ENEE236 & 241

Analog Electronics

L4 Diode Applications 2

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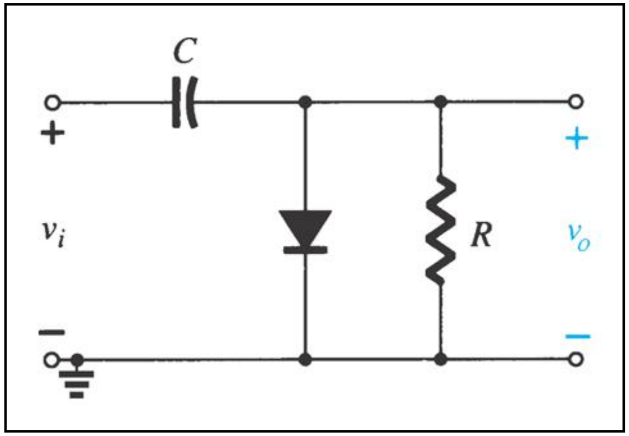
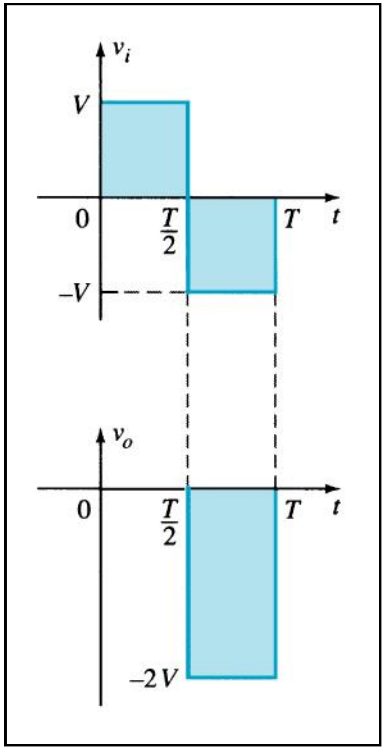
Clampers

Function: A Clamper shifts the input waveform up or down (adds a dc offset) while keeping its shape and peak to peak value unchanged.

It consists of a diode and capacitor (and maybe a series dc source) that can be combined to “clamp” an AC signal to a specific DC level and supply it to the load R





Steps for Clamper Circuit Analysis

1) Start analysis by examining Steps for the response of the portion of input that will forward bias the diode

2) During diode On period, assume that the cap is charged instantaneously to a voltage level defined by surrounding network

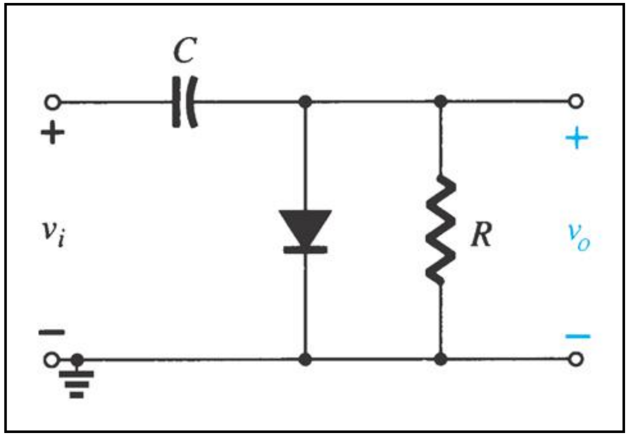
3) During OFF period, assume the cap holds the established voltage level (i.e. it behaves as constant dc voltage source)

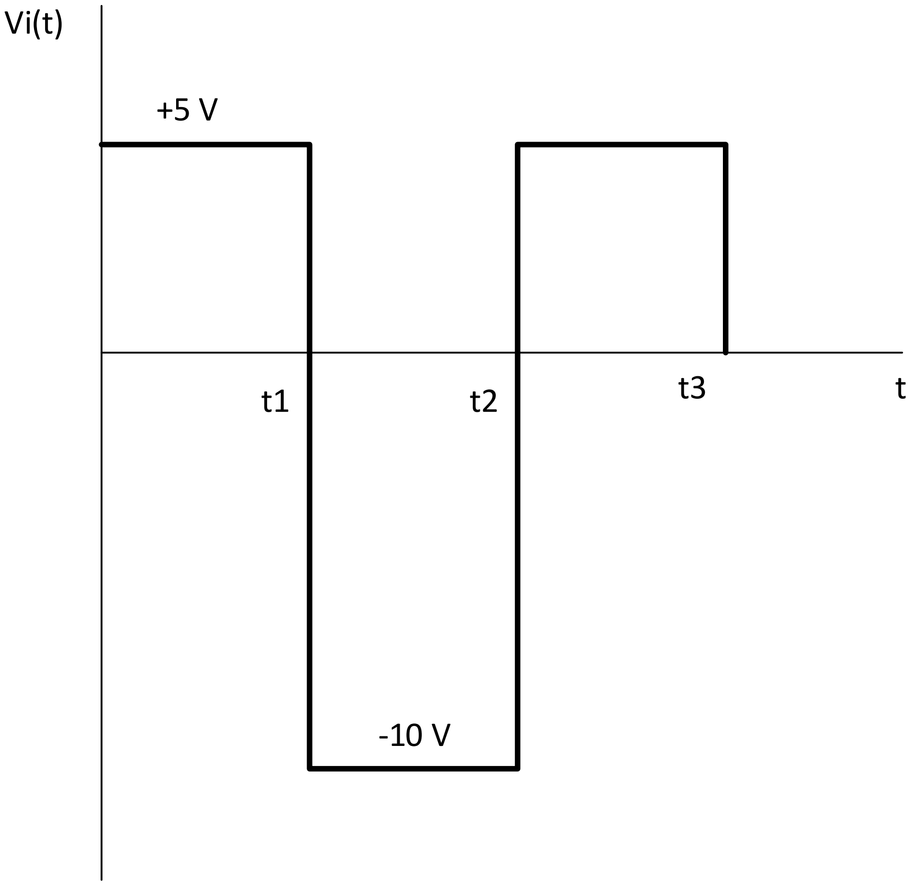
4) Consider value and polarity of Vo

5) Check that total swing (peak to peak) of output equal swing of input.

