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Dr. Vishwanath Karad
MIT WORLD PEACE UNIVERSITY | PUNE
TECHNOLOGY, RESEARCH, SOCIAL INNOVATION & PARTNERSHIPS

F. Y. B. Tech Academic Year 2021-22

Trimester: I/II/III **Subject:** Basics of Electrical and Electronics Engineering

Name: Krishnaraj Thadesar **Division 9**

Roll No: 109054 **Batch I3**

Experiment No: 5

Name of the Experiment: Design of inverting and non-inverting amplifiers using OPAMP.

Performed on: 21st January 2022

Submitted on: 21st January 2022

Aim: Design of inverting and non-inverting amplifiers using OPAMP.

Prerequisite:

- Understanding of ideal and practical parameters of OPAMP

Objectives:

- To get familiar with OPAMP as an amplifier
- To identify the pins of an OPAMP such as LM 741
- To measure gain of OPAMP and compare it with theoretical value
- To understand the different configurations of OPAMP

Components and equipment required:

Function generator, CRO, regulated power supply, resistors, capacitors, OPAMP LM741 circuit board, connecting wires, etc.

Theory:

An 'ideal' or perfect operational amplifier is a device with certain special characteristics such as infinite open-loop gain A_o, infinite input resistance R_{in}, zero output resistance R_{out}, infinite bandwidth and zero offset (the output is exactly zero when the input is zero). The amplified output signal of an operational amplifier is the difference between the two signals applied to the two inputs. The most commonly available and used of all operational amplifiers in basic electronic circuits is OPAMP 741. The basic symbol of OPAMP is shown in Fig. 7.1 and detailed pin diagram of general purpose OPAMP 741 is shown in Fig. 7.2.

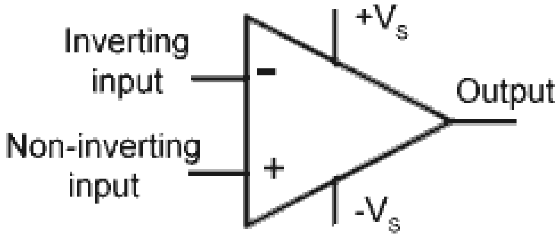


Fig.7.1 Symbol of OPAMP

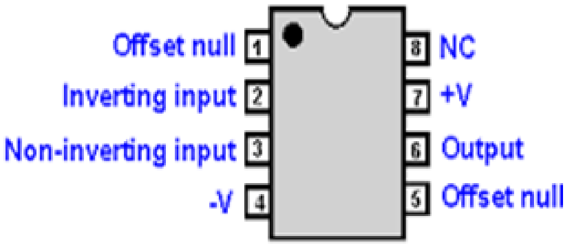


Fig.7.2 Pin diagram of OPAMP 741

Open Loop Gain, (A_{VL}) of an ideal operational amplifier can be very high, as much as 1,000,000 (120 dB) or more. However, this very high gain is of no real use as it makes the amplifier both, unstable and hard to control as the smallest of input signals, just a few micro-volts, (μV) would be enough to cause the output voltage to saturate and swing towards one or the other of the voltage supply losing complete control. As the open loop gain of an operational amplifier is extremely high, we can therefore afford to lose some of this high gain by connecting a suitable resistor across the amplifier from the output terminal back to the inverting input terminal to reduce and control the overall gain of the amplifier. This then produces an effect known commonly as negative feedback, and thus produces a very stable operational amplifier.

Table 7.1 Ideal and practical characteristics of OPAMP 741

Sr. No.	Parameter	Ideal	General purpose 741 Op-Amp
1	Open-loop voltage gain, Go(V/V)	∞	2,00,000
2	Input impedance, Zin(Ω)	∞	2 MΩ
3	Output impedance, Zo(Ω)	0	75 Ω
4	Input Offset current, Iio (nA)	0	20 nA
5	Input Bias current, Iib (nA)	0	80 nA
6	Input Offset voltage, Vio (mV)	0	2 mV
7	Slew rate, SR (V/μs)	∞	0.7 V/μs
8	CMRR	∞	90 dB

9	SVRR / PSRR	∞	96 dB
10	Bandwidth BW	∞	1 MHz

Negative Feedback is the process of feeding back a fraction of the output signal back to the input, but to make the feedback negative, we must feed it back to the negative or inverting input terminal of the OPAMP using an external feedback resistor called R_f. This effect produces a closed loop circuit to the amplifier resulting in the gain of the amplifier now being called its closed-loop gain. The closed-loop inverting amplifier uses negative feedback to accurately control the overall gain of the amplifier, improves input output impedance, increases the bandwidth but at a cost of reduction of the amplifiers gain. The ideal and practical characteristics of an OPAMP IC 741 are given in Table 7.1. Using negative feedback OPAMP can be used as an inverting and non-inverting amplifier.

Inverting Amplifier:

An inverting-amplifier circuit is built by grounding the positive input of the operational amplifier and connecting resistors R_1 and R_2, called the feedback networks, between the inverting input and the signal source and amplifier output node, respectively as shown in Fig. 7.3. The analysis of the circuit is performed by relating current I_1 with I_f and then calculating the output voltage V_o. Gain of the amplifier is given by:

$$A_{cl} = \frac{V_o}{V_{in}} = -\left(\frac{R_2}{R_1}\right) \tag{7.1}$$

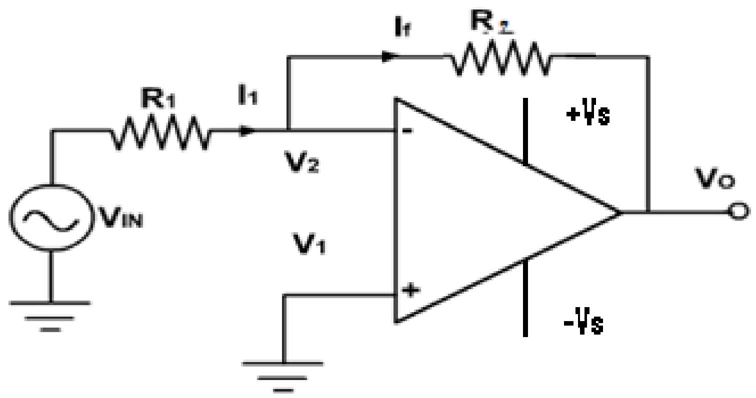


Fig. 7.3 Inverting amplifier configuration of an OPAMP

Non-Inverting Amplifier:

The operational amplifier can also be used to construct a non-inverting amplifier with the circuit indicated in Fig. 7.4. The input signal is applied to the positive or non-inverting input terminal of the operational amplifier, and a portion of the output signal is fed back to the negative input terminal. Analysis of the circuit is performed by relating the voltage at V_2 to both the input voltage V_{in} and the output voltage V_o. Gain of the amplifier is given by:

$$A_{cl} = \frac{V_o}{V_{in}} = \left(1 + \frac{R_2}{R_1}\right) \tag{7.2}$$

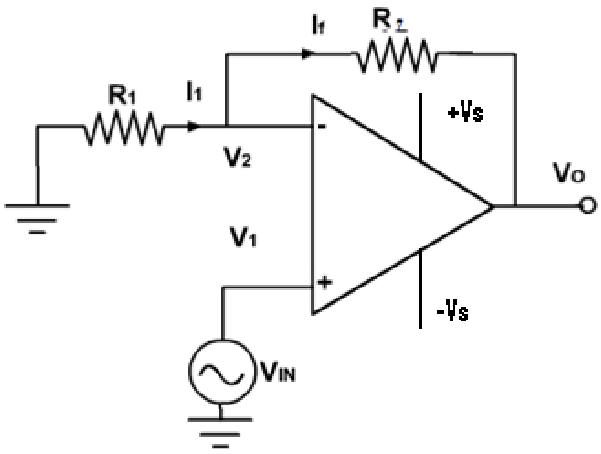


Fig. 7.4 Non-inverting amplifier configuration of an OPAMP

Procedure:

1. Connect the circuit for inverting amplifier as shown in the circuit diagram.
2. Select resistors R_1 and R_2 provided on the circuit board.
3. Set $+V_s$ to +12 V and $-V_s$ to -12V by using the dual power supply and switch on the supply.
4. Apply sine wave input of 1 KHz in the amplitude range of 500 mV to 1 V using signal generator.
5. Measure the peak to peak input and output voltages on CRO.
6. Calculate theoretical gain value using Eq. 7.1 for inverting amplifier and Eq. 7.2 for non-inverting amplifier and compare it with the experimental value obtained by dividing output voltage by the input voltage.
7. Draw input and output waveforms on the graph sheet.
8. Observe outputs of the amplifier circuit using different values of R_1 and R_2.
9. Repeat steps 2 to 8 for non-inverting amplifier configuration.

Observation Table:

1. Inverting Amplifier

Sr. No.	Input Voltage Amplitude V_{in}	*Input Voltage Type*	R_1 (k Ω)	R_2 (k Ω)	Output Voltage V_o	Gain (Practical)	Gain (Theoretical)
1	500mV	AC	1	10	5000mV	10	10
2	700mV	AC	1	10	7000mV	10	10
3	1000mV	AC	1	9	9000mV	9	9
4	1200mV	DC	1	8	9600mV	8	8
5	1400mV	DC	1	7	9800mV	7	7

2. Non-Inverting Amplifier

Sr. No.	Input Voltage V_{in}	*Input Voltage Type*	R_1 (k Ω)	R_2 (k Ω)	Output Voltage V_o	Gain (Practical)	Gain (Theoretical)
1	500mV	AC	1	10	5500mV	11	11
2	700mV	AC	1	10	7700mV	11	11
3	1000mV	AC	1	9	10000mV	10	10
4	1200mV	DC	1	8	10800mV	9	9
5	1400mV	DC	1	7	11200mV	8	8

Note: Students are instructed to do all the necessary calculations on separate sheets.

Conclusion:

The working of inverting and non-inverting Operational Amplifier was studied in detail. The Gain (A) of the amplifier was found out theoretically and practically.

Post Lab Questions:

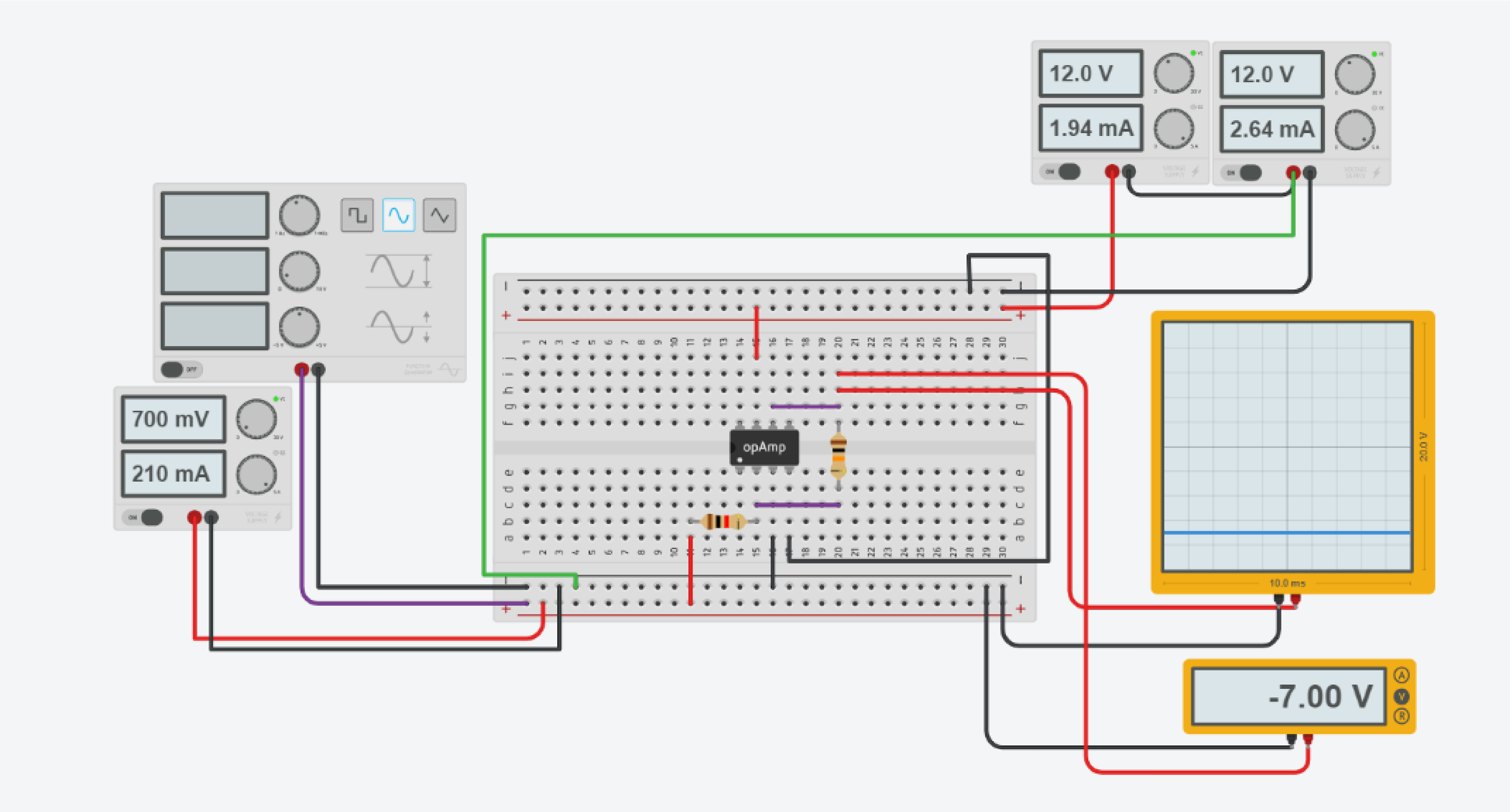
1. What is an operational amplifier?
2. Write applications of positive feedback and negative feedback in OPAMP.
3. Write gain equation for inverting and non-inverting amplifier of OPAMP?
4. What is OPAMP adder, OPAMP subtractor circuit?

Additional links for more information:

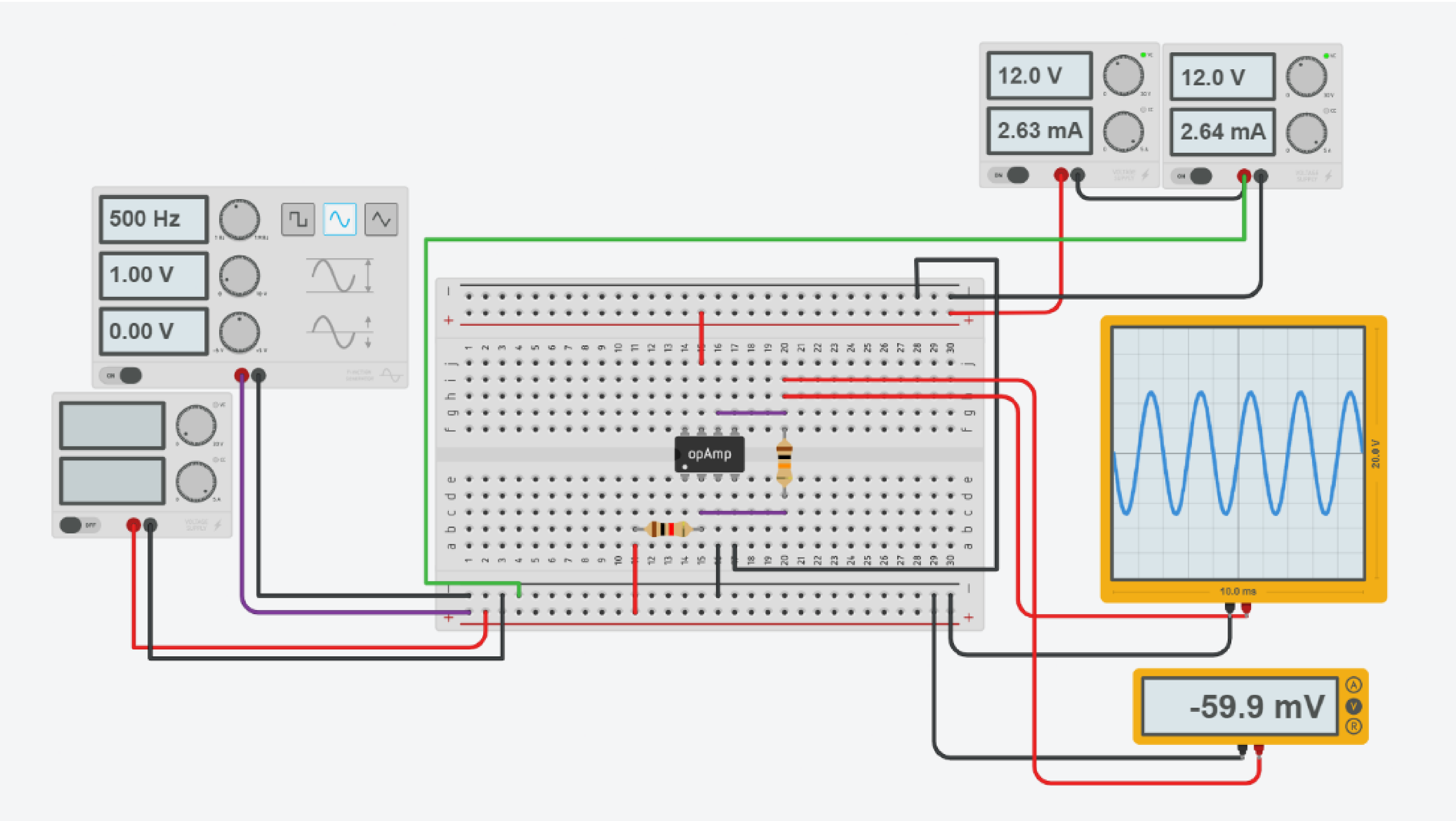
- http://dei.vlab.co.in/?sub=22&brch=60&sim=1119&cnt=2
- http://www.ti.com/lit/ds/symlink/lm741.pdf

