Example for Diode Limiter

Problem: Find the output voltage across R_L in the limiter circuit.

For the negative half cycle, diode will be forward biased

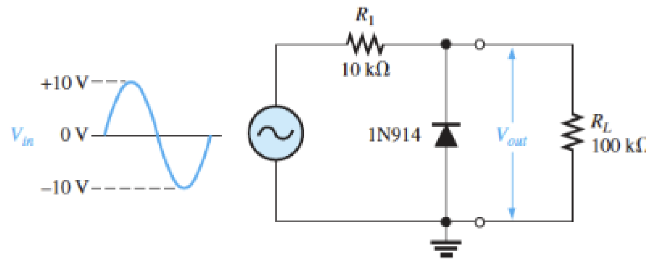
Diode is forward biased if

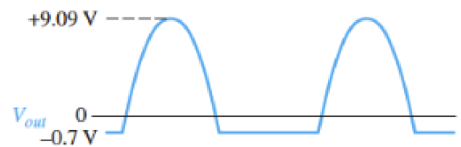
$V_{in} \leq -0.7\ V)$

The peak output voltage across R_L is

$$V_{p,out} = \left(\frac{V_{p(in)}}{R_1 + R_L}\right) R_L$$

$$= \left(\frac{10\ V}{10\ k\Omega + 100\ k\Omega}\right) 100\ k\Omega = 9.09\ V$$





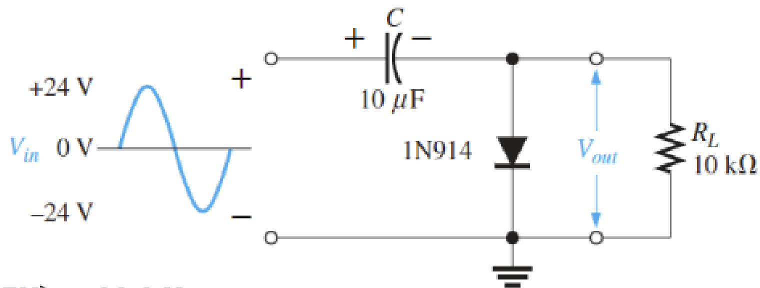
Output voltage waveform across R_L

Example for Diode Clamper

Problem: Find the output voltage across R_L in the clamping circuit.

During first quadrant

- Diode turns on
- Capacitor charged quickly due to low RC constant.

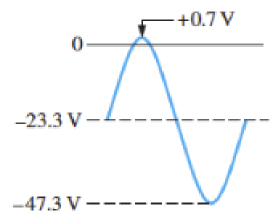


KVL after charging

$$-V_{in} + V_{c,p} + 0.7 = 0$$

$$V_{c,p} = (V_{in} - 0.7\ V) = (24\ V - 0.7V) = 23.3\ V$$

Now the capacitor will discharge slowly between peaks (large time constant). When discharging, diode is reverse biasing. The capacitor acts as a battery in series with the input voltage.



Output voltage waveform across R_L

$$V_{out} = \left(V_{in} - V_{c,p}\right) = (V_{in} - V_{p(in)} + 0.7\ V)$$

$$V_{p,out}^{-} = V_{p,in}^{-} - V_{p(in)} + 0.7\ V = (-24\ V - 23.3V) = -47.3\ V$$

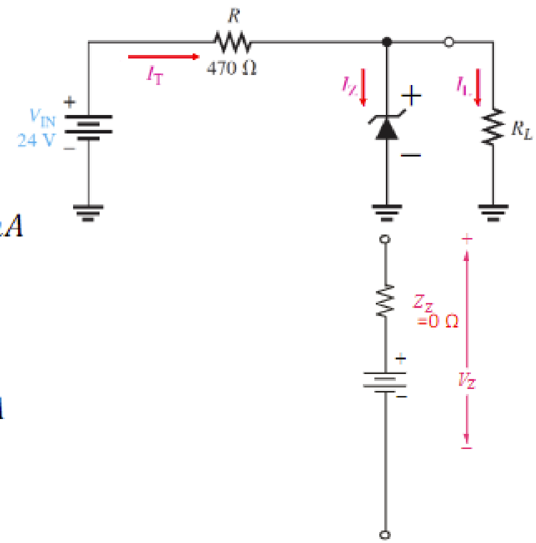
$$V_{p,out}^{+} = V_{p,in}^{+} - V_{p(in)} + 0.7\ V = (24\ V - 23.3V) = 0.7\ V$$

$$V_{DC} = -23.3\ V$$

Zener Diode for Load Regulation

Problem: Determine the minimum and maximum load currents for which the zener diode in Figure given below will maintain regulation. What is the minimum value of R_L that can be used? V_Z=12V, I_{ZK}= 1 mA, and I_{ZM}= 50 mA. Assume an ideal zener diode where Z_Z= 0 Ω and V_Z remains a constant 12 V over the range of current values, for simplicity.

