

EE-110 – Basic Electronics

Lecture #2 – Part 2

Diodes

Problem 2.28a

- Determine DC voltage for output

- Solution:

– V_m :

– V_o : $V_m = \sqrt{2}(V_{rms}) = \sqrt{2}(120) = 169.71 \text{ V}$

– So, V_{dc} : $V_o = 169.71 - 0.7 - 0.7 = 168.31 \text{ V}$

$$V_{dc} = 0.636(V_o) = 0.636(168.31)$$

Problem 2.28b

- Determine the required PIV rating for each diode from problem 2.28

- Solution:

– PIV:

$$\text{PIV} = V_m(\text{load}) + V_D = 168.31 + 0.7 = 169.01 \text{ V}$$

Problem 2.28c

- Find the maximum current through each diode

- Solution:

– $I_{D(\max)}$:

$$I_{D(\max)} = \frac{V_{0(\max)}}{R_L} = \frac{168.31}{1k} = 168.31 \text{ mA}$$

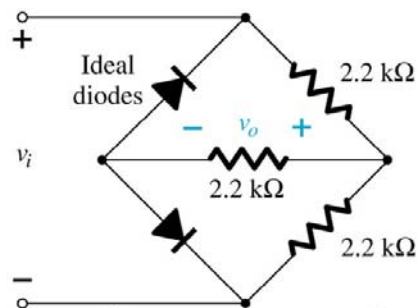
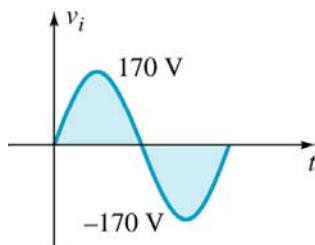
Problem 2.28d

- What is the required power for each diode?
- Solution:

$$P = I_{D(\max)} V_D = (168.31\text{m})(0.7) = 178.82\text{ mW}$$

Problem 2.31

- Sketch V_o and determine V_{dc}
- The input and circuit:

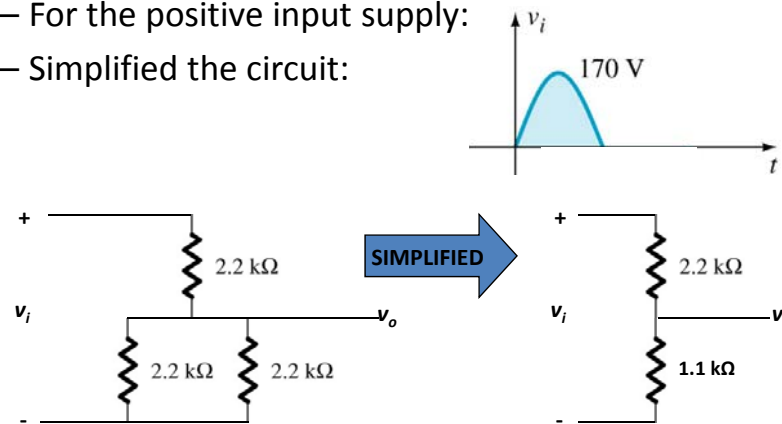


Problem 2.31

- Solution:

- For the positive input supply:

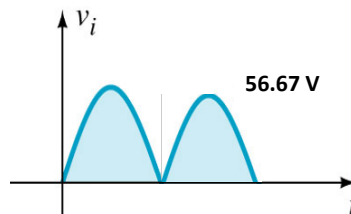
- Simplified the circuit:



Problem 2.31

- $V_o(\text{peak}): \frac{170 - V_0}{2.2k} = \frac{V_0}{1.1k}$
 $\therefore V_0 = 56.67 \text{ V}$

- The same for negative input supply
- So the output will becomes:

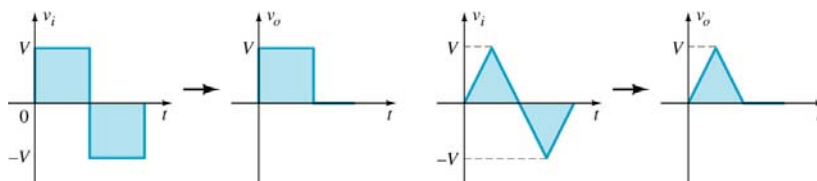
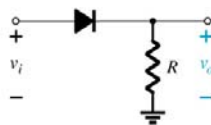


