Chapter 1

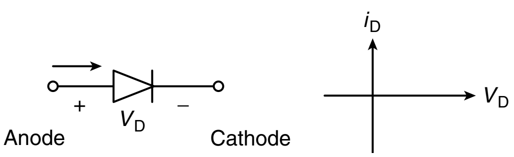
Diode Circuits

CHAPTER HIGHLIGHTS

- *Small Signal Equivalent Circuit of Diode*
- *Open Circuit Test*
- *Short Circuit Test*
- *Rectifiers*
- *Peak Inverse Voltage*
- *Unfiltered Rectifiers*
- *Clipping Circuits*
- *Clamper Circuits*
- *Voltage Multipliers*
- *Voltage Doubler Analysis*
- *Voltage Tripler Analysis*
- *6 Power Supplies*
- *Voltage Regulators*

Small Signal Equivalent Circuit of Diode

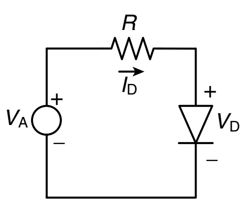
An ideal diode is a two-element device that has the circuit symbol and volt-ampere characteristic as shown in the following figure:



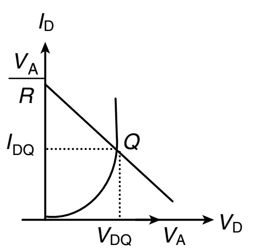
A diode is a two-terminal unipolar device that provides minimum resistance in the forward direction and maximum resistance in the reverse direction.

Ideal diode is a unilateral circuit element, as the current in the device is in one direction only. This behaviour is important in switching, as it provides an ON–OFF characteristics.

Practical P–N Junction Diode



Diode circuit



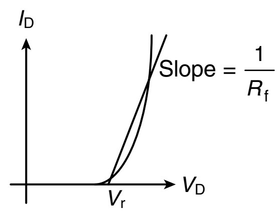
Diode characteristic and load line

From the circuit, $-V_A + I_D R + V_D = 0$ (KVL)

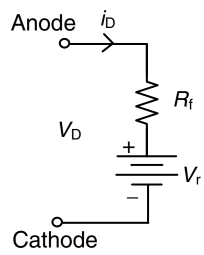
$$I_D = \frac{-1}{R} V_D + \frac{V_A}{R} A$$

This equation defines a straight line called load line. The load line and diode characteristic must be satisfied simultaneously at their point of intersection Q called quiescent or operating point. The values of current in and voltage across the diode are denoted by I_{DQ} and V_{DQ}, respectively.

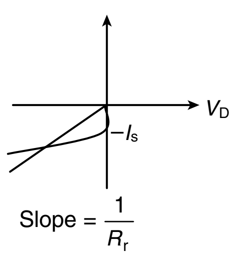
Large Signal Diode Models

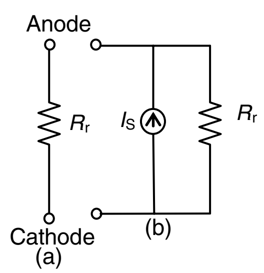


Piecewise linear diode forward characteristic



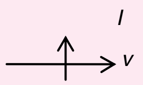
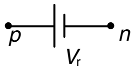
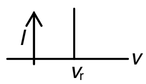
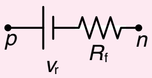
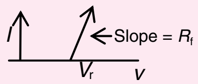
Diode model for forward bias





Piecewise linear reverse:

(a) Diode model based characteristic on piecewise of diode linear representation.
(b) Model to includesurface leakage.

Model	Equivalent Circuit	V-I characteristics
Ideal		
Simplified Model		
Piece – wise Linear model		

Open Circuit Test

1. Replace the diode with open circuit.
2. Find the voltage across the diode from 'p' to 'n' side. If it is positive, diode is in forward biased. If it is negative, diode is in reverse biased.

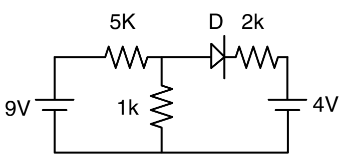
Short Circuit Test

1. Replace all the diodes with short circuit.
2. Find the current through the diode from 'p' to 'n' side say '*I*'. If *I* >0, diode is in forward biased. If *I* < 0, diode is in reverse biased.

Solved Examples

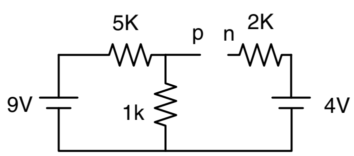
Example 1

Check whether the diode is in forward biased or not?



Solution

'D' is open



$$V_p = \frac{9}{6} = 1.5 \text{ v}$$

$$V_n = 4 \text{ v}$$

$$V_p < V_n$$

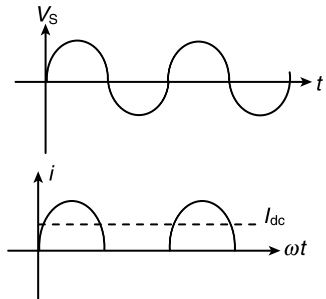
Hence, '*D*' is in reverse biased condition.

Elementary diode applications:

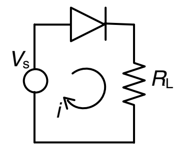
Rectifiers

A device like the semiconductor diode, which is capable of converting a sinusoidal input waveform into a unidirectional waveform with a non-zero average component is called rectifier.

Half Wave Rectifier

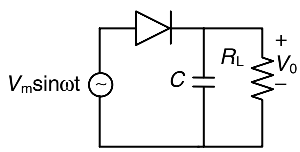


Voltage (V_S) and Current (i) waveforms

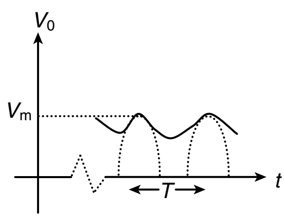


(i) Half wave rectifier

During the first half of cycle (positive cycle), the diode is ON and current $\frac{V_s}{R_L}$ exists. The diode is OFF during the negative half cycle of V_s, so that the current is zero as the current exists for only one half cycle, it is called half wave rectifier.



Rectifier with capacitor filter



Output voltage waveform

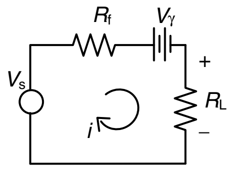
The circuit uses a capacitor '*C*' as a simple filter to convert the waveform to the nearly constant (DC) level. If the time constant $R_L C$ is much greater than the time period of *T* of input waveforms, the discharge will be slow.

The peak-to-peak ripple out of any capacitor input filter is $V_R = \frac{I}{fC}$

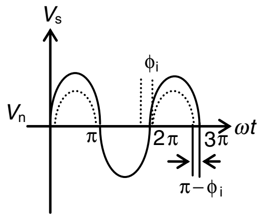
where V_R is the peak-to-peak ripple voltage; I is the DC load current; *f* is the ripple frequency; and *C* is the capacitance.

$$V_{rms} = \frac{V_{PP}}{2\sqrt{2}}$$

If we use real diode, the equivalent circuit is as shown in the figure.



Rectifier equivalent circuit



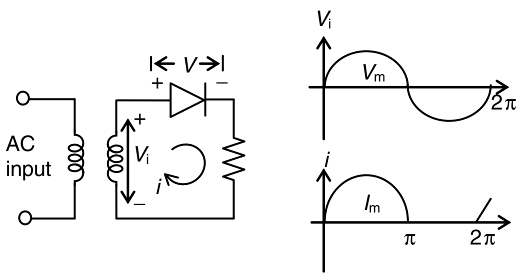
The current 'i' is obtained by KVL

$$i = \frac{V_s - V_\gamma}{R_L} = \frac{V_m \sin \omega t - V_\gamma}{R_L}$$

as it is greater than zero only when $V_s > V_\gamma$. Thus, current waveform does not start when $\omega t = 0$, but has a cut-in or ignition angle ϕ, given by $\phi_i = \sin^{-1}\left(\frac{V_\gamma}{V_m}\right)$

Similarly, extinction angle exists at the end of positive cycle and its value is $\pi - \phi_i$.

Half-wave Rectifier Analysis



Basic circuit of half wave rectifier:

$V_i = V_m \sin \omega t$ has peak value of V_m, which is mostly very high when compared to V_γ of diode, assume $V_\gamma = 0$.

The diode idealized to be a resistance R_f in the ON state and an open circuit in the OFF state. The current (i) in the diode or load R_L is

$$i = I_m \sin \omega t \text{ if } 0 \le \omega t \le \pi$$

$$= 0, \text{ if } \pi \le \omega t \le 2\pi$$

$$\text{and } I_m = \frac{V_m}{R_f + R_L}$$

DC current of value (average current):

$$I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i \, d(\omega t)$$

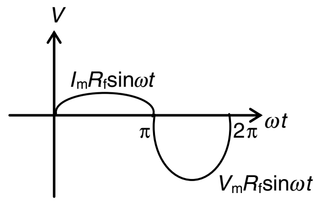
for half wave circuit, $I_{dc} = \frac{1}{2\pi}\int_0^{\pi} I_m \sin(\omega t) d(\omega t) = \frac{I_m}{\pi}$

The DC (average) output voltage is given as

$$V_{dc} = I_{dc} \cdot R_L = \frac{I_m R_L}{\pi} = \frac{V_m}{\pi}$$

The DC voltage across diode is not given by $I_{dc} R_f$, as diode acts as resistance that has two values.

R_f in the ON state, and ∞ in the OFF state.



Voltage across the diode

Therefore,

$$V_{dc} = \frac{1}{2\pi}\left[\int_0^{\pi} I_m R_f \sin \omega t \, d(\omega t) + \int_0^{2\pi} V_m \sin(\omega t) d(\omega t)\right]$$

$$= \frac{1}{\pi}(I_m R_f - V_m)$$

$$= \frac{1}{\pi}[I_m R_f - I_m (R_f + R_L)]$$

$V_{DC} = \frac{-I_m R_L}{\pi}$, so the DC diode voltage is seen to be equal to the negative of average voltage across the load resistor.

$$\text{The AC current } I_{rms} = \left(\frac{1}{2\pi}\int_0^{2\pi} i^2 d(\omega t)\right)^{1/2} = \frac{I_m}{2}$$

$$V_{rms} = I_{rms} R_L$$

$$V_{rms} = \frac{I_m}{2} R_L = \frac{V_m}{2}$$

Regulation

The variation of DC output voltage as a function of DC load current is called regulation.

$$\% \text{ of regulation} = \frac{V_{\text{no load}} - V_{\text{load}}}{V_{\text{load}}} \times 100\%$$

No load refers to zero current, and load indicates the normal load current.

NOTE

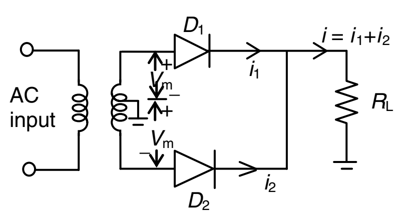
Ideal power supply has percentage regulation zero

$$I_{DC} = \frac{I_m}{\pi} = \frac{V_m/\pi}{R_f + R_L}\sqrt{2}, \; V_{DC} = I_{DC} R_L$$

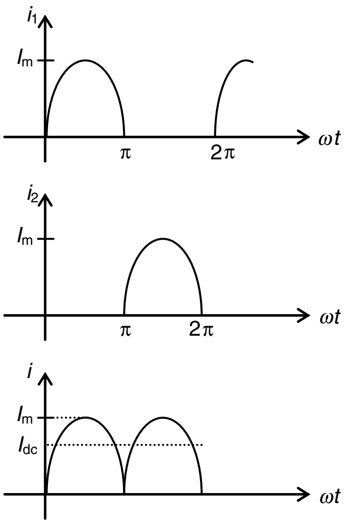
The DC output voltage varies as

$$V_{DC} = \frac{V_m}{\pi} - I_{DC} R_f$$

Full Wave Rectifier



A full wave rectifier circuit



The diode currents i_1 and i_2 and load current i, output voltage $V_o = iR_L$

The circuit is seen to comprise of two half wave rectifiers connected so that conduction takes place through one of the diodes at one half cycle.

$$I_{DC} = \frac{2I_m}{\pi}$$

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$V_{DC} = \frac{2I_m R_L}{\pi}$$

$$V_{DC} = \frac{2V_m}{\pi} - I_{DC} R_f$$

If we include V_γ of the diode

$$\theta_1 = \sin^{-1}\frac{V_\gamma}{V_m},\ \theta_2 = \pi - \theta_1$$

The average current I_{dc}:

$$I_{dc} = \frac{V_m}{\pi(R_f + R_L)}\cos\theta_1 - \frac{\pi - 2\theta_1}{2\pi}\frac{V_\gamma}{R_f + R_L}$$

(half wave rectifier)

$$I_{dc} = \frac{2V_m}{\pi(R_f + R_L)}\cos\theta_1 - \frac{\pi - 2\theta_1}{2\pi}\frac{V_\gamma}{R_f + R_L}$$

(full wave rectifier).

