Operational Amplifier: Amplifier

TE201414 - Rangkaian Elektronika 2

Program Studi Teknik Elektro

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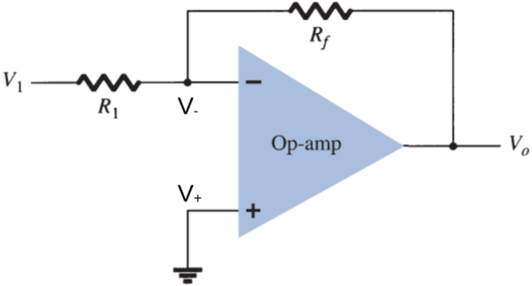
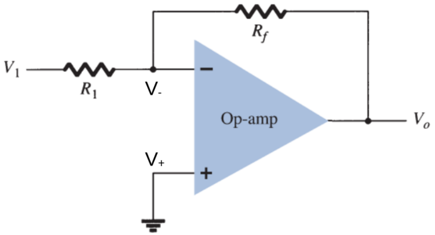
Negative Feedback

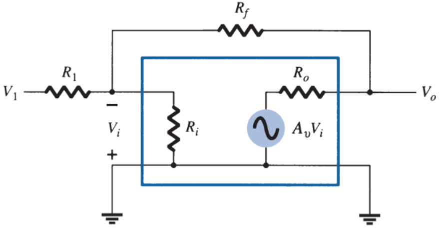
an op-amp can be operated as amplifier by giving negative feedback (connection between output and inverting input), which makes difference voltage at both input almost zero.



$$\boxed{V_- \cong V_+}$$

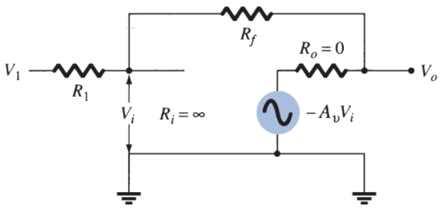
negative feedback on op-amp can be modeled as circuit below:

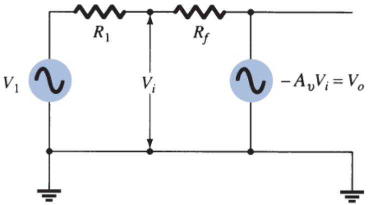




assume there is no current flows through input op-amp, so R_i is in Hi-Z (High Impedance) state.

Negative Feedback





superposition is used to analyze circuit model:
while source $-A_v V_i$ is at off state:

$$V_{i_1} = \frac{R_f}{R_1 + R_f} V_1$$

while source V_1 is at off state:

$$V_{i_2} = \frac{R_1}{R_1 + R_f} (-A_v V_i)$$

Negative Feedback

then voltage at inverting input op-amp V_i:

$$V_i = V_{i_1} + V_{i_2} = \frac{R_f}{R_1 + R_f} V_1 + \frac{R_1}{R_1 + R_f}(-A_v V_i)$$

$$V_i = \frac{R_f}{R_f + (1 + A_v)R_1} V_1$$

assume $A_v >> 1$ and $A_v R_1 >> R_f$, then:

$$V_i = \frac{R_f}{A_v R_1} V_1$$

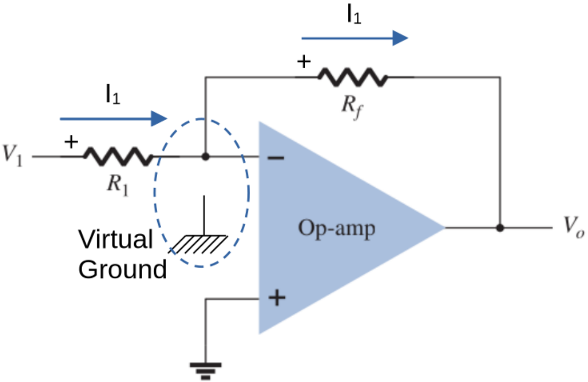
$$\boxed{\frac{V_o}{V_1} = \frac{-A_v V_i}{V_i} = \frac{-A_v}{V_i} \frac{R_f V_1}{A_v R_1} = -\frac{R_f}{R_1} \frac{V_1}{V_i}}$$

Amplifier Model

Op-amp as amplifier can be operated as:

- Inverting amplifier
- Non-inverting amplifier
- Voltage follower
- Sum amplifier
- Differential amplifier

inverting amplifier is an op-amp amplifier model which amplifies and reverses input signal.



