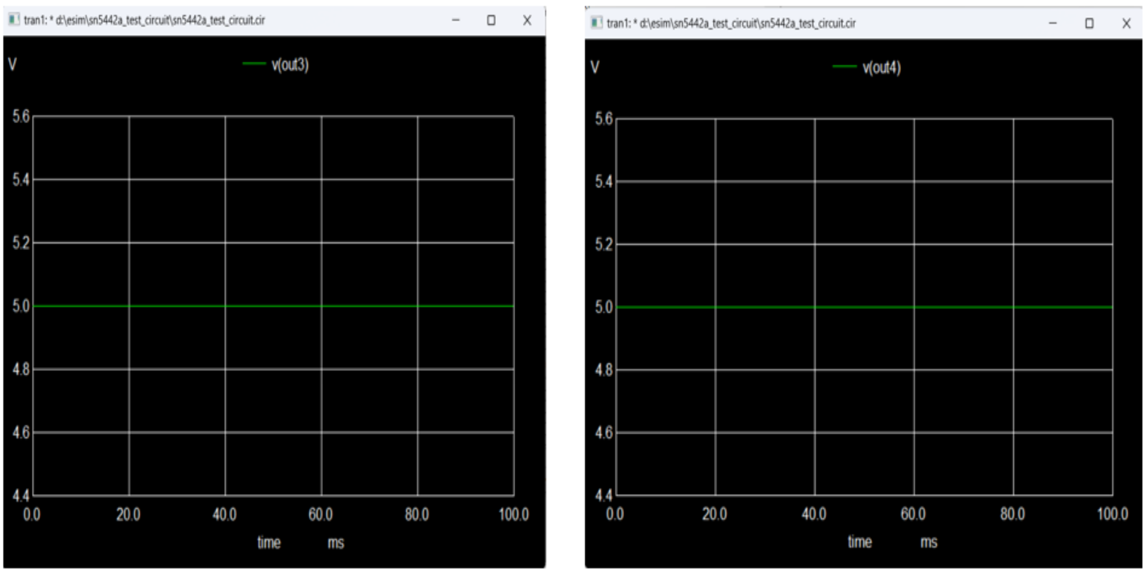


Figure 5.43: Output-3& 4 Voltage Waveform of SN5442A Ic

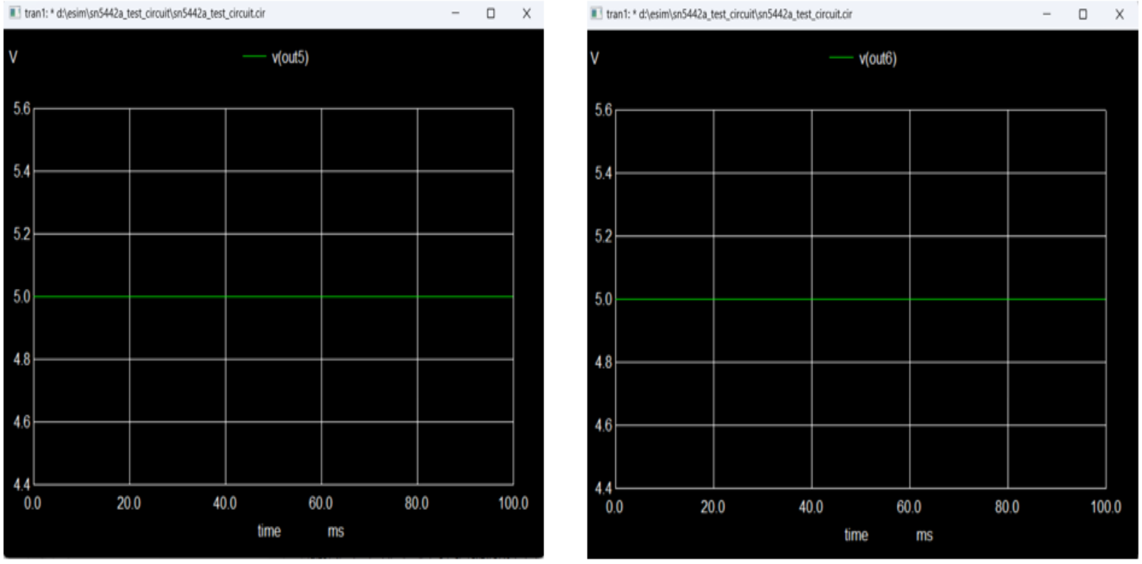


Figure 5.44: Output-5& 6 Voltage Waveform of SN5442A Ic

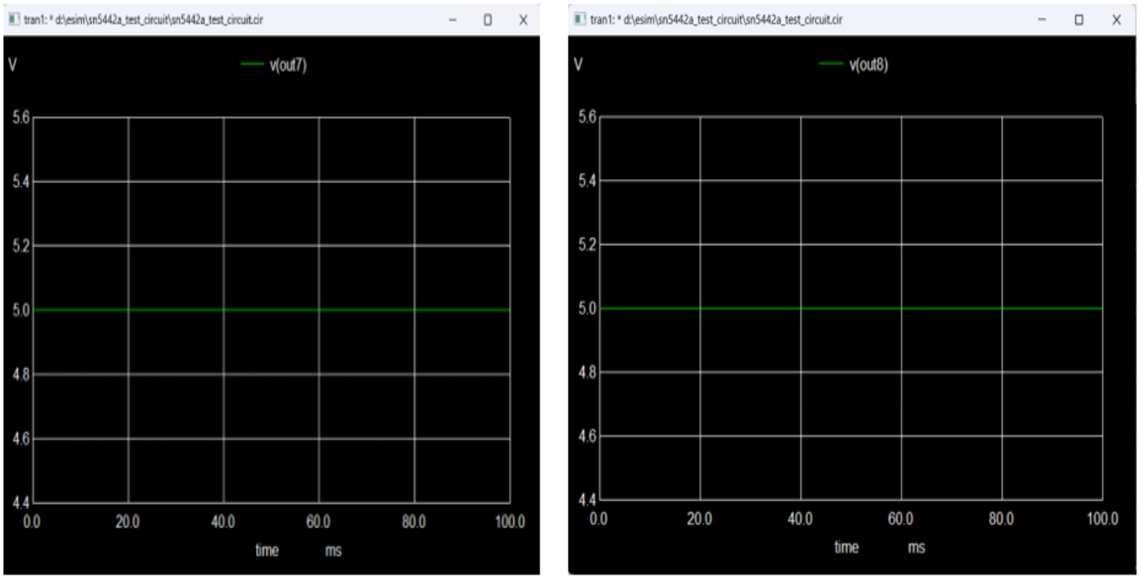


Figure 5.45: Output-7& 8 Voltage Waveform of SN5442A Ic

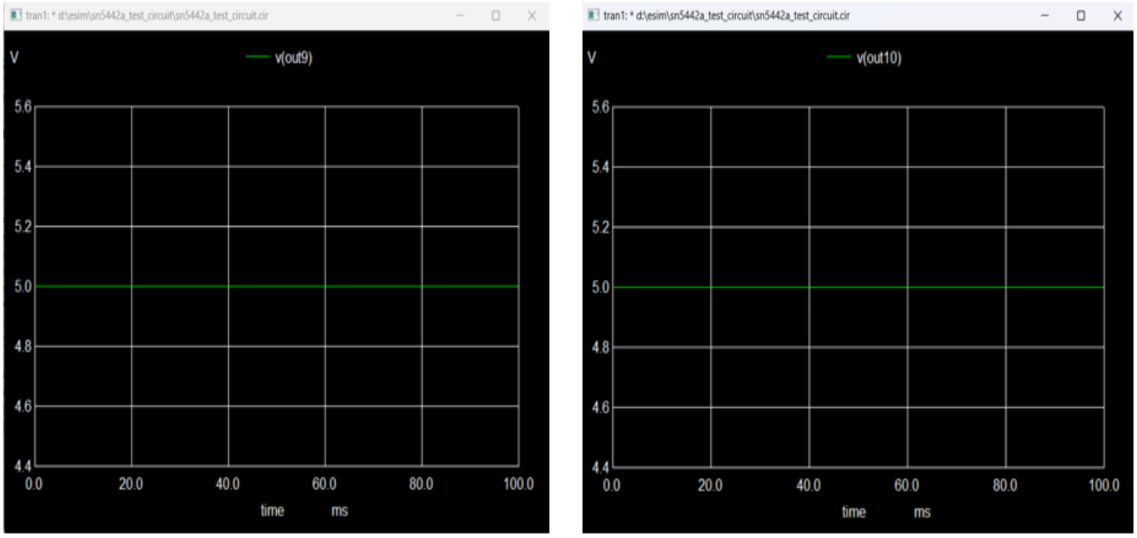


Figure 5.46: Output-9& 10 Voltage Waveform of SN5442A Ic

# Chapter 6

# Conclusion and Future Scope

We were successful to achieve the target of developing various subcircuits for both Analog and Digital Integrated Circuits. Each Integrated Circuit Model was developed strictly according to the information contained in their official data-sheets.The output of each IC was verified and tested successfully with the help of their test circuits. All of these IC Models, developed under this Fellowship are very basic circuit units, such as Op-Amps, Voltage Regulators, Precision Rectifier, Schmitt Trigger, Differential Amplifier, Instrumentation Amplifier, Comparator, Multiplexer, DeMultiplexer and various Logic gate ICs. Each of these ICs is ready to be integrated in the subcircuit library of eSim. Developers and Students can use these ICs in their projects and circuit models as units. With the development and expansion of the device model library in eSim, We expect more such ready to use IC models be developed to be used in eSim.

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