Example 2

A diode with an internal resistance of 10 Ω is used as a rectifier to supply power to a 500 Ω load from a 220 V (rms) source of supply. Calculate (a) the peak load current, (b) the DC load current, (c) the rms load current, (d) the DC diode voltage, (e) the total input power to the circuit, and (f) percentage regulation from no load to the given load.

Solution

A diode is used as rectifier, so half wave rectifier, if two diodes are used, it will be full wave rectifier.

1. $I_m = \frac{V_m}{R_f + R_L} = \frac{\sqrt{2}V_{ms}}{R_f + R_L} = \frac{\sqrt{2}\cdot 220}{(10+500)} = 0.61$ A

2. $I_{DC} = \frac{I_m}{\pi} = 0.19$ A

3. $I_{rms} = \frac{I_m}{2} = 0.305$ A

4. $V_{DC}{}^1 = \frac{I_m R_L}{\pi} = -0.61 \times \frac{500}{\pi}$

   $= -97.1$ v

5. Power delivered $= V_{rms} I_{rms}$

   $= (220\text{ V})\ (0.305\text{ A}) = 67.1$ W

6. $\%\text{ regulation} = \frac{I_{dc}R_f}{\frac{V_m}{\pi} - I_{dc}R_f} \times 100$

   $= \frac{\frac{V_m}{\pi(R_f + R_L)}\cdot R_f}{\left(\frac{V_m}{\pi} - \frac{V_m}{\pi(R_f + R_L)}R_f\right)} \times 100$

   $= \frac{R_f}{R_L} \times 100$

As R_L goes from ∞ (no load) to 500 Ω, percentage regulation will go from 0% to 2%.

Peak Inverse Voltage

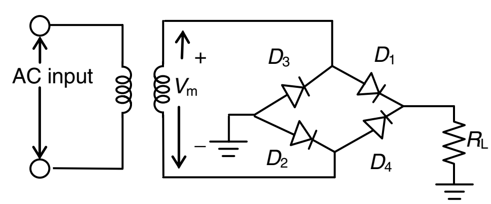
For each rectifier circuit, there is a maximum voltage to which the diode can be subjected. This potential is called peak inverse voltage. For half wave rectifier, the peak inverse voltage is V_m, and for full wave rectifier, PIV is $2V_m$. In full wave circuit, independent of the filter used, the PIV across each diode is twice the maximum transformer voltage (centre tap to the other end).

Peak inverse voltage is the maximum voltage across the non-conducting diode of rectifier, and the voltage must be less than the breakdown voltage of the diode, otherwise the diode will be destroyed.

PIV of half wave rectifier with capacitor input filter PIV $= 2V_m$.

Bridge rectifier with capacitor input filter, PIV $= V_m$.

Bridge Rectifier



A. Bridge rectifier

The bridge rectifier is similar to a full wave rectifier because it produces a full wave output voltage. Diodes D_1 and D_2 conduct on the positive half cycle and D_3 and D_4 conduct on the negative half cycle. As a result. rectified output flows during both half cycles

Features

1. The current drawn in both the primary and the secondary of the supply transformer are sinusoidal, and therefore, a smaller transformer may be used than for the full wave circuit for the same input.
2. A transformer without centre tap is used.

The advantage of this type of full wave rectification over the centre tapped version in the conventional full wave rectifier is entire secondary voltage of transformer can be used.

$$\text{DC output } (V) = \frac{2V_m}{\pi}$$

$$I_{DC} = \frac{2I_m}{\pi}$$

$$\text{Current through each diode} = I_{diode} = \frac{I_{DC}}{2}$$

Example 3

In a bridge rectifier, the input AC source has an amplitude of 5 V and the load resistance is 100 Ω. The diodes have an on resistance of 10 Ω, $V_r = 0.6$ V. The DC output voltage is ____

(A) 1.69 V (B) 1.81 V
(C) 2.35 V (D) 2.38 V

Solution

$$V_{dc} = 2\left[\frac{V_m R_L}{\pi(R_f + R_L)} - V_r\right]$$

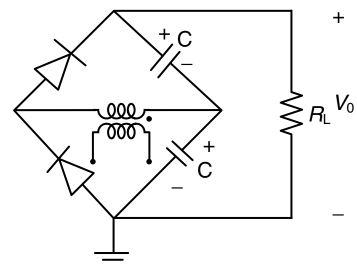
$$\cong 2\left[\frac{5}{\pi}\frac{100}{(100+10)} - 0.6\right] = 1.69$$

Unfiltered Rectifiers

	Half wave	Full wave	Bridge
Number of diodes	1	2	4
Peak output ideal	V_m	$\frac{V_m}{2}$ (centre tapped)	V_m
Peak output (practical)	$V_m - 0.7V$	$\frac{V_m}{2} - 0.7V$	$V_m - 1.4V$
DC output	$V_p(out)/\pi$	$2V_p(out)/\pi$	$\frac{2V_p(out)}{\pi}$
Ripple frequency	f_{in}	$2f_{in}$	$2f_{in}$

V_m is the peak secondary voltage and V_p(out) is the peak output voltage.

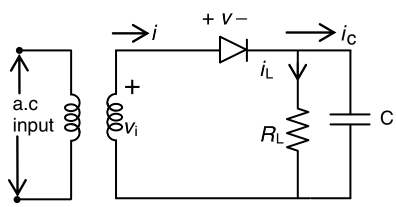
Voltage Multiplier



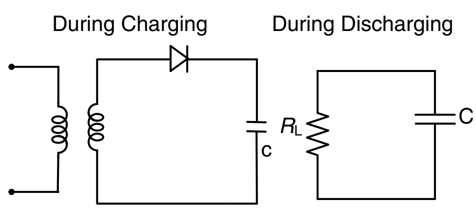
Bridge rectifier as voltage doubler

A common voltage doubling circuit that delivers a DC voltage approximately equal to twice the transformer maximum voltage at no load. The circuit is operated by alternately charging each of two capacitors to the transformer peak voltage V_m, current being continuously drained from capacitors through load. The capacitors also act to smooth out the ripple in the output.

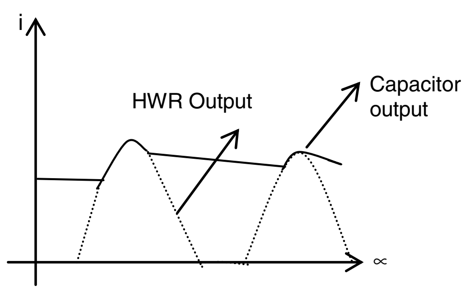
Capacitor Filters



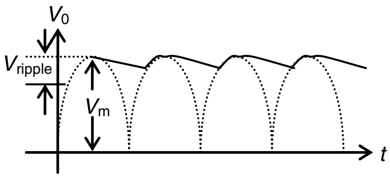
Capacitor stores the energy during the conduction period and delivers this energy to the load during non-conducting.



Diode having less forward resistance, and capacitor charges very fast and the value of R_L is designed to be so high to get the small ripple at the output.



Full wave rectifier with a capacitor filter is obtained by placing a capacitor 'C' across R_L.



Approximate load voltage waveform for full wave rectifier with capacitive fillter

The average value of the voltage is approximately

$$V_{DC} = V_m - \frac{V_{ripple}}{2}$$

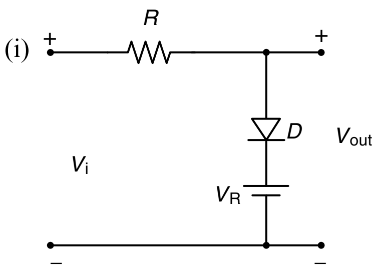
$$V_{ripple} = \frac{I_{dc}}{2fC} \text{ (for full wave rectifier)}$$

$$V_{DC} = V_m - \frac{I_{dc}}{4fC}$$

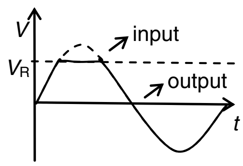
Clipping Circuits (Voltage Slicers)

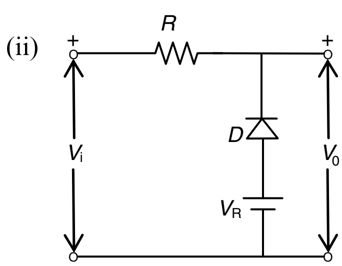
1. An electronic circuit that cuts the given input waveform.
2. The amount of clipping is decided by the supply voltage by which the circuit is driven.

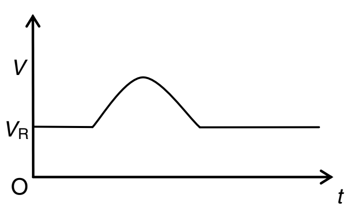
Considering Ideal Diode



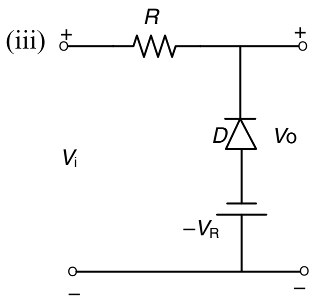
When $V_i > V_R$: diode is forward biased $\Rightarrow V_o = V_R$
$V_i < V_R$: diode is reverse biased $\Rightarrow V_o = V_i$







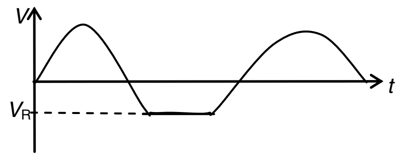
When $V_i > V_R$: diode is reverse biased $\Rightarrow V_o = V_i$
$V_i < V_R$: diode is forward biased $\Rightarrow V_o = V_R$



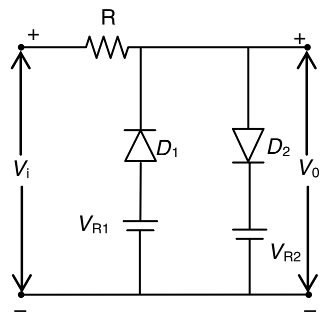
When $V_i > (-V_R)$: diode is reverse biased

$$\Rightarrow V_o = V_i$$

$V_i < (-V_R)$: diode is forward biased $\Rightarrow V_o = V_R$

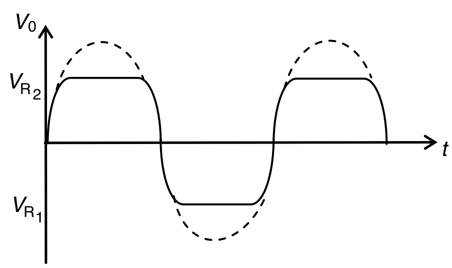


Clipping at Two independent Levels

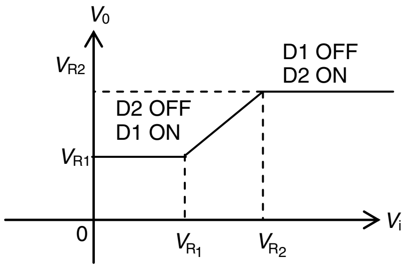


$(V_{R2} > V_{R1})$

Input	Diode state	V_o
$V_i \leq V_{R1}$	D_1 ON, D_2 OFF	V_{R_1}
$V_{R1} \leq V_i < V_{R2}$	D_1 OFF, D_2 OFF	V_i
$V_i \geq V_{R2}$	D_1OFF, D_2 ON	V_{R2}

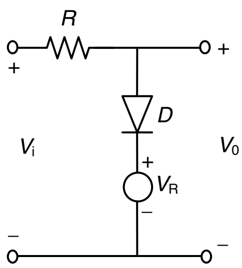


Transfer Characteristics

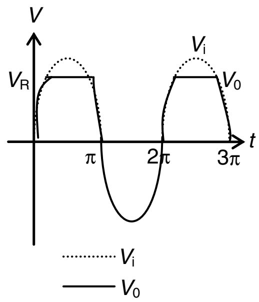


Clipping circuits are used to select for transmission, and that part of a waveform which lies above or below same reference level.

