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Analog Project

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Abstract

In this report, there is a detailed description of how to build an analog computer that is capable of performing three operations Addition, Subtraction, and multiplication within the frequency range of 1Hz - 10KHz.
This computer has appropriate biasing and gain adjusting techniques. This project is done by using operational amplifiers and resisters.
The device contains two PCBs. One is capable of performing basic calculations, and the second one is for powering up the circuit as a dual power supply. This device does not contain a transformer; hence it will be sold to customers with an AC adapter

Contents

1 Introduction and Functionality

1.1 Introduction

Analog computers represent a class of computing devices that perform calculations using continuous physical variables, typically electrical voltages or currents, as opposed to discrete digital signals. We have developed an analog computer with the functionality of basic computations using operational amplifiers (Opamps) within a specified frequency range, which uses voltage as the continuous physical variable.

Figure 1: Preview of the device.

1.2 Functionality

- Basic Operations:

  The analog computer is capable of performing fundamental arithmetic operations, including addition, subtraction, and multiplication. These operations are executed using operational amplifiers configured in specific circuits.

- Operational Amplifiers (Opamps):

  Opamps are the key components used for computation. They amplify the input voltage signals and can be configured in various circuit arrangements to perform mathematical operations.

- Voltage Representation:

  The analog computer operates with continuous voltage signals. Positive and negative input voltages are accommodated, allowing for a versatile range of computations.

- Addition Circuit:

  In addition, opamps are configured as summing amplifiers. Two input voltages are fed into the opamp, and the output represents the algebraic sum of these inputs.

- Subtraction Circuit:

  Subtraction is achieved by using a differential amplifier configuration. Two voltages to be subtracted are applied to the terminals of the operational amplifier.

- Multiplication Circuit:

  Multiplication is accomplished by employing a multiplication circuit that performs using both current and voltage. This circuit can do all four quadrant multiplications up to 0.9V.

- Frequency Range:

  The analog computer is designed to operate within a specified frequency range of 1Hz to 10kHz. This ensures that the computations are effective for signals within this frequency spectrum.

- Precision and Accuracy:

  The precision and accuracy of computations depend on the quality of the components, calibration, and circuit design. Opamp characteristics and tolerances play a crucial role in achieving accurate results. In order to achieve High precision and accuracy, we have carefully selected opamps with relevant slew rates and Gain Bandwidth Products.

- Signal Conditioning:

  The system incorporates signal conditioning circuits to adjust input signals, ensuring they fall within the appropriate range for reliable computation (Biasing).

In summary, this analog computer is a specialized device tailored for low-frequency analog computations, leveraging opamp circuits to perform addition, subtraction, and multiplication operations with positive and negative input voltages. Its design strikes a balance between simplicity and versatility, offering a unique approach to analog computation within the specified frequency range.

2 System Architecture

Overview:

The Analog Computer is designed to perform fundamental analog computations, including addition, subtraction, and multiplication, within the frequency range of 1Hz to 10kHz. Operational amplifiers (opamps) serve as the primary building blocks for computation, and the circuit is engineered to handle both positive and negative input voltages. The following outlines the system architecture, accompanied by relevant sketches.

2.1 Input Stage

Positive and Negative Input Handling:

- The input stage incorporates a differential amplifier configuration to handle both positive and negative input voltages. This ensures the versatility of the system in accommodating a broad range of electrical scenarios for all operations.
- Rotary switch ensures the operation to carry. A bias circuit defines the operating voltage of the signal, which eliminates the distortion of the signal.

