Semester Long Internship Report

On

Including Circuits/ Subckts In eSim Library

Submitted by

Devansh Raut
Under the guidance of

Prof.Kannan M. Moudgalya
Chemical Engineering Department
IIT Bombay

August 5, 2024

Contents

Chapter 1

Acknowledgment

The fellowship opportunity I had with FOSSEE Team was a great chance for me to learn and experience professional software development. Therefore, I consider myself lucky to have been provided with such a wonderful opportunity. I am also grateful for having a chance to meet so many skilled and talented professionals who led me through this internship. Bearing in mind, I'd like to use this opportunity to express my deepest gratitude and special thanks to Mr. Sumanto Kar who took time out to hear, guide and keep me on the correct path and allowing me to carry out assigned tasks at their esteemed organization during the training. I express my deepest thanks to Prof. Kannan M. Moudgalya for arranging all facilities during this Internship. I choose this moment to acknowledge his contribution gratefully. I perceive this opportunity as a big milestone in my career development. I will strive to use the gained skills and knowledge in the best possible way, and will continue to work on their improvement, in order to attain desired career objectives.

Chapter 2

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.

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.

A circuit is a closed loop that allows the flow of electric current. It consists of various electrical components like resistors, capacitors, inductors, diodes, transistors, and power sources (such as batteries or generators) connected by conductive wires or traces. Circuits are fundamental to all electronic devices and are used to perform a wide range of functions, from simple tasks like lighting a bulb to complex operations in computers and communication systems.

A subcircuit is a smaller, self-contained section of a larger circuit. It can perform a specific function independently within the larger system. Subcircuits are used to simplify the design and analysis of complex circuits by breaking them down into more manageable sections. This modular approach makes it easier to design, troubleshoot, and maintain electronic systems.

Open source software (OSS) refers to software whose source code is made available for anyone to inspect, modify, and enhance. Its relevance in daily life includes:

- Cost-Effective: OSS is typically free, reducing the cost for individuals and businesses.

- Transparency: Users can inspect the code to ensure there are no hidden vulnerabilities or malicious components.
- Customization: Users can modify the software to suit their specific needs, leading to more personalized and efficient solutions.
- Community Support: OSS is often supported by a community of developers who contribute to its improvement, ensuring continuous enhancement and quick bug fixes.
- Education: Open source projects are valuable learning resources for students and professionals to understand software development practices and contribute to real-world projects.
- Innovation: The collaborative nature of OSS fosters innovation, as developers worldwide can contribute ideas and improvements.

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. Because of this, it has the necessary packages and tools to integrate microcontroller into it.

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 3

Workflow

The steps to be carried out for creating a subcircuit are:

• Open the schematic window in eSim and create the desired circuit schematic by placing the components in the workspace

• Test the newly created schematic by applying the appropriate test signals and verify the output of the circuit.

• If the desired output is obtained then we can proceed to creating a subcircuit

• To convert the created schematic into a subcircuit you need to click on the subcircuit option in eSim and append the created schematic in that sheet.

• Disconnect all the applied voltages and connect port pins to create an IC subcircuit

• Select the library editor to create the IC Dip packages

•After creating the Dip package, you can create the desired test circuit to verify the workings of the created IC

• If you come across any error, try to debug it. Once the IC is error-free and is giving the desired output your working IC is ready.

Chapter 4

Subcircuits

4.1 LM340

The LM340 is a series of three-terminal positive voltage regulators designed to provide a fixed output voltage of 5V, 12V, or 15V with a wide range of input voltages. These regulators are available in different output voltage versions, such as LM340-5, LM340-12, and LM340-15, where the number indicates the output voltage in volts.

Key Features:

- Fixed output voltages: 5V, 12V, 15V
- Output current up to 1.5A
- Internal thermal overload protection
- Short-circuit current limiting
- Output transistor safe-area compensation

The LM340 series voltage regulators maintain a stable output voltage (5V, 12V, or 15V) as long as the input voltage is above the required minimum (dropout voltage) and below the maximum limit. If the input voltage falls below the dropout voltage, the output voltage drops proportionally. Operating above the maximum input voltage can damage the regulator.