Considering Practical Diode



Diode clipping circuit



Input and output voltage waveforms

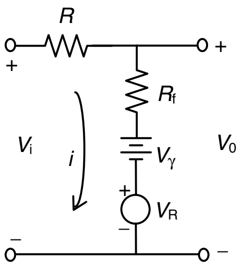


Figure 1 Model for circuit in forward bias $V_{in} > V_R + V_\gamma$

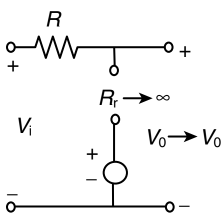


Figure 2 Model for circuit in reverse bias $V_{in} < V_R + V_\gamma$

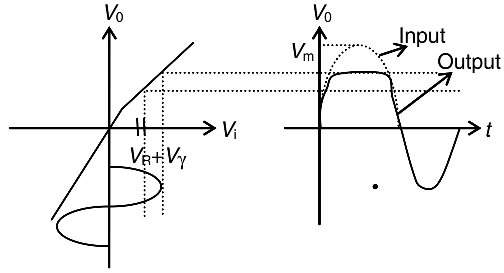
The diode will be ON during forward bias, as shown in Figure 1, by applying KVL

$$i = \frac{V_i - V_R - V_\gamma}{R_f + R}$$

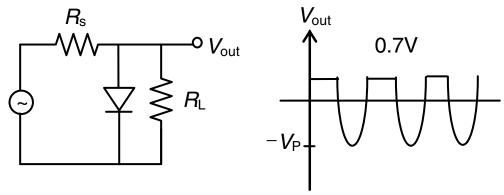
$$V_0 = iR_f + V_\gamma + V_R = \frac{R_f}{R_f + R} V_i + \frac{R}{R + R_f}(V_R + V_\gamma)$$

The translation from OFF to ON occurs when V_i equals to $V_\gamma + V_R$. This transition indicates abrupt change in slope in the plot of V_0 versus V_i called transfer characteristic.

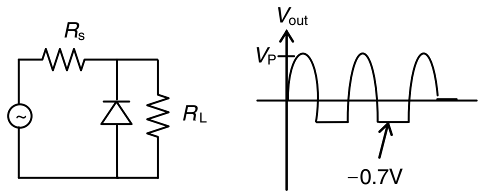
The slope is unity, when diode is OFF, as $V_i = V_0$ (from Figure 2).



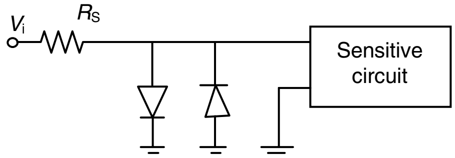
Transfer characteristic of clipping circuit



(1) Positive Clipper



(2) Negative Clipper

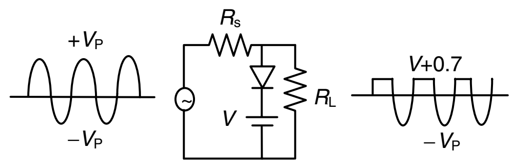


(3) Limiter or Diode Clamp

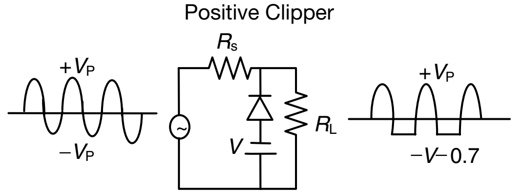
If the input signal is so small (say 20 mV), none of the diode will be turned ON, and therefore, these small voltages will be not affected. However, for higher voltages than ±0.7 V, one of the diode will be forward biased and the input to sensitive circuit will never cross ±0.7 V.

A limiter on the input side of an op amp will prevent excessive input voltage from being accidently applied.

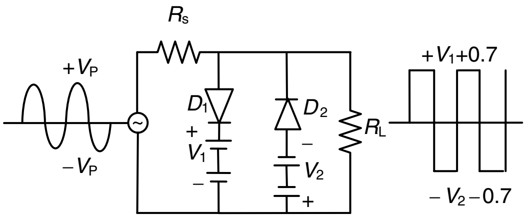
Biased Clippers



Positive Clipper

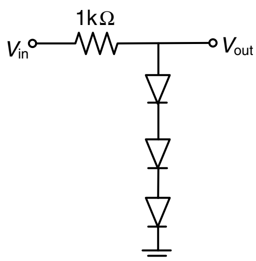


Negative Clipper



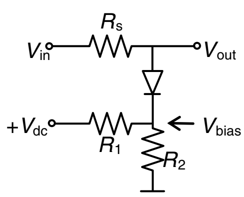
Biased positive-Negative Clipper

In the above combination, clipper diode D_1 clips off positive parts above positive bias level and diode D_2 clips off parts below the negative bias level. If input voltage is very large when compared to the bias levels, the output signal is a square wave.



2 (a) Clipper with three offset voltages

Since each diode has an offset of around 0.7 V, three diodes produce a clipping level of +2.1 V, we can use the same circuit (a) as a diode clamp to protect sensitive circuit that cannot tolerate more than 2.1 V input.



2 (b) Voltage divider biases clipper

This is another way to bias a clipper without batteries. The voltage divider R_1 and R_2 to set the bias level given by

$$V_{bias} = \frac{R_2}{R_1 + R_2} V_{DC}$$

In this case, the output voltage is clipped or limited when the input is greater than $V_{bias} + 0.7$ V.

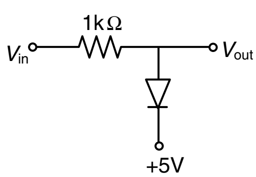
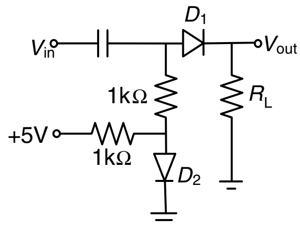


Figure 3 Diode clamp protects above 5.7 V

The circuit in Figure 3 can be used to protect sensitive circuits from excessive input voltages.



(D)

Figure 4 Circuit with zero offset

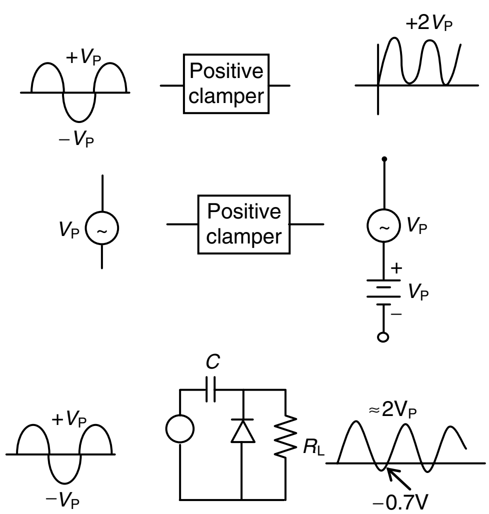
The circuit shown in Figure 4 is used to remove offset of limiting diode D_1. Diode D_2 is biased slightly into forward conduction, so it has 0.7 V across it. This 0.7V is applied to D_1 and R_L via 1 kΩ. This means that diode D_1 is on the verge of conduction. Therefore, when a signal carried in, diode D_1 conducts near 0 V.

Clamper Circuits

When a positive clamper has a sine wave input, it adds a positive DC voltage to the sine wave.

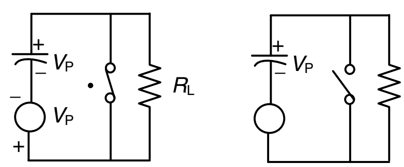
Stiff clamper: $R_L C > 100T$, where T is the time period.

The positive clamper shifts the AC reference level up to a DC level.

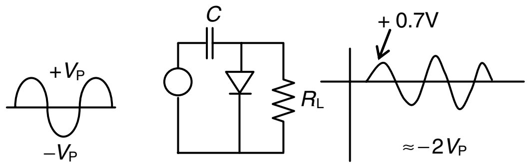


Practical clamper

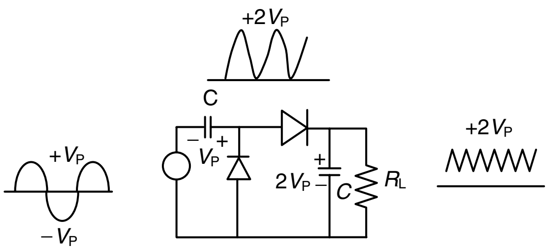
The first quarter of the cycle charges the capacitor fully, then the capacitor retains almost all of its charge during subsequent cycles. The small charge that is lost between cycles is replaced by diode conduction.



(1) At positive peak (2) Beyond positive peak capacitor acts as battery



(3) Negative Clamper



(4) Peak to peak detector

A half wave rectifier with a capacitor input filter produces a DC output voltage approximately equal to the peak of input signal.

If we cascade a clamper and a peak detector, we will get a peak to peak detector.

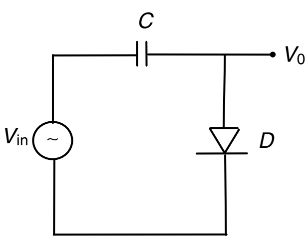
The RC time constant should be much greater than the period of the signal (T) to get good clamping.

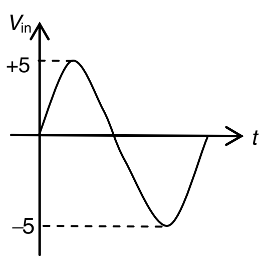
Steps to Draw Clamper Output

1. Find the voltage across the capacitor at input peak state.
2. Replace the diode with open circuit, and draw the output waveform.

Example 4

Find the output of clamper circuit in the given figure.





Solution

Under peak state, $V_c = +5$Volts

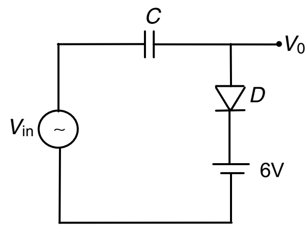
KVL at input side gives

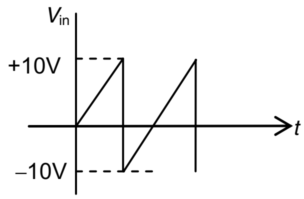
$$V_{in} - V_c - V_o = 0$$

$$\boxed{V_o = V_{in} - 5}$$

Example 5

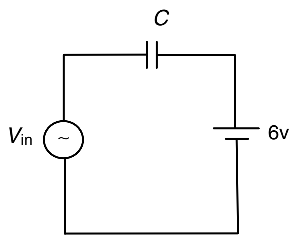
Find the output of clamper circuit in the given figure.





