Summer Fellowship Report

On

Integrated Circuit Design using Subcircuit feature of eSim

Submitted by

Sudheshna P

Under the guidance of

Mr. Sumanto Kar
Assistant Project Manager, FOSSEE
IIT Bombay

Prof. Kannan M. Moudgalya
Chemical Engineering Department
IIT Bombay

September 8, 2024

Acknowledgment

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

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

I would like to express my heartfelt appreciation to the entire FOSSEE team including our mentor Mr. Sumanto Kar for constantly guiding and mentoring me throughout the duration of the internship.

It is with their support that I have been able to fulfill our project demands successfully. Whenever faced with an issue, our mentors were always accessible to help me assess and debug them. My learnings from them have been invaluable and shall be of paramount importance to me 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 me in our pursuit of a successful career.

Contents

1 Introduction 5
- 1.1 eSim 5
- 1.2 NgSpice 6
- 1.3 Makerchip 6

2 Feautures Of eSim 7

3 Problem Statement 8
- 3.1 Approach 8

4 Analog IC's 10
- 4.1 LM384 - 5W Audio Power Amplifier 10
  - 4.1.1 IC Layout 10
  - 4.1.2 Subcircuit Schematic Diagram 11
  - 4.1.3 Test Circuit 11
  - 4.1.4 Input Plots 12
  - 4.1.5 Output Plots 12
- 4.2 LM110 - Voltage Follower 13
  - 4.2.1 IC Layout 13
  - 4.2.2 Subcircuit Schematic Diagram 14
  - 4.2.3 Test Circuit 14
  - 4.2.4 Input Plots 15
  - 4.2.5 Output Plots 15
- 4.3 CA3140 - BiMOS Operational Amplifier with MOSFET Input/Bipolar Output 16
  - 4.3.1 IC Layout 16
  - 4.3.2 Subcircuit Schematic Diagram 17
  - 4.3.3 Test Circuit 17
  - 4.3.4 Input Plots 18
  - 4.3.5 Output Plots 18
- 4.4 LM102 - Voltage Follower 19
  - 4.4.1 IC Layout 19
  - 4.4.2 Subcircuit Schematic Diagram 20
  - 4.4.3 Test Circuit 20
  - 4.4.4 Input Plots 21
  - 4.4.5 Output Plots 21
- 4.5 LM111 - Differential Comparator 22

4.5.1 IC Layout 22
4.5.2 Subcircuit Schematic Diagram 23
4.5.3 Test Circuit 23
4.5.4 Input Plots 24
4.5.5 Output Plots 24
4.6 LM123 - Positive Voltage Regulator 25
4.6.1 IC Layout 25
4.6.2 Subcircuit Schematic Diagram 26
4.6.3 Test Circuit 26
4.6.4 Input Plots 27
4.6.5 Output Plots 27
4.7 LM380 - 2.5W Audio Power Amplifier 28
4.7.1 IC Layout 28
4.7.2 Subcircuit Schematic Diagram 29
4.7.3 Test Circuit 29
4.7.4 Input Plots 30
4.7.5 Output Plots 30
4.8 LM341 - Linear voltage regulator 31
4.8.1 IC Layout 31
4.8.2 Subcircuit Schematic Diagram 32
4.8.3 Test Circuit 32
4.8.4 Input Plots 33
4.8.5 Output Plots 33
4.9 LM323A - 3-Amp, 5-Volt Positive Regulator 34
4.9.1 IC Layout 34
4.9.2 Subcircuit Schematic Diagram 35
4.9.3 Test Circuit 35
4.9.4 Input Plots 36
4.9.5 Output Plots 36

5 Digital IC's 37
5.1 SN7445 - BCD-To-Decimal Decoders/Drivers 37
5.1.1 IC Layout 37
5.1.2 Subcircuit Schematic Diagram 38
5.1.3 Test Circuit 38
5.1.4 Input Plots 39
5.1.5 Output Plots 39
5.2 SN7483A - 4 bit binary fully adder with fast carry 40
5.2.1 IC Layout 40
5.2.2 Subcircuit Schematic Diagram 41
5.2.3 Test Circuit 41
5.2.4 Input Plots 42
5.2.5 Output Plots 42
5.3 74HC688 43
5.3.1 IC Layout 43
5.3.2 Subcircuit Schematic Diagram 44
5.3.3 Test Circuit 44

5.3.4 Input Plots 45
5.3.5 Output Plots 45

Bibliography **46**

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. 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.

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 sub-circuits 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 subcircuit 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 data-sheets 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 LM384 - 5W Audio Power Amplifier

The LM384 is a power audio amplifier designed for consumer applications. To minimize system costs, it has an internally fixed gain of 34 dB. Its unique input stage allows for ground-referenced input signals, and the output automatically centers itself at half the supply voltage. The amplifier is protected against short circuits and includes

internal thermal limiting. It comes in a standard dual-in-line package with a copper lead frame, where the center three pins on either side serve as a heat sink. This design facilitates easy integration into standard printed circuit layouts. The LM384 is suitable

for applications such as simple phonograph amplifiers, intercoms, line drivers, teaching machine outputs, alarms, ultrasonic drivers, TV sound systems, AM-FM radios, and sound projector systems.

4.1.1 IC Layout

This figure represents the Pin Package Diagram of LM384 ic

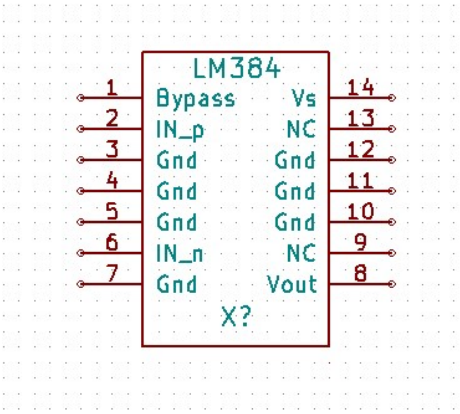

Figure 4.1: Pin diagram of LM384

4.1.2 Subcircuit Schematic Diagram

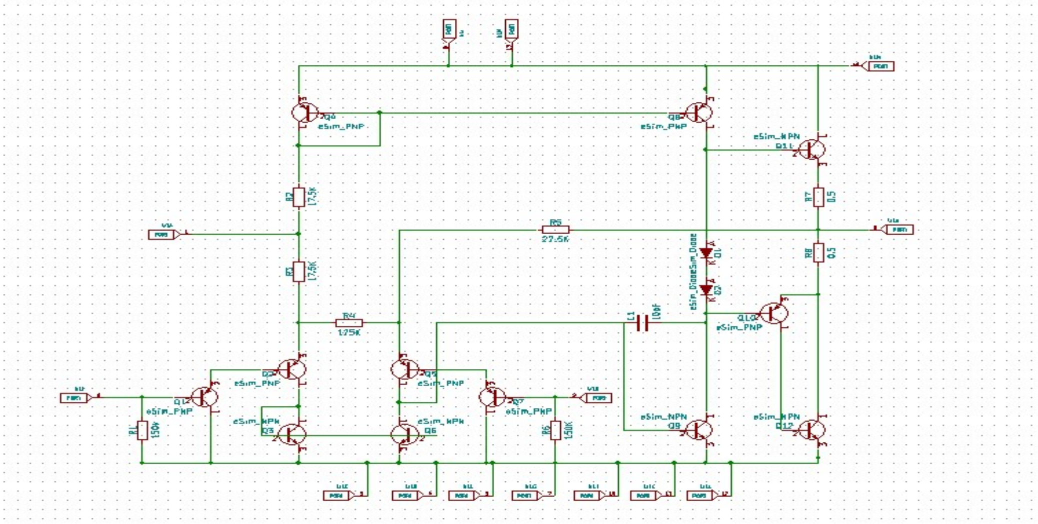

Figure 4.2: Subcircuit Schematic of LM384

4.1.3 Test Circuit

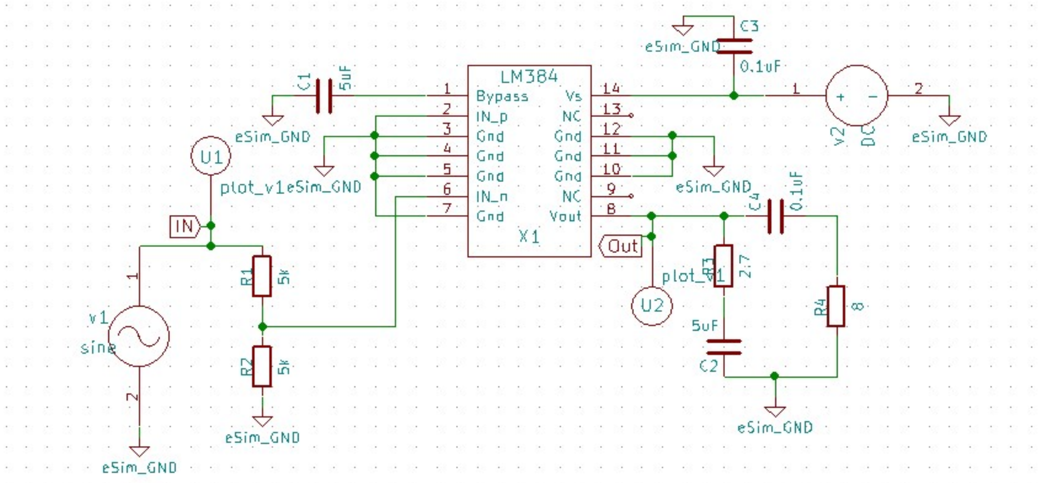

Figure 4.3: Test Circuit of LM384 IC

4.1.4 Input Plots

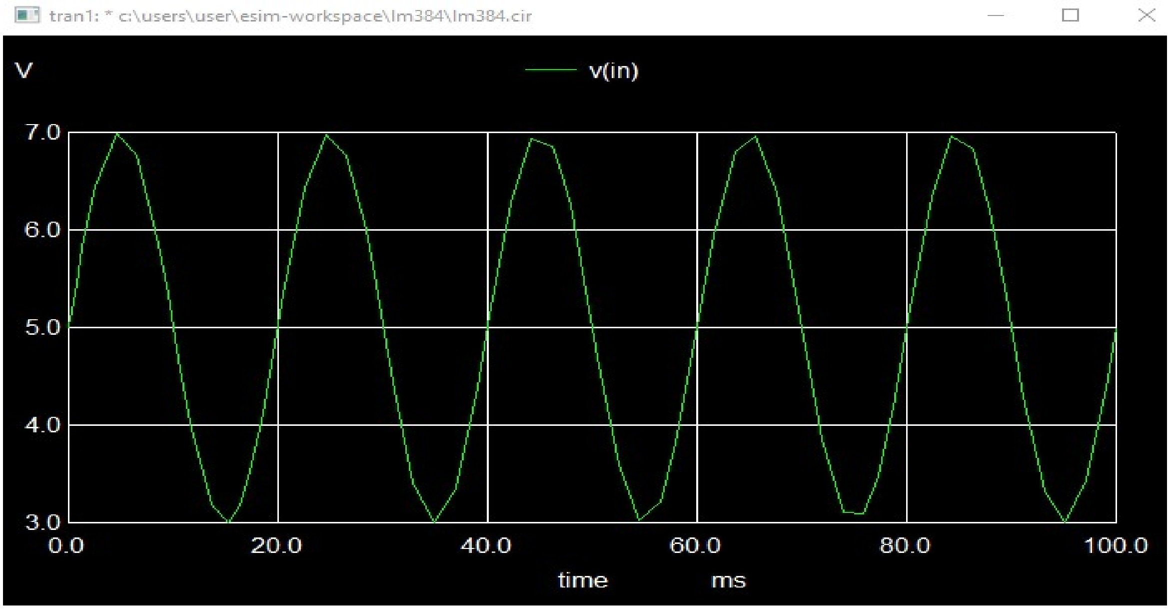

Figure 4.4: Input Voltage Waveform of LM384

4.1.5 Output Plots

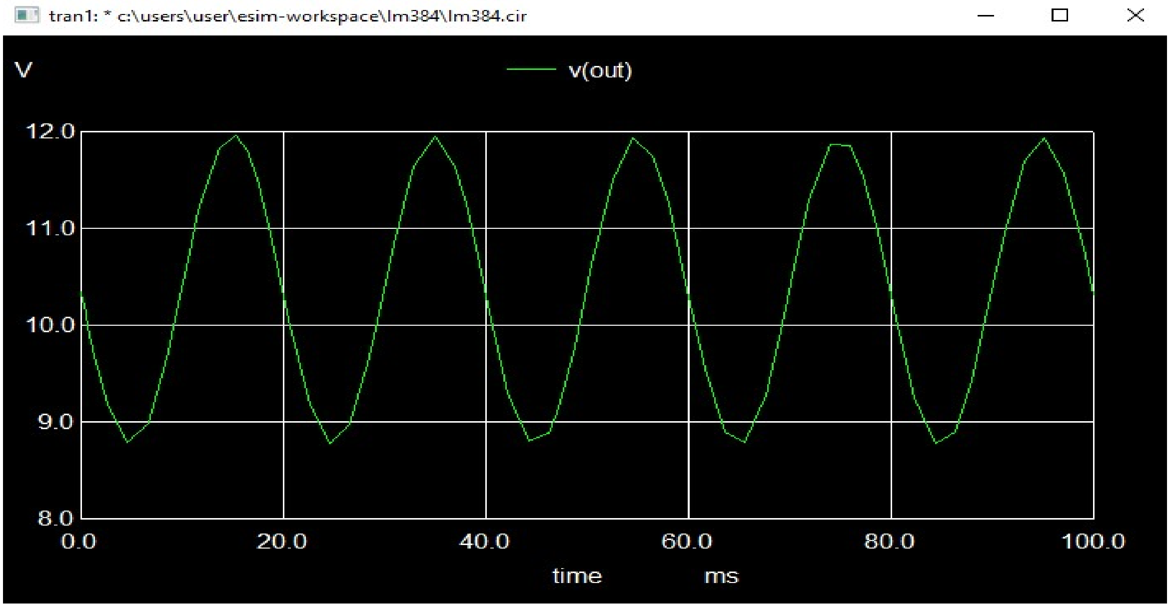

Figure 4.5: Output Voltage Waveform of LM384

4.2 LM110 - Voltage Follower

The LM110 series are monolithic operational amplifiers configured internally as unity-gain non-inverting amplifiers. They utilize super-gain transistors in the input stage to achieve low bias current while maintaining speed. These amplifiers are directly interchangeable with the 101, 741, and 709 models in voltage follower applications. They feature internal frequency compensation and options for offset balancing. The LM110 series is ideal for fast sample-and-hold circuits, active filters, and general-purpose buffers. Their enhanced frequency response, compared to standard IC amplifiers, allows them to be included in feedback loops without causing instability.

