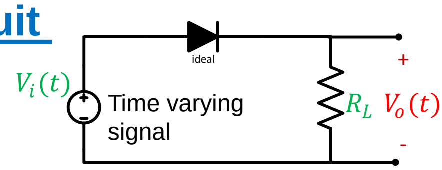
ENEE236
Analog Electronics

T3:
Diode Applications

Diode large – signal application

1) Diode clipper circuit

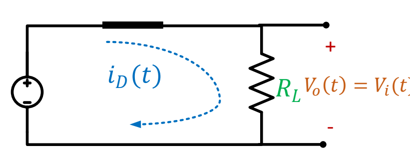


a) assume the diode is on
 replace it with short circuit

$i_D(t) > 0$

$i_D(t) = \frac{V_i(t)}{R_L} > 0$

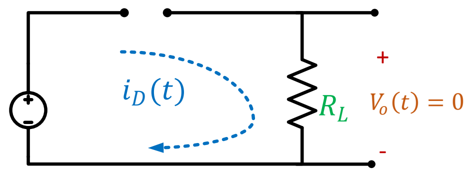
$\therefore\ V_i(t) > 0$

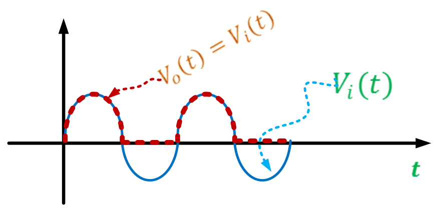


$\therefore$ when $V_i(t) > 0$, the diode is on and $V_O(t) = V_i(t)$

∴ when $V_i(t) < 0$, the diode is off and $V_O(t) = 0$.

$V_O(t) = 0$.



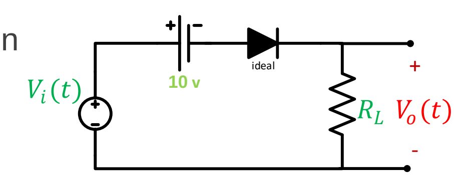


∴ the clipper circuit used to eliminate portion of the input signal .

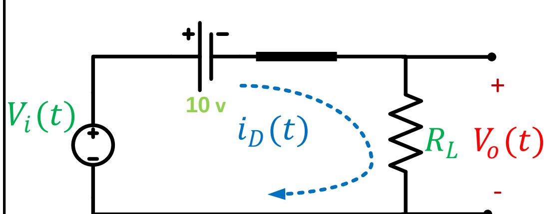
Example

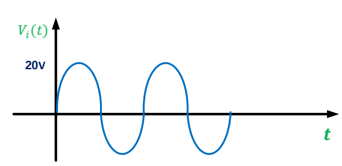
a) assume that the diode is on

➔ replace it with short circuit



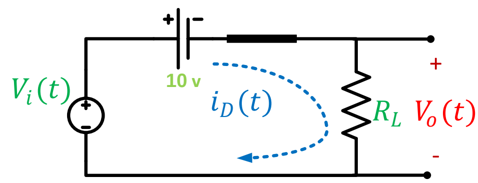
$i_D > 0$





$$i_D(t) = \frac{V_i(t) - 10}{R_L} > 0$$

$$i_D(t) = \frac{V_i(t) - 10}{R_L} > 0$$



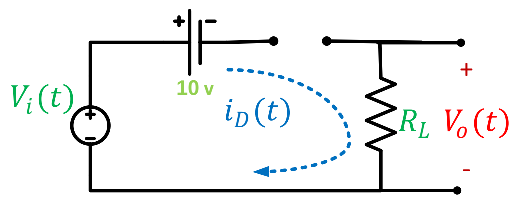
$\therefore\ V_i(t) - 10 > 0$

$\therefore\ V_i(t) > 10$

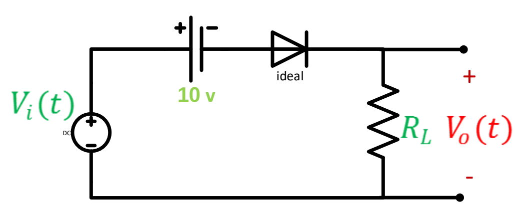
$\therefore$ when $V_i(t) > 10$ V , the diode is on and $V_O(t) = V_i - 10$

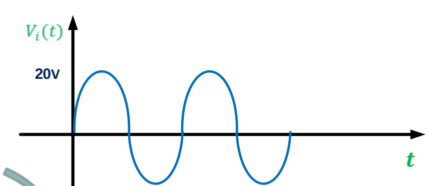
and also we can prove that when $V_i(t) < 10\ V$, the diode is off

