Summer Internship Report

On

Including Integrated Circuit (IC) Subcircuit on eSim

Submitted by

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Under the guidance of

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Acknowledgment

I would like to express my heartfelt gratitude to the entire **FOSSEE team** for granting me this esteemed **Fellowship opportunity**. Being part of an open-source organization like FOSSEE has been a truly enlightening and rewarding experience. During my time here, I had the chance to explore and work with **eSim**, a new simulation software, through which I gained significant knowledge in **problem-solving and debugging techniques** skills that I will carry forward into my future endeavors.
I extend my sincere appreciation to **Prof. Kannan M. Moudgalya** for his visionary leadership and commitment to this initiative. I am truly honored to have contributed, even in a small way, to a project under his guidance.
I am also deeply grateful to my mentors **Mr. Sumanto Kar and Mr. Rakesh Sinha** for their constant guidance, encouragement, and mentorship throughout my internship. Their support enabled me to fulfill my project responsibilities effectively. Whenever I encountered a challenge, they were always approachable and helped me find the right solutions with patience and clarity.
A special thanks goes to all my fellow interns, whose collaboration and motivation made this journey even more enjoyable and meaningful. Working alongside such enthusiastic individuals reinforced the spirit of teamwork and shared learning.
Overall, my internship at FOSSEE has been a delightful and transformative experience. It has provided me with valuable insights into open-source development and the practical aspects of engineering. As someone passionate about the semiconductor industry, this opportunity marks an important milestone in my career journey, and I will always cherish the knowledge and memories gained from this Fellowship.

Contents

Chapter 1

Introduction

FOSSEE (Free/Libre and Open Source Software for Education) is an initiative taken by the National Mission on Education through Information and Communication Technology (ICT), Ministry of Human Resource Development (MHRD), Government of India which has successfully developed various opensource tools and promotes the use of these tools in improving the quality of education and helping every individual avail these sources free of cost. The software is being developed in such a way that it can stay relevant with respect to the commercial softwares.

1.1 eSim

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.

1.2 NgSpice

Ngspice is a general purpose circuit simulation program for nonlinear dc, nonlinear transient, and linear ac analysis. Circuits may contain resistors, capacitors, inductors, mutual inductors, independent voltage and current sources, four types of dependent sources, lossless and lossy transmission lines (two separate implementations), switches, uniform distributed RC lines, and the five most common semiconductor devices: diodes, BJTs, JFETs, MESFETs, and MOSFET.

Chapter 2

Task Assigned

Implementing some standard Integrated Circuits (IC) as subcircuits into the eSim library and verifying the functionality by using the test circuits.

2.1 Approach

1. Selecting an Analog or Digital IC.
2. Browse through the datasheets that are available on the internet.
3. Selecting an appropriate datasheet that which consists of the detailed schematic of the IC.
4. Now based on the schematic the Subcircuit of that circuit has implemented and creating the IC component using the Library Editor.
5. Convert the subcircuit from Kicad to NgSpice and then create the .sub file based on the created component.
6. Now implement a test circuit that which can check the functionality of the subcircuit.
7. Convert the circuit from Kicad to NgSpice and simulate the output of the spice file and verifying the functionality of the IC.
8. If the functionality of the IC does not meet with the datasheet then try changing the circuit and try the above process again.

The same process is followed for all other subcircuits.

Chapter 3

Subcircuits Implemented

There are total seven Integrated Circuits(IC) implemented by me as subcircuits on eSim. Following are the schematic and description of each of them.

3.1 TL07X IC

3.1.1 TL071 IC

Developed by Texas Instruments, the **TL071** is a low-noise JFET-input operational amplifier designed for high-input impedance and excellent AC performance. This IC operates with low power consumption and supports a wide range of single or dual supply voltages. The TL071 features low total harmonic distortion, low input bias and offset currents, and high slew rate, making it suitable for audio and precision signal applications. It also includes internal frequency compensation and short-circuit protection.

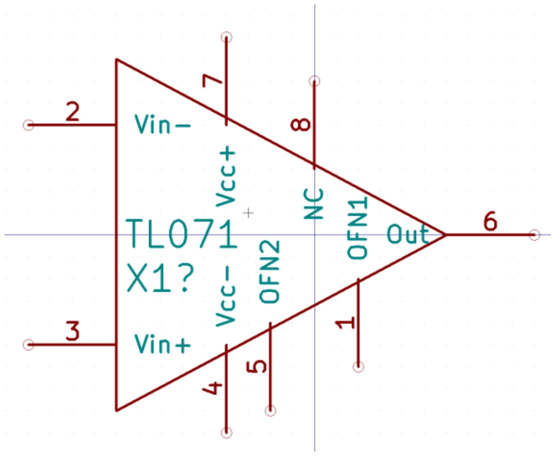
Some of the common applications of TL071 are:

1. Audio preamplifiers
2. Signal conditioning
3. Active filters

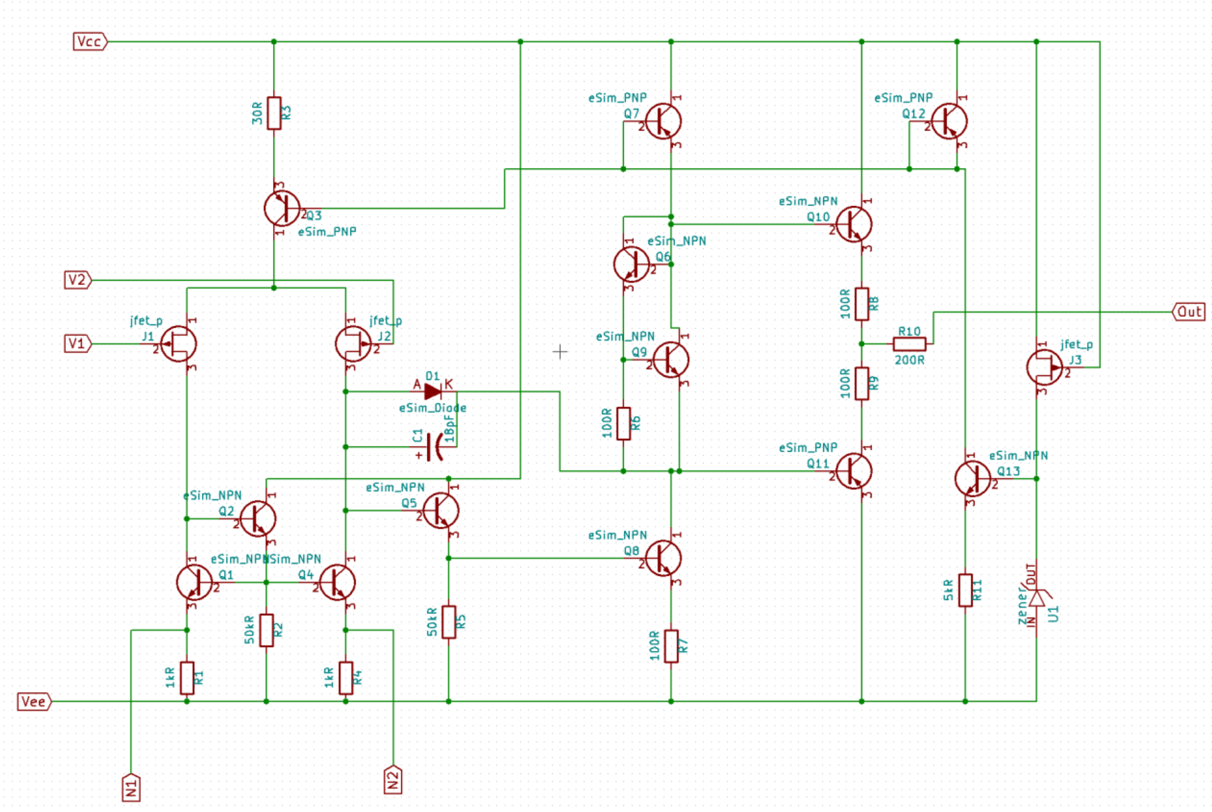
Some of the salient features of TL071 are:

1. Low noise JFET inputs
2. High slew rate (13 V/µs typical)
3. Low input bias and offset currents

3.1.1.1 Pin Diagram



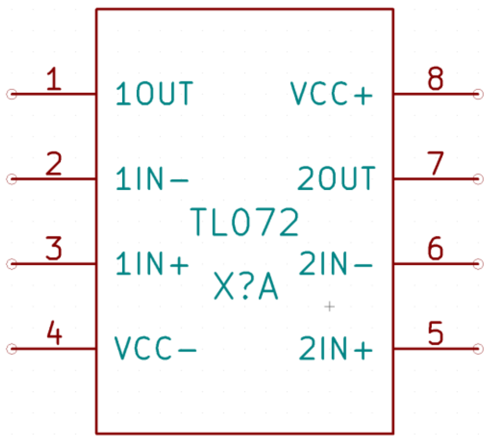
3.1.1.2 Subcircuit Schematic



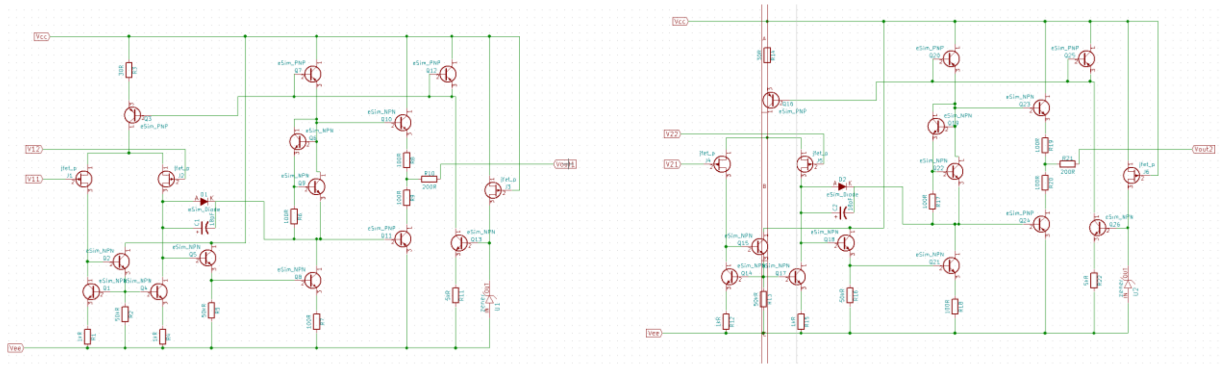
3.1.2 TL072 IC

The TL072 IC consists of two TL071 IC with common vcc and vee.

3.1.2.1 Pin Diagram



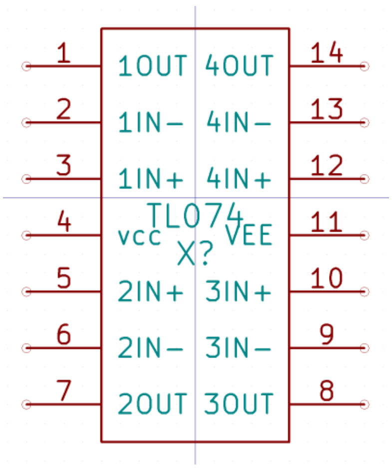
3.1.2.2 Subcircuit Schematic



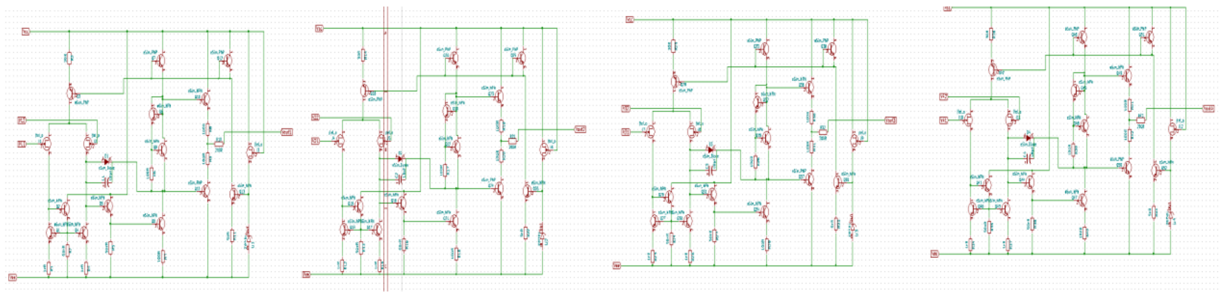
3.1.3 TL074 IC

The TL074 IC consists of four TL071 IC with common vcc and vee.

3.1.3.1 Pin Diagram



3.1.3.2 Subcircuit Schematic



3.2 SN54154 IC

The SN54154, manufactured by Texas Instruments, is a 4-line to 16-line decoder/demultiplexer integrated circuit designed for high-speed memory decoding and data routing applications. It accepts four binary-weighted input signals and decodes them into one of sixteen mutually exclusive outputs. The SN54154 features dual active-low enable inputs, providing additional flexibility for cascading or expanding decoding functions. The IC operates over a wide voltage range and is optimized for TTL-compatible logic levels.

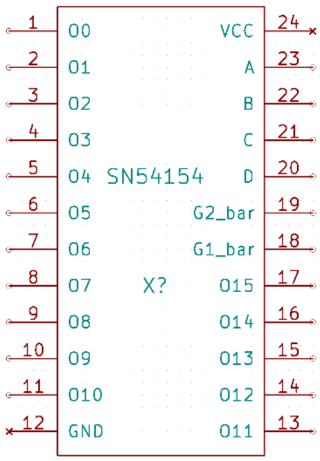
Some of the common applications of SN54154 are:

1. Memory address decoding
2. Data routing in digital systems
3. Control signal demultiplexing

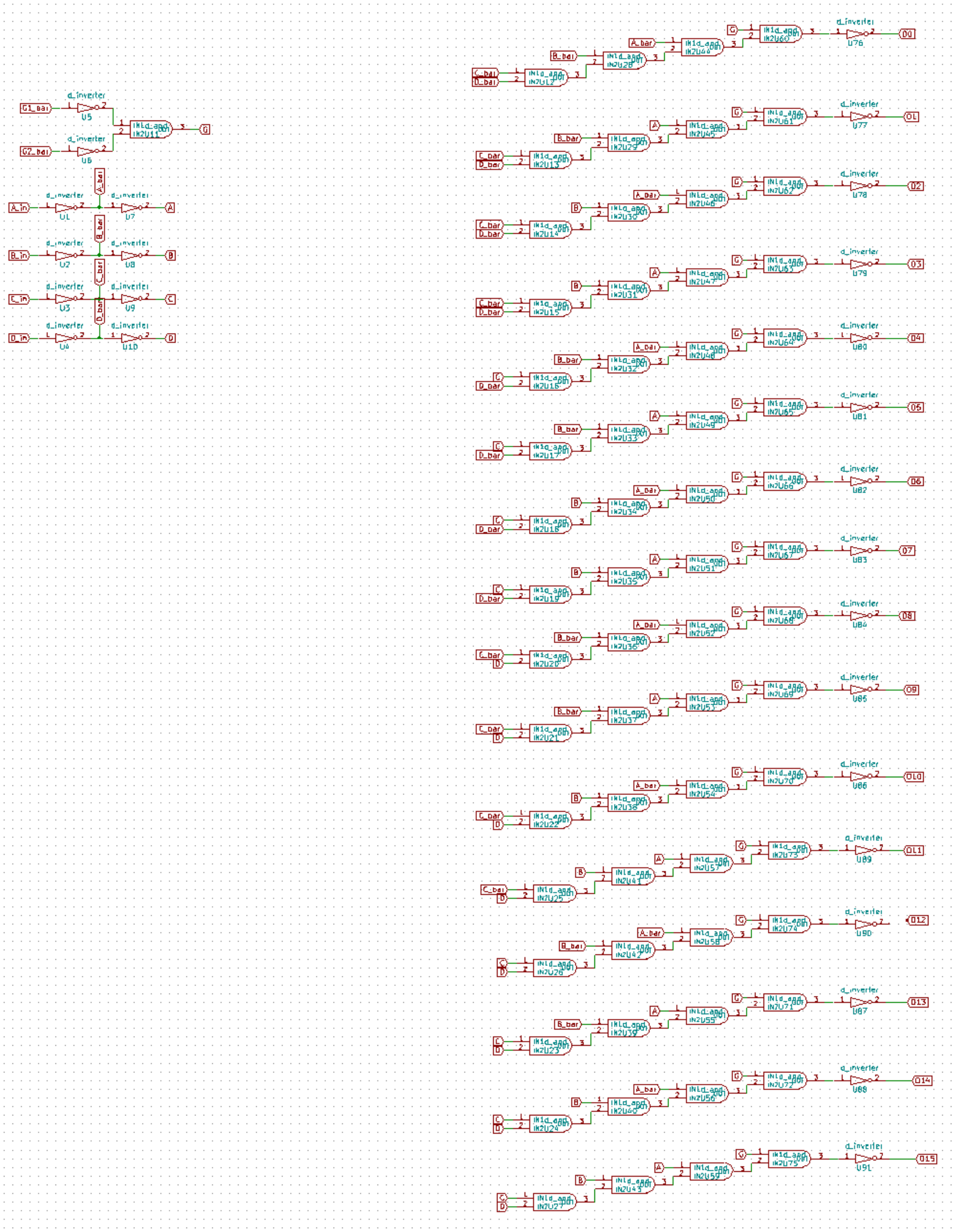
Some of the salient features of SN54154 are:

1. Fully decoded 4-to-16 line output
2. Dual active-low enable inputs for flexible control
3. TTL-compatible and fast switching times

3.2.1 Pin Diagram



3.2.2 Subcircuit Schematic



3.3 CD4093B IC

The CD4093B, developed by Texas Instruments, is a quad 2-input NAND Schmitt trigger integrated circuit that combines logic gating with noise immunity and signal shaping. Each gate has Schmitt trigger inputs, allowing for improved noise margin and clean transitions in slow or noisy input signals. The CD4093B is suitable for operation across a wide voltage range and is compatible with both CMOS and TTL systems. It is ideal for waveform shaping, oscillator circuits, and signal conditioning.