4.2.1 IC Layout

This figure represents the Pin Package Diagram of LM110

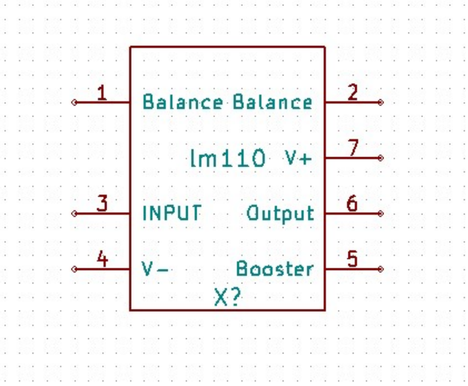

Figure 4.6: Pin diagram of LM110

4.2.2 Subcircuit Schematic Diagram

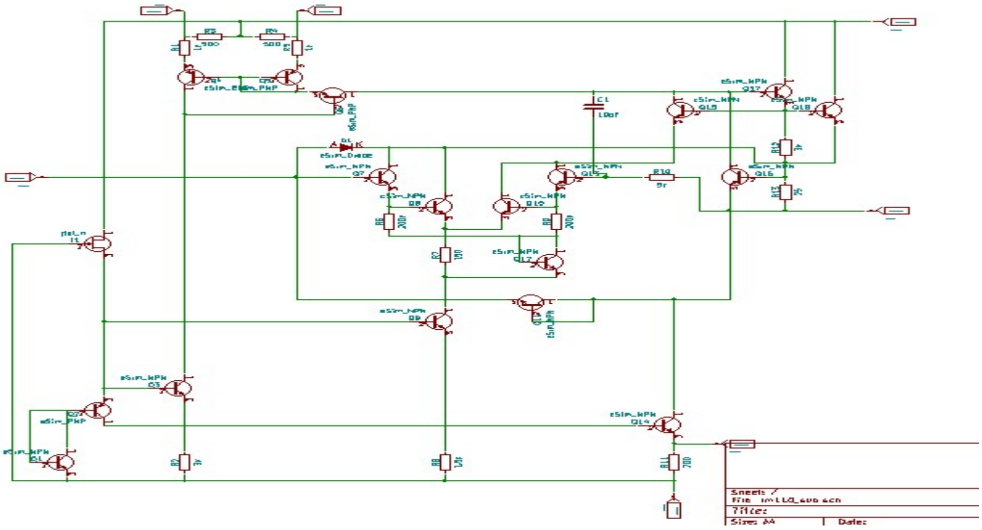

Figure 4.7: Subcircuit Schematic of LM110

4.2.3 Test Circuit

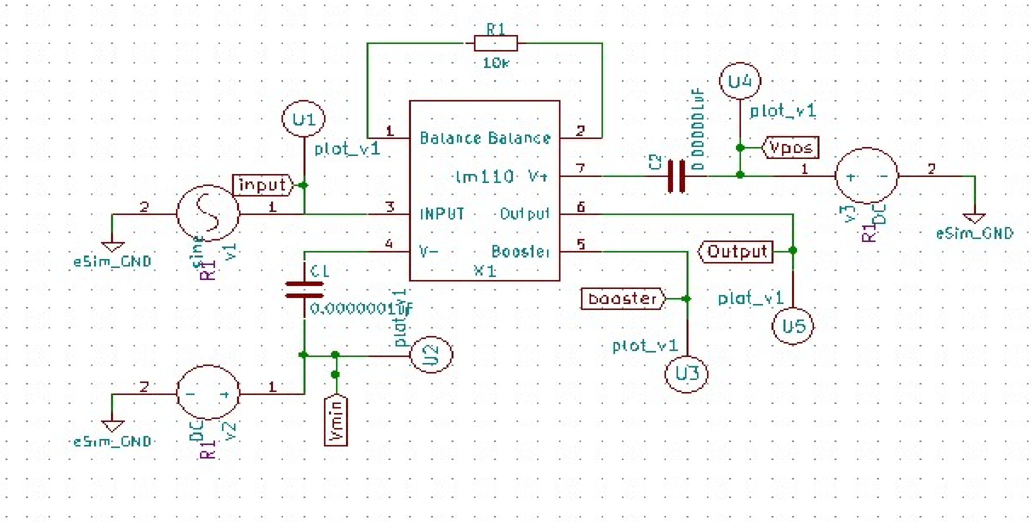

Figure 4.8: Test Circuit of LM110 IC

4.2.4 Input Plots

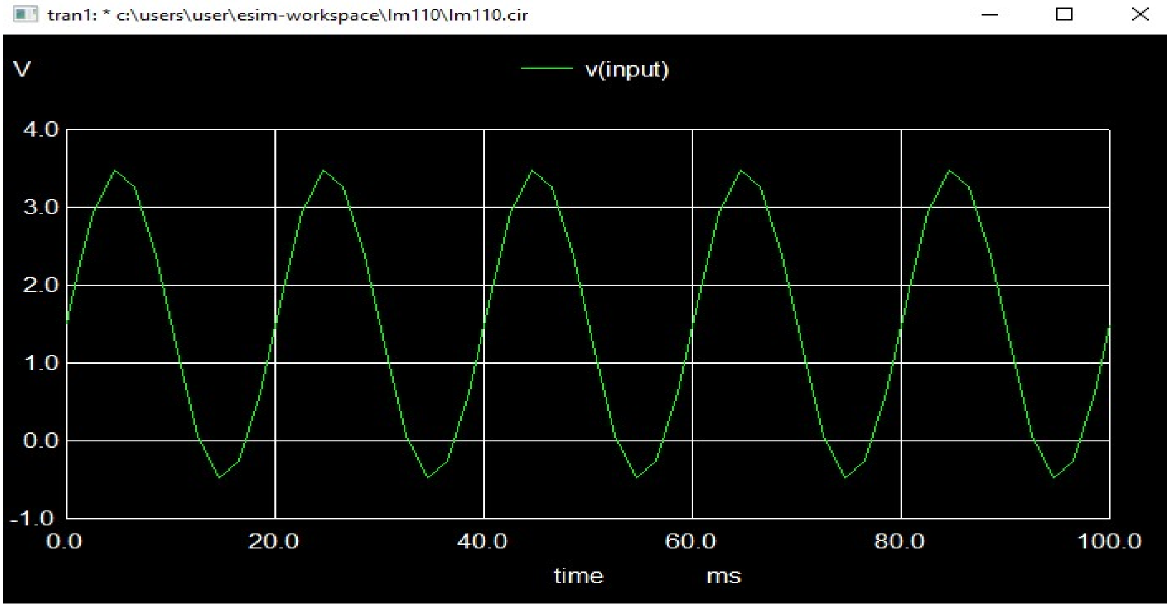

Figure 4.9: Input Voltage Waveform of LM110

4.2.5 Output Plots

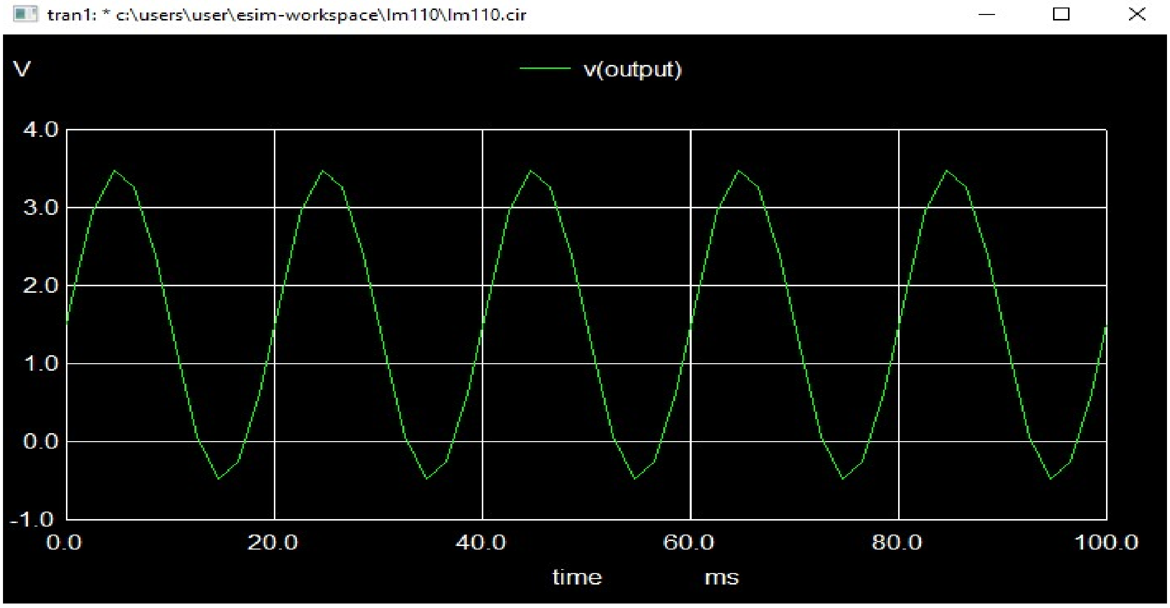

Figure 4.10: Output Voltage Waveform of LM110

4.3 CA3140 - BiMOS Operational Amplifier with MOSFET Input/Bipolar Output

The CA3140A and CA3140 are BiMOS operational amplifiers that integrate high-voltage PMOS and bipolar transistors on a single monolithic chip. They feature gate-protected MOSFET transistors in the input stage, which provide high input impedance, low input current, and high-speed performance. These amplifiers operate on supply voltages ranging from 4V to 36V. Designed for stable operation in unity

gain follower configurations, the CA3140A and CA3140 are internally phase compensated. They also include terminals for adding an external capacitor for additional frequency roll-off and for input offset voltage nulling, allowing for flexible performance tuning in various applications. The use of PMOS transistors in the input stage allows

the amplifiers to support common-mode input voltages down to 0.5V below the negative supply terminal, which is beneficial in single-supply applications. The bipolar transistor output stage provides built-in protection against damage from short circuits to either supply rail or ground, ensuring reliable operation under varying conditions.