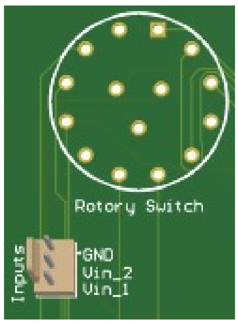
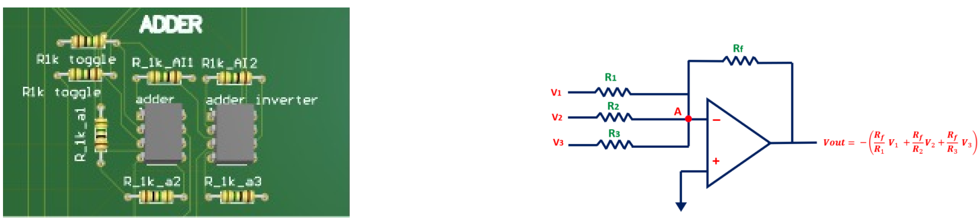


Figure 2: Input of the PCB.

2.2 Addition Circuit:

Summing Amplifier:

- For addition operations, a summing amplifier circuit is employed. Two input voltages are fed into the opamp, resulting in the algebraic sum at the output.
- This circuit is followed by a normal inverting unity gain amplifier to invert the output of the summing amplifier



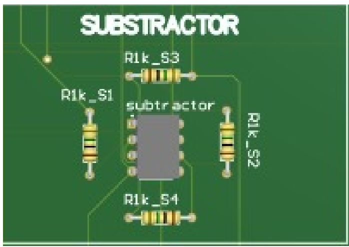
(a) Adder circuit (b) Schematic

Figure 3: Adder circuit of the Analog Computer

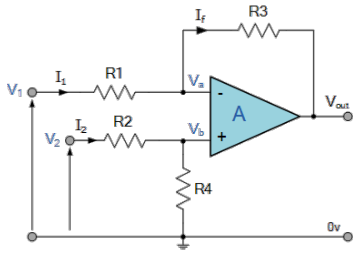
2.3 Subtraction Circuit:

Differential Amplifier:

- Subtraction is achieved by using a differential amplifier configuration. Two voltages to be subtracted are applied to the terminals of the operational amplifier



(a) Subtractor Circuit



(b) Subtractor Schematic

Figure 4: Subtractor Circuit of Analog Computer

2.4 Multiplication Circuit:

Opamp Multiplication:

- Multiplication is accomplished by employing a multiplication circuit that performs using both current and voltage. This circuit can do all four quadrant multiplications up to 0.9V.
- This circuit was implemented using research paper article [1]

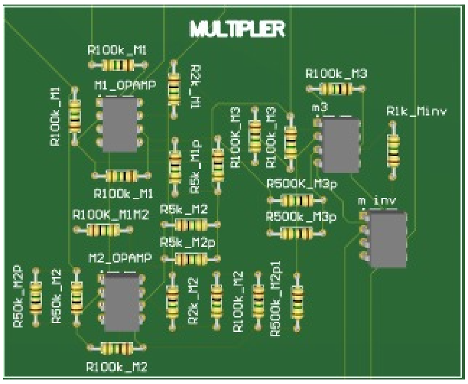


Figure 5: Multiplication circuit.

2.5 Output Stage:

Output Stage:

- Output waveform can be observed by using an oscilloscope, and Display shows the RMS value of the output voltage.

2.6 System Integration:

Overall System Sketch:

- An integrated sketch illustrates the overall architecture of the Analog Computer, showcasing the interconnected components and the flow of signals within the system.

Figure 6: Output of the PCB.

2.7 Equations

2.7.1 Multiplier Equation

These are the relevant equations for the analog multiplier circuit [1] shown in the figure 8

$$v_o = \frac{R_f R_s}{2R_c^2 RqIs} v_x v_y + 2(\frac{R_s}{2R_c} - \frac{Rf}{Rp})v_y$$

$(\frac{Rf}{Rp} = \frac{R_s}{2R_c})$,

2.7.2 subtractor

These are the relevant equations related to the analog subtracting circuit shown in figure 4b

$$v_o = \frac{R_f R_s}{2R_c^2 RqIs} v_x v_y = k_m v_x v_y$$

2.7.3 Adder

These are the relevant equations related to the analog adder circuit shown in figure 3b.

$$v_o = \frac{R_f v_1}{R_1} + \frac{R_f v_1}{R_1}$$

subtractor

$$v_{out} = -v_1(\frac{R_3}{R_1}) + v_2(\frac{R_4}{R_2 + R_4})(\frac{R_1 + R_3}{R_1})$$

if $R_1 = R_2 \texttt{and} R_3 = R_4$ then

$$v_{out} = -\frac{R_3}{R_1}(v_1 - v_2)$$

3 Component Selection

To achieve the given specifications, it is important to select the suitable components for the circuits. This is done through some calculations and by referring to the datasheets of the components. All the relevant calculations are shown above.

