NEUB CSE 214 LAB 7

North East University Bangladesh
Department of CSE
Course no: CSE 214
Experiment no: 07
Experiment Name: Mathematical Operation using op-amp

CAUTIONS:

1. **Don't switch on the supply of the circuit until you have verified the circuit carefully**
2. **Take readings of apparatus carefully**
3. **Take care of any bare circuit elements in energized condition**
4. **Never try to touch bare live wires**

Objective

The objective of this experiment is to implement circuit using op-amp to do mathematical operations like

- Addition
- Subtraction
- Multiplication
- Integration
- Differentiation

Theory

Summing Amplifier

The figure below shows a summing amplifier which adds up the input voltage. But the output polarity is opposite to input.

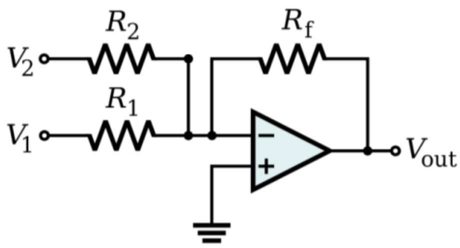

Figure 1 Inverting summing amplifier using op-amp

The output voltage v_{out} can be found using the equation

$$V_{out} = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2\right)$$

If all the resistors are chosen as same values ($R_1 = R_2 = R_f$) then

$$V_{out} = -(V_1 + V_2)$$

A special case

By setting the ratio $\frac{R_f}{R}$ equal to the reciprocal of the number of inputs (n), i.e. $\frac{R_f}{R} = \frac{1}{n}$ summing amplifier can be made to produce the mathematical average of the input voltages.

Subtraction

The function of a subtractor is to provide an output proportional to or equal to the difference of two input signals. A basic differential amplifier or a subtractor circuit is shown in figure below.

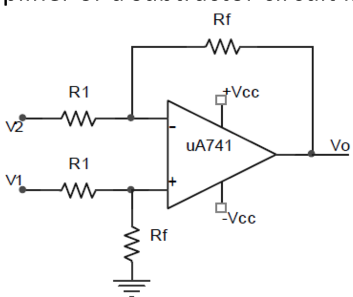

Figure 2 Difference amplifier configuration of op-amp

The output voltage of the differential amplifier can be expressed as

$$V_o = \frac{R_f}{R_1(V_1 - V_2)}$$

Thus it can be seen that the output voltage depends on the difference of the input voltages (V_1–V_2) can be suitably amplified by choosing the values of $\frac{R_f}{R_1}$. The circuit also behaves as a subtractor if $R_f = R_1$. In that case

$$V_0 = V_1 - V_2$$

Multipler

The normal inverting amplifier configuration can be easily considered as a multiplier (and in some sense a divider).

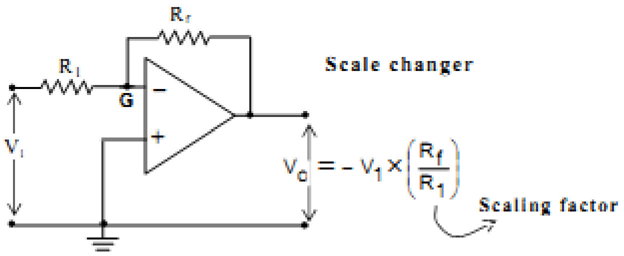

Figure 3 Multiplier circuit using op-amp

Integrator

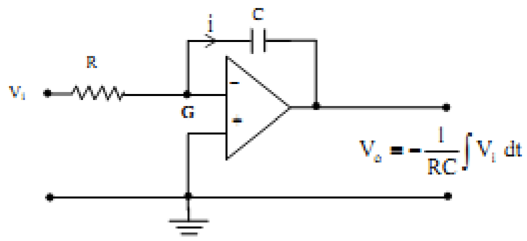

Figure 4 Op-amp integrator circuit

An integrator circuit is one whose output is proportional to the time integral of input voltage. The figure shows the use of an Op-amp as an integrator. G is the virtual ground. The input voltage V_i charges the capacitor to a voltage V_O. Let the charge on the capacitor be Q. The charge on the capacitor is given by,

$$Q = C(0 - V_o) \; Because\ voltage\ at\ G\ i = \ 0V$$

But $$Q = \int i\,dt\ [i\ is\ the\ cgarging\ current]$$

So $$-CV_o = \int i\,dt \quad \left[Where\ i = \frac{V_i}{R}\right]$$

$\therefore -CV_o = \int \frac{V_i}{R} dt$

Hence the output voltage $V_o = -\frac{1}{RC}\int V_i\,dt$

And the circuit works as an integrator.

If the input voltage is a square wave, the output waveform will be triangular. For rectangular or pulse waveform applied at the input, the output waveform will be a saw-tooth wave (ramp). The output will be a cosine wave for sine wave input. The output is a paraboloid waveform if the input is a triangular wave.

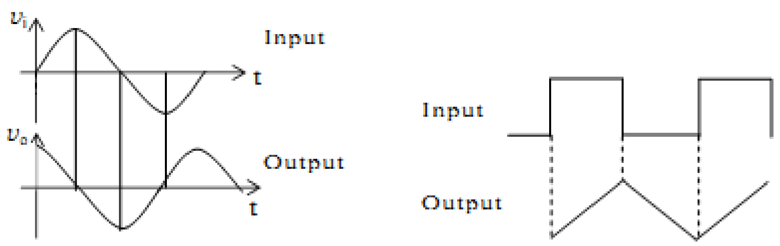

Figure 5 Output of integrator

But, the output waveforms of Op-Amp integrator will be inverted versions of the waveform shown above.