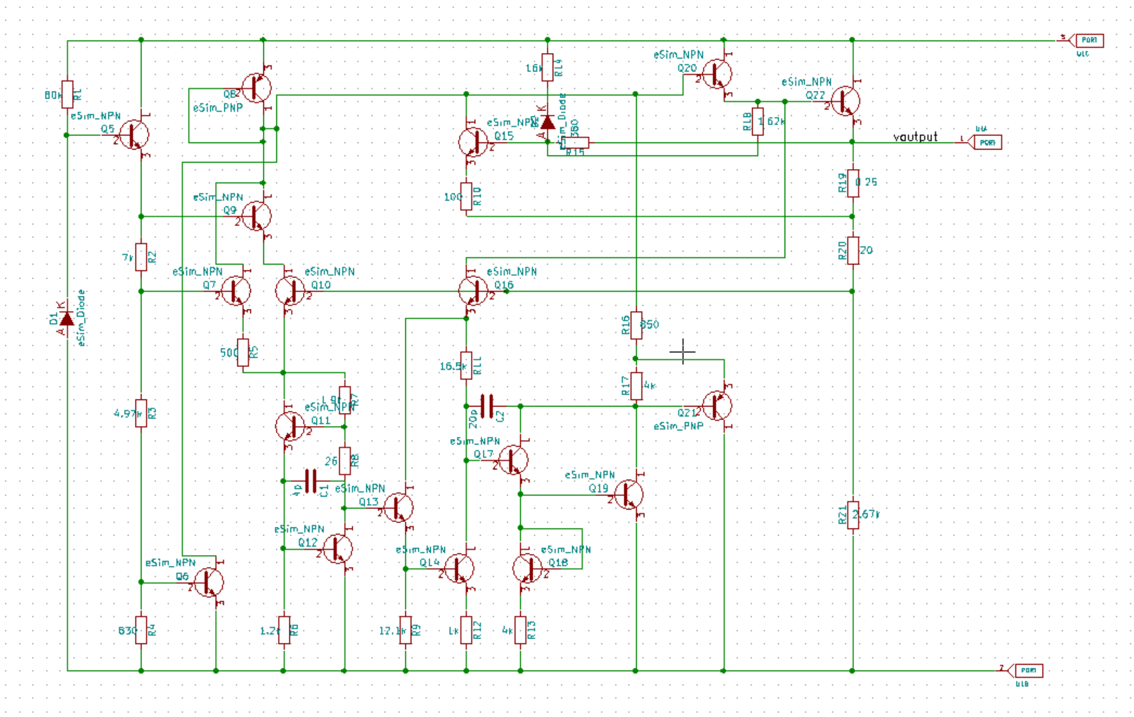

Figure 4.1: Schematic of LM340

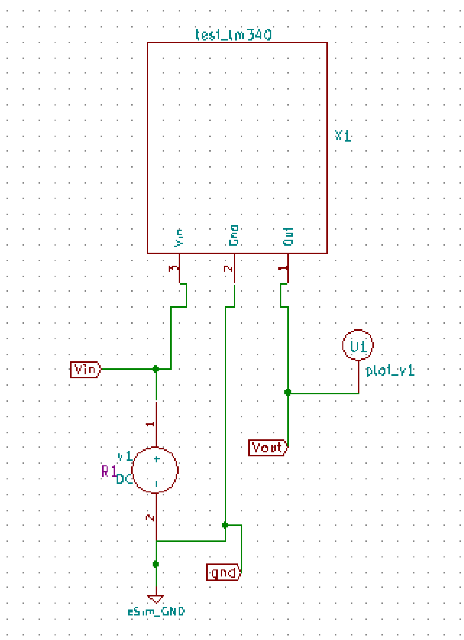

Figure 4.2: Test Circuit of LM340

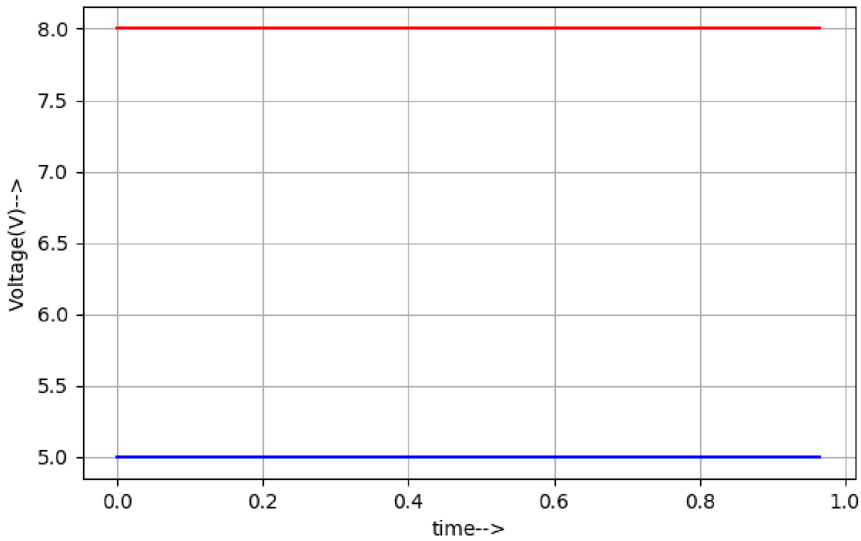

Figure 4.3: Voltage Output Graph (Red- Vin, Blue- Vout)

4.2 LM386

The LM386 is a low-voltage audio power amplifier designed for use in low-power consumer applications. It provides a high gain and operates with a single power supply ranging from 4V to 12V.

Key Features:

- Low quiescent current drain: 4mA
- Wide power supply range: 4V to 12V
- Voltage gain adjustable from 20 to 200
- Low distortion and noise
- Output power: up to 700mW

The LM386 amplifies the input audio signal to a higher output level, with the output power dependent on the input signal and the supply voltage. As the input signal increases, the output signal increases proportionally, up to the limits set by the supply voltage and the amplifier's maximum power capability.