Solution:



When I_L=0 A (R_L=∞), I_z → maximum

I_L =0 means R_L is removed I_z =I_T

$$I_{z(max)} = I_T = \frac{V_{IN} - V_z}{R} = \frac{24\ V - 12\ V}{470\ \Omega} = 25.5\ mA$$

Since $I_{Z(max)} < I_{ZM}$, $I_{L(min)}$ =0 is acceptable

$$I_{L(min)} = 0$$

$$I_{L(max)} = I_T - I_{zk} = 25.5\ mA - 1\ mA = 24.5\ mA$$

$$R_{L(min)} = \frac{V_z}{I_{L(max)}} = \frac{12\ V}{24.5\ mA} = 490\ \Omega$$

If R_L < 490 Ω, I_L is larger and I_Z is smaller

If $I_Z < I_{ZK}$, *ZD* does not work for voltage regulation.

$R_{L(min)}$ is 490 Ω.

Example for Non-Inverting OpAmp

Problem 1: Determine the voltage gain in dB, input resistance, output voltage, and output current for the Op-Amp circuit. Here, V_{in}=0.3 V, R_1=1 kΩ , R_f=39 kΩ.

Solution 1:

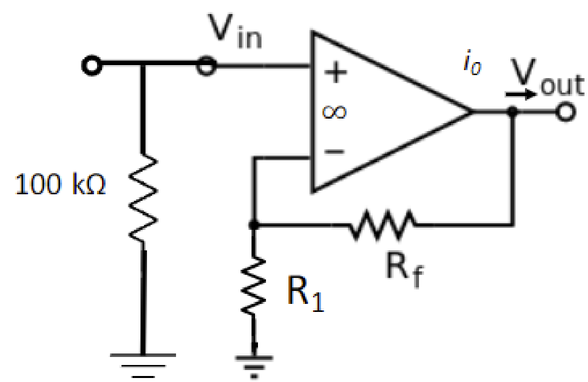
$$A_V = 1 + \frac{R_f}{R_1} = 1 + \frac{39\ k\Omega}{1\ \mathrm{k}\Omega} = 40$$

$$A_{V,dB} = 20log_{10}40 = 32\ dB$$

$$R_{in} = 100\ k\Omega \parallel \infty = 100\ k\ \Omega$$

$$V_0 = A_V \times V_i = 40 \times 0.3 = 12$$

$$i_0 = \frac{V_0}{40\ k} = \frac{12}{40\ k} = 0.3\ mA$$



Example for Ideal OpAmp

Problem 2: Find output voltage when an input voltage of 5 V is applied to the circuit. The feedback resistance is 4.4 kΩ.

Solution 2:

Negative feedback: Output terminal is connected to the inverted terminal.

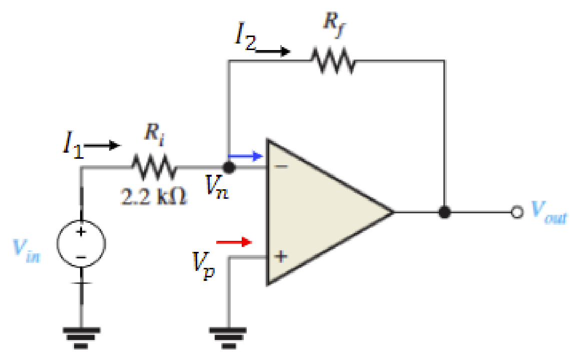
For negative feedback of Op-Amp $V_p = V_n$

Since V_p is connected to the ground $V_p = 0$

So V_n is virtually grounded

$V_p = V_n = 0$ $\quad I_p = I_n = 0$

Applying KCL, $I_1 = I_2 = \dfrac{V_i - 0}{2.2\ k\Omega} = \dfrac{0 - V_0}{4.2\ k\Omega}$



$$\frac{5-0}{2.2\ k\Omega} = \frac{0 - V_0}{4.2\ k\Omega} \qquad \frac{5}{1} = \frac{-V_0}{2} \qquad \boldsymbol{V_0 = -10\ V}$$

Example for Inverting OpAmp

Problem 3: Determine the voltage gain, source current, output current, and output voltage of the Op-Amp circuit. Here, V_{in}=0.5 V, R_1=78 kΩ , and R_f=490 kΩ.

