Winter Internship Report

On

Including Integrated Circuit (IC) Subcircuit on eSim

Submitted by

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Acknowledgment

I would like to convey my gratitude to the entire FOSSEE team for providing me with this esteemed Internship opportunity. This was a truly enlightening experience working with an open source organization such as this where I could learn about a new simulation software like eSim and acquire plenty of knowledge about approaching a problem and troubleshooting to find solutions. I deeply look forward to cherishing this learning experience in the forthcoming years of my career.

I would like to extend my sincere regards to Prof. Kannan M. Moudgalya for his vision and mission to take this initiative forward and providing me with a chance to be a small part of this project as an intern.

I also want to express my warm gratitude to the entire FOSSEE team including our mentors Mr. Sumanto Kar, Mrs. Vineeta Parmar and Mrs. Usha Vishwanathan for constantly guiding and mentoring me throughout the duration of my internship. It is with their support that I have been able to fulfil my project demands successfully. Whenever I faced an issue, our mentors were always accessible to help me debug through it and find the correct solution. My learnings from them have been most valuable and I shall carry it forward in my future.

A special thanks to all my fellow interns who have kept me motivated throughout the Internship to work together for this project in our respective capacities. Overall, it was a delightful experience interning at FOSSEE and contributing to its growth and I take away some great insights and knowledge from it. Also, as a beginner enthusiastic about the semiconductor industry, this internship is a milestone for me in my pursuit of a successful career.

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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 Chosen

Implementing some standard Integrated Circuits (IC) as subcircuits into the eSim library.

2.1 Approach

The approach used by me to implement the problem statement is to first look into the datasheets of some prominent Integrated Circuits manufactured by companies like Texas Instruments, Analog Devices, NXP Semiconductors among others. The ICs are so chosen such that there is a variety of utilities served. For example, the ones I have included range from precision amplifiers, comparators, and drivers to audio amplifiers etc. The subcircuits built are then tested to verify basic circuit configurations through Ngspice simulations. The point-by-point roadmap of the process is as follows:

1. Browse through datasheets of relevant ICs that are not previously included into the eSim library.
2. Check for the detailed schematic of the IC and implement the same in the eSim subcircuit builder.
3. Convert the subcircuit from KiCad to Ngspice and create a pin diagram for the IC so that it gets added to the library.
4. Then, the next part involves verifying the subcircuit through a test circuit. We create a new project and build a relevant circuit to test the IC.
5. Convert the test circuit from KiCad to Ngspice and simulate it. We verify the waveforms from the datasheet and assess if the IC operates as per standards.

The same process is followed for all other subcircuits.

Chapter 3

Subcircuit Builder Method

Subcircuit is a way to implement hierarchical modelling. Once a subcircuit for a component is created, it can be used in other circuits. eSim provides an easy way to create a subcircuit. The following section deals with the step-by-step method of creating a subcircuit.

3.1 Subcircuit Creation

The steps to create subcircuit are as follows:

1. After opening the Subcircuit tool, click on New Subcircuit Schematic button. It will ask the name of the subcircuit. Enter the name of subcircuit (without any spaces) and click OK.
2. After clicking OK button it will open KiCad schematic. Draw your circuit which will be later used as a subcircuit.
3. Once you complete the circuit, assign port to the node of your circuit which will be used to connect with the main circuit. PORTS can be found in the components section in the editor. These act as linkages to inputs and outputs of the main circuit.
4. As the next step, save the subcircuit and generate a KiCad netlist for the same.
5. Now, to use this as a subcircuit, create a block in the KiCad Eescchema and follow the below steps:
   i. Go to library viewer of Eschema
   ii. Choose the current working library as the eSim_Subckt. iii. Click on create a new component with reference X.
   iv. Start drawing the subcircuit block. Update and save it
6. Close the Eeschema window and click on Convert KiCad to Ngspice button in subcircuit builder tool. This will convert the KiCad spice netlist to Ngspice netlist.

   And it will save your subcircuit into eSim repository, which you can add in your main circuit.

Chapter 4

Subcircuits Implemented

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

4.1 CA3080 IC

Developed by RCA and later produced by various manufacturers, the CA3080 is an operational transconductance amplifier (OTA) that provides high-speed operation with a high slew rate. It is widely used in applications requiring variable gain amplification and analog signal processing. The CA3080 features a differential input stage and a current-source output, making it ideal for applications such as voltage-controlled amplifiers and oscillators.

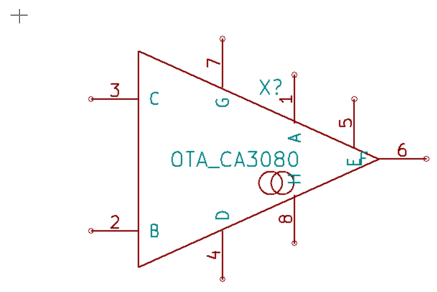
Some of the common applications of CA3080 are:

1. Voltage-controlled amplifiers
2. Analog signal processing
3. Multipliers and modulators

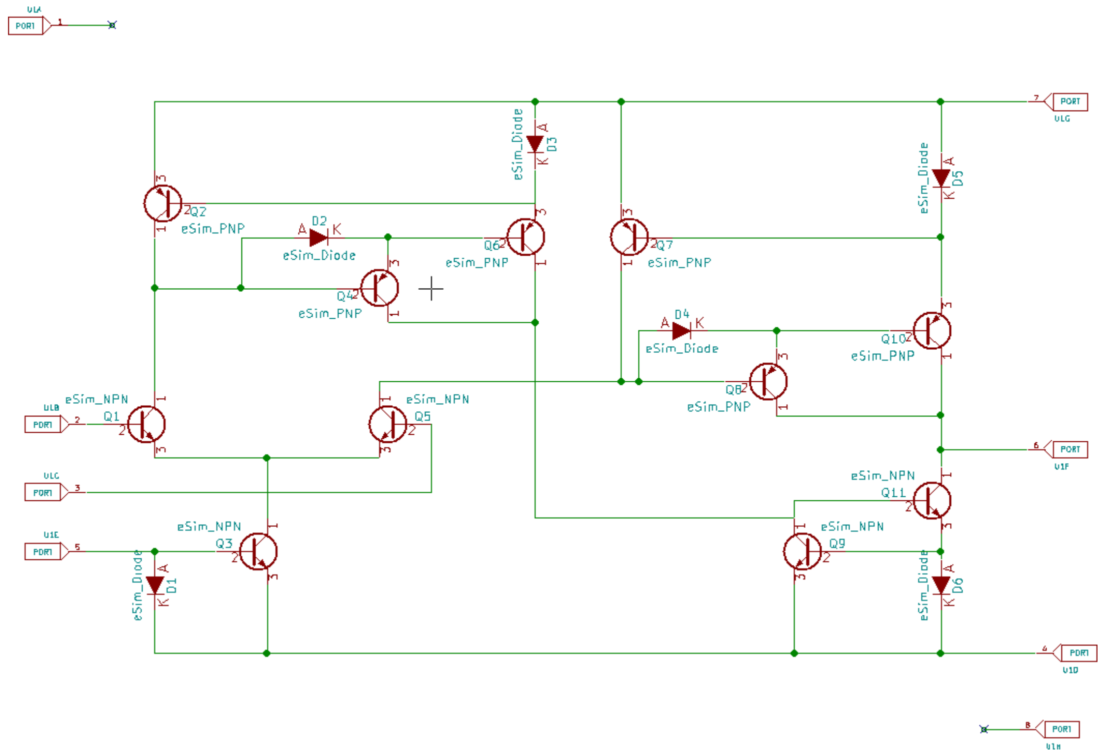
Some of the salient features of CA3080 are:

1. High-speed operation
2. High slew rate
3. Low input bias current

4.1.1 Pin Diagram



4.1.2 Subcircuit Schematic (CA3080 IC)



4.2 SN74LS00 IC

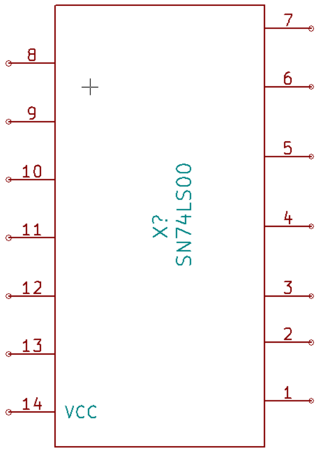
Manufactured by Texas Instruments, the SN74LS00 is a quad 2-input NAND gate IC belonging to the 74LS series of logic gates. It operates at a low power consumption while offering high-speed switching capabilities. The device is commonly used in digital logic design, where NAND gates form the fundamental building blocks of various circuits.
Some of the common applications of SN74LS00 are:

1. Logic circuit design
2. Pulse generation
3. Frequency dividers

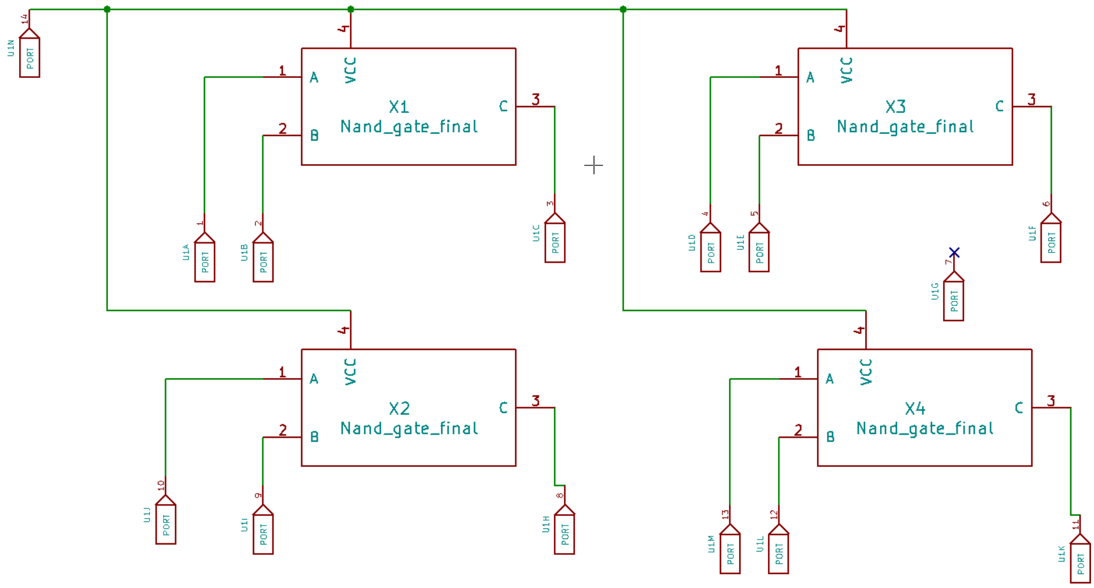
Some of the salient features of SN74LS00 are:

1. Low power dissipation
2. High noise immunity
3. TTL-compatible inputs and outputs

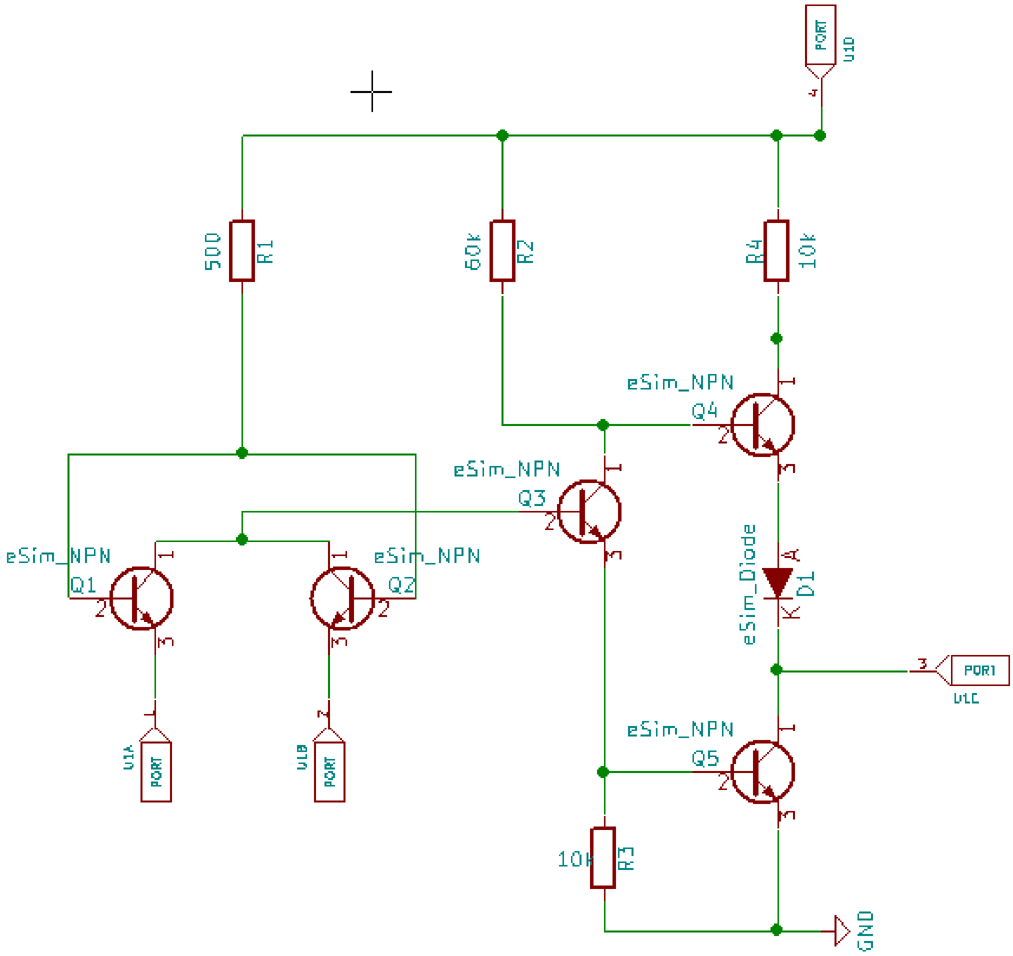
4.2.1 Pin Diagram



4.2.2 Subcircuit Schematic (SN74LS00 IC)



Nand Gate TTL used in SN74LS00 IC subcircuit -



(Nand_gate_final)

4.3 TDA7050 IC

Developed by Philips (now NXP Semiconductors), the TDA7050 is a low-power audio amplifier IC designed for battery-operated devices. It is a mono amplifier that offers a bridge-tied load (BTL) configuration, enabling higher output power without requiring an output capacitor. The IC is commonly used in portable audio applications.