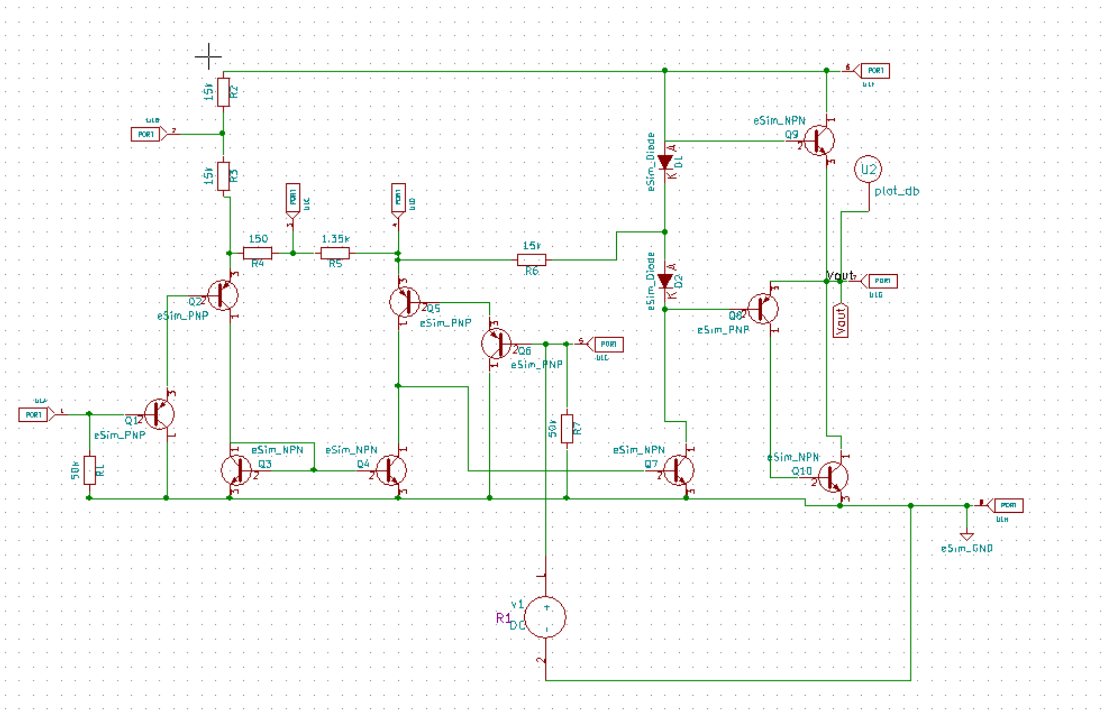

Figure 4.4: Schematic of LM386

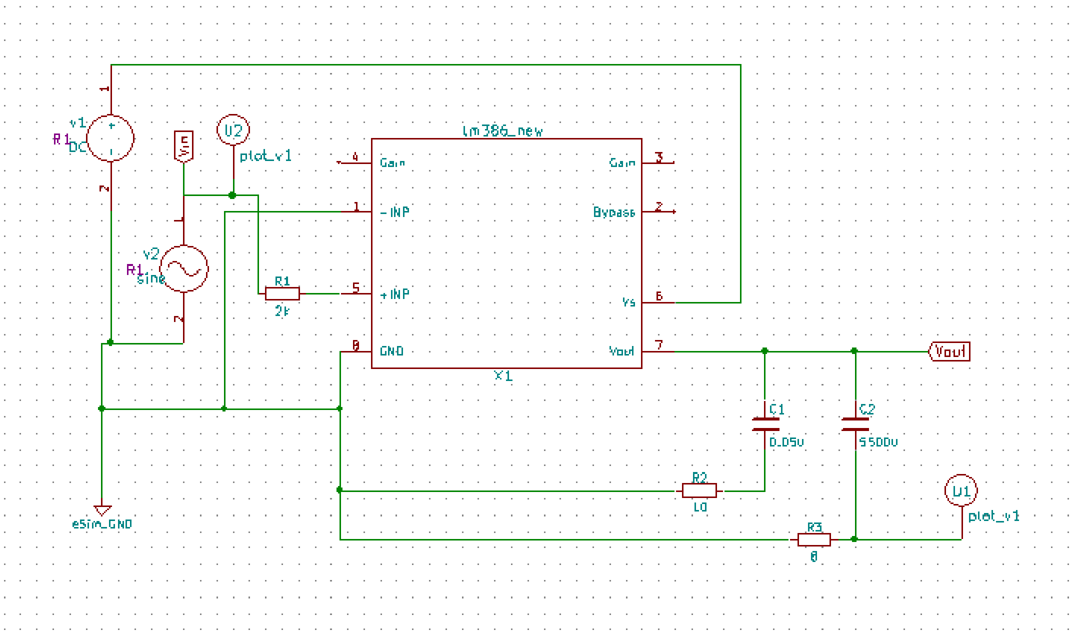

Figure 4.5: Test Circuit of LM386

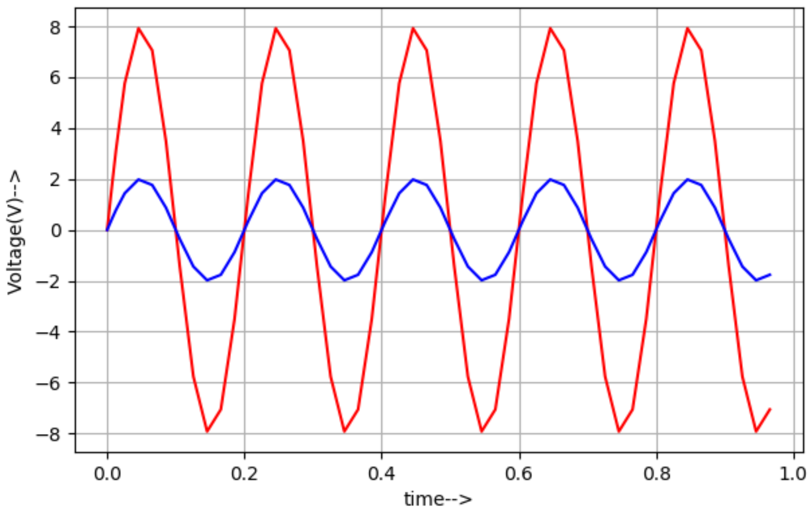

Figure 4.6: Voltage Output Graph (Blue- Vin, Red- Vout)

4.3 LM2903

The LM2903 is a dual comparator IC designed for use in a wide range of analog applications. It compares two input voltages and provides a digital output indicating which input is higher.

Key Features:

- Dual comparator: contains two independent comparators
- Wide supply voltage range: 2V to 36V (single supply) or ±1V to ±18V (dual supply)
- Low input bias current: 25nA typical
- Low input offset voltage: 2mV typical
- Open-collector output: allows for wired-AND connections and interfacing with various logic levels

Input vs. Output Relationship:

- **Input Voltage Comparison:** Each comparator compares two input voltages, VIN+V_{IN+}VIN+ (non-inverting) and VINV_{IN-}VIN (inverting).

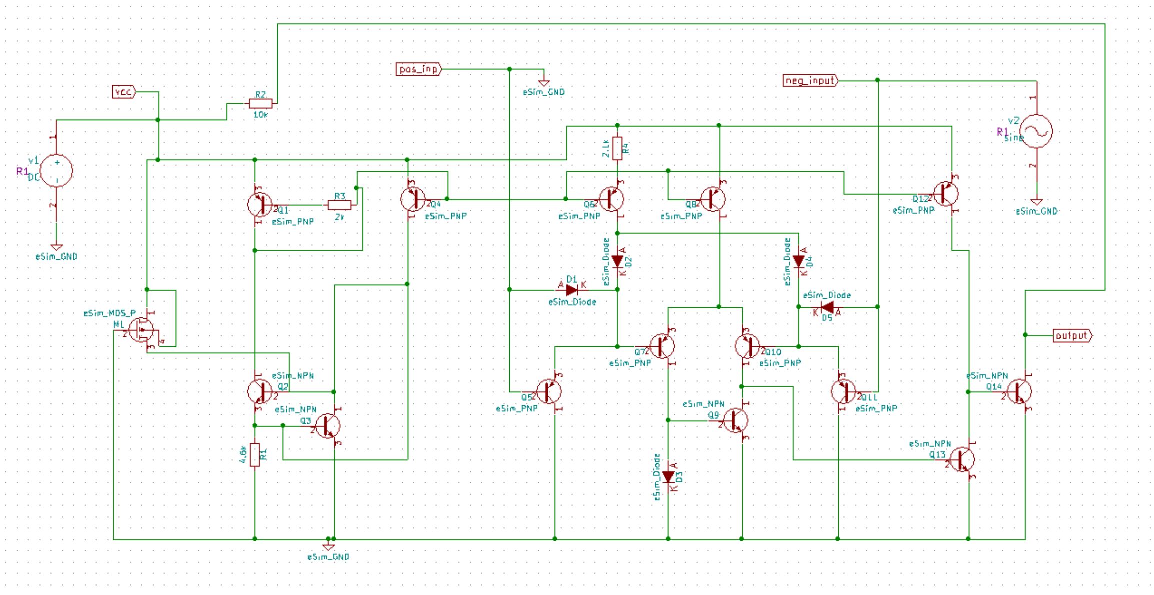

Figure 4.7: Schematic of LM2903

- **Output Voltage:** If VIN+>VINV_{IN+} > V_{IN-}VIN+>VIN, the output is low (close to 0V). If VIN+<VINV_{IN+} < V_{IN-}VIN+ <VIN, the output is high (depends on the pull-up resistor and supply voltage).

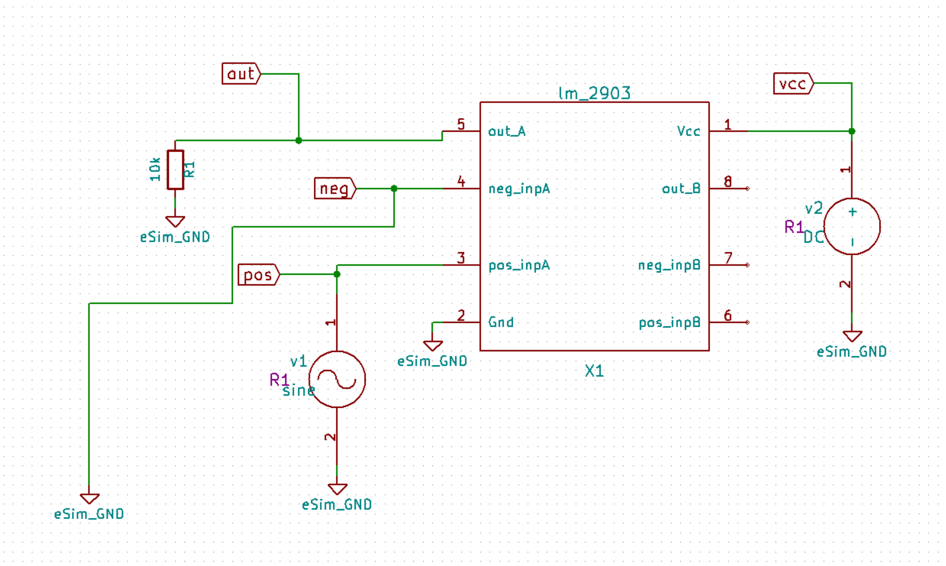

Figure 4.8: Test Circuit of LM2903

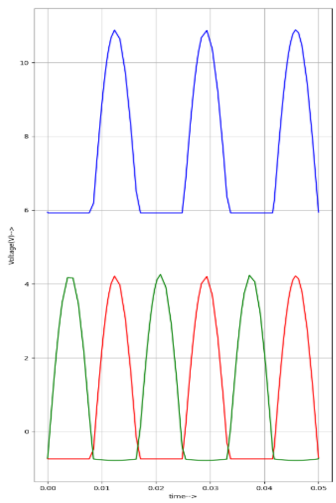

Figure 4.9: Voltage Output Graph (Blue- Vout, Red & Green-Vin)

4.4 INA118

The INA118 is a precision instrumentation amplifier designed for accurate, low-level signal amplification. It is commonly used in applications requiring high common-mode rejection and precise gain.

