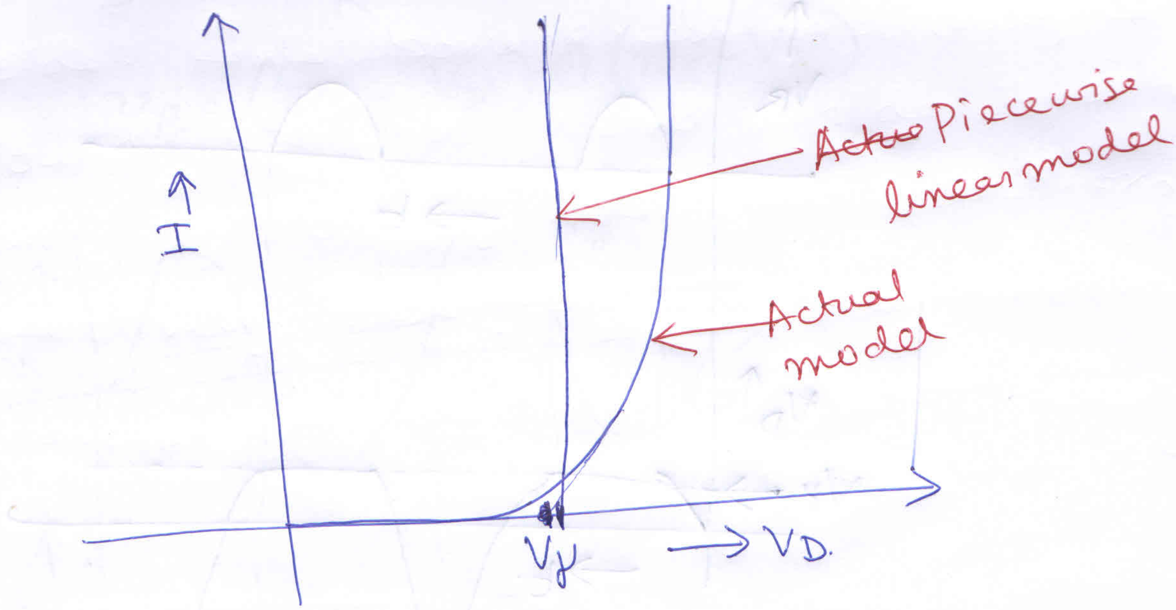
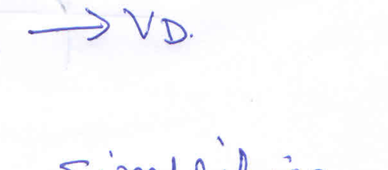
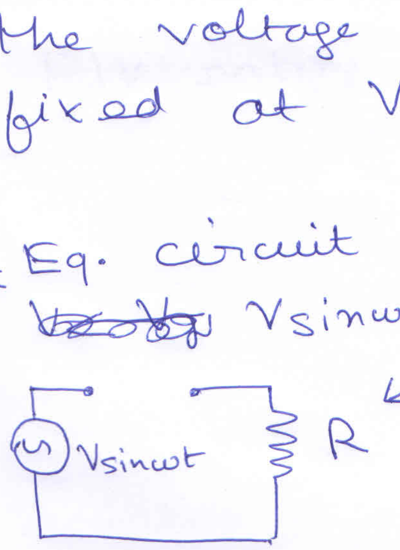
Note: When analyzing any diode circuit, except when stated particularly, it is common to approximate characteristics of the diode using piecewise linear model.



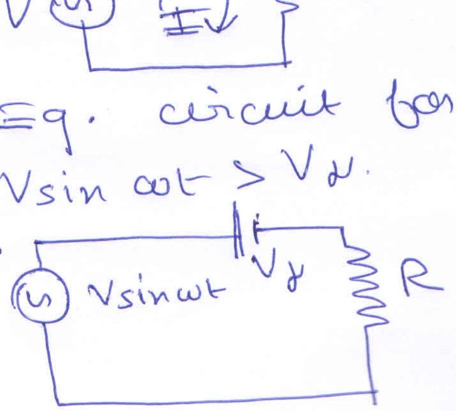
A piecewise linear model simplifies the circuits to a great extent since the model basically tells us that ~~we can~~ in forward conducting state, ~~if the~~ for any value of ~~cur~~ non-zero current, the voltage across the diode is always fixed at V_γ. Eg:



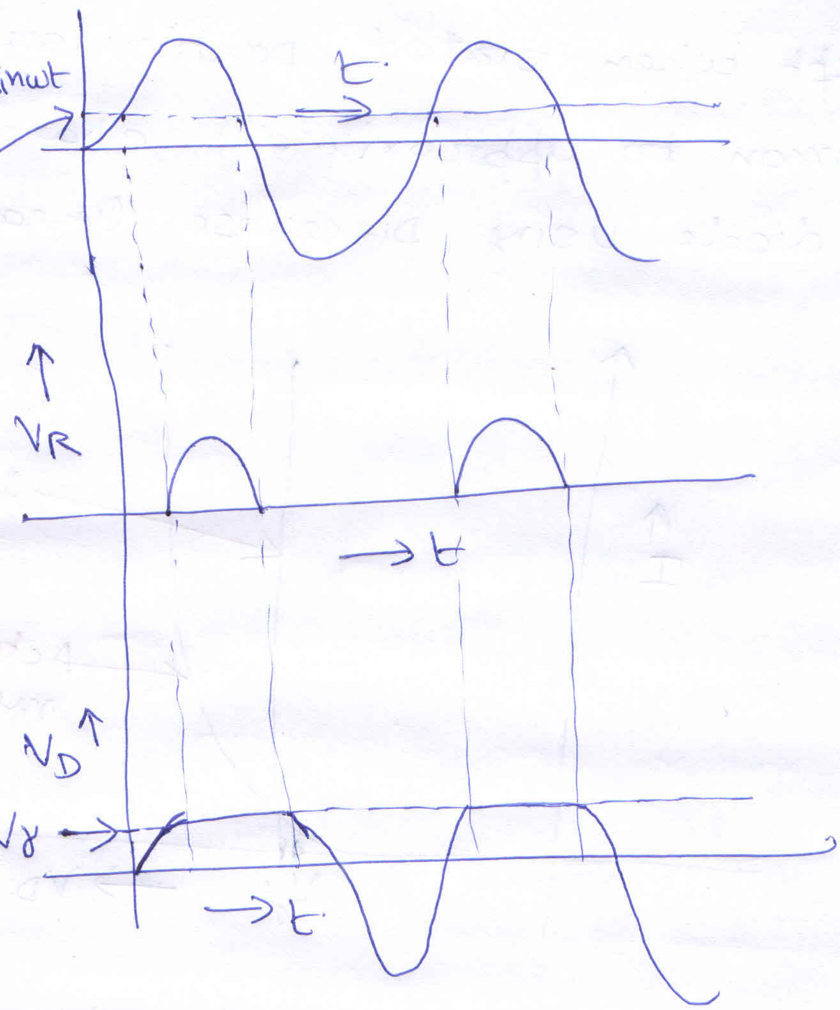
Eq. circuit for ~~$V\sin\omega t$~~ $V\sin\omega t < V_\gamma$.



