ELECTRONIC PRINCIPLES AND DEVICES

Department of Electronics and Communication Engineering

Clippers

- **Clippers** are networks that employ diodes to “clip” away a portion of an input signal without distorting the remaining part of the applied waveform.
- The half-wave rectifier is an example of the simplest form of diode clipper having one resistor and a diode.
- Depending on the orientation of the diode, the positive or negative region of the applied signal is “clipped” off.
- Two general categories:
  - **Series Clipper** (Diode is in series with the load)
  - **Parallel Clipper** (Diode in a branch parallel to the load)

Clippers - Classification

- Clippers
  - Series
    - Unbiased Series
    - Biased Series
  - Parallel
    - Unbiased Parallel
    - Biased Parallel

Series Clippers

- The **series configuration** is defined as one where the **diode is in series with the load.**
- Fig.1(a) shows the circuit of a series clipper.
- The response of the series configuration of Fig. 1(a) to a variety of alternating waveforms is shown in Fig. 1(b).
- There are **no boundaries on the type of signals** that can be applied to a clipper.

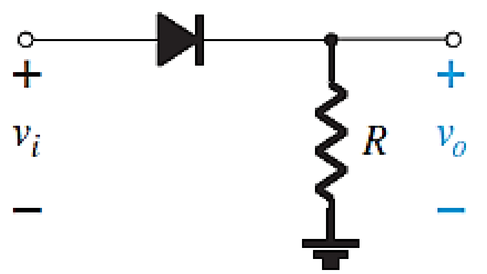


Fig. 1(a): Series Unbiased Clipper

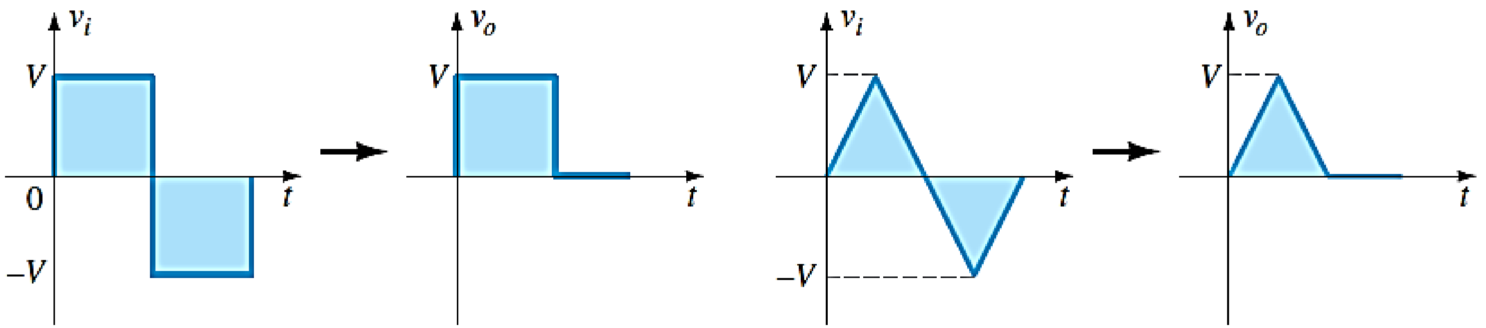


Fig. 1(b): Input-output Waveforms

Series Clippers

- Fig.2 shows the **series clipper with DC supply**. This configuration is called as **biased series clipper**.
- The **addition of a dc supply** to the network as shown in Fig. 2 can have a pronounced effect on the analysis of the series clipper configuration.
- The dc supply can be in the **leg between the supply and output** or in the **branch parallel to the output**.
- The output response is not as obvious because the **dc supply can aid or work against the source voltage.**

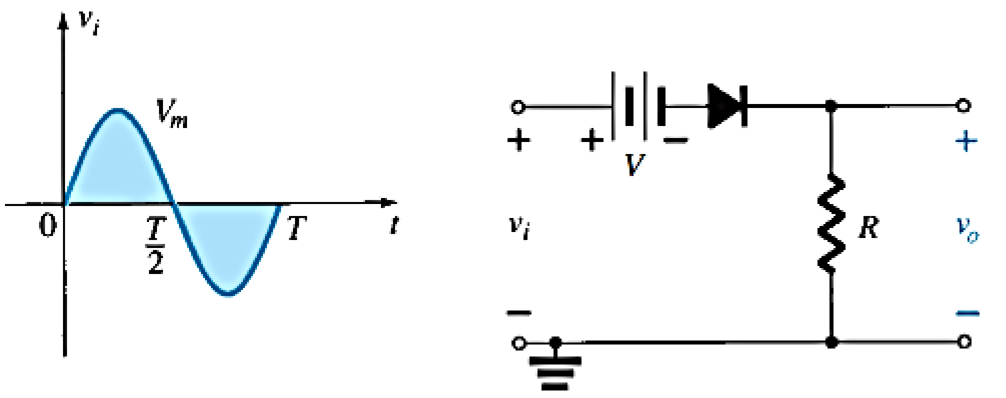


Fig. 2: Series clipper with DC supply

Series Clippers

General instructions for analysis:

1. **Take careful note of where the output voltage is defined**.

In Fig. 2 it is directly across the resistor R . In some cases it may be across a combination of series elements.

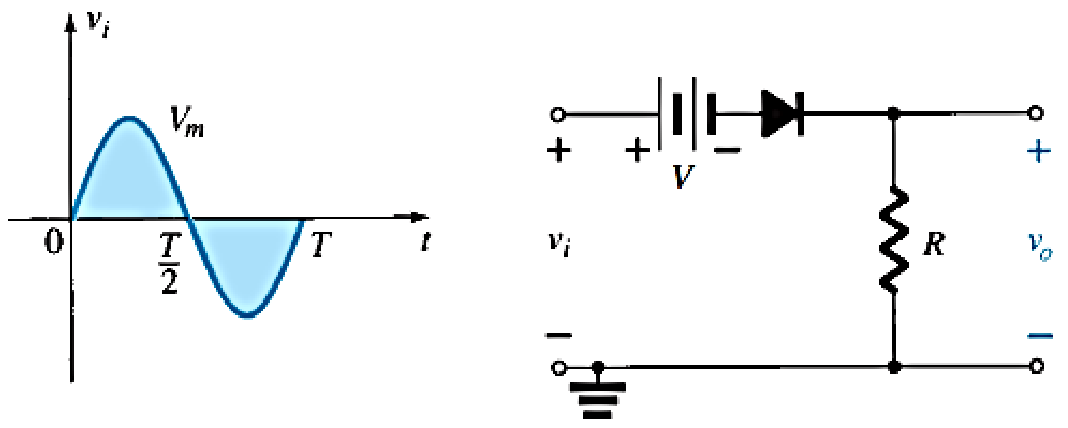


Fig. 2: Series clipper with DC supply

Series Clippers

General instructions for analysis: (cont….)

2. **Try to develop an overall sense of the response by simply noting the that how the input supply affects the conventional current direction through the diode.**

- In Fig. 2 , for instance, any positive voltage of the supply will try to turn the diode "ON" by establishing a forward bias current through the diode.
- However, the added dc supply V will oppose that applied voltage and try to keep the diode in the "OFF" state.
- The result is that any supply voltage greater than V volts will turn the diode "ON" and conduction can be established through the load resistor. (Note here that we are dealing with an ideal diode, so the turn-on diode voltage is simply 0 V)
- Therefore, the diode will be "ON" for any voltage vi that is greater than V volts and "OFF" for any lesser voltage.