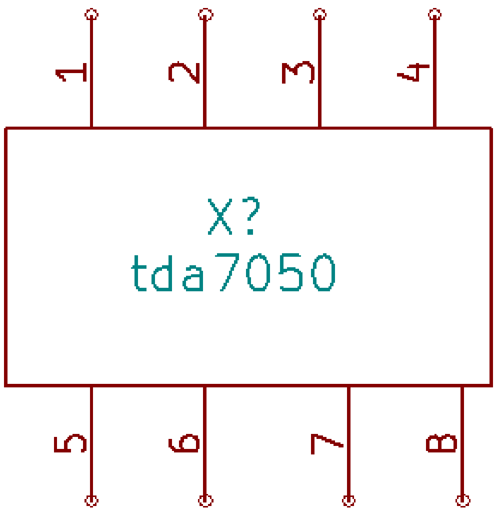
Some of the common applications of TDA7050 are:

1. Portable audio devices
2. Battery-operated amplifiers
3. Hearing aids

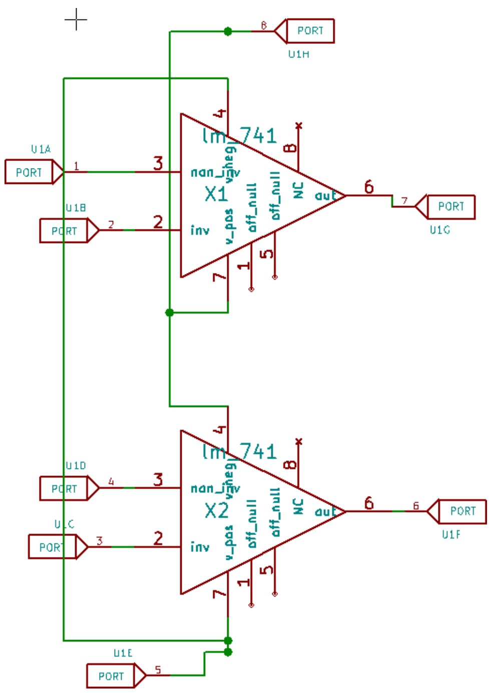
Some of the salient features of TDA7050 are:

1. Low voltage operation
2. High power efficiency
3. No output capacitor required (BTL mode)

4.3.1 Pin Diagram



4.3.2 Subcircuit Schematic



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4.4 MC1489 IC

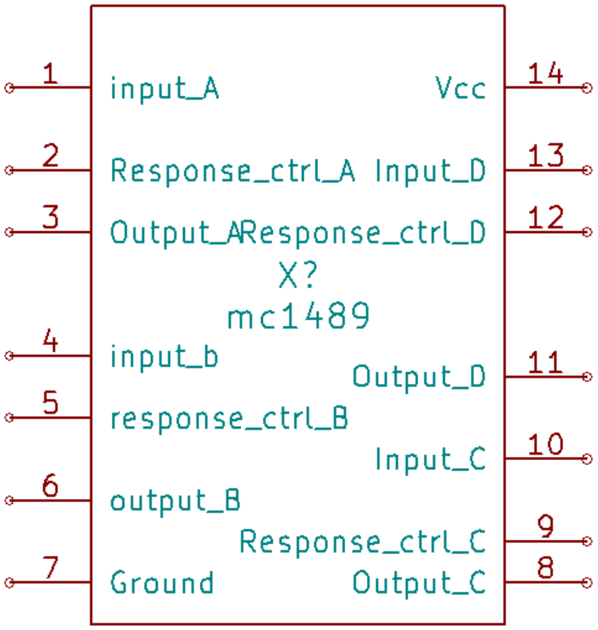
Produced by Motorola (now ON Semiconductor), the MC1489 is a quad line receiver designed for RS-232 communication. It converts RS-232 voltage levels to TTL logic levels, making it suitable for interfacing serial communication devices with digital circuits.
Some of the common applications of MC1489 are:

1. RS-232 serial communication
2. Data transmission and reception
3. Computer interface circuits

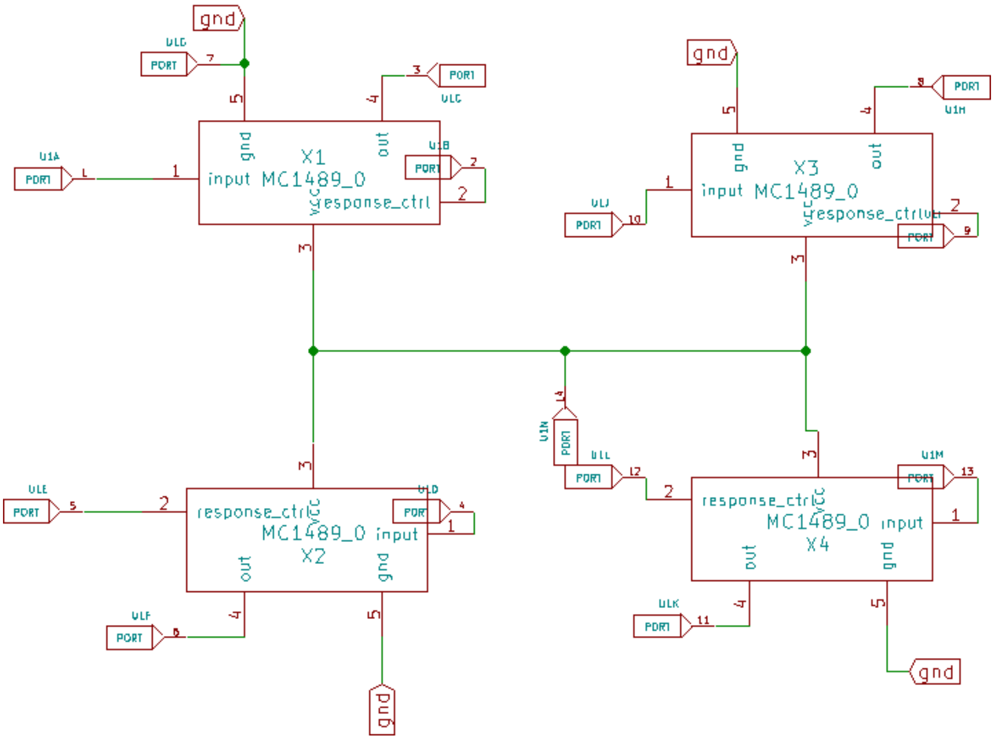
Some of the salient features of MC1489 are:

1. Converts RS-232 to TTL logic
2. High noise immunity
3. Low power consumption

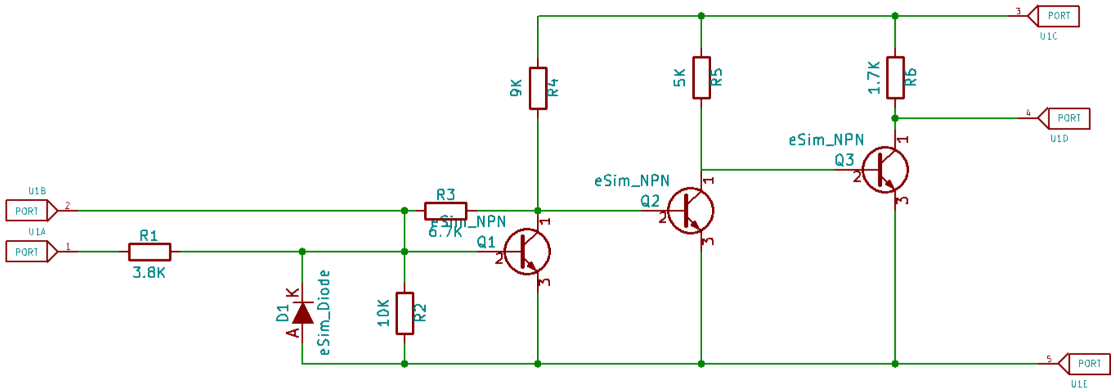
4.4.1 Pin Diagram



4.4.2 Subcircuit Schematic (MC1489 IC)



A single unit (1/4th of the subcircuit, here named MC1489_0), its subcircuit is shown below –



(MC1489_0)

4.5 MC1489A IC

The MC1489A is an improved version of the MC1489, offering enhanced input threshold characteristics and better noise immunity. Like its predecessor, it is used in RS-232 communication systems to translate voltage levels between serial devices and digital logic.

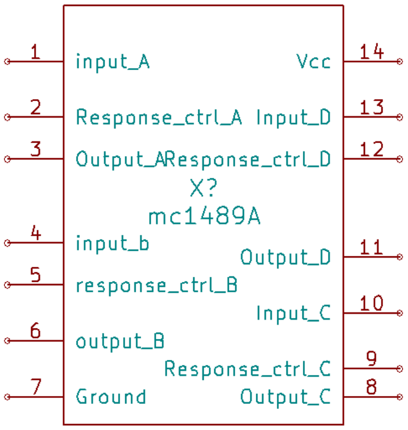
Some of the common applications of MC1489A are:

1. Serial data communication
2. RS-232 interface circuits
3. Computer peripheral connections

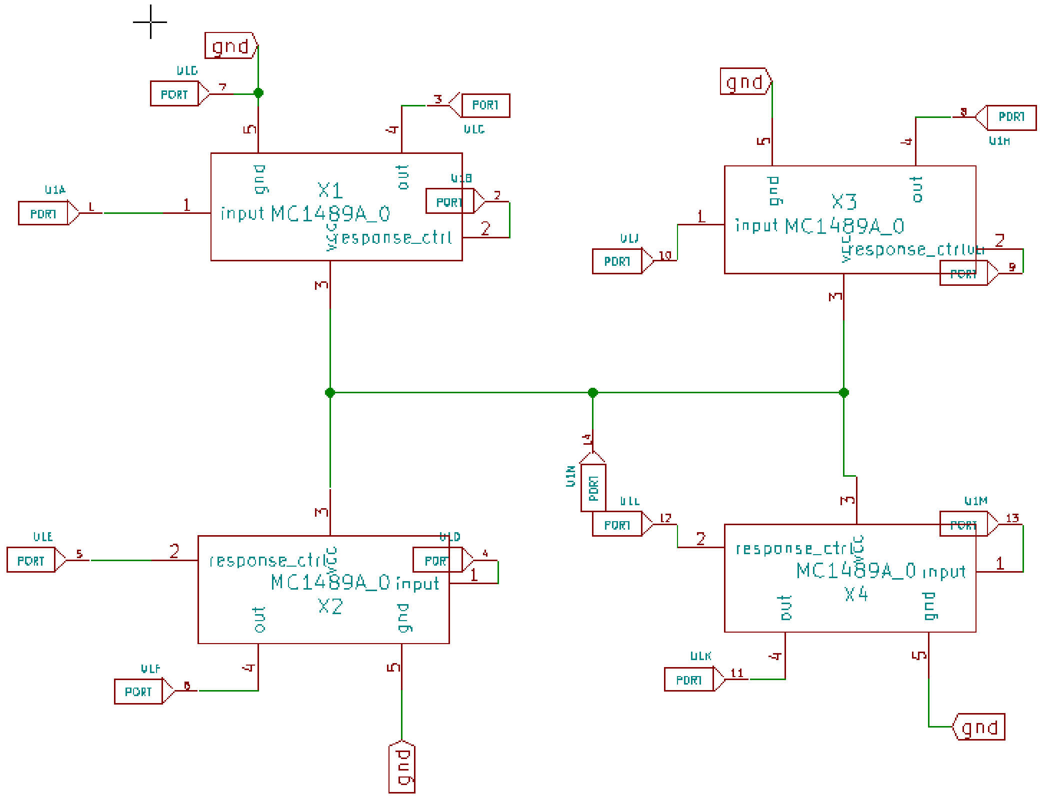
Some of the salient features of MC1489A are:

1. Improved input voltage threshold
2. Enhanced noise immunity
3. Low power dissipation

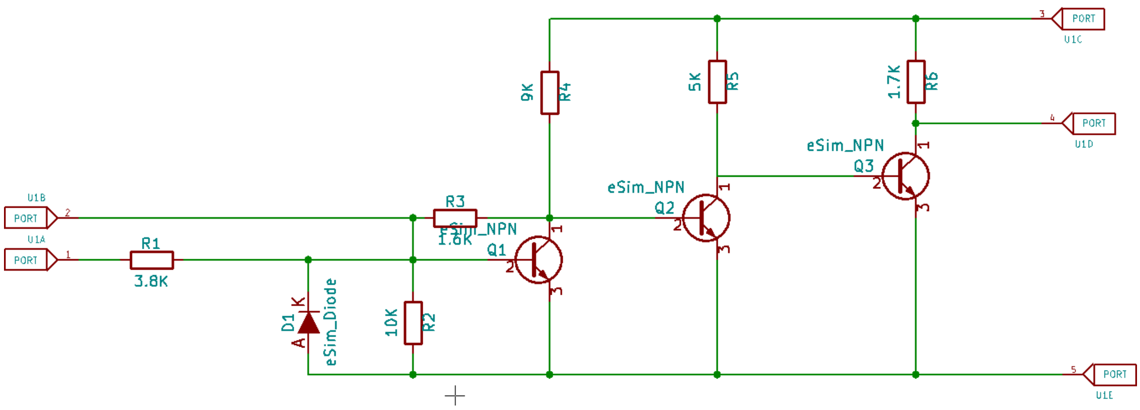
4.5.1 Pin Diagram



4.5.2 Subcircuit Schematic (MC1489A IC)



A single unit (1/4th of the subcircuit, here named MC1489A_0), its subcircuit is shown below –



(MC1489A_0)

4.6 SN55188 IC

The SN55188 is a dual differential line driver IC developed by Texas Instruments. It is used in digital data communication applications, particularly for long-distance transmission where differential signaling is required. The IC ensures high noise rejection and improved signal integrity.

