Sub-Group: A-7
Experiment 3: Study of Operational Amplifier

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1 Aim

To study operational amplifier (Op-Amp) as inverting and non-inverting amplifier and its application as adder and subtractor.

2 Theory

Operational amplifier also called op-amp, is a DC-coupled high-gain electronic voltage amplifier with differential inputs and a single output. In ideal case, the input impedence is kept at infinity and the output impedence is zero. In real case, the input imdepedence can not be at infinite, but it is quite high, and the output impedence is very close to zero. A simple representation for op-amp is shown below,

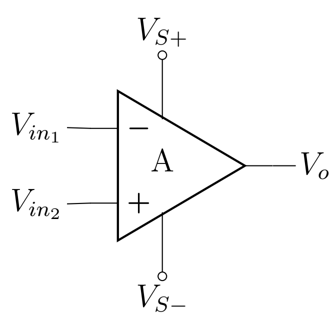

Figure 1: Representation of op-amp

In this picture, V_{in_1} is inverting input voltage, V_{in_2} is non-inverting voltage, V_o is output voltage, V_{S+} is positive power supply and V_{S-} is negative power supply. Actual operation amplifiers also has other terminals the helps in biasing the op-amp. When input voltage difference is zero, output voltage should be zero. Biasing means changing the bias voltage so that this happens. Pin configuration of an op-amp are,

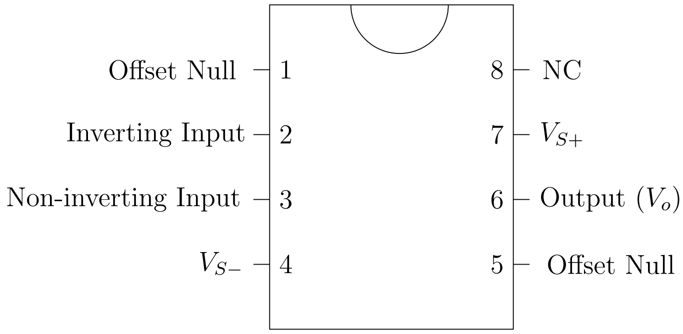

Figure 2: Pin configuration of op-amp

Even though the amplification for an op-amp is infinite, the output voltage is limited by the supply voltage V_{S+} and V_{S-}. Some important and useful op-amp circuits are shown below.

2.1 Inverting Op-Amp

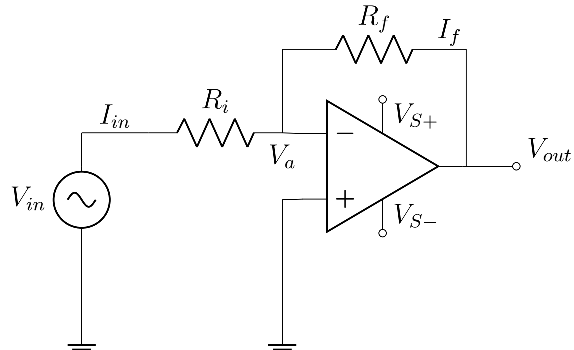

Figure 3: Inverting Op-amp

An operational amplifier can be operated as an inverting amplifier as shown in the figure. Biasing supply to op-amp, $V_{S\pm} = \pm 15$ V must be applied. The voltage gain in inverting op-amp is,

$$A = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}.$$

2.2 Non-inverting Op-Amp

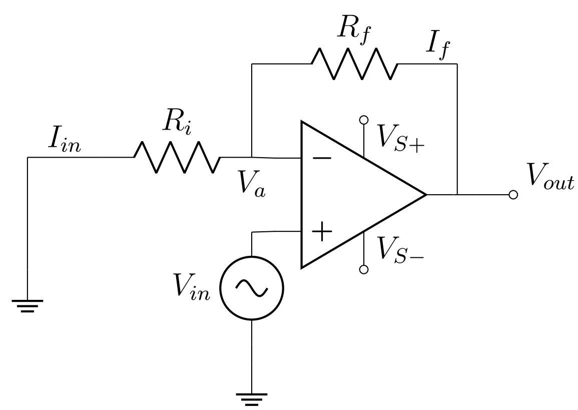

Figure 4: Non-inverting Op-Amp

An operational amplifier can be operated as a non-inverting amplifier as shown in the figure. For this circuit the gain is,

