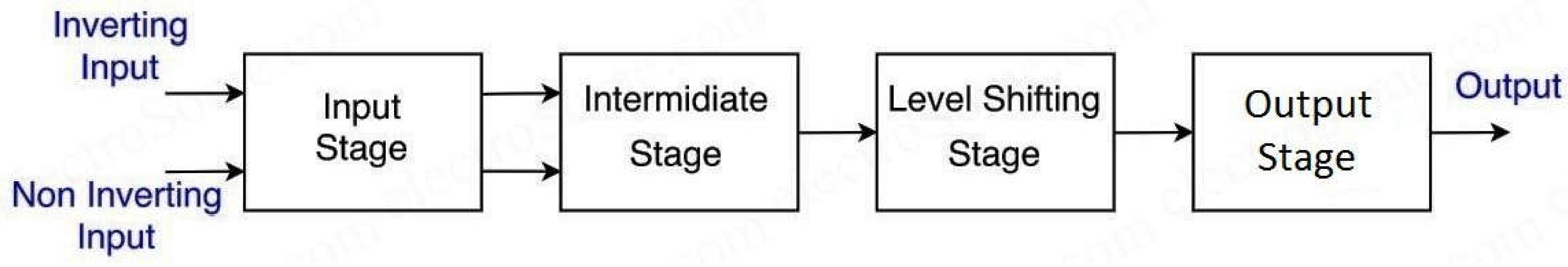
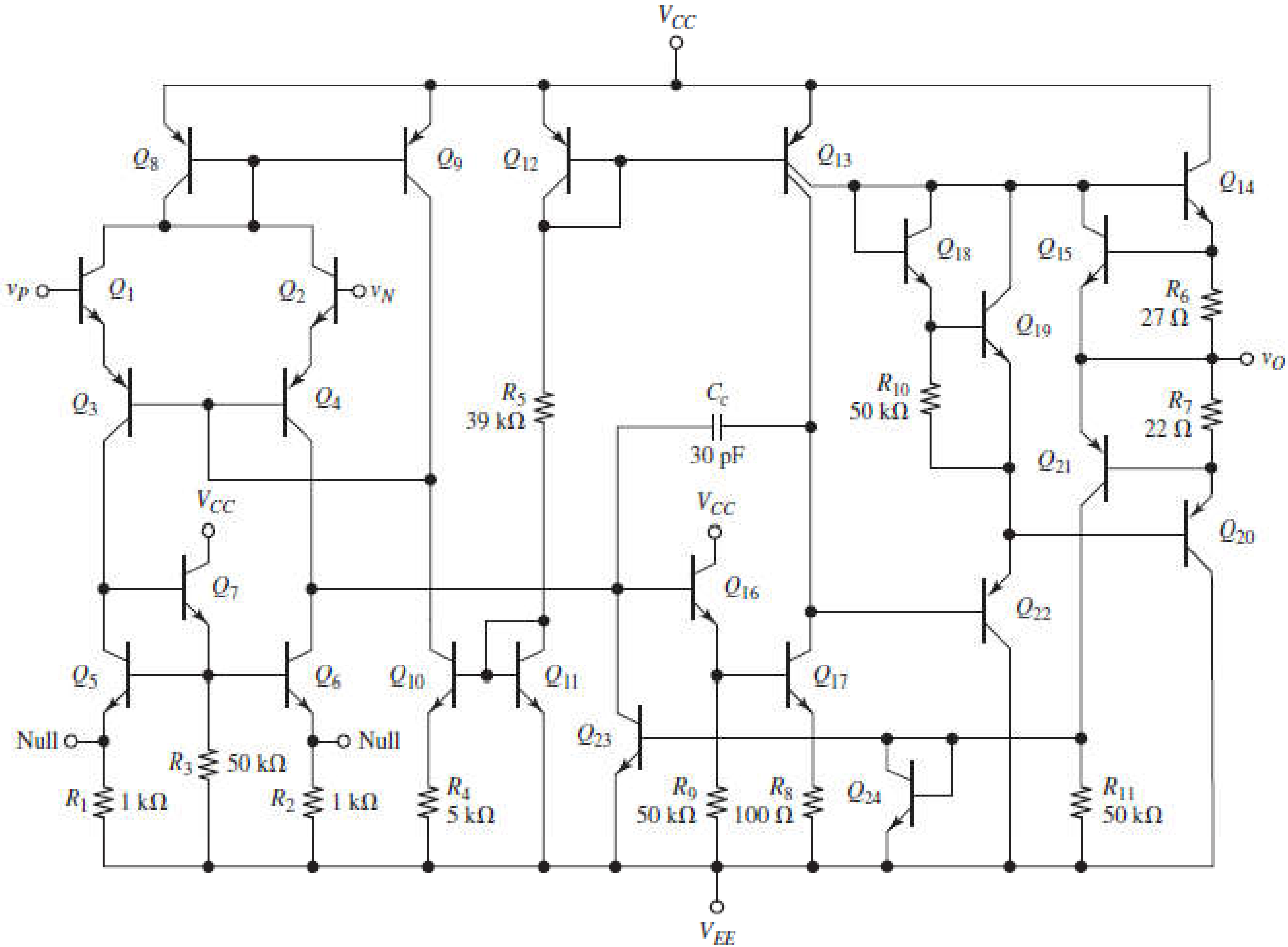
# Opamp