3.1 Opamps

For analog adder and subtractor, we used TL 071CN opamps (9a) [2], which we used mainly because of the slew rate of the opamp. The gain bandwidth product is in the required frequency range.

For analog Multiplier, we used LM 741 Opamps (9b) [3] because the circuit is tested to those parameters in the Research paper.

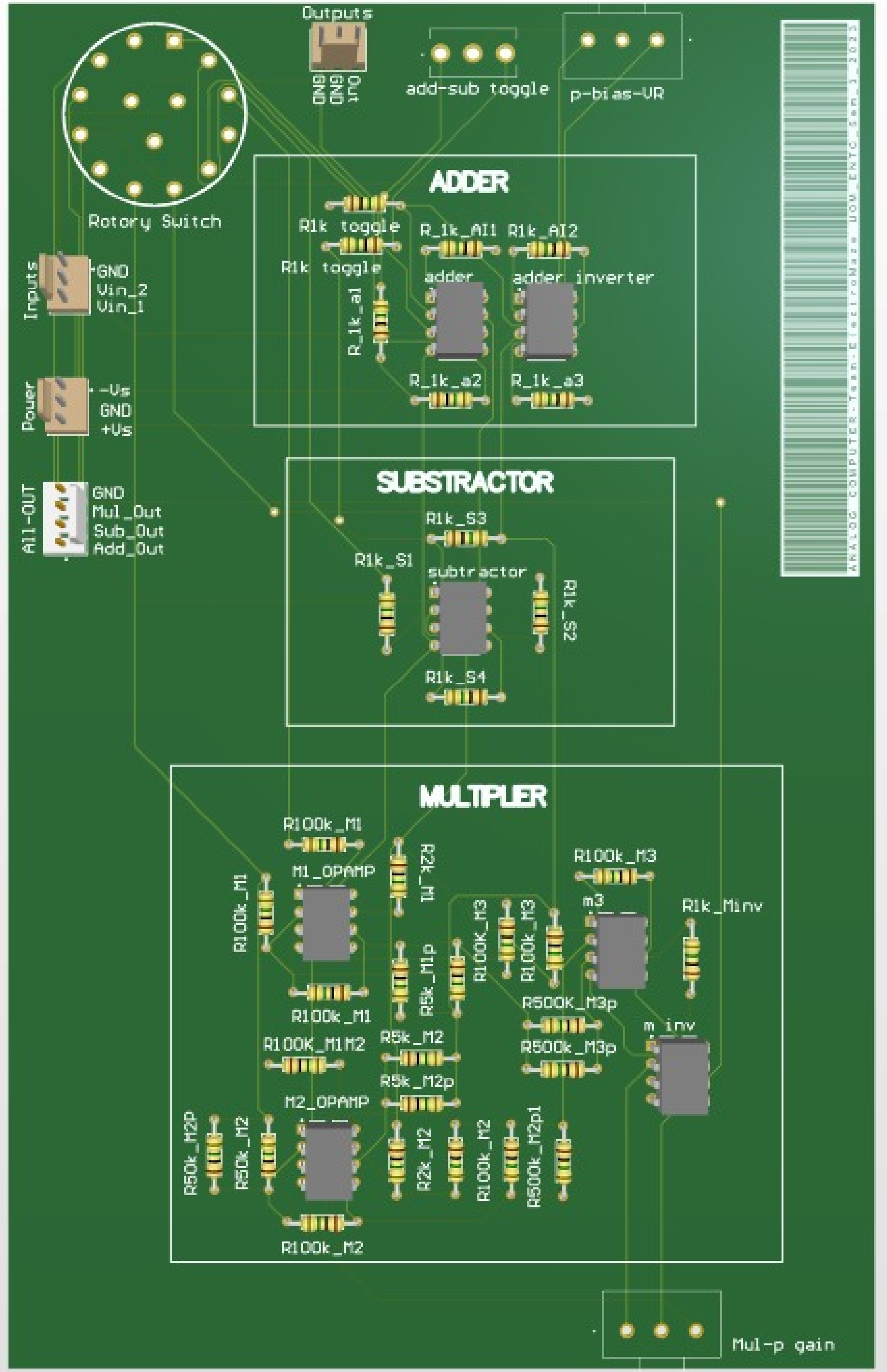


Figure 7: Full PCB of the Device.

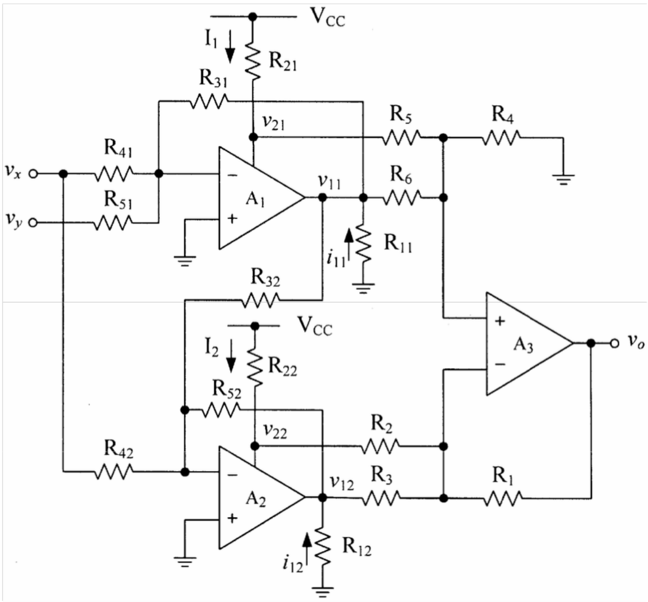
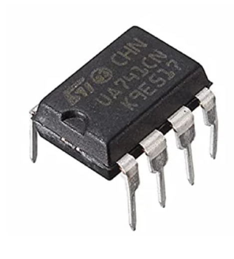


Figure 8: Circuit diagram of the analog multiplier.

(a) TL071CN opamp



(b) LM741 Opamp

Figure 9: Main Opamps

3.2 Resistors

Precision resistors were chosen to set accurate gain and establish reference values within the circuit. Low-temperature coefficient resistors were preferred for stability across varying operating conditions. We used 0.25W resisters because power dissipation is low as we use low current in the circuit.

3.3 Rotary Switch

We used a 4 pole 3 position rotary switch to select the operation to carry out. We used 4 poles because we needed to select the operation and also we needed to select the biasing voltage.

3.4 Potentiometers

We used 10k pentameters to adjust the gain of the Opamps.

4 PCB Design

After testing the circuits in protoboards, PCB designing is done using Altium software. All the circuits that were tested are combined into two separate circuits for PCB design. The power supply PCB and main PCB were separately printed. The Gerber output files were generated for the designs and sent to JLCpcb to print the PCBs. The designed PCBs are soldered after inserting components. Pentameters and rotary switches are used to change the gain, and bias and to switch between operations. They are directly connected to the PCB. The figures below show PCBs before and after soldering, respectively.

5 Enclosure Design

Enclosure:

The enclosure was designed using Solidworks software and then 3D printed using Thermostat plastics. 3mm thick outer walls were used to ensure a solid structure and durability. TFT screen was attached for the sake of completeness. The whole body is attached using metal screws in a detachable manner, and all the PCBs are fixed in position. To get inputs and outputs, we've used general male pins and 3 knobs, and a switch for controlling purposes.