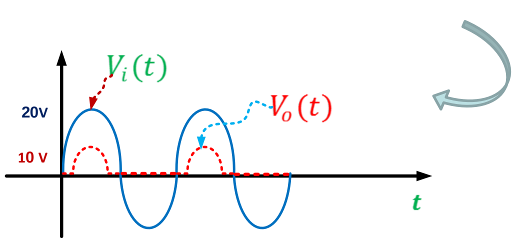
$\therefore\ V_O(t) = 0$



The output







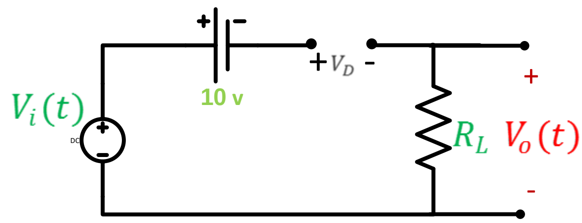
Second Method

assume that the diode is off ,replace it with open circuit

$V_D(t) < 0$

$V_D(t) = -10 + V_i$

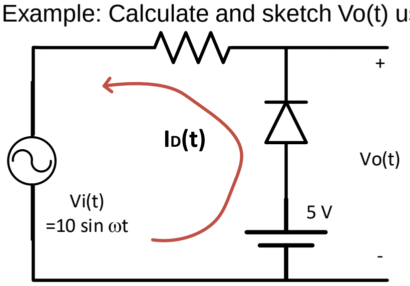
$V_i(t) < 10$ V

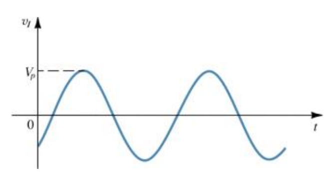


∴ when $V_i(t) < 10$ V , the diode is off and $V_O(t) = 0$

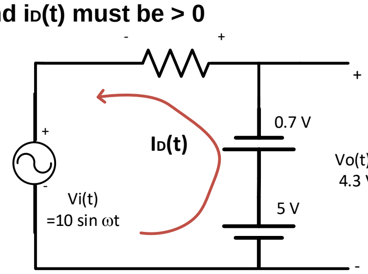
Limiters (=Clipping circuits) (1)

Example: Calculate and sketch Vo(t) using simplified diode model





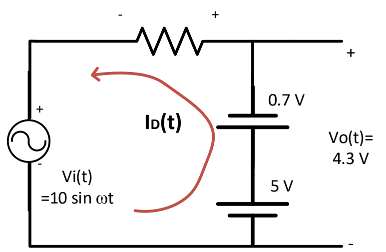
1) Assume diode is ON, so we replace it by 0.7 V and iD(t) must be > 0



$$5V - 0.7V - i_D(t).R - Vi(t) = 0$$
$$i_D(t).R = 4.3V - Vi(t)$$

$$i_D(t) = \frac{4.3V - Vi(t)}{R} > 0$$

Limiters (=Clipping circuits) (2)

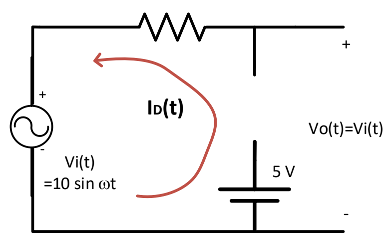


$$\therefore \quad 4.3V - Vi(t) > 0$$
$$\Rightarrow Vi(t) < 4.3V$$

when $Vi(t) < 4.3$ V diode is ON ar

$$Vo(t) = 4.3V$$

2) Otherwise, When Vi(t) is > 4.3 V, Diode will be off and it is replaced by open circuit

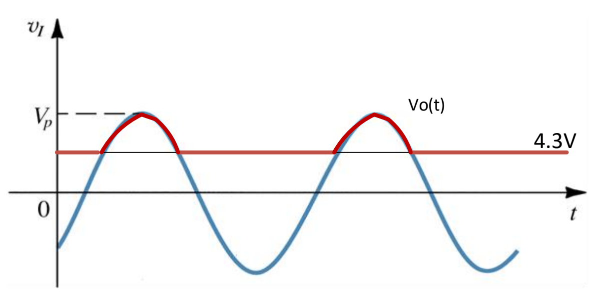


$$\Rightarrow Vi(t) > 4.3V$$
$$Vo(t) = Vi(t)$$

Limiters (=Clipping circuits) (3)