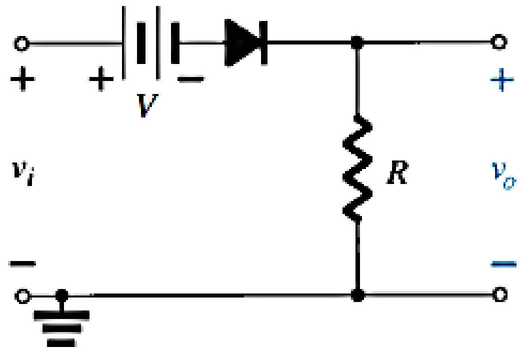


Fig.2: Series clipper with DC supply

Series Clippers

General instructions for analysis: (cont….)

3. **Determine the "transition voltage" that will result in a change of state for the diode from the "OFF" to the "ON" state.**

- This step will help to define a region of the applied voltage when the diode is "ON" and when it is "OFF".
- For an ideal diode this will occur when $V_D = 0$ V and $I_D = 0$ mA.
- For the approximate equivalent (non-ideal diode) this is determined by finding the applied voltage when the diode has a drop of 0.7 V across it (for silicon) and I_D 0 mA.
- Note the substitution of the short-circuit equivalent for the ideal diode in **Fig 3**, and the fact that the voltage across the resistor is 0 V because the diode current is 0 mA. The result is $\boldsymbol{v_i - V = 0}$ **or** $\boldsymbol{v_i = V}$ is the applied (transition) voltage.
- This permits drawing a line on the sinusoidal supply voltage as shown in **Fig. 4** to define the regions where the diode is on and off.

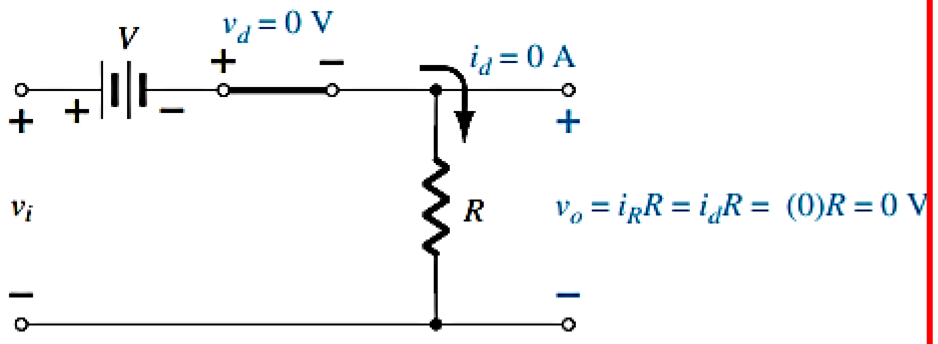


Fig. 3: Determining applied voltage for the circuit

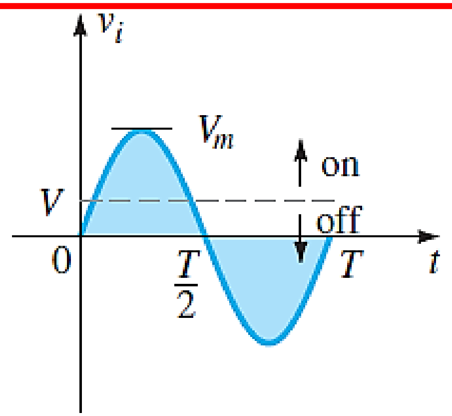


Fig.4: Define the "ON" and "OFF" regions.

Series Clippers

General instructions for analysis: (cont….)

- For the "ON" region, as shown in **Fig. 5**, the output voltage is defined by-
  - $v_o = v_i - V$ ………………… (1)
- For the "OFF" region, the diode is an open circuit, $I_D = 0$ mA, and the output voltage is
  - $v_o = 0\ V$ …………………..(2)

4. It is often helpful to draw the output waveform directly below the applied voltage using the same scales for the horizontal axis and the vertical axis.

- For the "ON" condition, **Eq. (1)** can be used to find the output voltage when the applied voltage has its peak value:
  - $v_{o\_peak} = V_m - V$ ………………..(3)
  - Output voltage, v_o is plotted in the **Fig. 6**.

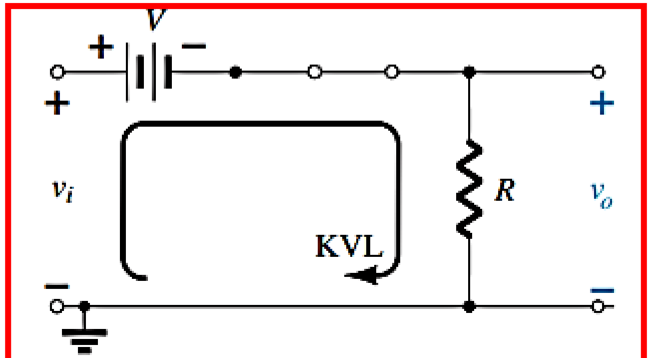


Fig. 5: Determining v_o for the diode in the "ON" state.

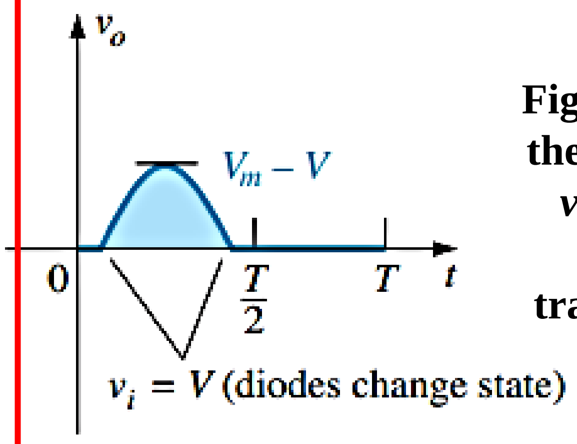


Fig. 6: Sketching the waveform of v_o above and below the transition level.

EXAMPLE 1: Determine the output waveform for the sinusoidal input of Fig. 7.

Step 1: The output is directly across the resistor R.

Step 2: The positive region of v_i and the dc supply are both working in same direction to turn the diode "ON". The result is that we can safely assume the diode is in the "on" state for the entire range of positive voltages for v_i .

Once the supply goes negative, it would have to exceed the dc supply voltage of 5 V before it could turn the diode "OFF".

Step 3: The transition model is substituted in **Fig. 8**, and we find that the transition from one state to the other will occur when,

