PH211- Electronics Lab

Arithmetic & Amplifier Circuits using Opamps.

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49/50

Expt. No - 3

Expt. Name - Arithmetic & Amplifier Circuits using Opamps

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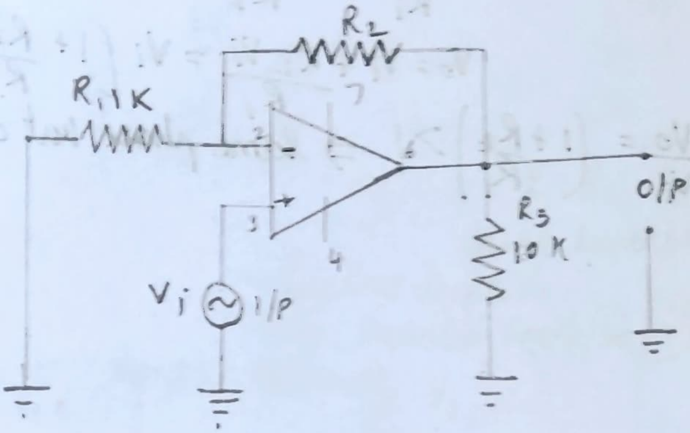
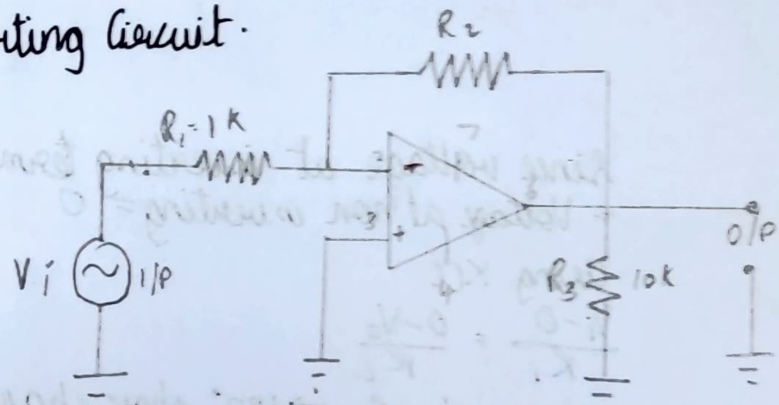
(a) an inverting amplifier (b) a non inverting amplifier (c) adder circuit and (d) subtractor circuit using 741 opamps.

Circuit Diagram:

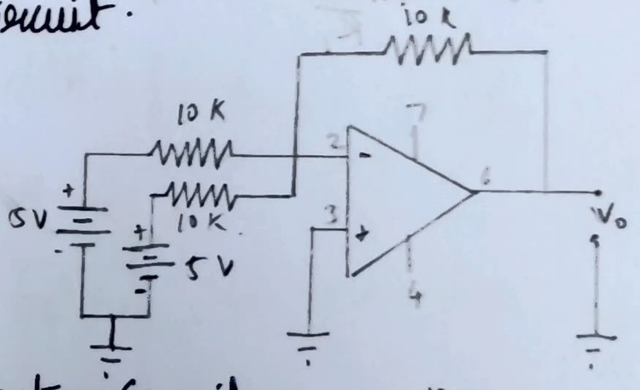
(a) Non Inverting Circuit



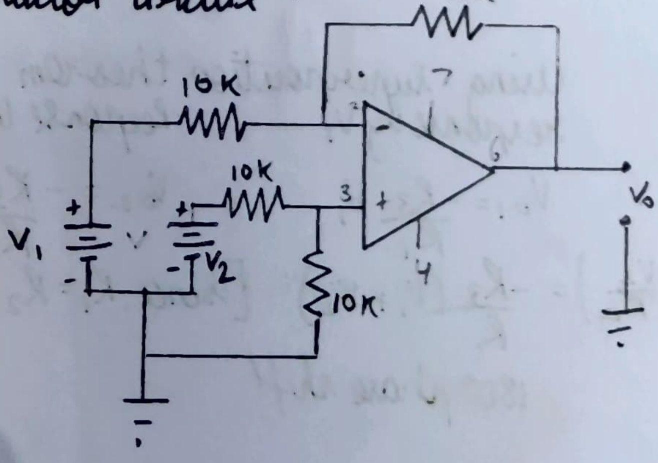
(b) Inverting Circuit.



