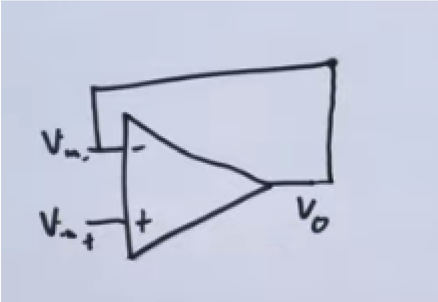
Op amps examples



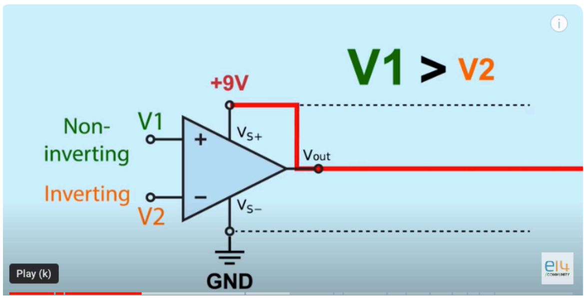
- High impedance input to low impedance output.
- After a resistor there will be less voltage so to increase voltage need an op amp
- The output will change so that both inputs are the same.
- the op amp amplifies only the difference in voltage between the two, which is called the *differential input voltage.* $V_0 = A[V_{in+} - V_{in-}]$
- No input in the currents.
- If the output is greater than the supply voltage then both input voltages will not be the same.

Example 1

Why there is no input in the current?

Because there is high impedance input. The assumption is that it is infinite.

Example 2



a) What happens when V1 > V2?

The output would go to 9V

b) What happens when V1 < V2?

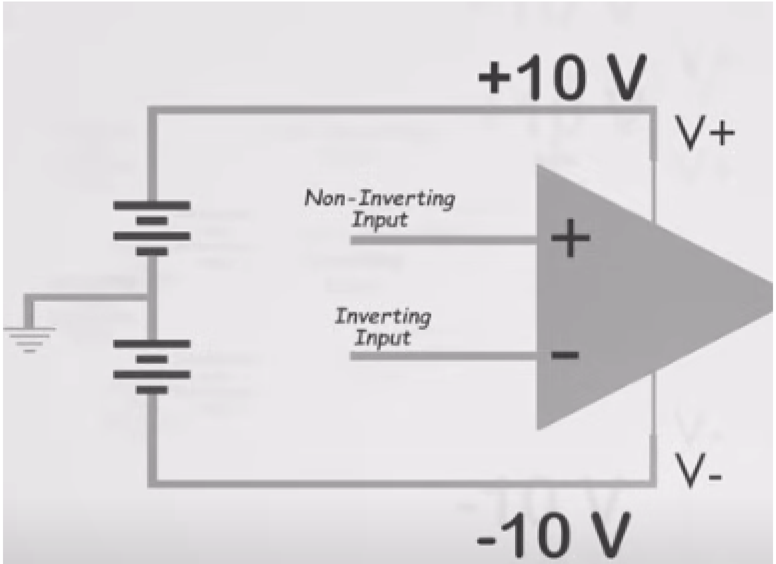
The output would go to ground or 0V.

c) What happens when output reaches either of these points?

Saturation which is the maximum gain.

Example 3

a) Describe the effect on the output



The output will oscillate between positive and negative volts.

b) What does the op amp amplify?

It amplifies the voltage difference?

c) If $V_{in+} = 0.02$, $V_{in-} = 0$ and Gain = 200 000.

What is V_{out}

$Gain = \frac{V_{out}}{V_{in+} - V_{in-}}$

V_{out} = 200V

d) Why is this impractical?

Op amps can only produce voltages up to the level of its power supply.

This is called saturation.

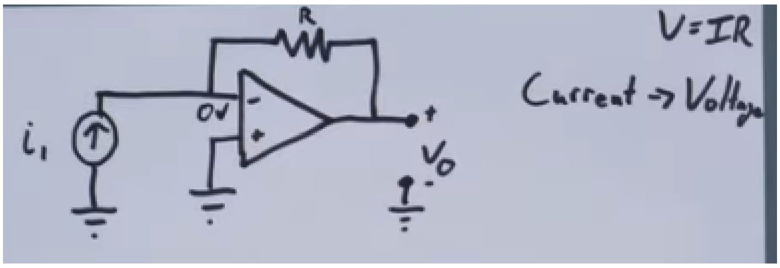
e) When the op ap saturate to the negative supply voltage?