Key Features:

- High precision: Low offset voltage (50µV max) and low drift
- Wide supply range: ±2.25V to ±18V
- High common-mode rejection ratio (CMRR): Up to 120dB
- Adjustable gain: Gain can be set from 1 to 10,000 via an external resistor
- Low input bias current: 5nA typical
- Low noise: 50nV/Hz at 1kHz

Input vs. Output Relationship:

- **Input Signals:** The INA118 amplifies the differential input voltage (difference between VIN+V_{IN+}VIN+ and VINV_{IN-}VIN) while rejecting common-mode signals (signals that are the same on both VIN+V_{IN+}VIN+ and VINV_{IN-}VIN).
- **Output Signal:** The output voltage (VOUTV_{OUT}VOUT) is proportional to the differential input voltage (VIN+VINV_{IN+} - V_{IN-}VIN+VIN), multiplied by the gain (G) set by an external resistor.

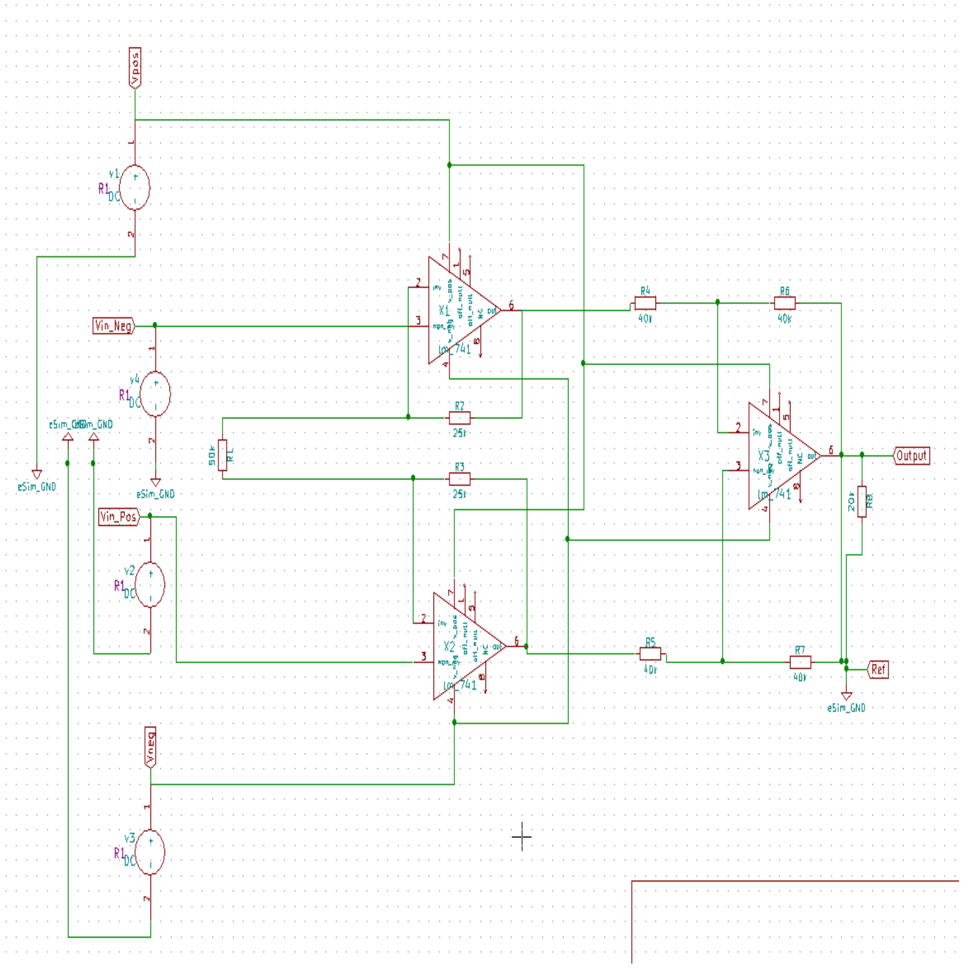

Figure 4.10: Schematic of INA118

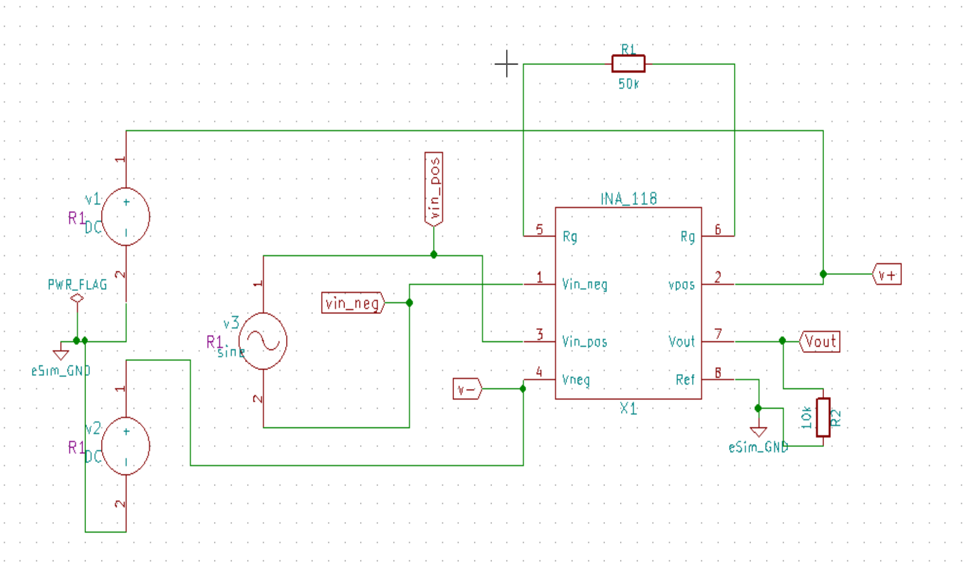

Figure 4.11: Test Circuit of INA118

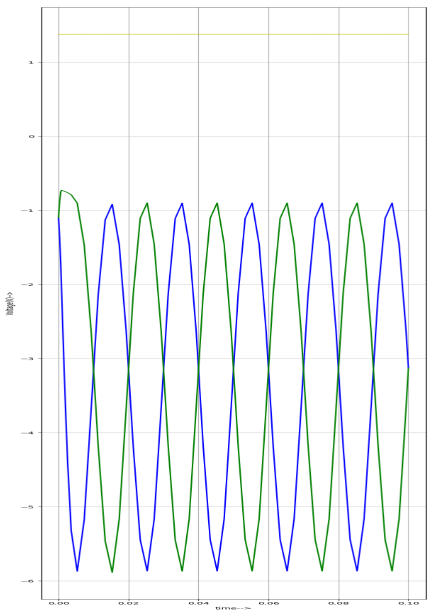

Figure 4.12: Voltage Output Graph (Yellow- Vout, Blue & Green-Vin)

4.5 CDX4HC

The CD74HC4051 (CDX4H) is an 8-channel analog multiplexer/demultiplexer IC, part of the 74HC series. It allows the selection of one of the eight input/output channels to be connected to a common terminal, facilitating the routing of analog or digital signals.