Eq. circuit for $V\sin\omega t > V_\gamma$.



So, the voltage drop across the resistor R ~~is:~~ and the diode is V_γ

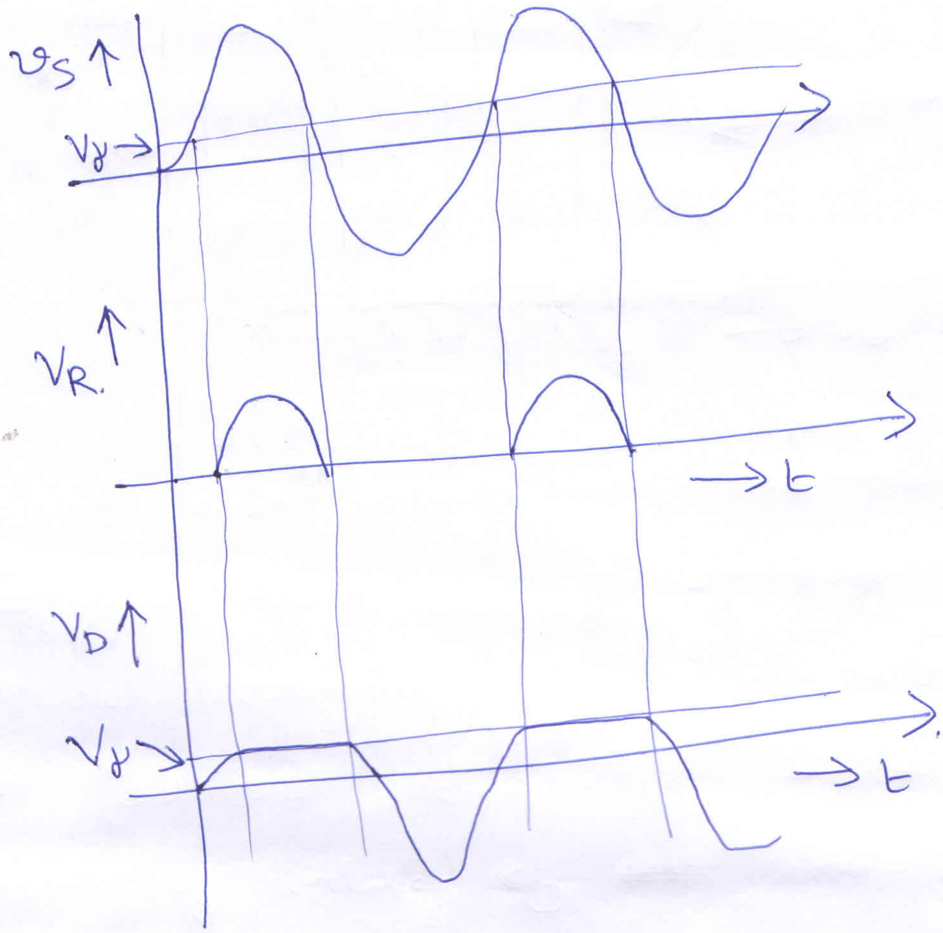


Half wave rectifier :-

$$\frac{v_i}{v_s} = \frac{N_1}{N_2}$$

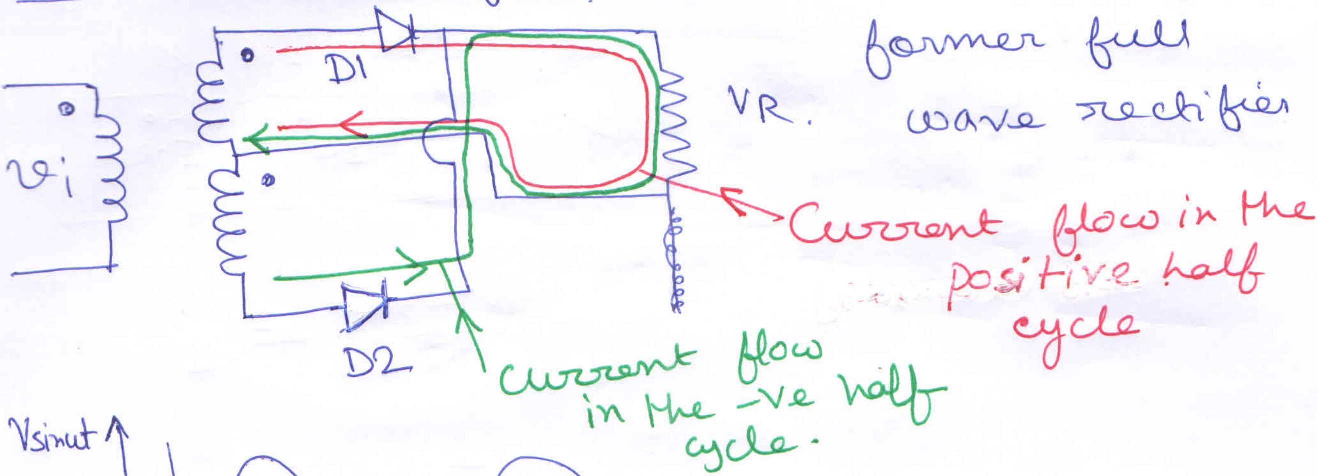
$$i_D \simeq \frac{v_s - V_\gamma}{R} \Theta \ \cancel{\text{when}}$$

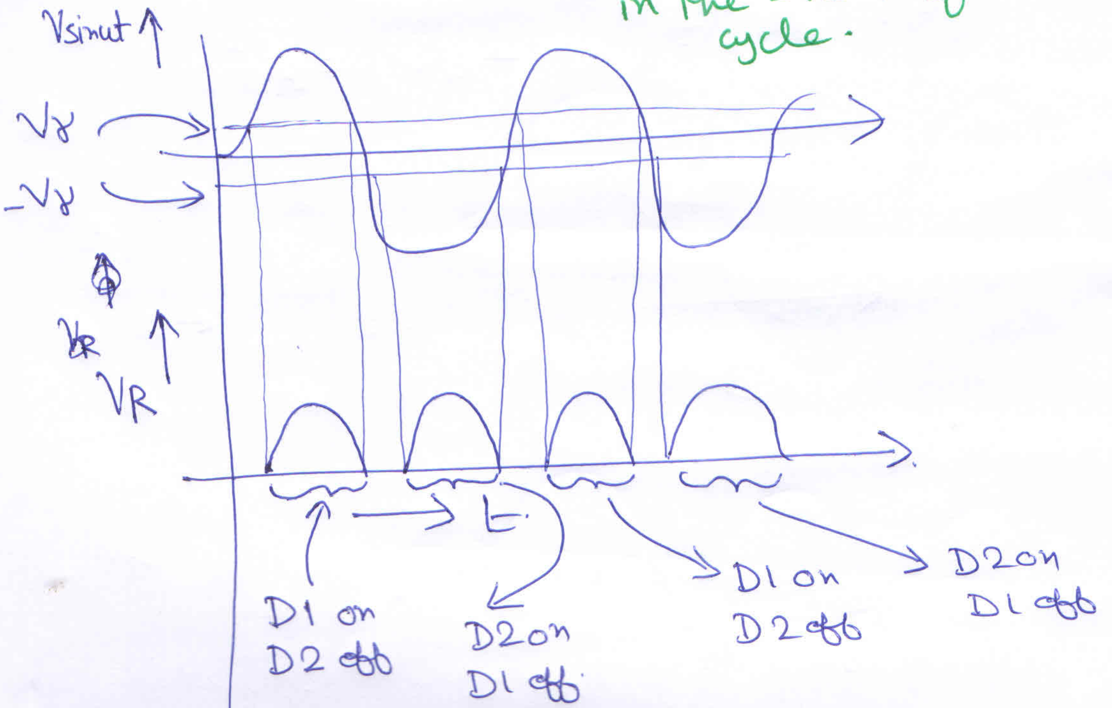
$$v_R = (v_s - V_\gamma)\,\Theta\,(v_s - V_\gamma)$$



