Power Electronics
No. 7: Operational Amplifier

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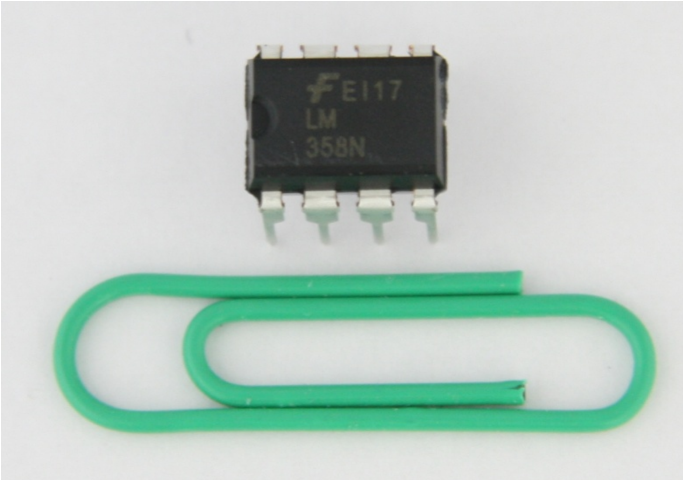
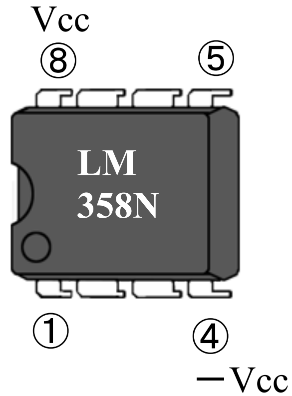
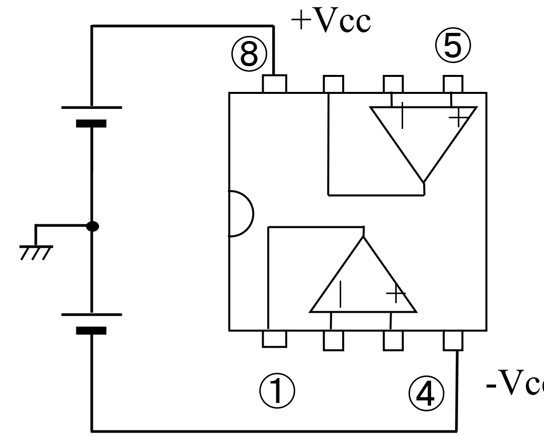


Appearance

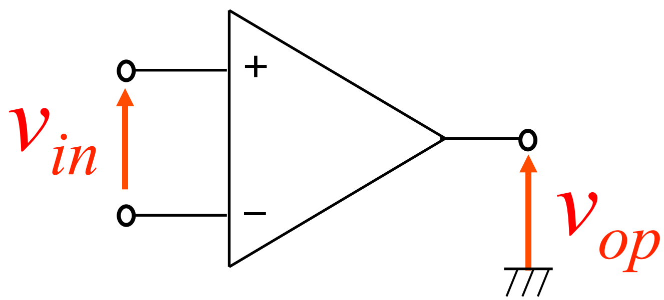


Solid figure



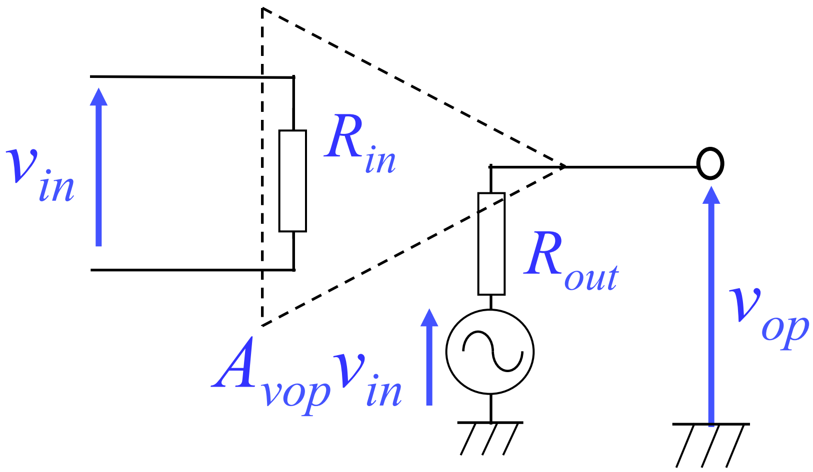
Pin Connections

Operational Amplifier (LM358N)