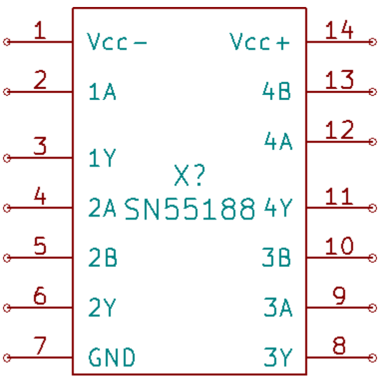
Some of the common applications of SN55188 are:

1. Differential signal transmission
2. Long-distance data communication
3. Industrial control systems

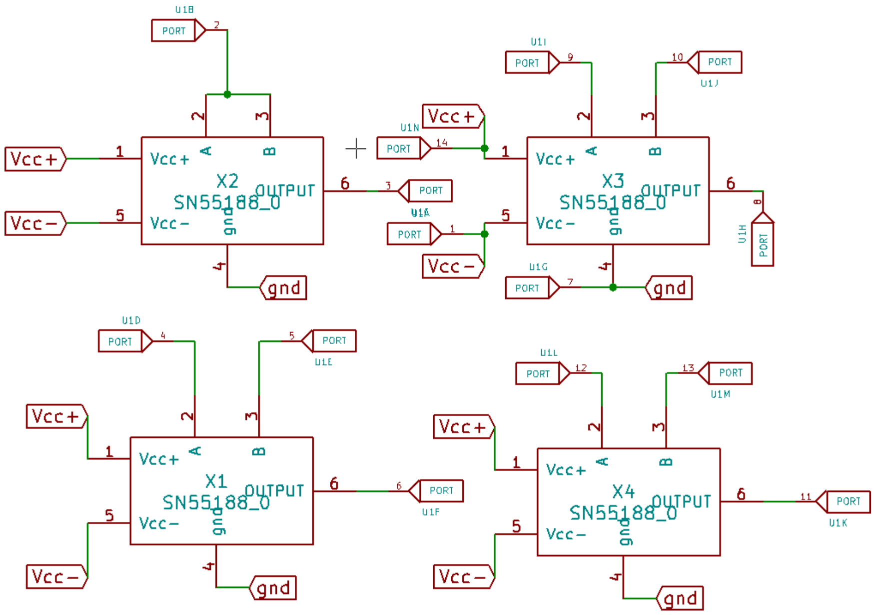
Some of the salient features of SN55188 are:

1. Dual differential line drivers
2. High noise reject
3. TTL-compatible inputs

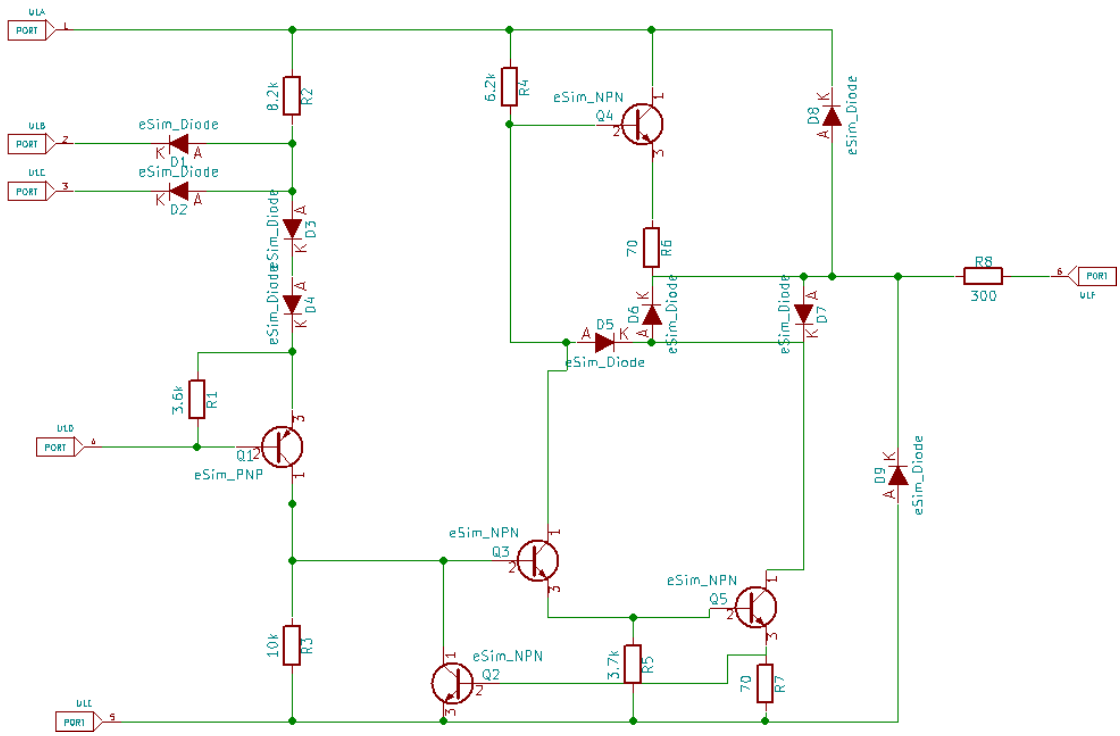
4.6.1 Pin Diagram



4.6.2 Subcircuit Schematic (SN55188 IC)



A single unit (1/4th of the subcircuit, here named SN55188_0), its subcircuit is shown below –



(SN55188_0)

Chapter 5

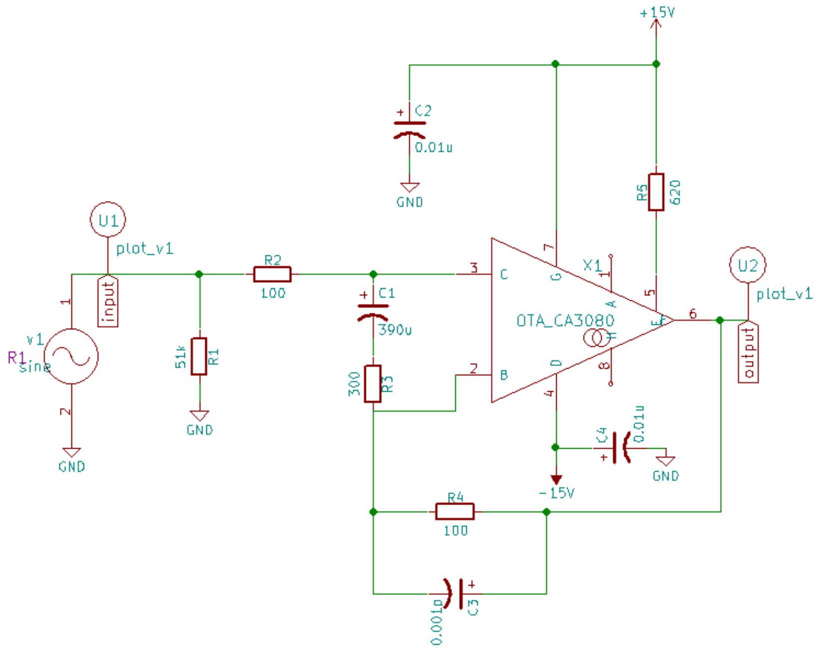
Ngspice Simulations of Subcircuits Tested

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.