4.3.1 IC Layout

This figure represents the Pin Package Diagram of CA3140

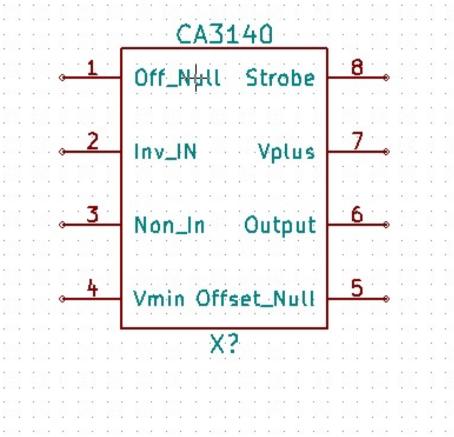

Figure 4.11: Pin diagram of CA3140

4.3.2 Subcircuit Schematic Diagram

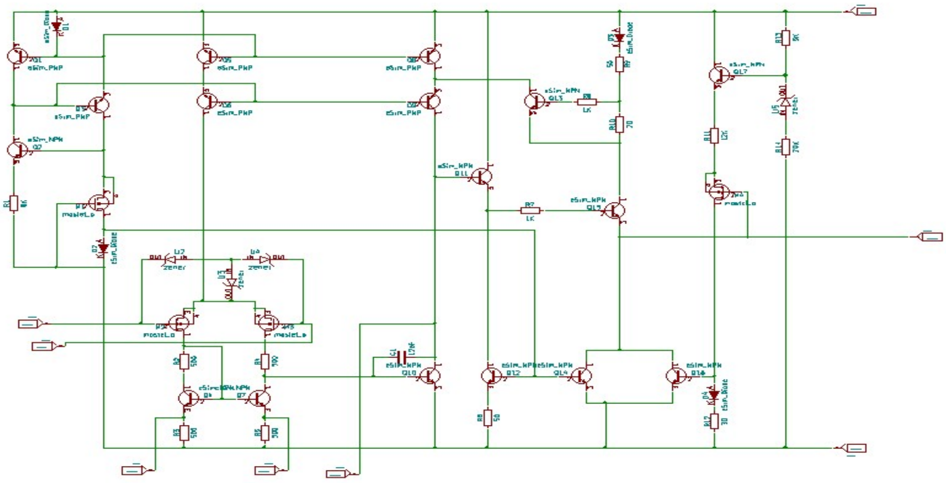

Figure 4.12: Subcircuit Schematic of CA3140

4.3.3 Test Circuit

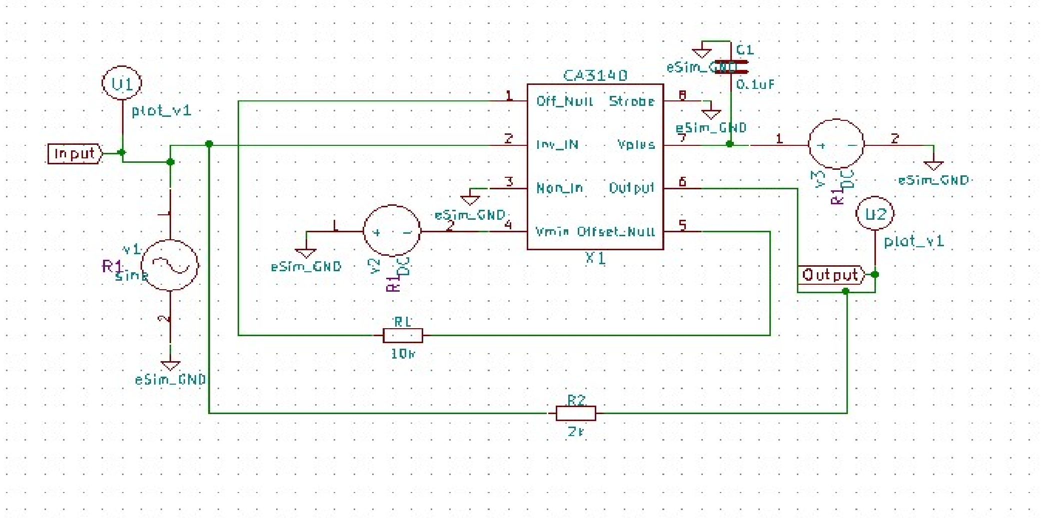

Figure 4.13: Test Circuit of CA3140 IC

4.3.4 Input Plots

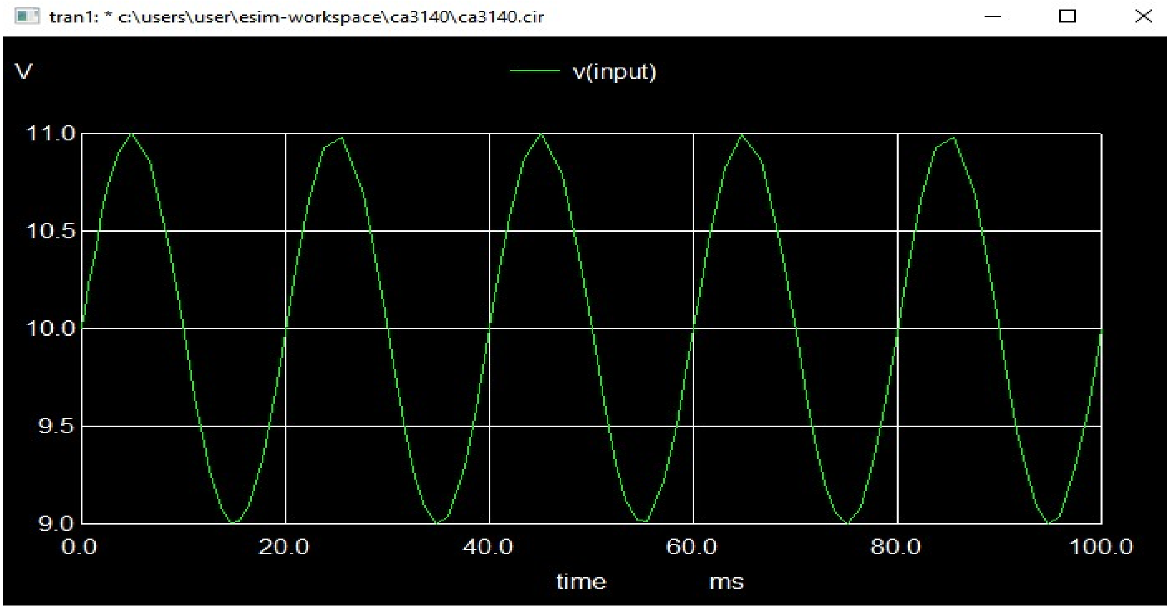

Figure 4.14: Input Voltage Waveform of CA3140

4.3.5 Output Plots

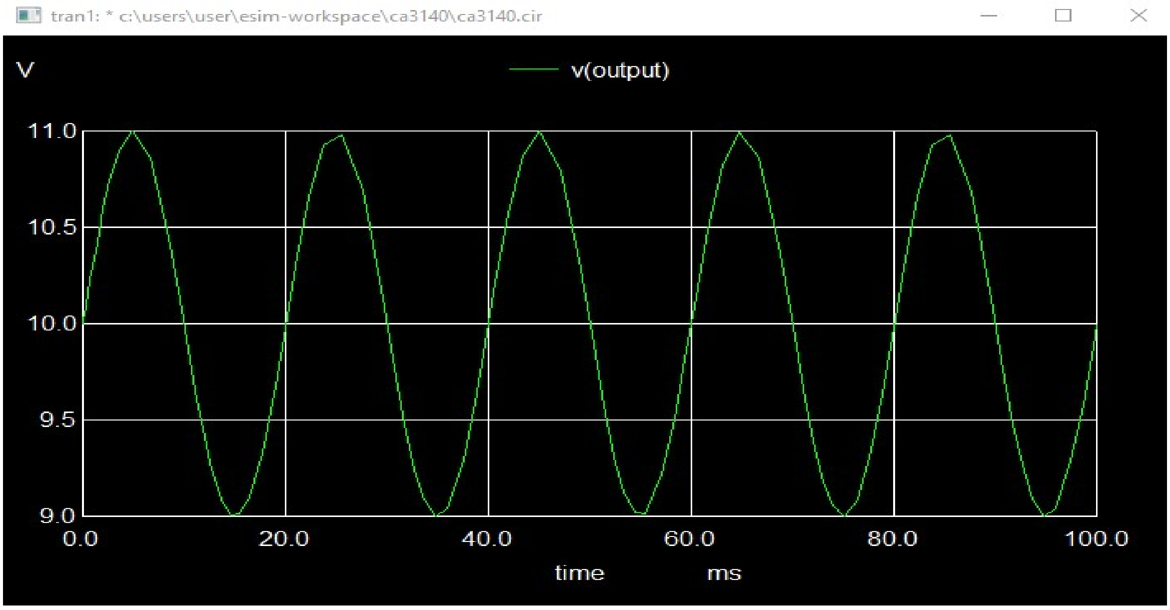

Figure 4.15: Output Voltage Waveform of CA3140

4.4 LM102 - Voltage Follower

The LM102 series are high-gain operational amplifiers specifically designed for unity-gain voltage follower applications. These devices are built on a single silicon chip using advanced processing techniques that ensure very low input current and high input impedance. The input transistors operate at zero collector-base voltage, effectively eliminating high-temperature leakage currents, allowing for operation in a temperature-stabilized environment to achieve extremely low input currents and minimal offset voltage drift. The LM102 is optimized for operation with supply voltages

between ±12V and ±15V. It also features low input capacitance and excellent small-signal and large-signal frequency response, which helps minimize high-frequency gain errors.

4.4.1 IC Layout

This figure represents the Pin Package Diagram of LM102

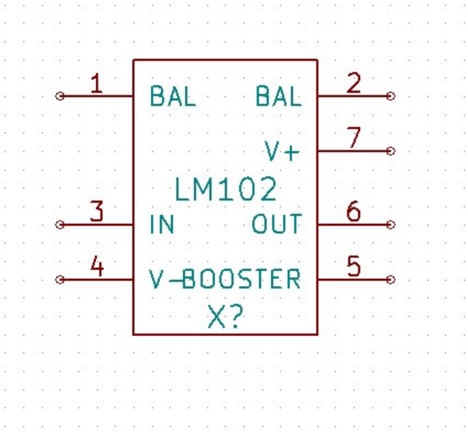

Figure 4.16: Pin diagram of LM102

4.4.2 Subcircuit Schematic Diagram

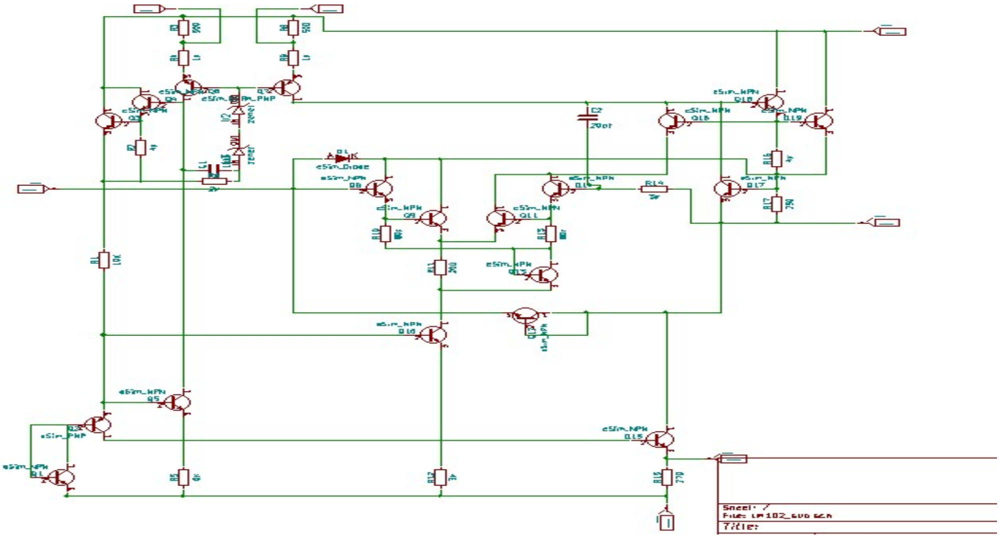

Figure 4.17: Subcircuit Schematic of LM102

4.4.3 Test Circuit

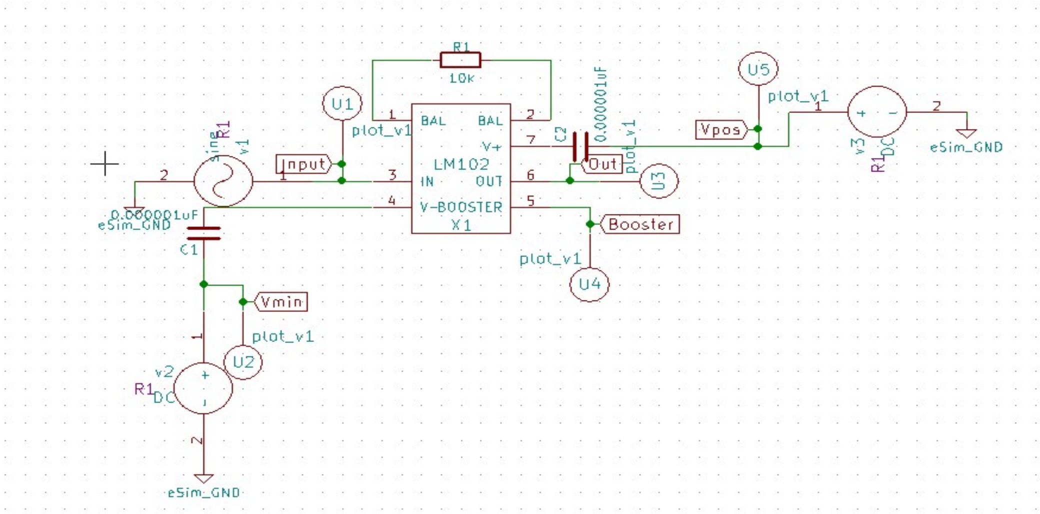

Figure 4.18: Test Circuit of LM102 IC

4.4.4 Input Plots

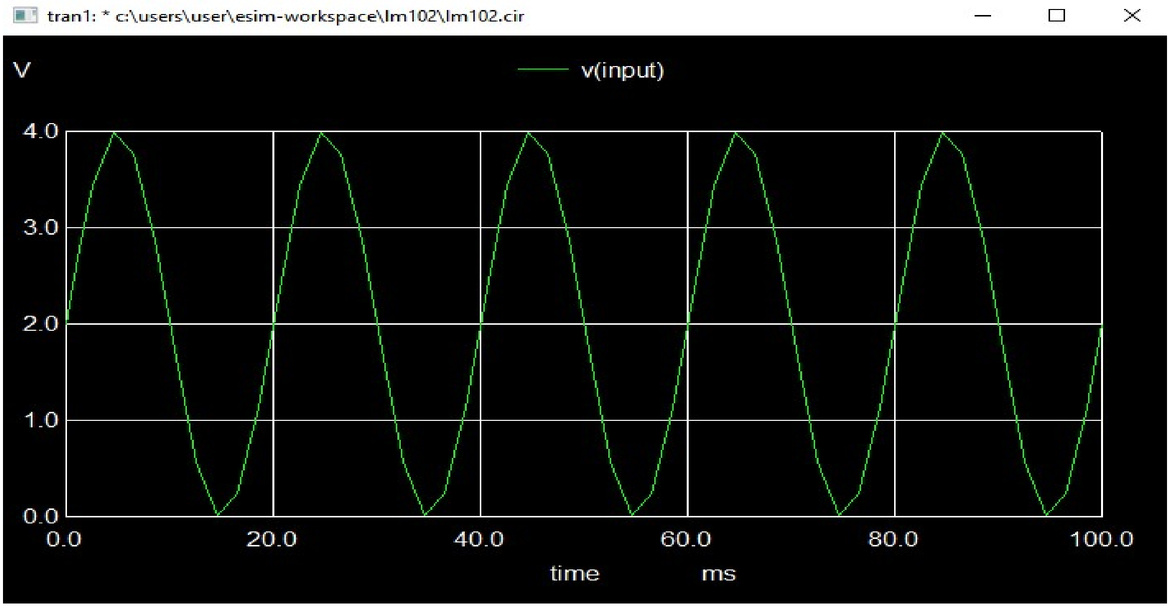

Figure 4.19: Input Voltage Waveform of LM102

4.4.5 Output Plots

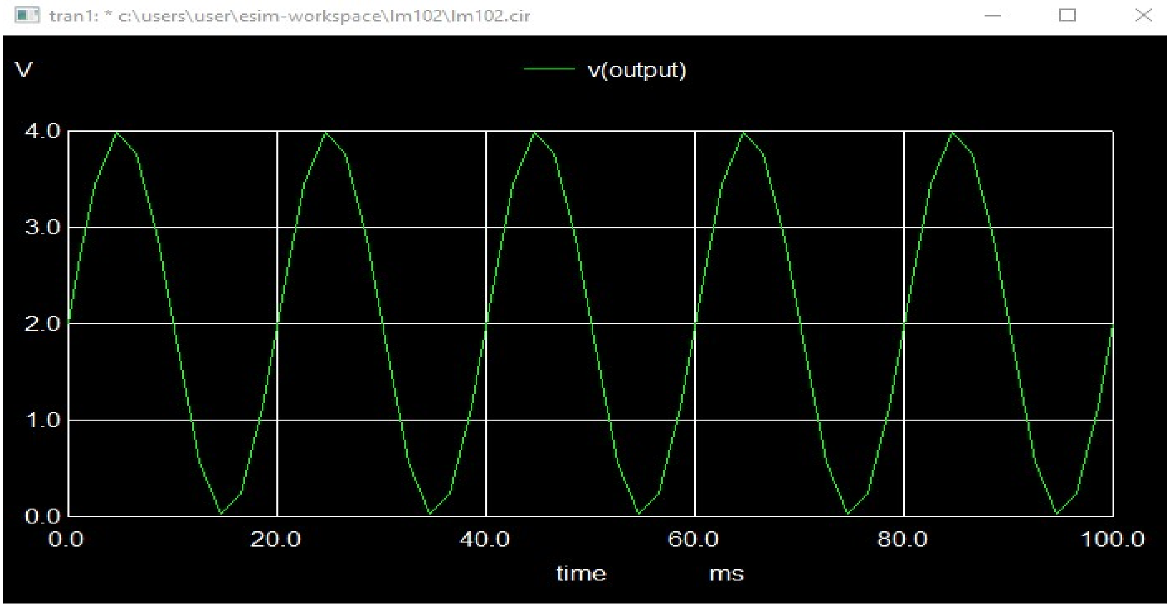

Figure 4.20: Output Voltage Waveform of LM102

4.5 LM111 - Differential Comparator

These devices also include features such as offset balancing, strobe functions, and the capability to wire-OR connect outputs. When the strobe input is held low, the output is disabled, regardless of the differential input, providing additional control over the output state.