$$v_i + 5V = 0V$$

Or $$v_i = -5V \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

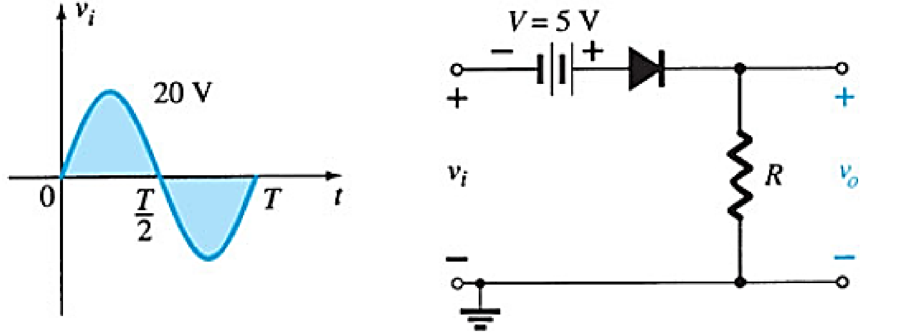


Fig. 7

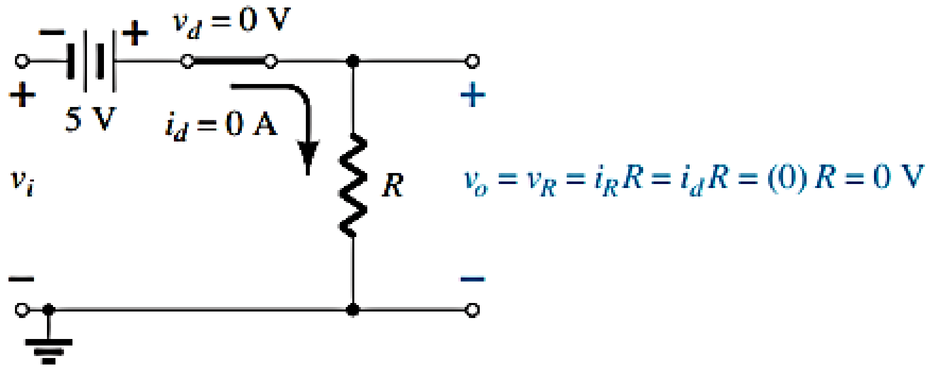


Fig. 8

EXAMPLE 1 (cont…..)

Step 4: In **Fig. 9** horizontal line is drawn through the applied voltage at the transition level.

For voltages less than 5V the diode is in the open-circuit state and the output is 0 V, as shown in the sketch of v_o .

Using **Fig. 9** , we find that for conditions when the diode is on and the diode current is established the output voltage will be the following, as determined using Kirchhoff's voltage law:

$$v_o = v_i + 5V \text{ …………..(2)}$$

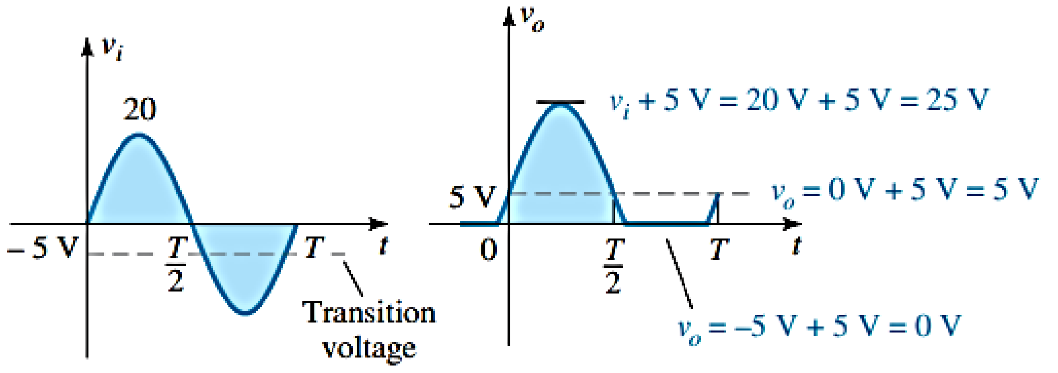


Fig. 9

Note: The analysis of clipper networks with square-wave inputs is actually easier than with sinusoidal inputs because only two levels have to be considered.

Series Clippers

EXAMPLE 2: Find the output voltage for the network examined in previous Example, if the applied signal is the square wave of **Fig. 10**.

- For v_i = 20 V (0 → T/2) the network of **Fig. 11** results. The diode is in the short-circuit state i.e. "ON", and

  v_o = 20 V + 5 V = 25 V ....(1)

- For v_i = -10 V (T/2 → T) the network of **Fig. 12**, results, moving the diode in the "OFF" state, and

  v_o = $i_R R$ = (0)R = 0 V ....(2)

- The resulting output voltage appears in **Fig. 13**.

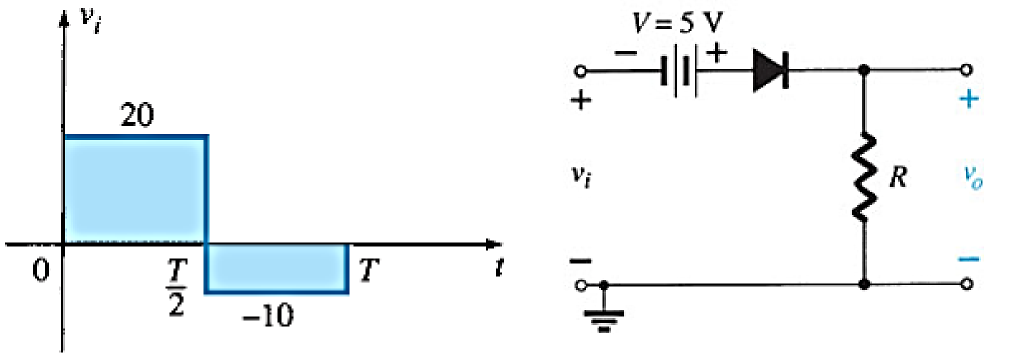


Fig. 10

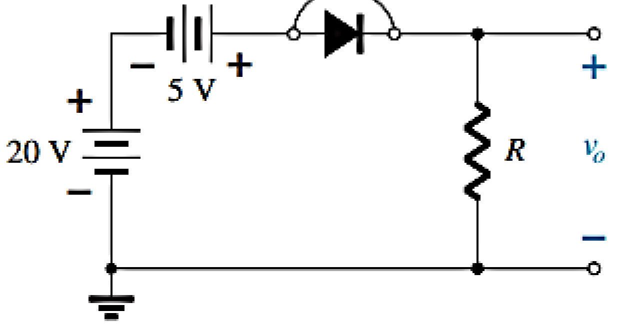


Fig. 11

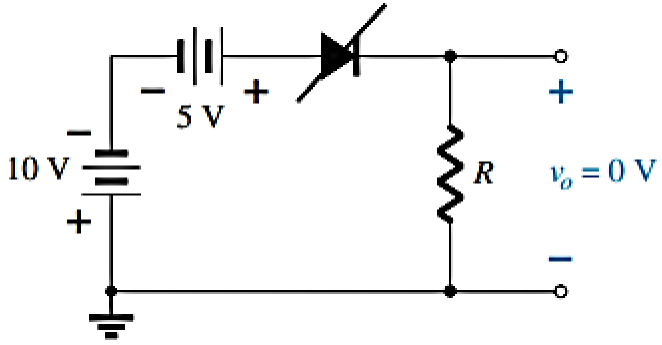


Fig. 12

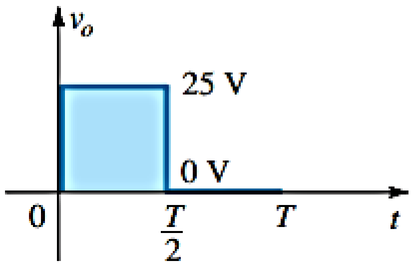


Fig. 13

Parallel Clippers without bias

- In parallel clippers, diode is connected in parallel with the load.
- The analysis of parallel configurations is very similar to that of series configurations.
- The simplest parallel clipper is shown in **Fig 14.**