# Opamp Block Diagram

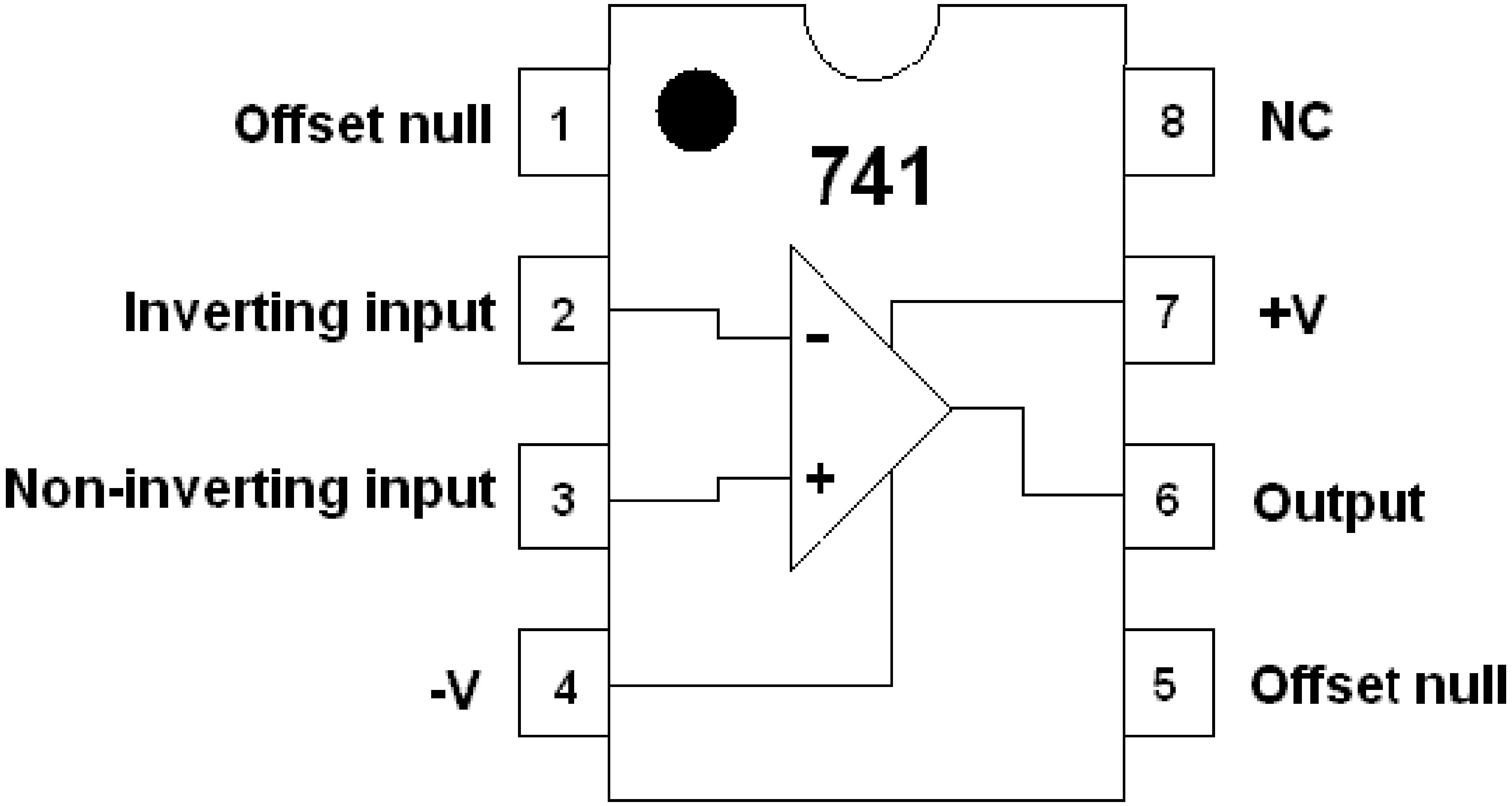


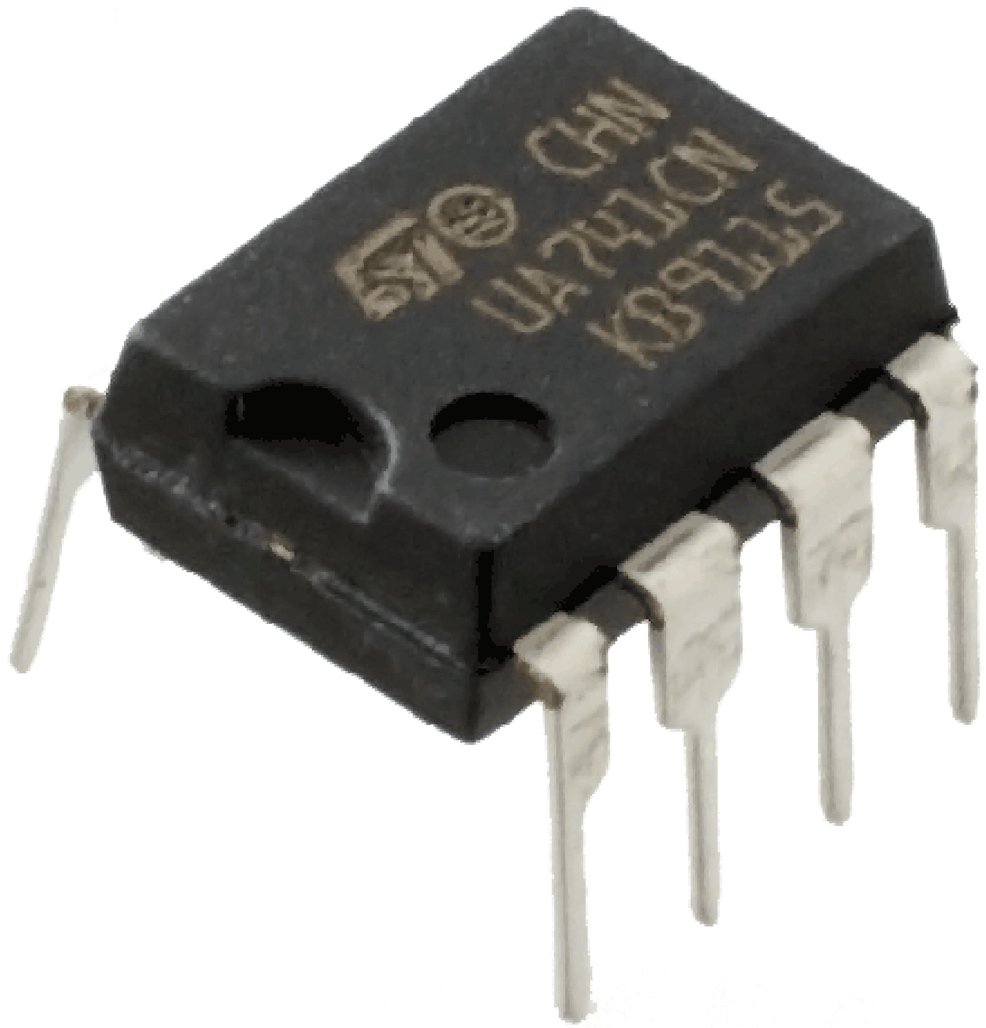

- An op amp is an active circuit element designed to perform mathematical operations of addition, subtraction, multiplication, division, differentiation, and integration, etc.