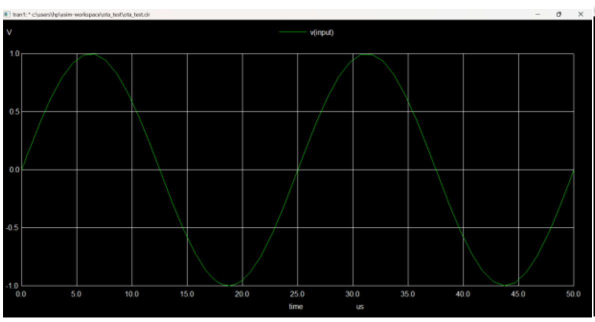
5.1 CA3080 IC

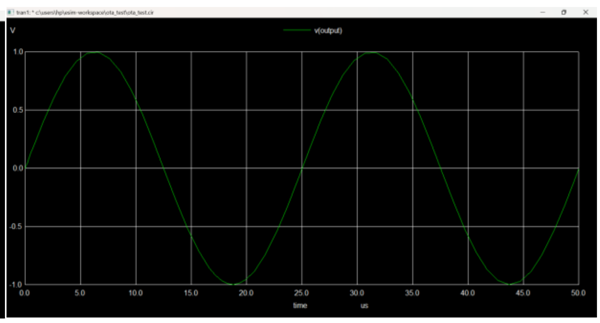
The CA3080 IC is tested in a unity gain voltage follower configuration. So, Vout=Vin Here I have applied a sine wave as input. The output shows a sine wave, as expected.

5.1.1 Test Schematic



5.1.2 Waveforms

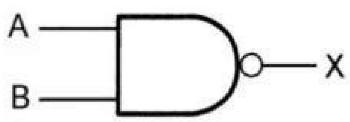




5.2 SN74LS00 IC

The SN74LS00 is tested as a simple NAND gate. The truth table for a NAND gate is:

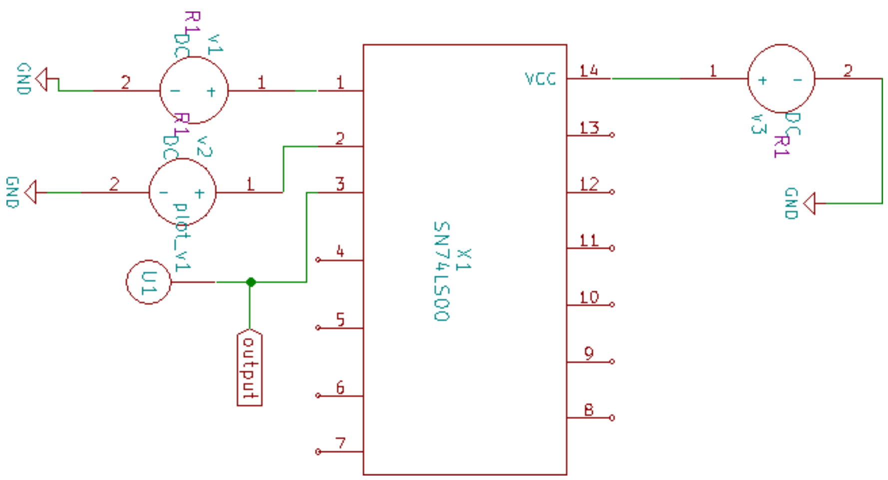
$$X = \overline{A.B}$$



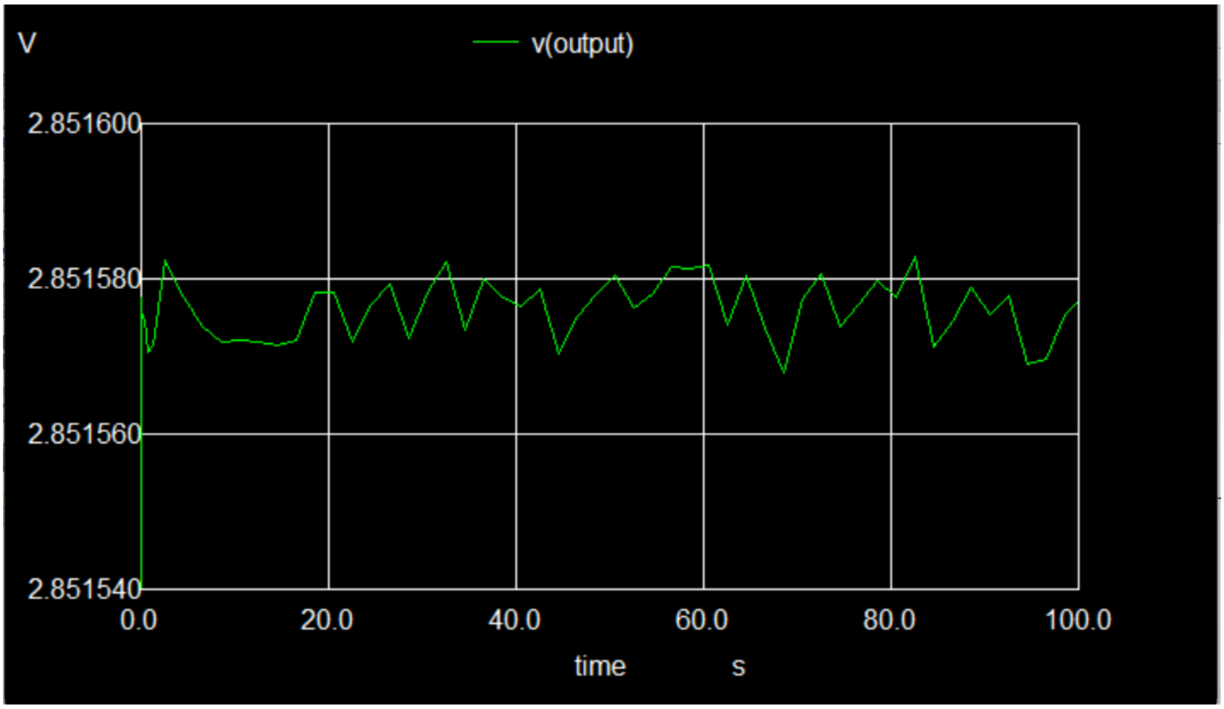
A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

Here I have inputted V3 (high X output) as 3V. If we put DC source v1=5V and v2=0V, we get high output.