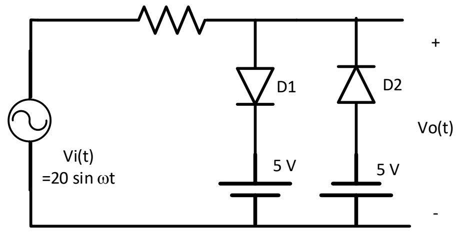
when $Vi(t) < 4.3V$, diode is ON & $Vo(t) = 4.3V$

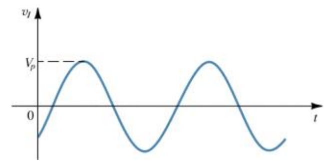
when $Vi(t) > 4.3V$, diode is off & $Vo(t) = Vi(t)$



Circuit Containing Two diodes

Example: Calculate and sketch Vo(t) using ideal diode model





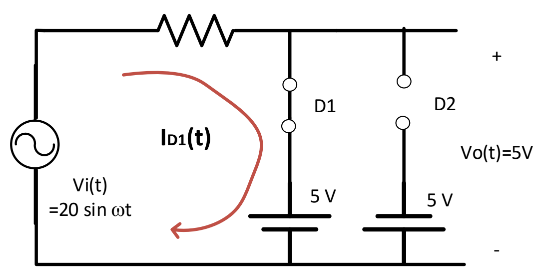
Since the circuit contains two diodes, each of them can be either On or Off,

➔ then there is 4 possible combinations for the states of D1 and D2

1) Assume D1 is ON and D2 is OFF

$i_{D1}(t) > 0$

$$i_{D1}(t) = \frac{Vi(t) - 5}{R} > 0$$



$$\text{when } Vi(t) > 5\,V \;,\; Vo(t) = 5V$$

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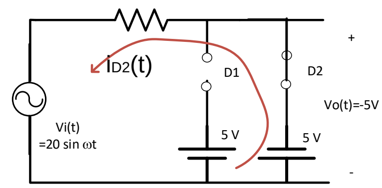
2) Assume D2 is ON and D1 is OFF
$i_{D2}(t) > 0$



$$i_{D2}(t) = \frac{-Vi(t) - 5}{R} > 0$$

$$\text{when } \; Vi(t) < -5\,V \;, \; Vo(t) = -5V$$

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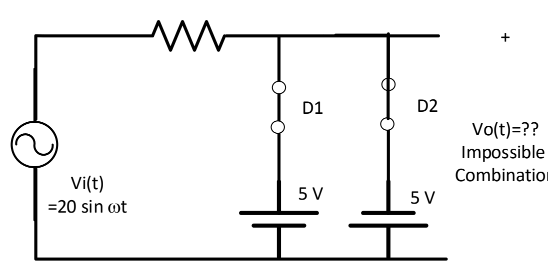
3) Assume D1 & D2 are ON

Vo=+5V ??
Vo=-5V ??

?

This is invalid configuration
and impossible to occur



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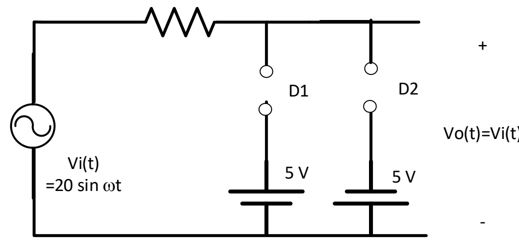
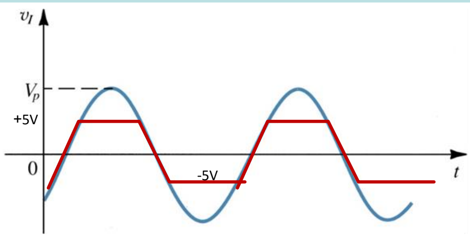
4) Assume D1 & D2 are both OFF

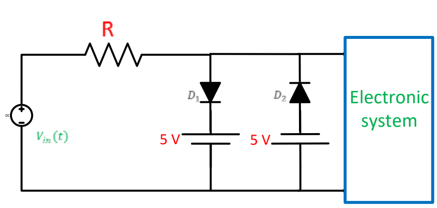
$\mathrm{Vo(t) = Vi(t)}$



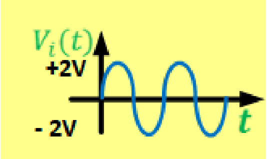
This occures for the remaining part of the input voltage waveform:
$-5\mathrm{V} < \mathrm{Vi(t)} < 5\mathrm{~V}$