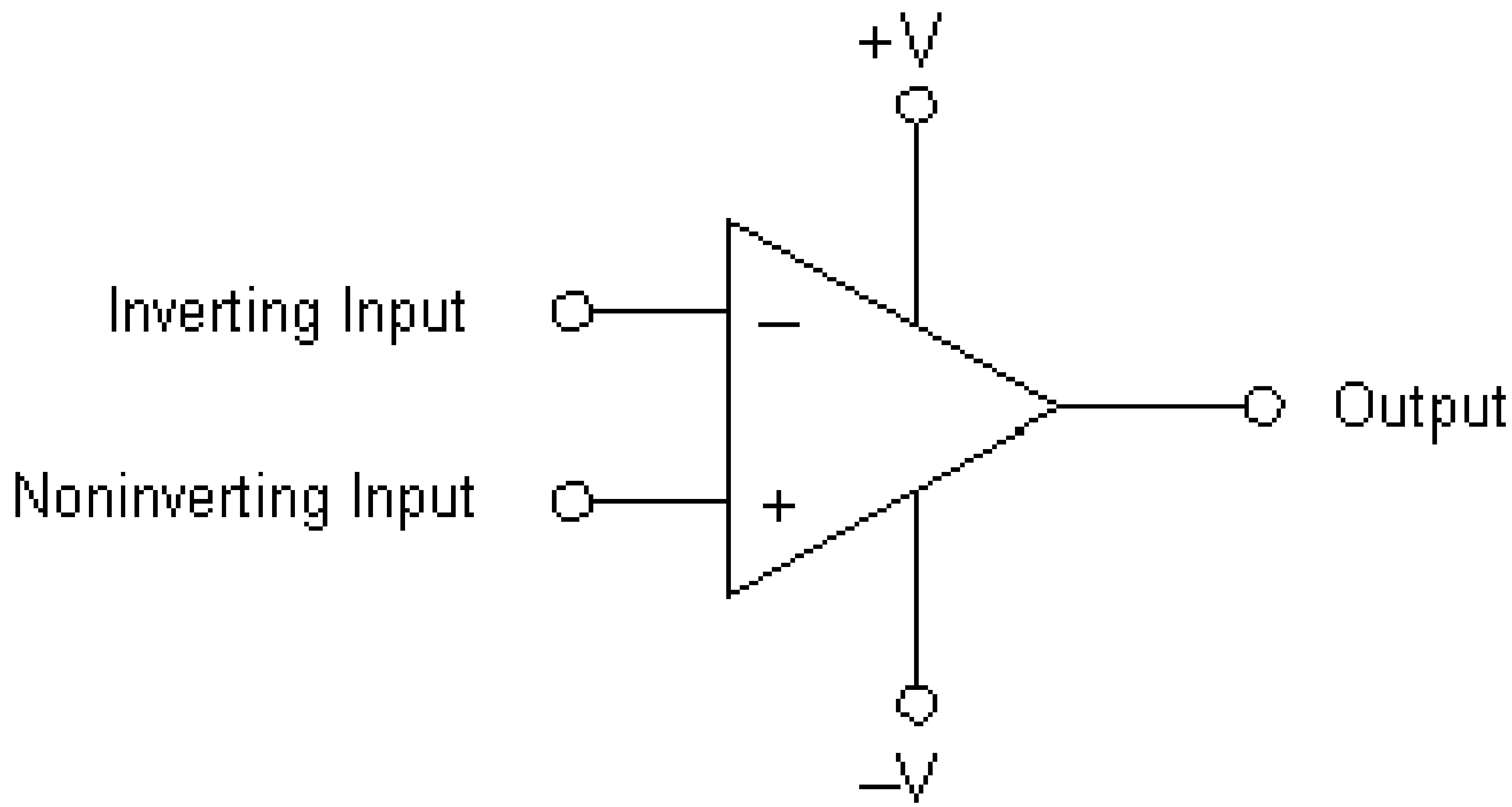
$V_{CC}$
$Q_8$
$Q_9$
$Q_{12}$
$Q_{13}$
$Q_{14}$
$v_P$
$Q_1$
$Q_2$
$v_N$
$Q_{18}$
$Q_{15}$
$R_6$
27 Ω
$Q_{19}$
$v_O$
$Q_3$
$Q_4$
$R_5$
39 kΩ
$C_c$
30 pF
$R_{10}$
50 kΩ
$R_7$
22 Ω
$Q_{21}$
$V_{CC}$
$V_{CC}$
$Q_{20}$
$Q_7$
$Q_{16}$
$Q_{22}$
$Q_5$
$Q_6$
$Q_{10}$
$Q_{11}$
$Q_{17}$
$Q_{23}$
Null
Null
$R_3$ 50 kΩ
$R_1$ 1 kΩ
$R_2$ 1 kΩ
$R_4$
5 kΩ
$R_9$
50 kΩ
$R_8$
100 Ω
$Q_{24}$
$R_{11}$
50 kΩ
$V_{EE}$