Inverting amplifier

the amplification of this amplifier can be derived as follow:

$$V_+ \cong V_-$$

then, voltage at invering input:

$$V_- = 0V$$

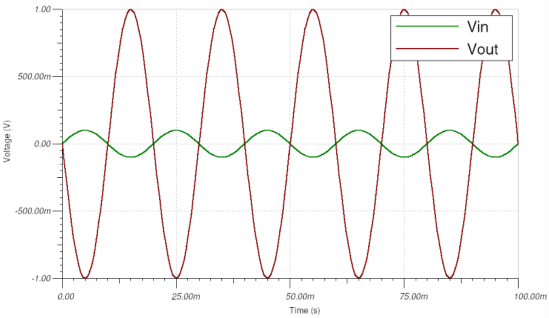
virtual ground at inverting input causes current flows through R_1

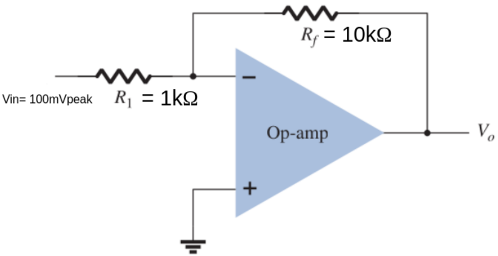
$$I_1 = \frac{V_1}{R_1}$$

due to its input impedance in hi-state (Hi-Z), $Z_i \cong \infty$, so the current I_1 flows through feedback resistor R_f and obtain output voltage of op-amp V_o.

$$\boxed{V_o = -I_1 R_f = -\frac{R_f}{R_1} V_1} \quad \boxed{\frac{V_o}{V_i} = -\frac{R_f}{R_1}}$$

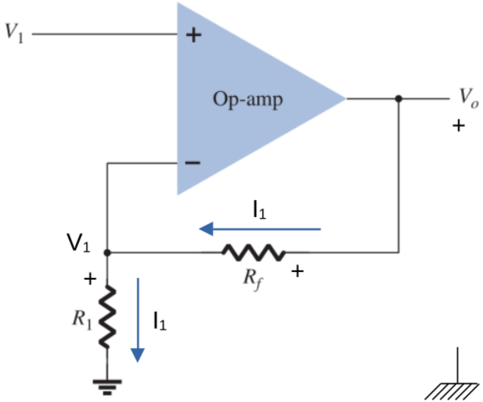
Inverting amplifier





Noninverting amplifier

non-inverting amplifier is an op-amp which amplifies the input voltage without reversing its polarity.



Noninverting amplifier

the amplification of the circuit can be derived by assuming the difference voltage between inputs are zero

$$V_+ \cong V_- \cong V_1$$

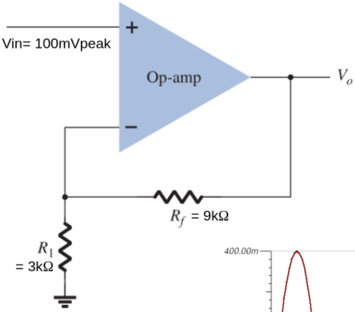
cause current flows I_1 through R_1 to the reference