6 Software Simulation and Hardware Testing

6.1 Software Simulation

The circuits were simulated and tested before designing the printed circuit boards(PCB). National Instruments(NI) Multisim is used as the simulation tool.

6.2 Hardware testing

We prototype our circuit physically on a breadboard and dot board before implementation

7 Conclusion & Future Works

As a conclusion, we successfully developed a low frequency (1Hz - 10kHz) analog signal computing device which has the capability to addition, subsection, and multiplication.

In the future, we can improve the accuracy of the device by using more precise PCB manufacturing methods and by adding a Display to show the output waveform. We expect to add more functions to the device, such as division, integration, and differentiation.

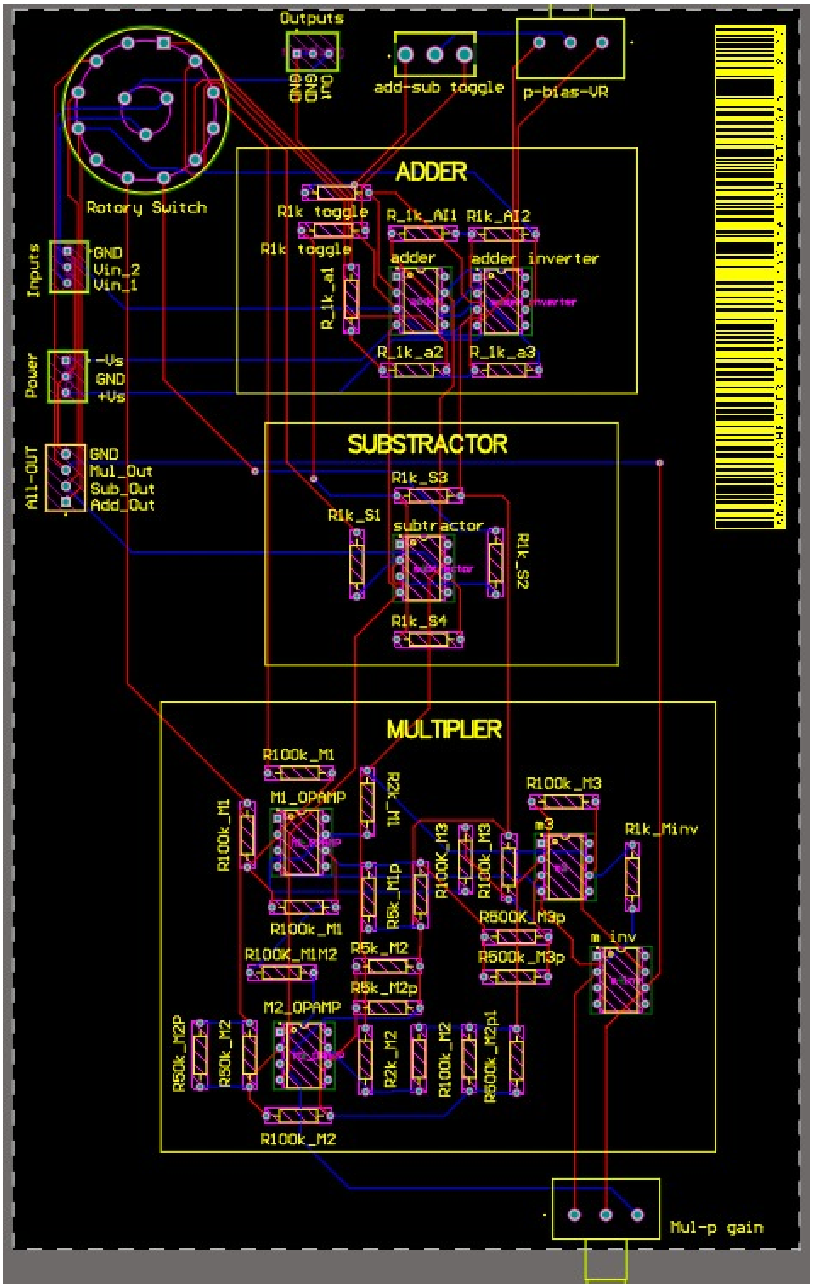


Figure 10: Output of the PCB.