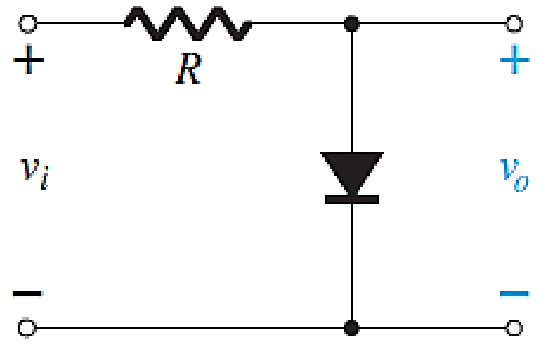


Fig. 14: Parallel Clipper

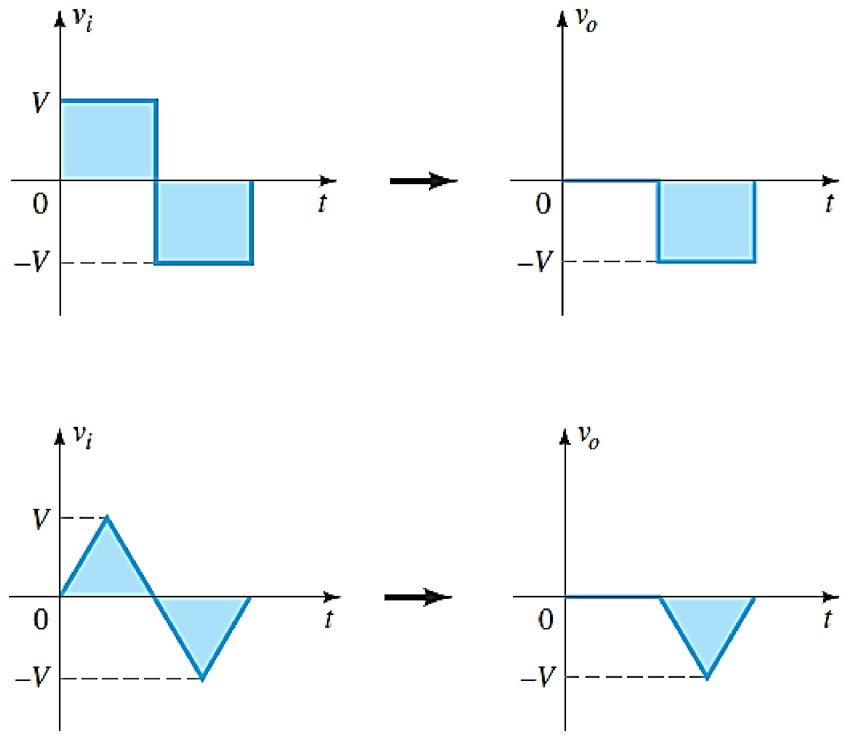


Fig. 15: Response to a parallel clipper.

Parallel Clippers with Bias

EXAMPLE 3: Determine v_o for the network of Fig. 16.

Step 1: In this example the output is defined across the series combination of the 4-V supply and the diode, not across the resistor R.

Step 2: The polarity of the dc supply and the direction of the diode strongly suggest that the diode will be in the "ON" state for a good portion of the negative region of the input signal.

When the diode is in its short-circuit i.e. "ON" state the output voltage will be directly across the 4-V dc supply, requiring that the output be fixed at 4 V. In other words, when the diode is "ON" the output will be 4 V.

When the diode is an open circuit i.e. "OFF" state, the current through the series network will be 0 mA and the voltage drop across the resistor will be 0 V. That will result in $\boldsymbol{v_o = v_i}$.

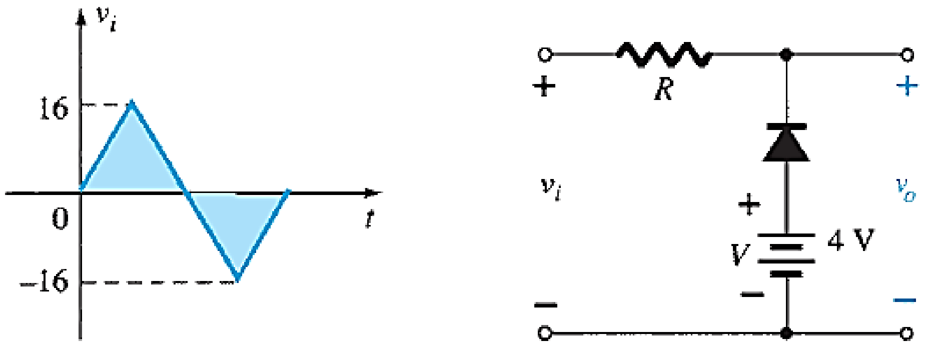


Fig. 16

Example 3 (cont….)

Step 3: The transition level of the input voltage can be found from **Fig. 17** by substituting the short-circuit equivalent and remembering the diode current is 0 mA at the instant of transition.
The result is a change in state when $v_i = 4$ V

Step 4: In **Fig. 18** the transition level is drawn along with $v_o = 4$ V when the diode is "ON".

Therefore, for v_i >= 4 V, $v_o = v_i$ …………………(1)

And, for v_i <= 4 V, $v_o = 4$ V, ……………….……(2)

As shown in **Fig. 18**.

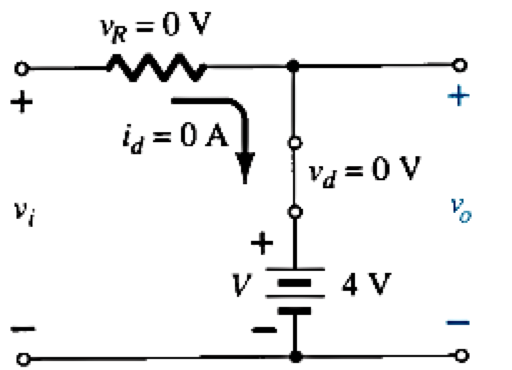


Fig. 17: Determining the transition level

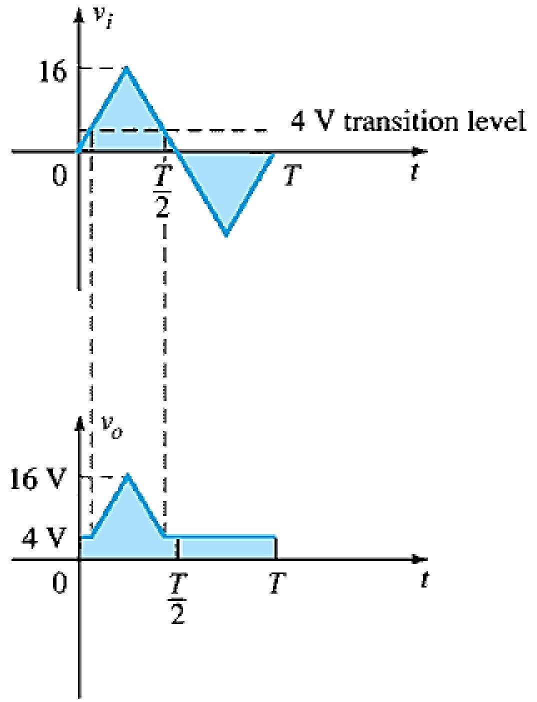


Fig. 18: Output Sketch

Parallel Clippers

EXAMPLE 4: Repeat Example 3, using a **silicon diode with V_K = 0.7 V**.

- Determine Transition voltage
  - Using the condition i_d = 0 A at $v_d = V_D$ = 0.7 V and obtaining the network of **Fig. 19** .
  - Applying KVL, $v_i + V_K - V = 0$
  - or $v_i = V - V_K$ = 4 V - 0.7 V = 3.3 V ………(1)
- Diode will be "OFF", for v_i > 3.3 V (in Fig. 19) and
  - $v_o = v_i$ …………………………………...….. (2)
- Diode will be "ON", for v_i < 3.3 V (in Fig. 20) and
  - v_o = 4 V - 0.7 V = 3.3 V ……………………(3)

- The resulting output waveform appears in **Fig. 21** .
- Note that the only effect of V_K was to drop the transition level to 3.3 from 4 V.