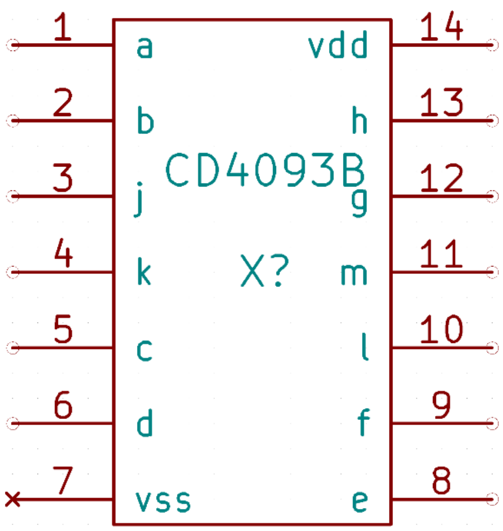
Some of the common applications of CD4093B are:

1. Oscillator and waveform generator circuits
2. Debouncing mechanical switches
3. Signal conditioning and waveform shaping

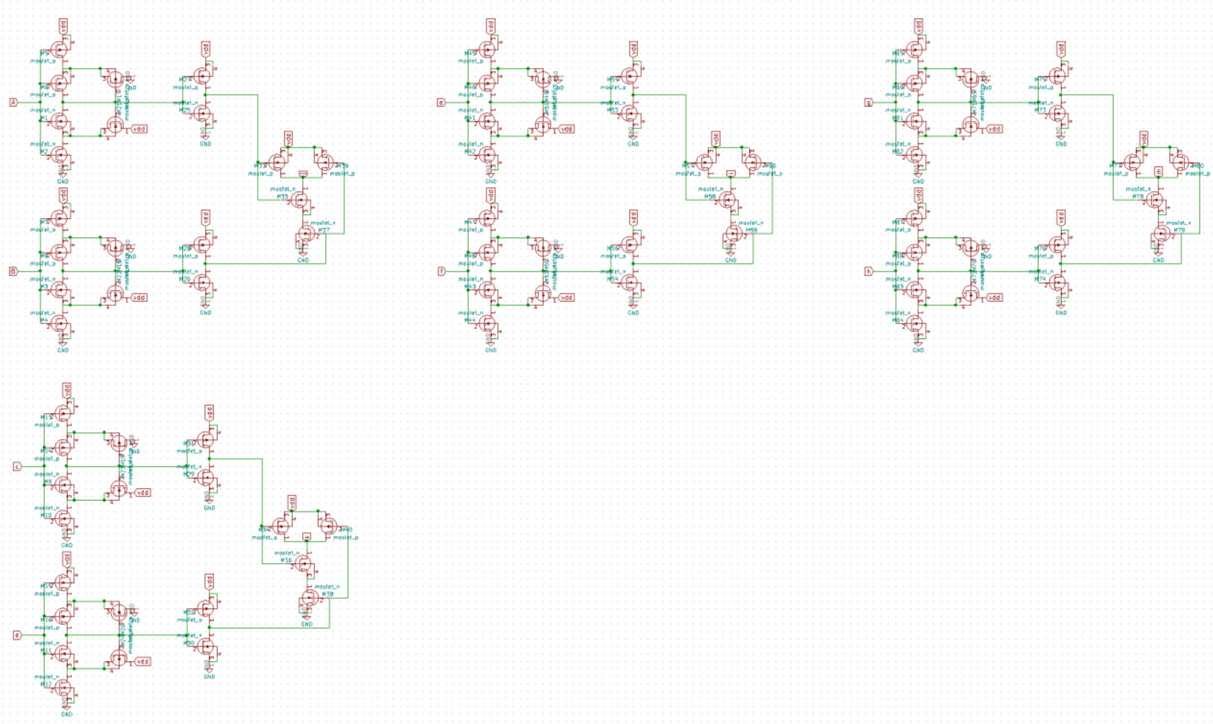
Some of the salient features of CD4093B are:

1. Schmitt trigger action on each input
2. Wide supply voltage range (3V to 15V)
3. Low power consumption and high noise immunity

3.3.1 Pin Diagram



3.3.2 Subcircuit Schematic



3.4 CD4015BC IC

The CD4015BC, manufactured by Fairchild Semiconductor, is a dual 4-stage static shift register designed for high-speed serial data storage and transfer. Each register has a separate clock and reset, and is capable of handling independent data streams. The CD4015BC operates over a wide supply voltage range and provides excellent noise immunity, making it suitable for digital delay lines, serial-to-parallel conversion, and data buffering in control systems.

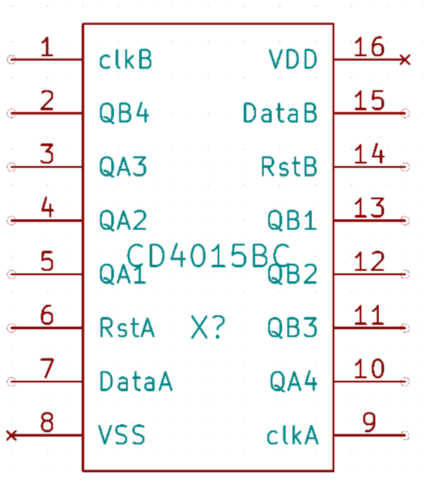
Some of the common applications of CD4015BC are:

1. Serial-to-parallel data conversion
2. Digital delay lines
3. Data buffering in control systems

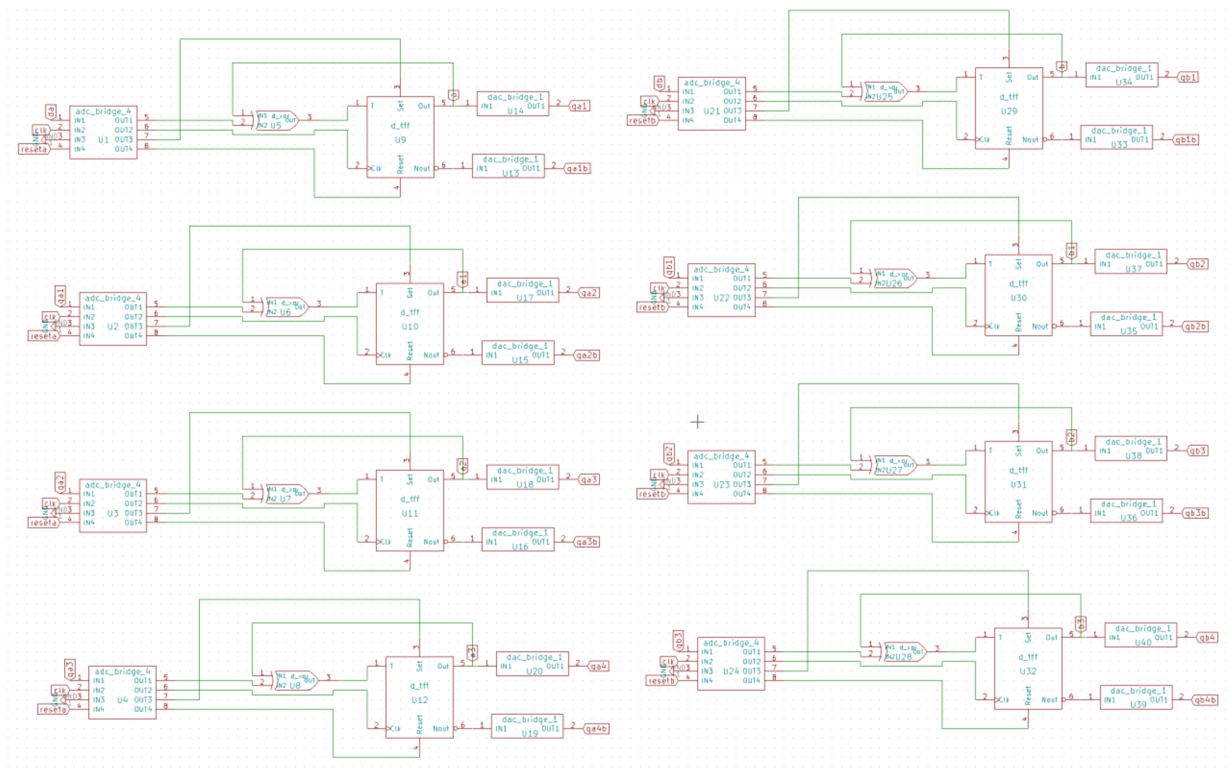
Some of the salient features of CD4015BC are:

1. Dual independent 4-stage shift registers
2. Wide supply voltage range (3V to 15V)
3. High noise immunity and low power consumption

3.4.1 Pin Diagram



3.4.2 Subcircuit Schematic



3.5 CD4040 IC

The CD4040, developed by Texas Instruments, is a 12-stage binary ripple counter designed for general-purpose counting applications. It consists of flip-flops connected in series to divide an input clock frequency by successive powers of two. The CD4040 operates over a wide voltage range and offers high noise immunity and low power consumption, making it ideal for frequency division, event counting, and digital timing applications.

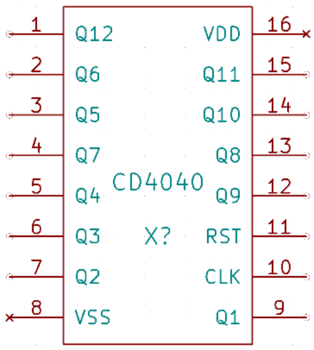
Some of the common applications of CD4040 are:

1. Frequency division
2. Digital counters
3. Time delay generation

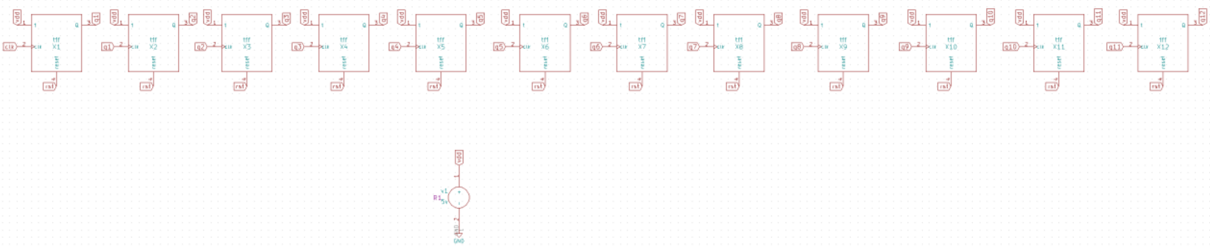
Some of the salient features of CD4040 are:

4. 12-bit binary counter
5. Wide supply voltage range (3V to 15V)
6. High noise immunity and low power consumption

3.5.1 Pin Diagram



3.5.2 Subcircuit Schematic



3.6 74LS3253 IC

The 74LS3253, manufactured by Texas Instruments, is a high-speed dual 4-channel analog multiplexer/demultiplexer with three-state outputs. It allows the selection of one of four binary inputs from each multiplexer channel, using a common set of selection lines. The IC supports both standard data routing and logic signal switching, making it suitable for a wide range of digital and mixed-signal applications. Its three-state outputs make it ideal for bus-oriented systems.

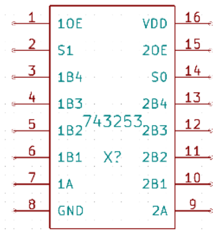
Some of the common applications of 74LS3253 are:

1. Digital data selection and routing
2. Bus multiplexing and demultiplexing
3. Logic signal control in microprocessor systems

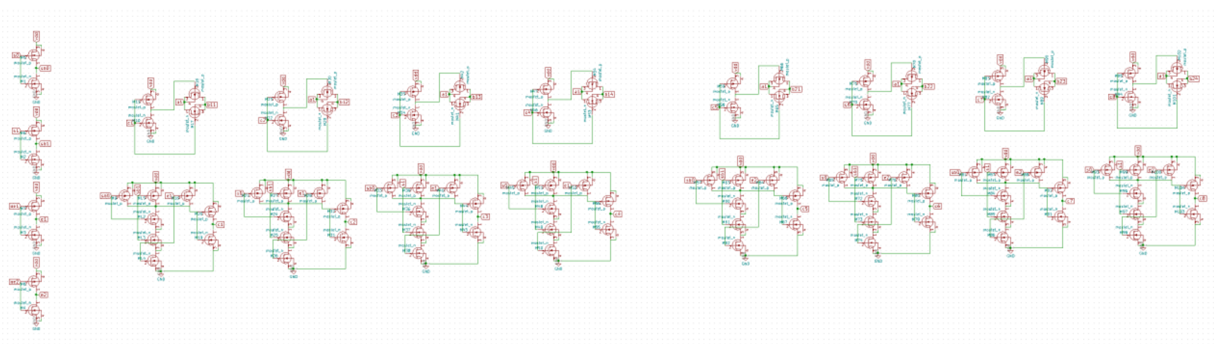
Some of the salient features of 74LS3253 are:

1. Dual 4:1 multiplexers with independent enables
2. TTL-compatible inputs and outputs
3. Three-state outputs for bus interface applications

3.6.1 Pin Diagram



3.6.2 Subcircuit Schematic



3.7 CD4020 IC

The CD4020, manufactured by Texas Instruments is a 14-stage binary ripple counter IC designed primarily for frequency division and time delay applications. It is widely used in digital systems for clock division, pulse counting, and timing operations. The device operates over a wide supply voltage range and is especially valued for its simplicity, high noise immunity, and low power consumption, making it ideal for a variety of digital timing circuits.

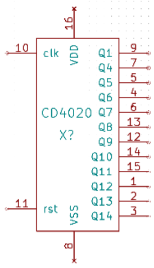
Some of the common applications of CD4020 are:

1. Frequency dividers in digital clocks and timers
2. Event counters in digital logic systems
3. Timing delay circuits in sequential logic designs

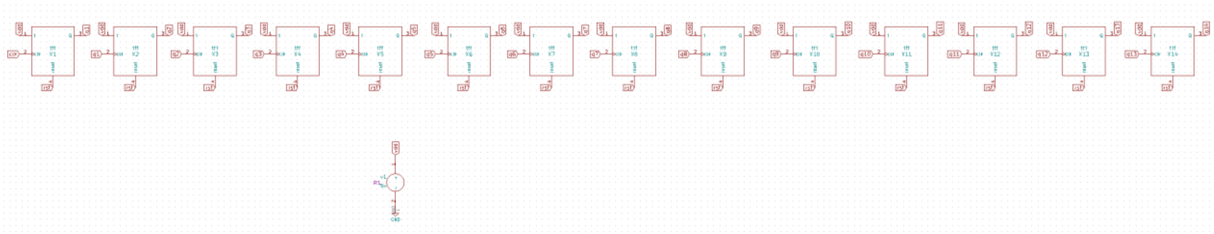
Some of the salient features of CD4020 are:

1. 14-stage binary ripple counter
2. Wide supply voltage range (3V to 15V)
3. High noise immunity and low power consumption
4. Compatible with other CMOS and TTL logic families

3.7.1 Pin Diagram



3.7.2 Subcircuit Schematic



3.8 CD4049 IC

The CD4049, manufactured by Texas Instruments is a CMOS hex inverting buffer IC primarily designed for logic-level shifting and signal inversion applications. It features six independent inverter gates with high input impedance and strong output drive capabilities. The device is widely used in digital systems for signal conditioning, waveform shaping, and interfacing between different logic levels. Its ability to handle both standard logic and analog signals makes it especially versatile in mixed-signal applications.

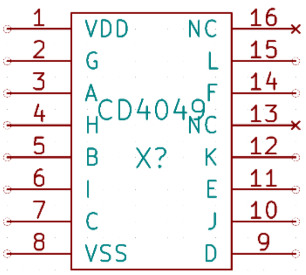
Some of the common applications of CD4049 are:

1. Logic level shifting between TTL and CMOS systems
2. Signal inversion and buffering in digital circuits
3. Oscillator and waveform generator circuits

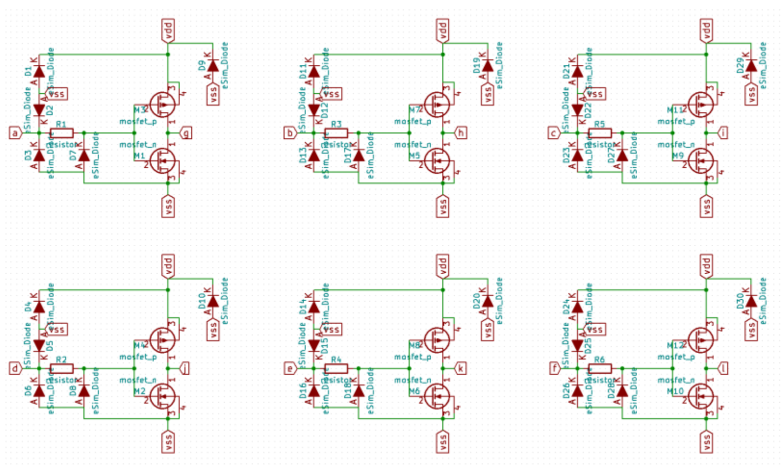
Some of the salient features of CD4049 are:

1. Six independent inverting buffers (hex inverter configuration)
2. Wide supply voltage range (3V to 15V)
3. High noise immunity and low power consumption

3.8.1 Pin Diagram



3.8.2 Subcircuit Schematic



Chapter 4

NgSpice Simulations of Subcircuits Tested

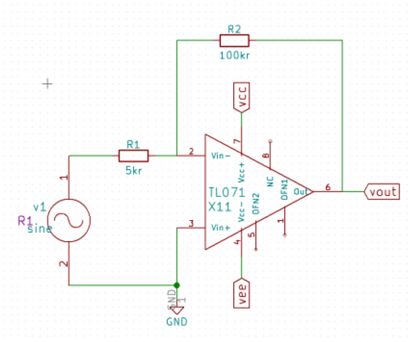
For each of the subcircuits, an NgSpice simulation is performed for a test circuit using the IC subcircuit and the results are verified in accordance with the equations and transfer functions in the datasheet. In the following section, I describe the nature of the test circuit and the waveforms obtained as a result of the simulations performed. For the sake of clarity, the waveforms attached are taken from python plots.

4.1.1 TL071 IC

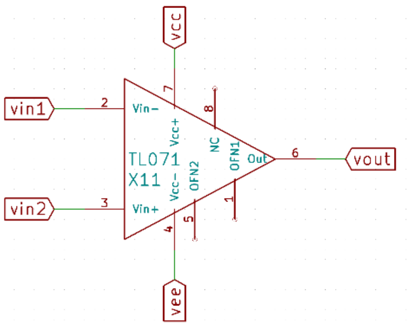
The Tl071 IC has been tested in many different ways that which consists of Common Mode Gain, Differential Mode Gain, Input Noise Spectrum, Offset Voltage, Power Dissipation, Slewrate, Transient Analysis with pulse, Common Mode Gain with Temperature variable, Differential Mode Gain with Temperature variable, Offset Voltage with Temperature Variable and a simple inverting amplifier with Rf = 100kr, Ri = 5kr and a voltage gain of 20.

