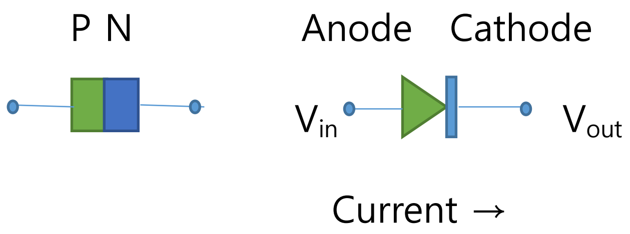
Lecture 9- Diode

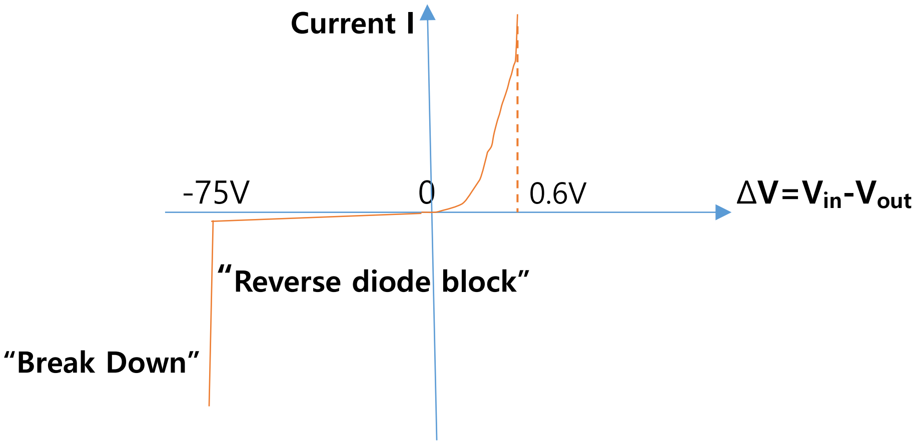
: Contacting of semiconductor materials to regulate current

Nonlinear device that gives nonlinear relationship between voltage(V) and current(I).

*Resistor,Capacitor,Inductor are all *linear* devices such that V=IZ(ω)



V-I Curve for Diode



Application:

Current Valve, Block for Reverse flow, Rectifier, Clamper, Voltage source

Laws:

(1) $Z\rightarrow=0$ and $Z\leftarrow=\infty$:

Current flows for the forward direction, but

Current is blocked for the reverse direction

∴ Current valve and Blocking for reverse flow, or reverse block

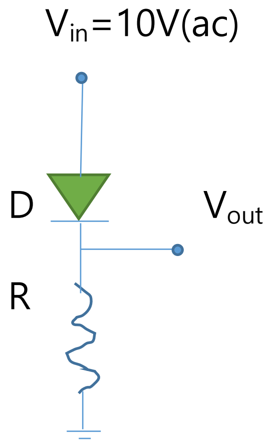
(2) $V_{out} = V_{in} - 0.6$

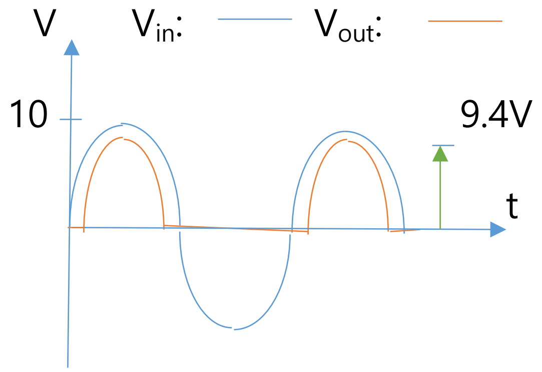
when the diode conducts current, and 0.6V is the diode drop.

$\Delta V_{out}=\Delta V_{in}$ and $\Delta V_{out}/\Delta V_{in}=\text{Gain}=1$

∴Any input voltage change is transferred to the output voltage change.