# 741 Package and Pin Details



# Schematic Symbol



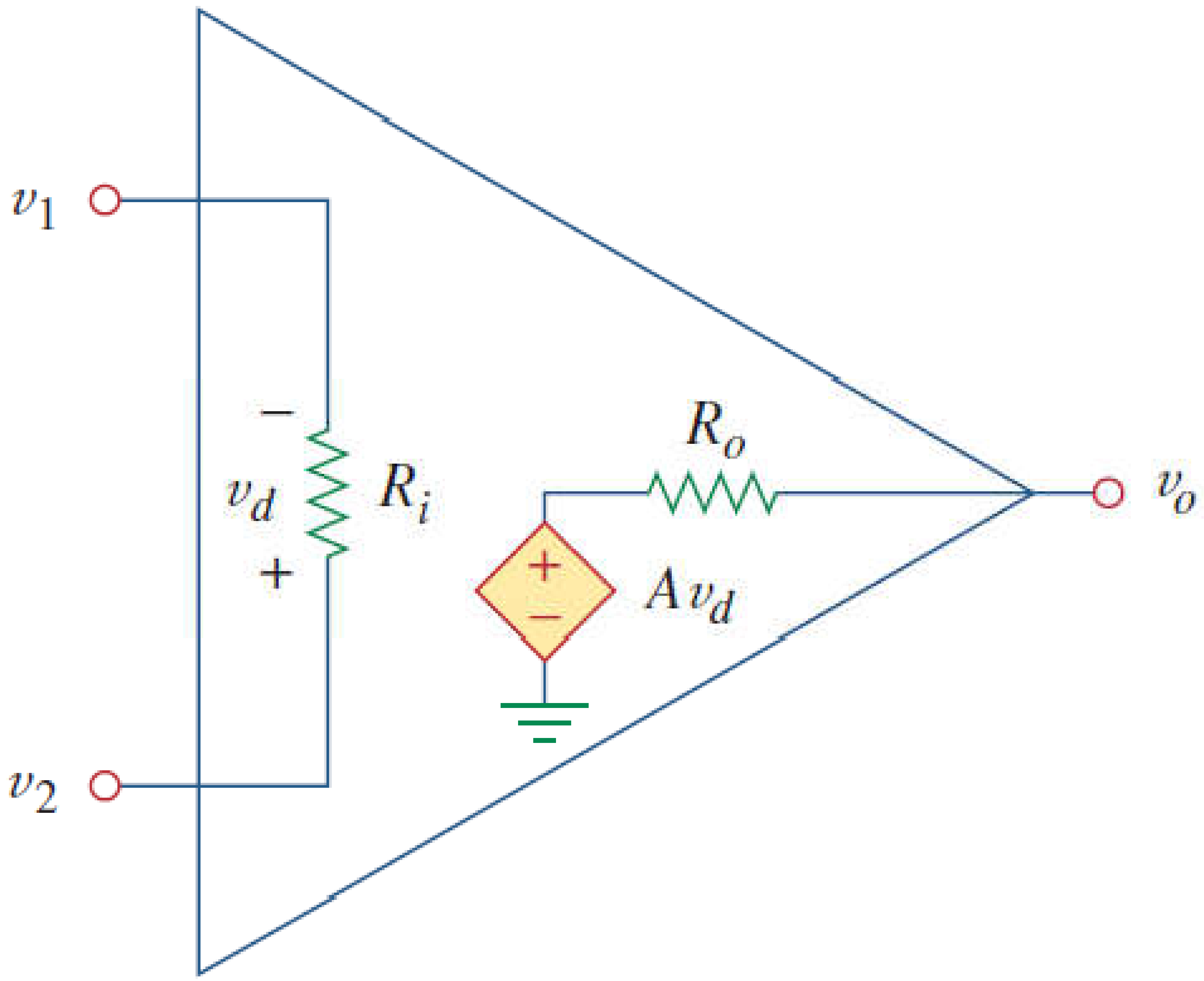
# An Ideal Op-Amp

- Infinite open loop gain
- Infinite input impedance
- Zero output impedance
- Infinite bandwidth
- Infinite CMRR

# Ideal versus Real Op-Amp

| Parameter | Ideal Op-Amp | Real Op-Amp |
|---|---|---|
| Differential Voltage Gain | $\infty$ | $10^5$ - $10^9$ |
| Gain Bandwidth Product (Hz) | $\infty$ | 1-20 MHz |
| Input Resistance (R) | $\infty$ | $10^6$ - $10^{12}$ Ω |
| Output Resistance (R) | 0 | 100 - 1000 Ω |

# Equivalent Circuit
# Non – Ideal Opamp



# Basics of an Op-Amp Circuit

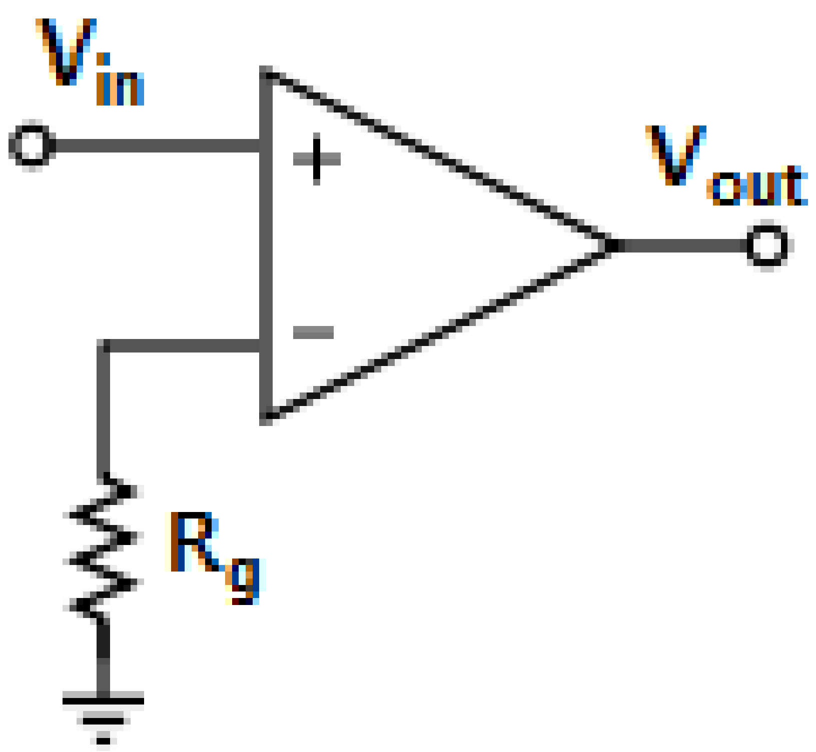
- An op-amp amplifies the difference of the inputs $V_+$ and $V_-$ (known as the differential input voltage)
- This is the equation for an *open loop* gain amplifier:

$$V_{out}=A(V_+-V_-)$$

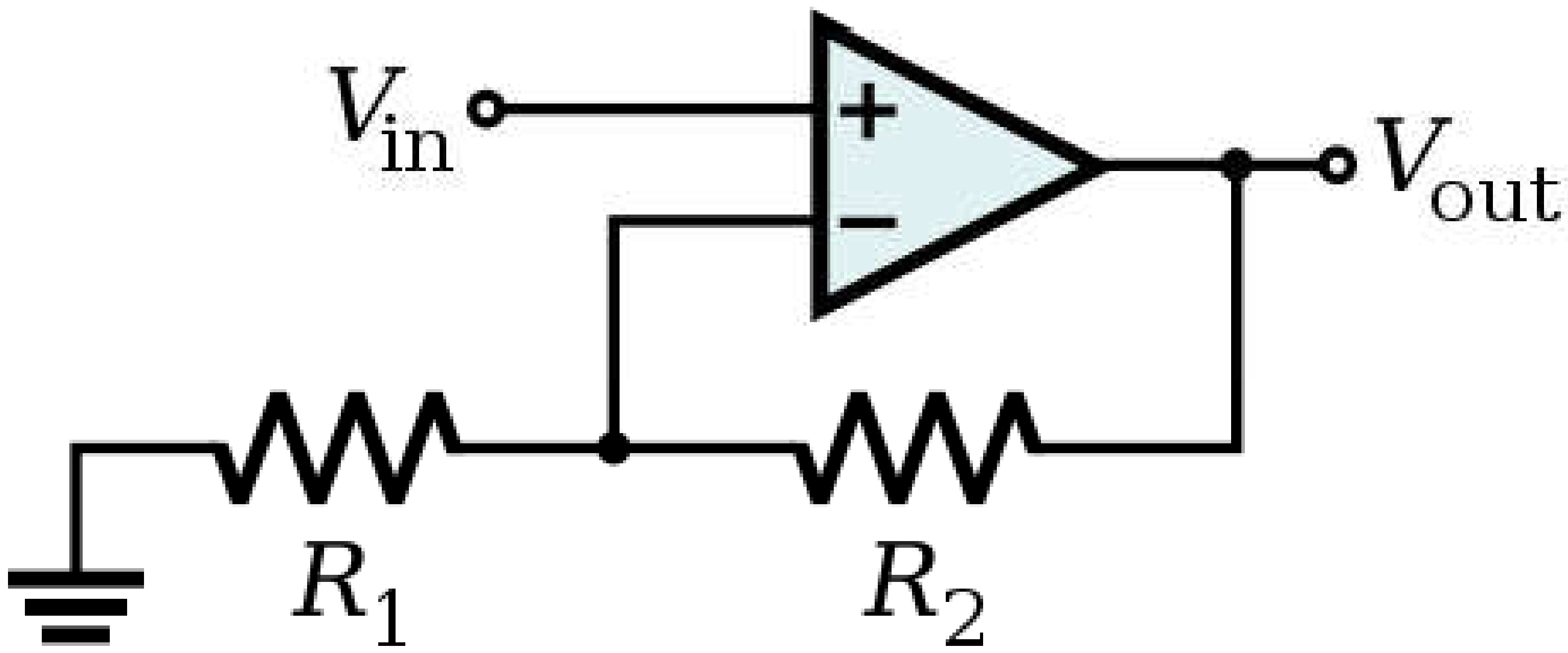
- K is typically very large – at around 10,000 or more for IC Op-Amps
- This equation is the basis for all the types of amps we will be discussing

# Open Loop vs Closed Loop

- A closed loop op-amp has feedback from the output to the input, an open loop op-amp does not