PIV rating of the diode = max (v_s)

Full-Wave rectifier: centre tapped transformer full wave rectifier

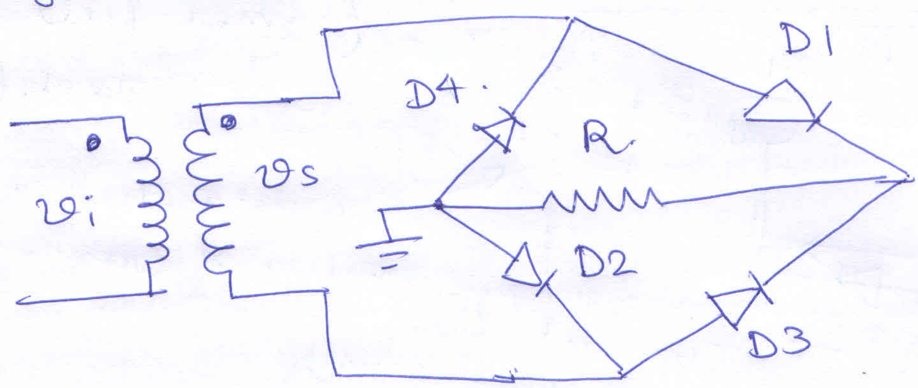


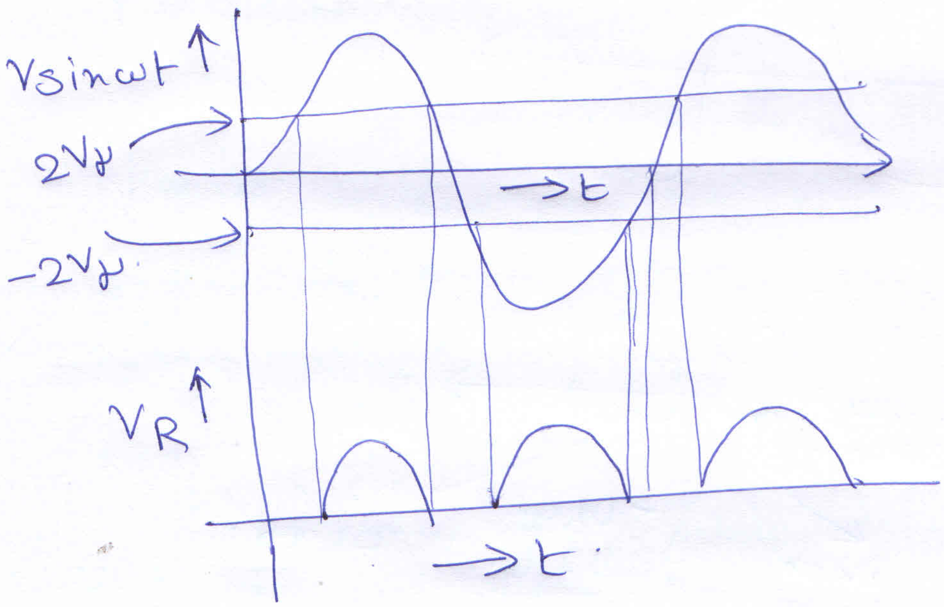


PIV rating of each diode must be.

$2v_s - V_\gamma$.

Bridge rectifier:-





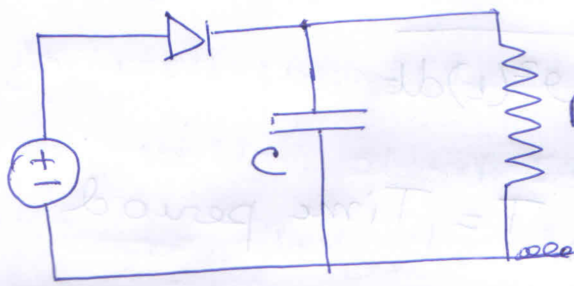
Disadvantage: ① More diodes are required to make this rectifier.

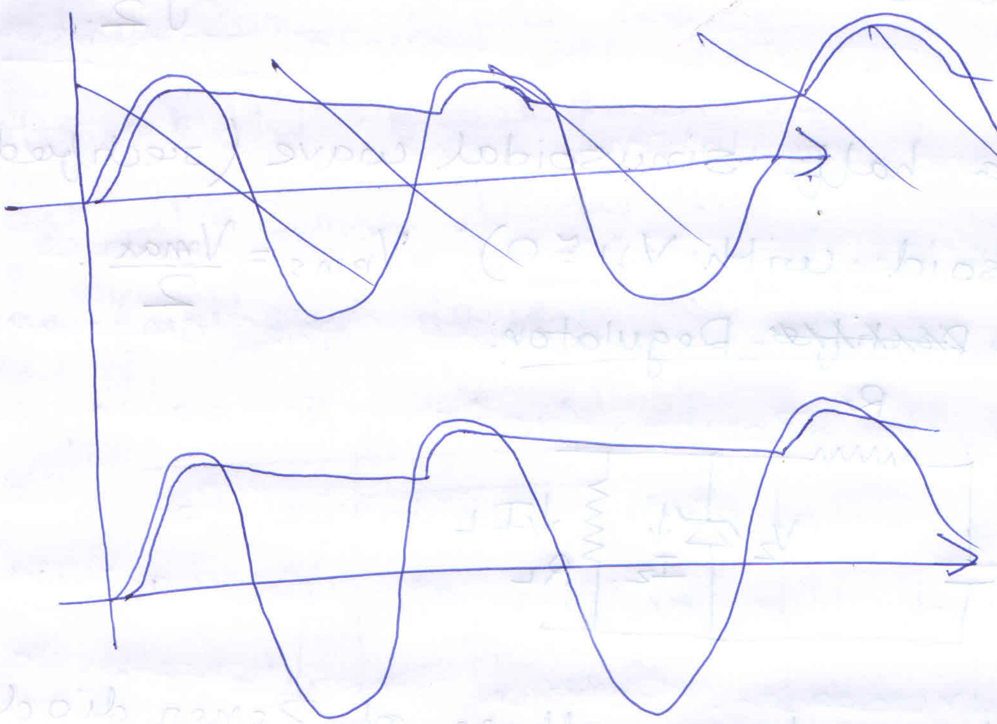
② The maximum value of the output voltage is $\max(v_s) - 2V_\gamma$, since there are two diodes. ~~Hence~~ Non-zero output also occurs for a lesser part of the timeperiod cycle.