When $v_{in+} = -0.001$ and $v_{in-} = 0$

f) What happens when the inverting input goes up?

The voltage output will go down.

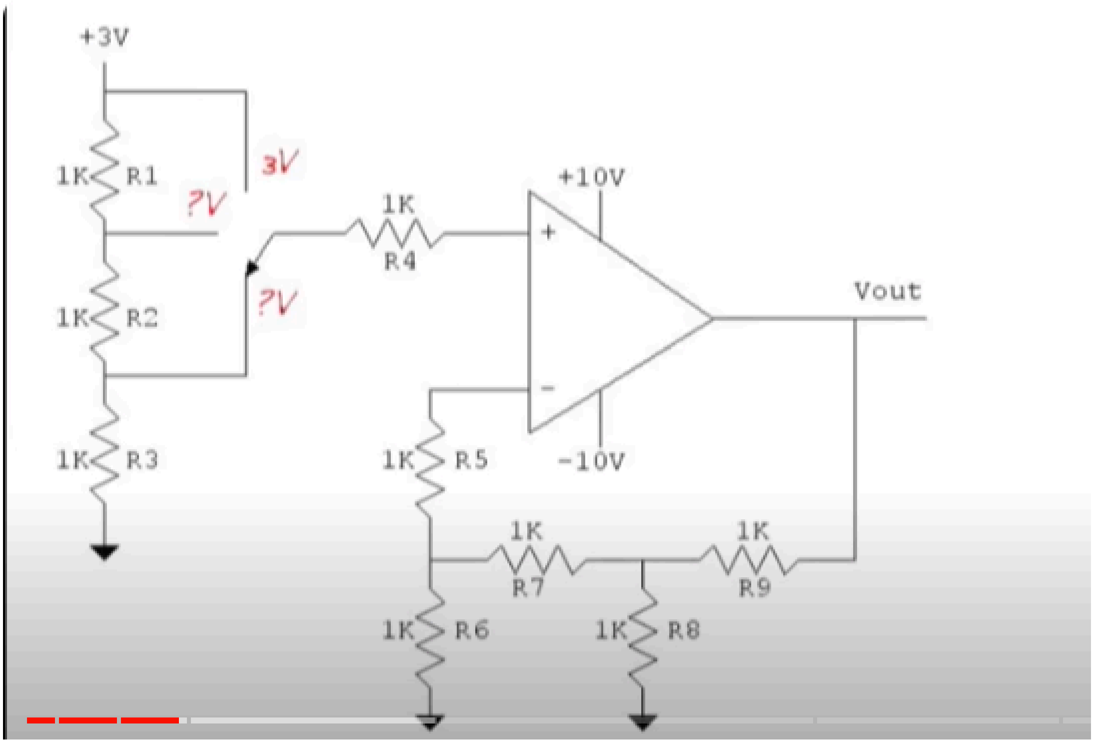
Example 5



Find an expression for the current.