Examples



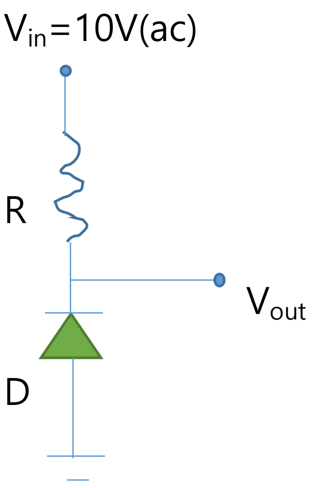


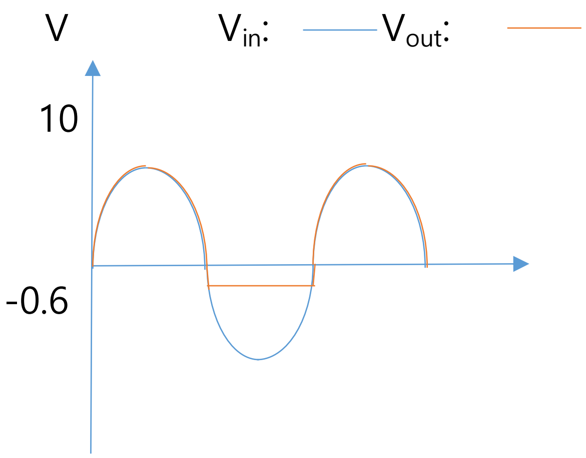
if $V_{in}\geq0.6$, then diode conducts, thus

$V_{out}=V_{in}-0.6$ and $\Delta V_{out}/\Delta V_{in}=R/(Z_D+R)\fallingdotseq1$ ($\because Z_D\fallingdotseq0$)

If $V_{in}<0.6$, no current flows, thus $V_{out}=0$ (∵ Ohm's law for R)

∴ Halfwave Rectifier



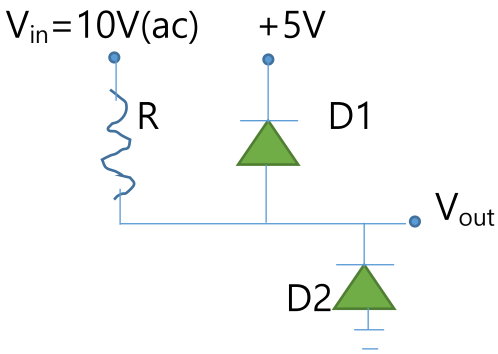


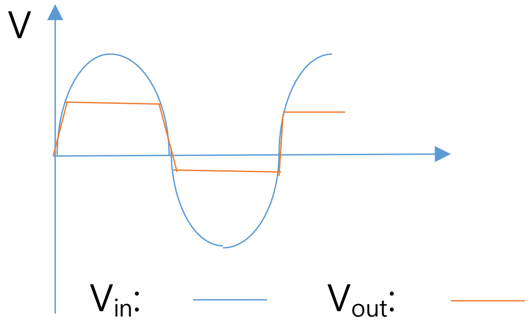
If $V_{in} > -0.6V$, then Diode blocks current, thus $Z_D = \infty$ and

$V_{out}/V_{in} = Z_D/(R+Z_D) \fallingdotseq 1$ ($\because Z_D = \infty$) $\therefore V_{out} = V_{in}$

If $V_{in} \leq -0.6V$, then Diode conducts and $V_{out} = -0.6V$ (Diode drop)

∴ <u>Clamper</u> between -0.6V to 10V, or [-0.6,10] from 10V(ac)





If $V_{in} \geq 5.6V$ then D1 conducts and $V_{out} = 5.6V$

If $V_{in} \leq -0.6V$ then D2 conducts and $V_{out} = -0.6V$

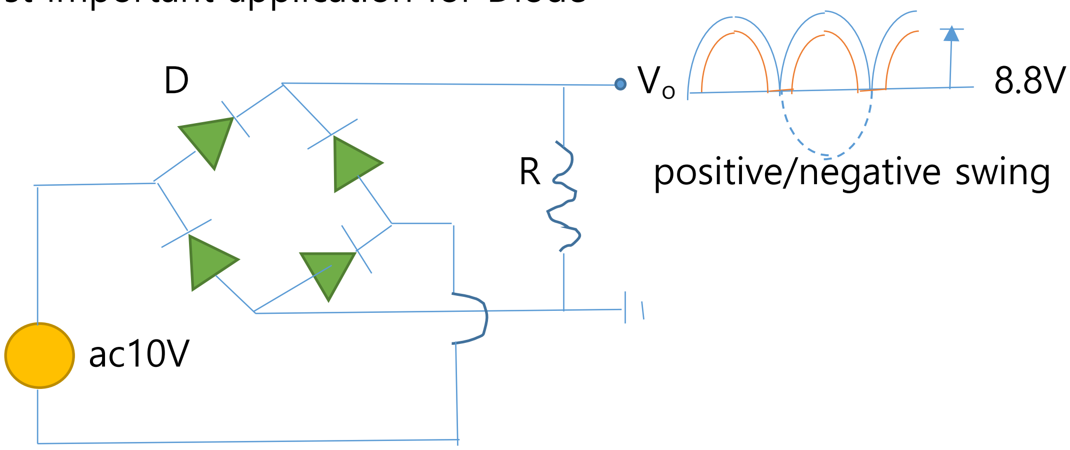
If $-0.6V < V_{in} < 5.6V$ then both diodes block current; $Z_{D1} = Z_{D2} = \infty$