Example

Find and sketch Vo(t)?





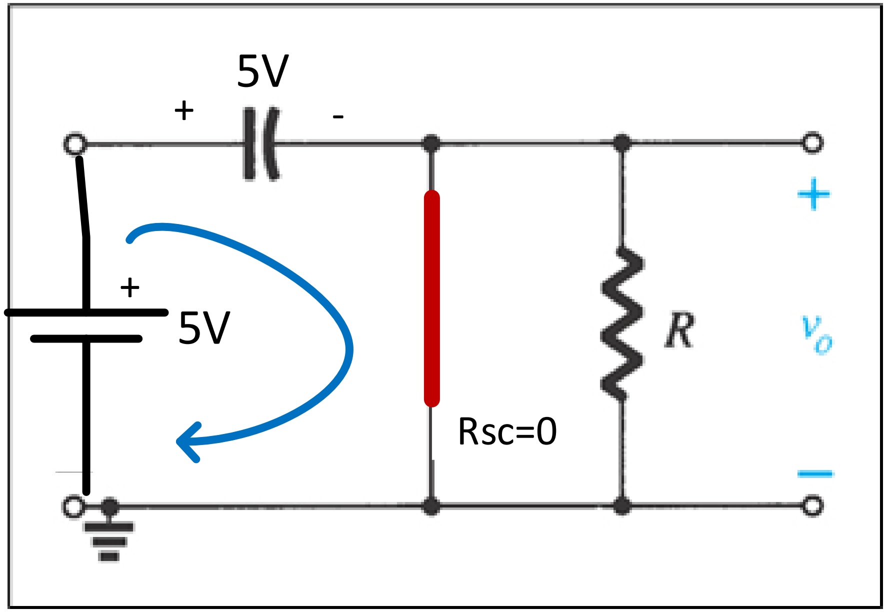
$$1)\ \text{For} < 0 \quad (t = 0^-) \qquad V_C(0^-) = 0$$

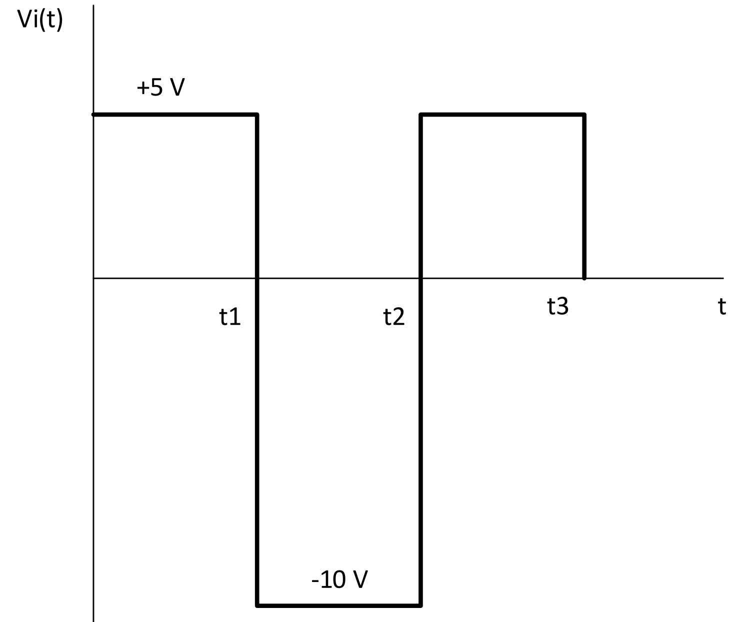
$$2)\ \text{For} > 0 \quad (t = 0+) \qquad V_C(0^+) = 0$$

$$Vi(0^+) = 5V$$

$$\Rightarrow D1\ \text{is ON and it is replaced by short circuit}$$

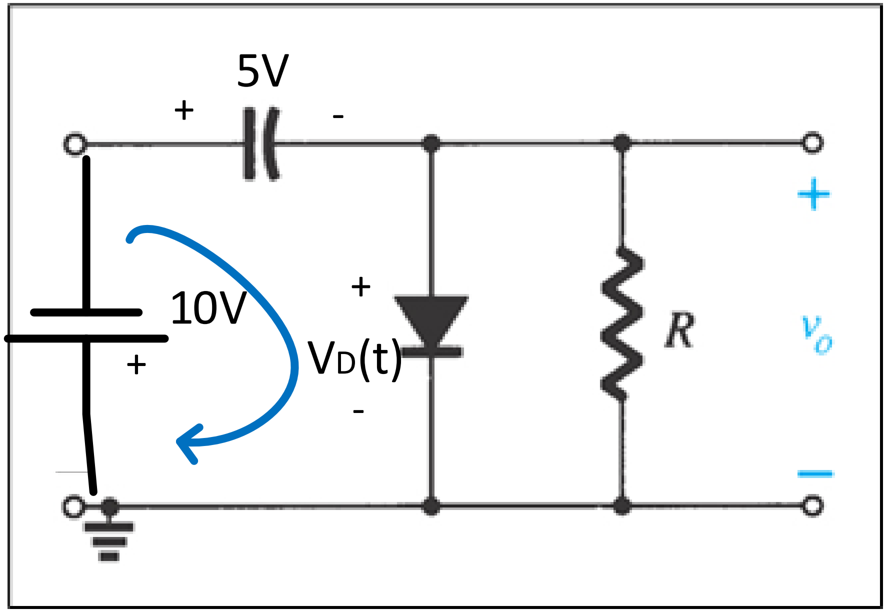
$$3)\ \text{for} \quad 0^+ < t < t_1 \quad \text{equivalent circuit is} \Rightarrow \text{see next page}$$