Peak inverse voltage of each diode

$= \max(v_s) - V_\gamma$.

Filters : Rectifiers with capacitance filters.





$$V_r = \frac{V_M}{2fRC}$$

$$i_{c,peak} = \pi \frac{V_M}{R} \sqrt{\frac{2V_M}{V_r}}$$

$$i_{c,avg} = \frac{\pi}{2} \frac{V_M}{R} \sqrt{\frac{2V_M}{V_r}}$$

$$i_{D,avg} = \frac{1}{\pi} \sqrt{\frac{2V_r}{V_M}} \frac{V_M}{R} \left(1 + \frac{\pi}{2} \sqrt{\frac{2V_M}{V_r}}\right)$$

☆ ☆ ☆ ☆

Let us assume that the maximum voltage drop across the capacitor is V_{MAX} (when v_s reaches its peak).

After v_s has reached its peak, the capacitor begins to discharge because the voltage across the diode can no longer be maintained at V_γ.

The capacitor discharges across the resistor R. So,

$$V_C = V_R = V_{Max}\, e^{-t/RC}$$

t is the time after both v_s and the output has reached its peak.

If T' is the time for which the capacitor discharges before it starts charging again, then the minimum voltage across the capacitor is

$$V_{MIN} = V_{MAX}\, e^{-T'/RC}$$

$$V_{RIPPLE} = V_{MAX} - V_{MIN}$$
$$= V_{MAX}\left(1 - e^{-T'/RC}\right)$$
$$\simeq V_{MAX}\frac{T'}{RC} \text{ if } T' << RC.$$

For a half wave rectifier, $T' \cong$ time period T.

$$\text{Hence, } V_{RIPPLE} = V_{MAX} \frac{T}{RC}$$

$$= \frac{V_{MAX}}{fRC}.$$

For a full-wave rectifier, $T' \cong T/2$.

$$\text{Hence } V_{RIPPLE} \cong \frac{V_{MAX}}{2fRC}.$$

Root mean square:-

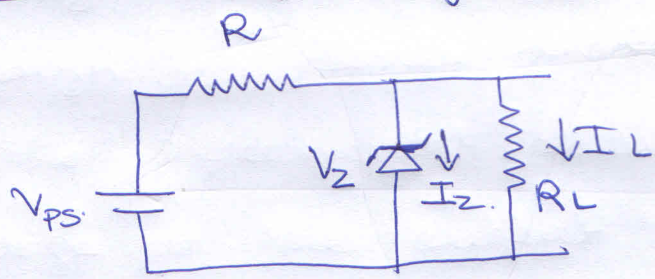
$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)dt}$$

T = Time period.

For a sinusoidal wave $V_{rms} = \frac{V_{max}}{\sqrt{2}}$.

For a half sinusoidal wave (rectified sinusoid with $V_\gamma \cong 0$), $V_{rms} = \frac{V_{max}}{2}$.

Zener ~~Rectifier~~ Regulator:

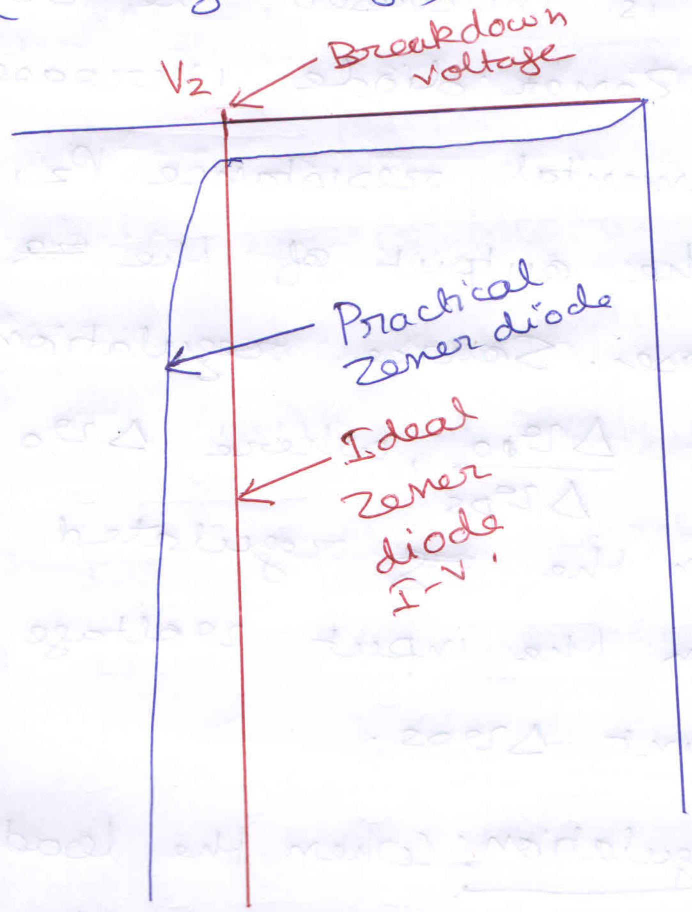


The breakdown voltage of Zener diode can be controlled easily. Voltage ranges from 5V to greater than 100V are possible. The cut-in voltage of the diode can't be controlled in a similar way. Moreover the reverse bias characteristics of a diode is much steeper than the forward bias characteristics making the reverse bias ideal for ~~a~~ voltage regulator.

applications.

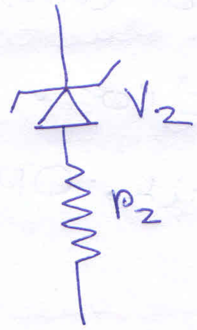
The resistance R must be chosen to limit the current through the zener diode to its maximum permissable limit. Otherwise the diode will burn.

An ideal Zener diode would have infinite slope (I-V plot) at the breakdown voltage. However practical Zener diodes have some finite slope (although large) of the I-V plot.



The ~~increase~~ I-V characteristic of a practical Zener diode is, hence, often modeled by a series combination of an ideal Zener diode and a resistance (also called incremental resistance)

Circuit model of a practical Zener diode :-



This model brings us two ~~fundament~~ parameters of a ~~vo~~ Zener diode voltage regulator to understand how ~~good~~ well the output voltage is regulated. These two parameters are source regulation and load regulation.

Source ~~reg~~ regulation: As the source voltage Vps is increased, the current through the Zener diode increases. Due to the incremental resistance R_z, the voltage at the output of the ~~reg~~ regulator also increases. Source regulation is defined as $\frac{\Delta v_o}{\Delta v_{ps}}$, where Δv_o is the variation in the ~~reg~~ regulated output voltage when the input voltage varies by an amount Δv_{ps}.