4.1.1.1 Test Schematic

- Inverting Amplifier Circuit :

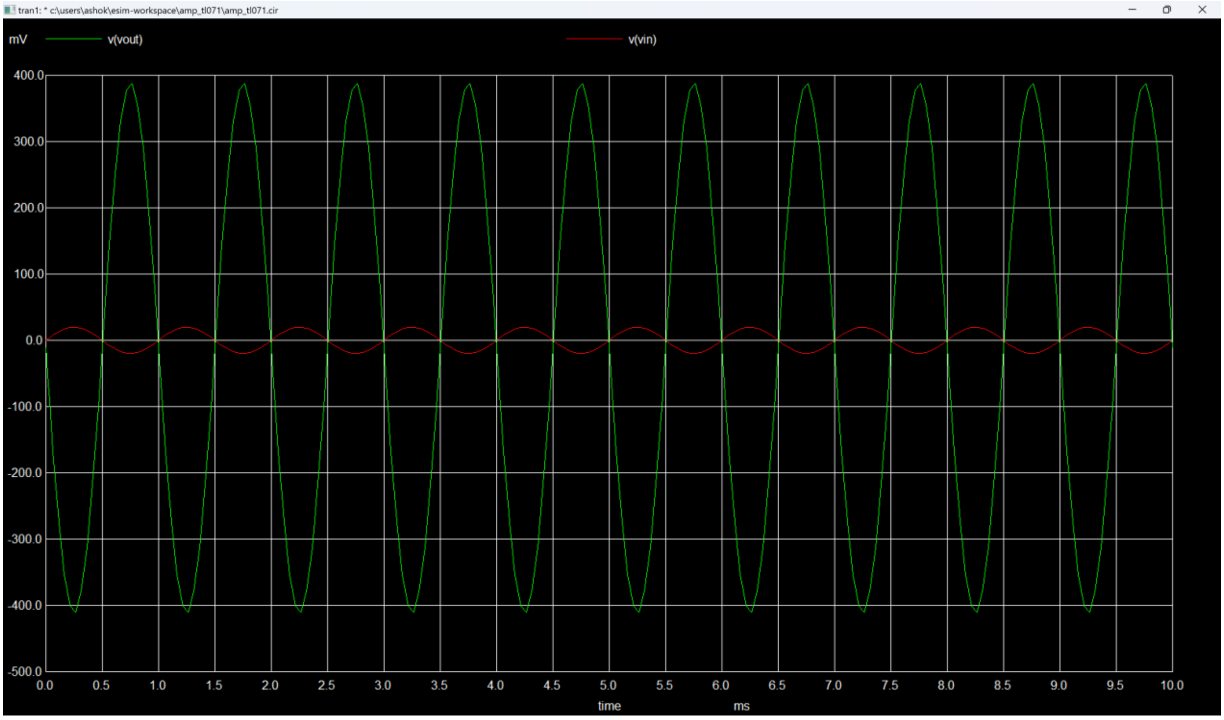


- General Circuit for other Tests :