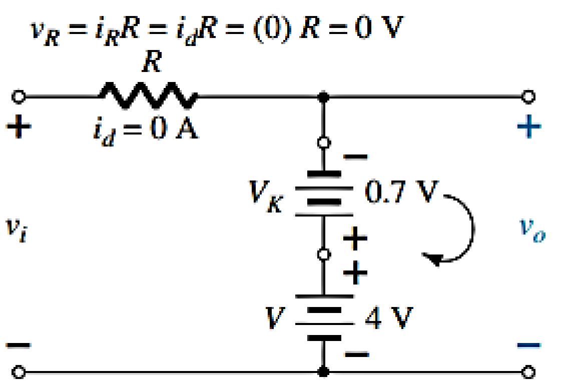


Fig. 19: Determining the output v_o

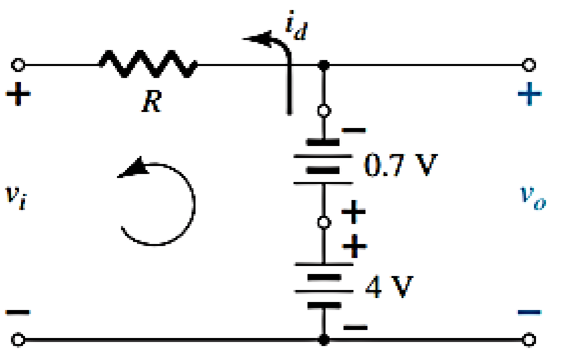


Fig. 20: Determining the output v_o

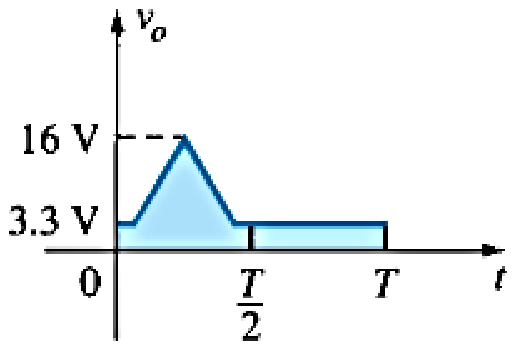
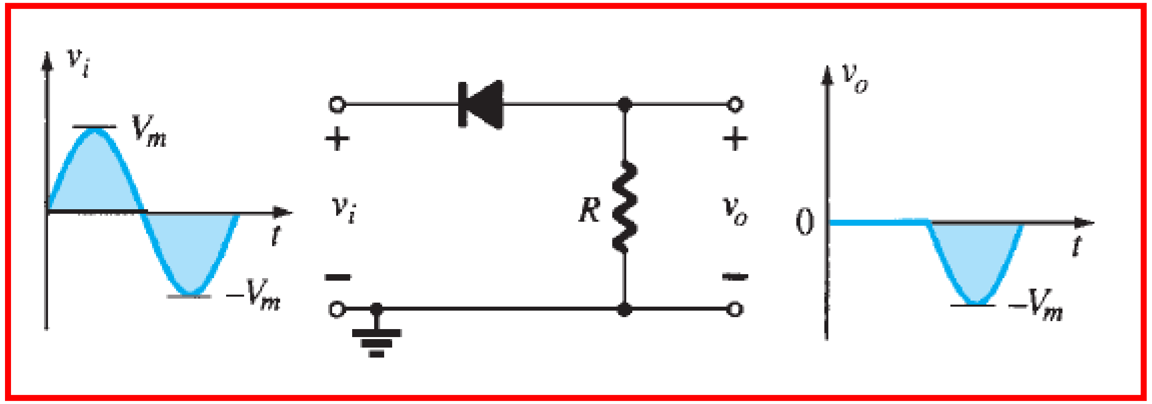


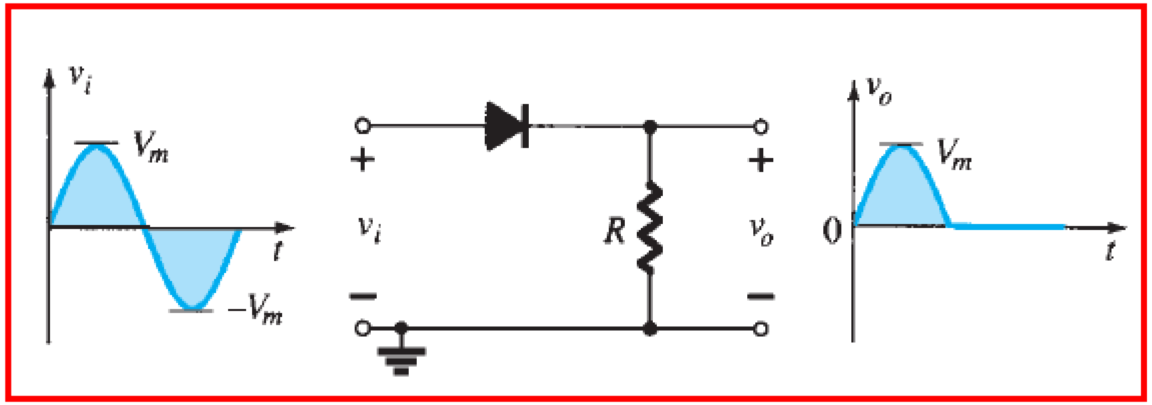
Fig. 21: Sketching v_o

Simple Series Clippers (Ideal Diodes)

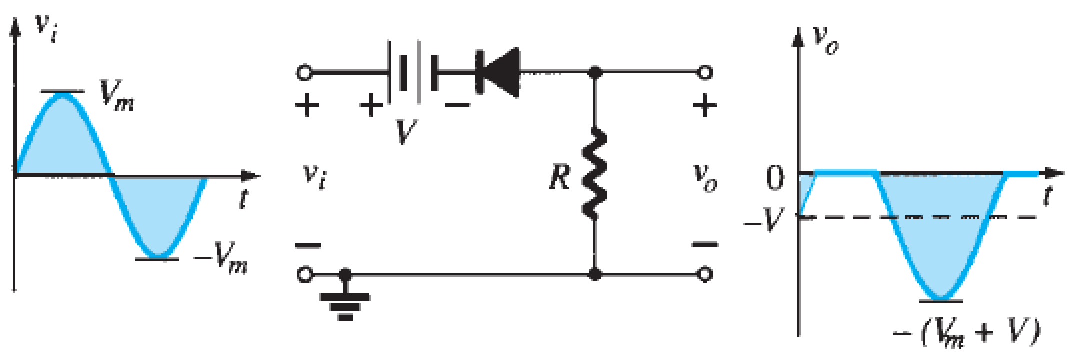


POSITIVE

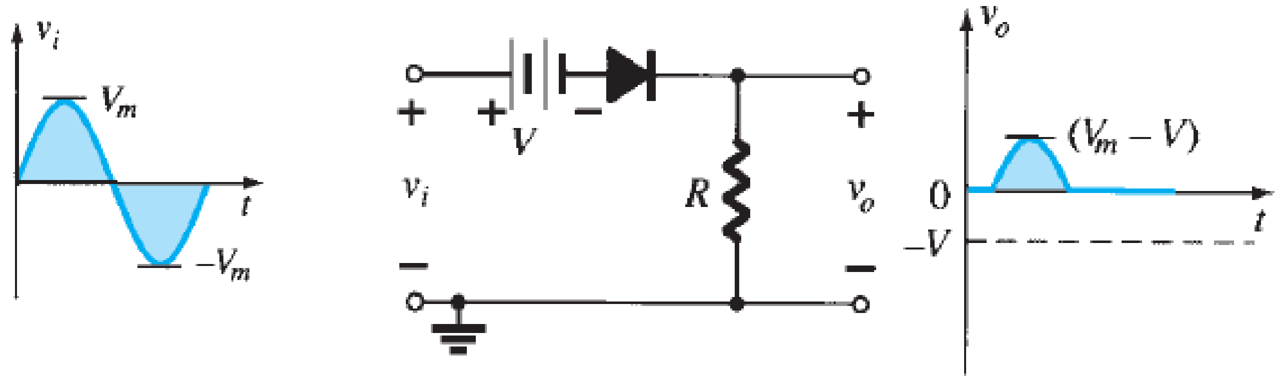
NEGATIVE



Biased Series Clippers (Ideal diodes)

