Summer Fellowship Report

On

Integrated Circuit Design using Subcircuit feature of eSim

Submitted by

Abhinav Tipathi

Aman Singh

Karthik Ayyala

Vignesh S

Under the guidance of

Prof. Kannan M. Moudgalya
Chemical Engineering Department
IIT Bombay

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Acknowledgment

We would like to express our gratefulness and sincere gratitude to the FOSSEE team for providing us such a wonderful opportunity to work for the welfare of humankind by contributing in the development of this open source software eSim.

First and foremost, we would like to express our gratefulness to Prof. Kannan M. Moudgalya for his valuable and constructive guidance throughout this FOSSEE fellowship program.

We would like to extend our heartful thanks to the whole eSim team for guiding us and providing us all the reources needed to complete this fellowship work. Special thanks to Mrs. Usha Viswanathan and Mrs. Vineeta Parmar for their extremely valuable guidance throughout this whole journey. Furthermore we would like to acknowledge and express our gratitude to our mentors Mr. Sumanto Kar and Mr. Rahul Paknikar for their invaluable support, their warm cooperation and willingness to share their knowledge and experiences with us made our journey truly enriching. Moreover, we would never forget our fellow friends for helping us to make this fellowship journey interesting and knowledgeable. It was a great experience working with them under the guidance of above-mentioned people.

Lastly, we would like to thank all the individual who directly or indirectly helped us in completing our fellowship. We would like to carry forward the lessons learned in this fellowship journey to make meaningful contribution in the betterment of this world.

Contents

Chapter 1

Introduction

FOSSEE (Free/Libre and Open Source Software for Education) project promotes the use of FLOSS tools to improve the quality of education in our country. It aims to reduce dependency on proprietary software in educational institutions. It encourages the use of FLOSS tools through various activities to ensure commercial software is replaced by equivalent FLOSS tools. It also develops new FLOSS tools and upgrade existing tools to meet requirements in academia and research.[1]

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

eSim is a free/libre and open source EDA tool for circuit design, simulation, analysis and PCB design developed by FOSSEE, IIT Bombay. It is an integrated tool built using free/libre and open source software such as KiCad, Ngspice, NGHDL and GHDL. eSim is released under GPL.

eSim offers similar capabilities and ease of use as any equivalent proprietary software for schematic creation, simulation and PCB design, without having to pay a huge amount of money to procure licenses. Hence it can be an affordable alternative to educational institutions and SMEs. It can serve as an alternative to commercially available/licensed software tools like OrCAD, Xpedition and HSPICE.

Chapter 2

Problem Statement

To design, develop and test various Analog Integrated Circuit Models using the subcircuit feature in eSim. These subcircuits are to be built using the device models already present in the eSim library. After successful testing of these IC models and their integration into the eSim subcircuit library, these models would be useful in the future for circuit designing purposes.

2.1 Approach

As we have access to the datasheets of all the Integrated Circuits(ICs) present in the market, we use these datsheets to get the internal circuit schematics of the individual ICs. Then we use following methodology:

- **Subcircuit Schematics:** Draw the internal circuit schematics of the selected ICs in eSim using its subcircuit feature and the device models already present in the eSim devices library. The circuit is designed by strictly following the information given in the datasheet.
- **Component Designing:** After the subcircuit designing is completed, the component/pin diagram of the respective ICs is drawn according to the data given in the datasheet. Hence, a component is formed with its pin configurations the same as mentioned in the datasheet. This component is saved in the eSim subcircuit library.
- **Test Circuit Designing:** These are the circuits that are given in the datasheet as the application of the ICs. Once the component of the IC is drawn and ready to use, we draw their test circuits to test them.
- **Testing of the Subcircuit:** When the test circuits are completed, various test cases are formed depending on the datasheet information. These ICs are tested against these test cases. If the result comes out to be satisfactory, they are verified else the subcircuit schematic is checked again. Testing is done by using KiCad to Ngspice conversion and then taking out the plots using the simulation feature in eSim.

If the output of the test circuit is not as per expectation, this means that the test case has failed. In such case we go back to design phase of the IC or the test circuits, to look for possible errors; and then repeat the testing process again after making required changes.

If the expected output of the test cases are correct and satisfies the expected results, then in that case the IC is declared working and verified. The test case has passed successfully and the designing process is complete.

Chapter 3

Analog ICs

3.1 TL074 Low Noise J-FET Quad Op-Amp IC

The LM1596/LM1496 are doubled balanced modulator-demodulators which produce an output voltage proportional to the product of an input (signal) voltage and a switching (carrier) signal. Typical applications include suppressed carrier modulation, amplitude modulation, synchronous detection, FM or PM detection, broadband frequency doubling and chopping.

3.1.1 Pin Configuration

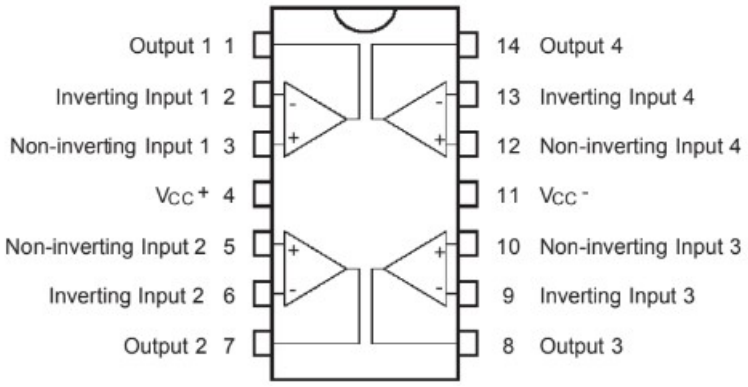


Figure 3.1: TL074 Pin Diagram

3.1.2 Single Op-amp Schematics Diagram

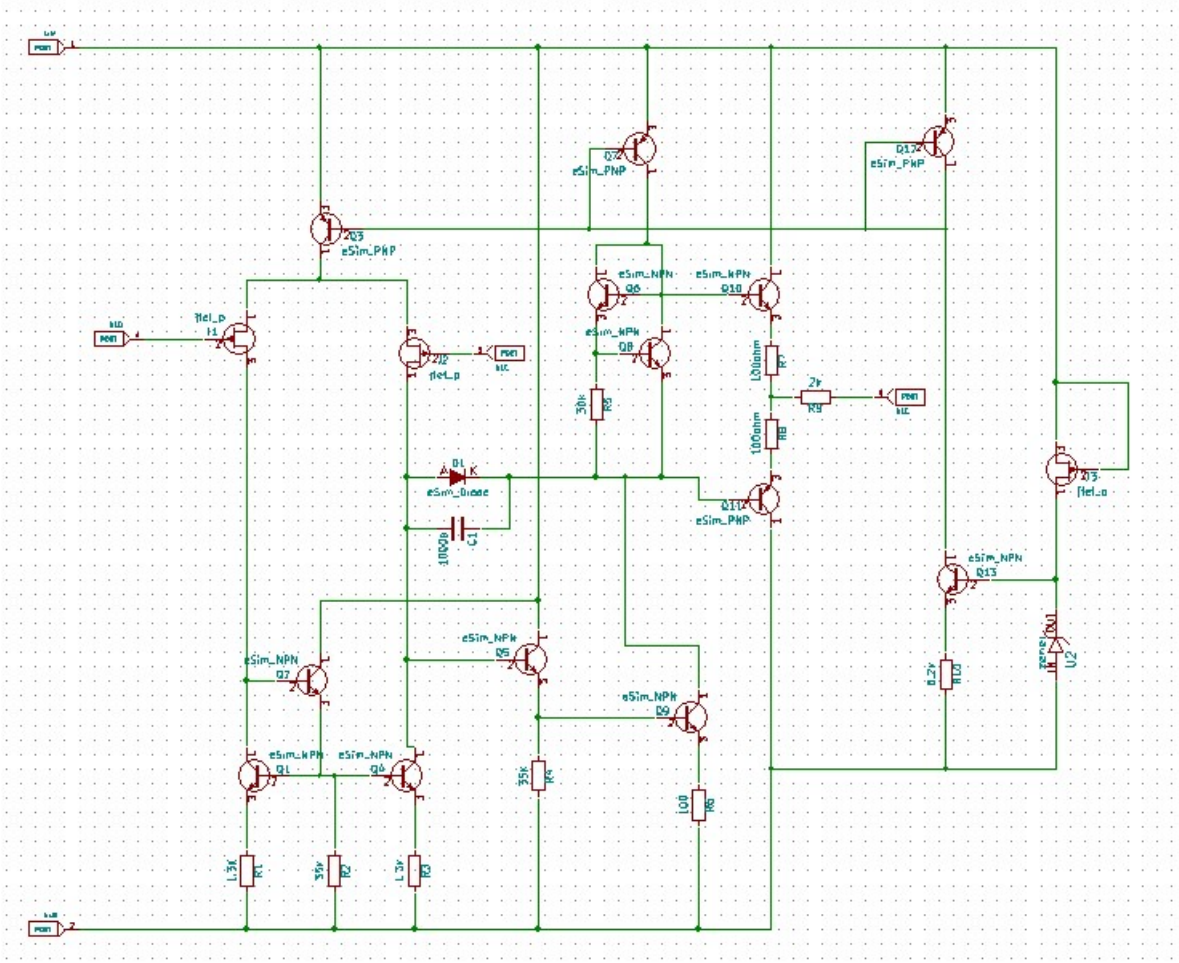


Figure 3.2: TL074 Schematics

3.1.3 Subcircuit test circuit

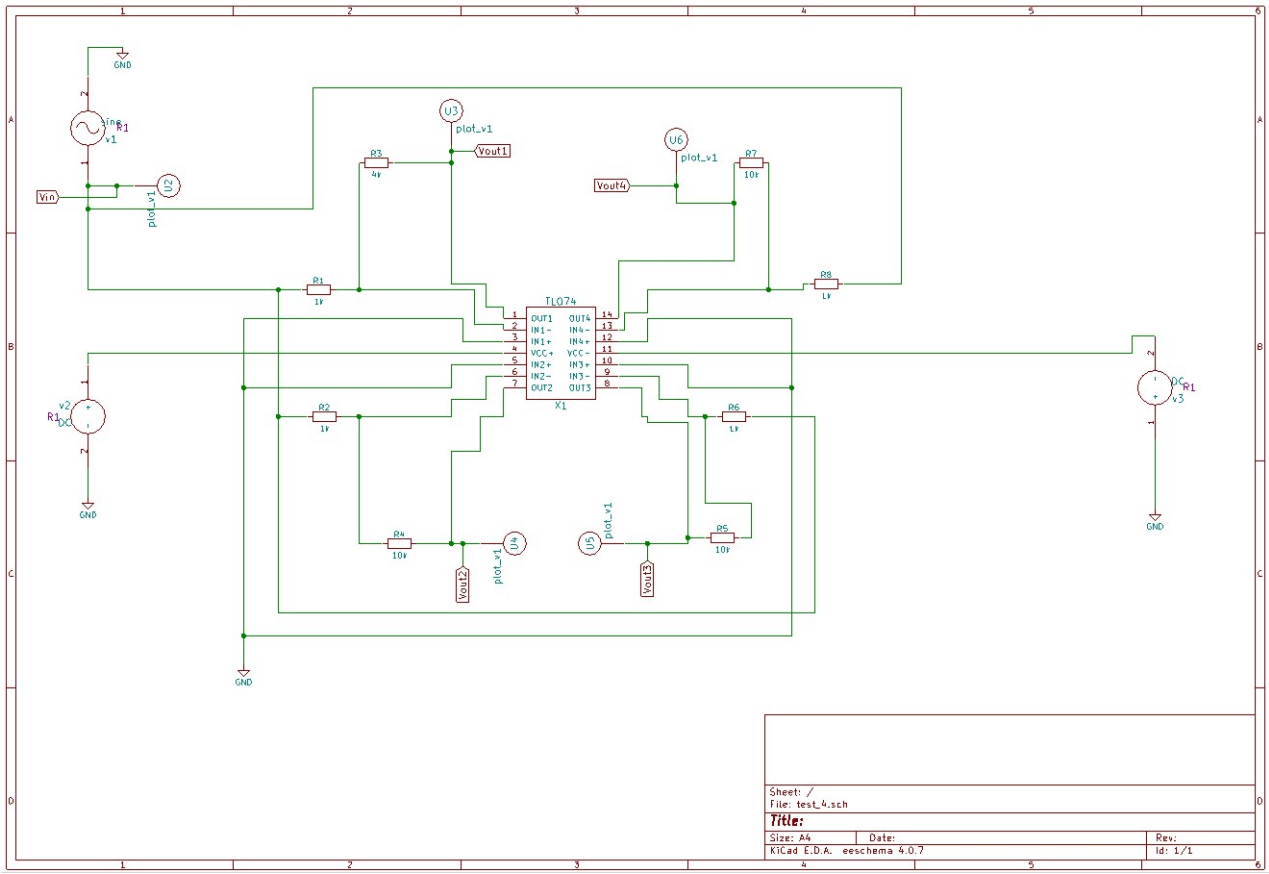


Figure 3.3: TL074 Schematics

3.1.4 Input Plot

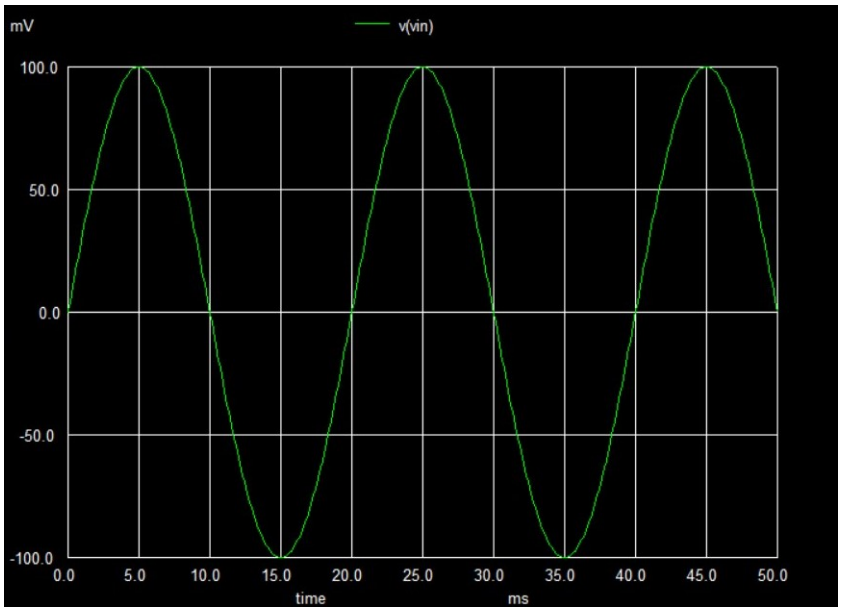


Figure 3.4: Input Signal

3.1.5 Output Plot

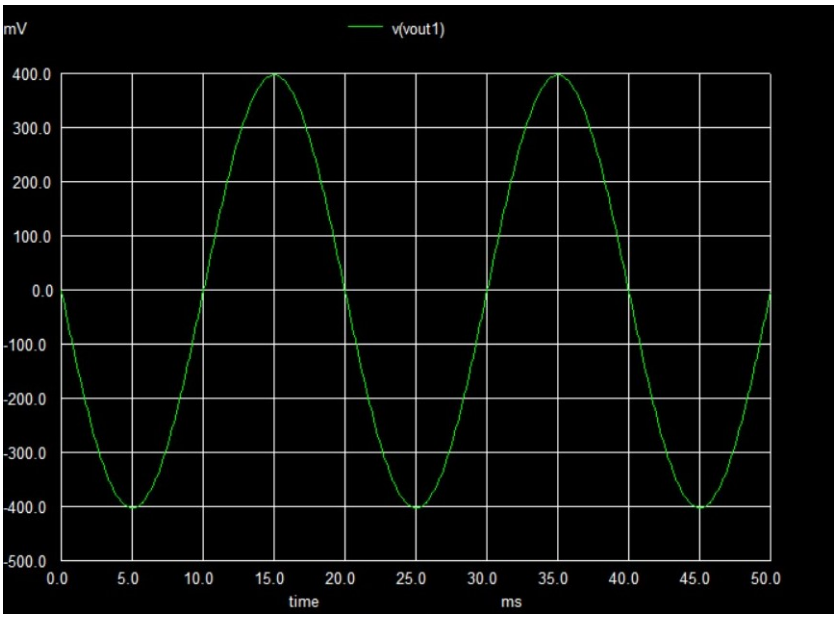


Figure 3.5: Gained Output Signal

3.2 TL081 J-FET Operation Amplifier IC

The TL081 is high-speed JFET input single operational amplifiers incorporating well matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit.The devices feature high slew rates, low inputbias and offset currents, and low offset voltage temperature coefficient.

3.2.1 Pin Configuration

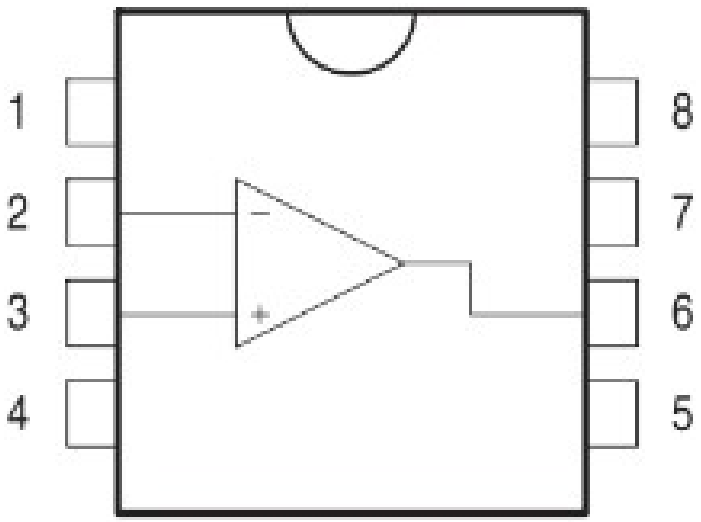


Figure 3.6: TL081 Pin Diagram

3.2.2 Op-amp Schematics Diagram

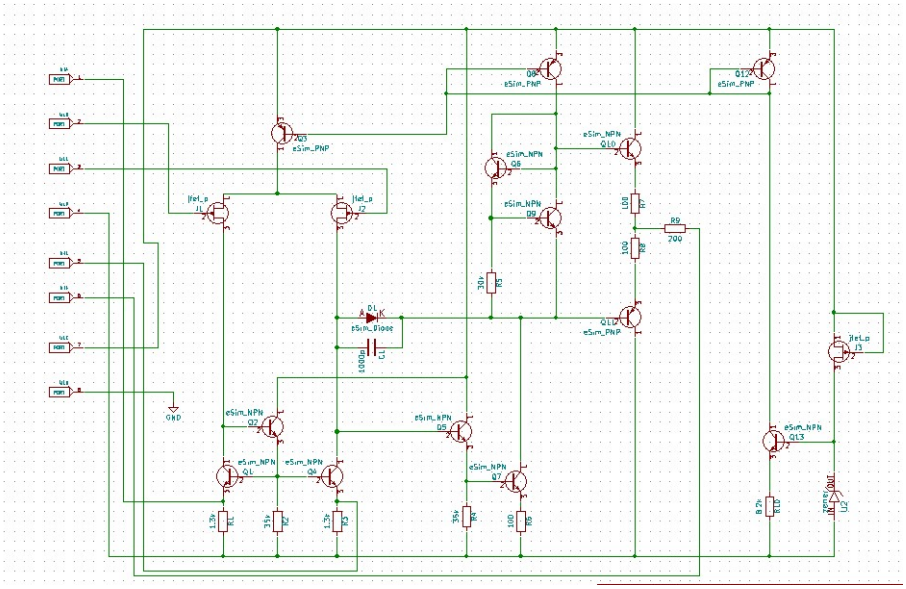


Figure 3.7: TL081 Schematics

3.2.3 Subcircuit test circuit

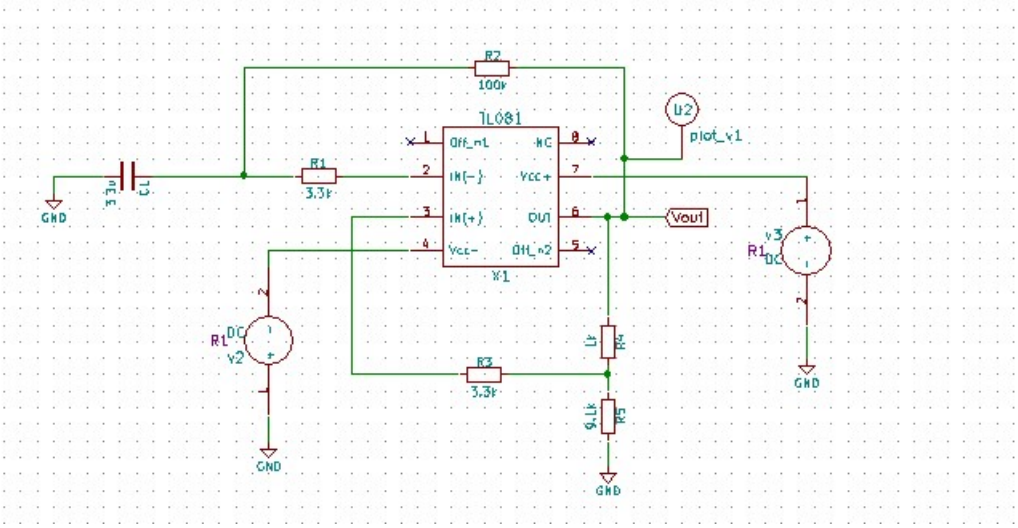


Figure 3.8: TL081 Test Circuit

3.2.4 Input Plot

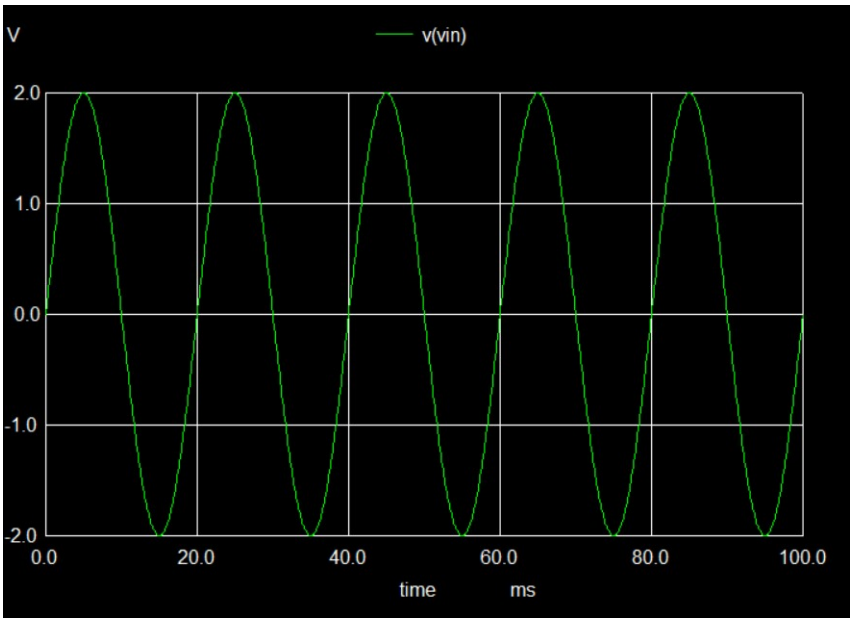


Figure 3.9: Input Sine Signal

3.2.5 Output Plot

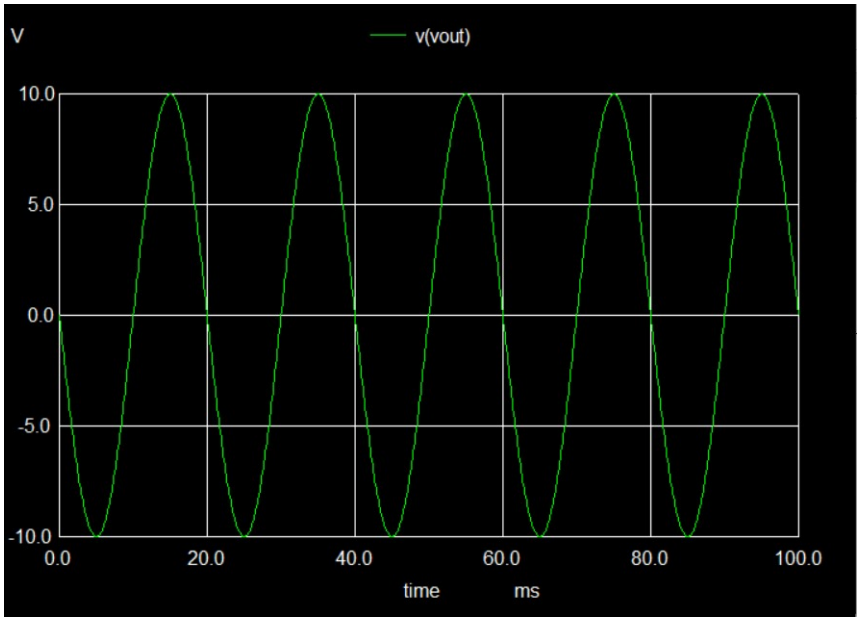


Figure 3.10: Gained Inverted Output Signal

3.3 LM120 Negative Voltage Regulator IC

The LM120 series are three-terminal negative regulators with a fixed output voltage of b5V, b12V, and b15V, and up to 1.5A load current capability. Where other voltages are required, the LM137 and LM137HV series provide an output voltage range of b1.2V to b47V. The LM120 need only one external component compensation capacitor at the output, making them easy to apply.

3.3.1 Pin Configuration

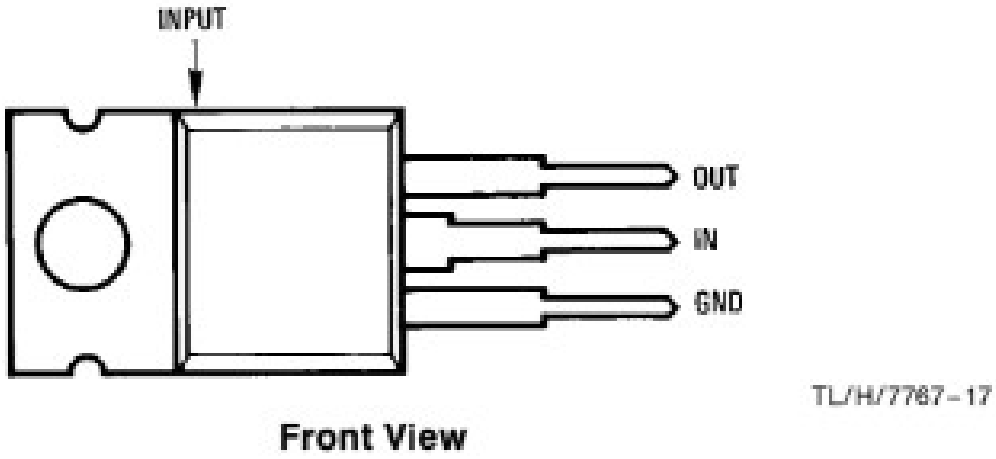


Figure 3.11: LM120 Pin Diagram

3.3.2 Subcircuit Schematics Diagram

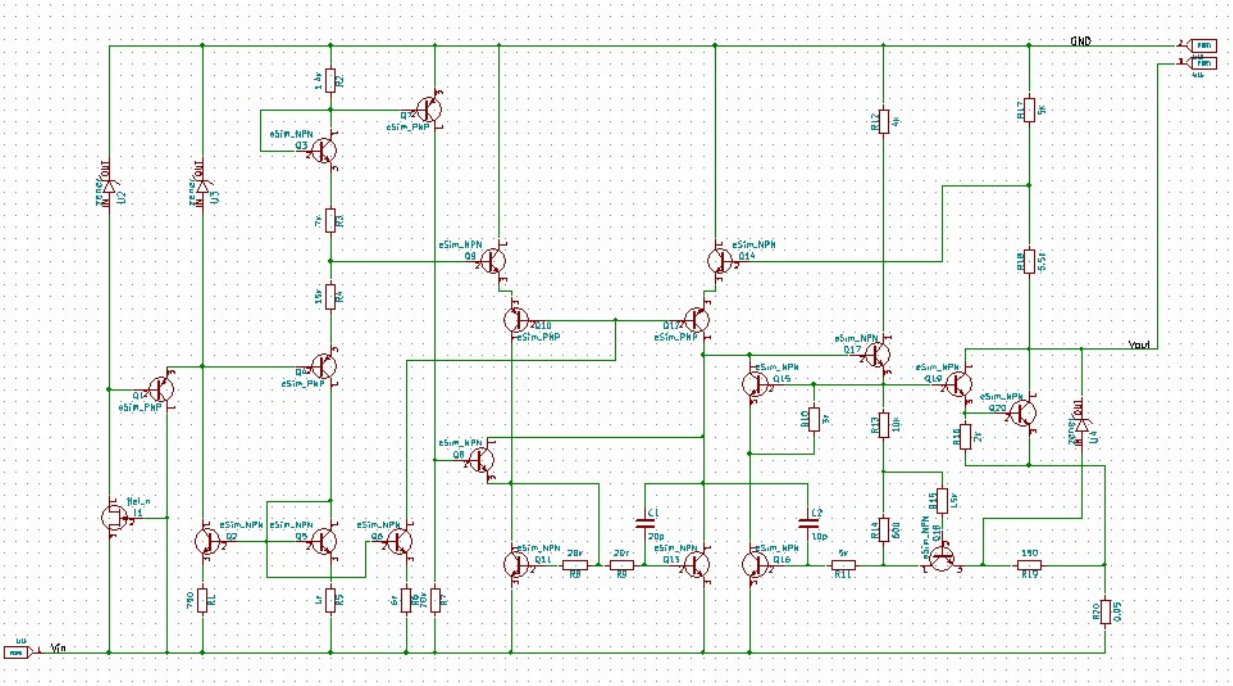


Figure 3.12: LM120 Schematics

3.3.3 Subcircuit test circuit

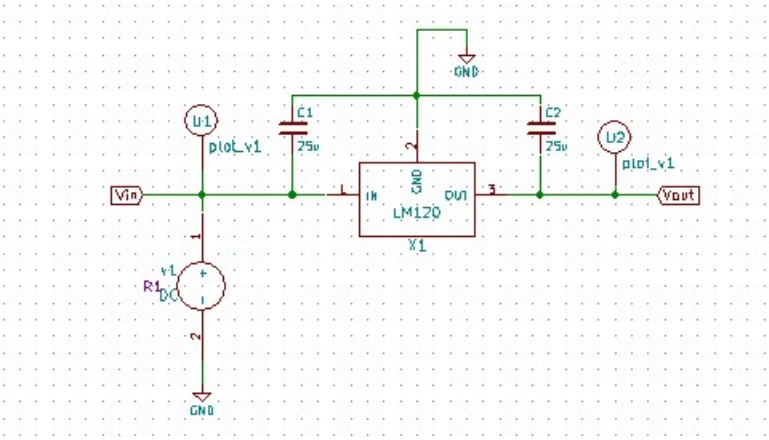


Figure 3.13: LM120 Test Circuit

3.3.4 Input Plot

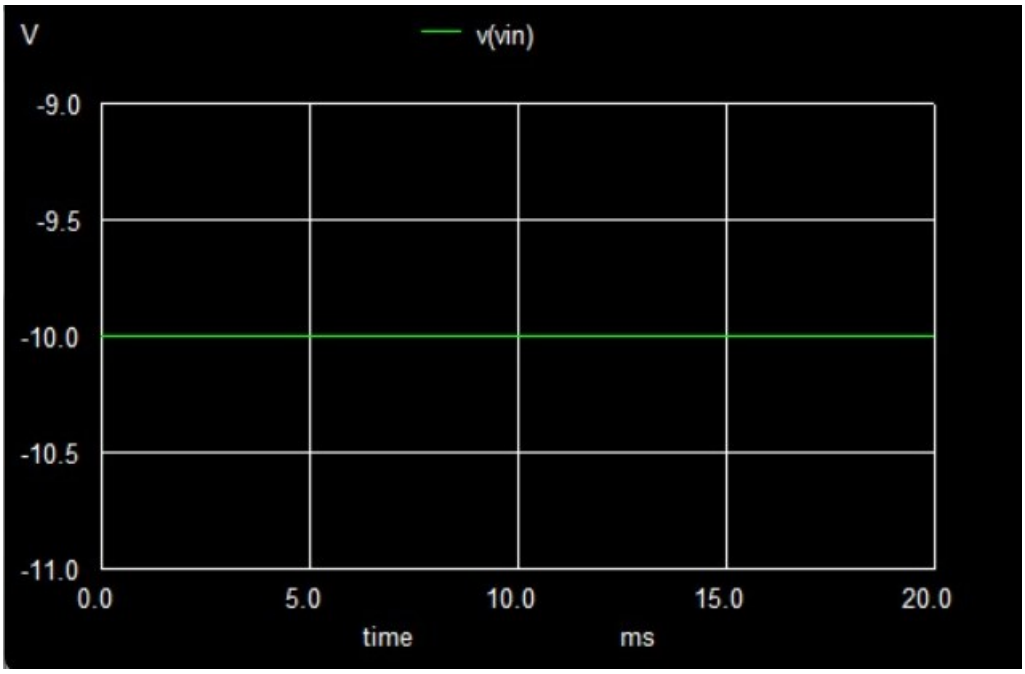


Figure 3.14: Input DC Signal

3.3.5 Output Plot

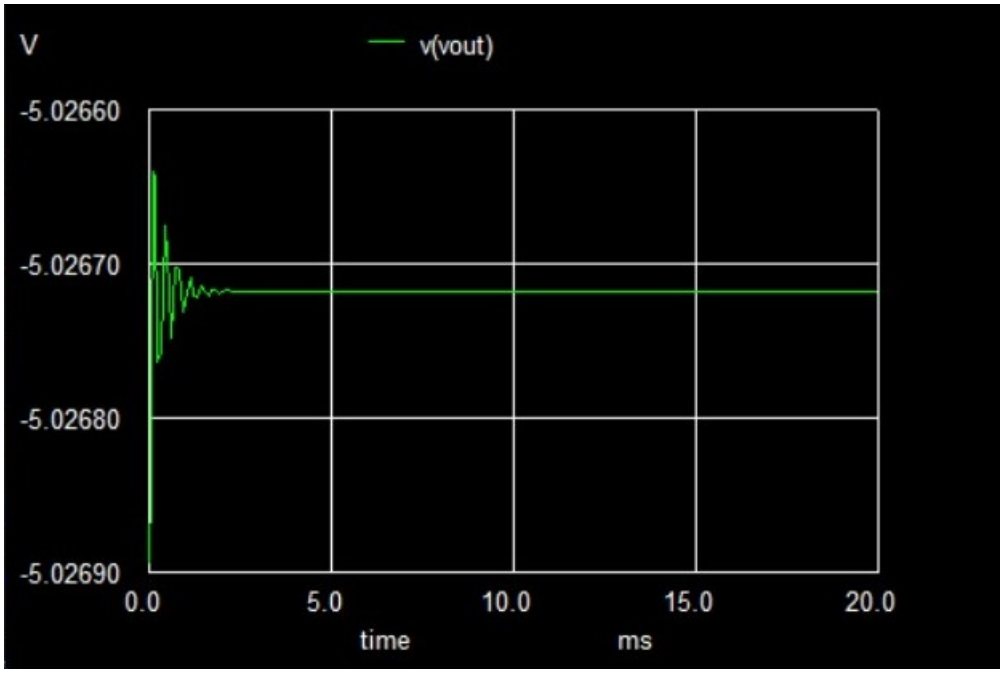


Figure 3.15: Output Constant DC Signal

3.4 LM709 Operational Amplifier IC

The LM709 series is a monolithic operational amplifier intended for general-purpose applications. Operation is completely specified over the range of voltages commonly used for these devices. External components are used to frequency compensate the amplifier. Although the unity-gain compensation network specified will make the amplifier unconditionally stable in all feedback configurations, compensation can be tailored to optimize high-frequency performance for any gain setting.

3.4.1 Pin Configuration

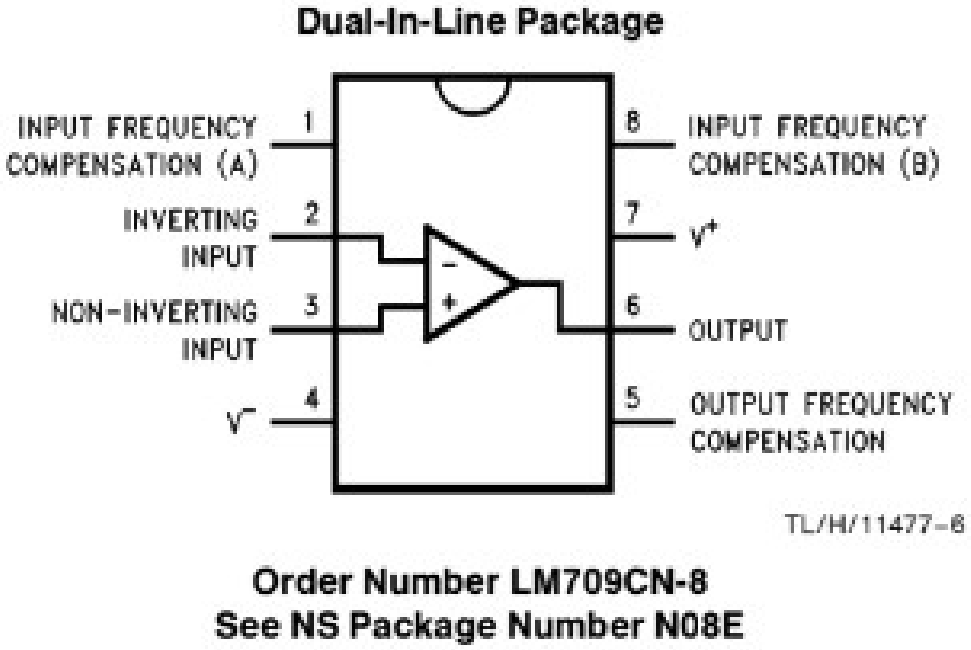


Figure 3.16: LM709 Pin Diagram

3.4.2 Subcircuit Schematics Diagram

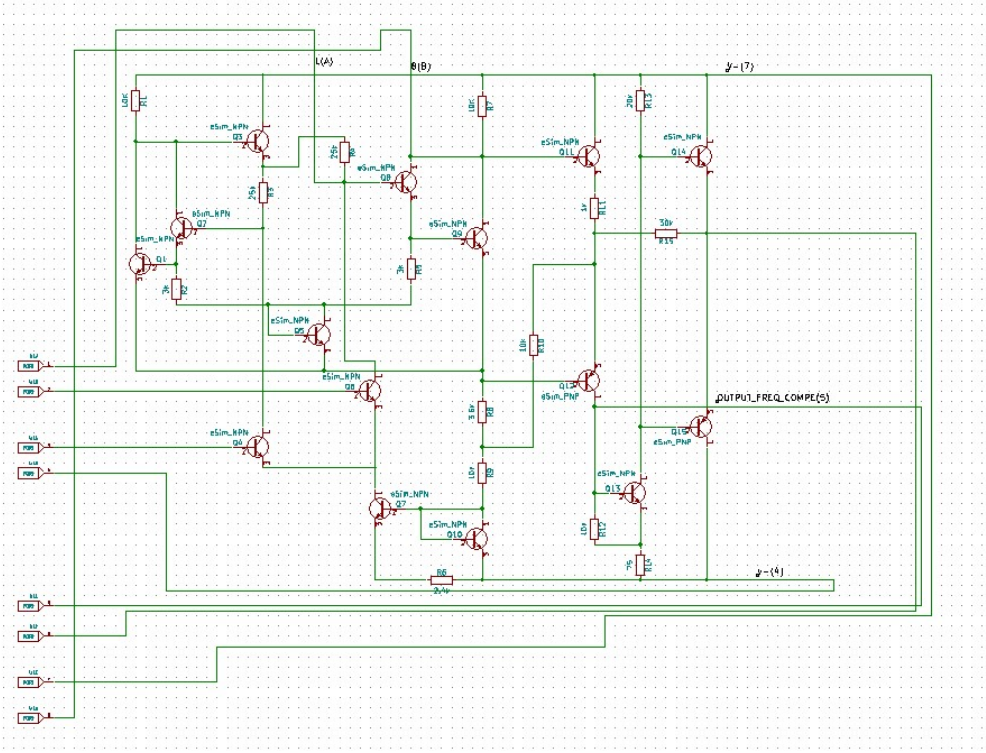


Figure 3.17: LM709 Schematics

3.4.3 Subcircuit test circuit

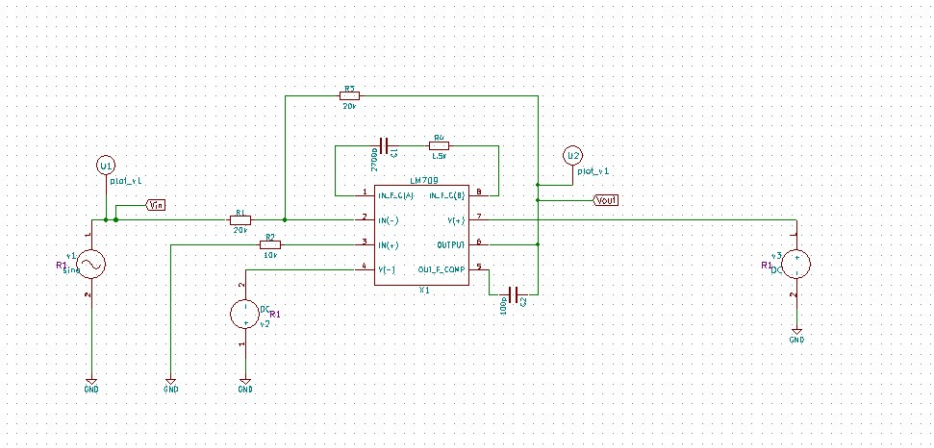


Figure 3.18: LM709 Test Circuit

3.4.4 Input Plot

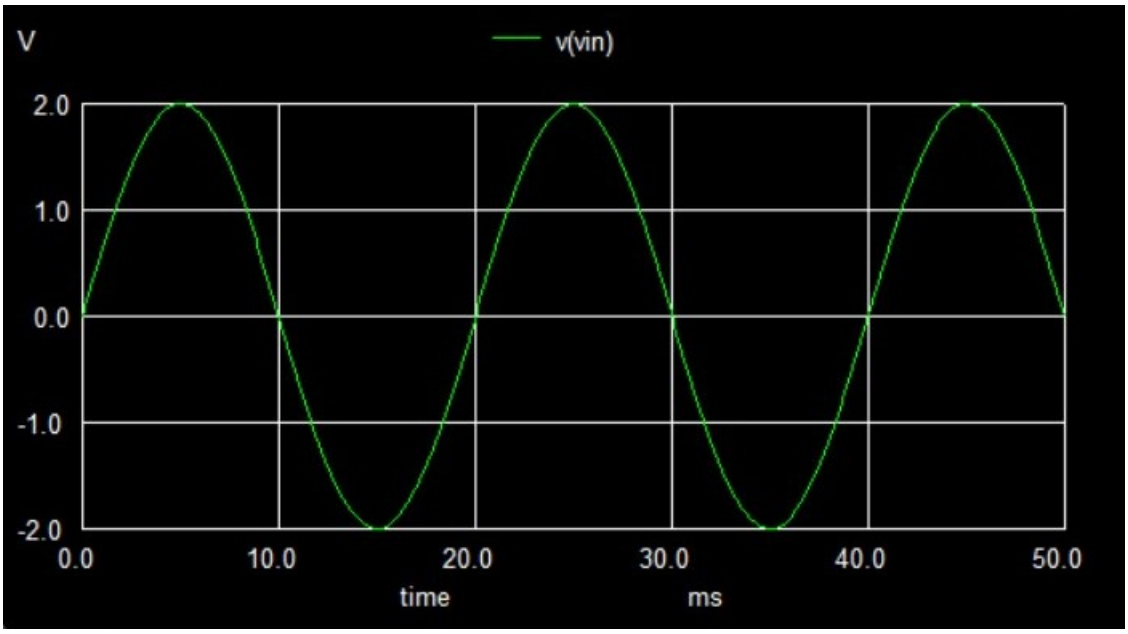


Figure 3.19: Input Sine Signal

3.4.5 Output Plot

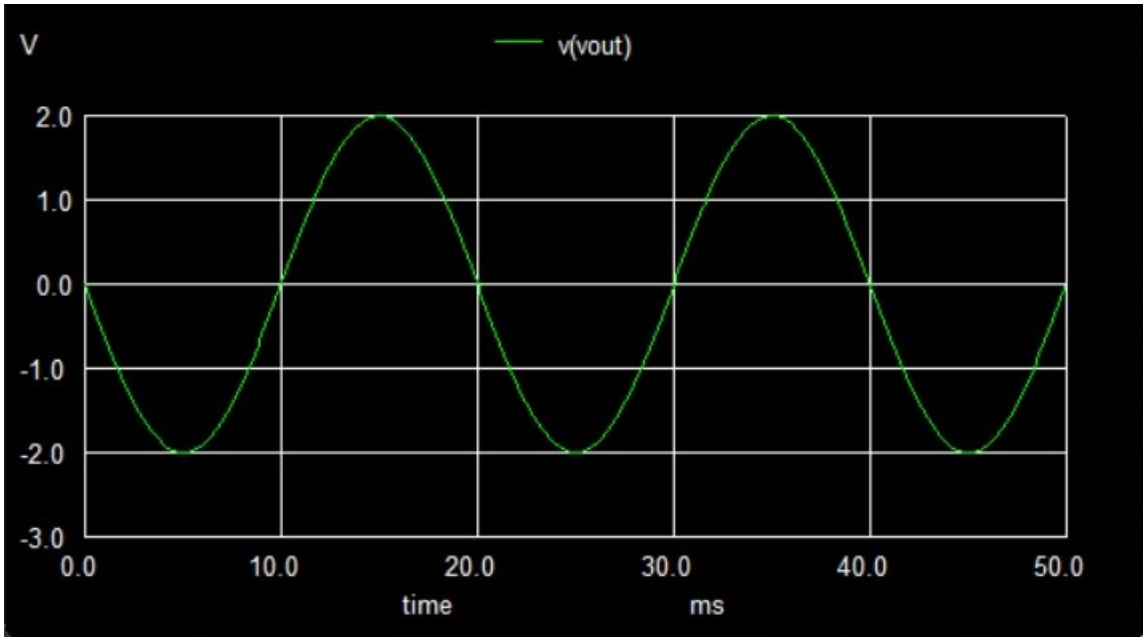


Figure 3.20: Output Unity Gain Inverted Signal

3.5 LM710 Voltage Comparator IC

The LM710 series are high-speed voltage comparators intended for use as an accurate, low-level digital level sensor or as a replacement for operational amplifiers in comparator applications where speed is of prime importance. The circuit has a differential input and a single ended output, with saturated output levels compatible with practically all types of integrated logic.

3.5.1 Pin Configuration

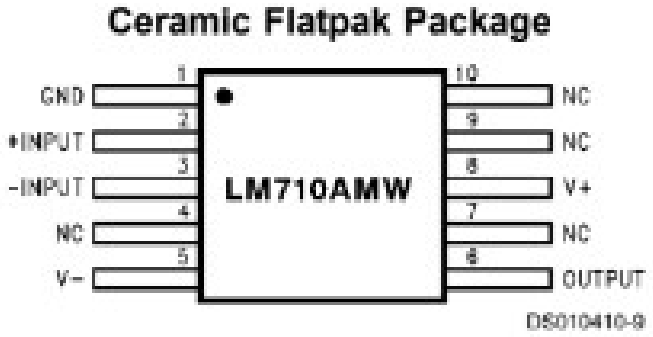


Figure 3.21: LM710 Pin Diagram

3.5.2 Subcircuit Schematics Diagram

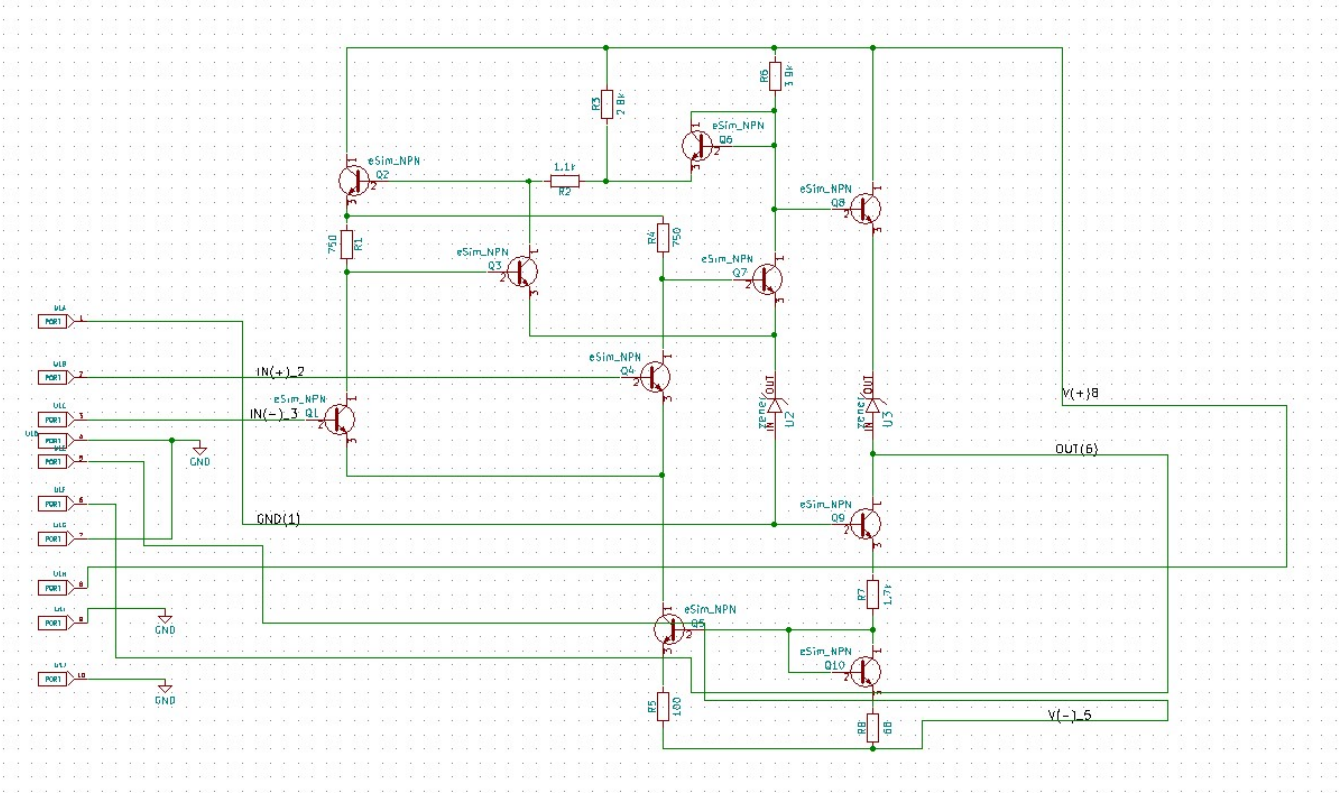


Figure 3.22: LM710 Schematics

3.5.3 Subcircuit test circuit

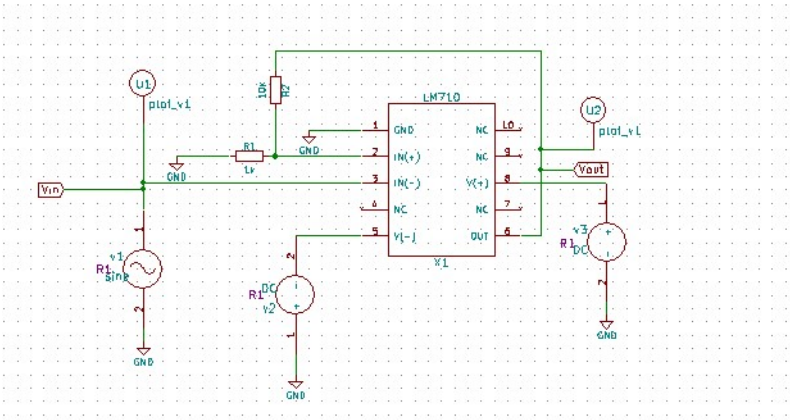


Figure 3.23: LM710 Schmitt Trigger Test Circuit

3.5.4 Input Plot

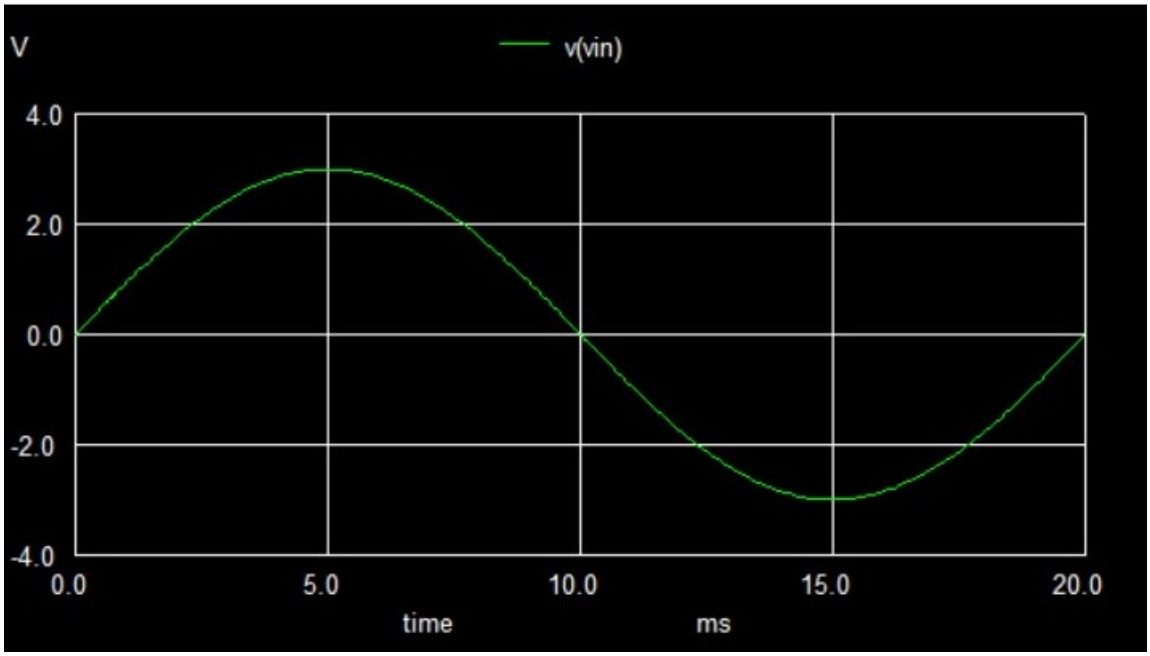


Figure 3.24: Input Sine Signal

3.5.5 Output Plot

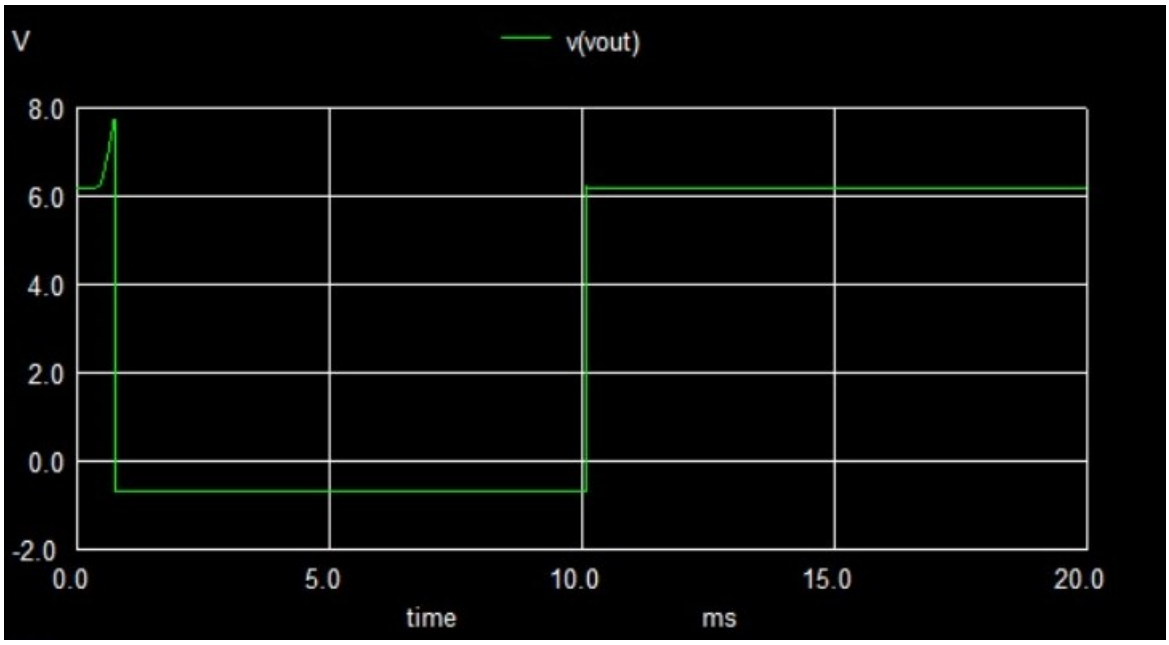


Figure 3.25: Output Signal(Schmitt Trigger)

3.6 LM725 Operational Amplifier IC

The LM725/LM725A/LM725C are operational amplifiers featuring superior performance in applications where low noise, low drift, and accurate closed-loop gain are required. With high common mode rejection and offset null capability, it is especially suited for low level instrumentation applications over a wide supply voltage range.