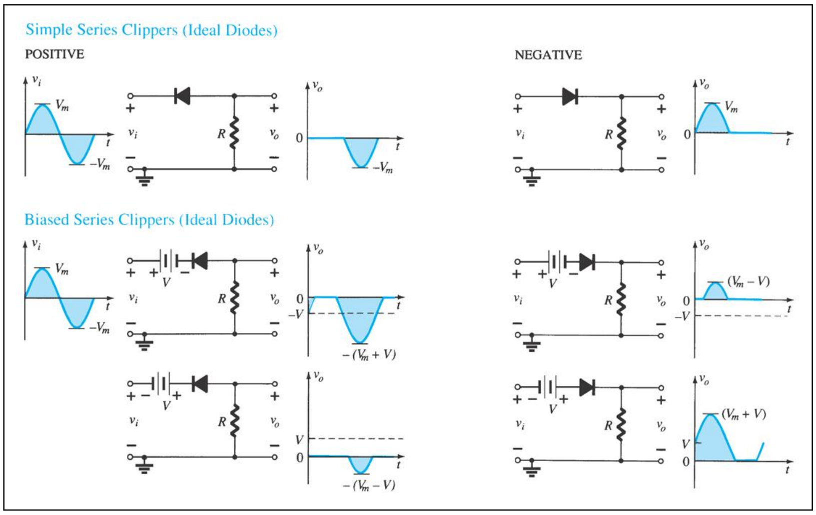
Limiter For protection



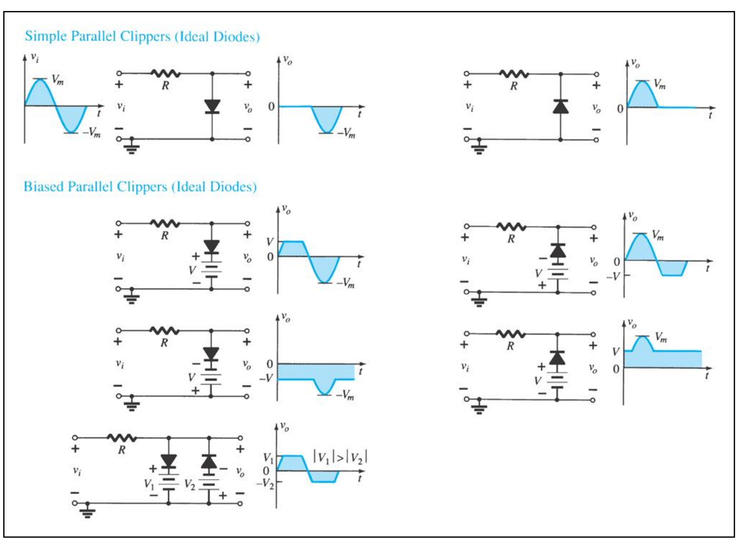
What happens if input is as shown below?



Summary of Clipper Circuits



Summary of Clipper Circuits



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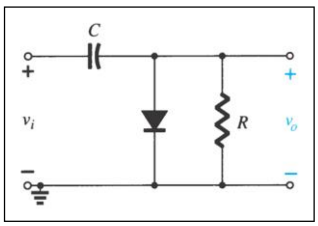
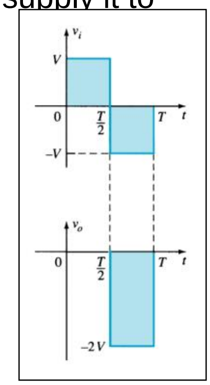
Clampers

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





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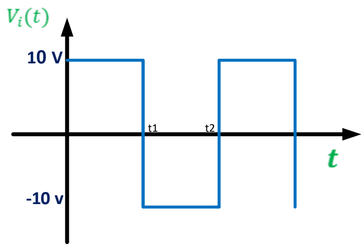
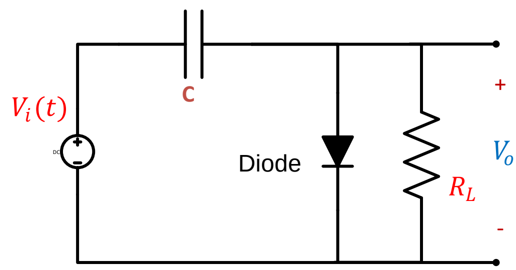
Steps for Clamper Circuit Analysis

1) Start analysis by examining 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 of Clamping circuit



