Example

$V_+ = V_-$

$i_+ = i_- = 0$

D9.1. Find the value of I_o in the network of Figure D9.1; assume an ideal op amp.

property of ideal amp.

$V_- = V_+ = 12V$

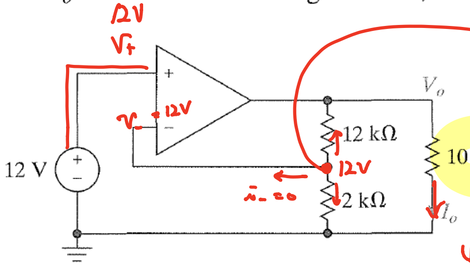


FIGURE D9.1

load register

KCL at node

$$\frac{12 - V_o}{12k} + \frac{12}{2k} + 0 = 0$$

$$12 - V_o + 6 \cdot 12 = 0$$

$$\boxed{V_o = 84V.}$$

$$I_o = \frac{84}{10k} = 8.4mA$$

Ans: $I_o = 8.4$ mA.

Example

D9.2 Figure D9.2 is a differential voltage amplifier, often called an instrumentation amplifier, which has a high input resistance, and therefore more appropriate for applications with a high source resistance (like the medical applications previously mentioned). It is also commonly used to measure sensor outputs from bridge circuits. Assuming ideal op amps; what is an expression for the output voltage in terms of the two inputs?

At node A

KCL

① $\frac{V_1 - V_o'}{R_1} + \frac{V_1 - V_2}{R_G} + \frac{V_1 - V_o}{R_2} + 0 = 0$

At node B

② $\frac{V_2}{R_2} + \frac{V_2 - V_1}{R_G} + \frac{V_2 - V_o'}{R_1} = 0$

①-②을 하면

$$\frac{V_1}{R_1} + \frac{1}{R_G}(V_1 - V_2) + \frac{V_1}{R_2} - \frac{V_2}{R_2} - \frac{1}{R_G}(V_2 - V_1) - \frac{V_2}{R_1} = \frac{V_o}{R_2}$$

$$\frac{1}{R_1}(V_1 - V_2) + \frac{2}{R_G}\cdot(V_1 - V_2) + \frac{1}{R_2}(V_1 - V_2) = \frac{V_o}{R_2}$$

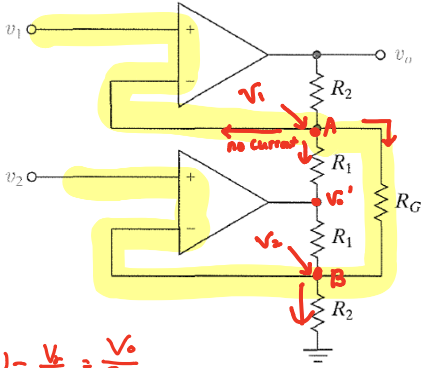


FIGURE D9.2

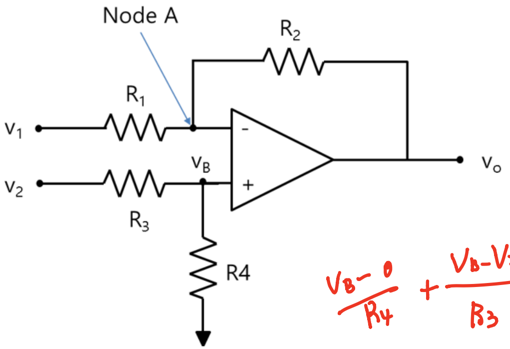
Ans:

$$v_o = (v_1 - v_2)\left[1 + \frac{R_2}{R_1} + \frac{2R_2}{R_G}\right]$$

Example

- Ex1

(10 points) Consider the following circuit including an ideal operational amplifier.



$$\frac{V_B - 0}{R_4} + \frac{V_B - V_2}{R_3} + 0 = 0$$

$$R_3(V_B) + R_4 \cdot (V_B - V_2) = 0$$

$$V_B(R_3 + R_4) = R_4 \cdot V_2$$

$$\boxed{V_B = \frac{R_4 \cdot V_2}{R_3 + R_4}}$$

(a) (4 points) Find v_B in terms of v_2, R_3, and R_4.

(b) (6 points) Apply KCL on node A and Find v_o in terms of v_1, v_2, R_1, R_2, R_3, and R_4.

$$\frac{V_A - V_o}{R_2} + \frac{V_A - V_1}{R_1} = 0 \xrightarrow{V_A = V_B} R_1 \cdot (V_A - V_o) + R_2(V_A - V_1) = 0$$

$$V_o = V_A + \frac{R_2 V_A}{R_1} - \frac{R_2 V_1}{R_1}$$

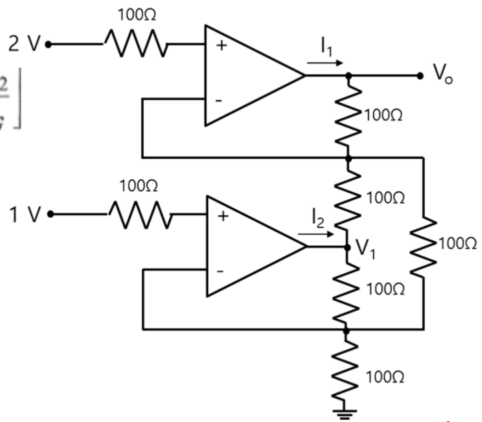
$$\boxed{V_o = \frac{R_4 \cdot R_2}{R_3 + R_4} + \frac{R_2 \cdot \frac{R_4 \cdot V_2}{R_3 + R_4}}{R_1} - \frac{R_2 \cdot V_1}{R_1}}$$

Example

- Ex2

$$v_o = (v_1 - v_2)\left[1 + \frac{R_2}{R_1} + \frac{2R_2}{R_G}\right]$$

(10 points) Consider the following circuit including an ideal operational amplifier.



