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On

Designing Integrated Circuit in eSim

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

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Chapter 1

Introduction

1.1 FOSSEE

FOSSEE, which stands for Free/Libre and Open Source Software for Education, is an organization based at IIT Bombay. It is a remarkable initiative aimed at promoting the use of open-source software in education and research. It was established with the mission to reduce 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 to empower 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

1.2 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, and 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.

1.3 NgSpice

NgSpice is an open-source SPICE simulator for electric and electronic circuits. It can simulate various circuit elements, including JFETs, bipolar and MOS transistors, passive elements (R, L, C), diodes and other devices, all interconnected in a netlist.

Digital circuits are also simulated, ranging from single gates to complex circuits, including combinations of analog, digital, and mixed-signal circuits. NgSpice offers a wealth of device models for active, passive, analog, and digital elements. Users input their circuits as netlists, and the output is one or more graphs of currents, voltages, and other electrical quantities, or saved in a data file

1.4 Makerchip

Makerchip is a platform that offers convenient and accessible 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 and proprietary tools, ensuring a comprehensive range of capabilities.

Users 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 userfriendly 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. While some are capable of PCB design (e.g., KiCad), others focus on simulations (e.g., EDA). To the best of our knowledge, there is no open-source software that combines circuit design, simulation, and layout design in one platform. eSim addresses this gap by integrating all these capabilities.

Chapter 2

Features of eSim

The objective behind the development of eSim is to provide an open-source EDA solution for electronics and electrical engineers. The software is capable of performing schematic creation, PCB design, and circuit simulation (analog, digital, and mixedsignal). It also provides 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 (Design Rule Check) 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 for future circuit design purposes by developers and users once they are successfully integrated into the eSim subcircuit library.

3.1 Approach

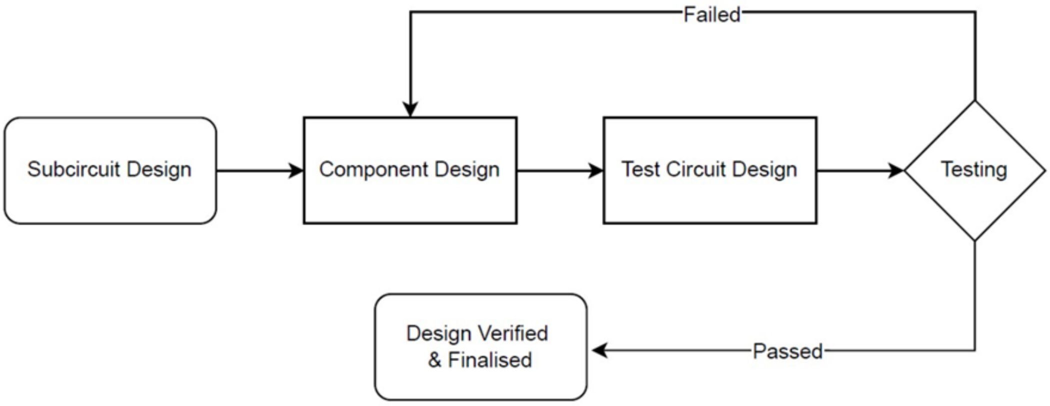

Figure 3.1: Flowchart of IC Design Approach Followed

Our approach to implementing the problem statement involved a systematic process, leveraging datasheets from leading Integrated Circuit (IC) manufacturers such as Texas Instruments, Analog Devices, Motorola (now NXP Semiconductors), and National Semiconductor. We focused on selecting ICs with diverse functionalities, including precision amplifiers, comparators, voltage regulators, and operational amplifiers. The process is outlined in the following steps:

1. Analyzing Datasheets: The first step involved an in-depth review of datasheets for various analog and digital ICs. We aimed to identify circuits suitable for implementation in eSim that were not already present in the eSim library. This process included scrutinizing the detailed schematics of each IC, evaluating component values, and understanding specifications. The goal was to select ICs that offered unique functionalities or enhancements not yet covered.

2. Subcircuit Creation: After selecting appropriate ICs, we proceeded to model these as sub-circuits within eSim. We utilized the model files available in the eSim device model library and ensured that our designs adhered strictly to the specifications outlined in the official datasheets. This phase also involved creating accurate symbol and pin diagrams for each IC, in accordance with the packaging and pin descriptions provided in the datasheets. This step was crucial for ensuring the fidelity of the subcircuit models.

3. Test Circuit Design: With the sub-circuits created, we then designed and built test circuits based on the datasheets. This step was essential for verifying the functionality of each sub-circuit. We developed a series of test cases and constructed corresponding test circuits to evaluate the performance and accuracy of the implemented IC models.

4. Schematic Testing: Following the construction of test circuits, we conducted simulations to analyze the outputs. This involved generating waveforms and plots to assess the behavior of the circuits. We employed KiCad for converting designs to NgSpice netlists and utilized eSim's simulation features to perform comprehensive testing.

If the simulated outputs deviated from expected results, it signaled potential errors in the schematic. In such instances, we revisited the design phase to identify and correct discrepancies. The iterative process of debugging and re-testing continued until the test cases produced satisfactory results. Once the IC models met the desired performance criteria, they were deemed successful, marking the completion of the design process

Chapter 4

LP339

4.1 General Description

The LP339 is an ultra-low power quad comparator integrated circuit, featuring four independent voltage comparators designed for operation from a single power supply. It is known for its minimal power consumption, making it particularly suitable for battery-powered applications. The device offers extremely tight regulation across a broad range of operating conditions, coupled with excellent temperature stability.

4.2 Key Features

- **Ultra-low Power Consumption:** The device typically draws 60 μA of supply current, which remains independent of the power supply voltage, translating to approximately 75 μW per comparator at +5 VDC.
- **Wide Supply Voltage Range:** Supports single supply operation from 2 VDC to 36 VDC, and can also operate from split supplies up to $\pm$18 VDC.
- **Low Input Characteristics:** Features low input biasing current (3 nA), low input offset current ($\pm$0.5 nA), and low input offset voltage ($\pm$2 mV).
- **MOS/CMOS Compatible Output:** The output voltage is compatible with MOS and CMOS logic families.

4.3 Applications

- **Limit Comparators:** Used for comparing input voltages against threshold limits.
- **Analog-to-Digital Converters:** Simple ADC implementations for signal conversion.
- **Pulse and Square-Wave Generators:** Generation of pulse and timing signals.
- **Battery-Powered Applications:** Ideal for portable devices due to low power consumption.
- **Voltage-Controlled Oscillators:** Used in VCO circuits for frequency modulation.

4.4 Pin Configuration

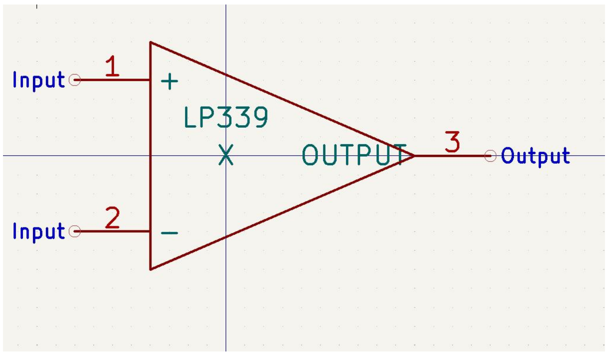

Figure 4.1: Pin Configuration of the LP339

4.5 Subcircuit Schematic Diagram

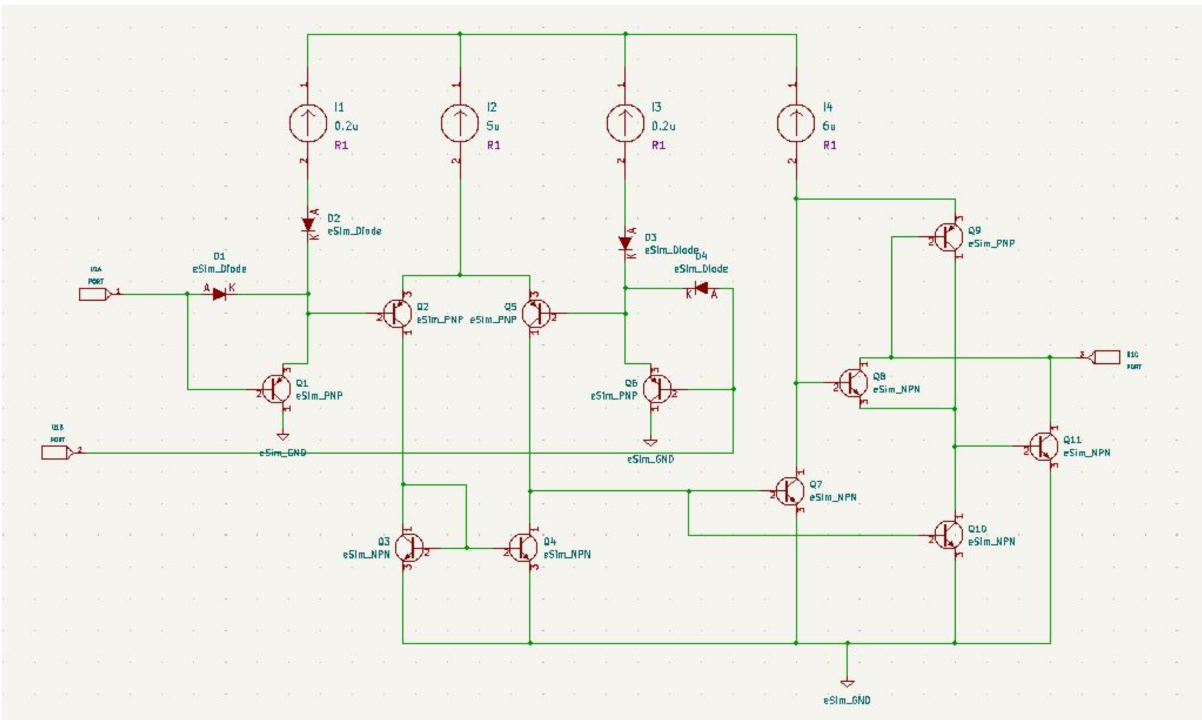

Figure 4.2: Subcircuit Schematic Diagram of the LP339

4.6 Test Circuit

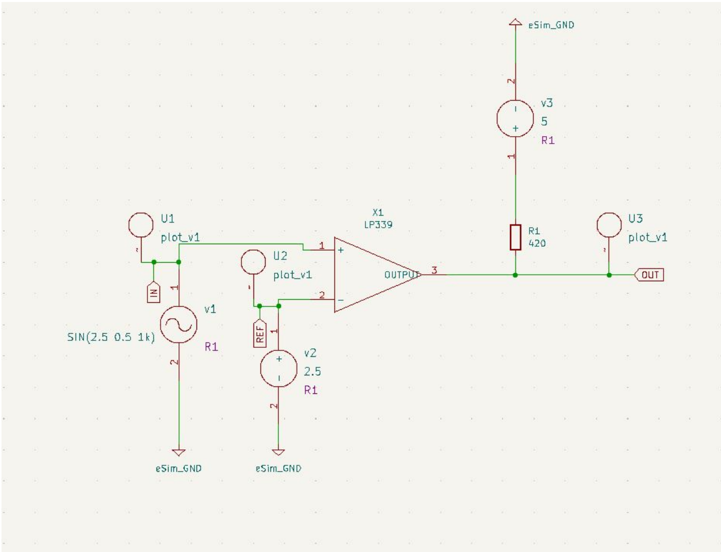

Figure 4.3: Test Circuit of the LP339

4.7 Input Plot

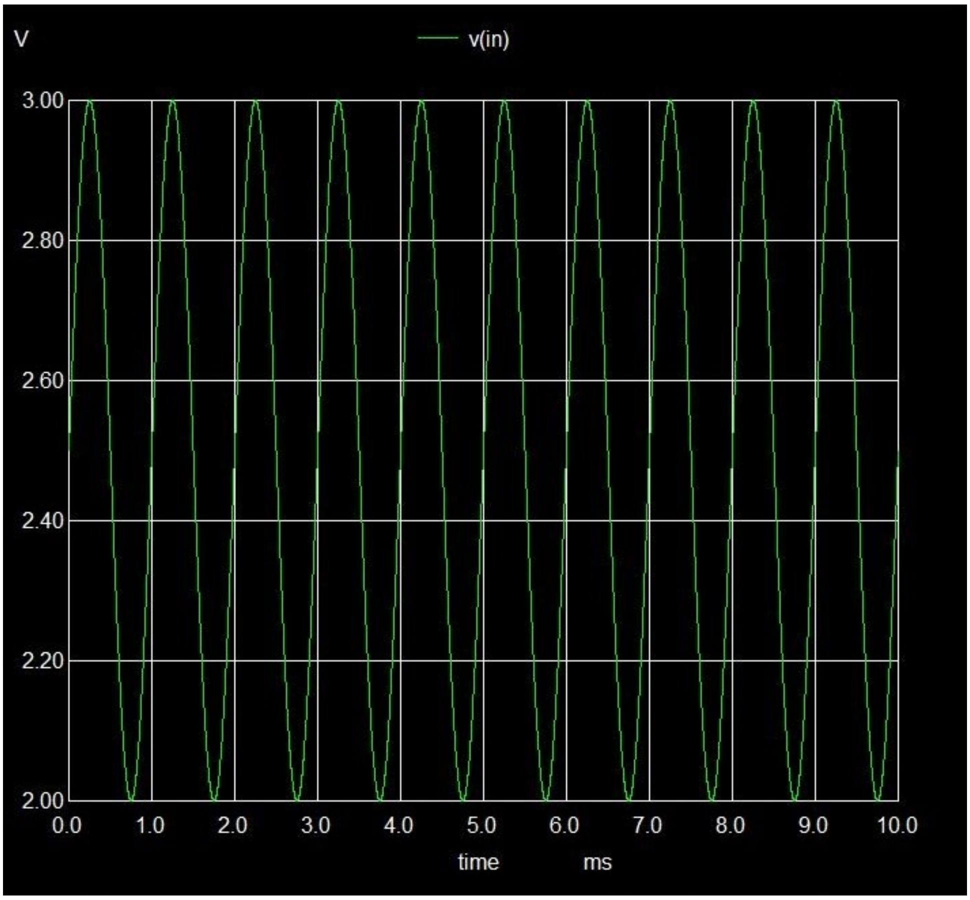

Figure 4.4: Input Plot of the LP339

4.8 Output Plot

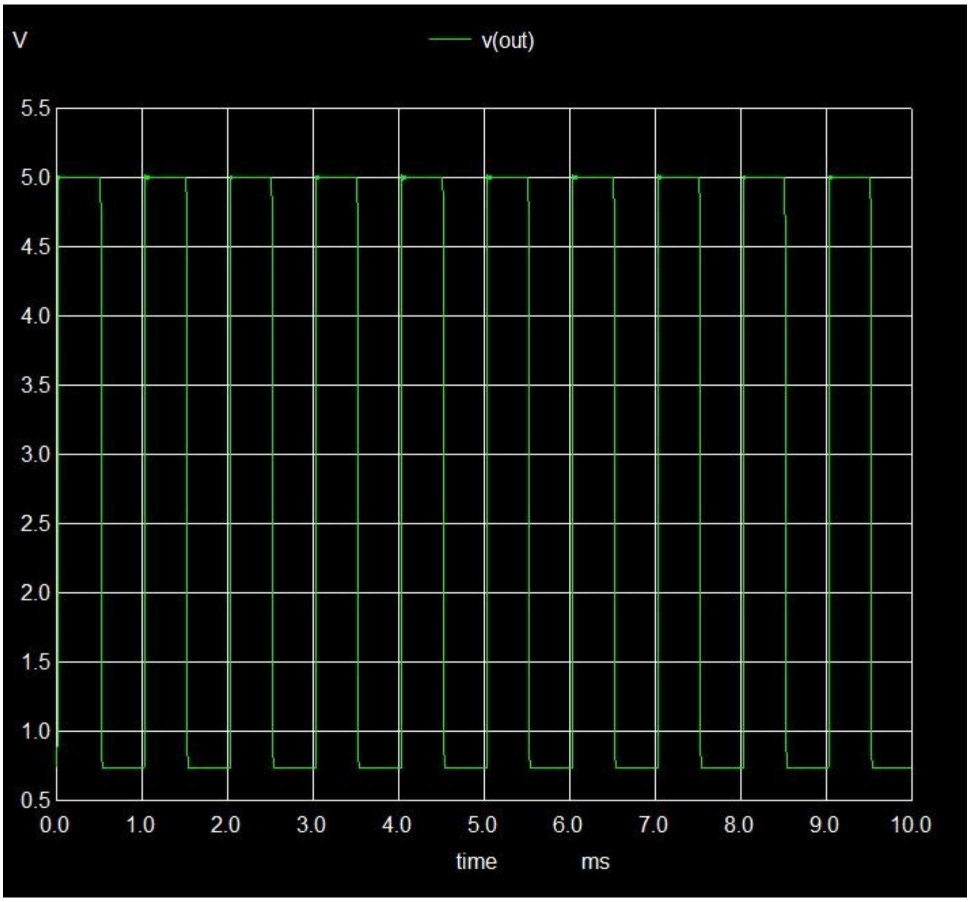

Figure 4.5: Output Plot of the LP339

Chapter 5

LM358N

5.1 General Description

The LM358N is a widely used dual operational amplifier (op-amp) integrated circuit, known for its versatility and low-power capabilities in general-purpose analog signal processing. It comprises two independent, high-gain, internally frequency-compensated operational amplifiers within a single 8-pin DIP package. The LM358N can operate from a wide range of power supplies and is suitable for battery-powered devices.