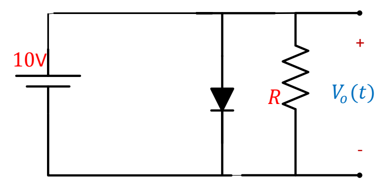


Diode is ideal , $V_c(0-) = 0$

1) at t= 0^+

$V_i(0^+) = 10V$; $V_c(0^+) = V_c(0^-) = 0$

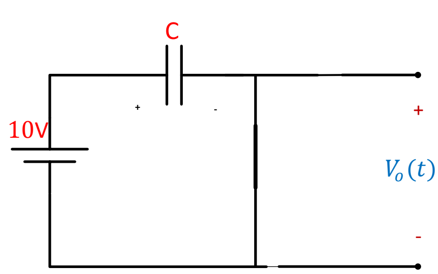
$\therefore$ $V_D(0^+) = 10V$,

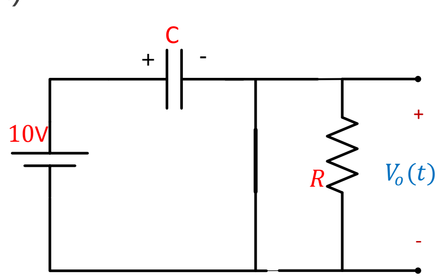


$\therefore$ **Diode is on and then replaced with short circuit**

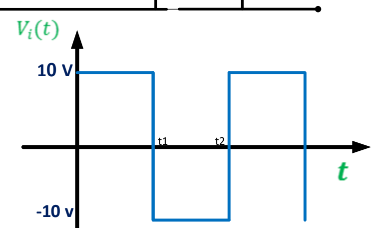
In the interval $t_1 > t > 0^+$

- $V_i = 10\ V$, Diode is on (short)



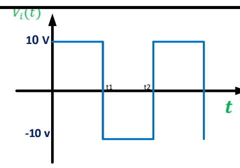


$V_0(t) = 0$



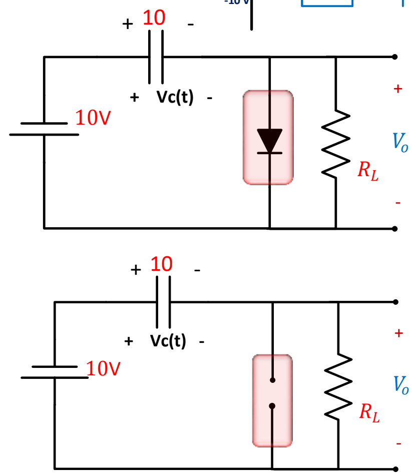
and the capacitor charges toward $+10V$ in 5τ = $5R_{eq}$C = 0

In the interval $t_2 > t > t_1$



$V_i = -10\ V$

The diode is off and replaced with open circuit

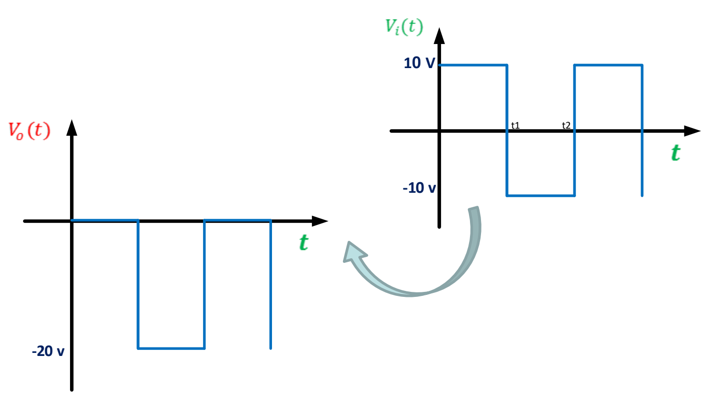


- $\therefore V_0(t) = -V_c(t) - 10$
- $V_0(t) = -10 - 10$

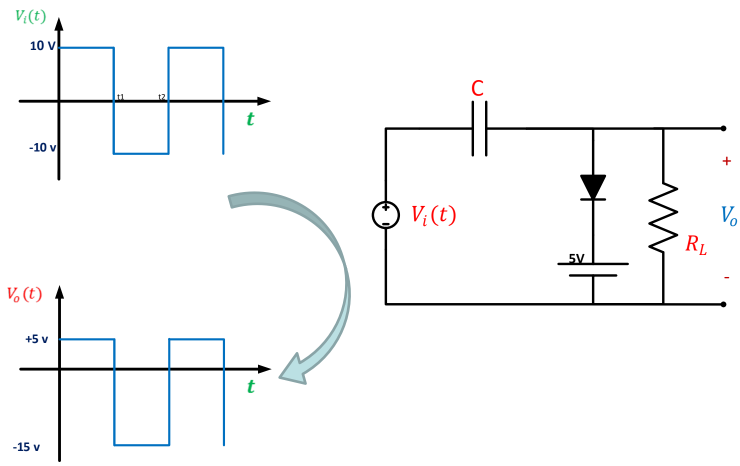
$V_0(t) = -20\ V$

We must choose $RC \gg (t_2 - t_1)$ so that $V_c(t) \equiv 10\ V$ in this interval