$$A = \frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_i}.$$

2.3 Adder Circuit

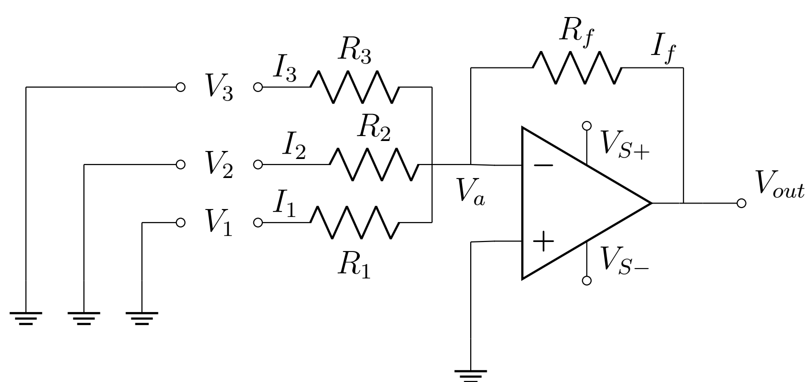

Figure 5: Adder Circuit

In the above configuration, the operation amplifier acts as an adder circuit. The output is proportional to the sum of all input voltages V_1, V_2, V_3. If the resistances $R_1 = R_2 = R_3 = R_f$, the output voltage is

$$V_{out} = -(V_1 + V_2 + V_3).$$

2.4 Subtractor Circuit

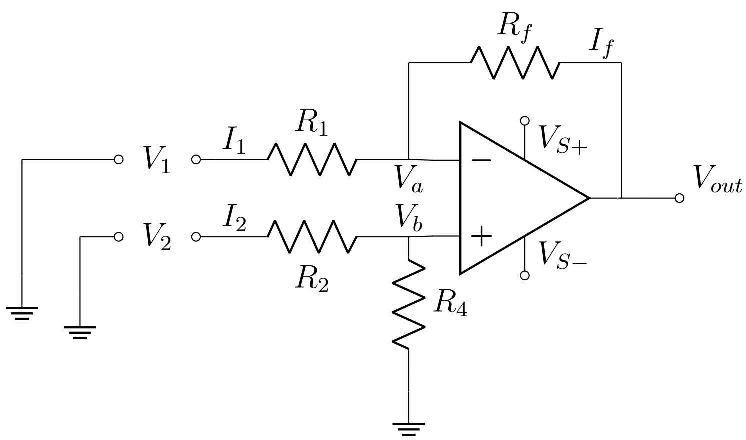

Figure 6: Subtractor Circuit

In the above configuration, op-amp circuit acts as a subtractor circuit. It subtracts one signal from the other signals. When the resistances $R_1 = R_2 = R_3 = R_4$, then the output voltage is

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

3 Data and Calculation

In this experiment, we set up circuits for op-amp configurations given above, and for each of the configuration we tabulated the data found.

3.1 Inverting Op-Amp

We set up the circuit by taking different values of R_f, and different values of R_i. We changed the input voltage V_{in}, and for each input voltage, we tabulated the data in the following table.

3.1.1 $R_i = 1\,k\Omega$ and $R_f = 2.2\,k\Omega$

V_{in}(Volt)	V_{out}(Volt)	Gain	Average
0	0.02		2.2773
0.5	1.22	2.44	
1	2.35	2.35	
1.5	3.39	2.26	
2	4.56	2.28	
2.5	5.64	2.256	
3	6.77	2.2567	
3.5	7.85	2.2428	
4	8.97	2.2425	
4.5	10.02	2.2267	
5	11.09	2.218	

3.1.2 $R_i = 1\,k\Omega$ and $R_f = 10\,k\Omega$

V_{in}(Volt)	V_{out}(Volt)	Gain	Average
0	0.12		10.8373
0.2	2.26	11.3	
0.4	4.56	11.4	
0.6	6.91	11.5167	
0.8	8.91	11.1375	
1	10.52	10.52	
1.2	12.67	10.5583	
1.4	13.2	9.4286	

3.1.3 $R_i = 10\,k\Omega$ and $R_f = 22\,k\Omega$

V_{in}(Volt)	V_{out}(Volt)	Gain	Average
0	0.02		2.3079
0.5	1.32	2.64	
1	2.38	2.38	
1.5	3.53	2.3533	
2	4.54	2.27	
2.5	5.67	2.268	
3	6.89	2.2967	
3.5	7.9	2.2571	
4	9	2.25	
4.5	10.13	2.2511	
5	11.22	2.244	
5.5	12.52	2.2763	
6	13.25	2.2083	

