Alexander-Sadiku

Fundamentals of Electric Circuits

Chapter 5

Operational Amplifier

Topics.

1. Op - Amp (Operational Amplifier)
2. femicmductor physic
3. Diode
4. Diode Application
5. Transistor
6. App. Tran.

Email. 『อาจารย์อำนาจ ขาวเนฺ』
kkamnach@hotmail.com (แบบไม่ทางการ)
amnach.kh@kmitl.ac.th

ปริมาณทางคณิตศาสตร์ : $\oplus, \ominus, \otimes, \oslash, \frac{dy}{dx}, \int$

ขยายสัญญาณ

Operational Amplifier - Chapter 5

กระแสไฟจะไหลจาก + ไป - คือกระแสของ hole
e- หลุดไปจะเป็น free e- เหมือ hole e- ไหลจาก -ไป +

5.1 What is an Op Amp?

5.2 Ideal Op Amp

5.3 Configuration of Op Amp

5.4 Cascaded Op Amp

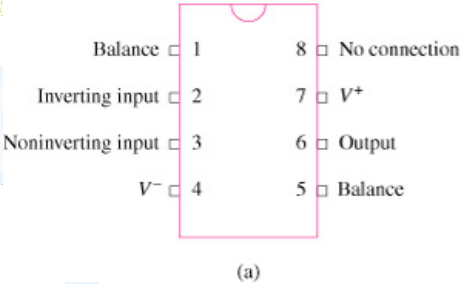
5.5 Application

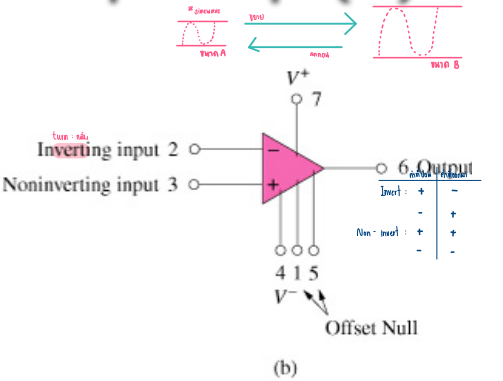
– Digital-to Analog Converter

5.1 What is an Op Amp (1)

- It is an electronic unit that behaves like a voltage-controlled voltage source. : VCVS
- It is an active circuit element designed to perform mathematical operations of ***addition***, ***subtraction***, ***multiplication***, ***division***, ***differentiation*** and ***integration***.
- The ability of the op amp to perform these mathematical operations is the reason it is called an operational amplifier. It is also the reason for the widespread use of op amps in analog design.

5.1 What is an Op Amp (2)

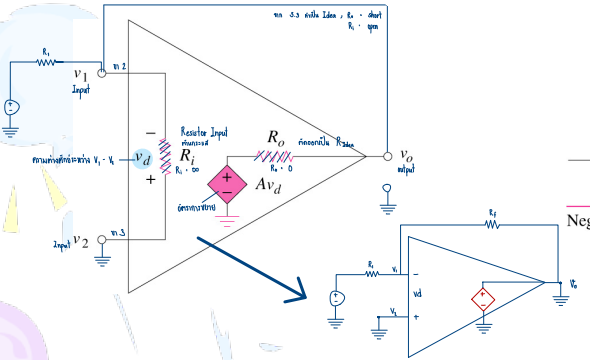




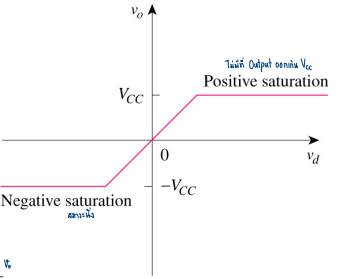
A typical op amp: (a) pin configuration, (b) circuit symbol

5.1 What is an Op Amp (3)

The equivalent circuit Of the non-ideal op amp



Op Amp output: vo as a function of Vd



$$vd = v2 - v1; \quad vo = Avd = A(v2 - v1)$$

5.1 What is an Op Amp (4)

Typical ranges for op amp parameters

Parameter	Typical range	Ideal values
Open-loop gain, A	105 to 108 Ω	∞
Input resistance, Ri	105 to 1013 Ω	∞ Ω
Output resistance, Ro	10 to 100 Ω	0 Ω
Supply voltage, VCC	5 to 24 V Ω	