Tinkercad Circuits

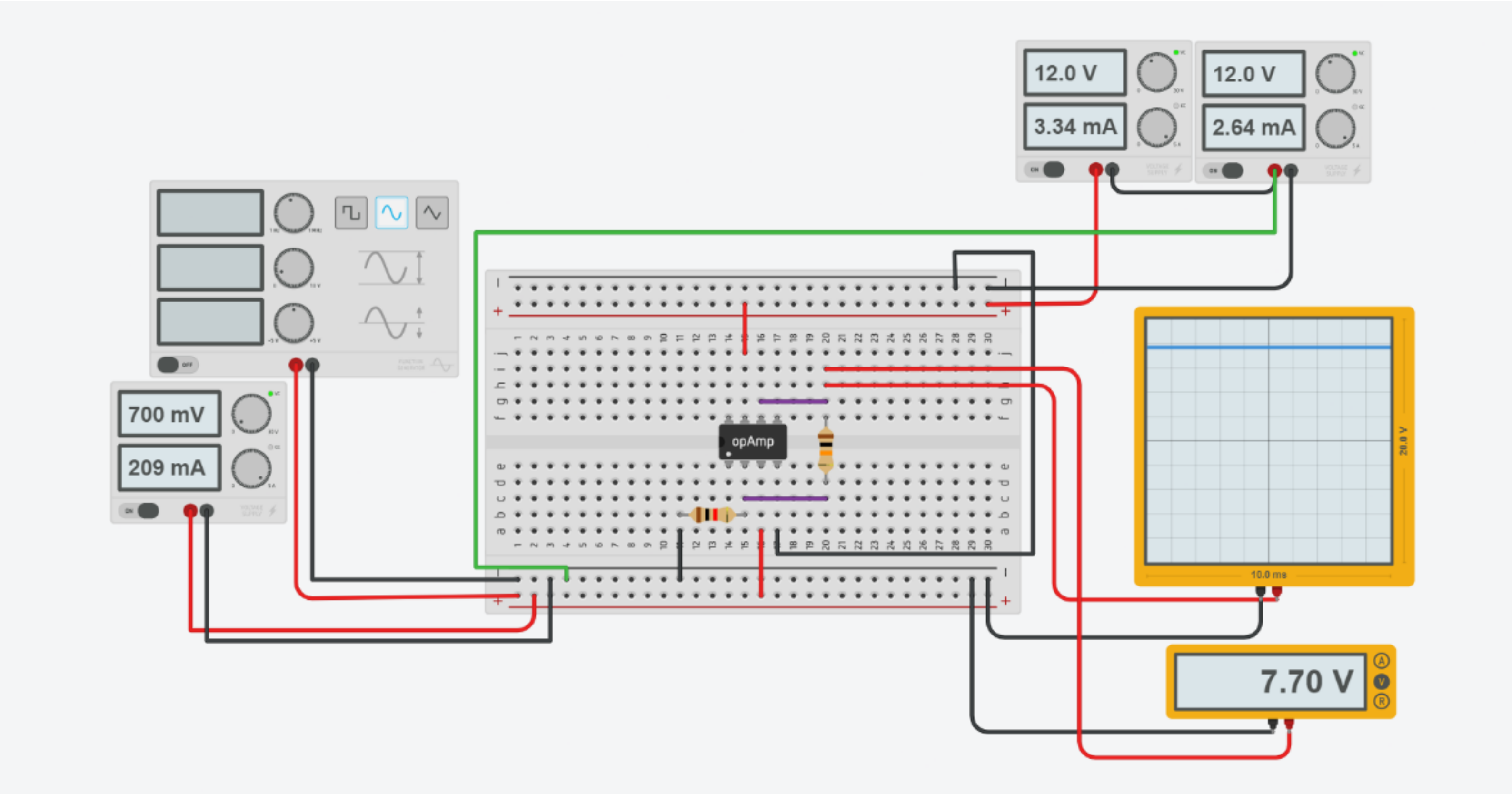
DC Input to Inverting Op-Amp



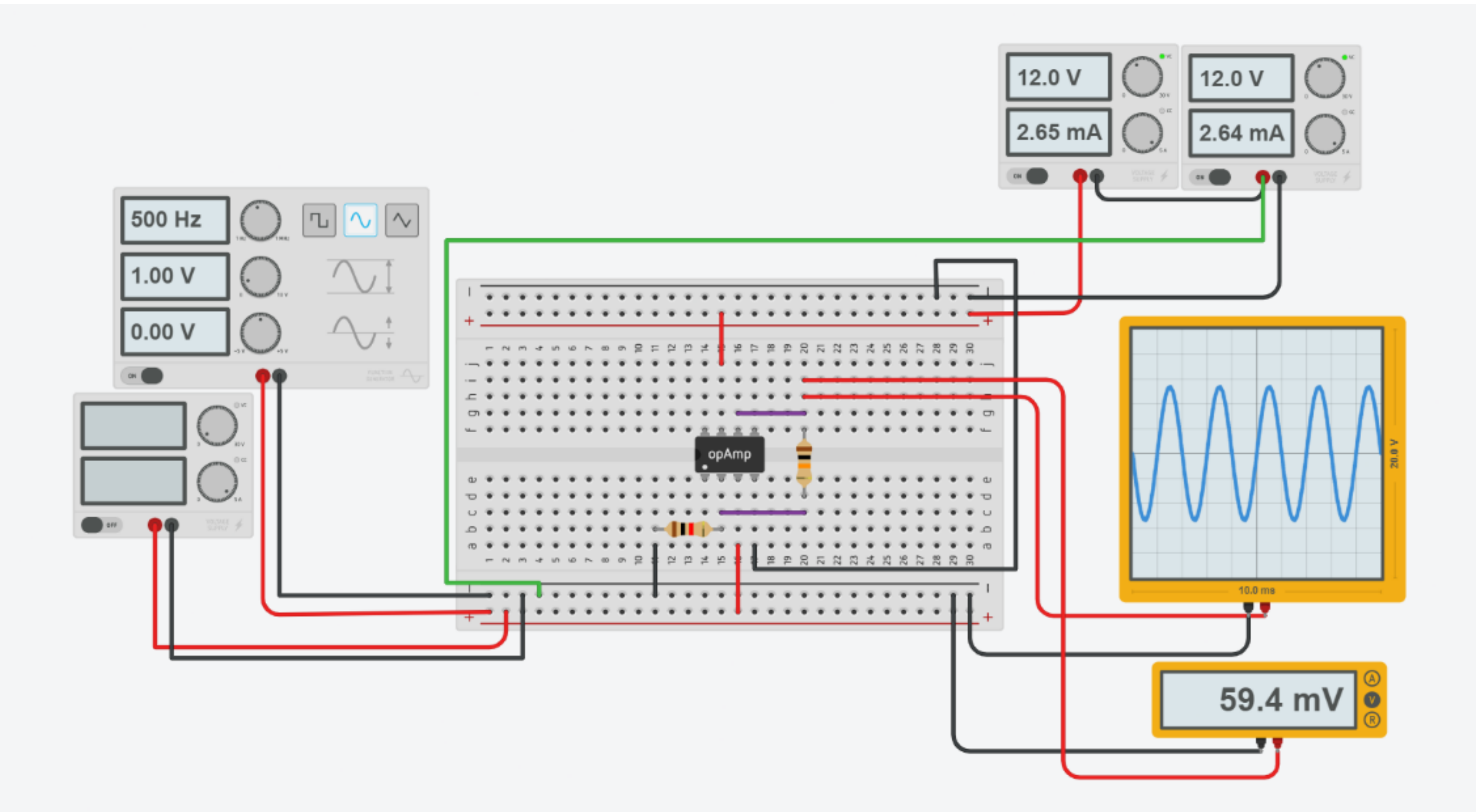
AC Input to Inverting Op-Amp



DC Input to Non-Inverting Op-Amp



AC Input to Non Inverting Op-Amp



Component List

Inverting Amplifier

Name	Quantity	Component
U1	1	741 Operational Amplifier
RRf	1	10 kΩ Resistor
RRi	1	1 kΩ Resistor
P1, P2	2	12 , 5 Power Supply
P3	1	0.7 , 5 Power Supply
FUNC1	1	500 Hz, 1 V, 0 V, Sine Function Generator
