Summer Fellowship Report

On

Integrated Circuit Design using Subcircuit Feature of eSim

Submitted by

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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 provided 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 throughout this fellowship program.

We would like to express our heartfelt appreciation to the entire FOSSEE team, including our mentors Mr. Sumanto Kar, Ms. Usha Vishwanathan and Ms. 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. 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. 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.

1.1 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, 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.

1.2 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.

1.3 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 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. While some are capable of PCB design (e.g., KiCad), others focus on simulations (e.g., gEDA). 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 mixed-signal). 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

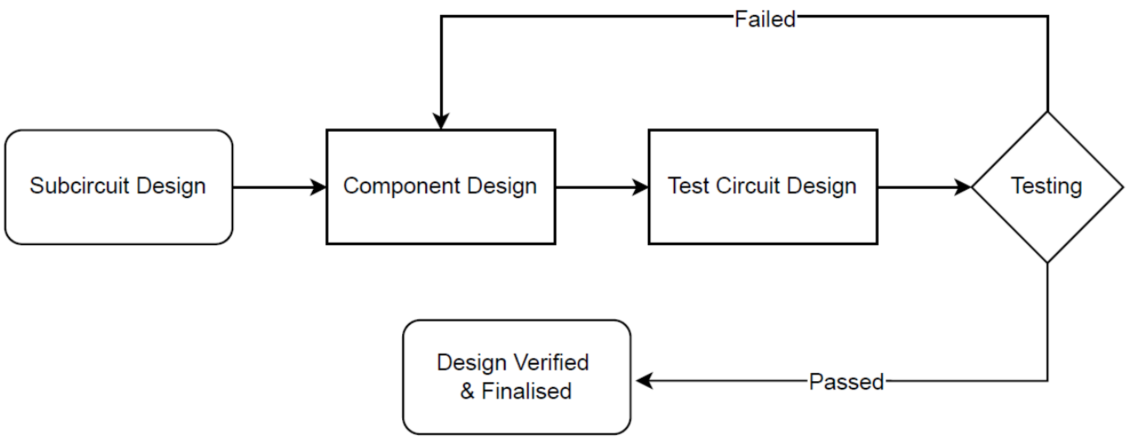

Figure 3.1: Flowchart of IC Design Approach Followed

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, and NXP Semiconductors. We focused on selecting ICs with diverse functionalities, including precision amplifiers, comparators, encoders, and audio 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 truth tables. 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 sub-circuit 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

LM113

4.1 General Description

The LM113 and LM313 are temperature-compensated, low-voltage reference diodes known for their exceptional performance and stability. These diodes offer extremely tight regulation across a broad range of operating currents, coupled with a notably low breakdown voltage and excellent temperature stability.

4.2 Key Features

- **Temperature Compensation:** The LM113/LM313 diodes are designed to maintain a stable output voltage despite fluctuations in temperature, thanks to their integrated temperature compensation.
- **Low Breakdown Voltage:** These diodes operate with an unusually low breakdown voltage, which contributes to their effectiveness in low-voltage applications.
- **High Stability and Low Noise:** Constructed using transistors and resistors within a monolithic integrated circuit, the LM113/LM313 provide the same low noise and long-term stability found in modern IC operational amplifiers.
- **Predictable Performance:** The output voltage of these reference diodes is determined by the highly predictable characteristics of the components within the IC, allowing for tight manufacturing tolerances.

4.3 Applications

The LM113/LM313 diodes are versatile components used in various applications, including:

- **Constant Current Source:** They are used in circuits requiring a stable and consistent current source.
- **Thermometer:** These diodes are employed in temperature measurement systems due to their stable voltage output that varies predictably with temperature.

- **Level Detector for Photodiode:** They are integrated into photodiode systems to detect and measure light levels accurately.
- **Low Voltage Regulator:** Their stable reference voltage makes them ideal for regulating low voltage supplies.

The LM113/LM313 diodes' combination of low noise, high stability, and precise regulation makes them an excellent choice for applications demanding reliable and consistent performance.

4.4 Pin Configuration

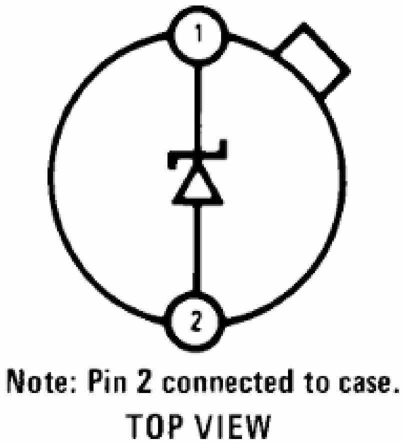

Figure 4.1: Pin Configuration of the LM113 diode

4.5 IC Layout

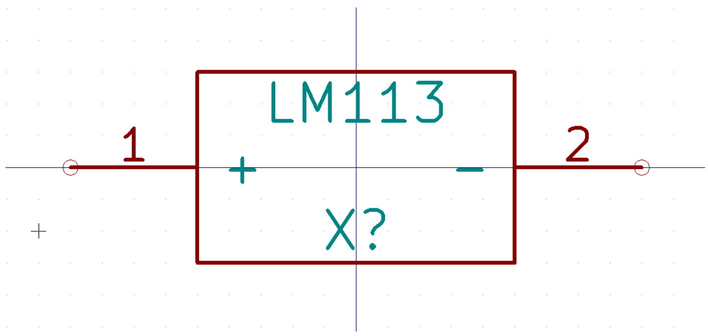

Figure 4.2: IC Layout of the LM113 diode

4.6 Subcircuit Schematic Diagram

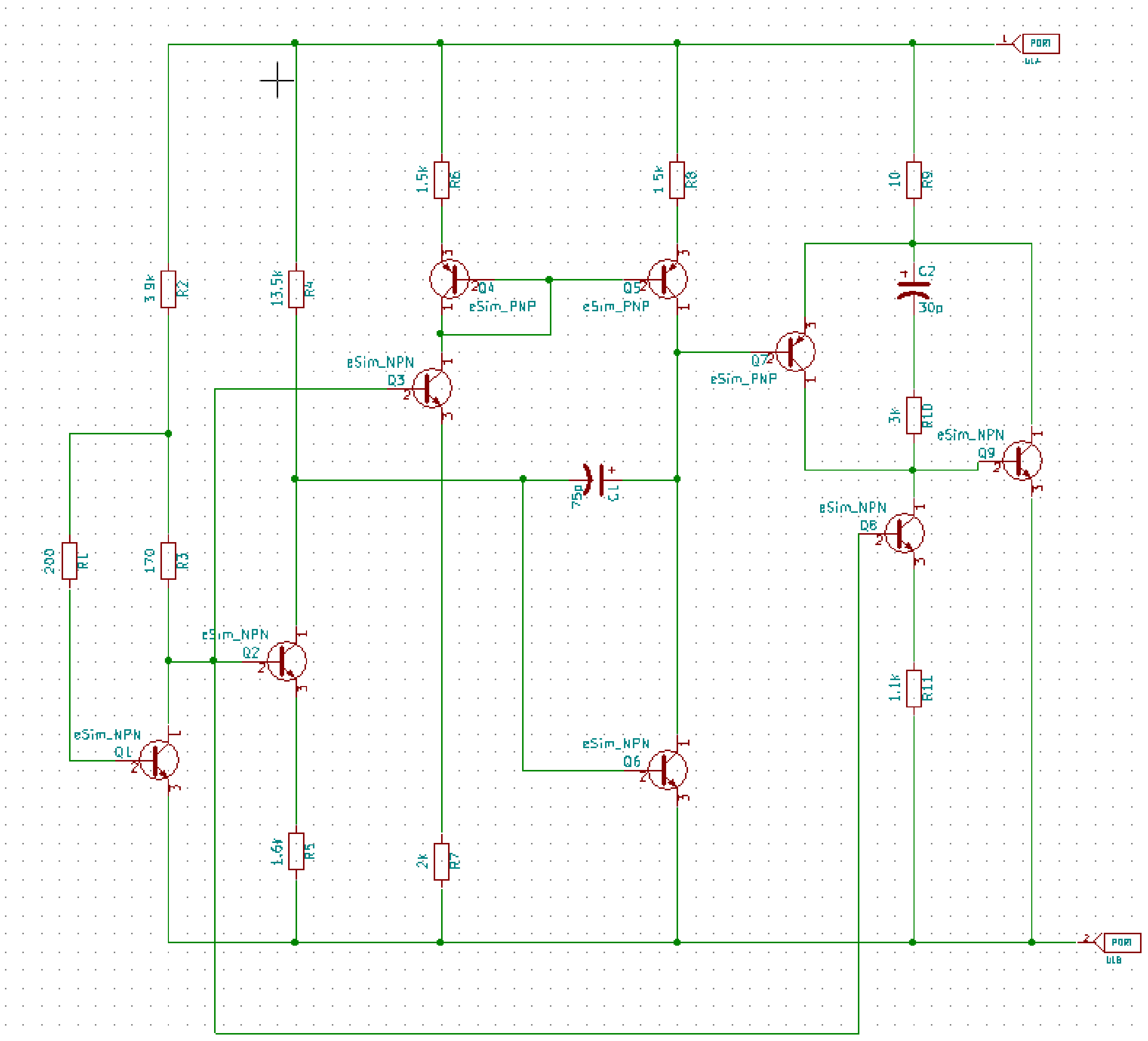

Figure 4.3: Subcircuit Schematic Diagram of the LM113 diode

Chapter 5

LM185

5.1 General Description

The LM185, LM285, and LM385 are micropower, 3-terminal adjustable band-gap voltage reference diodes designed for precision voltage regulation. They operate over a wide voltage range from 1.24V to 5.3V and can handle currents from 10 micro ampere to 20mA. These devices offer exceptionally low dynamic impedance and excellent temperature stability due to on-chip trimming, which ensures tight voltage tolerance. Their design, which relies solely on transistors and resistors, contributes to low noise and long-term stability.

The LM185's design accommodates capacitive loading, making it versatile for various reference applications. Its wide dynamic operating range enables it to function effectively with varying supply voltages, providing excellent regulation. The extremely low power consumption of the LM185 is particularly beneficial for micropower circuitry, extending battery life in portable meters, regulators, and other general-purpose analog circuits. Additionally, its wide operating current range allows it to replace older reference designs with tighter tolerance requirements.

5.2 Key Features

The LM185, LM285, and LM385 offer the following key features:

- **Adjustable Voltage Range:** Operates from 1.24V to 5.3V.
- **Wide Current Range:** Functional over a current range of 10 micro ampere to 20mA.
- **Low Dynamic Impedance:** Provides stable performance with minimal impedance.
- **Tight Voltage Tolerance:** Achieved through on-chip trimming.
- **Low Noise:** Due to the use of only transistors and resistors.
- **Capacitive Loading Tolerance:** Suitable for a wide range of reference applications.
- **Low Power Consumption:** Ideal for micropower and battery-operated circuits.

5.3 Applications

The LM185, LM285, and LM385 are utilized in various applications, including:

- **Low AC Noise Reference:** Provides a stable reference with minimal AC noise.
- **200 mA Shunt Regulator:** Acts as a shunt regulator with a current handling capability of 200mA.
- **25V Low Current Shunt Regulator:** Suitable for low current applications with a reference voltage of 25V.
- **Fast Positive Clamp:** Used in circuits requiring rapid positive voltage clamping.
- **Voltage Level Detector:** Detects specific voltage levels for circuit monitoring and control.
- **Bidirectional Clamp:** Provides voltage clamping in both positive and negative directions.

This chapter covers the key aspects of the LM185 series, highlighting their features and various applications in precision voltage regulation and micropower circuitry.

5.4 Pin Configuration

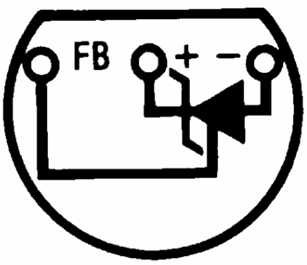

Figure 5.1: Pin Configuration of the LM185

5.5 IC Layout

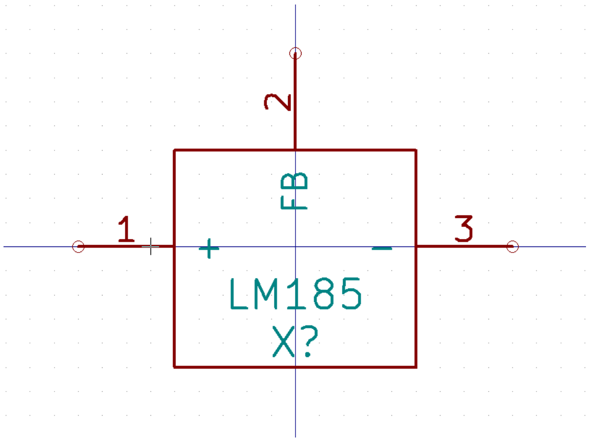

Figure 5.2: IC Layout of the LM185

5.6 Subcircuit Schematic Diagram

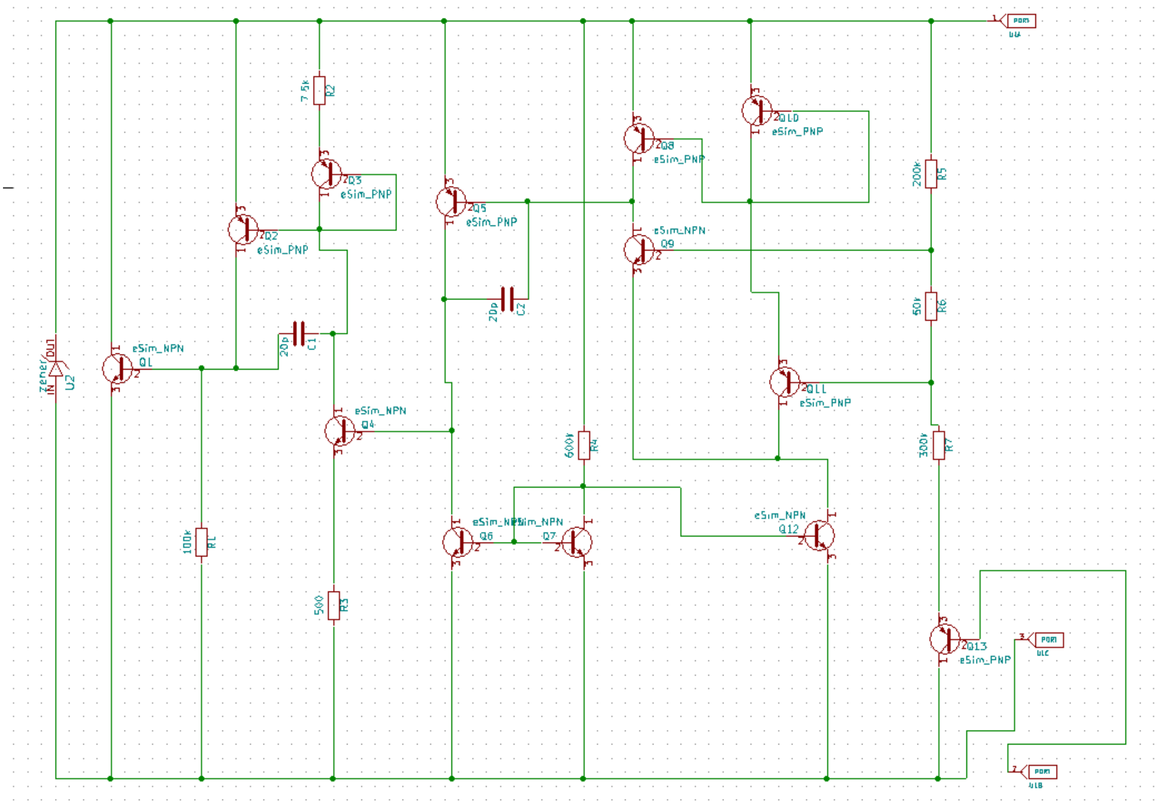

Figure 5.3: Subcircuit Schematic Diagram of the LM185

Chapter 6

LM301

6.1 General Description

The LM301 is a general-purpose operational amplifier designed to offer superior performance compared to industry standards like the LM709. It incorporates advanced processing techniques that significantly reduce input currents and improve biasing circuitry to minimize temperature drift of the input current.

6.2 Key Features

- **Improved Performance:** The LM301 delivers enhanced performance metrics compared to older models such as the LM709. It achieves this through advanced design techniques that drastically lower input currents and reduce temperature-induced drift.

- **No Latch-Up:** It is designed to prevent latch-up when the common-mode range is exceeded, enhancing overall stability.

- **Stability and Compensation:** The amplifier is free from oscillations and requires only a single 30 pF capacitor for compensation. This simplicity contrasts with many internal-compensation amplifiers, which often require more complex setups.

- **High Accuracy and Low Noise:** The LM301 offers superior accuracy and reduced noise levels, particularly in high-impedance circuits. Its low input currents make it ideal for applications requiring precise measurements over long intervals.

6.3 Applications

The LM301 is versatile and well-suited for various applications due to its advanced features:

- **Variable Capacitance Multiplier:** The amplifier can be used to build circuits that effectively multiply capacitance values.

- **Fast Inverting Amplifier with High Gain:** Suitable for applications requiring rapid signal inversion with high gain.
- **Simulated Inductor:** It can simulate inductors in circuit designs where actual inductors might be impractical or costly.
- **Sine Wave Oscillator:** Ideal for designing sine wave oscillators with high stability and precision.
- **Isolating Large Capacitive Loads:** The LM301 can be used to isolate and manage large capacitive loads efficiently.

In addition to these applications, the LM301 is particularly effective in circuits where matched transistor pairs are used to buffer inputs of conventional IC op amps. It offers lower offset voltage and drift at a lower cost compared to alternatives.