Load ~~reg~~ regulation: When the load current varies due to variation in the load resistance R_L, the current through the Zener diode must also change. For example, if the load resistance R_L

increases, the load current i_L decreases. So, the ~~ex~~ excess current must flow through the zener diode (since the current through R is almost constant). This increase in current through the zener diode current also increases the regulated output voltage v_o (due to the incremental resistance r_z). Load regulation is defined as:-

$$\frac{v_o|_{no\ load} - v_o|_{full\text{-}load}}{v_o|_{full\ load}}$$

where $v_o|_{no\text{-}load}$ is the output voltage under open-circuit condition ($R_L = \infty$, no load current) and $v_o|_{full\text{-}load}$ is the ~~reg~~ output voltage at the maximum rated load current (~~maxim~~ ~~R~~. i_L.

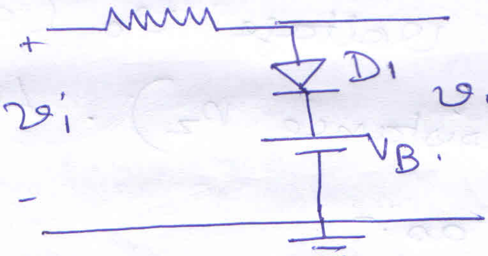
It has already been explained in class why voltage regulators must have a maximum rated load current i_L or a minimum rated load resister R_L. Think about it!

Another parameter: Percent regulation $= \dfrac{v_o^{max} - v_o^{min}}{v_o^{min}} \times 100\%$.

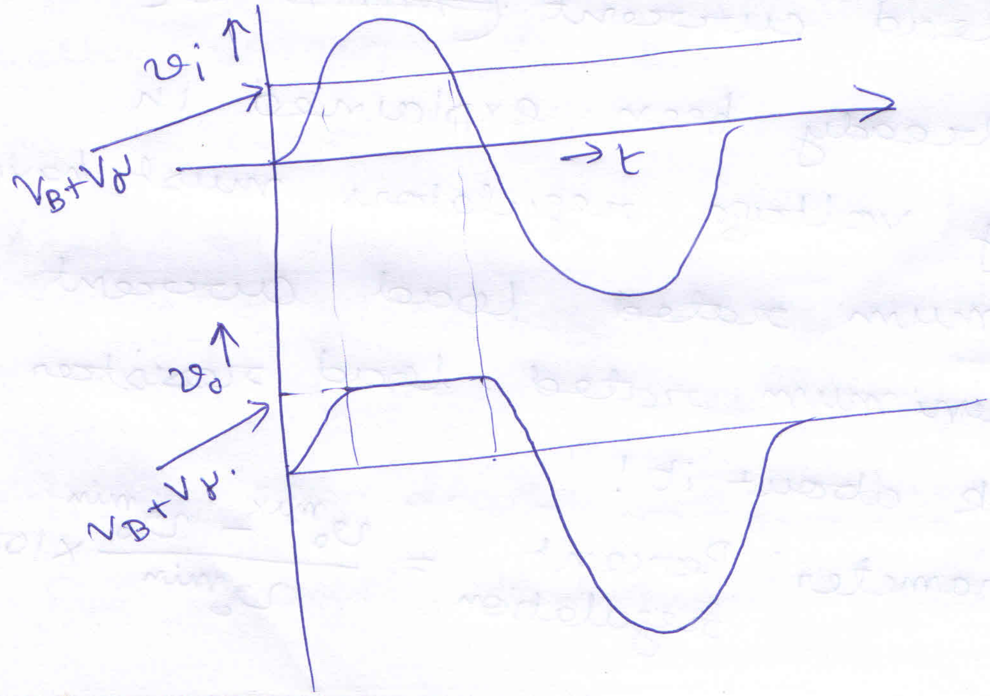
Clippers

– Also called limiter circuit. The main application of clippers is to limit the input voltage to a maximum (or minimum) value to prevent breakdown of the circuit.

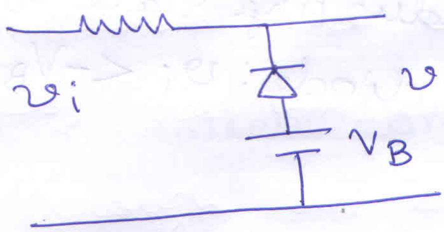
(1)

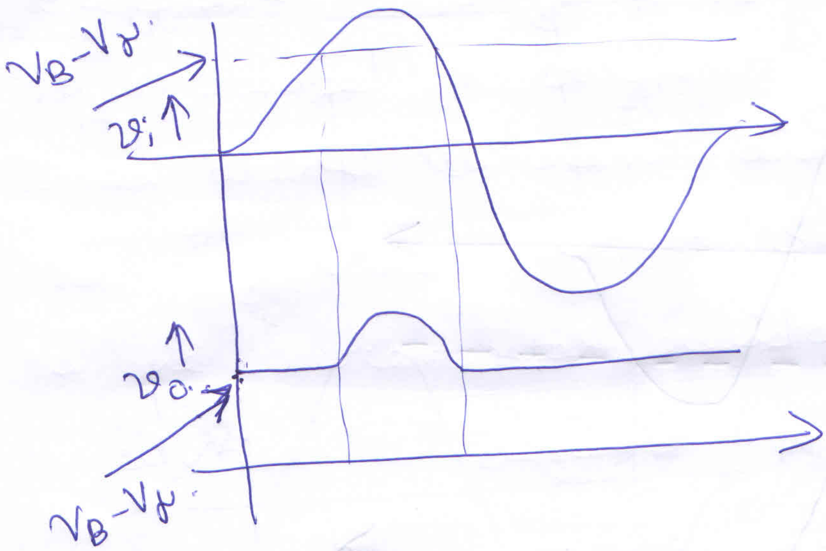


The diode D_1 is in conducting state when $v_i > V_B + V_\gamma$. When the diode is conducting the voltage across the diode is fixed at V_γ. So, the output voltage is $V_B + V_\gamma$. For $v_i \leq V_B + V_\gamma$, the diode is non-conducting and the voltage drop across the resistor is 0. So, the output is equal to the input voltage.