$$I_1 = \frac{0 - V_0}{R}$$

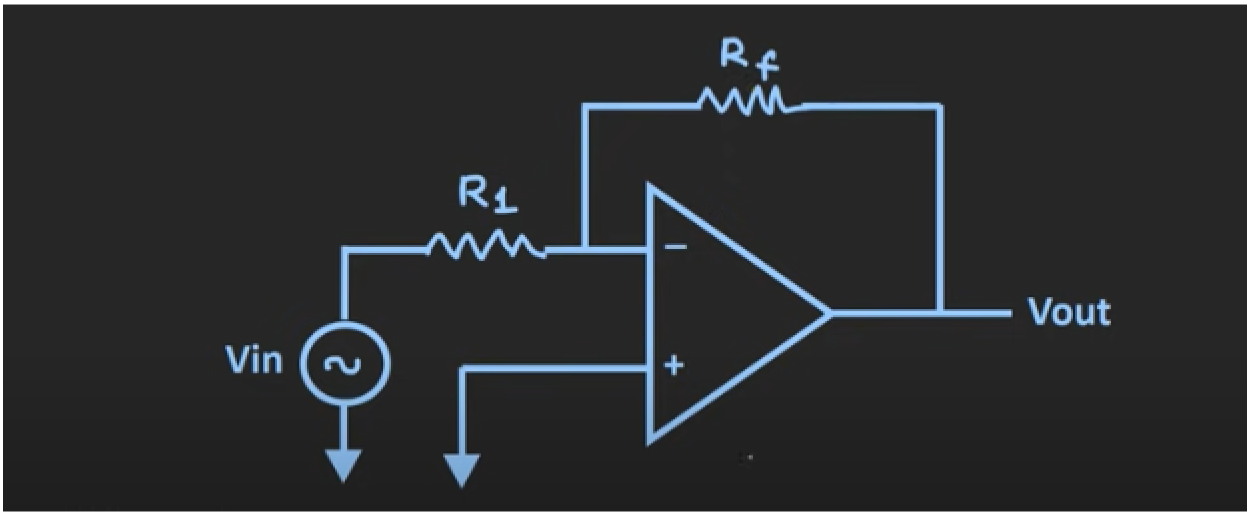
Example 6



What is the current at R4?

0 mA since no current enters the amplifier.

Example 8



a) What type of feedback is this?

Negative feedback -

b) given the the open loop gain is 10^6 and the output voltage is 10V. What is the differential input voltage?

$V_{out} = A_{OL}V_D$

$10 = 10^6 V_D$

$10^{-5} = V_D$

$10(10^{-6}) = V_D$

$10\mu V = V_D$

c) What is the relationship between V^+ and V^-

$V^+ - V^- \approx 0$

d) Given that V^+ is grounded what is V^{-1}

$V^- = 0$

e) What is V^{-1} is called a virtual ground?

Since it is 0. Both inputs have the same potential.

f) What is the current entering at the negative input?

0 because there is high impedance.

g) What is the relationship between the current before R_f and the current before R_1

$i_1 = i_f$

h) What is closed loop gain?

$\frac{V_{in}-V_x}{R_1} = \frac{V_x-V_{out}}{R_2}$

Since $V_x = 0$ because this is a virtual ground at the negative input.

$\frac{V_{in}}{R_1} = \frac{-V_{out}}{R_2}$

$\frac{-R_2}{R_1} = \frac{V_{out}}{V_{in}}$

i) if $R_f = 2k\Omega$, $R_1 = 1k\Omega$ and the $V_{in} = 1V$, what is V_{out}

$\frac{-2}{1} = \frac{V_{out}}{1}$

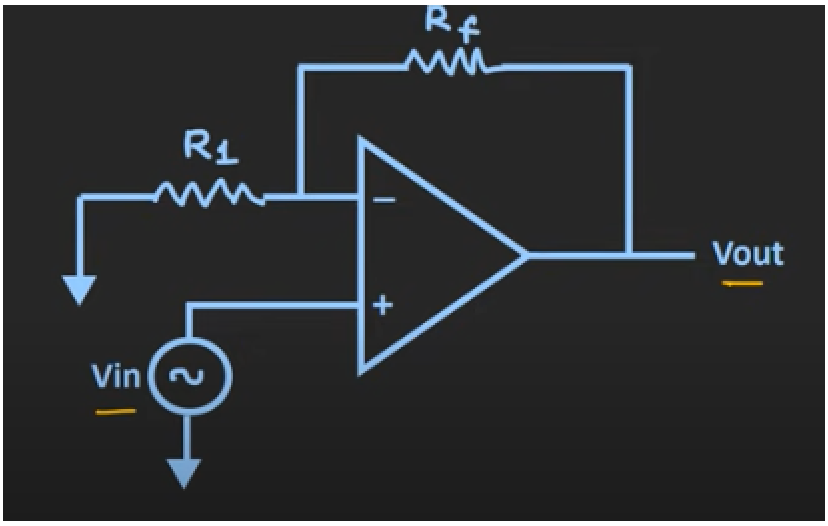
$V_{out} = -2$

j) What is the impedance of the inverting op-amp?