3.6.1 Pin Configuration

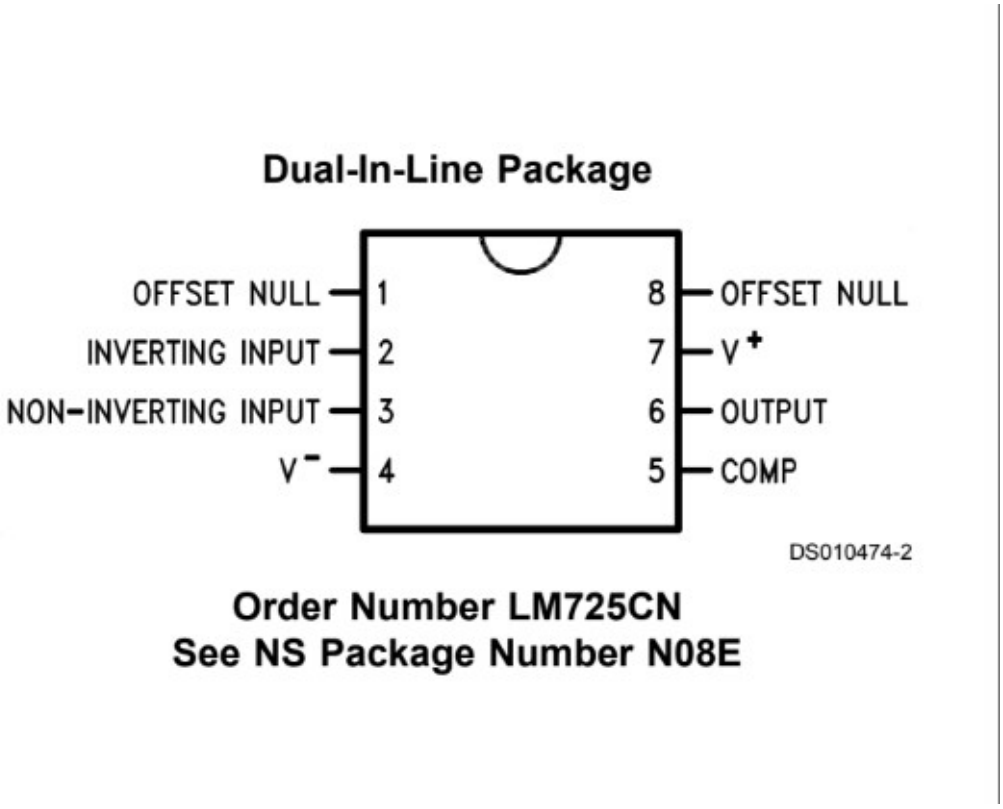


Figure 3.26: LM725 Pin Diagram

3.6.2 Subcircuit Schematics Diagram

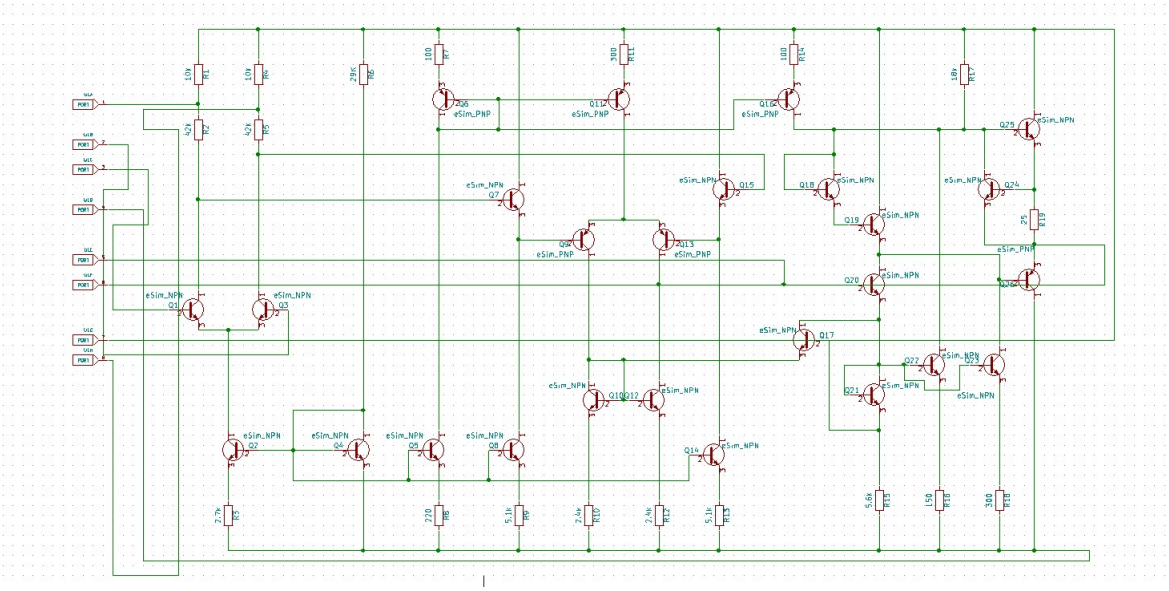


Figure 3.27: LM725 Schematics

3.6.3 Subcircuit test circuit

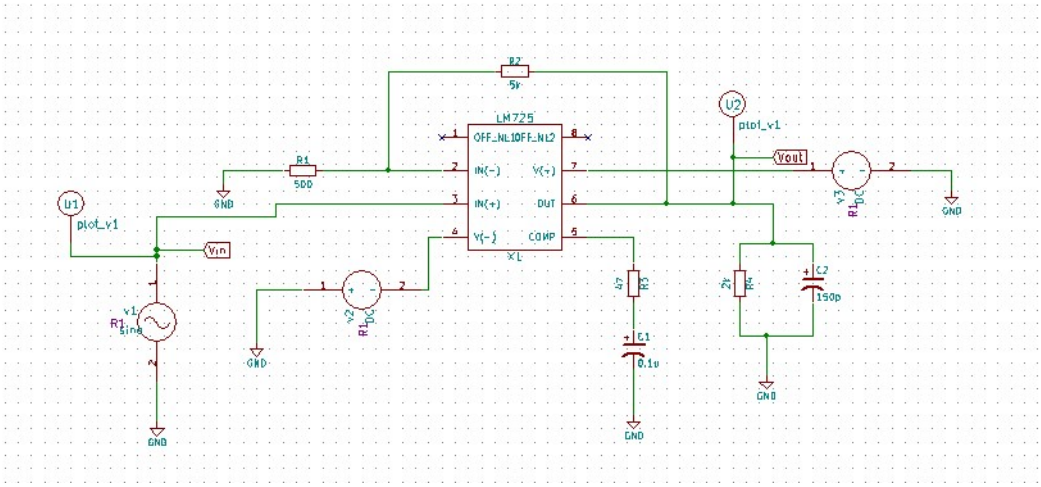


Figure 3.28: LM725 Test Circuit(Non-Inverting Amplifier)

3.6.4 Input Plot

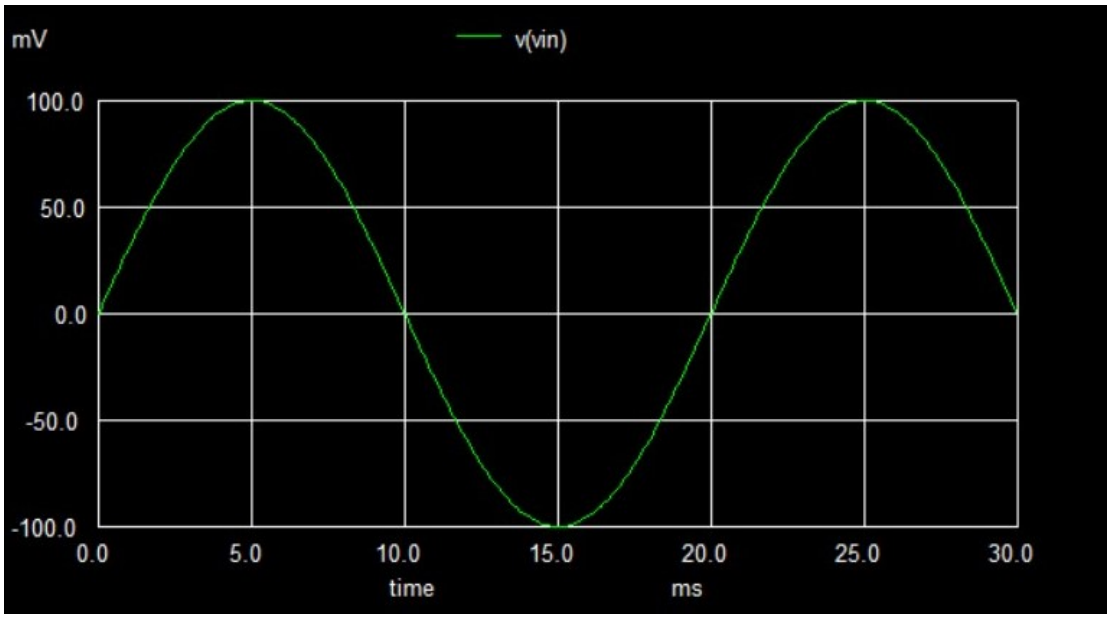


Figure 3.29: Input Sine Signal

3.6.5 Output Plot

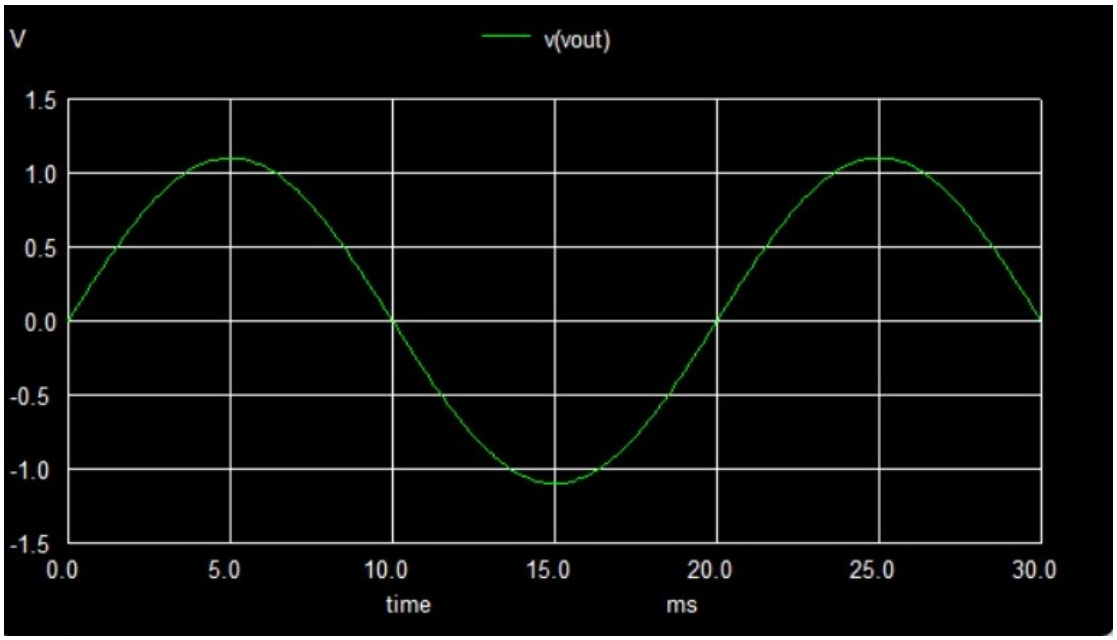


Figure 3.30: Output Signal

3.7 LM145 Negative Regulator IC

The LM145 is a three-terminal negative regulator with a fixed output voltage of 5V and up to 3A load current capability. This device needs only one external component compensation capacitor at the output, making it easy to apply. Worst case guarantees on output voltage deviation due to any combination of line, load or temperature variation assure satisfactory system operation.

3.7.1 Pin Configuration

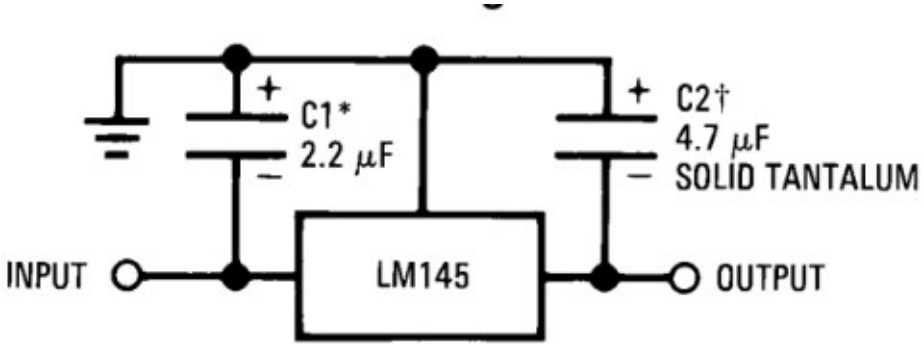


Figure 3.31: LM145 Pin Diagram

3.7.2 Subcircuit Schematics Diagram

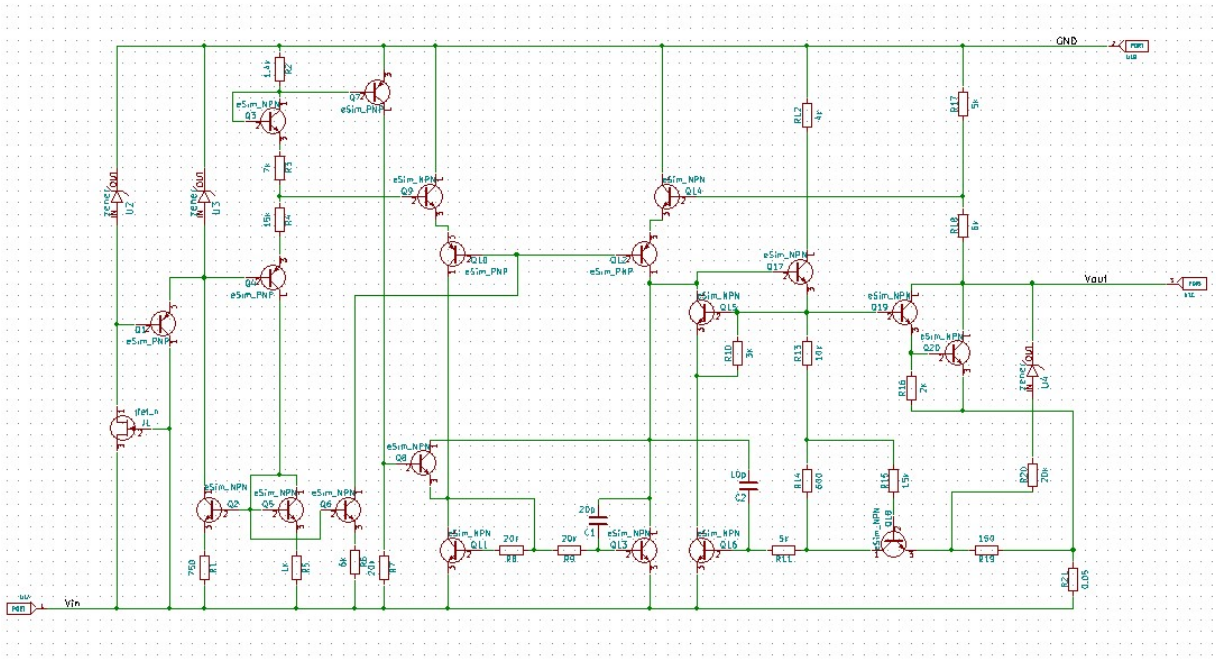


Figure 3.32: LM145 Schematics

3.7.3 Subcircuit test circuit

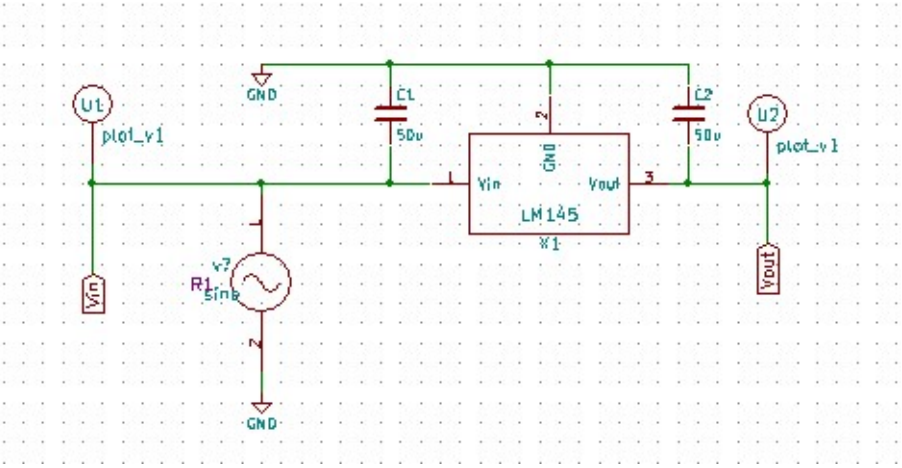


Figure 3.33: LM145 Test Circuit

3.7.4 Input and Output Plot Combined

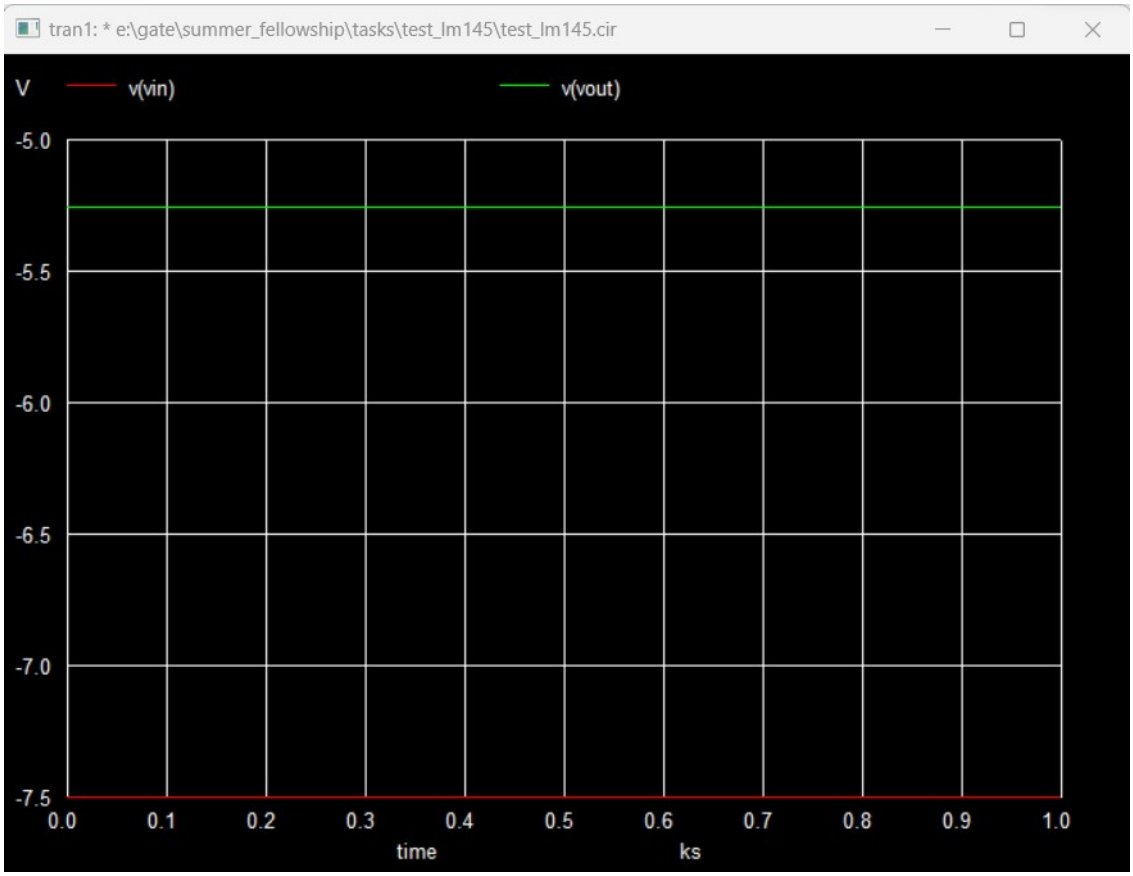


Figure 3.34: Input and Output DC Signals

3.8 NJM 1496 Balanced Modulator-Demodulator IC

The NJM1496 is a double balanced modulator-demodulator which produces an output voltage proportional to the product of an input(signal) voltage and a switching(carrier) signal. Typical applications include suppressed carrier modulation, amplitude modulation, synchronous detection, FM or PM detection, broadband frequency doubling and chopping.

3.8.1 Pin Configuration

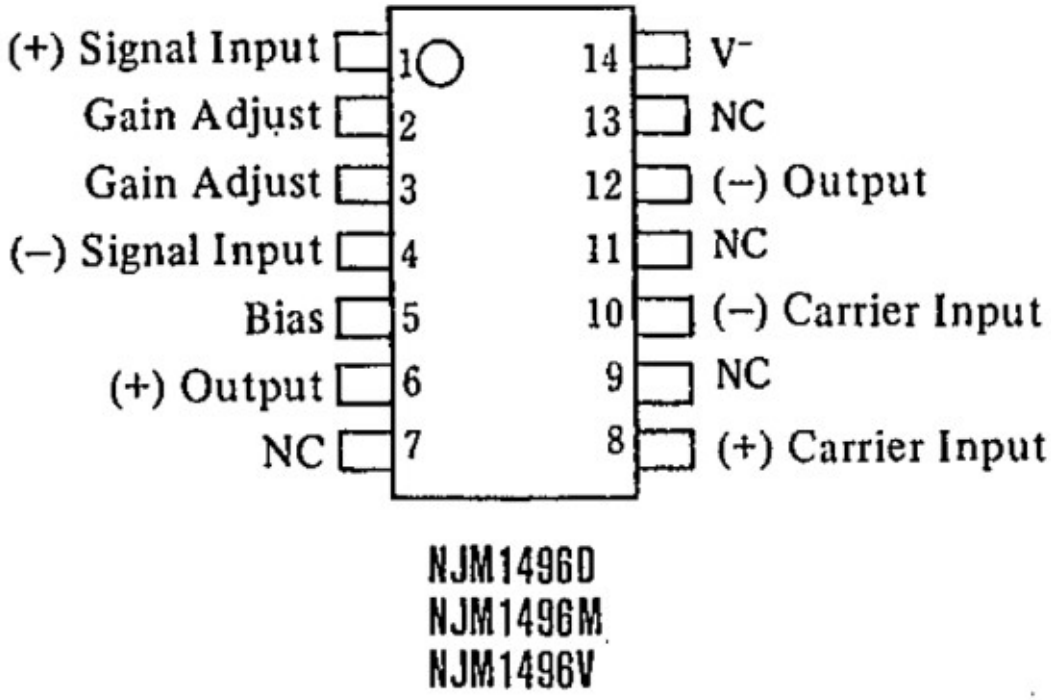


Figure 3.35: NJM1496 Pin Diagram

3.8.2 Subcircuit Schematics Diagram

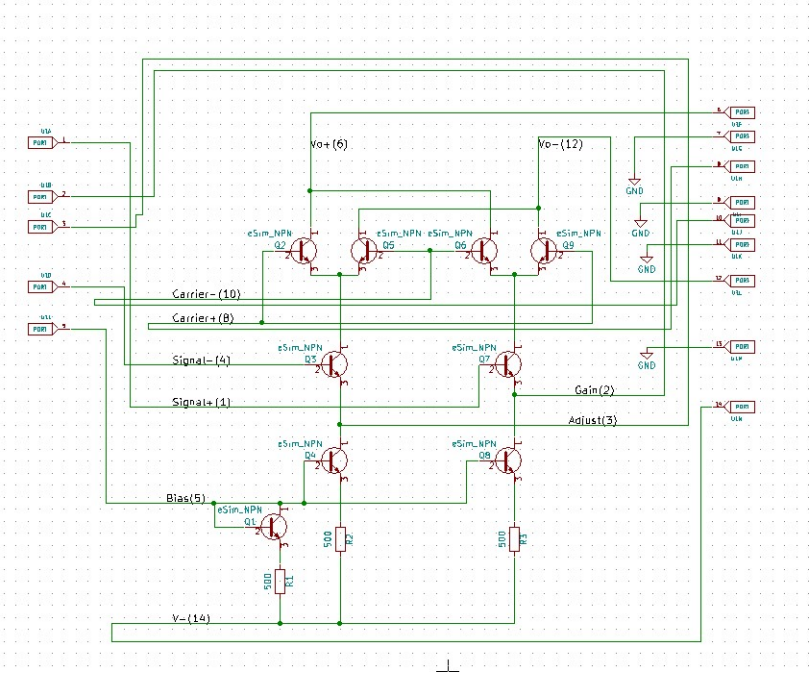


Figure 3.36: NJM1496 Schematics

3.8.3 Subcircuit test circuit

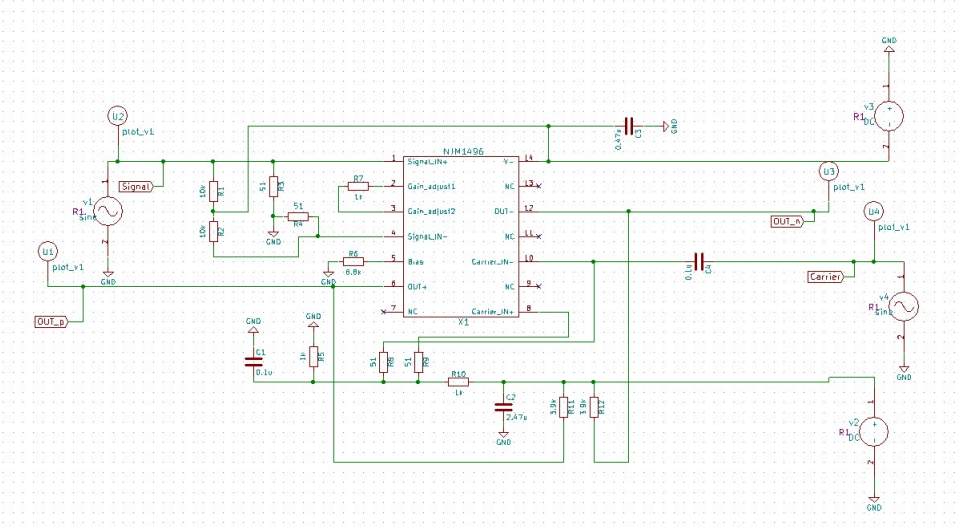


Figure 3.37: NJM1496 Test Circuit (Suppressed Carrier Modulation)

3.8.4 Input and Output Plots

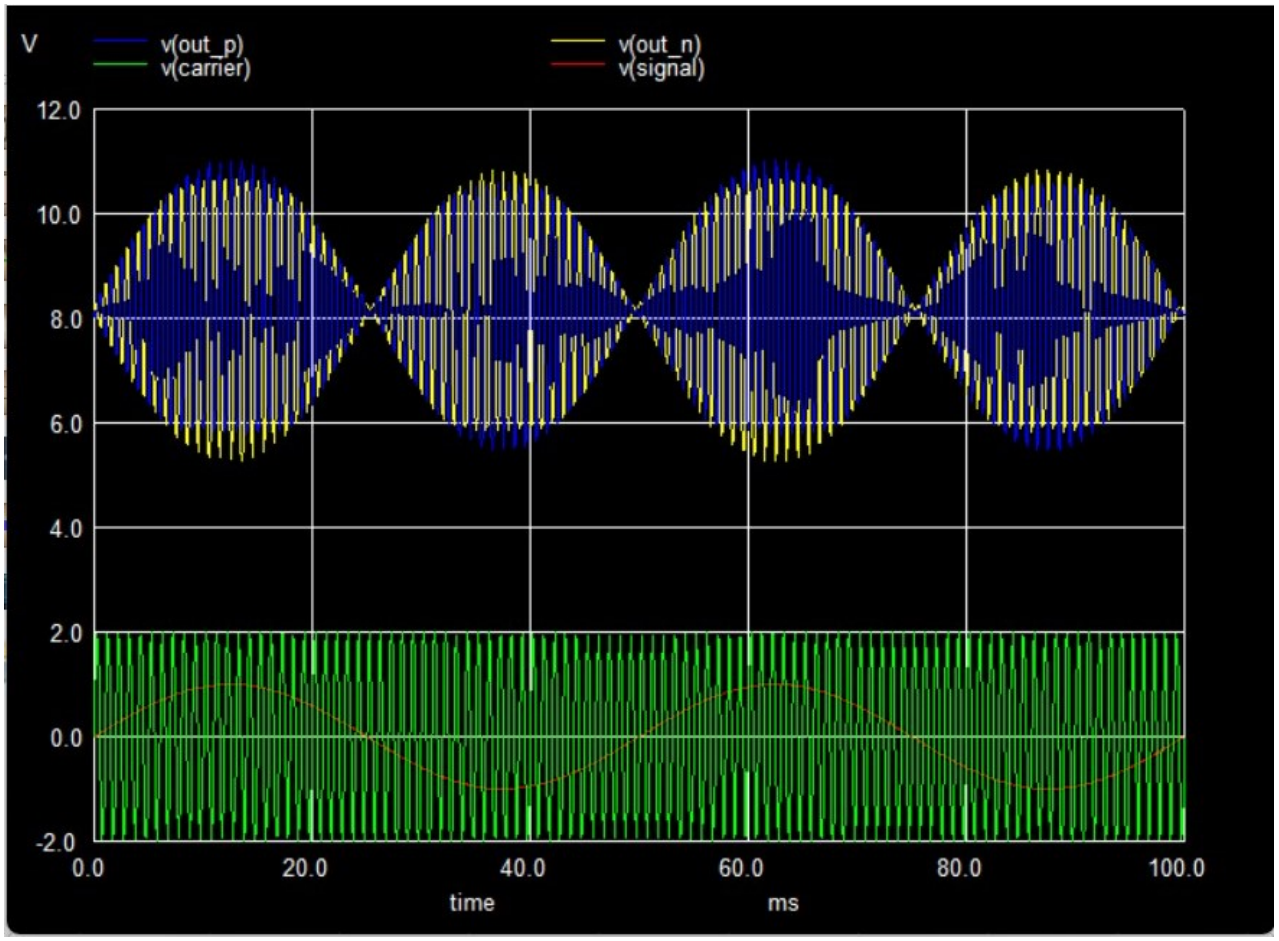


Figure 3.38: Input and Output Signals Combined

3.9 RC4558 Operational Amplifier IC

The RC4558 integrated circuit is a dual high-gain operational amplifier internally compensated and constructed on a single silicon IC using an advanced epitaxial process. It is especially well suited for applications in differential-in, differential-out as well as in potentiometric amplifiers and where gain and phase matched channels are mandatory.

3.9.1 Pin Configuration

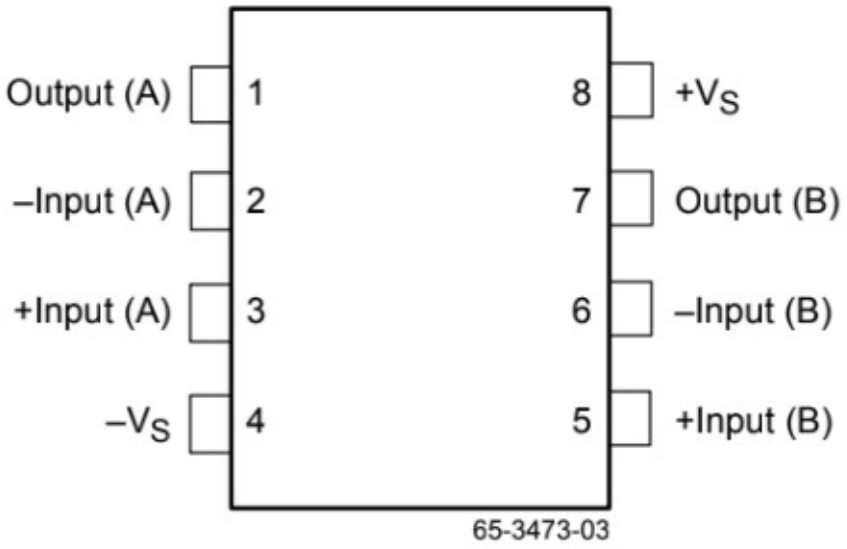


Figure 3.39: RC4558 Pin Diagram

3.9.2 Subcircuit Schematics Diagram

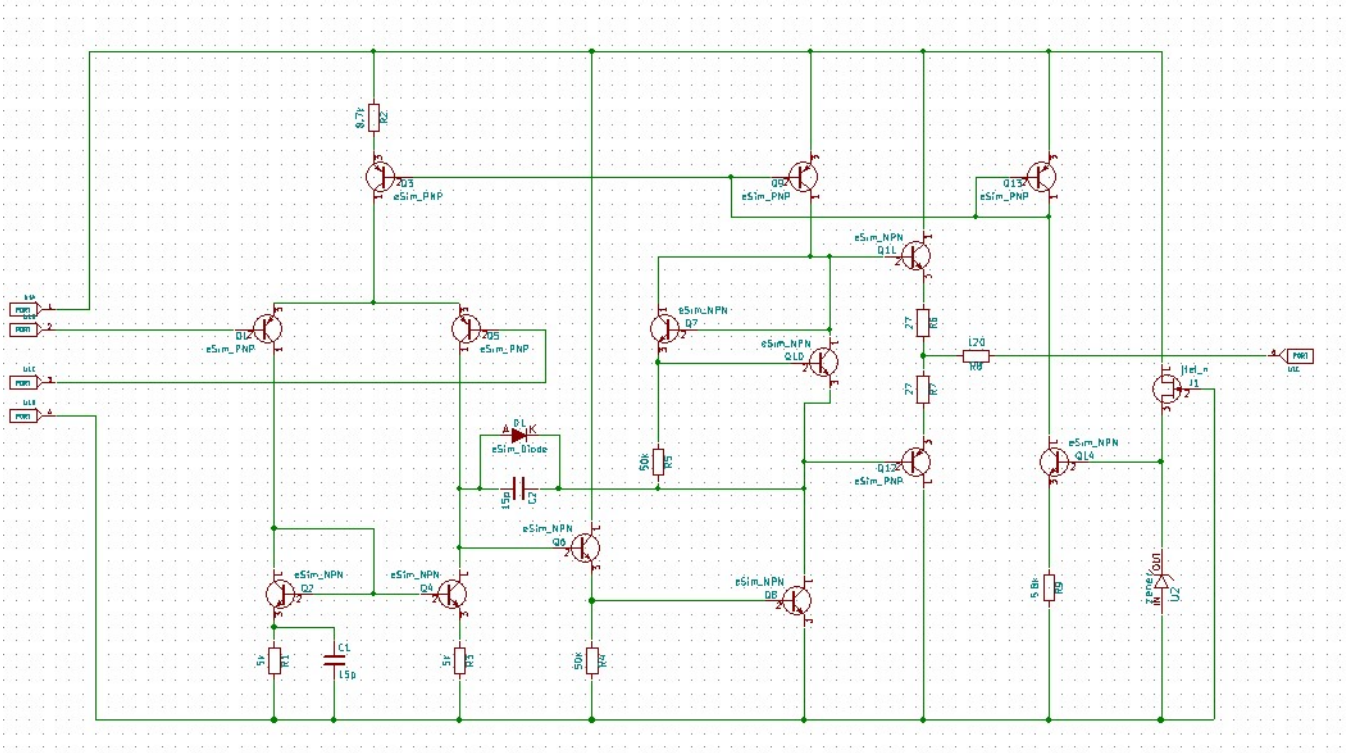


Figure 3.40: RC4558 Schematics

3.9.3 Subcircuit test circuit

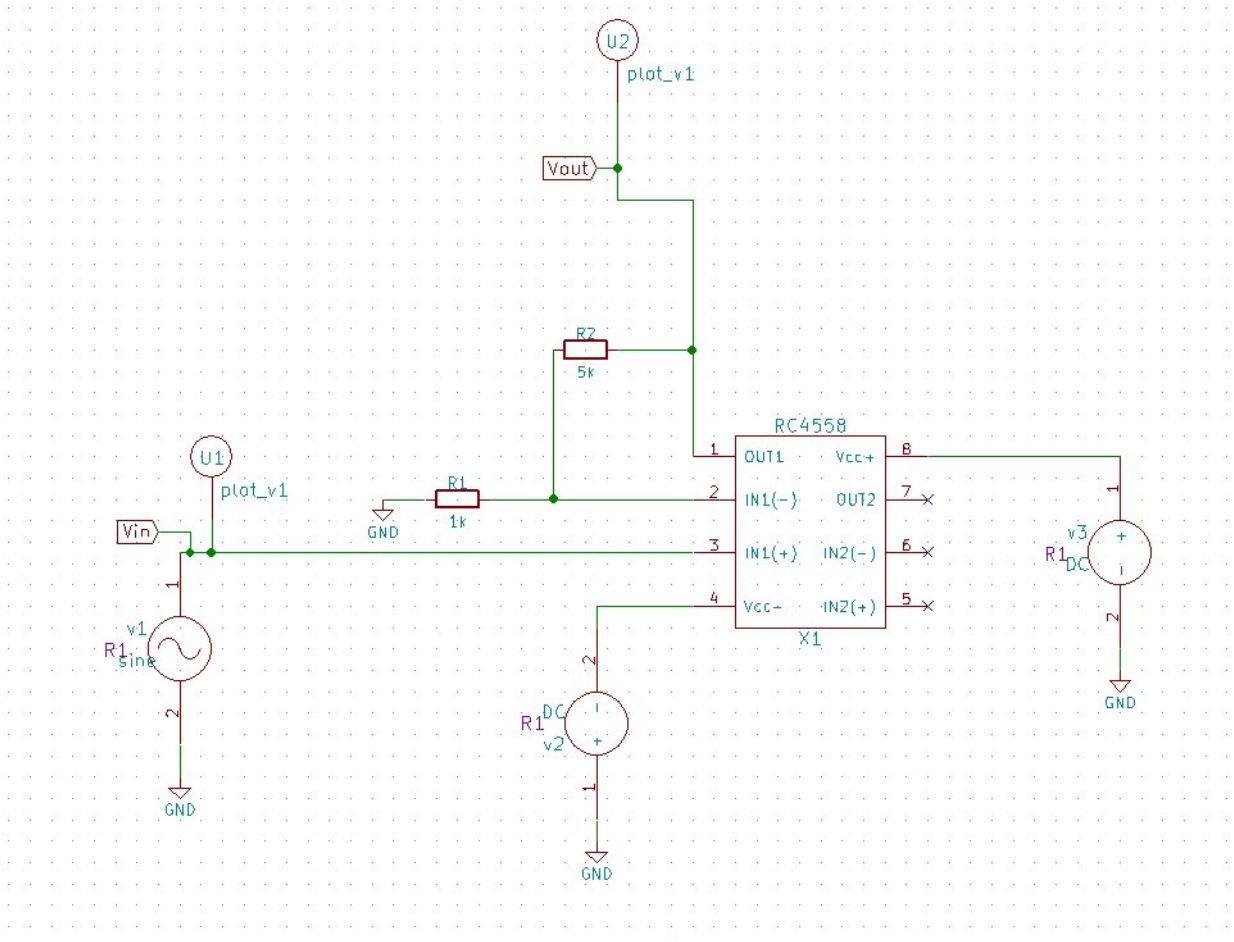


Figure 3.41: RC4558 Test Circuit(Non-Inverting Amplifier)

3.9.4 Input Plot

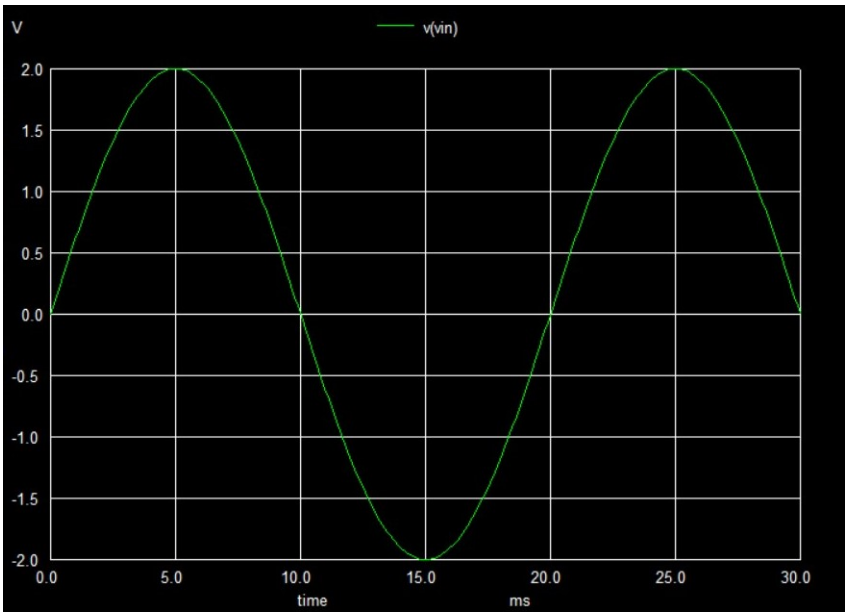


Figure 3.42: Input Sine Signal

3.9.5 Output Plot

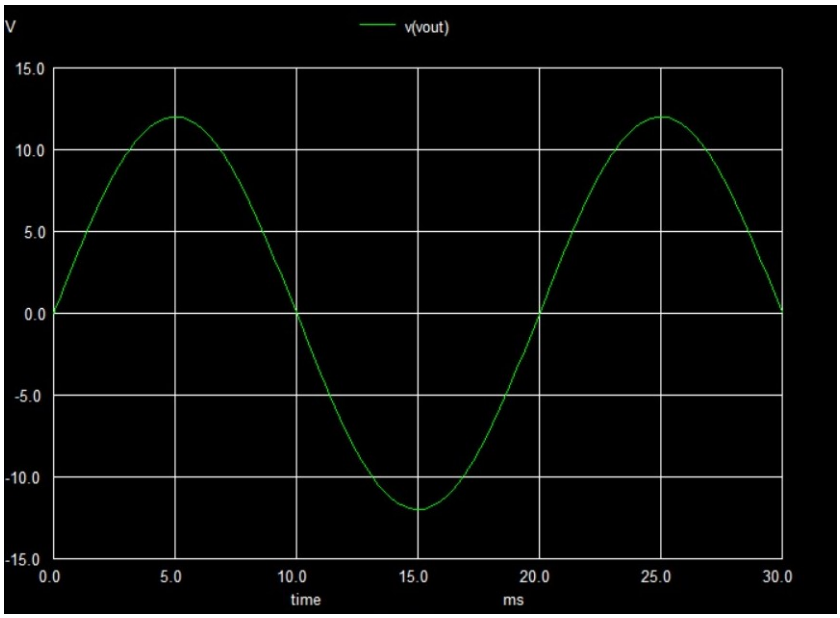
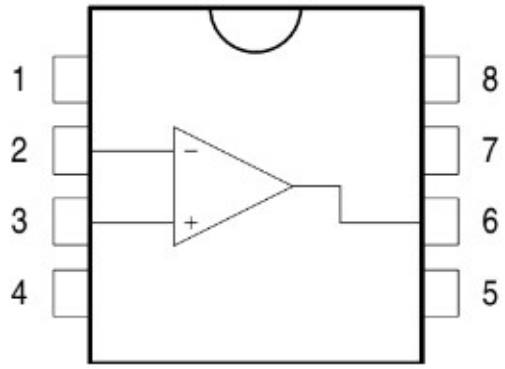


Figure 3.43: Output Amplified Signal

3.10 TL071 Low Noise J-FET Operational Amplifier IC

The TL071 is a high-speed JFET input single operational amplifier. This JFET input operational amplifier incorporates well matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit. The device features high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient.

3.10.1 Pin Configuration



1 - Offset null 1
2 - Inverting input
3 - Non-inverting input
4 - V_{CC}^-
5 - Offset null 2
6 - Output
7 - V_{CC}^+
8 - N.C.

Figure 3.44: TL071 Pin Diagram

3.10.2 Subcircuit Schematics Diagram

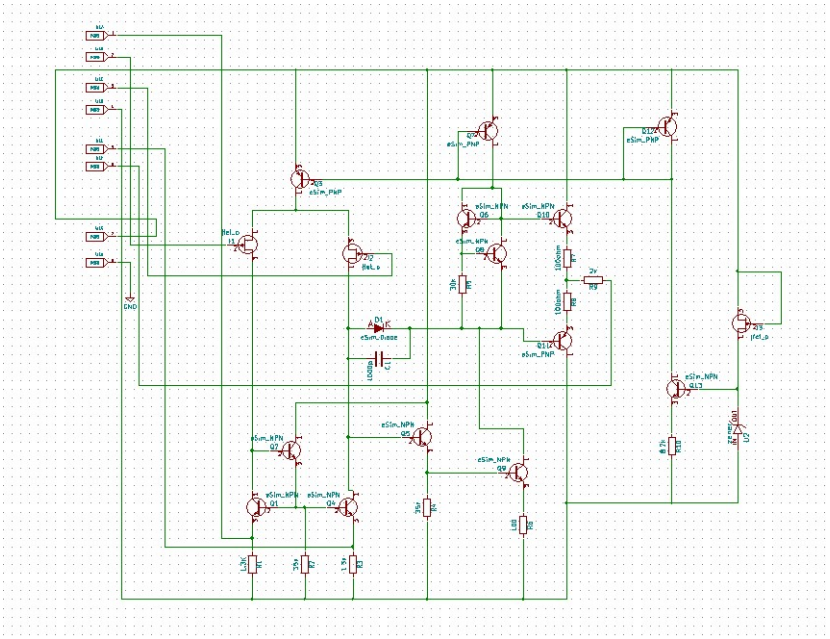


Figure 3.45: TL071 Schematics

3.10.3 Subcircuit test circuit

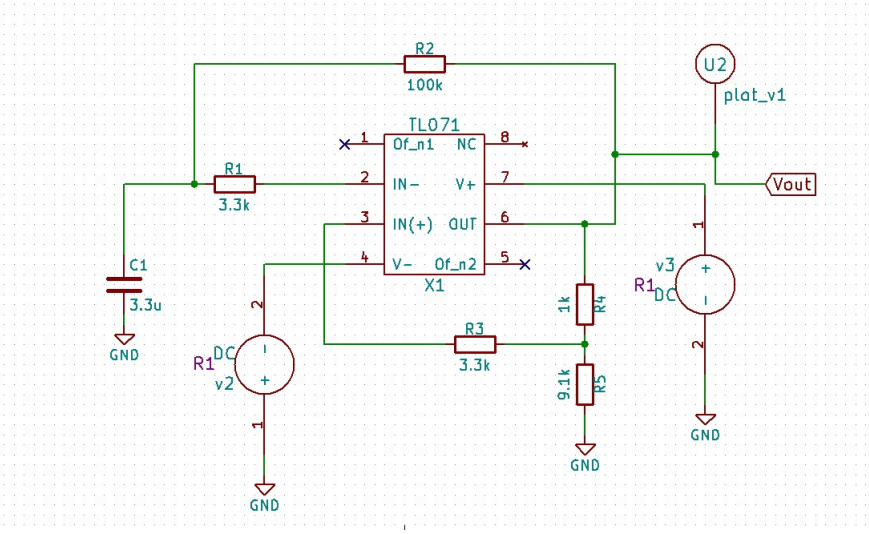


Figure 3.46: TL071 Test Circuit(Square Wave Generator)

3.10.4 Output Plot

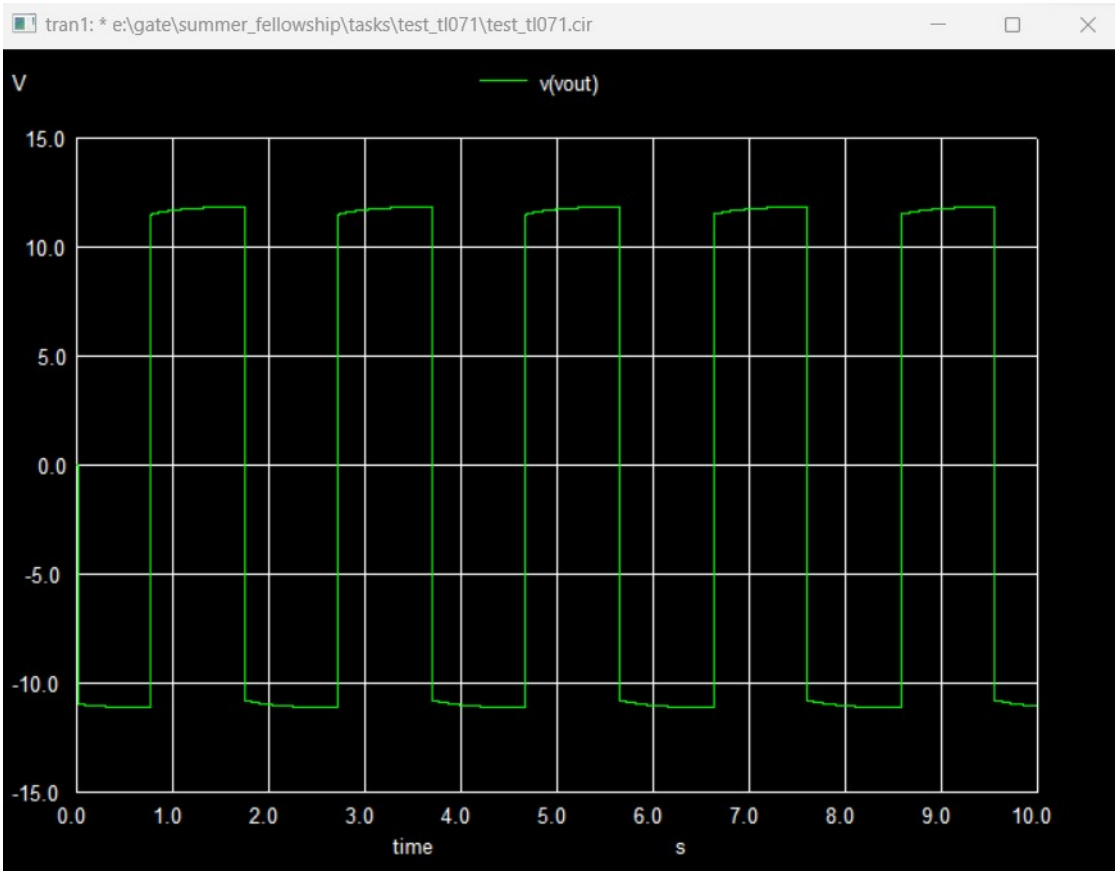


Figure 3.47: Output Square Wave Signal

3.11 LM747 Operational Amplifier IC

The LM747 is a general purpose dual operational amplifier. The two amplifiers share a common bias network and power supply leads. Otherwise, their operation is completely independent. Additional features of the LM747 are: no latch-up when input common mode range is exceeded, freedom from oscillations, and package flexibility.