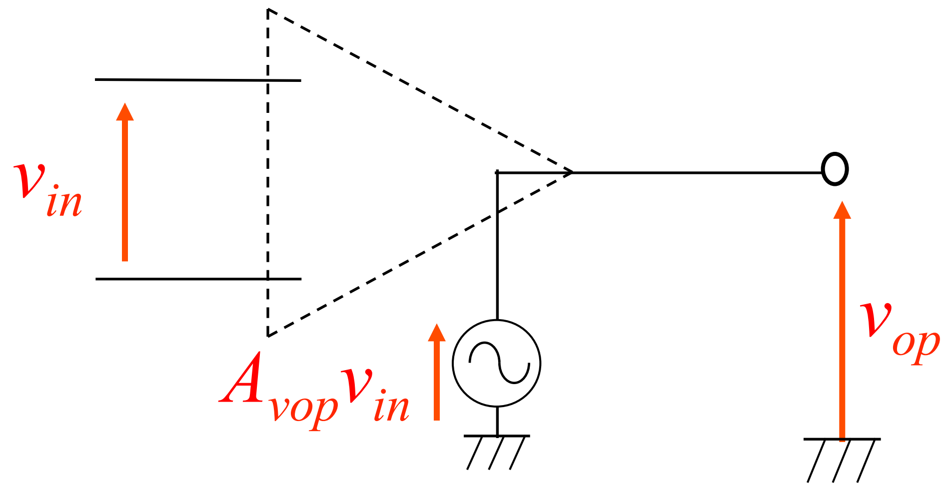


Op-amp symbol

Input resistor: R_{in}
Output resistor: R_{out}



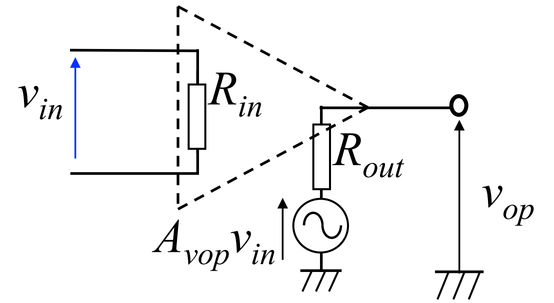
Op-amp equivalent circuit



Op-amp approximated equivalent circuit

Amplification degree of voltage ($A_{vop} = v_o / v_{in}$)

Principle of amplifier using op-amp



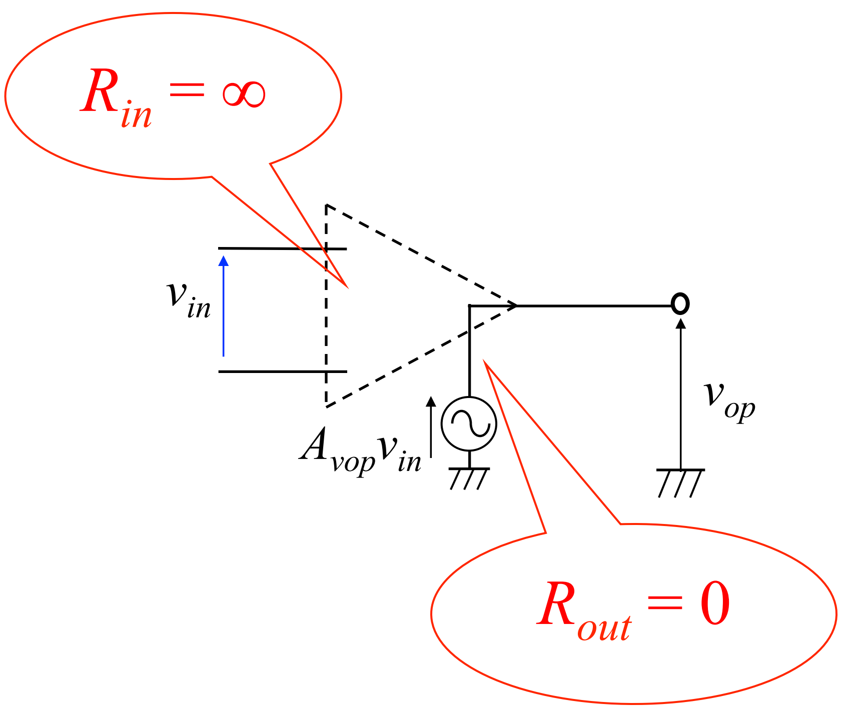
Op-amp equivalent circuit

3 major features of op-amp:

(a) Amplification degree of voltage
($A_{vop} = v_o / v_{in}$) is very large.
Typical value of LM358N is 100,000, i.e. if v_{in} = 10 [μV], then v_{op} = 1[V].