3.1.4 $R_i = 2.2\,k\Omega$ and $R_f = 10\,k\Omega$

V_{in}(Volt)	V_{out}(Volt)	Gain	Average
0	0.05		4.8453
0.2	1.07	5.35	
0.4	2.24	5.6	
0.6	2.92	4.8667	
0.8	3.99	4.9875	
1	4.7	4.7	
1.2	5.9	4.9167	
1.4	6.76	4.8286	
1.6	7.46	4.6625	
1.8	8.61	4.7833	
2	9.45	4.725	
2.2	10.47	4.7591	
2.4	11.21	4.6709	
2.6	12.37	4.7577	
2.8	13.07	4.6679	
3	13.21	4.4033	

3.2 Non-Inverting Circuit

3.2.1 $R_i = 2.2\,k\Omega$ and $R_f = 10\,k\Omega$

V_{in}(Volt)	V_{out}(Volt)	Gain	Average
0	0.07		6.0397
0.2	1.74	8.7	
0.4	2.6	6.5	
0.6	3.51	5.85	
0.8	4.75	5.9375	
1	5.71	5.71	
1.2	6.93	5.775	
1.4	7.96	5.6857	
1.6	9.07	5.6687	
1.8	10.46	5.8111	
2	11.68	5.84	
2.2	12.68	5.7636	
2.4	13.85	5.7708	
2.6	14.31	5.5038	

3.2.2 $R_i = 1\,k\Omega$ and $R_f = 2.2\,k\Omega$

V_{in}(Volt)	V_{out}(Volt)	Gain	Average
0	0.05		3.3234
0.5	1.91	3.82	
1	3.31	3.31	
1.5	4.92	3.28	
2	6.57	3.285	
2.5	8.24	3.296	
3	9.73	3.2433	
3.5	11.51	3.2886	
4	12.93	3.2325	
4.5	14.2	3.1556	

3.2.3 $\mathbf{R_i = 10\,k\Omega}$ and $\mathbf{R_f = 22\,k\Omega}$

V_{in}(Volt)	V_{out}(Volt)	Gain	Average
0	0.05		3.3902
0.5	1.84	3.68	
1	3.55	3.55	
1.5	5.15	3.4333	
2	6.76	3.38	
2.5	8.39	3.356	
3	10.07	3.3567	
3.5	11.55	3.3	
4	13.06	3.265	
4.5	14.36	3.1911	

3.3 Adder Circuit

V_1(Volt)	V_2(Volt)	V_3(Volt)	V_{out}(Volt)	Actual
0	0	0.01	0.02	0.01
1	1.06	1.07	3.18	3.13
1	0.68	1.08	2.79	2.76
1.5	1.01	1.28	3.83	3.79
1.5	0.85	0.85	3.25	3.2
2	1.12	1.33	4.47	4.45
2	2.09	1.12	5.22	5.21
2.5	1.52	1.66	5.66	5.68
3.1	1.72	2.57	7.33	7.39
3.1	2.68	2.57	8.28	8.35
3.5	2.91	2.91	9.21	9.32
4	2.96	3.22	9.96	10.18
4.5	3.36	2.37	10.01	10.23
4.5	4.35	2.9	11.44	11.75
5	2.55	2.53	9.88	10.08

3.4 Subtractor Circuit

V_1(Volt)	V_2(Volt)	V_{out}(Volt)	V_2-V_1(Volt)
1	0.79	0.29	-0.21
2	1.45	0.54	-0.55
2.5	2.52	0.06	0.02
2.5	1.82	0.65	-0.68
4.3	2.91	1.39	-1.39
5	3.37	1.6	-1.63
5.5	4.29	1.15	-1.21
6	4.32	1.58	-1.68
6.5	4.38	2.02	-2.12
7	4.64	2.21	-2.36
7.5	5.23	2.06	-2.27
8	5.52	2.18	-2.48
8.5	6.62	1.54	-1.88
9	7.32	1.48	-1.68
9.5	7.67	1.56	-1.83
10	8.19	1.64	1.81

4 Discussion and Conclusion