Key Features:

- 8-channel multiplexer/demultiplexer
- Wide supply voltage range: 2V to 10V
- Low ON resistance: 70 (typical) at VCC = 4.5V
- High-speed operation: Typical propagation delay of 10ns at VCC = 5V
- Low power consumption
- Digital control inputs: Compatible with standard CMOS logic levels

Input vs. Output Relationship:

- **Control Inputs:** The IC uses three digital control inputs (A, B, and C) to select one of the eight channels (Y0 to Y7).
- **Common Terminal:** The selected channel is connected to the common terminal (Z).
- **Multiplexing:** When a specific control code is applied to the control inputs, the corresponding channel is connected to the common terminal, allowing the signal to pass through.

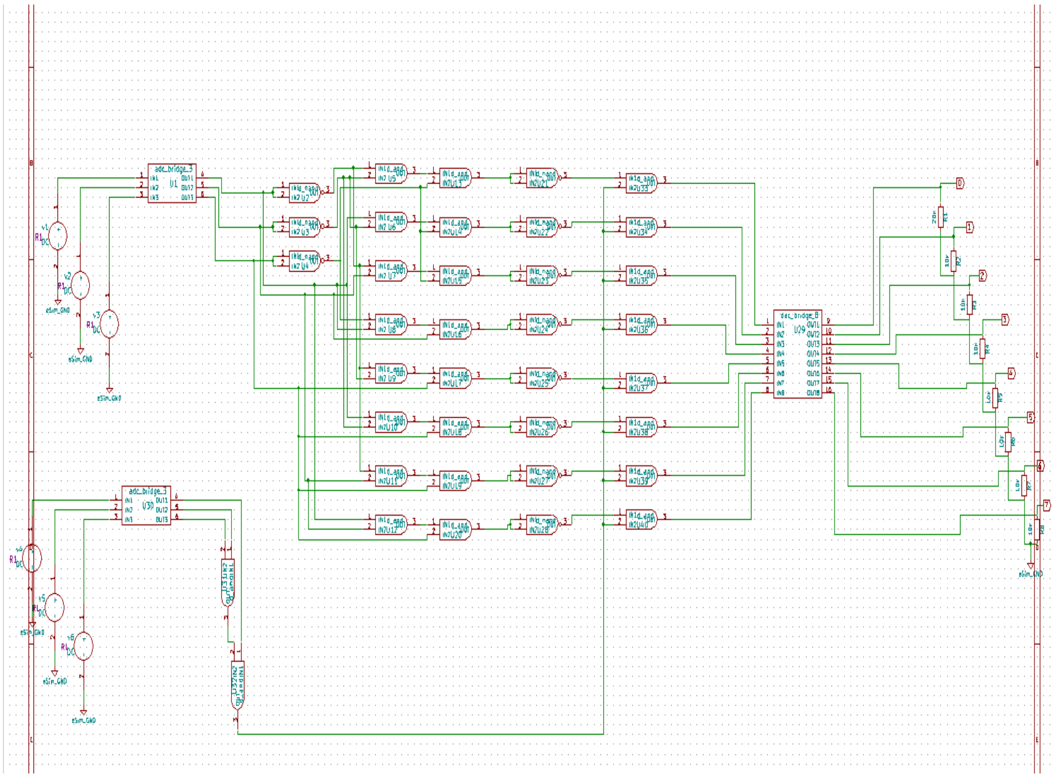

Figure 4.13: Schematic of CDX4HC

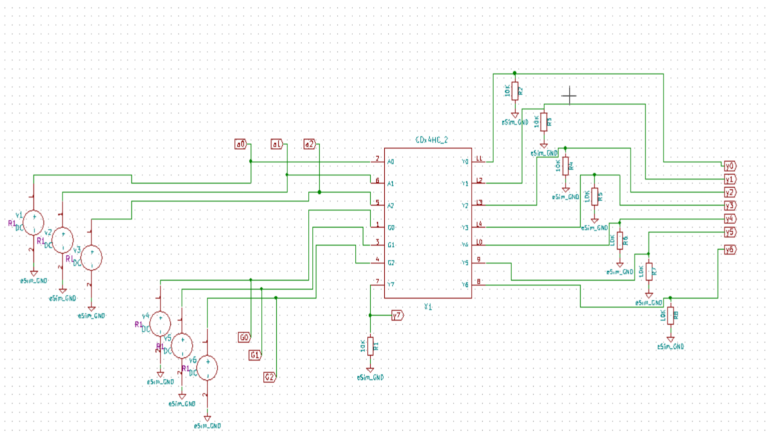

Figure 4.14: Test Circuit of LM2903

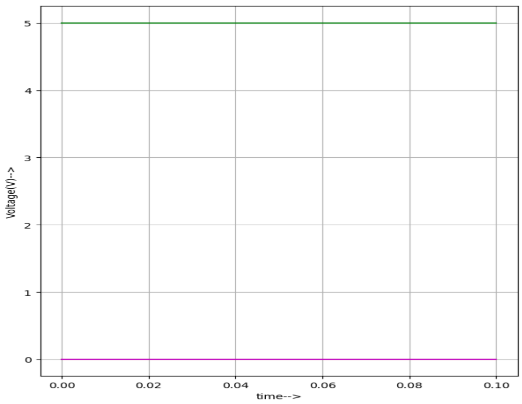

Figure 4.15: Voltage Output Graph (Input- a0,a1,a1: high, Output- y7: low)

4.6 74HC280

The 74HC280 is a high-speed CMOS 9-bit parity generator/checker IC. It is designed for error detection and correction in digital systems by generating and checking even or odd parity for binary data.

Key Features:

- 9-bit parity generator/checker
- High-speed CMOS technology
- Wide supply voltage range: 2V to 6V
- Low power consumption
- Standardized pin configuration for easy integration

Input vs. Output Relationship:

- **Inputs:** The IC takes nine data inputs (A1 to A9).
- **Outputs:** The output () represents the parity bit.
  - **Even Parity Mode:** If the number of high (1) inputs is even, the output is low (0); if odd, the output is high (1).
  - **Odd Parity Mode:** If the number of high (1) inputs is odd, the output is low (0); if even, the output is high (1).