Clippers

- Configuration that employ diodes to “clip” away a portion of an input signal without distorting the remaining part of the applied waveform
- Mainly, there are two types of configuration
 - Series
 - Parallel

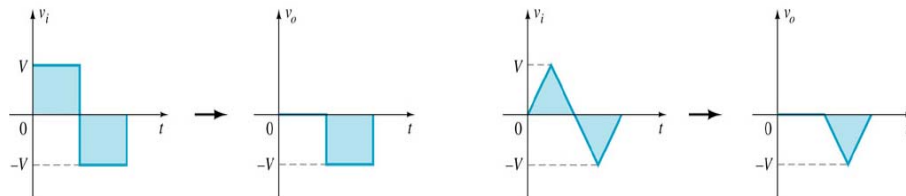
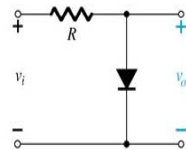
Clippers

- Example of series configuration and the output waveform:



Clippers

- Example of parallel configuration and the output waveform:



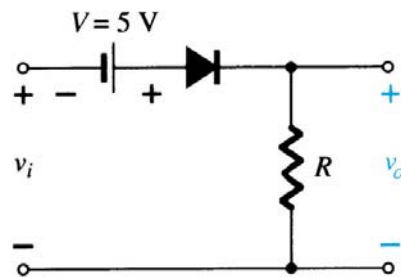
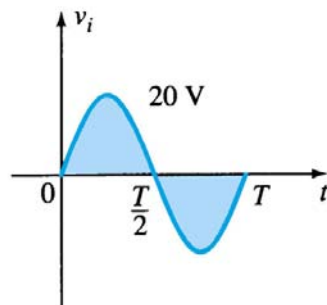
Clippers

- Notice something?
- Is the configuration similar to something?

**Half-wave rectifier
is a part of
CLIPPERS
configuration**

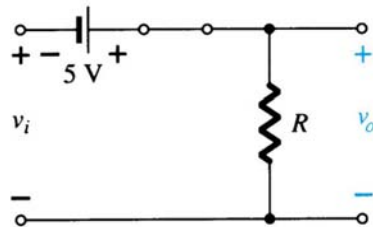
Example 2.18

- Sketch v_o



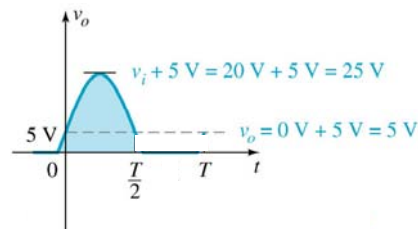
Example 2.18

- For positive input cycle:



- The output will be the sum of v_i and $+5V$ $v_o = v_i + 5$

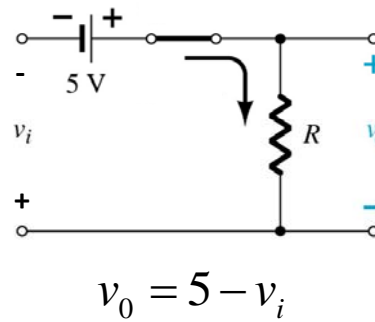
- The output waveform will become:



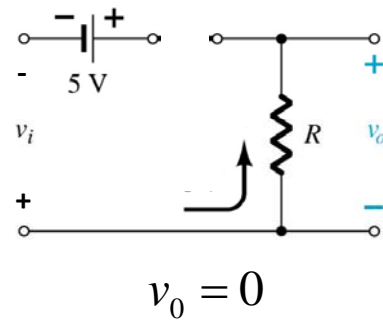
Example 2.18

- For negative input cycle:

– For $v_i \leq 5$:

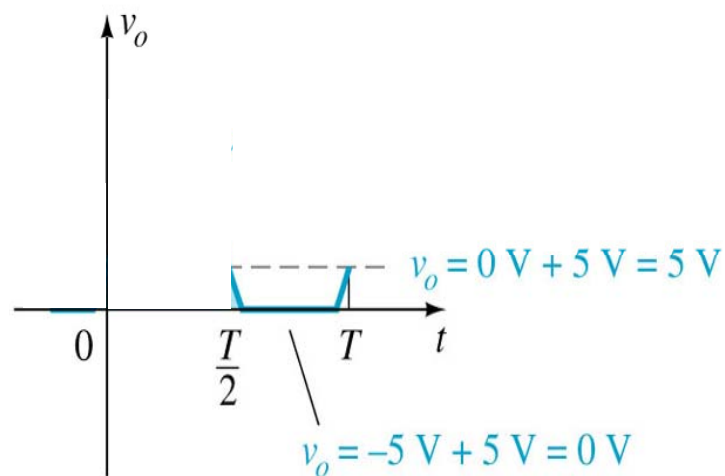


– For $v_i \geq 5$:



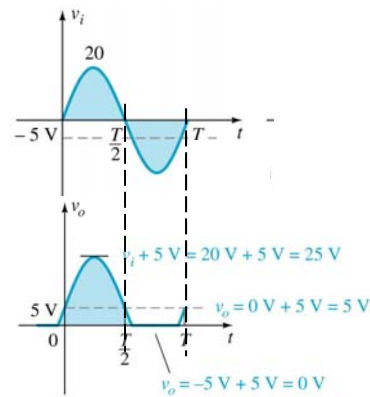
Example 2.18

- The output waveform will become:



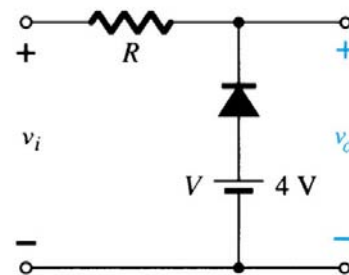
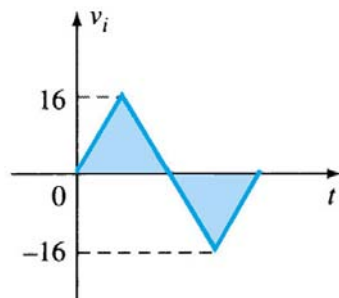
Example 2.18

- By comparing the input with the whole output:



Example 2.20

- Sketch v_o

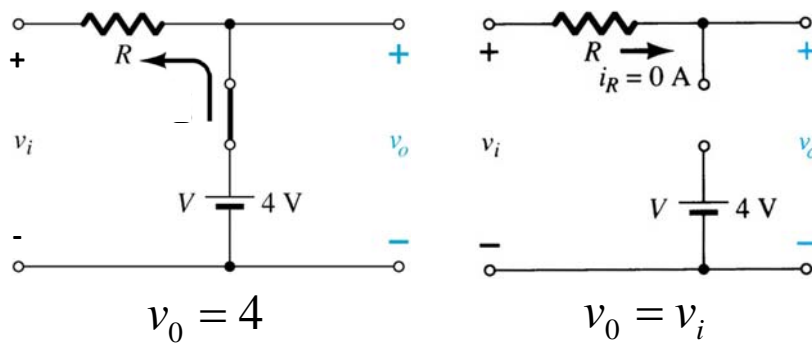


Example 2.20

- For positive input cycle:

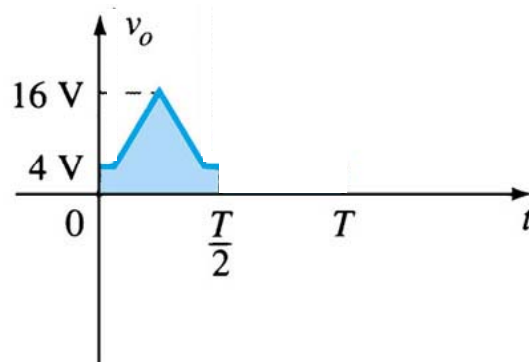
- For $v_i \leq 4$

- For $v_i \geq 4$



Example 2.20

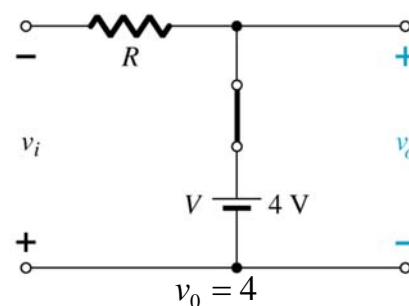
- The output waveform will become:



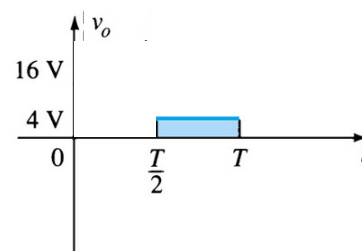
Example 2.20

- The output for negative input cycle will always +4V due to the external supply of 4V series with the diode
- The diode will always be in the "on" mode

– The circuit becomes:

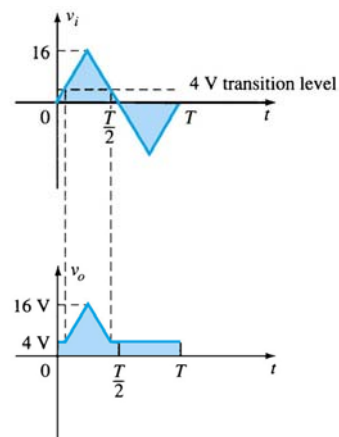


– The output



Example 2.20

- By comparing the input with the whole output:

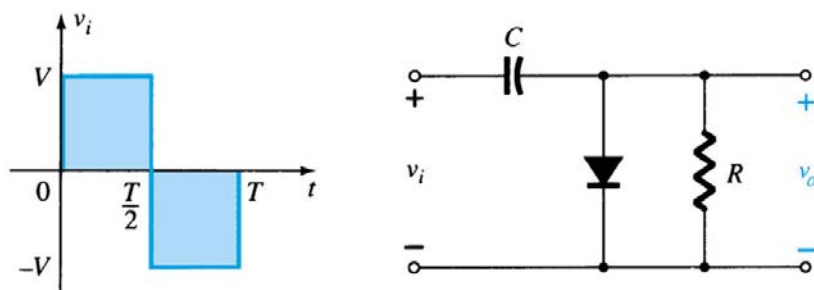


Clampers

- Construct of a diode, a resistor and a capacitor
- It will shift the waveform to a different level without changing the appearance of the original input signal
- The capacitor and resistor ($\tau = RC$) must be large to ensure it doesn't discharge during the interval that the diode is non-conducting

Clampers

- The circuit:



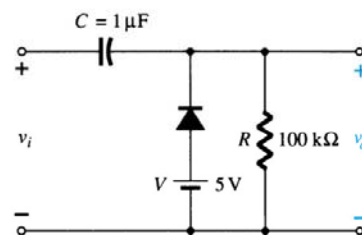
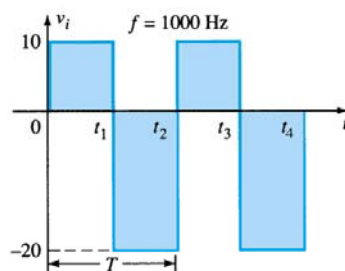
Clampers

Steps for clampers analysis:

1. Start the analysis with the condition where the diode is in forward bias
2. The capacitor will charge up instantaneously during the interval of +ve or -ve input supply where the diode is in forward-bias condition
3. The capacitor will discharge during the next interval of +ve or -ve input supply where the diode is in reverse-bias condition
4. Check that the total swing of the output is the same with the input