$V_{out}/V_{in} = Z_{D2}/(R+Z_{D2}) \fallingdotseq 1$ ($\because Z_{D2} = \infty$) $\therefore V_{out} = V_{in}$

∴ <u>Clamper</u> between [-0.6, 5.6] from 10V(ac)

Full-wave Rectifier

:Most important application for Diode

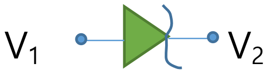


V_o: Ripple of max 8.8V (=10 – 2xDiode drop)

⇒Never good quality, thus should be regulated further.

Zenor diode as Voltage source

:Zenor diode(D_Z) breaks at low reverse voltage, $-V_{ZENOR}$ (e.g.-10V)



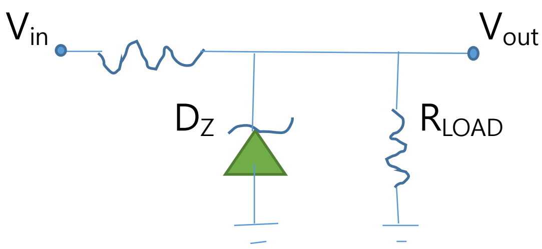
For Zenor Diode:

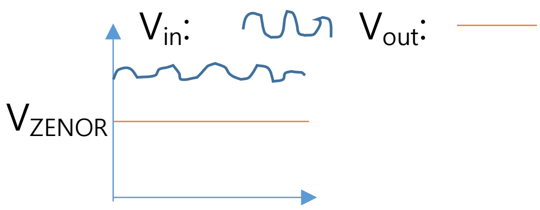
If $V_2 - V_1 \geq V_{ZENOR}$

Then the Diode breaks and $V_2 - V_1 = V_{ZENOR}$=const

Thus $V_2 - V_1$ is kept const (=V_{ZENOR})

and it can be used as the voltage source.





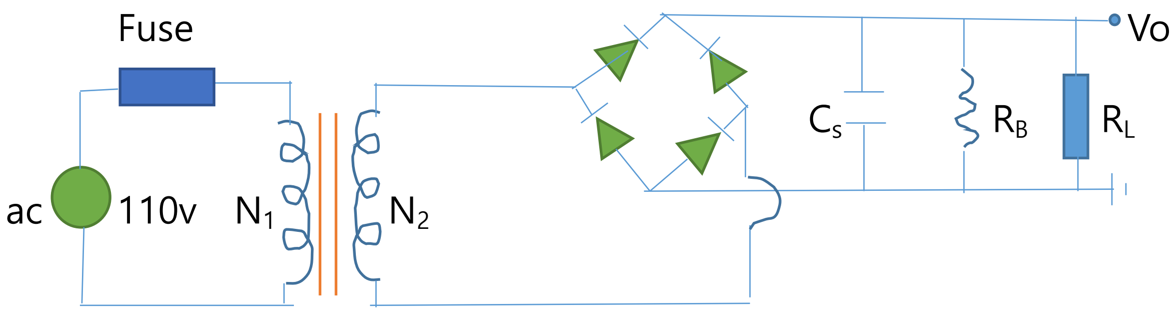
∴ For unregulated V_{in} ($\geq V_{ZENOR}$), V_{out} gives constant voltage, V_{ZENOR}

∴ Zenor diode can be a good voltage source (like battery!)

with *at least 10mA* *(thresh-hold)* flowing in Zenor diode

Power Supply : Most important Diode application

:To convert AC to DC that gives constant voltage supply



Design Specification

AC=110V@60Hz, Vo=20V, Voltage Ripple=2V, i_{max}=1A

(Source: P.Horowitz etal, The art of electronics student manual, p71,1989)

1. <u>Transformer Coil Ratio N_1:N_2</u>

N_1:N_2=V_1|rms :V_2|rms, and V_1|rms=110V

and V_2|rms=$\sqrt{\{\int V^2dt/T\}_2}$=$V_2$|peak/$\sqrt{2}$ for sinusoidal wave