6.4 Pin Configuration

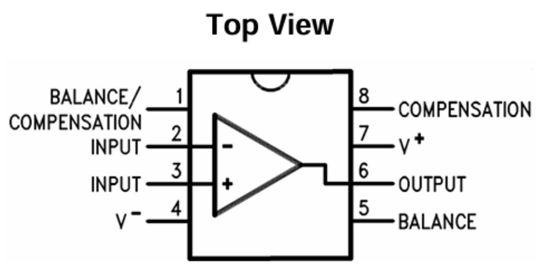

Figure 6.1: Pin Configuration of the LM301

6.5 IC Layout

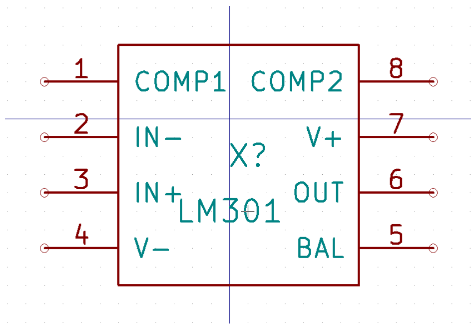

Figure 6.2: IC Layout of the LM301

6.6 Subcircuit Schematic Diagram

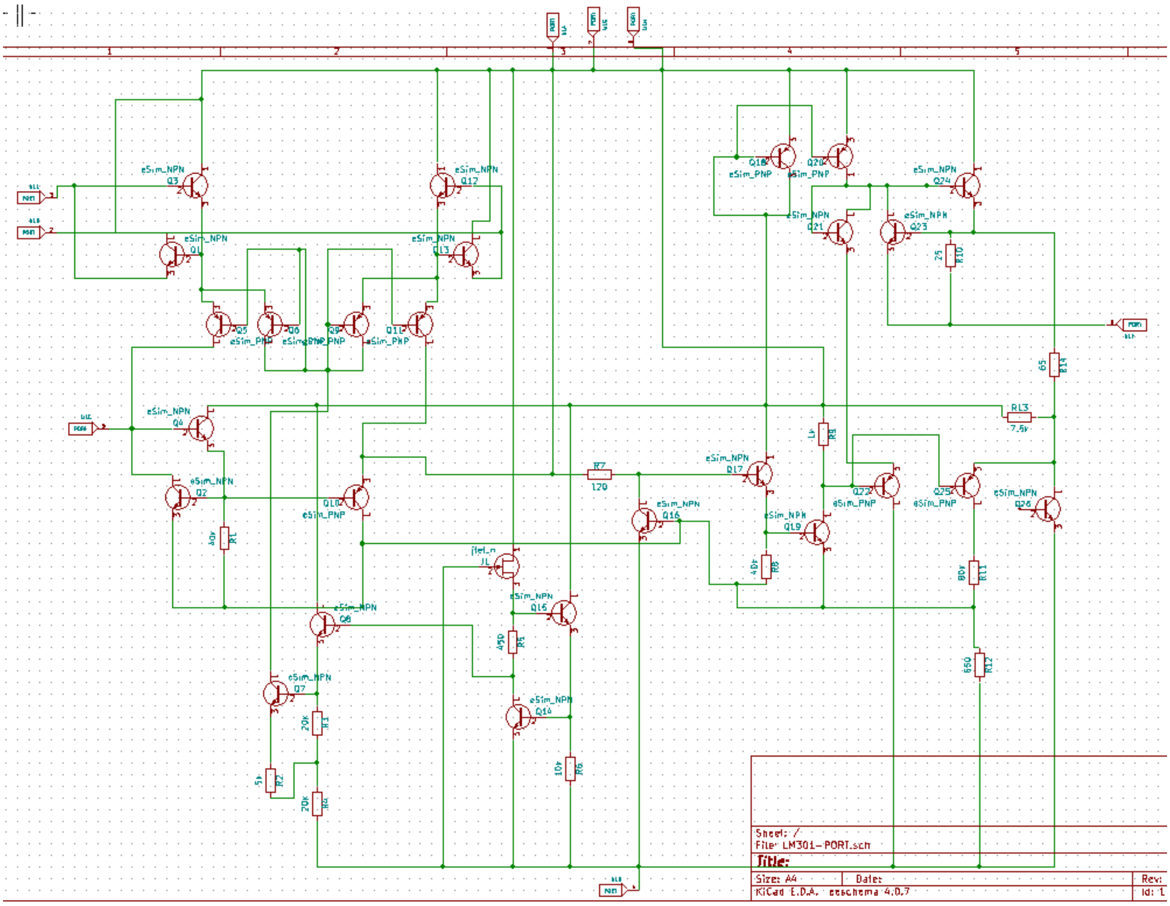

Figure 6.3: Subcircuit Schematic Diagram of the LM301

6.7 Test Circuit

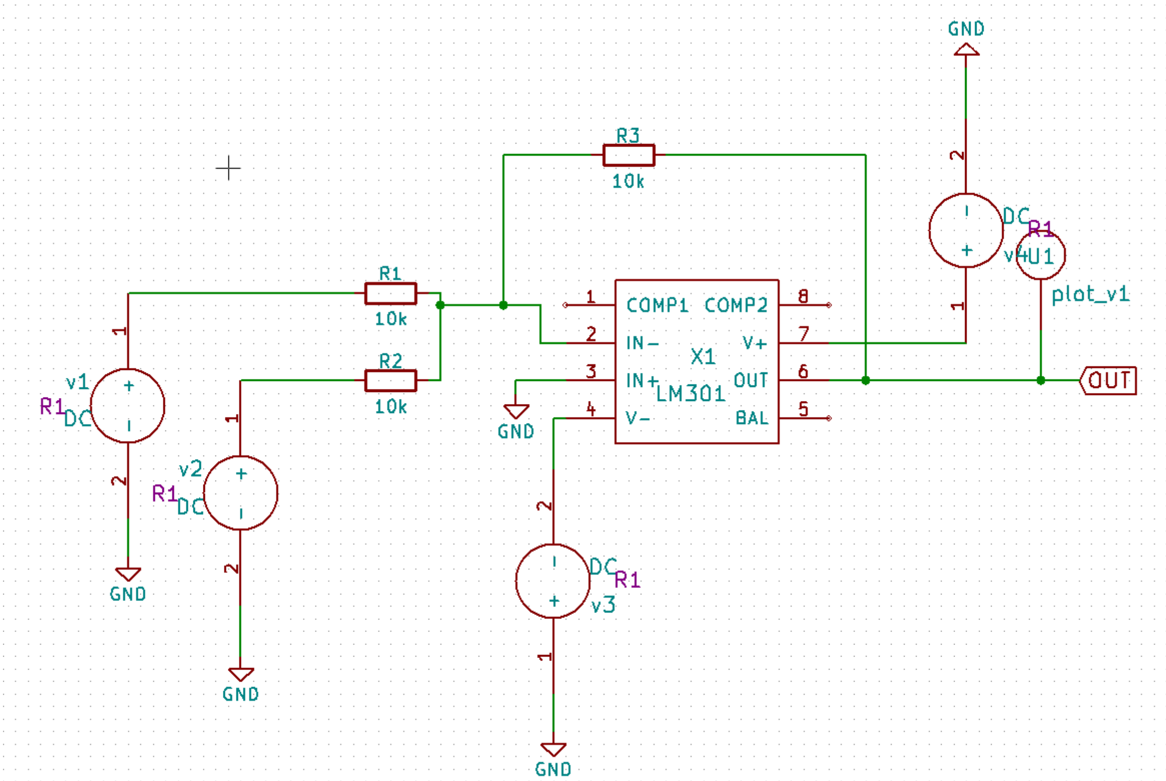

Figure 6.4: Test Circuit of the LM301

6.8 Input Plot

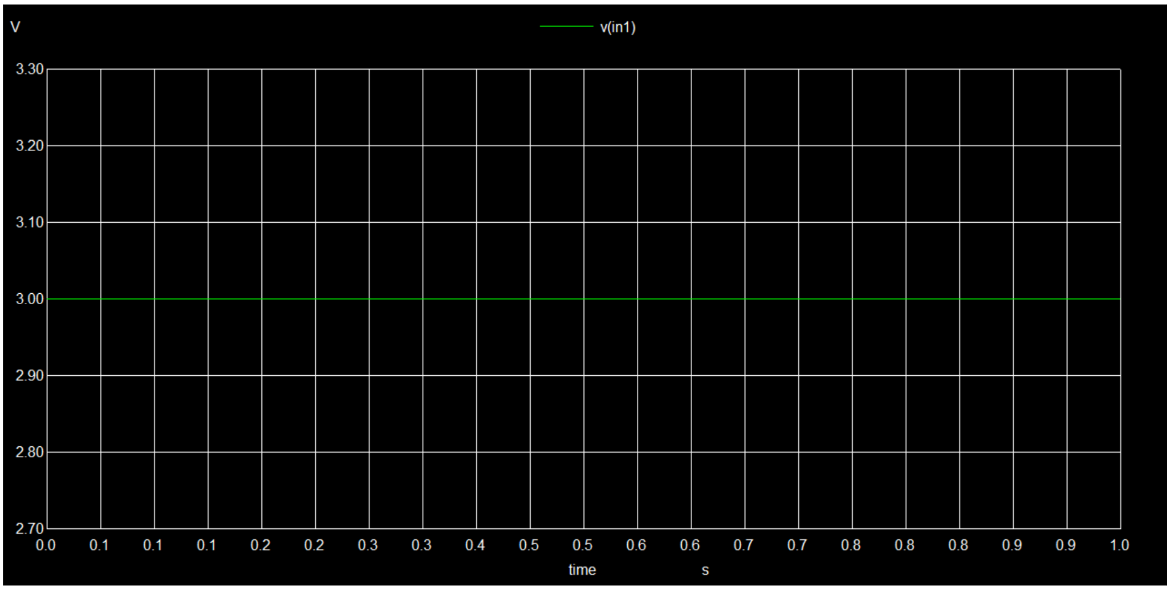

Figure 6.5: Input Plot 1 of the LM301.

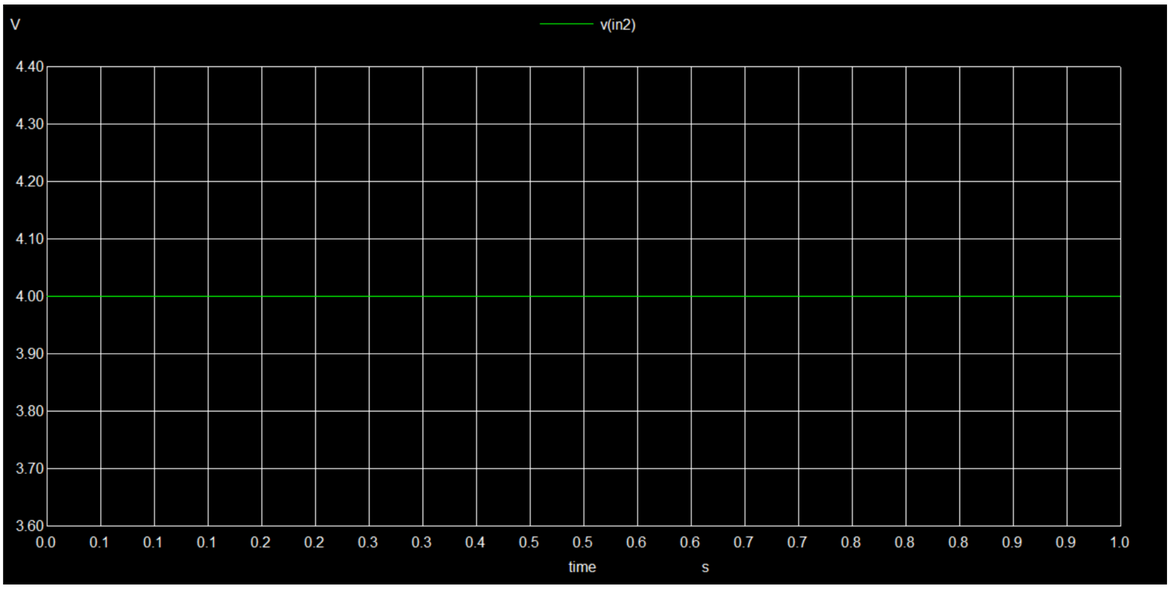

Figure 6.6: Input Plot 2 of the LM301

6.9 Output Plot

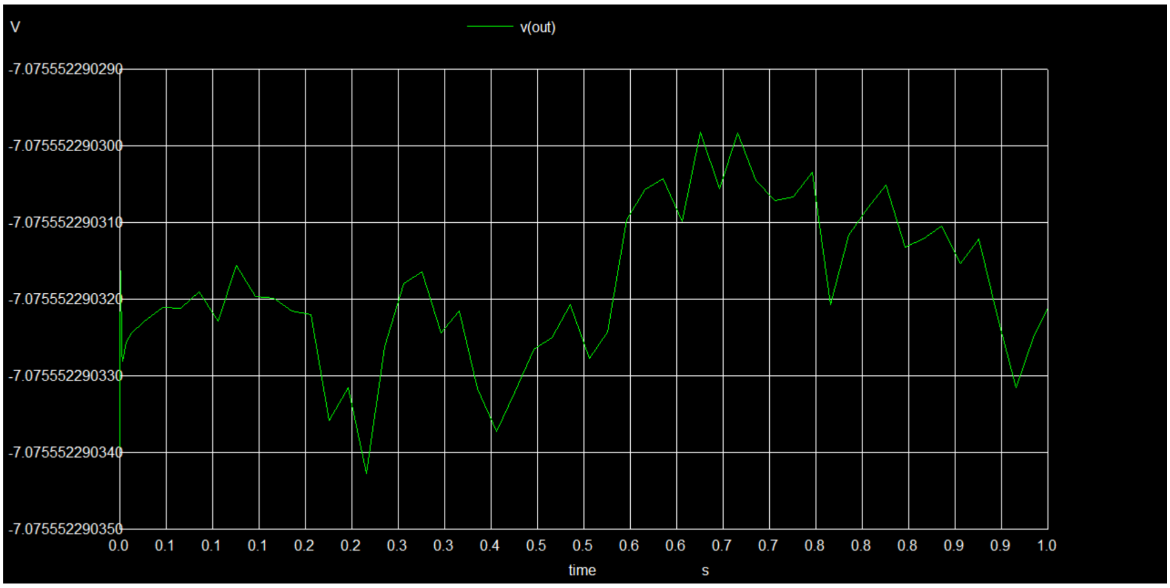

Figure 6.7: Output Plot of the LM301

Chapter 7

LM302

7.1 General Description

The LM102 series are high-gain operational amplifiers designed specifically for unity-gain voltage follower applications. Built on a single silicon chip, these devices incorporate advanced processing techniques to achieve very low input current and high input impedance. The input transistors are operated at zero collector-base voltage to virtually eliminate high-temperature leakage currents. As a result, the LM102 can be operated in a temperature-stabilized component oven to achieve extremely low input currents and minimal offset voltage drift.

7.2 Key Features

The LM102 offers several key features:

- **High Input Impedance:** The LM102 features high input impedance, which minimizes loading effects and ensures accurate signal transfer.
- **Low Input Current:** Advanced processing techniques allow the LM102 to achieve very low input current, reducing errors in sensitive applications.
- **Wide Supply Voltage Range:** The LM102 operates with supply voltages between $\pm 12V$ and $\pm 15V$, providing flexibility in various circuit designs.
- **Low Input Capacitance:** The amplifier has low input capacitance, which helps maintain signal integrity and minimize high-frequency gain errors.

7.3 Applications

The LM102 is well-suited for a variety of applications, including:

- **Sample and Hold with Offset Adjustment:** Ideal for circuits requiring precise sample and hold operations with adjustable offset.
- **High Pass Active Filter:** Suitable for implementing high pass filters to block low-frequency signals while allowing higher frequencies to pass.

- **High Input Impedance AC Amplifier:** Provides accurate amplification for AC signals with minimal loading effects due to its high input impedance.

These features make the LM102 a versatile and reliable choice for precision applications where performance and stability are crucial.