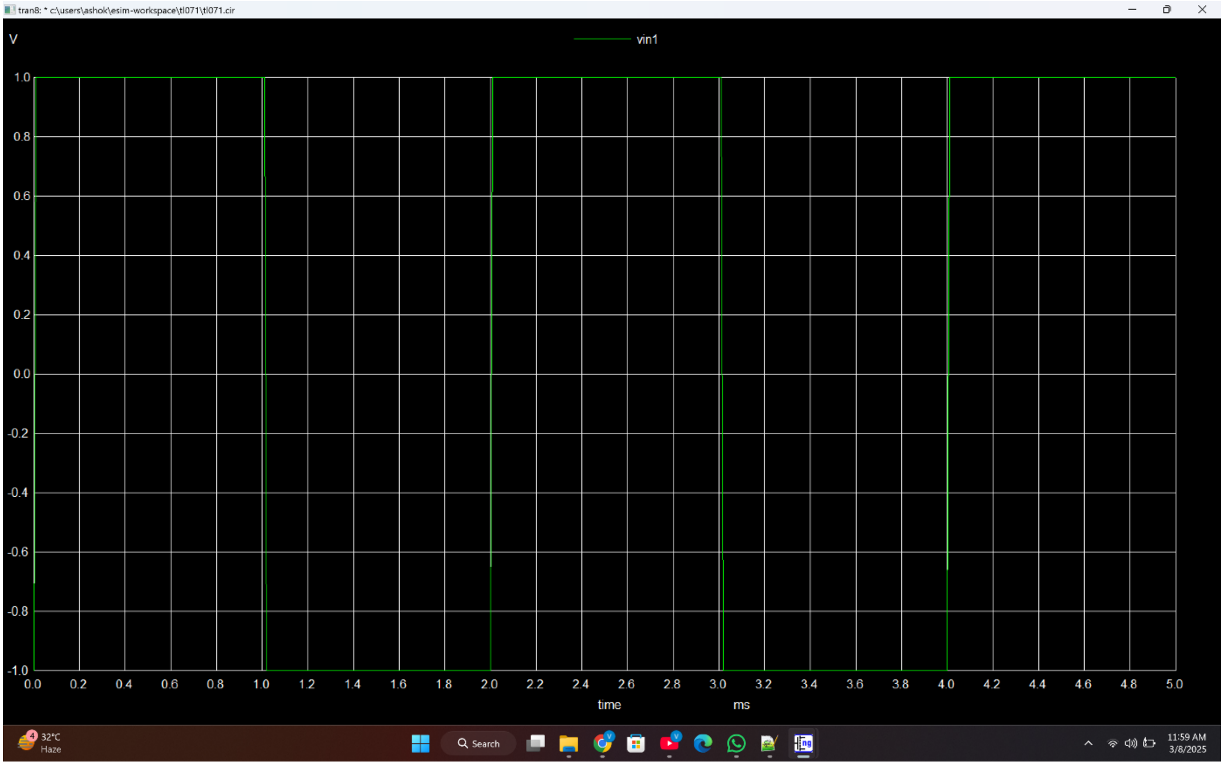


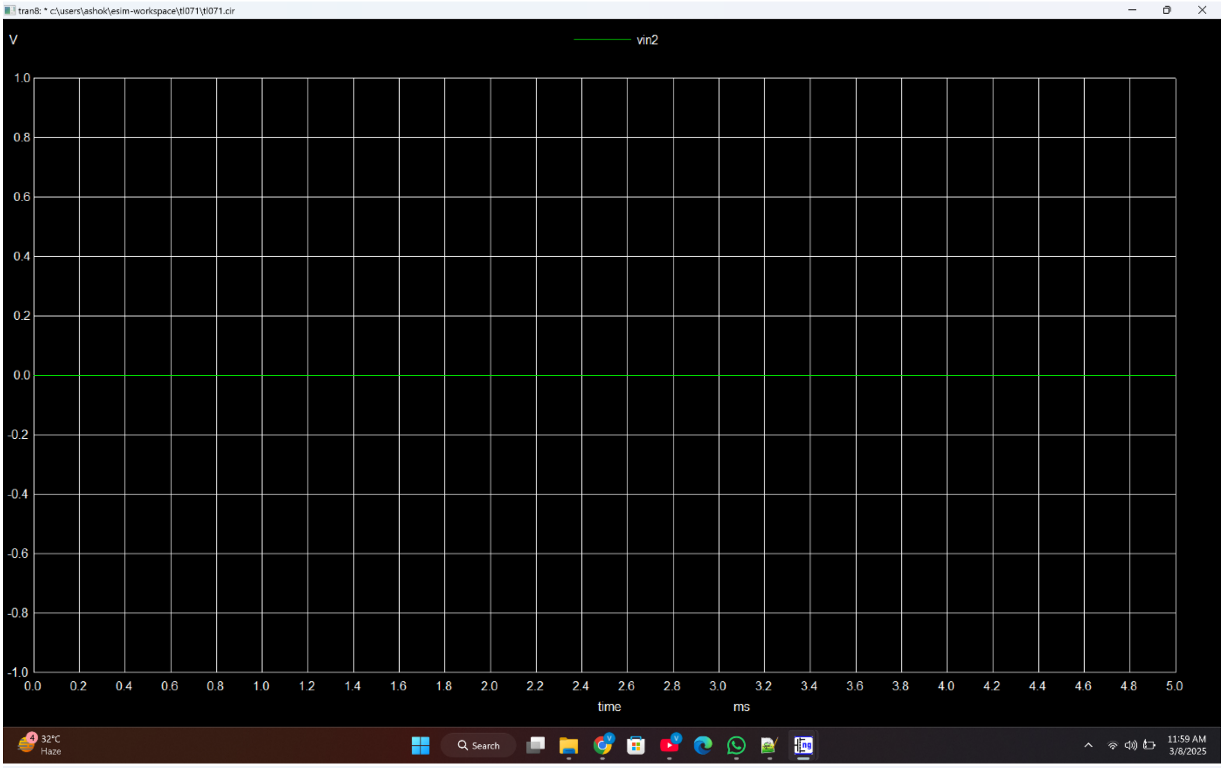
4.1.1.2 Waveforms

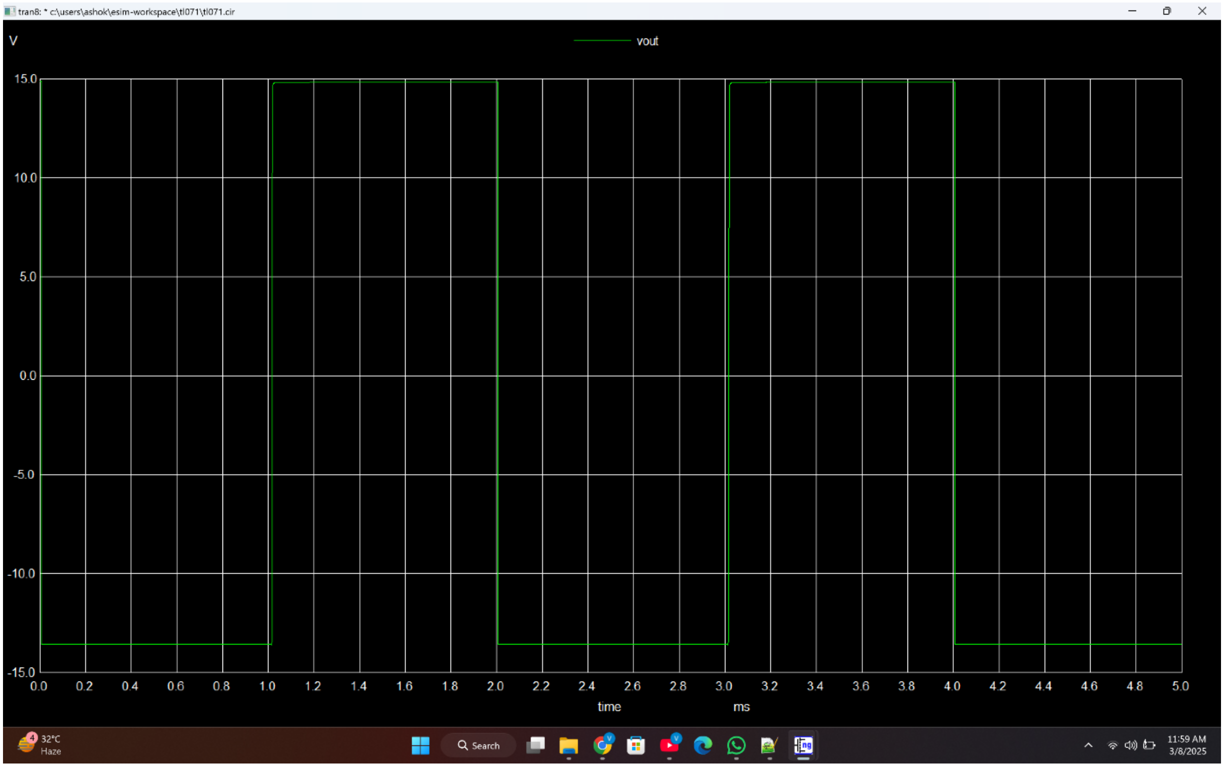
- Inverting Amplifier Waveforms



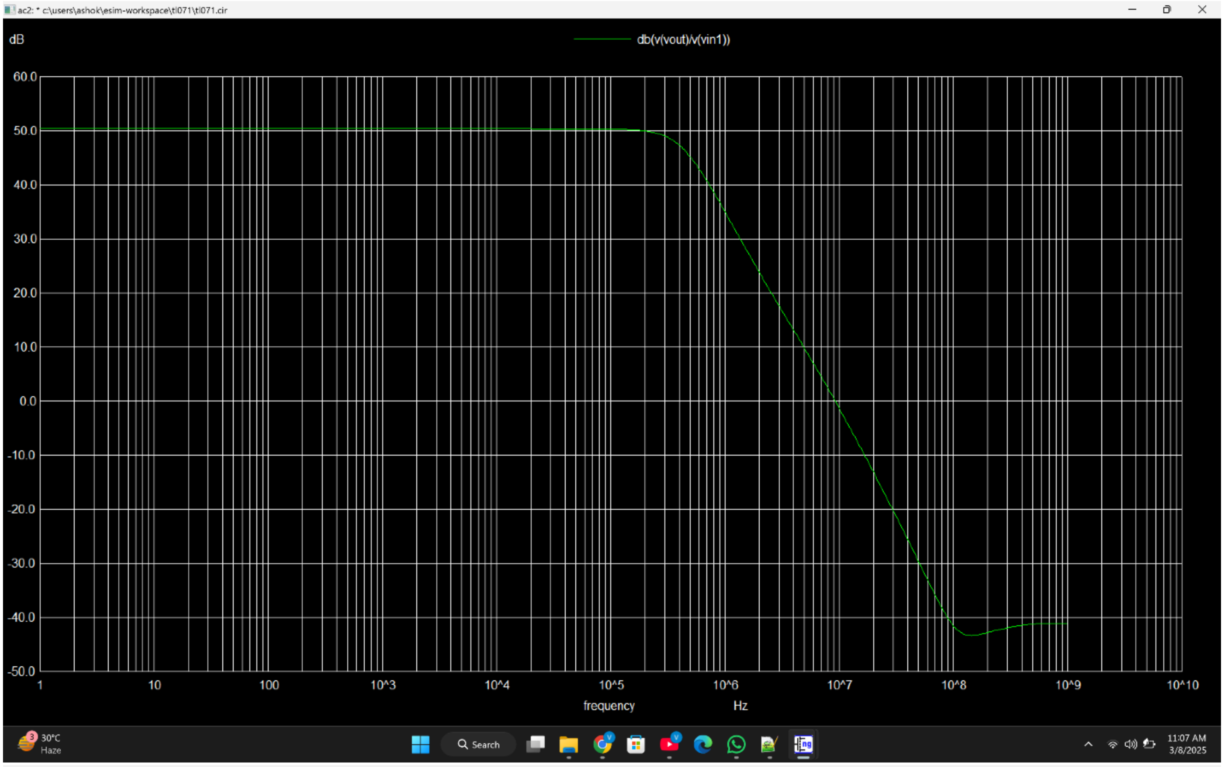
- Transient Analysis

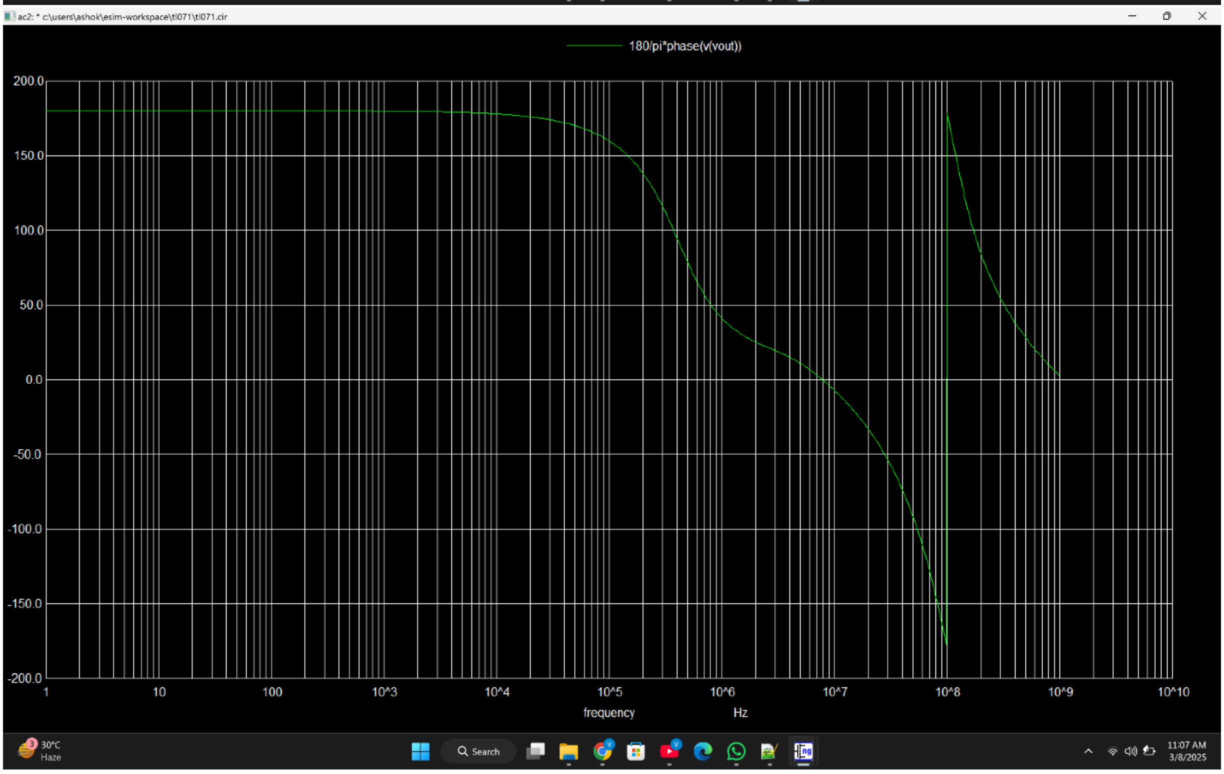



tran8: * c:\users\ashok\esim-workspace\tl071\tl071.cir
V
vin2
time
ms

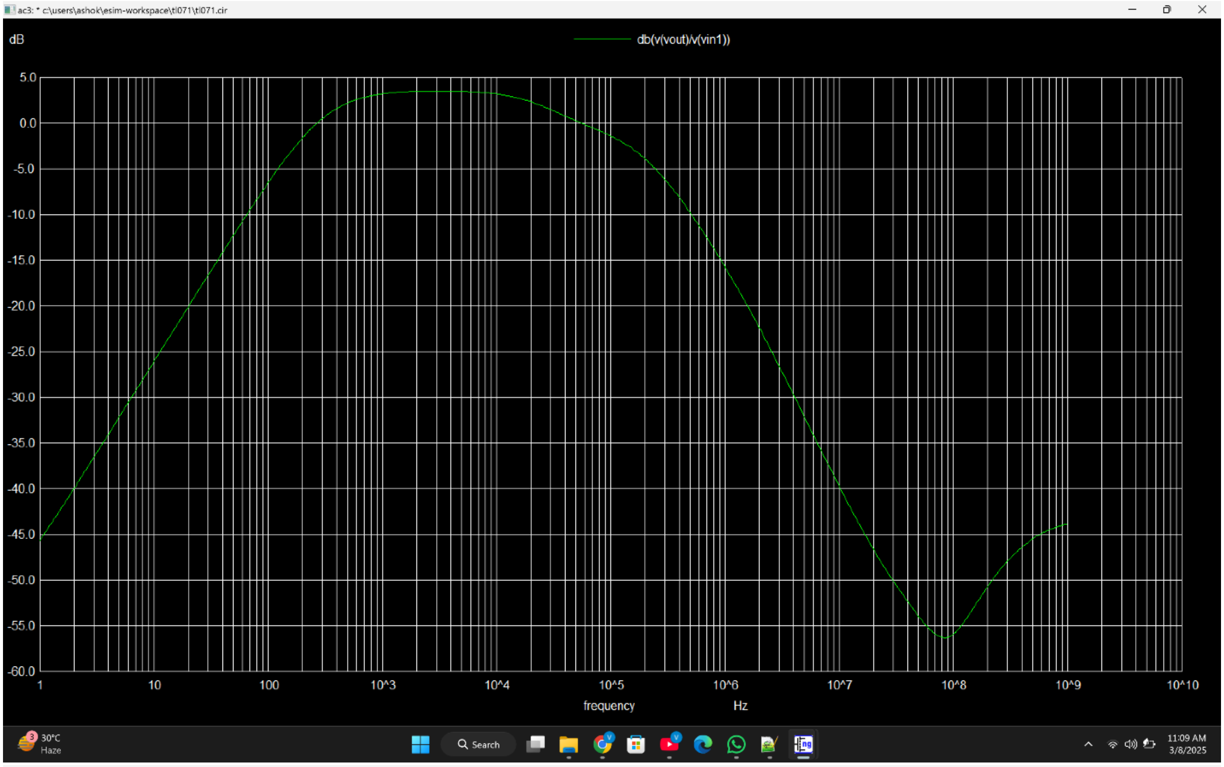

tran8: * c:\users\ashok\esim-workspace\tl071\tl071.cir
V
vout
time
ms

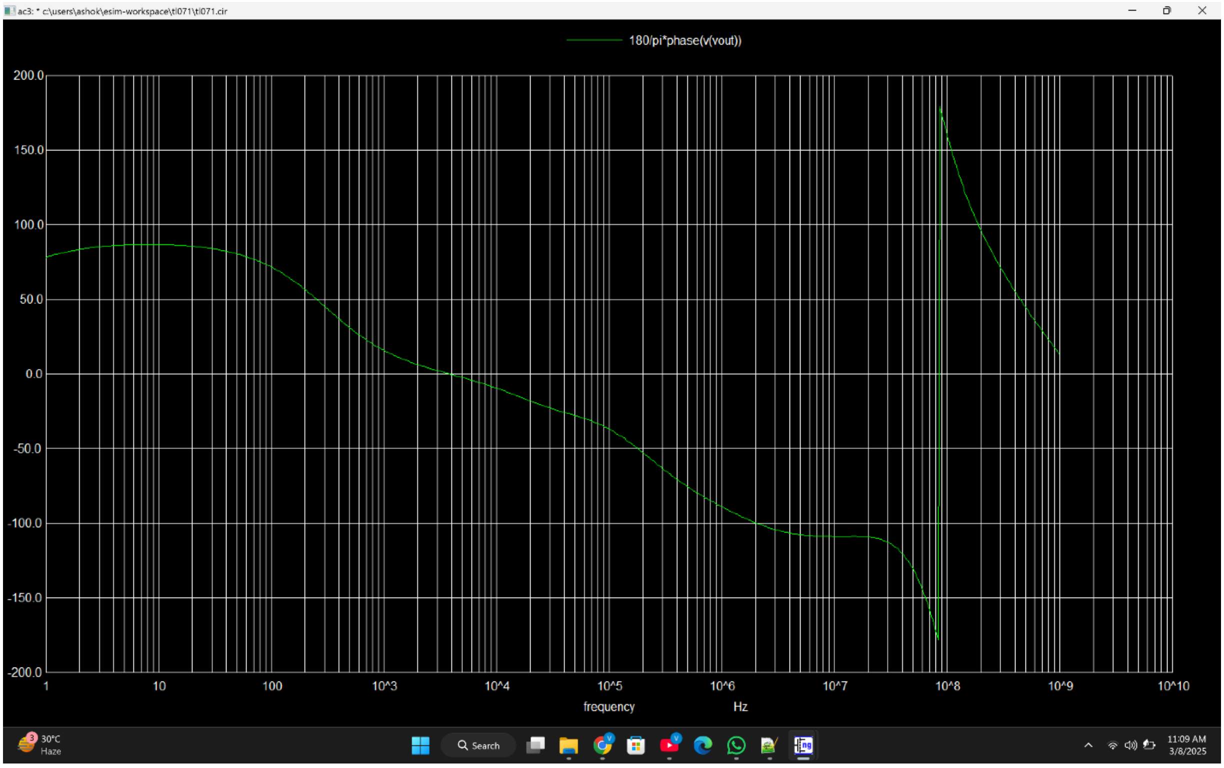
- Differential Mode Gain



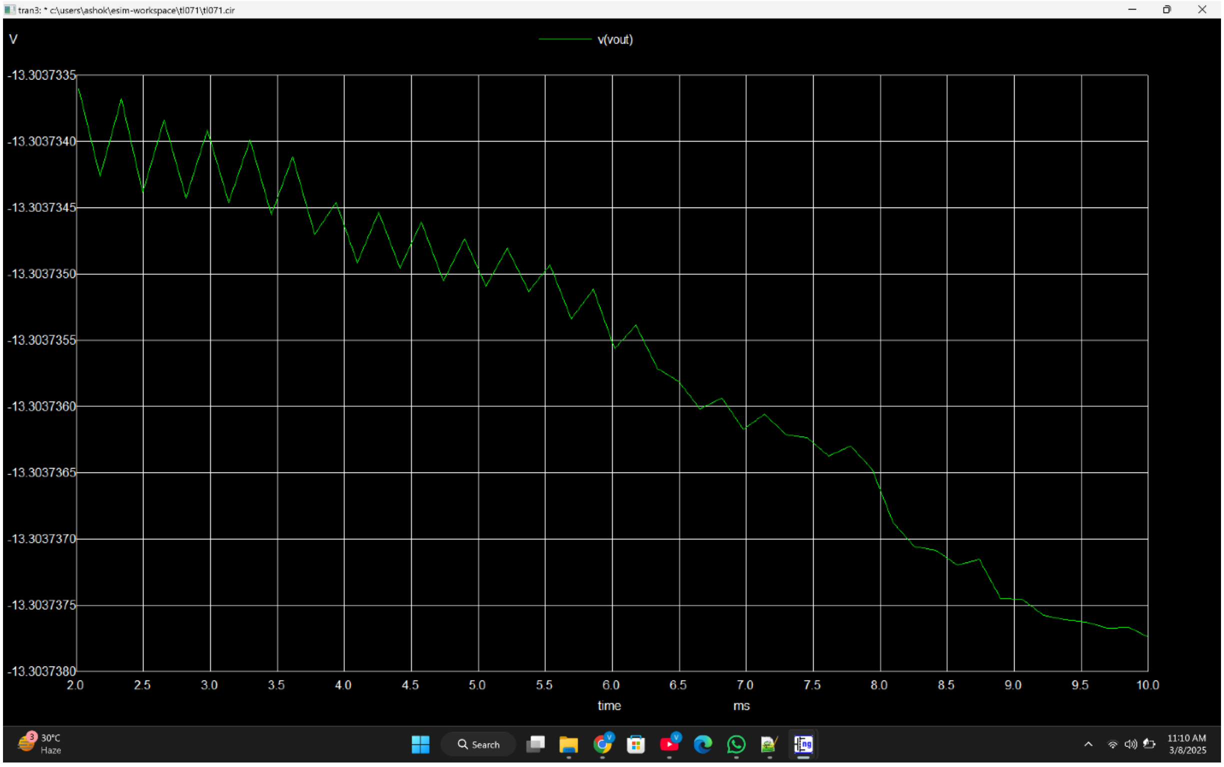


- Common Mode Gain

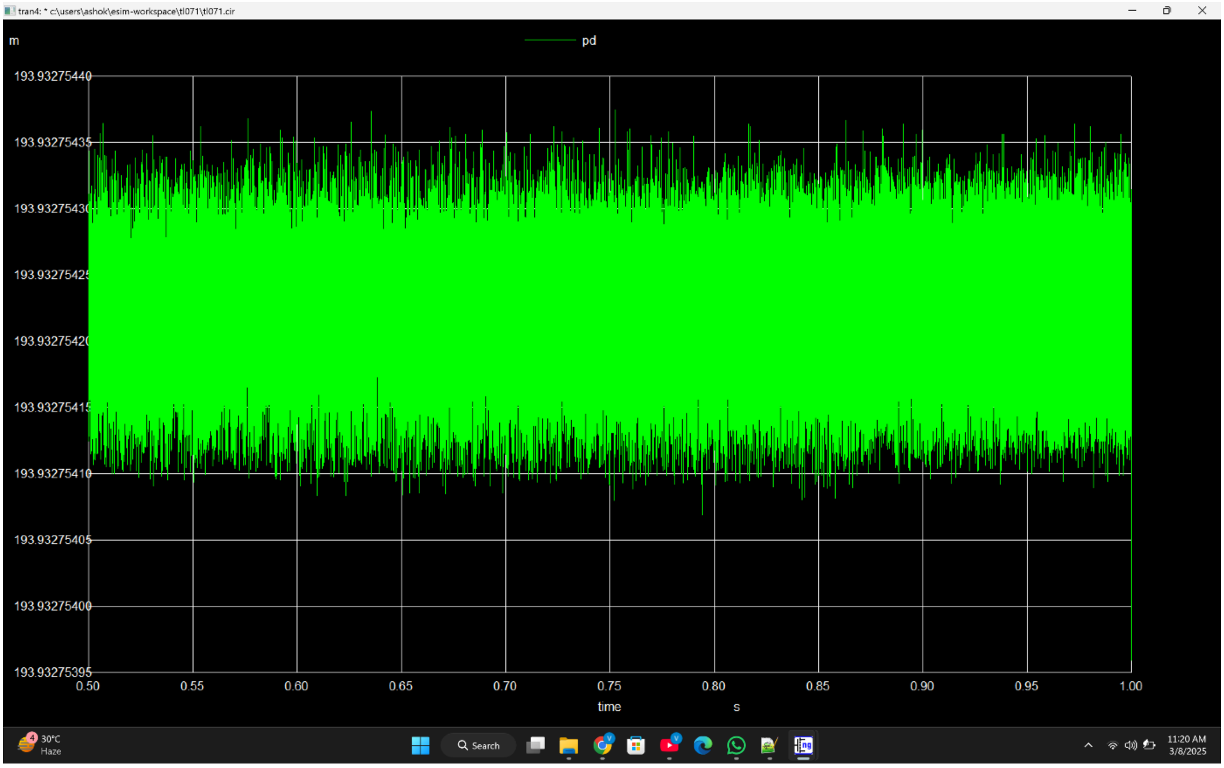




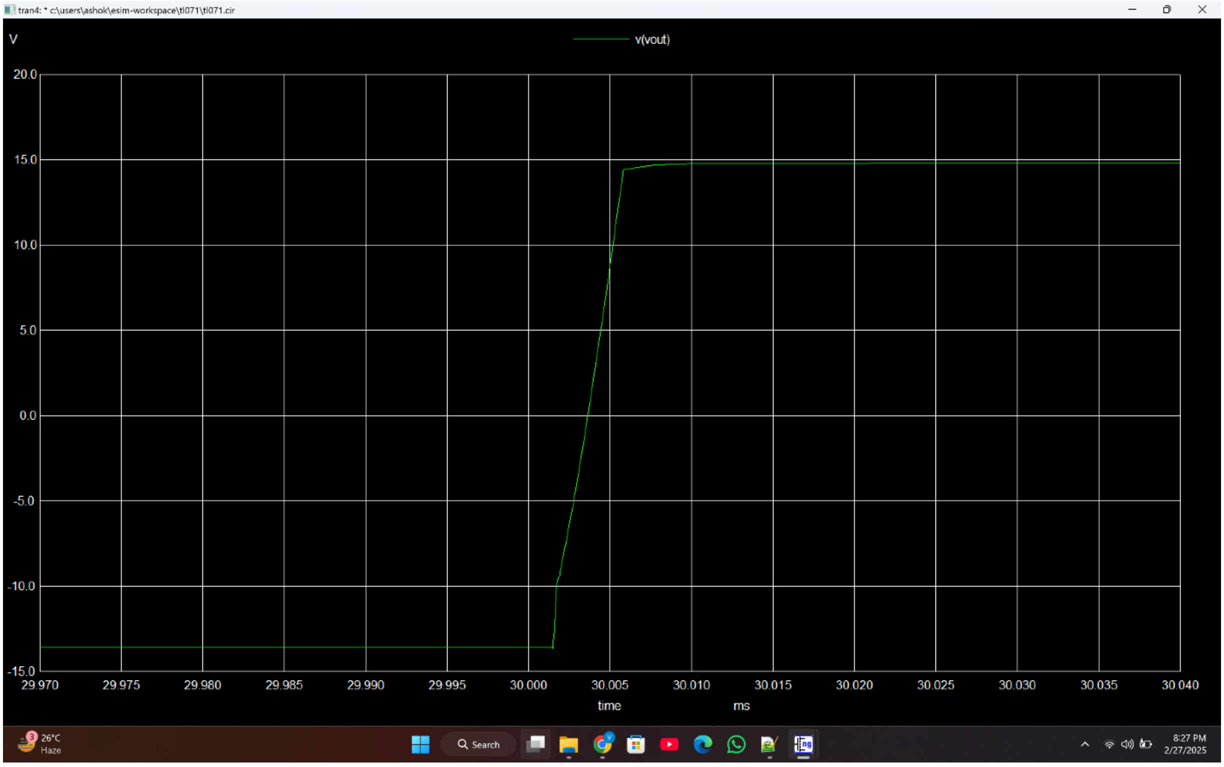
- Offset Voltage



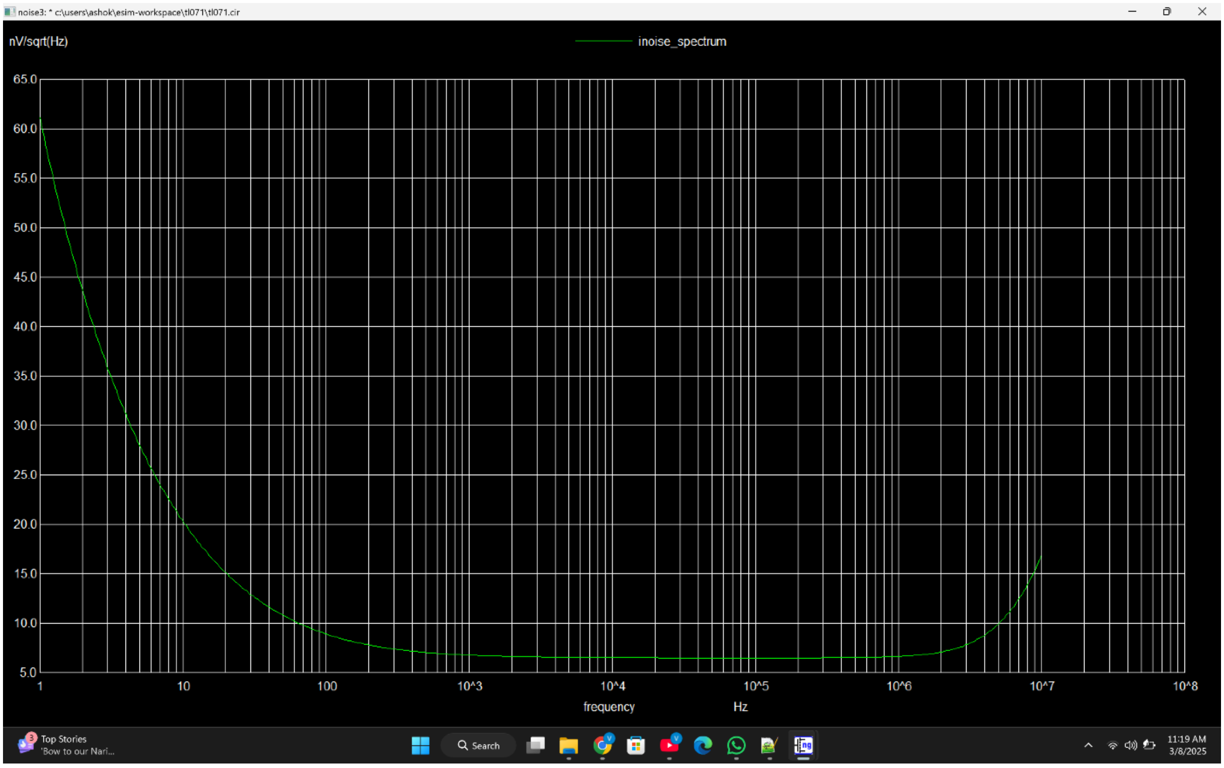
- Power Dissipation (0.2uWatts/Sec)



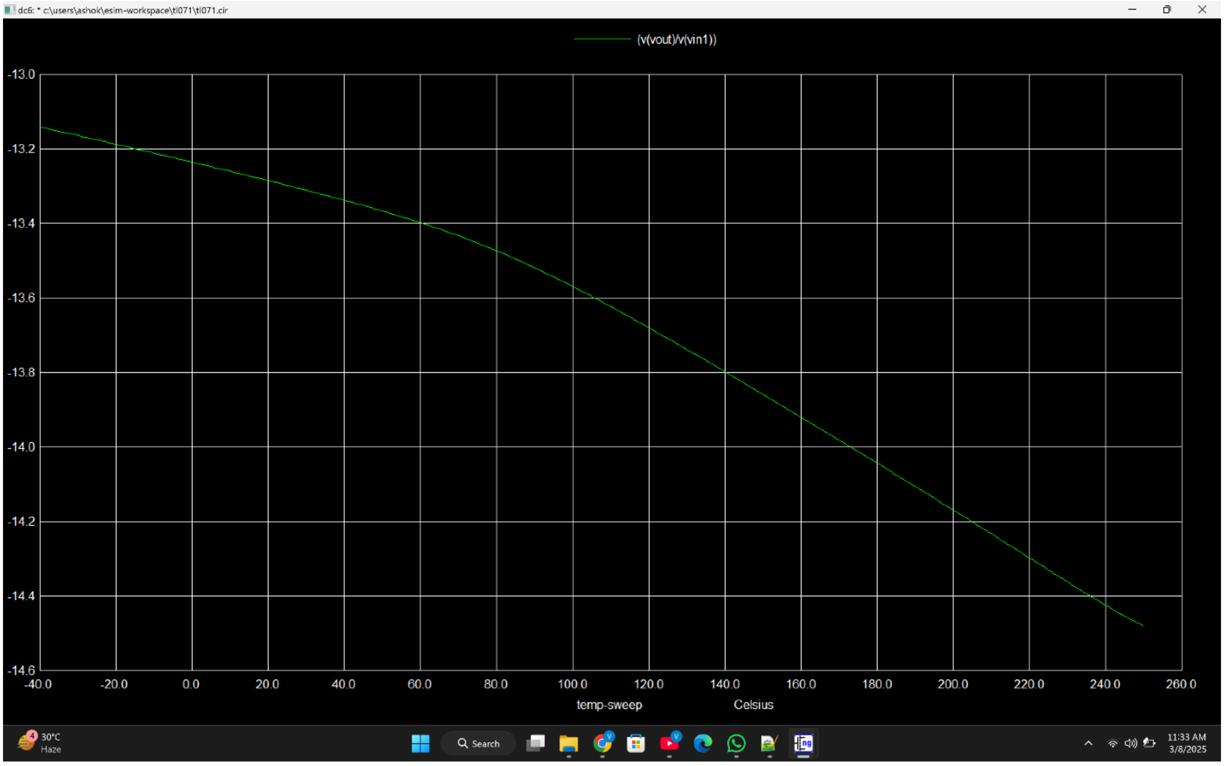
- Slew Rate (5.506 v/uSec)