3.11.1 Pin Configuration

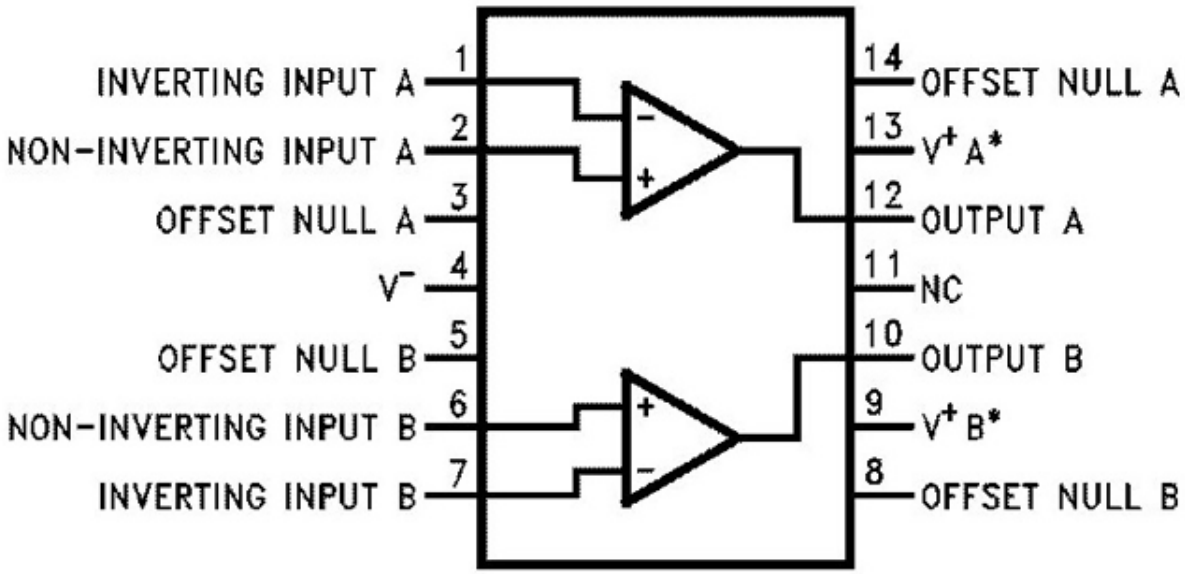


Figure 3.48: LM747 Pin Diagram

3.11.2 Subcircuit Schematics Diagram

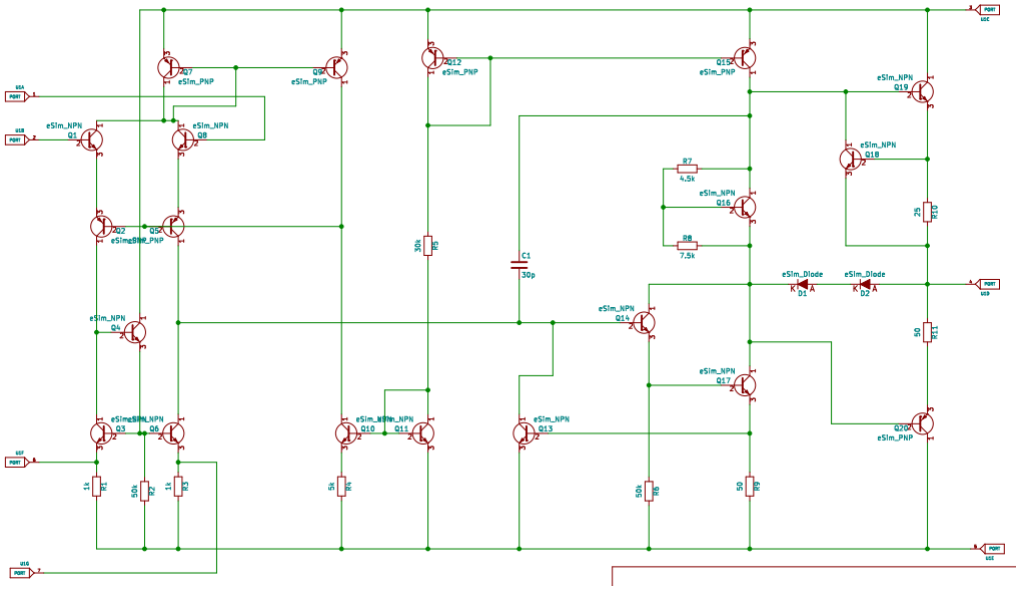


Figure 3.49: LM747 Schematics

3.11.3 Subcircuit test circuit

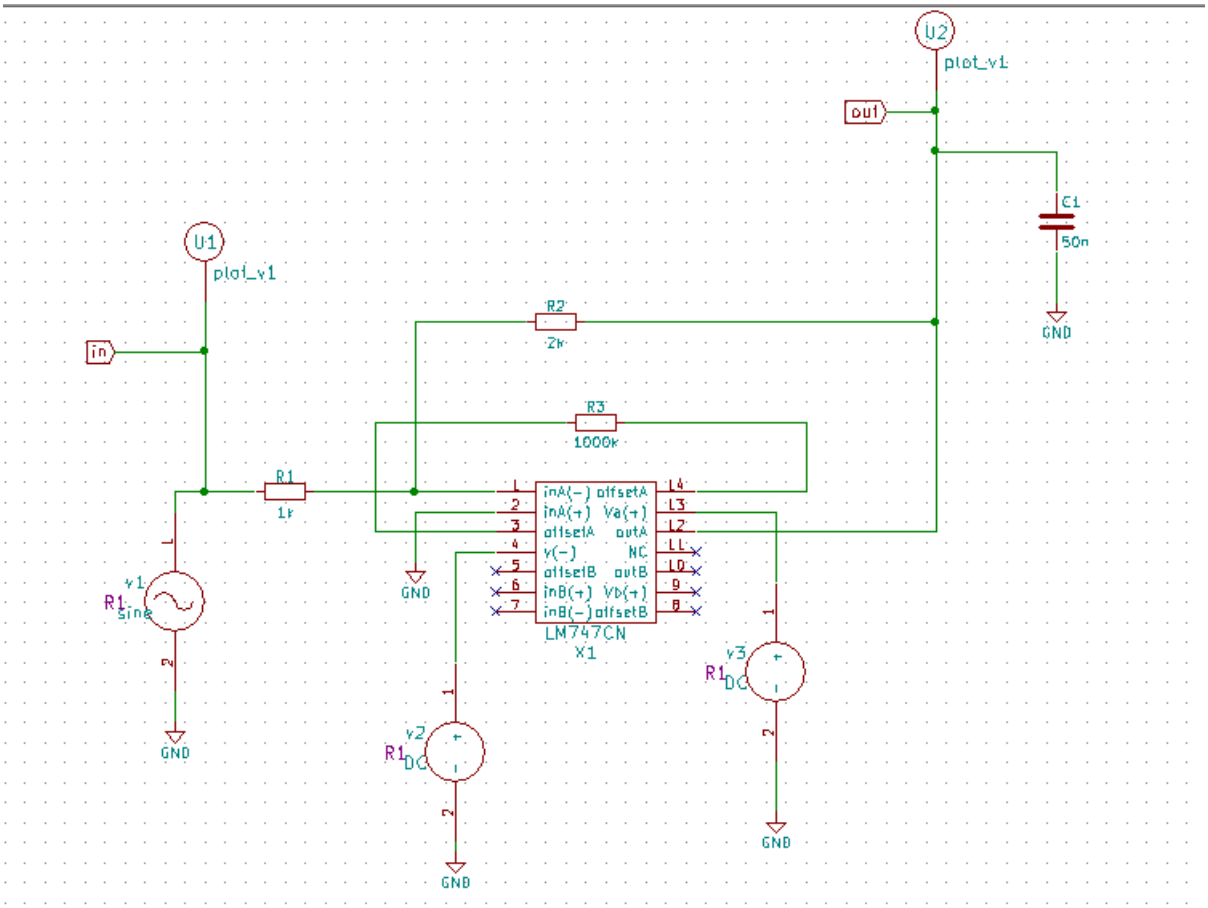


Figure 3.50: LM747 Test Circuit(Inverting Amplifier)

3.11.4 Input Plot

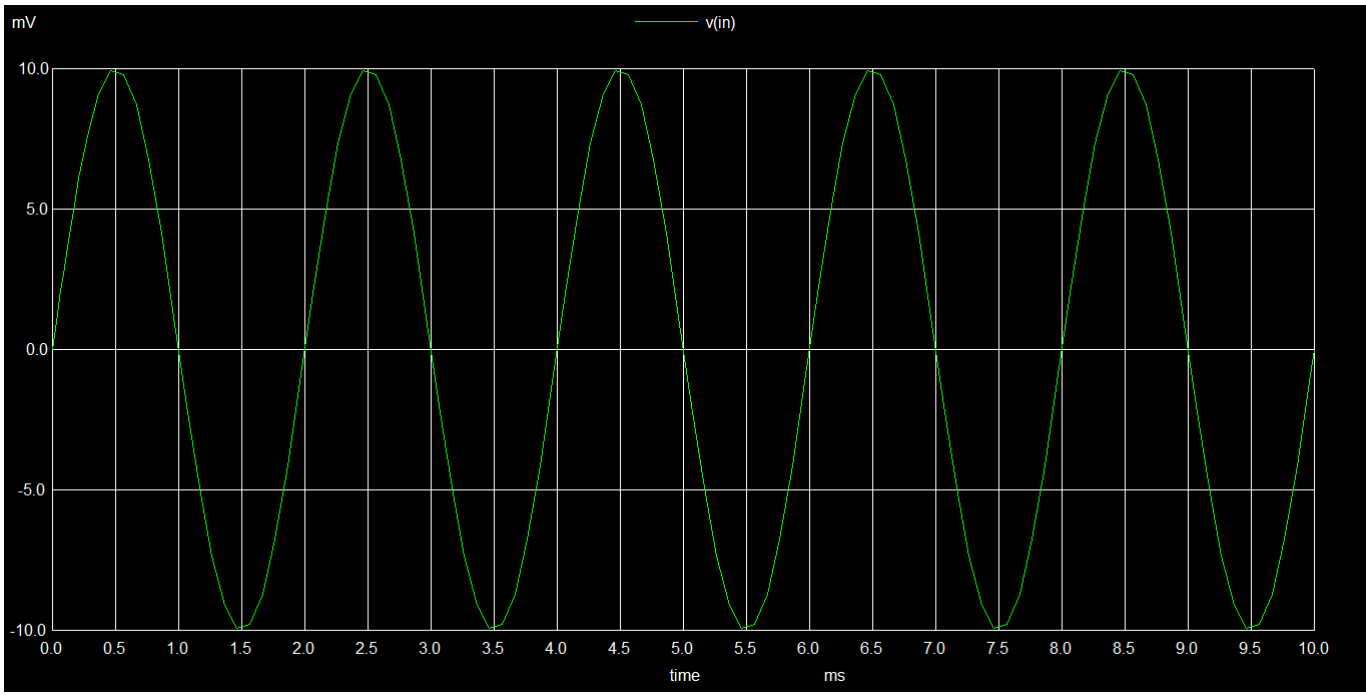


Figure 3.51: Input Sine Signal

3.11.5 Output Plot

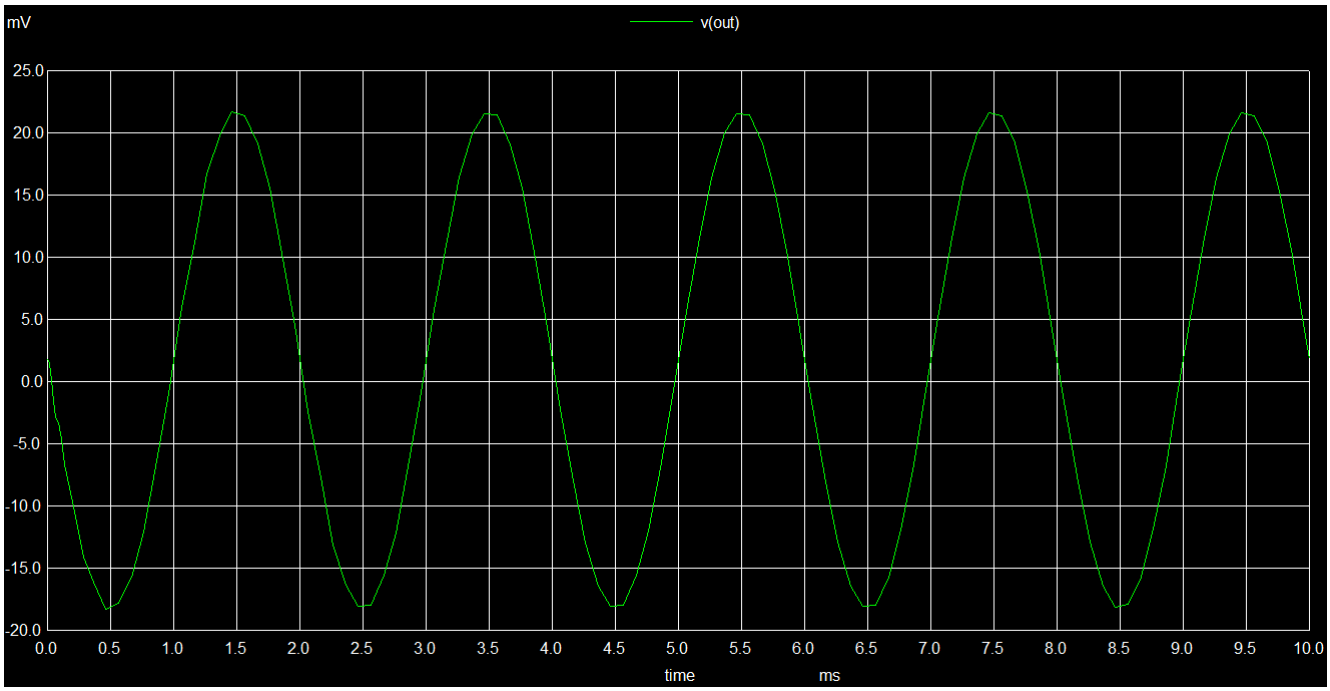


Figure 3.52: Output Signal

3.12 Ua709 Operational Amplifier IC

These circuits are general-purpose operational amplifiers, each having high-impedance differential inputs and a low-impedance output. Component matching, inherent with silicon monolithic circuit-fabrication techniques, produces an amplifier with low-drift and low-offset characteristics. Provisions are incorporated within the circuit whereby external components may be used to compensate the amplifier for stable operation under various feedback or load conditions. These amplifiers are particularly useful for applications requiring transfer or generation of linear or nonlinear functions. The uA709A circuit features improved offset characteristics, reduced input-current requirements, and lower power dissipation when compared to the uA709 circuit. In addition, maximum values of the average temperature coefficients of offset voltage and current are specified for the uA709A.

3.12.1 Pin Configuration

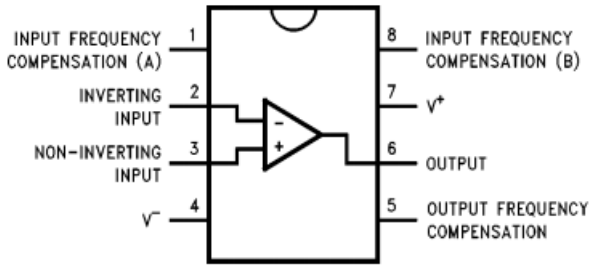


Figure 3.53: Ua709 Pin Diagram

3.12.2 Subcircuit Schematics Diagram

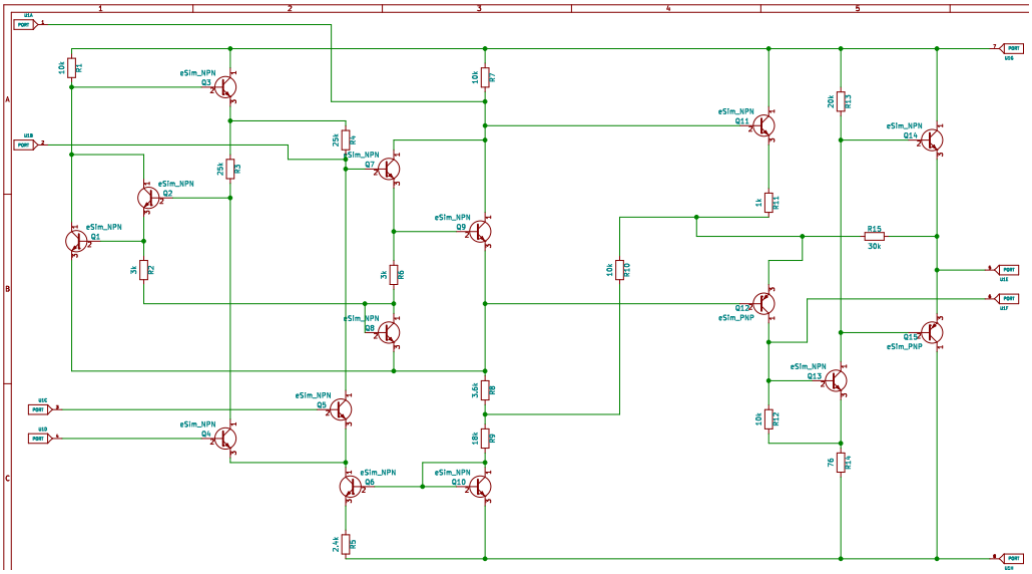


Figure 3.54: Ua709 Schematics

3.12.3 Subcircuit test circuit

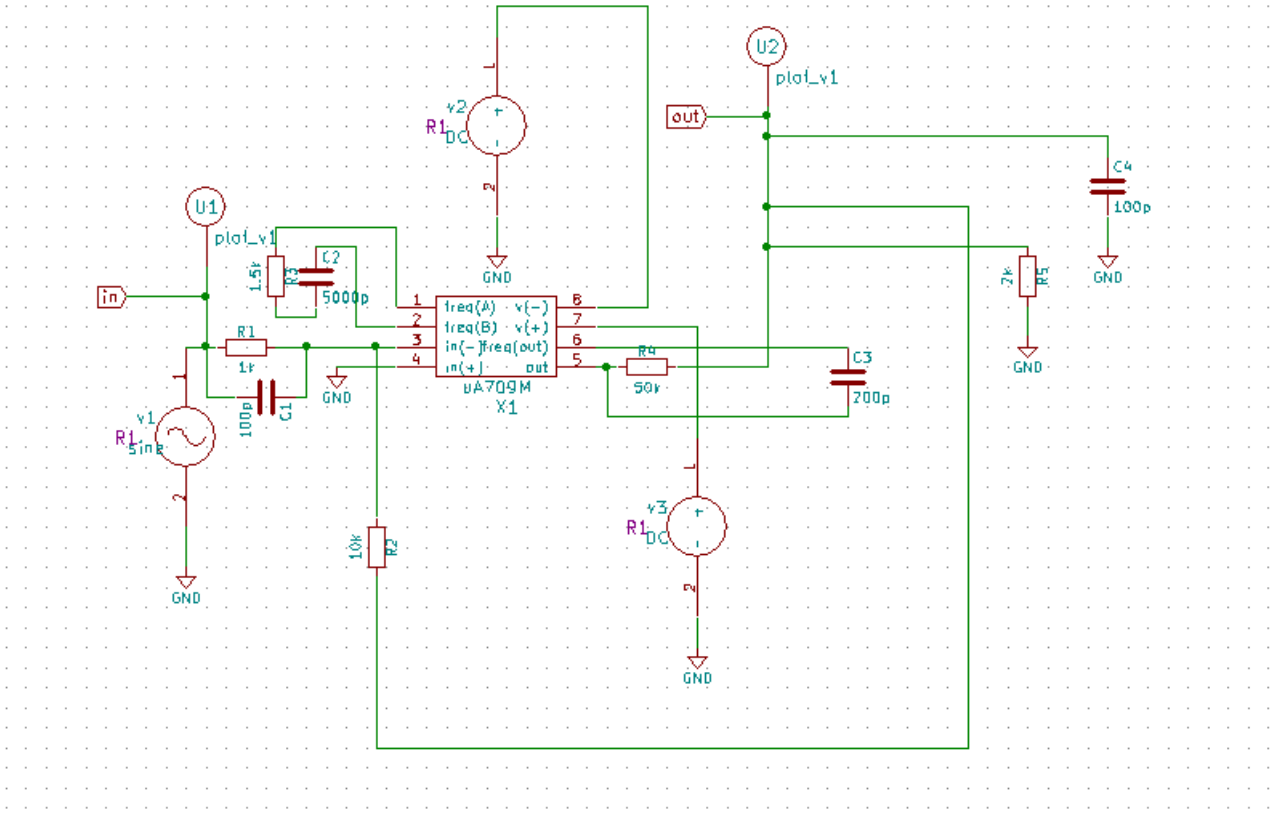


Figure 3.55: Ua709 Test Circuit(Inverting Amplifier)

3.12.4 Input Plot

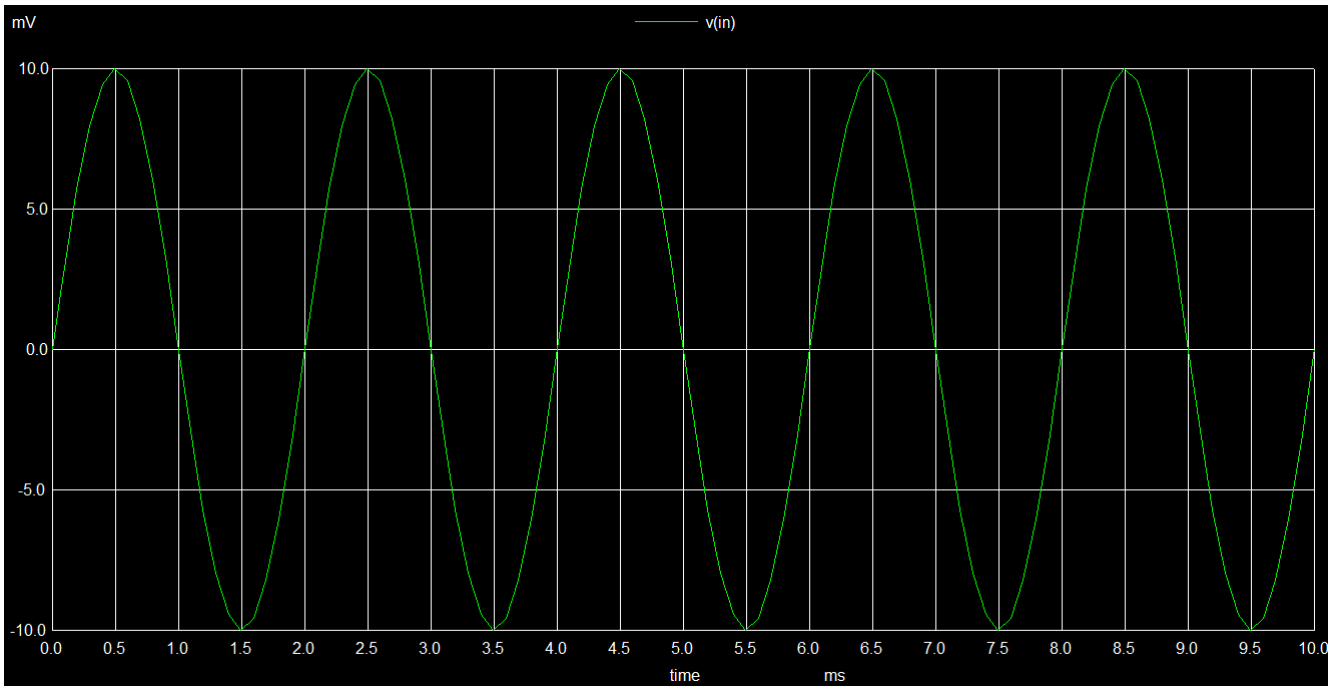


Figure 3.56: Input Sine Signal

3.12.5 Output Plot

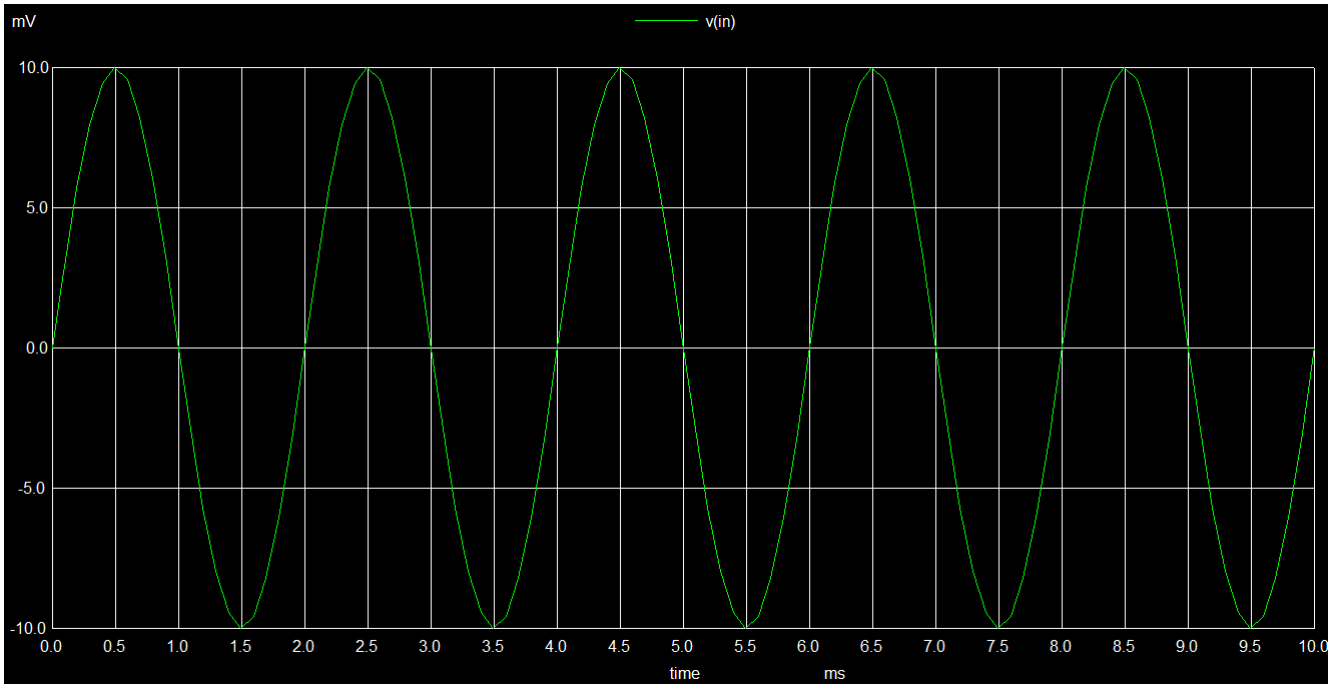
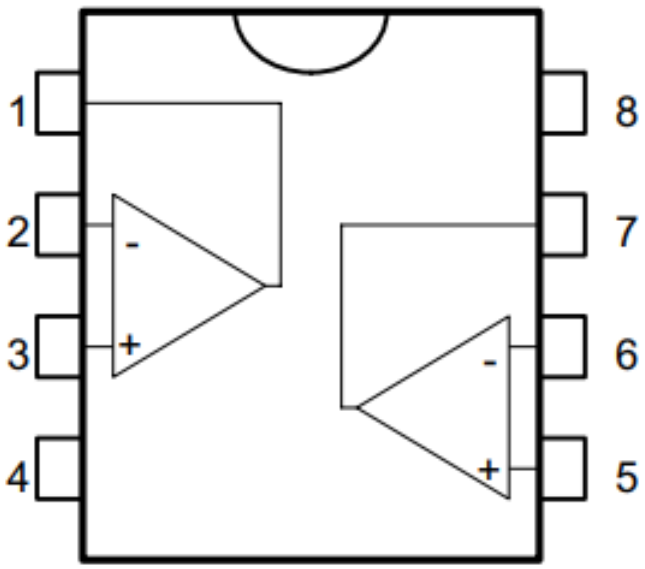


Figure 3.57: Output Signal

3.13 LF253 Operational Amplifier IC

These circuits are high speed JFET input dual operational amplifiers incorporating well matched, high voltage JFET and bipolar transistors in a monolithic integrated circuit. The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient

3.13.1 Pin Configuration



1 - Output1
2 - Inverting input 1
3 - Non-inverting input 1
4 - V_{CC}^-
5 - Non-inverting input 2
6 - Inverting input 2
7 - Output 2
8 - V_{CC}^+

Figure 3.58: LF253 Pin Diagram

3.13.2 Subcircuit Schematics Diagram

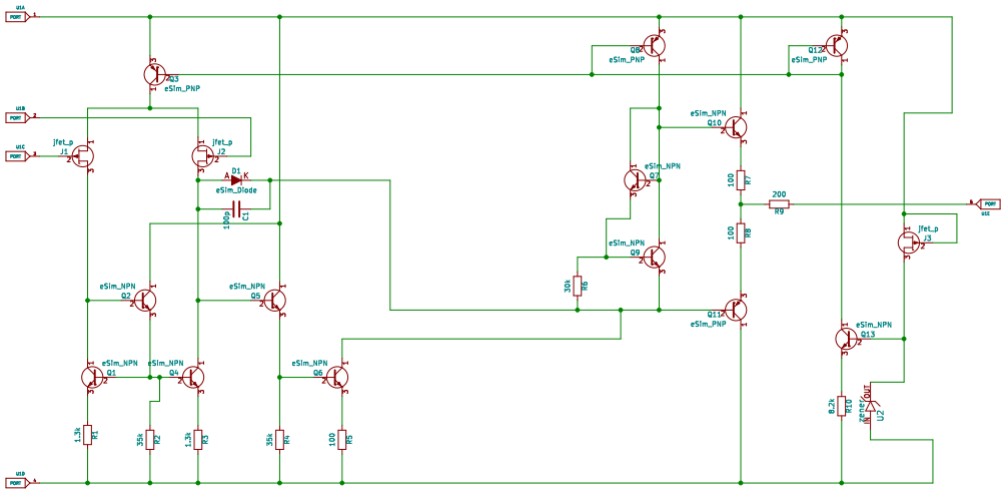


Figure 3.59: LF253 Schematics

3.13.3 Subcircuit test circuit

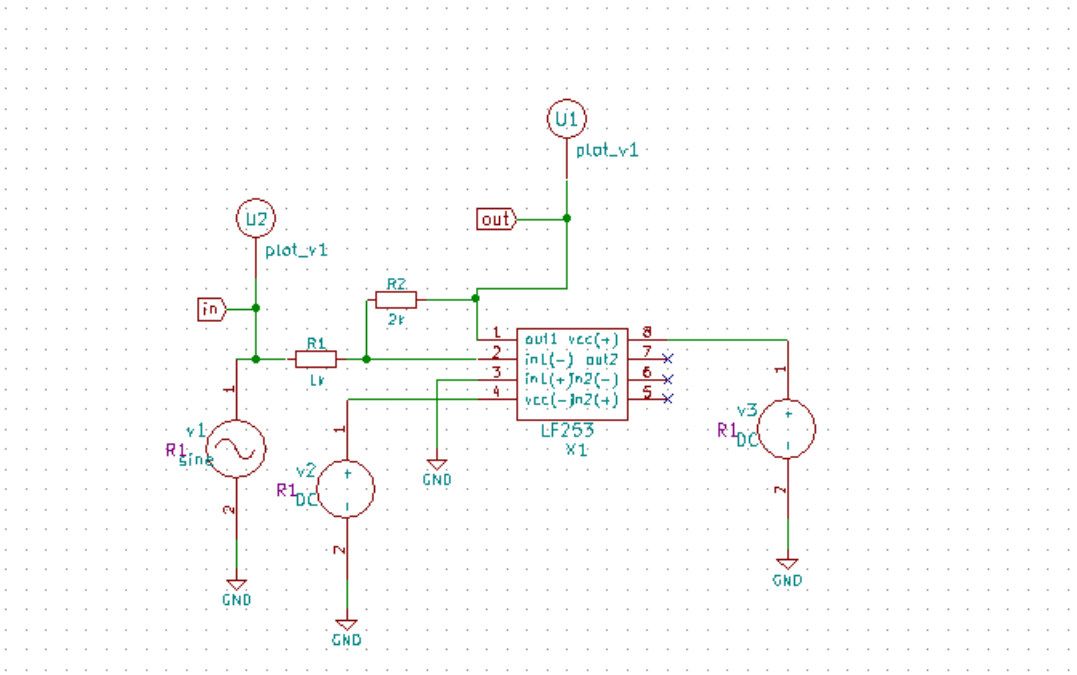


Figure 3.60: LF253 Test Circuit(Inverting Amplifier)

3.13.4 Input Plot

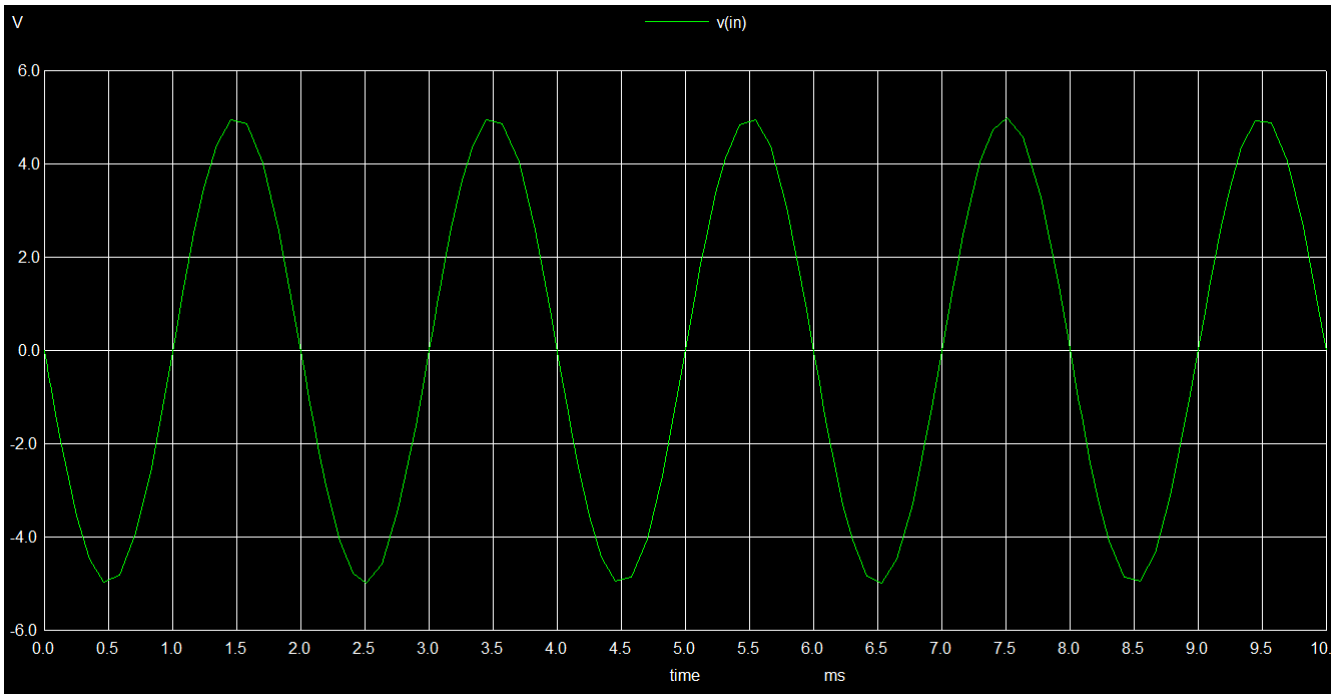


Figure 3.61: Input Sine Signal

3.13.5 Output Plot

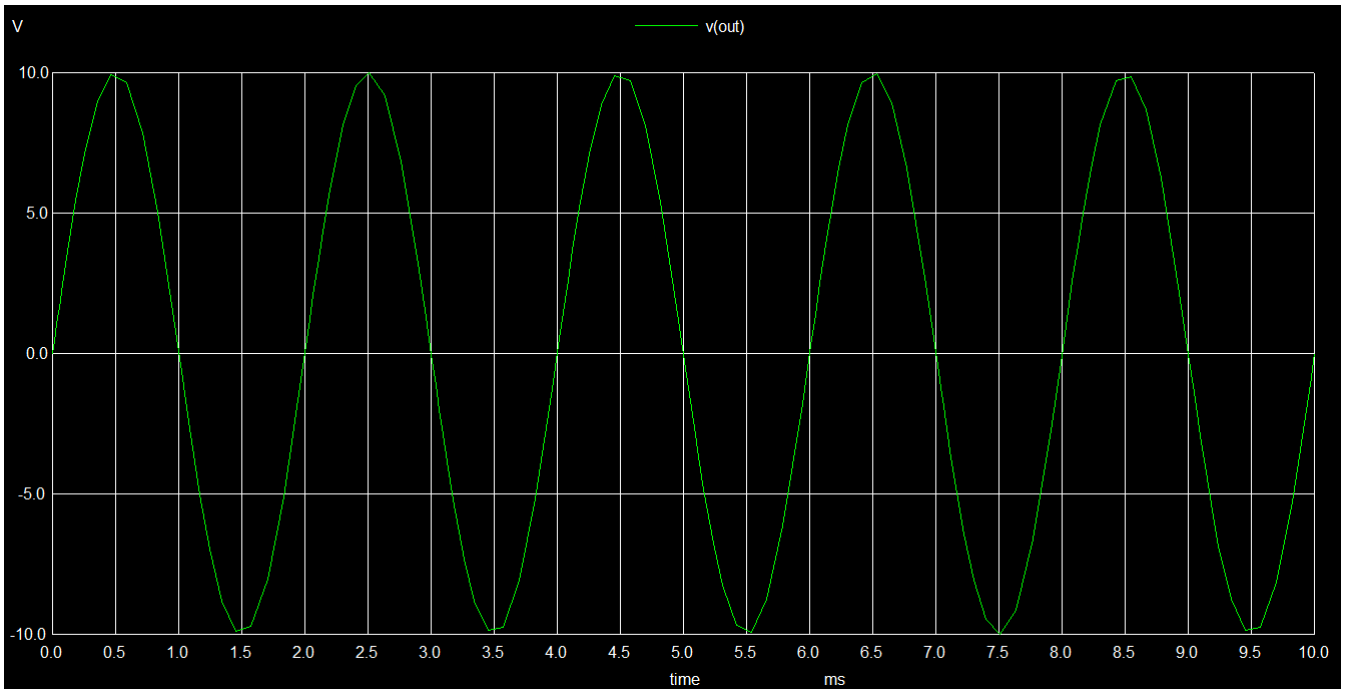


Figure 3.62: Output Signal

3.14 L7915 Voltage Regulator IC

The L79 series of three-terminal negative regulators is available in TO-220, TO-220FP and DPAK packages and several fixed output voltages, making it useful in a wide range of applications. These regulators can provide local on-card regulation, eliminating the distribution problems associated with single point regulation; furthermore, having the same voltage option as the L78 positive standard series, they are particularly suited for split power supplies. If adequate heat sinking is provided, they can deliver over 1.5 A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

3.14.1 Pin Configuration

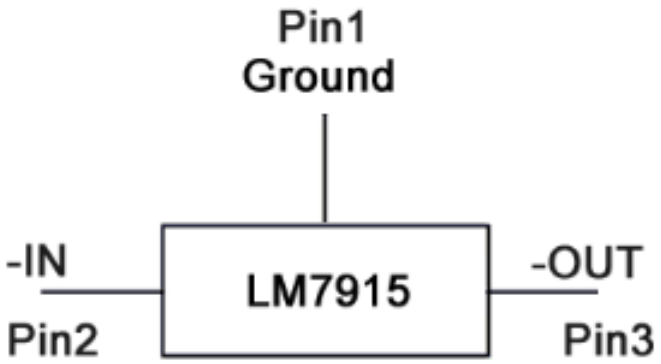


Figure 3.63: L7915 Pin Diagram

3.14.2 Subcircuit Schematics Diagram

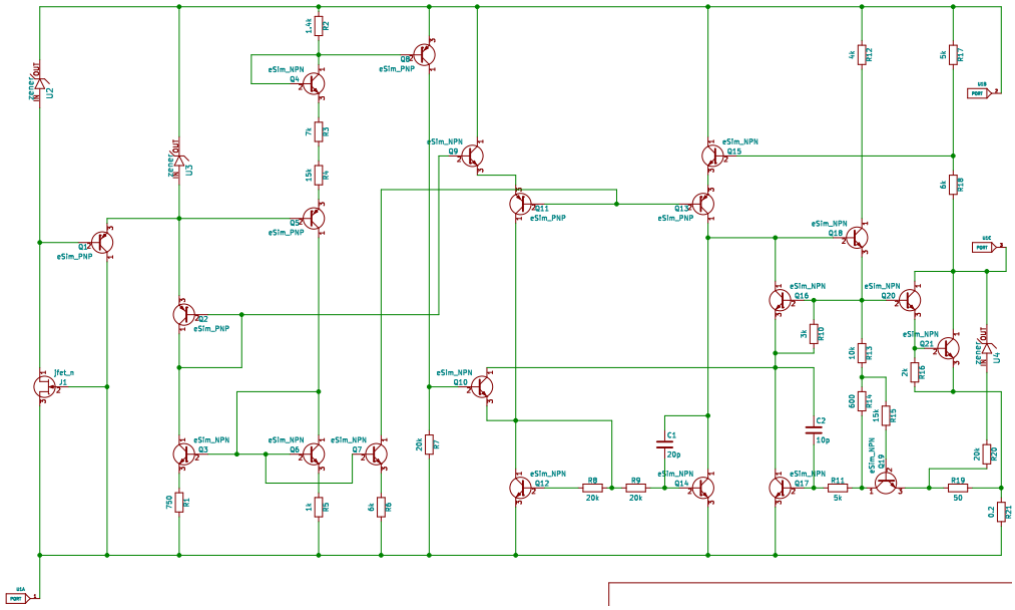


Figure 3.64: L7915 Schematics

3.14.3 Subcircuit test circuit

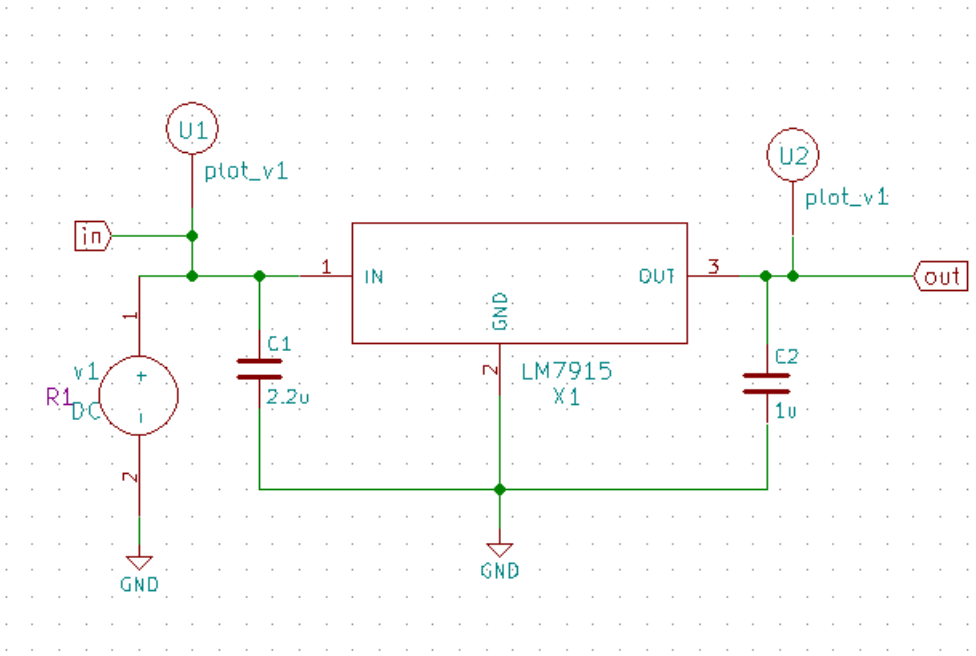


Figure 3.65: L7915 Test Circuit(Voltage Amplifier)

3.14.4 Input Output Plot

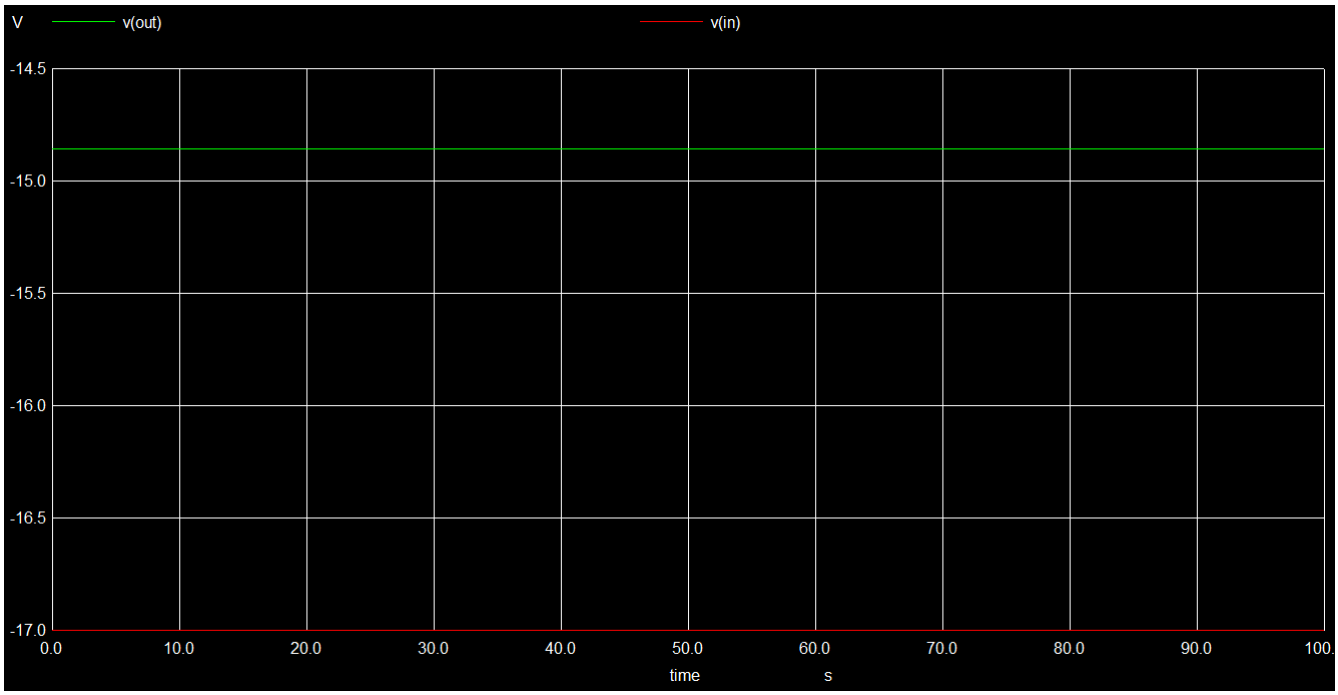


Figure 3.66: Input Output Plot

3.15 LM4136 Operational Amplifier IC

The LM4136 monolithic quad operational amplifier consists of four independent high gain, internally frequency compensated operational amplifiers. The specifically designed low noise input transistors allow the LM4136 to be used in low noise signal processing applications such as audio preamplifiers and signal conditioners. The simplified output stage completely eliminates crossover distortion under any load conditions, has large source and sink capacity, and is shortcircuit protected. A novel current source stabilizes output parameters over a wide power supply voltage range.