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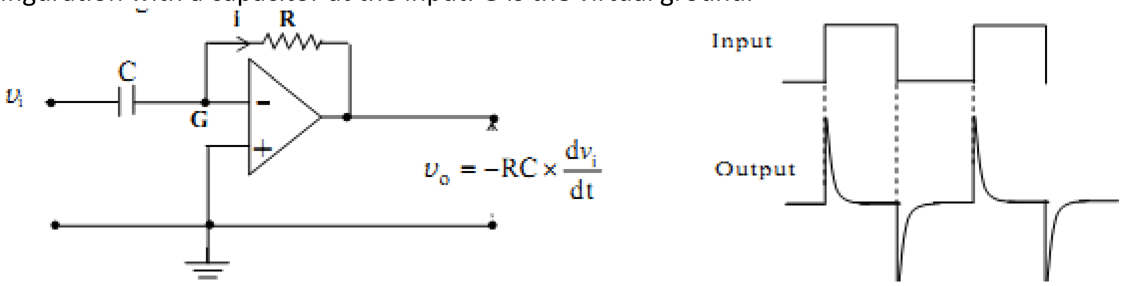
Differentiator

A differentiator circuit is one whose output voltage is proportional to time derivative of the input voltage. Figure shows a differentiating circuit using Op-amp. The circuit is an inverting amplifier configuration with a capacitor at the input. G is the virtual ground.



(a) (b)

Figure 6(a) Op-amp differentiator circuit (b) Differentiator output

If Q is the charge required by the capacitor the $Q = V_i C$differentiating the above equation gives

$$\frac{dQ}{dt} = C \times \frac{d}{dt}(V_i)$$

But $\frac{dQ}{dt} = i,$

$$\therefore i = C \times \frac{d}{dt}(V_i)$$

Due to the infinite input impedance of the Op-amp, the current through the op-amp is zero.
Applying KCL to node G,
Input current i.e., charging current I = Current through the feedback resistor.
∴Charging current or current through the feedback resistor is given by,

$$i = \frac{0 - V_o}{R} = -\frac{V_o}{R}$$

Equating 10.24 and 10.25 we get

$$C\frac{d}{dt}(V_i) = -\frac{V_o}{R}$$

$$\therefore V_o = -RC\frac{d}{dt}(V_i)$$

i.e. output = RC time constant × time derivative of the input. Therefore the circuit works as a differentiator.

If the input voltage is a square wave, the output waveform consists of positive and the negative spikes. The output will be a cosine wave for sine wave input and the output is a square waveform if the input is a triangular wave. The input and output waveform are shown in the figure 6b.

Apparatus Needed

- Trainer Board
- UA 741 op-amp
- Resistors
- Function generator
- DC Voltmeter
- DC Ammeter
- DC power supply
- Connecting wires

Procedure

1. Summing Amplifier
    a. Assemble the circuit in figure 1 with $R_1 = R_2 = R_f = 10k$.
    b. Feed Different voltage levels from trainer board into the inputs.
    c. Observe the output voltage and fill up the table 1
2. Subtractor
    a. Assemble the circuit in figure 2 with $R_1 = R_f = 10k$.
    b. Feed Different voltage levels from trainer board into the inputs.
    c. Observe the output voltage and fill up the table 2
3. Multiplier
    a. Implement the multiplier circuit in figure 3.
    b. Choose resistors such that the multiplication factor is 10.
    c. Feed Different voltage levels from trainer board into the inputs.
    d. Observe the output voltage and fill up the table 3

4. Integrator
    a. Implement the integrator circuit in figure 4
    b. Choose your Resistor and Capacitor values such that $RC = 1$.
    c. Feed a sine wave in the input and observe the output voltage in the oscilloscope
    d. Sketch the input and output in table 4
    e. Feed a square wave in the input and observe the output voltage in the oscilloscope.
    f. Sketch the input and output in table 4
5. Differentiator
    a. Implement the differentiator circuit in figure 6a
    b. Choose your Resistor and Capacitor values such that $RC = 1$.
    c. Feed a sine wave in the input and observe the output voltage in the oscilloscope
    d. Sketch the input and output in table 4
    e. Feed a square wave in the input and observe the output voltage in the oscilloscope.
    f. Sketch the input and output in table 4

Tables

Table 1

Sl.	V_1	V_2	Theoretical Output $V_o = -(V_1 + V_2)$	Observed output (V_o)
1				
2				
3				
4				

Table 2

Sl.	V_1	V_2	Theoretical Output $(V_1 - V_2)$	Observed output (V_o)
1				
2				
3				
4				

Table 3

Sl.	V_1	Theoretical Output $10 * V_1$	Observed output (V_o)
1			
2			
3			
4			

Table 4

	Sine wave input	Output	Square wave input	Output
Integrator				
Differentiator				

Report

1. Fill up all the requisite tables
2. For each table comment on the comparison between experimental and theoretical values
3. Comment on the learnings from this LAB