5.2 Key Features

- **Dual Op-Amps:** Integrates two independent operational amplifiers within a single package.
- **Wide Power Supply Range:** Can operate from a single supply from 3V to 32V or dual supplies from $\pm$1.5V to $\pm$16V.
- **Low Supply Current:** Typically 500 μA, largely independent of the supply voltage.
- **High Gain and Bandwidth:** Offers a large DC voltage gain of 100 dB and a wide bandwidth of 1.1 MHz.
- **Low Input Offset Voltage:** Typically 2 mV with low input bias current of about 20 nA.

5.3 Applications

- **Transducer Amplifiers:** Used for amplifying signals from sensors and transducers.
- **DC Gain Blocks:** Provides stable DC amplification for various circuits.
- **Integrators and Differentiators:** Used in analog computing circuits.
- **Voltage Followers:** Buffer circuits with high input impedance.
- **Active Filters:** Implementation of low-pass, high-pass, and band-pass filters.

5.4 Pin Configuration

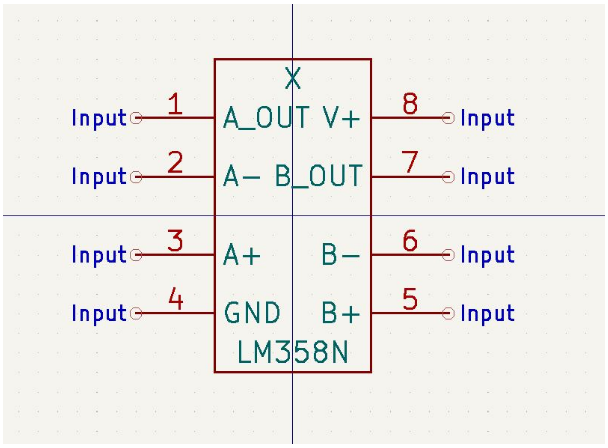

Figure 5.1: Pin Configuration of the LM358N

5.5 Subcircuit Schematic Diagram

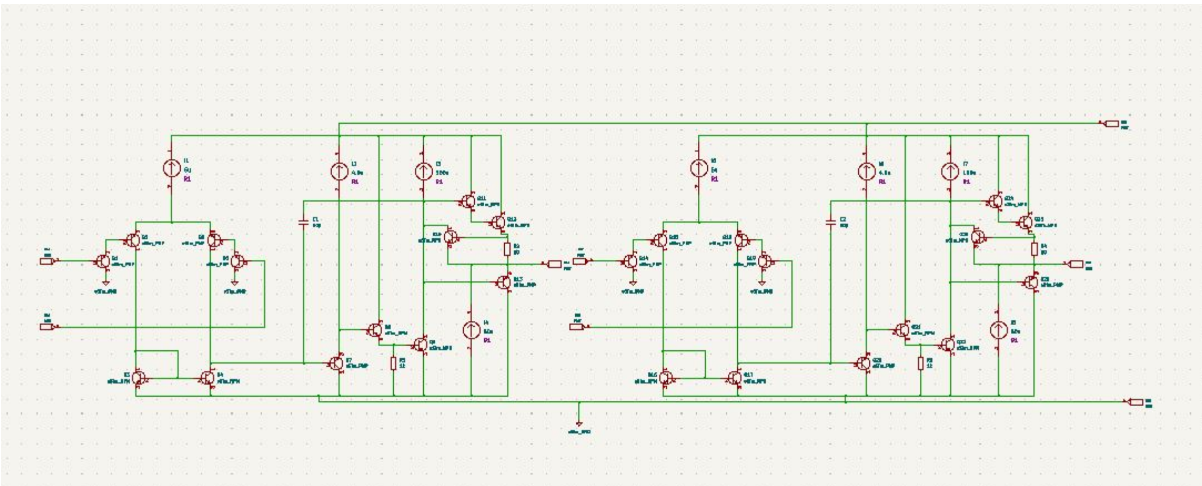

Figure 5.2: Subcircuit Schematic Diagram of the LM358N

5.6 Test Circuit

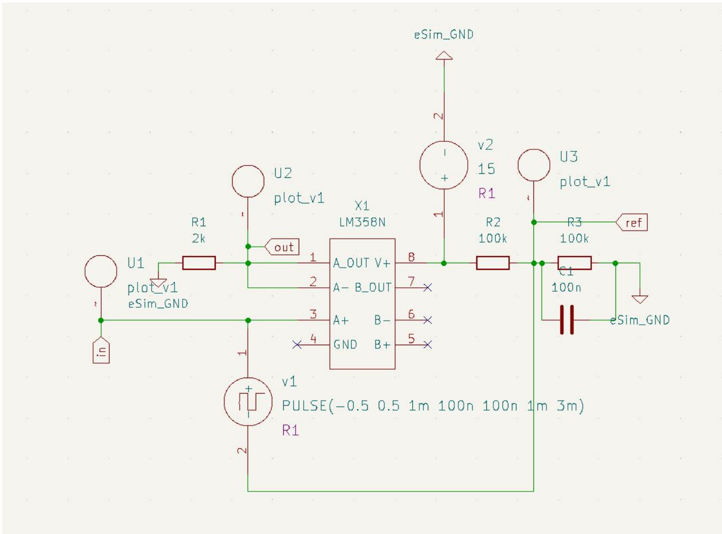

Figure 5.3: Test Circuit of the LM358N

5.7 Input Plot

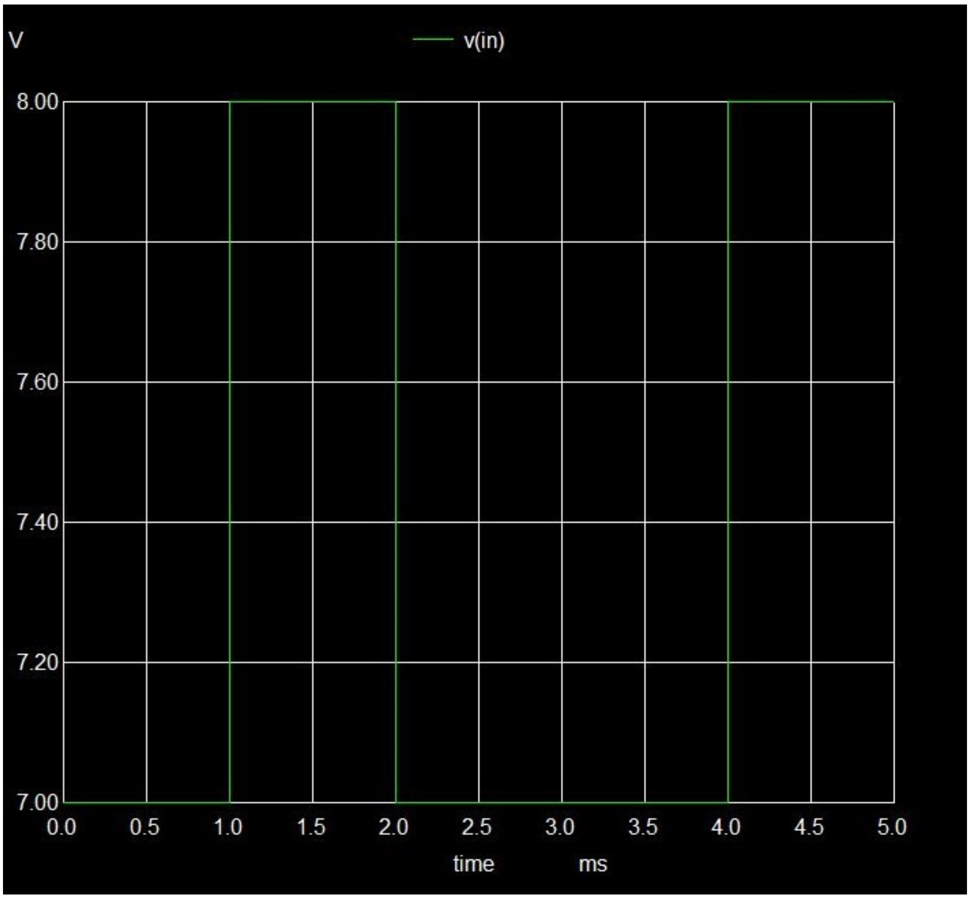

Figure 5.4: Input Plot of the LM358N

5.8 Output Plot

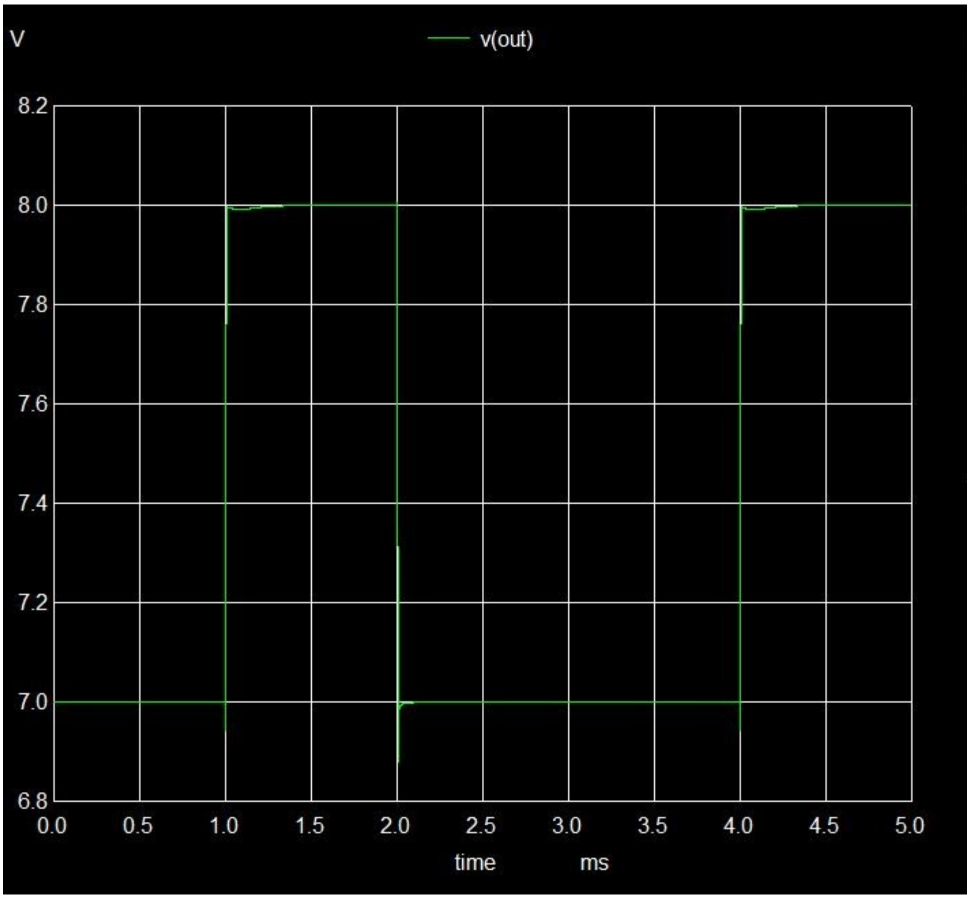

Figure 5.5: Output Plot of the LM358N

Chapter 6

LM318N

6.1 General Description

The LM318N is a fast operational amplifier designed for applications requiring wide bandwidth and a high slew rate. It offers significantly improved AC performance compared to general-purpose operational amplifiers. The device features internal frequency compensation, simplifying its application as no external components are strictly necessary for operation. It is pin compatible with general-purpose operational amplifiers and includes input and output overload protection.

6.2 Key Features

- **High Slew Rate:** Ensured 50 V/μs, with typical values reaching up to 150 V/μs with appropriate compensation.
- **Wide Bandwidth:** Small signal bandwidth of 15 MHz.
- **Low Bias Current:** Maximum bias current of 250 nA.
- **Wide Operating Voltage:** Operates from supplies ranging from $\pm$5V to $\pm$20V.
- **Internal Frequency Compensation:** No external components required for basic operation.

6.3 Applications

- **A/D Converters:** High-speed analog-to-digital conversion applications.
- **Oscillators:** Used in high-frequency oscillator circuits.
- **Active Filters:** Implementation of high-speed active filters.
- **Sample and Hold Circuits:** Fast acquisition sample and hold applications.
- **General-Purpose Amplifiers:** High-performance general amplification.