3.15.1 Pin Configuration

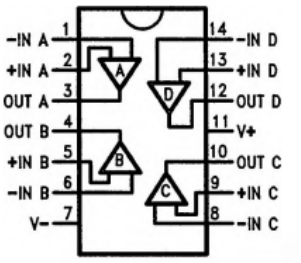


Figure 3.67: LM4136 Pin Diagram

3.15.2 Subcircuit Schematics Diagram

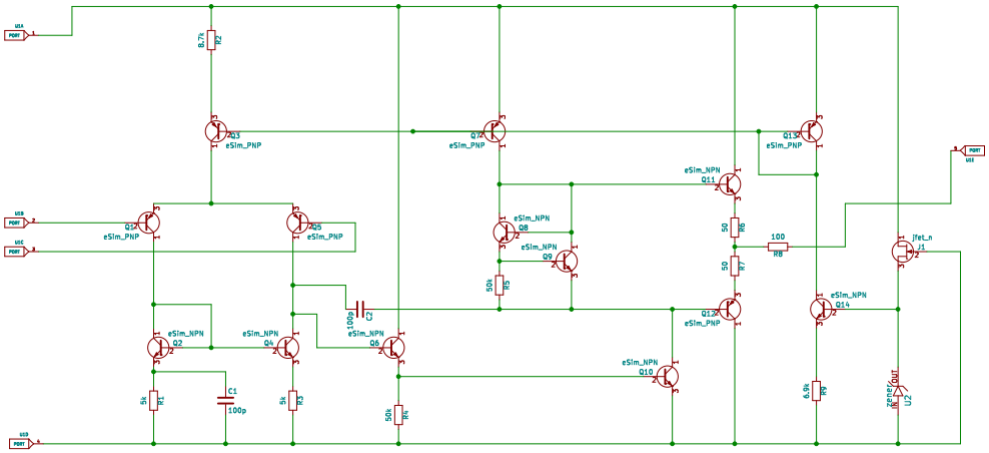


Figure 3.68: LM4136 Schematics

3.15.3 Subcircuit test circuit

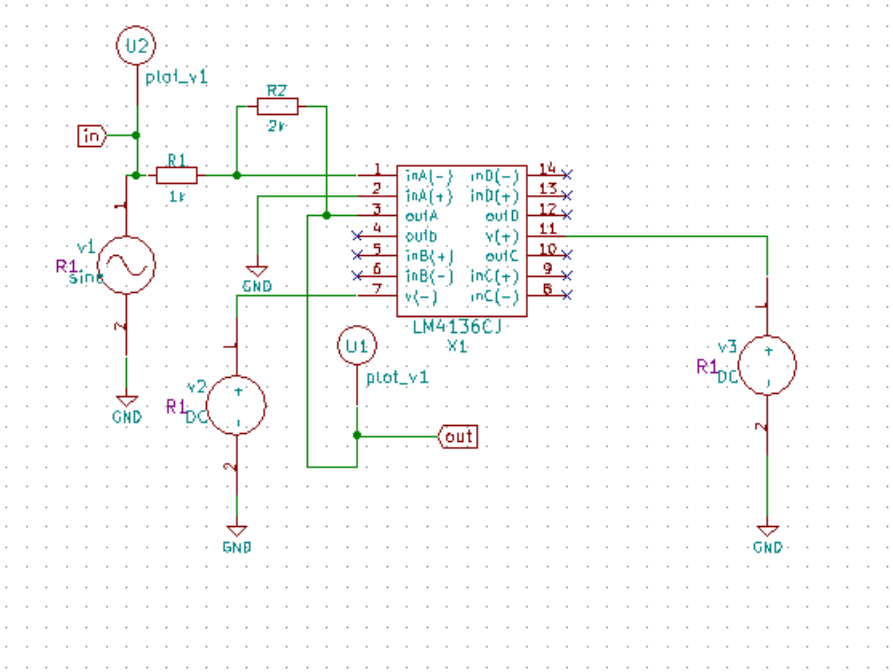


Figure 3.69: LM4136 Test Circuit(Inverting Amplifier)

3.15.4 Input Plot

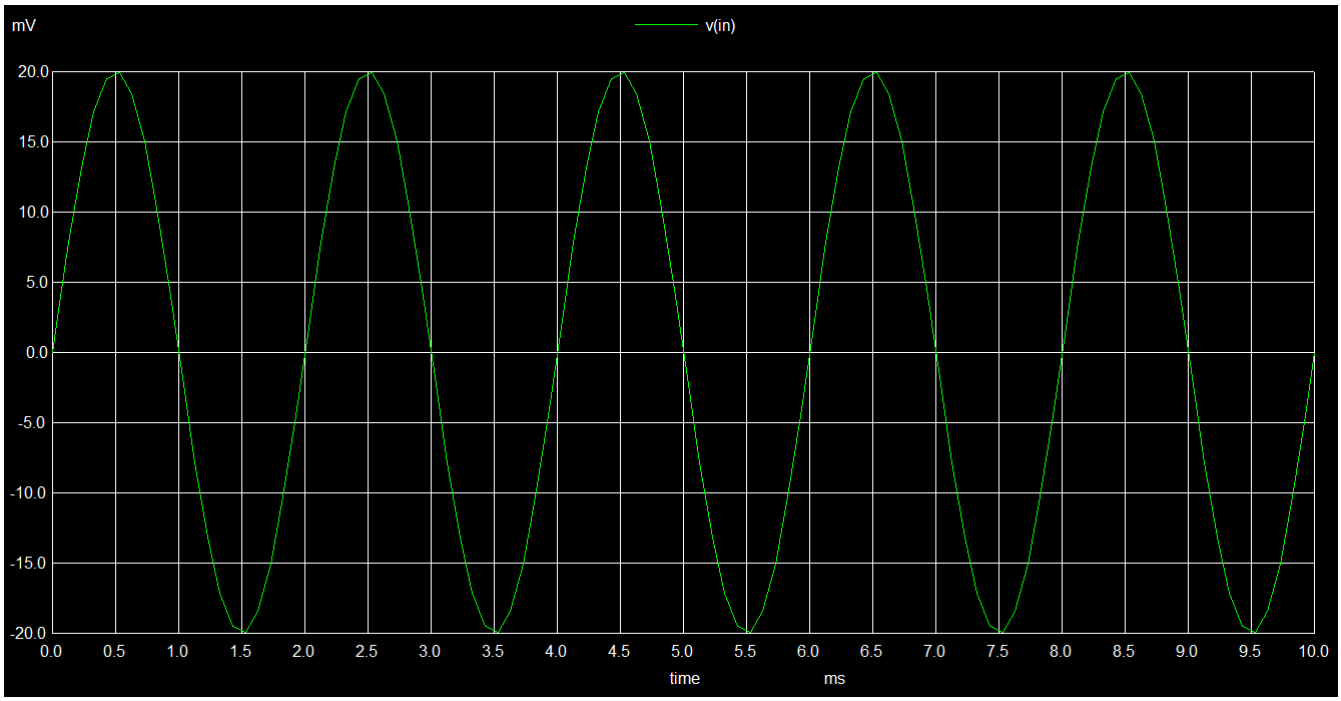


Figure 3.70: Input Sine Signal

3.15.5 Output Plot

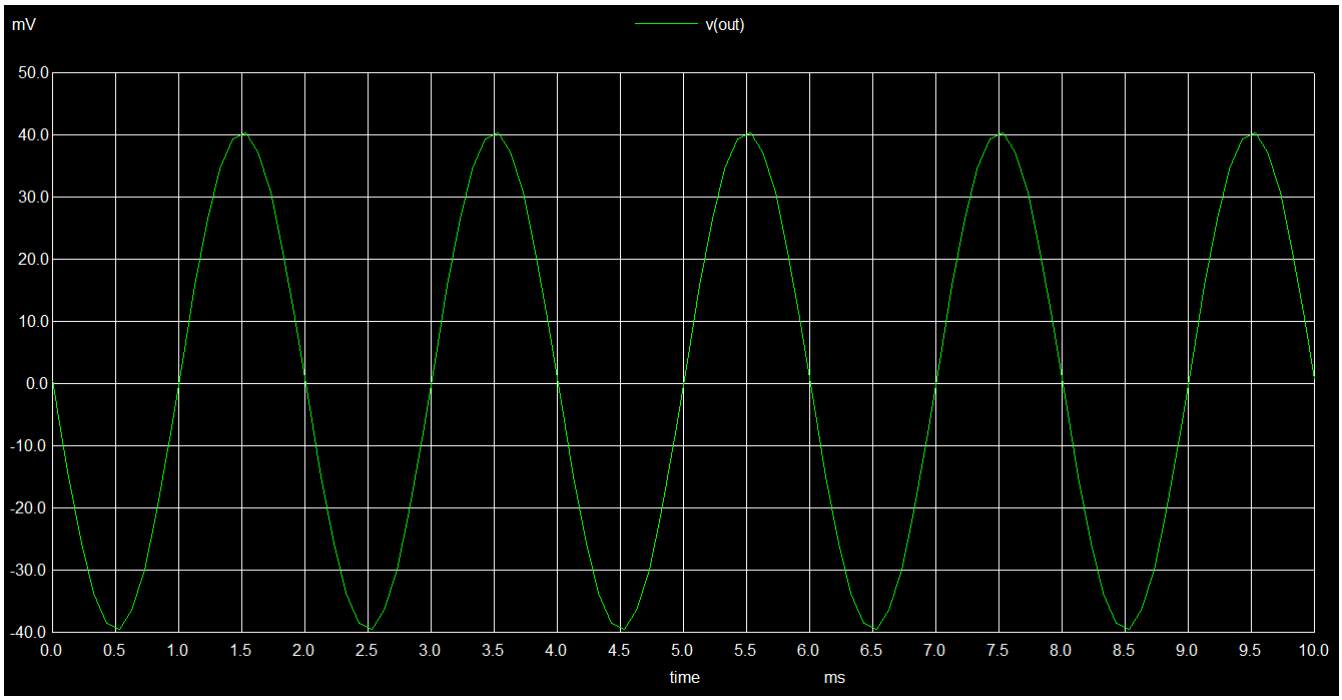


Figure 3.71: Output Signal

3.16 MC1558 Operational Amplifier IC

The MC1558 is a high-performance, monolithic, dual operational amplifier intended for a wide range of analog applications. The high gain and wide range of operating voltages provide superior performance in integrator, summing amplifiers, and general feedback applications.

subsectionPin Configuration

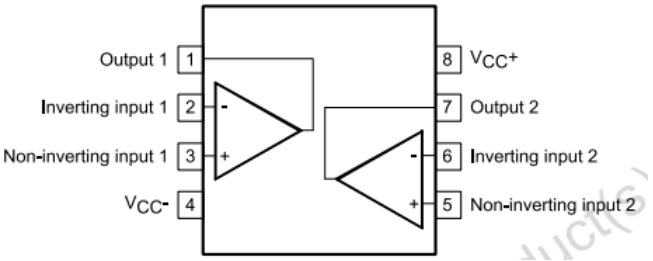


Figure 3.72: MC1558 Pin Diagram

3.16.1 Subcircuit Schematics Diagram

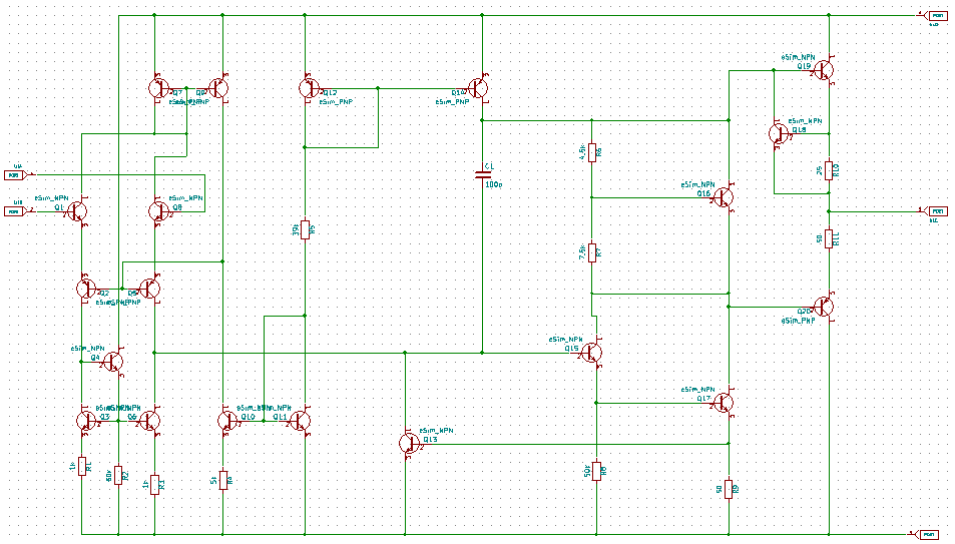


Figure 3.73: MC1558 Schematics

3.16.2 Subcircuit test circuit

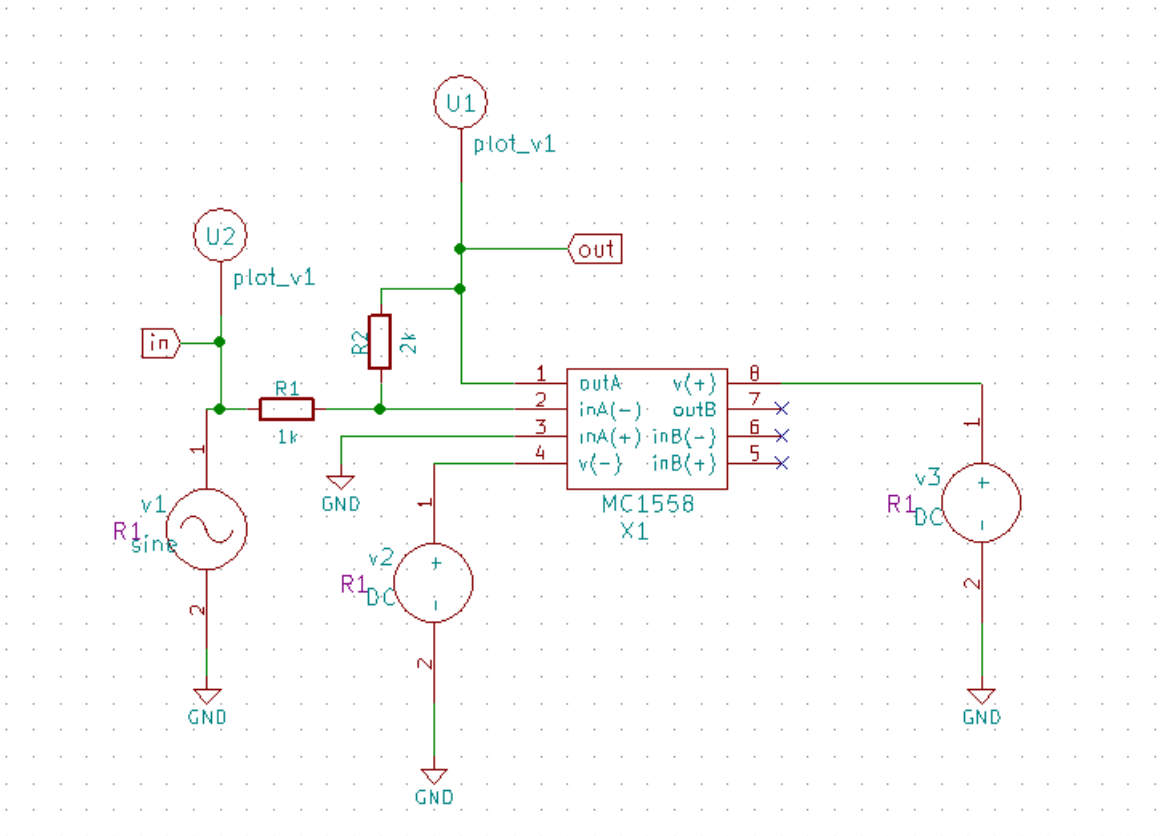


Figure 3.74: MC1558 Test Circuit(Inverting Amplifier)

3.16.3 Input Plot

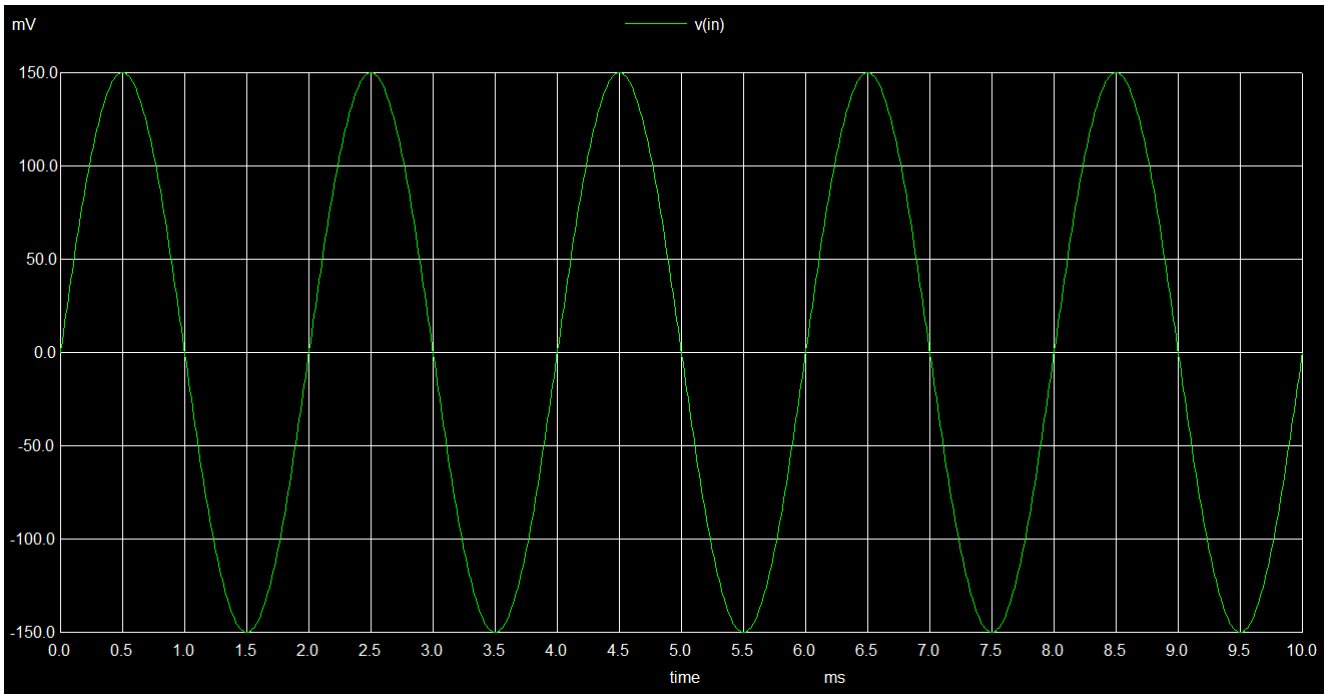


Figure 3.75: Input Sine Signal

3.16.4 Output Plot

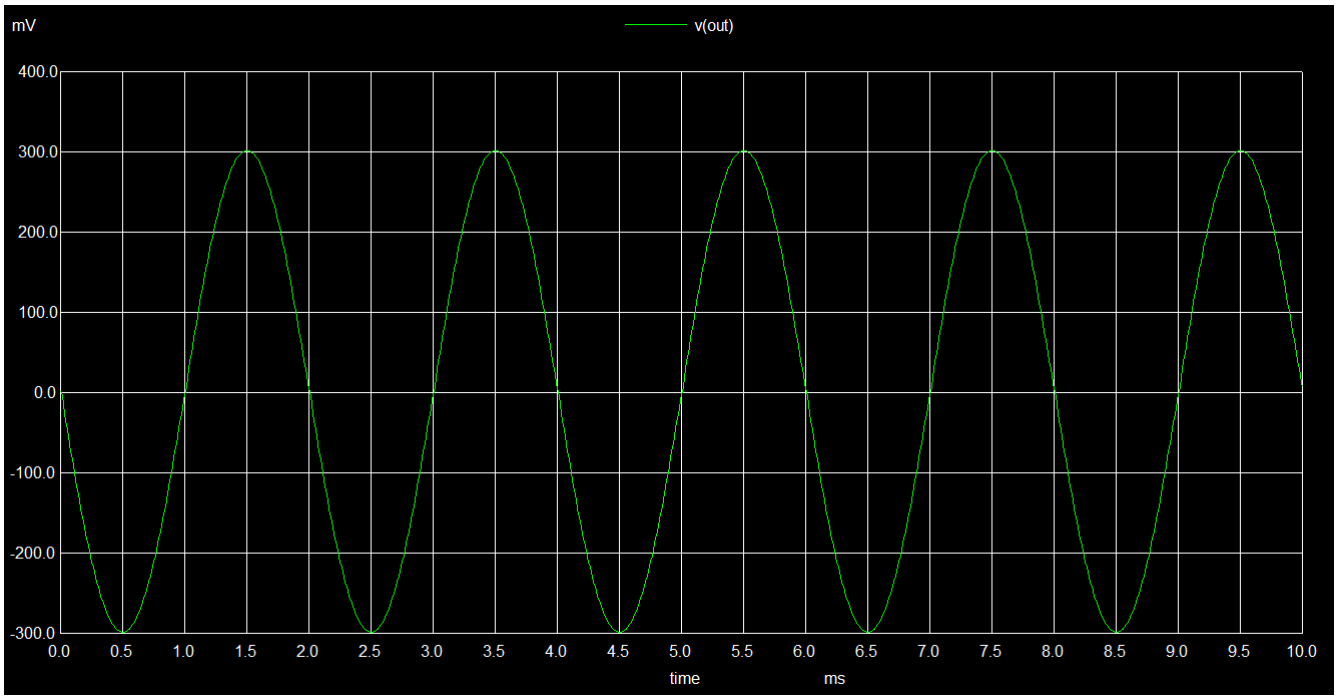


Figure 3.76: Output Signal

3.17 ULN2066 Quad Darlington switches

Designed to interface logic to a wide variety of high current, high voltage loads, these devices each contain four NPN Darlington switches delivering up to 1.5 A with a specified minimum breakdown of 50 V and a sustaining voltage of 35 V measured at 100 mA. The ULN2064B, ULN2066B and ULN2068B contain integral suppression diodes for inductive loads have common emitters. The ULN2074B feature isolated Darlington pinouts and is intended for applications such as emitter follower configurations. Inputs of the ULN2064B, ULN2068B and ULN2074B are compatible with popular 5 V logic families and the ULN2066B are compatible with 6 - 15 V CMOS and PMOS. Type ULN2068B includes a pre-driver stage to reduce loading on the control logic.

3.17.1 Pin Configuration

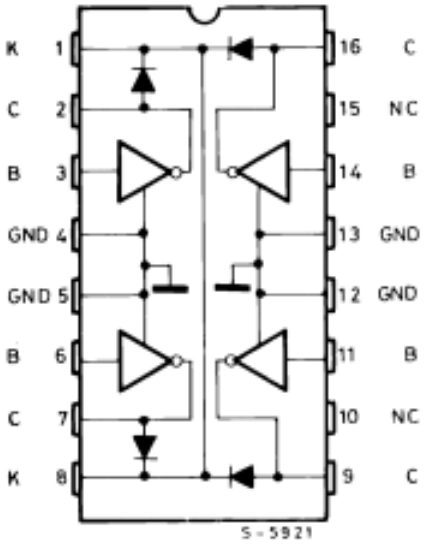


Figure 3.77: ULN2066 Pin Diagram

3.17.2 Subcircuit Schematics Diagram

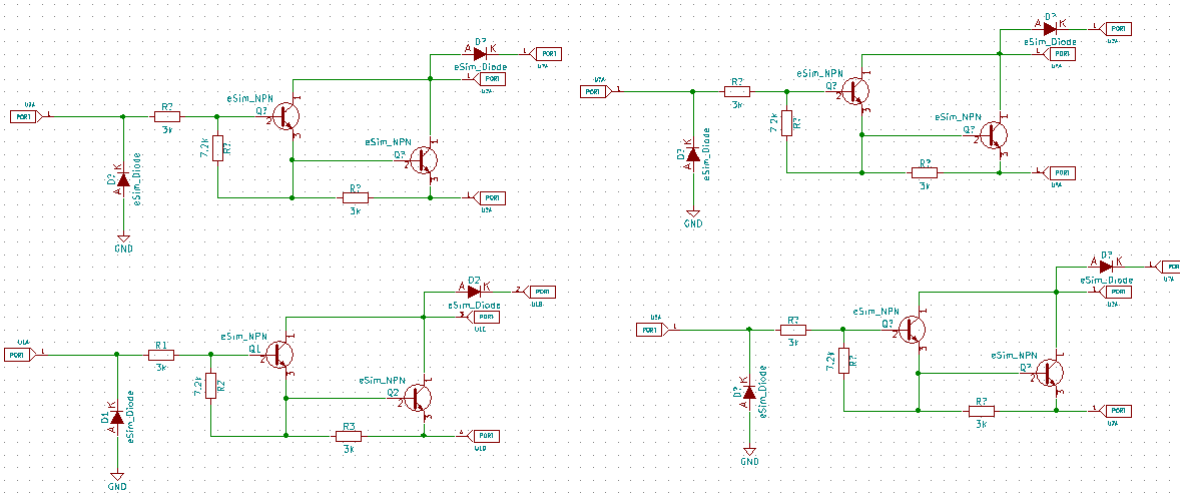


Figure 3.78: ULN2066 Schematics

3.17.3 Subcircuit test circuit

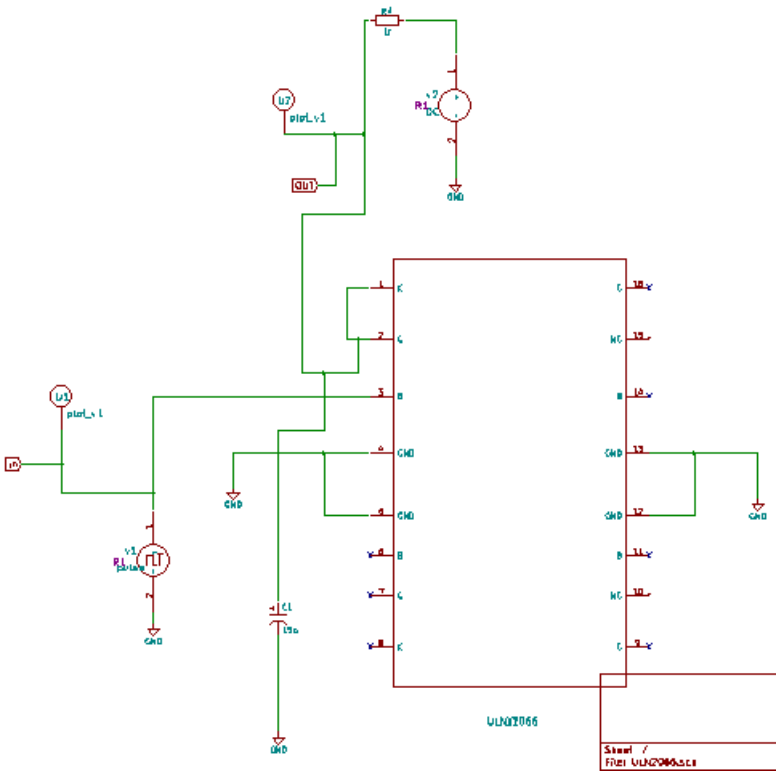


Figure 3.79: ULN2066 Test Circuit

3.17.4 Input Plot

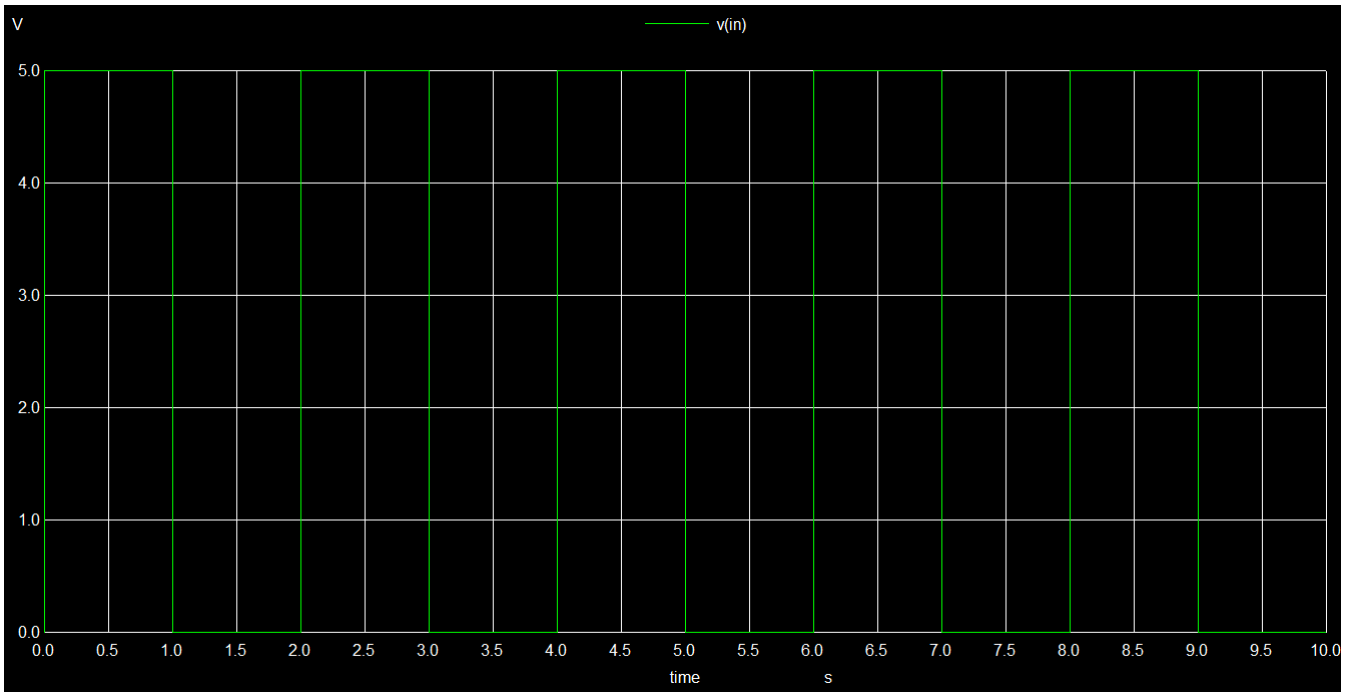


Figure 3.80: Input Signal

3.17.5 Output Plot

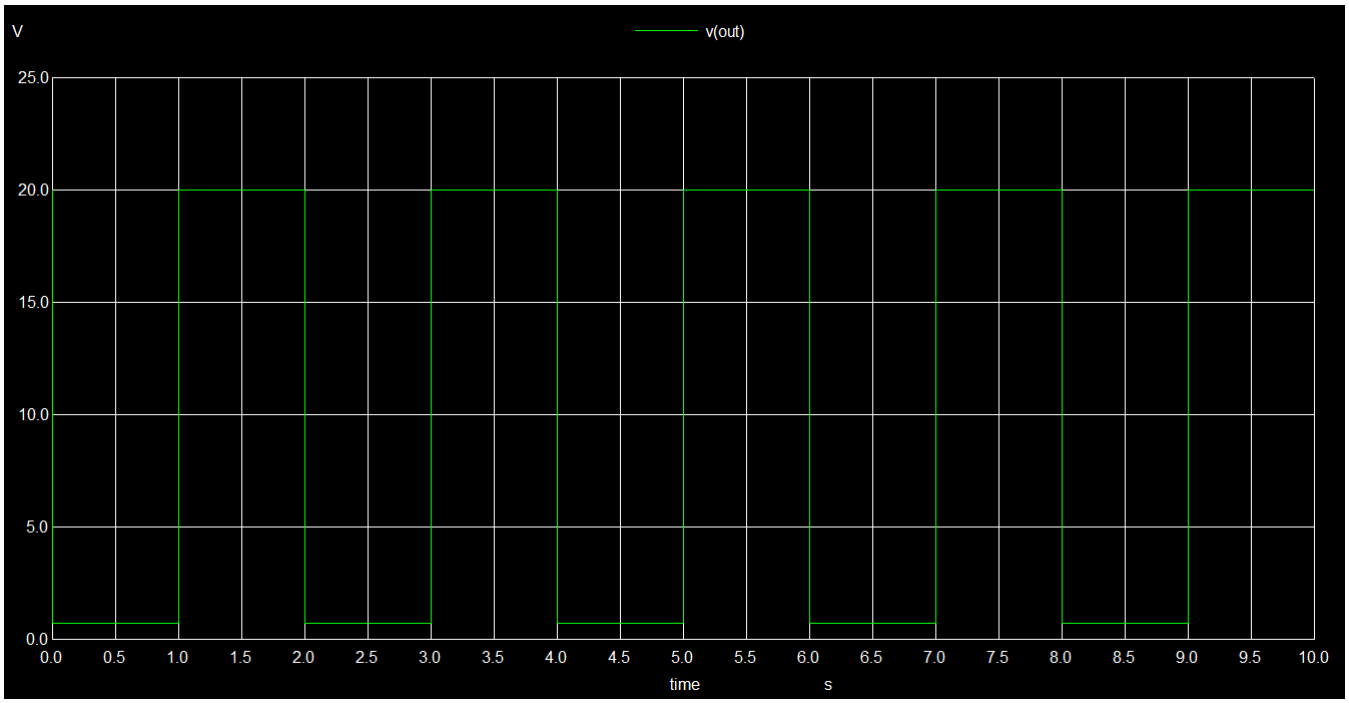


Figure 3.81: Output Signal

3.18 TL052 Operational Amplifier IC

The TL05x series of JFET-input operational amplifiers offers improved dc and ac characteristics over the TL07x and TL08x families of BiFET operational amplifiers. On-chip Zener trimming of offset voltage yields precision grades as low as 1.5 mV (TL051A) for greater accuracy in dc-coupled applications. Texas Instruments improved BiFET process and optimized designs also yield improved bandwidth and slew rate without increased power consumption. The TL05x devices are pin-compatible with the TL07x and TL08x and can be used to upgrade existing circuits or for optimal performance in new designs. BiFET operational amplifiers offer the inherently higher input impedance of the JFET-input transistors, without sacrificing the output drive associated with bipolar amplifiers. This makes them better suited for interfacing with high-impedance sensors or very low-level ac signals. They also feature inherently better ac response than bipolar or CMOS devices having comparable power consumption.

3.18.1 Pin Configuration

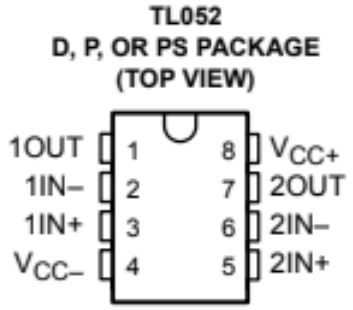


Figure 3.82: TL052 Pin Diagram

3.18.2 Subcircuit Schematics Diagram

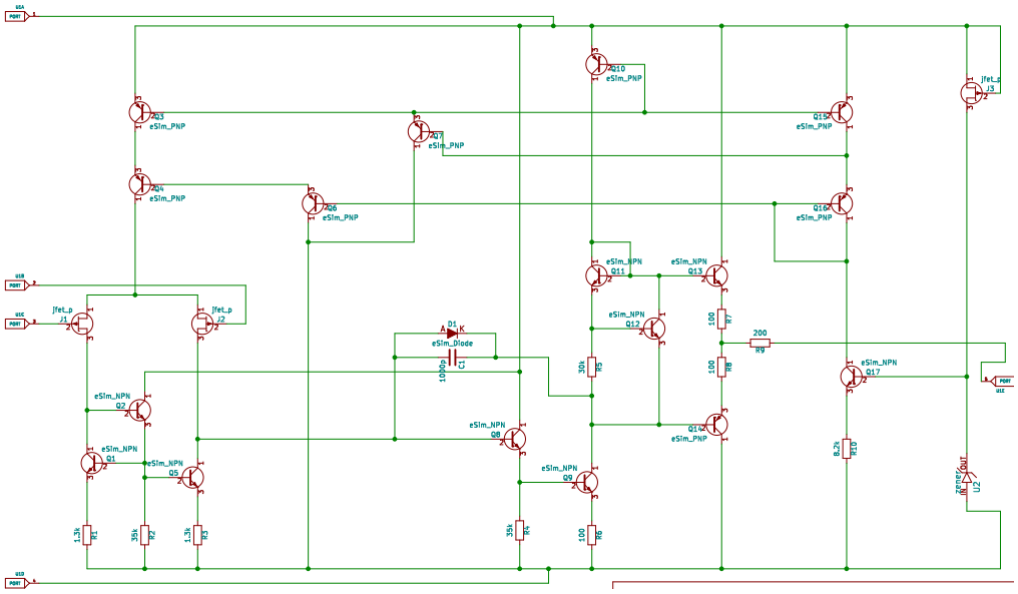


Figure 3.83: TL052 Schematics

3.18.3 Subcircuit test circuit

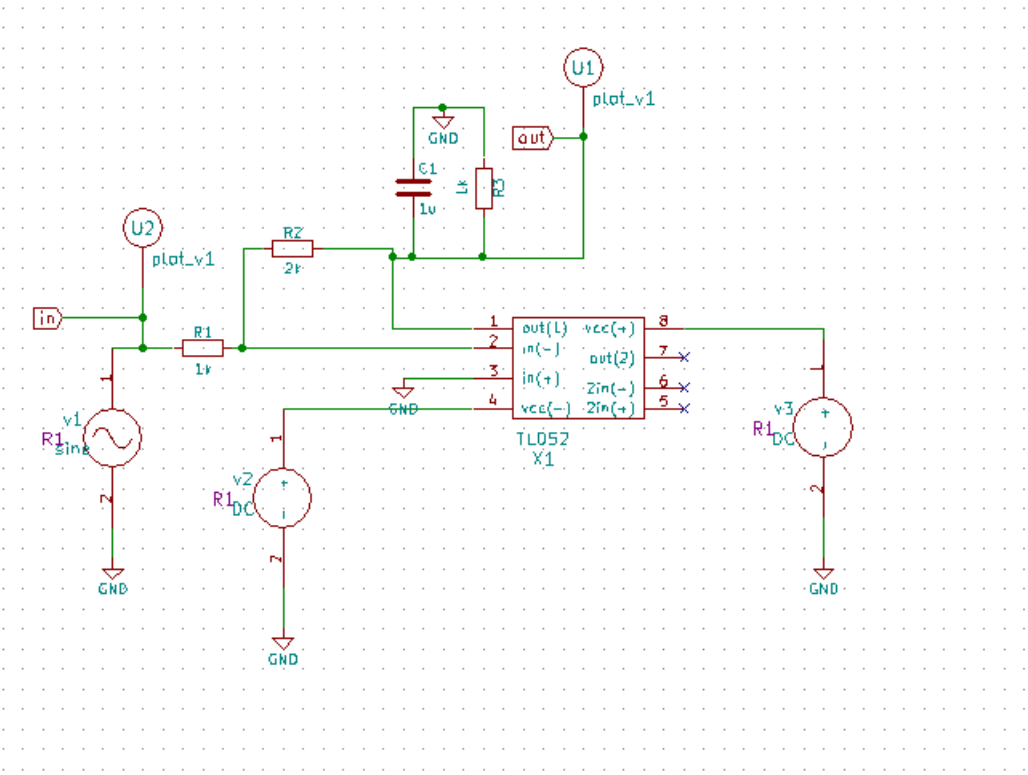


Figure 3.84: TL052 Test Circuit(Inverting Amplifier)

3.18.4 Input Plot

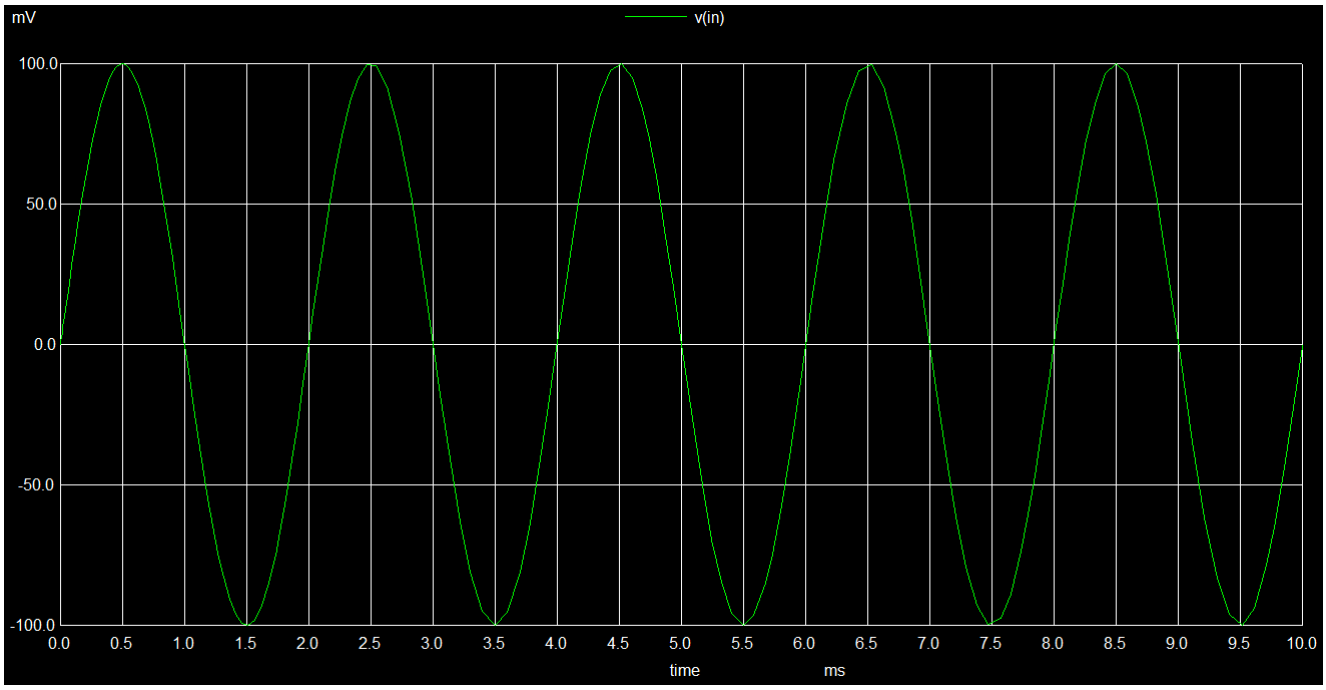


Figure 3.85: Input Sine Signal

3.18.5 Output Plot

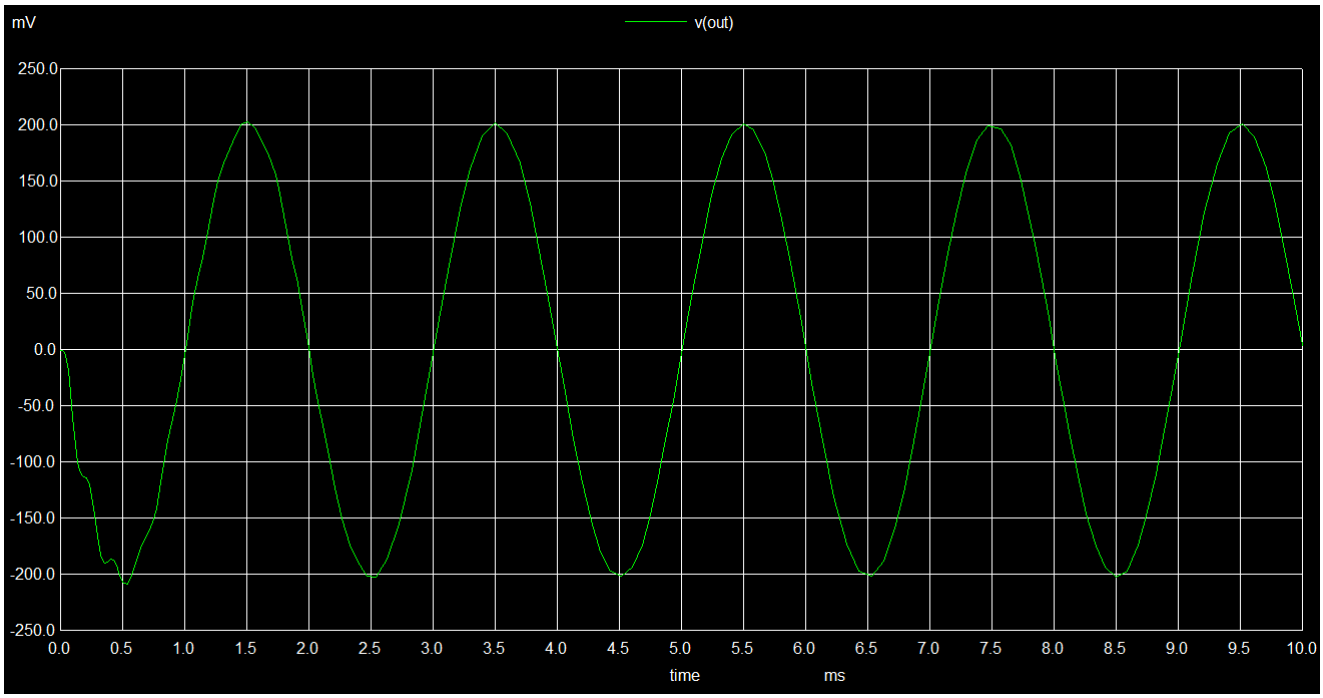


Figure 3.86: Output Signal

3.19 TL084 IC

The TL08xH (TL081H, TL082H, and TL084H) family of devices are the next-generation versions of the industry-standard TL08x (TL081, TL082, and TL084) devices. These devices provide outstanding value for cost-sensitive applications, with features including low offset (1 mV, typical), high slew rate (20 V/s), and common-mode input to the positive supply. High ESD (1.5 kV, HBM), integrated EMI and RF filters, and operation across the full 40C to 125C enable the TL08xH devices to be used in the most rugged and demanding applications.

3.19.1 Pin Configuration

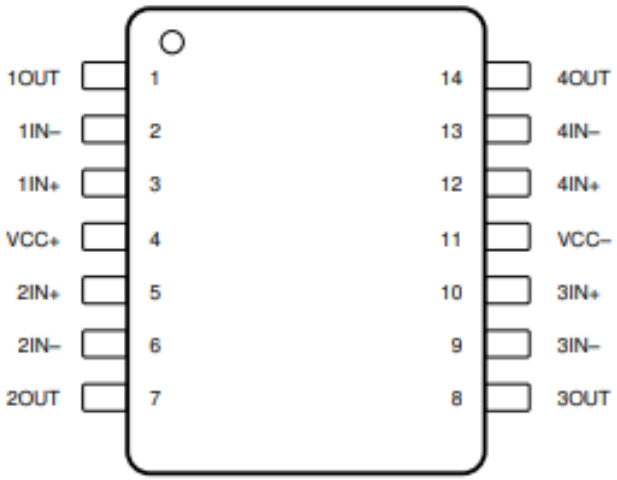


Figure 3.87: TL084 Pin Diagram

3.19.2 Subcircuit Schematics Diagram

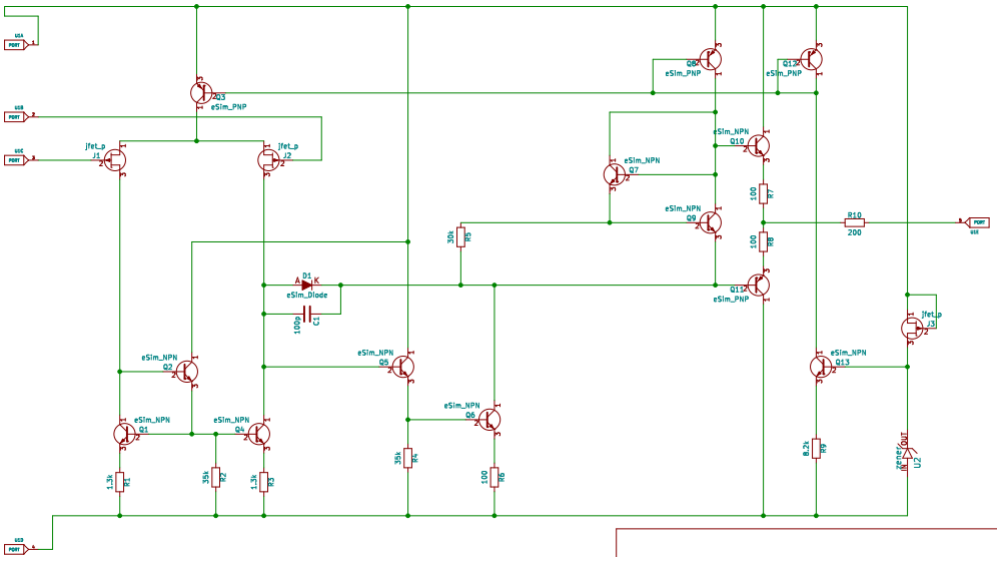


Figure 3.88: TL084 Schematics

3.19.3 Subcircuit test circuit

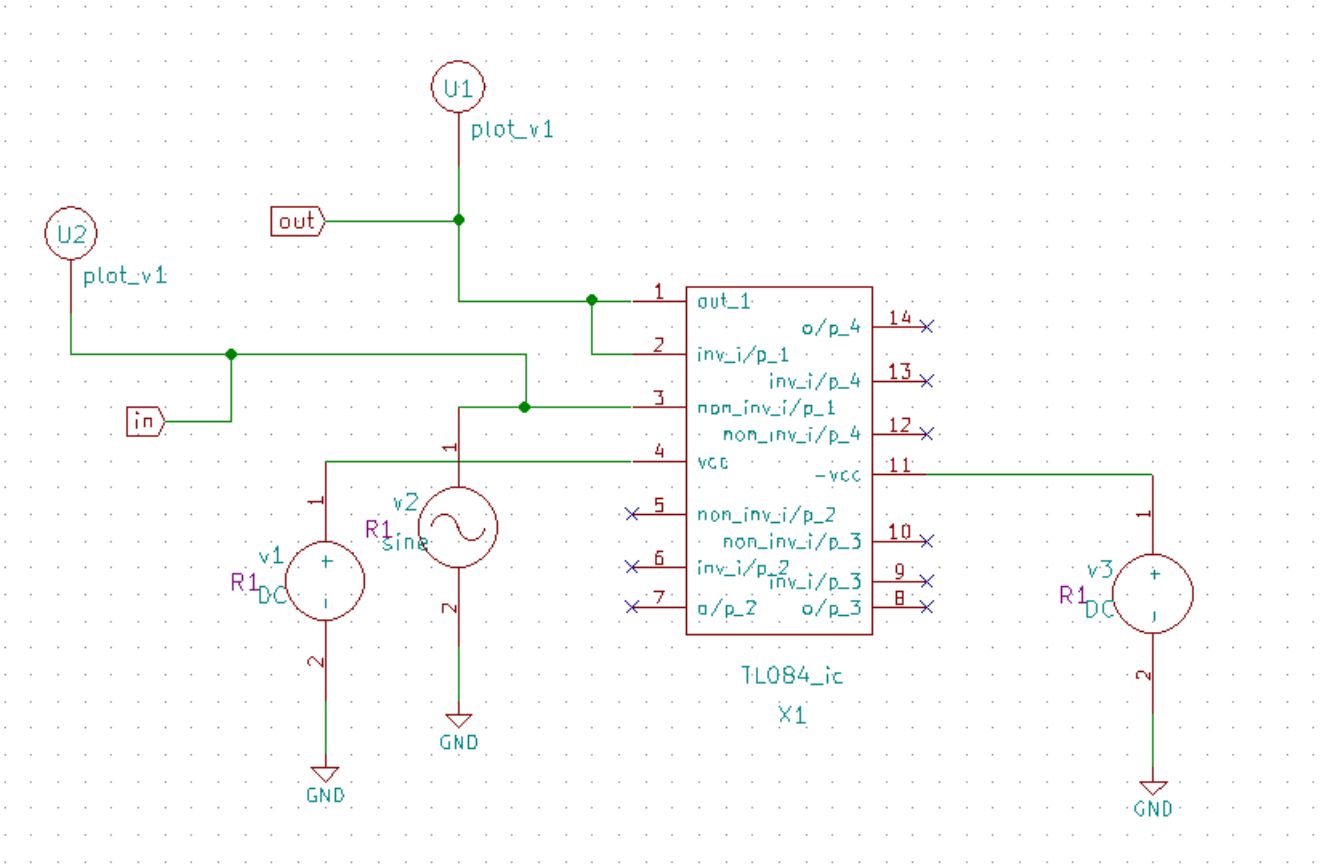


Figure 3.89: TL084 Test Circuit(Voltage follower)

3.19.4 Input Plot

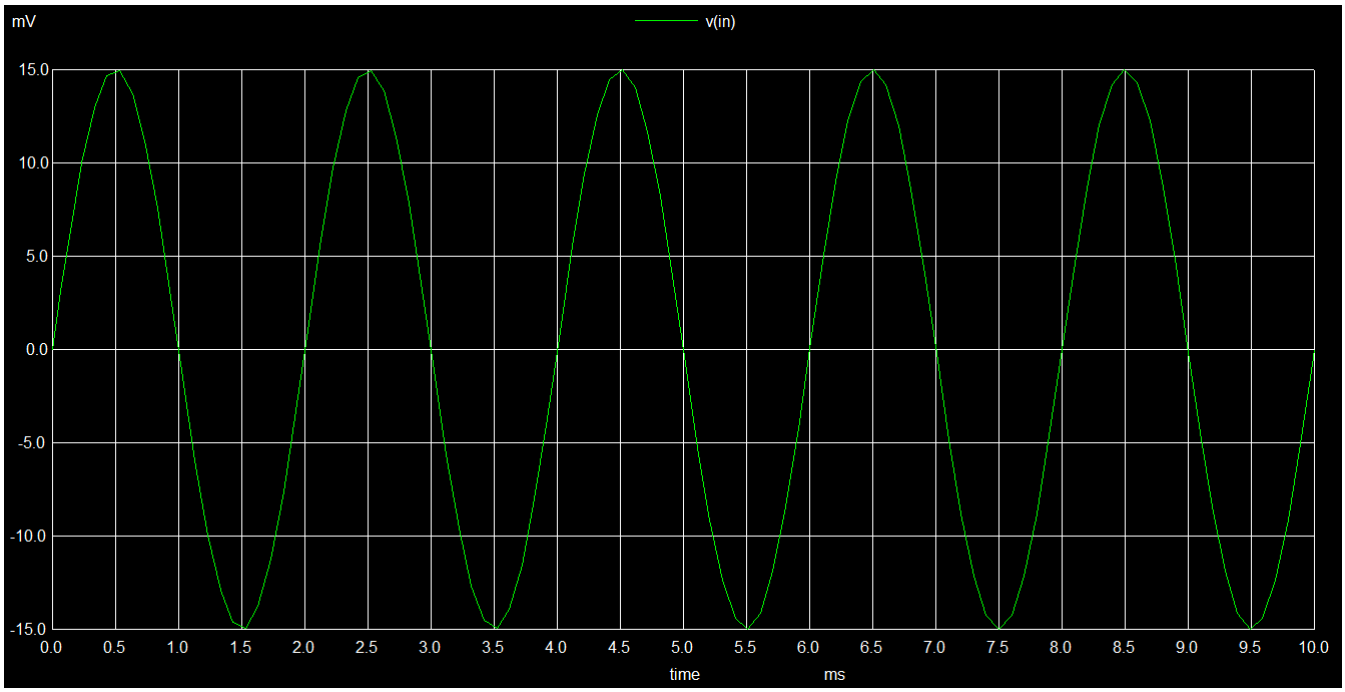


Figure 3.90: Input Sine Signal

3.19.5 Output Plot

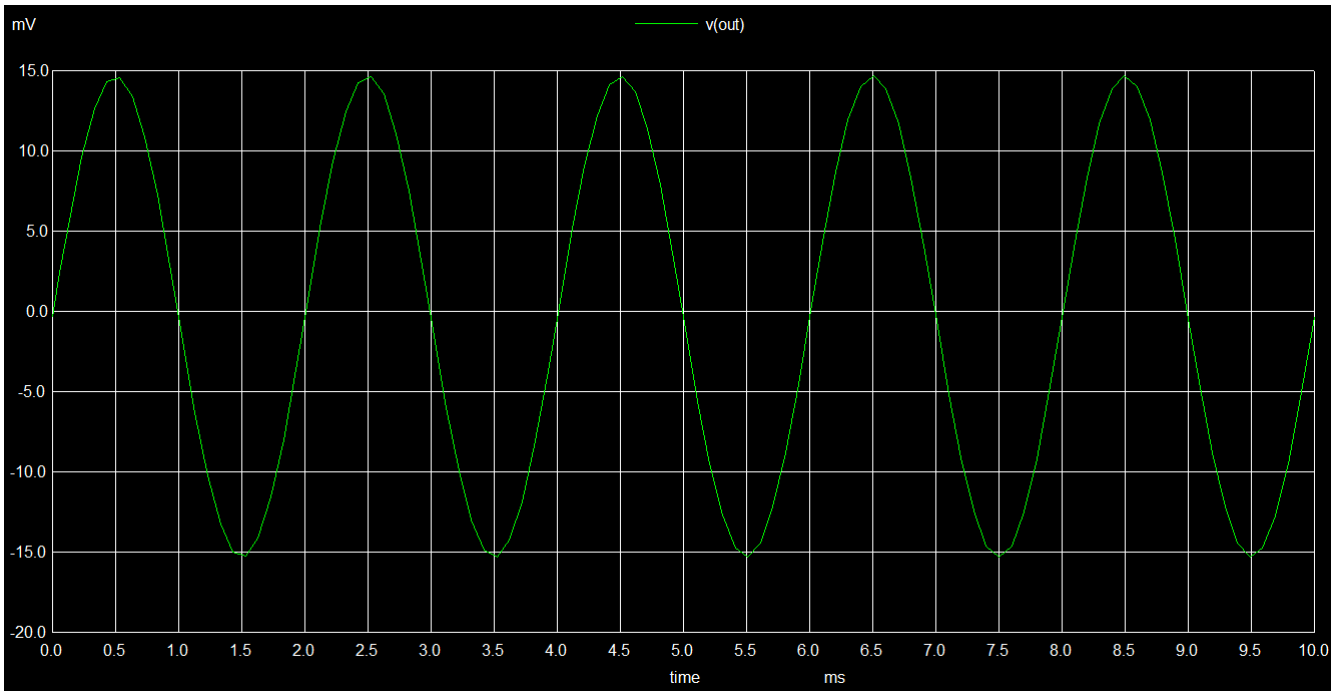


Figure 3.91: Output Signal

3.20 TL072 IC

The TL072, TL072A, and TL072B are high speed JFET input dual operational amplifiers incorporating well-matched, high-voltage JFET and bipolar transistors in a monolithic integrated circuit. The devices feature high slew rates, low input bias and offset current, and low offset voltage temperature coefficients.