$1+1+2$

$(2-1)\cdot 4$

$\frac{2}{100} = I_1$

$\frac{(1-2)}{100}$

(a) (4 points) Find V_o. and V_1. $V_o = 4V$ $V_1 = 1V$

(b) (3 points) Find I_1. $0.02A$

(c) (3 points) Find I_2. $-0.01A$

Example

9.14. For the circuit shown in Figure P9.14, assume the voltage source is given by $v_s = 0.1 \cos (2000\,t)\ V$.

(a) Write an expression for v_o, the output voltage across the load resistor, R_L?
(b) What is the maximum current through R_L?
(c) What is the maximum current from the output of the op amp?

$R_1 = 200\ \Omega$
$R_2 = 3.8\ \mathrm{k}\Omega$
$R_L = 2.0\ \mathrm{k}\Omega$

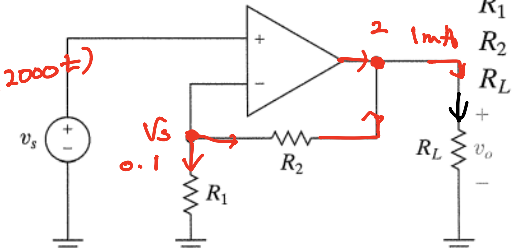


FIGURE P9.14

9.24. Determine the output voltage, v_o, across R_L in Figure P9.24, assuming an ideal op amp.

$R_1 = 1200\ \Omega$
$R_2 = 4200\ \Omega$
$R_L = 3000\ \Omega$

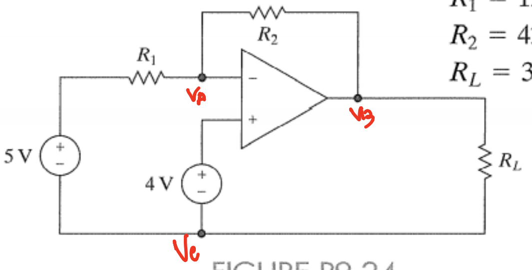


FIGURE P9.24

KCL

$$\frac{V_s}{R_1} + \frac{V_s - V_o}{R_2} = 0$$

(a) ∴ $V_o = \left(1+\frac{R_2}{R_1}\right)\cdot V_s = \left(1+\frac{3.8k}{200}\right)\cdot V_s$

$= 20\, V_s = 2\cos(2000t)$

9.14

(a) Write an expression for v_o, the output voltage across the load resistor, R_L?

KCL 적용하면.

$$\frac{V_s - 0}{R_1} + \frac{V_s - V_o}{R_2} = 0$$

$$V_o = \left(1+\frac{R_2}{R_1}\right)\cdot V_s = \left(1+\frac{3.8k}{200}\right) V_s$$

$$= 20 V_s = 2\cos(2000t)$$

(b) What is the maximum current through R_L?

$$\frac{2\cos(2000t)}{2k} \qquad I_{max} = \frac{2}{2k} = 1mA$$

(c) What is the maximum current from the output of the op amp?

$$V_s = \frac{1}{10}\cos(2000t) = max = 0.1$$

$$V_o = max = 2$$

$$I_{max} = \frac{2-0.1}{3.8k} = \frac{1.9}{3.8k} = 0.5mA + 1mA = 1.5mA$$

$$\frac{V_o - V_s}{R_2}$$

9.24

$$\frac{V_A - 5}{R_1} + \frac{V_B - V_A}{R_2} + 4 = 0$$

$$\frac{V_A - 5}{1200} + \frac{V_B - V_A}{4200} + 4 = 0$$

$$\frac{V_B + 4}{R_L} + \frac{V_B - V_A}{R_2} = 0$$

Example

$$v_o = -\left[\frac{R_2}{R_{1A}}v_{iA} + \frac{R_2}{R_{1B}}v_{iB}\right]$$

9.31. For the circuit in Figure P9.31, determine an expression for the output voltage, v_o, in terms of the input voltages, v_A, v_B, and v_C; assume an ideal op amp.

$-60-60-$

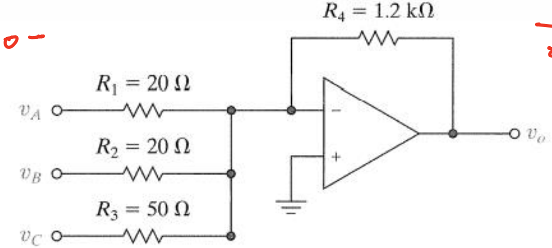


FIGURE P9.31

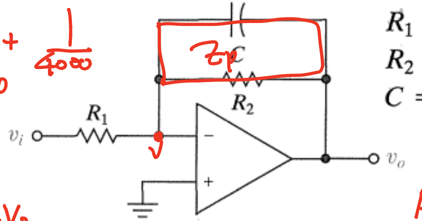
$v_o = -60V_A - 60V_B - 24V_C$

9.41. Determine the maximum gain and bandwidth of the filter shown in Figure P9.41; assume an ideal op amp.

$\frac{1}{j\omega C}$

$$\frac{1}{Z_p} = \frac{1}{\frac{10^6}{j\omega \times 120}} + \frac{1}{4000}$$

10^{-6}



$R_1 = 400\ \Omega$
$R_2 = 4000\ \Omega$
$C = 120\ \mu F$

$$\frac{V - V_{in}}{R_1} + \frac{V - V_o}{Z_p} = 0$$

FIGURE P9.41

$$A_F = \frac{V_o}{V_i} = -\frac{Z_p}{R_1}$$

$= -10$

Max gain $= -10$

BW $= 2.08$ rad/s

$= 0.33$ Hz