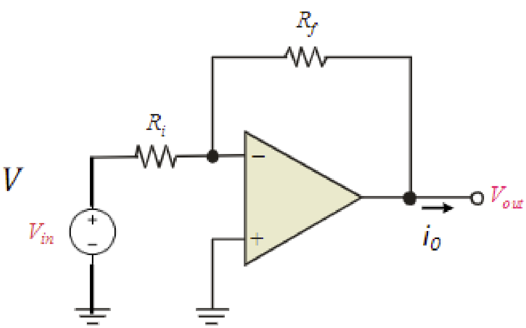
Solution 3:

$$A_v = Gain = -\frac{R_f}{R_1} = -\frac{490\ k\Omega}{78\ k\Omega} = -6.28$$

$$V_0 = A_v V_{in} = -\frac{R_f}{R_1} = -6.28\times 0.5 = -3.14\ V$$

$$I_s = \frac{V_s}{R_i} = \frac{0.5}{78\ k\Omega} = 6.41\ \mu A$$

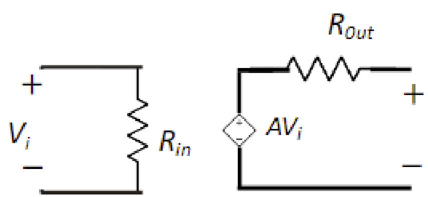
$$I_0 = -I_s = -6.41\ \mu A$$



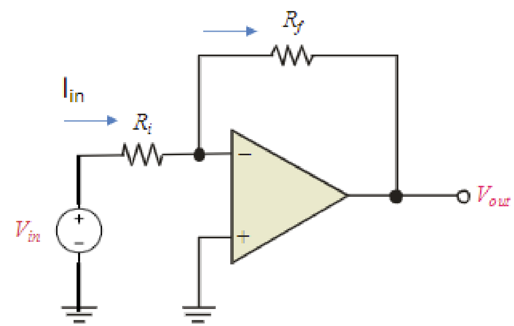
Example for Inverting OpAmp

Problem 4: Determine the voltage gain, input resistance, and output resistance of the inverting Op-Amp circuit. Consider R_{in}= 2 $k\Omega$, and R_f= 10 $k\Omega$

Solution 4:



Equivalent circuit of the amplifier



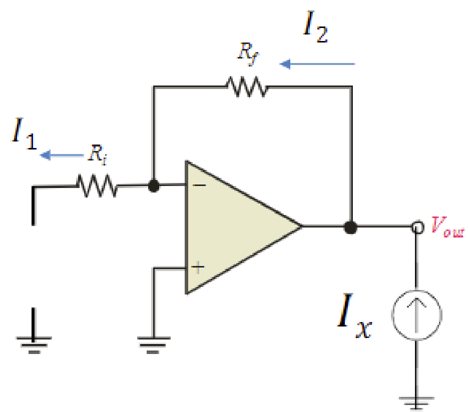
$$A_v = \frac{-10}{2} = -5$$

$$I_{in} = \frac{V}{2k\Omega} \qquad R_{in} = 2\ k\Omega$$

Example for Inverting OpAmp

Problem 4: Determine the voltage gain, input resistance, and output resistance of the inverting Op-Amp circuit. Consider R_{in}= 2 $k\Omega$, and R_f= 10 $k\Omega$

Solution 4:



If the input (V_i) is removed,

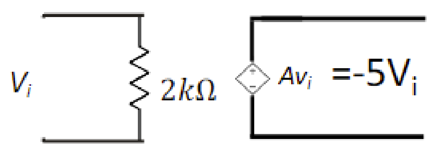
$$I_1 = 0\ A$$

$$I_2 = 0\ A$$

$$V_{out} = 0$$

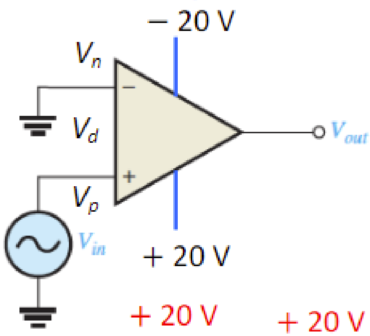
Regardless of I_x

$$R_{out} = 0\ \text{Ohm}$$



Example for Non-Inverted Comparator

Problem 1: Find V_{out} for the given circuit.