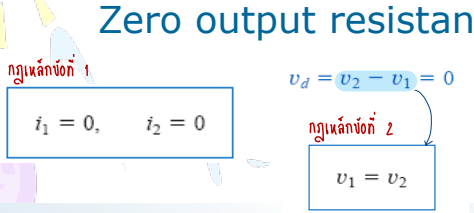
5.2 Ideal Op Amp (1)

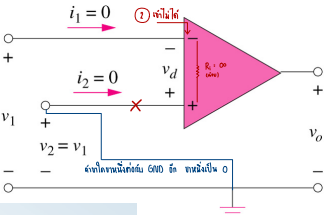
An ideal op amp has the following characteristics:

Infinite open-loop gain, A ≈ ∞

Infinite input resistance, Ri ≈ ∞

Zero output resistance, Ro ≈ 0



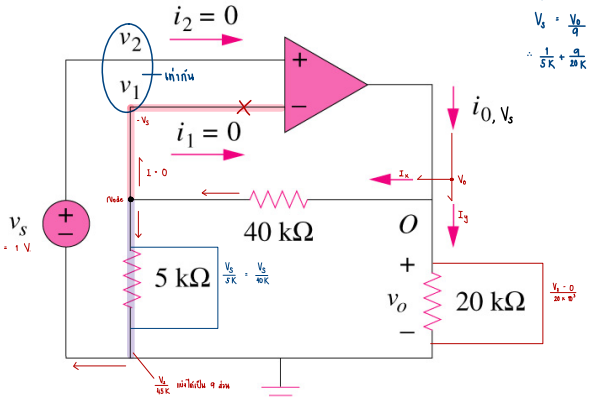


An **ideal op amp** is an amplifier with infinite open-loop gain, infinite input resistance, and zero output resistance.

5.2 Ideal Op Amp (2)

Example 1:

Determine the value of *io.*

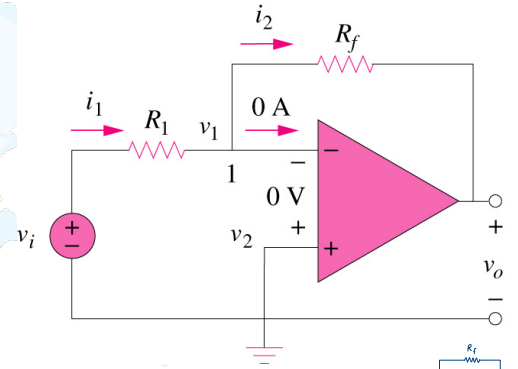


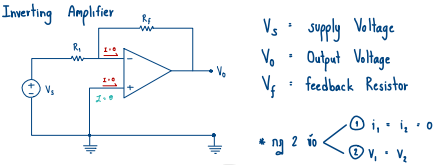
*Refer to in-class illustration, textbook

Ans: 0.65mA

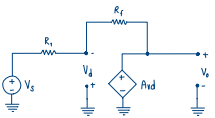
5.3 Configuration of Op amp (1)

- Inverting amplifier reverses the polarity of the input signal while amplifying it