(c) Adder Circuit.



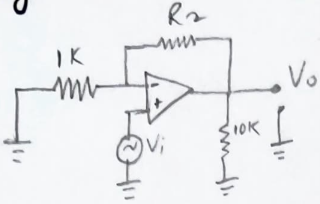
(d) Subtractor Circuit.



Formulas & expected output waveform:

(a) Non-inverting amplifier

Since voltage at inverting and non-inverting terminal equal $= V_i$

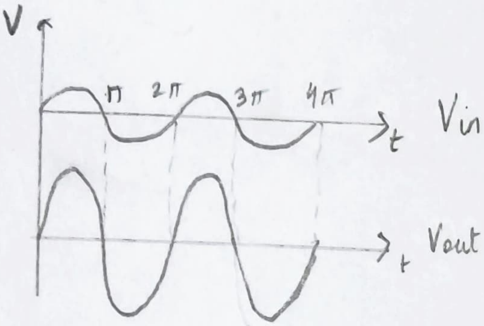


Using KCL at inverting terminal

$$\frac{0-V_i}{R_1} = \frac{V_i - V_o}{R_2}$$

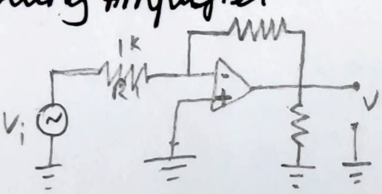
$$V_o = V_i + \frac{R_2 V_i}{R_1} = V_i\left(1+\frac{R_2}{R_1}\right)$$

Voltage gain $A_v = \frac{V_o}{V_i} = \left(1+\frac{R_2}{R_1}\right) > 1 \Rightarrow$ same phase but amplified



Expected Output

(b) Inverting Amplifier



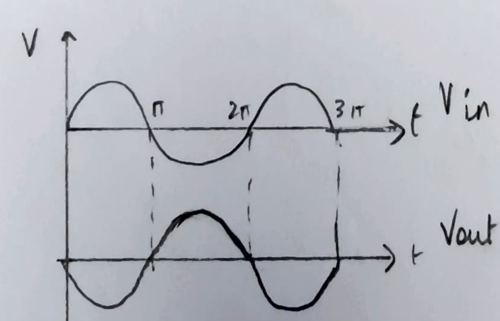
Since voltage at inverting terminal = Voltage at non inverting = 0

Using KCL

$$\frac{V_i - 0}{R_1} = \frac{0 - V_o}{R_2}$$

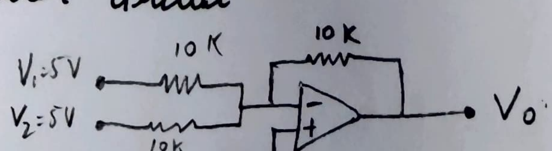
$$V_o = -V_1 \times \frac{R_2}{R_1} \rightarrow 180^\circ \text{ phase change}$$

$$A_v = \frac{V_o}{V_i} = -\frac{R_2}{R_1}$$



(phase change 180°, ∵ $R_2 > R_1$)