Open Loop

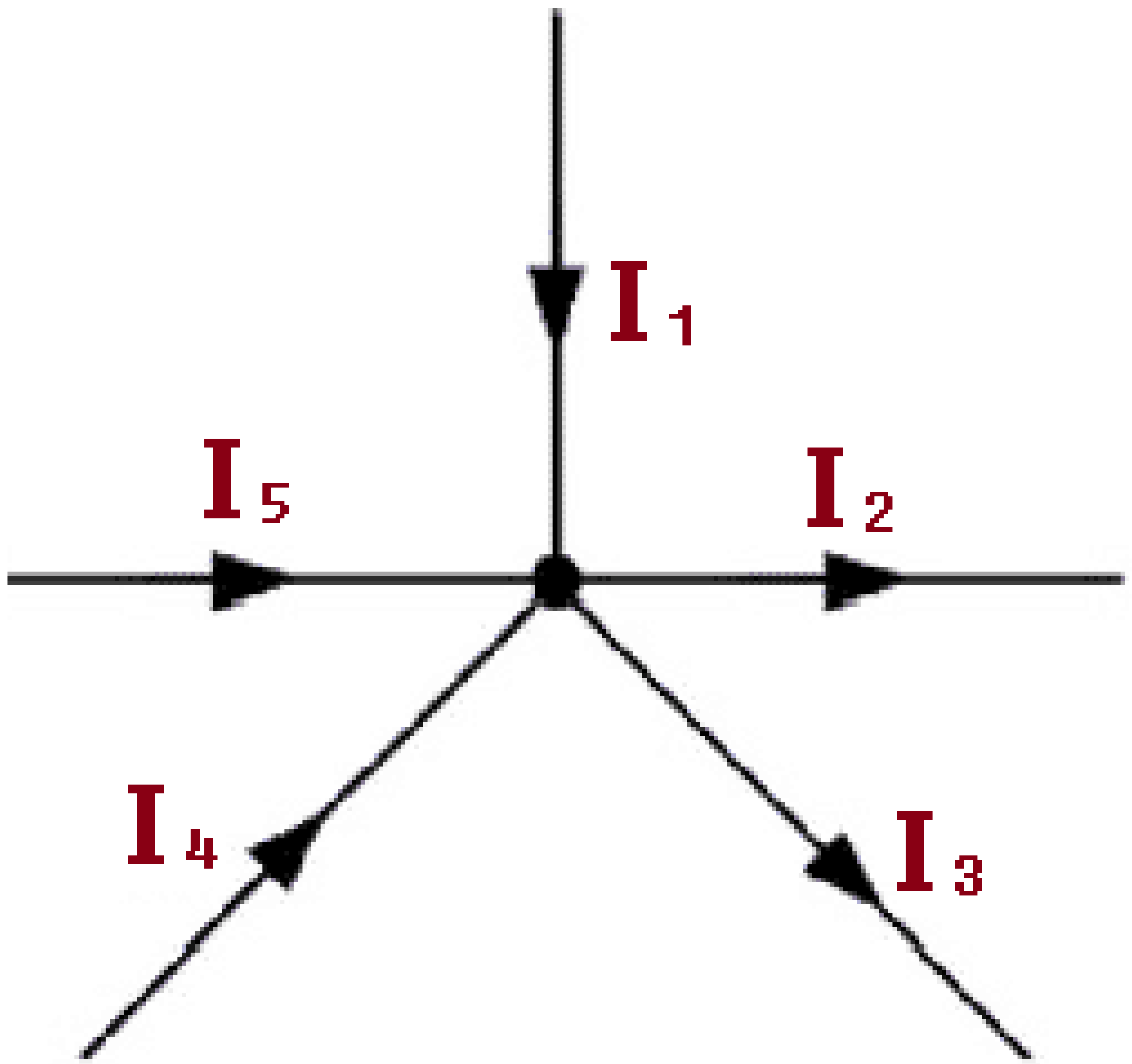



Closed Loop

# Analysis Steps

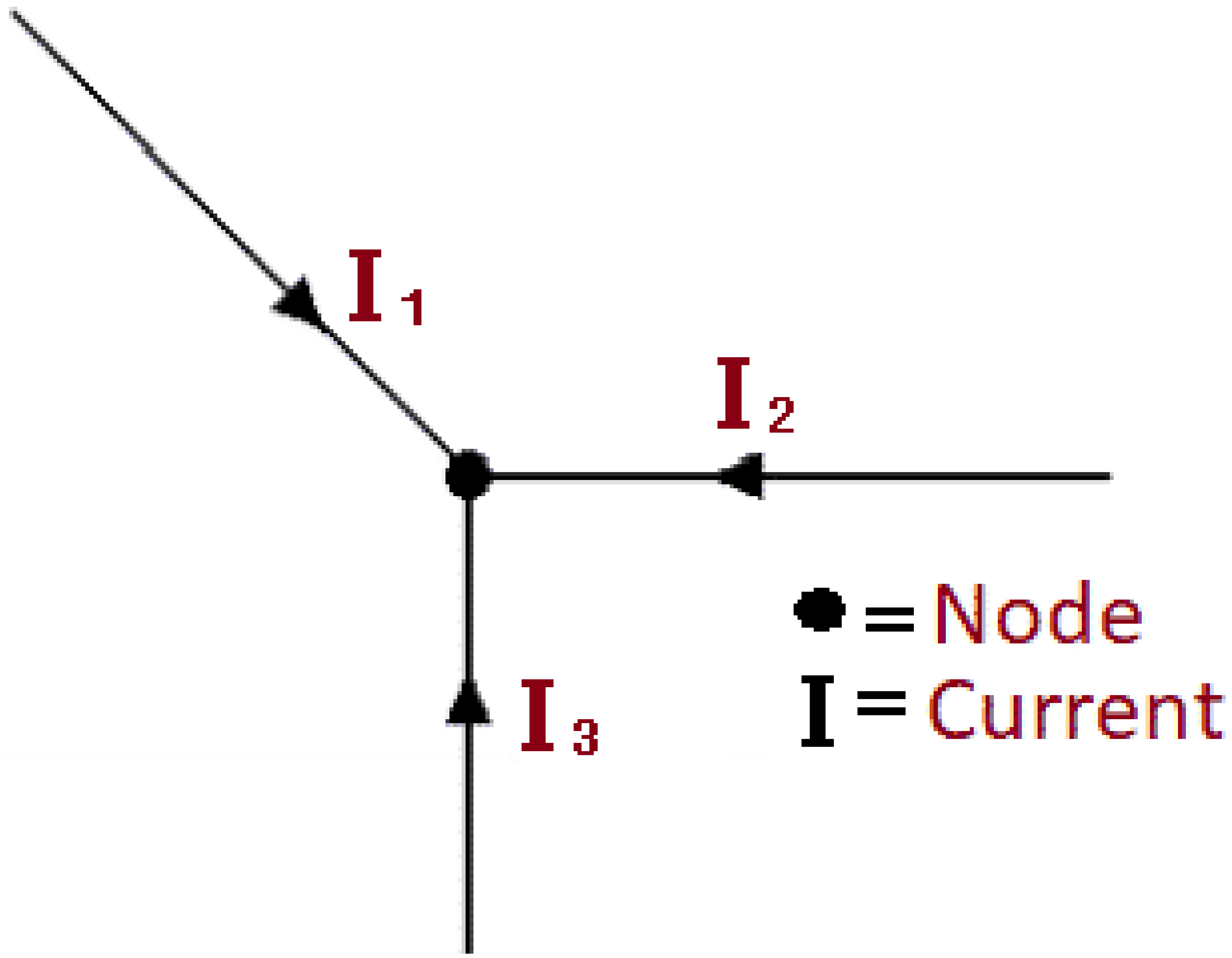
- **Ideal Opamp**
  - Opamp does not accepts any input current
  - Voltage at inverting Terminal = Voltage at non-inverting terminal.
  - Apply KCL at the input nodes.
  - No KCL at the output nodes (Reason ?)

