Op-Amp Applications

- 1. Custom Weighted Summing & Difference Amplifier
- 2. Op-Amp Integrator
- 3. Precision Rectifier (Super Diode)

Indian Institute of Technology
Hyderabad

Lab Assignment : 05

EE1200: Electrical Circuits Lab

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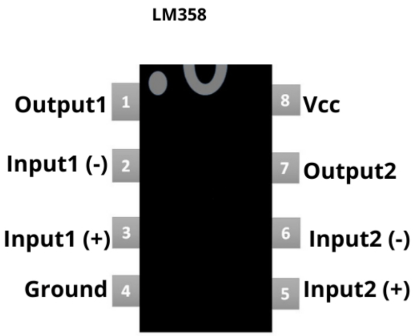
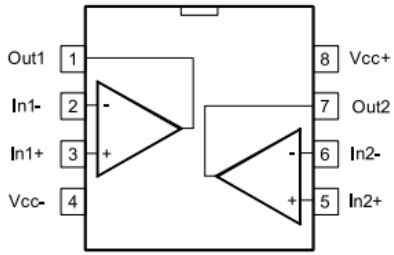
Contents

1 LM358

The LM358 is a low-power, dual-operational amplifier (op-amp) IC designed for general-purpose applications. It consists of two independent, high-gain op-amps that operate from a single power supply.





The pin-out diagram for LM358 is give above

Features and Uses

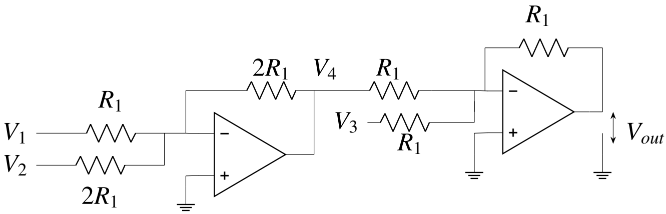
- Dual Op-Amp in a Single Package: Provides two independent op-amps, saving space and cost.
- Low Power Consumption: Each amplifier draws only $500\mu A$, making it ideal for low-power designs.
- Works with a wide voltage range (3V to 32V), unlike many op-amps that require dual supplies.
- Used to amplify signals from sensors like temperature sensors, strain gauges, and pressure sensors.
- Generates triangular and square waveforms when used in oscillator circuits.
- Used in low-pass, high-pass, and band-pass filters in audio and signal processing circuits.

2 Weighted Summing & Difference Amplifier

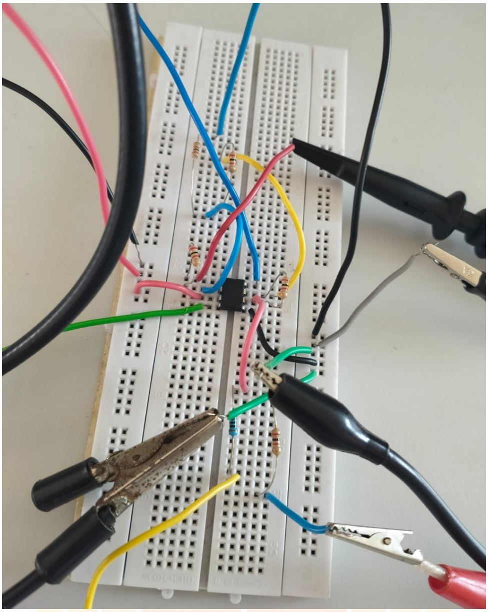
2.1 Components Required

- Op-Amp IC - LM358
- Resistors -
- Function Generator
- Oscilloscope
- DC Power Supply

2.2 *Circuit Diagram*



Breadboard Connection



2.3 *Procedure*

Derivation of the Weighted Summing and Difference Amplifier Output

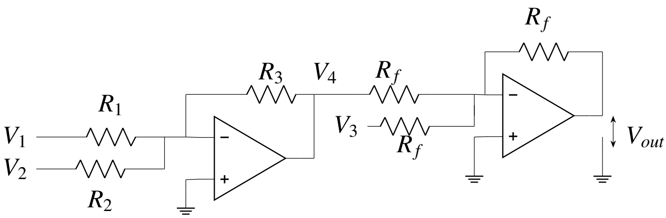
Circuit Design

The circuit consists of two operational amplifier (op-amp) stages:

1) **First op-amp (Inverting Summing Amplifier)**
   - Takes three input voltages: V_1, V_2, and V_3.
   - Performs weighted summation using properly chosen resistors.
   - Produces an intermediate output V_{out1}.
2) **Second op-amp (Inverting Amplifier)**
   - Takes V_{out1} as input and inverts it.
   - This inversion helps achieve the required final output V_{out}.

For general case,

Derivation of Output Equation



Applying Kirchhoff's Current Law (KCL) at the inverting input

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = \frac{V_{\text{out1}}}{R_f} \tag{2.1}$$

Multiplying by R_f:

$$V_{\text{out1}} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right) \tag{2.2}$$

Choosing resistors:

$$\frac{R_f}{R_1} = 2 \Rightarrow R_f = 2R_1$$
$$\frac{R_f}{R_2} = 1 \Rightarrow R_f = R_2$$
$$\frac{R_f}{R_3} = -1 \Rightarrow R_f = -R_3$$

Thus, we obtain:

$$V_{\text{out1}} = -(2V_1 + V_2 - V_3) \tag{2.3}$$

The second stage is an inverting amplifier with gain -1:

$$V_{\text{out}} = -V_{\text{out1}} \tag{2.4}$$

Substituting:

$$V_{\text{out}} = 2V_1 + V_2 - V_3 \tag{2.5}$$

This confirms that the circuit correctly implements the desired function.

Special Case for the Second Function

If $V_2 = 0$, then:

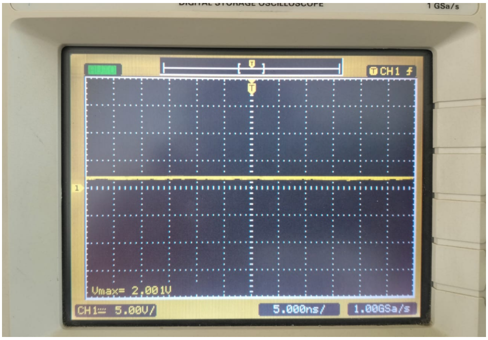
$$V_{\text{out}} = 2V_1 - V_3 \tag{2.6}$$

which matches the second required function.

Thus, the circuit fully satisfies the given mathematical functions.

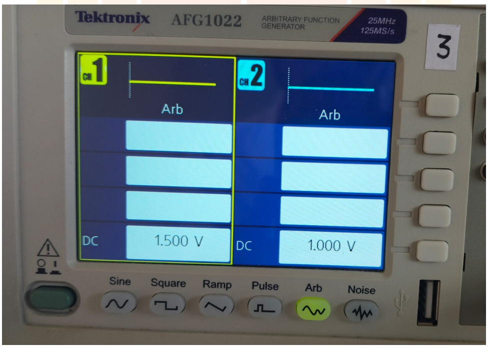
2.4 *Observation*

on Oscilloscope,



for the input power source,

input values in function generator,



Validation

checking the output voltage,

$$2V_1 + V_2 - V_3$$

Here,

- V_3 is the voltage reading in the power source i.e $2V$

$$V_1 = 1.5V$$
$$V_2 = 1V$$

Therefore the calucated output voltage,

$$2(1.5) + 1 - 2 = 2V$$

and it matches to the experimental output i.e $2.001V$

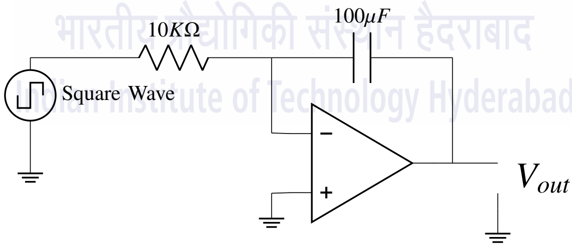
- The circuit correctly implements the weighted sum and difference as required.
- By selecting appropriate resistor values, the desired coefficients in the equation are achieved.
- The two-stage design ensures correct polarity of the final output.