(c) Adder Circuit



Using superposition theorem

response by V_1

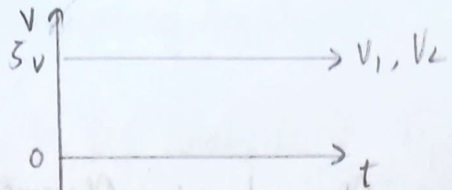
$$V_{o1} = -\frac{R_3}{R_1} V_1$$

Response by V_2

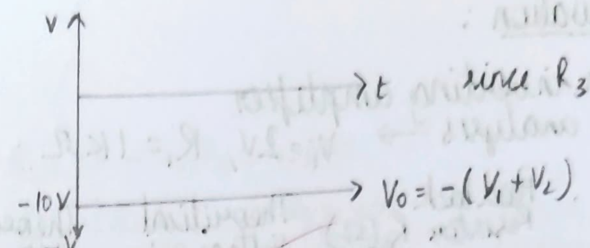
$$V_{o2} = -\frac{R_3}{R_2} V_2$$

$$V_o = V_{o1} + V_{o2} = -R_3\left(\frac{V_1}{R_1} + \frac{V_2}{R_2}\right) = -\frac{R_3}{R}(V_1 + V_2) \quad [\text{since } R_1 = R_2 = R]$$

180° phase shift

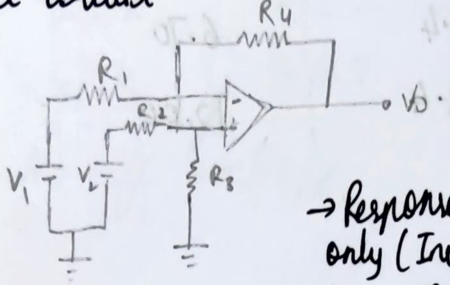


V input



since $R_3 = R_f = 10k\Omega$

(d) Subtract circuit



$R_1 = R_2 = R_3 = R_4 = 10k\Omega$

Using superposition theorem

→ Response due to V_1 only (Inverting Amplifier)

$$V_{01} = -\frac{R_4}{R_1} V_1$$

$$= -V_1$$

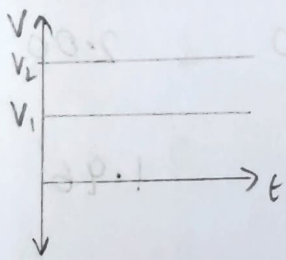
→ Response due to V_2 only (Non Inverting Amplifier)

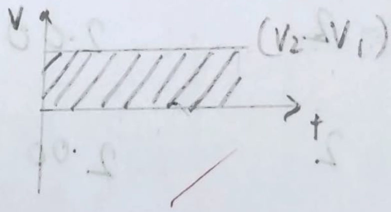
$$V_{02} = V'\left(1+\frac{R_4}{R_2}\right) = 2V'$$

where $V' = \left(\frac{V_2}{R_2+R_3}\right)R_3 = \frac{V_2}{2}$

$$\boxed{V_0 = V_{01} + V_{02} = (V_2 - V_1)}$$

(Since $R_1 = R_2 = R_3 = R_4$).





(e) bandwidth = $f_2 - f_1 \Rightarrow f_H - f_L$

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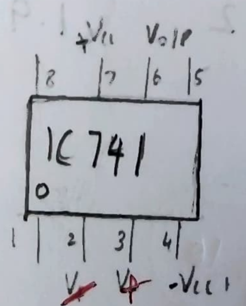
(f)



V_- → Inverting

V_+ → Non Inverting.

Observation :

(a) Non-inverting amplifier

DC analysis → $V_i = 2V$, $R_1 = 1K\Omega$

S.no	Feed back Resistor $R_2(\Omega)$	Theoritical Voltage Gain	Theoritical Voltage O/P (V)	Observed Voltage O/P (V)	Observed Gain
1	1K	2.0	4.0	4.17	2.085
2	2.2K	3.2	6.4	6.70	3.350
3	4.7K	5.7	11.4	12.00	6.000

$$A_V = \frac{V_o}{V_i} = \left(1 + \frac{R_2}{R_1}\right)$$

A.C Analysis → $R_2 = 1K\Omega$, $R_1 = 1K\Omega$, $V_i = 1V(p\text{-}p)$

S.no	Frequency (KHz)	Theoritical Voltage gain	Theoritical Voltage O/P (V)	Observed Voltage Output (V)	Observed Gain
1	1	2	2.00	2.00	2.00
2	2	2	2.00	1.96	1.96
3	5	2	2.00	1.96	1.96
4	10	2	2.00	1.92	1.92