7.4 Pin Configuration

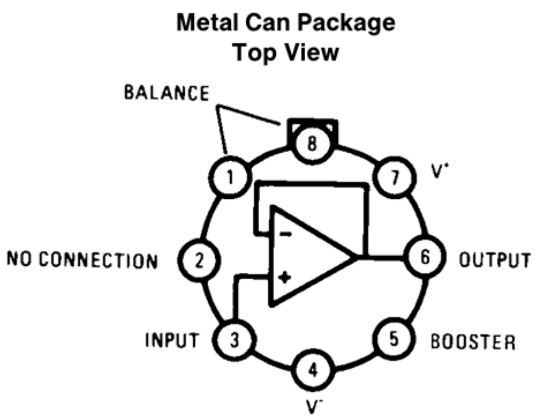

Figure 7.1: Pin Configuration of the LM302

7.5 IC Layout

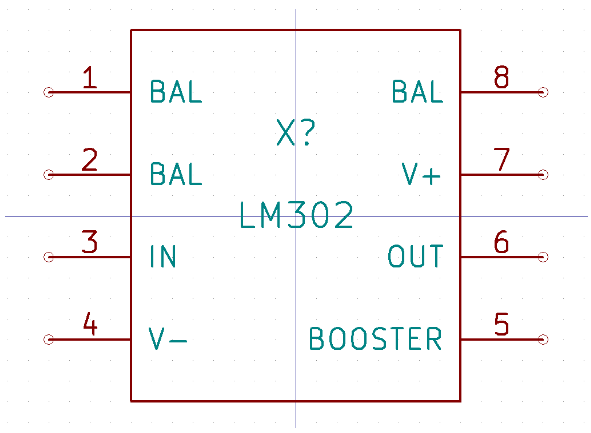

Figure 7.2: IC Layout of the LM302

7.6 Subcircuit Schematic Diagram

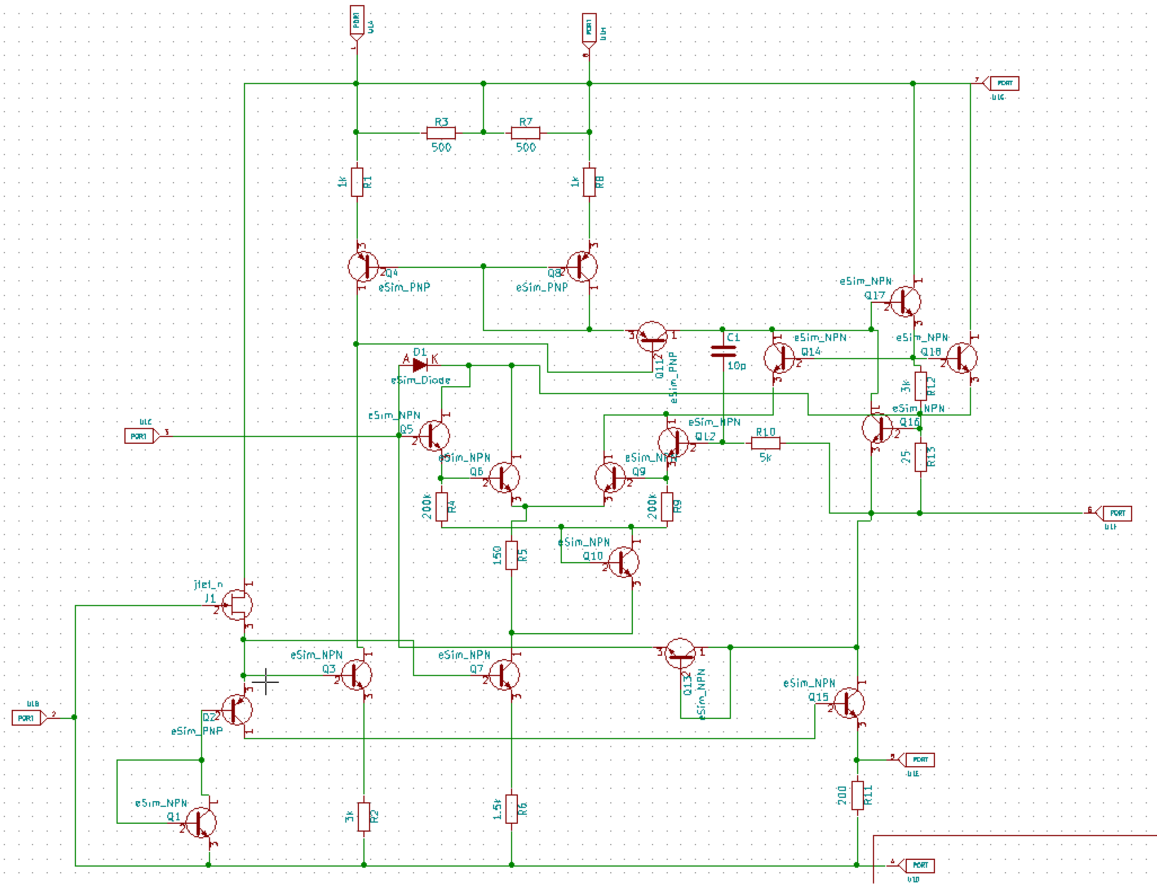

Figure 7.3: Subcircuit Schematic Diagram of the LM302

7.7 Test Circuit

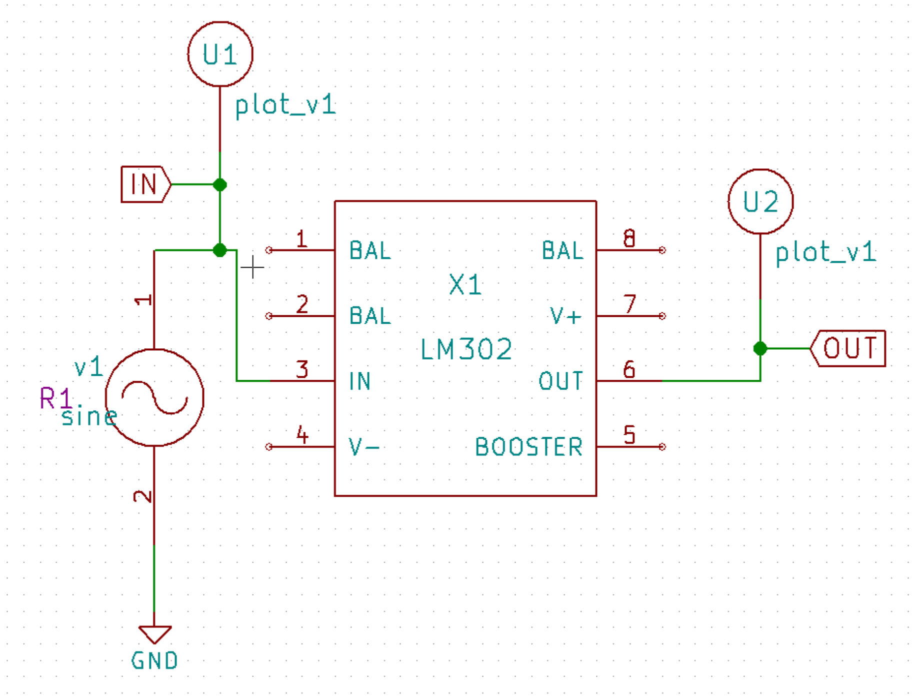

Figure 7.4: Test Circuit of the LM302

7.8 Input Plot

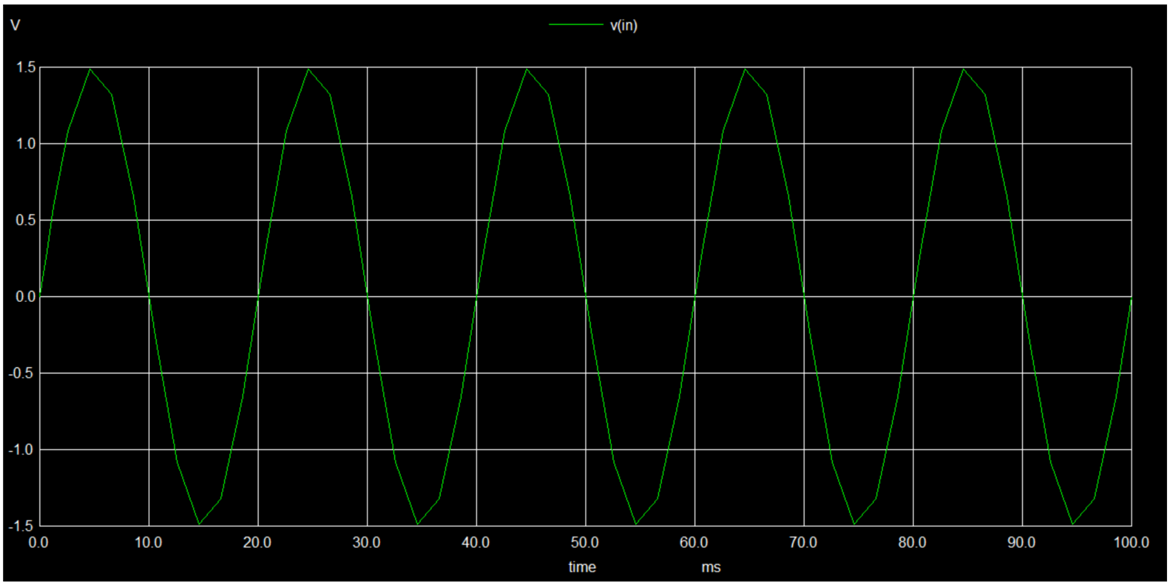

Figure 7.5: Input Plot of the LM302

7.9 Output Plot

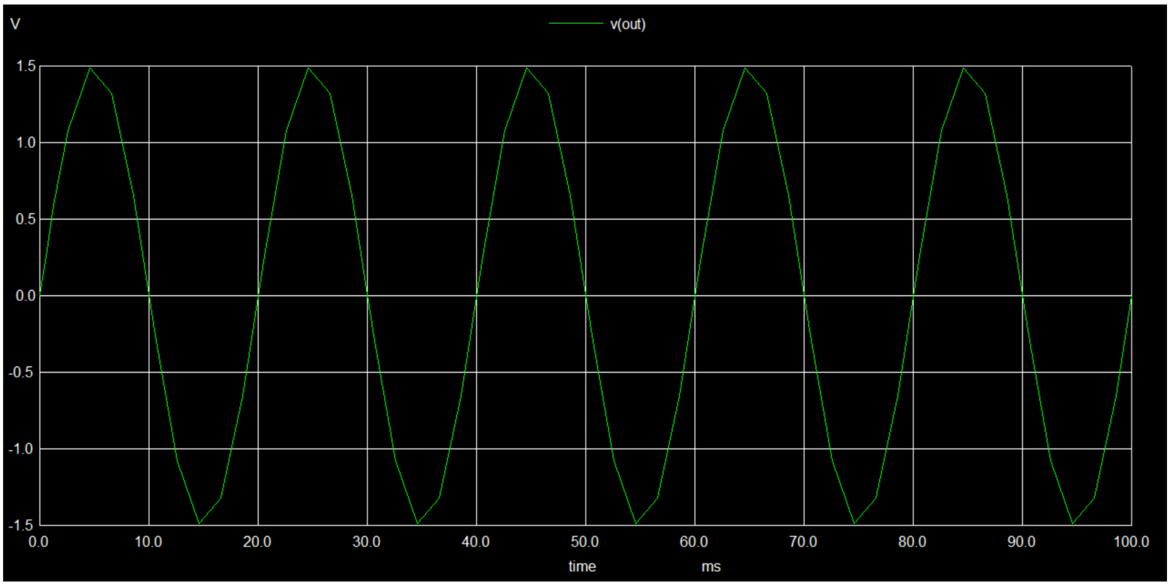

Figure 7.6: Output Plot of the LM302

Chapter 8

LM310

8.1 General Description

The LM110, LM210, and LM310 are monolithic operational amplifiers designed as unity-gain non-inverting amplifiers. These devices use super-gain transistors in the input stage to achieve low bias current without sacrificing speed. They are directly interchangeable with the 101, 741, and 709 in voltage follower applications. The LM310 offers lower offset voltage, drift, bias current, and noise, in addition to higher speed and a wider operating voltage range. These amplifiers have internal frequency compensation and provisions for offset balancing.

8.2 Key Features

The LM310 boasts several key features:

- Input Current: 10 nA maximum over temperature.
- Small Signal Bandwidth: 20 MHz.
- Slew Rate: 30 V/µs.
- Supply Voltage Range: +5V to +18V.

8.3 Applications

The LM310 is useful in various applications, including:

- **Differential Input Instrumentation Amplifier:** Suitable for accurate differential measurements.
- **Fast Integrator with Low Input Current:** Ideal for applications requiring rapid integration and minimal input current.
- **Zero Crossing Detector:** Useful for detecting the point where a signal crosses zero voltage.

- **Comparator for Signals of Opposite Polarity:** Effective for comparing signals with opposite polarities.

These amplifiers are particularly useful in fast sample and hold circuits, active filters, and as general-purpose buffers. Their frequency response is superior to standard IC amplifiers, allowing them to be included in feedback loops without introducing instability. They can also serve as plug-in replacements for the LM102 series voltage followers.

8.4 Pin Configuration

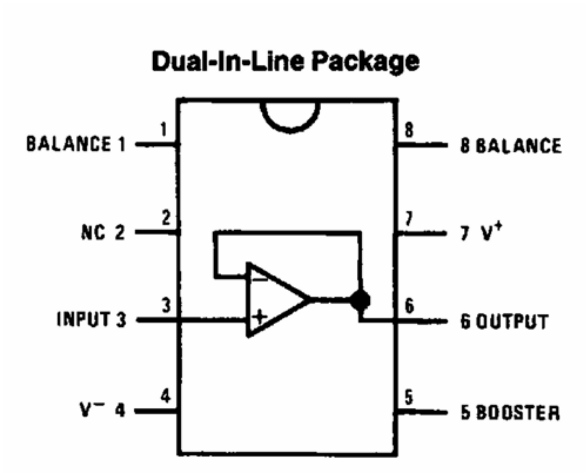

Figure 8.1: Pin Configuration of the LM310

8.5 IC Layout

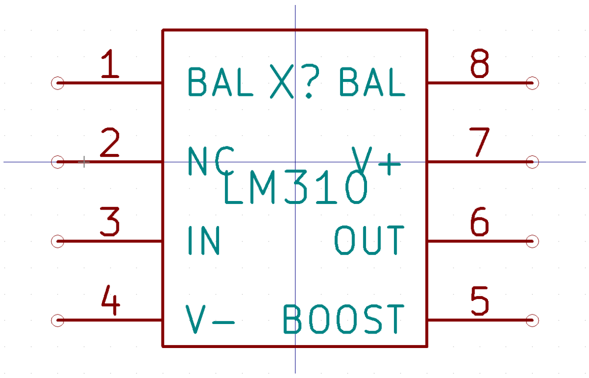

Figure 8.2: IC Layout of the LM310

8.6 Subcircuit Schematic Diagram

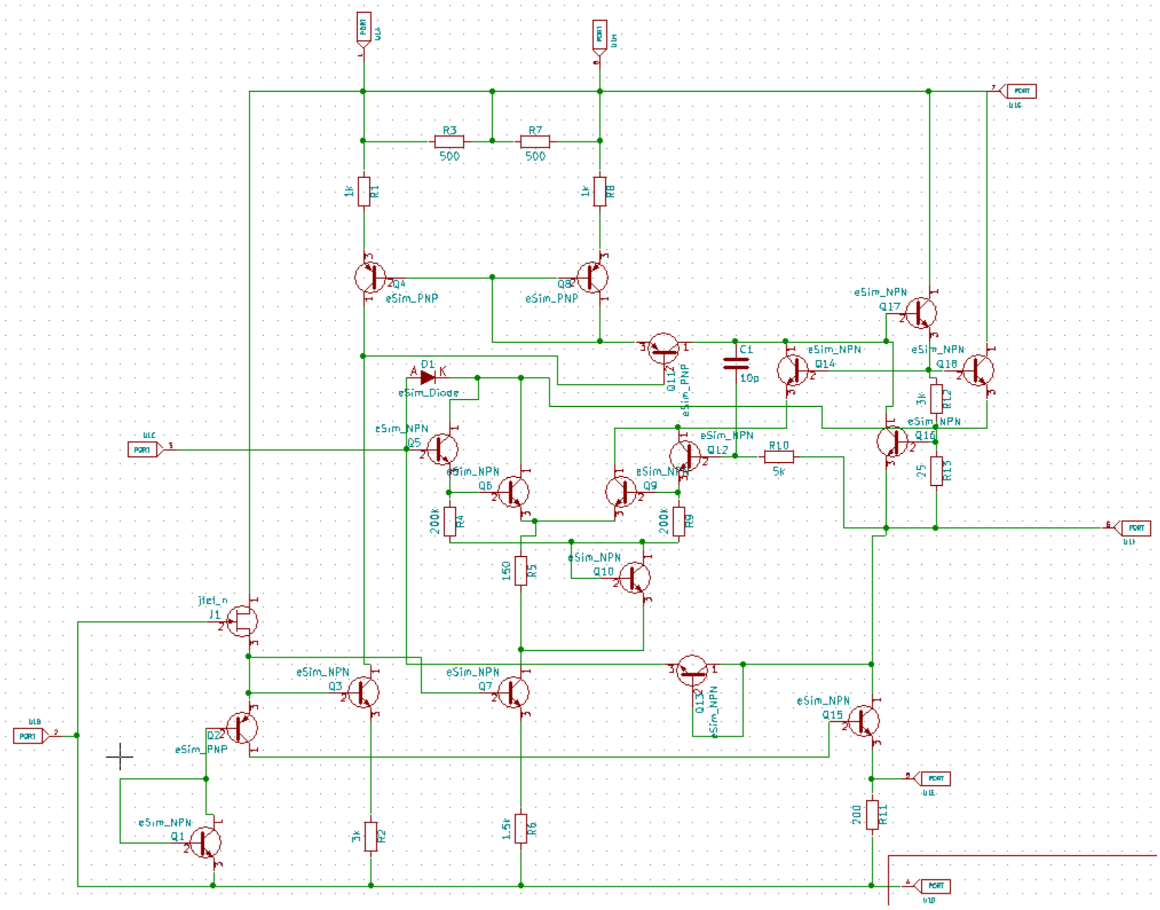

Figure 8.3: Subcircuit Schematic Diagram of the LM310

8.7 Test Circuit

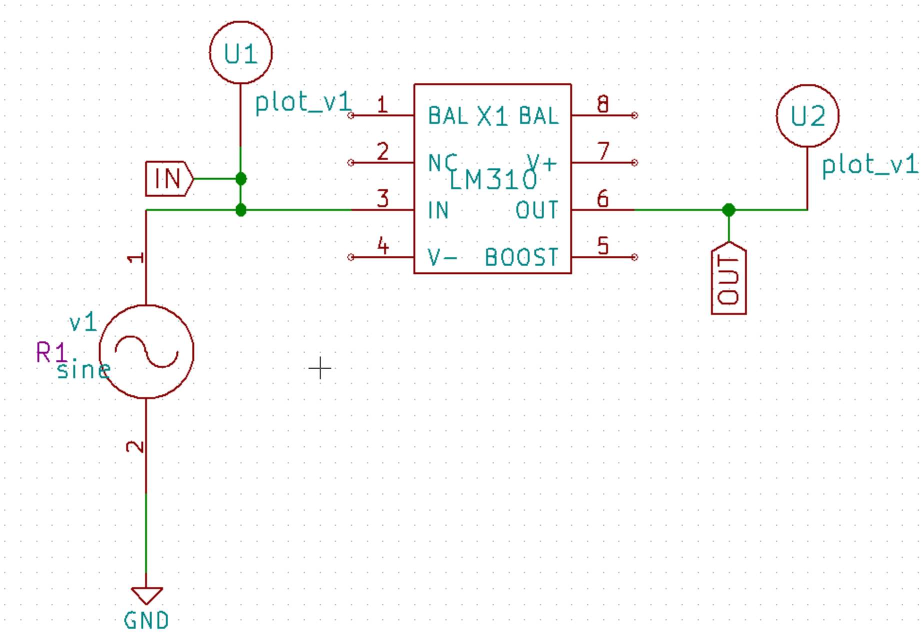

Figure 8.4: Test Circuit of the LM310

8.8 Input Plot

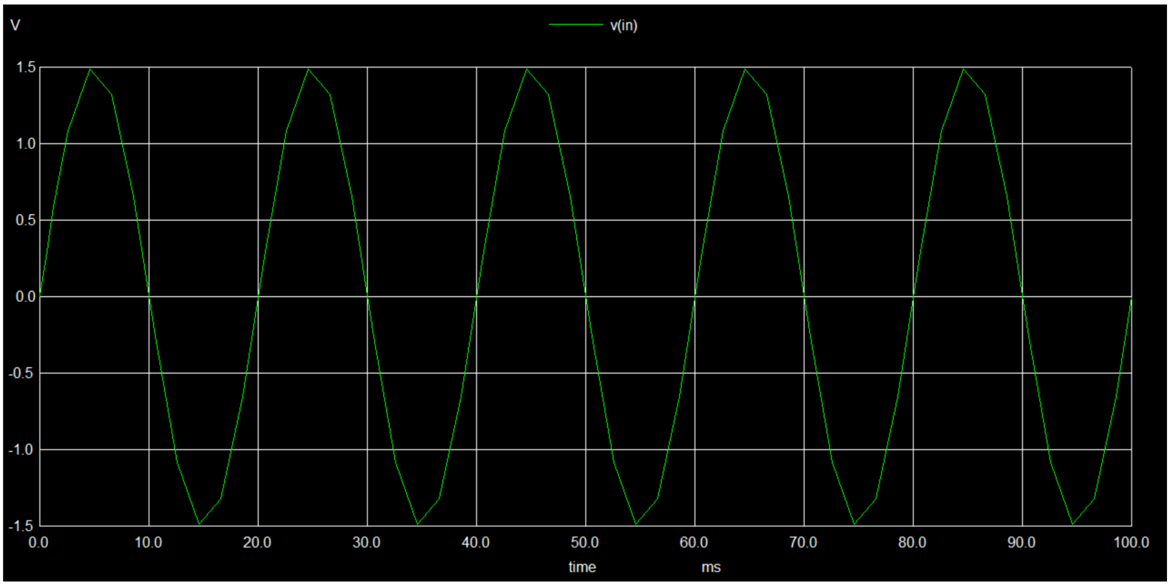

Figure 8.5: Input Plot of the LM310

8.9 Output Plot

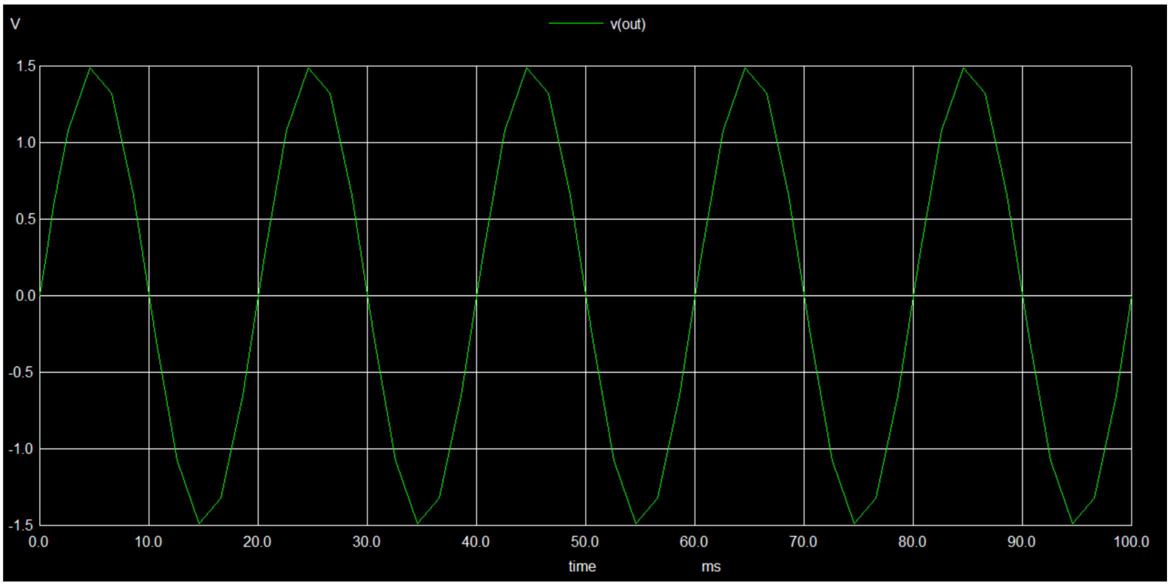

Figure 8.6: Output Plot of the LM310

Chapter 9

LM340_5V

9.1 General Description

The LM340 family of monolithic 3-terminal positive voltage regulators are designed to provide reliable, fixed output voltages with built-in protection features. These regulators incorporate internal current limiting, thermal shutdown, and safe-area compensation, which make them highly robust and virtually indestructible under normal operating conditions. When adequate heat sinking is provided, these regulators can deliver over 1.5 A of output current.

These devices are intended for use as fixed voltage regulators in a variety of applications, including local (on-card) regulation to eliminate noise and distribution problems associated with single-point regulation. Additionally, they can be configured with external components to achieve adjustable output voltages and currents, providing flexibility for different circuit requirements.

9.2 Key Features

The key features of the LM340 regulators include:

- **Internal Current Limiting:** Protects the regulator and connected circuits from excessive current by limiting the maximum current that can pass through the device.
- **Thermal Shutdown:** Provides protection against overheating by shutting down the regulator when it reaches a certain temperature, thus preventing damage.
- **High Output Current Capability:** Capable of delivering over 1.5 A of output current when adequate heat sinking is provided.
- **Safe-Area Compensation:** Ensures stable operation by maintaining the regulator's performance within safe limits of voltage and current.
- **Fixed Output Voltage:** Provides a stable and fixed output voltage for reliable performance in various applications.
- **Flexibility with Adjustable Output:** Can be configured with external components to achieve adjustable output voltages and currents.

- **No Need for Output Bypass (Optional):** Output bypassing is not necessary, though it can improve transient response.
- **Input Bypassing:** Required only if the regulator is positioned far from the power supply filter capacitor, ensuring stable input voltage.

9.3 Applications

The LM340 regulators are suitable for a range of applications, including:

- **Fixed Output Voltage Regulator:** Provides a stable and fixed output voltage for various electronic circuits.
- **Adjustable Output Regulator:** Can be configured with external components to produce adjustable output voltages and currents.
- **Current Regulator:** Used in applications where a stable current source is required.
- **High Input Voltage Circuit Implementation with Transistor:** Suitable for circuits requiring high input voltages with stable regulation.

These regulators are ideal for use in a wide range of electronic devices and systems, offering reliability and ease of integration.