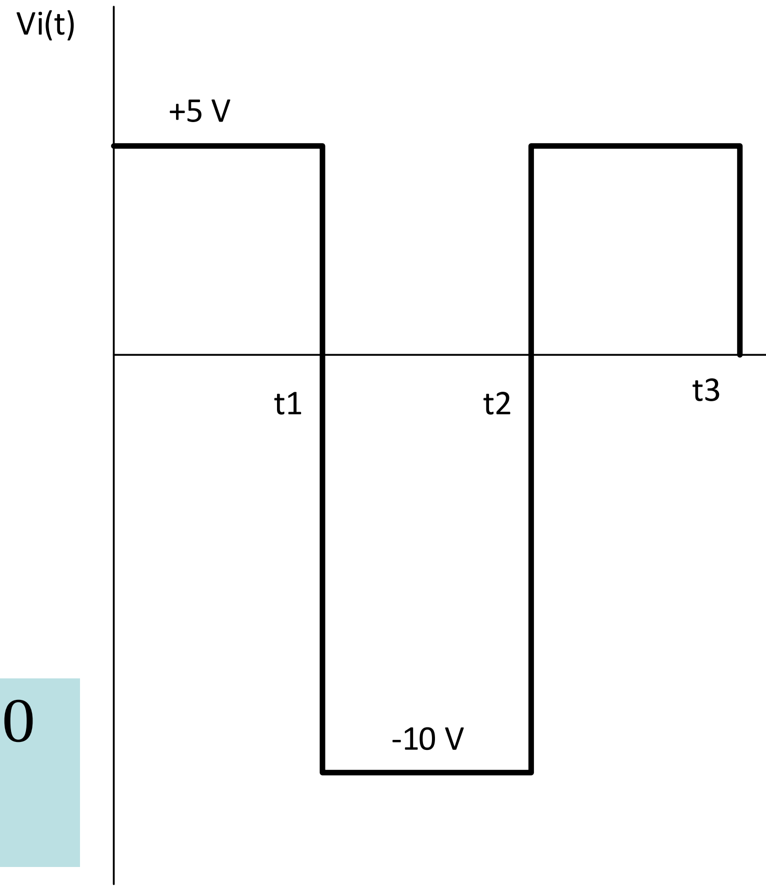




$\Rightarrow D1$ is ON, Cap charges instantously to + 5V with shown polarity since $\tau_{\text{charge}} = R_{sc}.C \cong 0$ and Vo(t) = 0 V

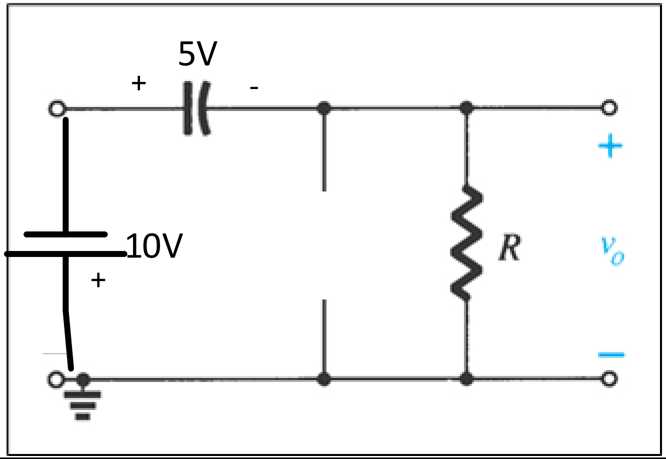
4) for $t_1 < t < t_2$ voltage source reverses polarity, Vi(t) = -10V while Cap keeps its charge Vc = 5V since $\tau_{\text{discharge}} = R.C$ is large