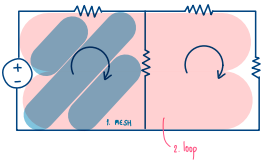


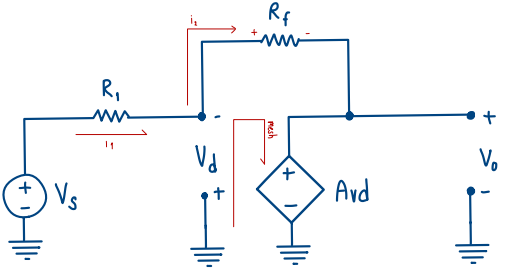


$$v_o = -\frac{R_f}{R_1} v_i$$



* Mesh Analysis : สรุปที่ไม่มีอะไรในสรุป





$$+V_d + i_2R_f + A_{vd} = 0 \quad *$$

ให้ $i_1 = i_2$ แทนค่า i_1 และ i_2 ในเทอมของแรงดัน

$$i_1 = \frac{V_s - V_d}{R_1} \; ; \; i_2 = \frac{V_d - V_o}{R_f}$$

$$\frac{V_s - V_d}{R_1} = \frac{V_d - V_o}{R_f}$$

$$\frac{V_s}{R_1} = \frac{-V_o}{R_f}$$

$$V_s = \frac{-R_1}{R_f} \cdot V_o$$

$$\boxed{\frac{V_o}{V_s} = \frac{-R_f}{R_1}} \quad *$$

$$V_o = \frac{-R_f}{R_1} \cdot V_s$$

กลับเฟส — Input Voltage

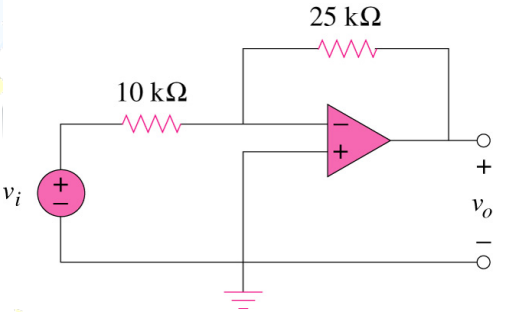
A : $\uparrow R_1$ ขยายน้อย, $\downarrow R_1$ ขยายมาก

Homework.

5.3 Configuration of Op amp (2)

Example 2

Refer to the op amp below. If vi = 0.5V, calculate: (a) the output voltage, vo and (b) the current in the 10kΩ resistor.



*Refer to in-class illustration, textbook

(a) $V_o = -\frac{R_f}{R_1} \cdot V_i$

$= -\frac{2.5}{10} \cdot 0.5$

$= -1.25$

(b) $I = \frac{V}{R}$

$= \frac{0.5\ V}{10K\ \Omega}$

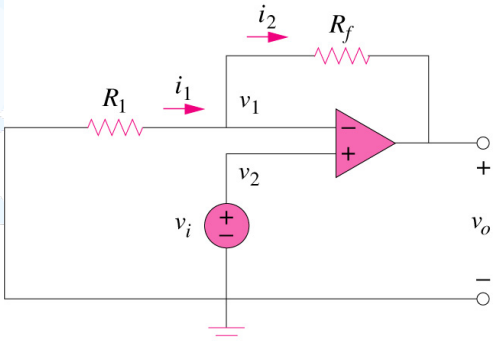
$= 50\ \mu A$

Ans:

(a) -1.25V; (b) 50μA

5.3 Configuration of Op amp (3)

- Non-inverting amplifier is designed to produce positive voltage gain

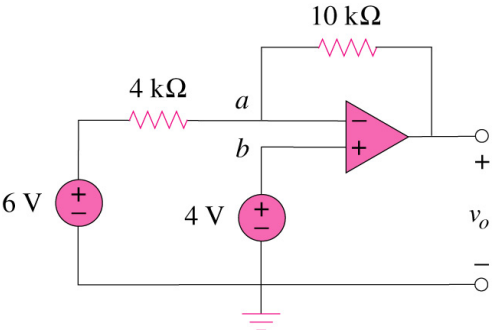


$$v_o = \left(1 + \frac{R_f}{R_1}\right)$$

5.3 Configuration of Op amp (4)

Example 3

For the op amp shown below, calculate the output voltage *vo*.

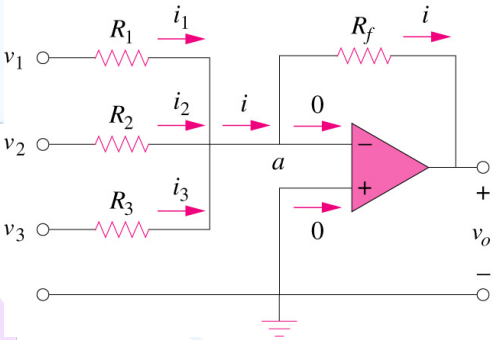


*Refer to in-class illustration, textbook

Ans: -1V

5.3 Configuration of Op amp (5)

- Summing Amplifier is an op amp circuit that combines several inputs and produces an output that is the weighted sum of the inputs.