The output



Biased clamping circuit



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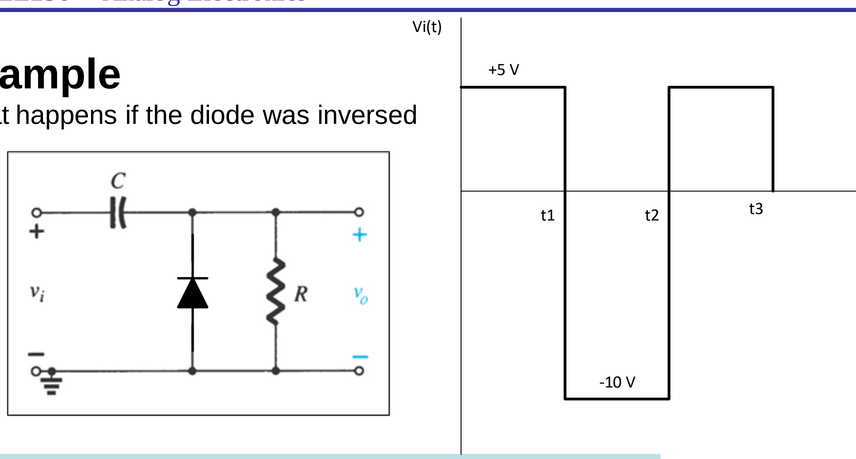
Example

What happens if the diode was inversed

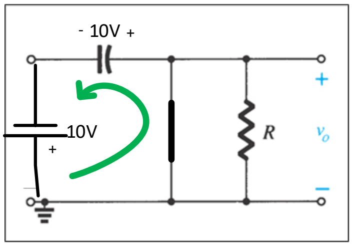


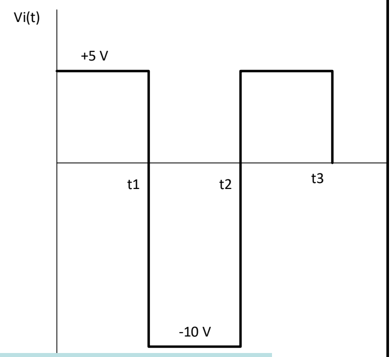
1) Consider $t_1 < t < t_2$ which makes the diode ON

$\Rightarrow D$ 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 $Vc = 10V$

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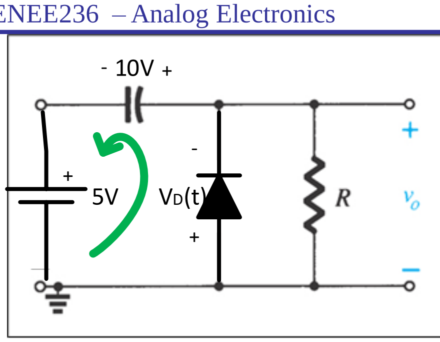
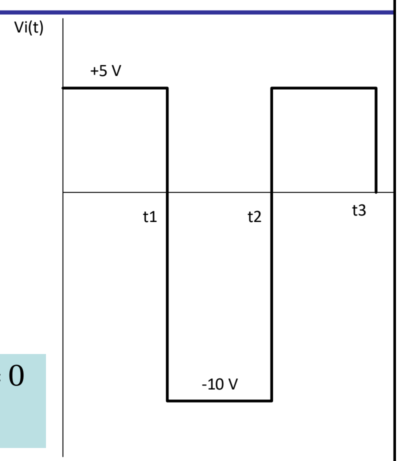
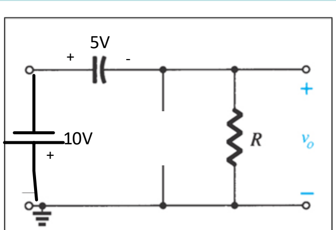




KVL around the loop: $10 + 5 + V_D(t) = 0$

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



$Vo(t) = -V_D(t) = 15\ V$

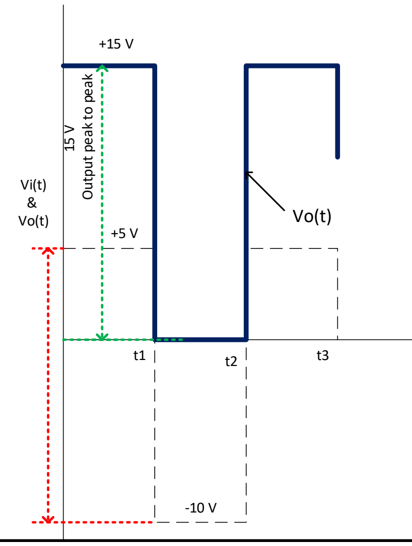
Afterwords for any value of the given Vi(t) diode remains OFF and $Vo(t) = Vi(t) + 10$