KVL around the loop : $-10 - 5 - V_D(t) = 0$

$\Rightarrow V_D(t) = -15\text{ V} < 0, \therefore$ diode is OFF



$Vo(t) = V_D(t) = -15\text{ V}$

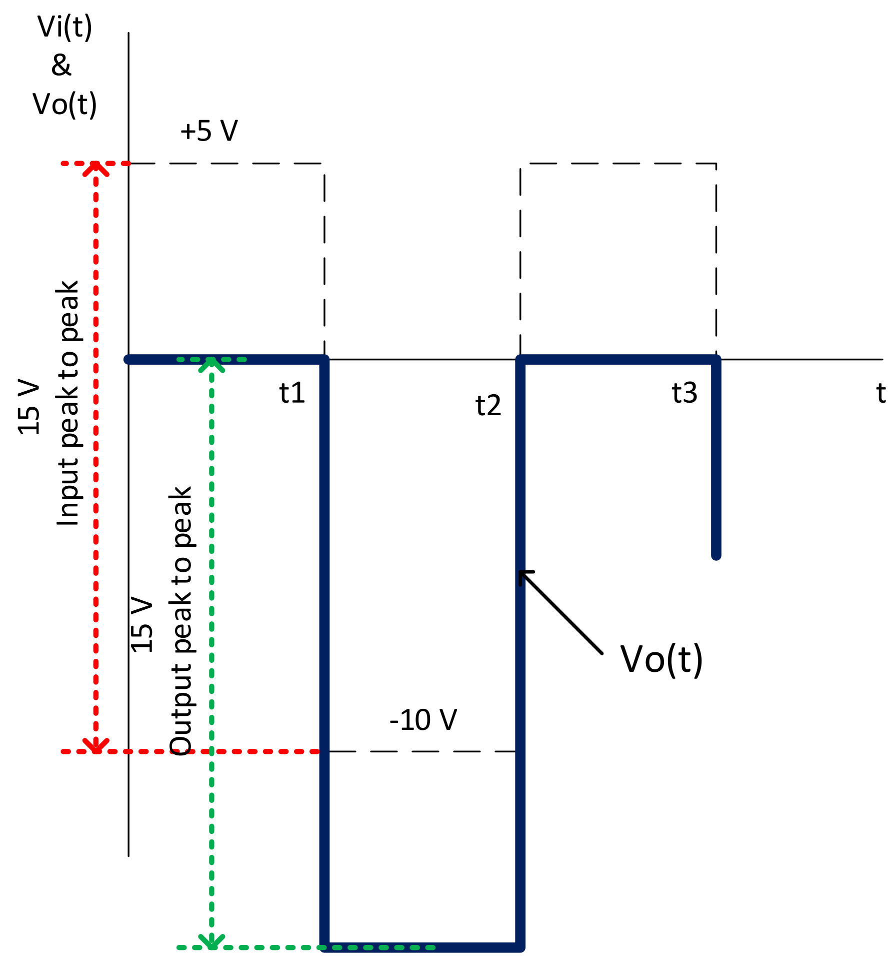
$$5)\ \text{for}\quad t_2 < t < t_3 \quad, Vi(t) = 5V$$

$$\text{while}\ \ Vc = 5V$$

$$V_D(t) = 5 - 5 = 0$$

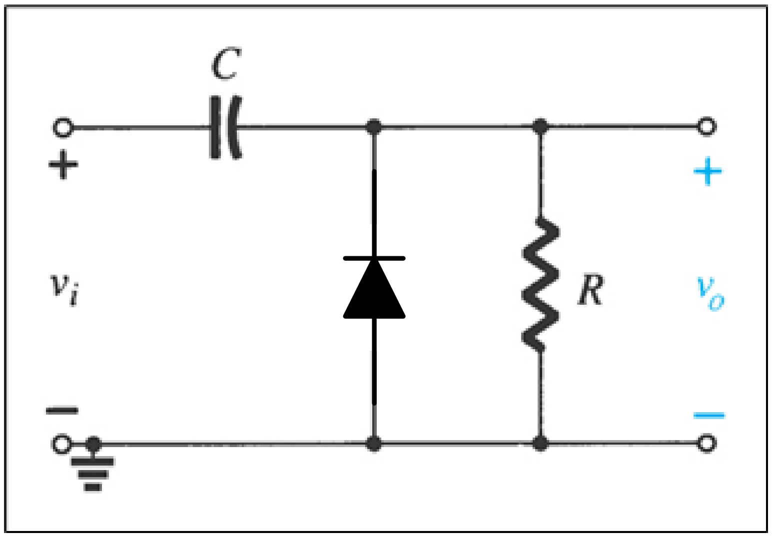
Diode is OFF and it will remain always off no matter what happens to Vi(t)