3.20.1 Pin Configuration

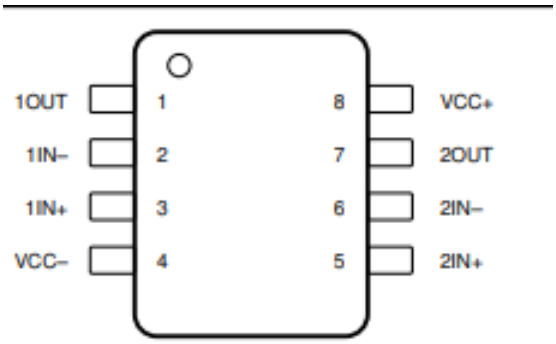


Figure 3.92: TL072 Pin Diagram

3.20.2 Subcircuit Schematics Diagram

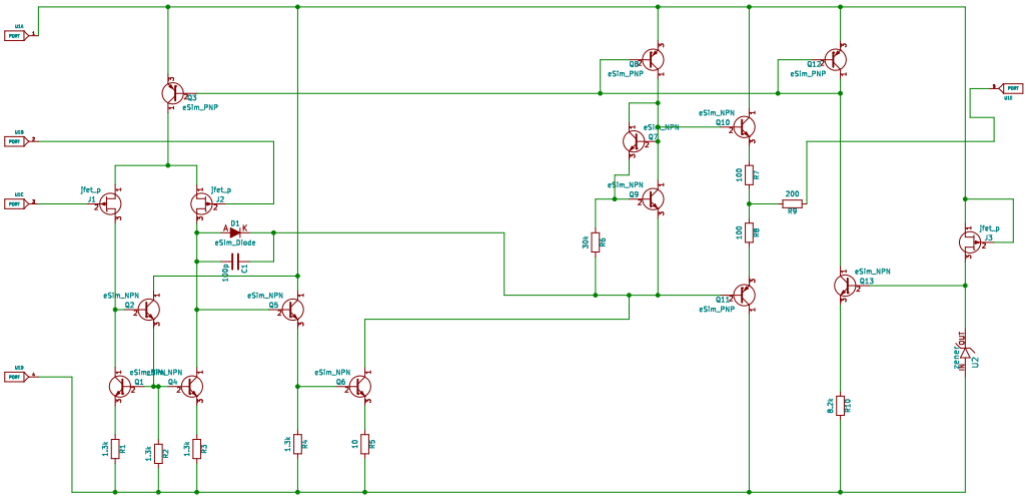


Figure 3.93: TL072 Schematics

3.20.3 Subcircuit test circuit

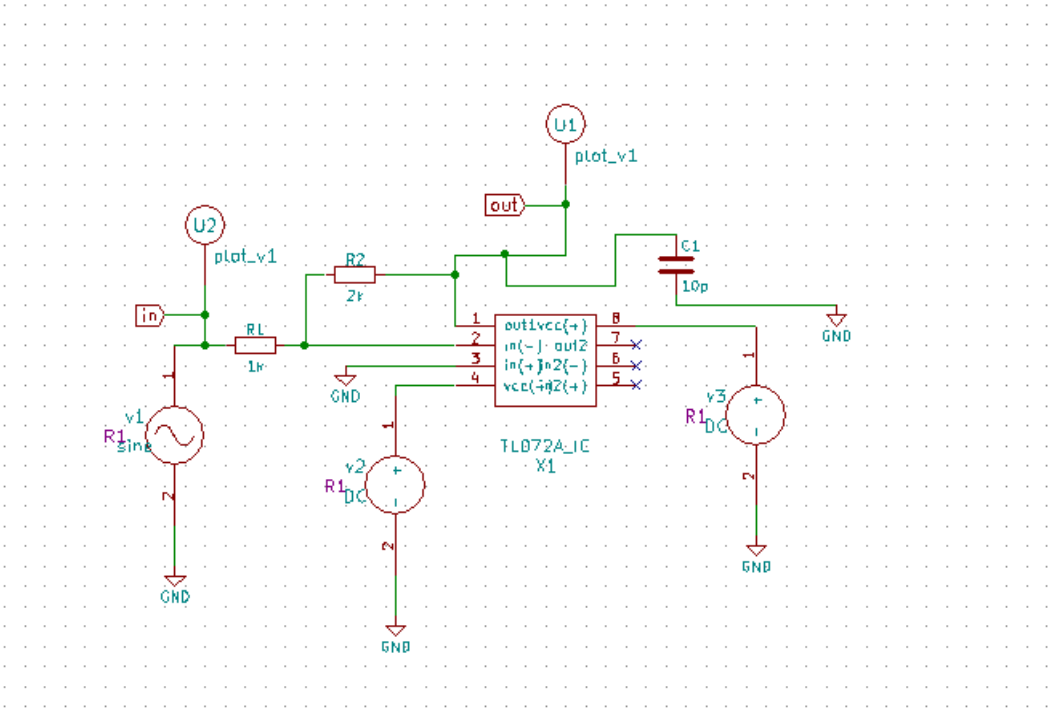


Figure 3.94: TL072 Test Circuit

3.20.4 Input Plot

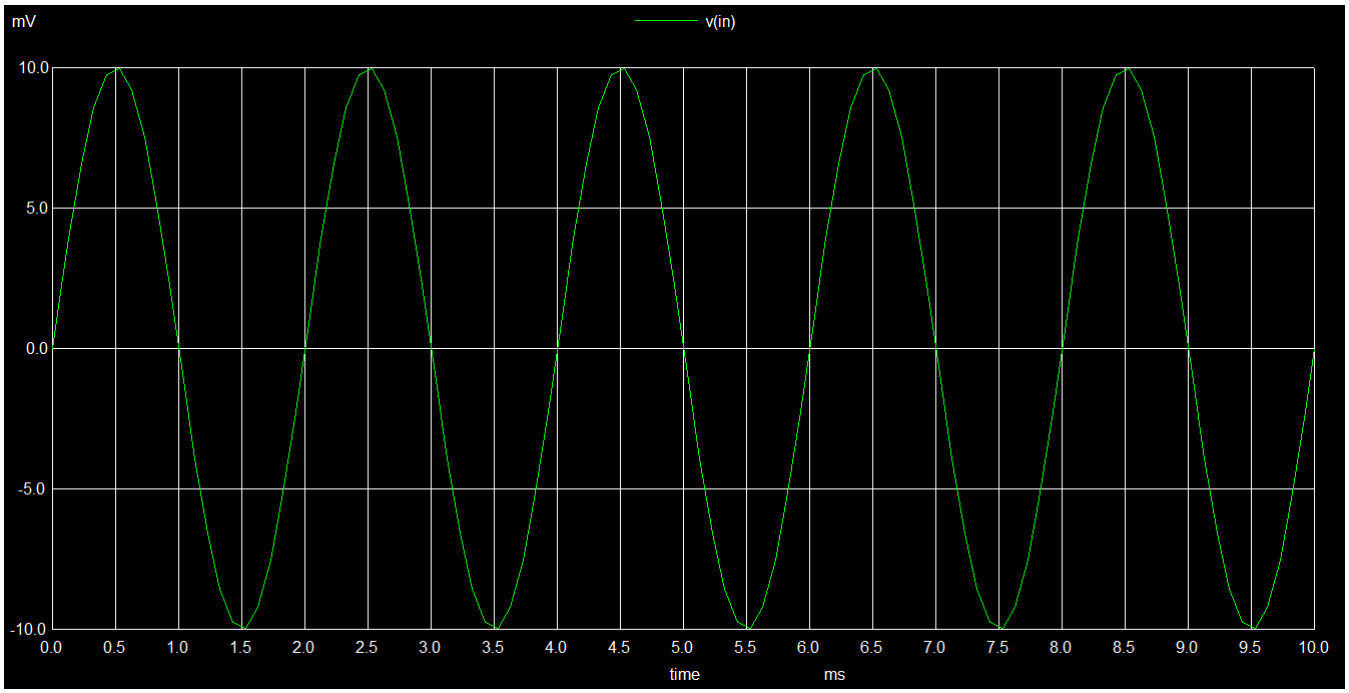


Figure 3.95: Input Sine Signal

3.20.5 Output Plot

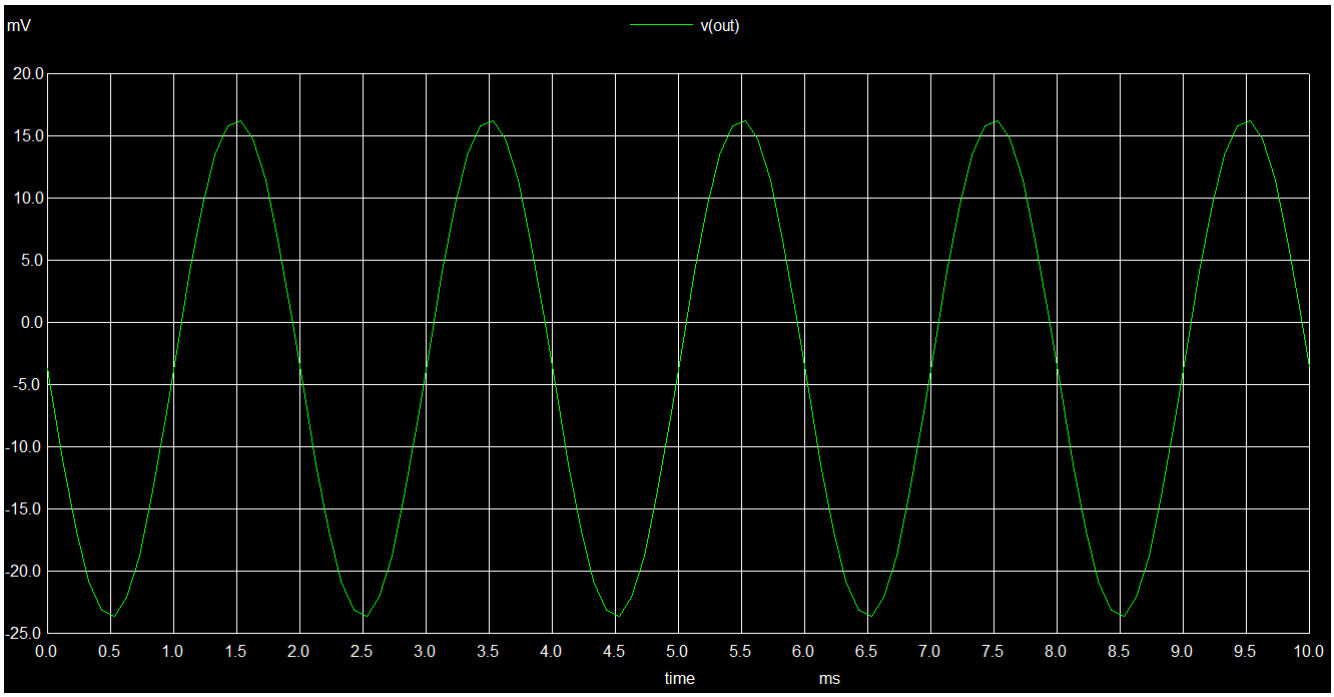


Figure 3.96: Output Signal

3.21 LF351 Operational Amplifier IC

LF351 is high speed JFET input single operational amplifiers incorporating well matched, high voltage JFET and bipolar transistors in a monolithic integrated circuit.The devices feature high slew rates, low input bias and offset currents, and low offset voltage temperature coefficient

3.21.1 Pin Configuration

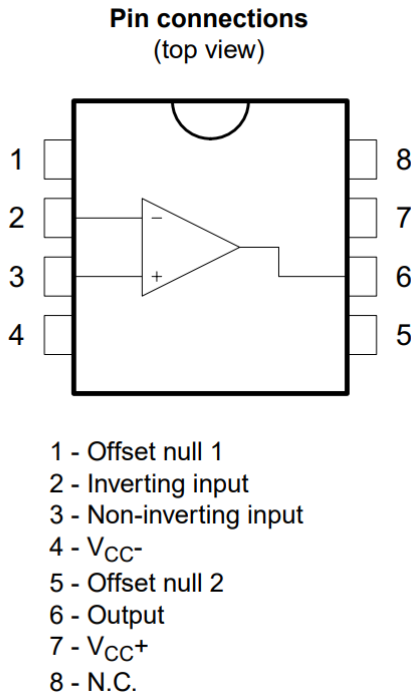


Figure 3.97: LF351 Pin Diagram

3.21.2 Subcircuit Schematics Diagram

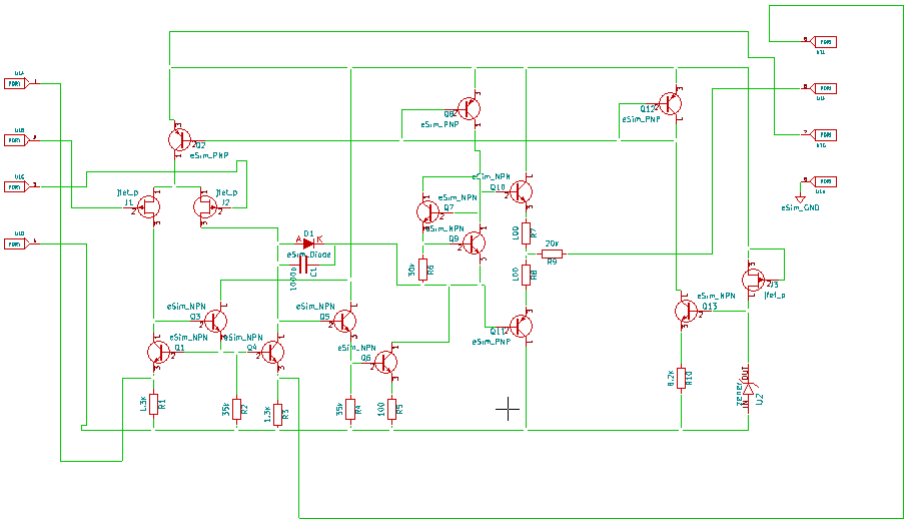


Figure 3.98: LF351 Schematics

3.21.3 Subcircuit test circuit

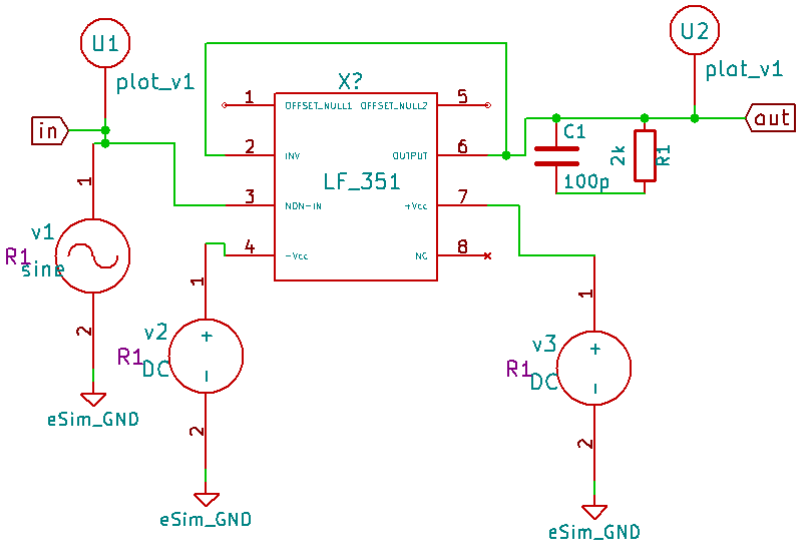


Figure 3.99: LF351 Test Circuit(Voltage Buffer)

3.21.4 Input Plot

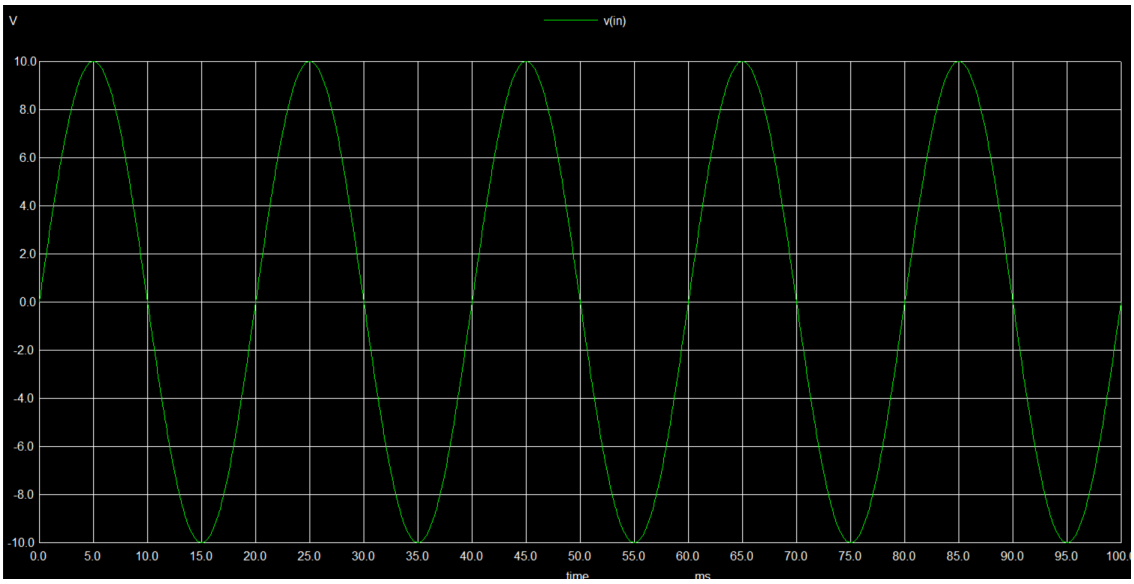


Figure 3.100: Input Signal

3.21.5 Output Plot

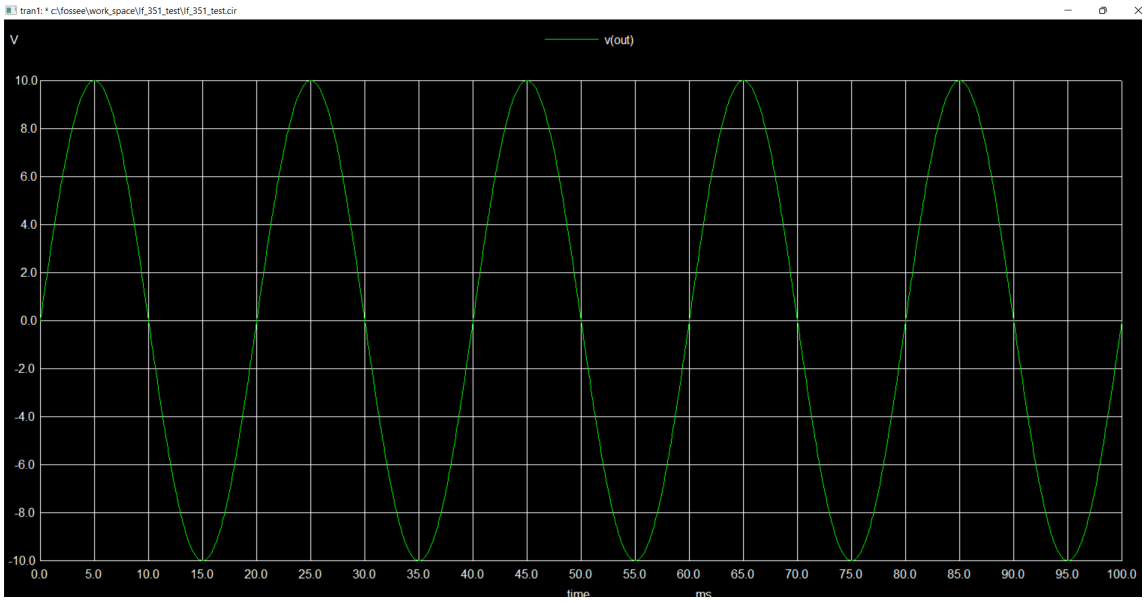


Figure 3.101: Output Signal

3.22 ULN2001 Seven Darlington arrays IC

The ULN2001, ULN2002, ULN2003 and ULN 2004 are high-voltage, high-current Darlington arrays each containing seven open collector Darlington pairs with common emitters. Each channel is rated at 500 mA and can withstand peak currents of 600 mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout.

3.22.1 Pin Configuration

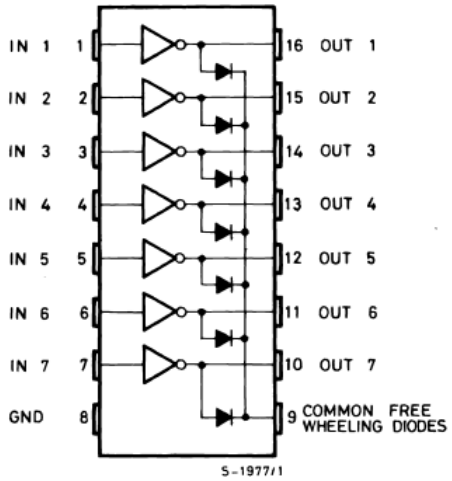


Figure 3.102: ULN Pin Diagram

3.22.2 Subcircuit Schematics Diagram

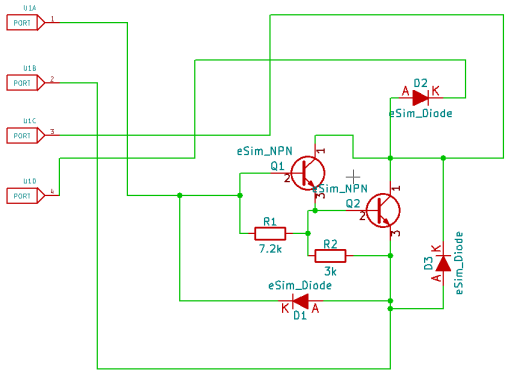


Figure 3.103: ULN2001 Schematic of a single pair

3.22.3 Subcircuit test circuit

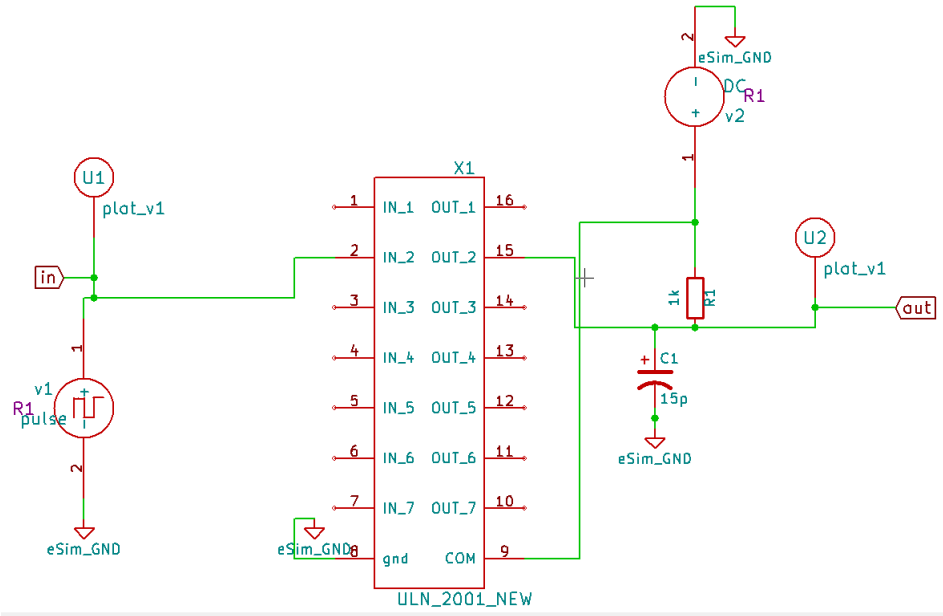


Figure 3.104: ULN2001 Test Circuit(Driver Circuit)

3.22.4 Input Plot

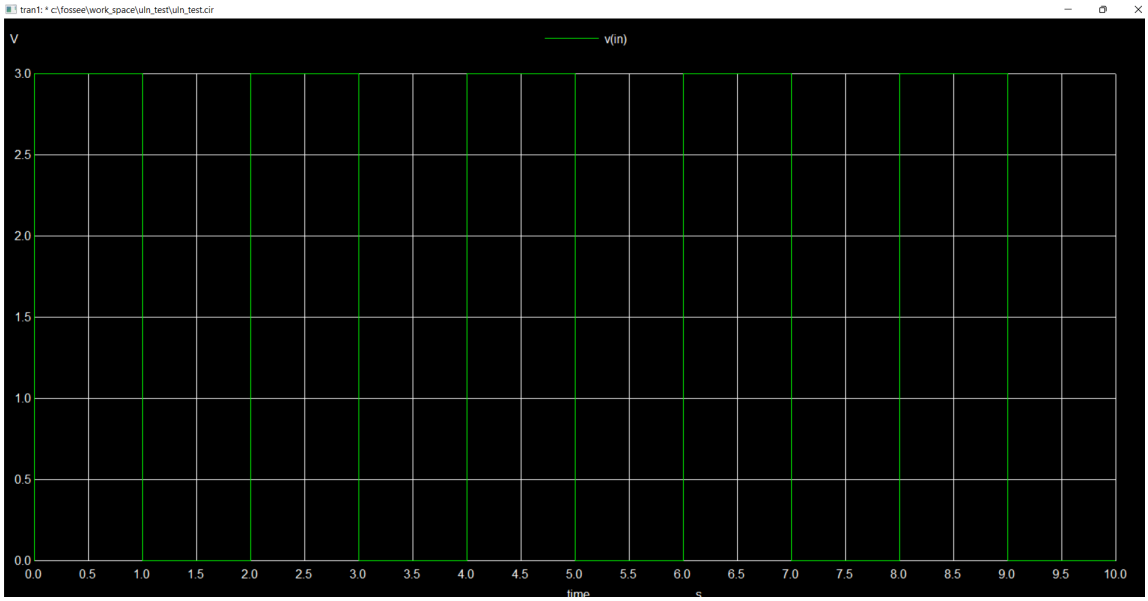


Figure 3.105: Input Signal

3.22.5 Output Plot

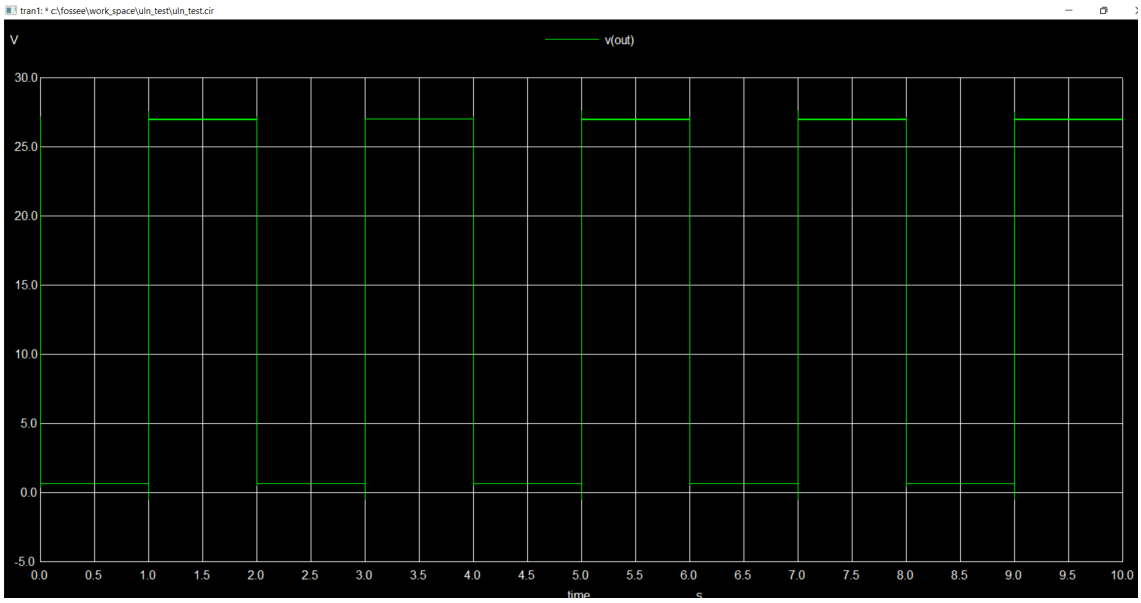


Figure 3.106: Output Signal

3.23 LM4040 Shunt voltage reference IC

The LM4040 series of shunt voltage references are versatile, easy-to-use references that cater to a vast array of applications. The 2-pin fixed-output device requires no external capacitors for operation and is stable with all capacitive loads. Additionally, the reference offers low dynamic impedance, low noise, and low temperature coefficient to ensure a stable output voltage over a wide range of operating currents and temperatures.

3.23.1 Pin Configuration

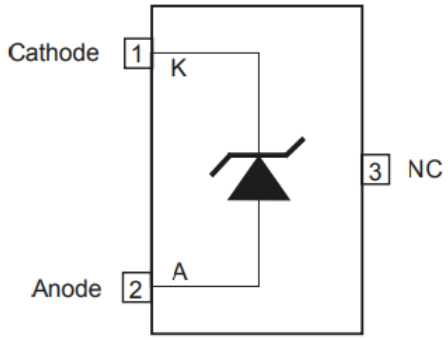


Figure 3.107: LM4040 Pin Diagram

3.23.2 Subcircuit Schematics Diagram

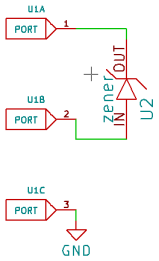


Figure 3.108: LM4040 Schematic of a single pair

3.23.3 Subcircuit test circuit

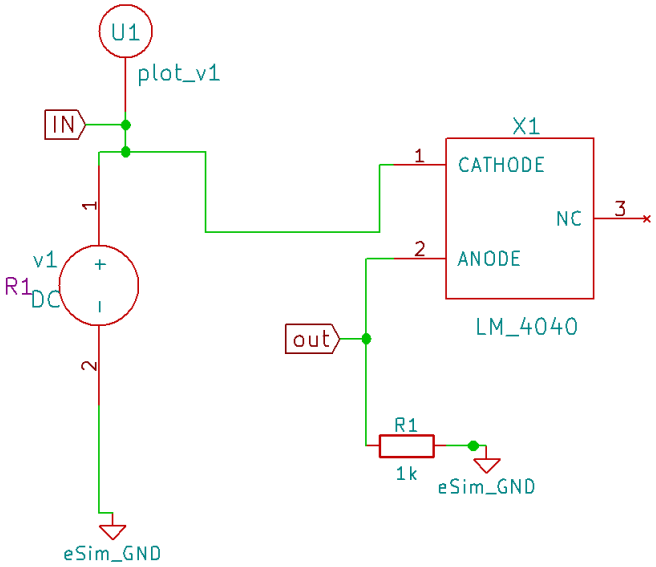


Figure 3.109: LM4040 Test Circuit

3.23.4 Input Plot

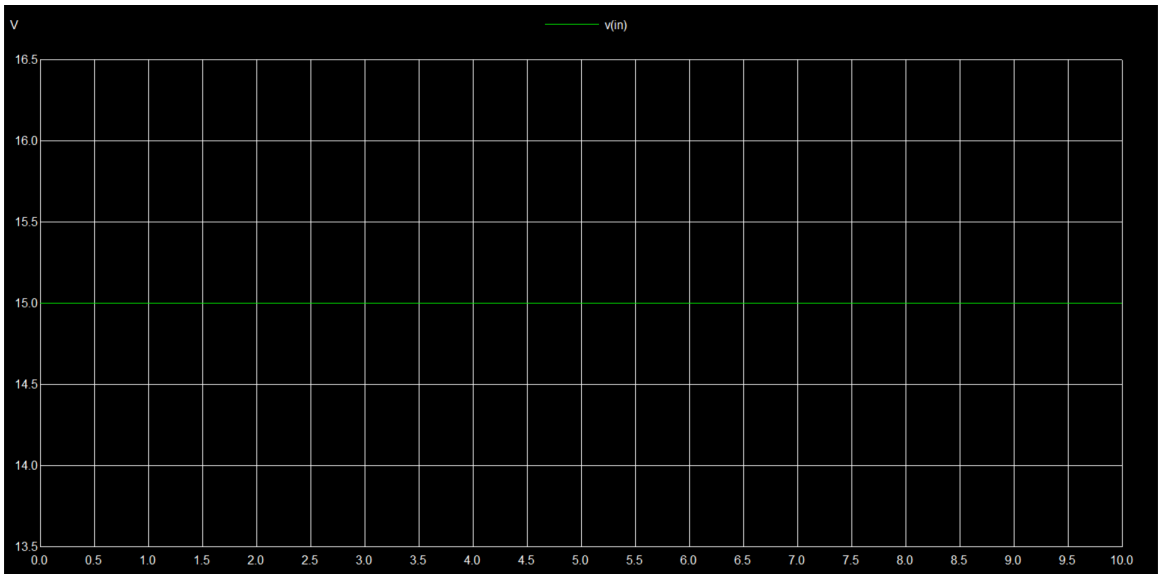


Figure 3.110: Input Signal

3.23.5 Output Plot

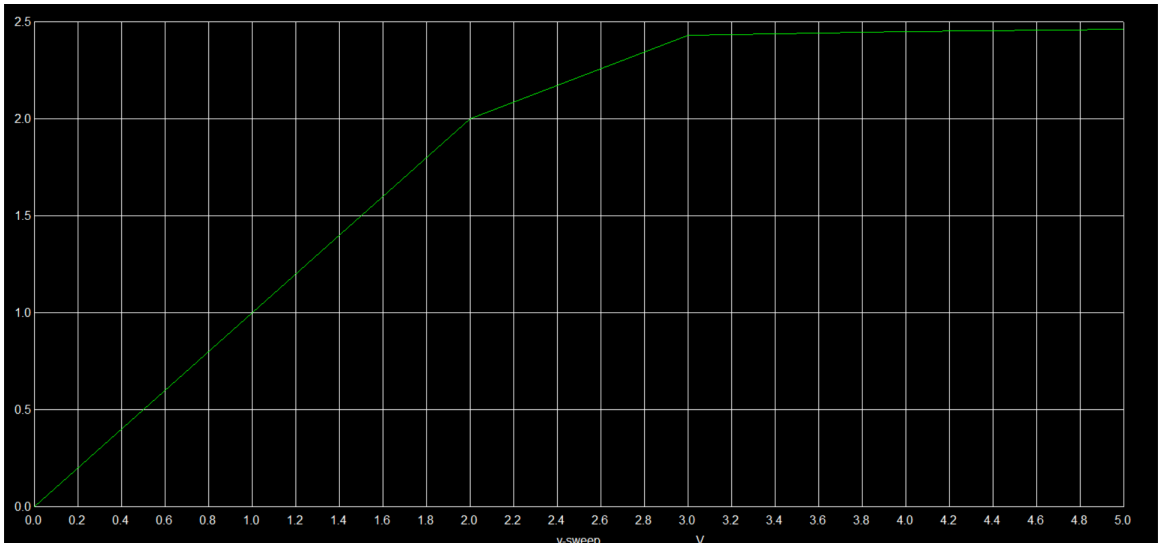


Figure 3.111: Output Signal

3.24 UC3611 Quad schottky diode array

This is a four-diode array designed for general purpose use as individual diodes or as a high-speed, high-current bridge. It is particularly useful on the outputs of high-speed power MOSFET drivers where Schottky diodes are needed to clamp any negative excursions caused by ringing on the driven line.These diodes are also ideally suited for use as voltage clamps when driving inductive loads such as relays and solenoids, and to provide a path for current free-wheeling in motor drive applications.

3.24.1 Pin Configuration

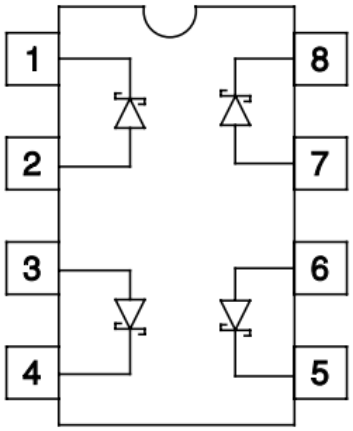


Figure 3.112: UC3611 Pin Diagram

3.24.2 Subcircuit Schematics Diagram

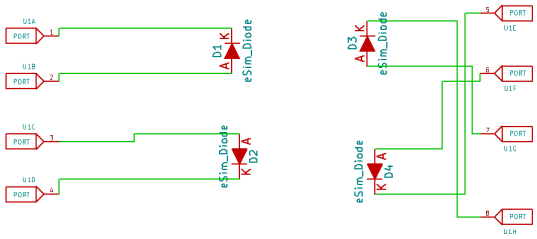


Figure 3.113: UC3611 Schematic of a single pair

3.24.3 Subcircuit test circuit

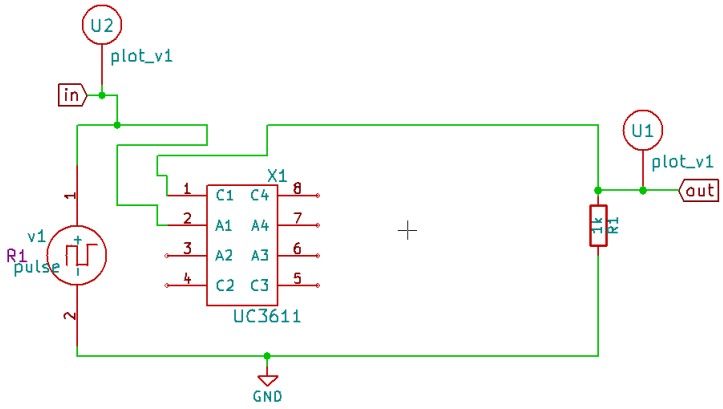


Figure 3.114: UC3611 Test Circuit

3.24.4 Input Plot

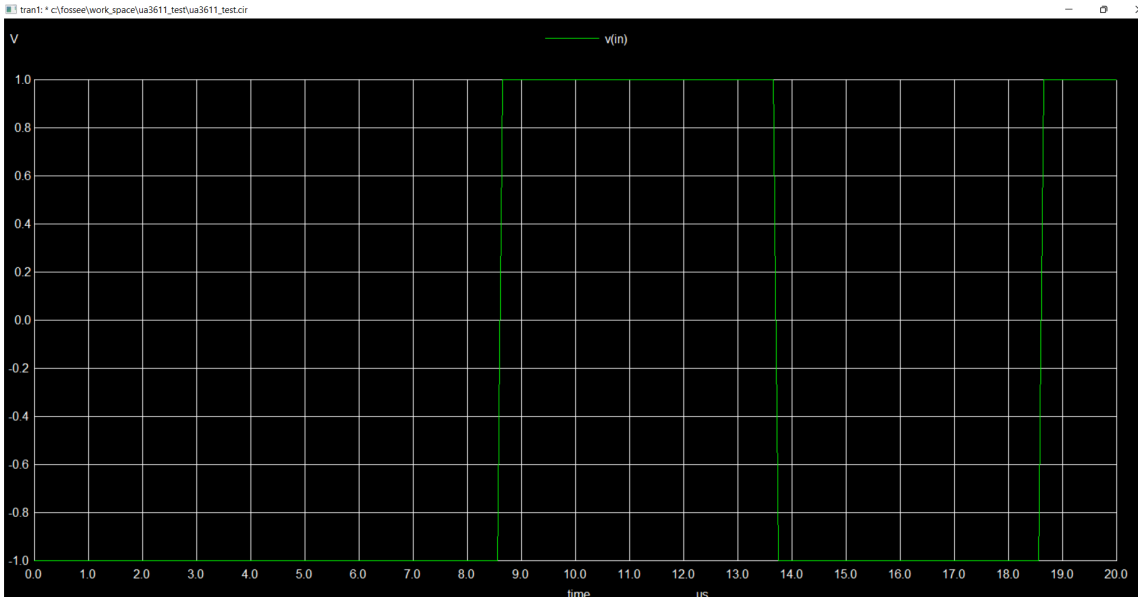


Figure 3.115: Input Signal

3.24.5 Output Plot

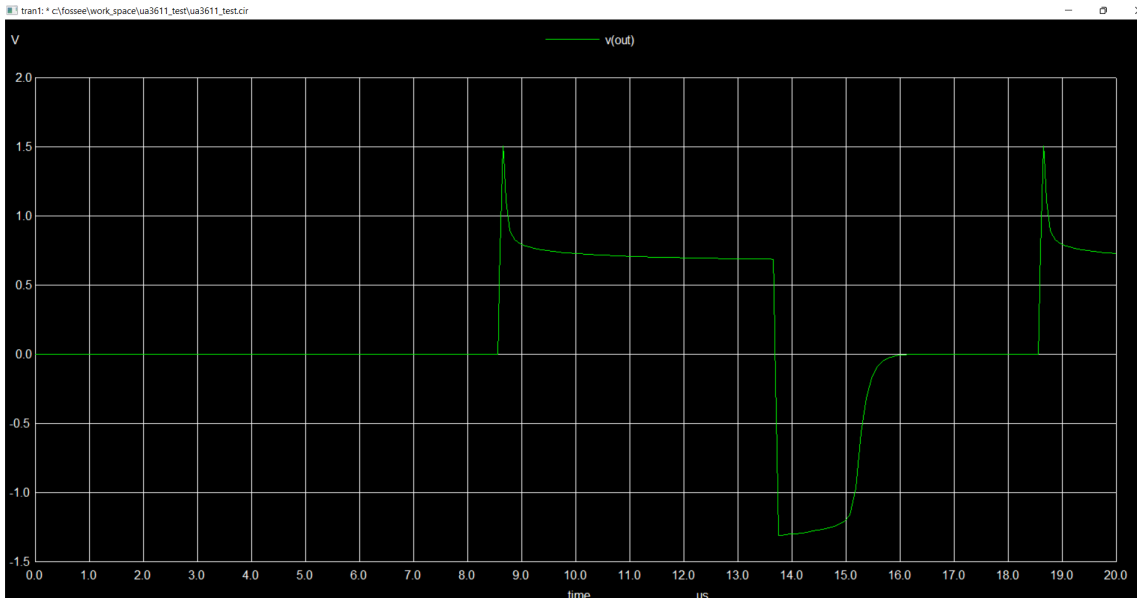


Figure 3.116: Output Signal

3.25 LM311 differential comparators

The LM311 devices are single high-speed voltage comparators. These devices are designed to operate from a wide range of power supply voltages, including 15-V supplies for operational amplifiers and 5-V supplies for logic systems. The output levels are compatible with most TTL and MOS circuits.

3.25.1 Pin Configuration

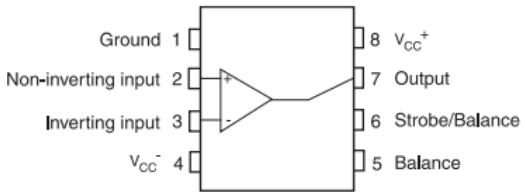


Figure 3.117: LM311 Pin Diagram

3.25.2 Subcircuit Schematics Diagram

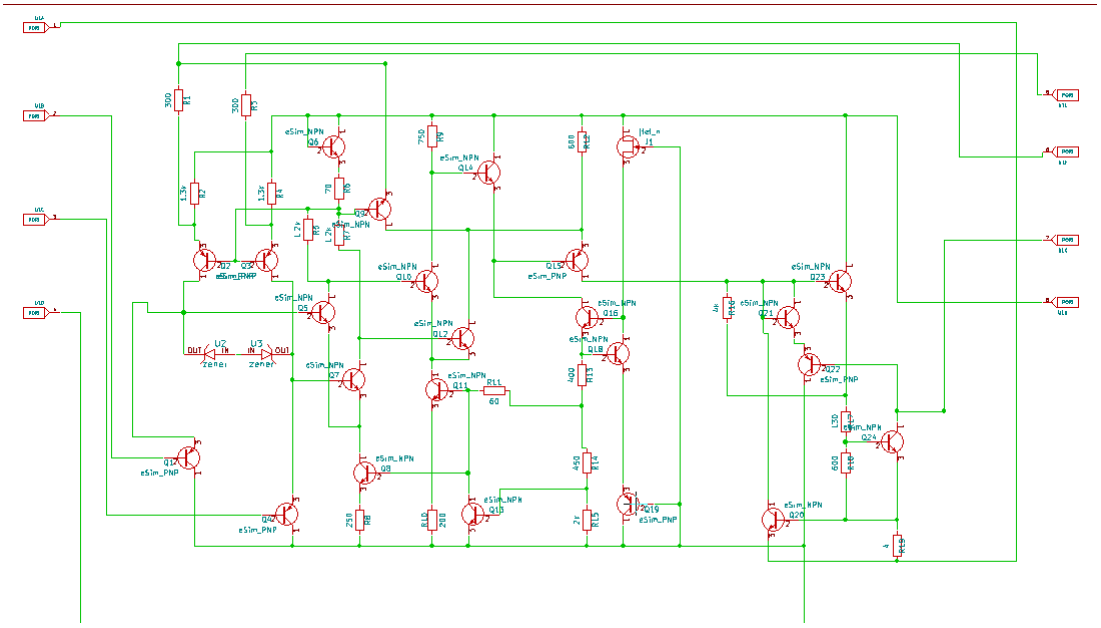


Figure 3.118: LM311 Schematic of a single pair

3.25.3 Subcircuit test circuit

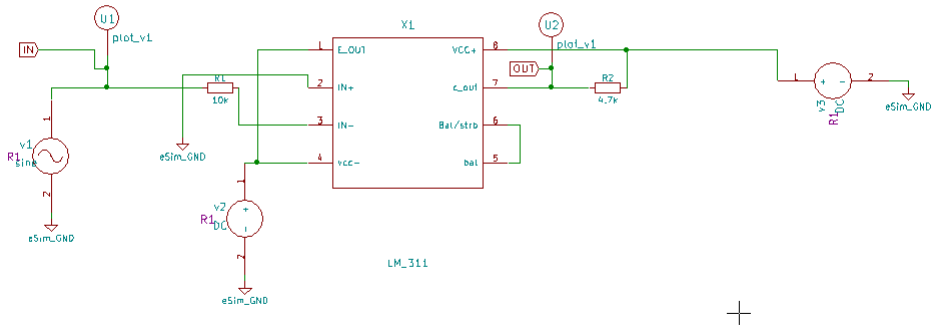


Figure 3.119: LM311 Test Circuit

3.25.4 Input Plot

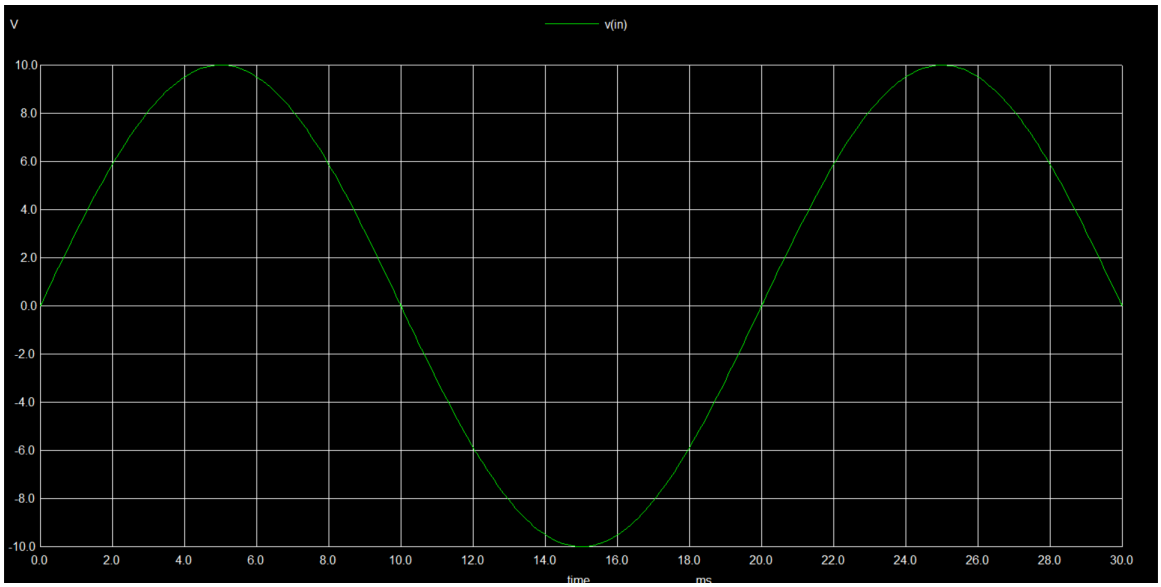


Figure 3.120: Input Signal

3.25.5 Output Plot

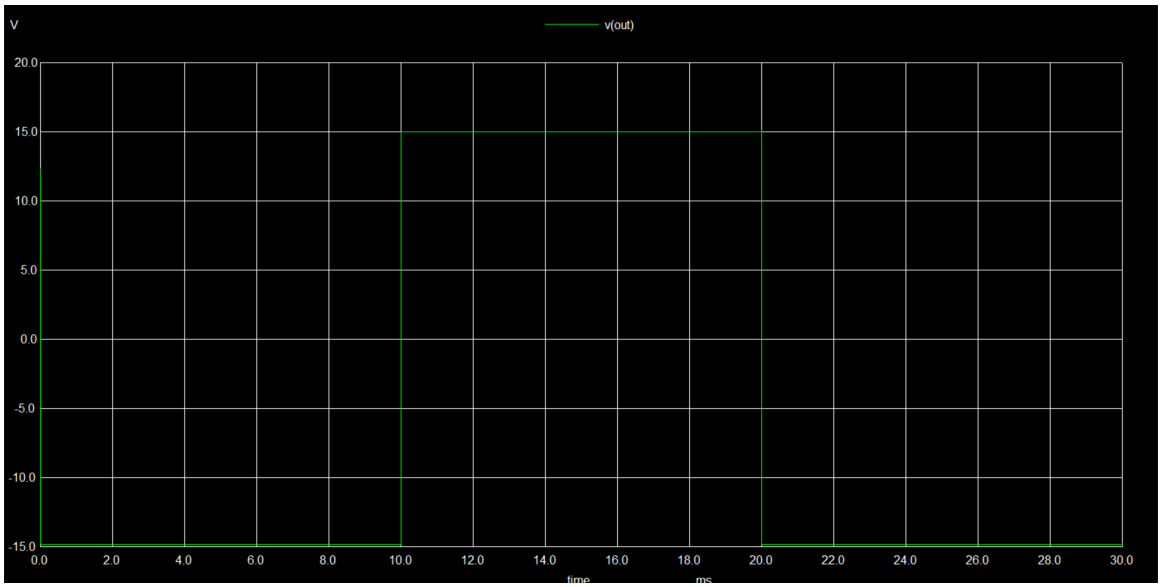


Figure 3.121: Output Signal

3.26 UC3610 Dual Schottky diode bridge

This eight-diode array is designed for high-current, low duty-cycle applications typical of flyback voltage clamping for inductive loads. The dual bridge connection makes this device particularly applicable to bipolar driven stepper motors

3.26.1 Pin Configuration

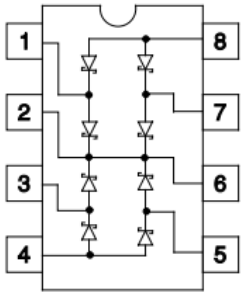


Figure 3.122: UC3610 Pin Diagram

3.26.2 Subcircuit Schematics Diagram

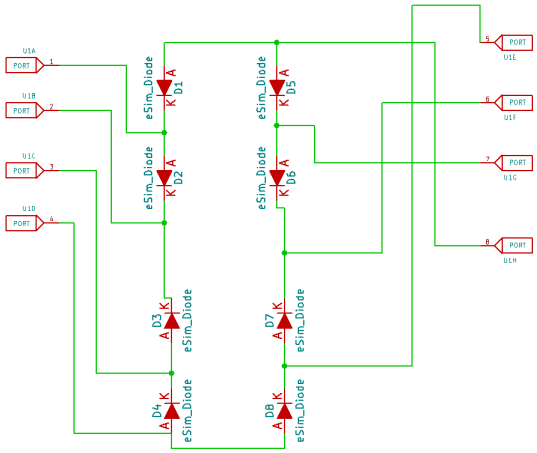


Figure 3.123: UC3610 Schematic

3.26.3 Subcircuit test circuit

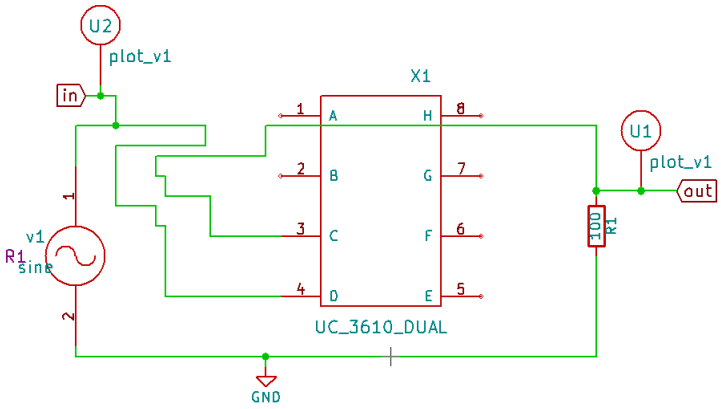


Figure 3.124: UC3610 Test Circuit - Half wave rectifier

3.26.4 Input Plot

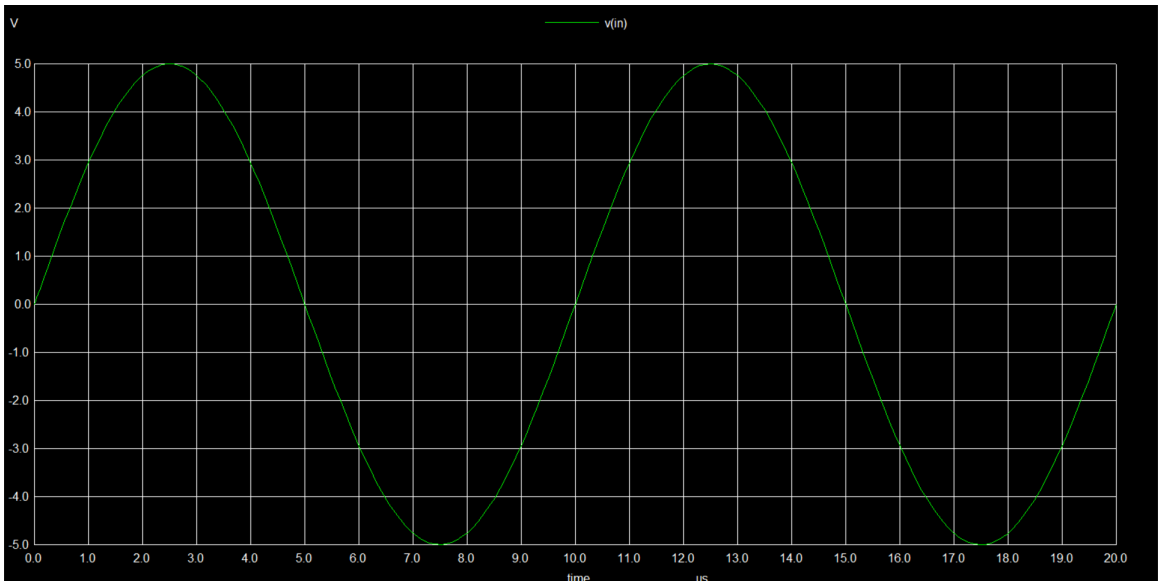


Figure 3.125: Input Signal

3.26.5 Output Plot

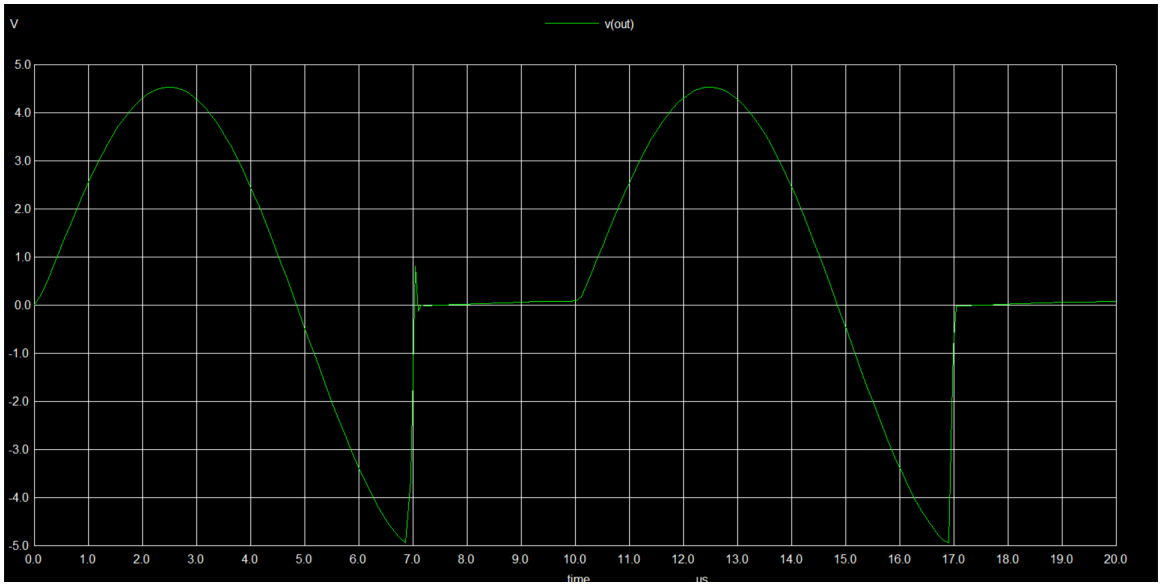


Figure 3.126: Output Signal

3.27 MC1458 Operational Amplifier

The MC1458 is a high-performance, monolithic, dual operational amplifier intended for a wide range of analog applications. The high gain and wide range of operating voltages provide superior performance in integrator, summing amplifiers, and general feedback applications.