$\therefore$ 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)

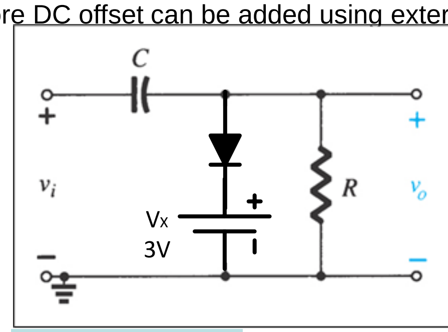
Important Note

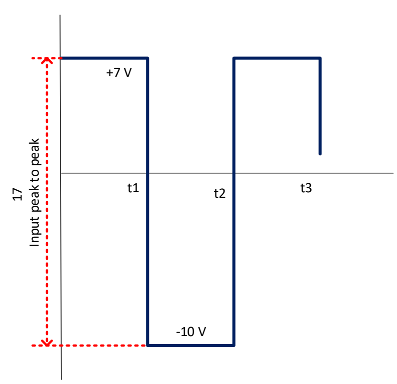
For Proper Clamping action, $\tau_{discharge}$ must be large enough (at least 10 times the period of the input waveform)

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



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 $Vi = -10V$

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

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

$$\Rightarrow Vo(t) = Vi(t) - V_C(t)$$
$$= Vi(t) - 4$$
$$= -10 - 4 = -14V$$

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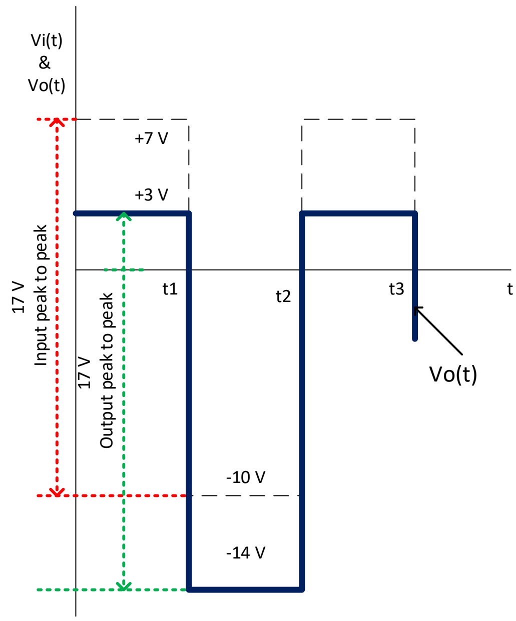

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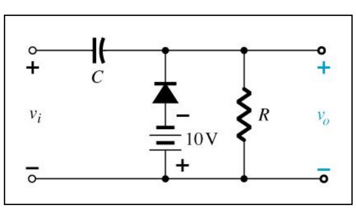
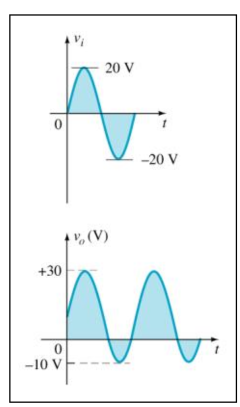
For Self study

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.



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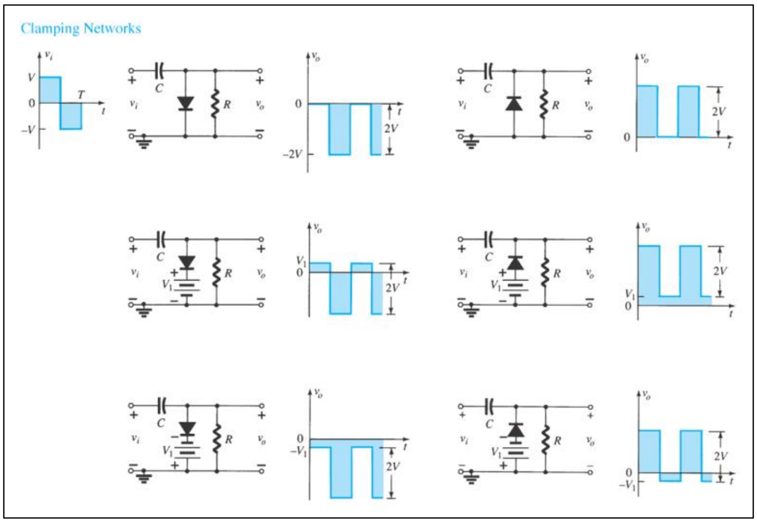
Summary of Clamper Circuits