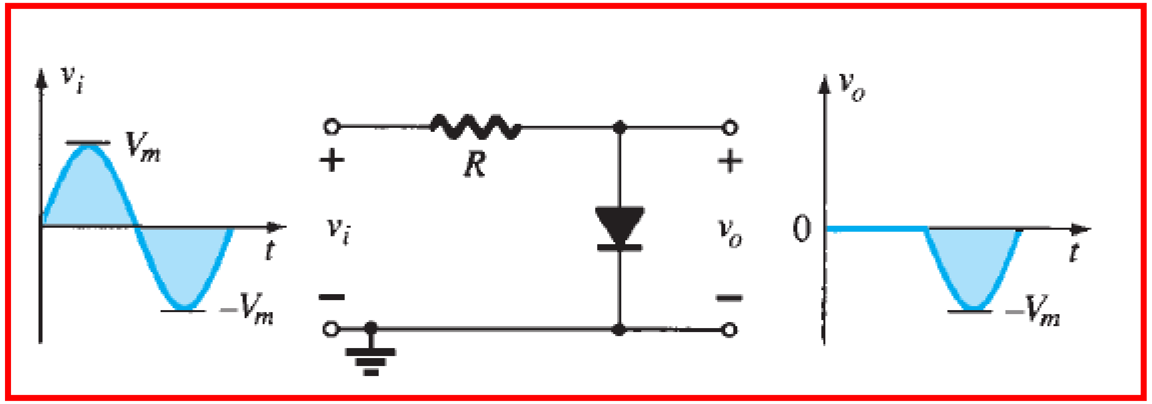


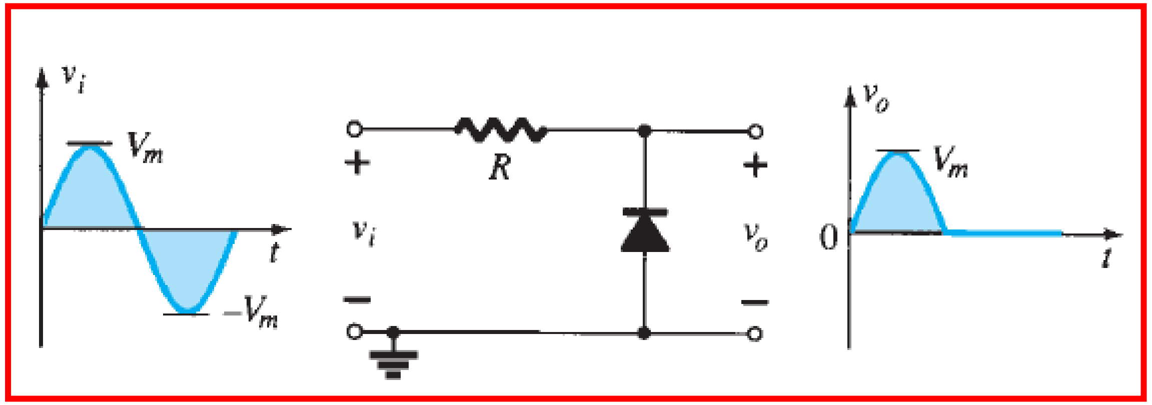
POSITIVE



NEGATIVE

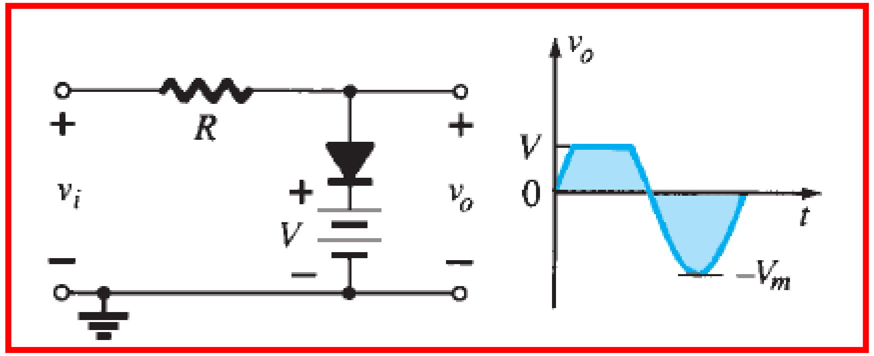
Simple Parallel Clippers (Ideal diodes)

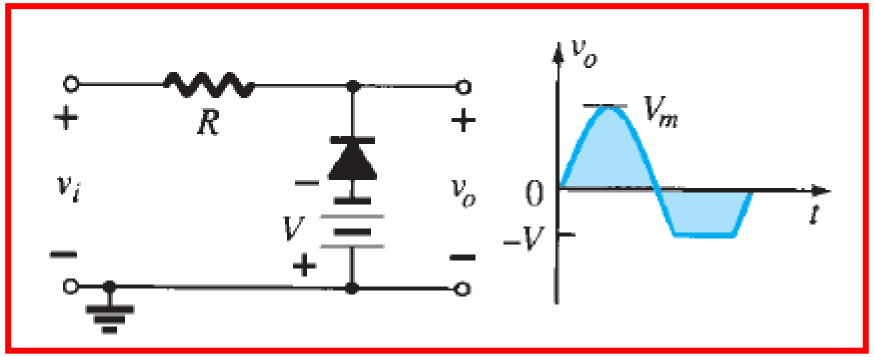


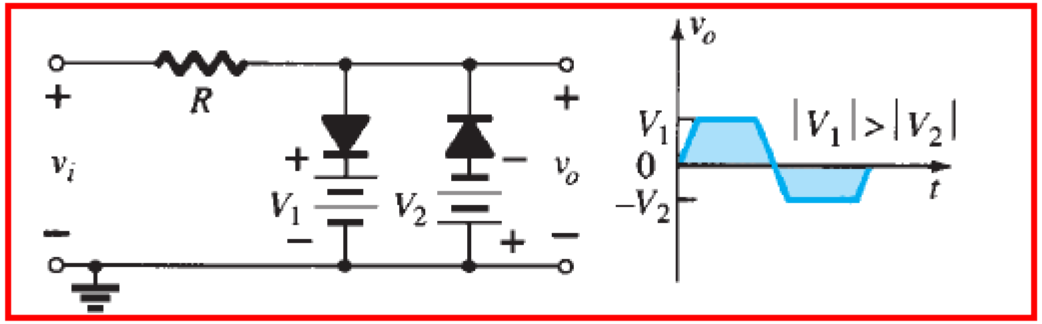


ELECTRONIC PRINCIPLES AND DEVICES

Biased Parallel Clippers (Ideal diodes)







Topic:

CLAMPERS

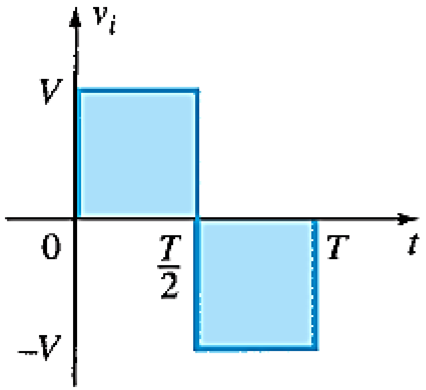
Introduction

- A clamper is a circuit with a diode, resistor, and capacitor that shifts a waveform to a new DC level without altering its shape.