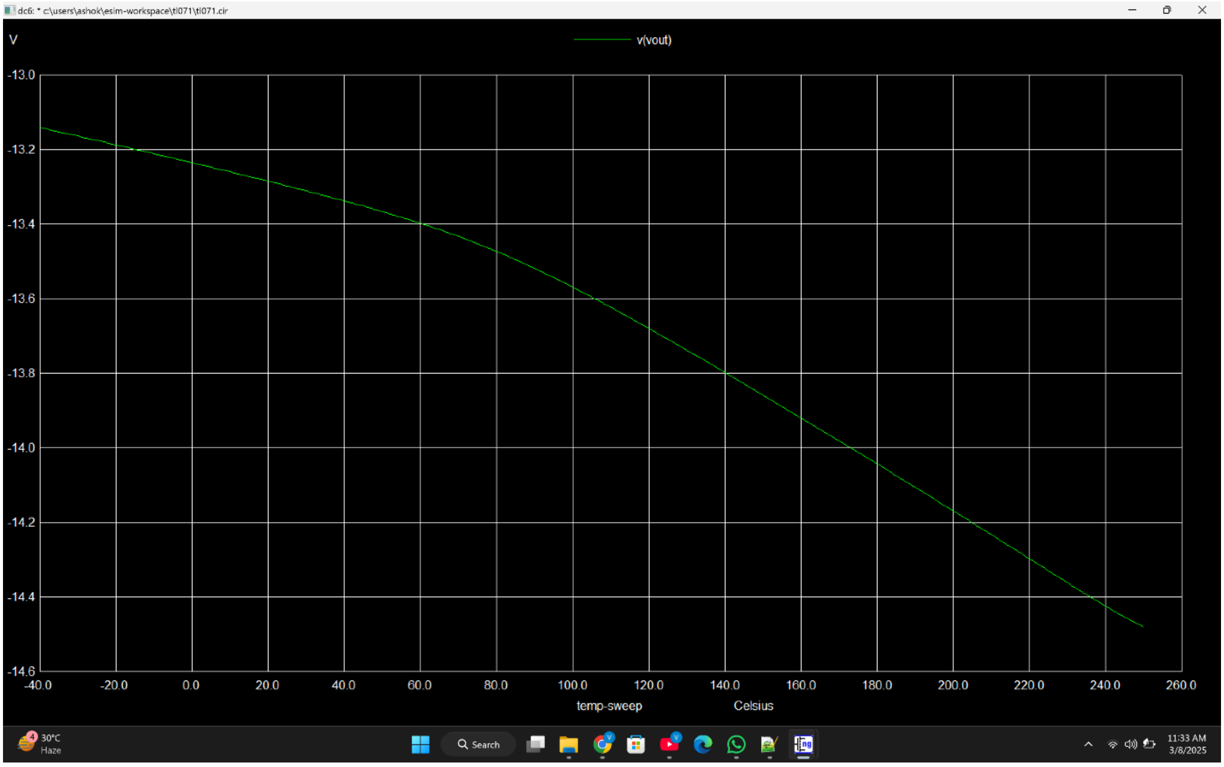


- Input Noise Spectrum

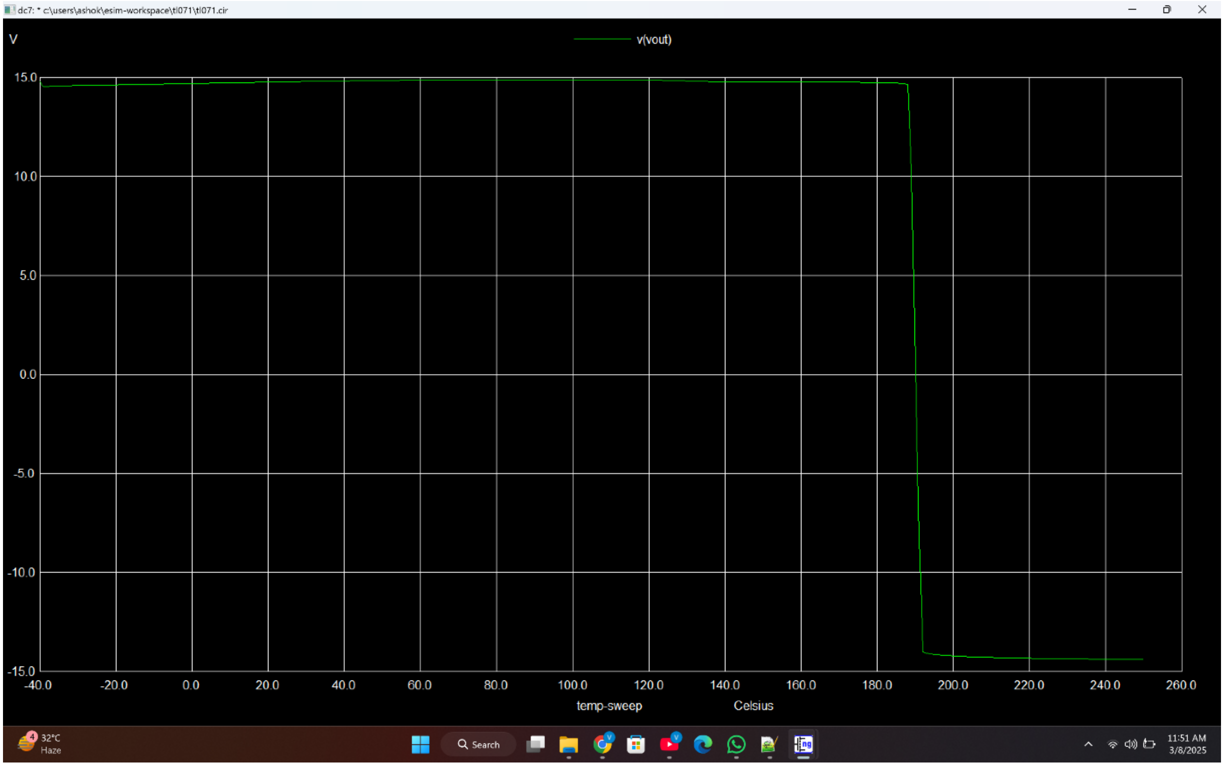


- Common Mode Gain with Temperature

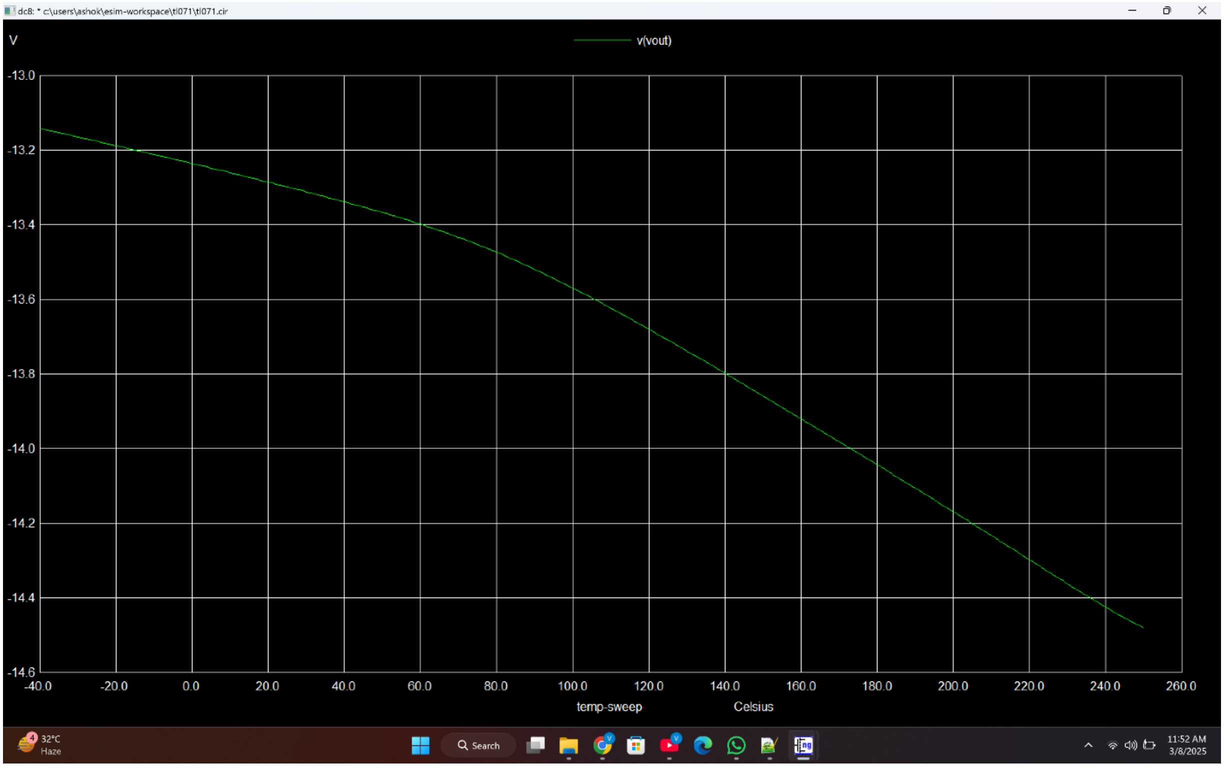




- Differential Mode Gain with Temperature



- Offset Voltage with Temperature

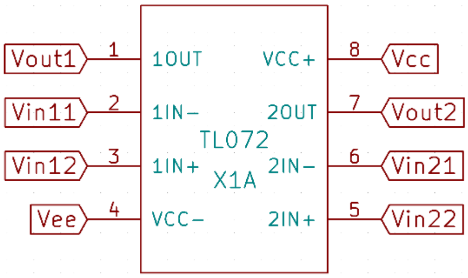


4.1.2 TL072 IC

The Tl071 IC has been tested in many different ways that which consists of Common Mode Gain, Differential Mode Gain, Input Noise Spectrum, Offset Voltage, Power Dissipation, Slewrate, Transient Analysis with pulse, Common Mode Gain with Temperature variable, Differential Mode Gain with Temperature variable, Offset Voltage with Temperature Variable and a simple inverting amplifier with Rf = 100kr, Ri = 5kr and a voltage gain of 20.

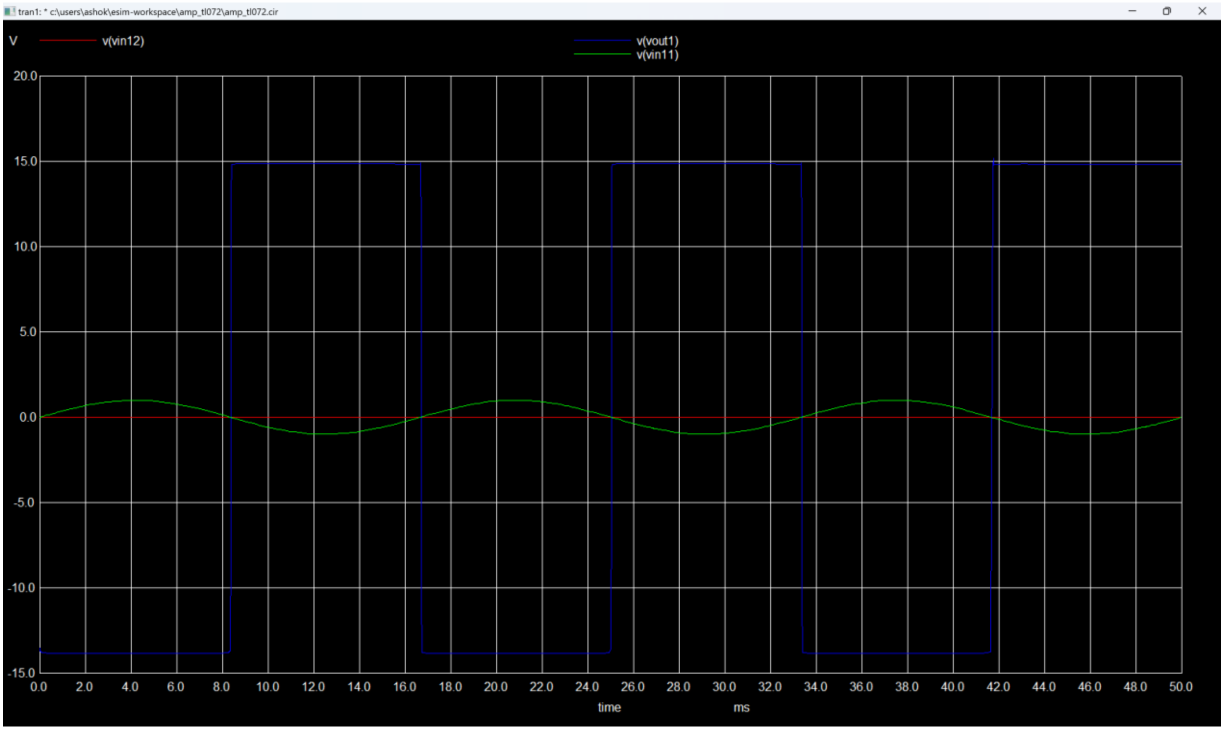
4.1.2.1 Test Schematic

- Inverting Amplifier Circuit :
  The first OpAmp Vin11 = sine signal and Vin12 = GND (Inverting)
  The second OpAmp Vin21 = GND and Vin22 = sine signal (NonInverting)

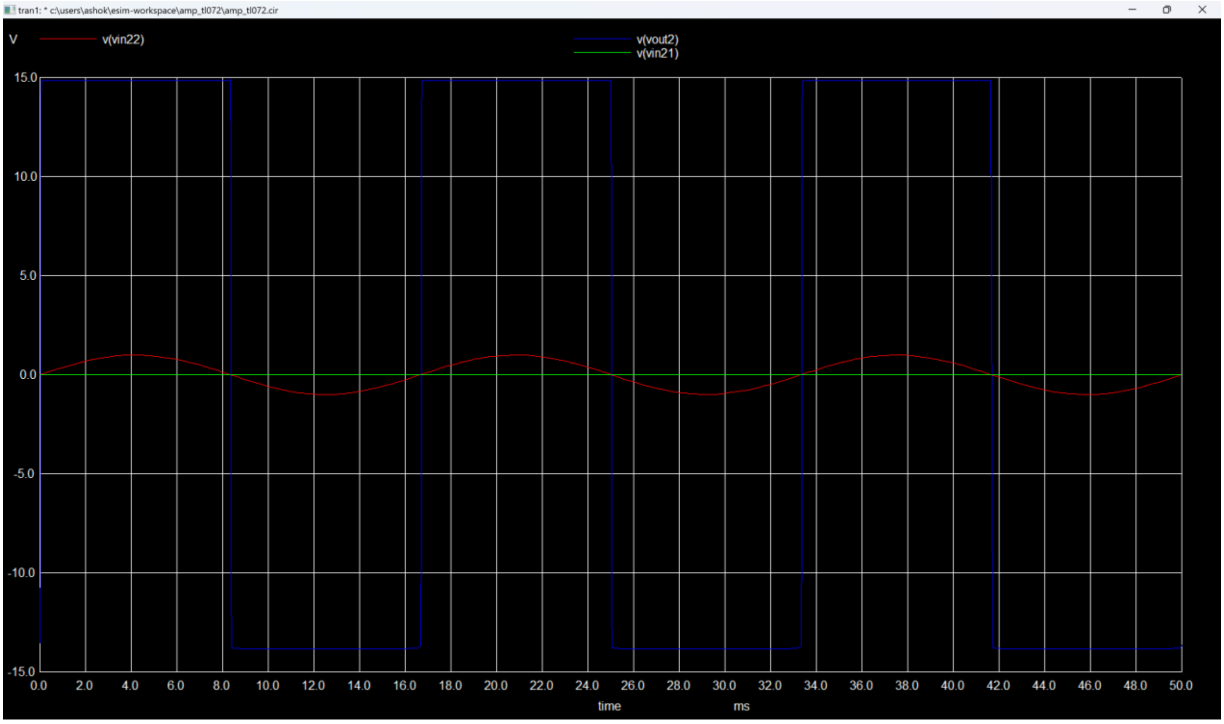


4.1.2.2 Waveforms

- Inverting Amplifier Waveforms (OpAmp-1)



- Non-Inverting Amplifier Waveforms (OpAmp-2)

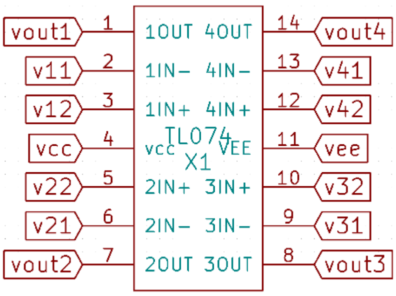


4.1.3 TL074 IC

The Tl071 IC has been tested in many different ways that which consists of Common Mode Gain, Differential Mode Gain, Input Noise Spectrum, Offset Voltage, Power Dissipation, Slewrate, Transient Analysis with pulse, Common Mode Gain with Temperature variable, Differential Mode Gain with Temperature variable, Offset Voltage with Temperature Variable and a simple inverting amplifier with Rf = 100kr, Ri = 5kr and a voltage gain of 20.