U2	1	1 ms Oscilloscope
Meter1	1	Voltage Multimeter

Non Inverting Amplifier

Name	Quantity	Component
U1	1	741 Operational Amplifier
RRf	1	10 kΩ Resistor
RRi	1	1 kΩ Resistor
P1, P2	2	12 , 5 Power Supply
P3	1	0.7 , 5 Power Supply
FUNC1	1	500 Hz, 1 V, 0 V, Sine Function Generator
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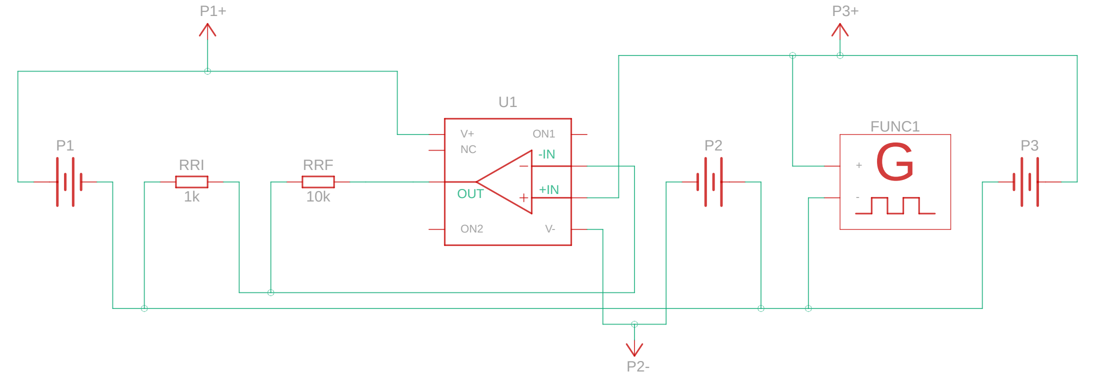

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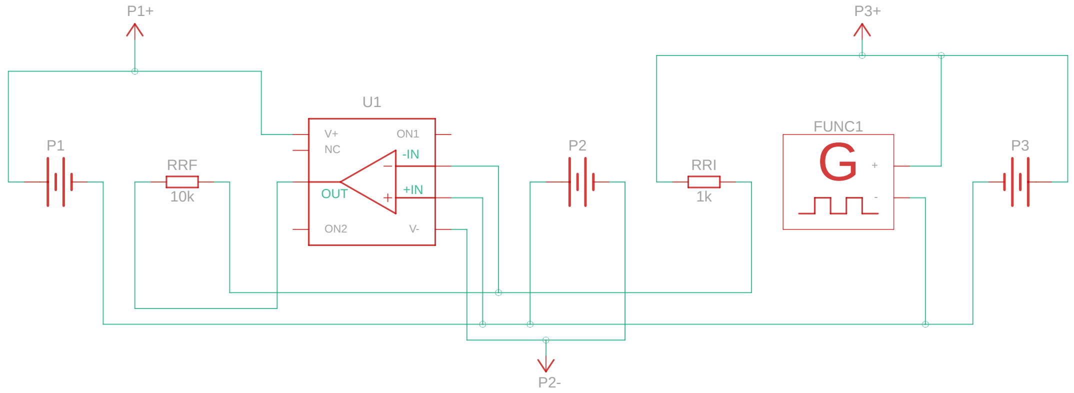