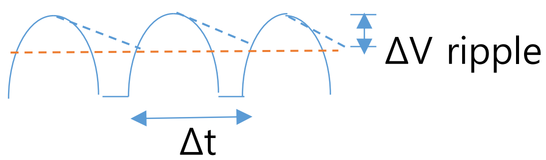
V_2|peak≒V_o+Ripple+2xDiode-Drop=20+2+1.2=23.2V

∴V_2|rms=23.2/$\sqrt{2}$=16.2V

Thus N_1:N_2= V_1|rms : V_2|rms =110:16.2≒55:8

2. <u>Smoothing Capacitor, C_s</u>

:To make smoothing the voltage by charging/discharging

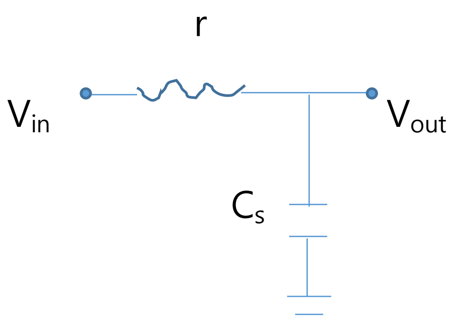


When the current flows into/from the capacitor, voltage rise/drop is followed accordingly. The concept of smoothing capacitor is to make complimentary voltage rise/drop by current flowing into/from the capacitor. The voltage rise/drop $\Delta V=\Delta Q/C=i\Delta t/C$, where i is the current flow into/from the capacitor, and Δt = 1/2f = 1/120[sec] during the full wave rectifying.

Thus for the maximum current of 1A, C_s=i/(ΔV/Δt)=1/{2/(1/120)}

=4E-3F=4000μF=4mF

It is interesting to note the C_s can be understood as a LPF as following: When r is a very small resistance of wiring connected to the C_s;



$V_{out}/V_{in}=1/j\omega C_s/(r+1/j\omega C_s)=1/(1+j\omega rC_s)$ ∴ It is a LPF.

Magnitude=$|H|=1/\sqrt{\{1+(\omega rC_s)^2\}}$ Phase=$\angle H=-\tan^{-1}(\omega rC_s)$

If $\omega=0$ (or DC) then $|H|=1$

If $\omega\gg 1$ then $|H|\ll 1$, and Ripple is more reduced with bigger C_s, and

this is the same conclusion as above.

3. Bleeding Resistor, R_B

When power is off, the electric charge is still left in the Cs capacitor, therefore it desirable to leak the electric charge through the bleeding resistor R_B for safety issue.

Let's consider the close loop consisting of C_s and R_B. From the Kirchhoff's voltage law,

$0=V_C+V_R=\int idt/C_s + iR_B=0$ Thus $R_BC_sdi/dt+i=0$

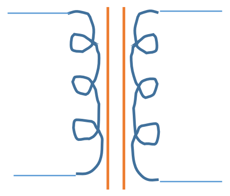
$\therefore i(t)=i_0\exp(-t/RC_s)$, and it is decaying 64% when $t=RC_s$

It is the designer's choice to set the time for 64% decay such as 4s.

thus $R_B=4/C_s=1K\Omega$

4. Fuse rating current

$I_1V_1 \fallingdotseq I_2V_2$



primary secondary

$I_1=I_2V_2/V_1=(1)(16.2)/110 \fallingdotseq 0.14(A)$

The fuse rating current=$(0.14A)C_{surge}C_{safety}=1.1A$

C_{surge}=Safety factor for heating effect and surge≒4 (from practice)

C_{safety}=Safety factor for the full load not to blow≒2 (from practice)

Q: What happen if one diode is burnt?

When one diode is burnt, either positive or negative swing is considered, thus Δt is changed to 1/60s.

Then voltage ripple, $\Delta V=i\Delta t/C_s=(1)(1/60)/0.004=4.16V$

Thus $Vo=V_2|peak-\Delta V-2(0.6)=23.2-4.16-1.2=17.8V$

Q: In Europe (AC 220V@50Hz),

what about the performance of the above power supply?

Voltage ripple, $\Delta V=i\Delta t/C_s=(1)(1/100)/0.004=2.5V$ (25% increase)

$V_2|rms= (N_2/N_1)\ V_1|rms=(8/55)220=32V$

Thus $Vo=V_2|peak - \Delta V - 2(0.6) =32\sqrt{2}-2.5-1.2=41.5V$

HW6) Design a power supply as follows;

AC 110V@60Hz, Vo=5V(desired), i_{max}=1A, Voltage ripple=0.5V