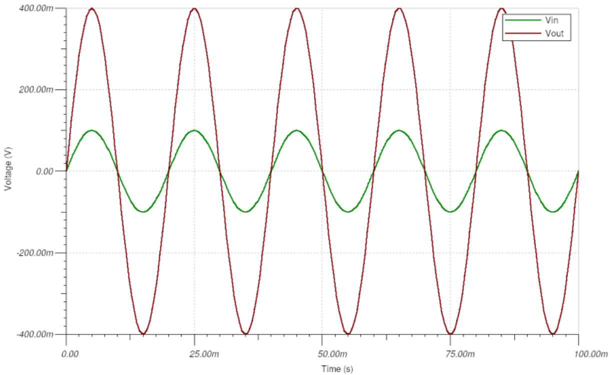
$$I_1 = \frac{V_1}{R_1}$$

op-amp input impedance is in Hi-Z causes current drown from its output through feedback resistor. the output voltage V_o can be derived:

$$\boxed{V_o = I_1 R_f + I_1 R_1 = 1 + \frac{R_f}{R_1})V_1} \boxed{\frac{Vo}{Vi} = 1 + \frac{R_f}{R_1}}$$

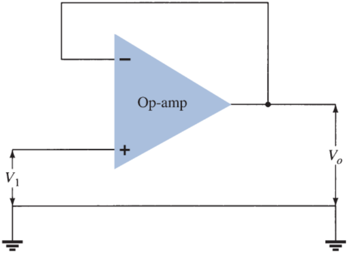
Noninverting amplifier





Buffer/Voltage Follower

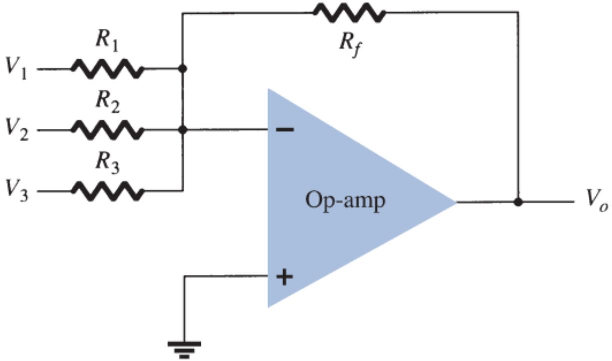
as its name "Voltage Follower" is an op-amp circuit that doesnt amplify input voltage. the advantage of using this circuit to obtain high impedance input as circuit isolation and make sure all signal dissipated in the circuit (less signal loss during transmission).



$$\boxed{V_o = V_1}$$

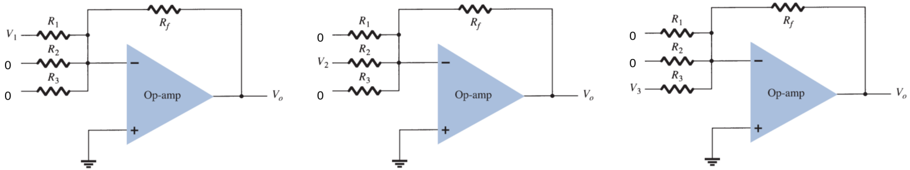
Summing Amplifier

Summing amplifier is an amplifier which has ability to execute addition and summing operation. the summing operation can be done if all resistor in circuit has same value. $R_1 = R_2 = R_3 = R_f = R$



Summing Amplifier

while voltage source is in off state, connected resistor takes role as dummy resistor due to virtual ground (refers to inverting amplifier). then derivation of the circuit can be separated as the number of input sources (superposition).