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Title: E5. Inverting Op-Amp

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Sheet: 1/1

TRIM-2 - BEEE

Krishnaraj P T.
109054 . I3

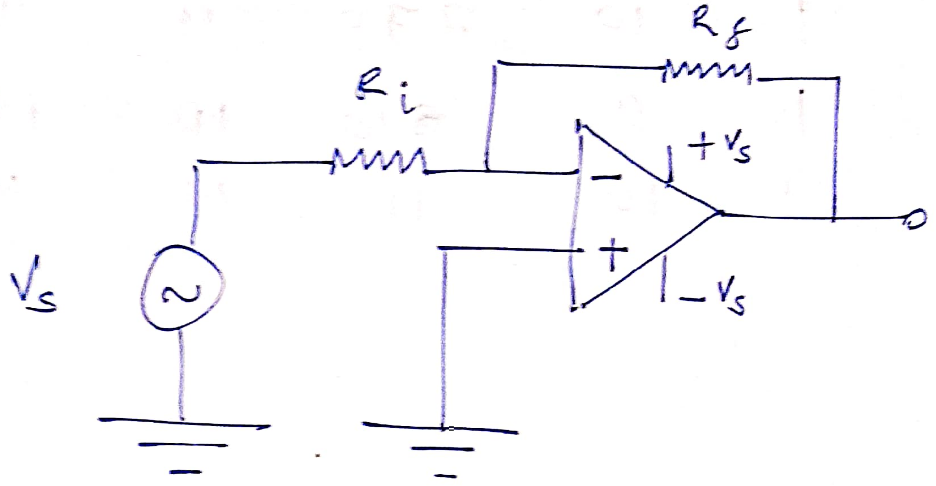
21/1/22

EXPERIMENT -5

Operational Amplifiers

(*) **Calculations**

(1) Inverting Amplifier:



(1) Calc - 1

$R_i = 1\ k\Omega$

$R_f = 10\ k\Omega$

$V_{in} = 500\ mV$ AC (~)

$V_o = 5000\ mV$ AC (~)

$$\text{Gain } (A) = A_{d_{\text{inverting}}} = \frac{V_o}{V_{in}} = \frac{-R_2}{R_1}$$

$$A_d = \frac{5000}{500} = \underline{10} = \frac{10\ k\Omega}{1\ k\Omega}$$

(2) Case - 2

$V_{in} = 700\ mV$

$V_{out} = 7000\ mV$

$R_i = 1\ k\Omega$

$R_f = 10\ k\Omega$

$A_{cl} = \frac{7000}{700} = \underline{\underline{10}}$

$= \frac{10\ k\Omega}{1\ k\Omega} = \underline{\underline{10}}$

(3) $V_{in} = 1000\ mV$

$V_{out} = 9000\ mV$

$R_i = 1\ k\Omega$

$R_f = 9\ k\Omega$

$A_{cl} = \frac{9}{1} = \frac{9000}{1000} = \underline{\underline{9}}$

(4) $V_{in} = 1200$, $V_{out} = 9600\ mV$

$R_i = 1\ k\Omega$, $R_f = \cancel{9800\ mV}$ $8\ k\Omega$

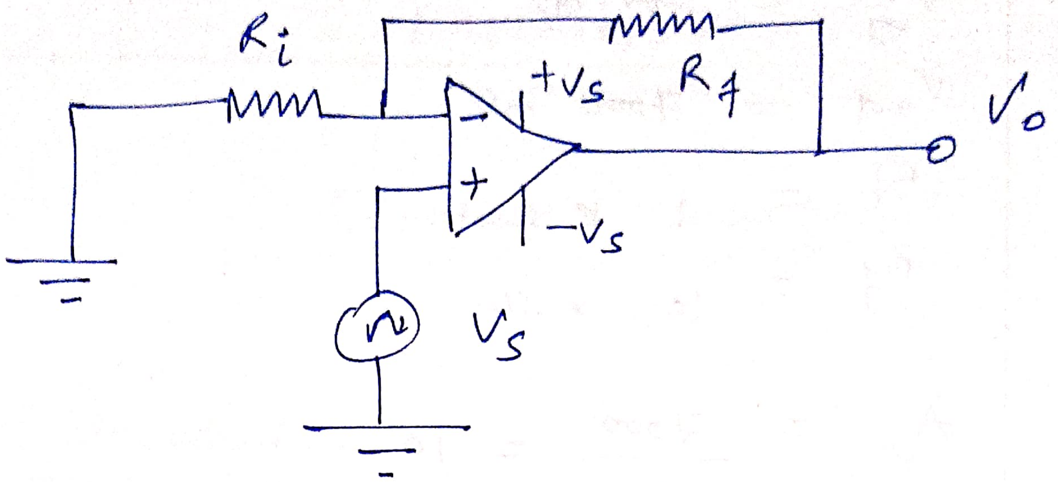
$A_{cl} = \frac{9600}{1200} = \frac{8000}{1000} = \underline{\underline{8}}$

(5) $V_{in} = 1400$, $V_{out} = 9800\ mV$

$R_i = 1000\ \Omega$, $R_f = 7000\ \Omega$

$A_{cl} = \frac{9800}{1400} = \frac{7000}{1000} = \underline{\underline{7}}$

Non-Inverting Amplifier



$$A_d = \frac{V_o}{V_{in}} = \left(1 + \frac{R_2}{R_1}\right)$$

(1) **Case - 1 :**

$V_{in} = 500 \text{ mV}$ $\qquad R_i = 1 \text{ K}\Omega$

$V_{out} = 5500 \text{ mV}$ $\qquad R_f = 10 \text{ K}\Omega$

Practical gain $\quad A_{d_P} = \frac{5500}{500} = \underline{\underline{11}}$

Theoretical gain $\quad A_{d_T} = 1 + \frac{10}{1} = \underline{\underline{11}}$

$$\underline{A_{d_T} = A_{d_P}}$$

(2) **Case - 2**

$V_{in} = 700 \text{ mV}$ $\qquad R_i = 1 \text{ K}\Omega$

$V_{out} = 7700 \text{ mV}$ $\qquad R_f = 10 \text{ K}\Omega$

$A_{d_T} = 1 + \frac{10}{1} = 11 .$;

$$A_{cl_p} = \frac{7700}{700} = 11$$

$$A_{cl_p} = A_{cl_T}$$

(3) Case – 3

$V_{in} = \cancel{700}$ 1000 mV $\qquad R_i = 1\,K\Omega$

$V_{out} = \cancel{9000}$ 10 V $\qquad R_f = 9\,K\Omega$

$$A_{cl_T} = 1 + \frac{9}{1} = 10$$

$$A_{cl_p} = \frac{10\,000}{1\,000} = 10 \;; \quad A_{cl_T} = A_{cl_p}$$

(4) Case – 4

$V_{in} = 1200$ mV $\qquad R_i = 1\,K\Omega$

$V_{out} = 10.8$ V $\qquad R_f = 8\,K\Omega$

$$A_{cl_p} = \frac{10.8}{1.2} = \cancel{108}\;9$$

$$A_{cl_T} = 1 + \frac{8}{1} = 9 \qquad A_{cl_p} = A_{cl_T}$$

(5)