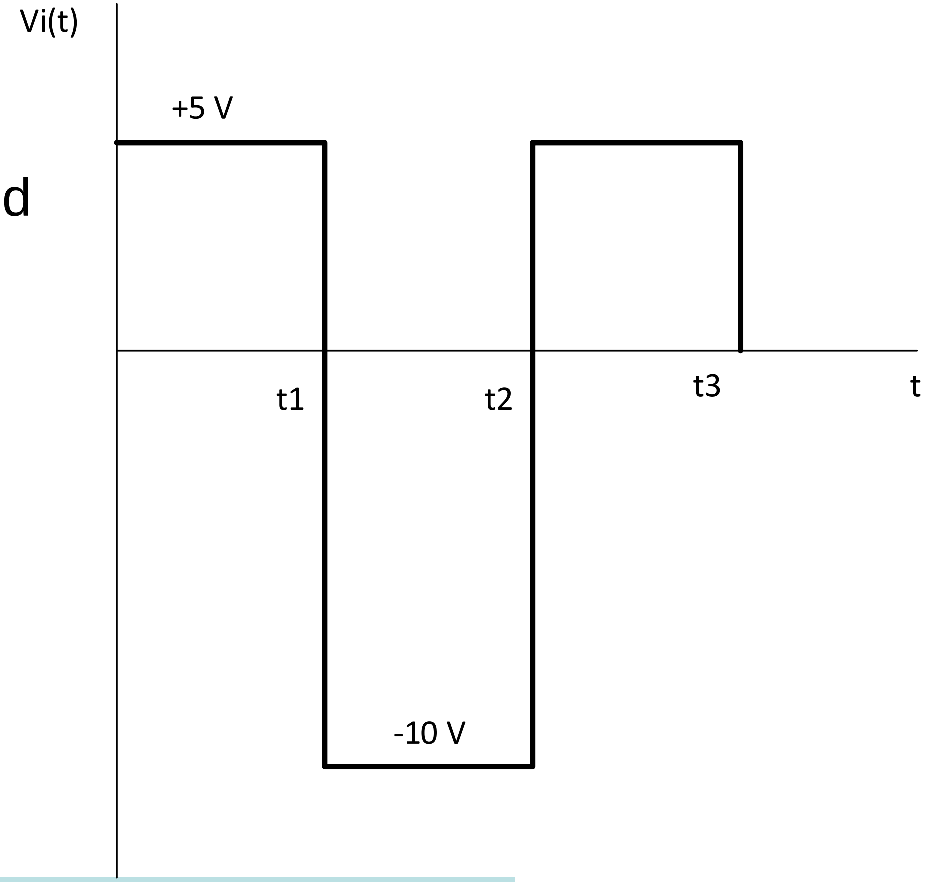
$$Vo(t) = V_D(t) = Vi(t) - 5$$



Example

What happens if the diode was inversed



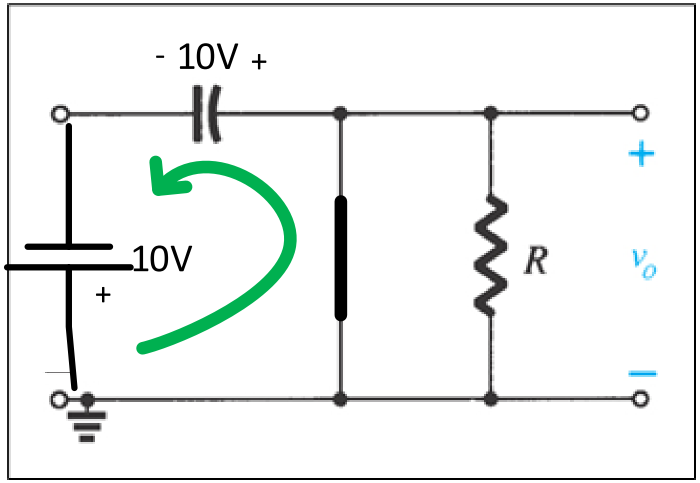


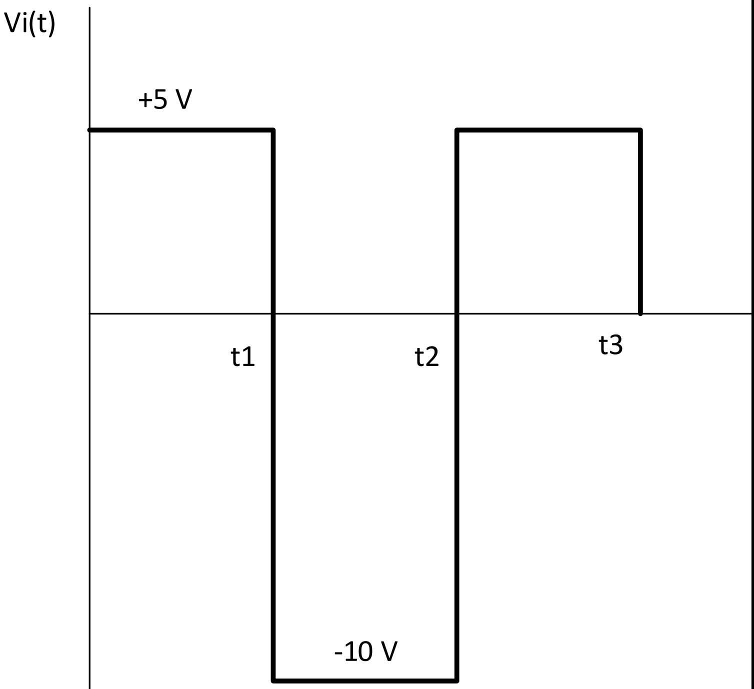
1) Consider $t_1 < t < t_2$ which makes the diode ON