Solution 1:

$$V_d = V_p - V_n$$

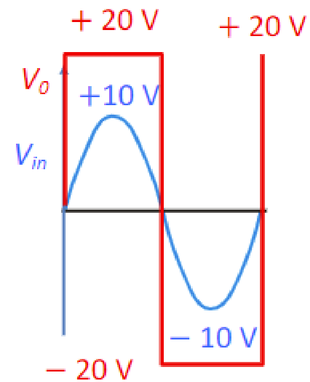
$$V_0 = AV_d = A(V_p - V_n)$$

When $V_p > V_n$ (0 V), then V_o is saturated

$$V_0 = +20\ V$$

When $V_p < V_n$ (0 V), then V_o is saturated

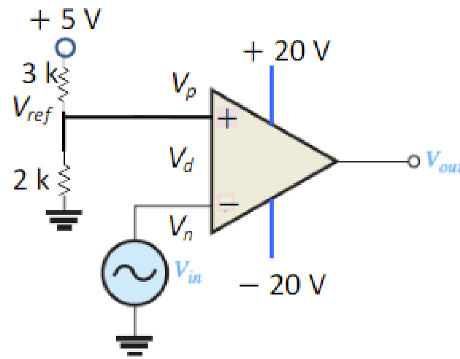
$$V_0 = -20\ V$$



Zero-level detection

Example for Inverted Comparator

Problem 2: Find V_{out} for the given circuit.



Solution 2:

$$V_0 = AV_d$$

$$V_d = V_{ref} - V_{in}$$

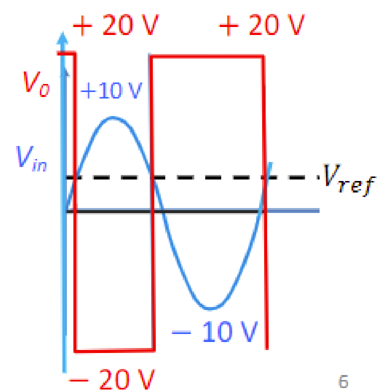
$$V_{ref} = \frac{2\ k}{2\ k + 3\ k} \times 5\ V = 2\ V$$

When V_{in} exceeds 2 V, then V_d is − ve

$$\text{Then, } V_0 = -20\ V$$

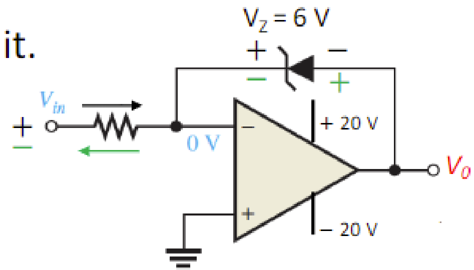
When V_{in} drops below 2 V, then V_d is + ve.

$$\text{Then, } \quad V_0 = +20\ V$$



Example for Output Bounding

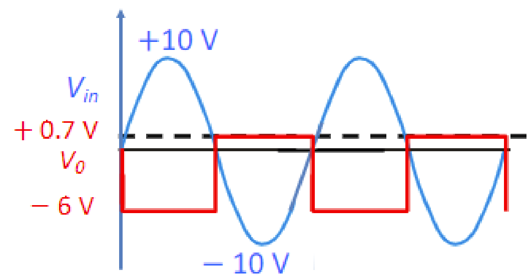
Problem 3: Find V_{out} for the given circuit.



Solution 3:

When V_i is + Ve, V_o is $-Ve$
At this condition, the Diode is RB
V_o is $-6\ V$

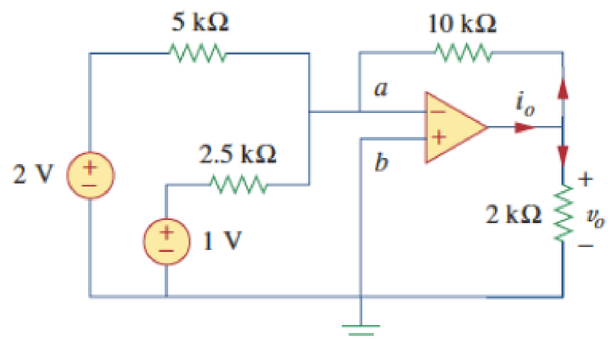
When V_i is − Ve, V_o is $+Ve$
At this condition, the Diode is FB
V_o is $+0.7\ V$



Example for Summing OpAmp

Problem 4: Find v_0 and i_o in the Op-Amp circuit.