3) Voltage Multiplier

D_1 , and D_2 are ideal

$V_{c1}(0^-) = V_{c2}(0^-) = 0$

A) **at t = 0^+**

$\boldsymbol{V_i(0^+) > 0 \quad V_{c1}(0^+) = V_{c2}(0^+) = 0}$

$\boldsymbol{V_{D1}(0^+) > 0V \quad \therefore D_1}$ **on**

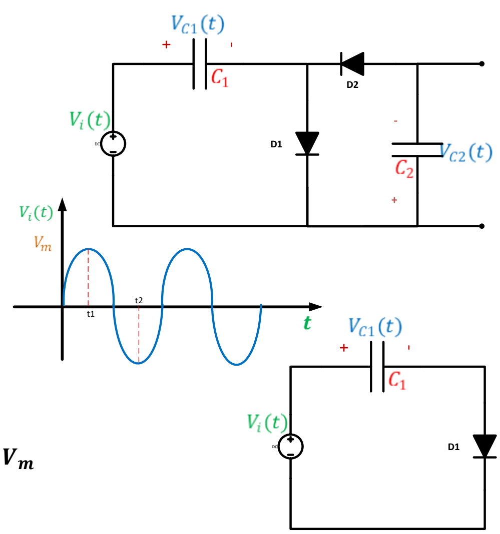
and $\boldsymbol{V_{D2}(0^+) < 0V \therefore D_2}$ **off**

B) in the interval $t1 > t > 0$

$\boldsymbol{V_{c1}(t) = V_i(t)}$

The capacitor C1 charges towards V_m

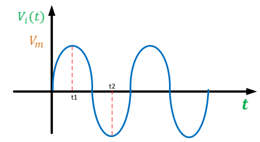
at t_1 ; $V_c(t_1) = V_m$



- C) at $t = t_1^+$

  $V_{c1}(t_1^+) = V_m$

  $V_i(t_1^+) < V_m \therefore D_1$ is off , and D_2 is on



- D) in the interval $t_2 > t > t_1$

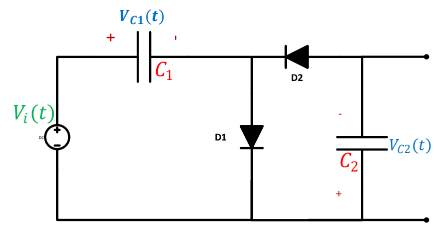
  C_2 charges toward $2V_m$

  at $t = t_2$

  $V_{c2}(t_2) = 2V_m$

  $V_{c2}(t_2) = -V_i(t_2) + V_m$

  $V_{c2}(t_2) = V_m + V_m = 2V_m$

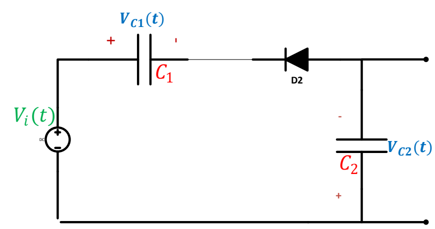


- E) at $t = t_2^+$

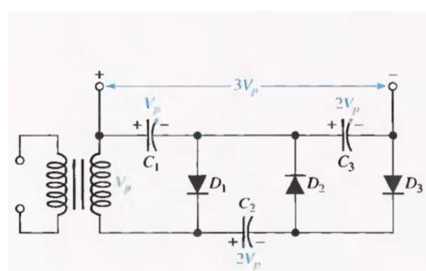
  D_2 is off, D_1 is off

  $V_{c1}(t_2^+) = V_m$

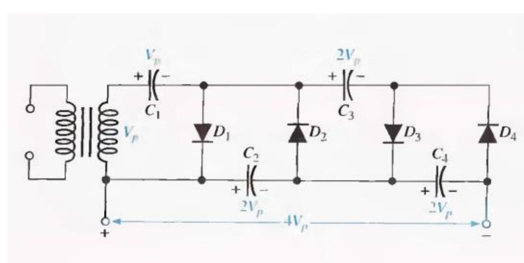
  $V_{c2}(t_2^+) = 2V_m$



Voltage Tripler



Voltage Quadrupler



Electric Bug Zapper