9.4 Pin Configuration

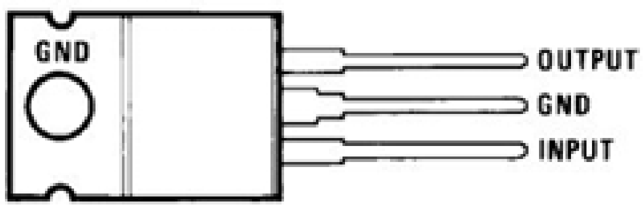

Figure 9.1: Pin Configuration of the LM340_5V

9.5 IC Layout

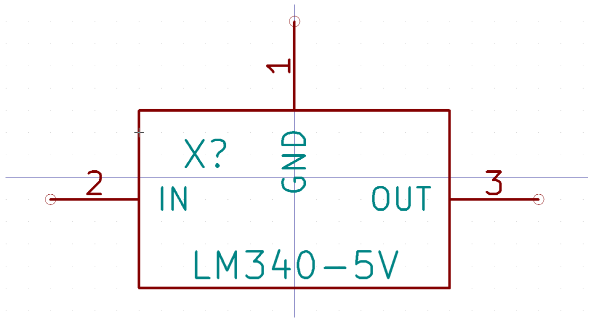

Figure 9.2: IC Layout of the LM340_5V

9.6 Subcircuit Schematic Diagram

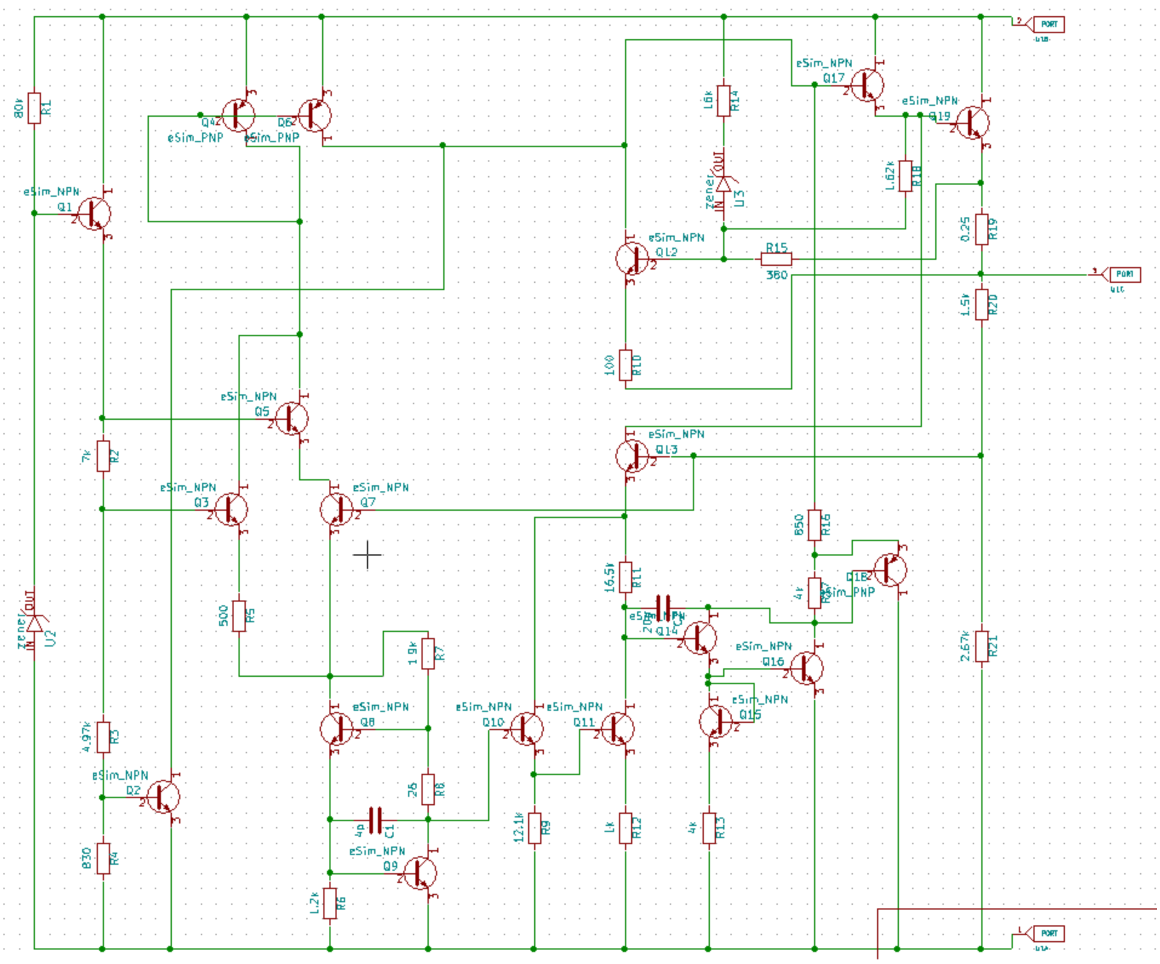

Figure 9.3: Subcircuit Schematic Diagram of the LM340_5V

9.7 Test Circuit

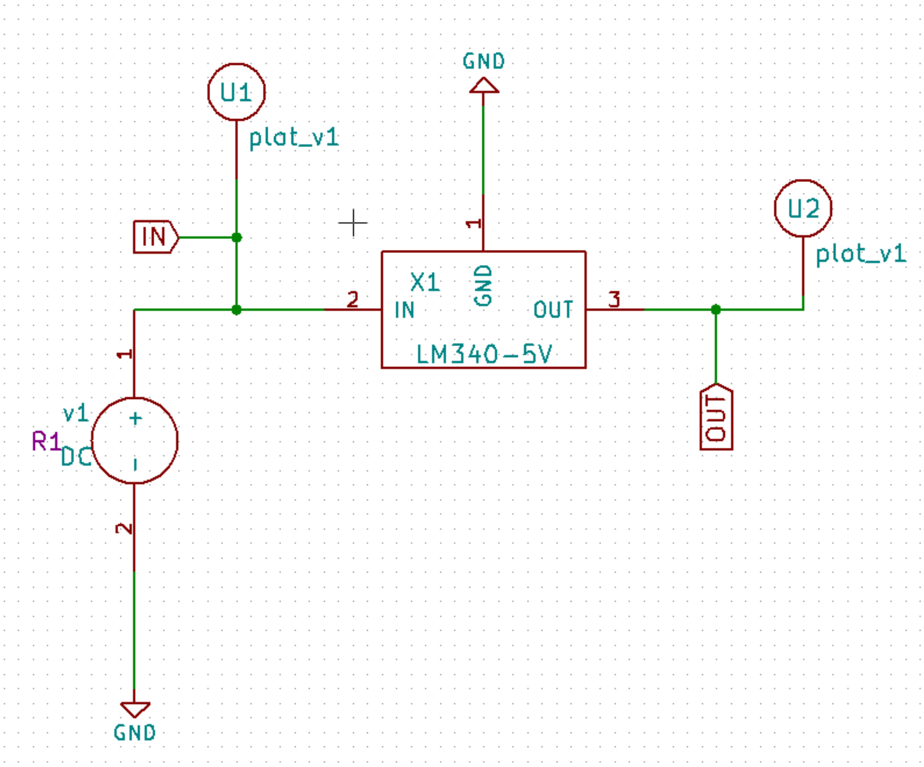

Figure 9.4: Test Circuit of the LM340_5V

9.8 Input Plot

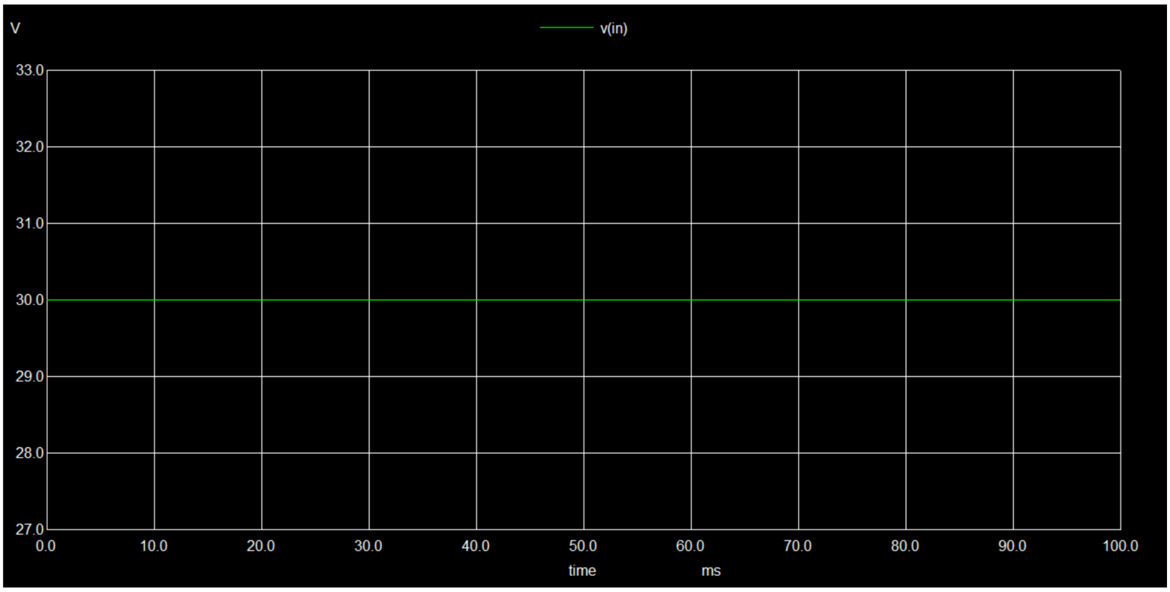

Figure 9.5: Input Plot of the LM340_5V

9.9 Output Plot

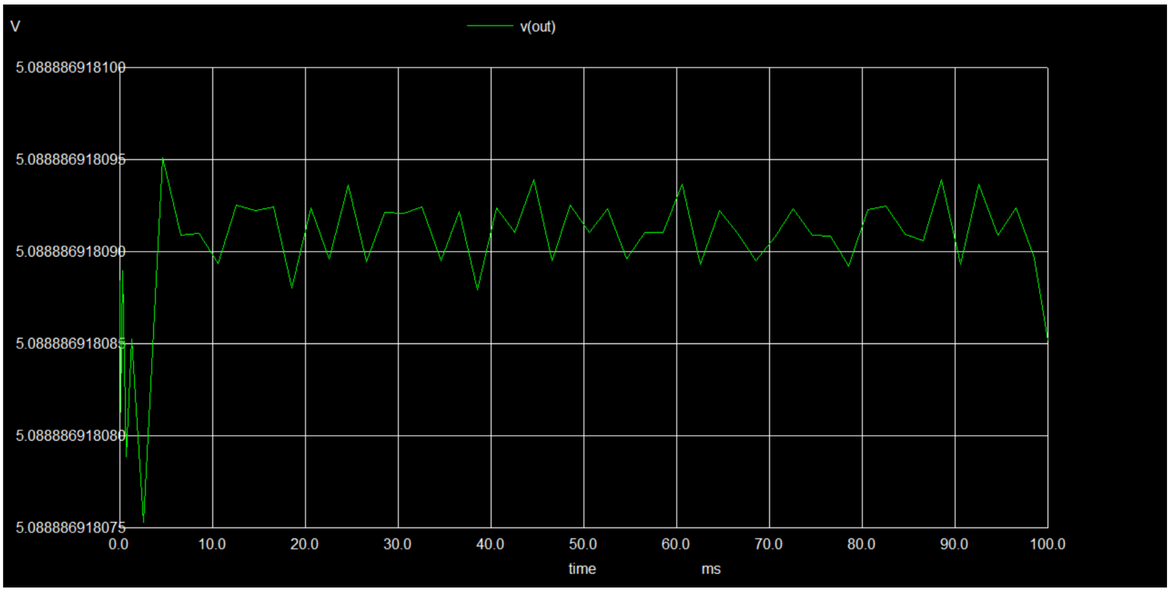

Figure 9.6: Output Plot of the LM340_5V

Chapter 10

LM340_12V

10.1 General Description

The LM340 family of monolithic 3-terminal positive voltage regulators are designed to provide reliable, fixed output voltages with built-in protection features. These regulators incorporate internal current limiting, thermal shutdown, and safe-area compensation, which make them highly robust and virtually indestructible under normal operating conditions. When adequate heat sinking is provided, these regulators can deliver over 1.5 A of output current.

These devices are intended for use as fixed voltage regulators in a variety of applications, including local (on-card) regulation to eliminate noise and distribution problems associated with single-point regulation. Additionally, they can be configured with external components to achieve adjustable output voltages and currents, providing flexibility for different circuit requirements.

10.2 Key Features

The key features of the LM340 regulators include:

- **Internal Current Limiting:** Protects the regulator and connected circuits from excessive current by limiting the maximum current that can pass through the device.
- **Thermal Shutdown:** Provides protection against overheating by shutting down the regulator when it reaches a certain temperature, thus preventing damage.
- **High Output Current Capability:** Capable of delivering over 1.5 A of output current when adequate heat sinking is provided.
- **Safe-Area Compensation:** Ensures stable operation by maintaining the regulator's performance within safe limits of voltage and current.
- **Fixed Output Voltage:** Provides a stable and fixed output voltage for reliable performance in various applications.
- **Flexibility with Adjustable Output:** Can be configured with external components to achieve adjustable output voltages and currents.

- **No Need for Output Bypass (Optional):** Output bypassing is not necessary, though it can improve transient response.
- **Input Bypassing:** Required only if the regulator is positioned far from the power supply filter capacitor, ensuring stable input voltage.

10.3 Applications

The LM340 regulators are suitable for a range of applications, including:

- **Fixed Output Voltage Regulator:** Provides a stable and fixed output voltage for various electronic circuits.
- **Adjustable Output Regulator:** Can be configured with external components to produce adjustable output voltages and currents.
- **Current Regulator:** Used in applications where a stable current source is required.
- **High Input Voltage Circuit Implementation with Transistor:** Suitable for circuits requiring high input voltages with stable regulation.

These regulators are ideal for use in a wide range of electronic devices and systems, offering reliability and ease of integration.

10.4 Pin Configuration

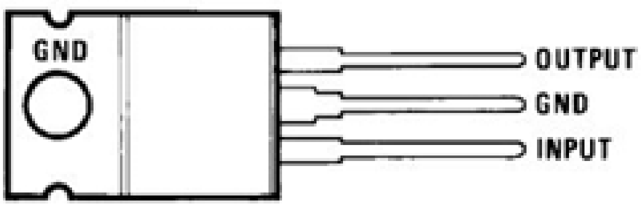

Figure 10.1: Pin Configuration of the LM340_12V

10.5 IC Layout

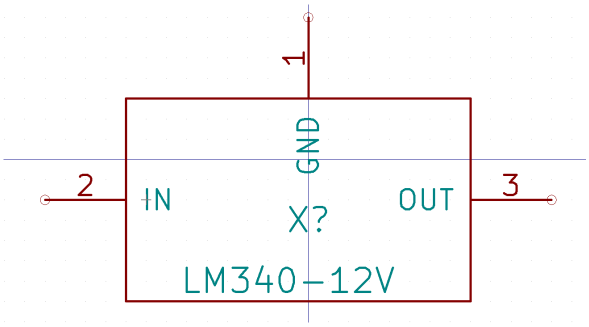

Figure 10.2: IC Layout of the LM340_12V

10.6 Subcircuit Schematic Diagram

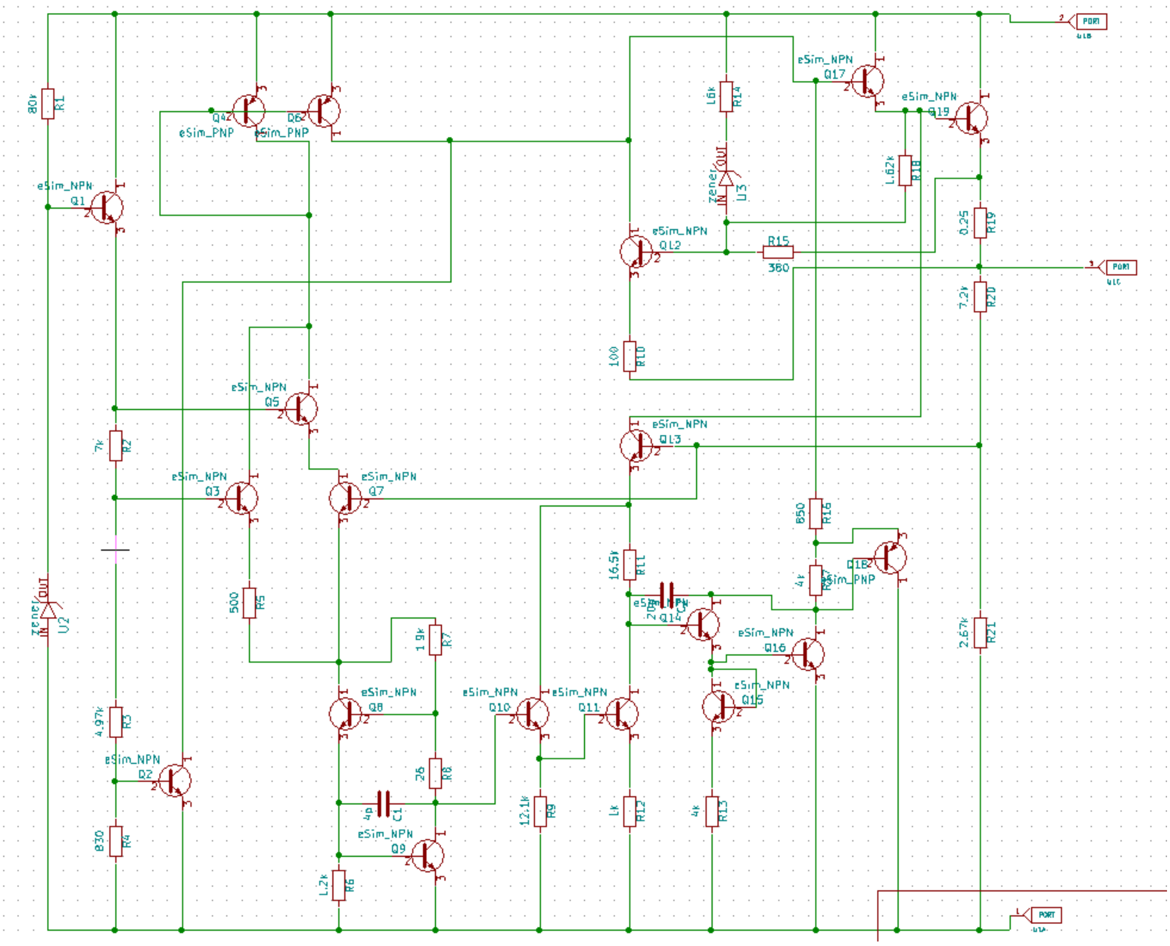

Figure 10.3: Subcircuit Schematic Diagram of the LM340_12V

10.7 Test Circuit

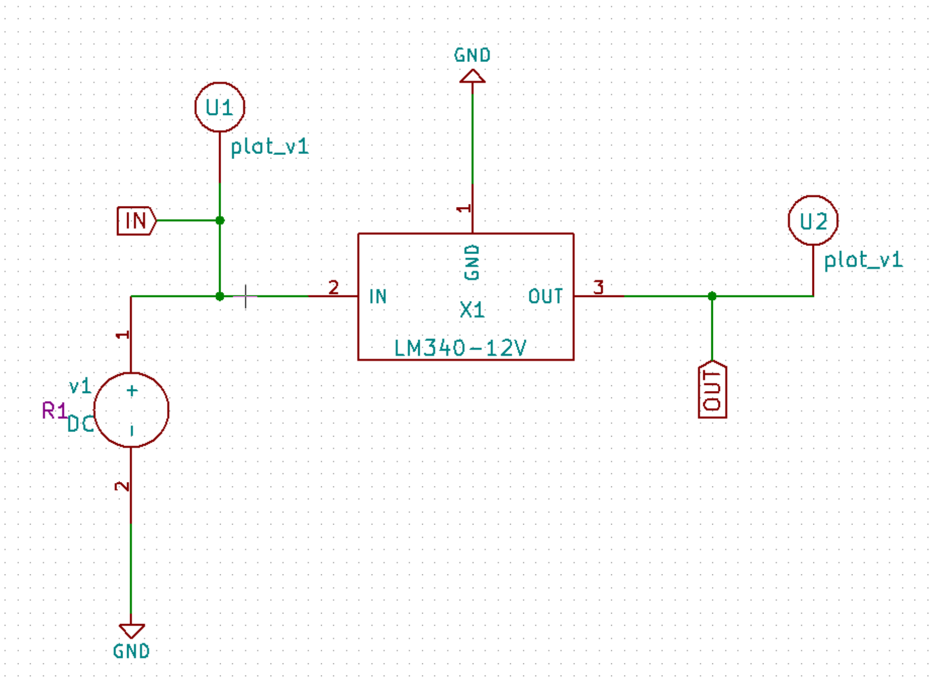

Figure 10.4: Test Circuit of the LM340_12V

10.8 Input Plot

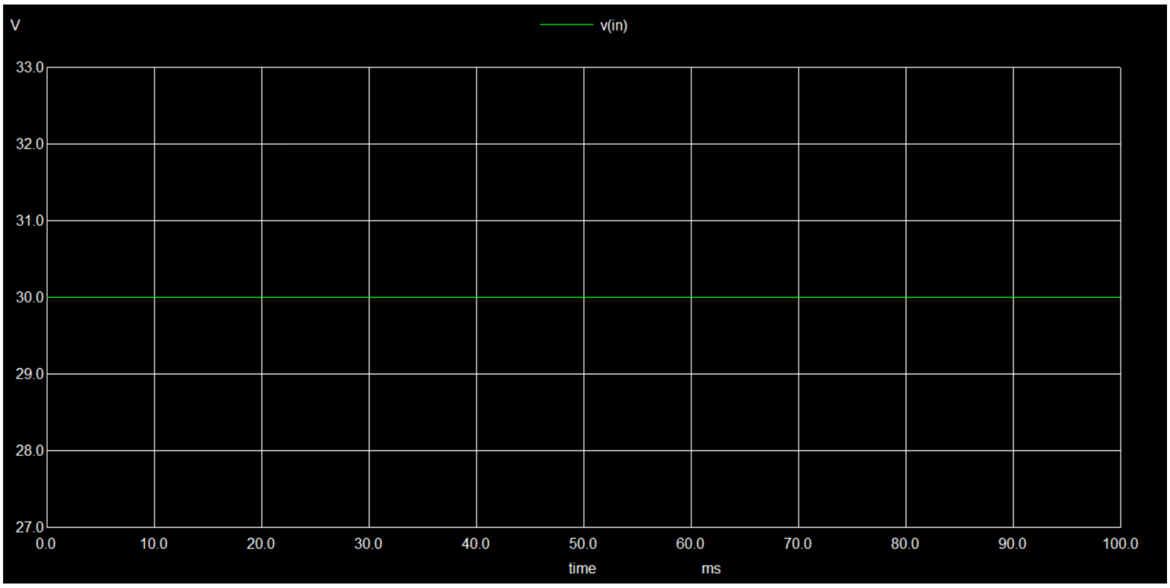

Figure 10.5: Input Plot of the LM340_12V

10.9 Output Plot

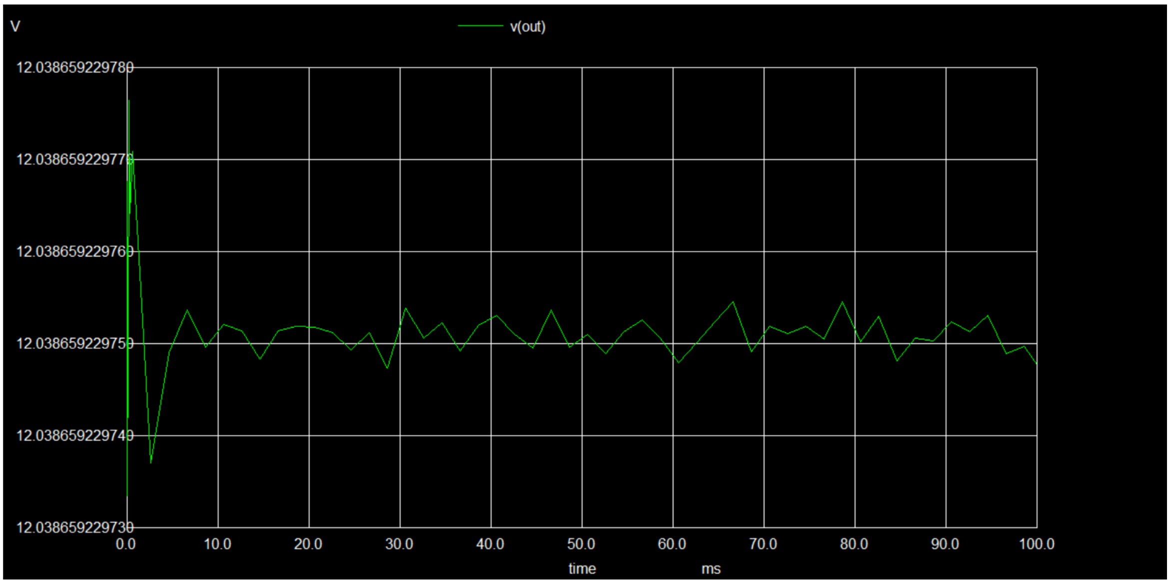

Figure 10.6: Output Plot of the LM340_12V

Chapter 11

LM340_15V

11.1 General Description

The LM340 family of monolithic 3-terminal positive voltage regulators are designed to provide reliable, fixed output voltages with built-in protection features. These regulators incorporate internal current limiting, thermal shutdown, and safe-area compensation, which make them highly robust and virtually indestructible under normal operating conditions. When adequate heat sinking is provided, these regulators can deliver over 1.5 A of output current.