$V_{in} = 1400$ mV $\qquad R_i = 1\,K\Omega$

$V_{out} = 11.2$ V $\qquad R_f = 7\,K\Omega$

$$A_{cl_p} = \frac{11.2}{1.4} = 8 \qquad A_{cl_p} = A_{cl_T}$$

$$A_{cl_T} = 1 + \frac{7}{1} = 8$$

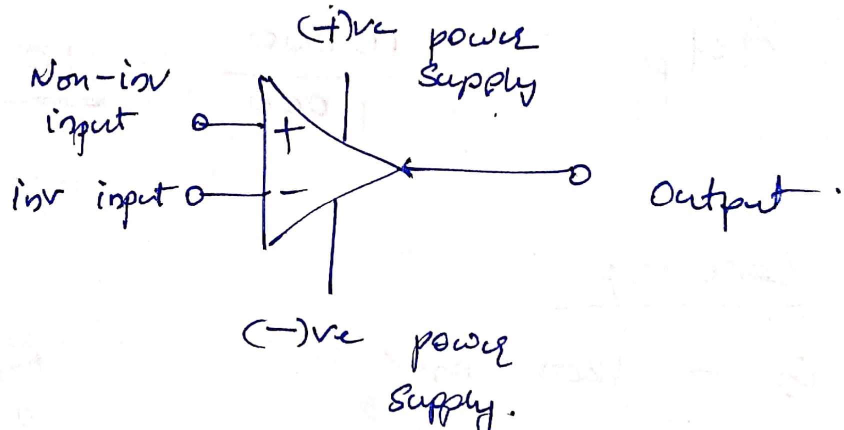
Post Lab Questions

Q.1 What is an operational Amplifier?

→ A operational amplifier is an integrated circuit that can amplify weak electric signals. It has 2 input pins and one output pin.

→ Basic role is ~~its~~ to amplify and output the voltage difference between the 2 input pins.

→

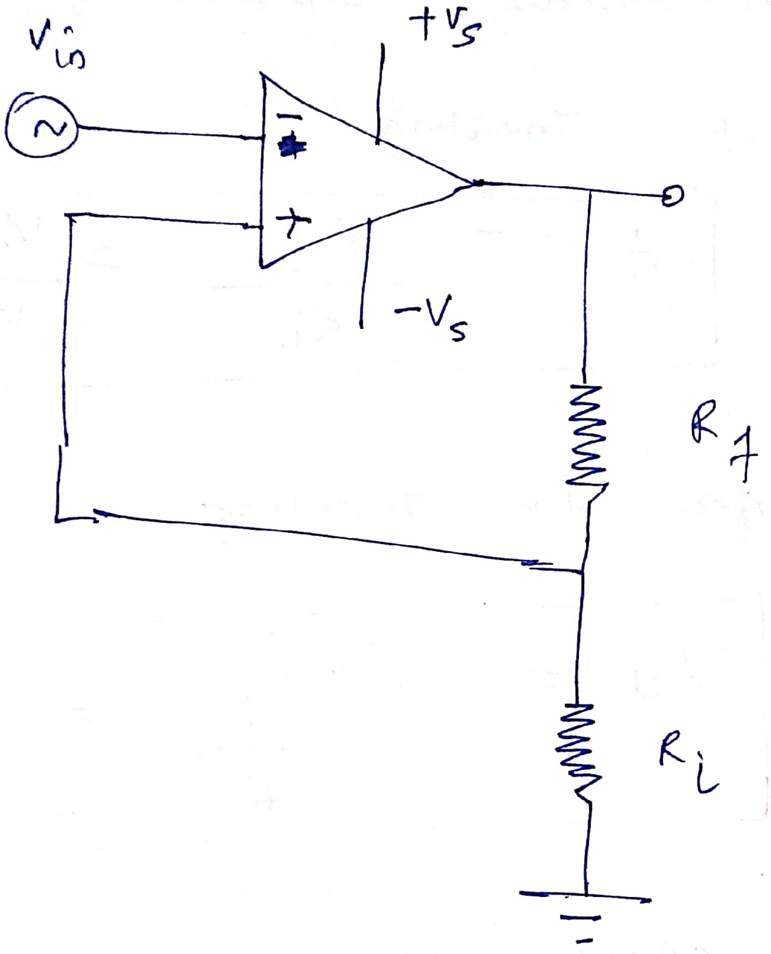


→ An Op Amp can perform many operations.

1. Amplify weak signals
2. Eliminate noise from input signal
3. Act as inverting and non inverting amplifier.
4. Used in ~~a~~ voltage follower circuit
5. Used in differential amplifier circuit

Q.2. Write applications of positive feedback and negative feedback in op-amp.

→ 1) Positive feedback :



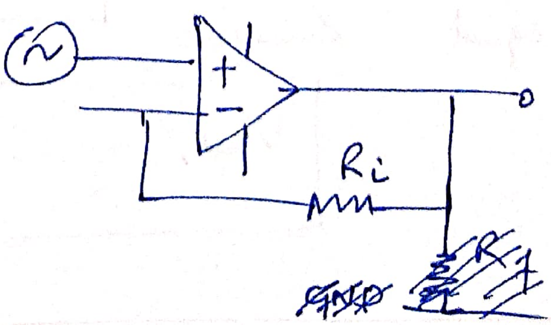
→ Used for oscillator circuit.