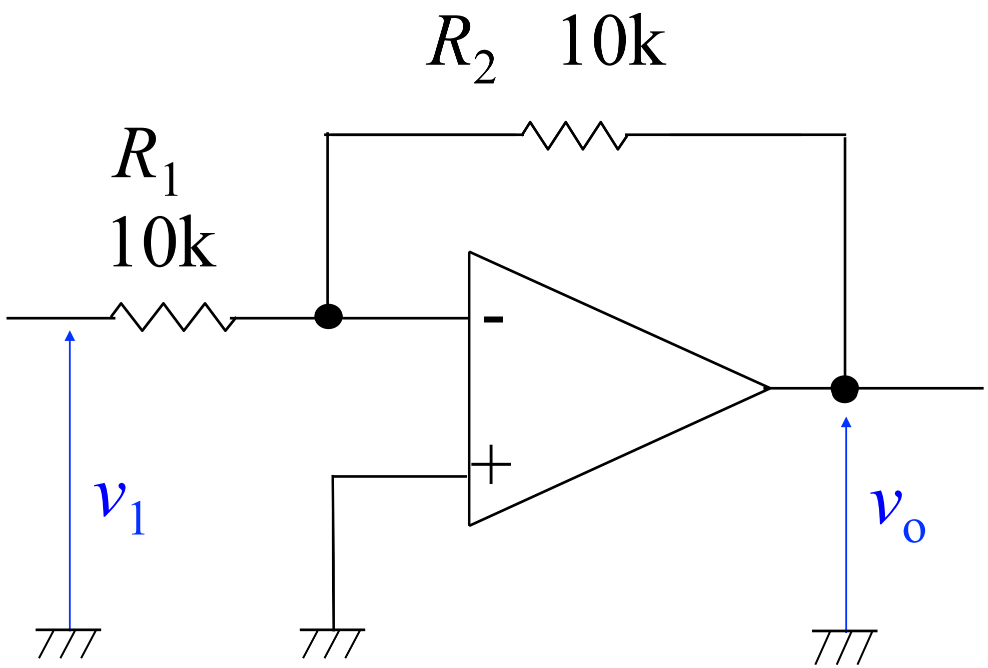
(b) Input resistance (R_{in}) is very large.
The minimum value of LM358N is 10^7 [Ω].

(c) Output resistance (R_{out}) is small.
$R_{out} \fallingdotseq$ 300 [Ω]



Op-amp approximated equivalent circuit

Inverting amplifier circuit



Inverting amplifier circuit

$$v_o = -\frac{R_2}{R_1} v_1$$

$$= A_v v_1$$

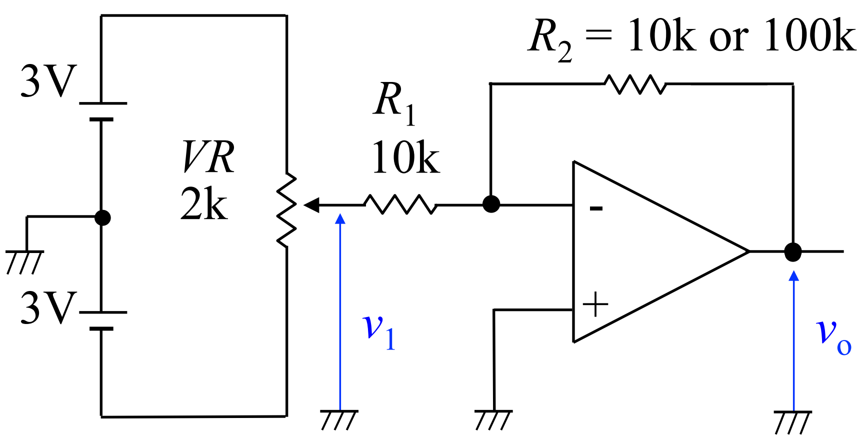
A_v: Amplification degree of voltage of amplifier

In this example

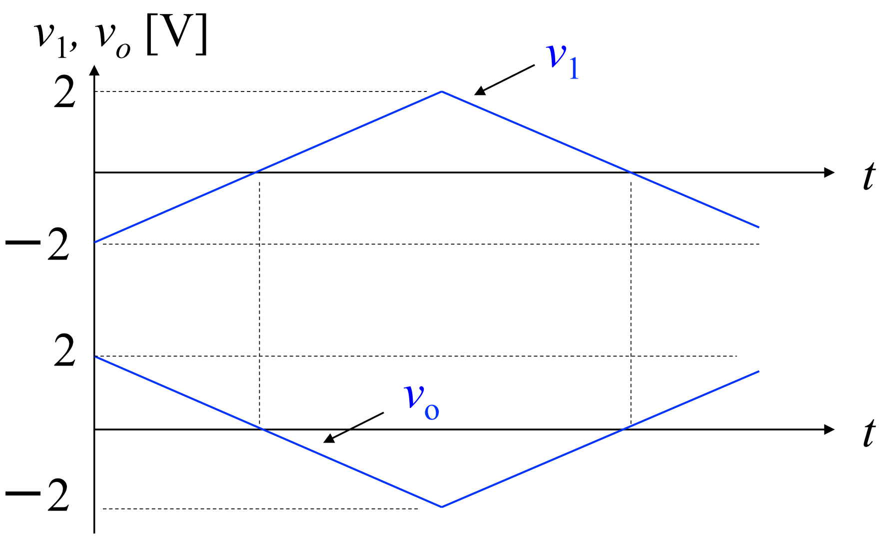
$$v_o = -\frac{10\,[\mathrm{k\Omega}]}{10\,[\mathrm{k\Omega}]} v_1$$