6.4 Pin Configuration

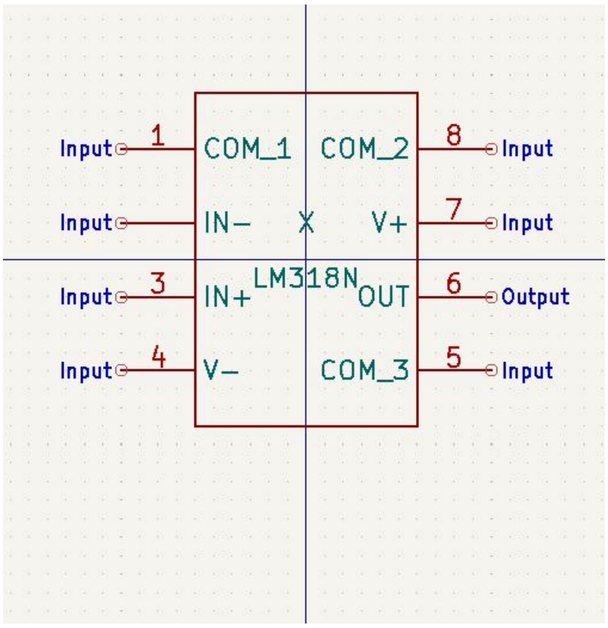

Figure 6.1: Pin Configuration of the LM318N

6.5 Subcircuit Schematic Diagram

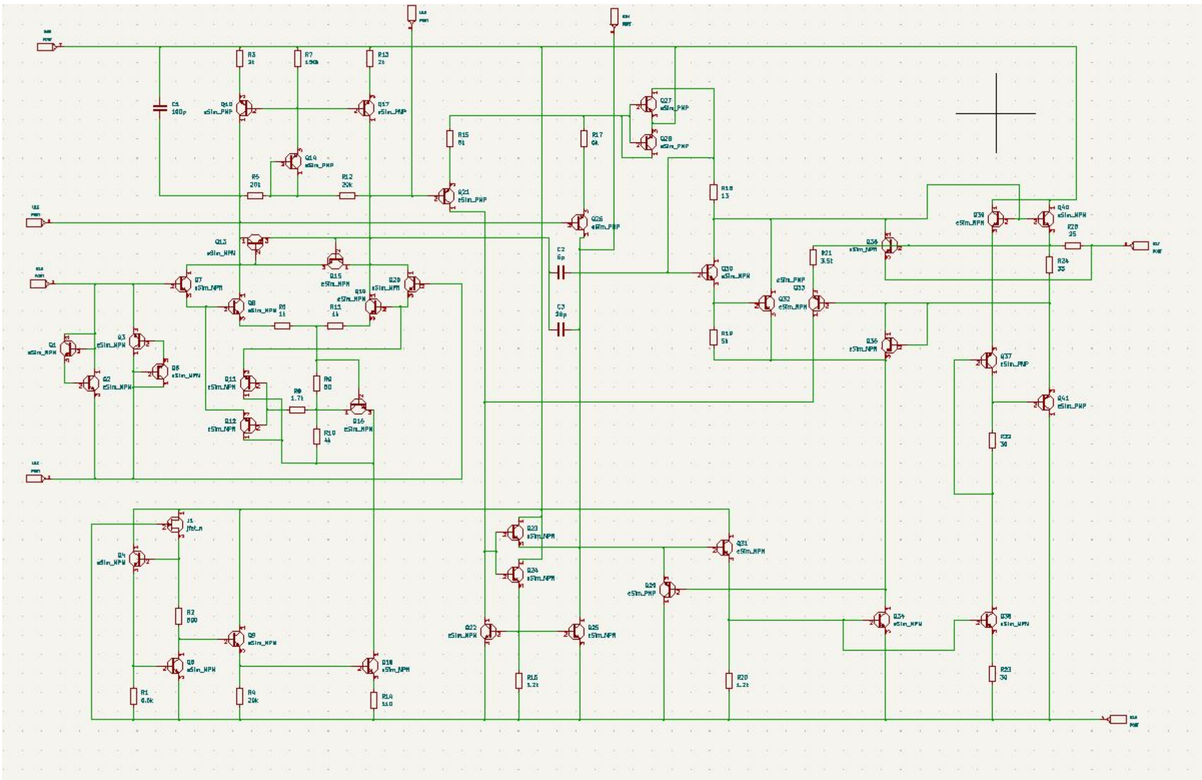

Figure 6.2: Subcircuit Schematic Diagram of the LM318N

6.6 Test Circuit

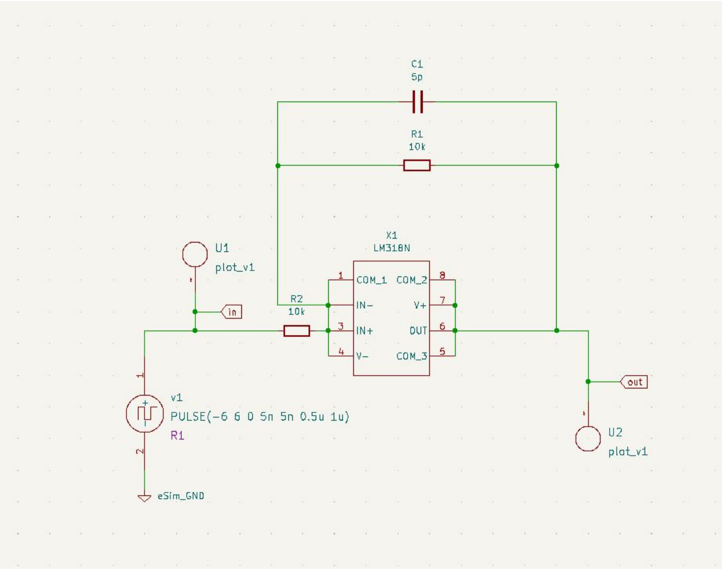

Figure 6.3: Test Circuit of the LM318N

6.7 Input Plot

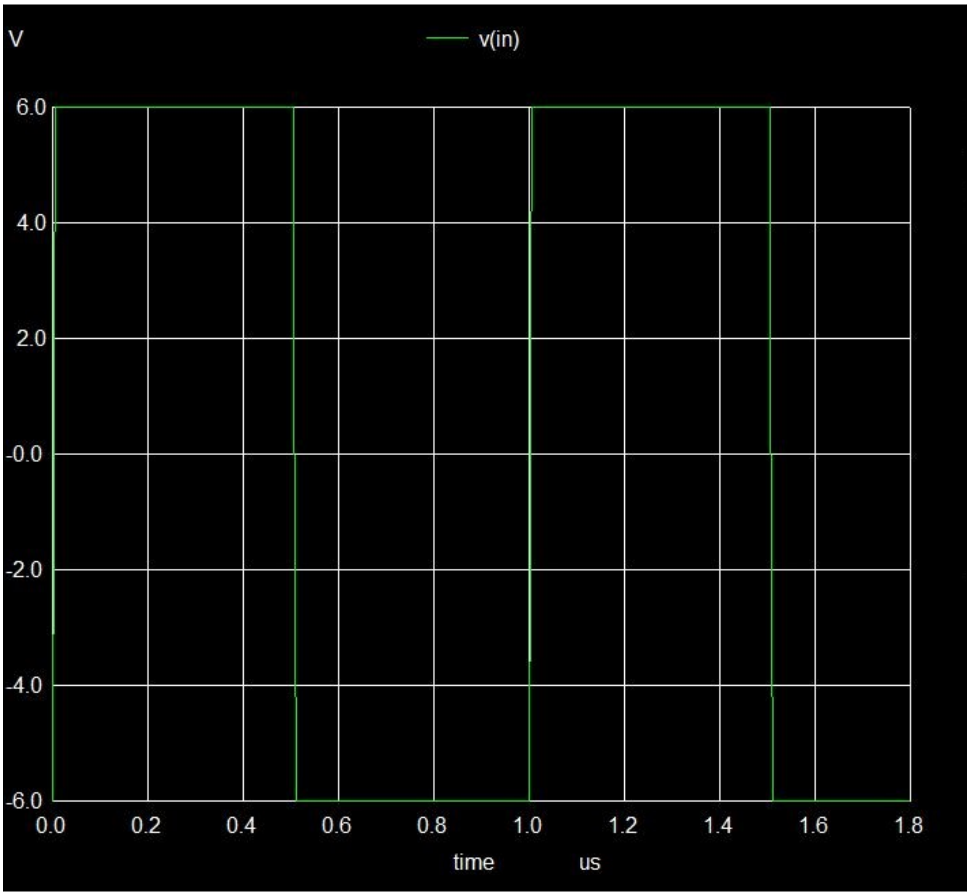

Figure 6.4: Input Plot of the LM318N

6.8 Output Plot

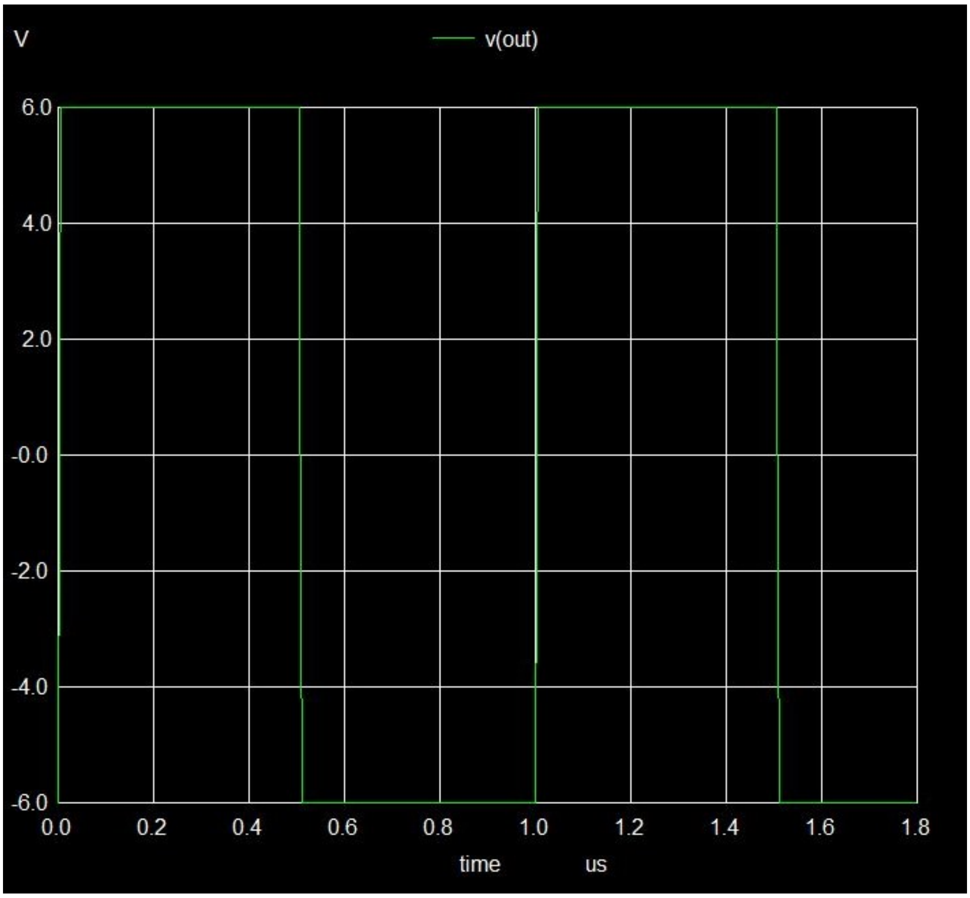

Figure 6.5: Output Plot of the LM318N

Chapter 7

LM150

7.1 General Description

The LM150 is a 3-terminal adjustable positive voltage regulator capable of supplying in excess of 3A over a 1.2V to 33V output range. It requires only two external resistors to set the output voltage. The device is designed for exceptional load and line regulation, and has internal current limiting, thermal overload protection, and safe area protection, making it essentially blow-out proof. The LM150 serves as a superior replacement for fixed regulators as it provides adjustable output voltage capability.

7.2 Key Features

- **Adjustable Output:** Output voltage adjustable from 1.2V to 33V.
- **High Output Current:** Capable of supplying over 3A of output current.
- **Internal Current Limiting:** Built-in current limiting for protection.
- **Thermal Overload Protection:** Prevents damage from overheating.
- **Excellent Load Regulation:** Maintains stable output under varying loads.

7.3 Applications

- **Adjustable Power Supplies:** Used in variable voltage power supply designs.
- **Constant Current Regulators:** Provides stable current output for LED drivers and battery chargers.
- **Programmable Output Regulators:** Output voltage can be programmed with external resistors.
- **Local On-Card Regulation:** Used for point-of-load regulation in circuit boards.
- **High-Power Systems:** Suitable for automotive and industrial applications.