Solution

At peak state condition, diode forward biased.



$$\therefore\ V_c\ (\text{saturation}) = 4 \text{ volts}$$

KVL at input gives after replacing diode with short circuit:

$$V_o = V_{in} - 4$$

Voltage Multipliers

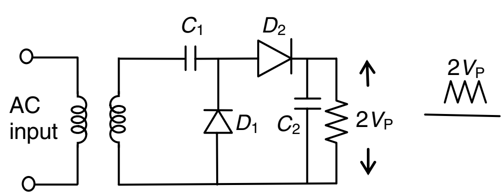


Figure 5 Voltage doubler with floating loads

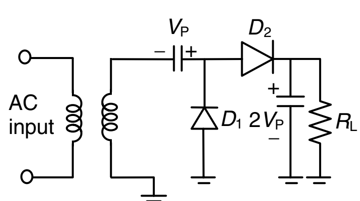


Figure 6 Voltage doubler with grounded loads

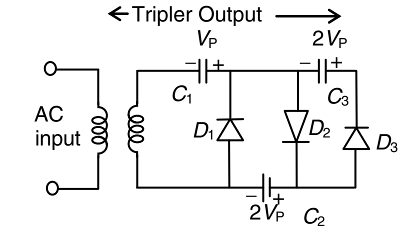


Figure 7 Voltage tripler with floating load

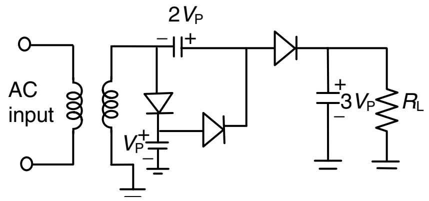


Figure 8 Voltage tripler with grounded load

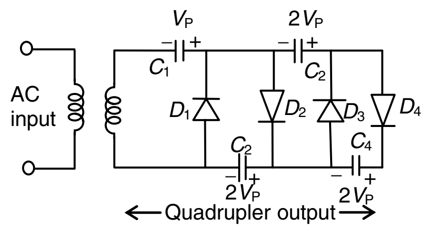


Figure 9 Voltage quadrupler with floating loads

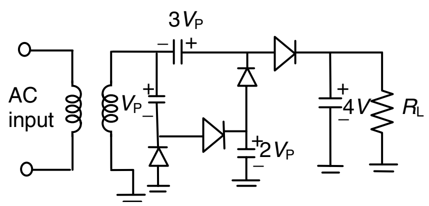


Figure 10 Voltage quadrupler with grounded load

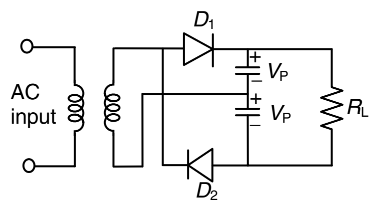


Figure 11 Voltage multiplier – full wave doubler

Voltage doubler is a redesign of the peak to peak detector, and it uses rectifier diodes instead of small signal diodes. It produces an output equal to the peak value of the rectified signal.

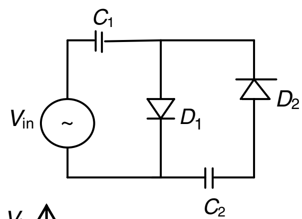
In voltage tripler, the first two sections act like a doubler at peak of the negative half cycle. D_3 is forward biased. This charges C_2 to $2V_p$ with the polarity shown in Figure 7. The tripler output appears across C_1 and C_3.

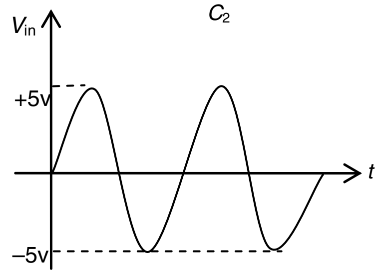
Voltage quadrupler with four sections in cascade, the first three sections are a tripler, and the fourth makes the overall circuit quadrupler. The quadrupler output is across the series connections C_2 and C_4.

Figure 11 shows a full wave voltage doubler on the positive half cycle of the source, and the upper capacitor charges to the peak voltage with the polarity shown on the peak next half cycle. Lower capacitor charges to the voltage with indicated polarity, and final output voltage is approximately $2V_p$.

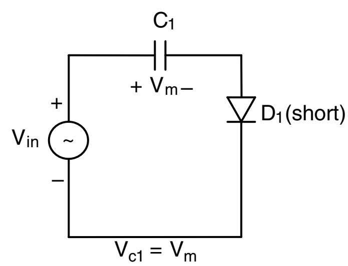
The voltage multipliers discussed earlier: (1) to (6) are half wave designs; this means the output ripple frequency is same as input frequency. However, in full wave voltage doubler, output ripple is double the input frequency. Therefore, it is easy to filter the ripple and PIV is also V_p only.

Voltage Doubler Analysis

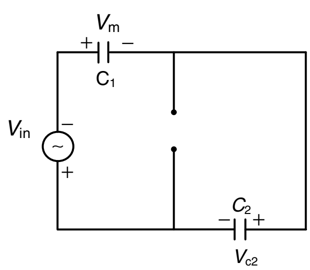




During positive half cycle, D_1 is ON. Hence, 'C_1' is charged to $+V_m$.



During negative cycle:



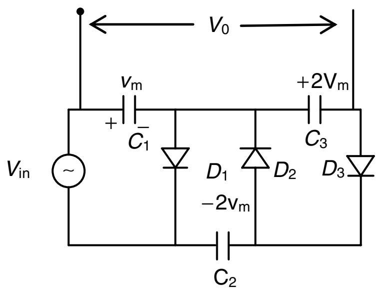
(During negative cycle)

$$-V_{in} - V_m - V_{c2} = 0$$

$$V_{c2} = -V_{in} - V_m$$

$$\boxed{V_{c2} = -2V_m}$$

Voltage Tripler Analysis

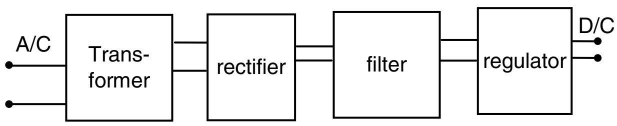


During the first positive half cycle, D_1 is ON, and during the next negative half cycle, D_2 alone ON.

$$\therefore V_o = V_{c1} + V_3 = 3V_m$$

During the second positive half cycle, D_1 and D_3 ON.

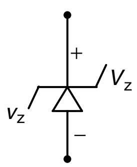
Power Supplies



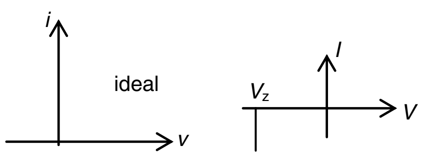
Transformers are used for step up or step down the level of input AC voltage.

Voltage Regulators

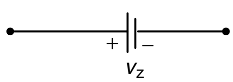
Zener diode can be used as a voltage regulator.



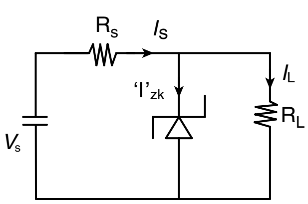
When Forward Biased Reverse biased



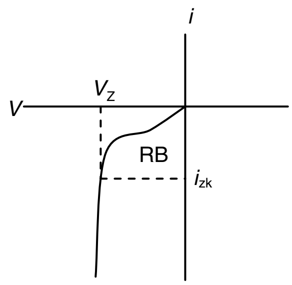
Zener Reverse ON condition



Zener Voltage Regulator



I–V Characteristics:



When source voltage varying:

$$I_s\,(\text{min}) = I_z\,(\text{min}) + I_L\,(\text{fix})$$
$$I_s\,(\text{max}) = I_z\,(\text{max}) + I_L\,(\text{fix})$$

When load is varying:

$$I_s\,(\text{fix}) = I_z\,(\text{min}) + I_z\,(\text{max})$$
$$I_s\,(\text{fix}) = I_z\,(\text{max}) + I_z\,(\text{min})$$

Zener diode withstand the current variations due to variations in source and load resistance when it is in reverse 'ON' condition; hence, it produces a constant output voltage across the load.

Steps to Determine the State of Zener Diode

1. Replace the Zener Diode with open circuit.
2. Find the terminal voltage across the diode from 'n' to 'p' side, for example, V_t.
3. If $V_t > V_z$, then Zener is reverse ON and diode is replaced with a voltage source of V_z.
4. If $V_t < V_z$, then Zener is OFF and hence replace it with open circuit.

Example 6

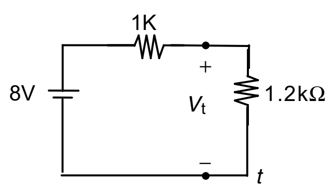
Check the status of Zener diode when

1. $R_L = 1.2\ \text{k}\Omega$
2. $R_L = 3.6\ \text{k}\Omega$

Given $V_z = 6$ v, $V_s = 8$ v and $R_s = 1\ \text{k}\Omega$. Determine the output voltage.

Solution

Case (i): $R_L = 1.2\ \text{k}\Omega$

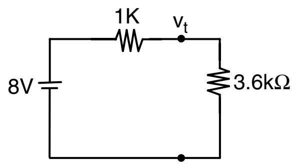


$$V_t = \frac{8(1.2)}{2.2} = 4.3 \text{ Volts}$$

$V_t < V_z$. Hence, Zener diode is in OFF condition

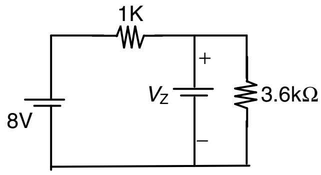
$$\therefore V_o = 4.3 \text{ Volts}$$

Case (ii): $R_L = 3.6\ \text{k}\Omega$



$$V_t = \frac{8(3.6)}{4.6} = 6.26087$$

$V_t < V_z$. Hence, Zener is in 'ON' condition.



$$\therefore\ V_o = V_z = 6 \text{ volts}$$

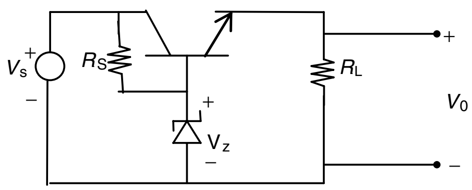
NOTE

The conventional direction of Zener voltage is considered to be opposite to the direction of ordinary p–n junction diode, because p–n junction is used in FB direction, and Zener diode is used in RB direction.

Characteristics of an Ideal Voltage Regulator

1. It should maintain a constant output voltage irrespective of variations in input and the load.
2. Load current should depend on R_L.

Voltage Regulator using BJT



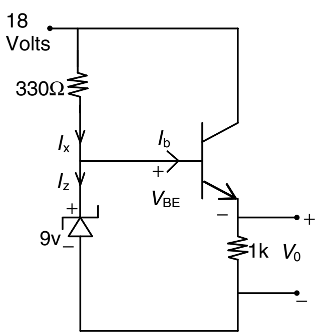
as 'V_s' changes $\Rightarrow$ V_z constant $\Rightarrow$ I_b is constant

$$I_E = (\beta + 1)\, I_b$$

Hence, I_E = constant

$V_o = I_E R_L$ = constant irrespective of variations in the input circuit.

Example 7



Find current I_z, if $\beta = 99$ and $V_{BE} = 0.7$ volts

(A) 0.0264 A (B) 0.352 A

(C) 0.476 A (D) 0.0123 A

Solution

KVL at input side gives $-9 + 0.7 + V_L = 0$

$$\text{KCL} \Rightarrow I_x = I_b + I_z$$

$$I_z = I_x - I_b$$

$$I_x = \frac{18-9}{330\Omega} = 0.02727 \text{ A}$$

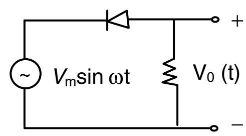
$$I_b = \frac{1}{100}\cdot\frac{V_L}{1\text{k}\Omega} = \frac{8.3}{100\text{k}\Omega} = 0.083 \text{ mA}$$

$$\therefore\ I_z = 0.0264 \text{ A}$$

Direction for questions 8 to 15: Select the correct alternative from the given choices.

Example 8

The average value of V_o (t) will be



(A) 0 (B) $\frac{-V_m}{\pi}$ (C) $\frac{-V_m}{\sqrt{2}}$ (D) $-V_m$

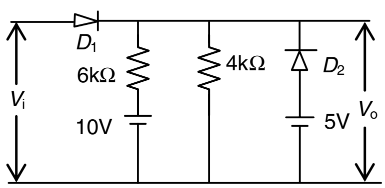
Solution

$$V_{av} = \frac{\int_{\pi}^{2\pi} V_m \sin\omega t\, d\omega t}{2\pi} = \frac{V_m\left[-\cos\omega t\right]_{\pi}^{2\pi}}{2\pi} = \frac{-V_m}{\pi}$$

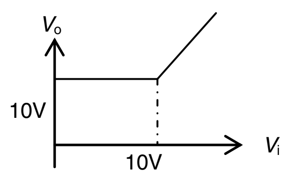
The diode will be ON for π to 2π

Example 9

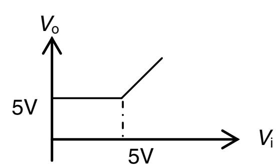
If D_1 and D_2 diode are ideal, which of the following represents transfer characteristics of circuit?



