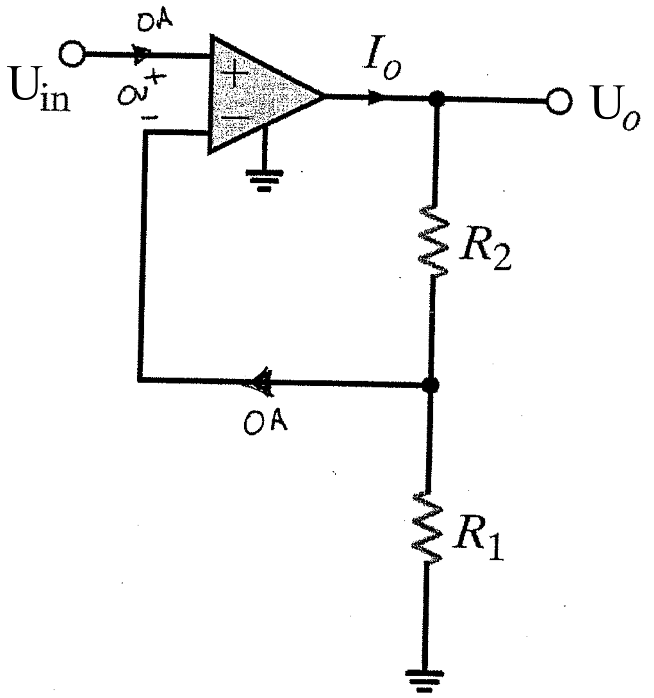
2.1 Determine the gain of the amplifier in Fig. P4.9. What is the value of I_o?



$R_2 = 20\ \mathrm{k\Omega}$

$R_1 = 3.3\ \mathrm{k\Omega}$

$U_{in} = 2\ \mathrm{V}$

Figure P4.9

SOLUTION:

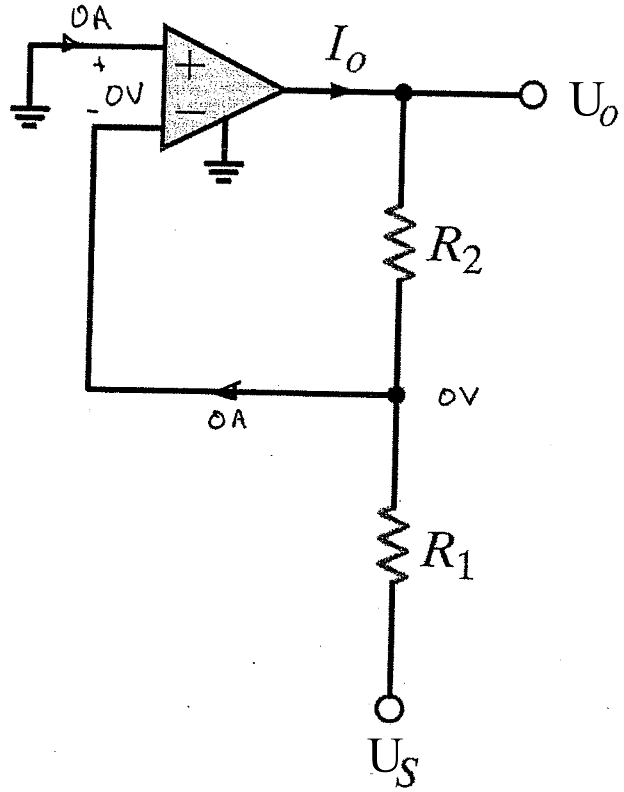
Basic noninverting configuration

$$\frac{U_o}{U_{in}} = 1 + \frac{R_2}{R_1} \Rightarrow \boxed{\frac{U_o}{U_{in}} = 7.06}$$

If $U_{in} = 2\mathrm{V}$, $U_o = 14.12\mathrm{V}$

$$I_o = \frac{U_o}{R_1 + R_2} = 606\ \mu\mathrm{A} \qquad \boxed{I_o = 606\ \mu\mathrm{A}}$$