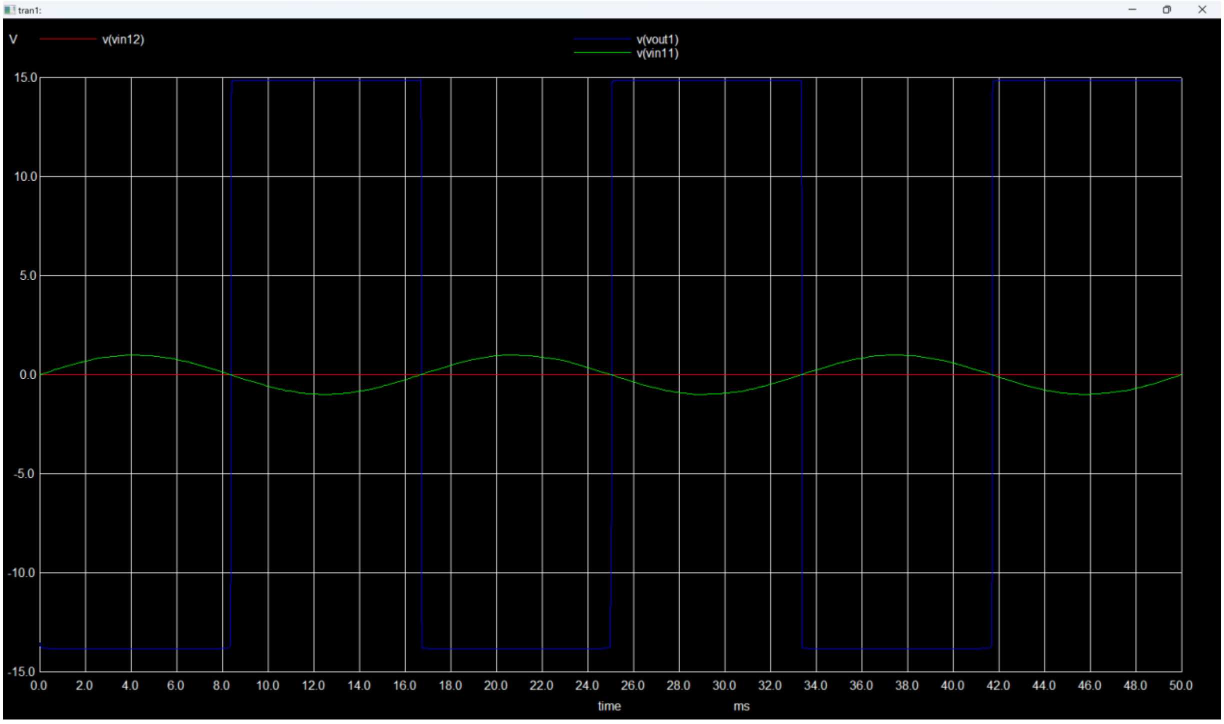
4.1.3.1 Test Schematic

- Inverting Amplifier Circuit :
  The first OpAmp Vin11 = sine signal and Vin12 = GND (Inverting)
  The second OpAmp Vin21 = GND and Vin22 = sine signal (NonInverting)
  The third OpAmp Vin31 = GND and Vin32 = sine signal (NonInverting)
  The fourth OpAmp Vin41 = sine signal and Vin32 = GND (Inverting)

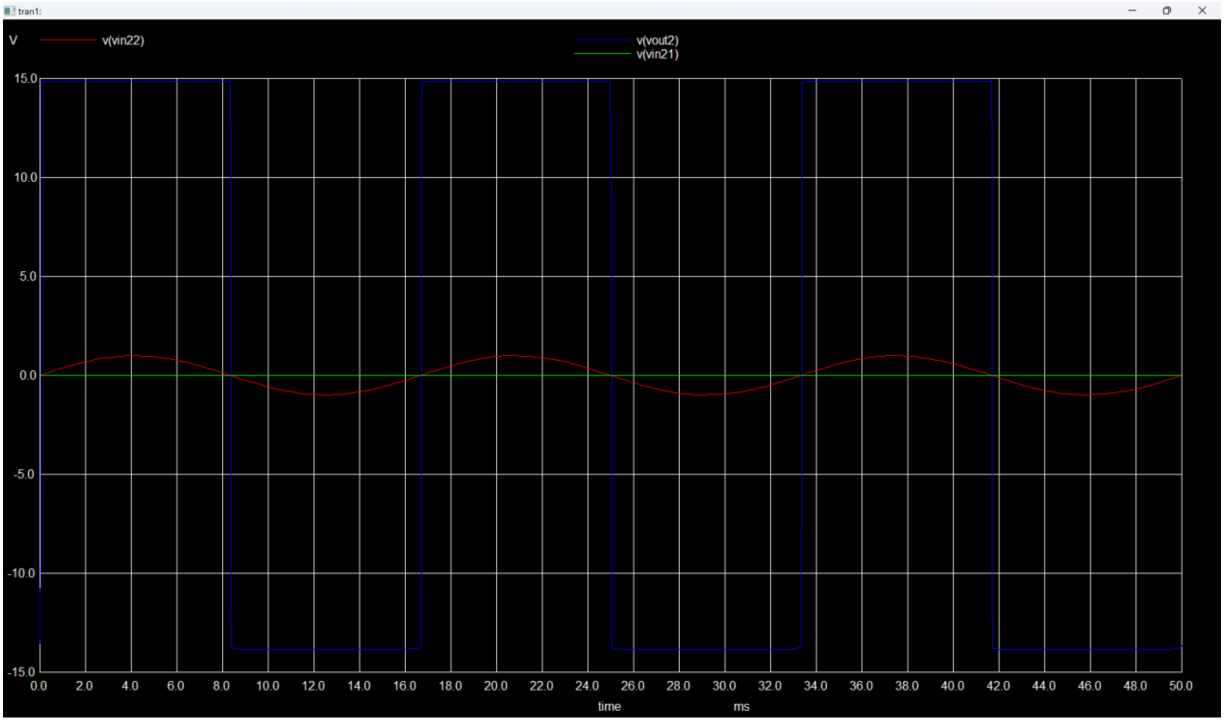


4.1.3.2 Waveforms

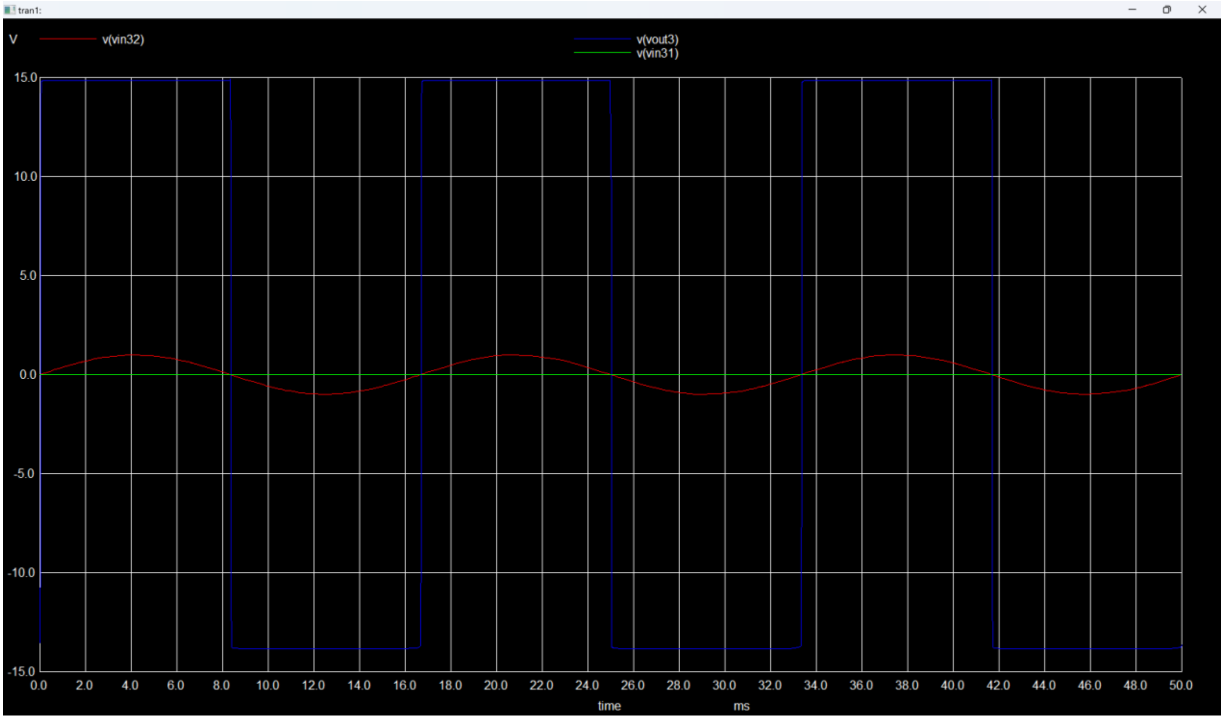
- Inverting Amplifier Waveforms (OpAmp-1)



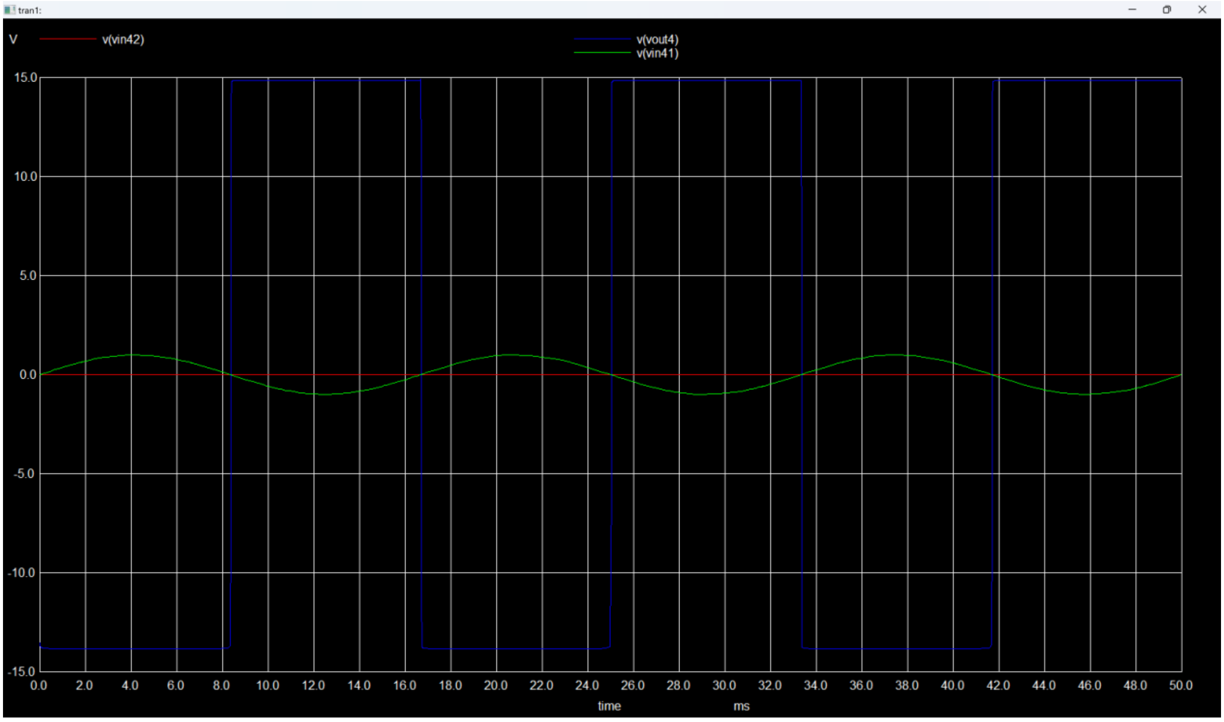
- Non-Inverting Amplifier Waveforms (OpAmp-2)



- Inverting Amplifier Waveforms (OpAmp-3)



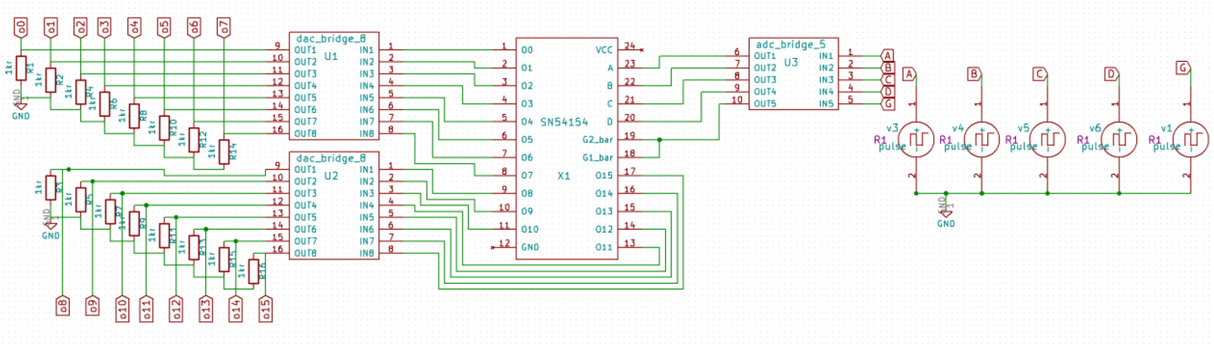
- Non-Inverting Amplifier Waveforms (OpAmp-4)



4.2 SN54154 IC

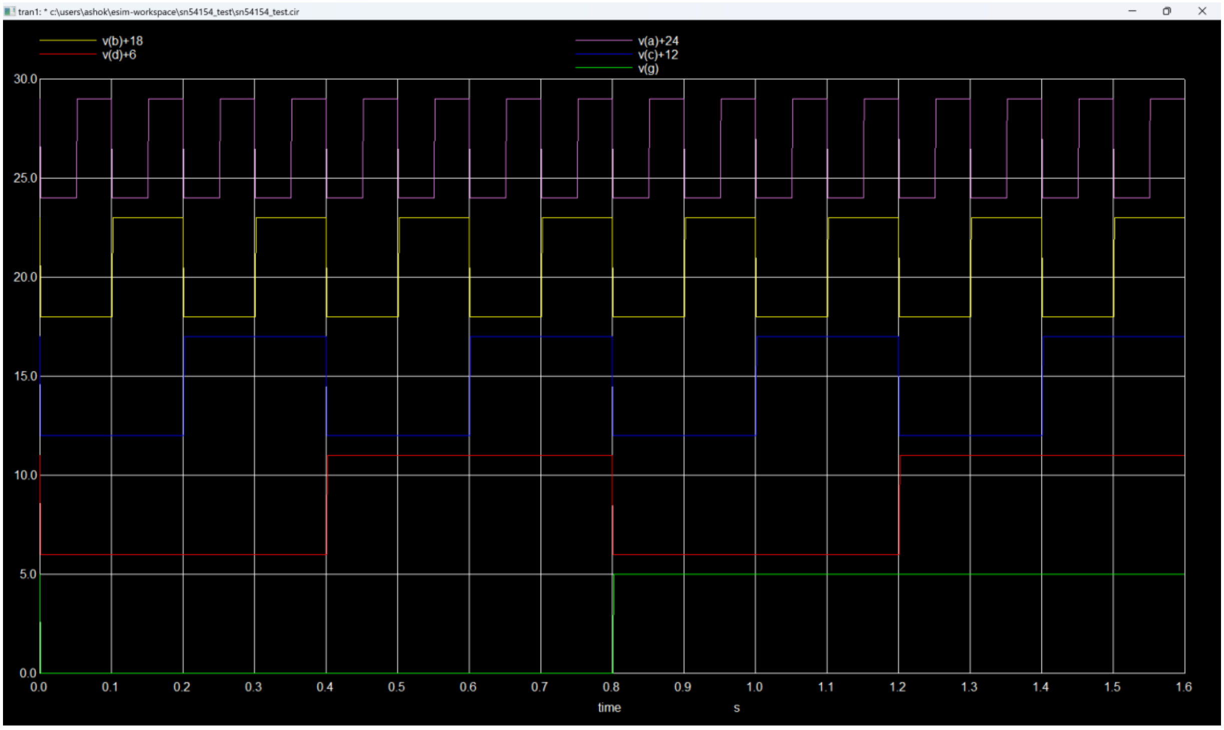
The SN54154 IC is an 4to16 Decoder/Demultiplexer which only activates when the selected G2_bar and the G1_bar are active low.