$$= -v_1$$

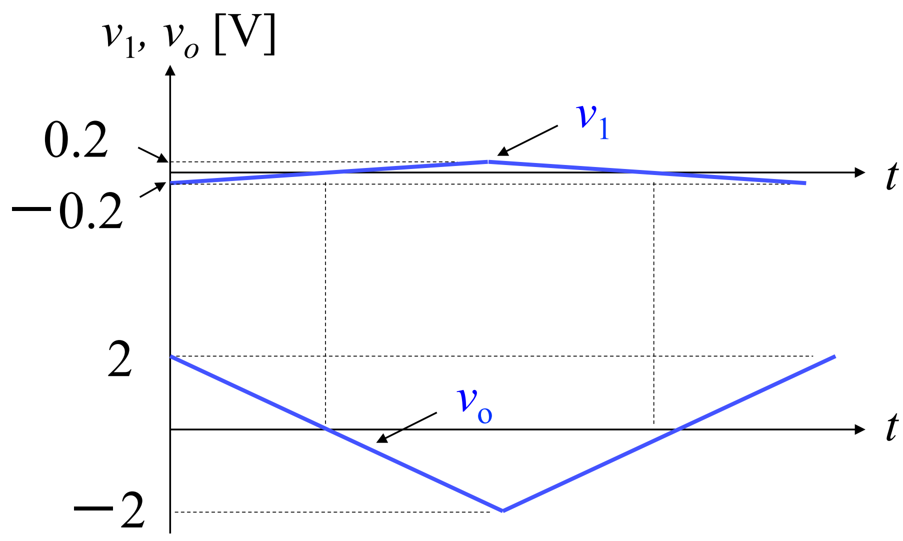
$$A_v = -1$$



Inverting amplifier circuit

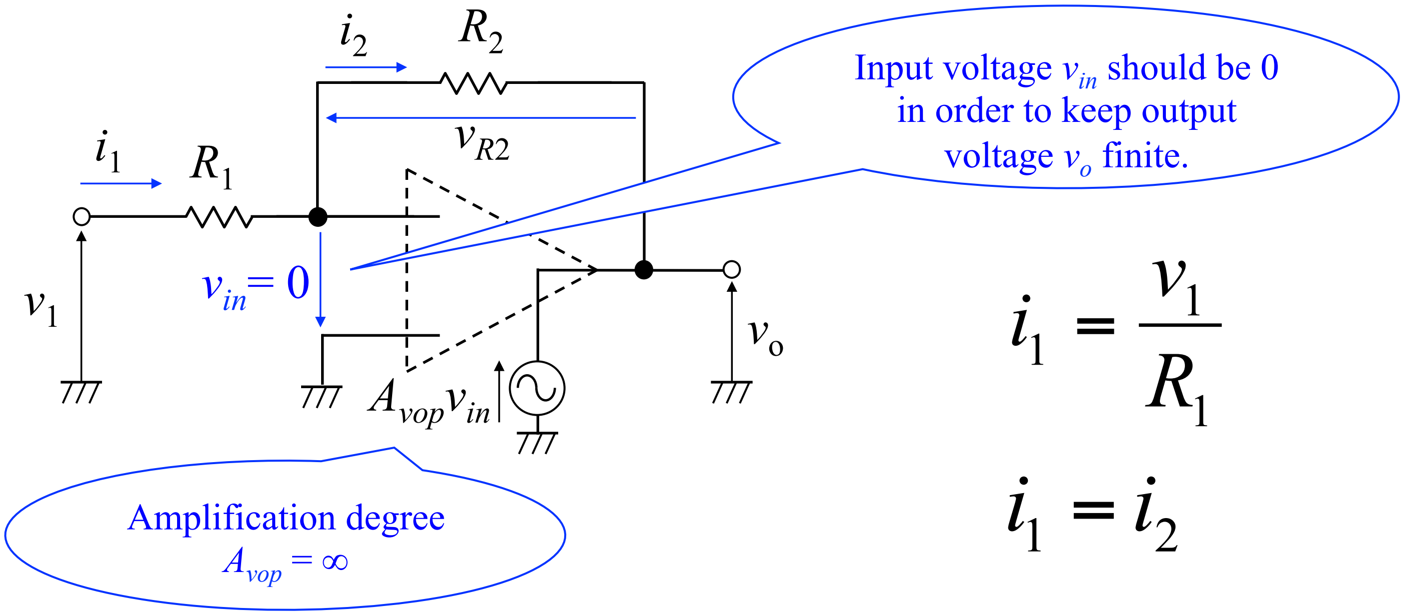


(a) R_2 = 10kΩ (A_v = -1)