3.27.1 Pin Configuration

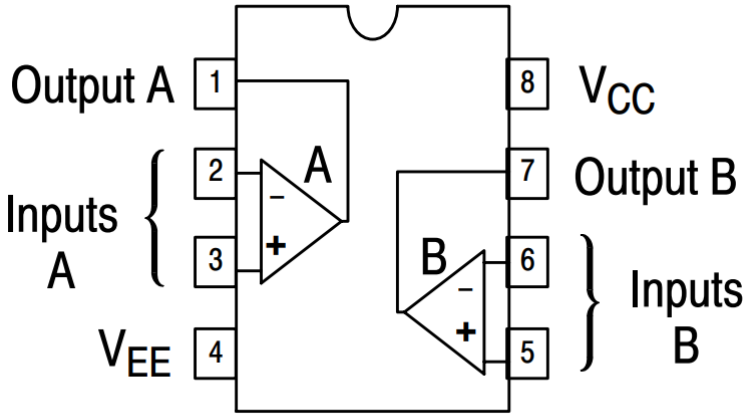


Figure 3.127: MC1458 Pin Diagram

3.27.2 Subcircuit Schematics Diagram

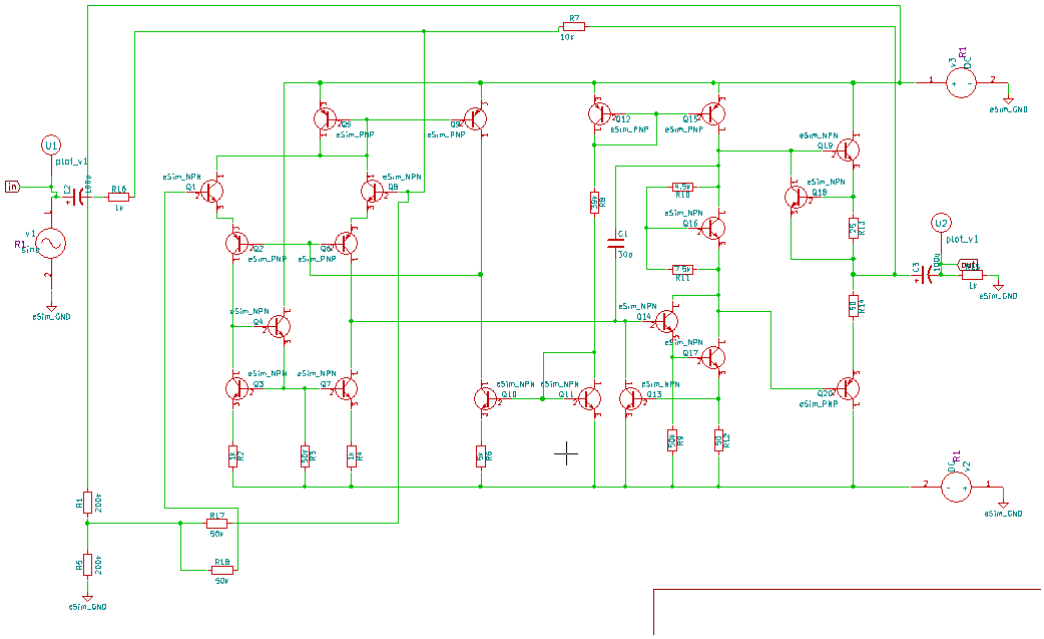


Figure 3.128: MC1458 Schematic of a single pair

3.27.3 Subcircuit test circuit

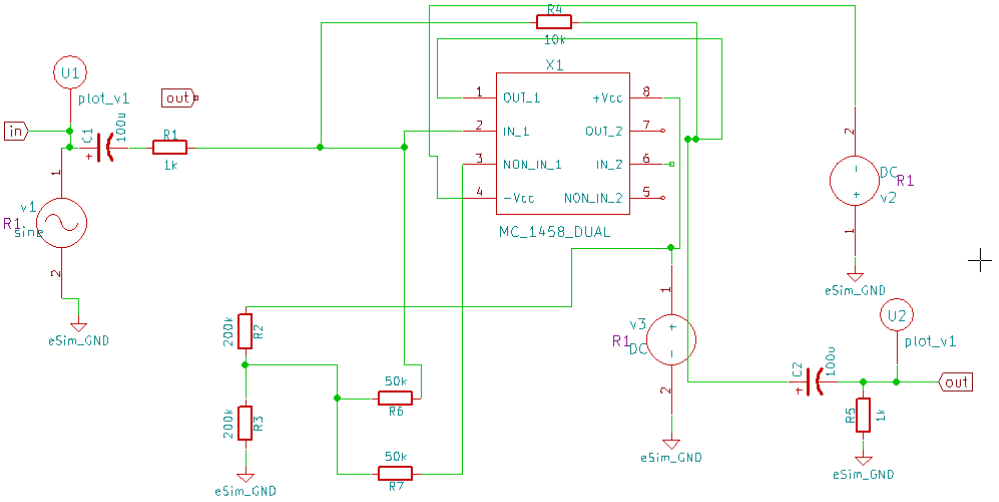


Figure 3.129: MC1458 Test Circuit

3.27.4 Input Plot

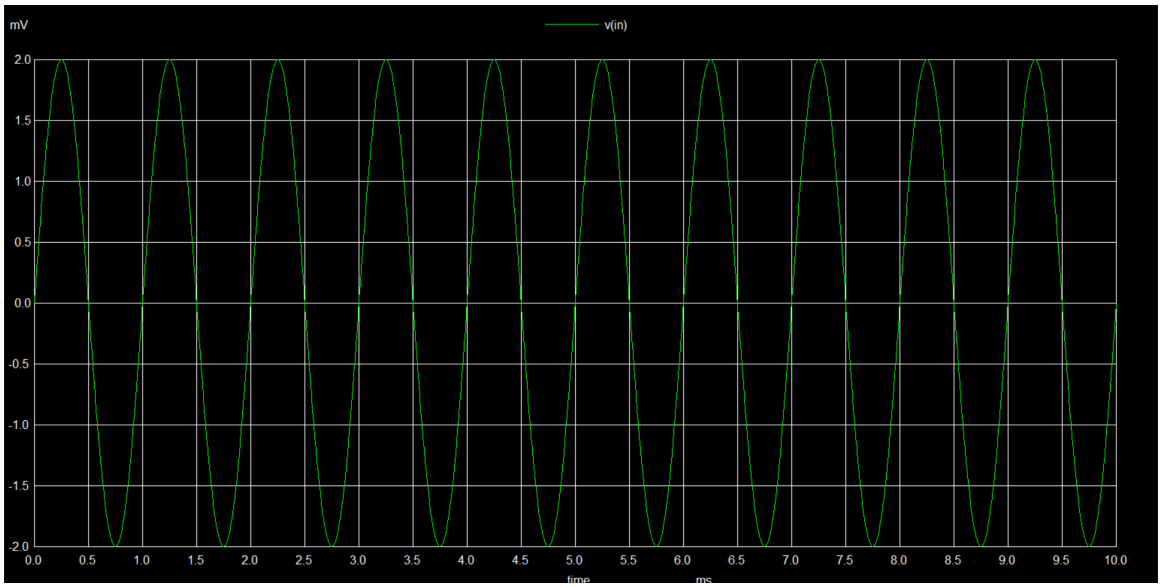


Figure 3.130: Input Signal

3.27.5 Output Plot

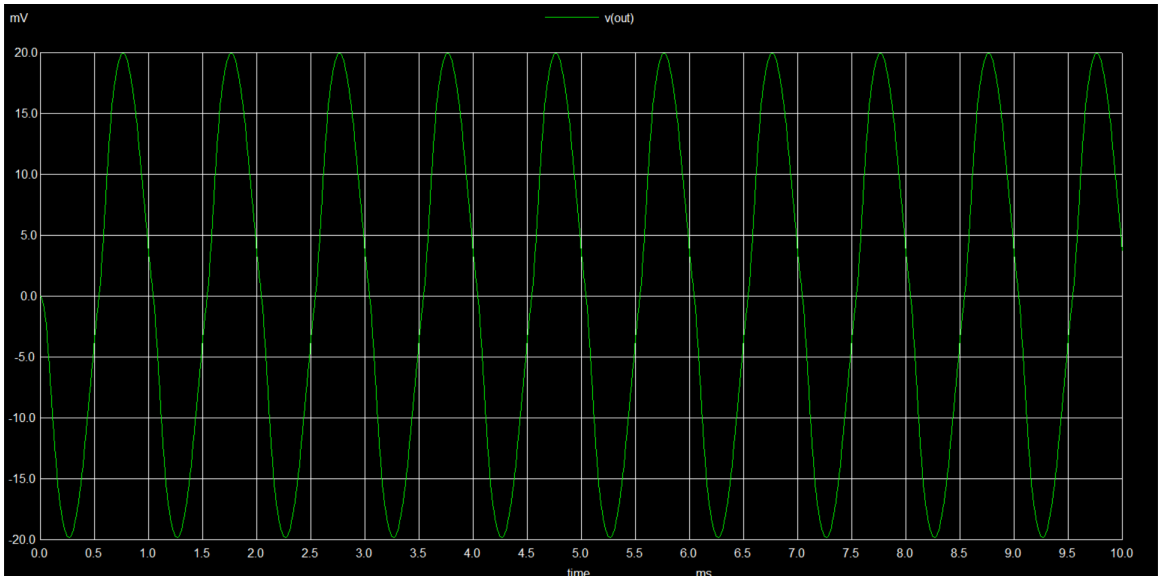


Figure 3.131: Output Signal

3.28 LM339 differential comparators

It consists of four independent precision-voltage comparators with an offset voltage specification as low as 2 mV maximum for LM339A, LM239A, and LM139A. Each comparator has been designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible. These comparators also have a unique characteristic in that the input common mode voltage range includes ground even though operated from a single power supply voltage

3.28.1 Pin Configuration

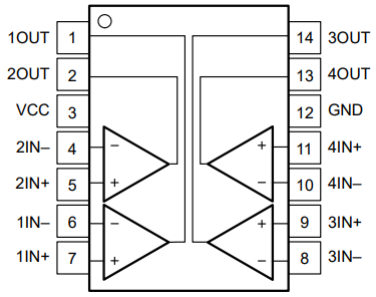


Figure 3.132: LM339 Pin Diagram

3.28.2 Subcircuit Schematics Diagram

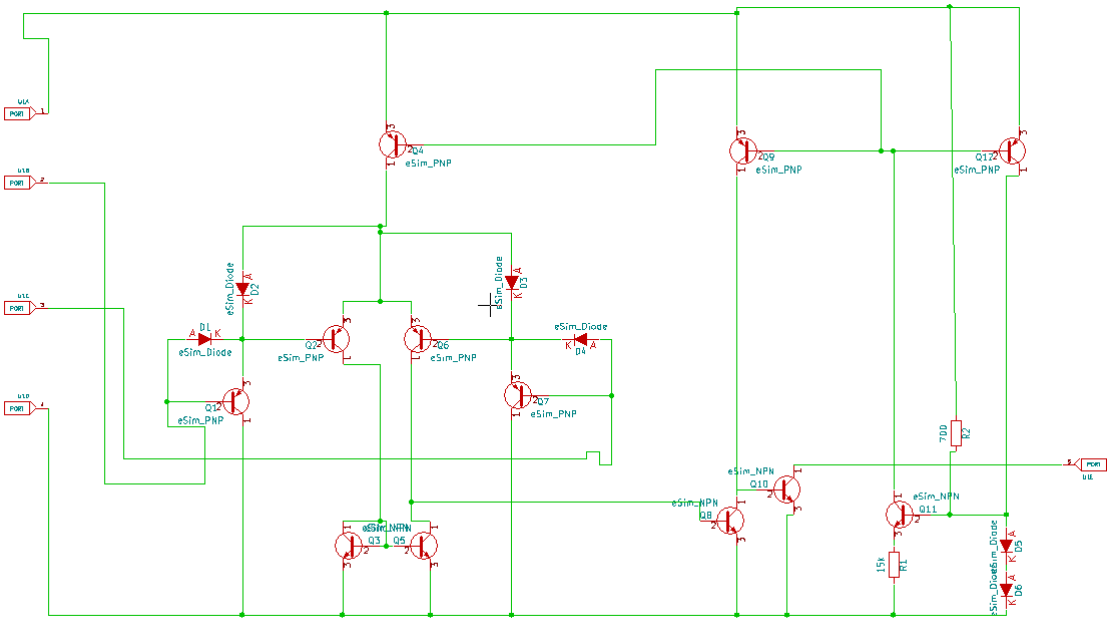


Figure 3.133: LM339 Schematic of a single pair

3.28.3 Subcircuit test circuit

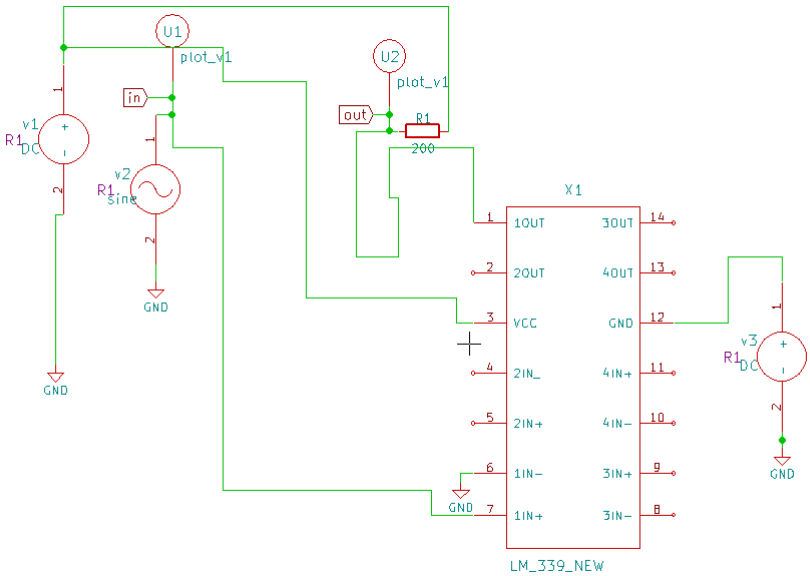


Figure 3.134: LM339 Test Circuit

3.28.4 Output Plot

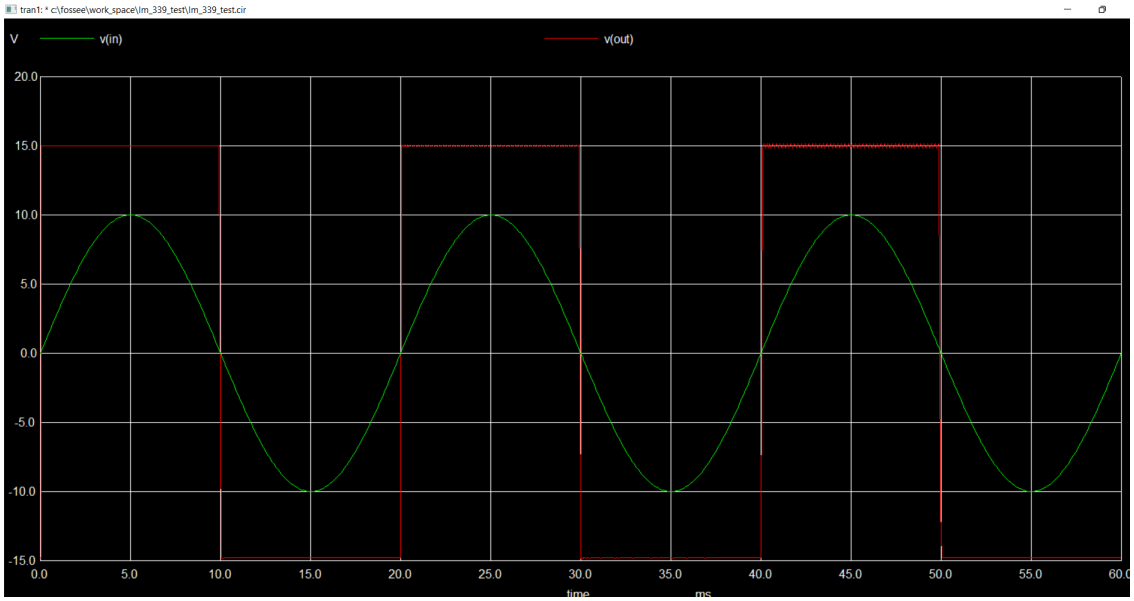


Figure 3.135: Output Signal

3.29 LF347 differential comparators

The LF347 is a low-cost, highspeed, JFET-input operational amplifiers. They require low supply current yet maintain a large gainbandwidth product and a fast slew rate. In addition, their matched high-voltage JFET inputs provide very low input bias and offset current.

3.29.1 Pin Configuration

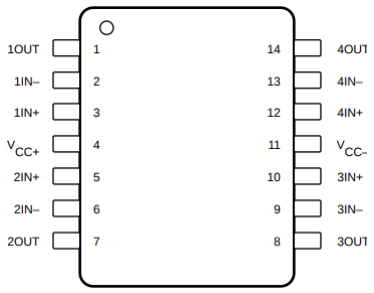


Figure 3.136: LF347 Pin Diagram

3.29.2 Subcircuit Schematics Diagram

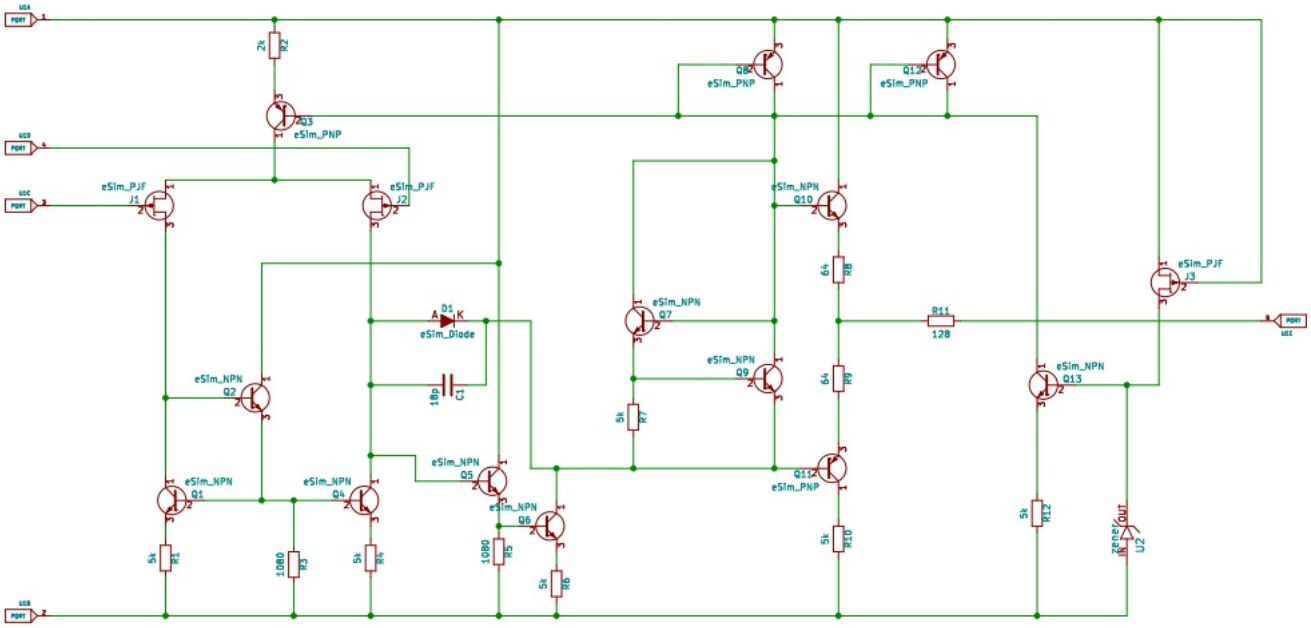


Figure 3.137: LF347 Schematic

3.29.3 Subcircuit test circuit

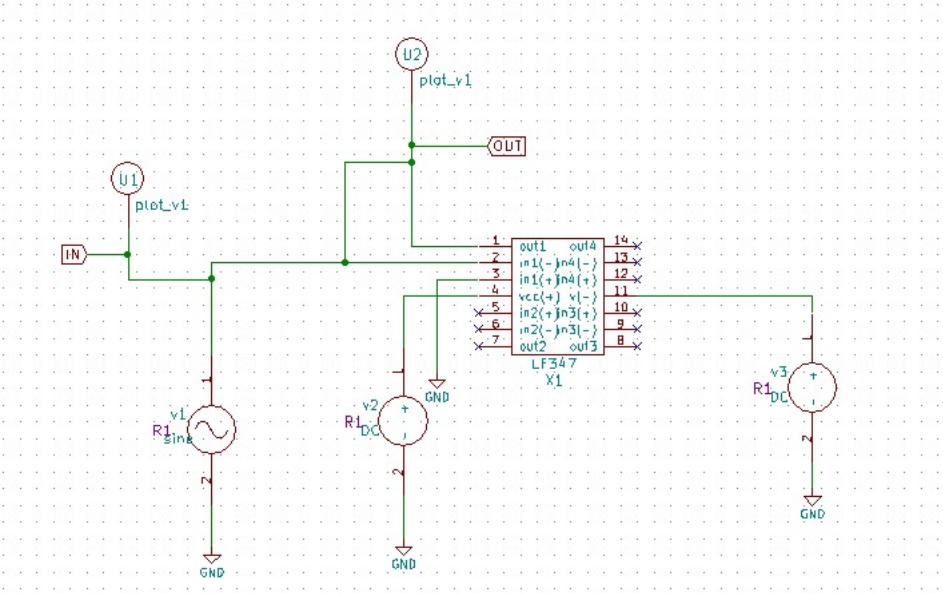


Figure 3.138: LF347 Test Circuit

3.29.4 Input Plot

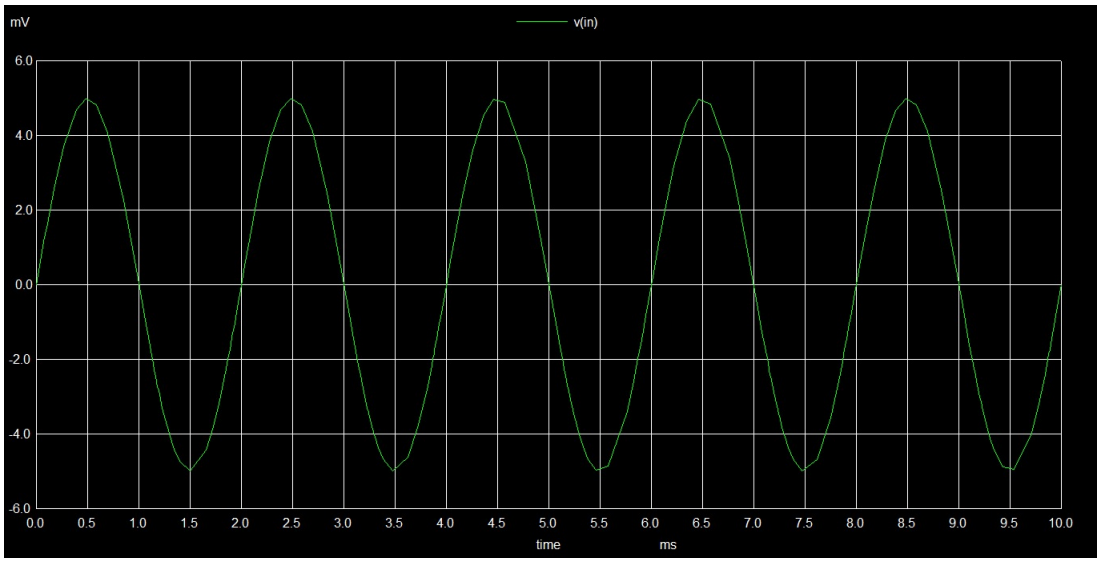


Figure 3.139: Input Signal

3.29.5 Output Plot

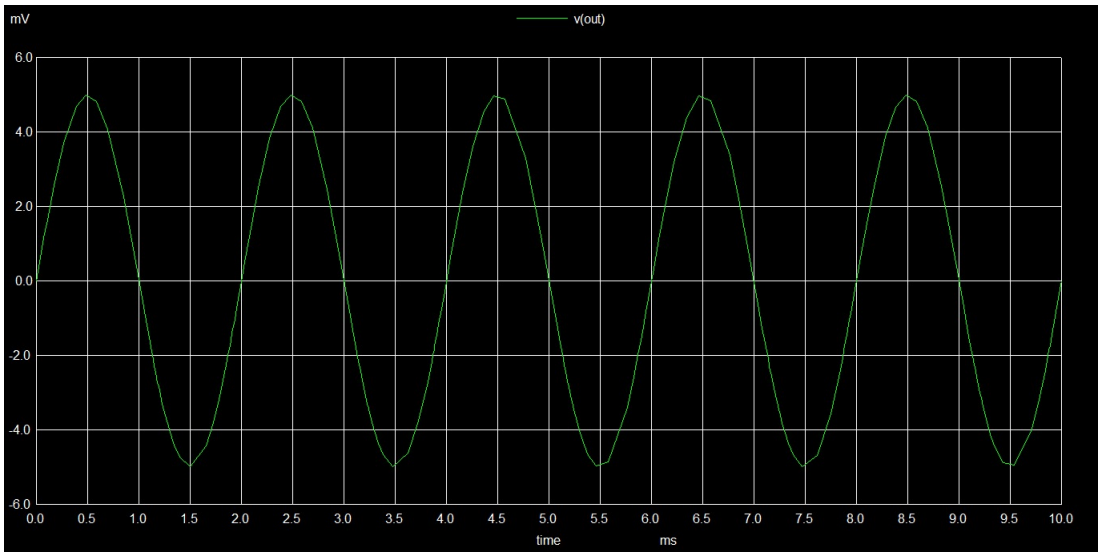


Figure 3.140: Output Signal

3.30 LM1596 Balanced Modulator-Demodulator

The LM1596 is a doubled balanced modulator-demodulators which produce an output voltage proportional to the product of an input (signal) voltage and a switching (carrier) signal. Typical applications include suppressed carrier modulation, amplitude modulation, synchronous detection, FM or PM detection, broadband frequency doubling and chopping.

3.30.1 Pin Configuration

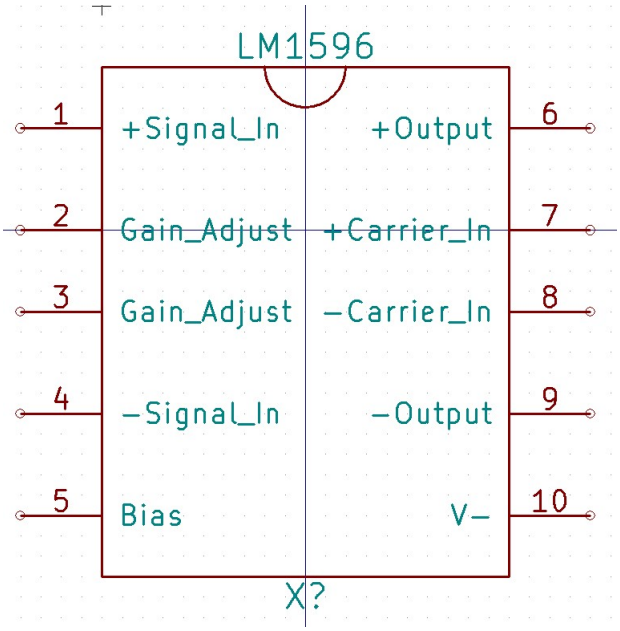


Figure 3.141: LM1596 Pin Diagram

3.30.2 Subcircuit Schematics Diagram

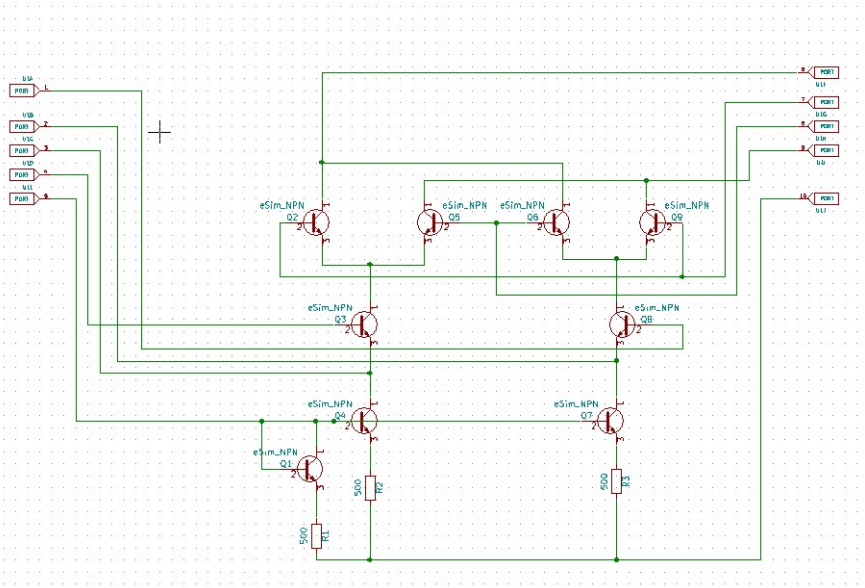


Figure 3.142: LM1596 Schematics

3.30.3 Subcircuit test circuit

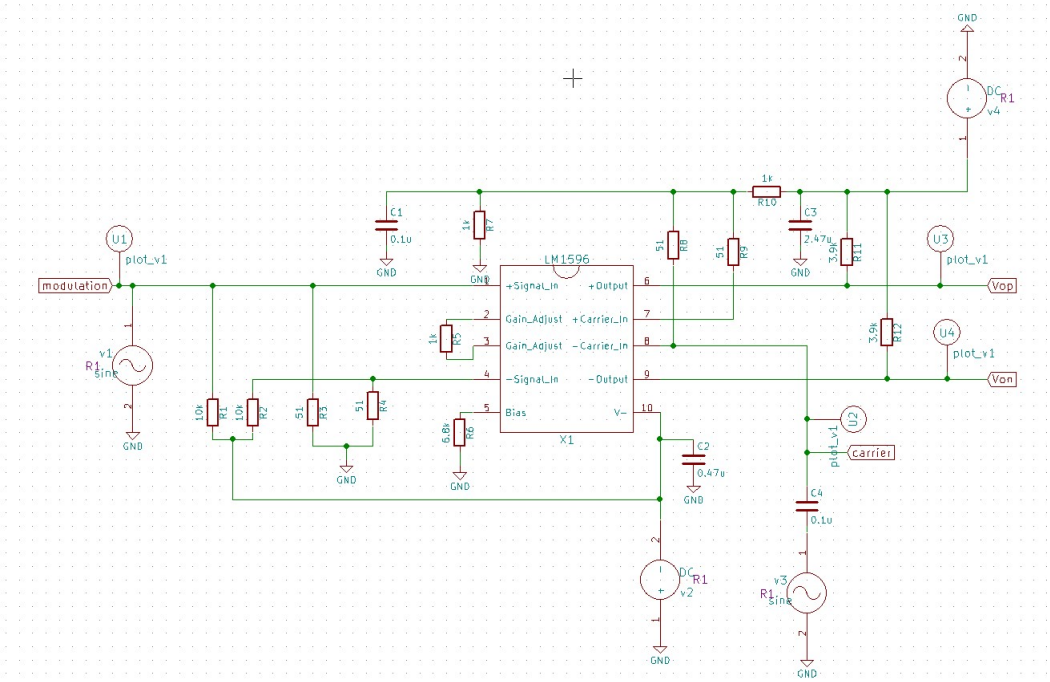


Figure 3.143: LM1596 Test Circuit(Suppressed Carrier Modulator)

3.30.4 Output Plot

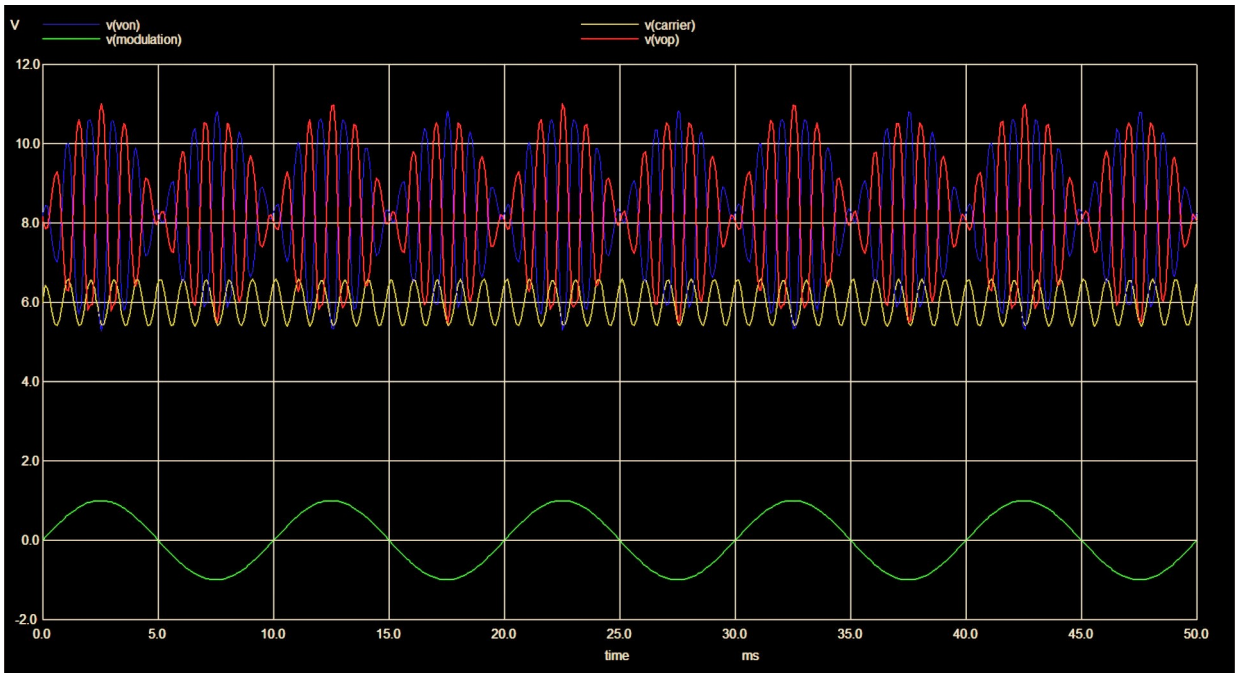


Figure 3.144: Output Suppressed Carrier Modulator

3.31 LM7905 3-Terminal Negative Regulator

The LM7905 is a 3-terminal regulators with fixed output voltage of 5V.These devices need only one external component a compensation capacitor at the output.

3.31.1 Pin Configuration

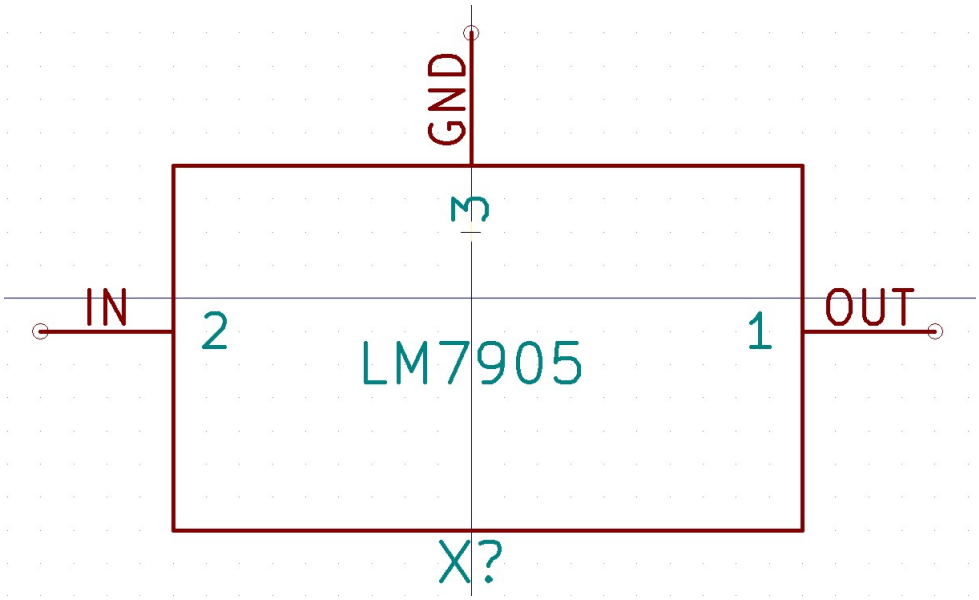


Figure 3.145: LM7905 Pin Diagram

3.31.2 Subcircuit Schematics Diagram

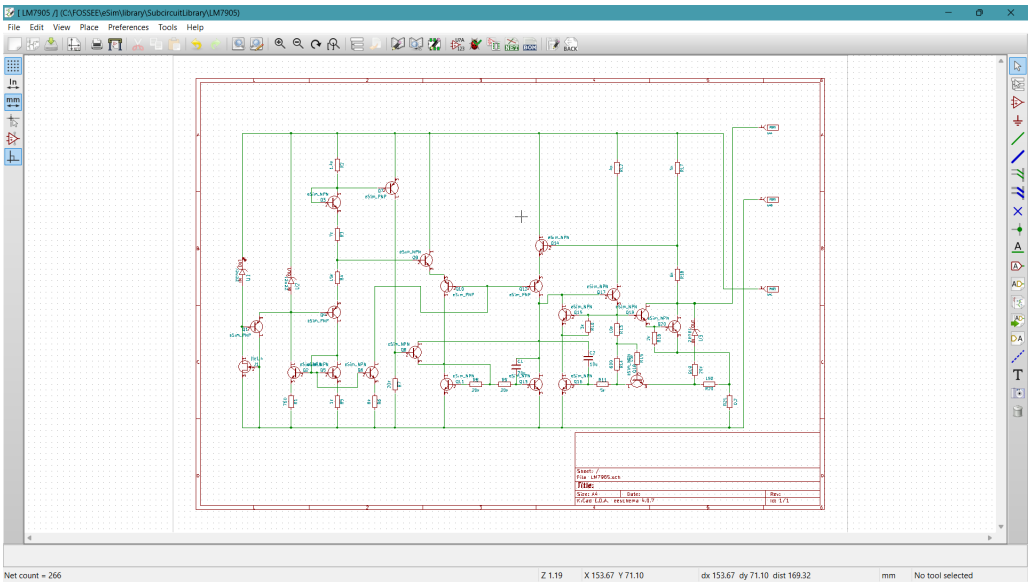


Figure 3.146: LM7905 Schematics

3.31.3 Subcircuit test circuit

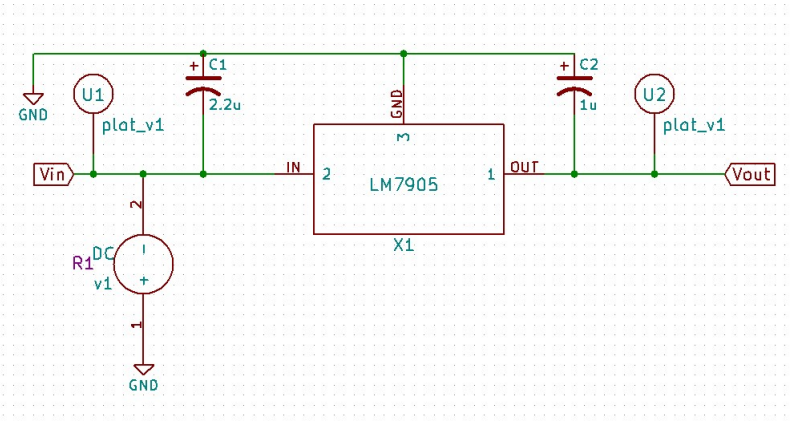


Figure 3.147: LM7905 Test Circuit(Fixed Regulator -5V)

3.31.4 Output Plot

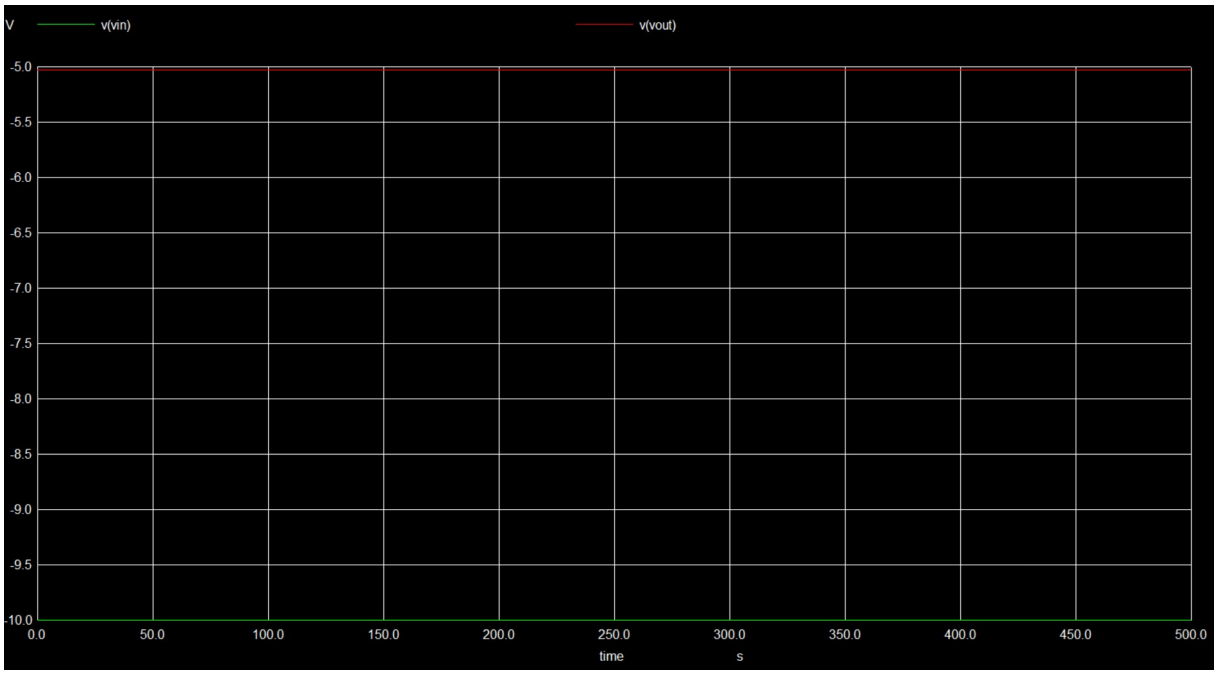


Figure 3.148: Output Fixed Regulator -5V

3.32 LM139 Quad Differential Comparator

This family of devices consists of four independent precision-voltage comparators with an offset voltage specification as low as 2 mV.Each comparator has been designed specifically to operate from a single power supply over a wide range of voltages.