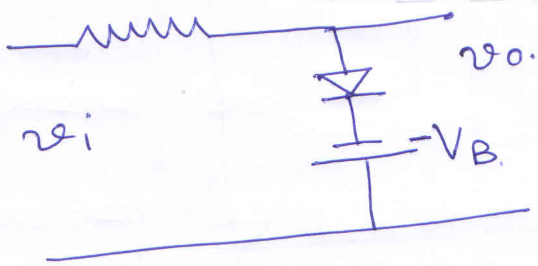


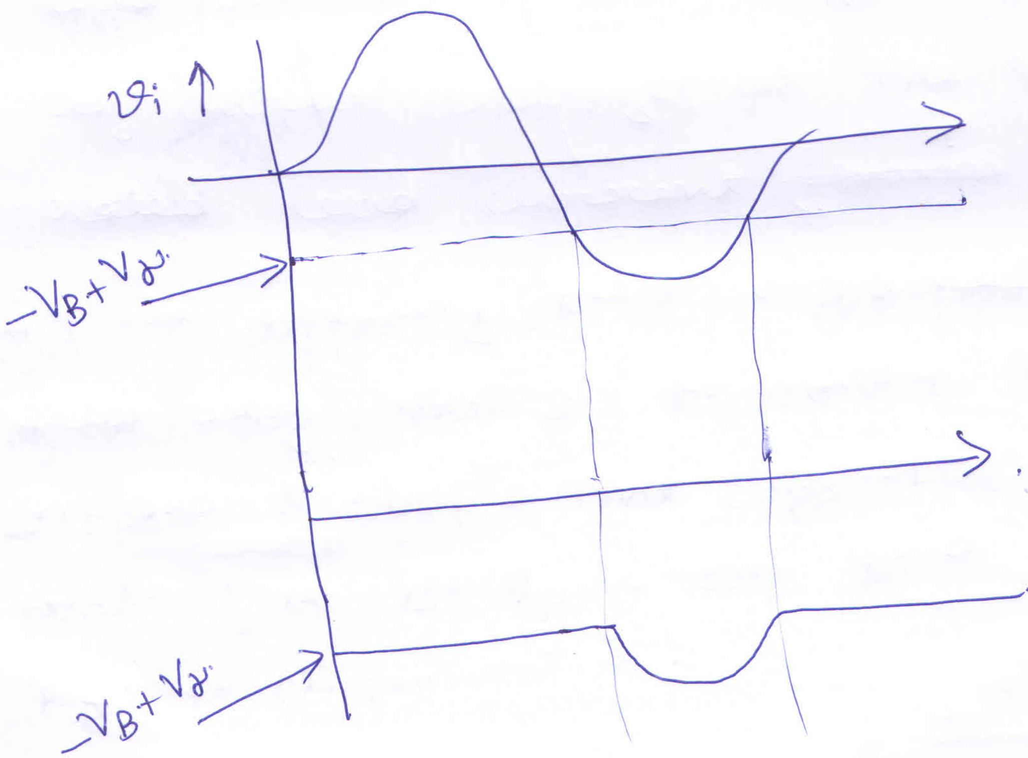
② Conducting state of the diode: $v_i < V_B - V_\gamma$

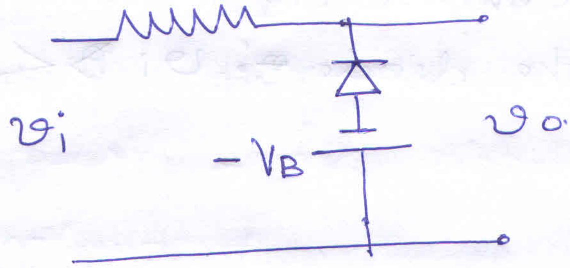




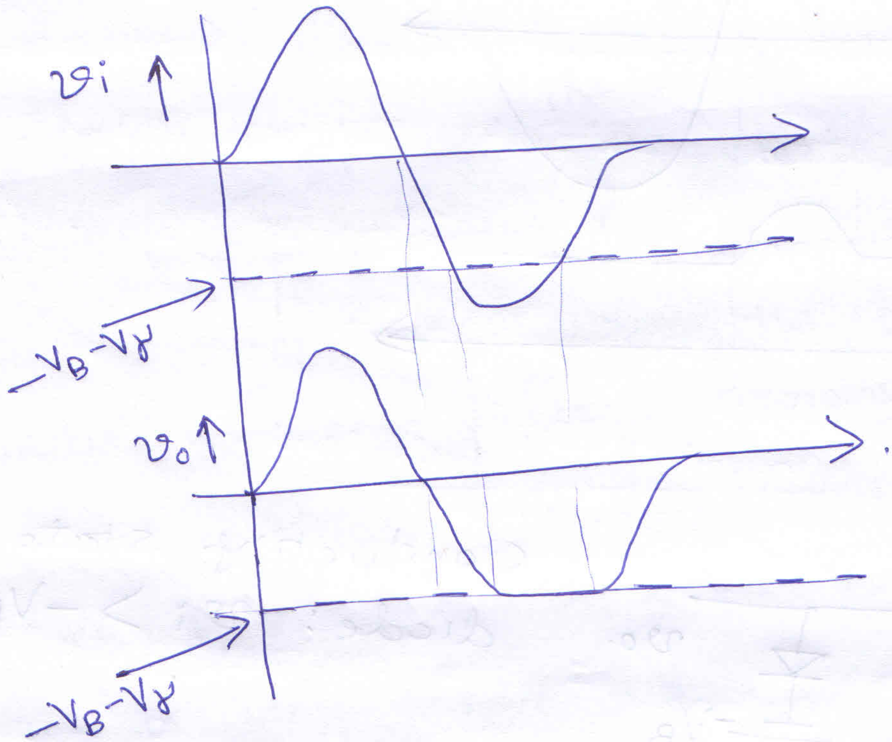
③ Conducting state of diode: $v_i > -V_B + V_\gamma$



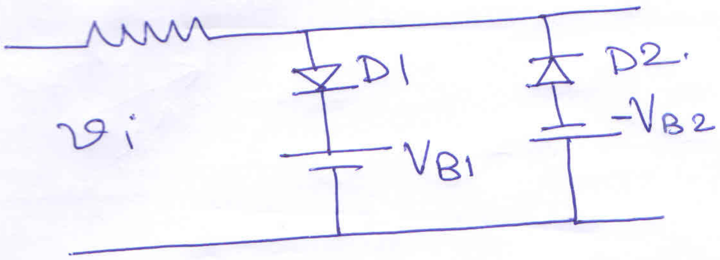


④ 

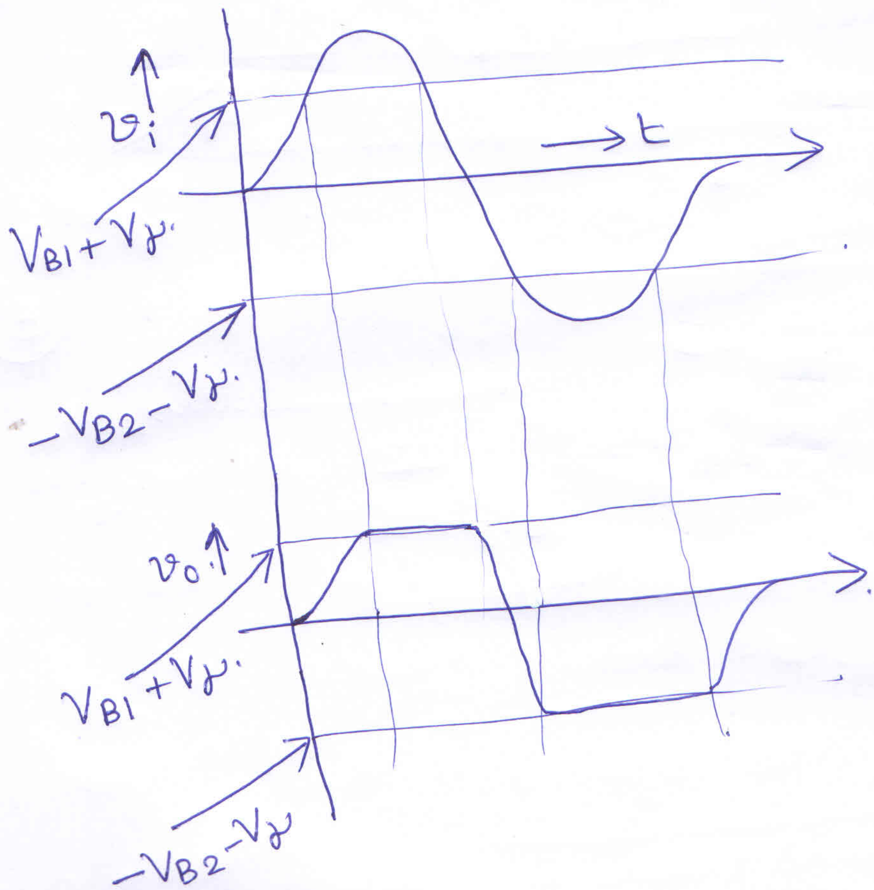
Conducting state of the diode: $v_i < -V_B - V_\gamma$