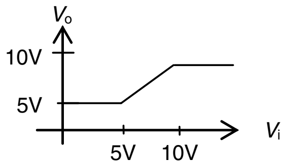
(A)



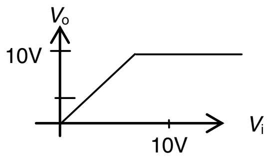
(B)



(C)



(D)



Solution

For $0 \le V_i \le 5$ V

D_2 is ON and $V_o = 5$ V

For $5 \le V_i \le 10$ V

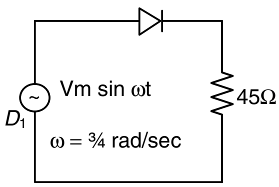
D_2 is OFF and $V_o = V_i$

for $V_i > 10$V, D_1 is ON, D_2 is OFF

$$V_o = V_i$$

Example 10

The forward resistance of the diode shown in circuit is 5 Ω, and the other parameters are the same as those of an ideal diode. Then, what is the DC component of the source current?



(A) $\dfrac{V_m}{50\pi}$ (B) $\dfrac{V_m}{45\pi\sqrt{2}}$

(C) $\dfrac{V_m}{100\pi\sqrt{2}}$ (D) $\dfrac{2V_m}{45}$

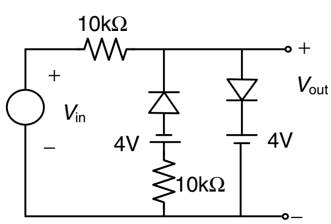
Solution

$$I_{DC} = \frac{\int_0^{\pi} V_m \sin \omega t . d\omega t}{2\pi . R} = \frac{\left|V_m . \cos \omega t\right|_0^{\pi}}{2\pi . R} = \frac{V_m}{50\pi}$$

$$R = R_{f\,(diode)} + 45\ \Omega = 5 + 45\ \Omega = 50\ \Omega$$

Example 11

A voltage signal 10 sinwt is applied to the circuit with ideal diode, as shown in the figure. The maximum and minimum values of the output waveform V_{out} of the circuit are, respectively,

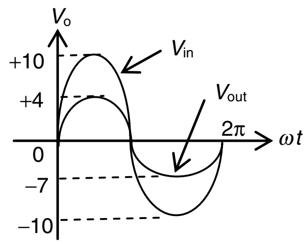


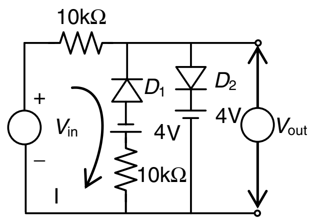
(A) +10 V and –10 V (B) +4 V and –4 V

(C) +7 V and –4 V (D) +4 V and –7 V

Solution

The voltage waveform at the output will be as shown in the following figure for positive cycle.





D_2 ON, D_1 OFF, $V_{out} = 4$ V,

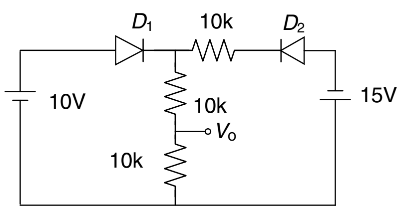
for negative cycle D_1 ON, D_2 OFF

$$I = \frac{V_{in} + 4}{20} = \frac{-10 + 4}{20} = \frac{-3}{10}\text{mA}$$

$$V_{out} = I.R - 4 = -7 \text{ V}$$

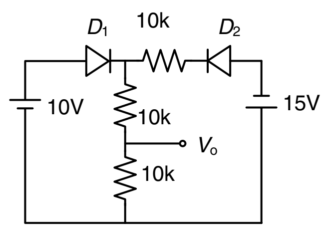
Example 12

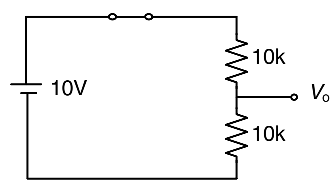
Assuming that the diode in the given circuit is ideal, the voltage V_o is



(A) 4 V (B) 5 V (C) 7.5 V (D) 12.1 V

Solution



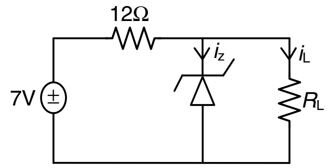


In this case, the diode D_2 is always reverse biased

$$V_o = \frac{10\text{k}}{10\text{k}+10\text{k}} \times 10 = 5\text{V}$$

Direction for questions 13 to 15:

Example 13



In the voltage regulator circuit shown, the Zener diode current is to be limited to the range $5 \le i_z \le 100$ mA

$$V_z = 4\text{ V},\ R_z = 0\ \Omega$$

The range of possible load current is

(A) $5 \le i_L \le 130$ mA (B) $25 \le i_L \le 250$ mA
(C) $10 \le i_L \le 110$ mA (D) $150 \le i_L \le 245$ mA

Solution

Current through 12 Ω resistor $i = \dfrac{7-4}{12}$

$= 250$ mA

$i_L = i - i_z$, and i_z is in range of 5 to 100 mA

Therefore, i_L will be $150\text{ mA} \le i_L \le 245$ mA.

Example 14

Range of possible load resistance is
(A) $60 \le R_L \le 375\ \Omega$
(B) $20 \le R_L \le 60\ \Omega$
(C) $40.1 \le R_L \le 92.1\ \Omega$
(D) $16.3 \le R_L \le 26.6\ \Omega$

Solution

$i_L R_L = 4$ V, $150\text{ mA} \le i_L \le 245$ mA

Therefore, R_L will be $16.3\ \Omega \le R_L\ \Omega\ 26.67$.

Example 15

The power rating required for load resistance is
(A) 576 mW (B) 480 mW
(C) 360 mW (D) 980 mW

Solution

The power rating required for output resistance is $i_L =$ 245 mA, $V_Z = 4$ V,

$$i_L V_Z = 0.98\text{ W}$$

Exercises

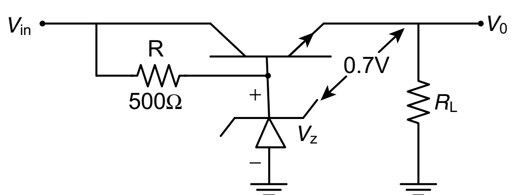
Practice Problems I

Direction for questions 1 to 28: Select the correct alternative from the given choices.

1. A power supply having an output resistance 1.5 Ω supplies full load current of 500 mA to a 50 Ω load. What is the percentage voltage regulation of supply?
(A) 2% (B) 3% (C) 6% (D) 1.5%

2. What is the no-load output voltage of the supply in the abovementioned problem?
(A) 25 V (B) 24.25 V
(C) 25.75 V (D) 25.25 V

3. A transistor series voltage regulator is shown in the following figure. The input voltage V_{in} can carry from 18 V to 30 V.
If $V_Z = 10$ V, $R_L = 1$ kΩ, β-very high



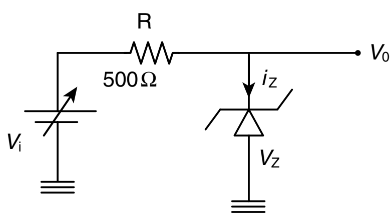
The minimum collector to emitter voltage (V_{CE}) of the transistor is
(A) 8.7 V (B) 20.7 V (C) 7.3 V (D) 19.3 V

4. The minimum power dissipated in the transistor is
(A) 0.192 W (B) 2.1 W
(C) 80.9 mW (D) None

5. The maximum current supplied by V_{in} is
(A) 40 mA (B) 9.3 mA
(C) 24.5 mA (D) 49.3 mA

6. An FWR is operated form 230 V, 50 Hz line has a capacitor filter across its output. Calculate the minimum value of capacitance required if the load is 1 kΩ and the ripple must not exceed 5%.
(A) 57.8 μF (B) 10 μF (C) 28.6 μF (D) 5.7μF

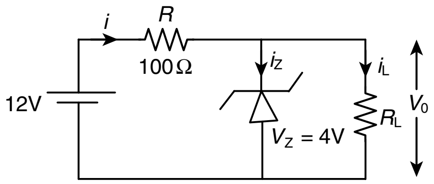
7. A Zener diode voltage regulator is given in the following figure with following specifications $I_{Zmin} = 4$ mA, $I_{zmax} = 24$ mA, $V_z = 4.8$ V, and $R_Z = 10\ \Omega$



Calculate minimum and maximum input voltage that can be regulated by Zener diode
(A) 9.8 V, 25.04 V (B) 6.84 V, 25.04 V
(C) 9.8 V, 17.04 V (D) 6.84 V, 17.04 V

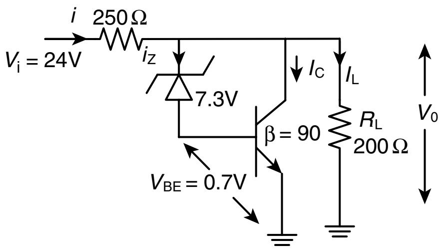
8. The line regulation is
(A) 1.3% (B) 2.5% (C) 1.96% (D) 0%

9. In the following circuit, the knee current of ideal Zener diode is 8 mA. To maintain 4 V across R_L, the minimum value of R_L and minimum power rating of Zener diode in mW, respectively, are



(A) 55 Ω, 320 mW (B) 55 Ω, 288 mW
(C) 50 Ω, 320 mW (D) 50 Ω, 288 mW

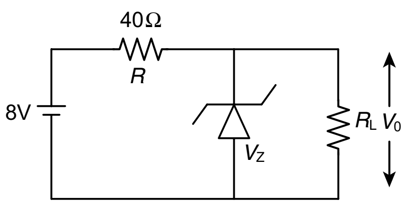
10. A transistor shunt voltage regulator is given in the following figure.



The collector current i_c is
(A) 10 mA (B) 24 mA (C) 64 mA (D) 40 mA

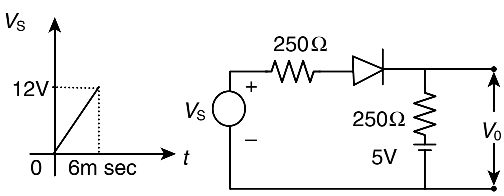
11. The power dissipation in Zener diode is
(A) 1.89 mW (B) 2.5 W
(C) 3.1 mW (D) None of these

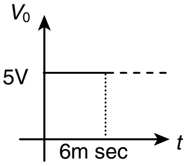
12. A Zener diode in the circuit shown in the following figure has a knee current of 4 mA and power dissipation of 200 mW.
What are the minimum and maximum load currents that can be drawn safely from the circuit, keeping the output $V_0 = 5$ V?

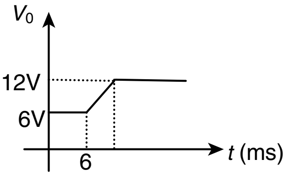


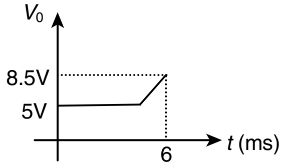
(A) 0 mA, 200 mA (B) 4 mA, 11 mA
(C) 35 mA, 71 mA (D) 35 mA, 200 mA

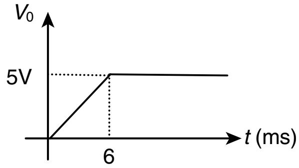
13. Sketch the output V_0 of the circuit given for $0 \le t \le 6$ ms, assume the diode is ideal



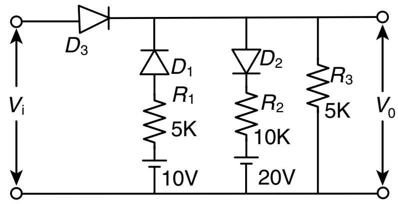
(A)


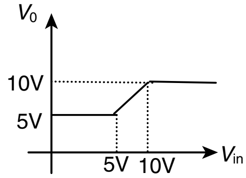
(B)


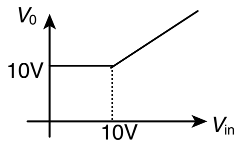
(C)


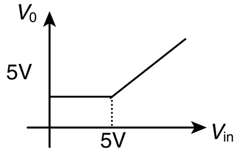
(D)


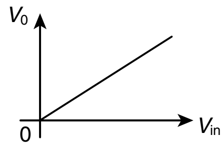
14. Draw the transfer characteristic (V_0 Vs V_i) for the following circuit.