(b) R_2 = 100kΩ (A_v = -10)

Waveforms of input/output voltages

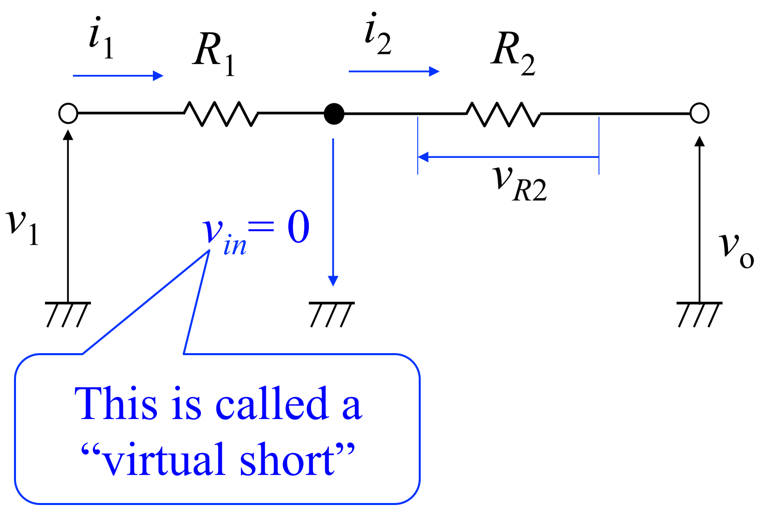


(a) Equivalent circuit

$$i_1 = \frac{v_1}{R_1}$$

$$i_1 = i_2$$

$$v_{R2} = R_2\, i_2 = \frac{R_2}{R_1} v_1$$

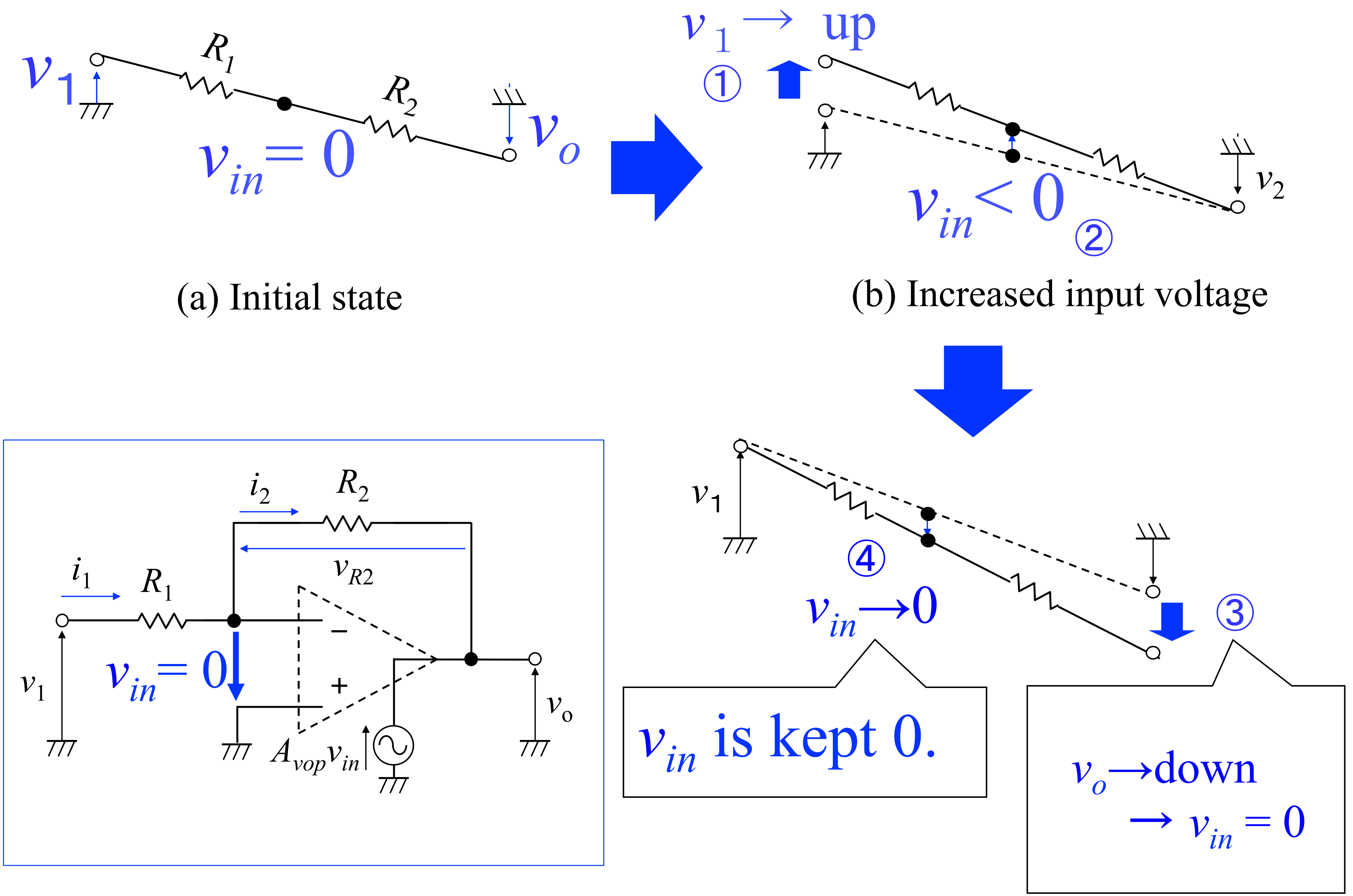


(b) Approximated equivalent circuit