Solution 4:



$$v_0 = -\left(\frac{10\ k}{5\ k}\times 2\ V + \frac{10\ k}{2.5\ k}\times 1\ V\right)$$

$$v_0 = -(4+4)V = -8\ V$$

$$i_0 = i_{10k} + i_{2k}$$

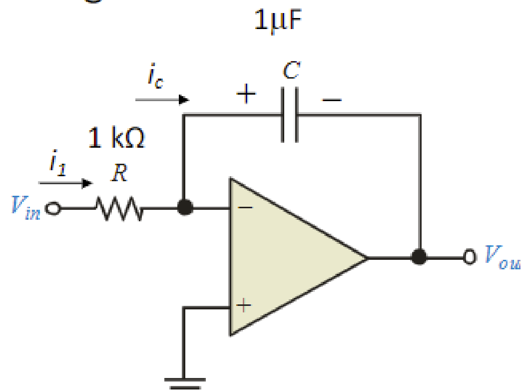
Since $v_a = v_b = 0$

$$i_0 = \frac{V_0 - 0}{10\ k} + \frac{V_0 - 0}{2\ k}$$

$$i_0 = \frac{-8}{10\ k} + \frac{-8}{2\ k} = -0.8 - 4 = -4.8\ mA$$

Example for OpAmp Integrator

Problem 2: Find the output waveform for the given circuit.



Solution 2:

When V_i is +ve ⟶ i_1 is + ve ⟶ i_c is – ve

$$V_{out} = -V_c = -\frac{1}{C}\int i\,dt$$

$$V_{out} = -\frac{I * t}{C} = -\frac{1\ V}{1\ k\Omega} \times \frac{10\times10^{-3}}{10^{-6}} = -10\ V$$

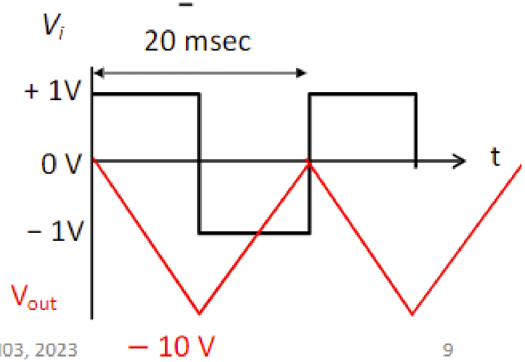
$$V_{out,min} = -10\ V$$

When V_i is –ve ⟶ i_1 is – ve ⟶ i_c is + ve

⟶ Capacitor is discharging

i_1=i_C=Constant

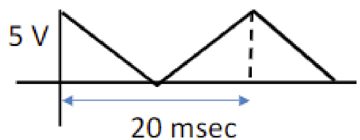
V_{out} decreases linearly from 0 as capacitor charges.

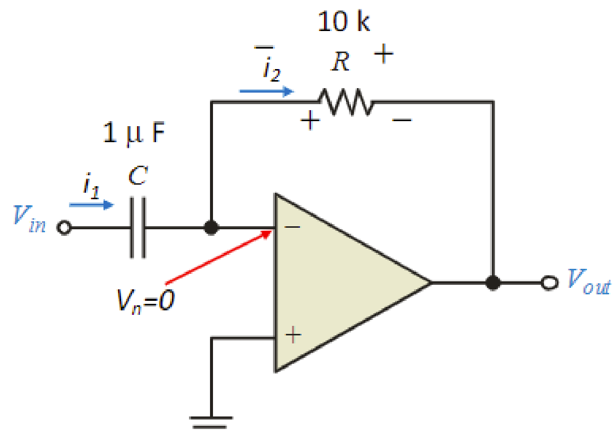


Example for OpAmp Differentiator

Problem 3: Determine the output waveform for the given circuit.

Solution 3:





$$i_1 = C\frac{dV}{dt}$$

$$\frac{dV}{dt} = \frac{-5}{10\ msec} = -500\ V/sec$$

$$\frac{dV}{dt} = \frac{5}{10\ msec} = 500\ V/sec$$

$$i_1 = \pm 500 \times C = \pm 500 \times 10^{-6} = \pm 0.5\ mA$$

$$V_0 = -i_2 \times R = -i_1 \times R = \pm 0.5\ mA \times 10\ k = \pm 5\ V$$