- Also known as DC restorer.

- Clamping networks have a capacitor connected directly from input

- Resistive element connected in parallel with the output signal.



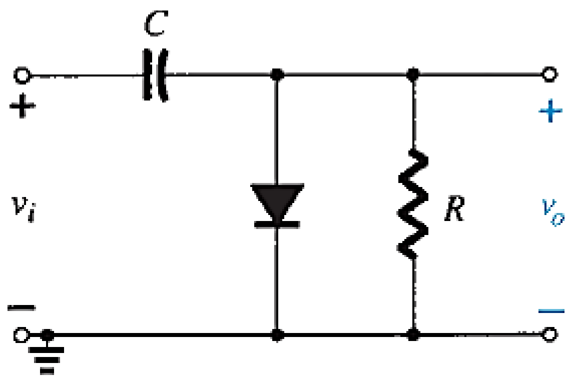


Fig.1: Clamper

- The diode is also in parallel with the output signal but may or may not have a series dc supply as an added element.

Steps used for analysis:

Step 1: Examine the response of the portion of the input signal that will forward bias the diode.

- For Fig. 2, the diode is forward biased during the positive portion of the signal.
- The short-circuit equivalent for the diode results in $V_o = 0$ V for t = 0 to T/2 .

Step 2: During the on period of the diode, assume that the capacitor will charge up instantaneously to a voltage level determined by the surrounding network.

Step 3: Assume the capacitor retains its voltage while the diode is "off."

Step 4: Track the position and polarity of v_o to ensure correct levels.

- When the input turns negative, the network appears as in Fig. 3, with the diode as an open circuit and voltage stored across the capacitor.

Step 5: Check that the total swing of the output matches that of the input. (see Fig. 4)

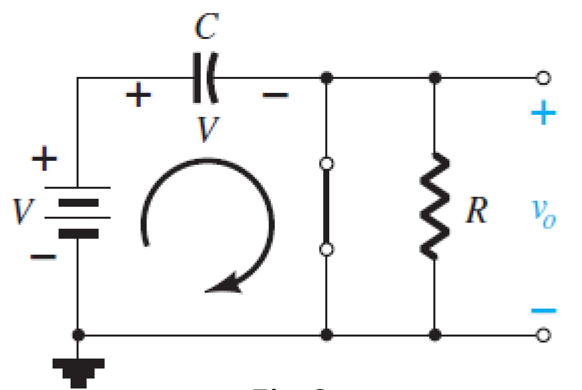


Fig.2

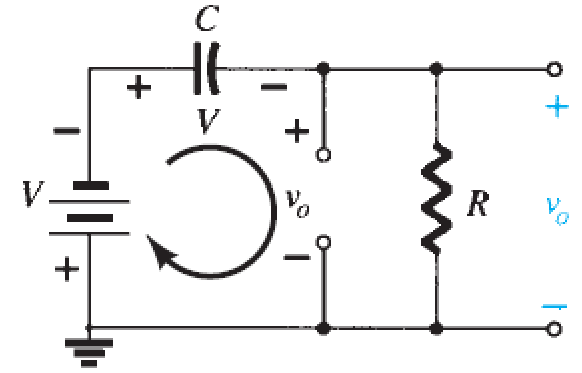


Fig.3

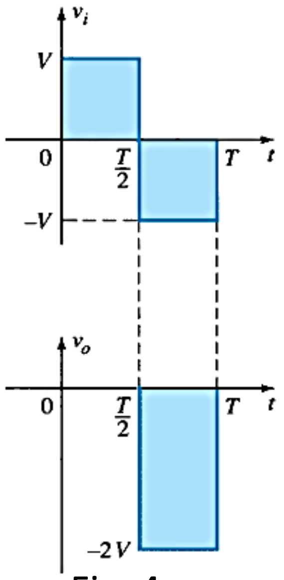


Fig. 4

Numerical

Example1: Determine v_o for the network of shown below, for the input indicated in Fig. 1.1

Solution:

Note: f = 1000 Hz => time period, T= 1 ms

<u>Step 1</u>: For *t1→ t2 of the* v_i since the diode is in its short-circuit state. The network appears as shown in Fig. 1.2 .

<u>Step 2</u>: The output is across *R (also directly across the 5-V battery)*. So, $v_o = 5$ V.

Applying KVL around the input loop

$-20\ V + V_C - 5\ V = 0$

and $V_C = 25$ V =>*the capacitor charges to 25 V.*

<u>*Step 3*</u>*:* For the period $t_2 \rightarrow t_3$ *the network will appear as shown in Fig. 1.3 .*

Applying KVL around the outside loop of the network

$+10\ V + 25\ V - v_o = 0$

$\boldsymbol{v_o = 35\ V}$

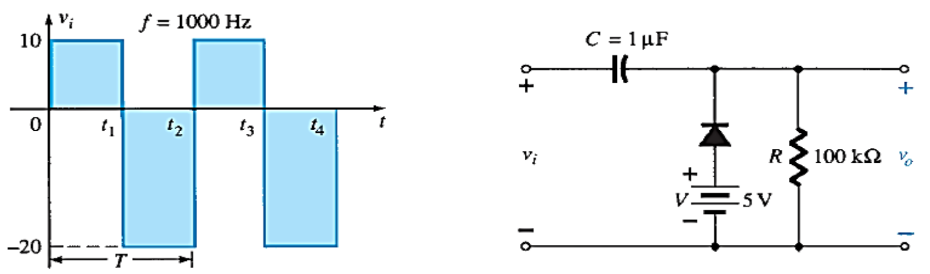


Fig. 1.1

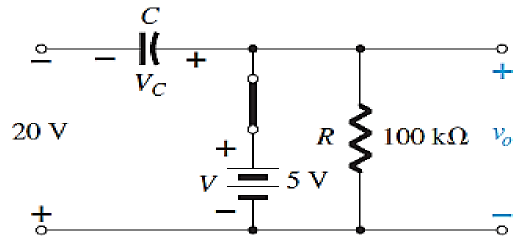


Fig. 1.2 : Determining V_o and V_C with the diode in the “on” state.

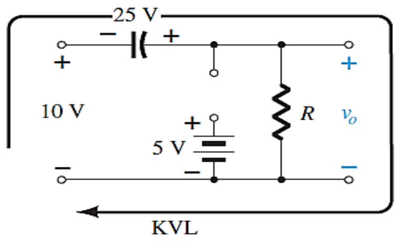


Fig. 1.3: Determining v_o with the diode in the “off” state.

Numerical

Step 4: The time constant of the network of Fig. 1.3 is determined by the product *RC and has the magnitude*

$\zeta = RC = (100\ k\Omega)(0.1\ \mu F) = 0.01\ s = 10\ ms$

The total discharge time is: $5\ \zeta = 5(10\ ms) = 50\ ms$

Step 5: The resulting output appears in Fig. 1.4 with the input signal.