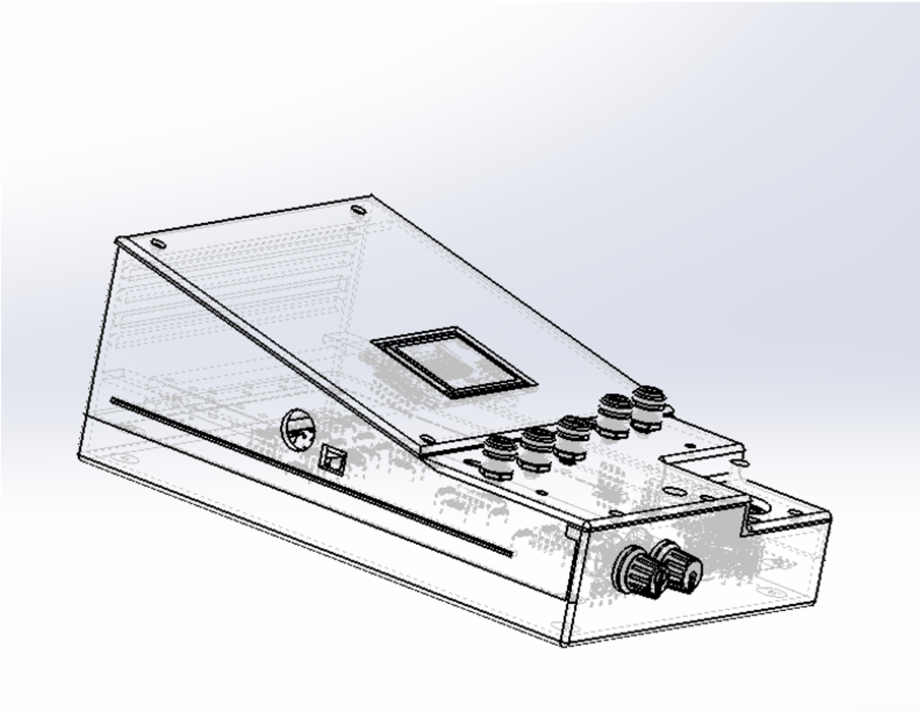
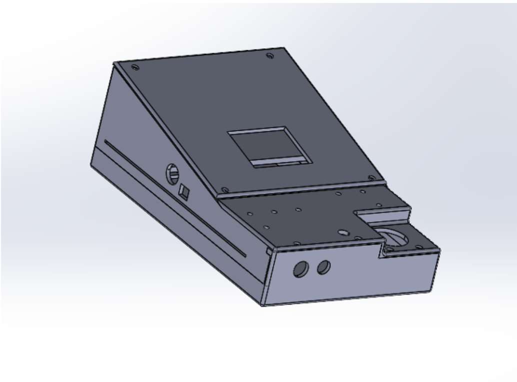
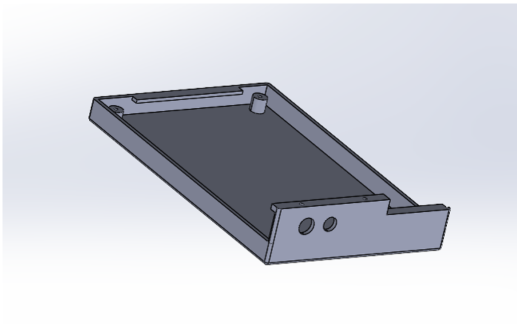


Figure 11: Enclosure design.