2.2 For the amplifier in Fig. P4.10, find the gain and I_o?



$R_2 = 20\ \text{k}\Omega$

$R_1 = 3.3\ \text{k}\Omega$

$U_S = 2\ \text{V}$

Figure P4.10

SOLUTION:

Basic inverting configuration, $\frac{U_o}{U_S} = -\frac{R_2}{R_1} \Rightarrow \boxed{-6.06 = \frac{U_o}{U_S}}$

$I_o = U_o / R_2$ $\quad U_o = (-6.06) U_S = -12.12$

$\boxed{I_o = -606\ \mu A}$

2.3 Using the ideal op-amp assumptions, determine the values of U_o and I_1 in Fig. P4.11.

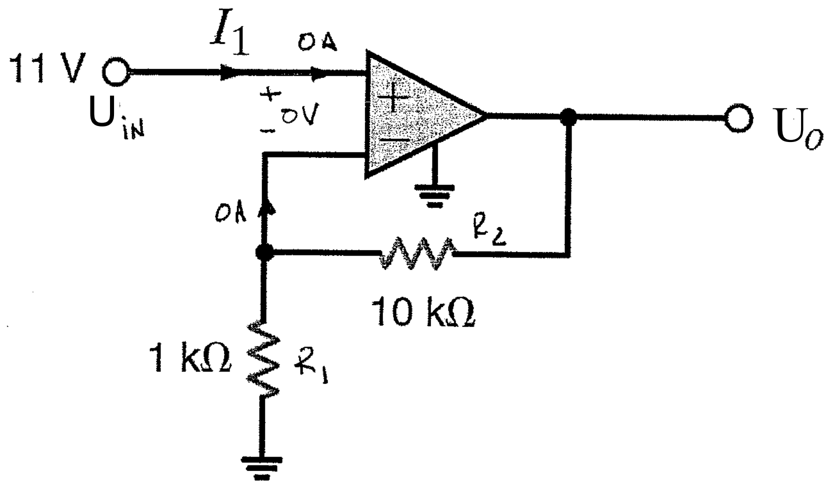


Figure P4.11

SOLUTION:

Basic non-inverting configuration,

$$\frac{U_o}{U_{IN}} = 1 + \frac{R_2}{R_1} = 11 \quad \Rightarrow \quad U_o = 11 U_{IN} \qquad \boxed{U_o = 121\text{V}}$$

Since $R_{in} = \infty$, $I_{in} = 0$ $\qquad \boxed{I_1 = 0\text{ A}}$

2.4 Using the ideal op-amp assumptions, determine I_1, I_2, and I_3 in Fig. P4.12.

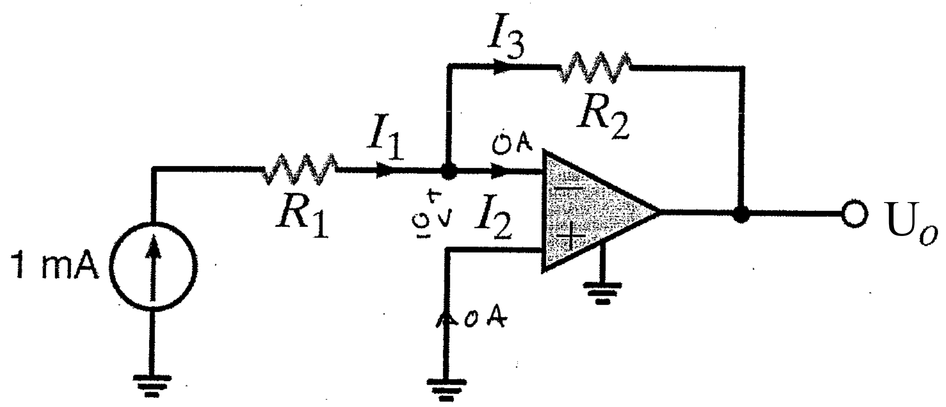


Figure P4.12

SOLUTION:

$I_1 = 1mA$ $I_2 = 0A$ (ideal op-amp)

By KCL,

$I_3 = I_1 - I_2$ $I_3 = 1mA$

2.5 For the circuit in Fig. P4.17,

(a) find U_o in terms of U_1 and U_2.