Example 2.22

- Sketch v_o



Example 2.22

- Just to check whether the capacitor is appropriate for clamper's configuration:

$$\tau = RC = (100k)(0.1\mu) = 10 \text{ ms}$$

- For the input given: $T = \frac{1}{f} = \frac{1}{1000} = 1 \text{ ms}$

- For every half interval (+ve or -ve input cycle):

$$\frac{T}{2} = \frac{1 \text{ ms}}{2} = 0.5 \text{ ms}$$

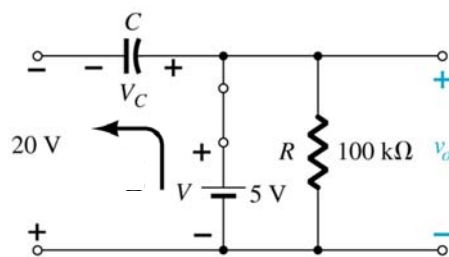
- This shows that the capacitor is capable of charging and discharging according to the clamper's configuration requirement

$$\tau \gg \frac{T}{2}$$

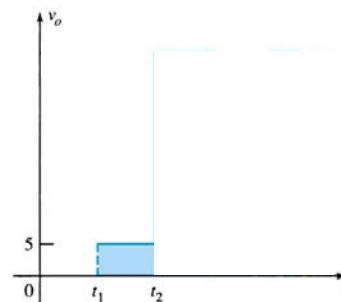
Example 2.22

- To start the analysis with the diode in forward-bias mode, the negative input cycle has to be inserted first into the circuit

– The circuit:



- The output waveform:

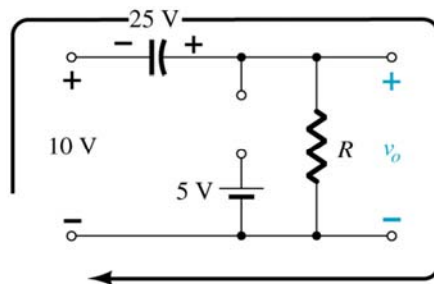


The capacitor will charge up to 25V

Example 2.22

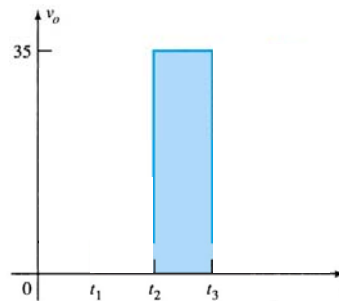
- For the next half input cycle that is the +ve cycle:

– The circuit:



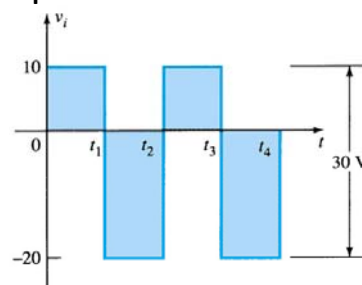
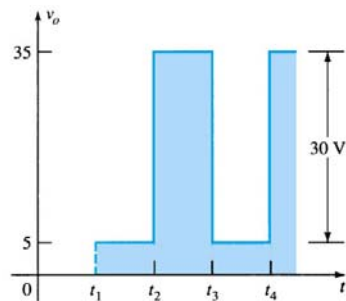
The capacitor will discharge the voltage of 25V

- The output



Example 2.22

- The whole output waveform will become:
- Checking the total swing of the output must match the input:



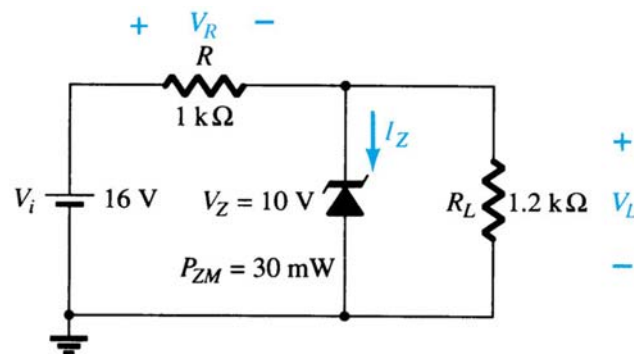
The total swing of the output is the same with the input that is 30 V

Zener Diodes

- The application of Zener diodes have been explained in Subtopic 1.3
- The analysis of Zener diodes can be divided into 3 categories:
 - Fixed V_i and R_L
 - Fixed V_i , variable R_L
 - Variable V_i , fixed R_L
- To make the analysis simple, the analysis will be explain directly from the examples