4.5.1 IC Layout

This figure represents the Pin Package Diagram of LM111

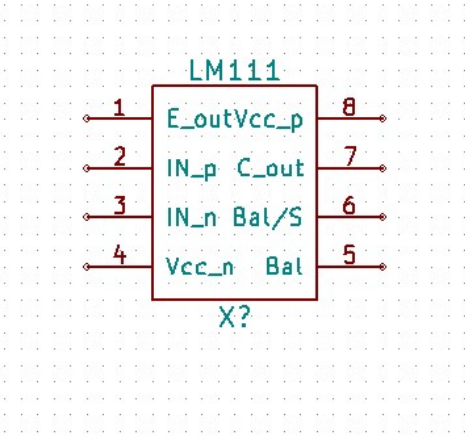

Figure 4.21: Pin diagram of LM111

4.5.2 Subcircuit Schematic Diagram

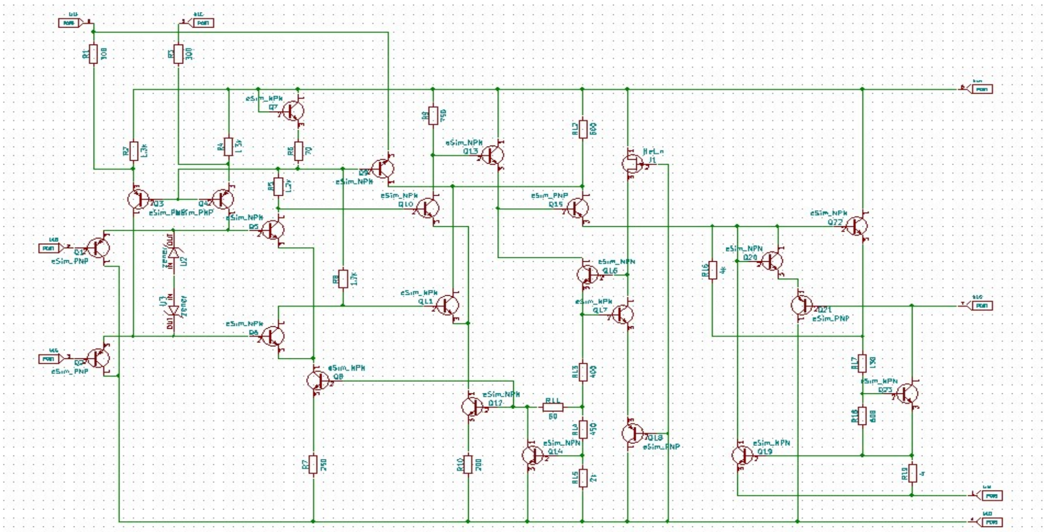

Figure 4.22: Subcircuit Schematic of LM111

4.5.3 Test Circuit

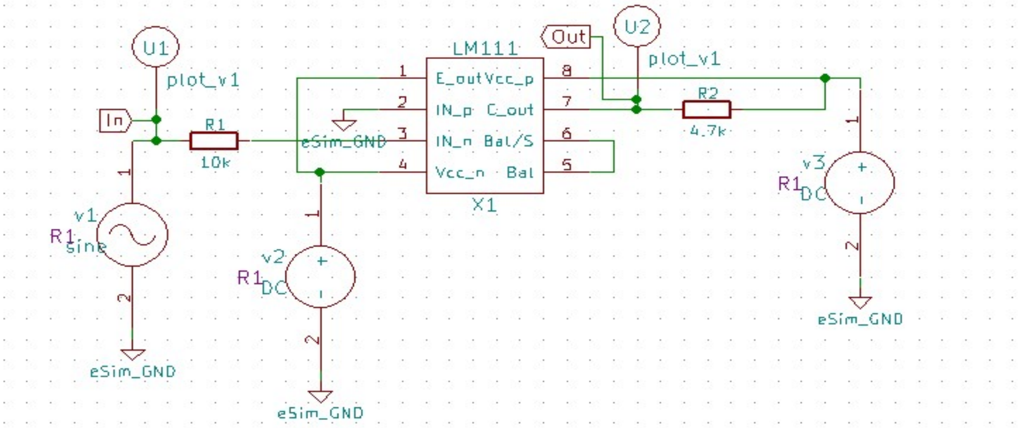

Figure 4.23: Test Circuit of LM111 IC

4.5.4 Input Plots

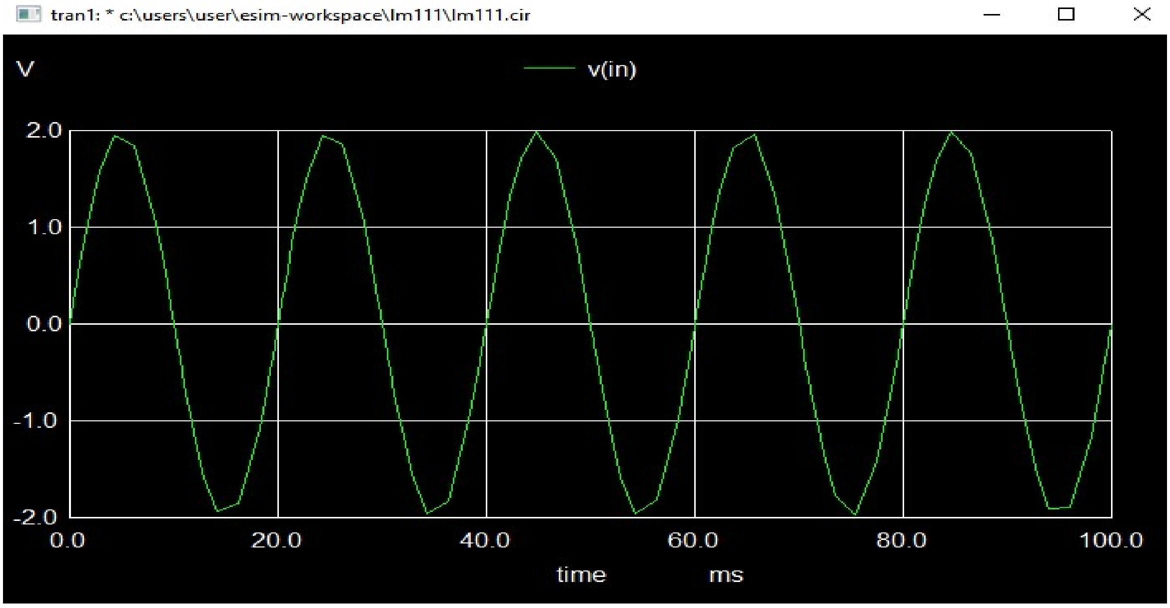

Figure 4.24: Input Voltage Waveform of LM111

4.5.5 Output Plots

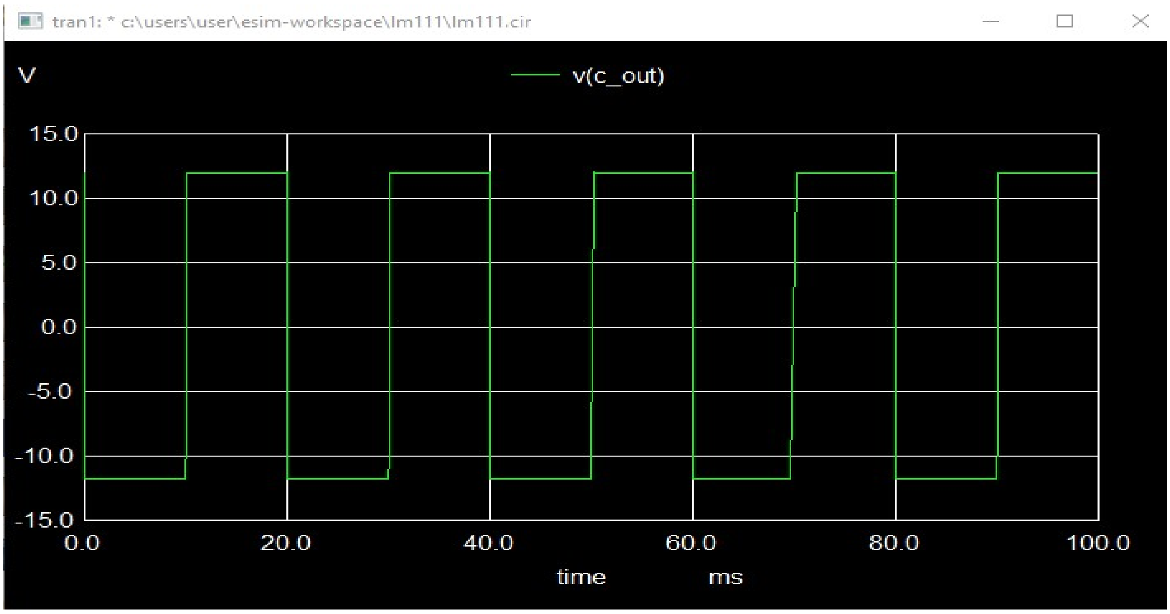

Figure 4.25: Output Voltage Waveform of LM111

4.6 LM123 - Positive Voltage Regulator

The LM123 is a three-terminal positive voltage regulator that provides a fixed 5V output and can handle up to 3 amps of current. It uses advanced circuit designs and processing techniques to achieve high current output while maintaining the stability typical of lower-current regulators. The LM323A variant offers enhanced precision, with tighter specifications for output voltage tolerance, line regulation, and load regulation compared to the standard LM323-N.