4.2.1 Test Schematic

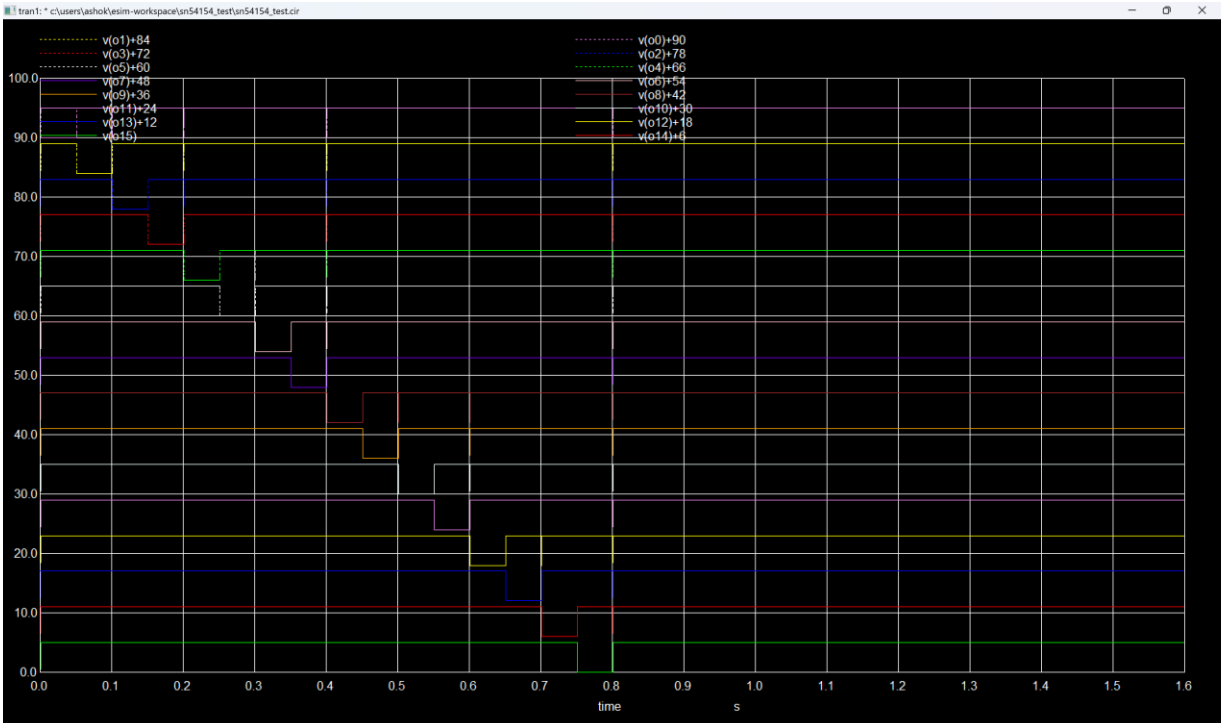


4.2.2 Waveforms

- Inputs



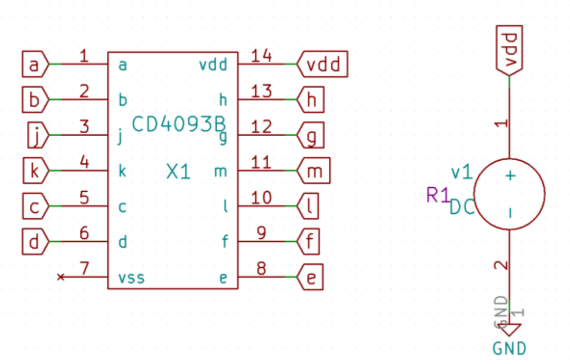
- Outputs



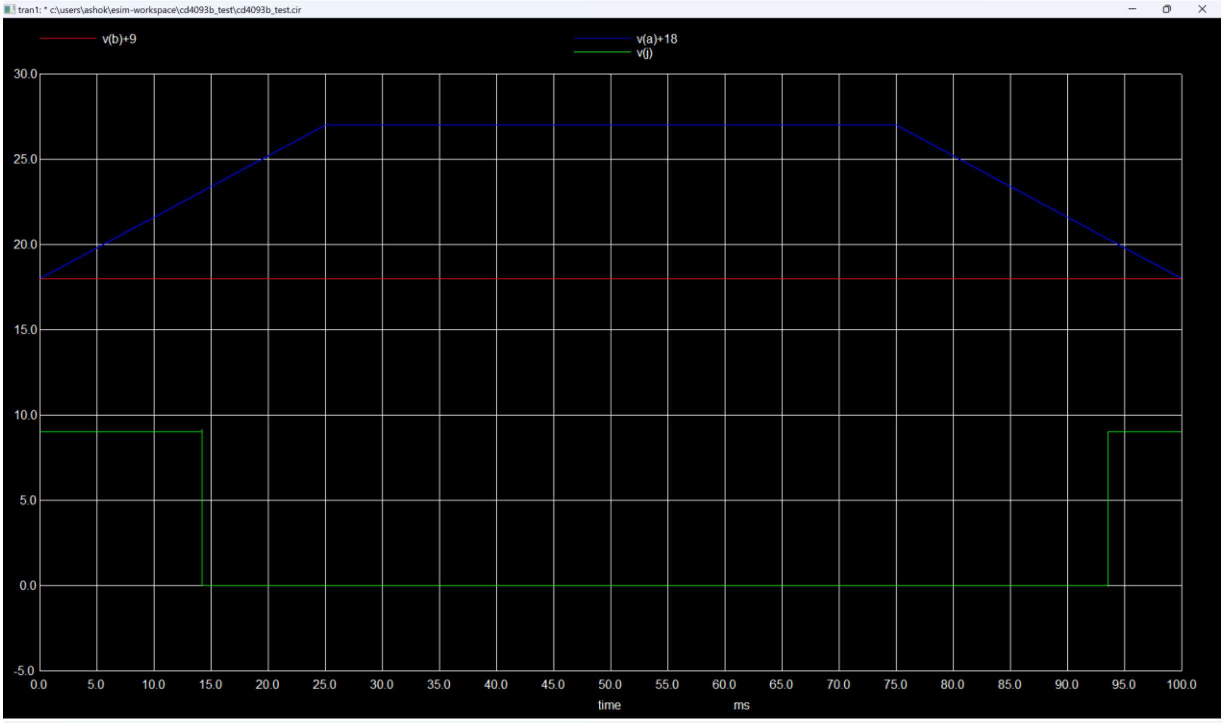
4.3 CD4093B IC

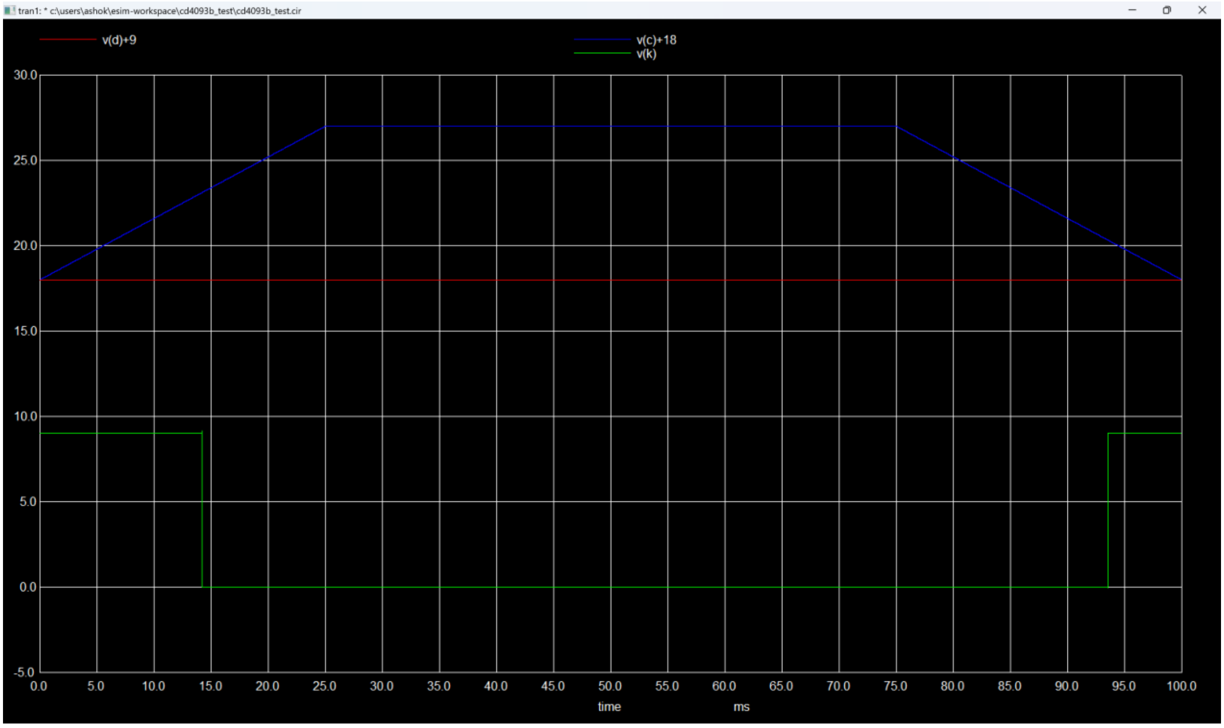
The CD4093B is an NAND-Gate based Schmitt Trigger that consists of four NAND-Gates with the inputs (a,b), (c,d), (e,f) and (g,h) and the outputs are j, k, l and m respectively.

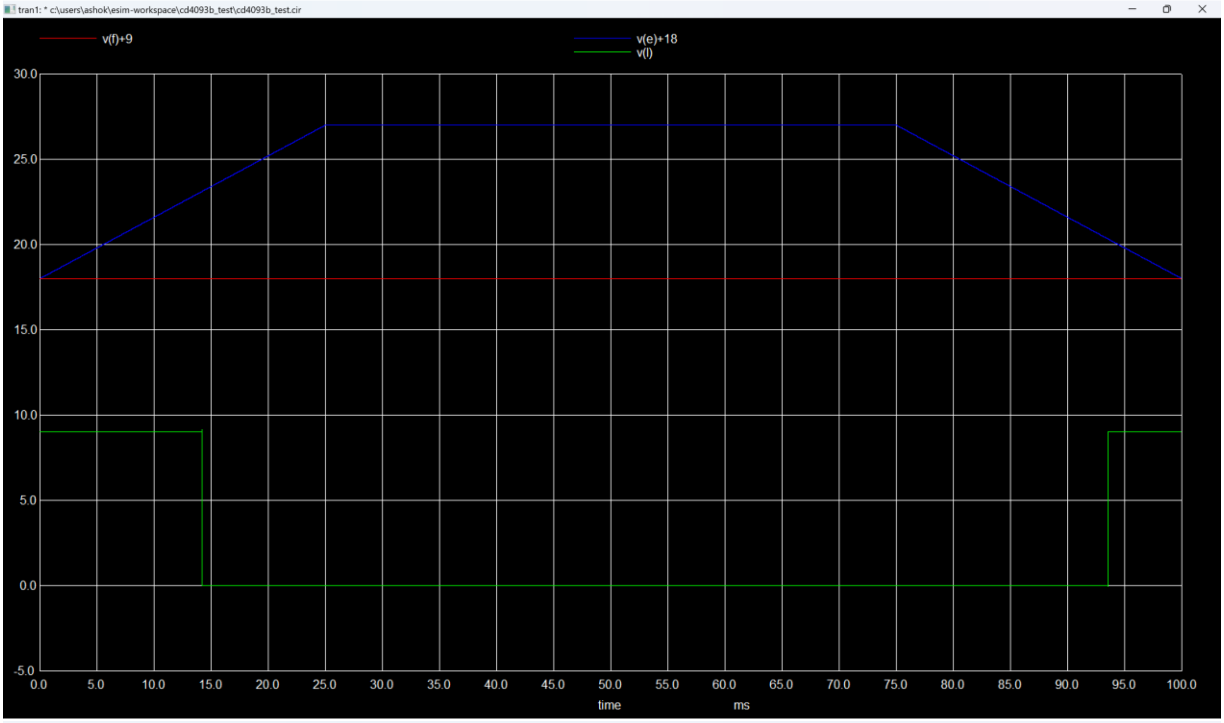
4.3.1 Test Schematic

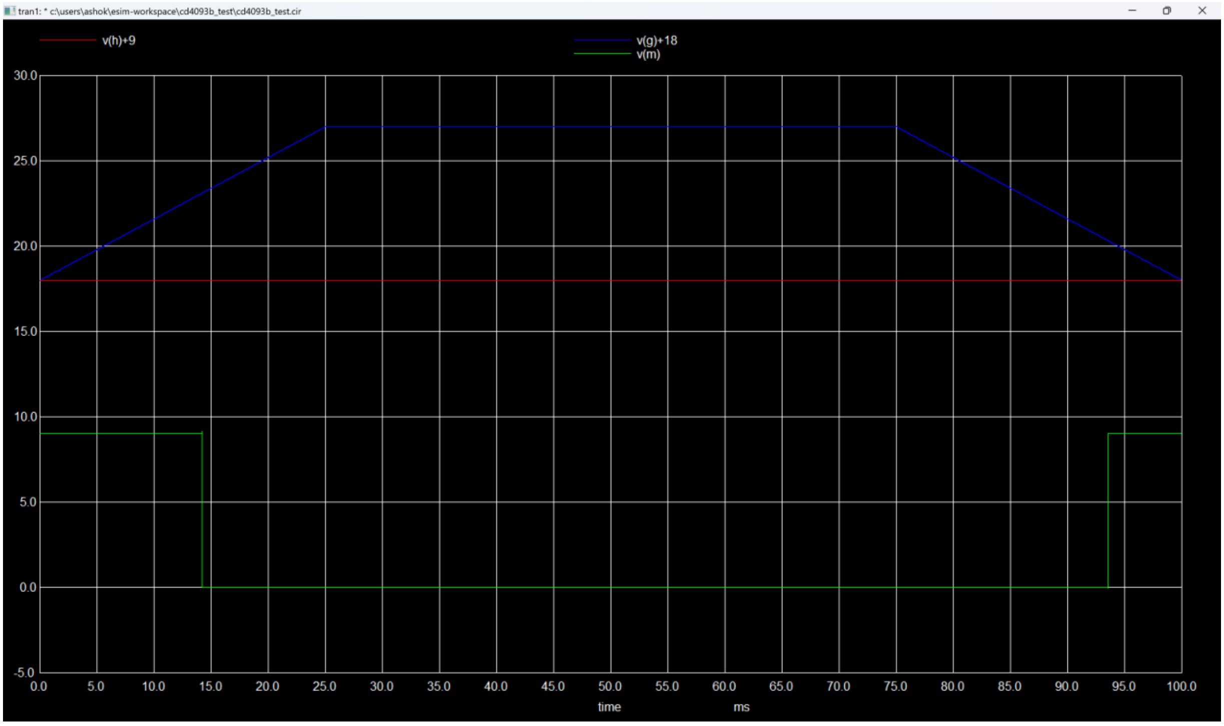


4.3.2 Waveforms





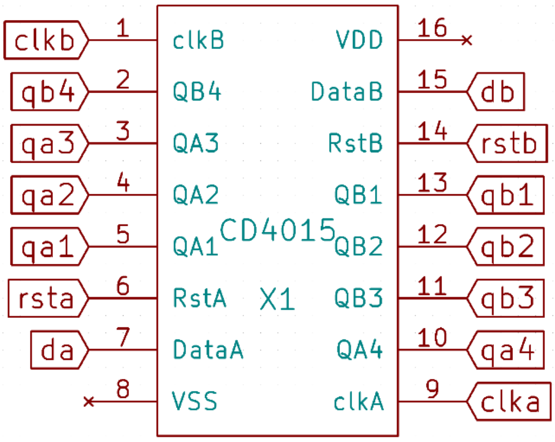

tran1: * c:\users\ashok\esim-workspace\cd4093b_test\cd4093b_test.cir
v(f)+9
v(e)+18
v(l)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
time
ms


tran1: * c:\users\ashok\esim-workspace\cd4093b_test\cd4093b_test.cir
v(h)+9
v(g)+18
v(m)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
time
ms

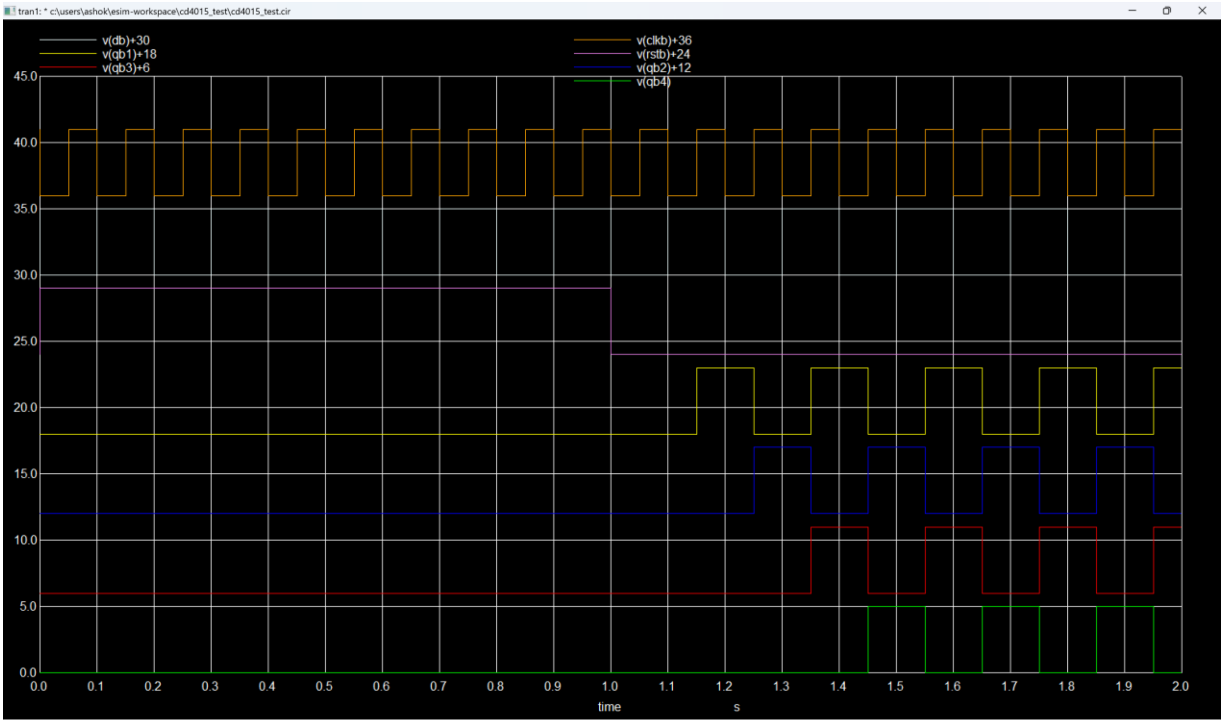
4.4 CD4015 IC

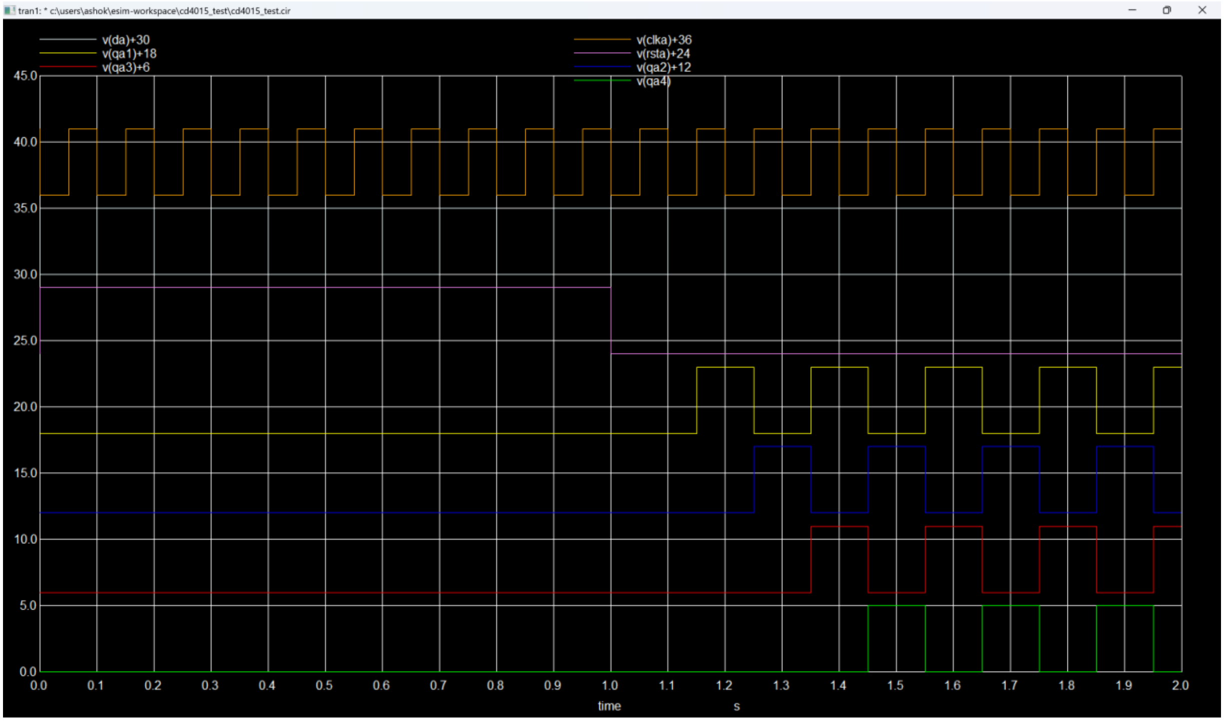
The CD415 IC is an Dual 4-Bit Serial input parallel Output Shift Register with positive edge triggered clock and active low reset .