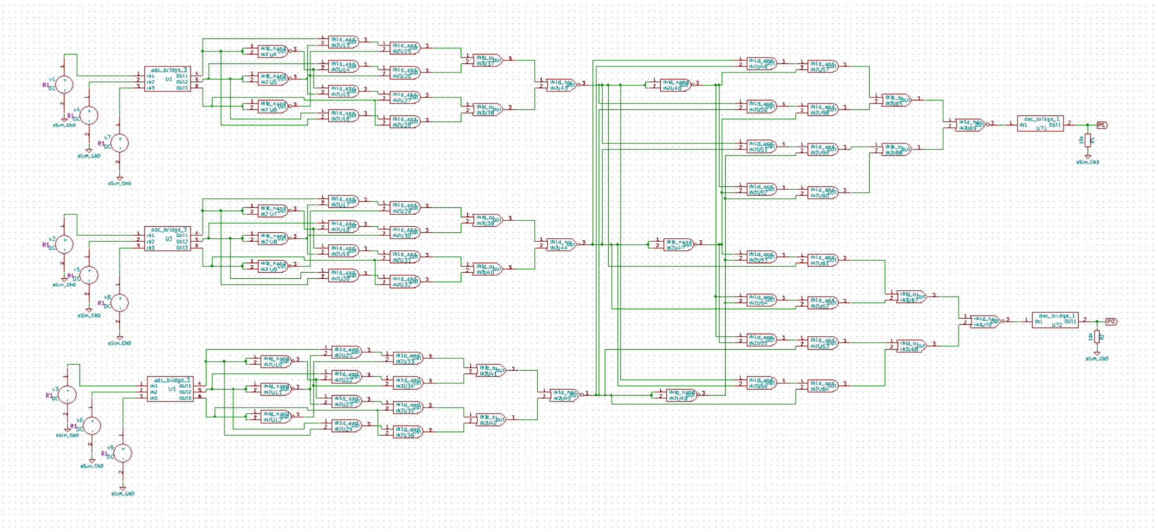

Figure 4.16: Schematic of 74HC280

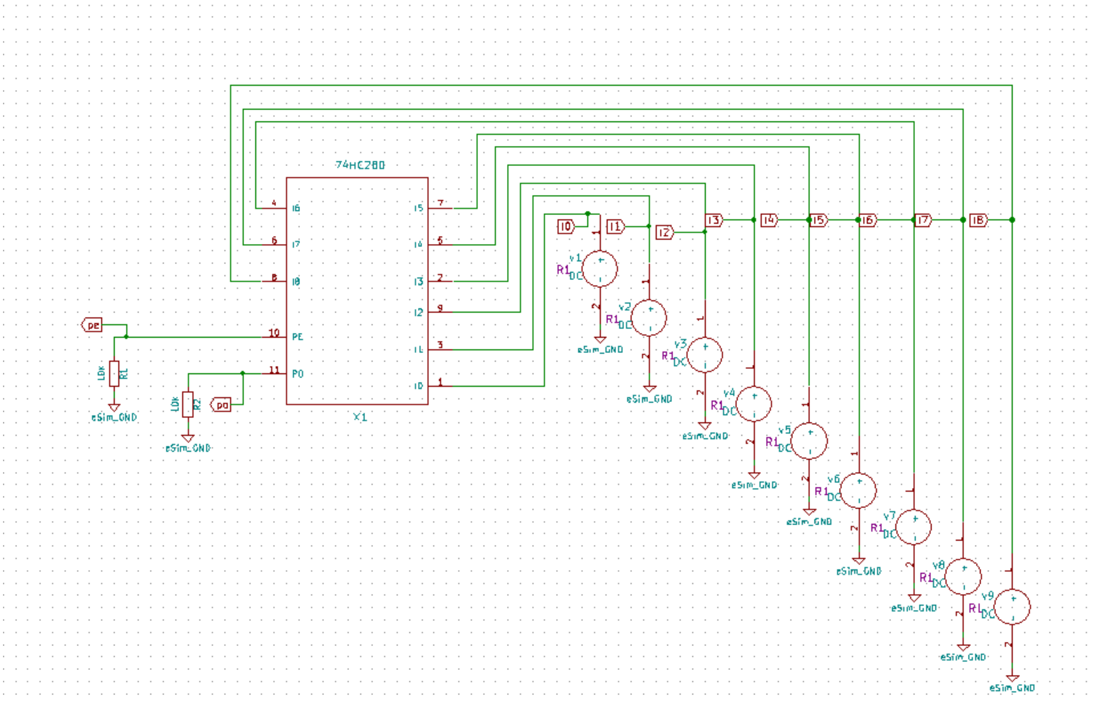

Figure 4.17: Test Circuit of 74HC280

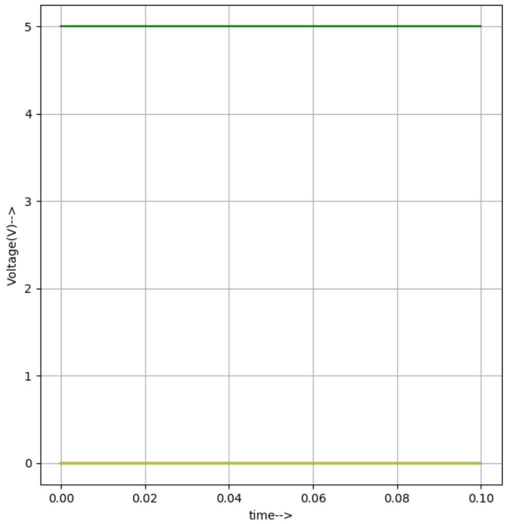

Figure 4.18: Voltage Output Graph (Input- I0: high, Output- low)

4.7 LF353

The LF353 is a high-speed dual JFET-input operational amplifier designed for applications requiring wide bandwidth, high input impedance, and low noise. It is widely used in analog signal processing.

Key Features:

- Dual operational amplifier
- High input impedance: Typically 10^{12} ohms
- Wide bandwidth: 4 MHz
- Low input bias current: Typically 50 pA
- Low noise: 12 nV/Hz
- Wide supply voltage range: ±3V to ±18V

Input vs. Output Relationship:

- **Input Signals:** The LF353 amplifies the difference between its two input terminals (inverting input VINV_{IN-}VIN and non-inverting input VIN+V_{IN+}VIN+).