5.2.1 Test Schematic



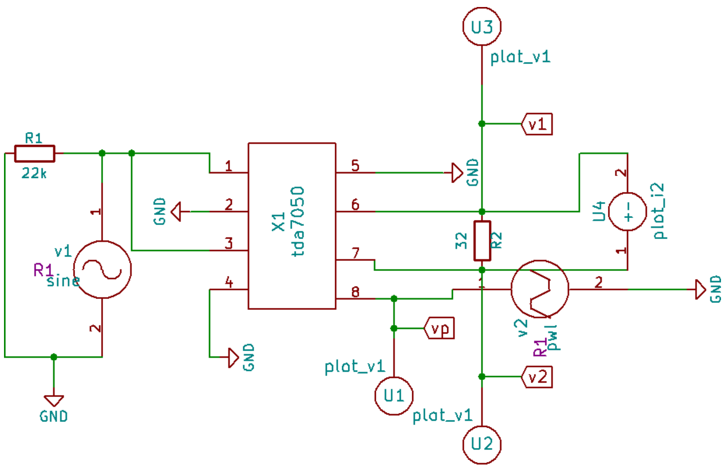
5.2.2 Waveforms



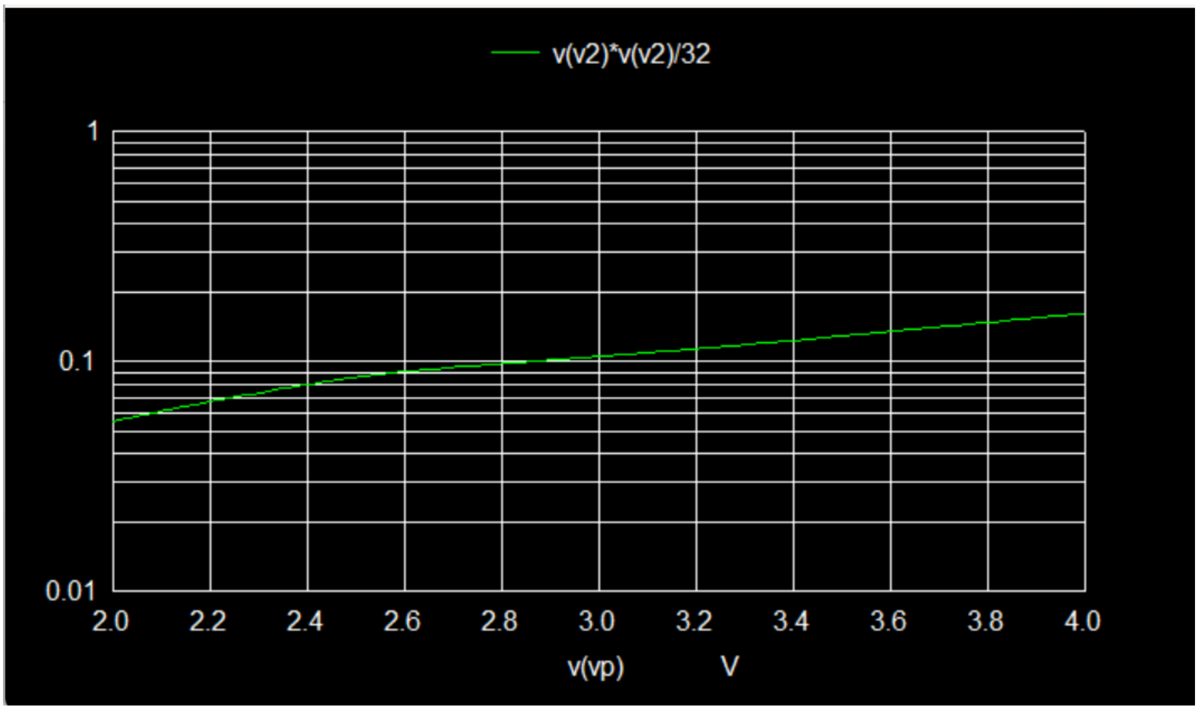
5.3 TDA7050 IC

The TDA7050 is tested in a bridge-tied load (BTL) configuration with a 10Ω speaker as the load. The gain of the amplifier is fixed at 32 dB, and the output voltage is given by: VOUT =G×VIN. The test waveform shows the output power across the load impedance (RL) as a function of supply voltage (VP) in BTL application. Measurements were made at f = 1 kHz.

5.3.1 Test Schematic



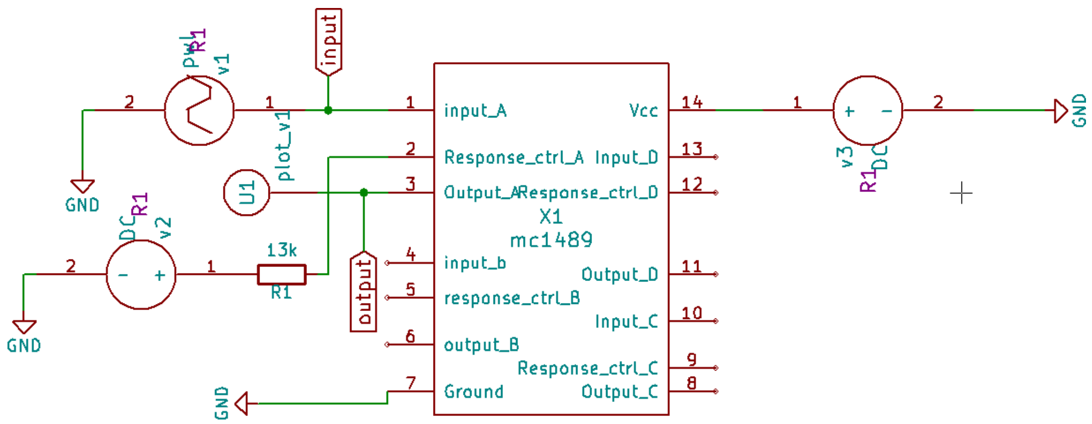
5.3.2 Waveforms



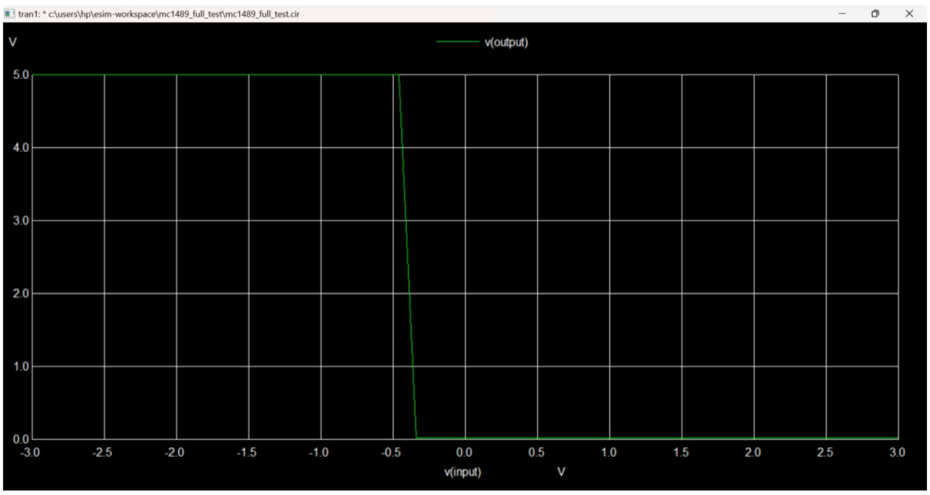
5.4 MC1489 IC

Here I kept Vcc = 5V and the response control voltage=5V and resistor = 13k. The output is the same as provided in the datasheet as expected.