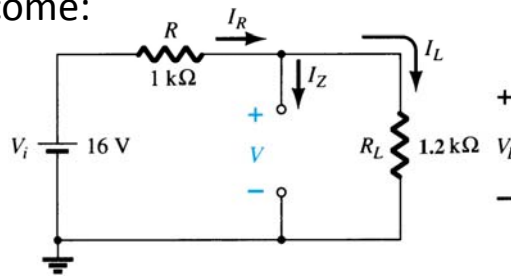
Example 2.26a (Fixed V_i and R_L)

- Determine V_L , V_R and I_Z



Example 2.26a (Fixed V_i and R_L)

- To check whether V_Z is in the “on” or “off” mode, the value of V_L must be determine first
- To do that, take out the Zener diode from the diode
- The circuit become:



Example 2.26a (Fixed V_i and R_L)

- By doing a nodal analysis for the node V_L

$$\frac{16 - V_L}{1k} = \frac{V_L}{1.2k}$$

$$\therefore V_L = 8.73 \text{ V}$$

- As we can see, the value of V_L is smaller than V_Z , so the Zener diode is in the “off” mode
- Which will result in:

$$I_Z = 0 \text{ A}$$

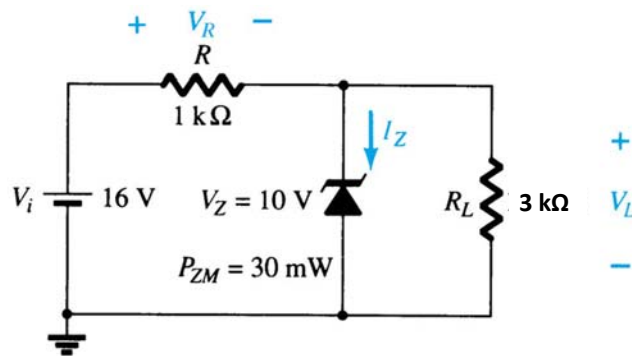
- And:

$$V_i = V_R + V_L$$

$$\therefore V_R = 16 - 8.73 = 7.27 \text{ V}$$

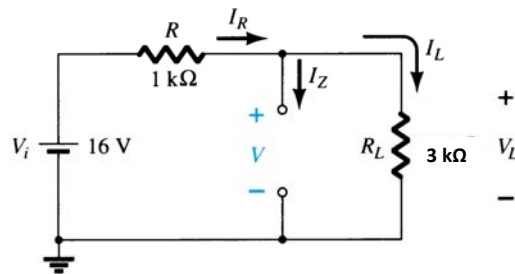
Example 2.26b (Fixed V_i and R_L)

- Repeat Example 2.26a with $R_L = 3\text{ k}\Omega$



Example 2.26b (Fixed V_i and R_L)

- The same analysis is repeated from Example 2.26a where the Zener diode is taken out to examine the value of V_L
- The circuit becomes:



Example 2.26b (Fixed V_i and R_L)

- By doing a nodal analysis for the node VL

$$\frac{16 - V_L}{1k} = \frac{V_L}{3k}$$

$$\therefore V_L = 12 \text{ V}$$

- As we can see, the value of VL is larger than VZ, so the Zener diode is in the “on” mode
- When the Zener diode is in the “on” mode, it will maintain the voltage of 10V. Because of that VL becomes: $V_L = V_Z = 10 \text{ V}$
- And VR becomes: $V_R = 16 - 10 = 6 \text{ V}$

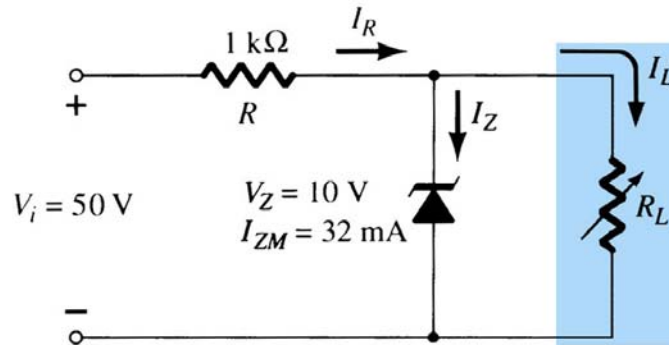
Example 2.26b (Fixed V_i and R_L)