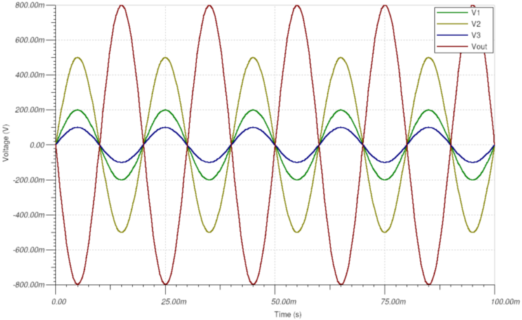
$$V_o = -\frac{Rf}{R_1} V_1$$
$$V_o = -V_1$$

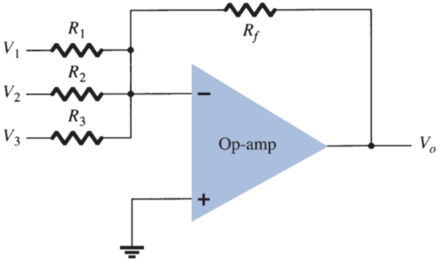
$$V_o = -\frac{Rf}{R_2} V_2$$
$$V_o = -V_2$$

$$V_o = -\frac{Rf}{R_3} V_3$$
$$V_o = -V_3$$

$$\boxed{V_o = -V_1 - V_2 - V_3 = -(V_1 + V_2 + V_3)}$$

Summing Amplifier

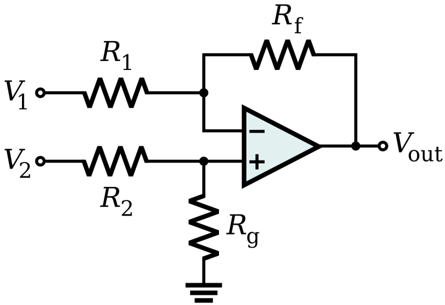




$$R_1 = R_2 = R_3 = R_f = R = 1k\Omega$$

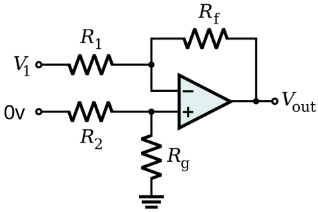
Differential Amplifier

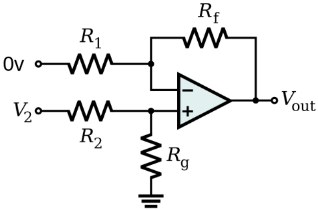
Differential amplifier is an amplifier that has ability to execute substract operation. the operation can be done if all resistor connected has the same value $R_1 = R_2 = R_f = R_g$.



Differential Amplifier

superposition theorm is used to find transfer function of the circuit.



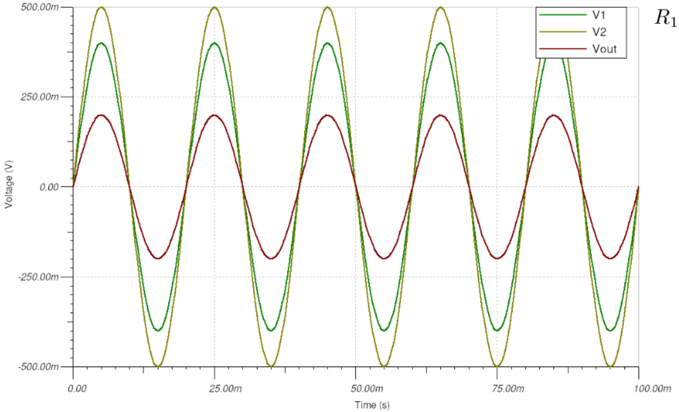


inverting amp:
$V_{out} = -\frac{R_f}{R_1} V_1$
$V_{out} = -V_1$

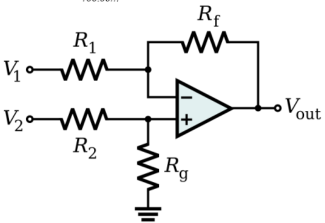
non-inverting amp:
$V_{out} = (\frac{R_f}{R_1} + 1) V_+$
$V_+ = R_g/(R_g + R_2) V_2 = 1/2 V_2$
$V_{out} = 2R * 0.5R * V_2 = V_2$

$$\boxed{V_o = V_2 - V_1}$$

Differential Amplifier



$R_1 = R_2 = R_g = R_f = 1k\Omega$



References

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