$\Rightarrow D$ is ON and it is replaced by short circuit

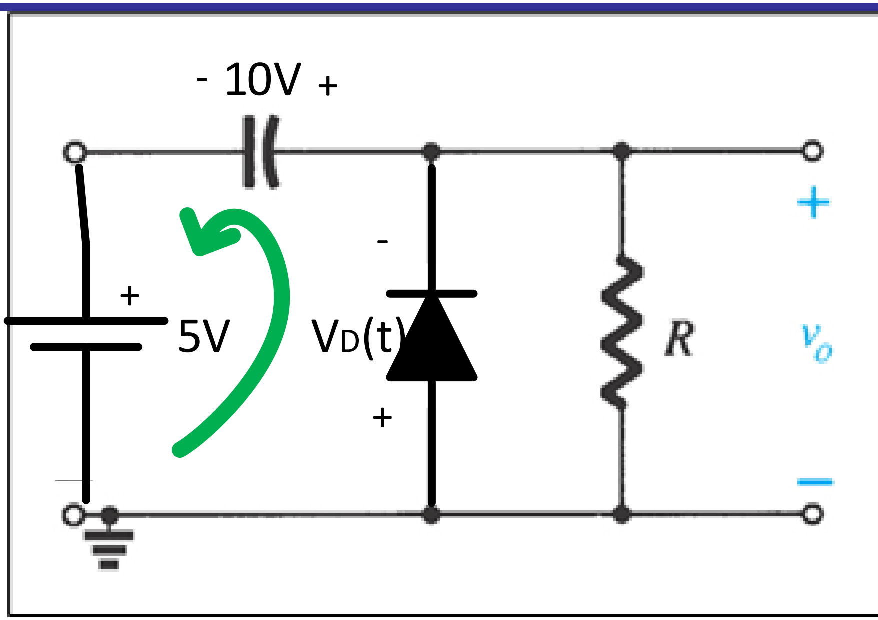
$Vo(t) = 0V$

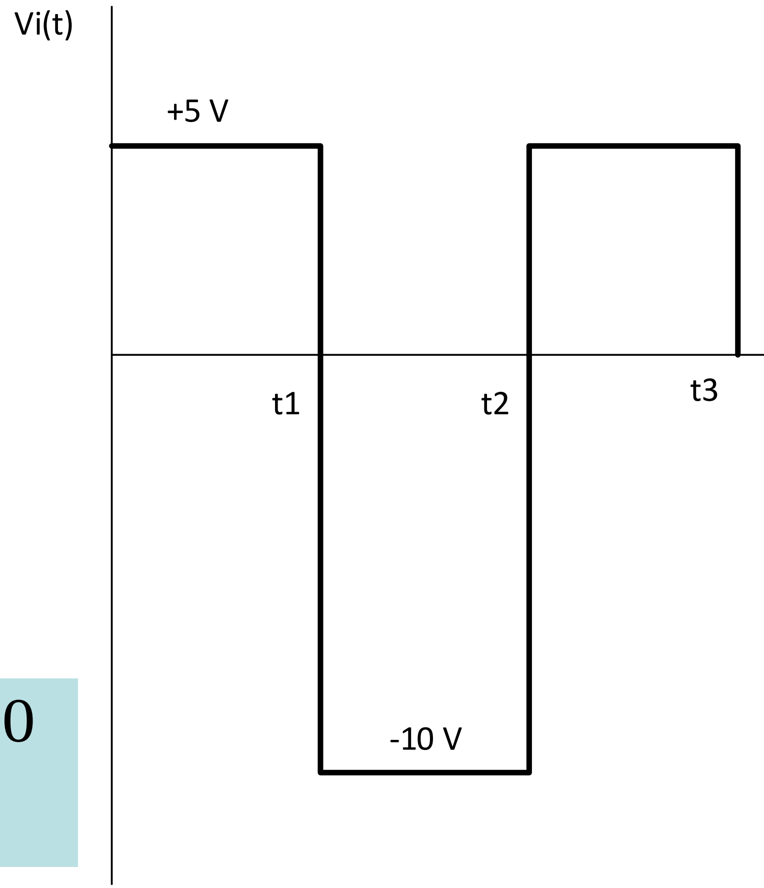
Cap is charged to 10V with shown polarity due to diode forward current Vo(t) = 0 V





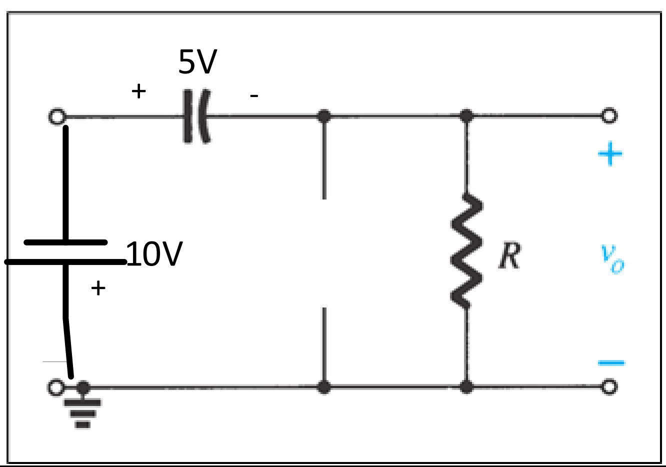
2) for $t_2 < t < t_3$ voltage source reverses polarity, Vi(t) = +5V while Cap keeps its charge Vc = 10V





$$\text{KVL around the loop: } 10 + 5 + V_D(t) = 0$$

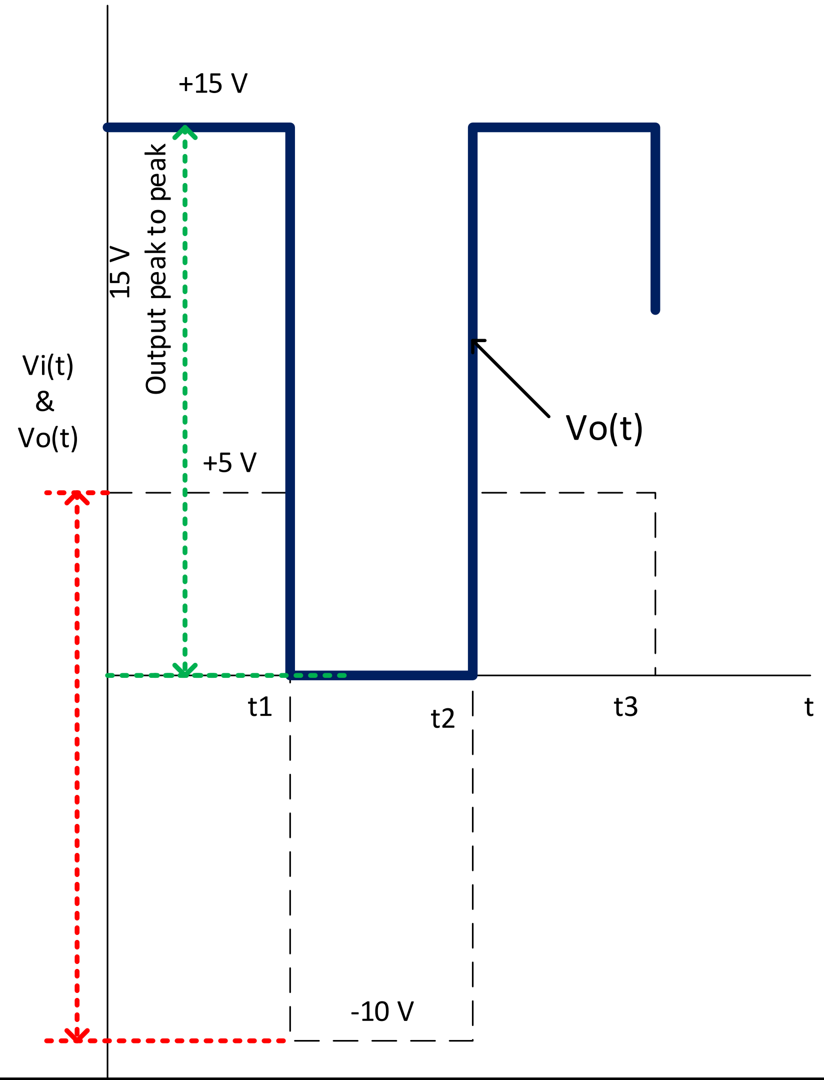
$$\Rightarrow V_D(t) = -15\text{ V} < 0, \therefore \text{diode is OFF}$$



$$Vo(t) = -V_D(t) = 15\text{ V}$$

Afterwords for any value of the given Vi(t) diode remains OFF and $Vo(t) = Vi(t) + 10$