# KCL




$I_1-I_2-I_3+I_4+I_5=0$

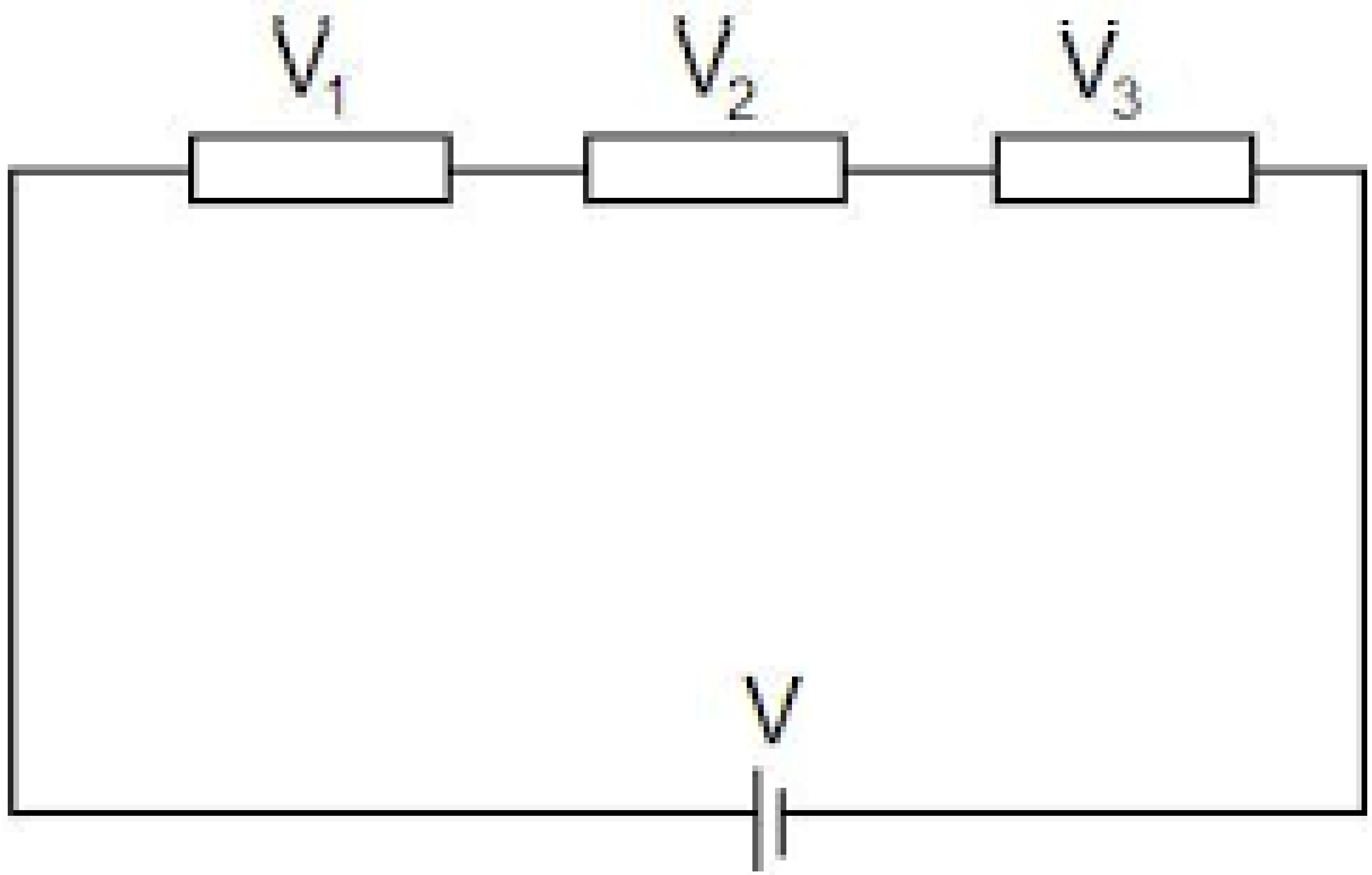
(a)




$I_1+I_2+I_3 =0$

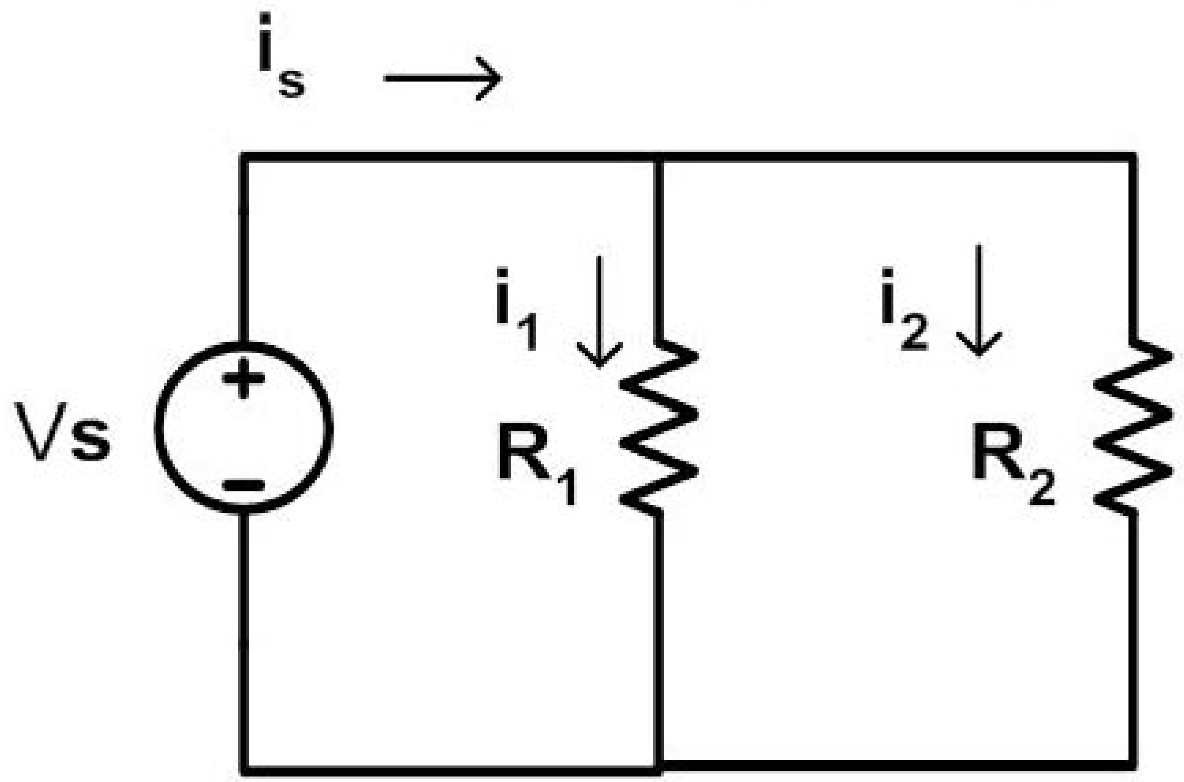
(b)