These devices are intended for use as fixed voltage regulators in a variety of applications, including local (on-card) regulation to eliminate noise and distribution problems associated with single-point regulation. Additionally, they can be configured with external components to achieve adjustable output voltages and currents, providing flexibility for different circuit requirements.

11.2 Key Features

The key features of the LM340 regulators include:

- **Internal Current Limiting:** Protects the regulator and connected circuits from excessive current by limiting the maximum current that can pass through the device.
- **Thermal Shutdown:** Provides protection against overheating by shutting down the regulator when it reaches a certain temperature, thus preventing damage.
- **High Output Current Capability:** Capable of delivering over 1.5 A of output current when adequate heat sinking is provided.
- **Safe-Area Compensation:** Ensures stable operation by maintaining the regulator's performance within safe limits of voltage and current.
- **Fixed Output Voltage:** Provides a stable and fixed output voltage for reliable performance in various applications.
- **Flexibility with Adjustable Output:** Can be configured with external components to achieve adjustable output voltages and currents.

- **No Need for Output Bypass (Optional):** Output bypassing is not necessary, though it can improve transient response.

- **Input Bypassing:** Required only if the regulator is positioned far from the power supply filter capacitor, ensuring stable input voltage.

11.3 Applications

The LM340 regulators are suitable for a range of applications, including:

- **Fixed Output Voltage Regulator:** Provides a stable and fixed output voltage for various electronic circuits.

- **Adjustable Output Regulator:** Can be configured with external components to produce adjustable output voltages and currents.

- **Current Regulator:** Used in applications where a stable current source is required.

- **High Input Voltage Circuit Implementation with Transistor:** Suitable for circuits requiring high input voltages with stable regulation.

These regulators are ideal for use in a wide range of electronic devices and systems, offering reliability and ease of integration.

11.4 Pin Configuration

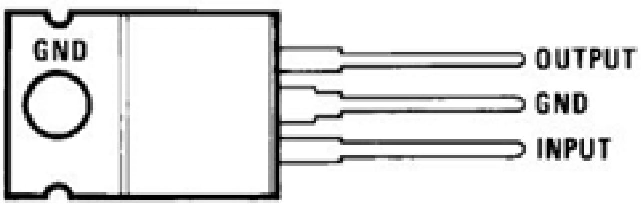

Figure 11.1: Pin Configuration of the LM340_15V

11.5 IC Layout

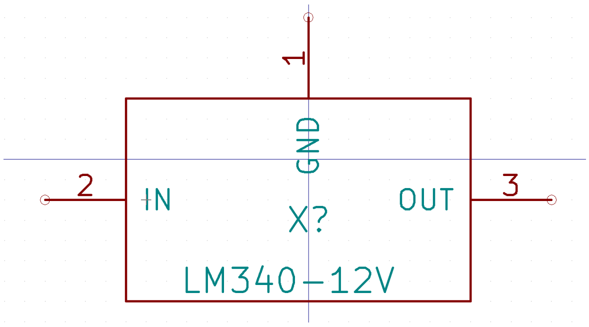

Figure 11.2: IC Layout of the LM340_15V

11.6 Subcircuit Schematic Diagram

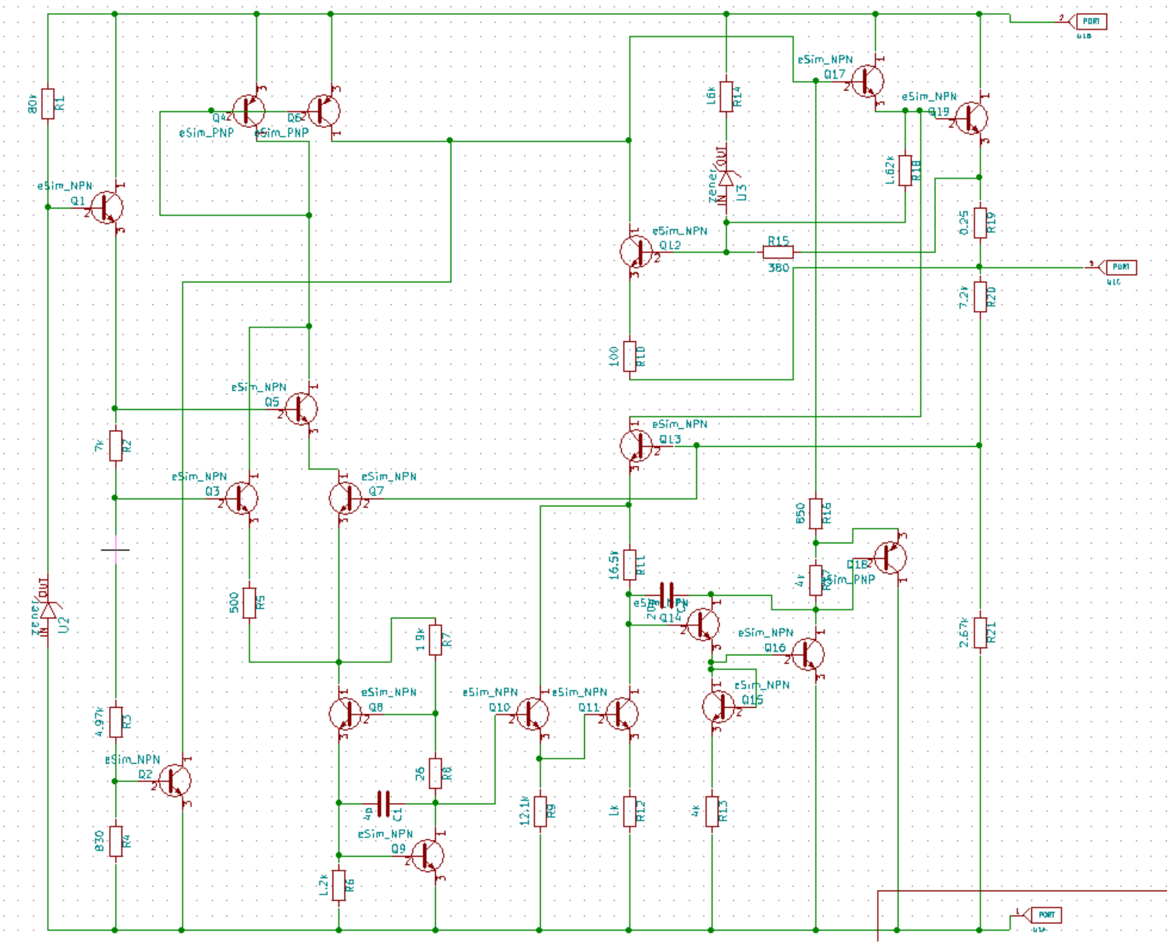

Figure 11.3: Subcircuit Schematic Diagram of the LM340_15V

11.7 Test Circuit

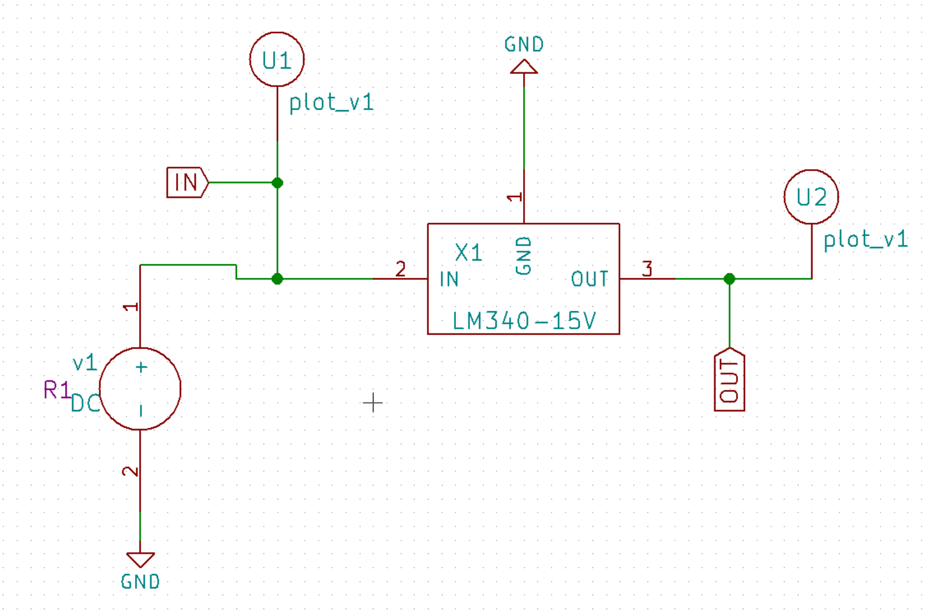

Figure 11.4: Test Circuit of the LM340_15V

11.8 Input Plot

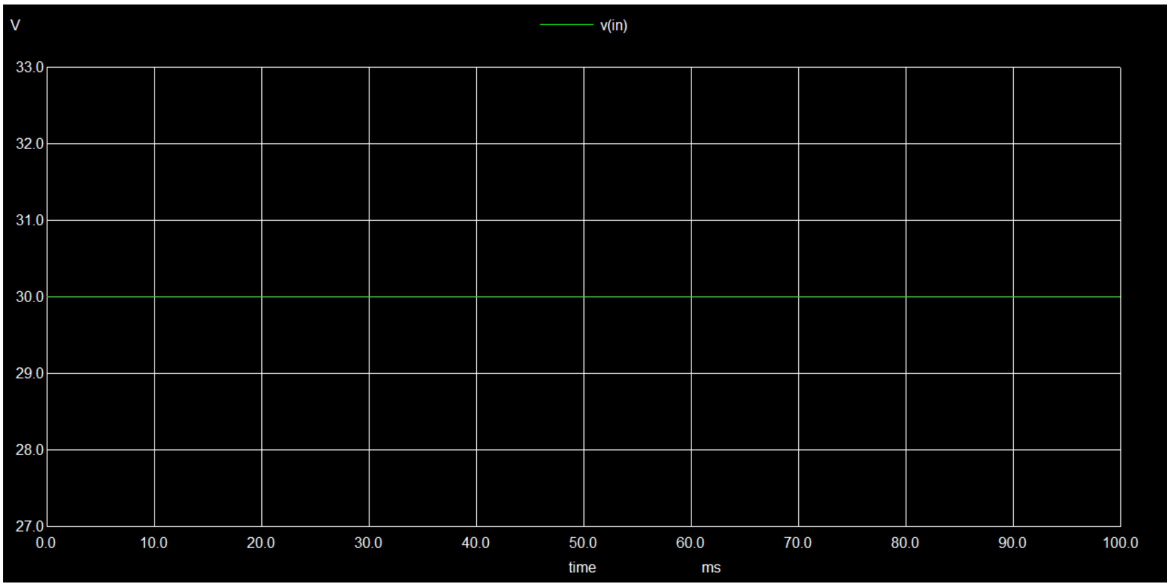

Figure 11.5: Input Plot of the LM340_15V

11.9 Output Plot

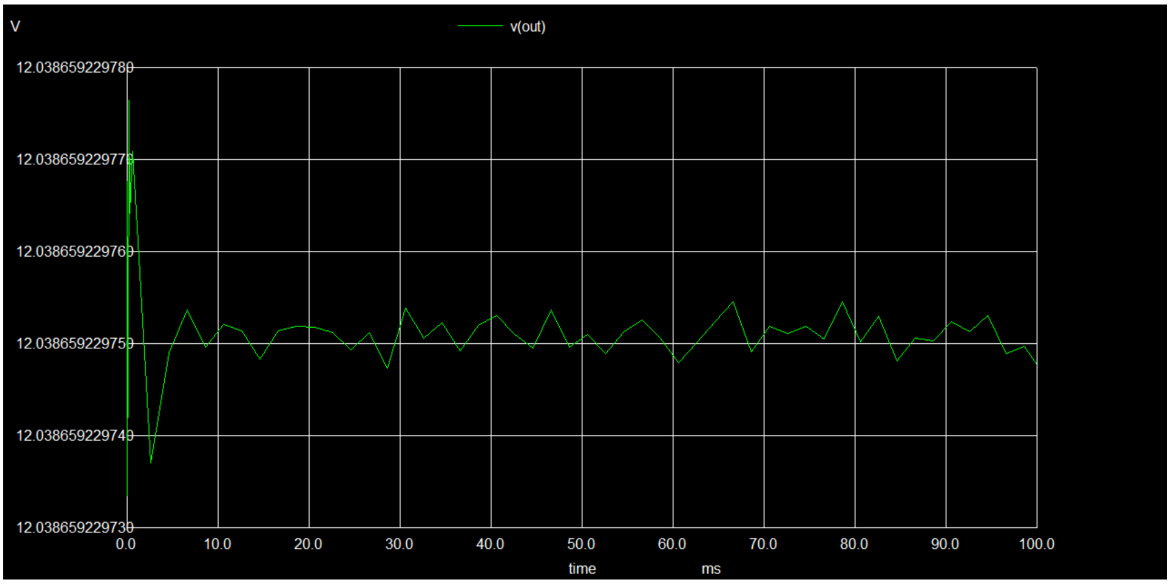

Figure 11.6: Output Plot of the LM340_15V

Chapter 12

LM7905

12.1 General Description

The LM79XX series are 3-terminal voltage regulators designed to provide stable and fixed negative output voltages. Available in configurations of -5V, -12V, and -15V, these regulators are packaged in the TO-220 power package and can deliver up to 1.5A of output current. They are straightforward to use, requiring only a compensation capacitor at the output for stable operation.

12.2 Key Features

The LM79XX series offers several key features:

- **Fixed Negative Output Voltages:** Available in -5V, -12V, and -15V configurations to suit various applications.
- **High Output Current Capability:** Can supply up to 1.5A of output current, making it suitable for demanding applications.
- **Internal Protection Features:** Includes current limiting, safe-area protection, and thermal shutdown to protect against overload conditions and ensure reliable operation.
- **Low Ground Pin Current:** Allows for easy boosting of the output voltage above the preset value using a resistor divider.
- **Low Quiescent Current Drain:** Ensures minimal power consumption and good regulation in the voltage-boosted mode.
- **Simple External Component Requirement:** Requires only a compensation capacitor at the output for stable operation.
- **TO-220 Package:** Ensures efficient heat dissipation and easy integration into various circuit designs.

12.3 Applications

The LM79XX regulators are versatile and can be used in a variety of applications, including:

- **Light Controller Using Silicon Photo Cell:** Provides a stable negative voltage for controlling light-based applications.
- **$\pm$15V, 1 Amp Tracking Regulators:** Useful in applications requiring dual tracking regulators for precise voltage regulation.
- **High Stability 1 Amp Regulator:** Suitable for applications needing stable and reliable negative voltage regulation.
- **Current Source:** Can be used in circuits requiring a stable current source with precise negative voltage regulation.