$\therefore$ the clamper charges a cap and uses this charge to add up to the input to shift it up or down (i.e. add dc offset)

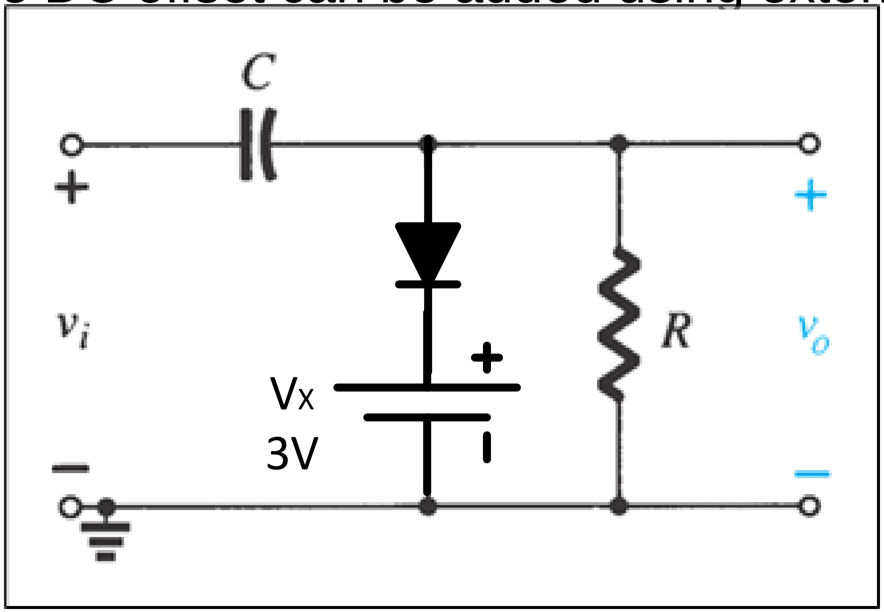


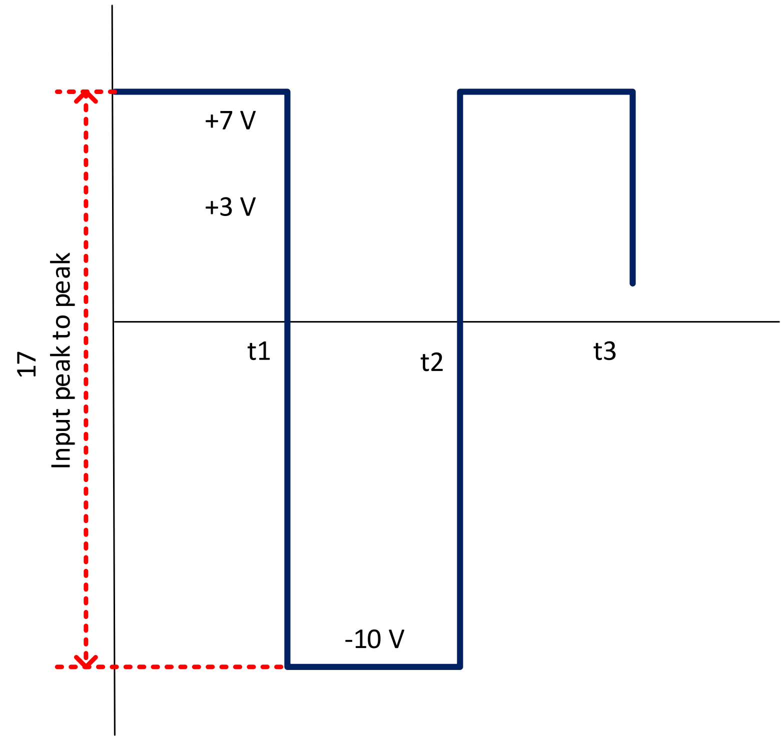
Important Note

For Proper Clamping action, $\tau_{discharge}$ must be large enough (at least 10 times the period of the input waveform)