3 Op-Amp Integrator

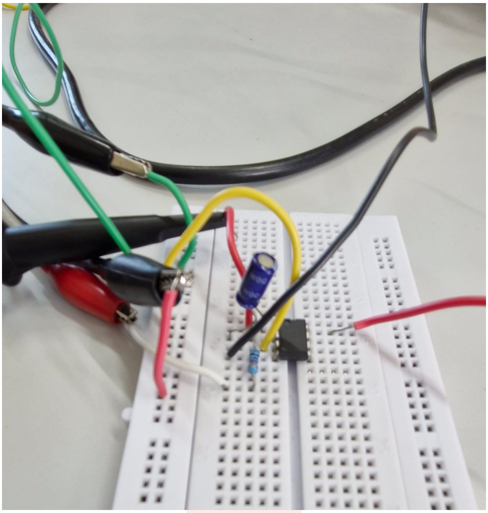
3.1 Components Required

- Op-Amp IC - LM358
- Resistor - $10k\Omega$
- Capacitor - $100\mu F$
- Function Generator
- Oscilloscope
- DC Power Supply

3.2 Circuit Diagram



Breadboard Connections



3.3 Theory

An Op-Amp integrator is a circuit that performs mathematical integration of the input siganl. The output signal is proportional to the integral of the input signal, which is given by
It consists of

- A resistor in series with the input signal
- A capacitor in the feedback loop

$$V_{out} = -\frac{1}{RC}\int V_{in}dt$$

For $R = 10k\Omega$ and $C = 100\mu F$

$$V_{out} = -1\int V_{in}dt$$

This means that the output voltage is the negative integral of the input voltage.

Applications

- It converts a square wave to triangular waveform - Waveform Generation
- Low pass filtering effect

1) **Power Connections:**
   - Connect +12 V from the power supply to the V_{cc+} pin of the op-amp. (Pin 8)
   - Connect 0 V to the V_{cc-} pin of the op-amp. (Pin 4)
   - Connect the ground (GND) of the power supply to the circuit ground.
2) **Resistor and Capacitor Connections:**

- Connect one end of the resistor (R) to the input voltage source (square wave from function generator).
- Connect the other end of the resistor (R) to the inverting input ($-$) of the op-amp.
- Connect the capacitor (C) between the output of the op-amp and the inverting input ($-$) of the op-amp .
- Connect the non-inverting input (+) of the op-amp to ground.

3) **Function Generator:**
   - Set up the function generator to produce a square wave signal (e.g., 1 kHz frequency, 5V peak-to-peak).
   - Connect the function generator output to the resistor (R).
4) **Oscilloscope Connection:**
   - **Channel 2 (CH2)** of the oscilloscope: Connect to the input square wave signal.
   - **Channel 1 (CH1)** of the oscilloscope: Connect to the output of the op-amp.

Note: The ground clips of both **CH1** and **CH2** probes must be connected to the circuit ground (**GND**) to ensure proper reference and avoid floating signals.

