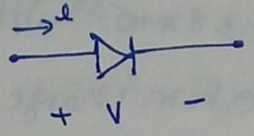
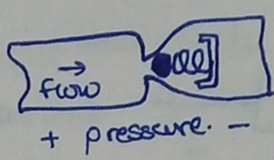
Week3

Lecture 13: Diode circuits - 1

Diode:

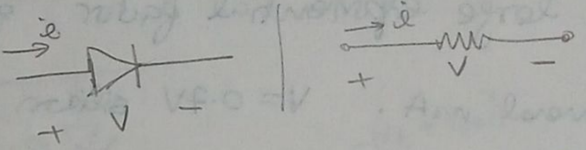
- It is a 2 terminal device



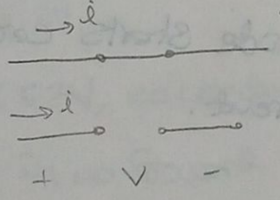

- A check valve presents a small resistance if pressure $p>0$ but blocks the flow (presents large resistance) if $p<0$.

- Similarly a diode presents a small resistance in the forward direction and a large resistance in the reverse direction.




$R = R_{on}$ if $V>0$
$R = R_{off}$ if $V<0$

- With $R_{on} = 0$ & $R_{off} = \infty$, the diode behaves like an ideal switch.




S closed, $V>0$

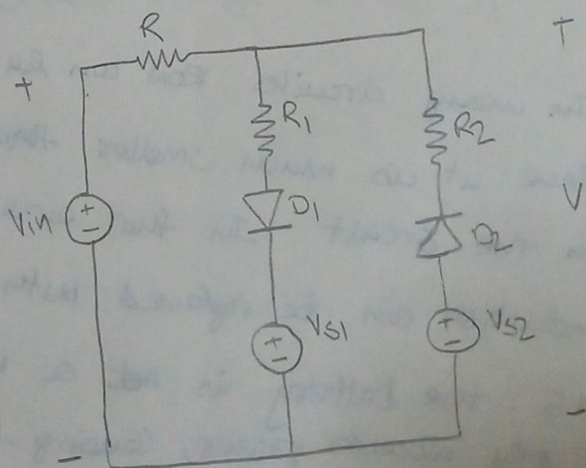
S open $V<0$

Forward bias: $i > 0A$, $V = 0V$ → S is closed.

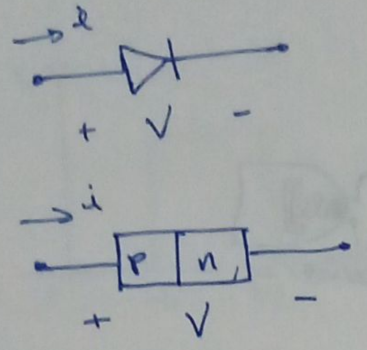
Reverse bias: $V < 0V$, $i = 0A$ → S is open.

The diode is said to "block" the reverse applied voltage.

PARALLEL CLIPPER CIRCUIT ⟹



# Schockley Diode Equation




$i = I_S\left[e^{V/V_T} - 1\right]$ where $V_T = k_B T/q$

$k_B$ = Boltzmann's constant
$= 1.38 \times 10^{-23}$ J/K

$q$ = electron charge = $1.602 \times 10^{-19}$ coul

$T$ = temperature in °K

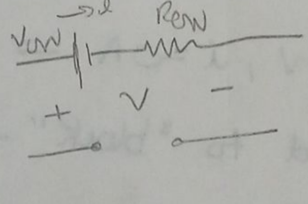
$V_T = 25$ mV at room Temp. = 300K
(thermal voltage)

- $I_S$ is called "reverse saturation current."
- It is normally very small, but since it gets multiplied by a large exponential factor, gives diode current in several mA. $V = 0.7$V silicon diode
- The "turn on" voltage ($V_{on}$) of a diode depends on the value of $I_S$. $V_{on}$ may be defined as the voltage at which the silicon diode starts carrying a substantial forward current.

Diode circuit model

$V > V_{on}$ :

$V < V_{on}$ :




- In many circuits Ron can be neglected (assumed to be on) since it is much smaller than the other resistances in the circuit. In that case, the diode in forward conduction can be replaced with simply a battery.

NOTE : the battery is not a "source" of power! It can only absorb power, causing heat dissipation.

Reverse Breakdown.