$Z_{in} = \frac{V_{in}}{I_{in}}$

$Z_{in} = R_1$

Example 9



a) What is Vx. which is the voltage after Rf, in terms of V_{out}

$\frac{V_x}{V_out} = \frac{R_1}{R_1+R_f}$

b) Show that $V_x = V_{in}$

$V_x = V^- = V^+ = Vin$

$\frac{V_{in}}{V_{out}} = \frac{R_1}{R_1+R_f}$

$\frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_1}$

c) if $V_{in} = 1V$, $R_f = 2k\Omega$, $R_1 = 1k\Omega$, What is the gain?

$\frac{V_{out}}{V_{in}} = 1 + \frac{2}{1} = 3$

d) What is the advantage of non inverting operational amplifier.

The output and input are in phase.

e) What is the impedance of the non-inverting op-amp?

$Z_{in} = \frac{V_{in}}{I_{in}}$

Since there is no current going into the terminal, therefore you can say that

$Z_{in} \approx \infty$

f) $R_f = 0$ and $R_1 = \infty$ what is the effect on the non-inverting op amp.

Becomes a buffer (voltage follower)

$V_- = V_{out}$

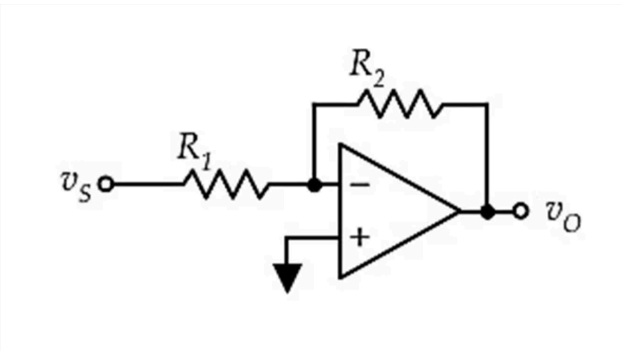
$V_+ = V_{in}$

$V_+ = V_{in}$

Since there is no current going into the positive terminal

$Z_{in} = \infty$

Example 10



a) What is the input impedance?

Infinite.

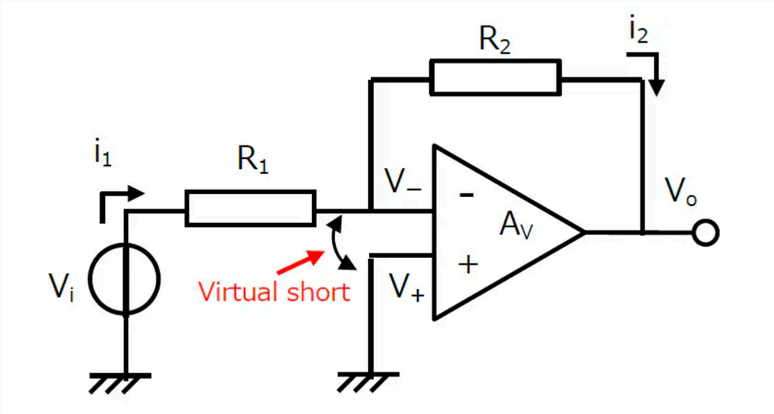
b) What is the current entering the input (inverting) terminal?

0 because of high impedance and virtual ground

c) What is the difference between the input terminals?

0. The inverting (-) and non-inverting (+) pins are the same.

Example 11



Write two expressions for i_1?

$$i_1 = \frac{V_i - V-}{R_i}$$

$$i_1 = \frac{V_{-} - Vo}{R_2}$$

Find the gain of the op amp?

$$A_v = \frac{V_o}{V_+ - V_-}$$

c) Assuming the gain of the opp amp is infinite what is the relationship between the input terminals.

$$V_+ = V_-$$

d) Why can we conclude that there is no voltage in the negative terminal.