$$\tau_{discharge} = R.C > 10\,(t_1 + t_2)$$

More DC offset can be added using external voltage source





1) When $Vi = +7\ V$

$$7 - Vc(t) - Vx = 0$$

$$\therefore Vc(t) = 7 - 3 = 4\ V$$

$$\Rightarrow Vo(t) = Vx = 3\ V$$

2) for $Vi = -10V$

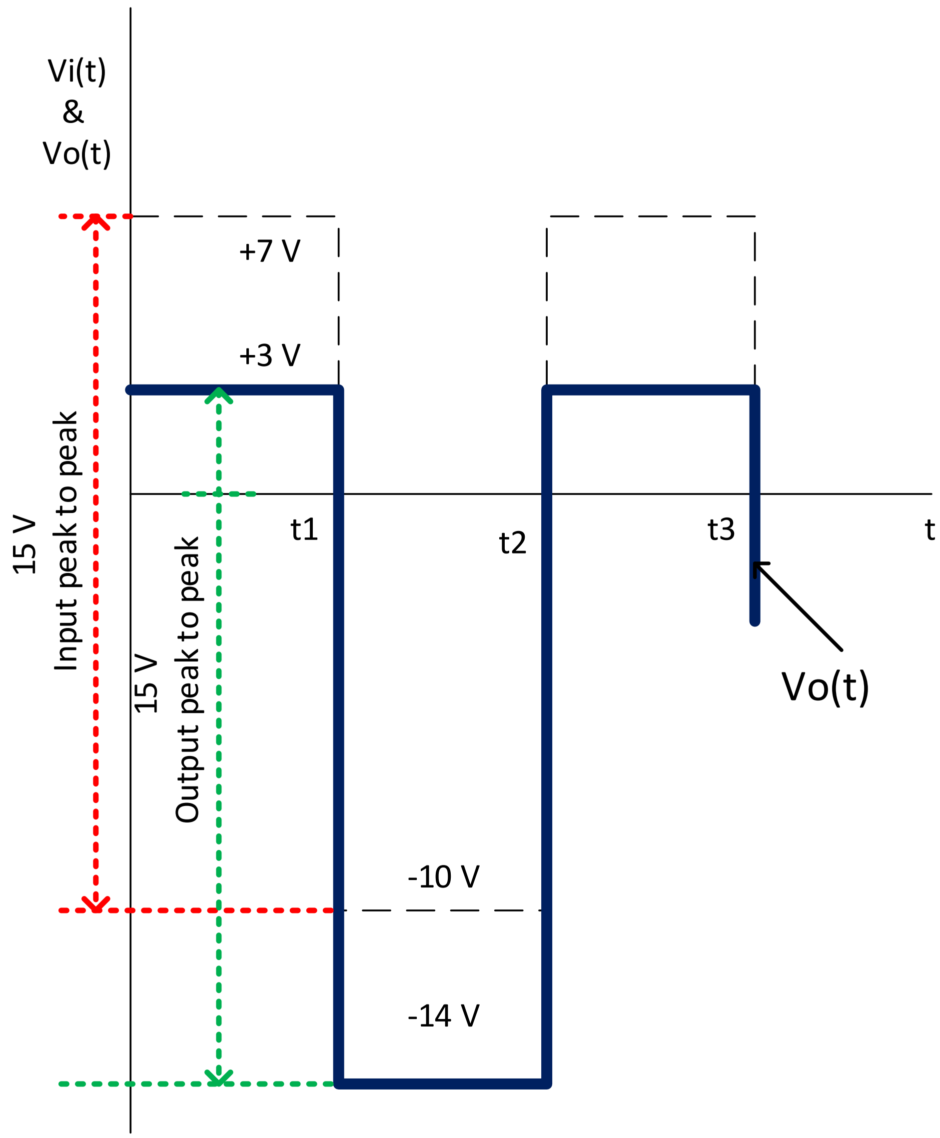
$$-10 - 4 - V_D(t) - 3 = 0$$

$$\Rightarrow V_D(t) = -17\ V \ < 0 \text{ and diode is OFF}$$

$$\Rightarrow Vo(t) = Vi(t) - V_C(t)$$

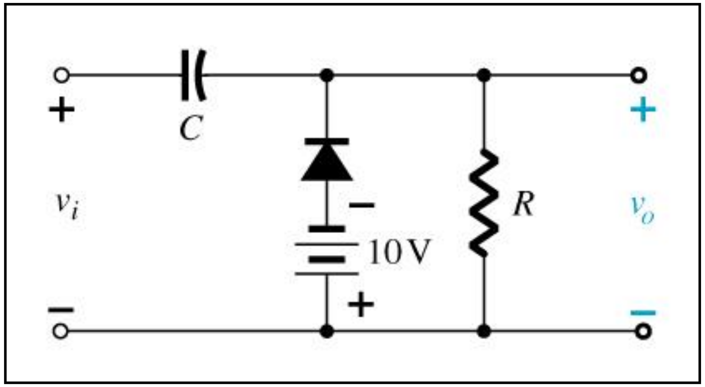
$$= Vi(t) - 4$$

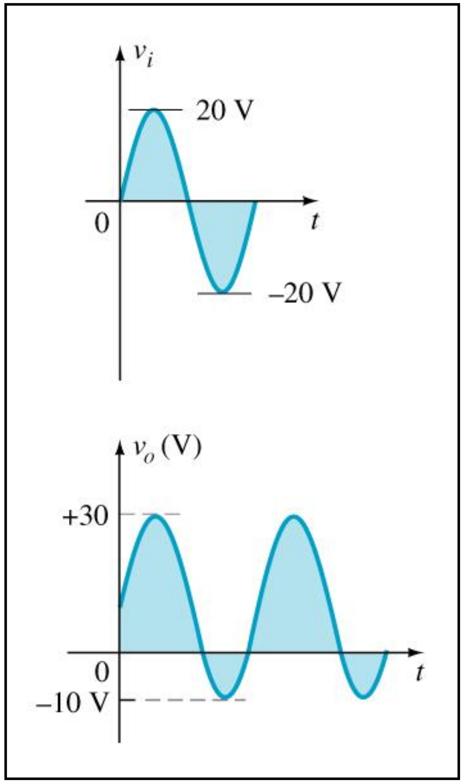
$$= -10 - 4 = -14V$$


Vi(t)
&
Vo(t)
+7 V
+3 V
15 V
Input peak to peak
15 V
Output peak to peak
t1
t2
t3
t
Vo(t)
-10 V
-14 V

Biased Clamper Circuits

The input signal can be any type of waveform such as a sine, square, or triangle wave.





The DC source lets you adjust the DC clamping level.

Summary of Clamper Circuits