7.4 Pin Configuration

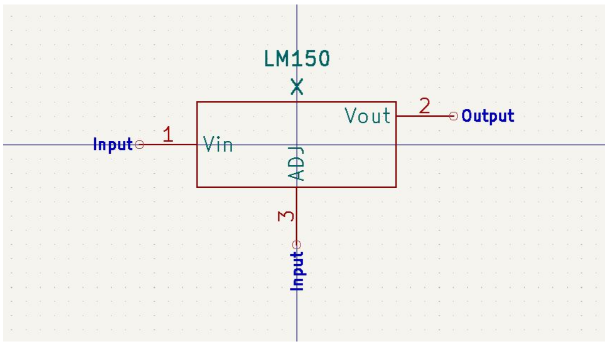

Figure 7.1: Pin Configuration of the LM150

7.5 Subcircuit Schematic Diagram

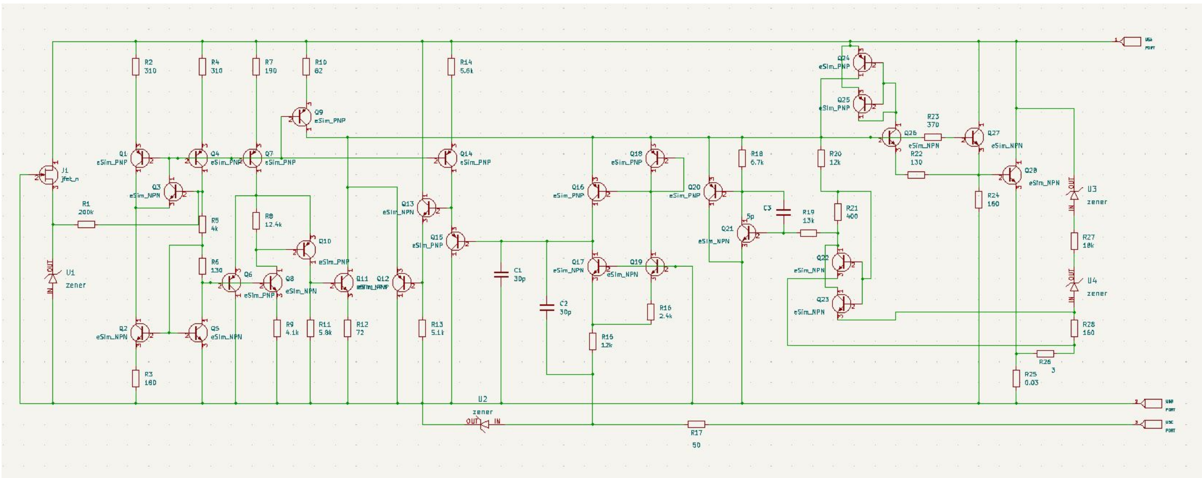

Figure 7.2: Subcircuit Schematic Diagram of the LM150

7.6 Test Circuit

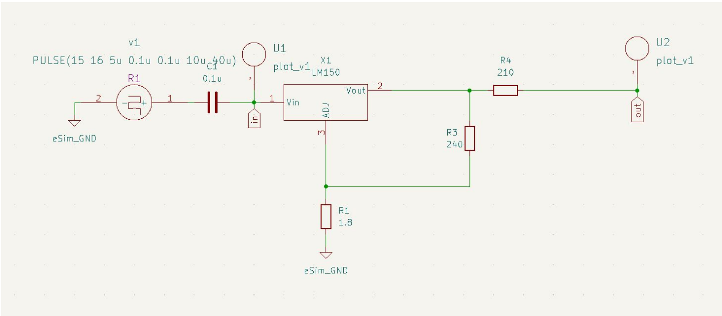

Figure 7.3: Test Circuit of the LM150

7.7 Input Plot

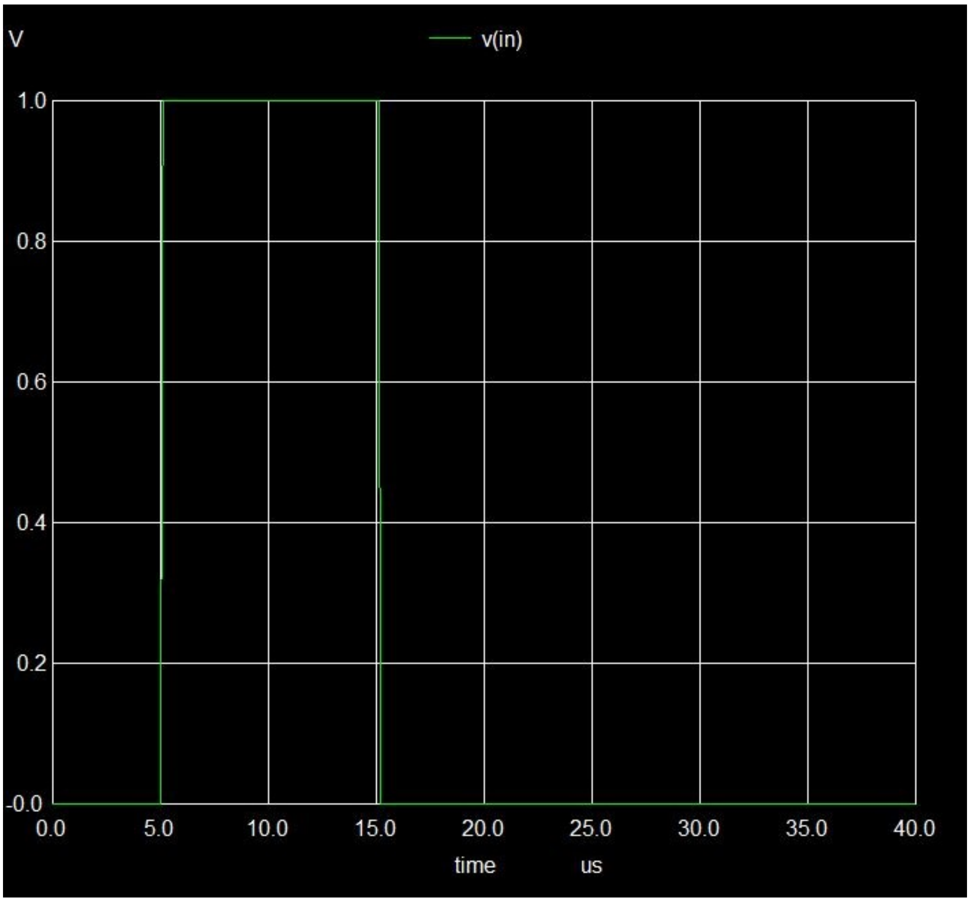

Figure 7.4: Input Plot of the LM150

7.8 Output Plot

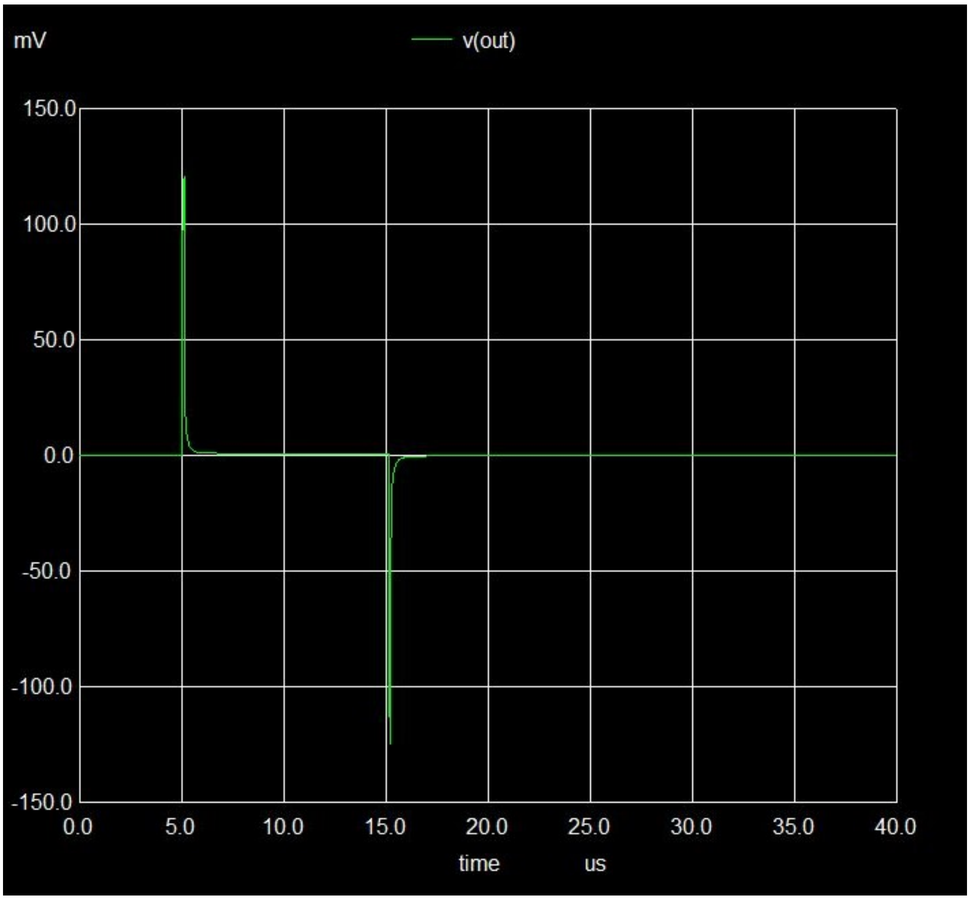

Figure 7.5: Output Plot of the LM150

Chapter 8

LM104

8.1 General Description

The LM104 is a precision negative voltage regulator designed by National Semiconductor. It offers programmable output voltages and can be programmed by a single external resistor to supply any voltage from -40V down to zero. The LM104 can provide 0.01-percent regulation from no load to full load, with excellent temperature stability and ripple rejection. It serves as the complementary part to the LM105 positive regulator, intended for systems requiring regulated negative voltages.

8.2 Key Features

- **Programmable Output:** Can supply any voltage from -40V down to zero using a single external resistor.
- **High Precision:** Provides 0.01-percent regulation from no load to full load.
- **Output Current:** Can deliver output currents up to 25 mA, extendable with external transistors.
- **Temperature Stability:** Offers excellent temperature stability over the operating range.
- **Current Limiting:** Both constant and foldback current limiting options available.

8.3 Applications

- **Negative Voltage Power Supplies:** Used in systems requiring regulated negative voltages.
- **Precision Instruments:** Suitable for high-accuracy measurement equipment.
- **Laboratory Equipment:** Used in test and measurement applications.
- **Dual Supply Systems:** Provides the negative rail for dual supply systems.
- **Operational Amplifier Biasing:** Provides negative supply for op-amp circuits.

8.4 Pin Configuration

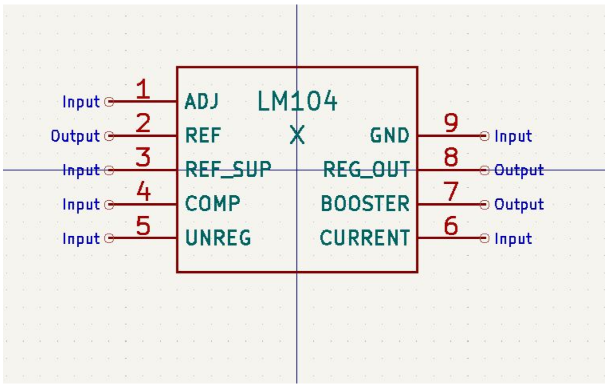

Figure 8.1: Pin Configuration of the LM104

8.5 Subcircuit Schematic Diagram

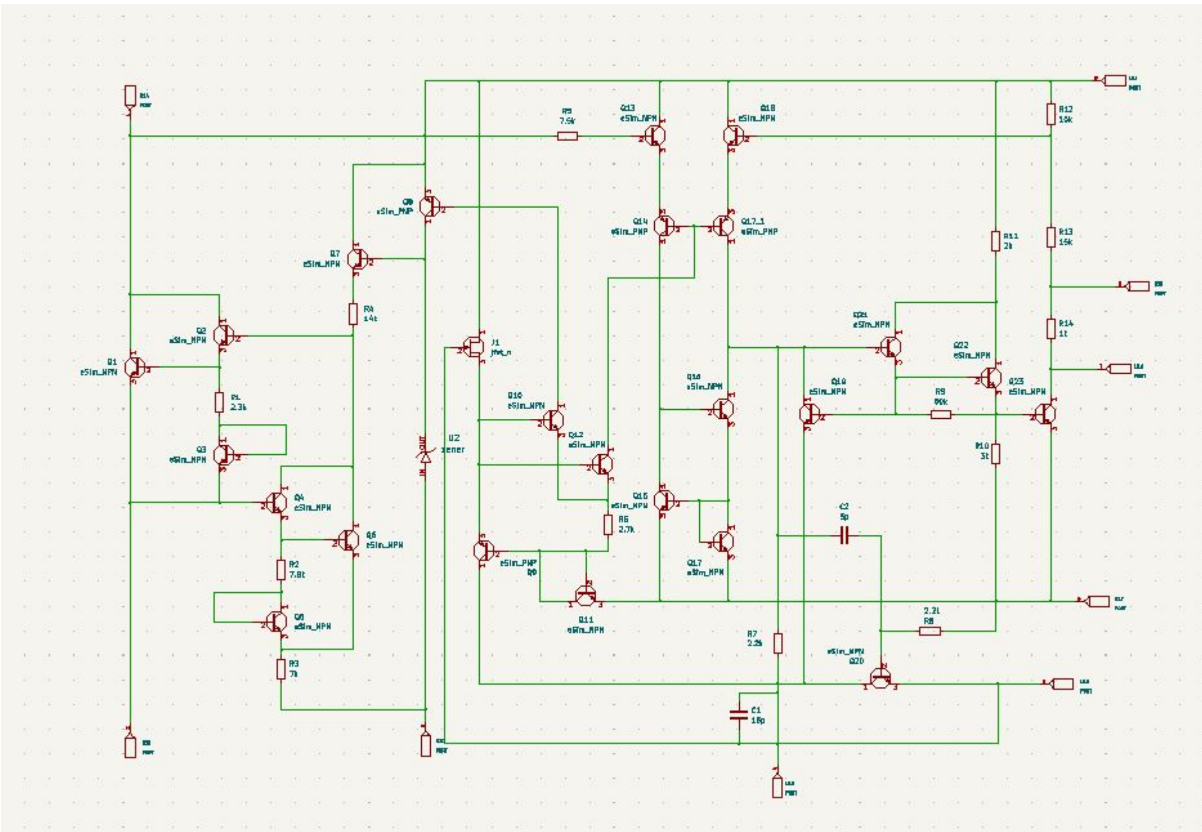

Figure 8.2: Subcircuit Schematic Diagram of the LM104

8.6 Test Circuit

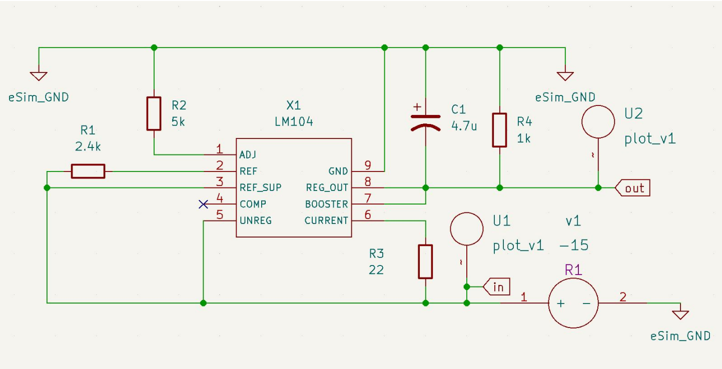

Figure 8.3: Test Circuit of the LM104

8.7 Input Plot

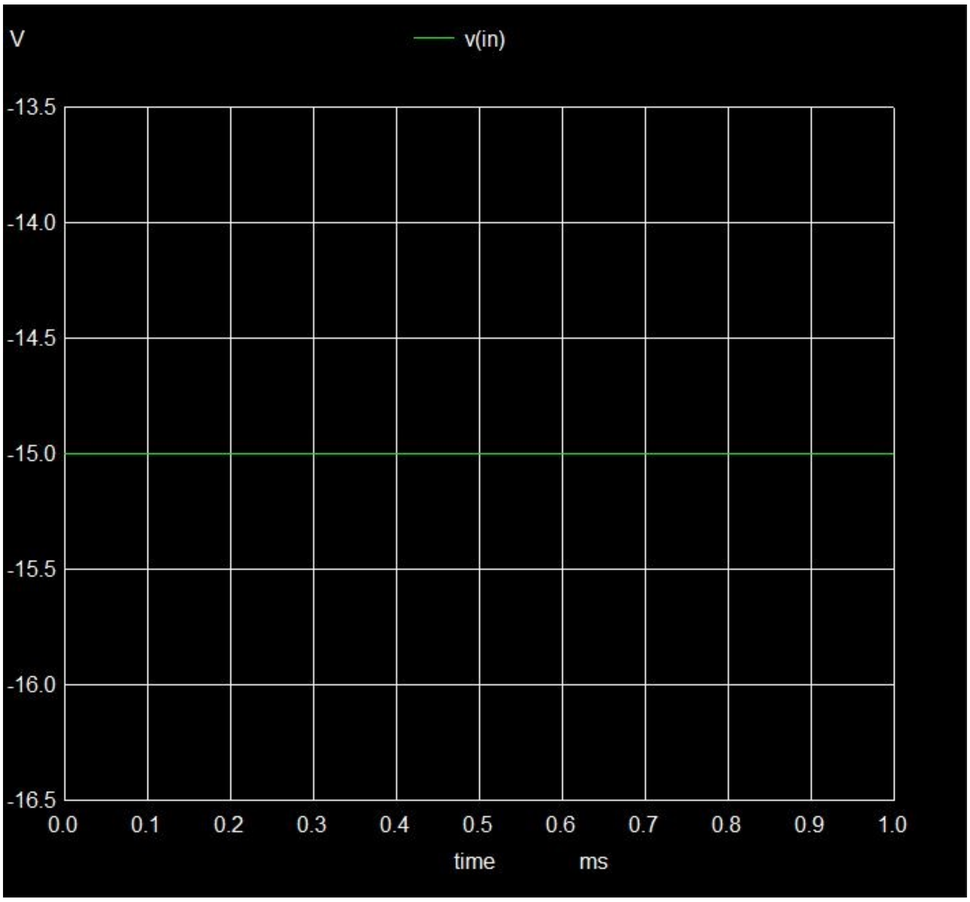

Figure 8.4: Input Plot of the LM104

8.8 Output Plot

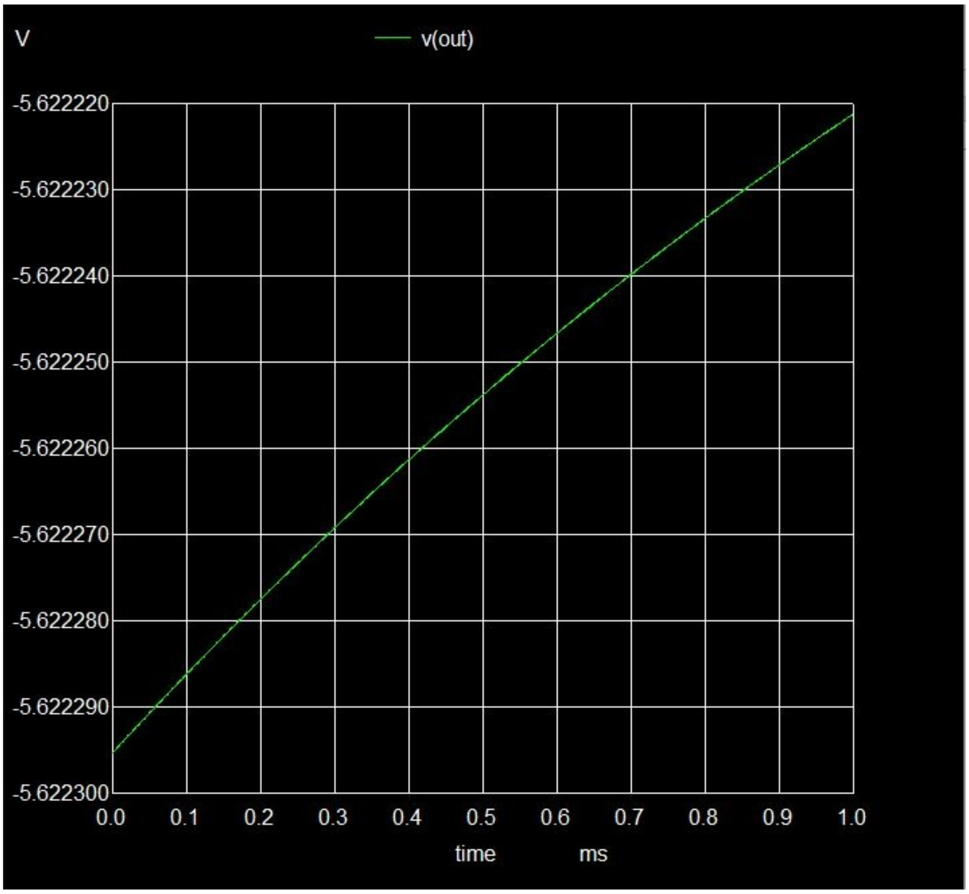

Figure 8.5: Output Plot of the LM104

Chapter 9

MC1463

9.1 General Description

The MC1463 is a negative-power-supply voltage regulator manufactured by Motorola (now NXP Semiconductors/Freescale). It is designed to provide stable regulated negative voltages for various electronic applications. The device offers excellent regulation and is suitable for systems that require regulated negative supply voltages with a common ground to the unregulated supply.

9.2 Key Features

- **Negative Voltage Regulation:** Provides stable regulated negative output voltage.
- **High Regulation:** Offers excellent line and load regulation.
- **Temperature Stability:** Maintains stable performance across operating temperature range.
- **Current Capability:** Supports adequate current for typical applications.
- **Protection Features:** Includes overload and short-circuit protection.