4.6.1 IC Layout

This figure represents the Pin Package Diagram of LM123

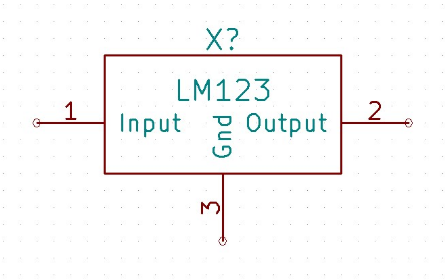

Figure 4.26: Pin diagram of LM123

4.6.2 Subcircuit Schematic Diagram

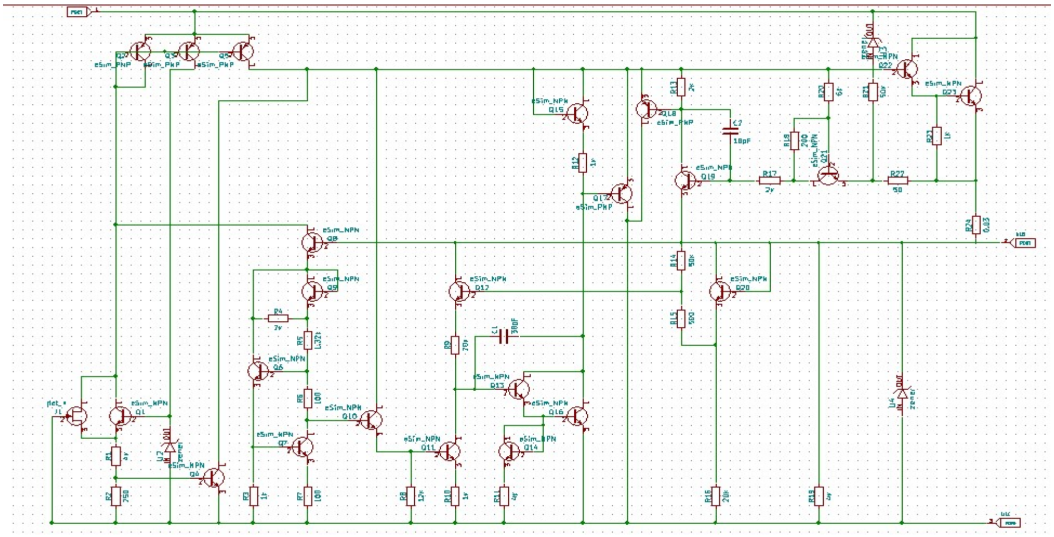

Figure 4.27: Subcircuit Schematic ofLM123

4.6.3 Test Circuit

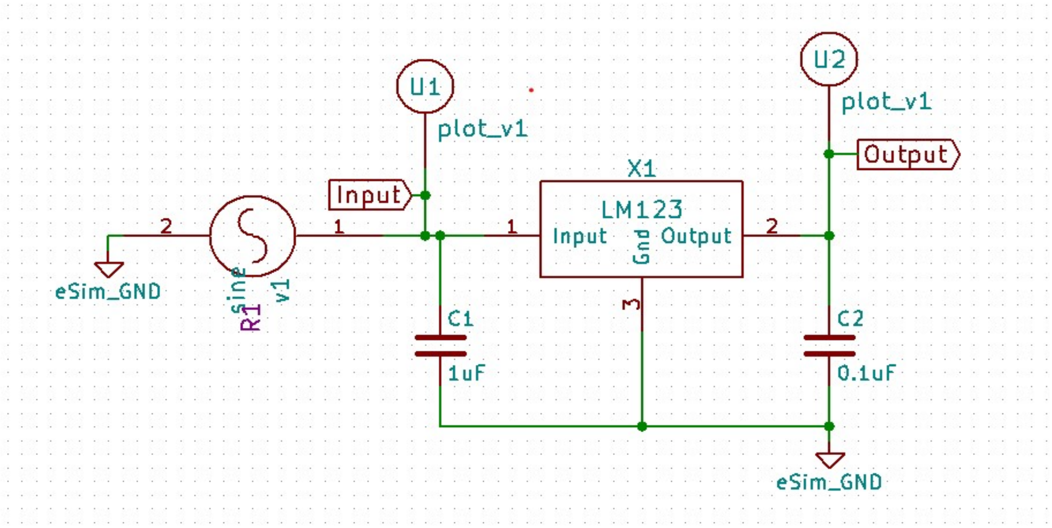

Figure 4.28: Test Circuit of LM123 IC

4.6.4 Input Plots

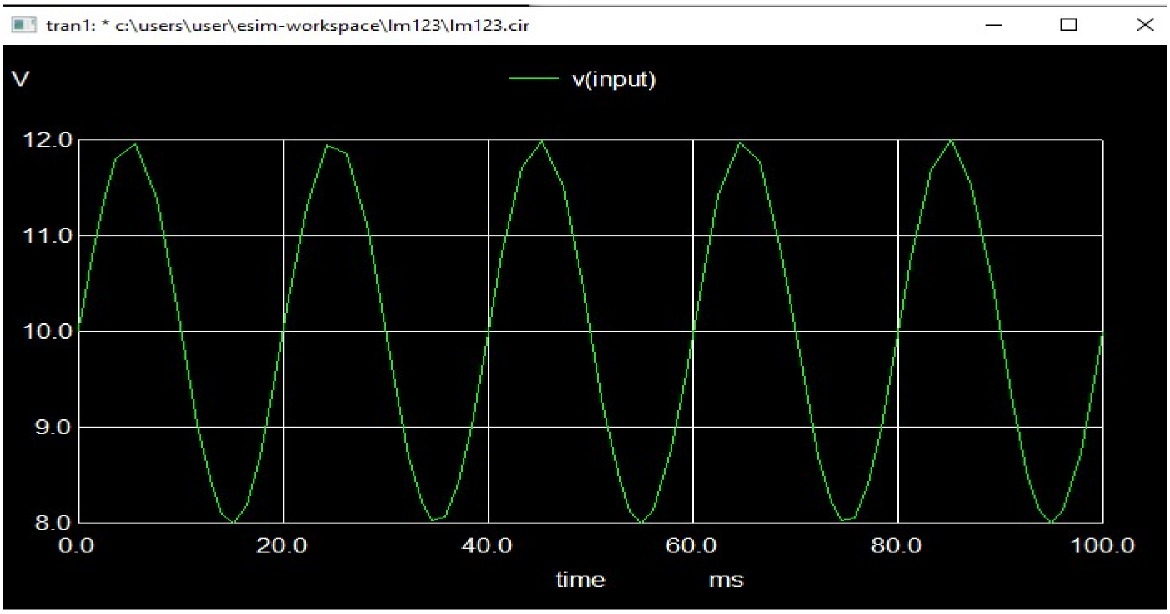

Figure 4.29: Input Voltage Waveform of LM123

4.6.5 Output Plots

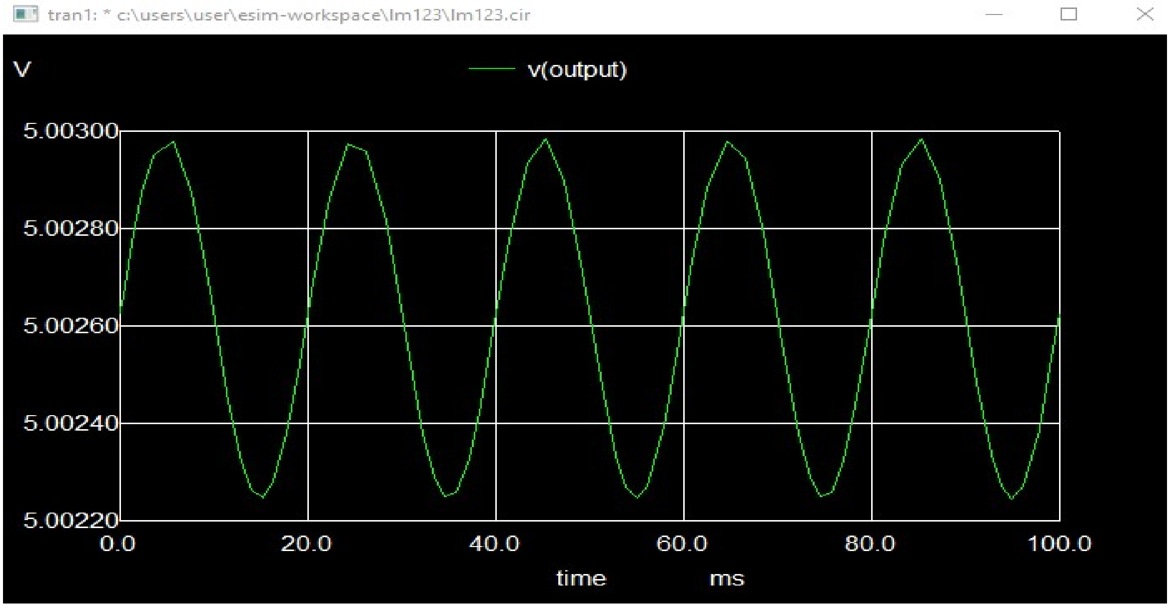

Figure 4.30: Output Voltage Waveform of LM123

4.7 LM380 - 2.5W Audio Power Amplifier

The LM380 is a power audio amplifier designed for consumer applications, featuring a fixed gain of 34 dB to keep system costs low. Its unique input stage allows for ground-referenced input signals, and the output automatically centers itself at half the supply voltage. The amplifier includes short-circuit protection and internal thermal limiting to enhance durability. The device is housed in a standard dual-in-line package, with the LM380N model utilizing a copper lead frame and a heat sink incorporated into the center three pins on each side, facilitating integration into standard PC layouts. The LM380 is versatile, suitable for use in simple phonograph amplifiers, intercoms, line drivers, teaching machine outputs, alarms, ultrasonic drivers, TV sound systems, AM-FM radios, small servo drivers, and power converters, among other applications.

4.7.1 IC Layout

This figure represents the Pin Package Diagram of LM380

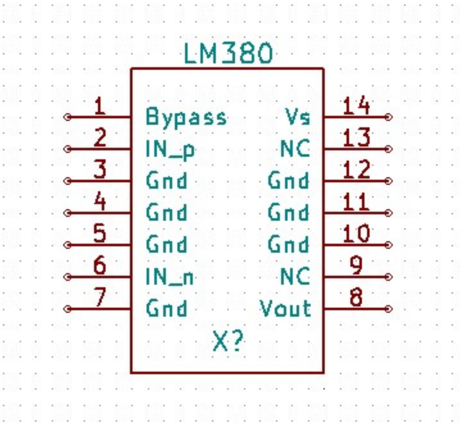

Figure 4.31: Pin diagram of LM380

4.7.2 Subcircuit Schematic Diagram

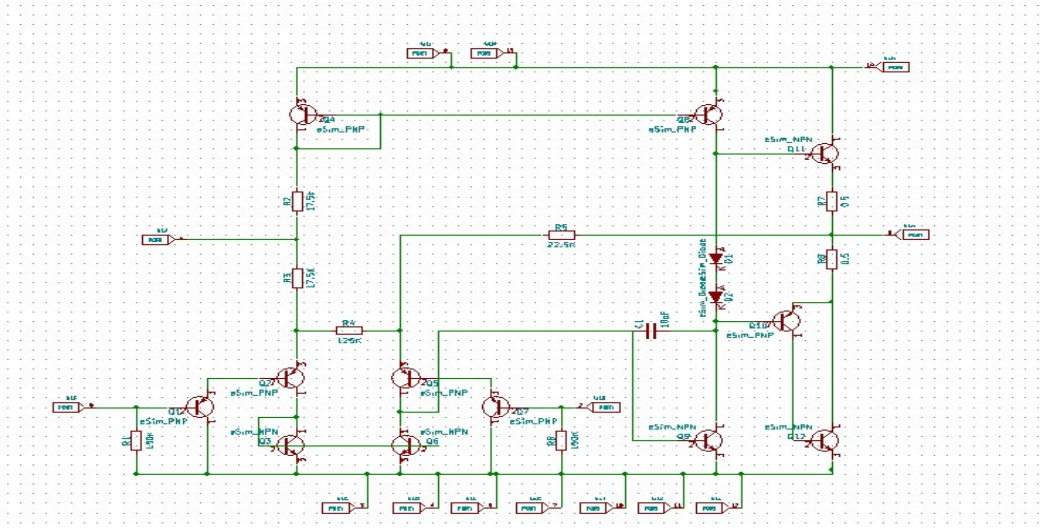

Figure 4.32: Subcircuit Schematic of LM380

4.7.3 Test Circuit

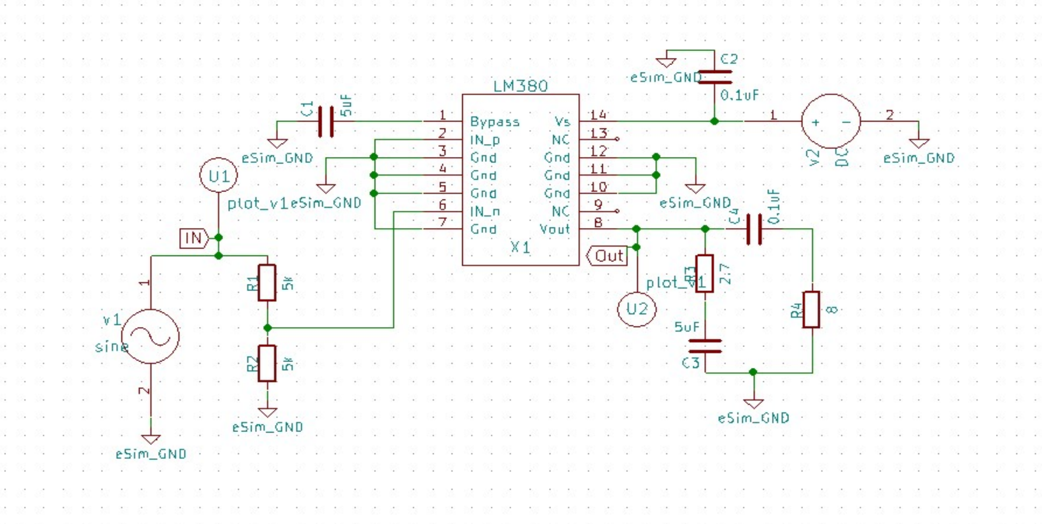

Figure 4.33: Test Circuit of LM380 IC

4.7.4 Input Plots

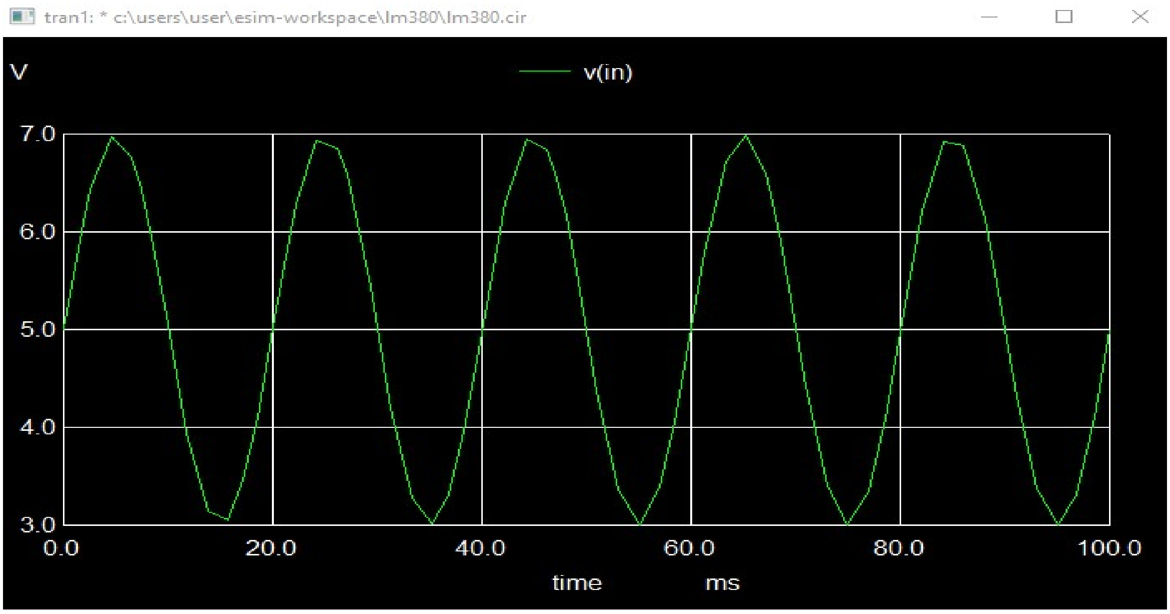

Figure 4.34: Input Voltage Waveform of LM380

4.7.5 Output Plots

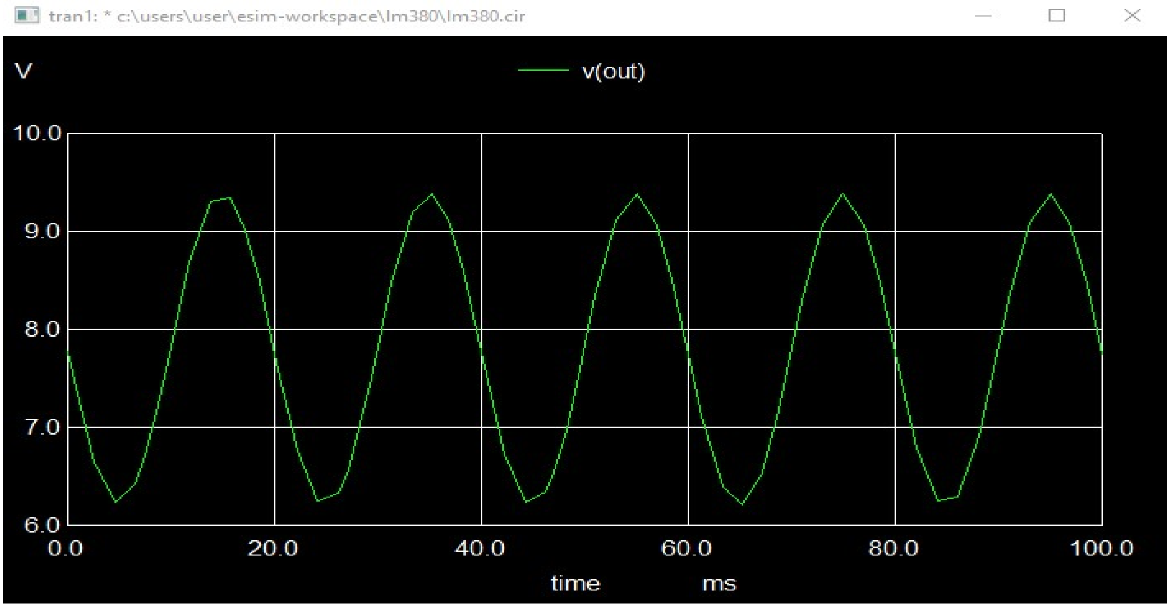

Figure 4.35: Output Voltage Waveform of LM380

4.8 LM341 - Linear voltage regulator

The LM341 is a three-pin positive voltage regulators equipped with built-in current limiting, thermal shutdown, and safe-operating area protection. These features safeguard the regulators from damage due to output overloads and ensure reliable operation. With proper heat sinking, they can deliver more than 0.5 amps of output current. These regulators are particularly useful in applications requiring local (on-card) regulation, where they help mitigate noise and enhance performance by providing stable voltage directly on the circuit board. They are well-suited for a variety of electronic devices, including those sensitive to voltage fluctuations. Additionally, their design simplifies the power management in electronic systems, reduces the need for external protection components, and improves overall reliability by isolating the regulation function closer to the load.