(b) If $U_1 = 2$ V and $U_2 = 6$ V, find U_o.

(c) If the op-amp supplies are ±12 V, and $U_1 = 4$ V, what is the allowable range of U_2?

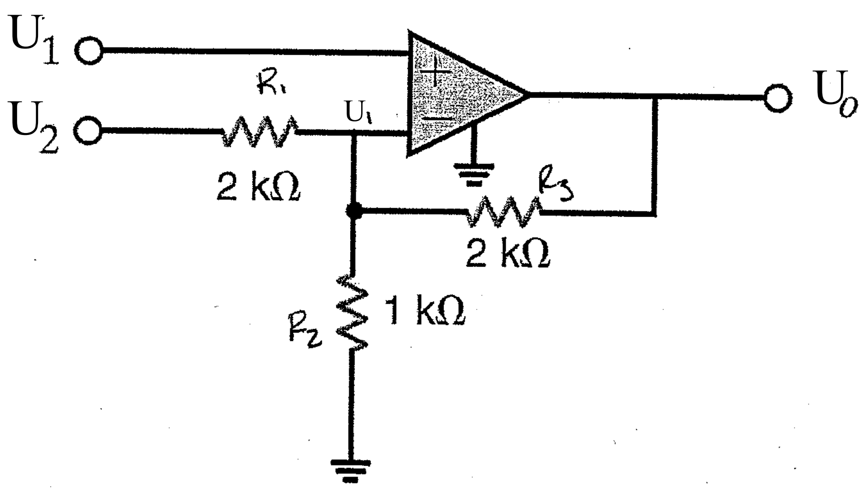


Figure P4.17

SOLUTION:

a) KCL at u₋ input: (remember $u_+ = u_- = U_1$)

$$\frac{U_2 - U_1}{R_1} = \frac{U_1}{R_2} + \frac{U_1 - U_o}{R_3} \Rightarrow 0 = U_1\left(1 + \frac{R_3}{R_1} + \frac{R_3}{R_2}\right) - U_2\left(\frac{R_3}{R_1}\right)$$

$$\boxed{U_o = 4U_1 - U_2}$$

b) $U_o = 4(2) - 6$ $\boxed{U_o = 2\text{ V}}$

c) $U_o = |4(4) - U_2| \leq 12\text{ V}$ $\boxed{4\text{V} \leq U_2 \leq 28\text{ V}}$

2.6 Find U_o in the circuit in Fig. P4.18 assuming the op-amp is ideal.

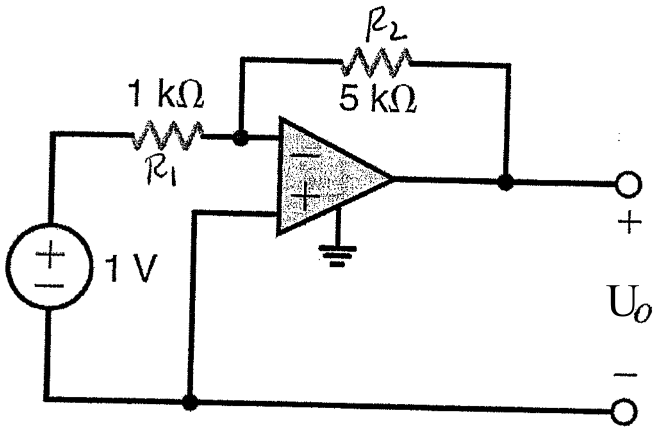


Figure P4.18

SOLUTION:

Basic inverting configuration.

$U_o = U_s \left[-R_2/R_1 \right]$

$U_o = 1 \left(-\frac{5000}{1000} \right)$

$\boxed{U_o = -5V}$

2.7 The network in Fig. P4.19 is a current-to-voltage converter or transconductance amplifier. Find u_o / i_S for this network.