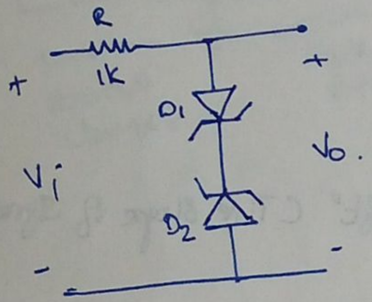
- A real diode cannot withstand indefinitely large reverse voltages and "breaks down" at a certain voltage called "the breakdown voltage".

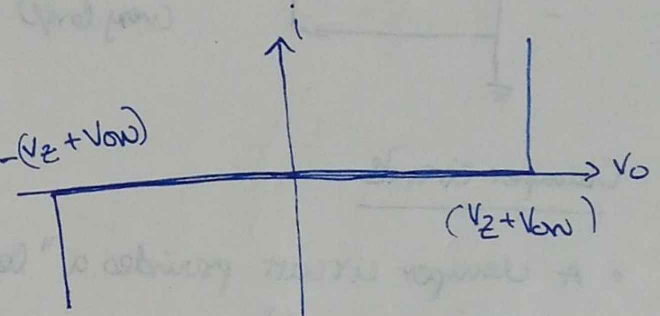
- When the reverse bias $V_R > V_{BR}$, the diode allows a large amount of current. If the current is not constrained by the external circuit, the diode would get damaged.

- Diodes with high $V_{BR}$ are generally used in power electronics applications and therefore also designed to carry a large forward current (tens or hundreds of Amps).

Zener diode.

Diode circuit example (voltage limiter)



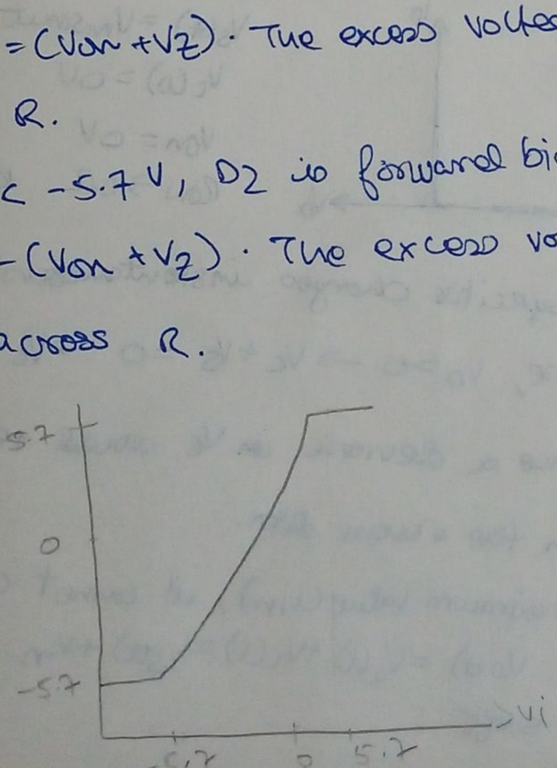




$V_{on} = 0.7V \quad V_Z = 5V$

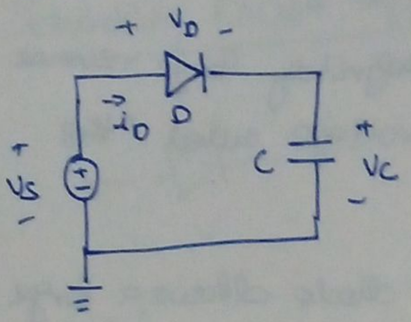
for $-5.7V < V_i < 5.7V$, no conduction is possible $\rightarrow V_o = V_i$

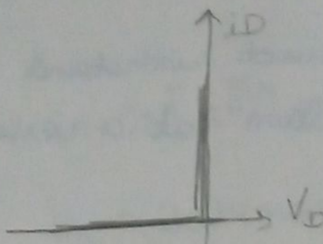
for $V_i > 5.7V$, $D_1$ is forward biased, $D_2$ is reversed-biased and $V_o = (V_{on} + V_Z)$. The excess voltage $(V_i - (V_{on} + V_Z))$ drop across R.

for $V_i < -5.7V$, $D_2$ is forward biased, $D_1$ is reverse biased $V_o = -(V_{on} + V_Z)$. The excess voltage $(-V_i - V_{on} + V_Z))$ drop across R.