9.3 Applications

- **Negative Power Supplies:** Used in electronic equipment requiring negative voltage rails.
- **Dual Supply Systems:** Provides the negative rail for analog circuits.
- **Operational Amplifier Circuits:** Supplies negative voltage for op-amp biasing.
- **Audio Equipment:** Used in audio amplifier power supply sections.
- **Test and Measurement:** Suitable for precision test equipment.

9.4 Pin Configuration

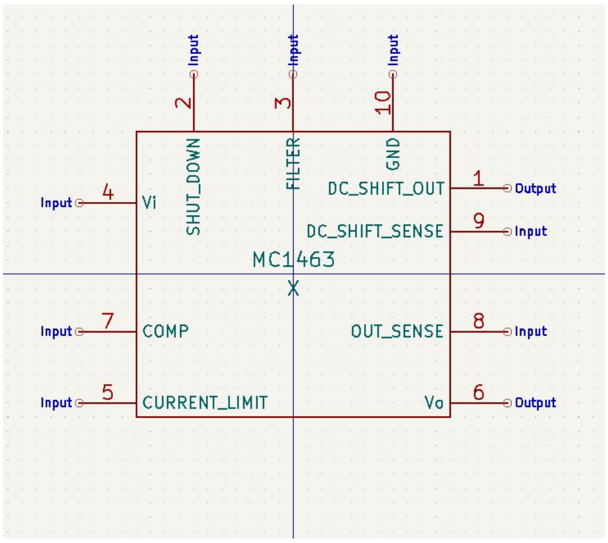

Figure 9.1: Pin Configuration of the MC1463

9.5 Subcircuit Schematic Diagram

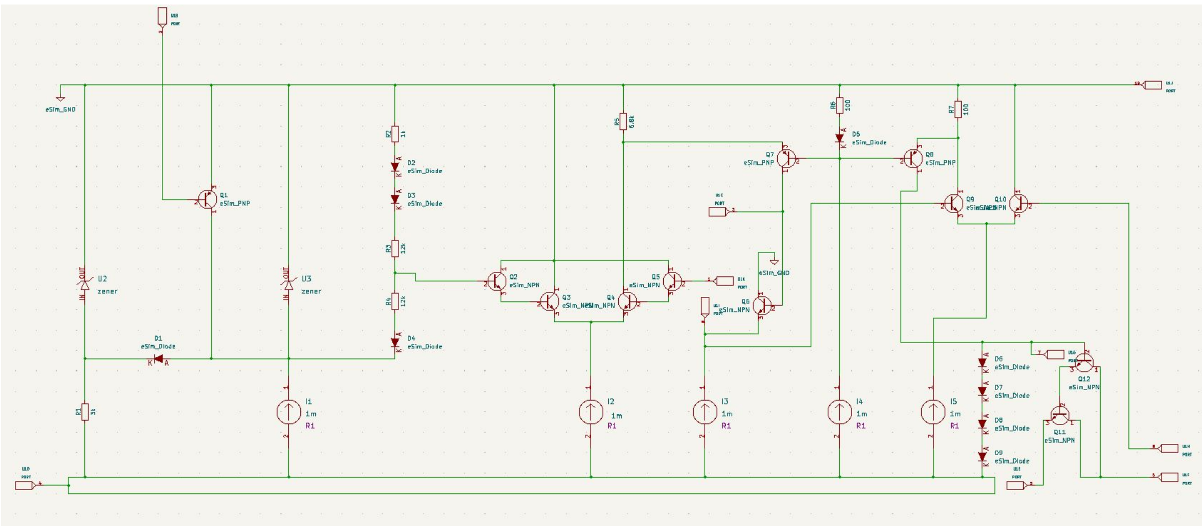

Figure 9.2: Subcircuit Schematic Diagram of the MC1463

9.6 Test Circuit

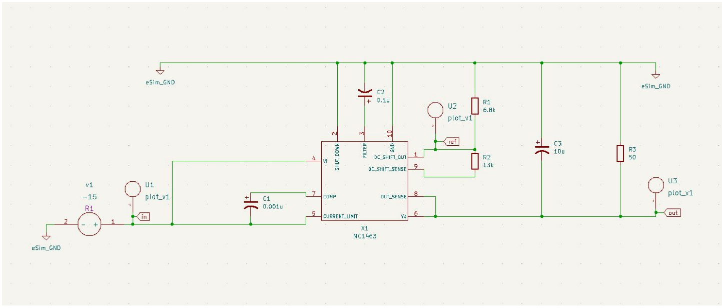

Figure 9.3: Test Circuit of the MC1463

9.7 Input Plot

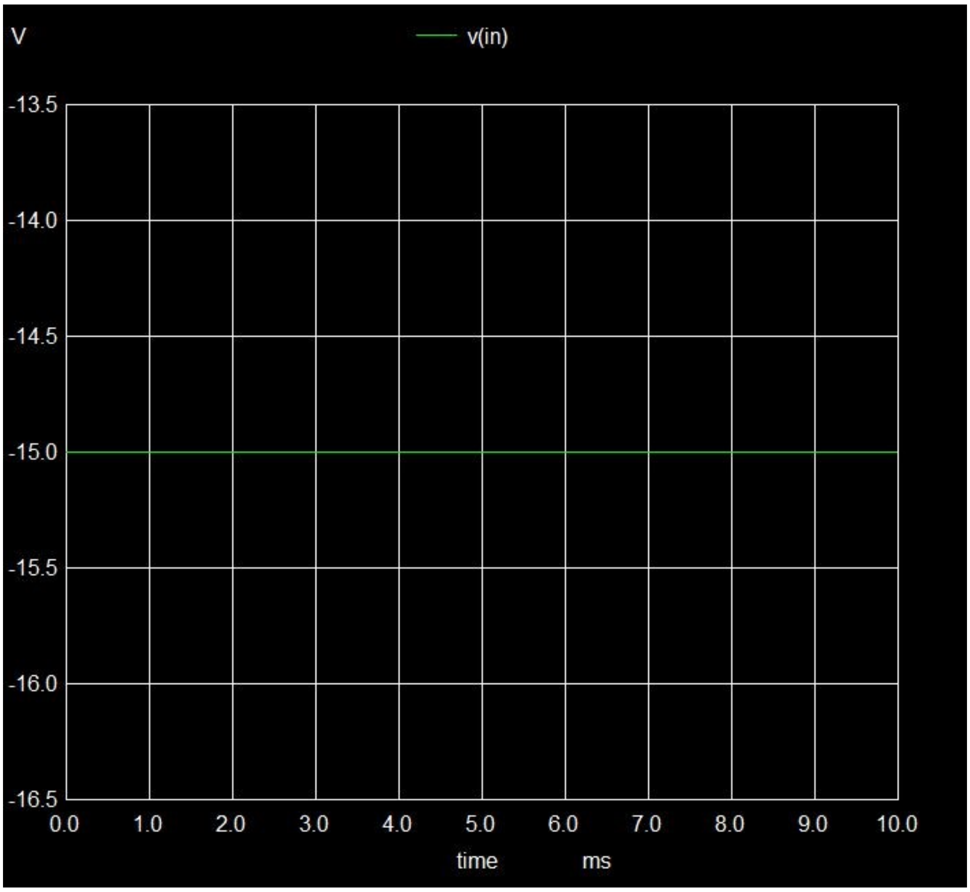

Figure 9.4: Input Plot of the MC1463

9.8 Output Plot

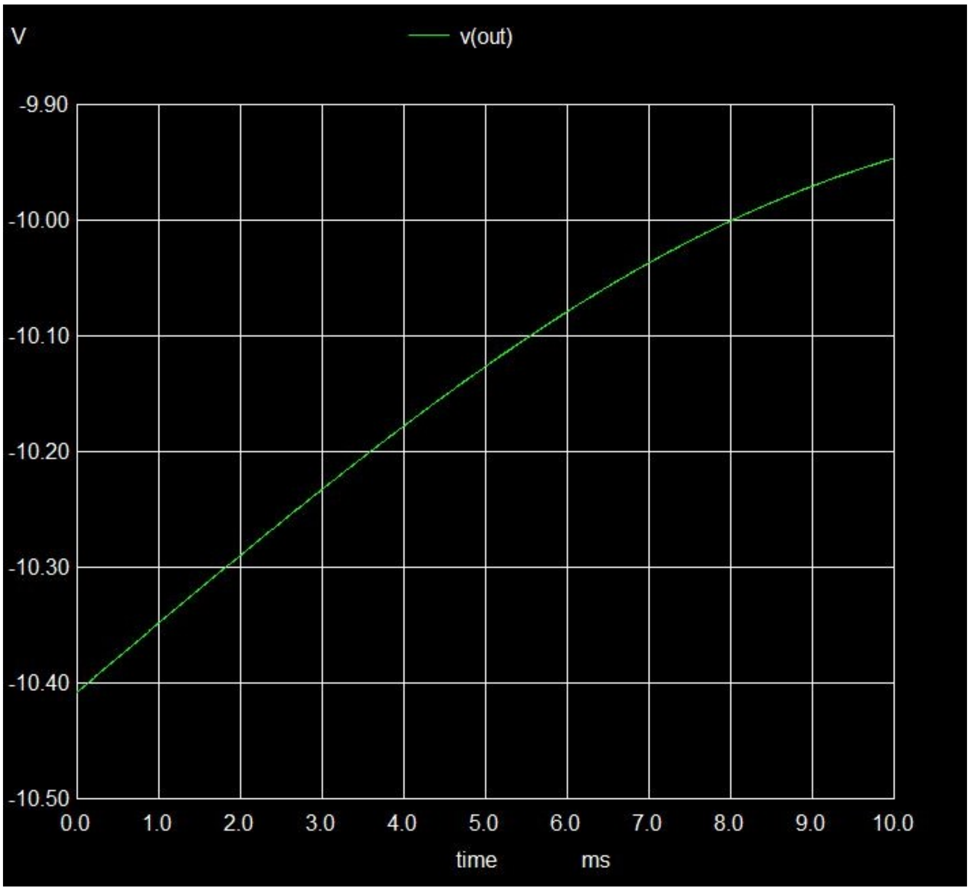

Figure 9.5: Output Plot of the MC1463

Chapter 10

MC1466L

10.1 General Description

The MC1466L is a precision wide-range voltage and current regulator manufactured by Motorola. This ”floating” regulator is designed to deliver high voltages, limited primarily by external series pass transistors, and offers adjustable output voltage and current. The MC1466L was a common and inexpensive component in the 1970s and is now considered an obsolete part, though it remains useful for vintage equipment repair and educational purposes.

10.2 Key Features

- **Wide Range Regulation:** Capable of regulating over a wide voltage range.
- **Floating Design:** Can be used with external pass transistors for higher power applications.
- **Adjustable Output:** Both voltage and current can be externally adjusted.
- **Precision Control:** Offers precise control over output parameters.
- **Versatile Configuration:** Can be configured for various voltage and current requirements.

10.3 Applications

- **High Voltage Power Supplies:** Used in power supplies requiring high output voltages.
- **Programmable Power Supplies:** Suitable for laboratory power supply designs.
- **Current Sources:** Can be configured as a programmable current source.
- **Vintage Equipment:** Used in repair and restoration of classic electronic equipment.
- **Industrial Control Systems:** Applied in industrial power regulation applications.