$$v_o = -v_{R2} = -\frac{R_2}{R_1} v_1$$

$$= A_v v_1$$

Equivalent circuit of inverting amplifier circuit



(a) Initial state

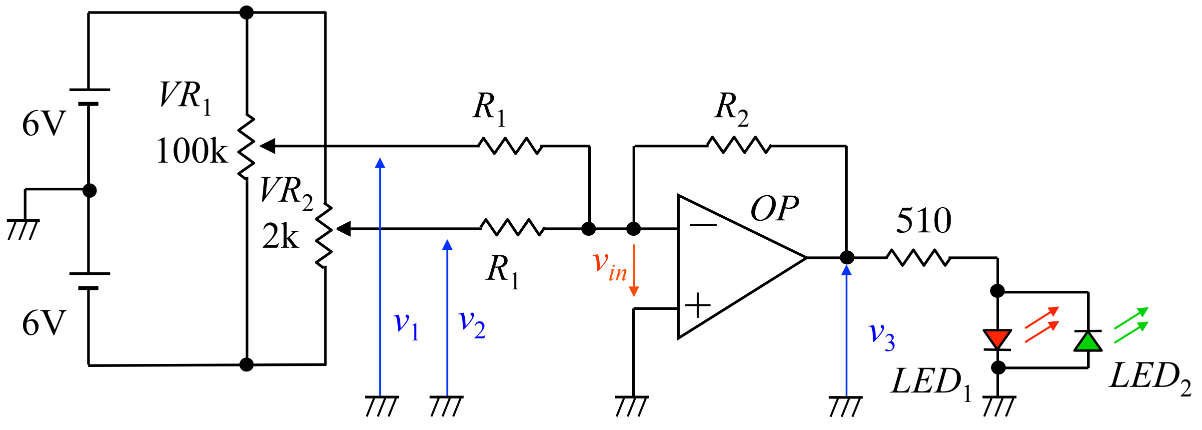
(b) Increased input voltage

(c) Toward virtual short

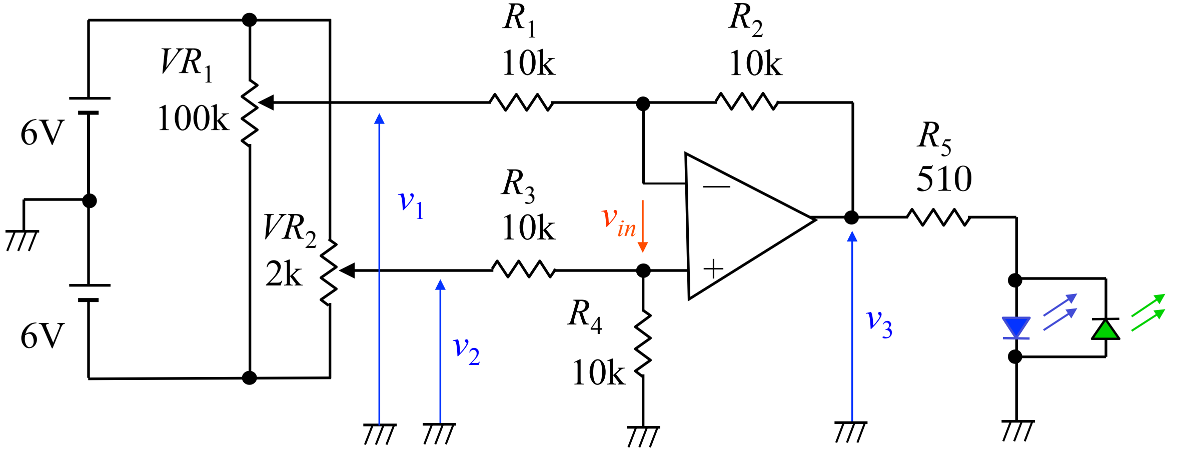
Image of virtual short

Ref. Summing amplifier