Note: The output swing of 30 V matches the input swing.

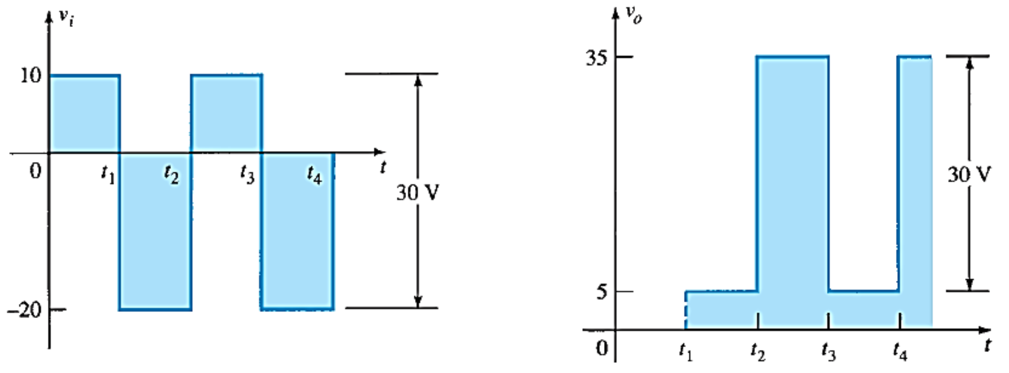


Fig. 1.4: Input and Output Waveform

Numerical

Example 2: Repeat example 1, using a silicon diode with V_k = 0.7 V.

Solution:

For the short-circuit state, the network appears as in Fig. 2.1 , and v_o *is determined by KVL in the output section as:*

$+5\text{ V} - 0.7\text{ V} - v_o = 0$

and $v_o = 4.3\text{ V}$

For the input section, KVL results in

$-20\text{ V} + V_C + 0.7\text{ V} - 5\text{ V} = 0$

and $V_C = 24.3\text{ V}$

For the period $t_2 \rightarrow t_3$ *the network will now appear as in Fig. 2.2 , with the only change* being the voltage across the capacitor.

Applying KVL yields

$+10\text{ V} + 24.3\text{ V} - v_o = 0$

and $\boldsymbol{v_o = 34.3\text{ V}}$

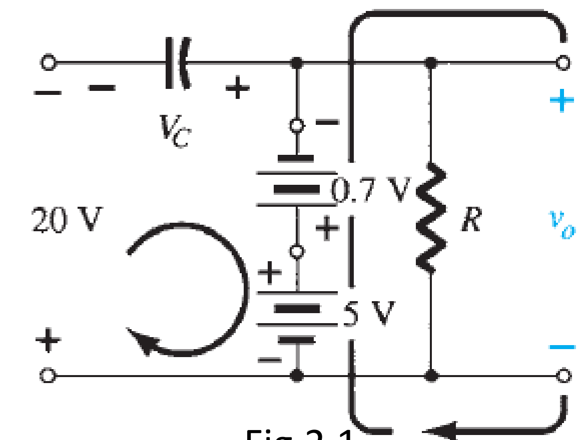


Fig.2.1

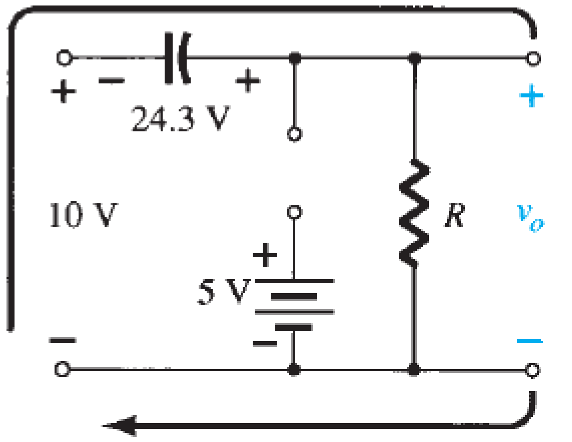


Fig.2.2

Numerical

The resulting output appears in Fig. 2.3 , verifying the statement that the input and output swings are the same.

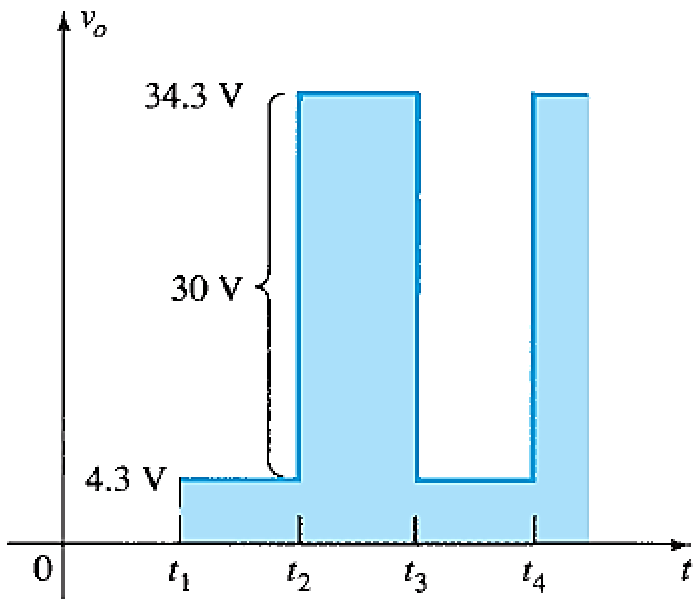
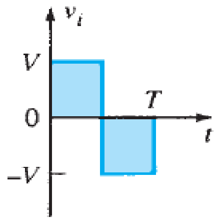
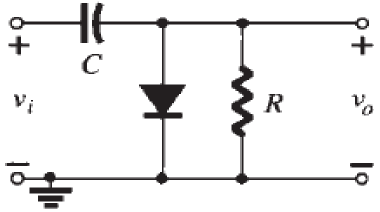
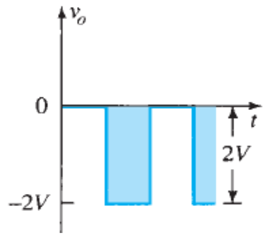
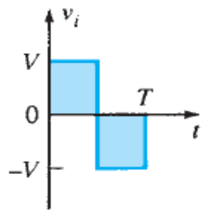
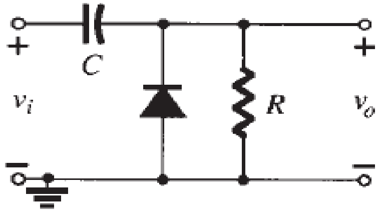
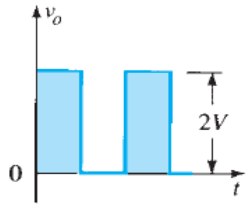
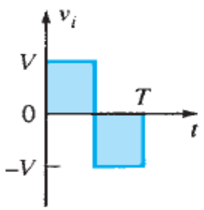
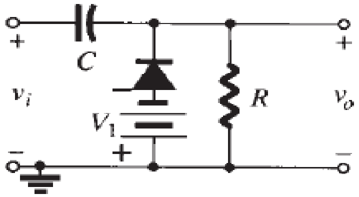
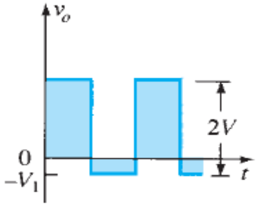


Fig. 2.3: Output Waveform

CLAMPING NETWORKS

Input Waveform	Clamping Circuit	Output Waveform
		
		
		

THANK YOU

Department of Electronics and Communication