4.8.1 IC Layout

This figure represents the Pin Package Diagram of LM341

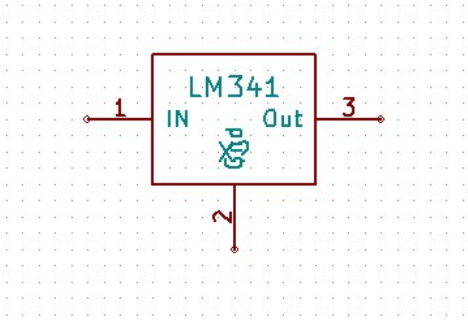

Figure 4.36: Pin diagram of LM341

4.8.2 Subcircuit Schematic Diagram

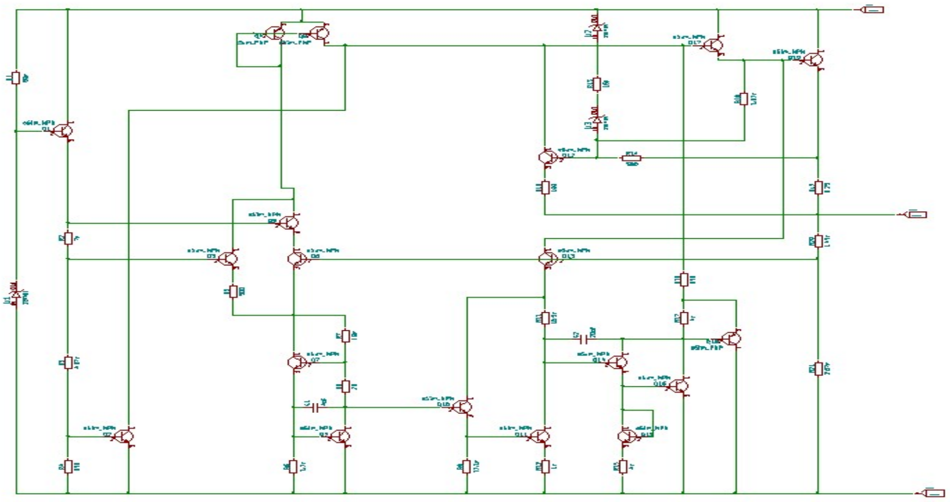

Figure 4.37: Subcircuit Schematic of LM341

4.8.3 Test Circuit

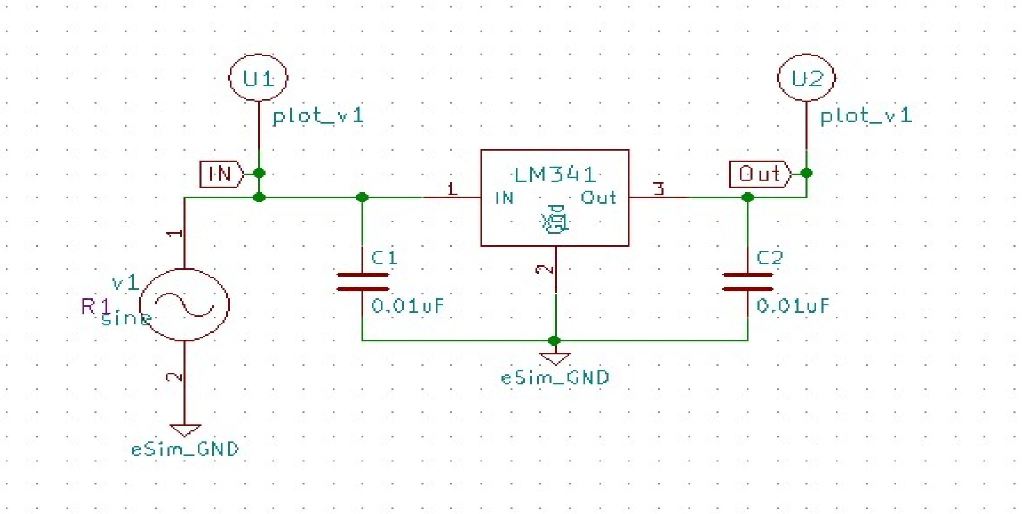

Figure 4.38: Test Circuit of LM341 IC

4.8.4 Input Plots

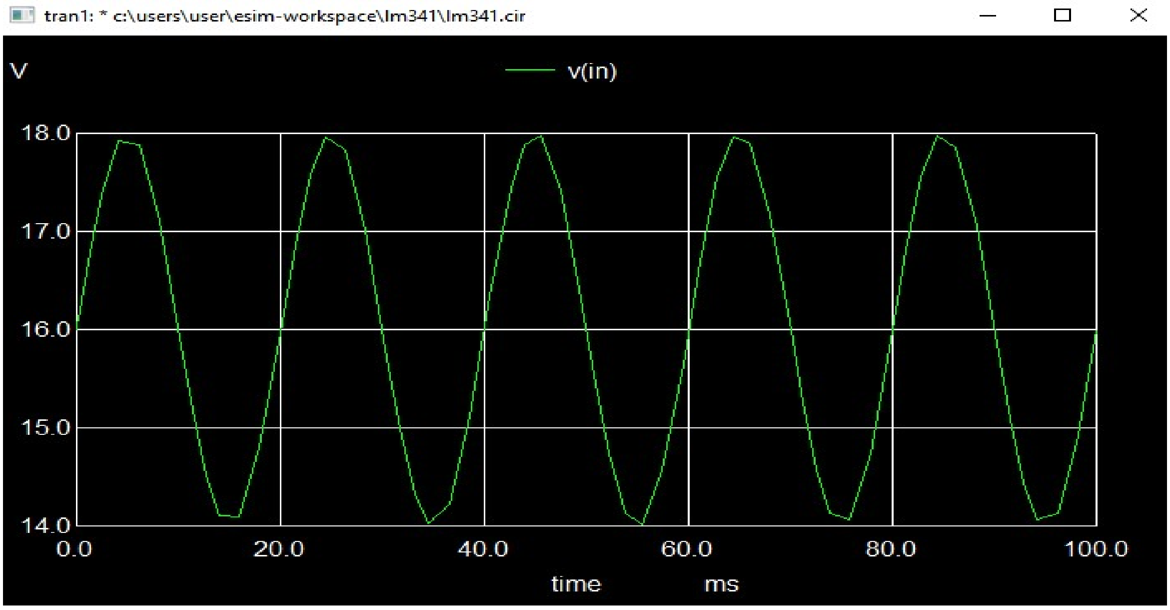

Figure 4.39: Input Voltage Waveform of LM341

4.8.5 Output Plots

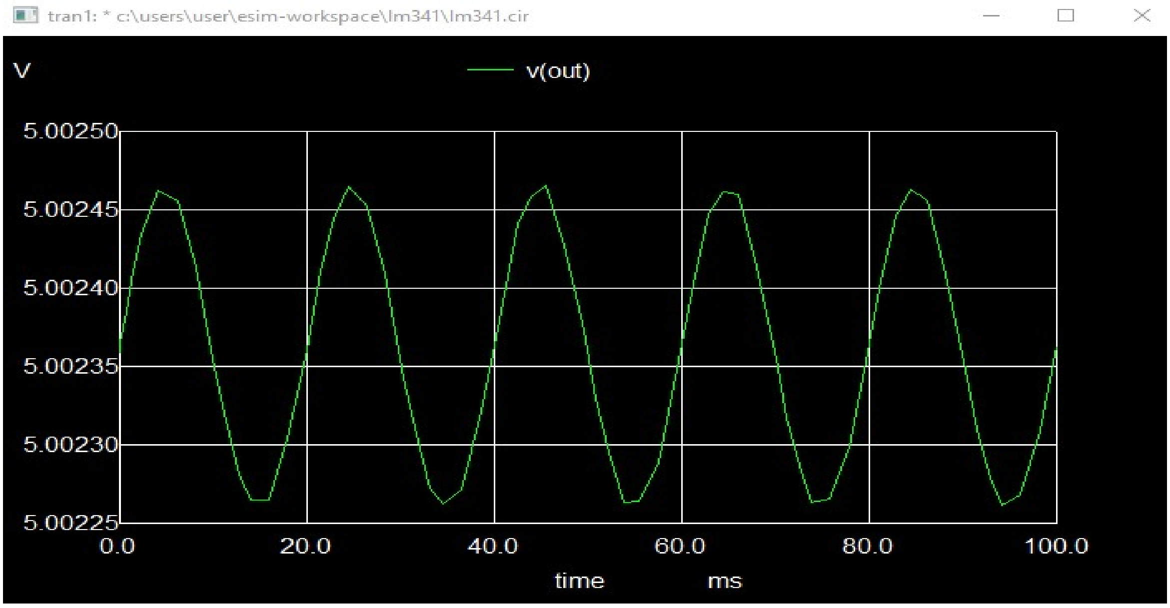

Figure 4.40: Output Voltage Waveform of LM341

4.9 LM323A - 3-Amp, 5-Volt Positive Regulator

The LM123 is a three-terminal positive voltage regulator designed to deliver a fixed 5V output and handle up to 3 amps of load current. Utilizing advanced circuit design and processing techniques, it achieves high output current while maintaining the stable regulation typically found in lower current regulators. The LM323A variant provides

enhanced precision compared to the standard LM323-N, with tighter specifications for output voltage tolerance, line regulation, and load regulation. This improvement ensures more accurate and reliable performance. The LM123 is built to handle a range of operating conditions with minimal variation in output, making it suitable for demanding applications.

4.9.1 IC Layout

This figure represents the Pin Package Diagram of LM323A

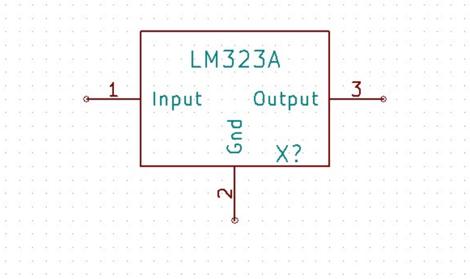

Figure 4.41: Pin diagram of LM323A

4.9.2 Subcircuit Schematic Diagram

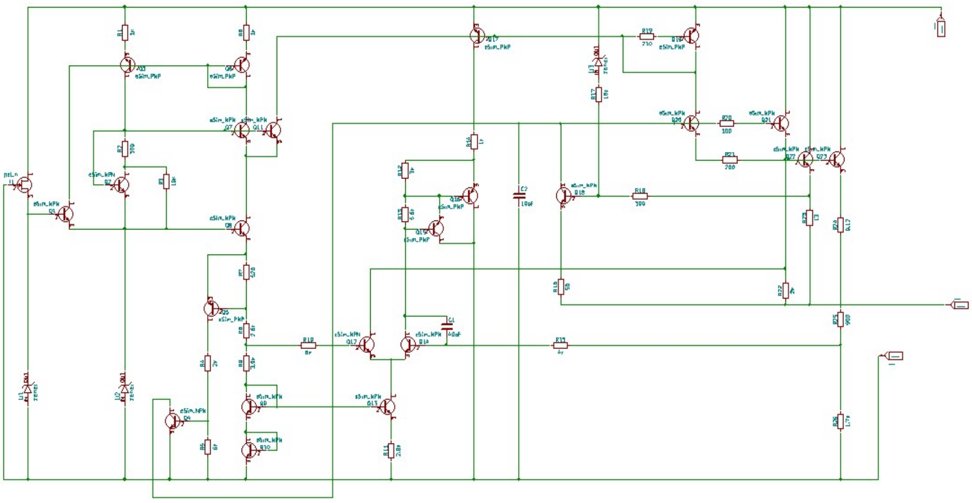

Figure 4.42: Subcircuit Schematic of LM323A

4.9.3 Test Circuit

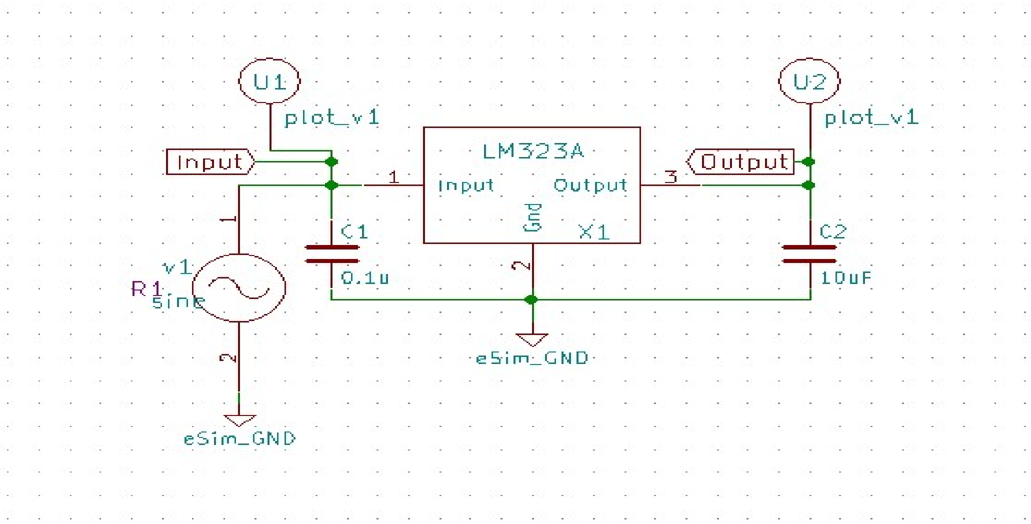

Figure 4.43: Test Circuit of LM323A IC

4.9.4 Input Plots

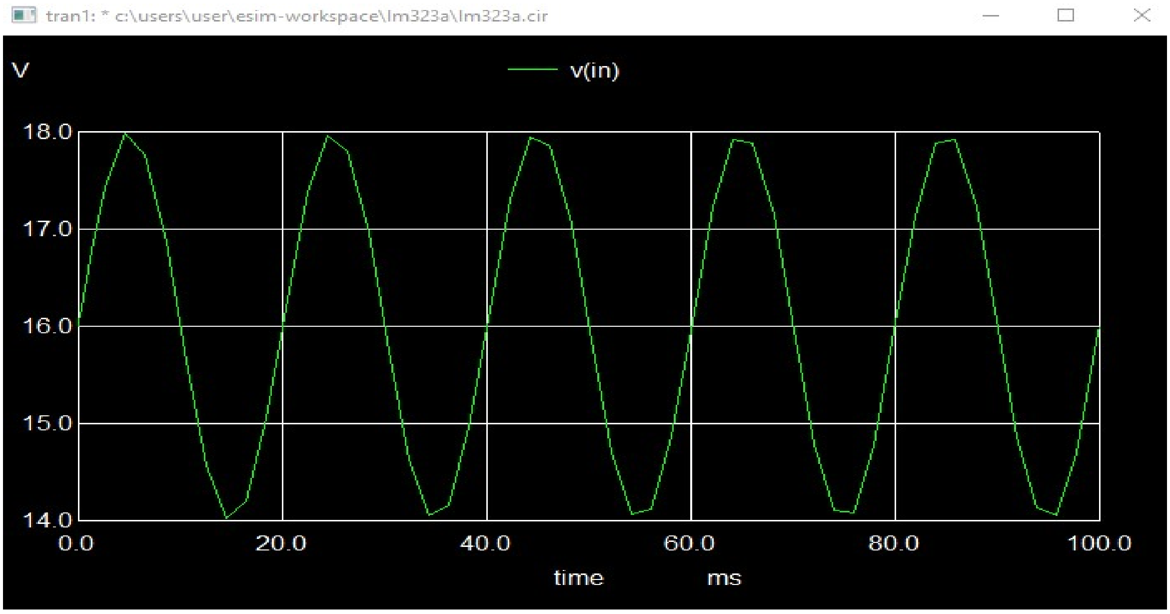

Figure 4.44: Input Voltage Waveform of LM323A

4.9.5 Output Plots

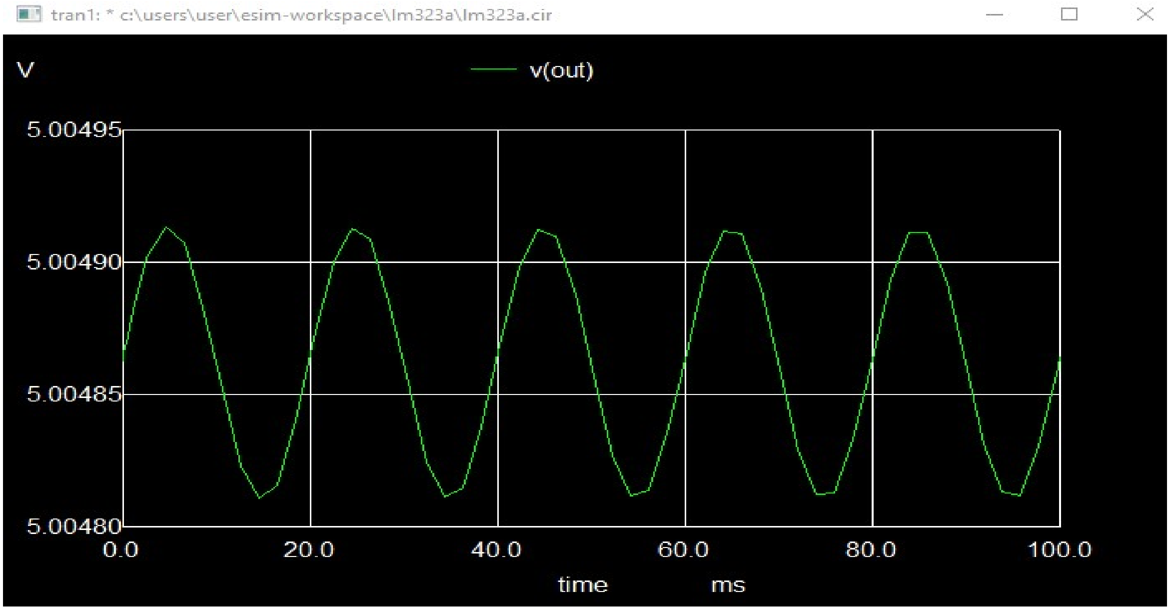

Figure 4.45: Output Voltage Waveform of LM323A

Chapter 5

Digital IC's

5.1 SN7445 - BCD-To-Decimal Decoders/Drivers

These monolithic BCD-to-decimal decoders/drivers are composed of eight inverters and ten four-input NAND gates. The inverters are paired to enable BCD input data decoding via the NAND gates. Proper decoding of valid BCD input logic ensures that all outputs remain inactive for any invalid binary input conditions. These decoders are

equipped with TTL inputs and high-performance n-p-n output transistors, designed for use as indicator/relay drivers or as open-collector logic circuit drivers. Each output transistor, capable of withstanding high breakdown voltages (30 volts), can handle up to 80 milliamperes of current. The inputs are standardized to Series 54/74 load, making them fully compatible with TTL logic circuits. Additionally, the outputs are suitable for interfacing with most MOS integrated circuits. Power dissipation is generally around 215 milliwatts.