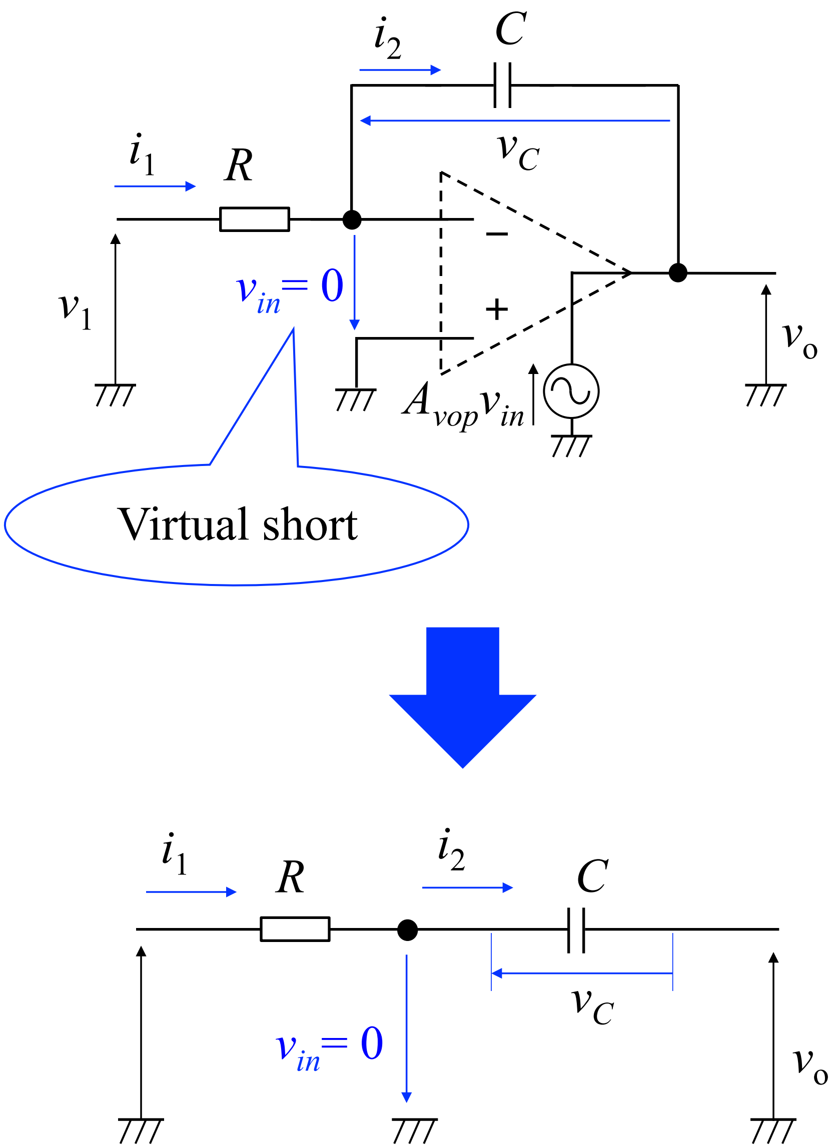
Output voltage of this circuit is given by $v_3 = -k(v_1 + v_2)$, where $k = R_2 / R_1$.



Ref. Differential amplifier $v_3 = -(v_1 - v_2)$



Integrator circuit



$$i_1 = \frac{v_1}{R_1}$$

$$i_1 = i_2$$

$$v_o = -v_C$$
$$= -\frac{1}{C}\int i_2 \, dt$$
$$= -\frac{1}{RC}\int v_1 \, dt$$