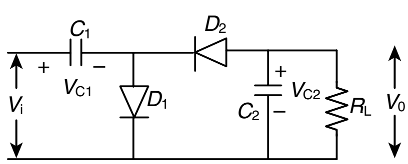
(A)


(B)


(C)


(D)


15. A voltage doubler is given in the following figure.

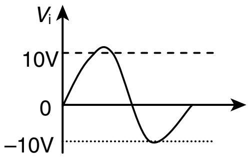


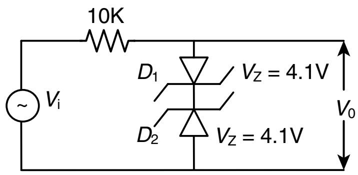
where $V_i = 6 \sin\omega t$ volt
The voltage across C_1 and C_2 are

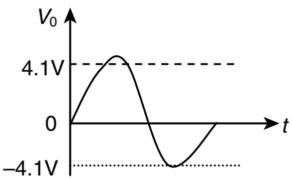
(A) 6 V and 6 V (B) 6 V and –12 V
(C) 6 V and 12 V (D) –6 V and –12 V

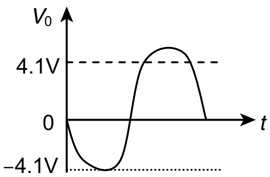
16. The PIV of D_1 and D_2 are
(A) 6 V and 6 V (B) 6 V & 12 V
(C) 12 V and 12 V (D) 12 V & 6 V

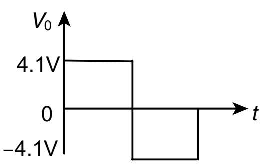
17. Draw the output V_0 of the following figure.

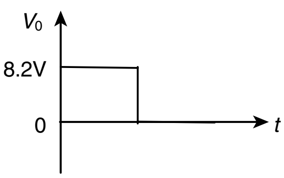




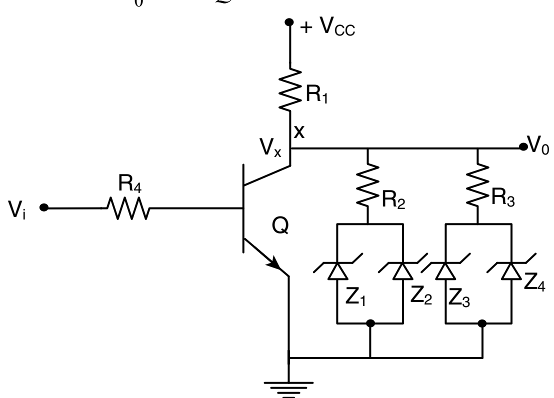
(A)


(B)


(C)


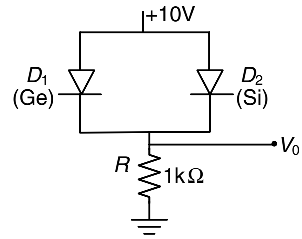
(D)


18. In the following circuit, assume that $V_{CC} = 12$ V, Z_1, Z_2, Z_3, and Z_4 are identical Zener diodes with breakdown voltage of 4 V. $R_1 = R_4 = 4$ kΩ and $R_2 = R_3 = 8$ kΩ. Calculate V_0 when Q is OFF.



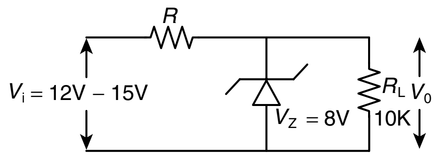
(A) 7.3 V (B) 8 V
(C) 10 V (D) 8.5 V

19. In the given circuit, two diodes made up of Ge (cut in voltage = 0.3 V) and Si (cut in voltage = 0.7 V) are used. What is the value of V_0?



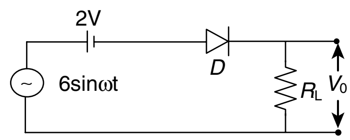
(A) 10 V (B) 9 V (C) 9.7 V (D) 9.3 V

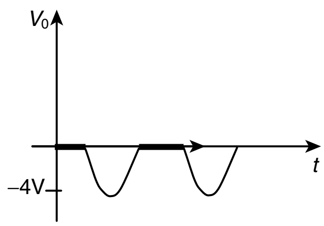
20. What is the minimum value of R to maintain $V_0 = 8$ V constant and I_z is negligible?

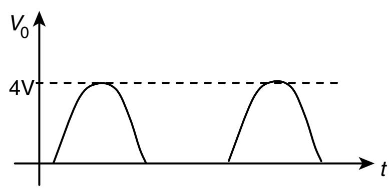


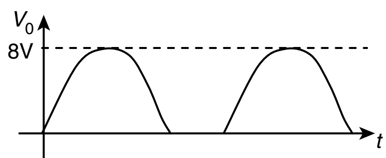
(A) $R \leq 5$ kΩ (B) $R > 8.75$ kΩ
(C) $5K < R < 8.75K$ (D) None of these

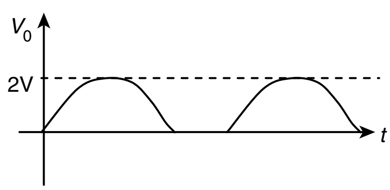
21. Draw the output V_0 of the following figure (assume diode is ideal).



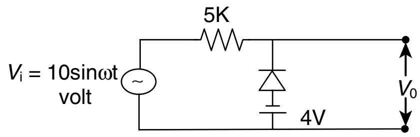
(A)


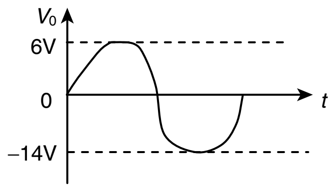
(B)


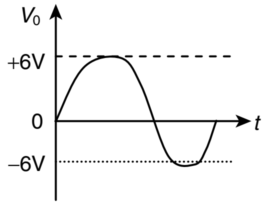
(C)


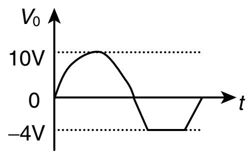
(D)


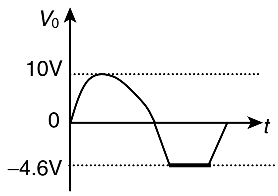
22. Draw the output V_0, assume diode FB voltage drop is 0.6 V.



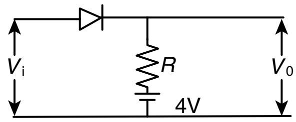
(A)


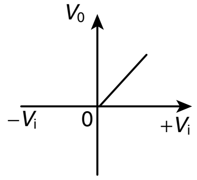
(B)


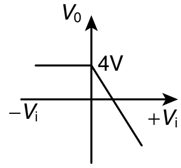
(C)


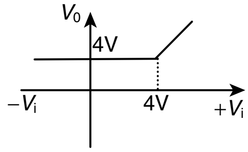
(D)


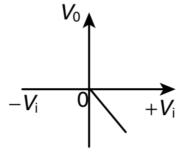
23. Draw the transfer characteristic of the following figure (assume diode is ideal).



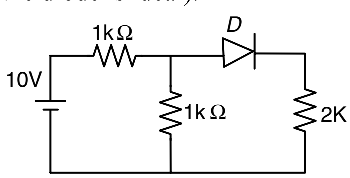
(A)


(B)


(C)


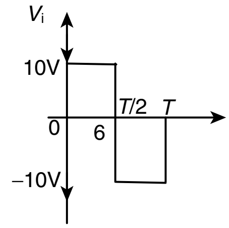
(D)


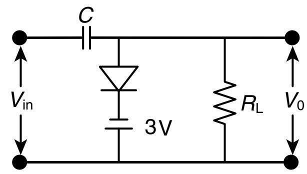
24. Calculate the voltage drop across 2 kΩ of the figure (assume the diode is ideal).

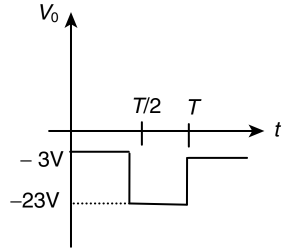


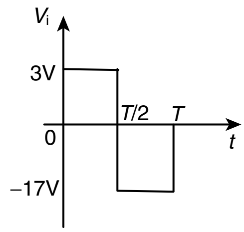
(A) 10 V (B) 2 V (C) 4 V (D) 0 V

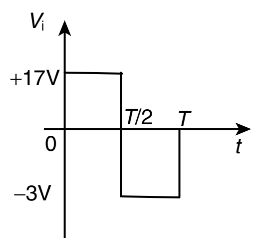
25. Sketch the output waveform for the circuit given.

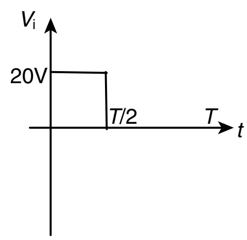




(A)


(B)


(C)


(D)


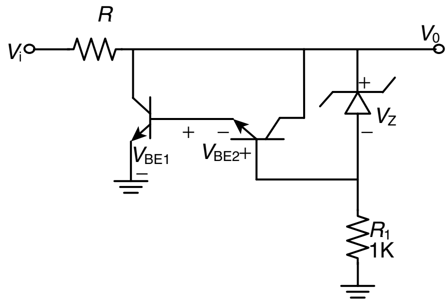
26. An HWR uses a transformer of turn ratio 2:1 and a load resistance of 500 Ω. If the rms primary voltage is 240 V. The DC output voltage is

(A) 54 V (B) 38 V
(C) 76 V (D) None of these

27. The PIV of diode is

(A) 120 V (B) 240 V (C) 360 V (D) 170 V

28. Find the output voltage of a shunt regulator in the following figure with following specifications.



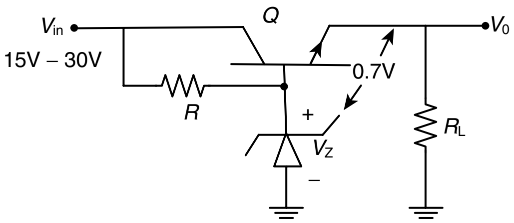
$V_{BE1} = V_{BE2} = 0.6$ V and $V_Z = 10$ V

(A) 10.6 V (B) 8.8 V
(C) 10 V (D) 11.2 V

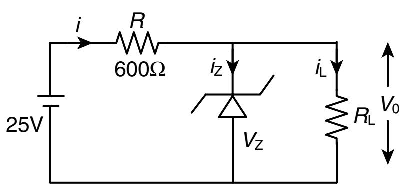
Practice Problems 2

Direction for questions 1 to 26: Select the correct alternative from the given choices.

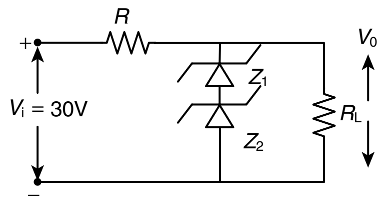
1. The DC output voltage is 45 V at full load and 47 V at no load. The percentage regulation factor is
 (A) 2.5% (B) 1% (C) 4.25% (D) 4.44%
2. In a FWR, the rms output is 10 V. What is its DC output voltage?
 (A) 10 V (B) 9 V (C) 5 V (D) 6 V
3. A transistor series voltage regulator is given in the following figure.



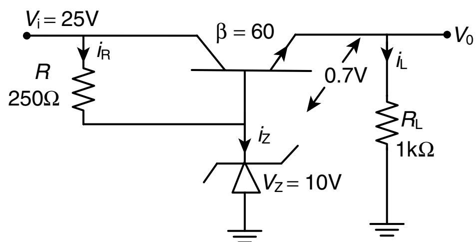
 What breakdown voltage V_Z should the Zener diode have, if the load voltage is to be maintained at 12 V?
 (A) 11.3 V (B) 12.7 V
 (C) 12 V (D) None of these
4. If the Zener diode must conduct 12 mA to remain in the breakdown region, what minimum value should R have (in abovementioned problem)?
 (A) 500 Ω (B) 1.4 kΩ
 (C) 2 kΩ (D) 192 Ω
5. A Zener diode voltage regulator is given in the following figure with following specifications. $V_Z = 4.1$ V, $I_{ZK} = 3$ mA, $I_{Zmax} = 28$ mA and $r_z = 0$



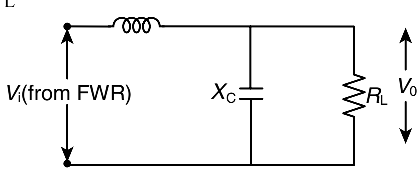
 Calculate minimum and maximum load currents for which Zener diode will maintain regulation.
 (A) 3 mA , 31.83 mA (B) 6.83 mA, 31.83 mA
 (C) 6.83 mA, 28 mA (D) 3 mA, 28 mA
6. For abovementioned problem, calculate the minimum value of R_L used.
 (A) 128 Ω (B) 85 Ω (C) 600 Ω (D) 117 Ω
7. The following circuit uses two Zener diodes, each is rated at 12 V, 100mA and assume that load current is negligible.