12.4 Pin Configuration

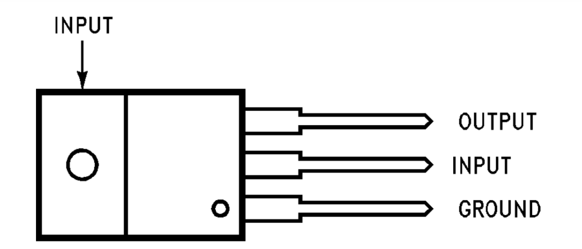

Figure 12.1: Pin Configuration of the LM7905

12.5 IC Layout

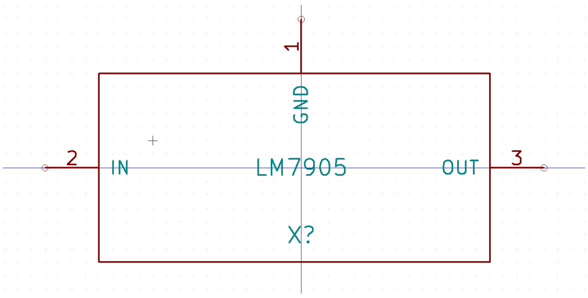

Figure 12.2: IC Layout of the LM7905

12.6 Subcircuit Schematic Diagram

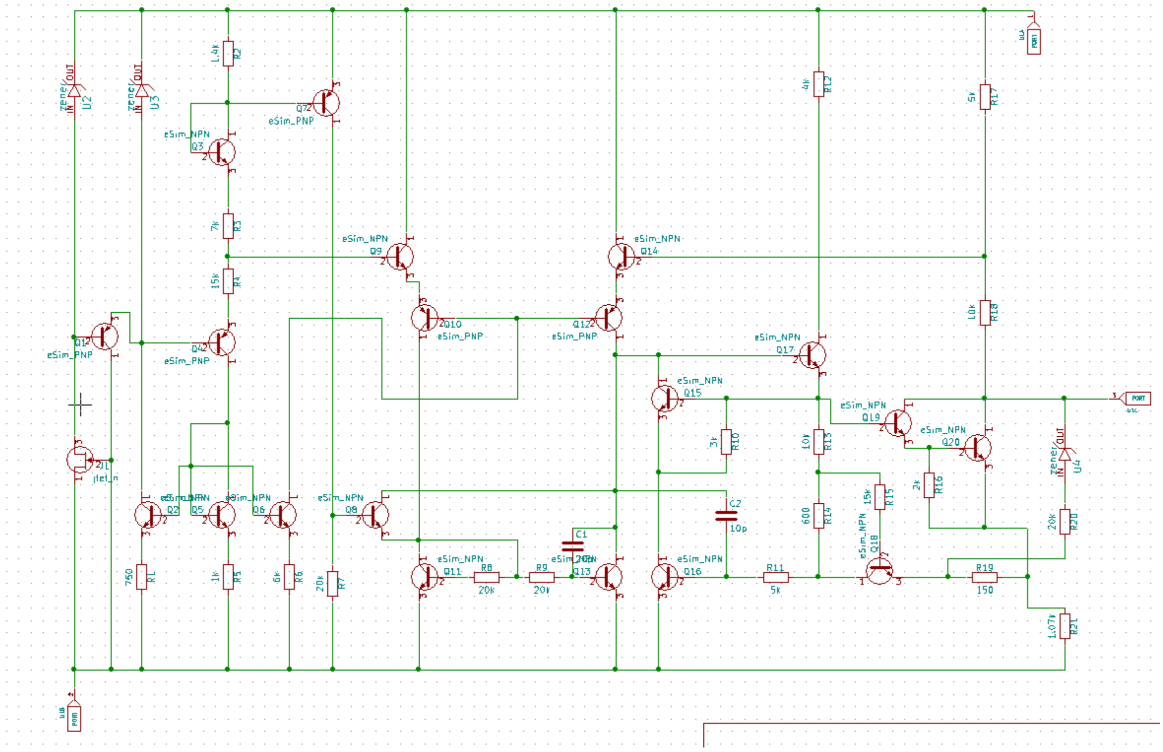

Figure 12.3: Subcircuit Schematic Diagram of the LM7905

12.7 Test Circuit

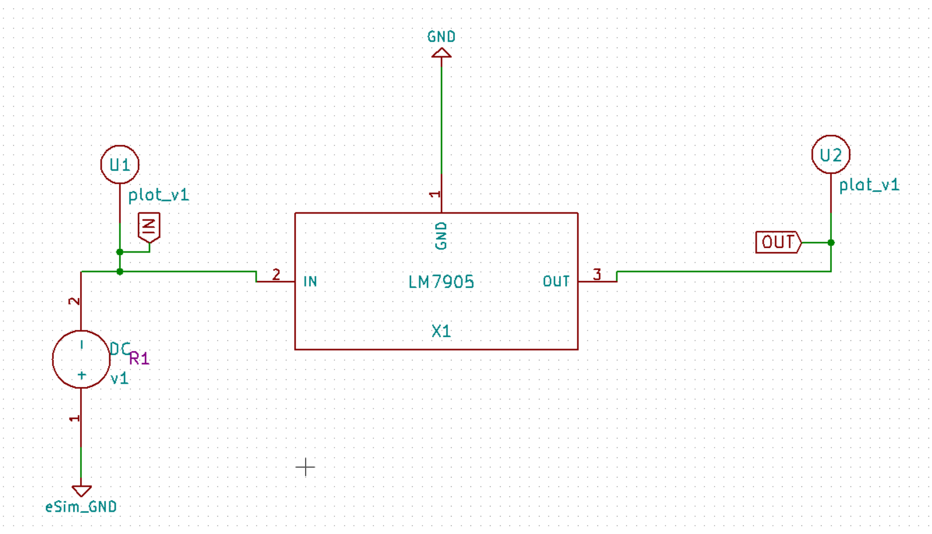

Figure 12.4: Test Circuit of the LM7905

12.8 Input Plot

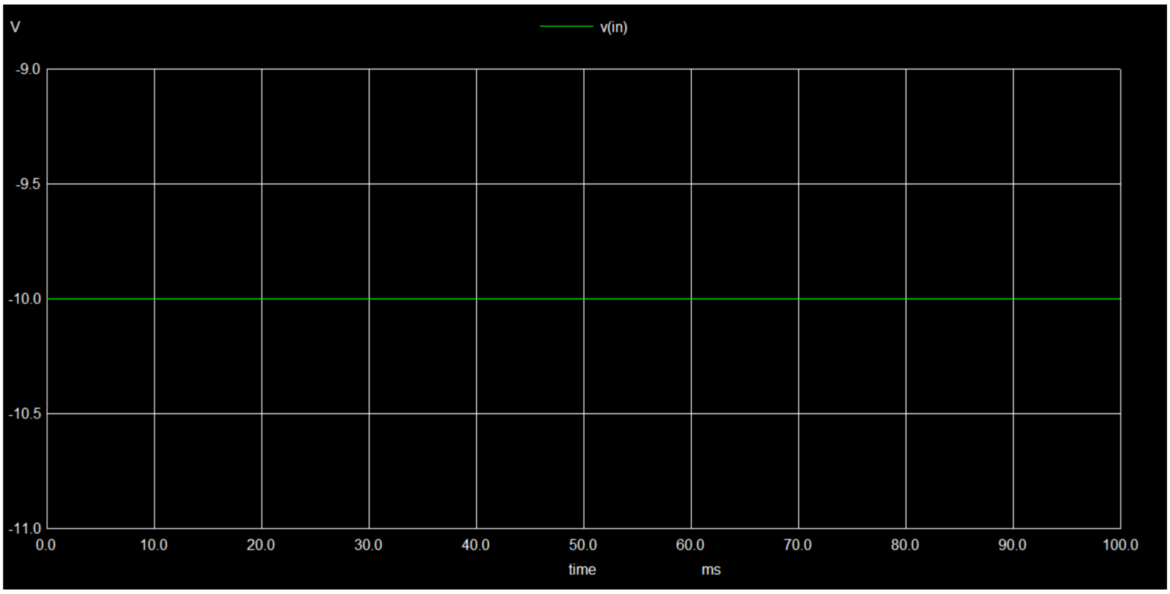

Figure 12.5: Input Plot of the LM7905

12.9 Output Plot

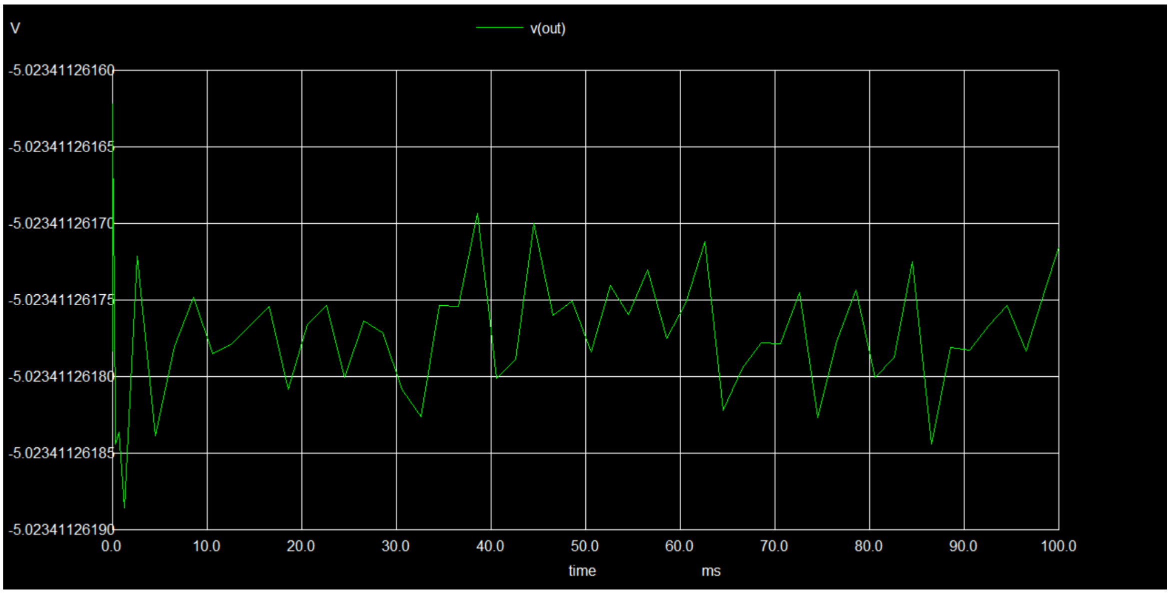

Figure 12.6: Output Plot of the LM7905

Chapter 13

LM7912

13.1 General Description

The LM79XX series are 3-terminal voltage regulators designed to provide stable and fixed negative output voltages. Available in configurations of -5V, -12V, and -15V, these regulators are packaged in the TO-220 power package and can deliver up to 1.5A of output current. They are straightforward to use, requiring only a compensation capacitor at the output for stable operation.

13.2 Key Features

The LM79XX series offers several key features:

- **Fixed Negative Output Voltages:** Available in -5V, -12V, and -15V configurations to suit various applications.
- **High Output Current Capability:** Can supply up to 1.5A of output current, making it suitable for demanding applications.
- **Internal Protection Features:** Includes current limiting, safe-area protection, and thermal shutdown to protect against overload conditions and ensure reliable operation.
- **Low Ground Pin Current:** Allows for easy boosting of the output voltage above the preset value using a resistor divider.
- **Low Quiescent Current Drain:** Ensures minimal power consumption and good regulation in the voltage-boosted mode.
- **Simple External Component Requirement:** Requires only a compensation capacitor at the output for stable operation.
- **TO-220 Package:** Ensures efficient heat dissipation and easy integration into various circuit designs.

13.3 Applications

The LM79XX regulators are versatile and can be used in a variety of applications, including:

- **Light Controller Using Silicon Photo Cell:** Provides a stable negative voltage for controlling light-based applications.
- **±15V, 1 Amp Tracking Regulators:** Useful in applications requiring dual tracking regulators for precise voltage regulation.
- **High Stability 1 Amp Regulator:** Suitable for applications needing stable and reliable negative voltage regulation.
- **Current Source:** Can be used in circuits requiring a stable current source with precise negative voltage regulation.

13.4 Pin Configuration

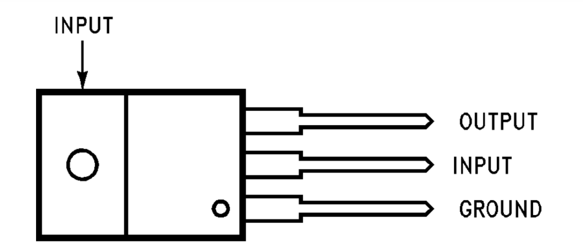

Figure 13.1: Pin Configuration of the LM7912

13.5 IC Layout

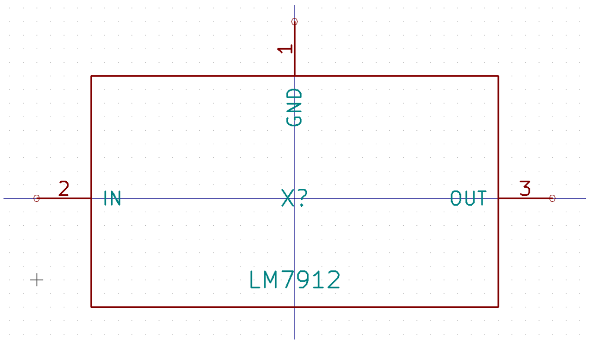

Figure 13.2: IC Layout of the LM7912

13.6 Subcircuit Schematic Diagram

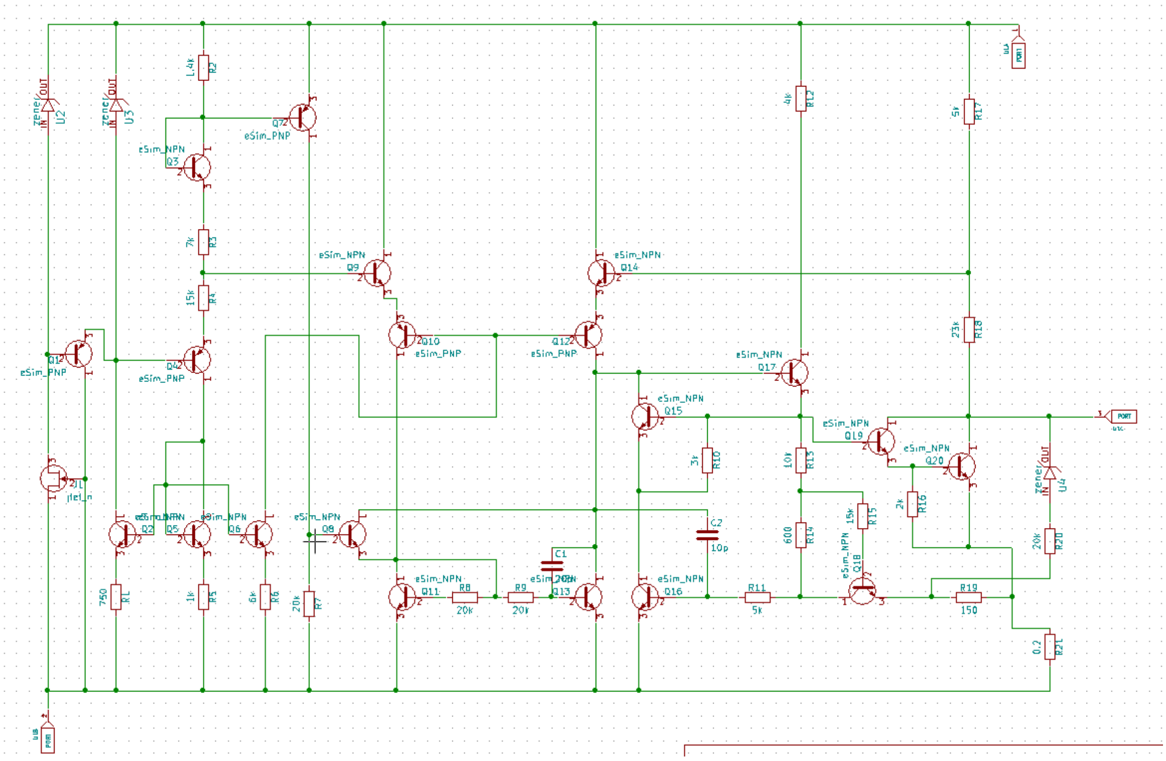

Figure 13.3: Subcircuit Schematic Diagram of the LM7912

13.7 Test Circuit

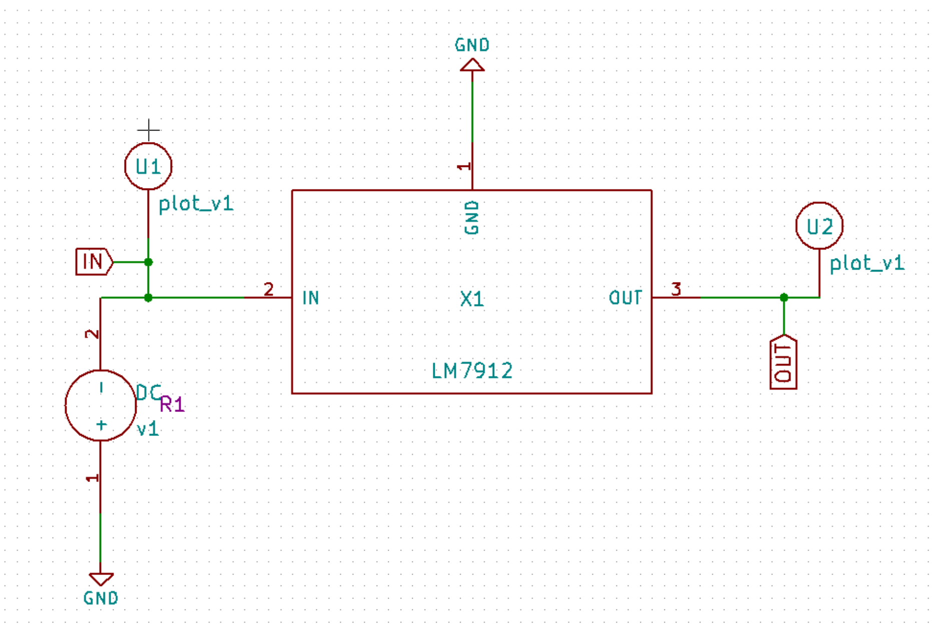

Figure 13.4: Test Circuit of the LM7912

13.8 Input Plot

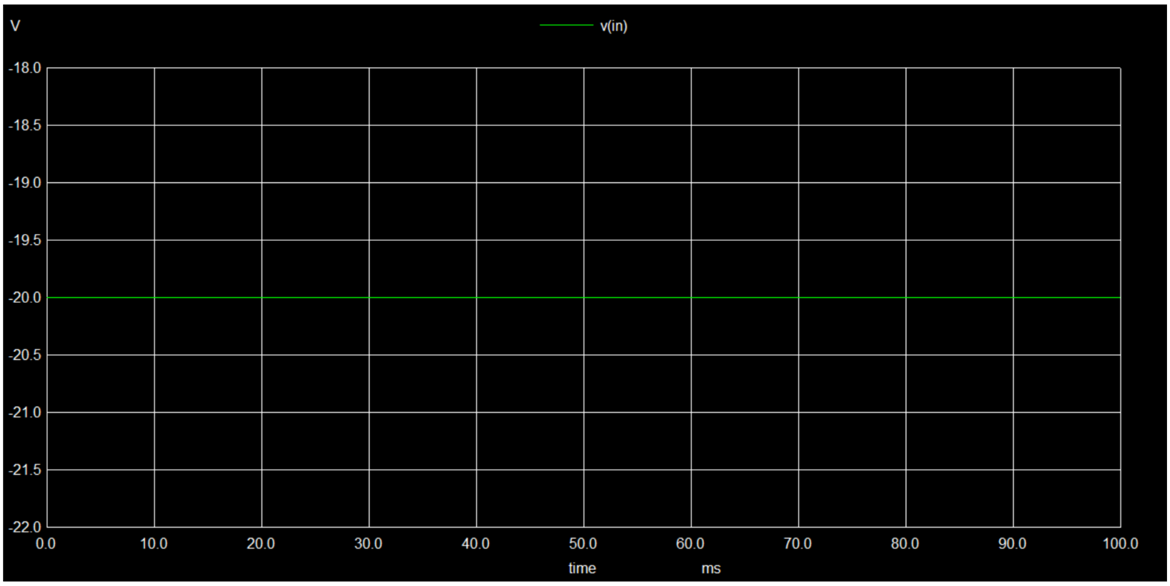

Figure 13.5: Input Plot of the LM7912

13.9 Output Plot

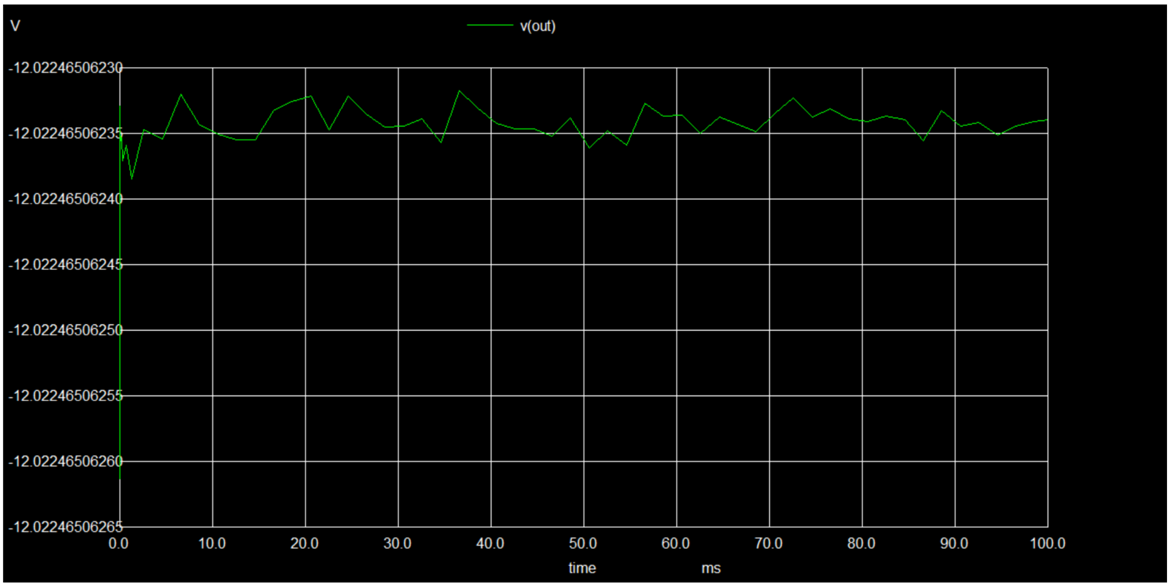

Figure 13.6: Output Plot of the LM7912

Chapter 14

LM7915

14.1 General Description

The LM79XX series are 3-terminal voltage regulators designed to provide stable and fixed negative output voltages. Available in configurations of -5V, -12V, and -15V, these regulators are packaged in the TO-220 power package and can deliver up to 1.5A of output current. They are straightforward to use, requiring only a compensation capacitor at the output for stable operation.

14.2 Key Features

The LM79XX series offers several key features:

- **Fixed Negative Output Voltages:** Available in -5V, -12V, and -15V configurations to suit various applications.
- **High Output Current Capability:** Can supply up to 1.5A of output current, making it suitable for demanding applications.
- **Internal Protection Features:** Includes current limiting, safe-area protection, and thermal shutdown to protect against overload conditions and ensure reliable operation.
- **Low Ground Pin Current:** Allows for easy boosting of the output voltage above the preset value using a resistor divider.
- **Low Quiescent Current Drain:** Ensures minimal power consumption and good regulation in the voltage-boosted mode.
- **Simple External Component Requirement:** Requires only a compensation capacitor at the output for stable operation.
- **TO-220 Package:** Ensures efficient heat dissipation and easy integration into various circuit designs.

14.3 Applications

The LM79XX regulators are versatile and can be used in a variety of applications, including:

- **Light Controller Using Silicon Photo Cell:** Provides a stable negative voltage for controlling light-based applications.
- **±15V, 1 Amp Tracking Regulators:** Useful in applications requiring dual tracking regulators for precise voltage regulation.
- **High Stability 1 Amp Regulator:** Suitable for applications needing stable and reliable negative voltage regulation.
- **Current Source:** Can be used in circuits requiring a stable current source with precise negative voltage regulation.