Parallel based Clipper: Clippers consisting of a parallel combination of two clippers

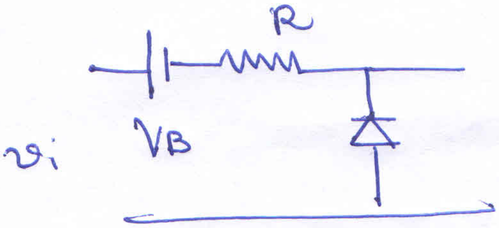


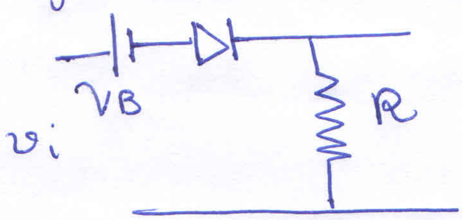
Conducting state of D1: $v_i > V_{B1} + V_\gamma$.
Conducting state of D2: $v_i < -V_{B2} - V_\gamma$

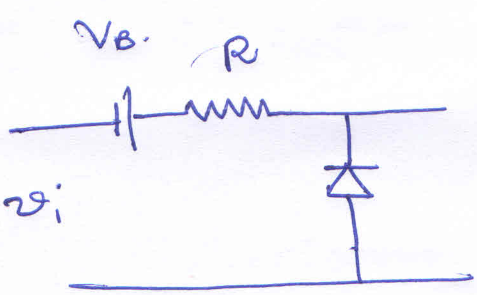


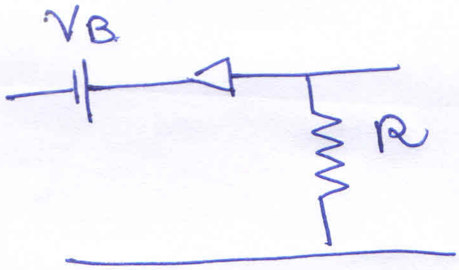
Note: A clipper that clips the positive parts of the waveform is known as a positive clipper. A clipper that clips the negative parts of a waveform are known as negative clipper.

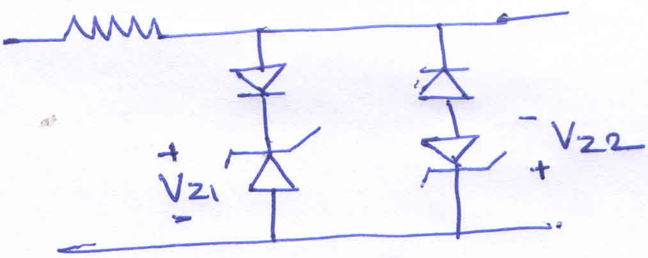
Other clipper circuits: (Analyze these circuits yourself. These are taken from the textbook)