10.4 Pin Configuration

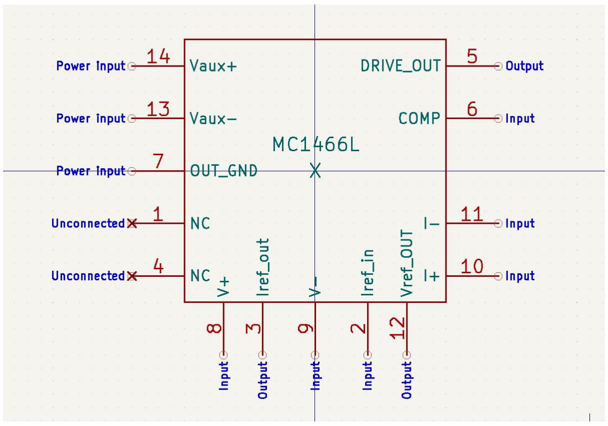

Figure 10.1: Pin Configuration of the MC1466L

10.5 Subcircuit Schematic Diagram

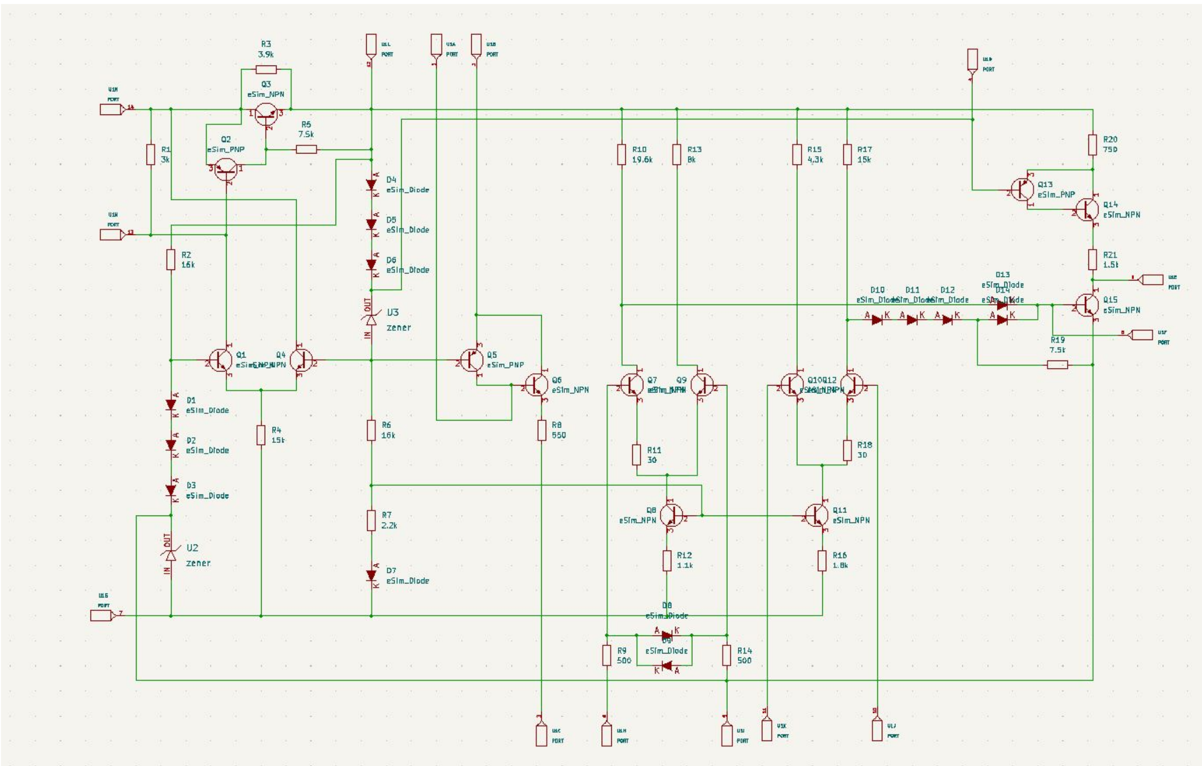

Figure 10.2: Subcircuit Schematic Diagram of the MC1466L

10.6 Test Circuit

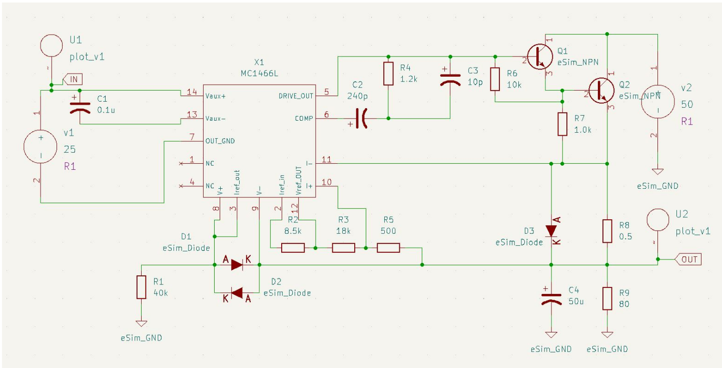

Figure 10.3: Test Circuit of the MC1466L

10.7 Input Plot

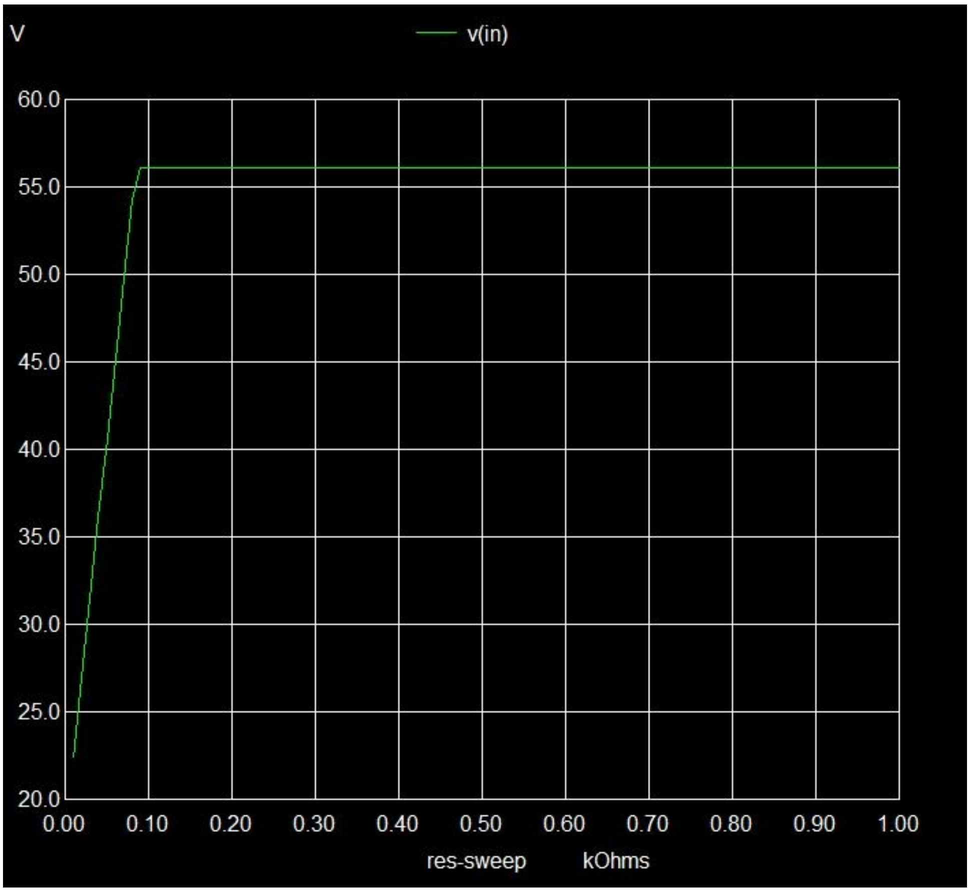

Figure 10.4: Input Plot of the MC1466L

10.8 Output Plot

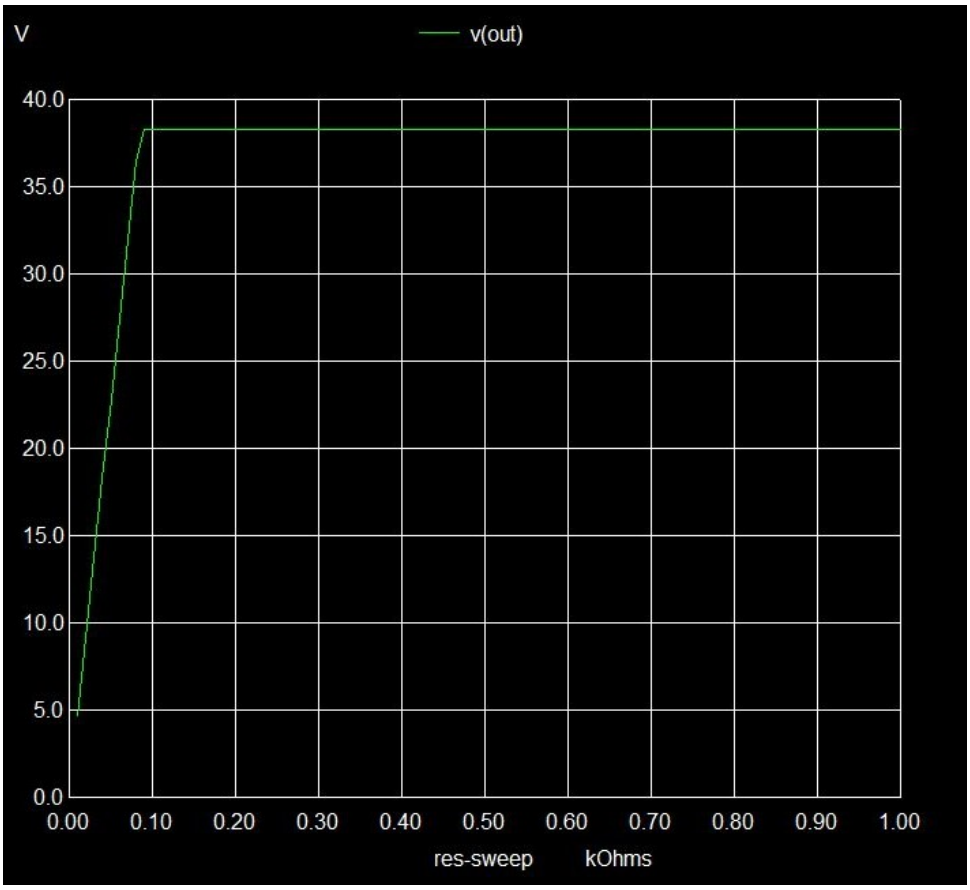

Figure 10.5: Output Plot of the MC1466L

Chapter 11

MC1468

11.1 General Description

The MC1468 is a dual polarity tracking regulator manufactured by Motorola (now NXP Semiconductors). It is designed to provide balanced positive and negative output voltages for systems requiring dual supply rails. The device is internally set for ±15V outputs, but these can be externally adjusted from 8.0V to 20V. The MC1468 can supply output currents up to 100 mA and accommodate input voltages up to ±30V.

11.2 Key Features

- **Dual Polarity Output:** Provides both positive and negative regulated voltages.
- **Tracking Regulation:** Ensures balanced output voltages for symmetrical operation.
- **Adjustable Output:** Internally set for ±15V, externally adjustable from 8.0V to 20V.
- **Current Capability:** Supplies output currents up to 100 mA per rail.
- **Current Limiting:** Features adjustable current limiting and remote sensing provisions.

11.3 Applications

- **Operational Amplifier Power Supplies:** Provides dual rails for op-amp circuits.
- **Audio Equipment:** Used in audio amplifier and preamplifier power supplies.
- **Data Acquisition Systems:** Provides symmetrical power for A/D and D/A converters.
- **Instrumentation:** Suitable for precision measurement and test equipment.
- **Analog Signal Processing:** Powers analog circuits requiring dual supplies.

11.4 Pin Configuration

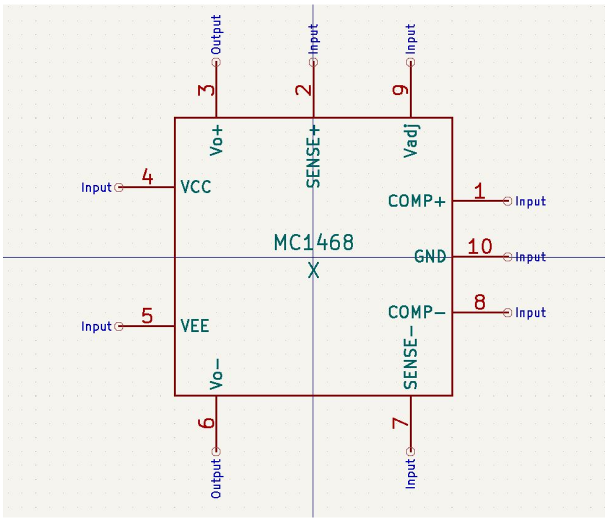

Figure 11.1: Pin Configuration of the MC1468

11.5 Subcircuit Schematic Diagram

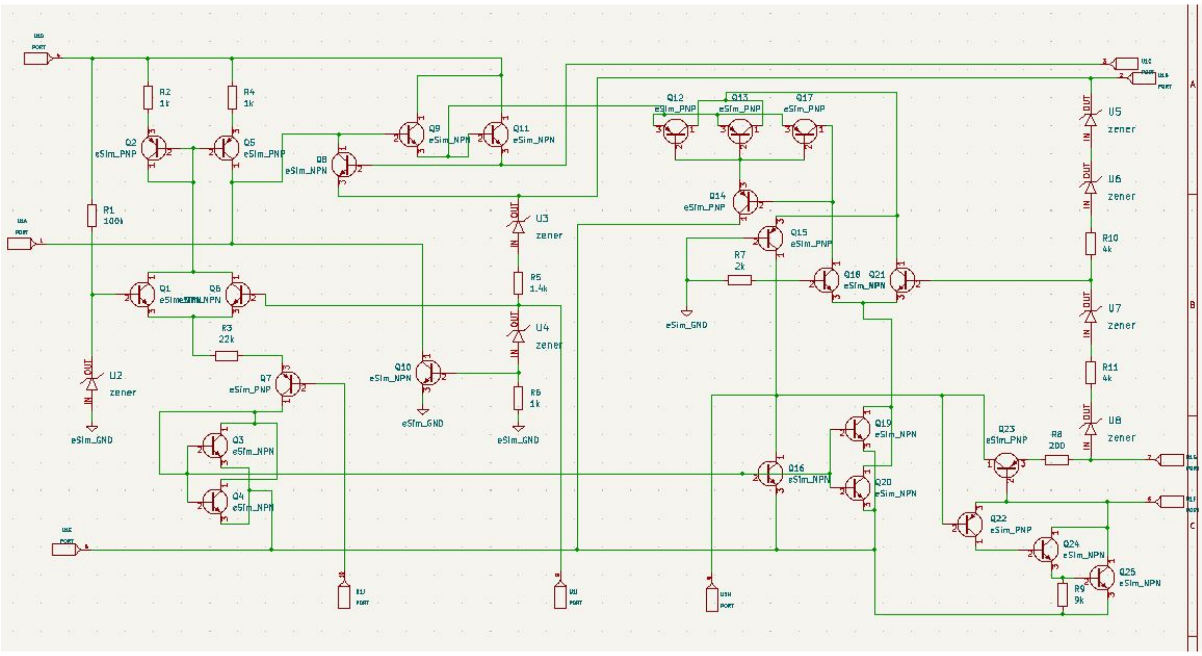

Figure 11.2: Subcircuit Schematic Diagram of the MC1468

11.6 Test Circuit

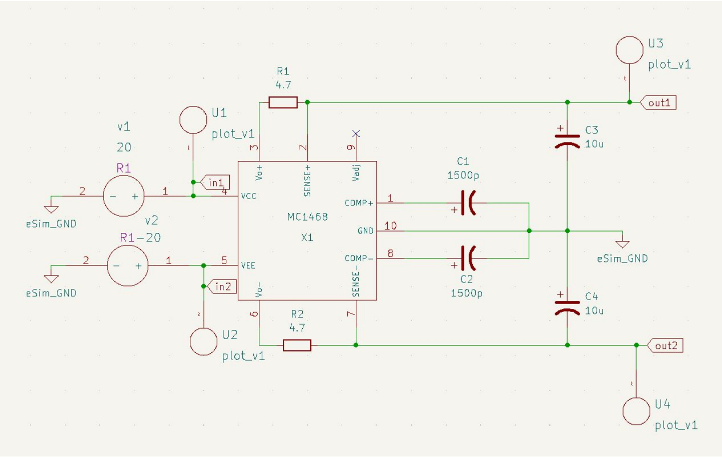

Figure 11.3: Test Circuit of the MC1468

11.7 Input Plot

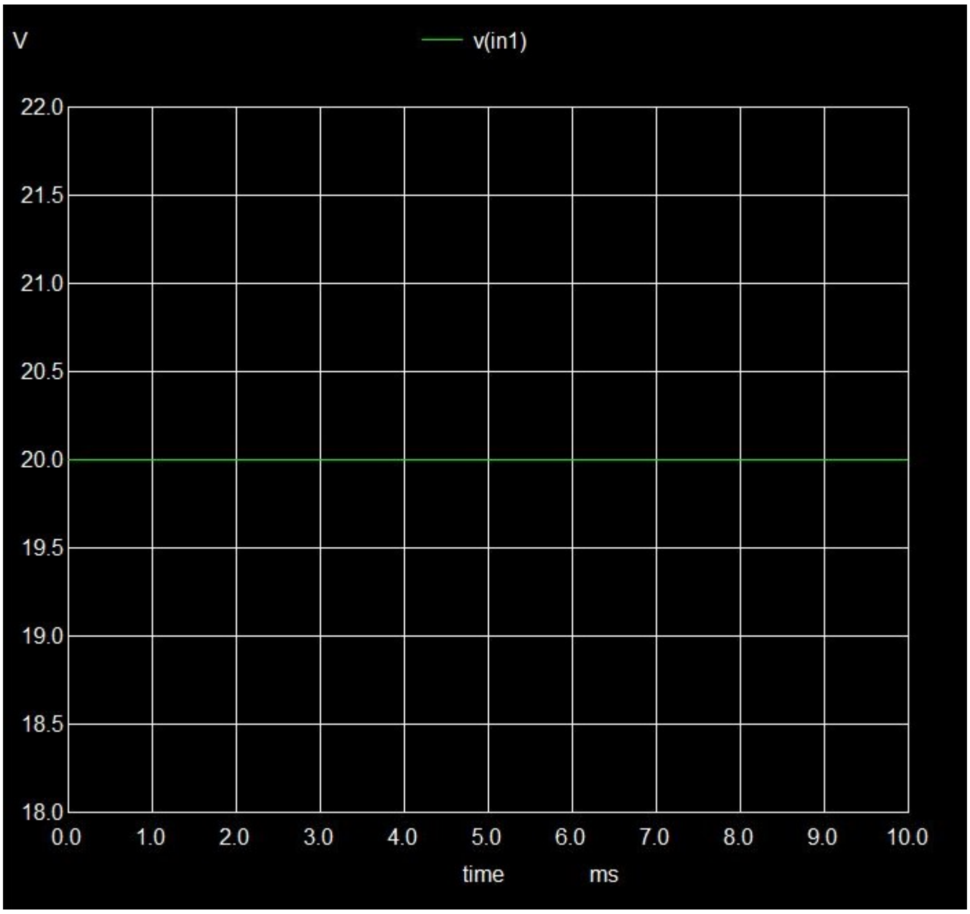

Figure 11.4: Input Plot of the MC1468

11.8 Output Plot

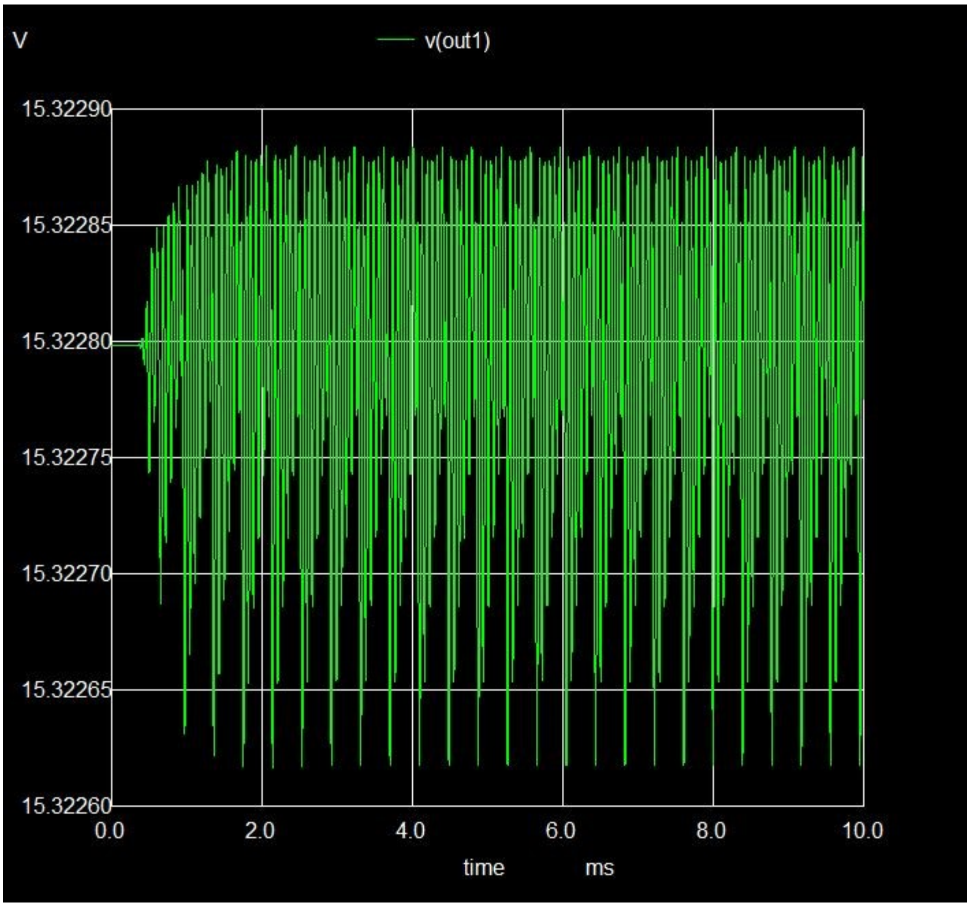

Figure 11.5: Output Plot of the MC1468

Chapter 12

MC1469

12.1 General Description

The MC1469 is a positive monolithic voltage regulator manufactured by Motorola (now NXP Semiconductors). It can deliver a continuous load current of up to 500 mAdc, with an output voltage adjustable from 2.5 Vdc to 37 Vdc. The MC1469 operates within a temperature range of 0 to +70°C and features excellent load regulation, high power capability, and excellent temperature stability.