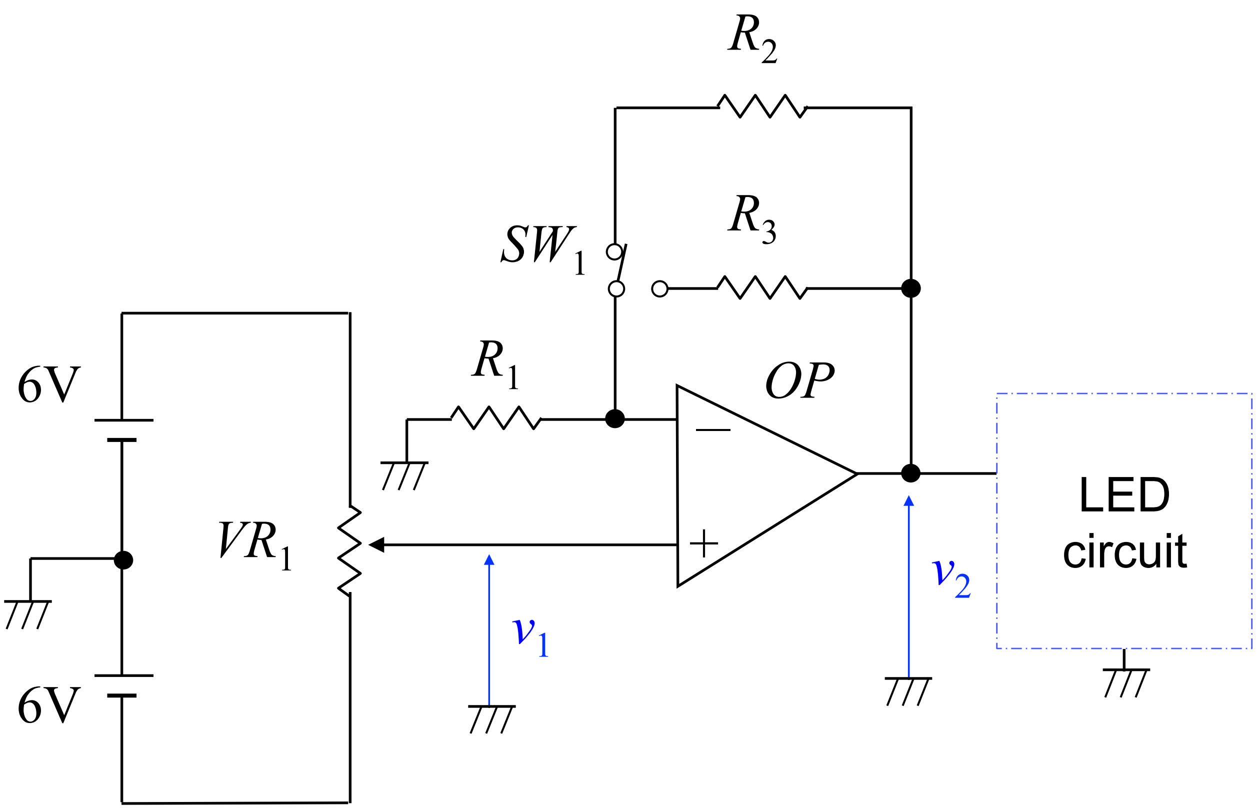
Step 6. Circuit construction practice

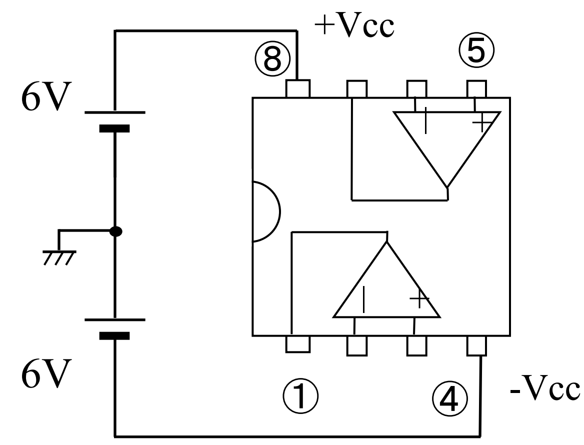
The circuit below is a non-inverting amplifier circuit.

(1) Obtain $A_v = v_2/v_1$, where switch SW_1 is on the R_2 side.

(2) Design the resistor values so that $A_v = 2$ and 11 by switching R_2 and R_3.

(3) Construct the circuit.

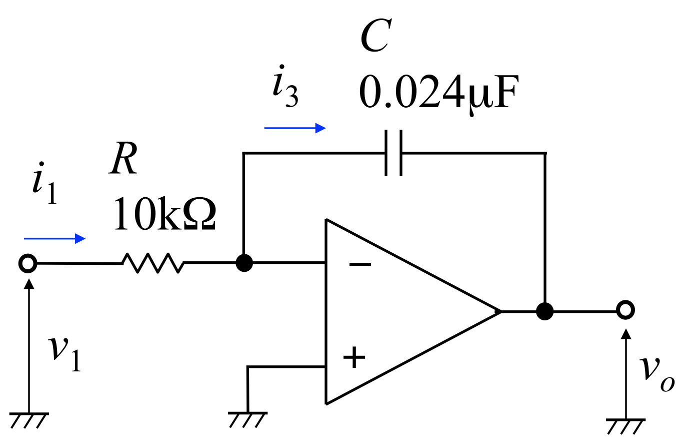




Voltage source connection to op-amp

Step 6. Problem（Integrator circuit）

Draw waveform of output voltage v_o when input voltage v_1 is given by the figure below (i.e., a triangular waveform with peak voltage V_{tp} = 1[V] and repetition frequency f = 1 [kHz]), where C = 0.024 [μF] and R=10[kΩ].



Integrator circuit