The non-inverting terminal is grounded and the difference between the input terminals is 0.

e) Show that the Voltage gain is $\frac{R_2}{R_1}$

$$i_1 = i_2$$

We can conclude that no current flows to the V_- input since the V_- voltage is equal to GND and the input impedance is infinite

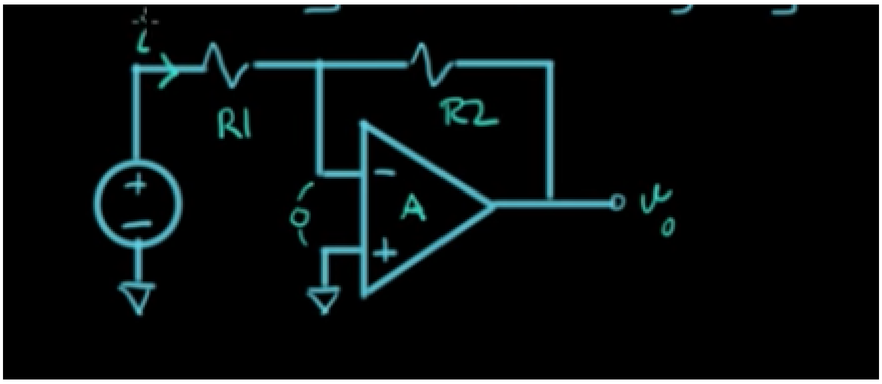
$i_1 = \frac{V_i}{R_1}$

$i_1 = \frac{Vo}{R_2}$

$\frac{V_i}{R_1} = \frac{Vo}{R_2}$

$\frac{R_2}{R_1} = \frac{Vo}{V_i}$

Example 12



a). What is the voltage between R1 and R2?

0 volts because of virtual ground

b) What is i?

$i = \frac{V_{in}-0}{R_1} = \frac{V_{in}}{R_1}$

c) What is the current entering the inverting terminal?

0 as there is no current.

d) What is a consequence of this?

i is going through R_2

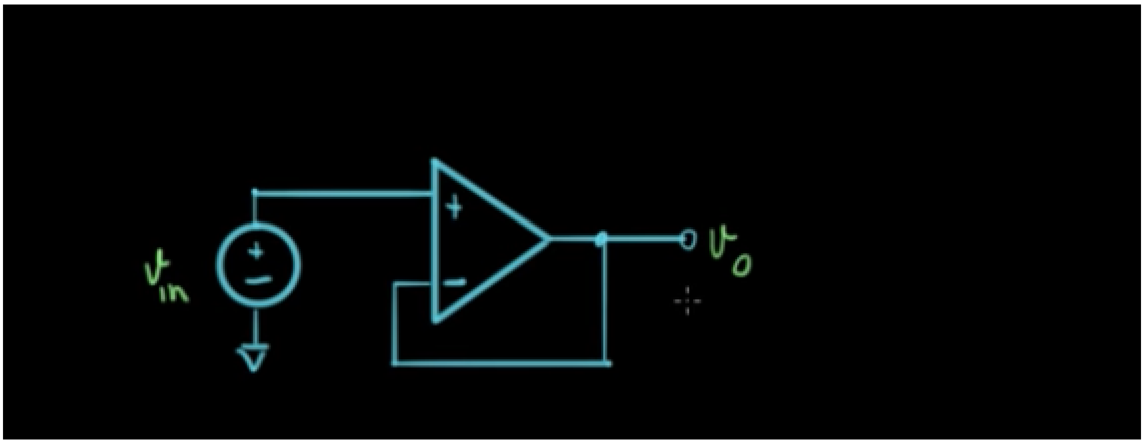
$i = \frac{0-V_0}{R_2}$

e) Find an expression for the voltage gain in the inverting op-amp in terms of its resistance.