12.2 Key Features

- **Adjustable Output:** Output voltage adjustable from 2.5 Vdc to 37 Vdc.
- **High Output Current:** Can deliver continuous load current up to 500 mA.
- **High Power Capability:** Supports power dissipation up to 17.5 Watts.
- **Electronic Shut-Down:** Incorporates electronic ”Shut-Down” control feature.
- **High Ripple Rejection:** Provides excellent ripple rejection for clean output.

12.3 Applications

- **Portable Equipment:** Used in battery-operated devices requiring voltage regulation.
- **Embedded Systems:** Provides regulated power for microcontroller circuits.
- **Industrial Equipment:** Suitable for industrial control power supplies.
- **Consumer Electronics:** Powers various consumer electronic devices.
- **Telecommunications:** Used in telecom equipment power supply sections.

12.4 Pin Configuration

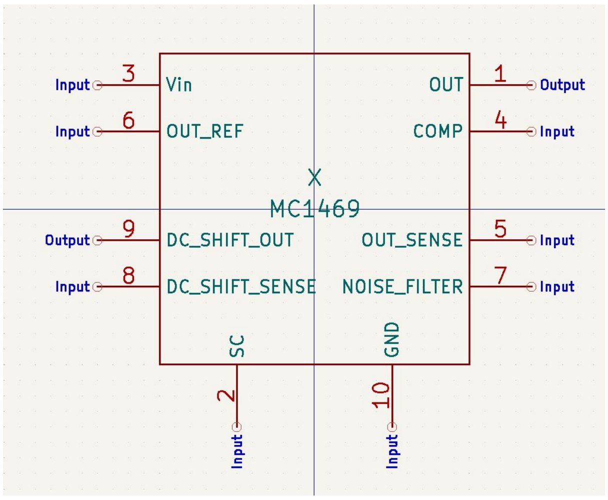

Figure 12.1: Pin Configuration of the MC1469

12.5 Subcircuit Schematic Diagram

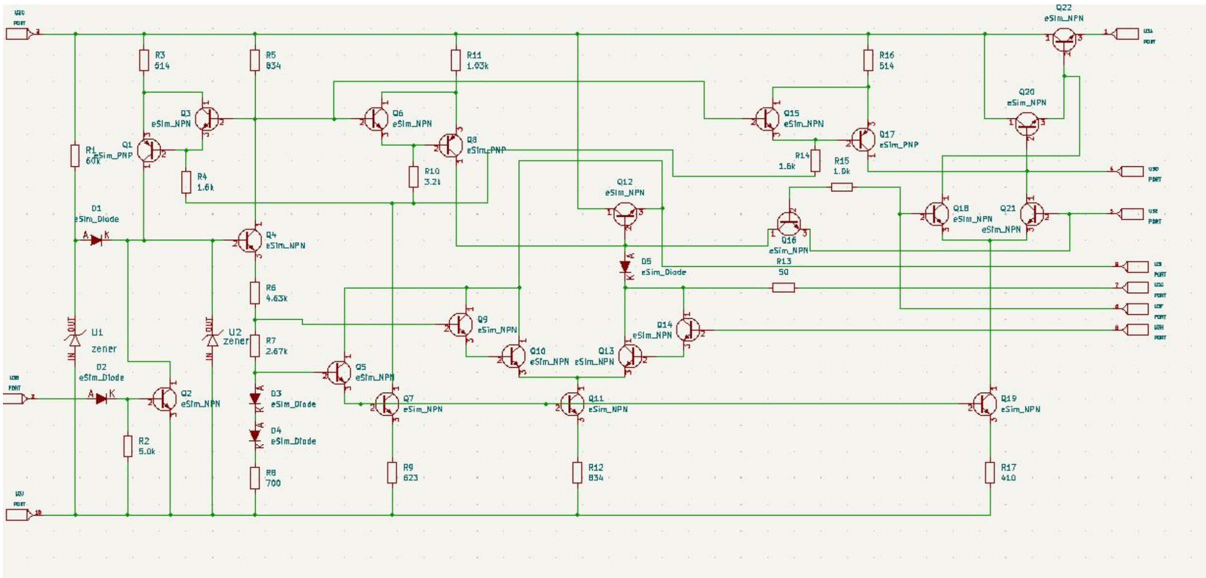

Figure 12.2: Subcircuit Schematic Diagram of the MC1469

12.6 Test Circuit

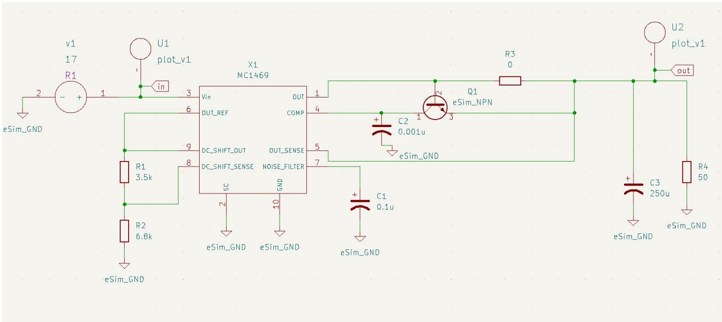

Figure 12.3: Test Circuit of the MC1469

12.7 Input Plot

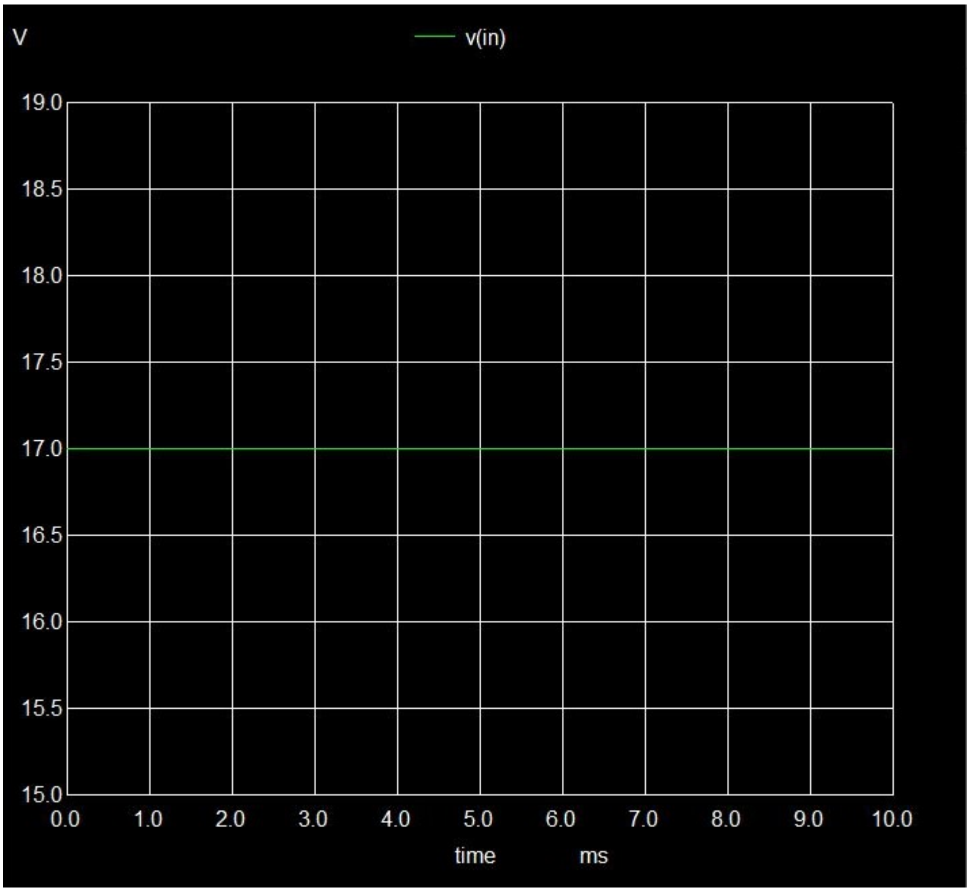

Figure 12.4: Input Plot of the MC1469

12.8 Output Plot

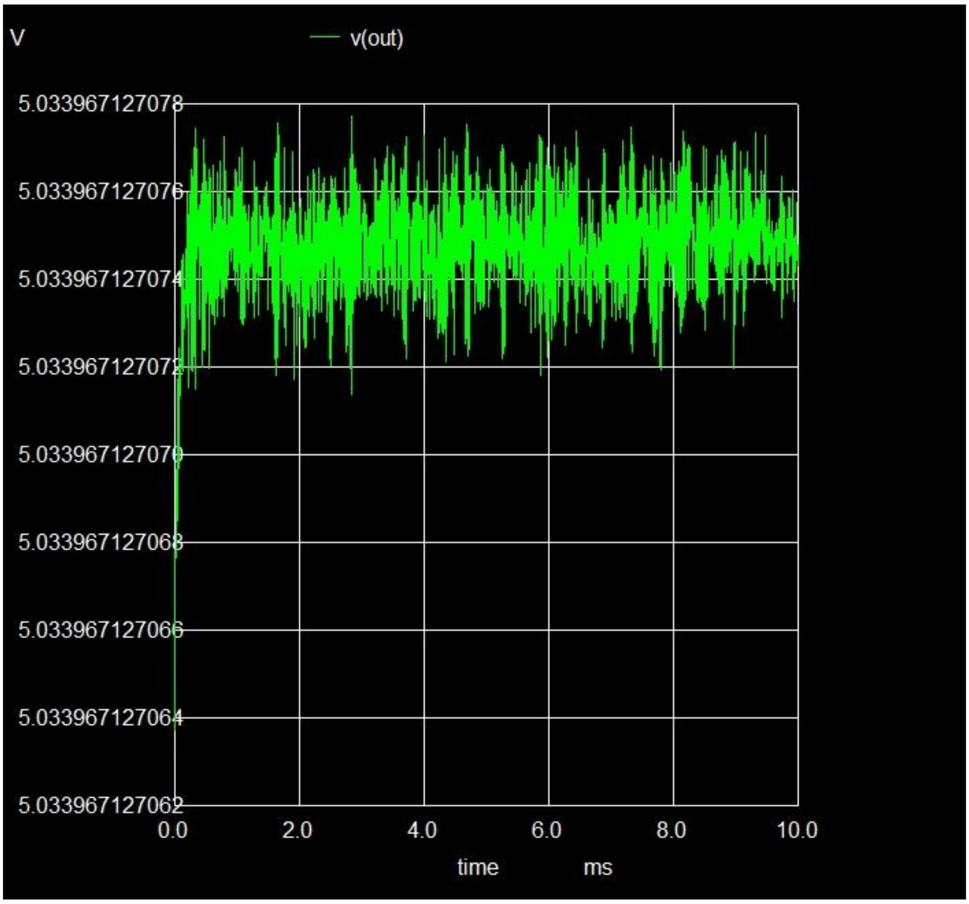

Figure 12.5: Output Plot of the MC1469

Chapter 13

LF411

13.1 General Description

The LF411 is a low-cost, high-speed JFET-input operational amplifier known for its very low input offset voltage and guaranteed input offset voltage drift. It is designed to operate with a low supply current while maintaining a large gain-bandwidth product and a fast slew rate. The device's matched high-voltage JFET input circuitry provides very low input bias and offset currents. The LF411 is also pin-compatible with the standard LM741, allowing for performance upgrades in existing designs.

13.2 Key Features

- **Low Input Offset Voltage:** Typically 0.5 mV (max) with internal trimming.
- **Low Input Offset Voltage Drift:** Maximum of 10 μV/°C.
- **Low Input Bias Current:** Typically 50 pA.
- **Wide Unity-Gain Bandwidth:** Typically 3-4.5 MHz.
- **Fast Slew Rate:** Typically 10-15 V/μs.
- **High Input Resistance:** Typically 10^{12} Ω.

13.3 Applications

- **High-Speed Integrators:** Used in high-performance analog computing circuits.
- **Fast D/A Converters:** Suitable for high-speed digital-to-analog conversion.
- **Sample-and-Hold Circuits:** Fast acquisition for data acquisition systems.
- **Active Filters:** Implementation of high-performance active filter designs.
- **Precision Instrumentation:** Used in high-accuracy measurement circuits.