# KVL



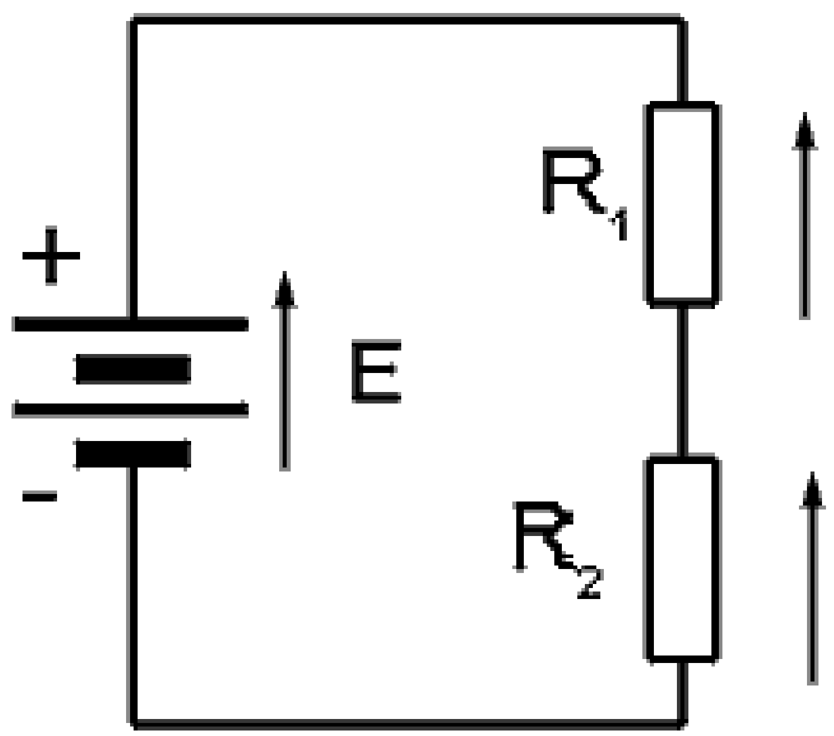

$$V = V_1 + V_2 + V_3$$

# Current Division & Voltage Division




$$i_1 = \frac{R_2}{R_1 + R_2} i_s$$

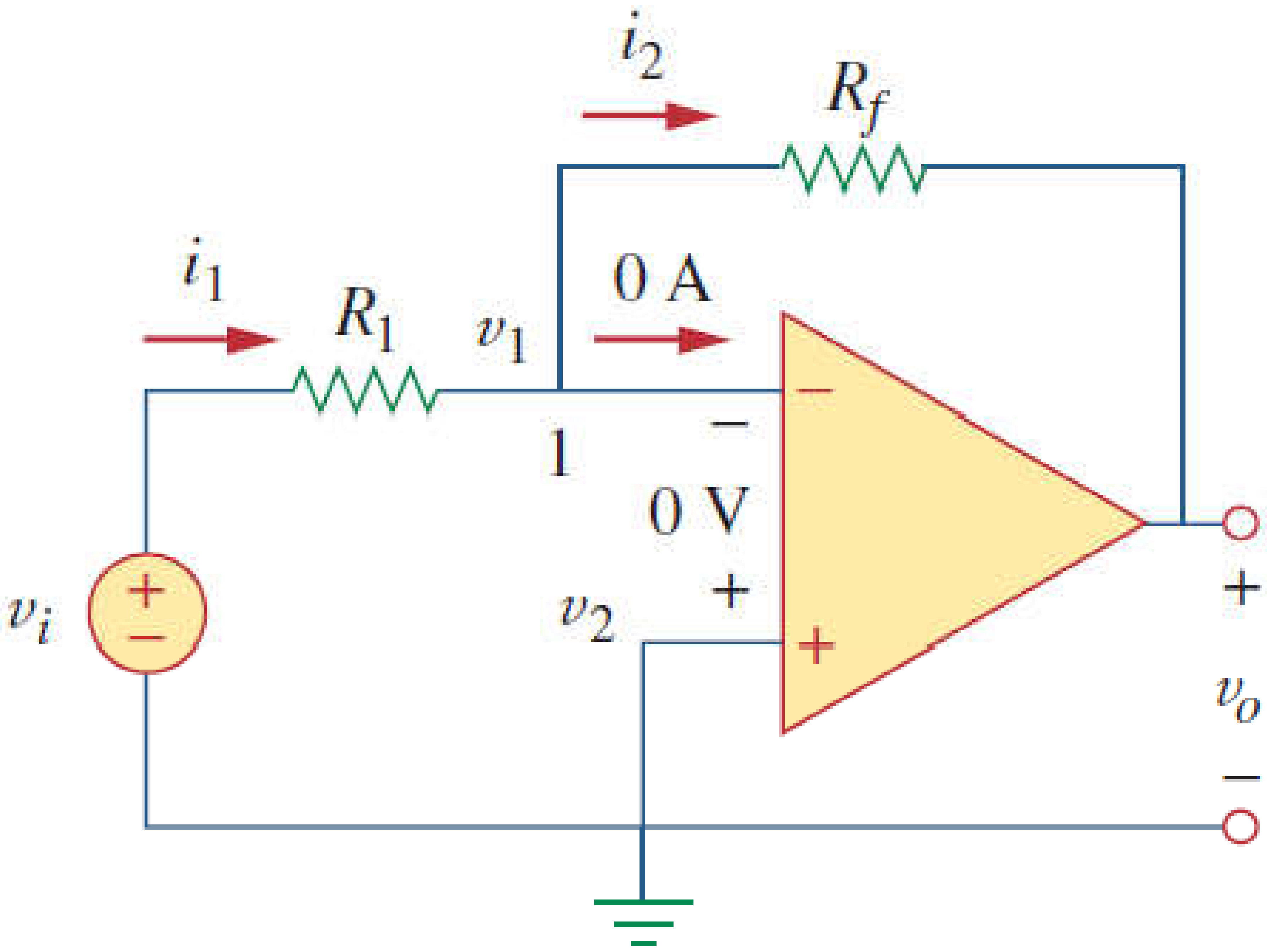
$$i_2 = \frac{R_1}{R_1 + R_2} i_s$$




$$V_{R1} = E\frac{R_1}{(R_1 + R_2)}$$

$$V_{R2} = E\frac{R_2}{(R_1 + R_2)}$$

# Inverting Amplifier



# Gain Equation

$$i_1 = i_2 \quad \Rightarrow \quad \frac{v_i - v_1}{R_1} = \frac{v_1 - v_o}{R_f}$$

$$v_o = -\frac{R_f}{R_1} v_i$$

To Be Continued…