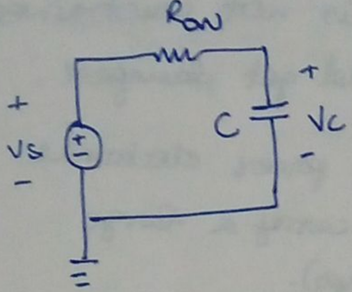


## Peak Detector (with $V_{ON} = 0V$)

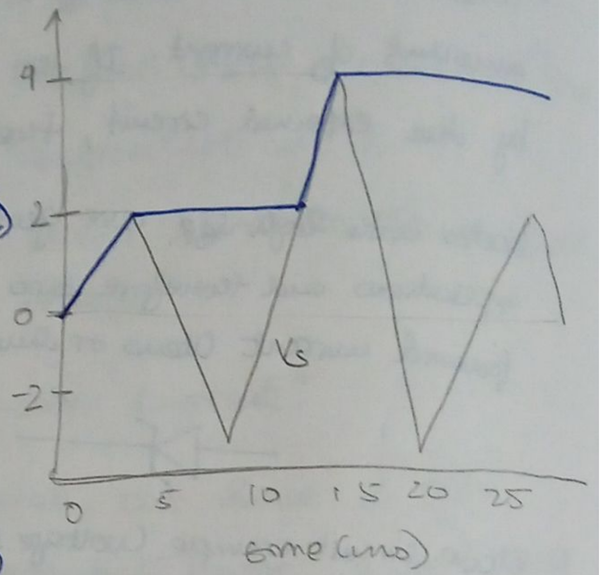


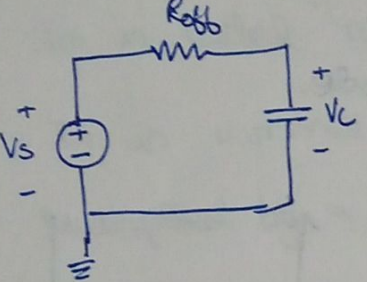




$V_C(0) = 0V$
$V_{ON} = 0V$
$R_{ON} \rightarrow 0\,\Omega$
$R_{off} \rightarrow \infty\,\Omega$




$V_S > V_C$
$\tau = R_{ON} C$
(very small)



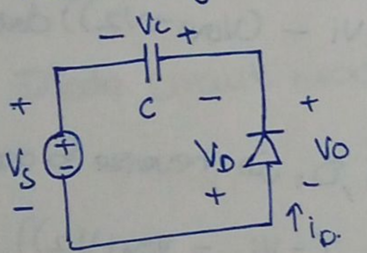



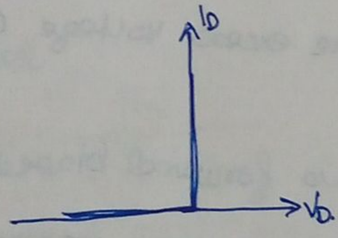

$V_S < V_C$.
$\tau = R_{off} C$
(very large)

## Clamper circuits

- A clamper circuit provides a "level shift" (The shape of signal is not altered).
- The shift could be positive or negative.

Positive Shift Clampers circuit.




$V_S(t) = V_m \sin \omega t$
$V_C(0) = 0V$
$V_{ON} = 0V$
$R_{ON} \rightarrow 0\,\Omega$ $\quad R_{off} \rightarrow \infty\,\Omega$

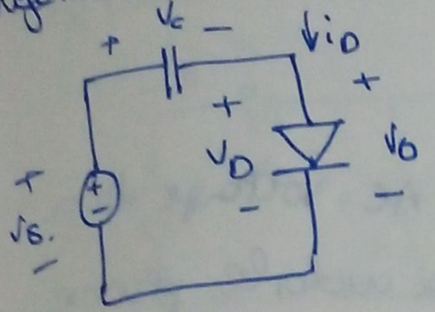
When D conducts, the capacitor charges instantaneously since $R_{ON}$ is small. In this phase, $V_D = 0 \rightarrow V_C + V_S = 0 \rightarrow V_C = -V_S$.

$V_C$ can only increase since a decrease in $V_C$ would require the diode to conduct in the reverse dirn.

After $V_C$ reaches its maximum value ($V_m$), it cannot change any more. We then have $V_O(t) = V_S(t) + V_C(t) = V_S(t) + V_m$

i.e. positive level shift

negative level shift clamper circuit.




$V_D = 0 \Rightarrow V_c - V_s = 0 \Rightarrow V_c = V_s$

$V_o(t) = V_s(t) - V_c(t) = V_s(t) - V_m(t)$

$\therefore$ negative level shift.

Voltage doubler (peak to peak detector).