 The regulated output V_0 is
 (A) 24 V (B) 12 V (C) 6 V (D) 0 V
8. For abovementioned problem, the value of series resistance R is
 (A) 180 Ω (B) 15 Ω
 (C) 60 Ω (D) None of these
9. A transistor series voltage regulator is given in the following figure.

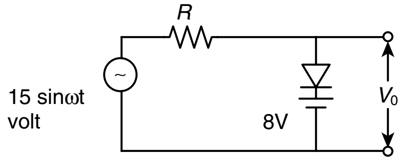


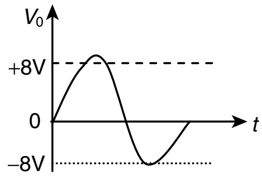
 The output voltage V_0 is
 (A) 9.3 V (B) 10.7 V (C) 10 V (D) 0.7 V
10. For abovementioned problem Zener current i_z is
 (A) 60 mA (B) 0.15 mA
 (C) 59.84 mA (D) 10 mA
11. Calculate the ripple factor (γ) of L-section filter given in the following figure. With $X_C = 10$ Ω, $X_L = 100$ Ω, and $R_L = 1$ kΩ

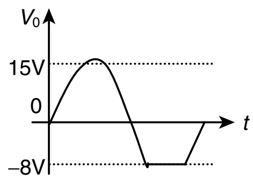


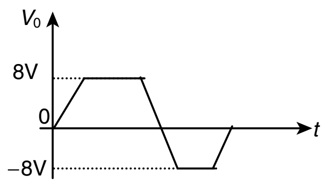
(A) 0.14 (B) 0.047
(C) 0.482 (D) 0.52

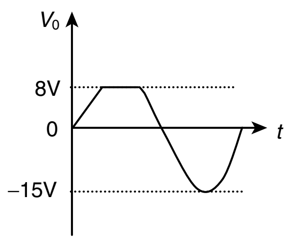
12. For the circuits given, assume the diode is ideal sketch output V_0.



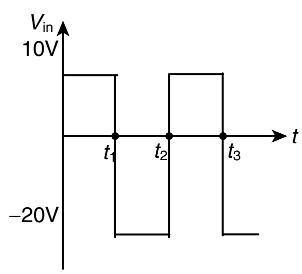
(A)


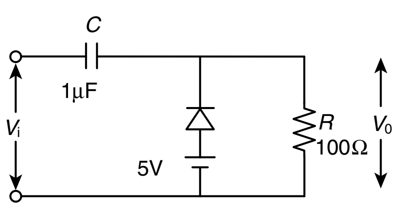
(B)


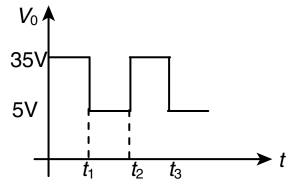
(C)


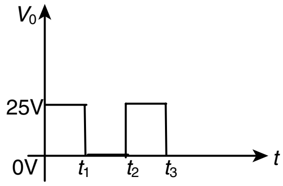
(D)


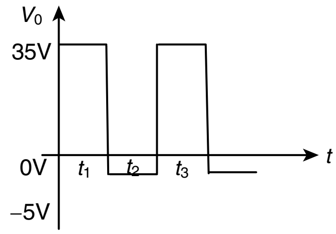
13. A DC restorer is shown in the following figure. Sketch output V_0

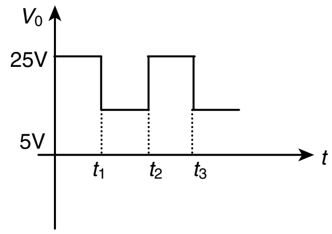




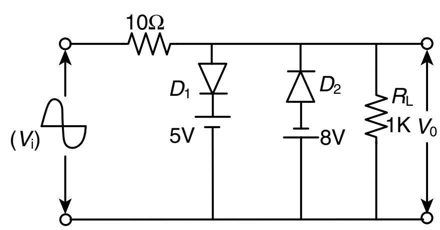
(A)


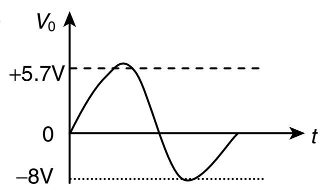
(B)


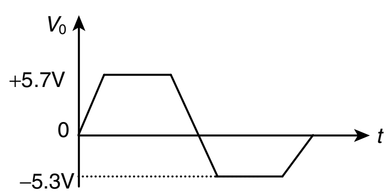
(C)


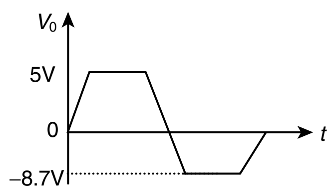
(D)


14. Draw the output V_0 of the figure given. Assume forward voltage drop of each diode is 0.7 V

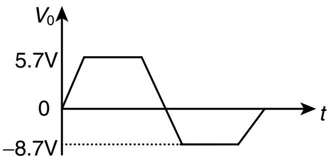


(A)


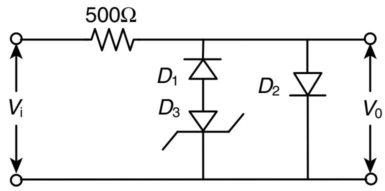
(B)


(C)


(D)

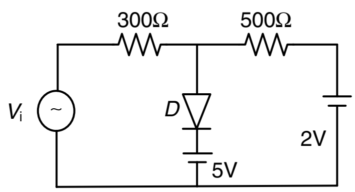


15. In the following limiter circuit, an input voltage $V_i = 12 \sin 100\pi t$ v is applied. Assume that the diode forward voltage drop is 0.6 V and Zener breakdown voltage is 4.2 V. What is the minimum and maximum value of output voltage?



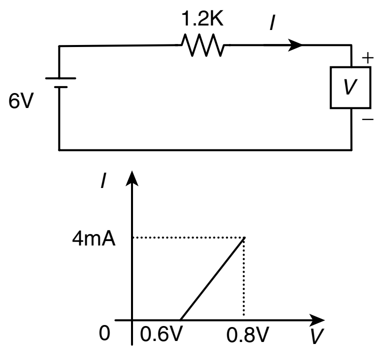
(A) –0.6 V, 4.8 V (B) –4.8 V, 0.6 V
(C) 0.6 V, 4.2 V (D) –4.2 V, –0.6 V

16. Find input V_i for the diode to be FB



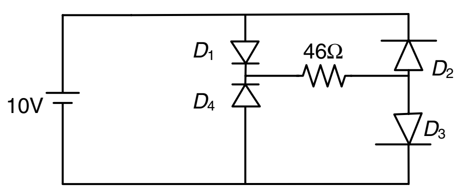
(A) 7 V (B) 6.8 V (C) 3 V (D) 5 V

17. Find current I for the given characteristic



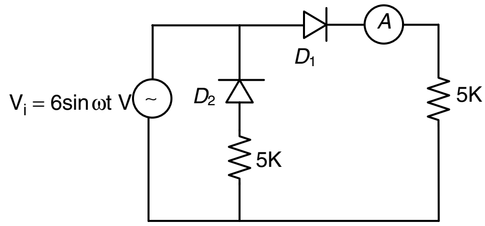
(A) 4.32 mA (B) 5 mA (C) 4 mA (D) 0

18. If the cut-in voltage and forward resistance of each diode are 0.6 V and 2 Ω, respectively. The current passing through 46 Ω is



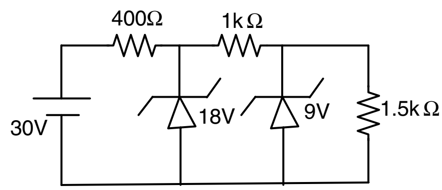
(A) 0.176 A (B) 0.16 A (C) 0 A (D) 0.2 A

19. In the circuit shown, assume that diodes are ideal an ammeter is rms value indicating meter with zero internal resistance. The ammeter reading is



(A) 0.3 mA (B) 1.2 mA
(C) 0.6 mA (D) $\frac{1.2}{\pi}$ mA

20. What is the output voltage across 1.5 kΩ load in the circuit given in the following figure?



(A) 18 V (B) 10.8 V (C) 9 V (D) 5.4 V

21. An AC supply of 200 V, 50 Hz is applied to bridge rectifier through a transformer turn ratio 4:1. The diode forward resistance is 200 Ω and load R_L = 1 kΩ
What is the DC output current?
(A) 31.8 mA (B) 26.54 mA
(C) 106 mA (D) None of these

22. What is the peak inverse voltage of diode?
(A) 50 V (B) 100 V (C) 200 V (D) 400 V

23. Output ripple frequency is
(A) 100 Hz (B) 50 Hz
(C) 25 Hz (D) 0 Hz

24. A power supply is delivering 100 W to a load of 10 kΩ. What is the AC (ripple) voltage across the load if the ripple factor is 0.1%?
(A) 100 V (B) 10 V (C) 1 V (D) 0.1 V

25. A full wave rectifier uses a centre tapped transformer. The AC voltage from its centre tap to either end is 20sin314t v. The load resistance of the circuit is 80 Ω and diode resistance is 20 Ω.
What is rms value of output current (I_{rms})?
(A) 0.2 A (B) 2 mA
(C) 20 mA (D) 0.14 A

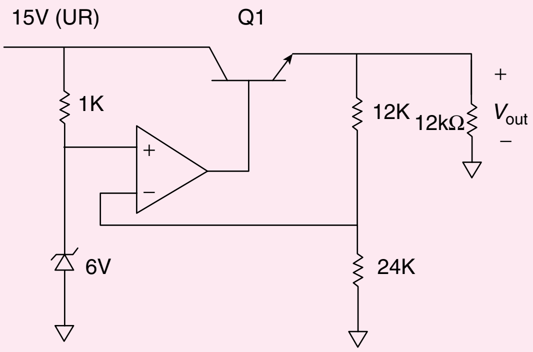
26. Rectifier efficiency is
(A) 81.2% (B) 64.96%
(C) 58.7% (D) 40.6%

Previous Years' Questions

Direction for questions 1 and 2:

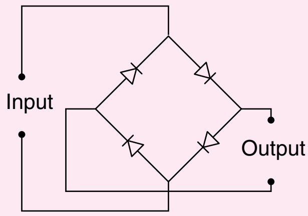
A regulated power supply shown in the following figure has an unregulated input (UR) of 15 v and generates a regulated output V_{out}. Use the component values shown in the figure.

In the abovementioned figure, the ground has been shown by the symbol ∇.