5.4.1 Test Schematic



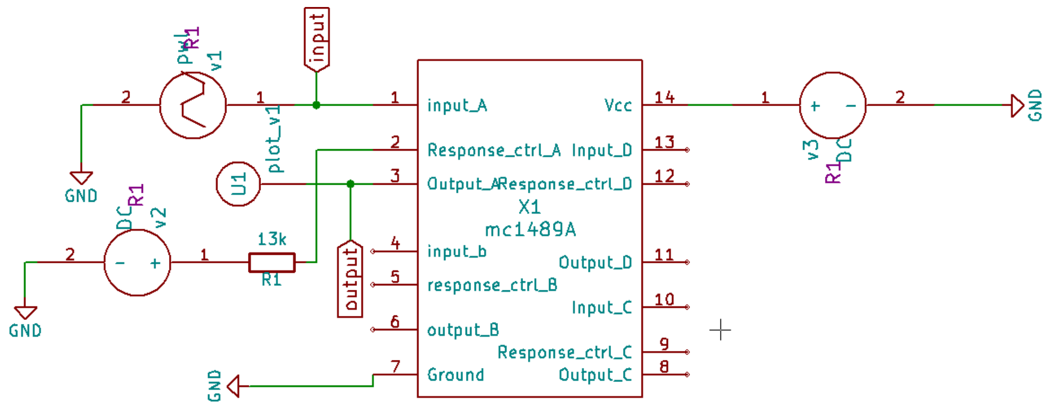
5.4.2 Waveforms



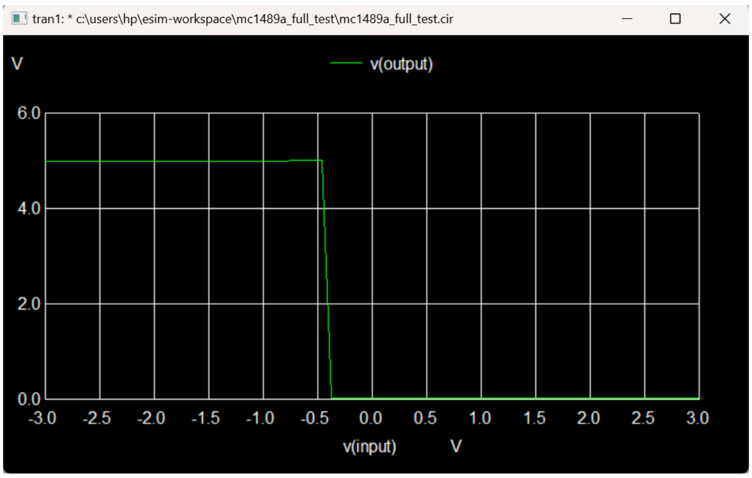
5.5 MC1489A

ULN2803A is tested as a circuit from the datasheet that performs as an inverter.

5.5.1 Test Schematic



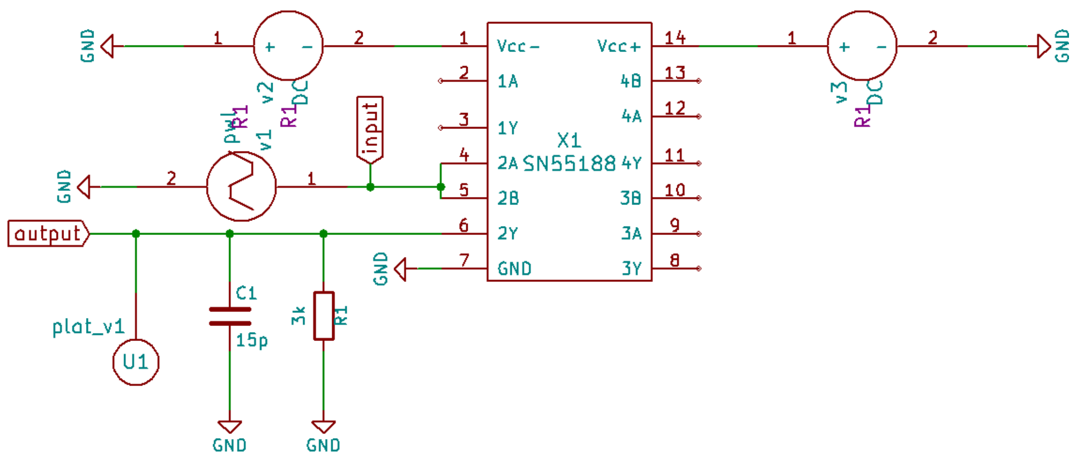
5.5.2 Waveforms



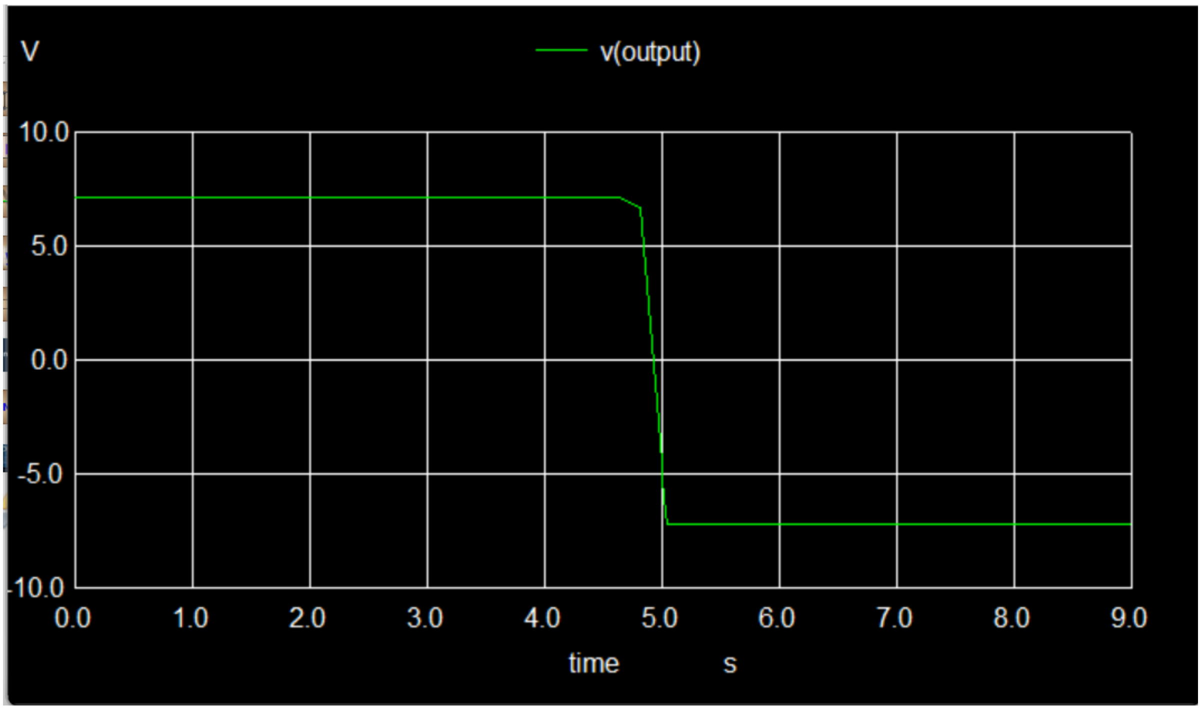
5.6 SN55188

The SN55188 is tested for its voltage transfer characteristics. We vary input voltage and check output voltage. Here I have applied Vcc=9V , Vcc-= -9V

5.6.1 Test Schematic



5.6.2 Waveforms



Bibliography

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[6] SN55188 Datasheet https://www.ti.com/lit/ds/slls094c/slls094c.pdf?ts=1739049251400&ref_url=https%253A%252F%252Fwww.google.com%252F

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