14.4 Pin Configuration

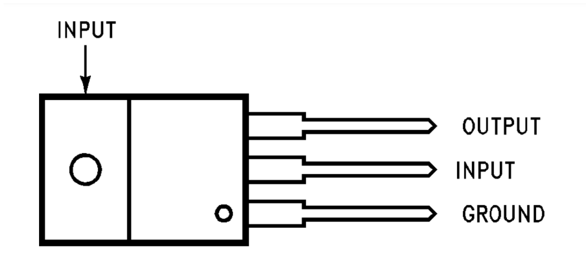

Figure 14.1: Pin Configuration of the LM7915

14.5 IC Layout

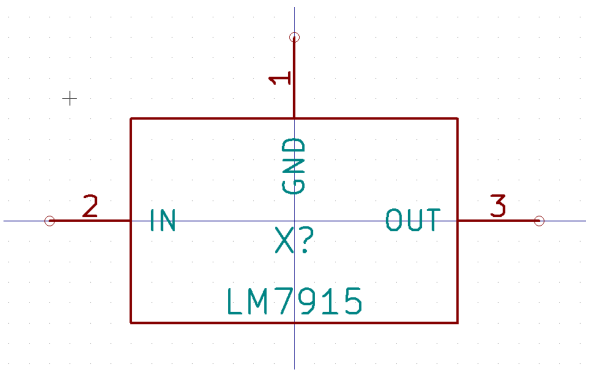

Figure 14.2: IC Layout of the LM7915

14.6 Subcircuit Schematic Diagram

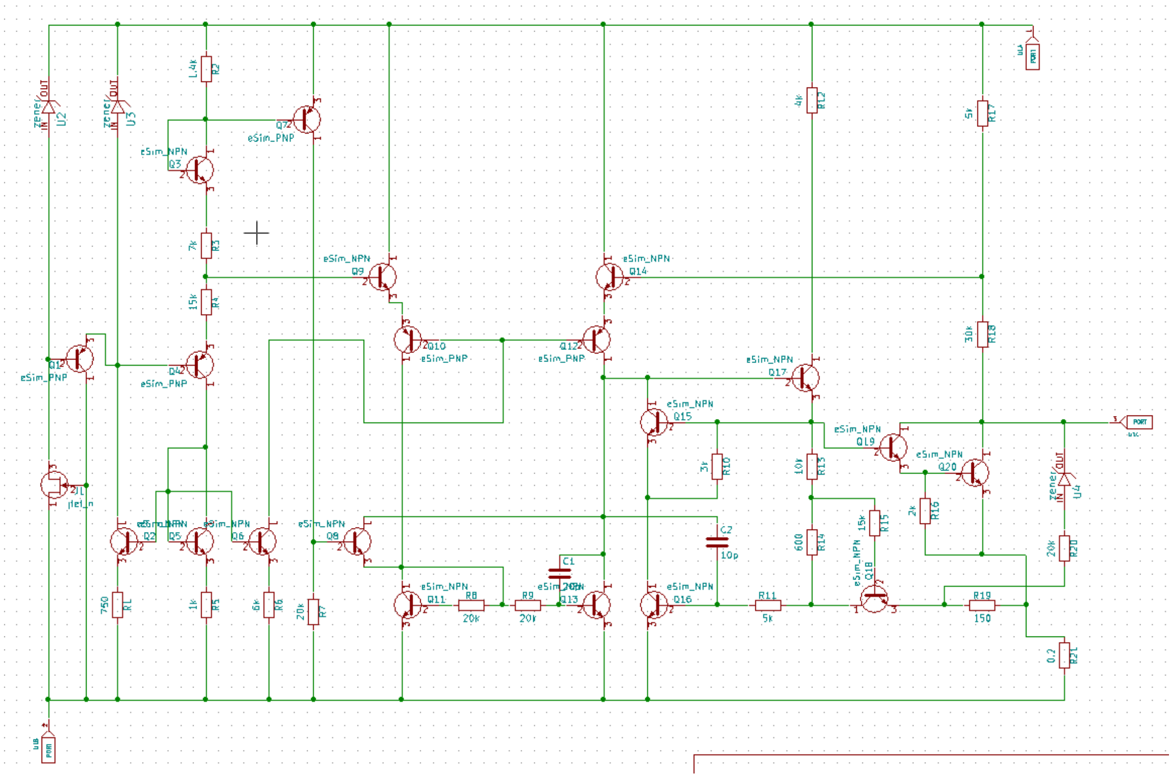

Figure 14.3: Subcircuit Schematic Diagram of the LM7915

14.7 Test Circuit

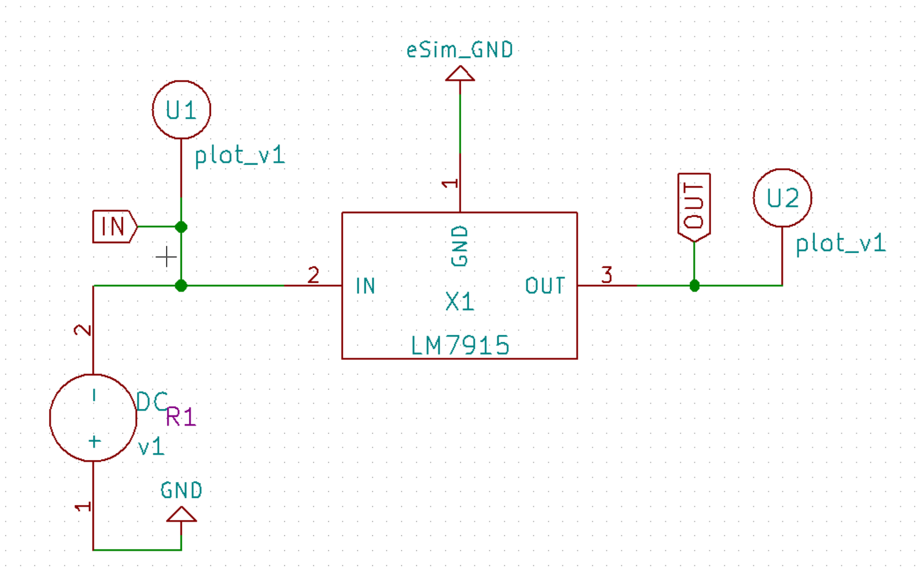

Figure 14.4: Test Circuit of the LM7915

14.8 Input Plot

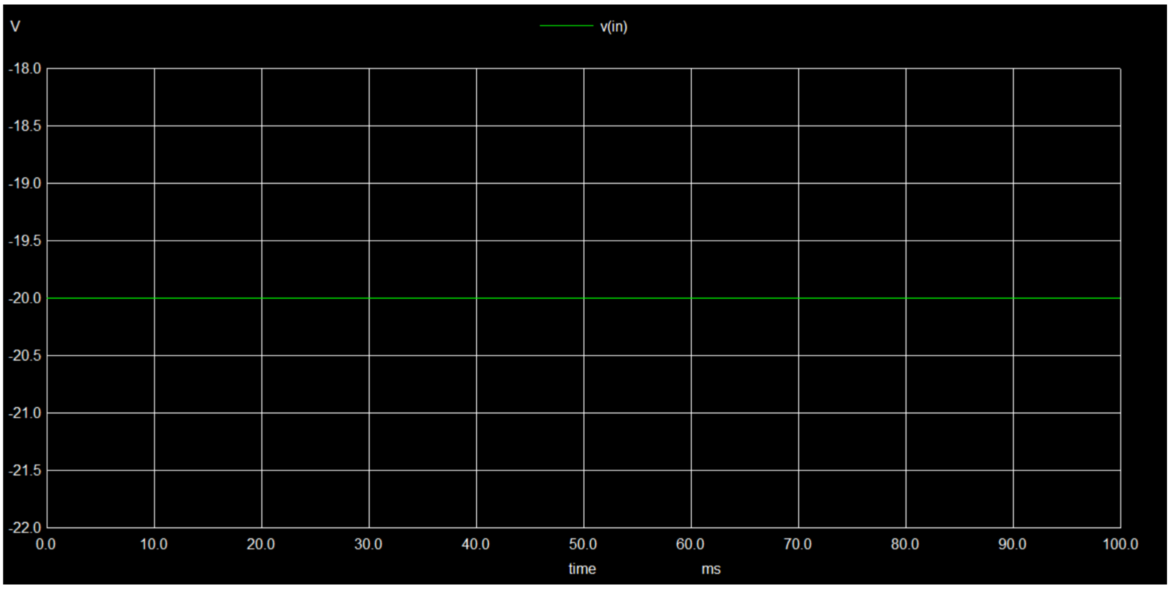

Figure 14.5: Input Plot of the LM7915

14.9 Output Plot

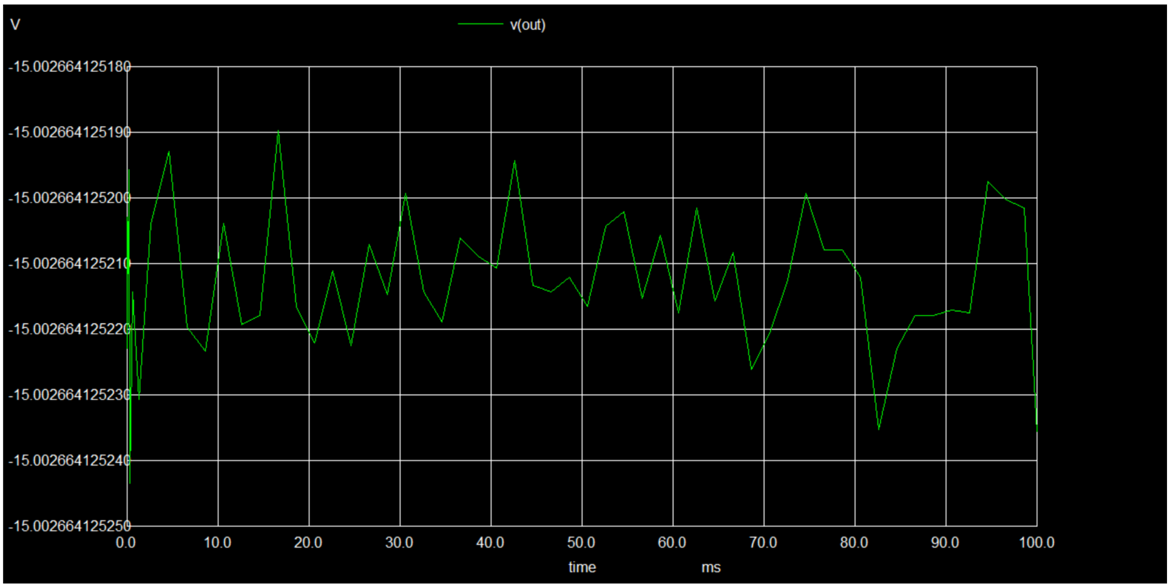

Figure 14.6: Output Plot of the LM7915

Chapter 15

LM431

15.1 General Description

The TL431 and TL432 are three-terminal adjustable shunt regulators known for their thermal stability across automotive, commercial, and military temperature ranges. These devices allow for output voltages to be set between approximately 2.5V and 36V using two external resistors. They are characterized by a low output impedance of approximately 0.2 Ohm and provide a sharp turn-on characteristic. This makes them excellent replacements for Zener diodes in various applications, including on-board regulation, adjustable power supplies, and switching power supplies.

While the TL432 offers the same functionality and electrical specifications as the TL431, it features different pinouts for the DBV, DBZ, and PK packages. Both devices are available in three grades with initial tolerances of 0.5%, 1%, and 2% for the B, A, and standard grades, respectively. Their low output drift versus temperature ensures stability across the entire temperature range.

15.2 Key Features

The TL431 and TL432 devices offer the following features:

- **Adjustable Output Voltage:** Can be set between 2.5V and 36V with two external resistors.
- **Low Output Impedance:** Typical output impedance of 0.2 Ohm for stable performance.
- **Sharp Turn-On Characteristic:** Provides rapid response, making it suitable as a replacement for Zener diodes.
- **Thermal Stability:** Maintains stability over automotive, commercial, and military temperature ranges.
- **Precision Grades:** Available in B, A, and standard grades with initial tolerances of 0.5
- **Low Output Drift:** Ensures good stability over the entire temperature range.

- **Versatile Pinouts:** TL432 offers different pinouts for various package types while retaining the same functionality as the TL431.

15.3 Applications

The TL431 and TL432 are versatile devices used in a wide range of applications, including:

- **Rack Server Power:** Provides stable voltage regulation for high-reliability server systems.
- **Industrial AC/DC:** Used in industrial power supply systems for reliable operation.
- **AC Inverter & VF Drives:** Offers precise voltage regulation in AC inverter and variable frequency drive systems.
- **Servo Drive Control Module:** Ensures stable control voltage in servo drive applications.
- **Notebook PC Power Adapter Design:** Utilized in power adapters for portable computers to maintain consistent voltage output.

15.4 Pin Configuration

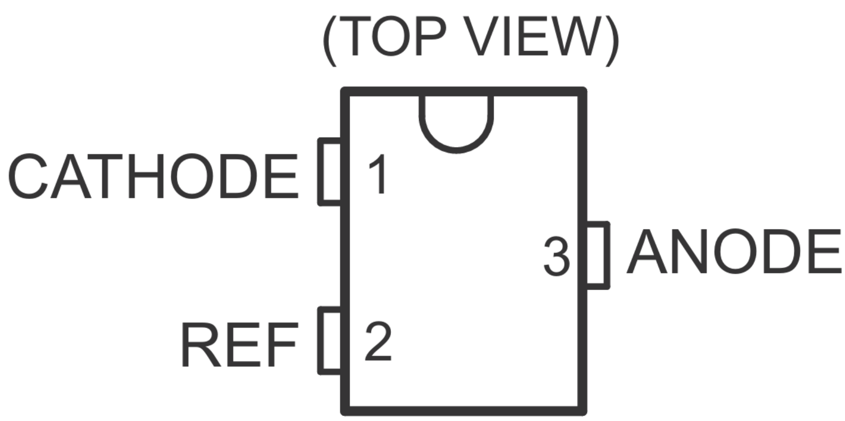

Figure 15.1: Pin Configuration of the TL431

15.5 IC Layout

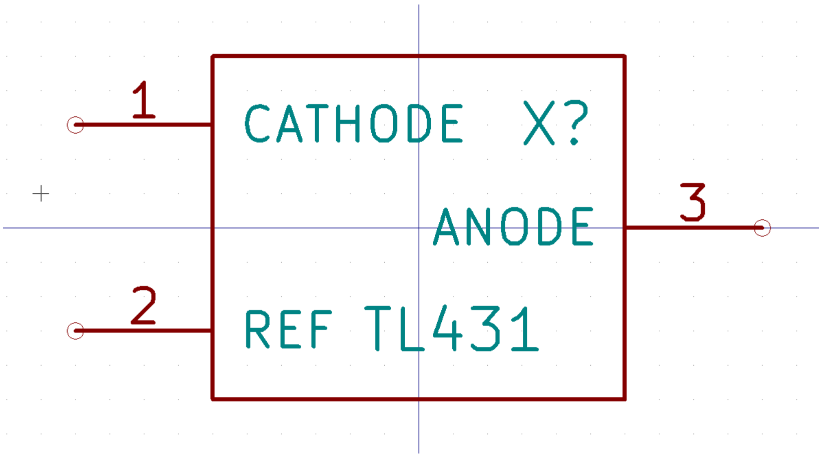

Figure 15.2: IC Layout of the TL431

15.6 Subcircuit Schematic Diagram

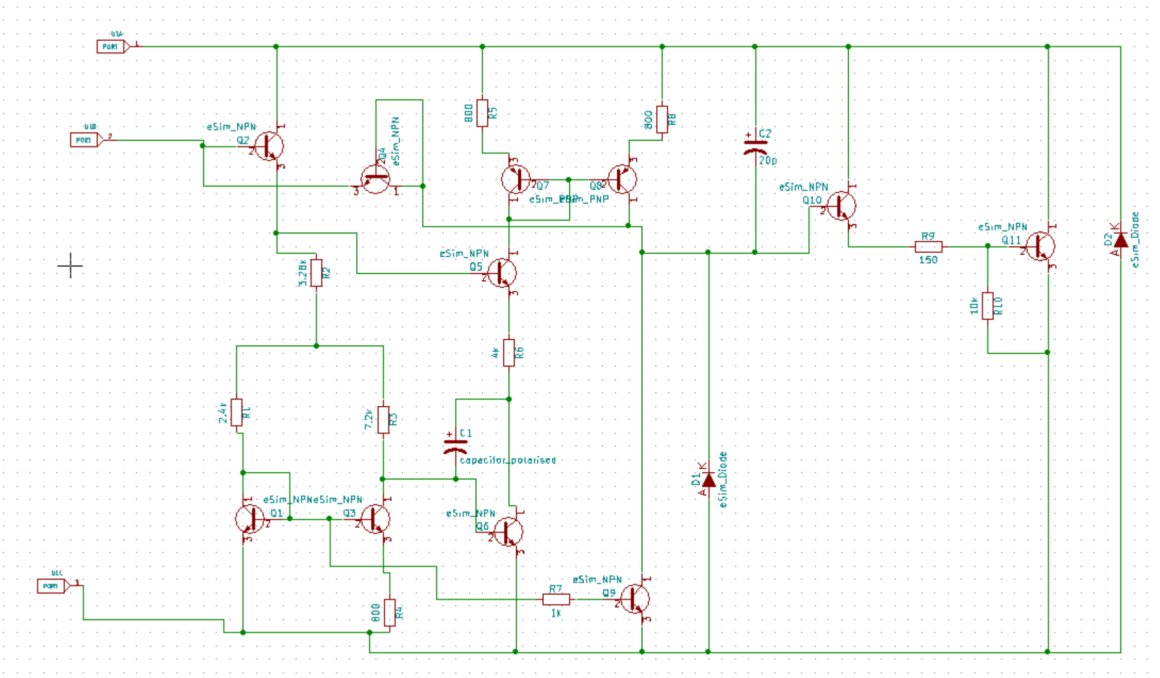

Figure 15.3: Subcircuit Schematic Diagram of the TL431

Chapter 16

Failed Circuits

16.1 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.

16.2 Failed Circuit 1: CA3130

16.2.1 Circuit Diagram

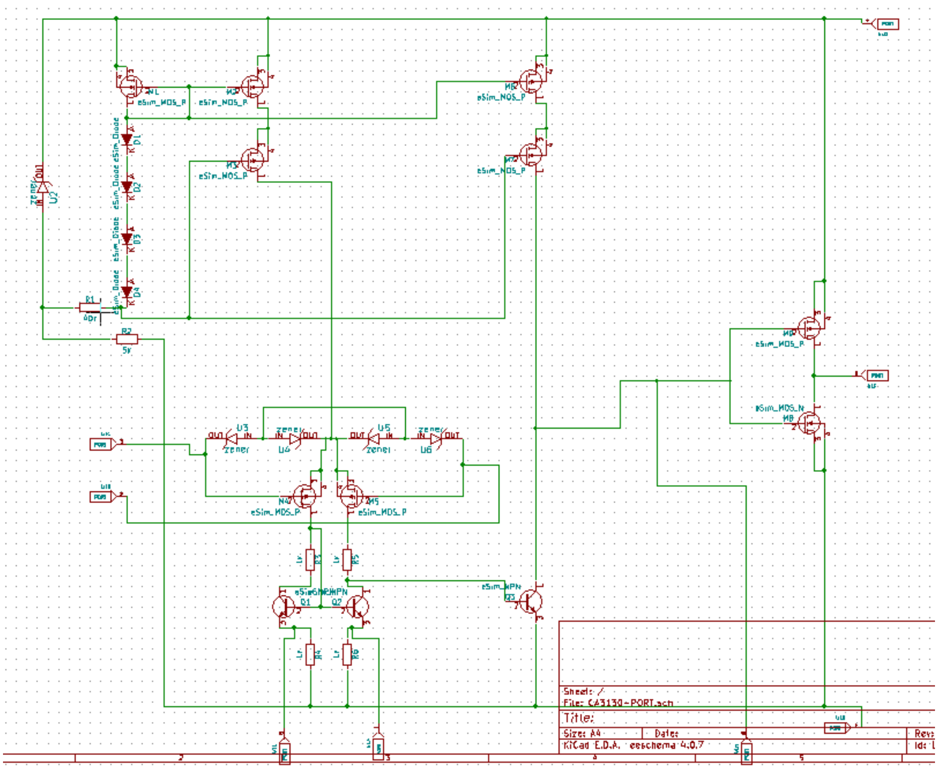

Figure 16.1: Subcircuit Schematic diagram of the CA3130

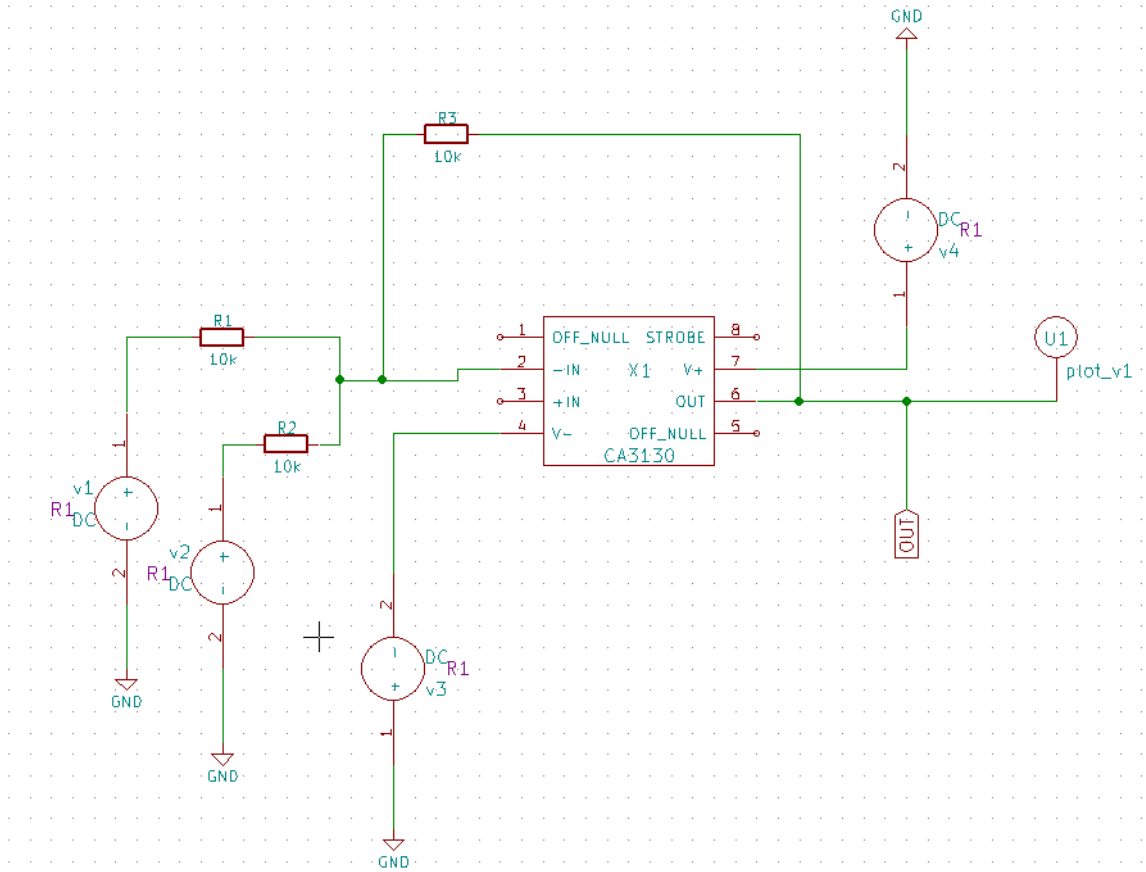

Figure 16.2: Subcircuit Schematic diagram of the CA3130

16.2.2 Issue Description

The CA3130 operational amplifier circuit was designed to perform a basic function, but we encountered an issue where the output did not match the expected result when two inputs were applied. Specifically, the expected addition of the two input signals was not observed.