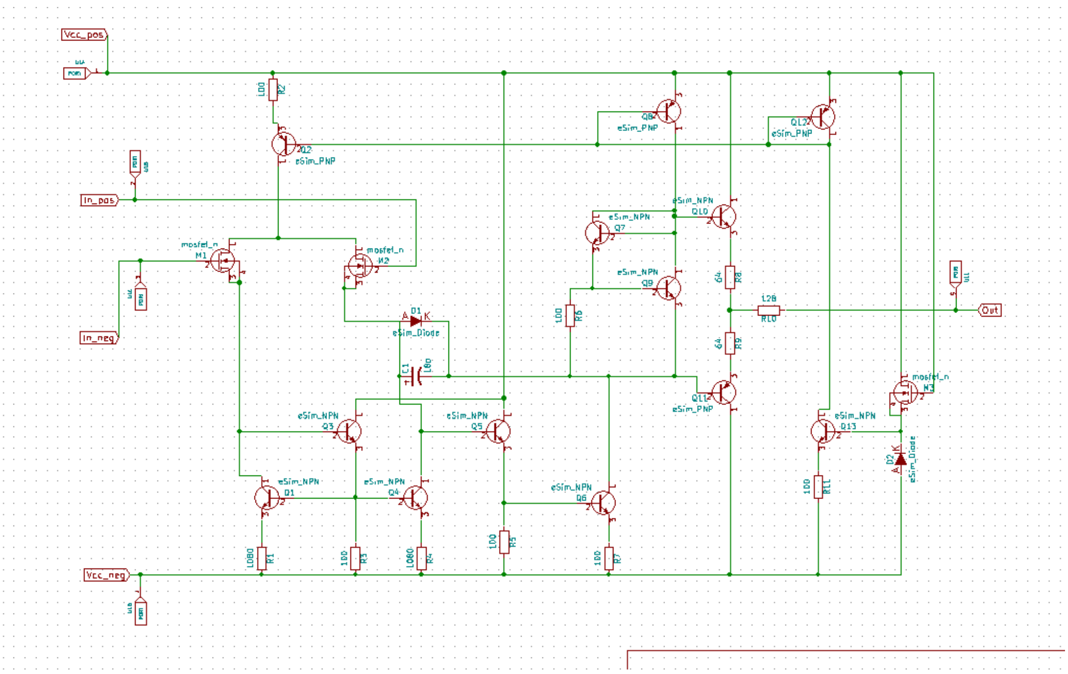

Figure 4.19: Schematic of LF353

- **Output Voltage (VOUTV_{OUT}VOUT):** The output is a function of the differential input voltage (VIN+VINV_{IN+} - V_{IN-}VIN+ VIN) multiplied by the amplifier's gain.

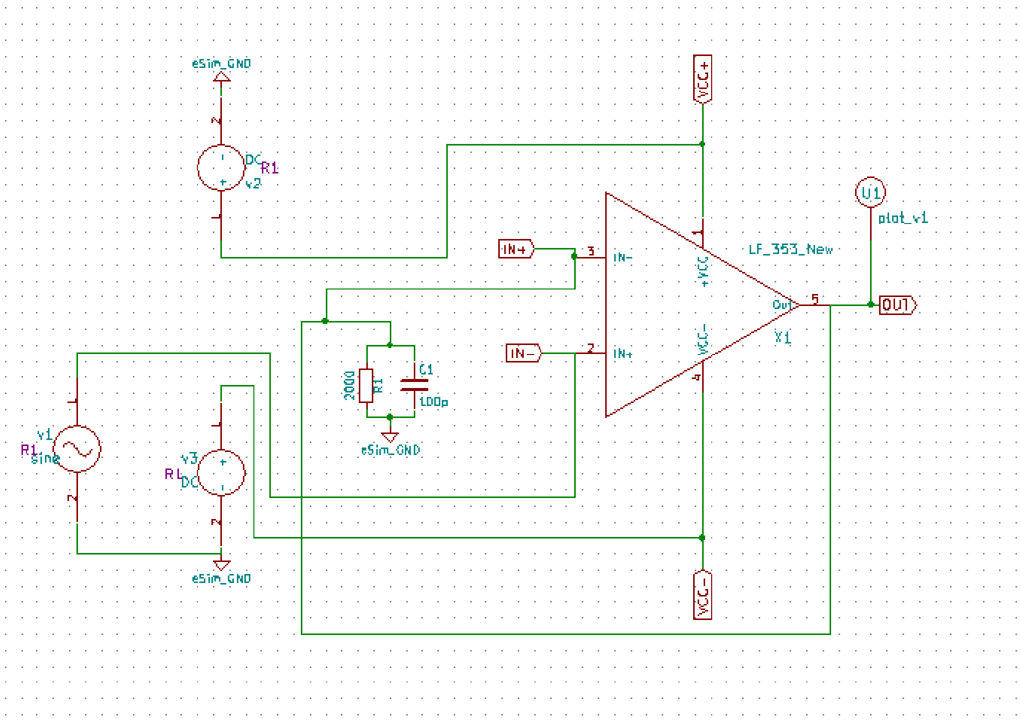

Figure 4.20: Test Circuit of LF353

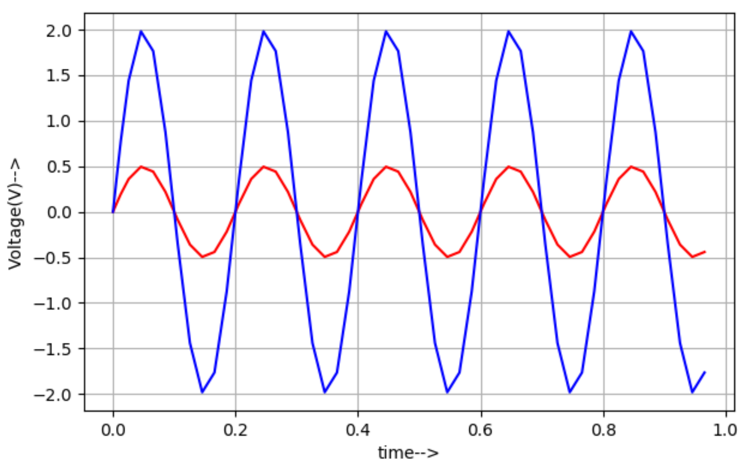

Figure 4.21: Voltage Output Graph (Blue - Vout, Red -Vin)

4.8 WEIGHTED SUM of Digital Signals

An Efficient Mixed Signal Circuit to Find the Weighted Sum of Digital Current Signals. Finding the weighted sum of voltage signals is straight forward and the method is well known. But finding the weighted sum of current signals is unfortunately not so simple. And the situation gets more complicated when the value of the current signals are only available in digital form. There are purely digital and purely analog methods to address this problem, but both have its own limitations. This schematic presents a median method to solve this problem which overcomes the limitations of the pure methods.