Analysis

For $R = 10k\Omega$ and $C = 100\mu F$

$$V_{out} = -1 \int V_{in} dt$$

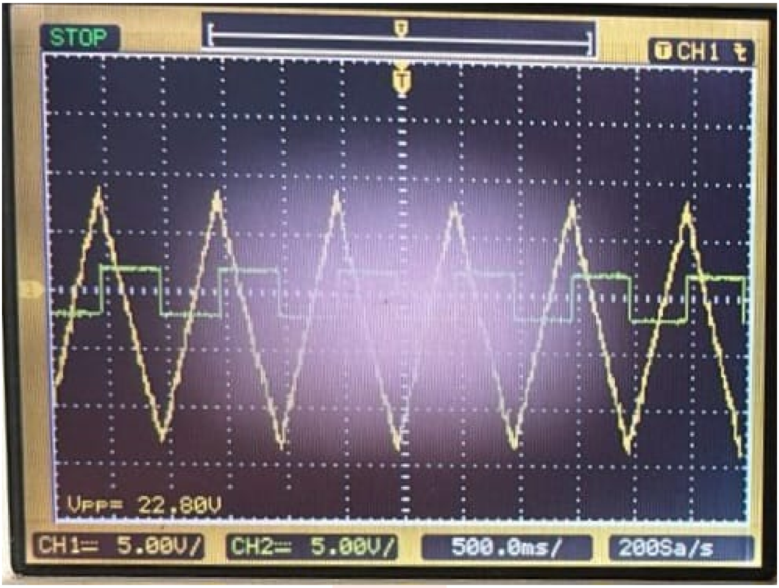
CH2 is the input signal with

- Frequency = 1Hz
- Amplitude = 2.0V

CH1 is the measure output signal across the ends of the $1k\Omega$ Resistor

3.4 Observation

We observe that the square wave input is converted into triangular wave output.

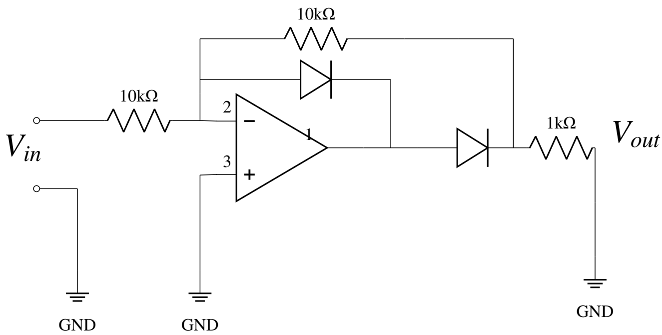


4 Precision Rectifier

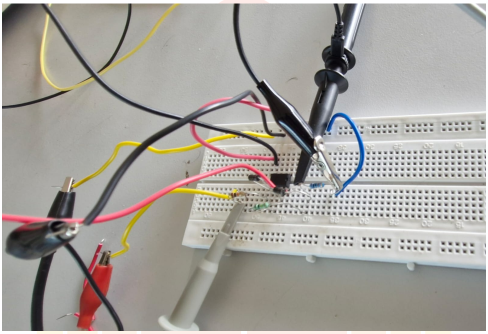
4.1 Components Required

- Op-Amp IC - LM358
- Diode - 1N4148
- Resistors
- AC Signal Generator
- Oscilloscope

4.2 Circuit Diagram



Breadboard Connections



4.3 Circuit set-up

- Connect one end of the resistor($10k\Omega$) to pin 2 of LM358 and the other end to the V_{in}
- Connect the pin 3 of LM358 to GND
- Connect a resistor($10k\Omega$) between pin 2 and pin 1 of LM358
- Connect 2 diodes in series between pin 2 and pin 1
- Connect a resistor ($1k\Omega$) from pin 1 to GND and measure the V_{out}

4.4 Theory

A precision rectifier, also called a super diode, is an op-amp-based rectifier circuit that can rectify signals with very small voltages, overcoming the 0.7V diode forward voltage drop of conventional rectifiers.

Half-Wave Rectifier

- The circuit connections are shown in the diagram above
- A half-wave precision rectifier allows only the positive half of an AC signal to pass while blocking the negative half.

Operation

- During the positive half-cycle, the op-amp output drives the diode into conduction, allowing the signal to pass.
- During the negative half-cycle, the diode blocks conduction, preventing the negative signal from reaching the output.
- Which results in a half wave rectifier

Analysis

For the input sine wave

$$V_{in}(t) = Asin(2\pi f)$$

where

- $f = 80kHz$
- $A = 1$

for $V_{in} > 0$

- The diode conducts, and the output follows the input.

$$V_{out}(t) = V_{in}(t) = sin(2\pi 80000)t$$

for $V_{in} < 0$

- The diode blocks the signal, and the output is zero.

$$V_{out}(t) = 0$$

The waveform is given by

$$V_{out}(t) = \begin{cases} \sin(2\pi(80,000)t), & \text{if } V_{in} > 0 \\ 0, & \text{if } V_{in} < 0 \end{cases}$$

the following waveform can be observed below

4.5 Observations