16.3 Failed Circuit 2: LM3411

16.3.1 Circuit Diagram

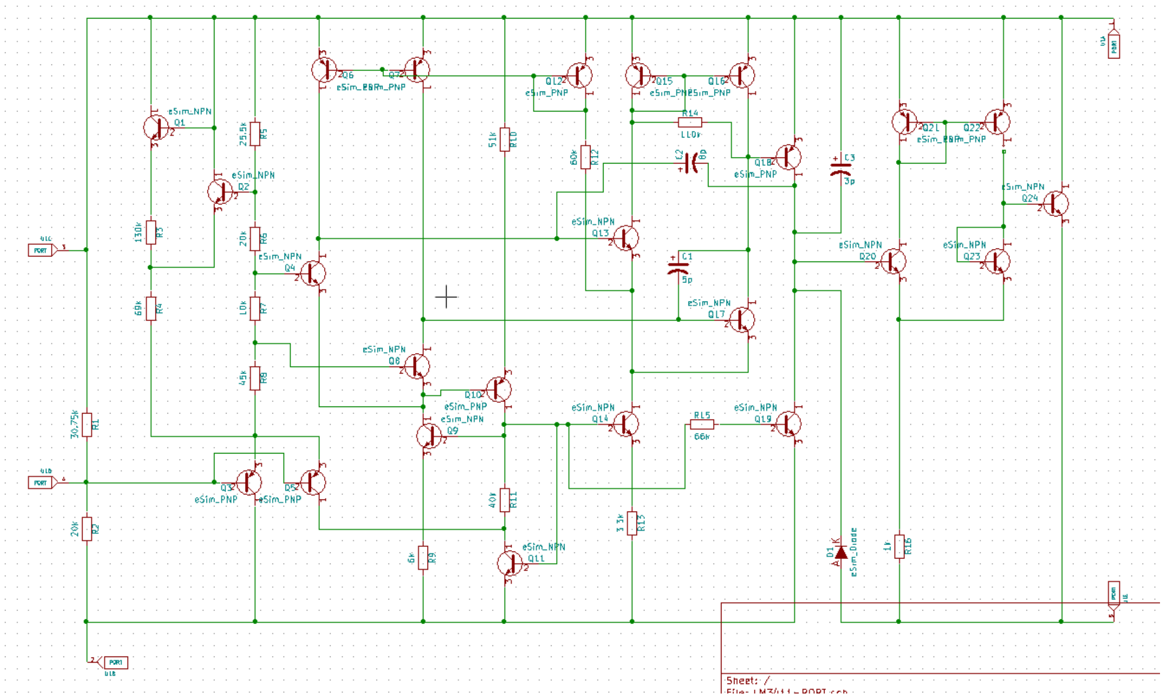

Figure 16.3: Subcircuit Schematic diagram of the LM3411

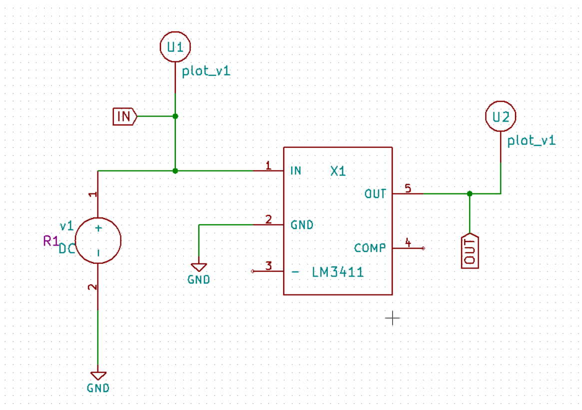

Figure 16.4: Test Circuit of the LM3411

16.3.2 Issue Description

The LM3411 Precision Secondary Regulator and Driver circuit, intended to function as a voltage regulator, did not produce the expected regulated output. Instead, it behaved more like a voltage follower, where the output closely followed the input voltage rather than maintaining a stable, regulated output.

16.4 Failed Circuit 3: REF102

16.4.1 Circuit Diagram

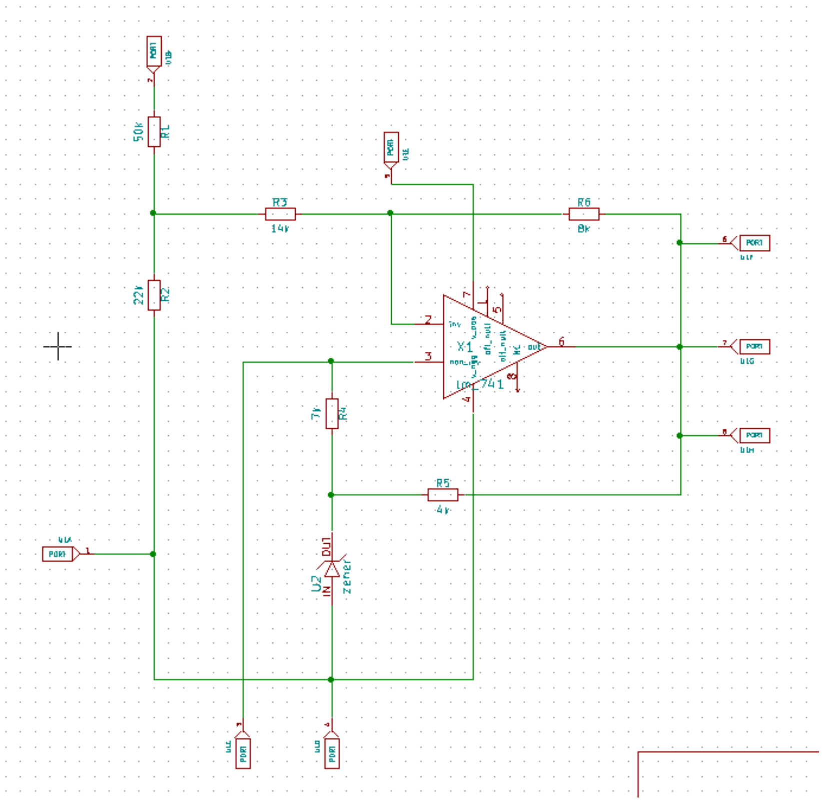

Figure 16.5: Subcircuit Schematic diagram of the REF102

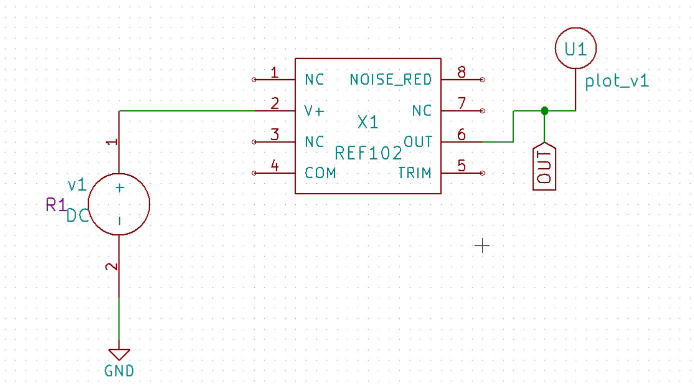

Figure 16.6: Test Circuit of the REF102

16.4.2 Issue Description

The REF102 10V Precision Voltage Reference circuit did not produce the expected 10V output. Instead, the output voltage deviated significantly from the specified value, indicating that the circuit was not performing as a stable voltage reference.

16.5 Failed Circuit 4: TL317

16.5.1 Circuit Diagram

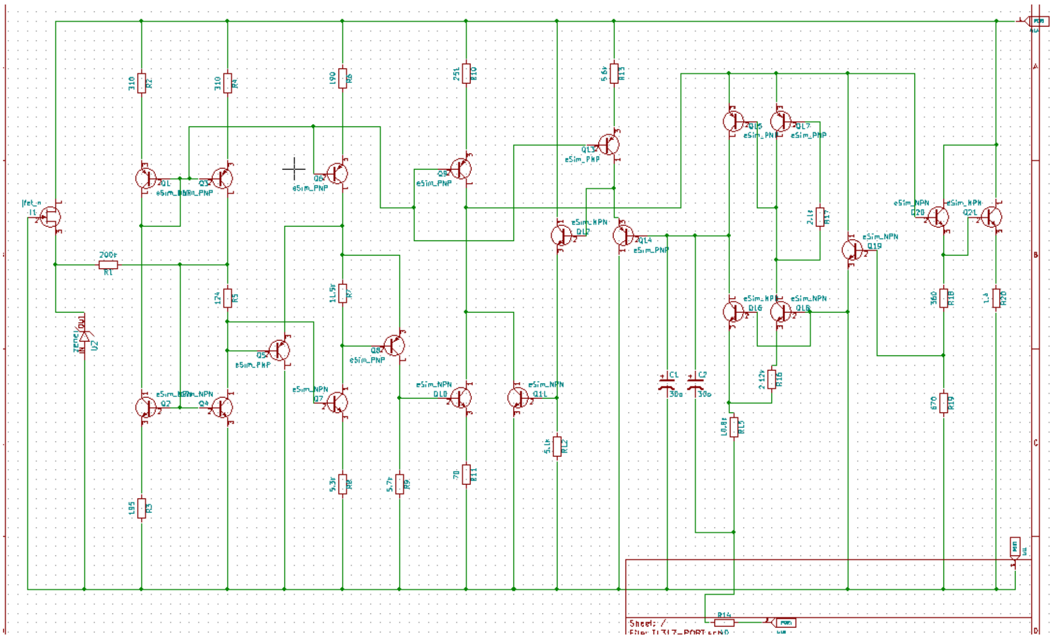

Figure 16.7: Subcircuit Schematic diagram of the TL317

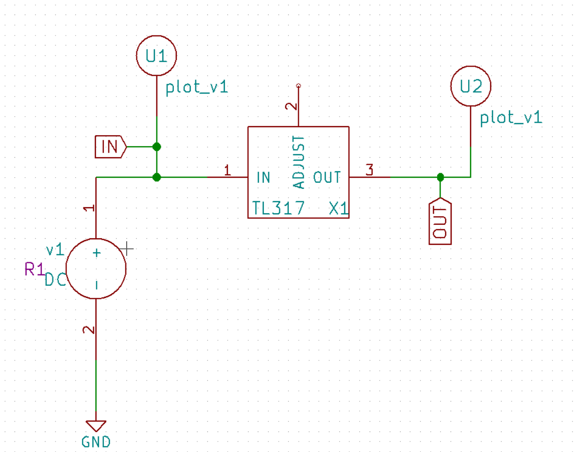

Figure 16.8: Test Circuit of the TL317

16.5.2 Issue Description

The TL317 Adjustable Positive Voltage Regulator circuit did not perform as expected. Instead of regulating the output voltage to the desired level, the circuit acted as a voltage follower, meaning the output voltage closely followed the input voltage without proper regulation.

16.6 Failed Circuit 5: OPT101

16.6.1 Circuit Diagram

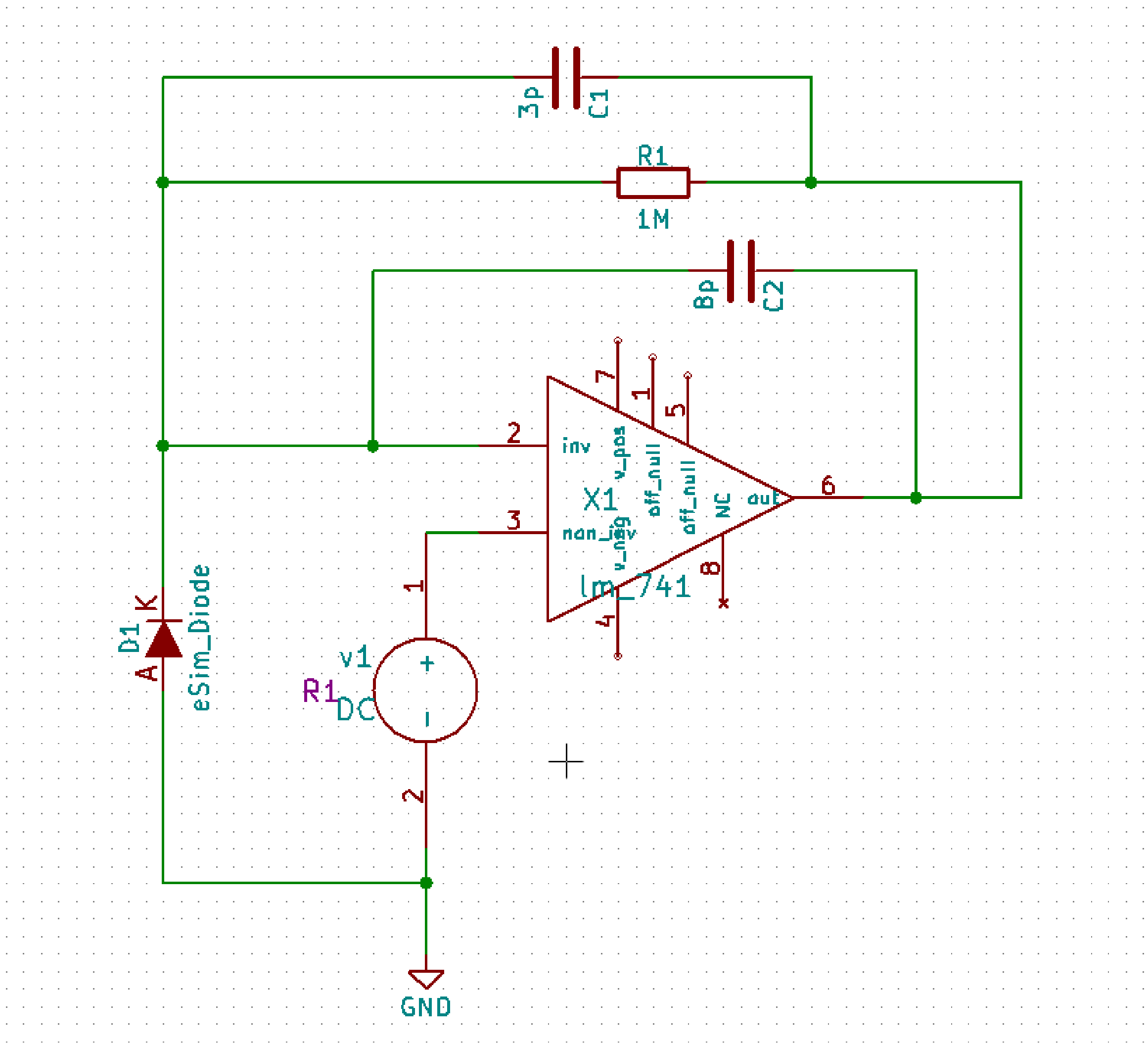

Figure 16.9: Subcircuit Schematic diagram of the OPT101

16.6.2 Issue Description

The OPT101 Monolithic Photodiode and Single-Supply Transimpedance Amplifier circuit did not produce the expected results. The primary issue was the unavailability of the photodiode component, which prevented the circuit from functioning as intended.

16.7 Failed Circuit 6: OPT301

16.7.1 Circuit Diagram

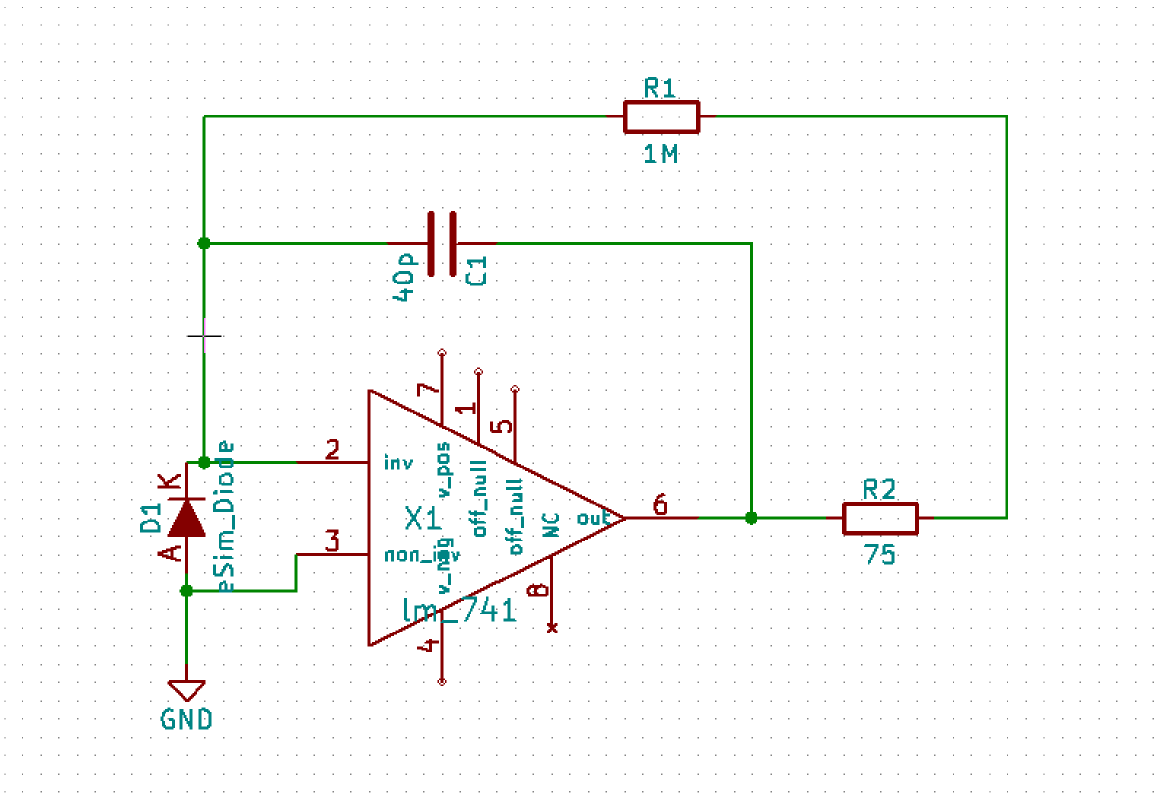

Figure 16.10: Subcircuit Schematic diagram of the OPT301

16.7.2 Issue Description

The OPT301 is an opto-electronic integrated circuit that integrates a photodiode and a transimpedance amplifier on a single dielectrically isolated chip. Due to the unavailability of the photodiode component, the OPT301 circuit did not produce the expected results. The absence of the photodiode, which is integral to the OPT301's design, resulted in the circuit not functioning as intended.

Chapter 17

Conclusion and Future Scope

The project achieved its objective of developing a wide range of subcircuits for both Analog and Digital 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, Precision Rectifiers, Schmitt Triggers, Differential Amplifiers, Instrumentation Amplifiers, Comparators, Multiplexers, De-Multiplexers, and various Logic Gate ICs.

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 18

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 both analog and digital ICs, covering a wide range of functionalities.

18.1 Sree Vishnu Varthini S

List of ICs:

1. **LM113/LM313** - Low Voltage Reference Diodes
2. **LM301** - General Purpose Operational Amplifier
3. **LM302** - High-Gain Operational Amplifier
4. **LM310** - Voltage Follower
5. **LM340_5V** - 5V Voltage Regulator
6. **LM340_12V** - 12V Voltage Regulator
7. **LM340_15V** - 15V Voltage Regulator
8. **LM7905** - -5V Voltage Regulator
9. **LM7912** - -12V Voltage Regulator
10. **LM7915** - -15V Voltage Regulator
11. **LM431** - Adjustable Shunt Regulator
12. **LM185** - Micropower Adjustable Band-Gap Voltage Reference Diodes
13. **CA3130** - BiMOS Operational Amplifier *(Failed Circuit)*
14. **LM3411** - Precision Secondary Regulator and Driver *(Failed Circuit)*
15. **REF102** - 10V Precision Voltage Reference *(Failed Circuit)*

16. **TL317** - 100-mA 3-Terminal Adjustable Positive Voltage Regulator *(Failed Circuit)*

17. **OPT101** - Monolithic Photodiode and Single-Supply Transimpedance Amplifier *(Failed Circuit)*

18. **OPT301** - Opto-Electronic Integrated Circuit *(Failed Circuit)*

These ICs represent a diverse collection of essential components, expanding the available resources for users of eSim in their electronic circuit designs.

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