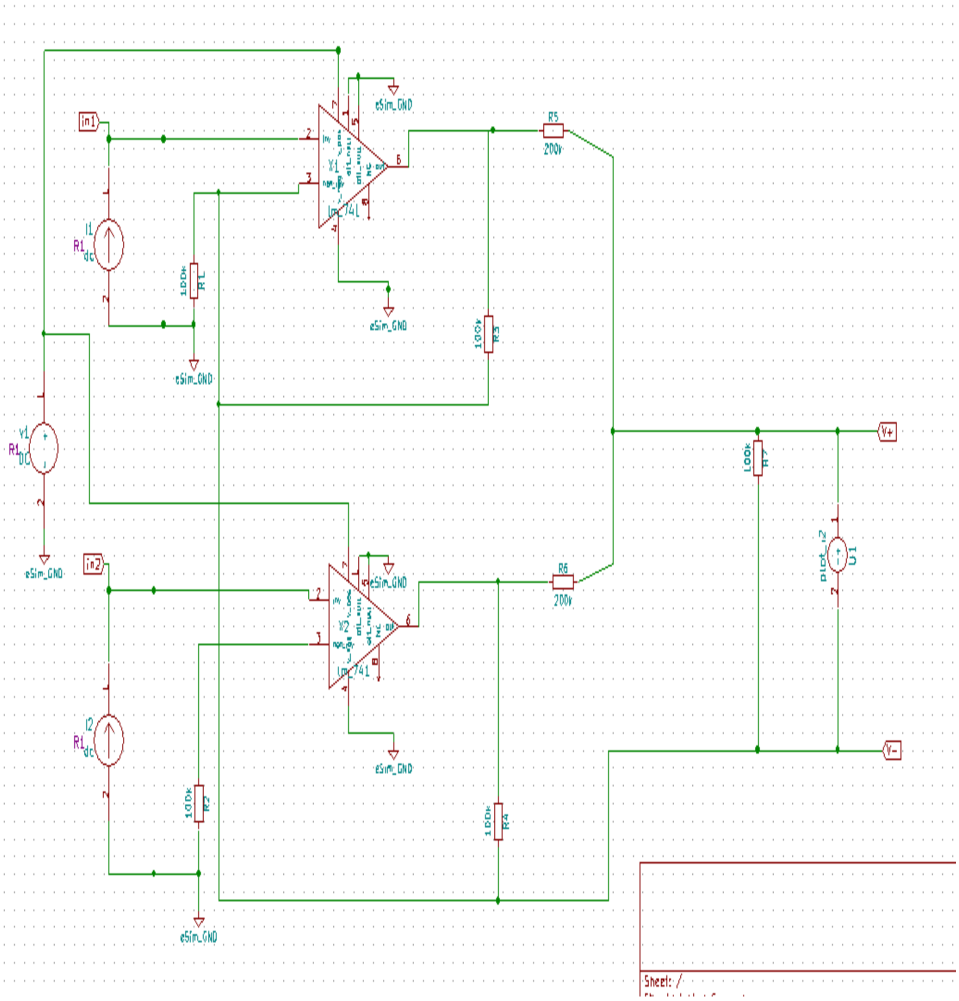

Figure 4.22: Schematic of Weighted Sum

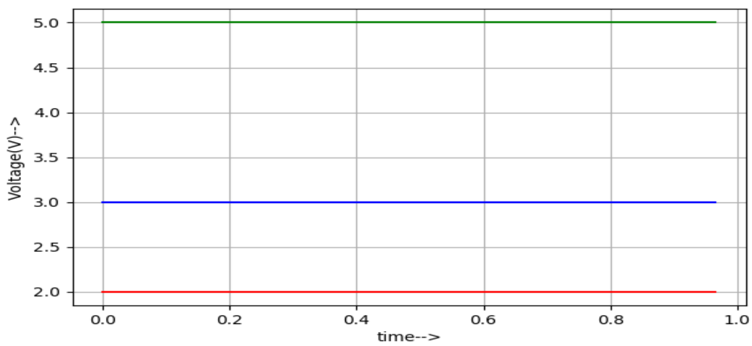

Figure 4.23: Voltage Output Graph (Green- Vout, Blue & Red-Vin)

4.9 LM565

The LM565 is a Phase-Locked Loop (PLL) IC used for frequency synthesis, modulation, demodulation, and signal synchronization in communication systems. It is designed to lock onto an input signal frequency and maintain a constant phase relationship with it.

Key Features:

- Wide supply voltage range: 6V to 12V
- Operating frequency range: 0.001 Hz to 500 kHz
- Low power consumption
- High stability and accuracy
- Internal voltage-controlled oscillator (VCO) and phase detector
- Wide capture and lock range

Input vs. Output Relationship:

- **Input Signals:**
  - **Reference Signal (f_in):** The input signal frequency to which the PLL locks.
  - **VCO Control Voltage (V_C):** An analog input voltage that controls the frequency of the internal VCO.
- **Output Signals:**
  - **VCO Output (f_out):** The frequency of the VCO output, which is adjusted to match the input frequency finf_{in}fin.
  - **Phase Detector Output:** A DC voltage representing the phase difference between the input signal and the VCO output.

Due to its complicated Test Circuit, Its IC couldn't be tested in KiCad

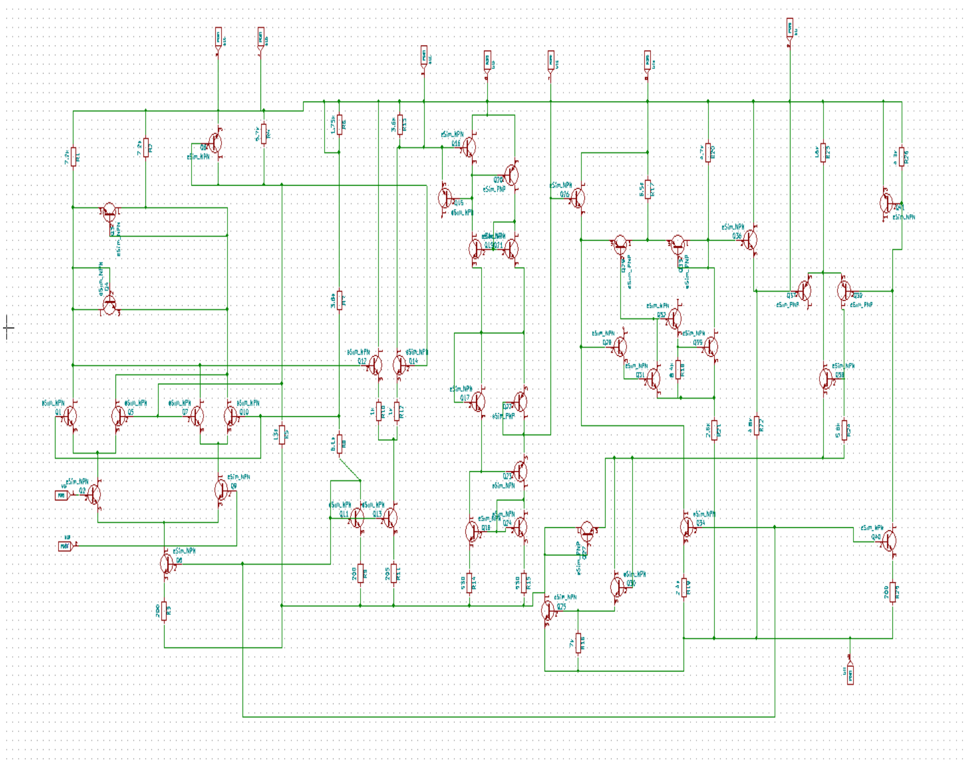

Figure 4.24: Schematic of LM565

Chapter 5

Conclusion And Future Scope

5.1 Conclusion

We were able to successfully convert the schematics files to Subcurcuits in KiCad schematic and library files. The user can open the schematic and generate the desired circuit design. If the user wants to simulate the circuit then the user has to change the reference according to the Ngspice reference.

5.2 Future Work

In PSpice and KiCad libraries, most of the DIP packages are labeled as U (user) references. To ensure compatibility with Ngspice, these references need to be changed to x (subcircuit). Currently, this conversion is done manually.

Chapter 6

References

- https://www.ti.com/lit/ds/symlink/lm386.pdf
- https://ieeexplore.ieee.org/document/8821119
- https://www.egr.msu.edu/eceshop/Parts_Inventory/lm565.pdf
- https://www.ti.com/product/LM2903
- https://www.ti.com/product/LM340
- https://www.ti.com/lit/gpn/LF353
- https://www.ti.com/lit/gpn/INA118
- https://www.mouser.com/datasheet/2/405/1/cd74hct540.pdf
- https://www.nexperia.com/products/74HC280-74HCT280.html