$\frac{V_{in}}{R_1} = \frac{0-V_0}{R_2}$

$\frac{V_O}{V_{in}} = -\frac{R_2}{R_1}$

Example 13



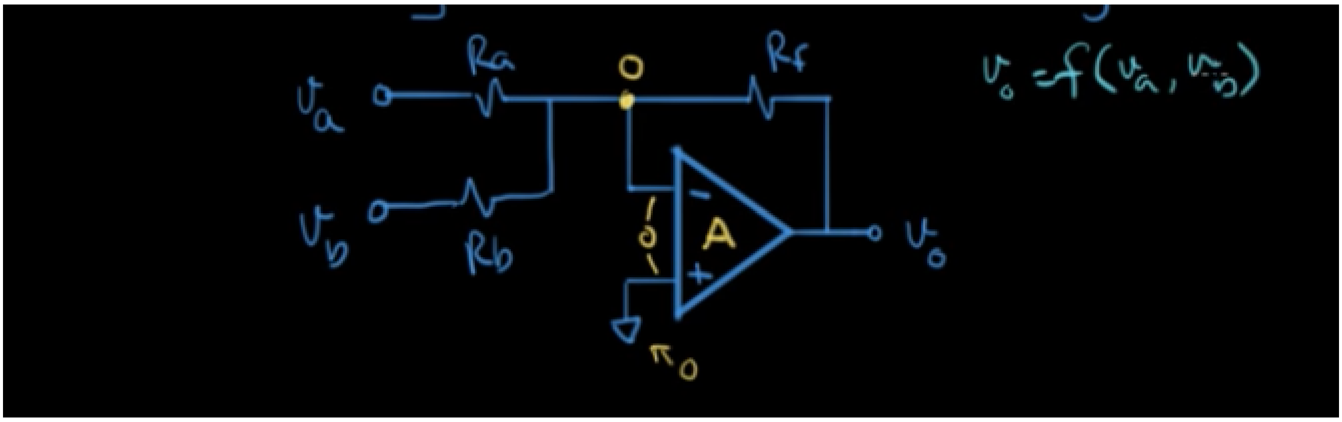
What is the Gain?

$$V_0 = V_{in}$$

$$\frac{V_0}{V_{in}} = 1$$

This configuration is called the buffer.

Example 14



a) What is i between R_a and R_b?

$$i = i_a + i_b$$

$$i = \frac{V_a - 0}{R_a} + \frac{V_b - 0}{R_b}$$

$$i = \frac{V_a}{R_a} + \frac{V_b}{R_b}$$

b) What is the current at R_f ?

$$i = \frac{0 - V_0}{R_f} = \frac{-V_0}{R_f}$$

c) Find an expression for V_0?

$V_0. = -[\frac{R_f V_a}{R_a} + \frac{R_f V_b}{R_b}]$

d) if $R_a = R_b = R_f = 10k\Omega$ what is V_0

$V_0. = -[V_a + V_b]$

e) Decide the resistance of the resistors so that $V_0. = -[2V_a + 3V_b]$

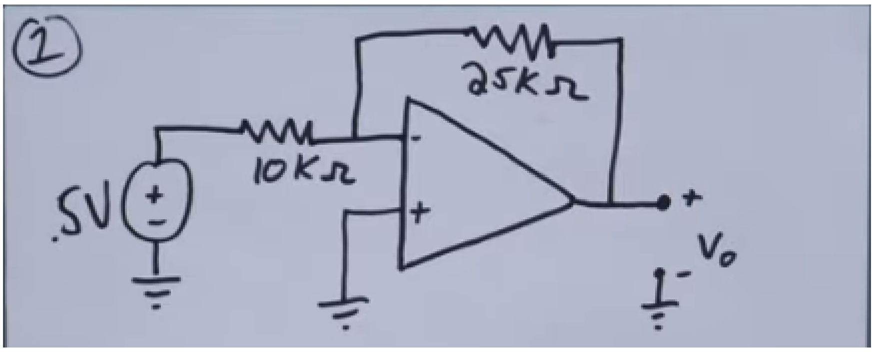
$\frac{R_f}{R_a} = 2$, $\frac{R_f}{R_b} = 3$

$R_f = 12k\Omega$

$R_a = 6k\Omega$

$R_b = 4k\Omega$

Example 15



a) What is the voltage at V_{in-} ?

This is zero because V_{in+} is connected to the ground..

b) What is the current at the first resistor?

V = IR

$(0.5 - 0) = 10000(I_1) = 0.5 \times 10^{-5}$ amps

c) What is this in microamps?

$5 \times 10^{-5} = 50$ microamps.