3.32.1 Pin Configuration

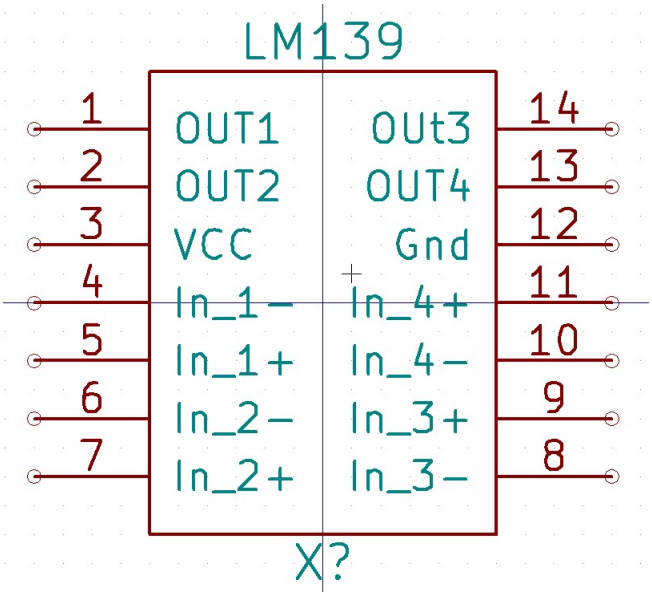


Figure 3.149: LM139 Pin Diagram

3.32.2 Subcircuit Schematics Diagram

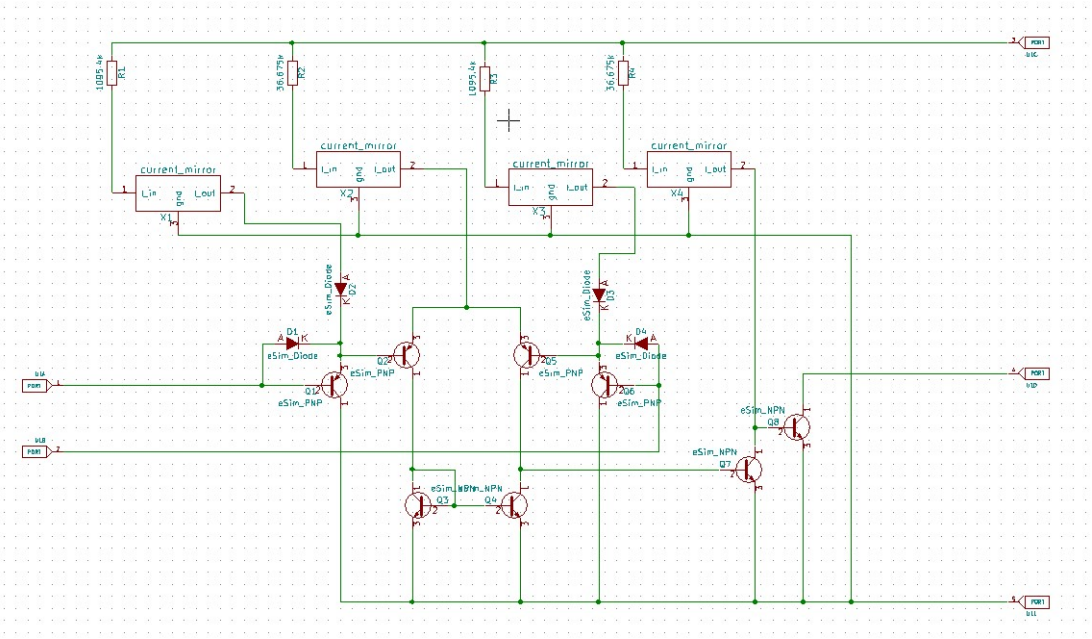


Figure 3.150: LM139 Schematics

3.32.3 Subcircuit test circuit

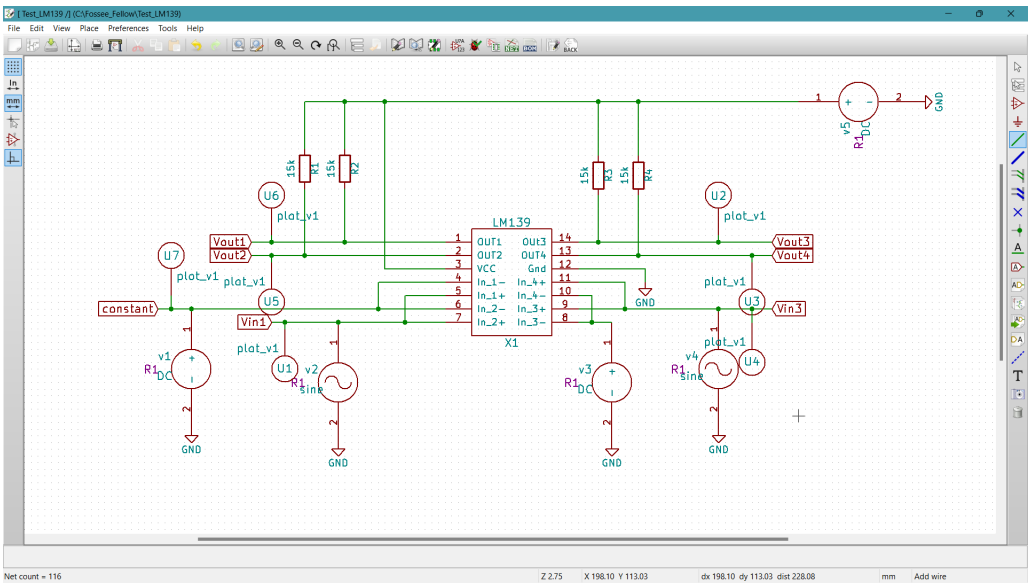


Figure 3.151: LM139 Test Circuit(Comparator)

3.32.4 Output Plot

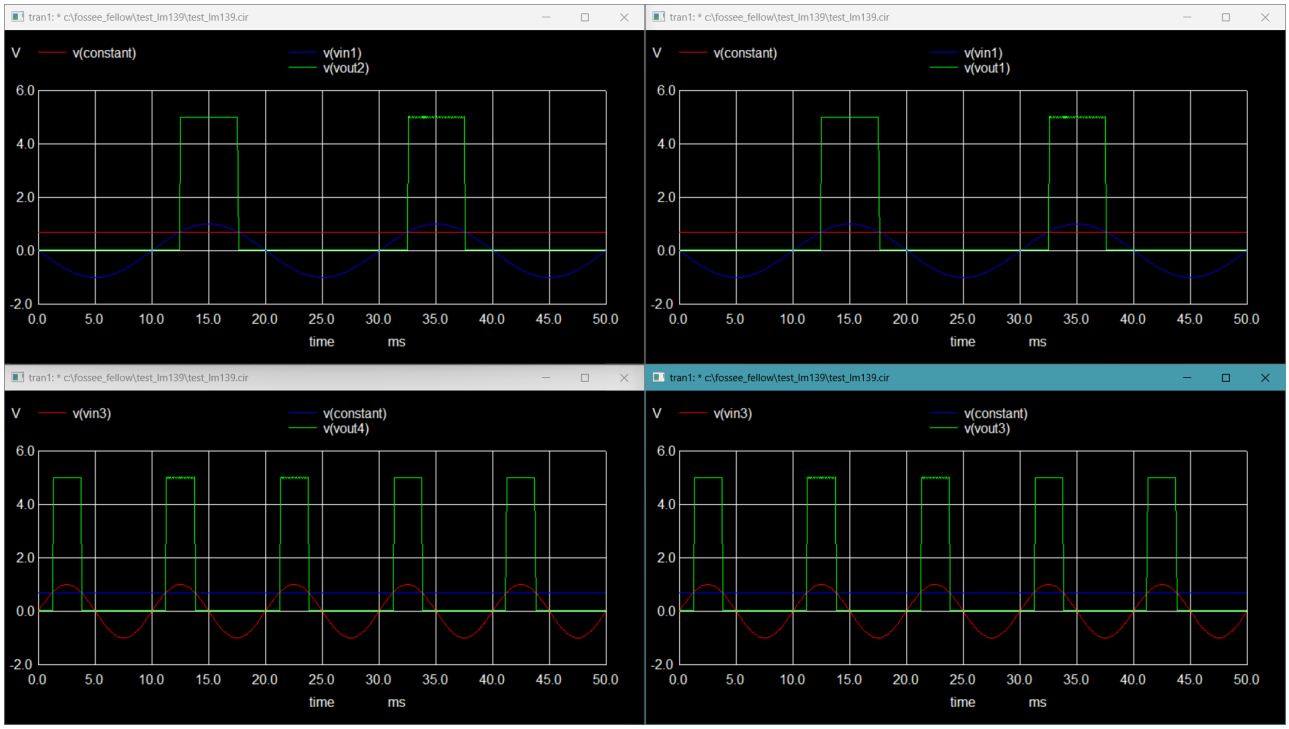


Figure 3.152: Output Comparator

3.33 UA702M Dual OP-AMP

The UA702 is a high-gain, wideband operational amplifier having differential inputs and single-ended emitter-follower outputs. Provisions are incorporated within the circuit whereby external components may be used to compensate the amplifier for stable operation under various feedback or load conditions

3.33.1 Pin Configuration

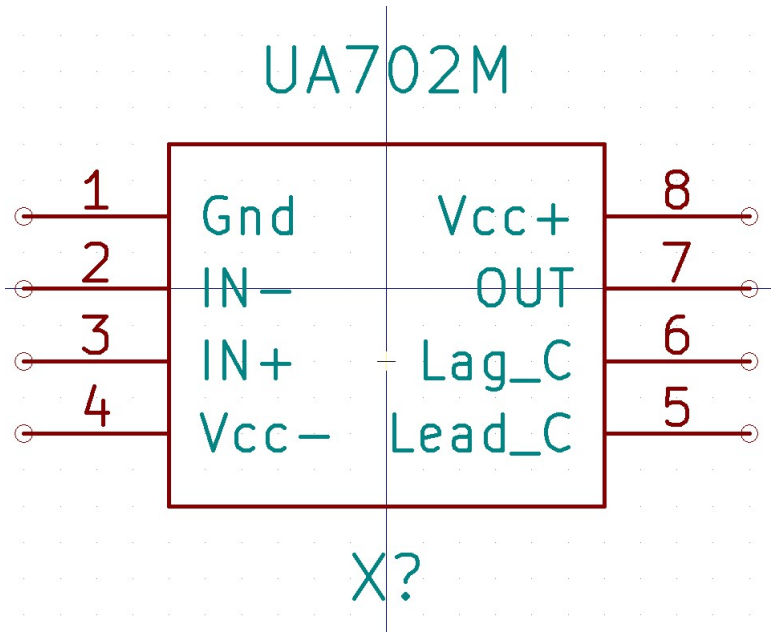


Figure 3.153: UA702 Pin Diagram

3.33.2 Subcircuit Schematics Diagram

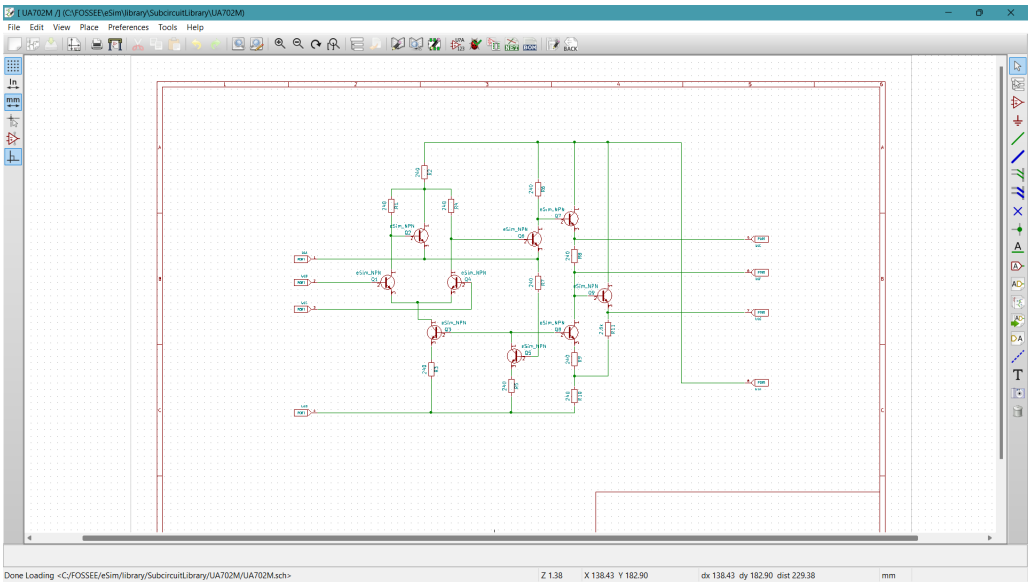


Figure 3.154: UA702 Schematics

3.33.3 Subcircuit test circuit

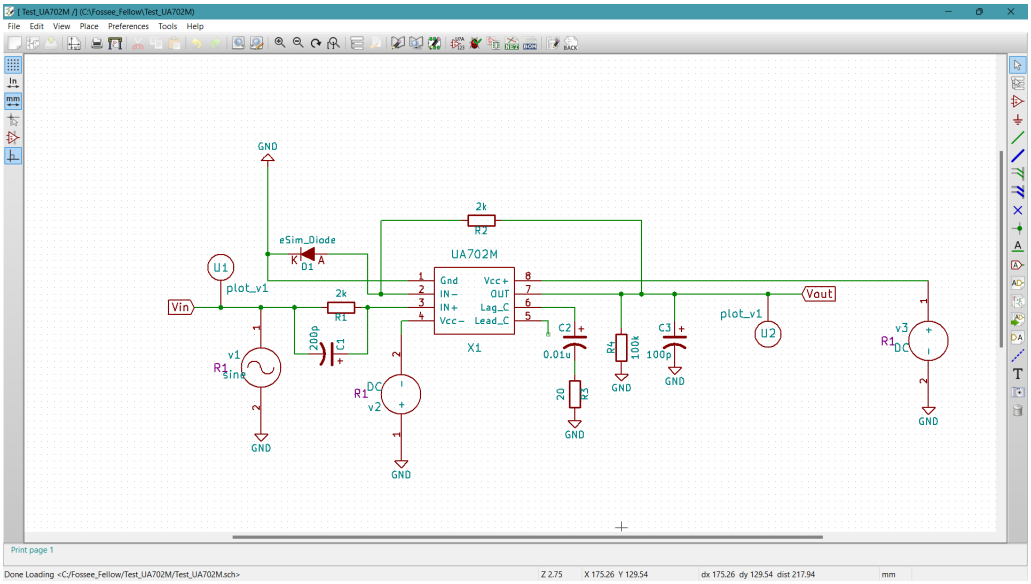


Figure 3.155: UA702 Test Circuit(Unity Gain Amplifier)

3.33.4 Output Plot

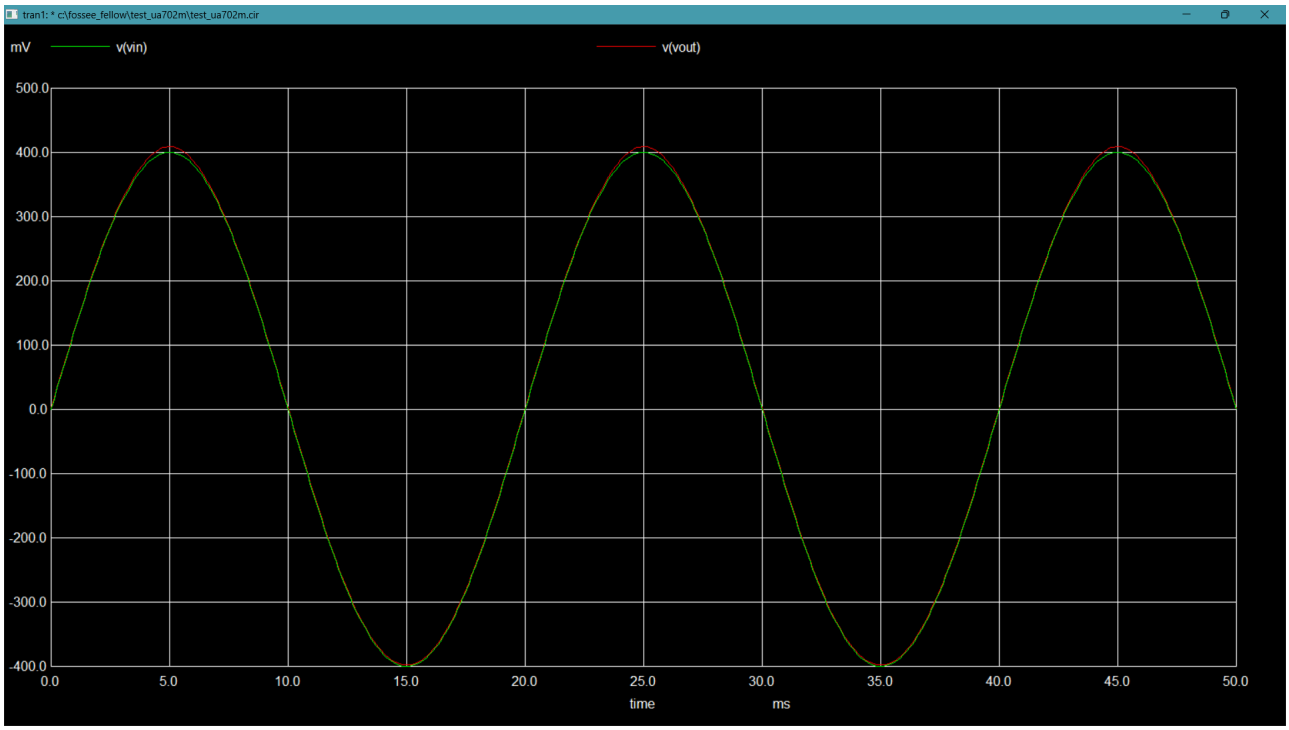


Figure 3.156: Output Unity Gain Amplifier

3.34 TL431 3-Terminal Adjustable Shunt Regulator

The TL431 device is three-terminal adjustable shunt regulator, with specified thermal stability over applicable automotive, commercial, and military temperature ranges. The output voltage can be set to any value between Vref (approximately 2.5 V) and 36 V, with two external resistors.

3.34.1 Pin Configuration

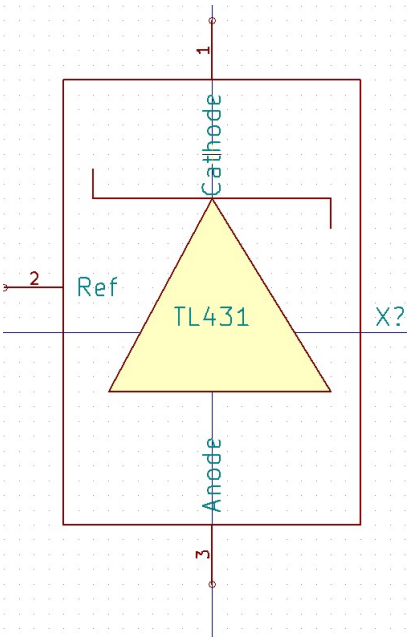


Figure 3.157: TL431 Pin Diagram

3.34.2 Subcircuit Schematics Diagram

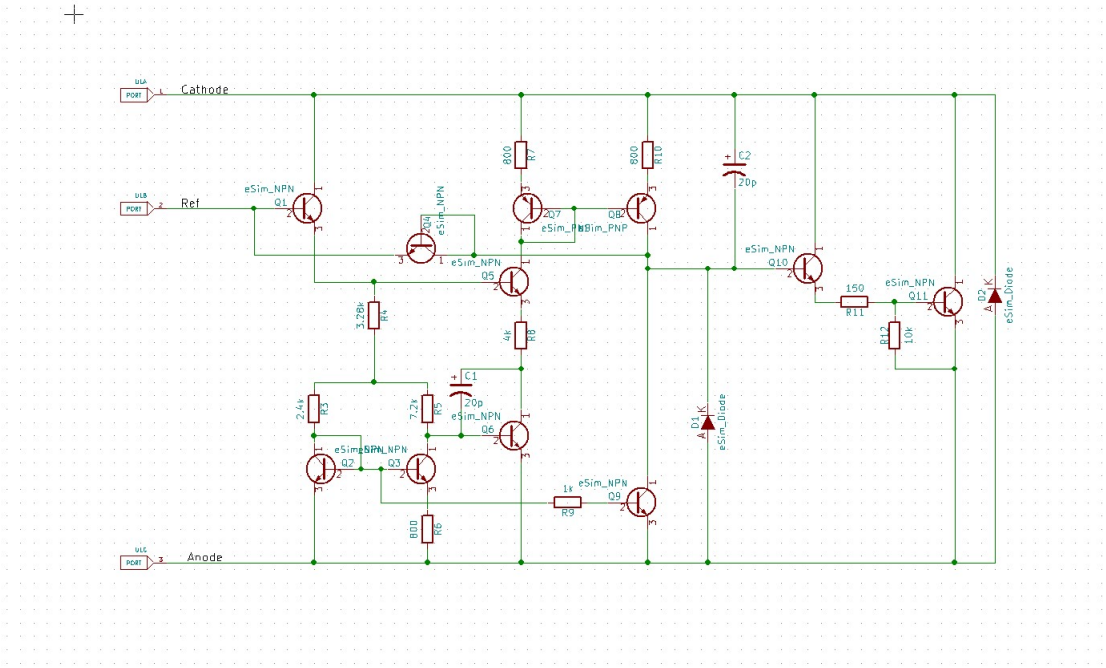


Figure 3.158: TL431 Schematics

3.34.3 Subcircuit test circuit

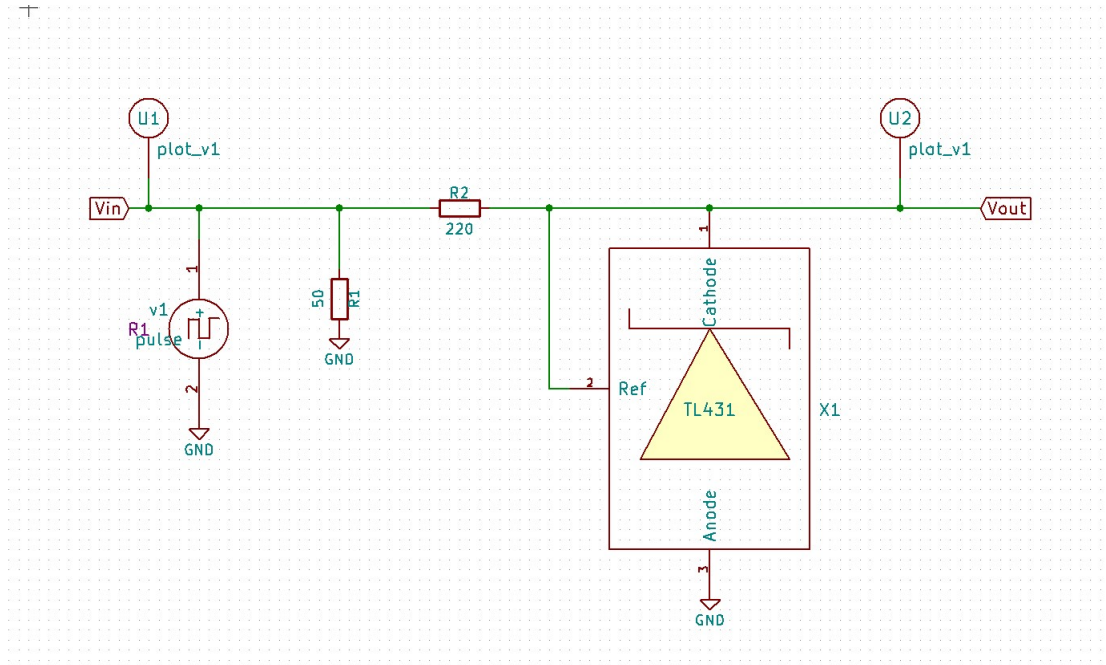


Figure 3.159: TL431 Test Circuit(Pulse Response)

3.34.4 Output Plot

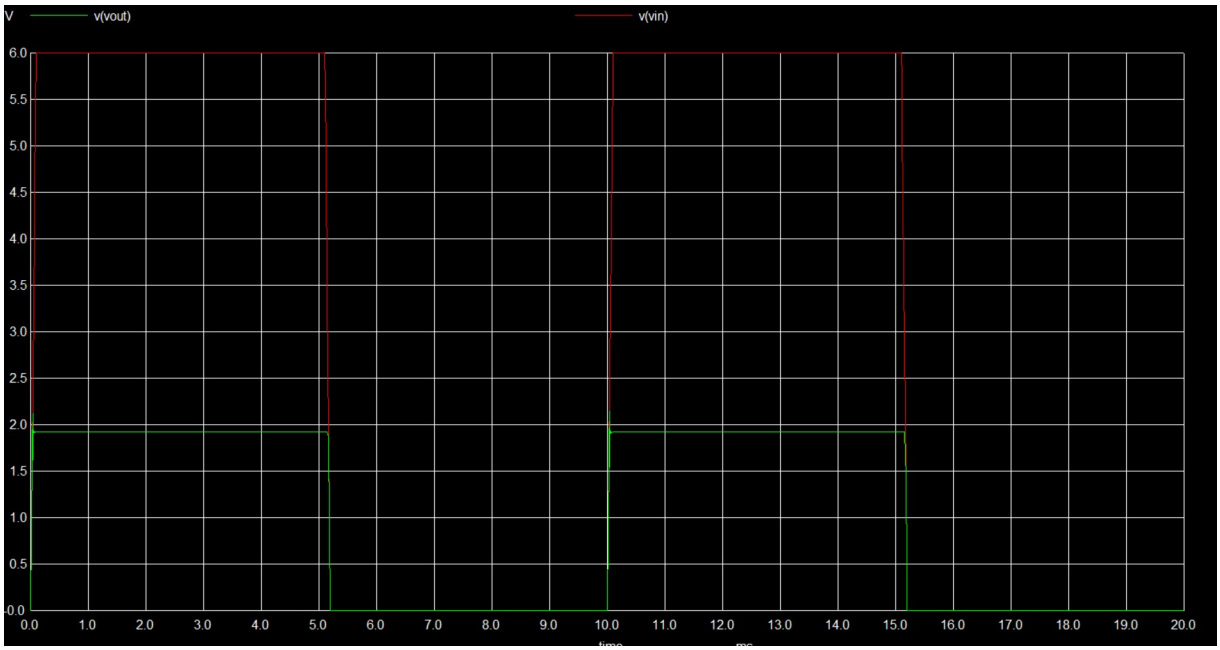


Figure 3.160: Output Pulse Response

3.35 BA4560 Dual high slew rate OP-AMP

The BA4560, BA4560F, and BA4560N are dual operational amplifiers which achieve approximately twice the high output current of the BA4558, as well as featuring a higher slew rate of 4V / s, a gain band width of 10MHz, and animproved frequency characteristic.

3.35.1 Pin Configuration

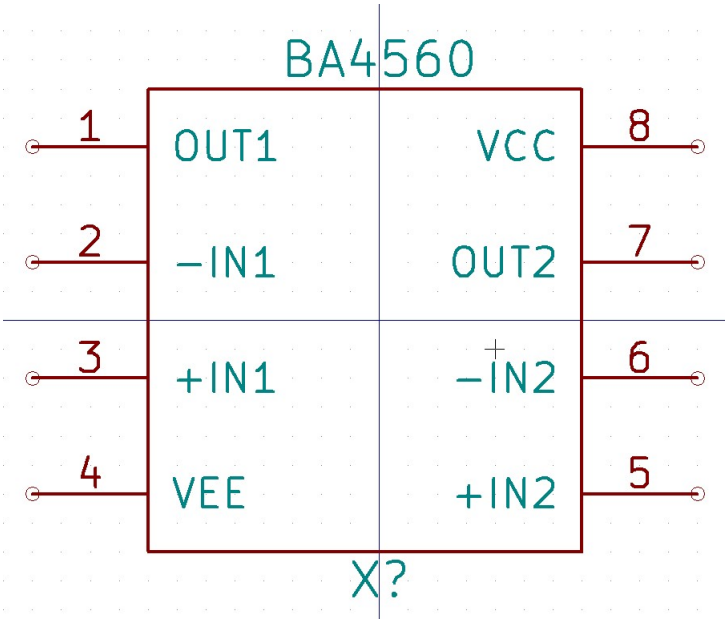


Figure 3.161: BA4560 Pin Diagram

3.35.2 Subcircuit Schematics Diagram

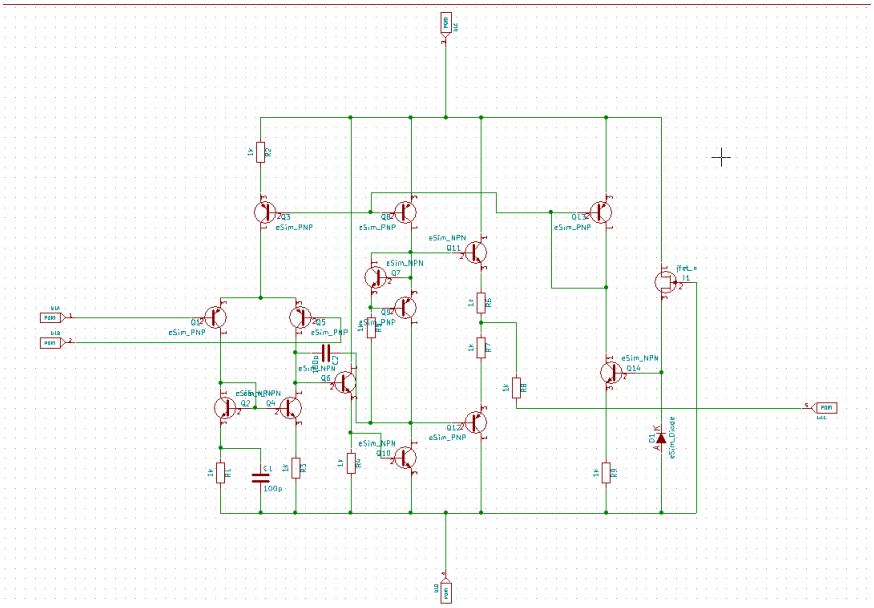


Figure 3.162: BA4560 Schematics

3.35.3 Subcircuit test circuit

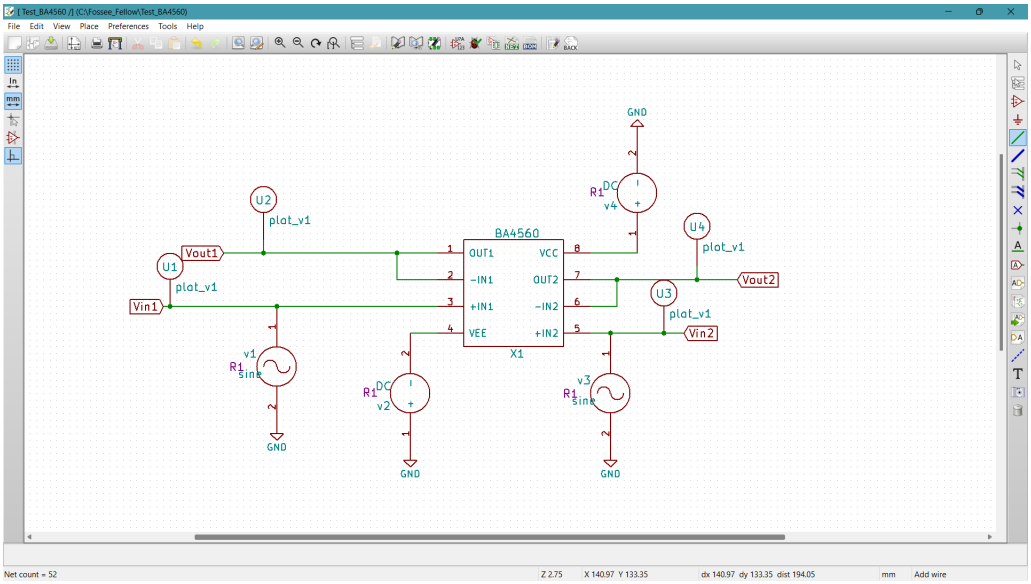


Figure 3.163: BA4560 Test Circuit(Non-Inverting Amplifier)

3.35.4 Output Plot

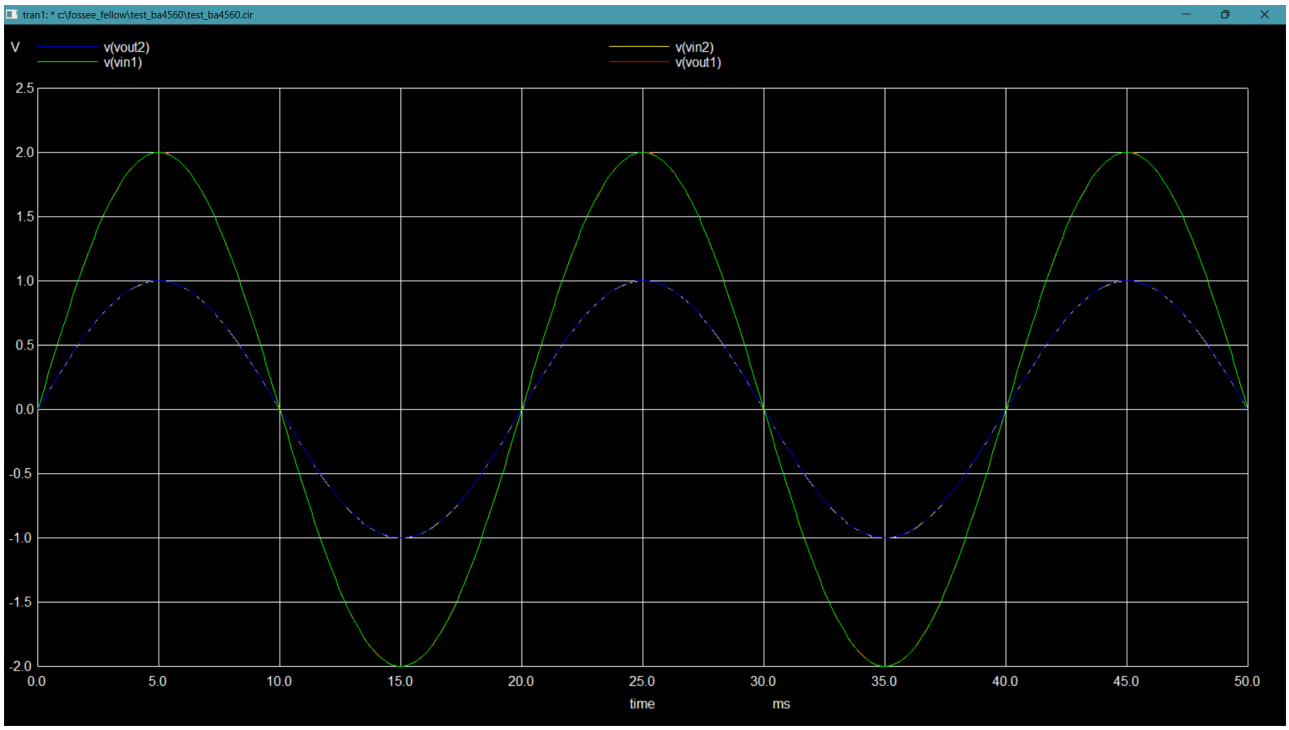


Figure 3.164: Output Non-Inverting Amplifier

3.36 UA733 Differential Video Amplifier

The A733 is a monolithic two-stage video amplifier with differential inputs and differential outputs. Internal series-shunt feedback provides wide bandwidth, low phase distortion, and excellent gain stability.Emitter-follower outputs enable the device to drive capacitive loads, and all stages are current-source biased to obtain high common-mode and supply-voltage rejection ratios.

3.36.1 Pin Configuration

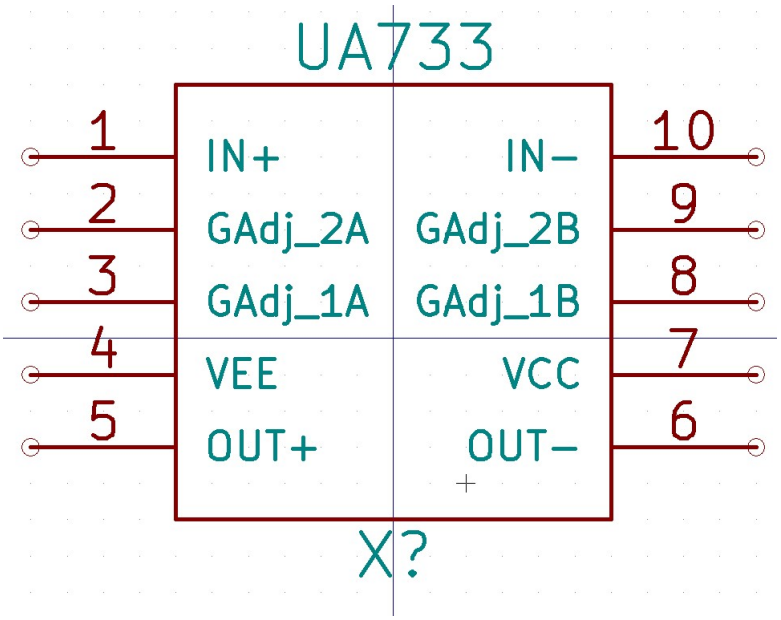


Figure 3.165: UA733 Pin Diagram

3.36.2 Subcircuit Schematics Diagram

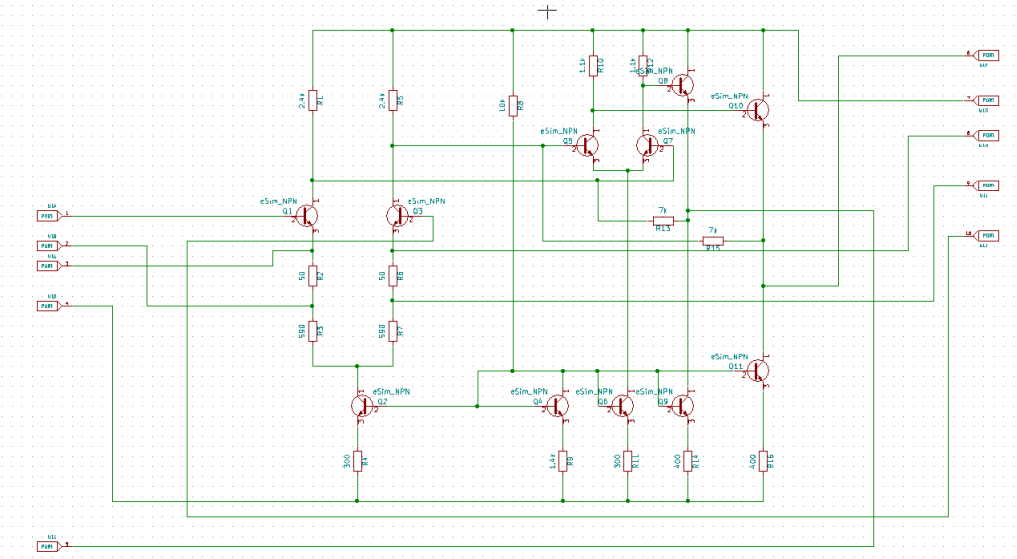


Figure 3.166: UA733 Schematics

3.36.3 Subcircuit test circuit

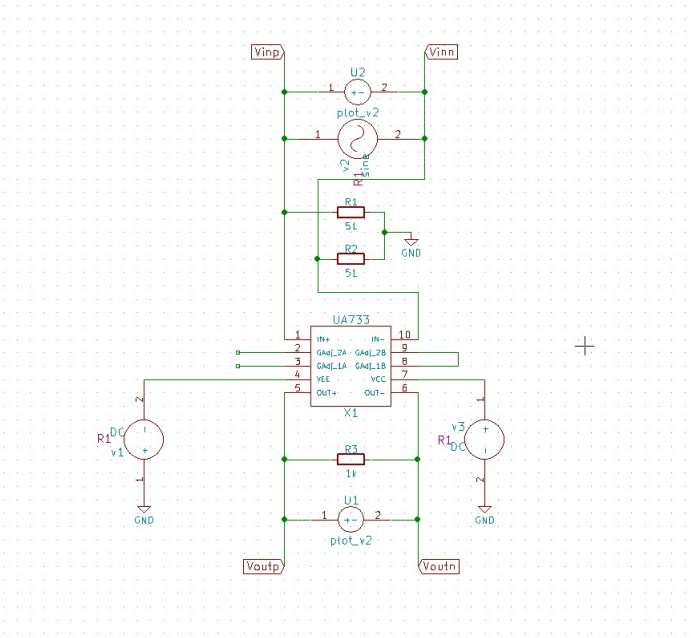


Figure 3.167: UA733 Test Circuit(Non-Inverting Amplifier)

3.36.4 Output Plot

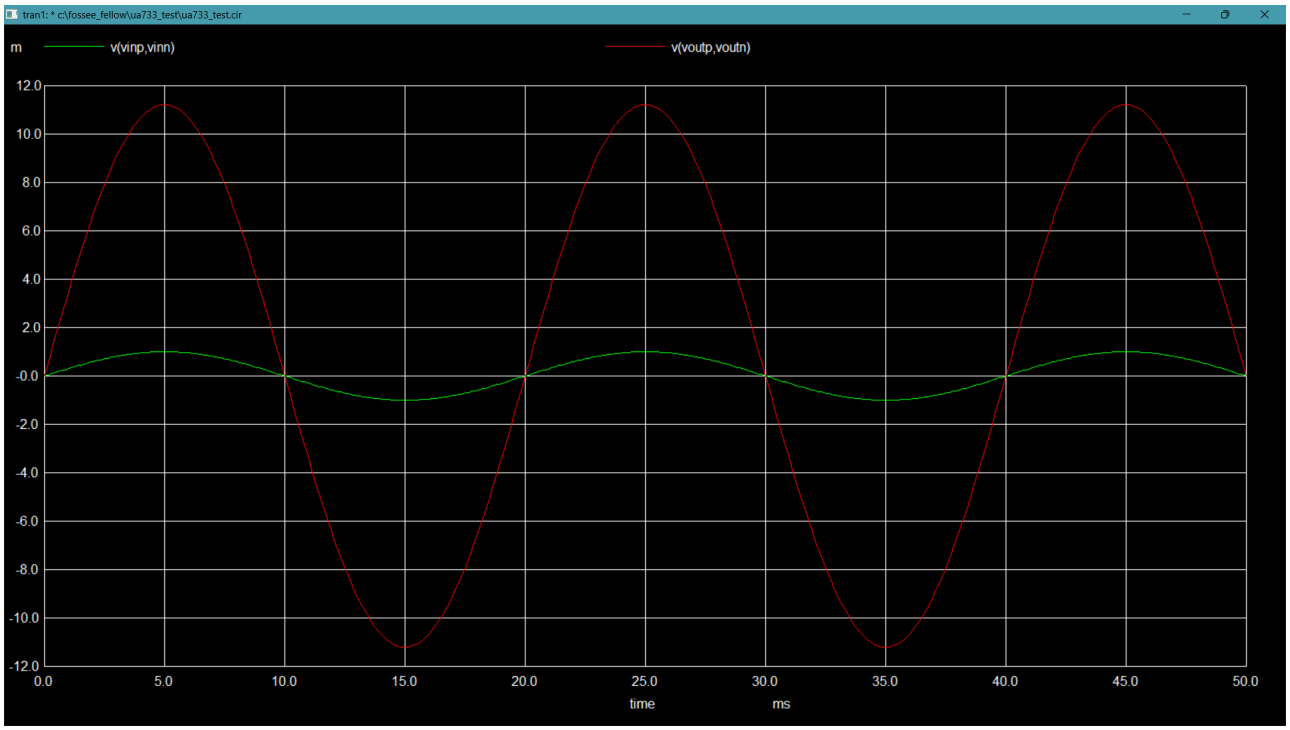


Figure 3.168: Output Non-Inverting Amplifier

3.37 LM185 Dual Adjustable Voltage Reference Diode

The LM185/LM285/LM385 are micropower 3-terminal adjustable band-gap voltage reference diodes. Operating from 1.24 to 5.3V and over a 10A to 20mA current range.

3.37.1 Pin Configuration

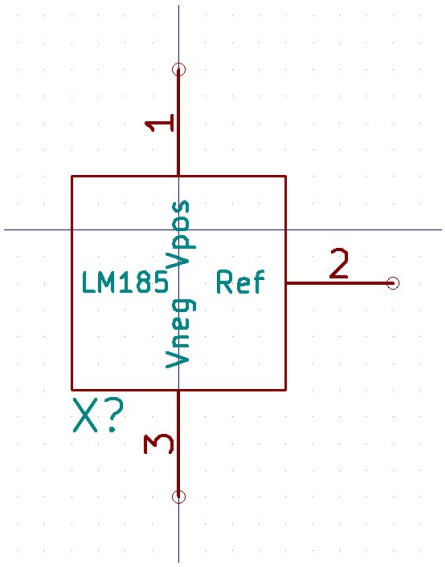


Figure 3.169: LM185 Pin Diagram

3.37.2 Subcircuit Schematics Diagram

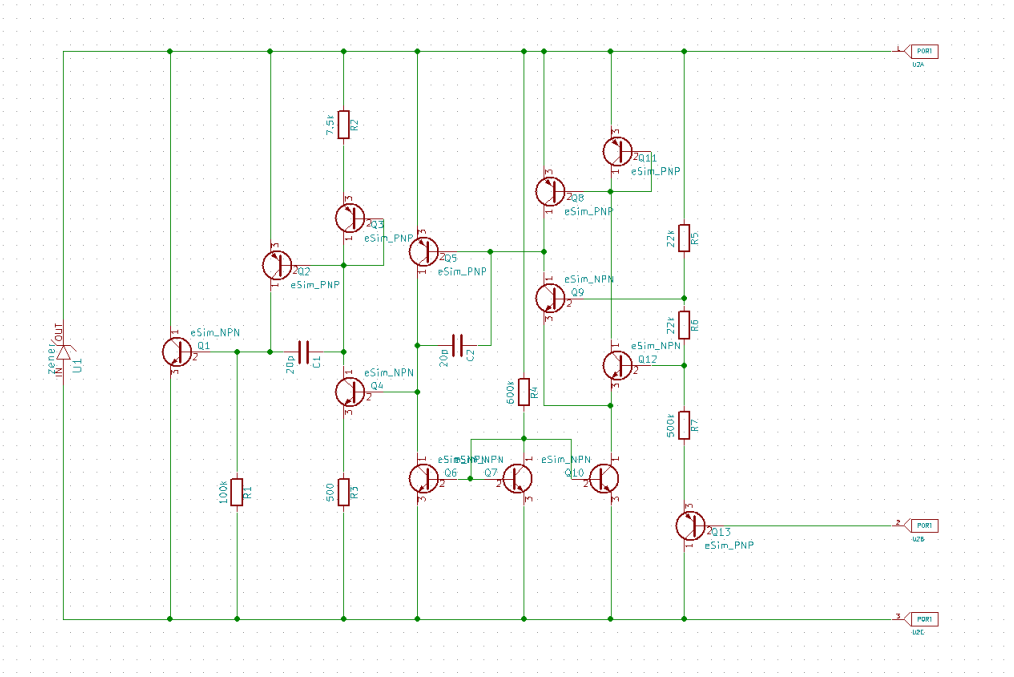


Figure 3.170: LM185 Schematics

3.37.3 Subcircuit test circuit

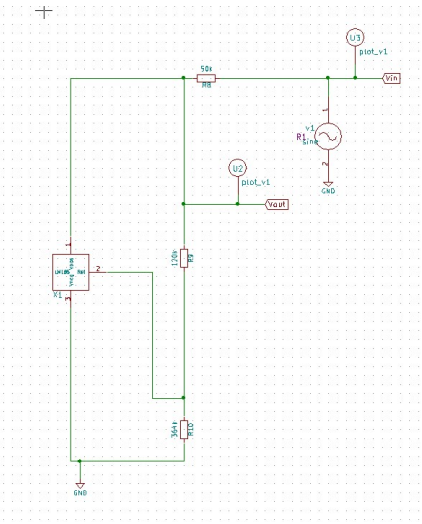


Figure 3.171: LM185 Test Circuit(Voltage Regulator +5V)

3.37.4 Output Plot

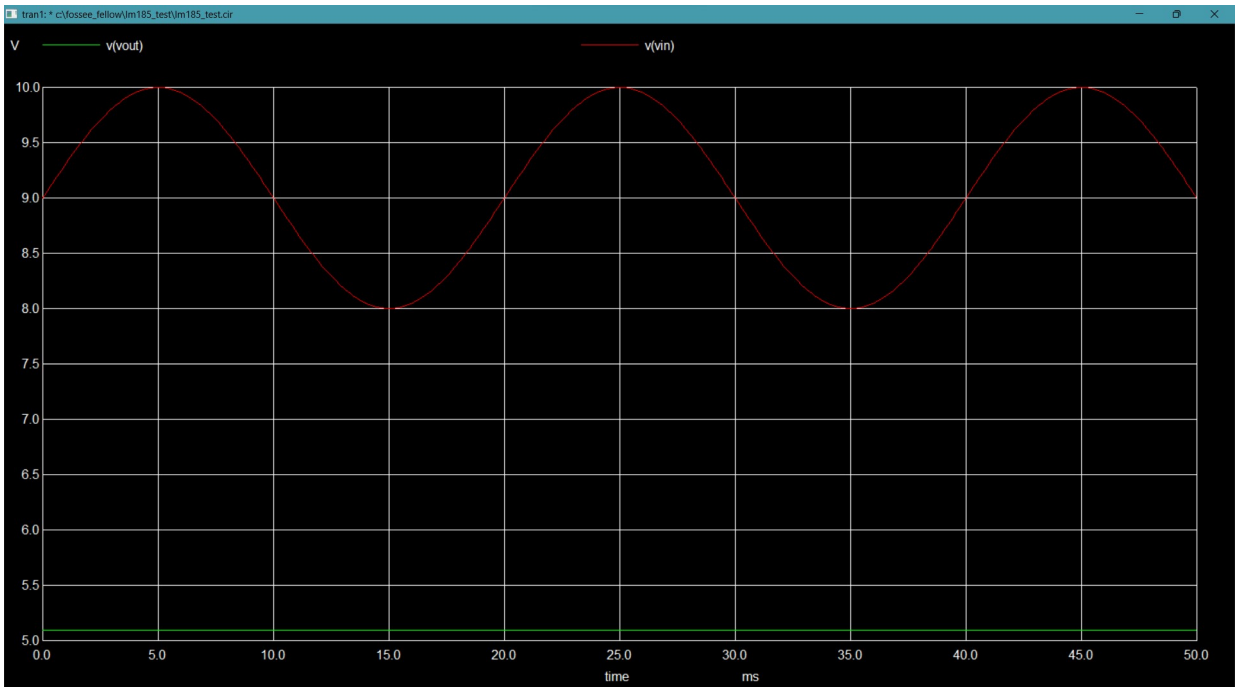


Figure 3.172: Output Voltage Regulator +5V

3.38 LM193 Voltage Dual Comparators

The LM193 series consists of two independent precision voltage comparators with an offset voltage specification as low as 2.0 mV max for two comparators which were designed specifically to operate from a single power supply over a wide range of voltages.

3.38.1 Pin Configuration

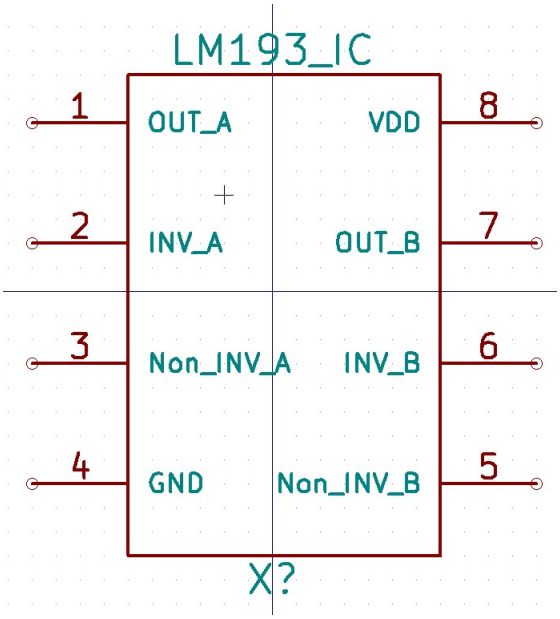


Figure 3.173: LM193 Pin Diagram

3.38.2 Subcircuit Schematics Diagram

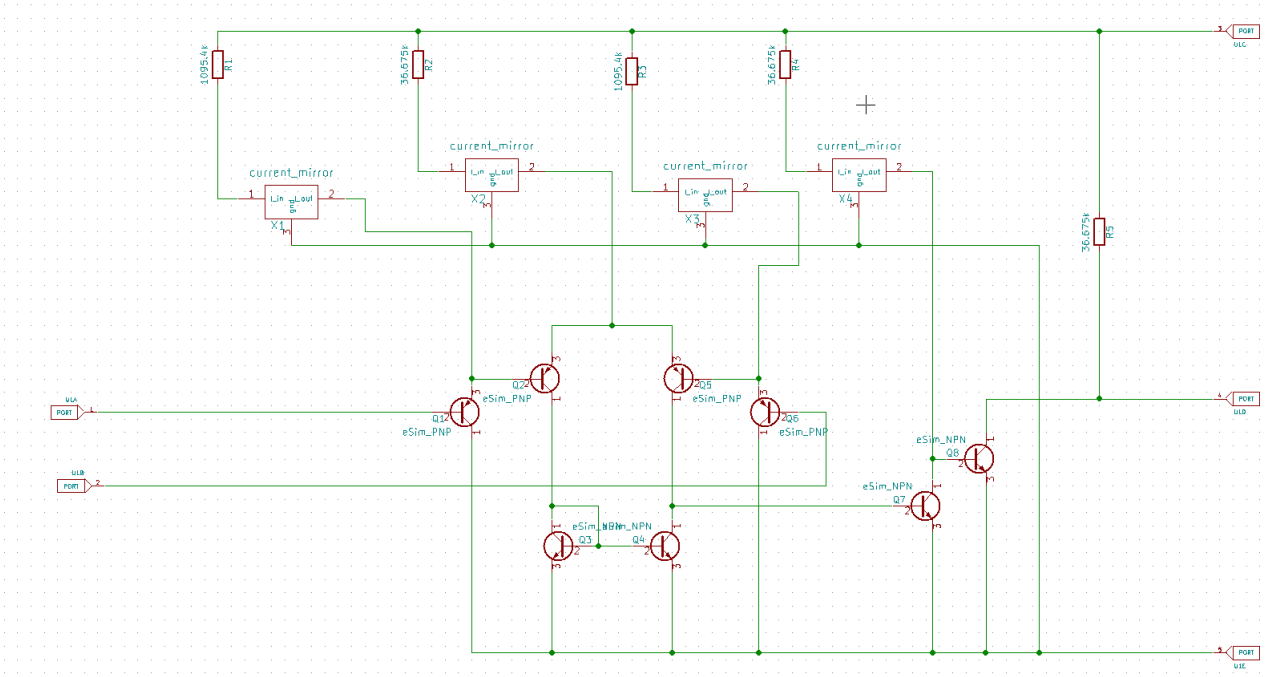


Figure 3.174: LM193 Schematics

3.38.3 Subcircuit test circuit

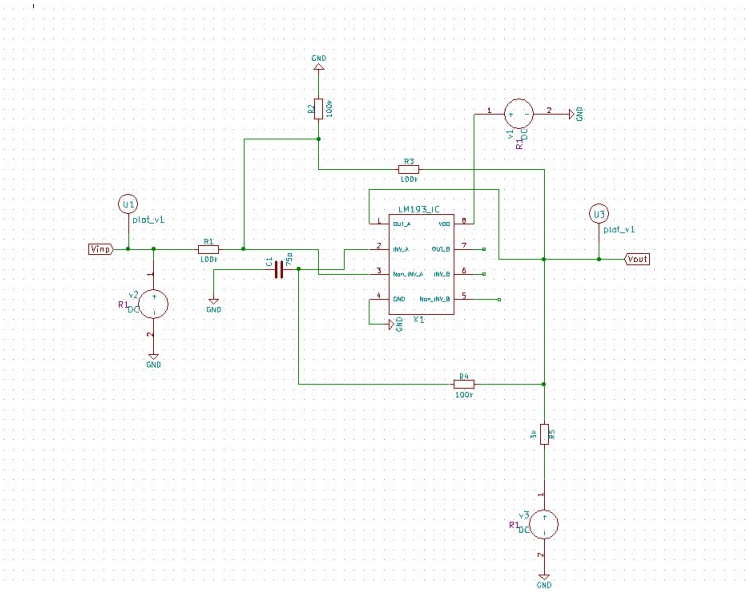


Figure 3.175: LM193 Test Circuit(Square Wave Generator)

3.38.4 Output Plot

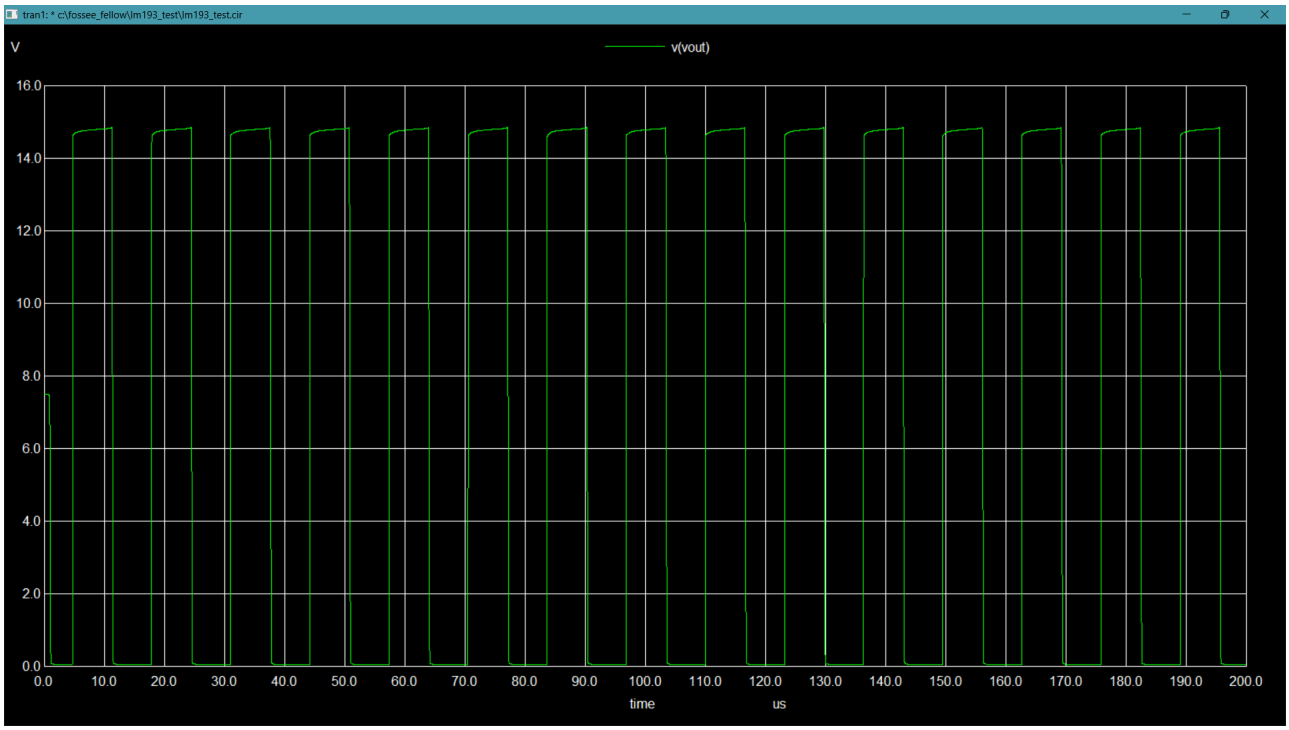


Figure 3.176: Output Square Wave Generator

3.39 LM13600 Dual OTA IC

The LM13600 series consists of two current controlled transconductance amplifiers each with differential inputs and a push-pull output. The two amplifiers share common supplies but otherwise operate independently. Linearizing diodes are provided at the inputs to reduce distortion and allow higher input levels.