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b) Inverting Amplifier

D.C Analysis → $V_i = 2V$, $R_1 = 1K\Omega$, $R_3 = 10K\Omega$

S.No	Feedback Resistor $R_2 (\Omega)$	Theoritical Voltage Gain (V)	Theoritical Voltage o/p (V)	Observed Voltage o/p (V)	Observed Gain
1	1K	-1	-2	-2.08	-1.04
2	2.2K	-2.2	-4.40	-4.60	-2.3
3	4.7K	-4.7	-9.40	-9.93	-4.96

$$A_V = \frac{V_0}{V_i} = -R_2/R_1$$

AC-Analysis → $V_i = 1V_{p-p}$, $R_2 = 1K\Omega$, $R_1 = 1K\Omega$

S.No	Frequency (KHz)	Theoritical Voltage Gain	Theoritical Voltage o/p (V)	Observed Voltage o/p (V)	Observed Gain
1	1	-1	-1	-1	-1
2	2	-1	-1	-1	-1
3	5	-1	-1	-0.96	-0.96
4	10	-1	-1	-0.92	-0.92

(c) Adder Circuit

$V_1 = 4.5V$, $R_1 = 10K\Omega$, $R_2 = 10K\Omega$, $R_3 = 10K\Omega$

S.No	V_2 (V)	V_o Theoritical (V)	V_o Experimental (V)
1	0	-4.5	-4.58
2	1	-5.5	-5.71
3	2	-6.5	-6.76
4	3	-7.5	-7.74
5	4	-8.5	-8.77

$\Rightarrow V_o = -(V_1 + V_2)$

(d) Subtraction Circuit.

$V_1 = 4.5V$ $R_1 = R_2 = R_3 = R_4 = 10K\Omega$

S.No	V_2 (V)	V_o Theoritical (V)	V_o Experimental (V)
1	0	- 4.5	-4.69
2	1	- 3.5	-3.55
3	-1	- 5.5	-5.51
4	2	- 2.5	-2.56
5	-2	- 6.5	-6.54
6	3	- 1.5	-1.49
7	-3	- 7.5	- 7.6
8	4	- 0.5	-0.51
9	-4	- 8.5	-8.70

obs = 10

$\Rightarrow V_o = V_2 - V_1$

Apparatus Used:
Digital storage Oscilloscope, multimeter, function Generator, Multiple power supply, connecting wires, Opamp (IC 741), Resistors ($1K\Omega$, $4.7K\Omega$, $2.2K\Omega$, $10K\Omega$).

V_1 =

V_2 =

phase = 0°

Frequency = [illegible] kHz

[illegible]

For the Inverting Circuit

V_1 =

phase shift = [illegible]

V_2 =

[illegible]

For Inverting Circuit

Calculation:

(a) For Non-Inverting circuit.

Voltage gain $A_v = \frac{V_0}{V_i} = \left(1+\frac{R_2}{R_1}\right)$ (DC Analysis).

Observation ①:

Theoritical gain $= 1+\frac{R_2}{R_1}$

$= 1+\frac{10}{10}$

$= 2$

$\Rightarrow \frac{V_0}{V_i} = 2$

Theoritical Output $V_0 = 4(1) = 4V$

Experimental Output $V_0 = 4.17$ V

Experimental gain $A_v = \frac{V_0}{V_i}$

$= \frac{4.17}{2}$

$A_v = 2.085$

Observation ② →

Theoritical gain $= 1+\frac{R_2}{R_1}$

$= 1+\frac{22}{10}$

$= 3.3$

$\frac{V_0}{V_i} = 3.2$

Theortical Output $V_0 = 3(1) = 3V$

Experimental Output $= 6.70$ V

Experimental gain $A_v = \frac{V_0}{V_i}$

$\frac{6.70}{2}$

$= 3.35$

AC-Analysis

Observation ① →

Theoritical gain $= 1+\frac{R_2}{R_1}$

$= 1+\frac{10}{10}$

$= 2$

$\Rightarrow V_0/V_i = 2$.