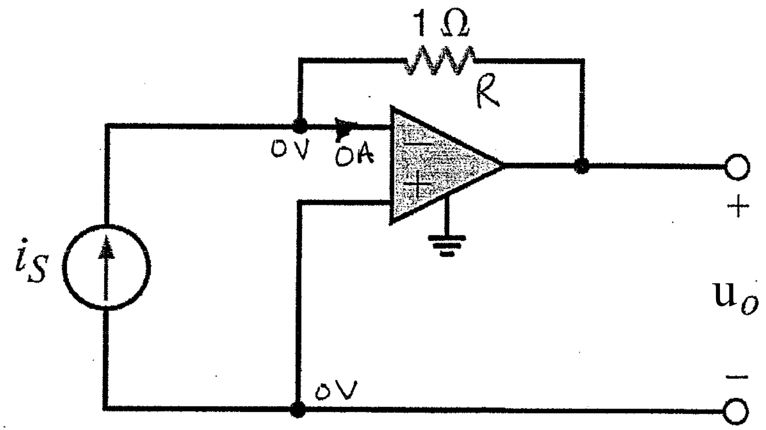


Figure P4.19

SOLUTION:

KCL at u- input: $i_S = \frac{0 - u_o}{R}$

$\frac{u_o}{i_S} = -R$

$\boxed{\frac{u_o}{i_S} = -1}$

2.8 Calculate the transfer function i_o/u_1 for the network shown in Fig. P4.20.

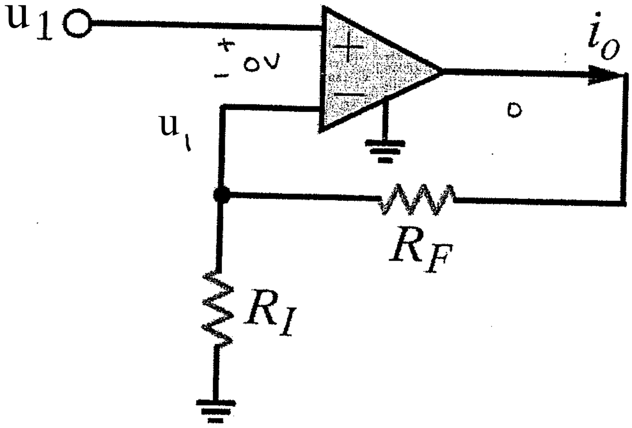


Figure P4.20

SOLUTION:

KCL at u- input:
$$\frac{u_1}{R_I} = \frac{u_0 - u_1}{R_F}$$

$$\frac{u_0}{u_1} = 1 + \frac{R_F}{R_I} = \frac{R_I + R_F}{R_I}$$

$$i_0 = \frac{u_0}{R_I + R_F} = u_1/R_I$$

$$\boxed{\frac{i_0}{u_1} = \frac{1}{R_I}}$$

2.9 Determine the relationship between u_1 and i_o in the circuit shown in Fig. P4.21.

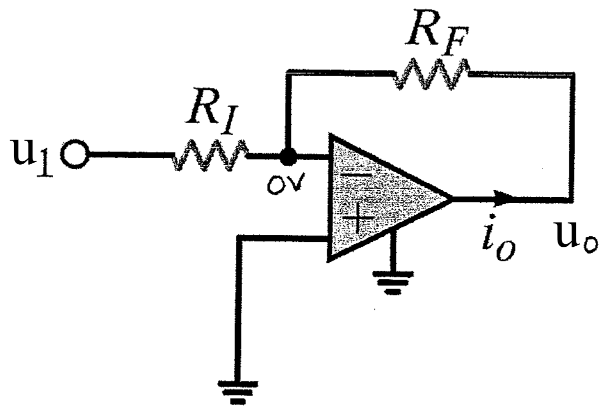


Figure P4.21

SOLUTION:

Basic inverting configuration:

$$\frac{u_o}{u_I} = -\frac{R_F}{R_I} \qquad i_o = \frac{u_o}{R_F} = -u_I / R_I$$

$$\boxed{\frac{i_o}{u_I} = -\frac{1}{R_I}}$$

2.10 Find U_o in the network in Fig. P4.22 and explain what effect R_1 has on the output.

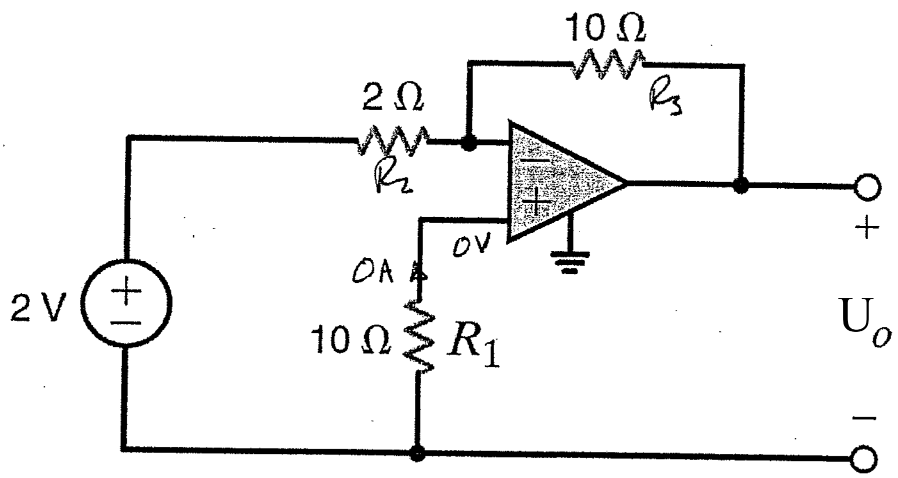


Figure P4.22

SOLUTION:

Since $i_{in} = 0$ for ideal op amp, voltage across $R_1 = 0$ and u_+ input is at 0V as well. Result is a basic inverting configuration.

$$u_o = -2\left(R_3/R_2\right) \Rightarrow \boxed{U_o = -10\,V}$$

R_1 has no impact on the circuit at all!

2.11 Determine the expression for u_o in the network in Fig. P4.23.

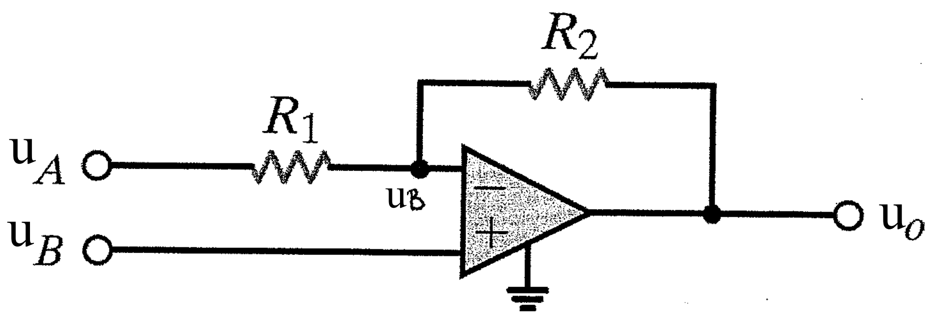


Figure P4.23

SOLUTION:

KCL at u- node:

$$\frac{u_A - u_B}{R_1} + \frac{u_o - u_B}{R_2} = 0$$

$$\boxed{u_o = u_B\left(1 + \frac{R_2}{R_1}\right) - u_A\left(R_2/R_1\right)}$$

2.12 Show that the output of the circuit in Fig. P4.24 is

$$U_o = \left[1 + \frac{R_2}{R_1}\right]U_1 - \frac{R_2}{R_1}U_2$$

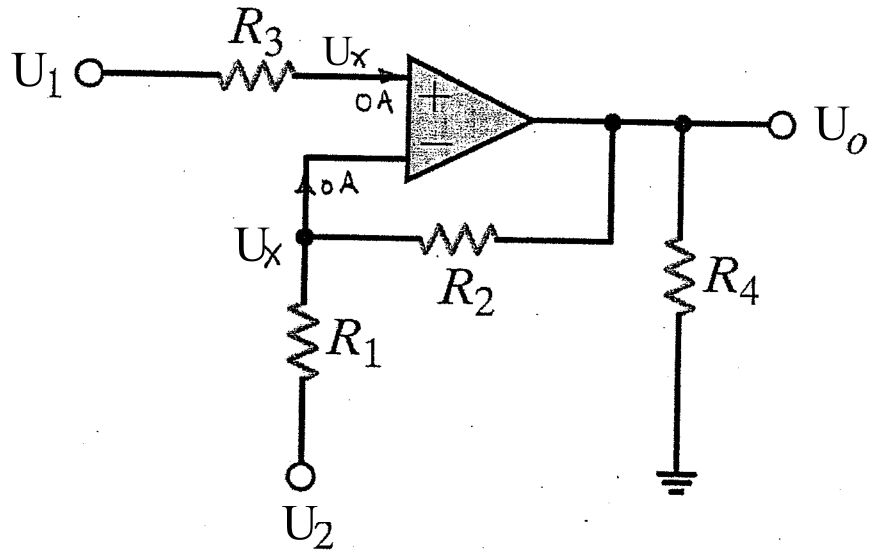


Figure P4.24

SOLUTION:

KCL at U_+ input: $\Rightarrow \frac{U_1 - U_x}{R_3} = 0 \Rightarrow U_1 = U_x$

$\frac{U_2 - U_x}{R_1} + \frac{U_o - U_x}{R_2} = 0$ $\qquad U_o = U_x\left(1 + \frac{R_2}{R_1}\right) - U_2\left(R_2/R_1\right)$

$$U_o = \left[1 + \frac{R_2}{R_1}\right]U_1 - \frac{R_2}{R_1}U_2$$

2.13 Find U_o in the network in Fig. P4.25.

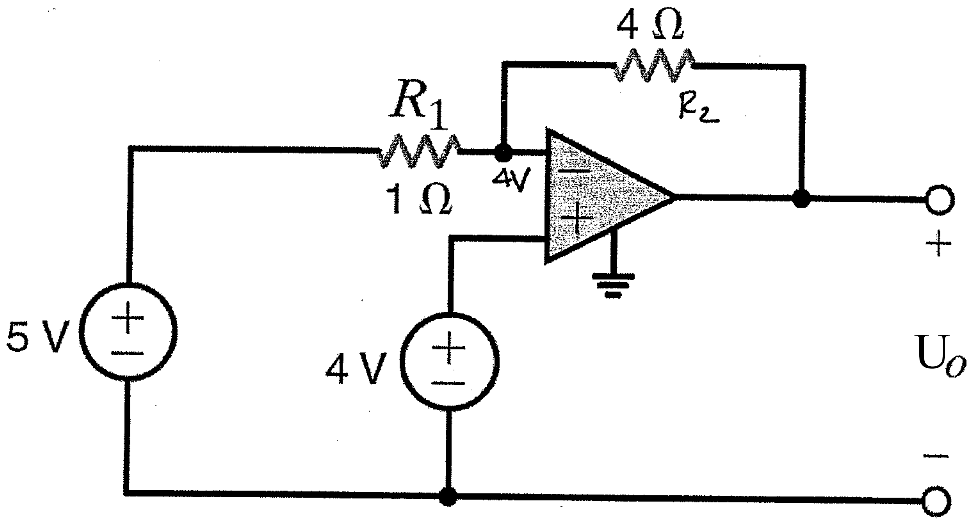


Figure P4.25

SOLUTION:

KCL at u- input: $\frac{5-4}{R_1} + \frac{U_o - 4}{R_2} = 0$

$U_o = 0V$

2.14 Find the voltage gain of the op-amp circuit shown in Fig. P4.26.

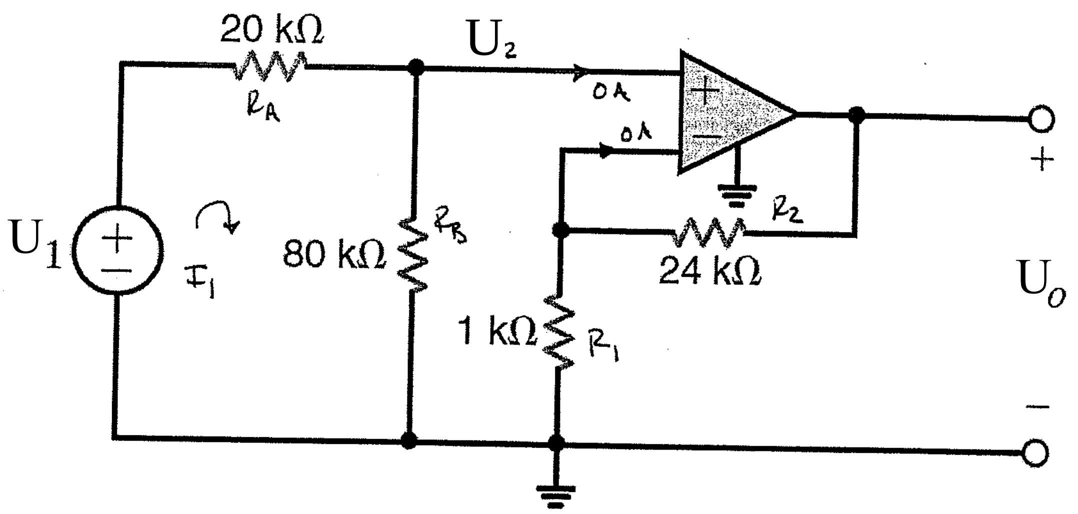


Figure P4.26

SOLUTION:

Two step solution: 1) Find U_2/U_1
2) Find U_o/U_2

1) Loop analysis:

$$U_1 = I_1 R_A + I_1 R_B \quad \& \quad U_2 = I_1 R_B$$

$$I_1 = U_2/R_B \qquad \frac{U_2}{U_1} = \frac{R_B}{R_A+R_B} = 0.8$$

2) Op-amp is in basic non-inverting configuration.

$$\frac{U_o}{U_2} = 1 + \frac{R_2}{R_1} = 25$$

Overall gain is $U_o/U_1 = (U_2/U_1)(U_o/U_2)$ $\boxed{\frac{U_o}{U_1} = 20}$

2.15 For the circuit in Fig. 4.27 find the value of R_1 that produces a voltage gain of 10.

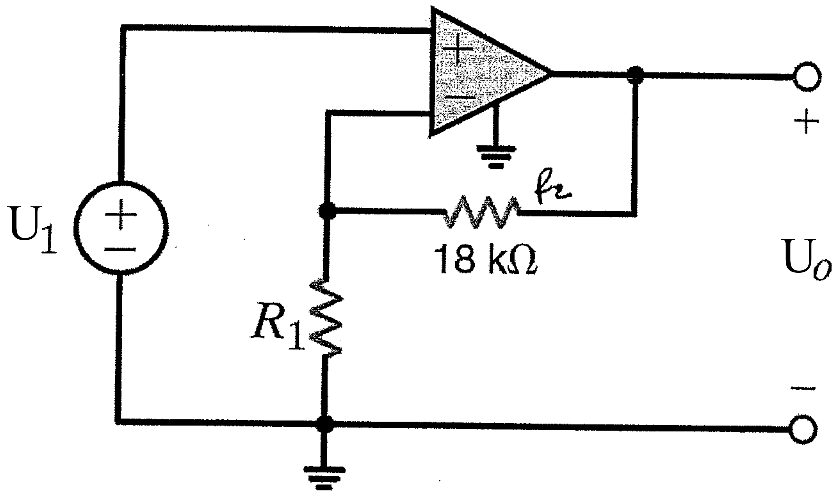


Figure P4.27

SOLUTION:

Basic non-inverting configuration:

$$\frac{U_o}{U_1} = 1 + \frac{R_2}{R_1} = 1 + \frac{18 \times 10^3}{R_1} = 10$$

$$\boxed{R_1 = 2k\Omega}$$

2.16 Determine the relationship between U_o and U_{in} in the circuit in Fig. P4.28.

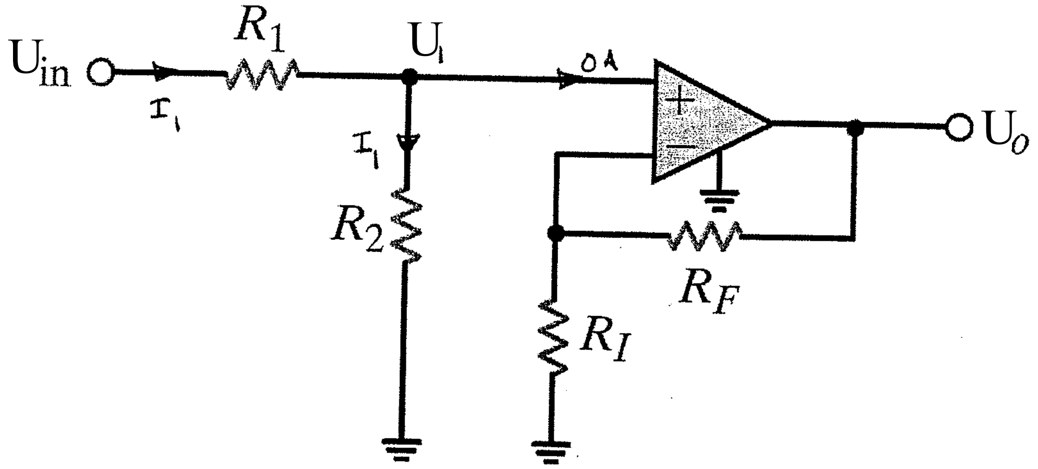


Figure P4.28

SOLUTION: Two step solution: 1) find U_1/U_{in}
2) find U_o/U_1

1) $U_{in} = I_1 R_1 + I_1 R_2$ $\quad U_1 = I_1 R_2$ $\Rightarrow \frac{U_1}{U_{in}} = \frac{R_2}{R_1+R_2}$

2) Opamp is in basic non-inverting configuration

$$\frac{U_o}{U_1} = 1 + \frac{R_F}{R_I}$$

Overall gain $\frac{U_o}{U_{in}} = \left(\frac{U_o}{U_1}\right)\left(\frac{U_1}{U_{in}}\right)$.

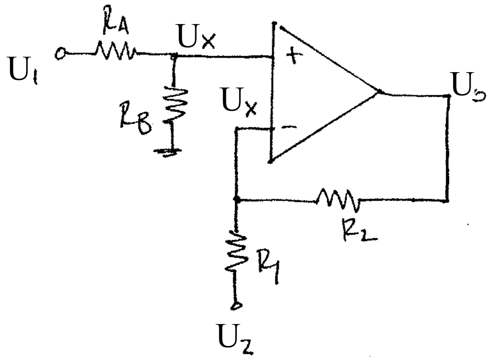
$$\boxed{\frac{U_o}{U_{in}} = \left(\frac{R_2}{R_1+R_2}\right)\left(\frac{R_I+R_F}{R_I}\right)}$$

2.17 Design an op-amp-based circuit to produce the function

$$U_o = 5U_1 - 7U_2$$

SOLUTION:

Use both + & - inputs to get + & - gains.



KCL at u_+ input,

$$\frac{U_1-U_x}{R_A} = \frac{U_x}{R_B} \Rightarrow \frac{U_x}{U_1} = \frac{R_B}{R_A+R_B}$$

KCL at u_- input

$$\frac{U_o-U_x}{R_2} = \frac{U_x-U_2}{R_1}$$

$$U_o = U_x\left(1+\frac{R_2}{R_1}\right) - \frac{R_2}{R_1}U_2$$

$$U_o = U_1\left(\frac{R_B}{R_A+R_B}\right)\left(1+\frac{R_2}{R_1}\right) - \frac{R_2}{R_1}U_2$$

$$R_2/R_1 = 7$$

$$\left(\frac{R_B}{R_A+R_B}\right)8 = 5$$

Choose $R_1 = 1k\Omega \Rightarrow R_2 = 7k\Omega$

Choose $R_B = 5k\Omega \Rightarrow R_A = 3k\Omega$