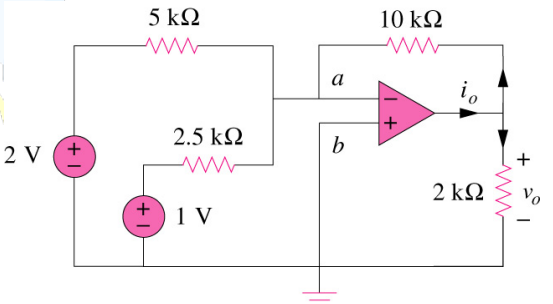


$$v_o = -\left(\frac{R_f}{R_1}v_1 + \frac{R_f}{R_2}v_2 + \frac{R_f}{R_3}v_3\right)$$

5.3 Configuration of Op amp (6)

Example 4

Calculate *vo* and *io* in the op amp circuit shown below.

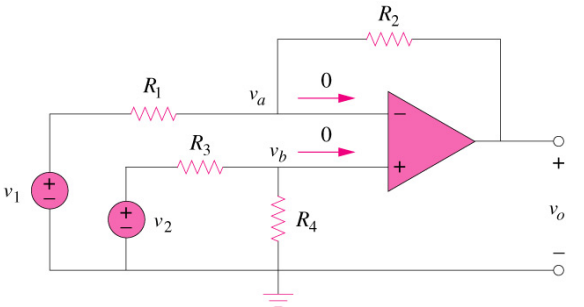


*Refer to in-class illustration, textbook

Ans: -8V, -4.8mA

5.3 Configuration of Op amp (7)

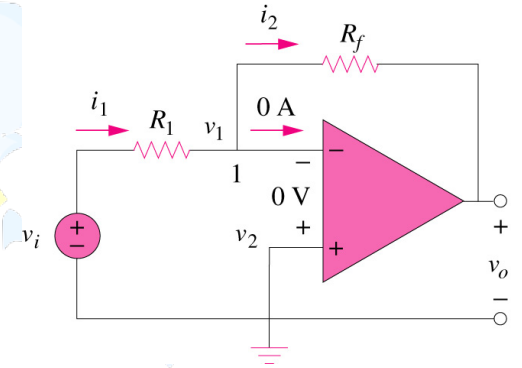
- Difference amplifier is a device that amplifies the difference between two inputs but rejects any signals common to the two inputs.



$$v_o = \frac{R_2(1+R_1/R_2)}{R_1(1+R_3/R_4)}v_2 - \frac{R_2}{R_1}v_1 \Rightarrow v_o = v_2 - v_1 \text{, if } \frac{R_2}{R_1} = \frac{R_3}{R_4} = 1$$

5.3 Configuration of Op amp (1)

- Inverting amplifier reverses the polarity of the input signal while amplifying it

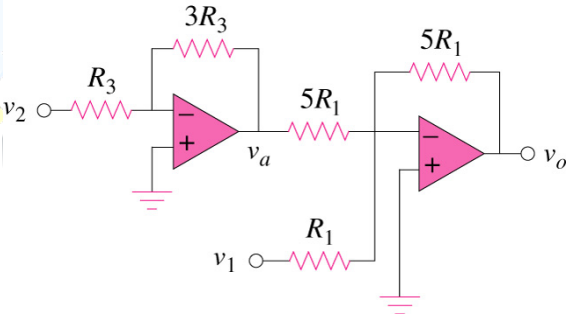


$$v_o = -\frac{R_f}{R_1} v_i$$

5.3 Configuration of Op amp (6)

Example 5

Determine R1, R2, R3 and R4 so that vo = -5v1+3v2 for the circuit shown below.