5.1.1 IC Layout

This figure represents the Pin Package Diagram of SN7445

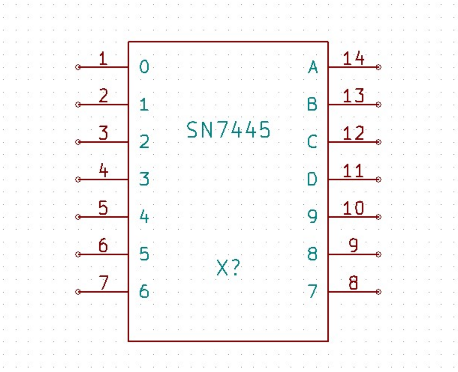

Figure 5.1: Pin diagram of SN7445

5.1.2 Subcircuit Schematic Diagram

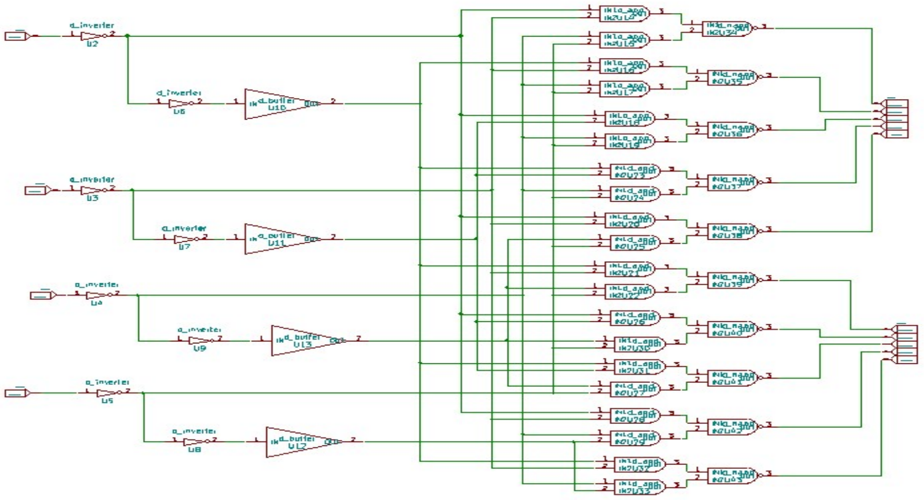

Figure 5.2: Subcircuit Schematic of SN7445

5.1.3 Test Circuit

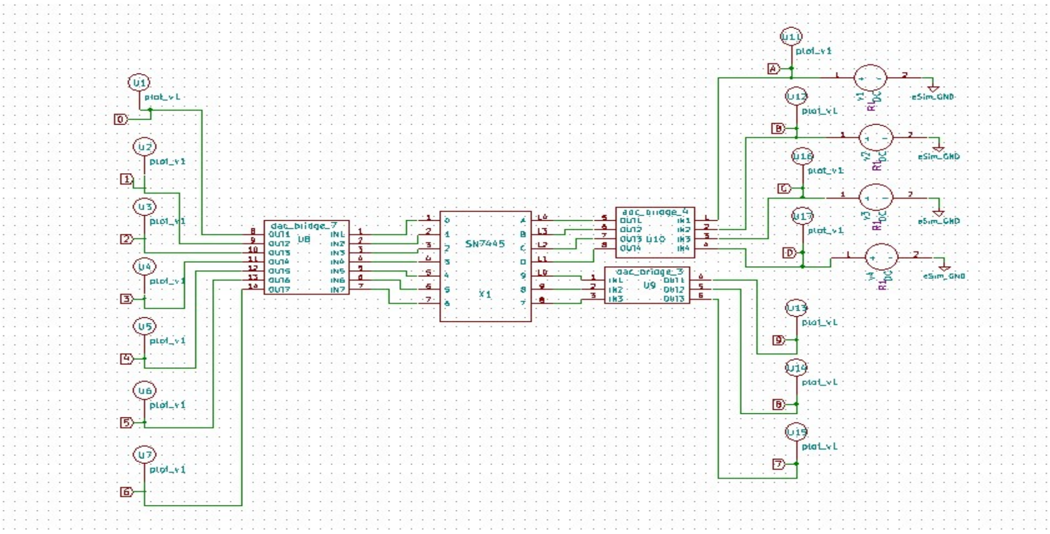

Figure 5.3: Test Circuit of SN7445 IC

5.1.4 Input Plots

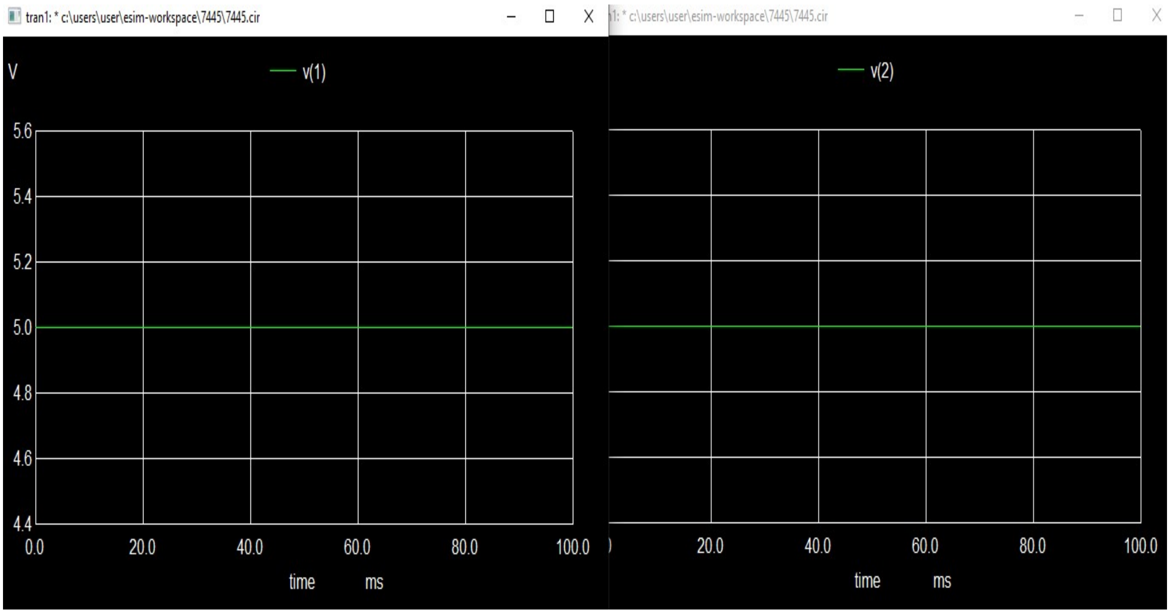

Figure 5.4: Input Voltage Waveform of SN7445

5.1.5 Output Plots

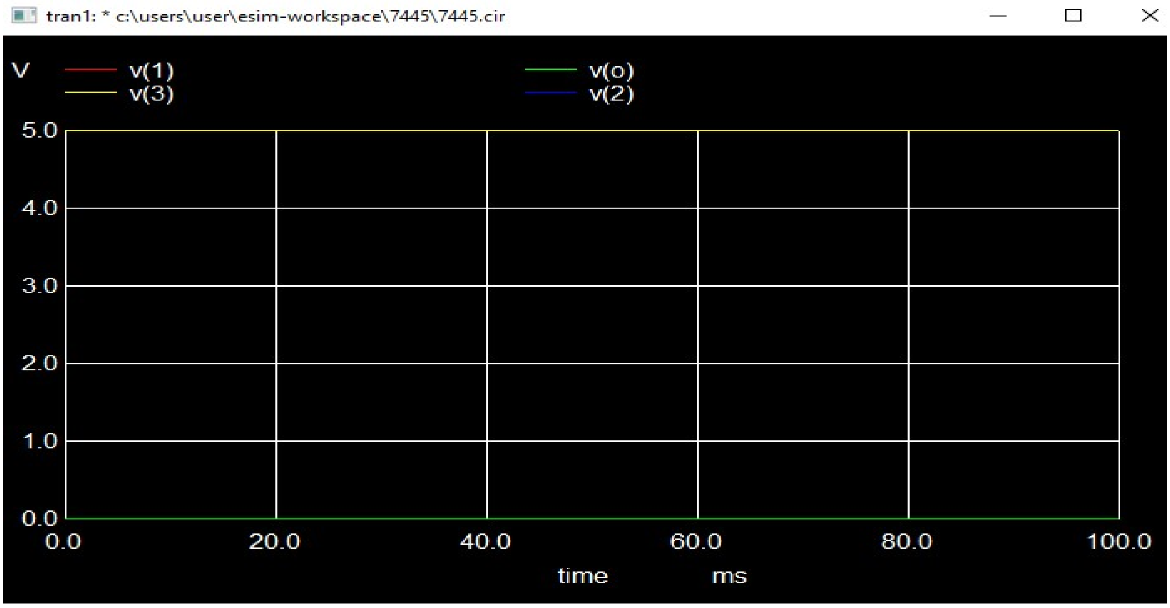

Figure 5.5: Output Voltage Waveform of SN7445

5.2 SN7483A - 4 bit binary fully adder with fast carry

These advanced full adders perform 4-bit binary addition, providing sum outputs for each bit and a carry (C4) from the fourth bit. With full internal look-ahead, they generate the carry in about ten nanoseconds, offering partial look-ahead performance at a reduced cost. The carry logic is implemented directly, allowing the end-around carry without additional logic. Designed for medium-speed applications, these circuits

are TTL-compatible with other logic families. Series 64 and 54LS circuits operate from+++–, -55°C to 125°C, while Series 74 and 74LS function from 0°C to 70°C.