Express i in terms of V_0

$i = \frac{0-V_0}{R_2}$

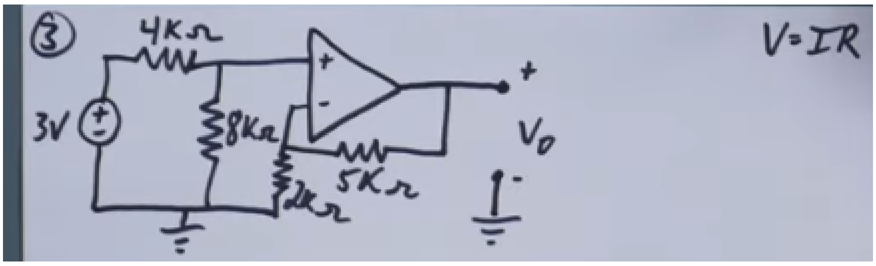
What is V_0

$i = \frac{0-V_0}{R_2}$

$5 \times 10^{-5} = \frac{0-V_0}{25000}$

$V_0 = -(5 \times 10^{-5})(25000) = -1.25V$

Example 16



a) What the voltage at each inputs?

$\frac{3-V}{4} = i$

$\frac{V-0}{8} = i$

$8(3 - V) = 4V$

24 =12V

V =2

The voltage at each input is 2V

b) What is the current through the inverting terminal?

0

c) What is the current through the 2k ohms resistor?

$i = \frac{2}{2000} = 10^{-3} = 1mA$

d) What is the current through the 5k ohms resistor?

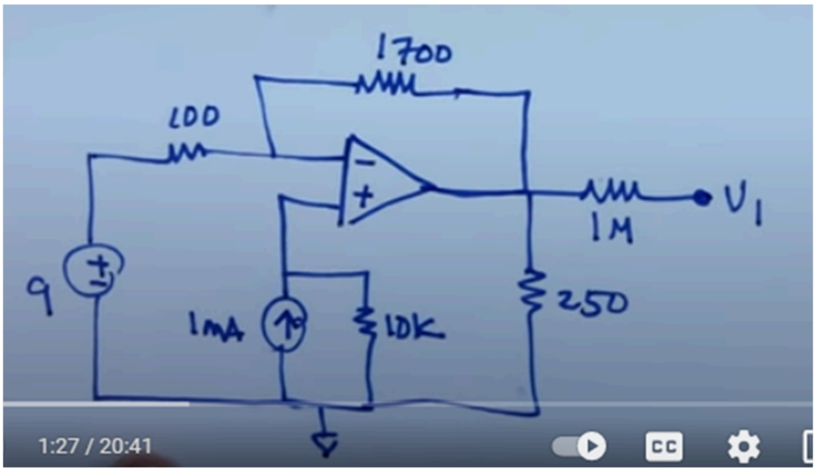
$i = 1mA$

c) What is V_0?

$i = \frac{V_0-2}{5000} = 10^{-3}$

V_0 = 7V

Example 17



a) What is the relationship between the inverting terminal and the non-inverting terminal

$$V_{+} = V_{-}$$

b) What is the current going in the inverting terminal and out the non-inverting terminal

0

c) What is the current that is going through the 10k ohms resistor?

Since there is no current coming from the op-amp therefore we have a series circuit and the current is 1mA.

d) What is the voltage at 10k ohms resistor?

V = IR = 0.0001(10000) = 10V

e) What is the voltage at the inverting terminal?

10V

e) What is the relationship between current going through the 100 ohms resistor and 1700 ohms resistor?

$$I_x = I_y$$

f) What is current going through the 100 ohms resistor?

$$I_x = \frac{V}{R} = \frac{9-10}{100} = 0.01$$

f) What is current going through the 1700 ohms resistor in terms of V_{out}?

$$I_y = \frac{10-V_{out}}{1700}$$

g) What is the voltage out?

$$\frac{10-V_{out}}{1700} = 0.01$$

$$V_{out} = 27$$

h) What is the current at the 1M ohms resistor?

0 because it is an open circuit.

i) What is V_1

$V_1 = V_{out}$ + Voltage at the resistor

$V_1 = V_{out} + I_z(1M)$

$V_1 = V_{out} = 27$

j) What is the current at the 250 ohms resistor?