Ans:

R1 = 10kΩ

R2 = 50kΩ

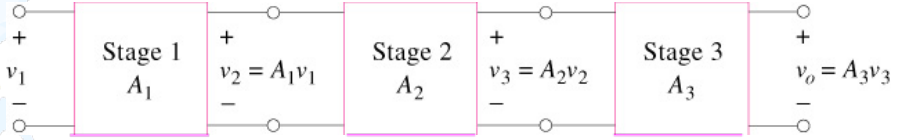
R3 = 20kΩ

R4 = 20kΩ

*Refer to in-class illustration, textbook

5.4 Cascaded Op Amp (1)

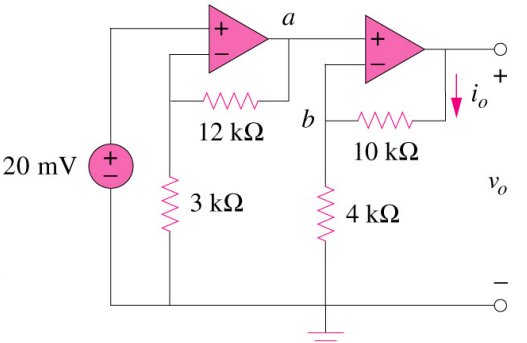
- It is a head-to-tail arrangement of two or more op amp circuits such that the output to one is the input of the next.



5.4 Cascaded Op Amp (2)

Example 6

Find vo and io in the circuit shown below.



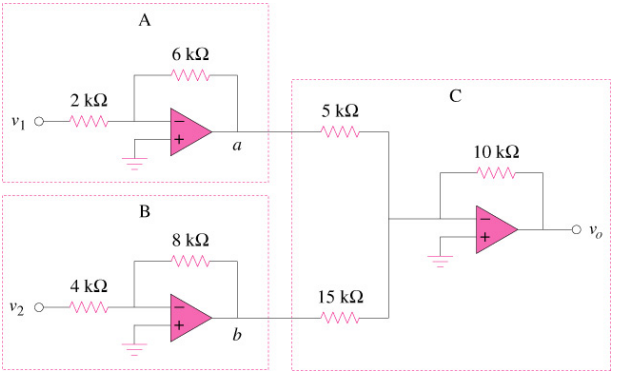
*Refer to in-class illustration, textbook

Ans: 350mV, 25μA

5.4 Cascaded Op Amp (3)

Example 7

If v1 = 1V and v2 = 2V, find vo in the op amp circuit shown below.



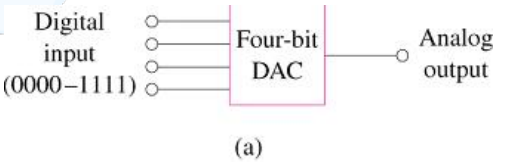
*Refer to in-class illustration, textbook

Ans: 8.667 V

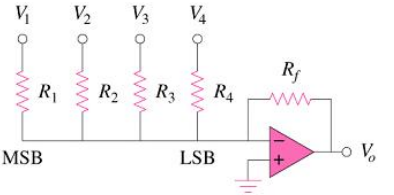
5.5 Application (1)

- Digital-to Analog Converter (DAC) : it is a device which transforms digital signals into analog form.

Four-bit DCA: (a) block diagram (b) binary weighted ladder type



(a)



(b)

$$-V_0 = \frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3 + \frac{R_f}{R_4}V_4$$

where

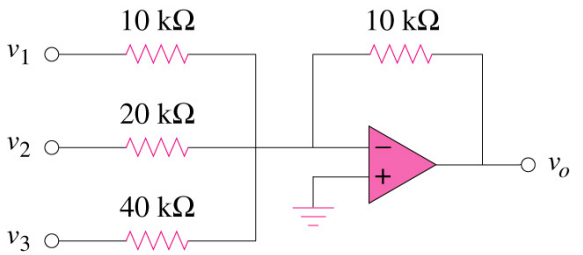
V1 – MSB, V4 – LSB

V1 to V4 are either 0 or 1 V

5.5 Application(2)

Example 8

For the circuit shown below, calculate vo if v1= 0V,v2=1V and v3 = 1V.



*Refer to in-class illustration, textbook

Ans:-0.75V