- Using current divider theory:

$$\begin{aligned} I_Z &= I_i - I_L \\ &= \frac{V_R}{R} - \frac{V_L}{R_L} \\ &= \frac{6}{1k} - \frac{10}{3k} \\ &= 2.67 \text{ mA} \end{aligned}$$

Example 2.27 (Fixed V_i , Variable R_L)

- Determine the range of R_L and I_L that will result in V_L being maintained at 10 V



Example 2.27 (Fixed V_i , Variable R_L)

- To maintain V_L at 10 V, the Zener diode must be in the “on” mode
- For $I_{ZM} = 32$ mA, the current at load:

$$\begin{aligned} I_L &= I_R - I_{ZM} \\ &= \frac{50 - 10}{1k} - 32m \\ &= 8 \text{ mA} \end{aligned}$$

- The load would be:

$$R_L = \frac{V_L}{I_L} = \frac{10}{8m} = 1.25 \text{ k}\Omega$$

Example 2.27 (Fixed V_i , Variable R_L)

- For $I_Z(\min)$, the Zener diode are assume “off” but the voltage V_Z are maintained at 10 V

- The load current would be: $I_L = I_R$

$$= \frac{50 - 10}{1k}$$



$$= 40 \text{ mA}$$

- The load would be:

$$R_L = \frac{V_L}{I_L} = \frac{10}{40m} = 250 \Omega$$

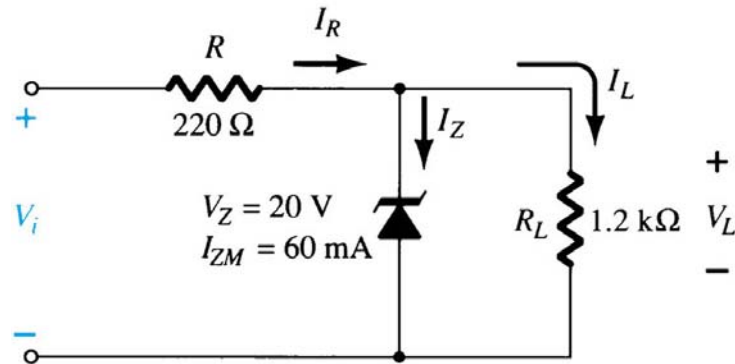
Example 2.27 (Fixed V_i , Variable R_L)

- Retrieve back all the I_L and R_L value:

$I_L (\min)$		$R_L (\max)$
$I_L = 8 \text{ mA}$		$R_L = 1.25 \text{ k}\Omega$
$I_L = 40 \text{ mA}$		$R_L = 250 \Omega$
$I_L (\max)$		$R_L (\min)$

Example 2.28 (Variable V_i , Fixed R_L)

- Determine the range of V_i that will maintain the Zener diode in the “on” mode



Example 2.28 (Variable V_i , Fixed R_L)

- To maintain Zener diode in “on” mode, V_Z must equal to V_L :

$$V_Z = V_L = 20 \text{ V}$$

- Taking the maximum current of the Zener diode, input current becomes:

$$\begin{aligned} I_R &= I_{ZM} + I_L \\ &= 60\text{m} + \frac{20}{1.2\text{k}} \\ &= 76.67 \text{ mA} \end{aligned}$$

- The input voltage will become:

$$V_i - 20 = I_R R = (76.67\text{m})(220)$$

$$\therefore V_i = 36.87 \text{ V}$$



Example 2.28 (Variable V_i , Fixed RL)