$I_w = \frac{V_{out}}{250} = \frac{27}{250} = 108$mA

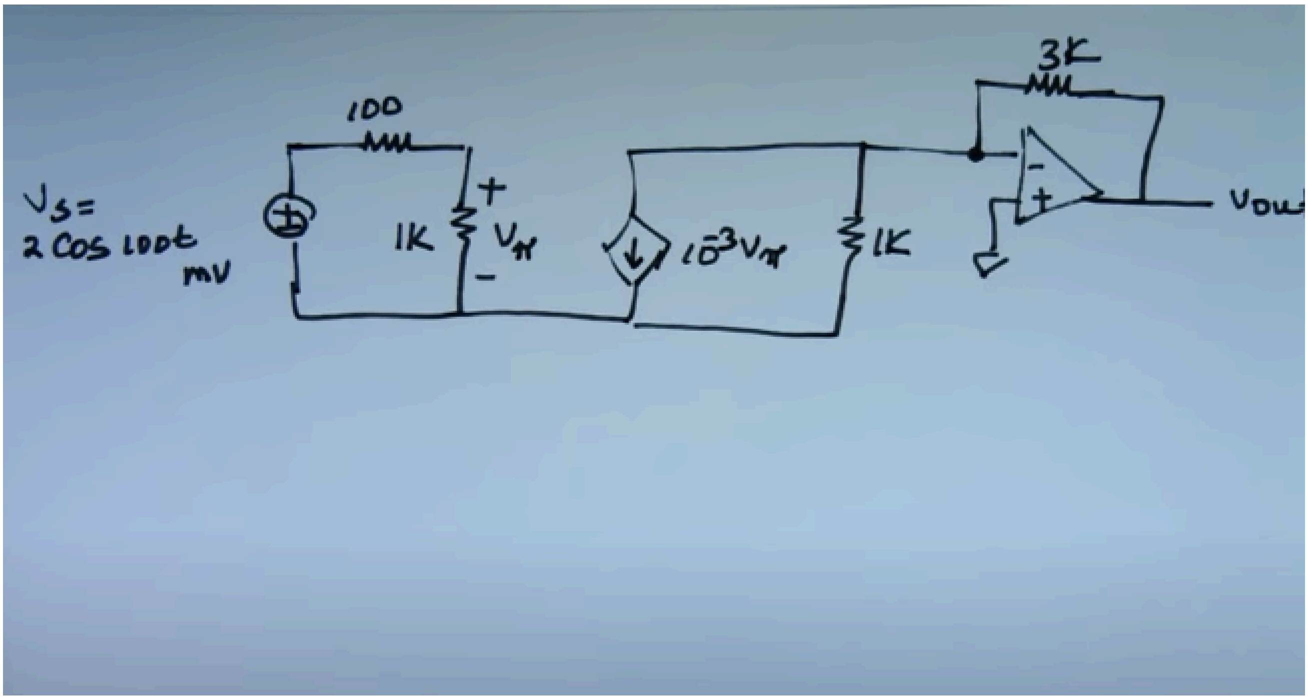
k) What is the current going into the op amp from V_{out}?

$I_y = I_z + I_w + I_o$

$-0.01 = I_z + 0.108 + I_o$

$I_o = -0.118$

Example 18



a) Find V_π

$V_s = I_s R_s$

$I_s = \frac{V_S - V_\pi}{100}$

$I_s = \frac{V_\pi}{1k}$

$\frac{V_S - V_\pi}{100} = \frac{V_\pi}{1k}$

$$1kV_S - 1kV_\pi = 100V_\pi$$

$$1kV_S = 100V_\pi + 1kV_\pi$$

$\frac{1k}{100+1k} V_S = V_\pi$

$\frac{10}{11} V_S = V_\pi$

b) What does the diamond symbol with the arrow mean?

Current dependent source. Indicates flow of current.

c) What is the voltage through the 1k ohm resistor?

0 V since connected to ground.

c) What is the current through the 1k ohm resistor?

0 since the voltage is 0

c) What is the voltage at the inverting terminal?

0

What is the current at the 3k resistor?

$$10^{-3} V_\pi$$

What is the voltage output?

$$V_{out} - 0 = IR$$

$$V_{out} - 0 = 10^{-3} V_\pi (3k)$$

$$V_{out} = 3V_\pi$$

https://www.youtube.com/watch?v=iItYjrScGqU

https://www.youtube.com/watch?v=iaFW3z3vwpc