3.39.1 Pin Configuration

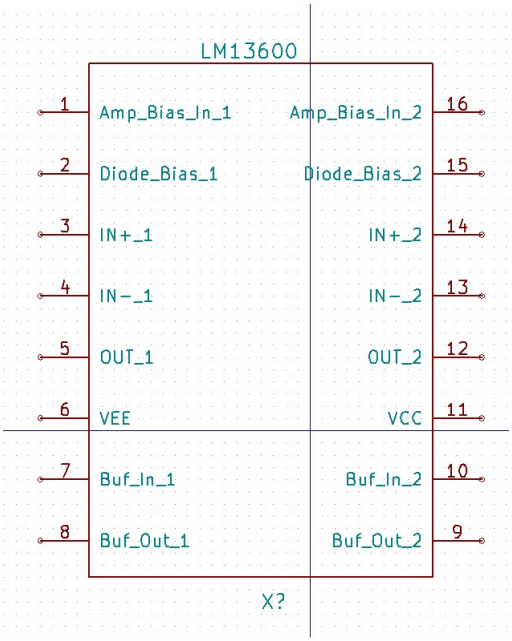


Figure 3.177: LM13600 Pin Diagram

3.39.2 Subcircuit Schematics Diagram

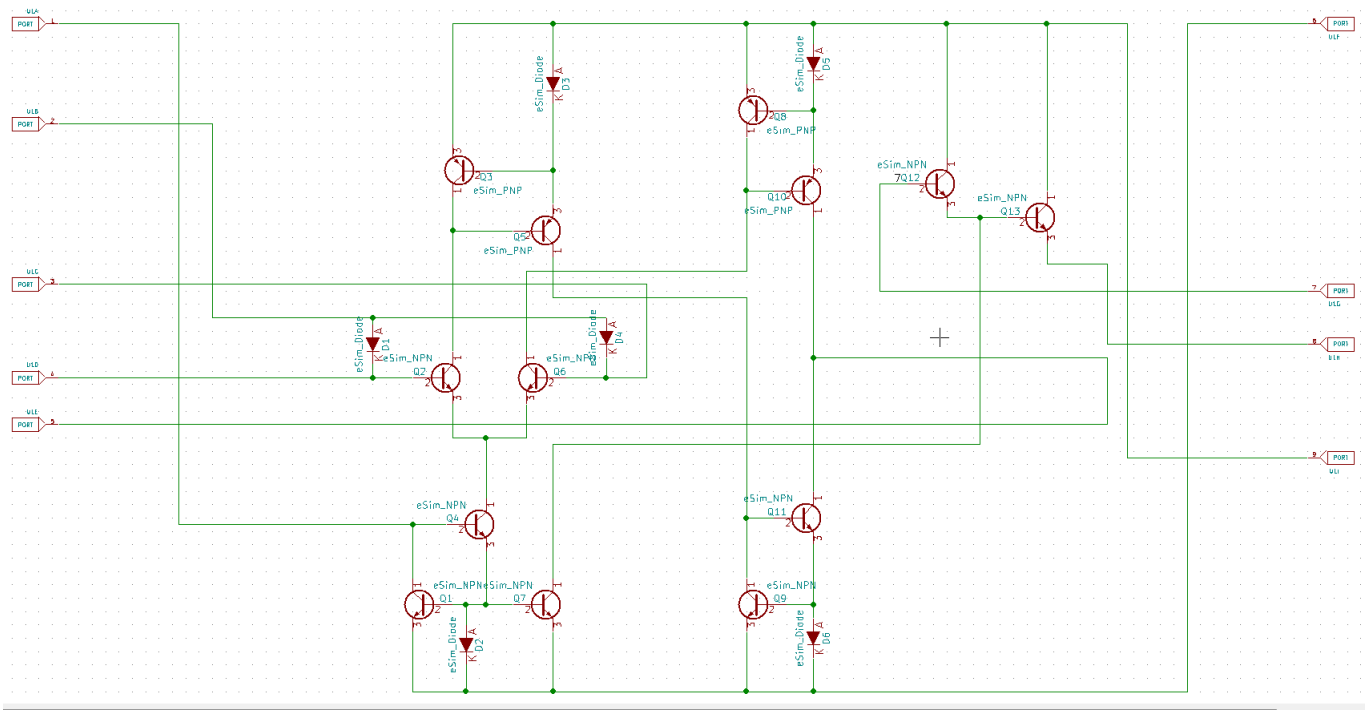


Figure 3.178: LM13600 Schematics

3.39.3 Subcircuit test circuit

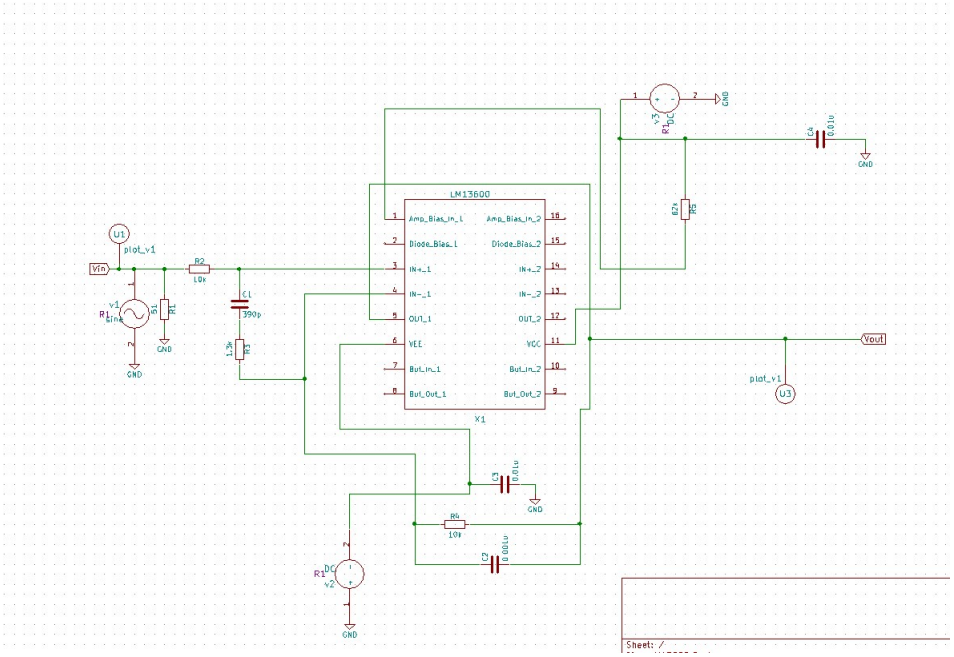


Figure 3.179: LM13600 Test Circuit(Unity Follower)

3.39.4 Output Plot

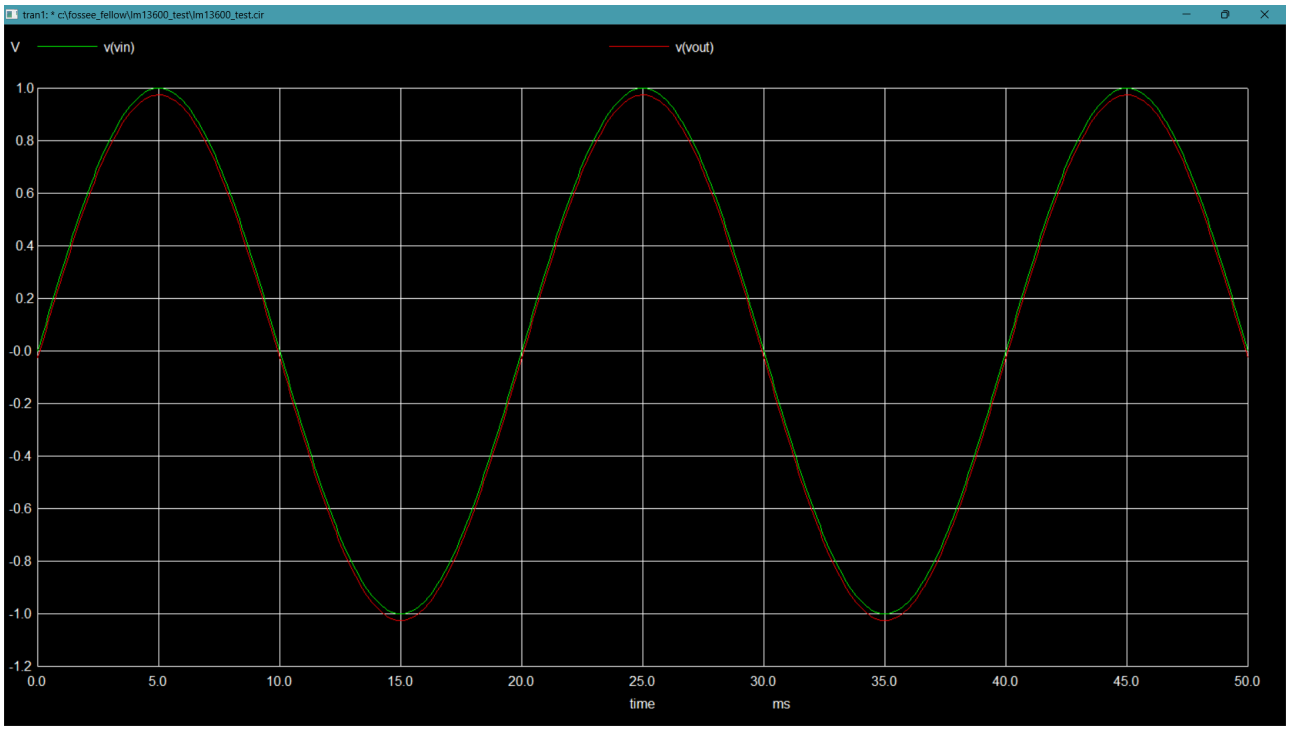


Figure 3.180: Output Unity Follower

3.40 LM106 Voltage Comparator

The LM106 series are high-speed voltage comparators designed to accurately detect low-level analog signals and drive a digital load. The circuits can drive RTL, DTL or TTL integrated circuits directly. Furthermore, their outputs can switch voltages up to 24V at currents as high as 10 mA.

3.40.1 Pin Configuration

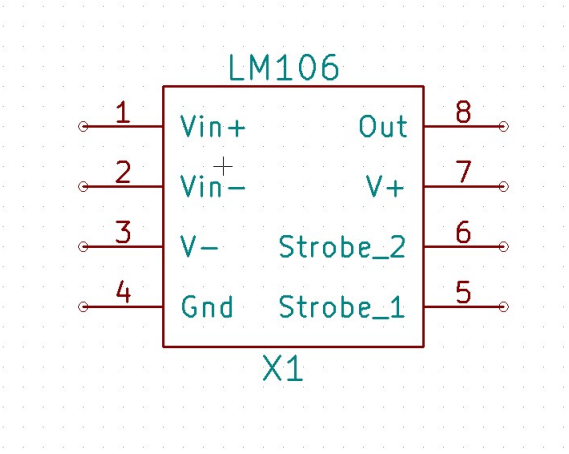


Figure 3.181: LM106 Pin Diagram

3.40.2 Subcircuit Schematics Diagram

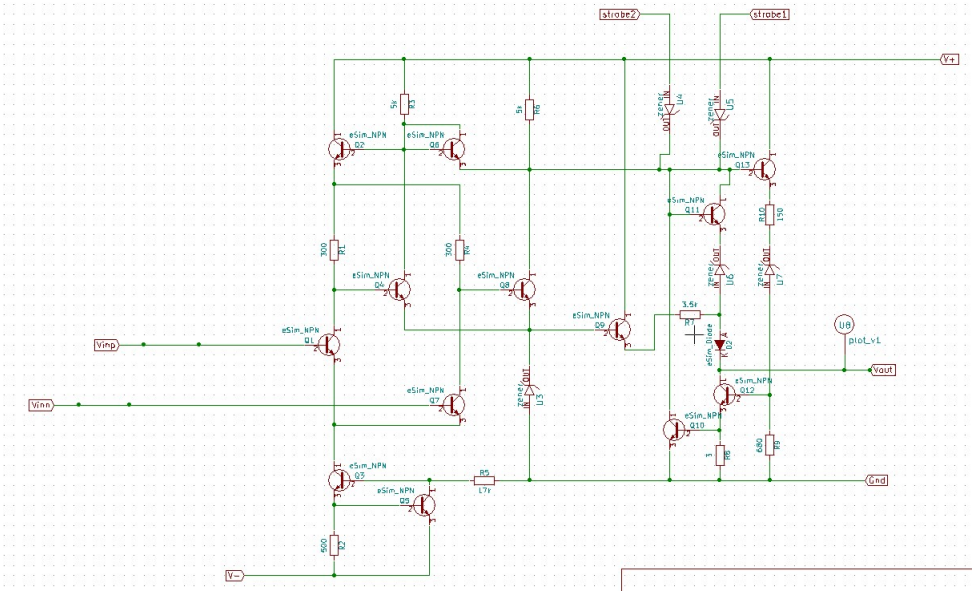


Figure 3.182: LM106 Schematics

3.40.3 Subcircuit test circuit

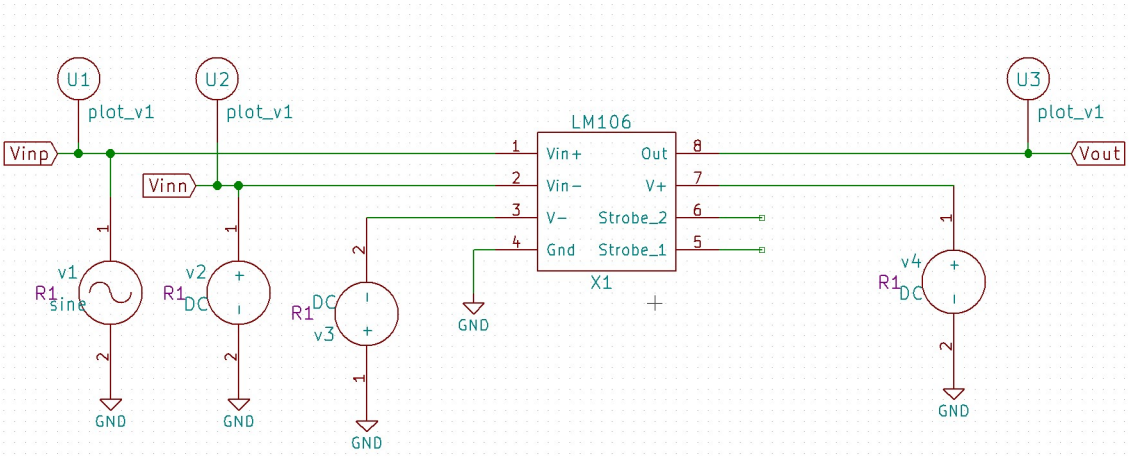


Figure 3.183: LM106 Test Circuit(Voltage Comparator)

3.40.4 Output Plot

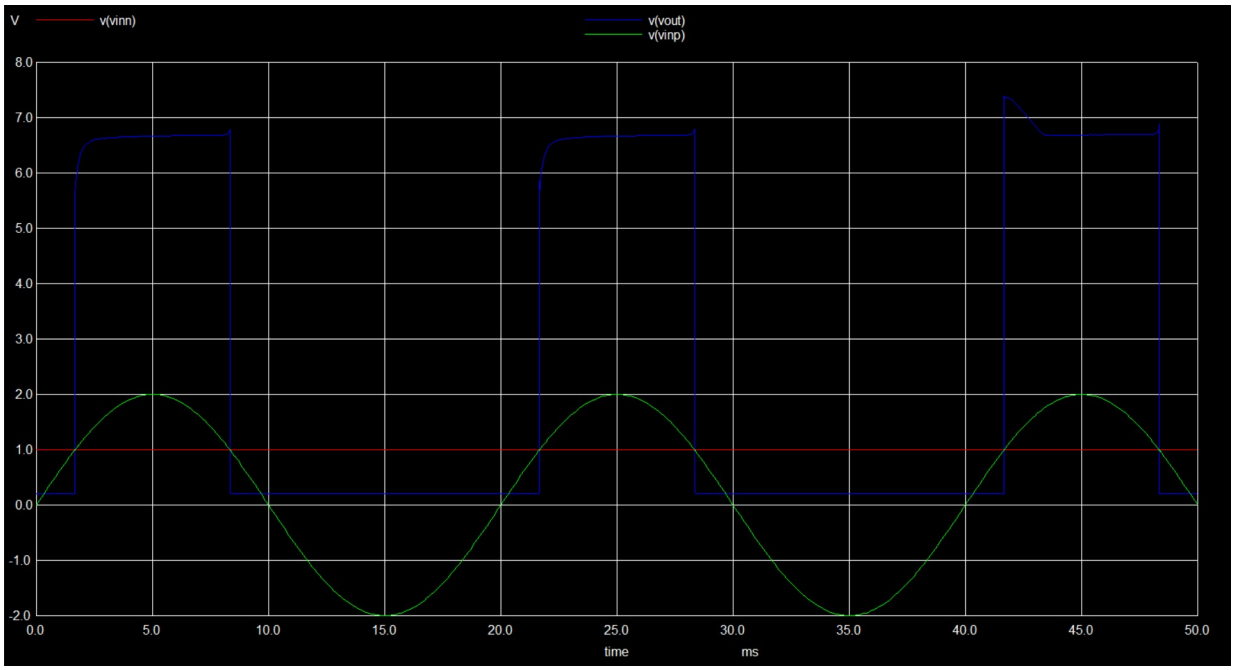


Figure 3.184: Output Voltage Comparator

3.41 LM7915 Negative Voltage Regulator

The LM7915 is a 3-terminal regulators with fixed output voltage of 15V.These devices need only one external component a compensation capacitor at the output.

3.41.1 Pin Configuration

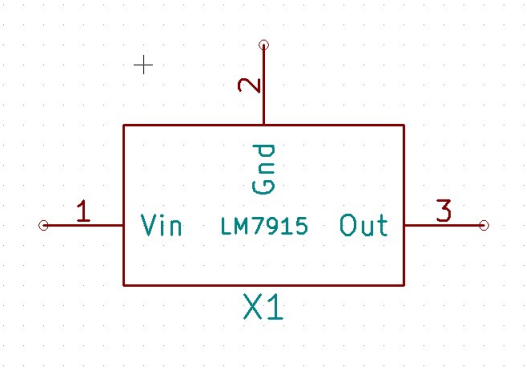


Figure 3.185: LM7915 Pin Diagram

3.41.2 Subcircuit Schematics Diagram

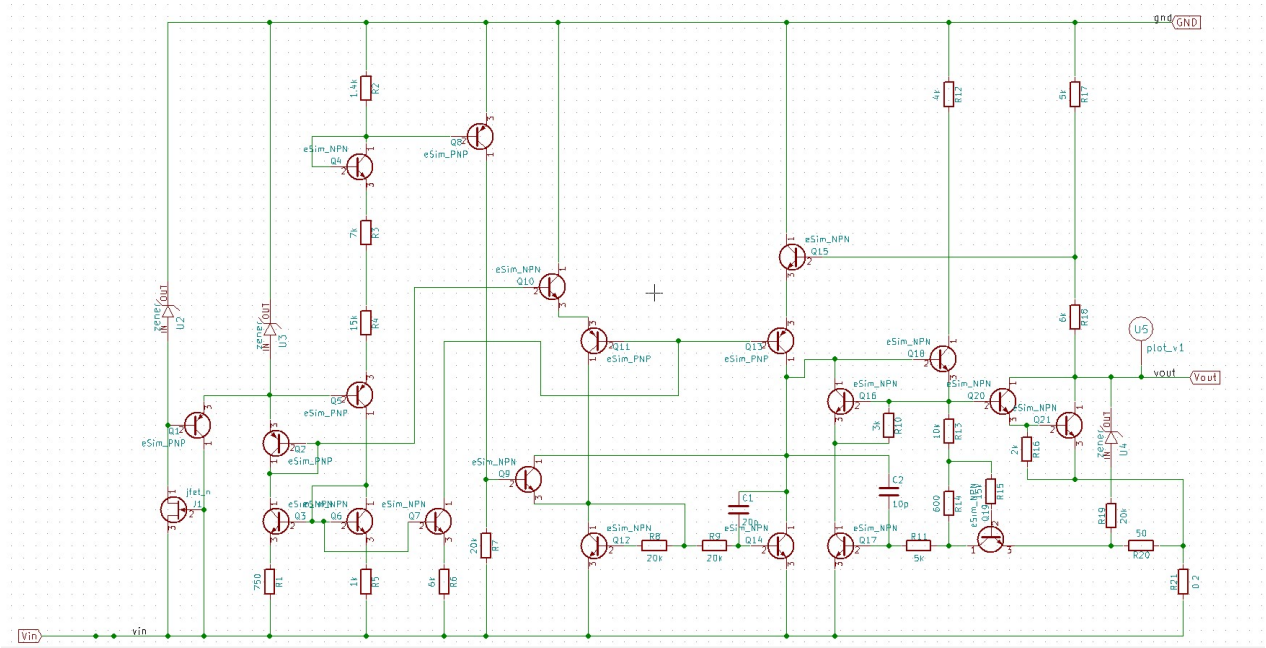


Figure 3.186: LM7915 Schematics

3.41.3 Subcircuit test circuit

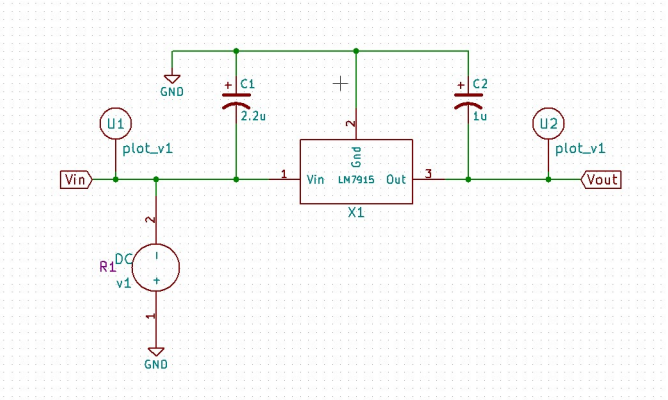


Figure 3.187: LM7915 Test Circuit

3.41.4 Output Plot

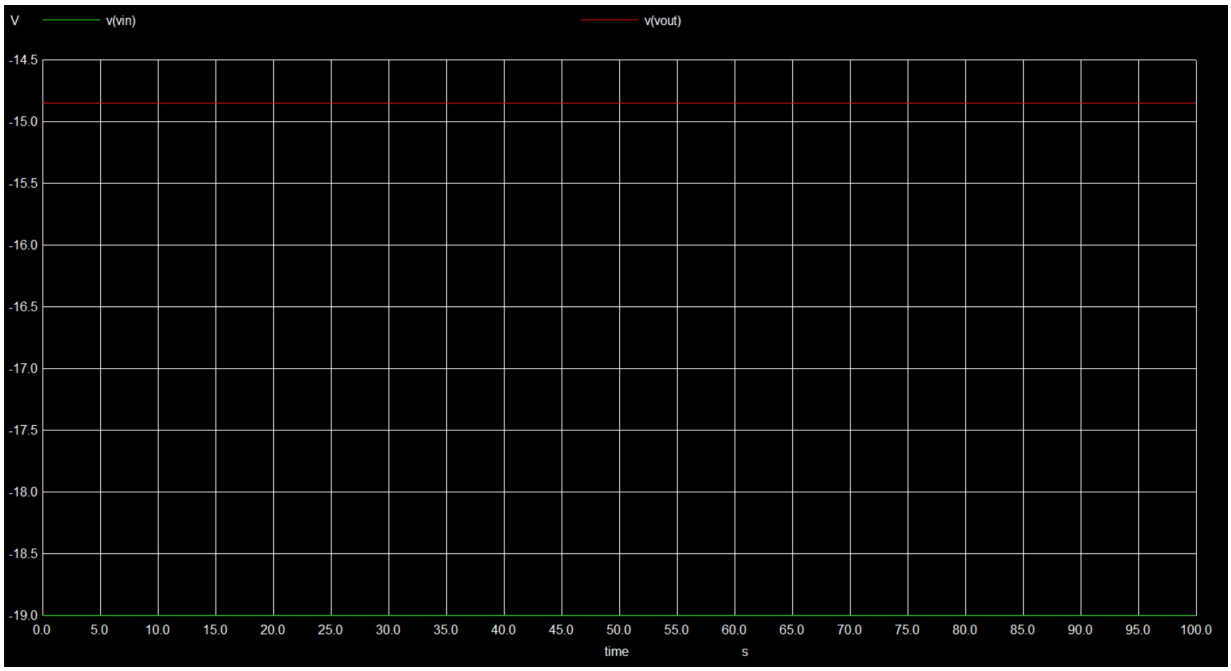


Figure 3.188: Output -15V

3.42 NE4558 Dual OpAmp

The 4558 is a dual operational amplifier that is internally compensated. Excellent channel separation allows the use of a dual device in a single amp application.

3.42.1 Pin Configuration

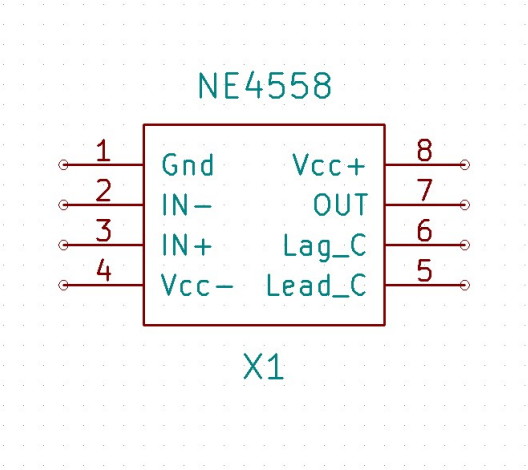


Figure 3.189: NE4558 Pin Diagram

3.42.2 Subcircuit Schematics Diagram

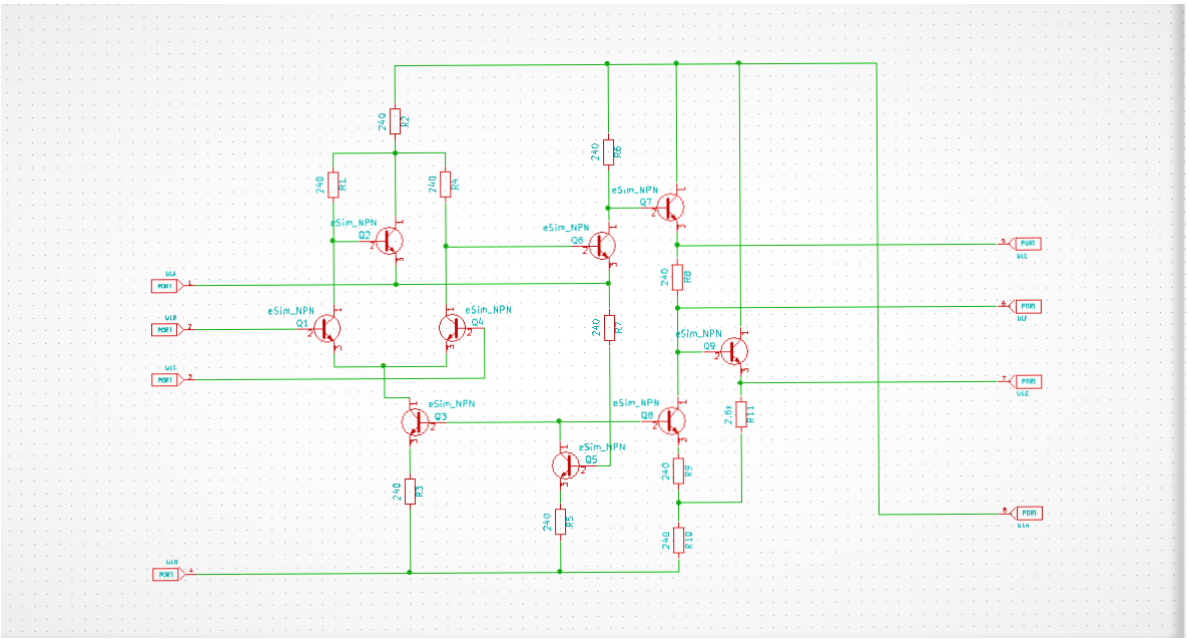


Figure 3.190: NE4558 Schematics

3.42.3 Subcircuit test circuit

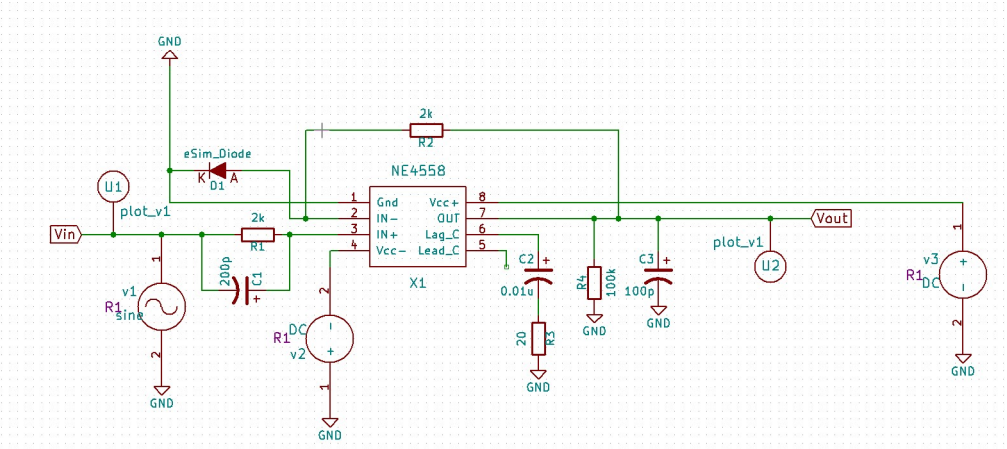


Figure 3.191: NE4558 Test Circuit (Unity Follower)

3.42.4 Output Plot

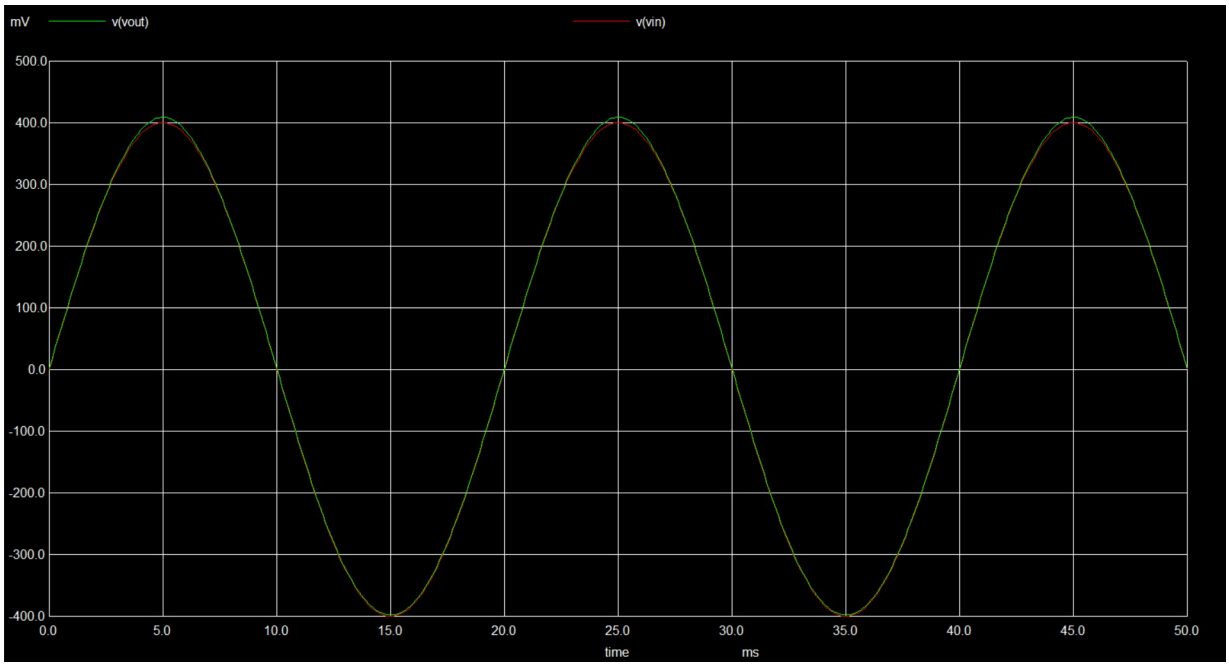


Figure 3.192: Output Unity Follower

3.43 LM2903 Voltage Comparator

This device consists of two independent low power voltage comparators designed specifically to operate from a single supply over a wide range of voltages. Operation from split power supplies is also possible. These comparators also have a unique characteristic in that the input common-mode voltage range includes ground even though operated from a single power supply voltage.

3.43.1 Pin Configuration

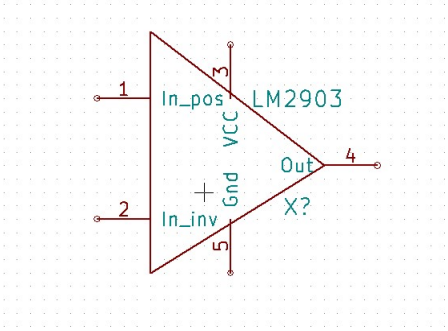


Figure 3.193: LM2903 Pin Diagram

3.43.2 Subcircuit Schematics Diagram

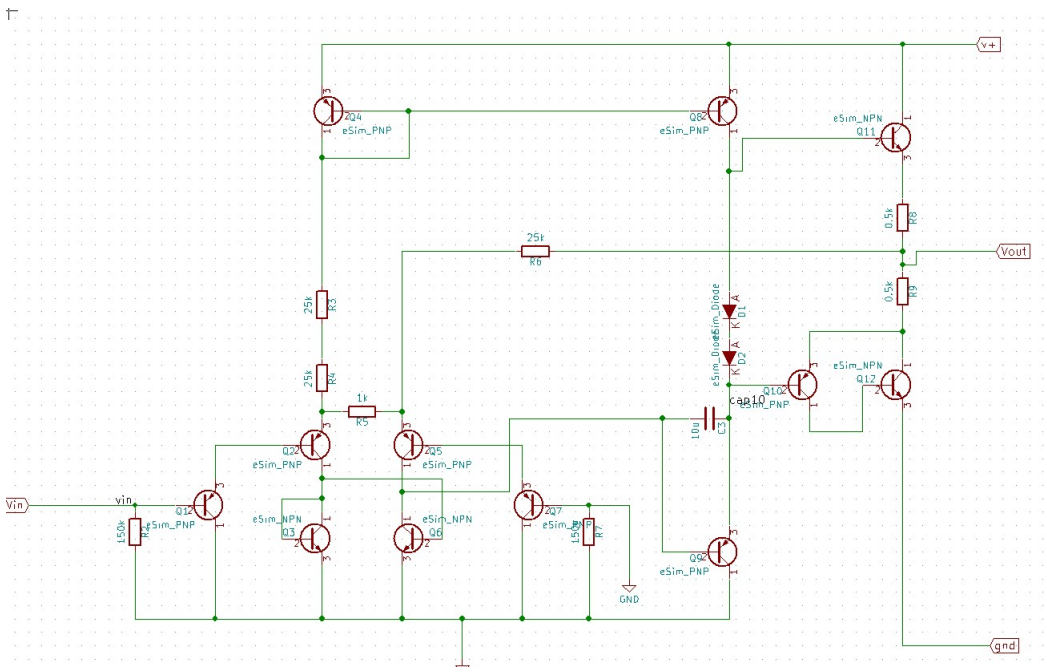


Figure 3.194: LM2903 Schematics

3.43.3 Subcircuit test circuit

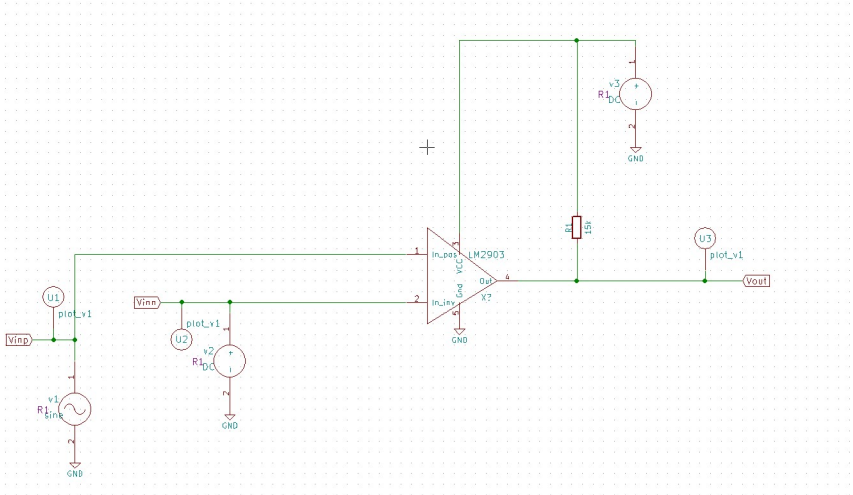


Figure 3.195: LM2903 Test Circuit (Voltage Comparator)

3.43.4 Output Plot

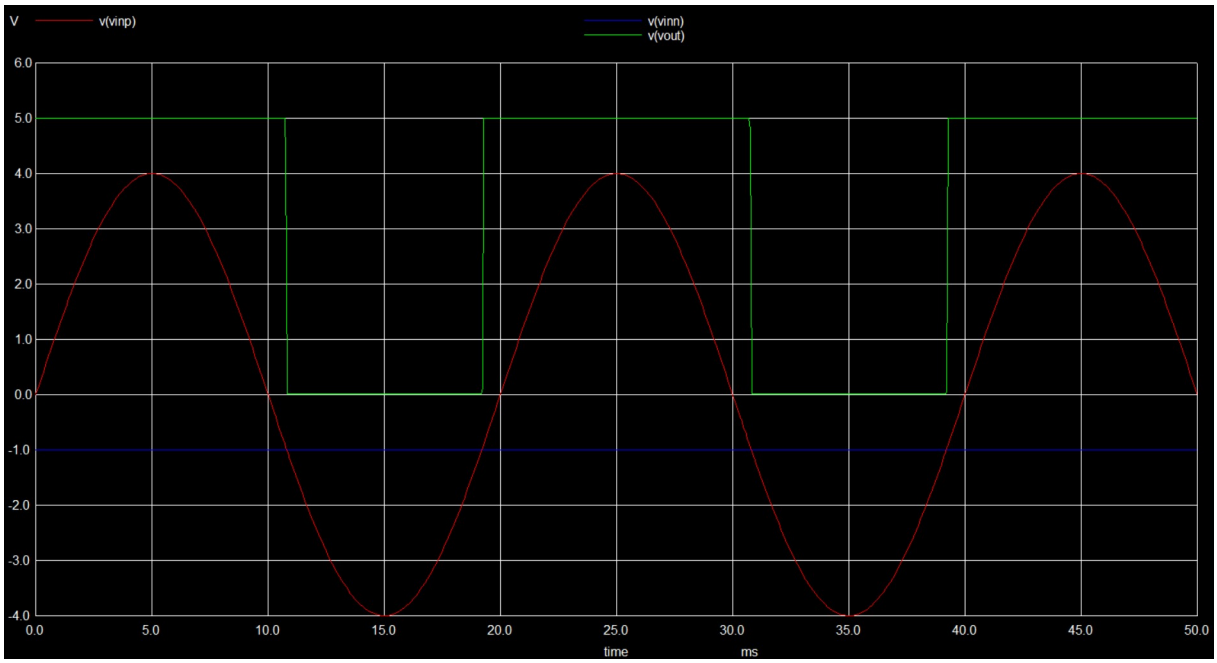


Figure 3.196: Output Voltage Comparator

3.44 uA78S40 Switching Regulator Sub-system

The A78S40 is a switching regulator subsystem, consisting of a temperature compensated voltage reference, controlledduty cycle oscillator with an active current limit circuit, comparator, highcurrent and highvoltage output switch, capable of 1.5 A and 40 V, pinnedout power diode and an uncommitted operational amplifier, which can be powered up or down independent of the IC supply.

3.44.1 Pin Configuration

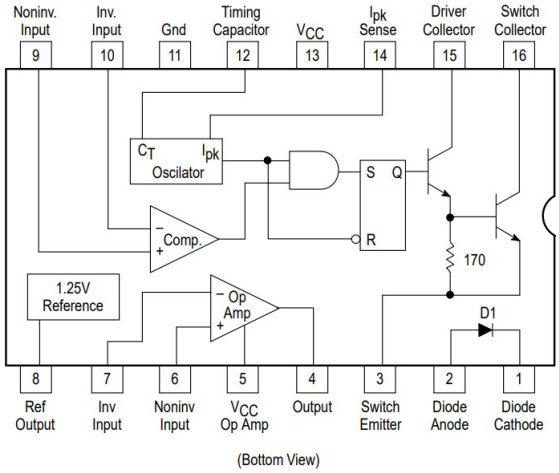


Figure 3.197: uA78S40 Pin Diagram

3.44.2 Subcircuit Schematics Diagram

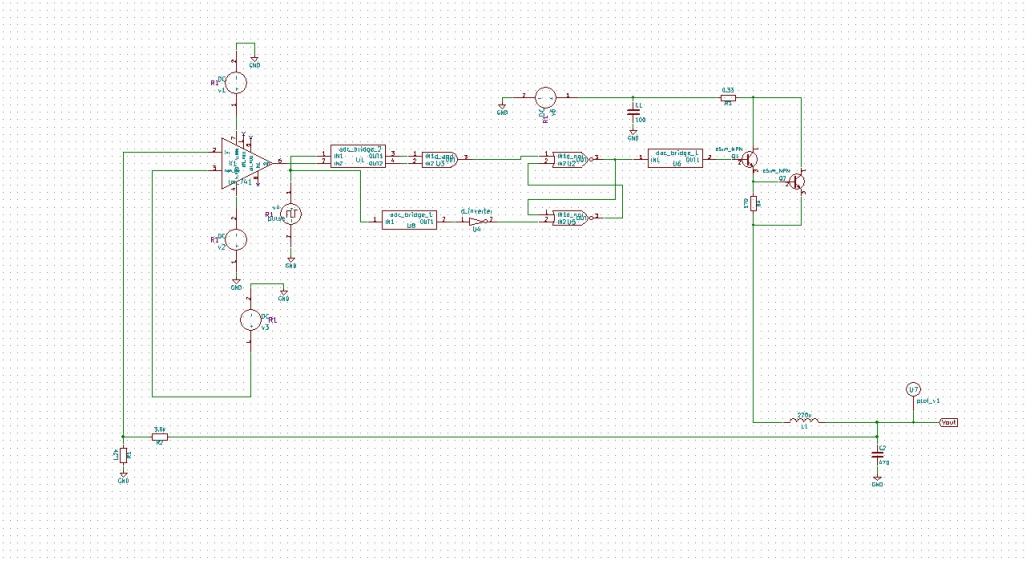


Figure 3.198: UA78S40 Schematics and test circuit

3.44.3 Output Plot

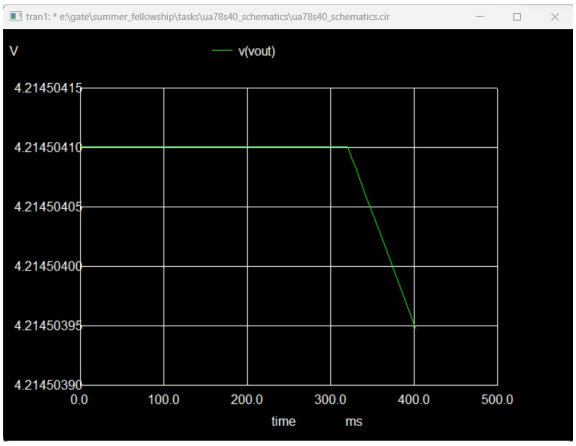


Figure 3.199: Output

3.45 TL061 Low Power J-FET Operational Amplifier

The TL061, TL061A and TL061B are high speedJ-FET input single operational amplifier family.Each of these J-FET input operational amplifiersincorporates well matched, high voltage J-FET andbipolar transistors in a monolithic integrated circuit.The devices feature high slew rates, low input biasand offset currents, andlow offset voltage tempera-ture coefficient.

3.45.1 Pin Configuration

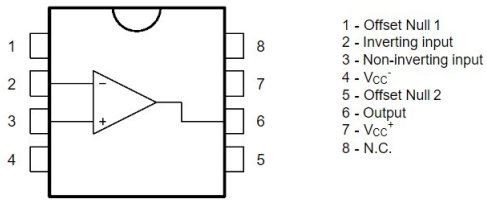


Figure 3.200: TL061 Pin Diagram

3.45.2 Subcircuit Schematics Diagram

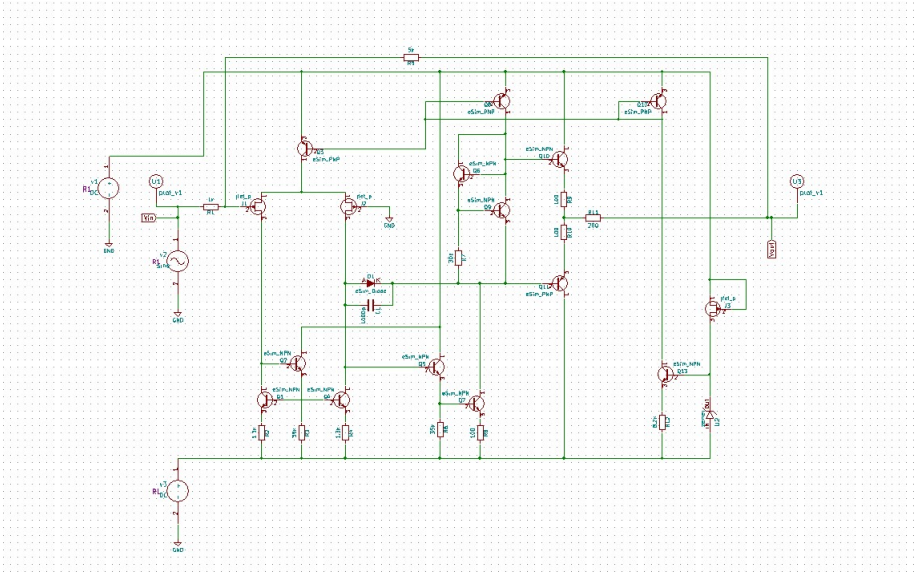


Figure 3.201: TL061 Schematics

3.45.3 Subcircuit test circuit

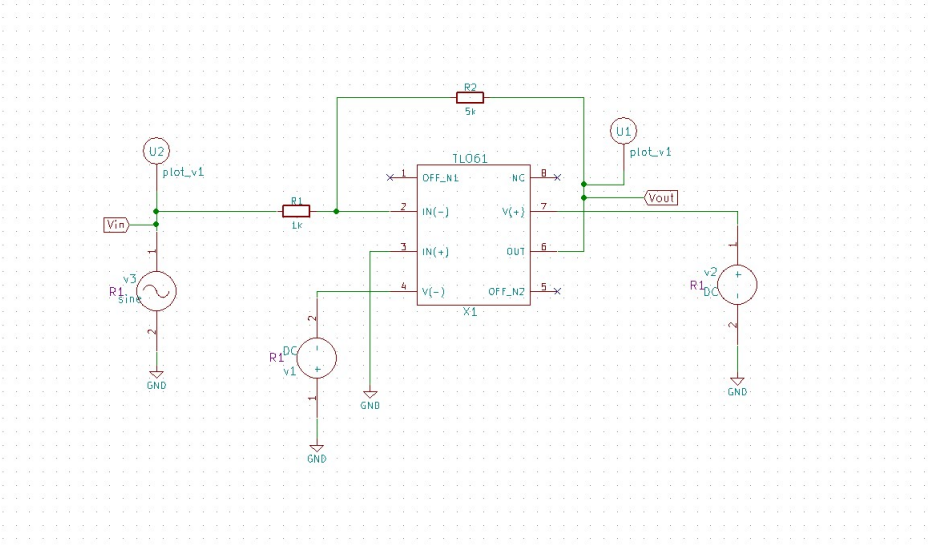


Figure 3.202: Test Circuit Schematics

3.45.4 Output Plot

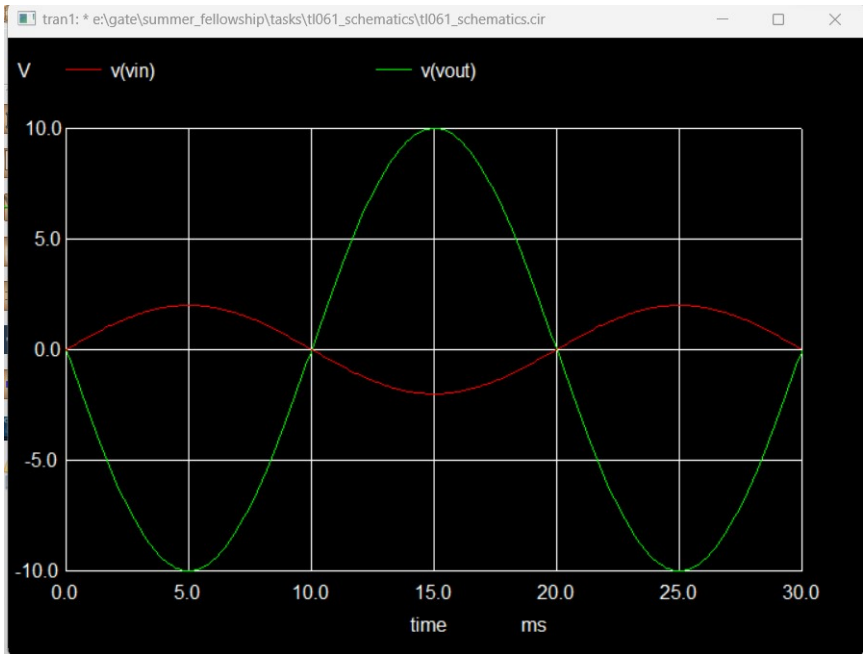


Figure 3.203: Output

Chapter 4

Conclusion and Future Scope

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

Chapter 5

Circuits Contribution

5.0.1 Abhinav Tripathi

1. TL074 Low Noise J-FET Quad Op-Amp IC
2. TL081 J-FET Operational Amplifier IC
3. LM120 Negative Voltage Regulator IC
4. LM709 Operational Amplifier IC
5. LM710 Voltage Comparator IC
6. LM725 Operational Amplifier IC
7. LM145 Negative Regulator IC
8. NJM 1496 Balanced Modulator-Demodulator IC
9. RC4558 Operational Amplifier IC
10. TL071 Low-Noise J-FET Operational Amplifier IC
11. uA78S40 Universal Switching Regulator Sub-system
12. TL061 Low Power J-FET Operational Amplifier

5.0.2 Aman Singh

1. LM1596 Balanced Modulator-Demodulator
2. LM7905 3-Terminal Negative Regulator
3. LM139 Quad Differential Comparator
4. UA702M Dual Op-Amp
5. TL431 3-Terminal Adjustable Shunt Regulator
6. BA4560 Dual high slew rate Op-Amp
7. UA733 Differential Video Amplifier
8. LM185 Dual Adjustable Voltage Reference diode
9. LM193 Voltage Voltage Dual Comparator
10. LM13600 Dual OTA IC
11. LM106 Voltage Comparator
12. LM7915 Negative Voltage Regulator
13. NE4558 Dual Op-Amp
14. LM2903 Voltage Comparator

5.0.3 Karthik Ayyala

1. LM747 Op-Amp
2. uA709 Op-Amp
3. LF253 Op-Amp IC
4. LM4136 Op-Amp IC
5. MC 1558 Op-Amp IC
6. ULN2066 Quad Darlington switches
7. TL052 Op-Amp IC 8. TL084 IC
9. TL072 IC
10. L7915 Voltage Regulator IC

5.0.4 Vignesh S

1. ULN2001 Seven Darlington arrays IC
2. LM4040 Shunt Voltage Reference IC
3. UC3611 Quad Schottky Diode Array
4. LM311 Differential Comparator
5. UC3610 Dual Schottky Diode bridge
6. MC1458 Operational Amplifier
7. LM339 Differential Comparator
8. LF347 Differential Comparator
9. LF351 Operational Amplifier IC

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