4.4.1 Test Schematic



4.4.2 Waveforms

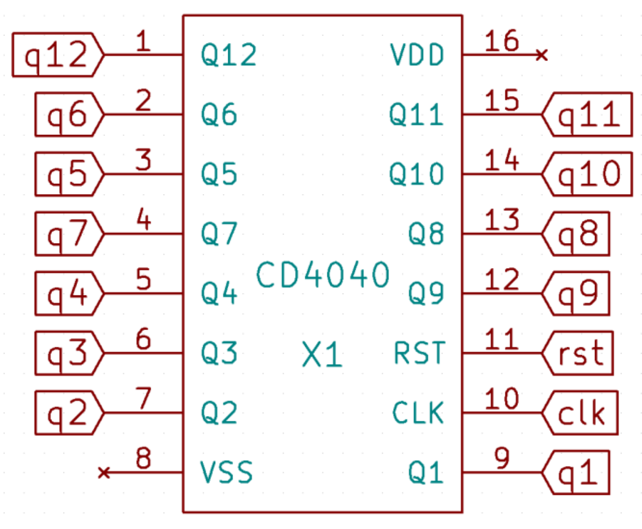




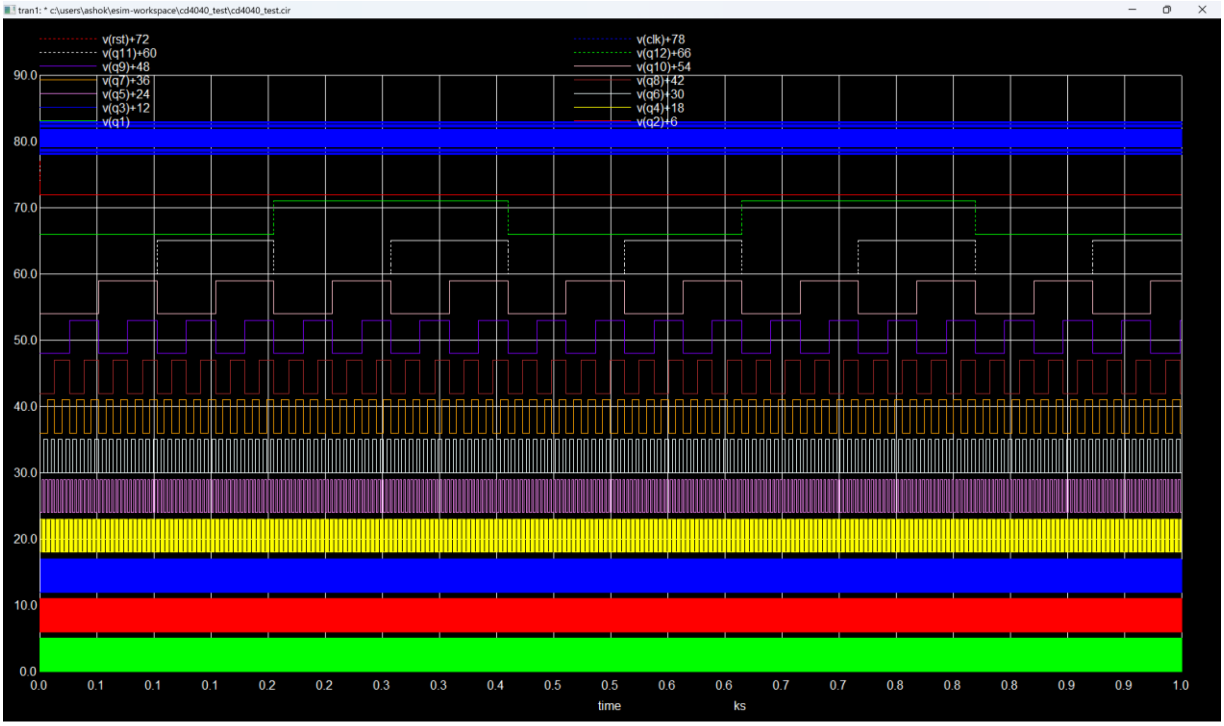
4.5 CD4040 IC

The CD4040 is an simple 12-bit counter IC with negative edge triggered clock and active high reset.

4.5.1 Test Schematic



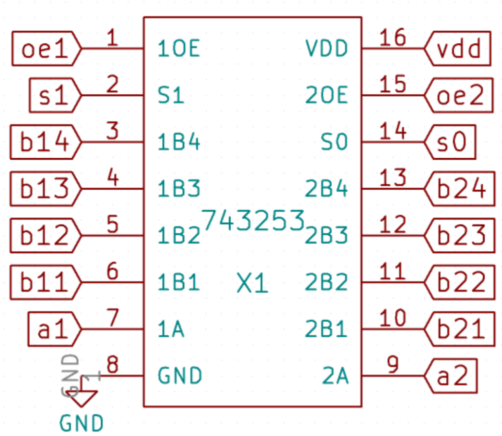
4.5.2 Waveforms



4.6 74LS3253 IC

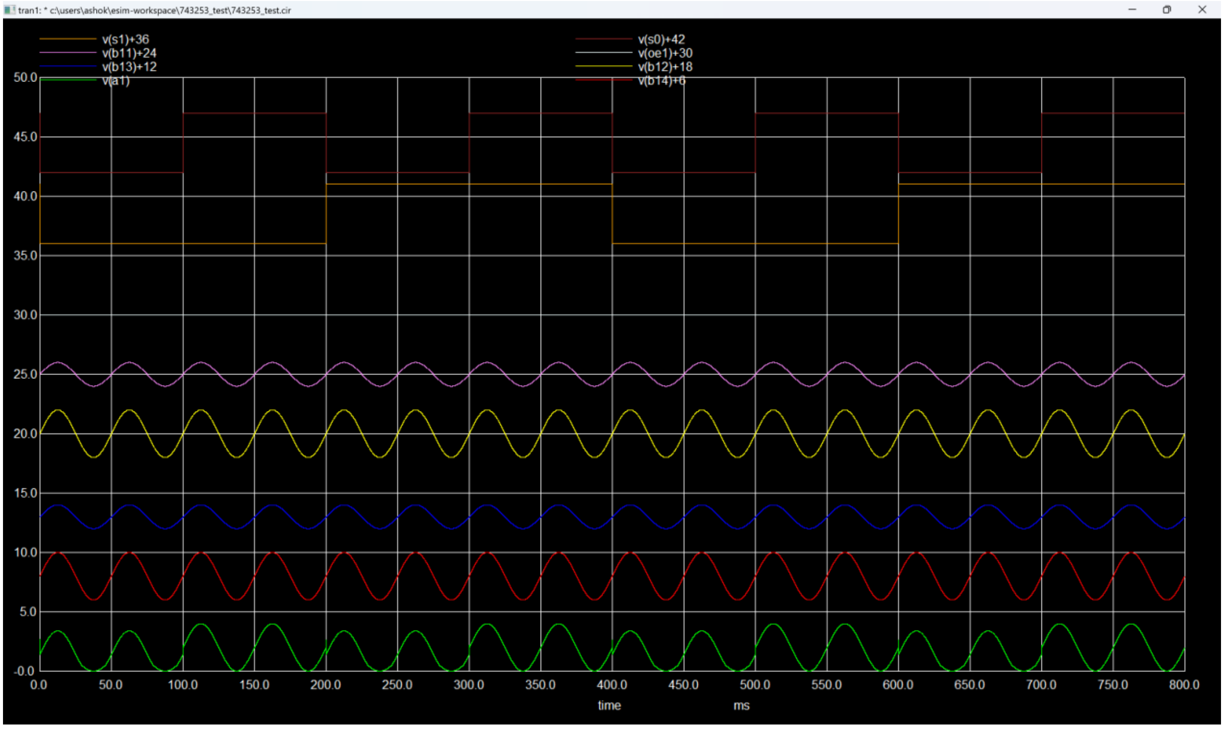
The 74LS3243 IC is an Dual Analog Multiplexer and DeMultiplexer and the oe1 and oe2 are the active low enable pins that which activates the working of the IC.

4.6.1 Test Schematic

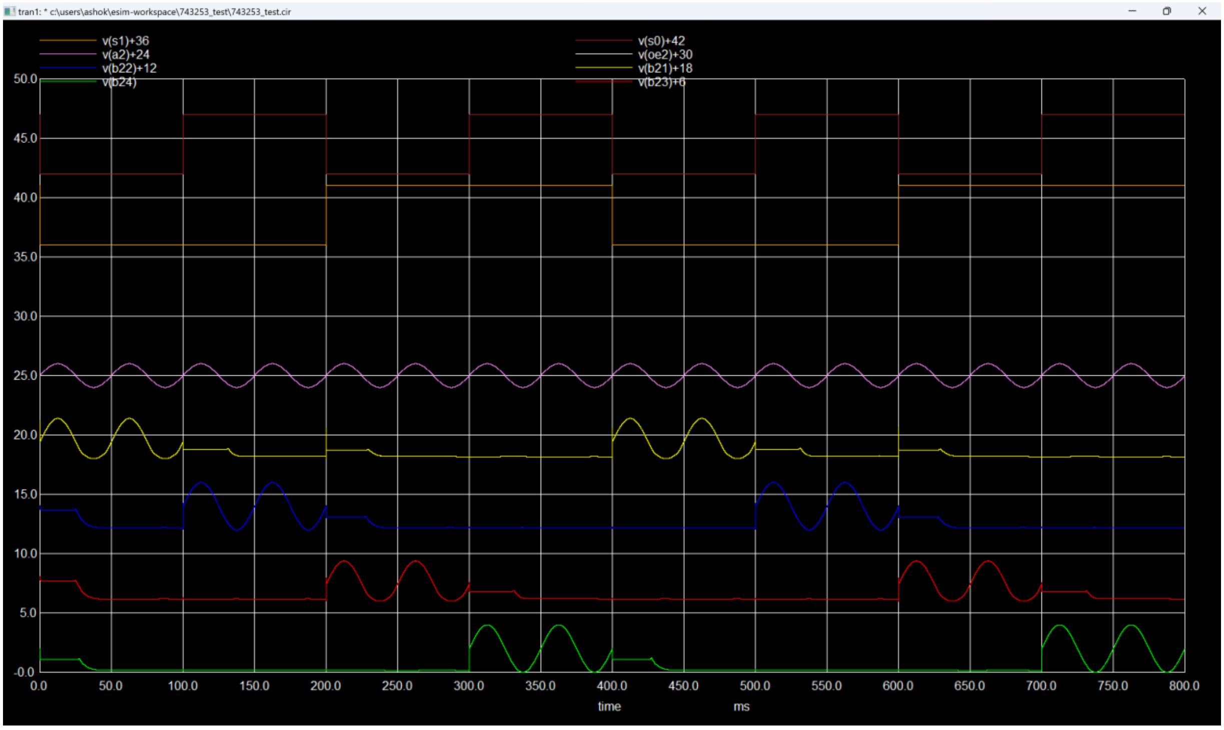


4.6.2 Waveforms

- Analog Multiplexer



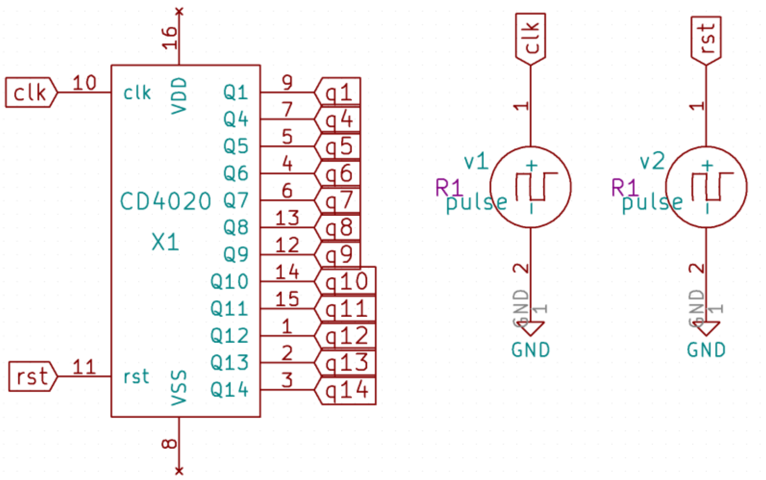
- Analog DeMultiplexer



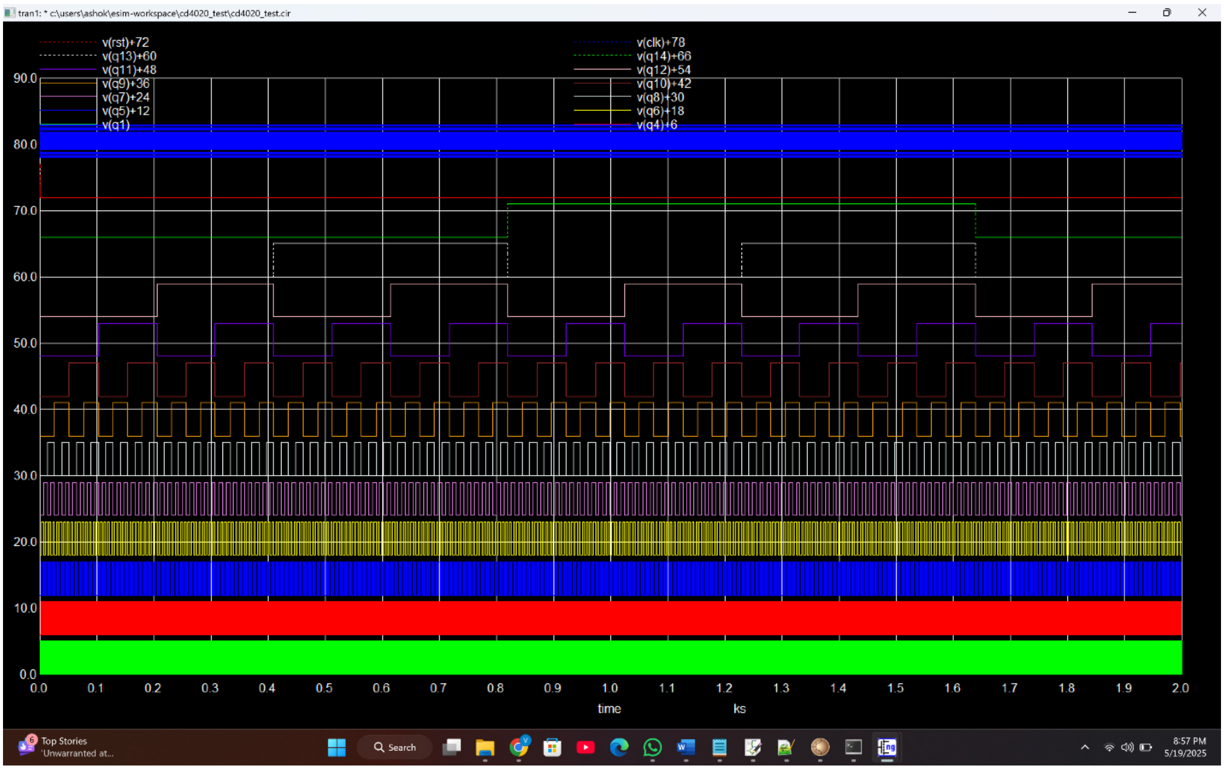
4.7 CD4020 IC

The CD4020 is an simple 14-bit counter IC with negative edge triggered clock and active high reset and it only consists q1,q4 to q14 as outputs.

4.7.1 Test Schematic



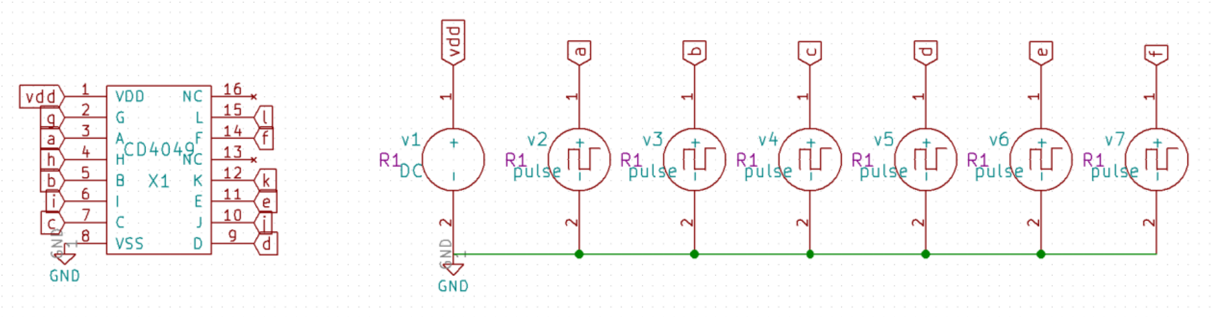
4.7.2 Waveforms



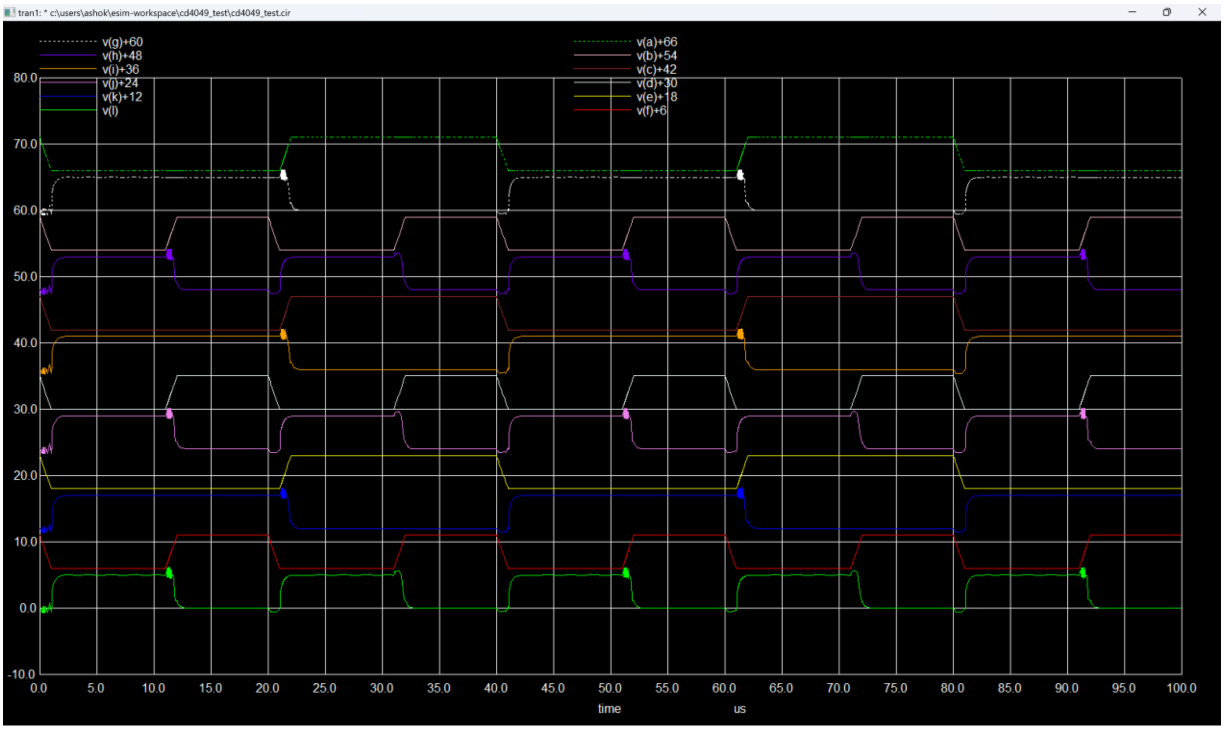
4.7 CD4049 IC

The CD4020 is an simple 14-bit counter IC with negative edge triggered clock and active high reset and it only consists q1,q4 to q14 as outputs.

4.7.1 Test Schematic



4.7.2 Waveforms



Bibliography

[1] TL071/TL072/TLO74 Datasheet
https://www.alldatasheet.com/datasheet-pdf/view/555722/TI/TL071.html

[2] SN53154 Datasheet
https://www.alldatasheet.com/datasheet-pdf/view/27367/TI/SN54154.html

[3] CD4093B Datasheet
https://www.alldatasheet.com/datasheet-pdf/view/26894/TI/CD4093B.html

[4] CD4015BC Datasheet
https://www.alldatasheet.com/datasheet-pdf/view/50837/FAIRCHILD/CD4015BC.html

[5] CD4040 Datasheet
https://www.alldatasheet.com/datasheet-pdf/view/546114/TI/CD4040.html

[6] 74LS3253 Datasheet
https://www.alldatasheet.com/datasheet-pdf/view/27420/TI/74LS32.html

[7] CD4020 Datasheet
https://www.alldatasheet.com/datasheet-pdf/view/26858/TI/CD4020B.html

[8] CD4049 Datasheet
https://www.alldatasheet.com/datasheet-pdf/view/26882/TI/CD4049.html