5.2.1 IC Layout

This figure represents the Pin Package Diagram of SN7483A

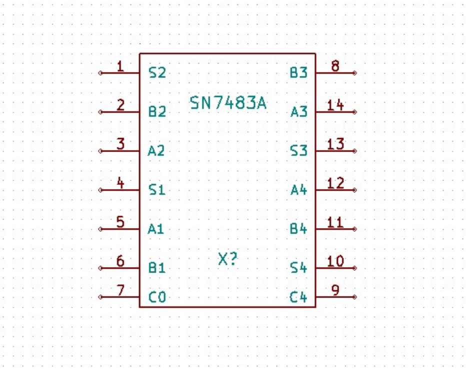

Figure 5.6: Pin diagram of SN7483A

5.2.2 Subcircuit Schematic Diagram

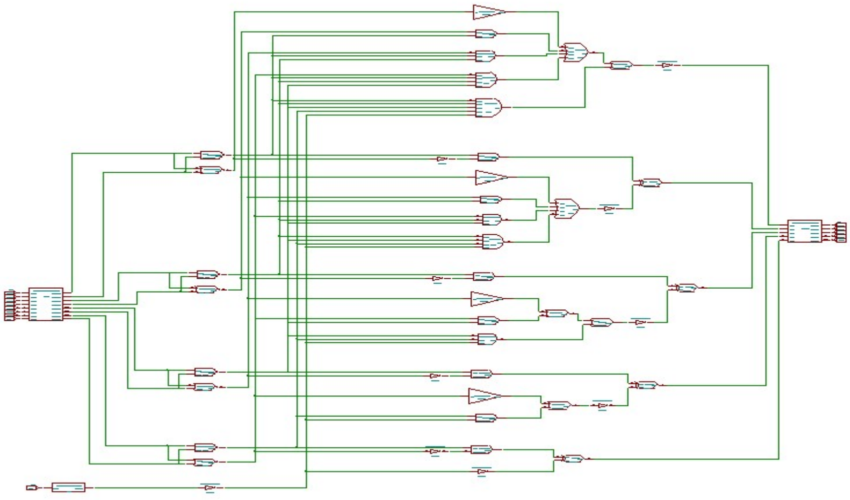

Figure 5.7: Subcircuit Schematic of SN7483A

5.2.3 Test Circuit

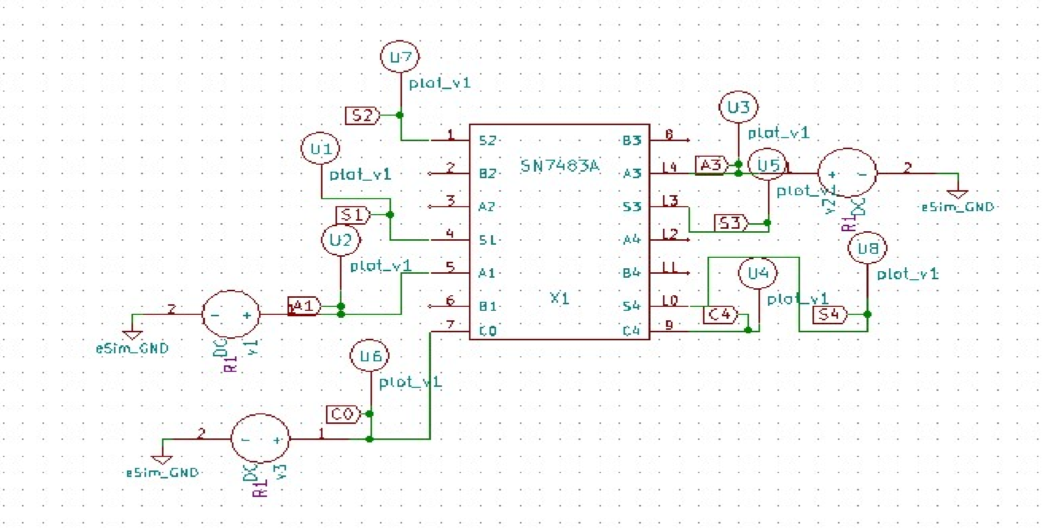

Figure 5.8: Test Circuit of SN7483A IC

5.2.4 Input Plots

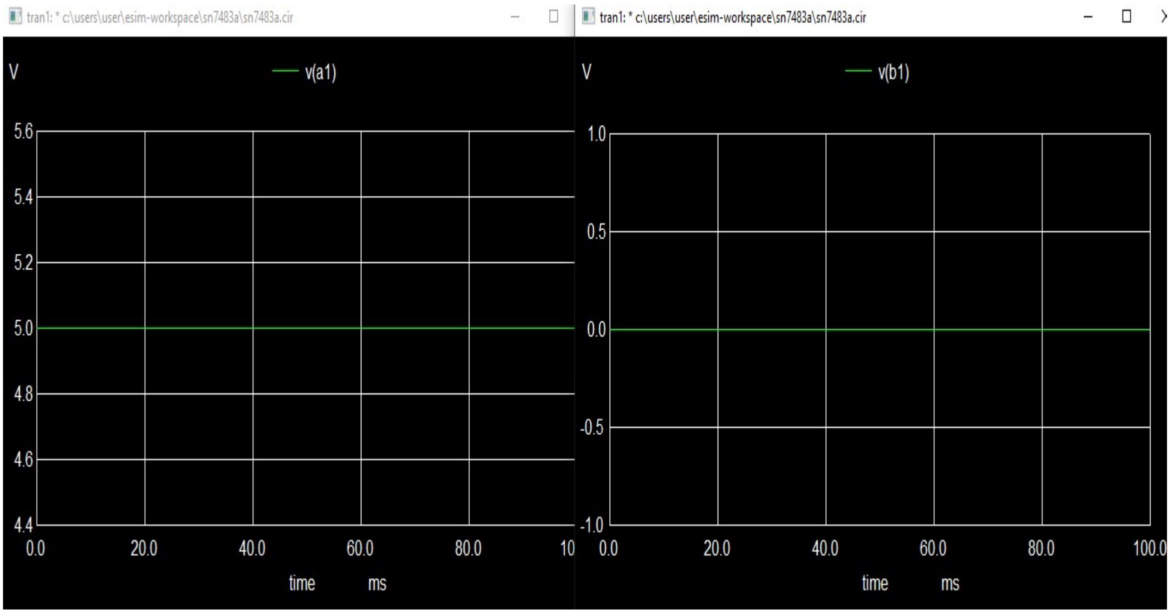

Figure 5.9: Input Voltage Waveform of SN7483A

5.2.5 Output Plots

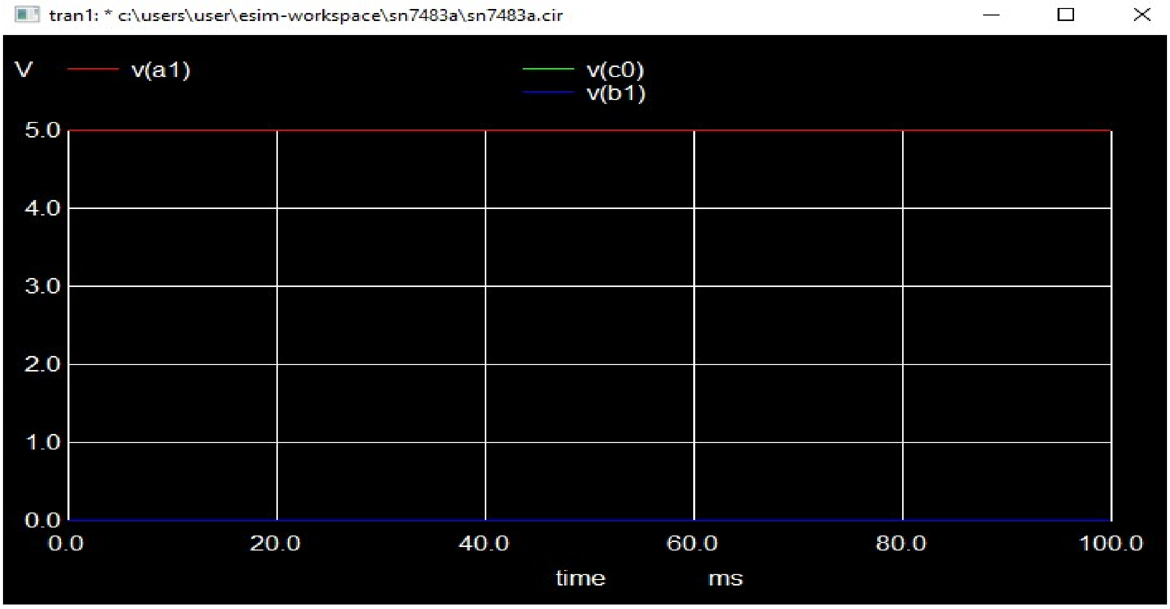

Figure 5.10: Output Voltage Waveform of SN7483A

5.3 74HC688

These advanced full adders perform 4-bit binary addition, providing sum outputs for each bit and a carry (C4) from the fourth bit. With full internal look-ahead, they generate the carry in about ten nanoseconds, offering partial look-ahead performance at a reduced cost. The carry logic is implemented directly, allowing the end-around carry without additional logic.The 74HC688 is an 8-bit magnitude comparator designed to compare two 8-bit binary or BCD words. It includes clamp diodes on the inputs, allowing for the use of current limiting resistors to interface with voltages higher than VCC. Key features include its ability to compare 8-bit words, a wide operating voltage range from 2.0 to 6.0 V, and compatibility with CMOS input levels. The device offers low power dissipation, high noise immunity, and superior latch-up performance, exceeding 100 mA as per JESD 78 Class II Level B standards. Additionally, it complies with JEDEC standards JESD8C (2.7 V to 3.6 V) and JESD7A (2.0 V to 6.0 V), and provides robust ESD protection, withstanding more than 2000 V per HBM JESD22-A114-F and over 200 V per MM JESD22-A115-A. The 74HC688 operates effectively across a temperature range of -40°C to +85°C and -40°C to +125°C.

Designed for medium-speed applications, these circuits are TTL-compatible with other logic families. Series 64 and 54LS circuits operate from -55°C to 125°C, while Series 74 and 74LS function from 0°C to 70°C.

5.3.1 IC Layout

This figure represents the Pin Package Diagram of 74HC688

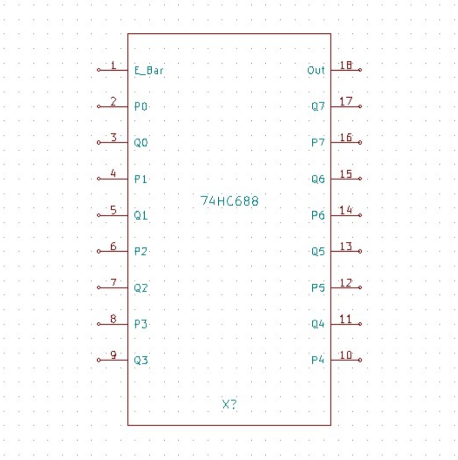

Figure 5.11: Pin diagram of 74HC688

5.3.2 Subcircuit Schematic Diagram

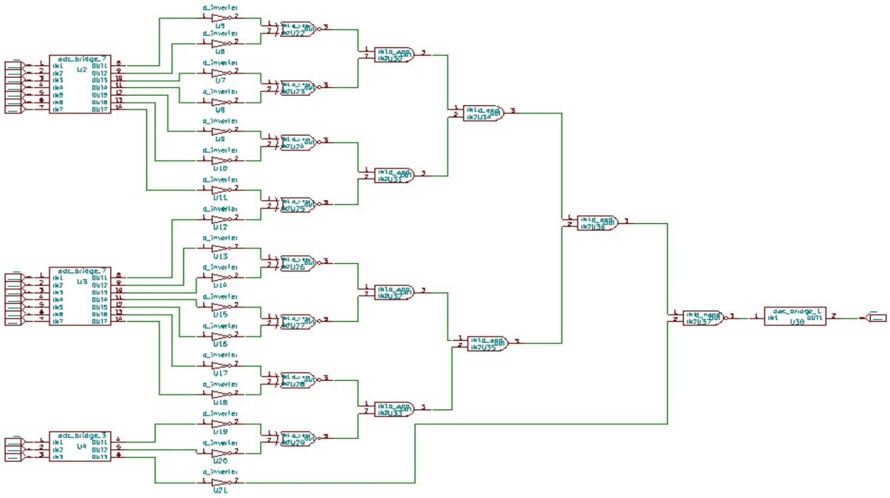

Figure 5.12: Subcircuit Schematic of 74HC688

5.3.3 Test Circuit

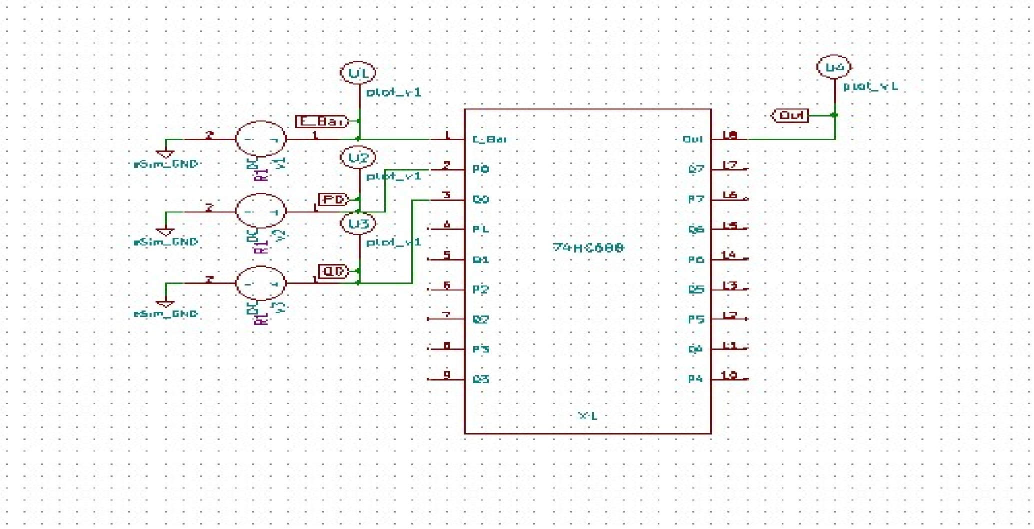

Figure 5.13: Test Circuit of 74HC688 IC

5.3.4 Input Plots

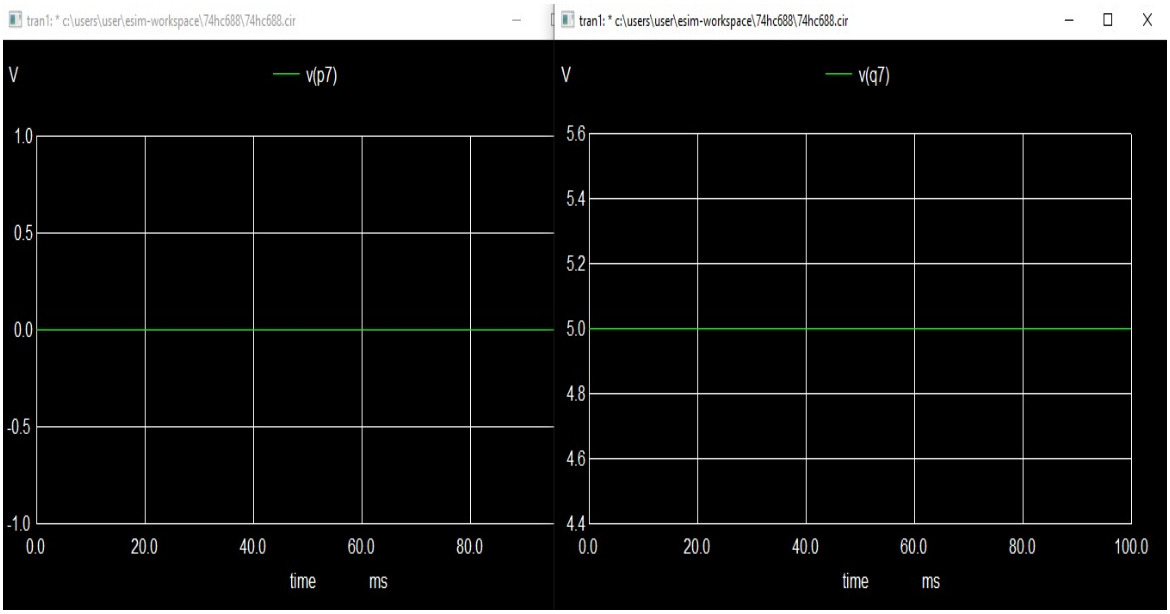

Figure 5.14: Input Voltage Waveform of 74HC688

5.3.5 Output Plots

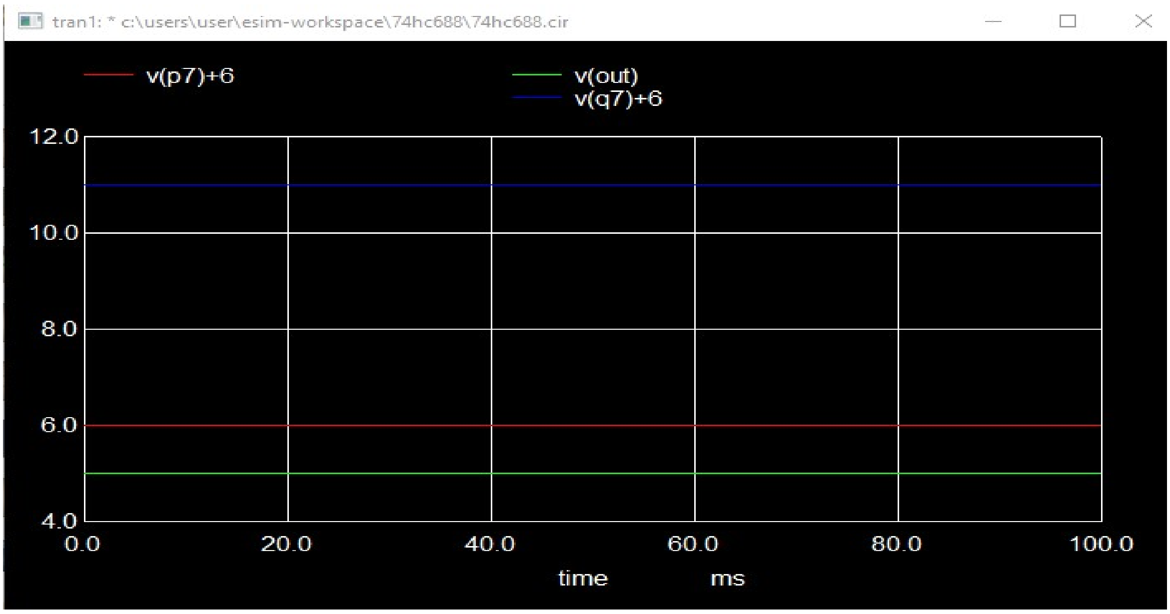

Figure 5.15: Output Voltage Waveform of 74HC688

Bibliography

[1] FOSSEE Official Website
URL: https://fossee.in/about

[2] eSim Official website
URL: https://esim.fossee.in/

[3] Datasheet Catalog
URL:https://www.datasheetcatalog.com

[4] ALLDATASHEET.COM
URL:https://www.alldatasheet.com/

[5] Mouser.in
URL:https://www.mouser.in/

[6] URL:https://www.ti.com/

[7] Datasheet4u National Semiconductor
URL: https://www.datasheet4u.com/

[8] Analog Devices
URL:https://www.analog.com/en/product-category.html