13.4 Pin Configuration

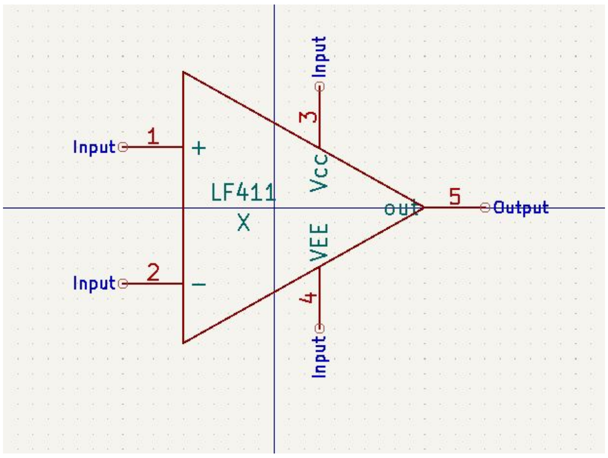

Figure 13.1: Pin Configuration of the LF411

13.5 Subcircuit Schematic Diagram

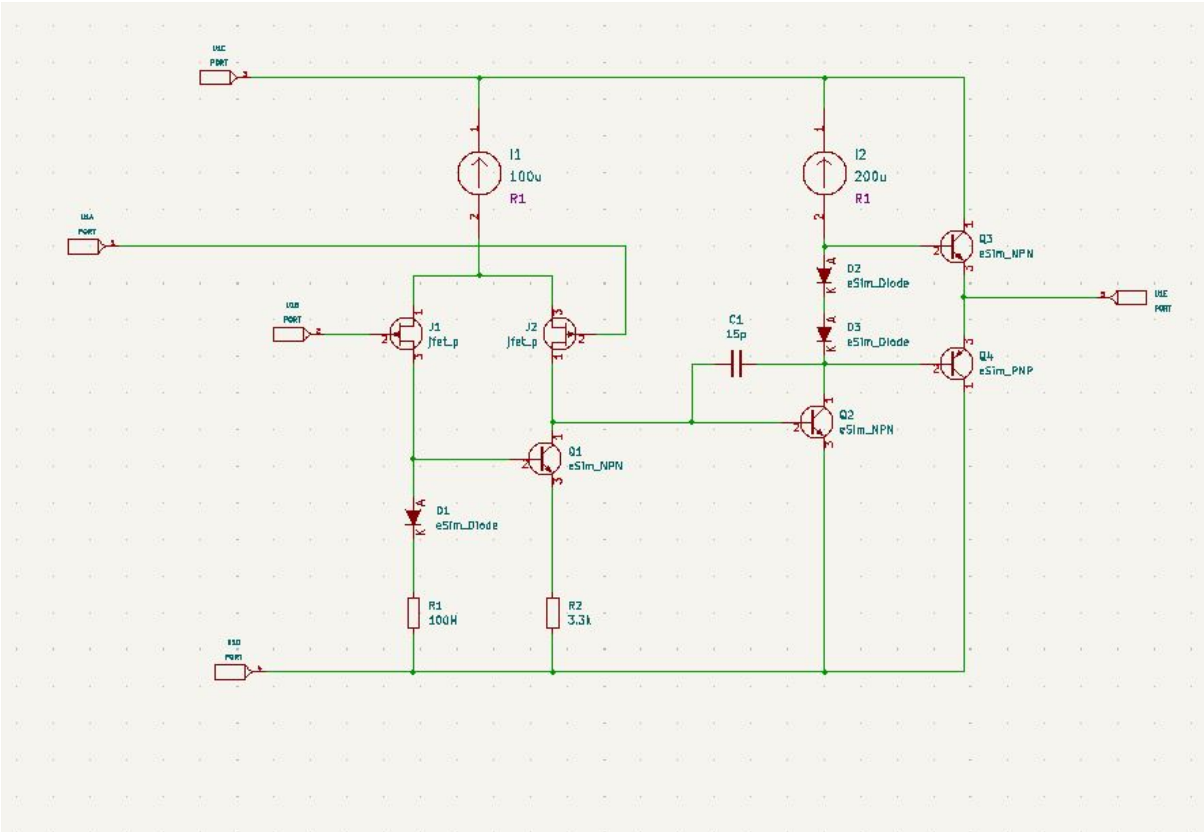

Figure 13.2: Subcircuit Schematic Diagram of the LF411

13.6 Test Circuit

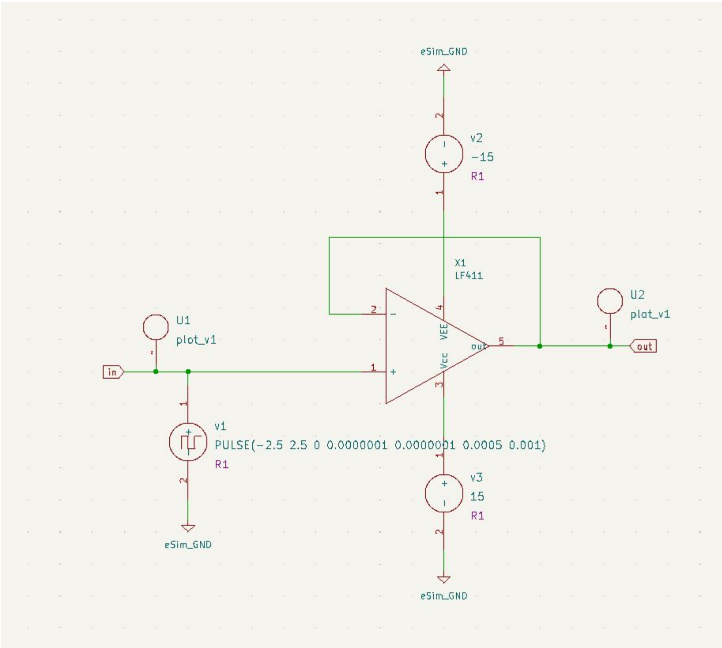

Figure 13.3: Test Circuit of the LF411

13.7 Input Plot

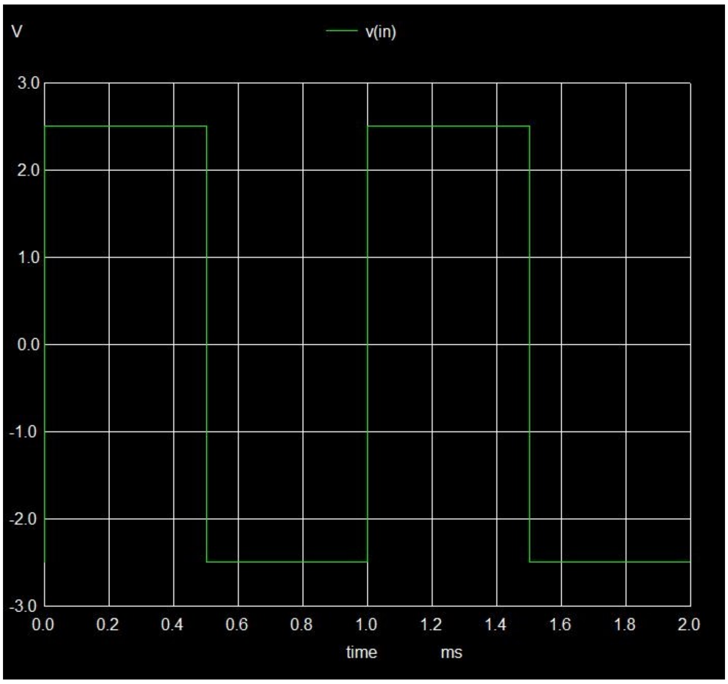

Figure 13.4: Input Plot of the LF411

13.8 Output Plot

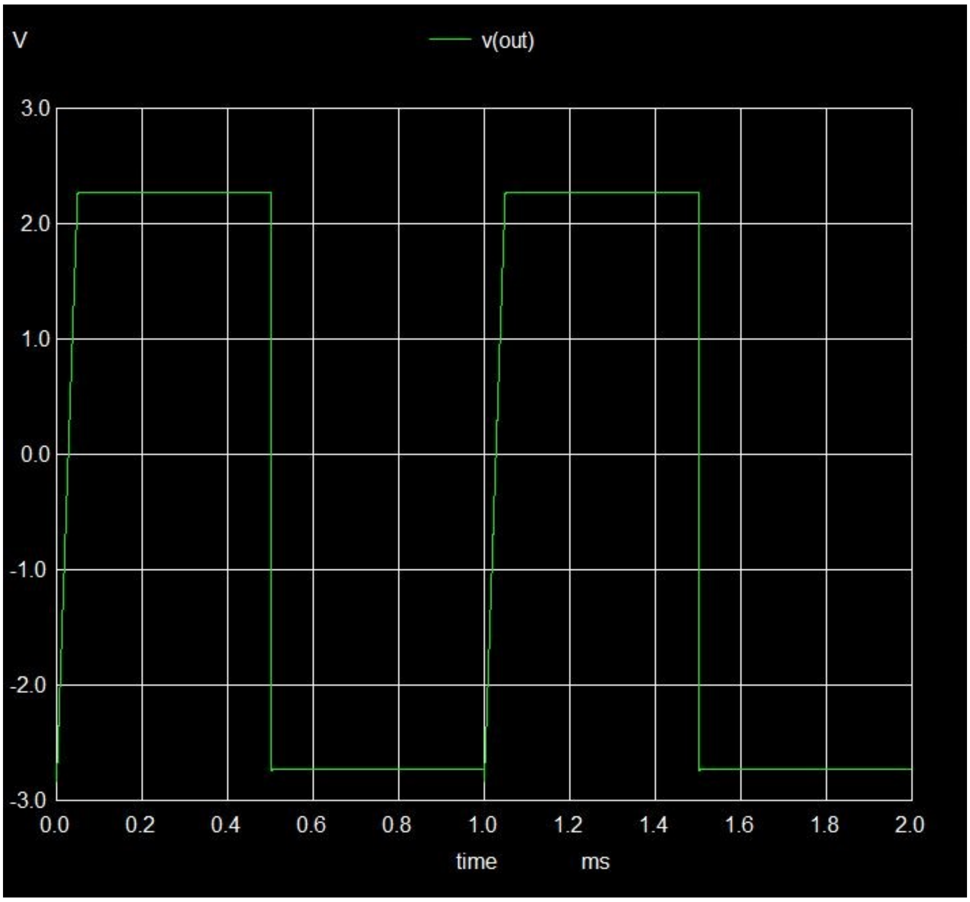

Figure 13.5: Output Plot of the LF411

Chapter 14

Failed Circuits

14.1 Overview

In this section, we discuss circuits that did not perform as expected during testing. Understanding the reasons for these failures helps in diagnosing issues and improving circuit design. Each failed circuit is analyzed to identify the potential causes of failure and to suggest corrective measures.

14.2 LM1875

14.2.1 General Description

The LM1875 is a monolithic audio power amplifier designed for high-quality consumer audio applications, offering low distortion and robust performance. Manufactured by Texas Instruments, it is capable of delivering 20 watts into a 4Ω or 8Ω load with ± 25V supplies. With an 8Ω load and ± 30V supplies, it can provide over 30 watts of power.

14.2.2 Key Features

- **High Output Power:** Delivers 20W into $4\Omega/8\Omega$ loads at ± 25V supplies.
- **Low Distortion:** Typically 0.015% THD at 1 kHz and 20W into 8Ω.
- **Wide Power Bandwidth:** 70 kHz power bandwidth.
- **High Gain:** Open-loop voltage gain of 90 dB.
- **Protection Features:** AC/DC short circuit protection, thermal protection.

14.2.3 Circuit Diagram

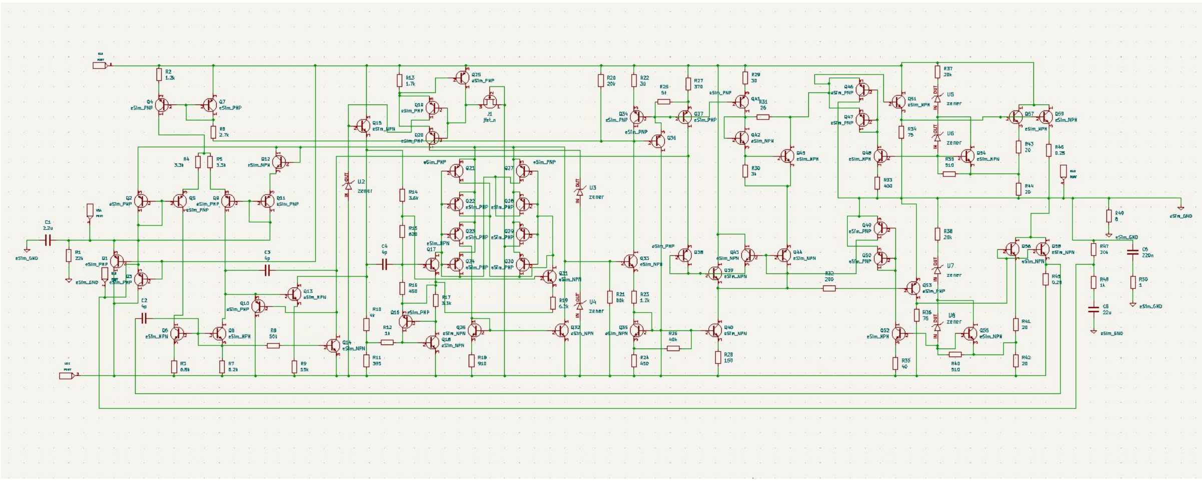

Figure 14.1: Subcircuit Schematic of the LM1875

Test Circuit

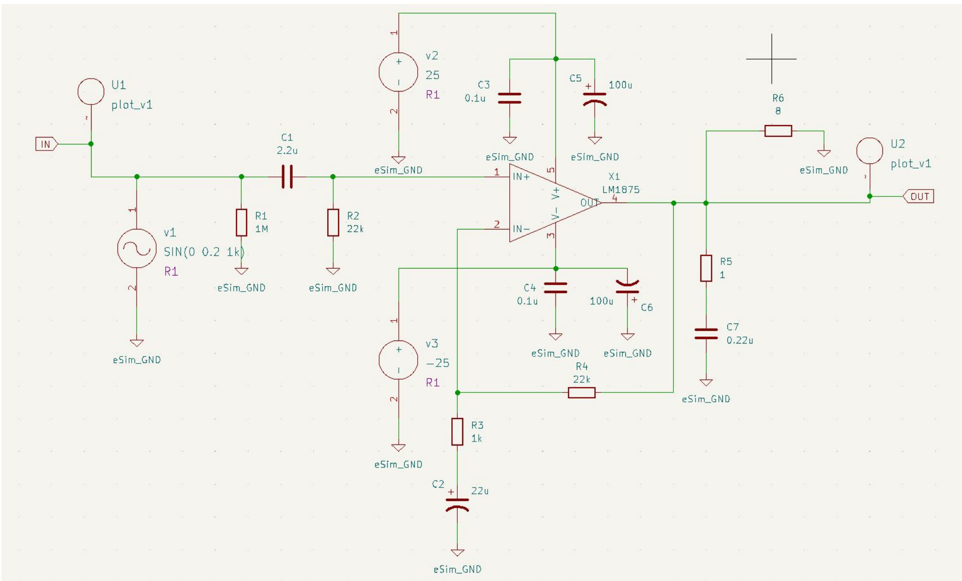

Figure 14.2: Test Circuit of the LM1875

14.2.4 Issue Description

The LM1875 audio power amplifier circuit exhibited unexpected behavior during simulation testing. The output waveform showed significant deviation from the expected audio amplification characteristics. The issues observed may stem from:

- **Model Limitations:** The SPICE model used may not accurately capture all the internal characteristics of the LM1875, particularly the power output stage and thermal characteristics.
- **Component Values:** The external feedback network and compensation capacitors may require fine-tuning to achieve stable operation in simulation.
- **Power Supply Requirements:** The high-power nature of the LM1875 requires careful attention to power supply decoupling and load conditions.
- **Simulation Constraints:** Audio power amplifiers with high current capability can be challenging to simulate accurately in SPICE due to convergence issues and model complexity.

Further investigation is required to resolve these issues and achieve successful implementation of the LM1875 subcircuit in eSim.

Chapter 15

Conclusion and Future Scope

The project achieved its objective of developing a wide range of subcircuits for both Analog Integrated Circuits, with each IC model meticulously crafted based on the specifications provided in their official datasheets. Through rigorous testing and verification using corresponding test circuits, these IC models were validated for accuracy and functionality. The components developed under this fellowship encompass fundamental circuit elements such as Operational Amplifiers (Op-Amps), Voltage Regulators, Comparators, and JFET Operational Amplifiers.

The ICs developed include the LP339 quad comparator, LM358N dual op-amp, LM318N fast op-amp, LM150 adjustable voltage regulator, LM104 negative voltage regulator, MC1463 negative voltage regulator, MC1466L precision regulator, MC1468 dual tracking regulator, MC1469 positive voltage regulator, and LF411 JFET op-amp. One circuit, the LM1875 audio power amplifier, encountered simulation challenges and requires further development.

These models are now ready for integration into the eSim subcircuit library, providing a robust resource for developers, students, and researchers. The inclusion of these models in the eSim library will significantly enhance the tool's capabilities, enabling users to easily incorporate these fundamental ICs into their own projects and circuit designs.

Looking ahead, this project sets the foundation for the continued expansion of eSim's device model library. We anticipate that more such ready-to-use IC models will be developed, broadening the scope of available components and further empowering the eSim community. This ongoing development will not only aid in academic and research endeavors but also contribute to the growing ecosystem of open-source electronic design automation (EDA) tools.

Chapter 16

Circuits Contribution

This chapter lists all the Integrated Circuits (ICs) contributed during the fellowship. Each IC has been carefully modeled and tested, and is now part of the eSim library. The contributions include analog ICs covering a wide range of functionalities.

16.1 List of ICs Contributed

1. LP339 - An ultra-low power quad comparator IC
2. LM358N - A dual operational amplifier IC
3. LM318N - A fast operational amplifier IC with high slew rate
4. LM150 - A 3A adjustable positive voltage regulator
5. LM104 - A precision negative voltage regulator
6. MC1463 - A negative power-supply voltage regulator
7. MC1466L - A precision wide-range voltage and current regulator
8. MC1468 - A dual polarity tracking regulator
9. MC1469 - A positive monolithic voltage regulator
10. LF411 - A low-cost high-speed JFET operational amplifier
11. LM1875 - A monolithic audio power amplifier (Failed IC)

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