- For $I_Z(\text{min})$, the Zener diode are assume “off” but the voltage V_Z are maintained at 20 V
- Using nodal analysis at node VL:

$$\frac{V_i - 20}{220} = \frac{20}{1.2k}$$

$$\therefore V_i = 23.67 \text{ V}$$

$$V_i = 36.87 \text{ V} \quad V_i = 23.67 \text{ V}$$

$V_i(\text{max})$  $V_i(\text{min})$ 

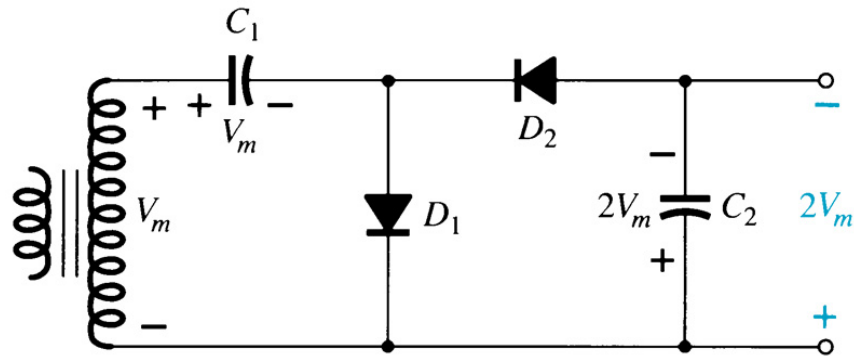
- Retrieve back all the value of V_i :

Voltage Multiplier Circuits

Voltage multiplier circuits use a combination of diodes and capacitors to step up the output voltage of rectifier circuits.

- Voltage Doubler
- Voltage Tripler
- Voltage Quadrupler

Voltage Doubler

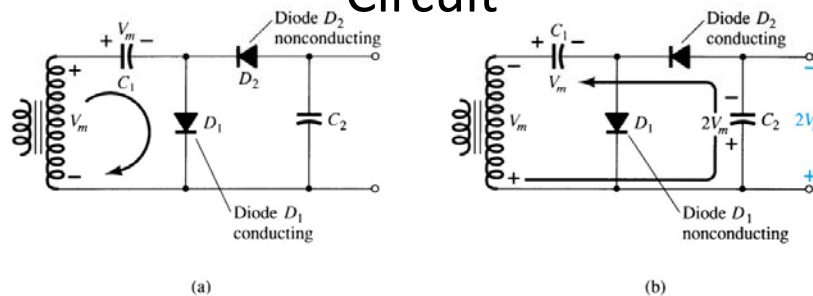


This half-wave voltage doubler's output can be calculated as

$$V_{out} = V_{C2} = 2V_m$$

V_m = peak secondary voltage of the transformer.

Operation of a Voltage Doubler Circuit

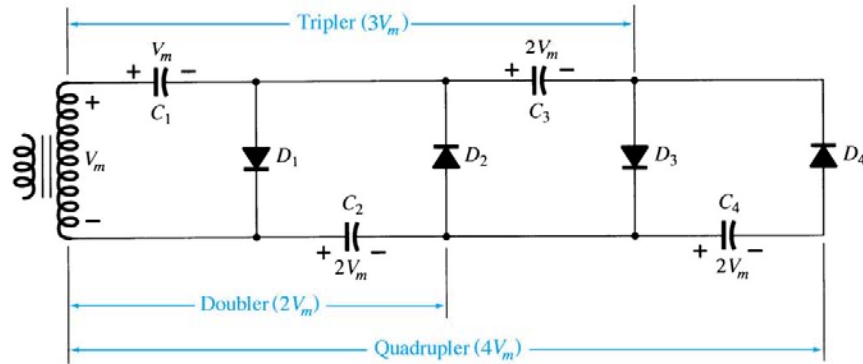


The 1st capacitor charges up to V_m during the positive half of the cycle, then the 2nd capacitor charges up to V_m in the same polarity as the 1st capacitor,

finally the output is the sum of the voltages across both capacitors:

$$V_{out} = 2V_m$$

Voltage Tripler and Quadrupler Circuits



By adding more diode-capacitor networks the voltage can be increased.

Practical Applications of Diode Circuits

Rectifier Circuits

- Conversions of AC to DC for DC operated circuits
- Battery Charging Circuits

Simple Diode Circuits

- Protective Circuits against Overcurrent
- Polarity Reversal
- Currents caused by an inductive kick in a relay circuit

Zener Circuits

- Overvoltage Protection
- Setting Reference Voltages