Theoritical output $= V_0 = 2V_i$

$= 2$

Observed gain $= 2.00$

Observed Output $= 2.00$V

for freq $= 1$KHz

Observation ② →

Theoritical gain $= 1+\frac{R_2}{R_1}$

$= 1+\frac{1}{1}$

$= 2$

$\Rightarrow V_0/V_1 = 2$

Theoritical Output $= 2.00$V

Observed Gain $= 2.00$

Observed Output $= 2.00$ V

for freq $= 2$KHz

(b) Inverting Amplifier.

Voltage Gain $A_V = \frac{V_o}{V_i} = \frac{-R_2}{R_1}$

D.C Analysis

Observation ①:

Theoritical gain $= -\frac{R_2}{R_1}$

$= -\frac{1}{1}$

$= -1$

$V_o/V_i = -1$

Theoritical Output: $V_o = -2V$

Experimental Output: $V_o = -2.08$

Experimental Gain $= -1.04$

Observation ②:

Theoritical gain $= -\frac{R_2}{R_1}$

$= \frac{-2.2}{1}$

$= -2.2$

$V_o/V_i = -2.2$

Theoritical Output $= -4.40$

Experimental Output $= -4.60$

Experimental Gain $= -2.3$

A C Analysis.

$R_1 = R_2 = 1K\Omega$

Observation ①

freq = 1KHz

Theoritical Gain $= -R_2/R_1$

$= -1$

Theoritical Output $V_o = -1 V_{p-p}$

Observed gain $= -1$

Observed Output: $V_o = -1 V_{p-p}$

Observation ②

freq = 10KHz

Theoritical Gain $= -R_2/R_1$

$= -1$

Theoritical Output $= V_o = -1 V_{p-p}$

Observed Gain $A_V = -0.92$

Observed Output $V_o = -0.92 V_{p-p}$.

Adder Circuit

V_o Theoritical $= -(V_1+V_2)$ $\quad V_1 = 4.5\,V$

$= -(4.5+0) = -4.58V$ Obv. 1

$= -(4.5+1) = -5.71V$ Obv 2

$= -(4.5+2) = -6.76V$ Obv 3

d) Subtraction Circuit.

V_o Theoritical $= V_2 - V_1$ $\quad (V_1 = 4.5V)$

$= 1 - 4.5 = -3.55$ Obv 1

$= 2 - 4.5 = -2.56$ Obv 2

$= 3 - 4.5 = -1.49$ Obv 3

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Brief Summary & Result:

① In Non-inverting circuit, the observed voltage gain differs from the theoritical gain by a range of (0.17 - 0.60) V

② There is a fall in the observed voltage gain when frequency is increased in AC analysis of both inverting & Non-inverting amplifier circuits. (Reason)

③ In Inverting Circuit, the observed gain differs from the theoritical gain by a range of £(0.08 - 0.53) V

④ Bandwidth achieved in inverting circuit during AC-Analysis is (Not Required)

⑤ In both the Adder and the Subtractor circuit, the experimental Output Voltage achieved is very close to the theoritical voltage Output.

Result

(a) Non-Inverting

$V_o = -\cancel{2.08}\ 4.17V$

$A_v = -2.085$

for $R_2 = 1K\Omega$

(b) Inverting

$V_o = -2.08$

$A_v = -1.04$

for $R_2 = 1K\Omega$

(c) Adder

for $V_1 = 4.5V, V_2 = 0V$

$V_o = -4.58V$

(d) Subtractor

for $V_1 = 4.5V, V_2 = 0V$

$V_o = -4.69V$

Precaution:

(1) Connect the Op-Amp pins correctly in the circuit to prevent any damage to it.

(2) Use small value resistors in feedback network.

(3) Be ~~cau~~ careful and mindful of any short circuit as it might damage component.

4) Do not connect DSO or other instrument at the op amp input terminal.

Result: 9