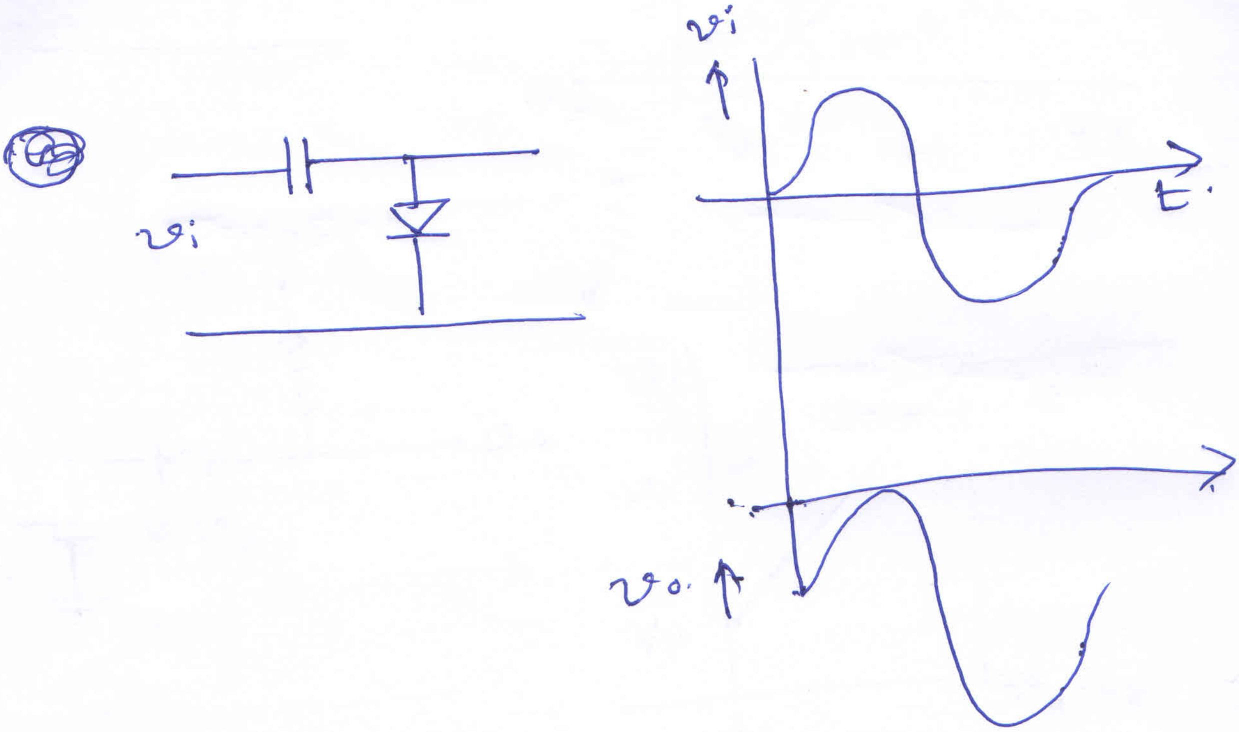


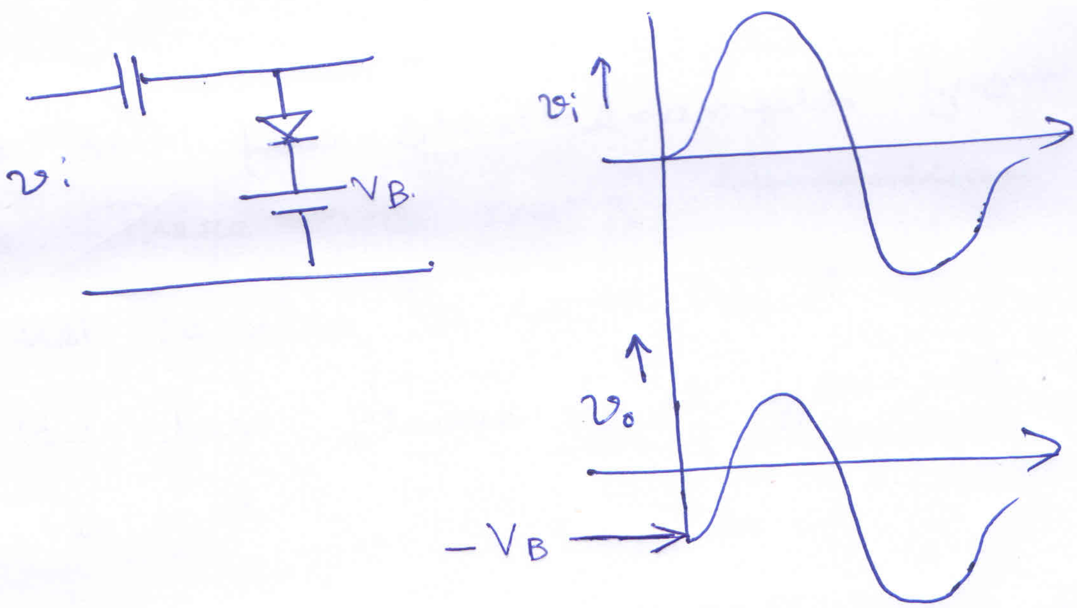




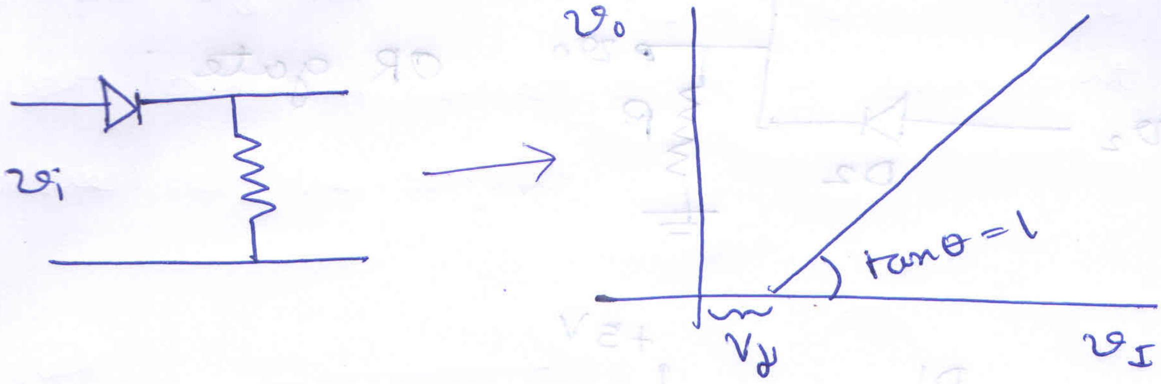


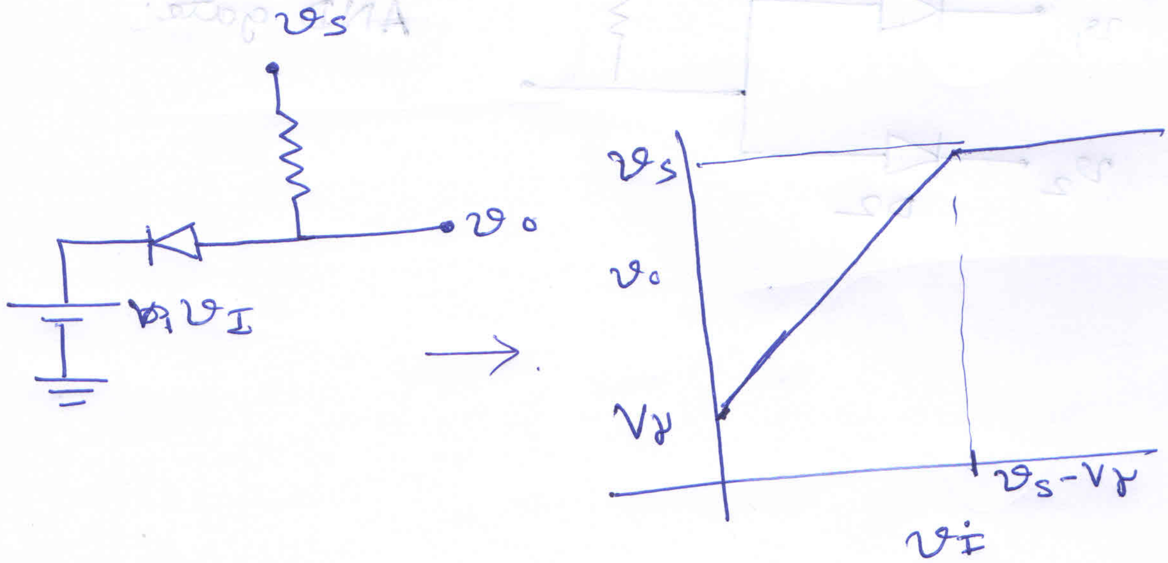
Clampers: Clampers donot change the ~~sau~~ shape of the incoming signals. They just add or subtract a constant value to the signal.



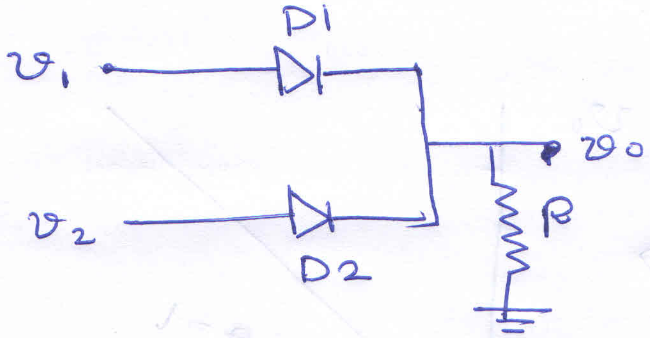


Multiple diode circuits :-

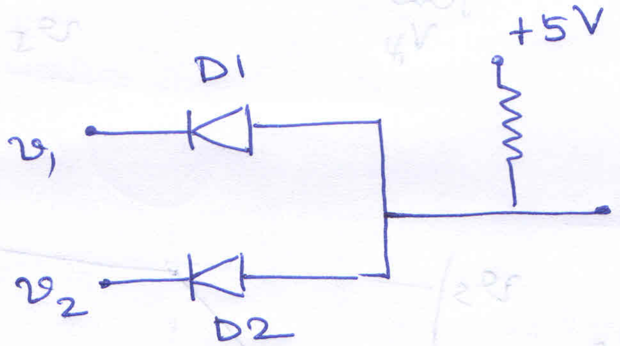




Check out few other examples from the book. There are many. ~~All of these~~ It is not possible to cover all of these in the class. Please do it yourself from the textbook.



OR gate.



AND gate.