→ Wein-Bridge oscillator circuit

→ RC oscillator circuit.

→ Schmitt trigger – can de-bounce a signal.

2) Negative feedback



→ Used in amplifiers

→ Gain can be changed easily

→ inverter and non-inverting circuits.

Q(3) Write Gain equation for inverting and non-inverting amplifier of OPAMP.

→ Gain for Inverting

$$\boxed{A_{cl} = \frac{R_f}{R_i} = \frac{V_o}{V_{in}}}$$

Gain for Non-Inverting

$$\boxed{A_{cl} = 1 + \frac{R_f}{R_i} = \frac{V_o}{V_{in}}}$$

Q.(4)- What is OPAMP adder OP AMP subtractor circuit?

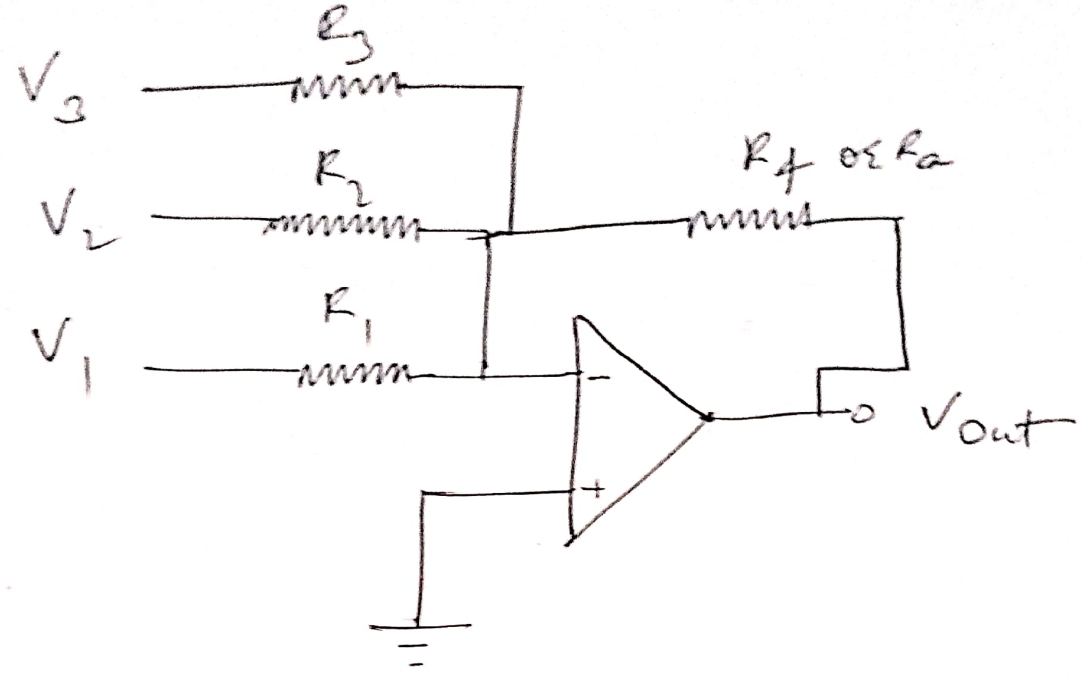
→ <u>Adder</u>

1. A circuit whose output is the sum of several input signals.
2. For Resistors equal, $\boxed{\begin{array}{l} V_{out} = \Sigma V_{in} \\ \text{gain} = +1. \end{array}}$

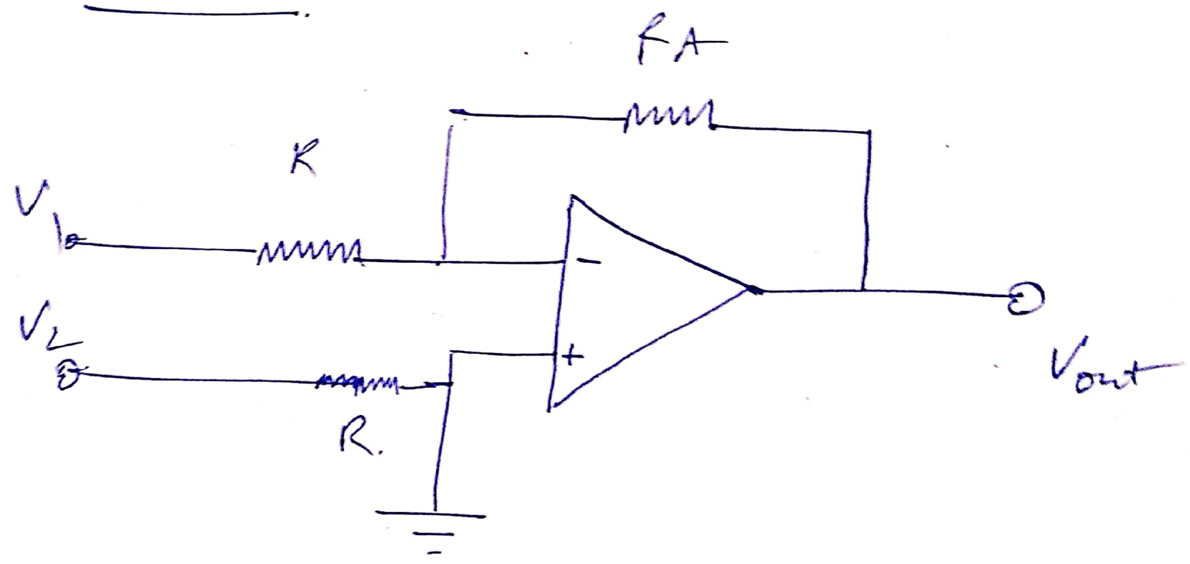
For unequal resistors,

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

Inverting Summer or adder circuit



Subtractor



Subtrator is also called differential amplifier. Uses both inverting and non-inverting inputs to produce a output which is a difference between the input voltages V_1 and V_2 allowing 1 signal to be subtracted from each other.

$$V_o = V_2 - V_1$$