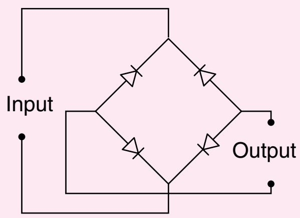


1. The power dissipation across the transistor Q_1 shown in the figure is **[2006]**
   (A) 4.8 W (B) 5 W (C) 5.4 W (D) 6 W
2. If the unregulated voltage increases by 20%, the power dissipation across the transistor Q1 **[2006]**
   (A) increases by 20% (B) increases by 50%
   (C) remains unchanged (D) decreases by 20%
3. The correct full wave rectifier circuit is **[2007]**

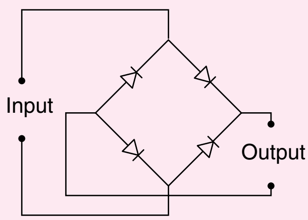
(A)



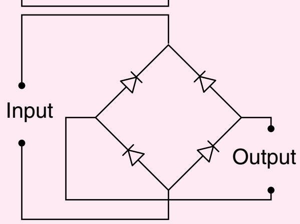
(B)



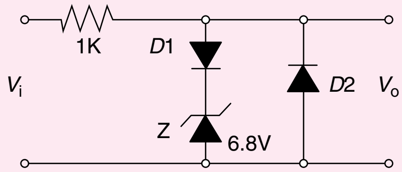
(C)



(D)



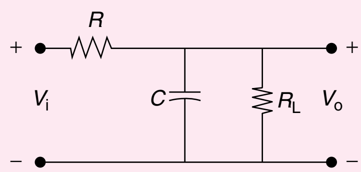
4. In the following limiter circuit, an input voltage $V_i = 10 \sin 100\pi t$ applied. Assume that the diode drop is 0.7 V when it is forward biased. The Zener breakdown voltage is 6.8 V. **[2008]**



The maximum and minimum values of the output voltage, respectively, are
(A) 6.1 V, −0.7 V (B) 0.7 V, −7.5 V
(C) 7.5 V, −0.7 V (D) 7.5 V, −7.5 V

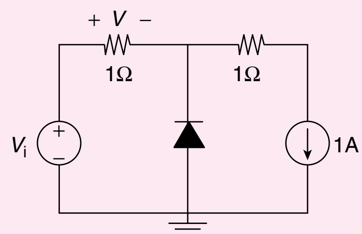
5. If the transfer function of the following network is

$$\frac{V_0(s)}{V_i(s)} = \frac{1}{2 + sCR}$$



The value of the load resistance R_L is **[2009]**
(A) $R/4$ (B) $R/2$ (C) R (D) $2R$

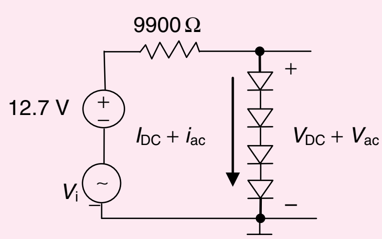
6. In the following circuit, the diode is ideal. The voltage V is given by **[2009]**



(A) min (V_i ,1) (B) max (V_i, 1)
(C) min ($-V_i$, 1) (D) max ($-V_i$, 1)

Direction for questions 7 and 8:

In the following circuit, assume that the voltage drop across a forward biased diode is 0.7 V. The thermal voltage $V_t = kT/q = 25$ mV. The small signal input $V_i = V_P \cos(\omega t)$ where $V_P = 100$ mV.



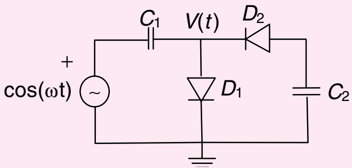
7. The bias current I_{DC}, through the diodes is **[2011]**

(A) 1 mA (B) 1.28 mA
(C) 1.5 mA (D) 2 mA

8. The AC output voltage v_{ac} is **[2011]**

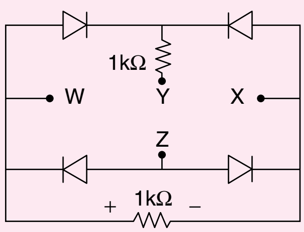
(A) $0.25\cos(\omega t)$ mV (B) $1\cos(\omega t)$ mV
(C) $2\cos(\omega t)$ mV (D) $22\cos(\omega t)$ mV

9. The diodes and capacitors in the circuit shown are ideal. The voltage $V(t)$ across the diode D_1 is **[2012]**



(A) $\cos(\omega t) - 1$
(B) $\sin(\omega t)$
(C) $1 - \cos(\omega t)$
(D) $1 - \sin(\omega t)$

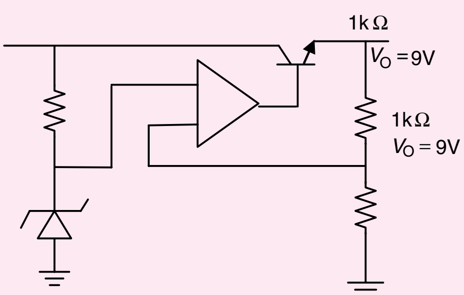
10. A voltage 1,000 $\sin\omega t$ volts is applied across YZ. Assuming ideal diodes, the voltages measured across WX in volts is **[2013]**



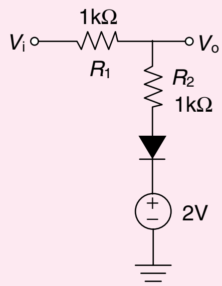
(A) $\sin \omega t$
(B) $(\sin \omega t + |\sin \omega t|)/2$
(C) $(\sin \omega t - |\sin \omega t|)/2$
(D) 0 for all t

11. In the voltage regulator circuit shown in the figure, the op amp is ideal. The BJT has $V_{BE} = 0.7$ V and $\beta = 100$, and the Zener voltage is 4.7 V. For a regulated output of 9 V, the value of R (in Ω) is ____________.

[2014]



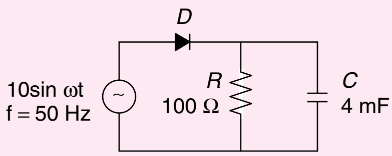
12. The diode in the circuit shown has $V_{on} = 0.7$ V, but is ideal otherwise. If $V_i = 5\sin(\omega t)$ V, the minimum and maximum values of V_o (in Volts) are, respectively, **[2014]**



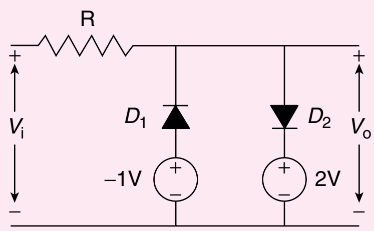
(A) –5 and 2.7 (B) 2.7 and 5
(C) –5 and 3.85 (D) 1.3 and 5

13. The figure shows a half wave rectifier. The diode D is ideal. The average steady-state current (in Amperes) through the diode is approximately _____.

[2014]

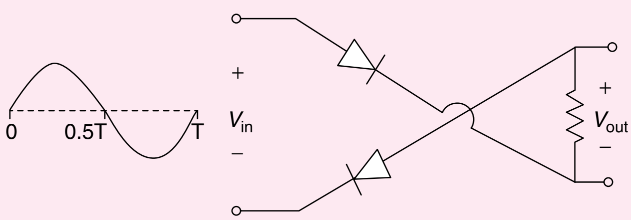


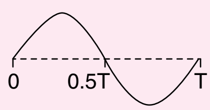
14. Two silicon diodes, with a forward voltage drop of 0.7 V, are used in the circuit shown in the figure. The range of input voltage V_i for which the output voltage $V_o = V_i$ is **[2014]**

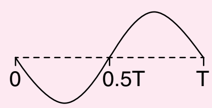


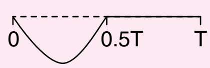
(A) $-0.3\ V < V_i < 1.3\ V$ (B) $-0.3\ V < V_i < 2\ V$
(C) $-1.0\ V < V_i < 2.0\ V$ (D) $-1.7\ V < V_i < 2.7\ V$

15. For the current with ideal diodes shown in the figure, the shape of the output (v_{out}) for the given sine wave input (v_{in}) will be **[2015]**



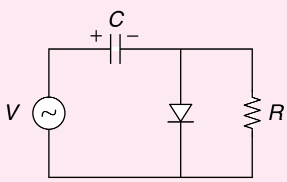
(A) 

(B) 

(C) 

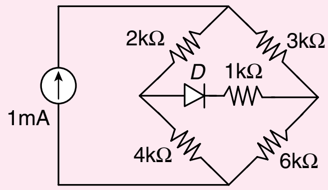
(D) 

16. If the circuit shown has to function as a clamping circuit, then which one of the following conditions should be satisfied for the sinusoidal signal of period T? **[2015]**

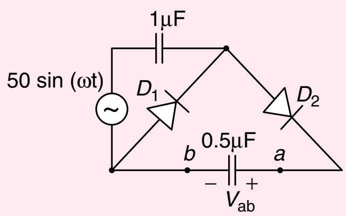


(A) $RC << T$ (B) $RC = 0.35\ T$
(C) $RC \approx T$ (D) $RC >> T$

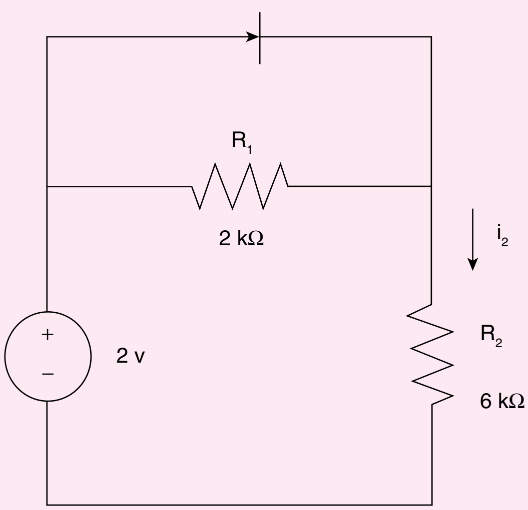
17. The diode in the circuit given below has $V_{ON} = 0.7$ V but is ideal otherwise. The current (in mA) in the 4kΩ resistor is ______. **[2015]**



18. In the circuit shown, assume that diodes D_1 and D_2 are ideal. In the steady-state condition, the average voltage V_{ab} (in volts) across the 0.5 μF capacitor is _________. **[2015]**

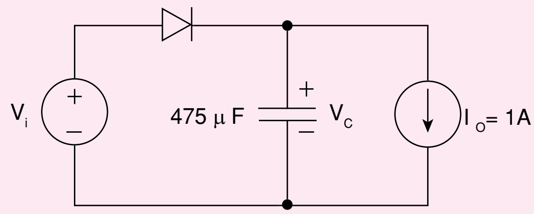


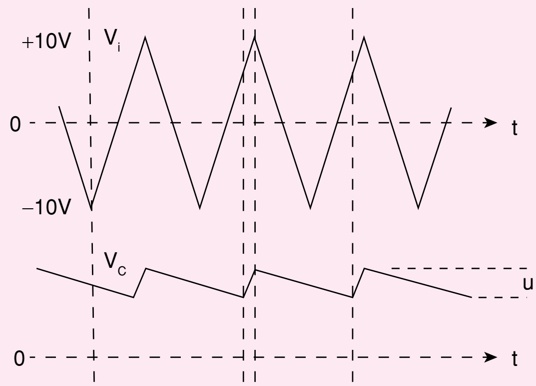
19. Assume that the diode in the figure has $V_{on} = 0.7$ V, but is otherwise ideal. **[2016]**



The magnitude of the current i_2 (in mA) is equal to __________.

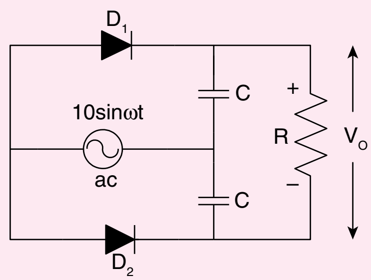
20. The figure shows a half wave rectifier with a 475 μF filter capacitor. The load draws a constant current $I_0 =$ 1 A from the rectifier. The figure also shows the input voltage V_i, the output voltages V_c and the peak to peak voltage ripple u on V_c. The input voltage V_i is a triangle wave with an amplitude of 10 V and a period of 1 ms . **[2016]**





The value of the ripple u(in volts) is _______.

21. The diodes D1 and D2 in the figure are ideal and the capacitors are identical. The product RC is very large compared to the time period of the ac voltage. Assuming that the diodes do not breakdown in the reverse bias, the output voltage V_0 (in volt) at the steady state is ___________ . **[2016]**



Answer Keys

Exercises

Practice Problems 1

1. B	**2.** C	**3.** A	**4.** A	**5.** D	**6.** A	**7.** D	**8.** C	**9.** A	**10.** B
11. A	**12.** C	**13.** C	**14.** C	**15.** B	**16.** C	**17.** C	**18.** B	**19.** C	**20.** A
21. B	**22.** D	**23.** C	**24.** C	**25.** A	**26.** A	**27.** D	**28.** D		

Practice Problems 2

1. D	**2.** B	**3.** B	**4.** D	**5.** B	**6.** A	**7.** A	**8.** C	**9.** A	**10.** C
11. B	**12.** D	**13.** A	**14.** D	**15.** B	**16.** B	**17.** A	**18.** A	**19.** C	**20.** C
21. B	**22.** A	**23.** A	24. C	**25.** D	**26.** B				

Previous Years' Questions

1. D	**2.** B	**3.** C	**4.** C	**5.** C	**6.** A	**7.** A	**8.** C	**9.** A	**10.** D
11. 1092 to 1094		**12.** C	**13.** 0.08 to 0.9		**14.** D	**15.** C	**16.** D	**17.** 0.59 to 0.61.	
18. 100 V		**19.** 0.25mA			**20.** 2.07V		**21.** 0 V		