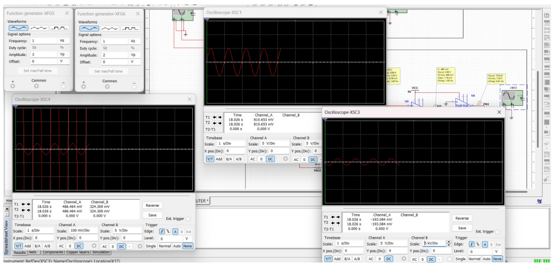


(a) Top view of the enclosure

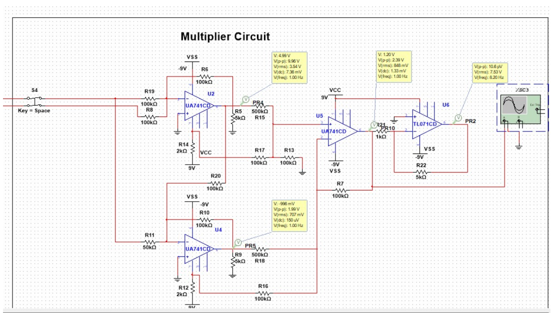


(b) Bottom view of the enclosure

Figure 12: Enclosure design

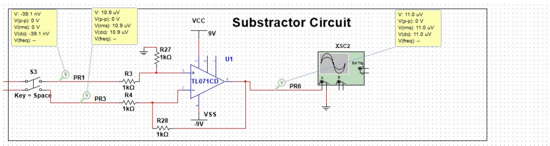


(a) Multisim software simulation of all circuits

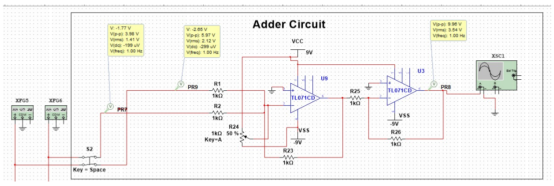


(b) Multisim software simulation of Multiplier

Figure 13: Software simulations

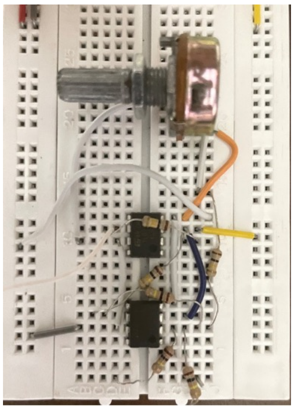


(a) Multisim software simulation of Subtractor

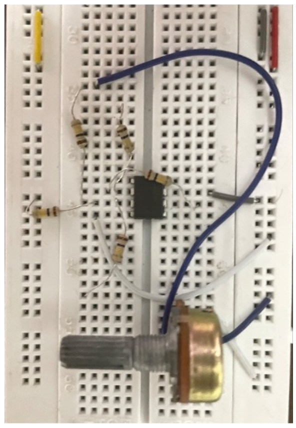


(b) Multisim software simulation of Adder

Figure 14: Software simulations



(a) Adder breadboard implementation



(b) Subtractor breadboard Implementation

Figure 15: Breadboard implementations

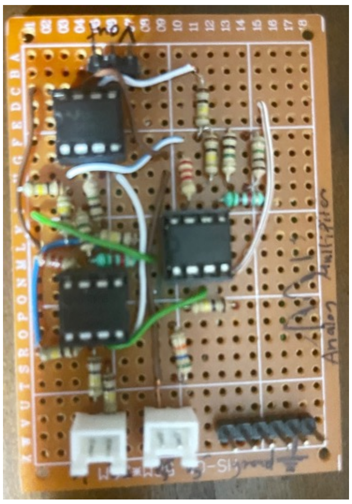


Figure 16: Multiplier Breadboard Implementation.

8 Contribution of Group Members

Table 1 shows an example table.

Table 1: Example Table.

Team Member	**Contribution**
Kaveendra Alwis	Altium and Testing
Lohan Atapattu	Documentation and Testing
Imasha Nethmal	Enclosure design
Kanishka Abeywardana	Testing

9 Acknowledgment

References

[1] A. R. Vanchai Riewruja, "Analog multiplier using operational amplifiers," *Indian Journal of pure and applied physics*, pp. 67–70, january 2010.

[2] STMicroelectronics, *TL071 Operational Amplifier*.

[3] Texas Instruments, *LM 741 Operational Amplifier*, MAY 1998 – REVISED OCTOBER 2015.