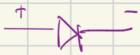
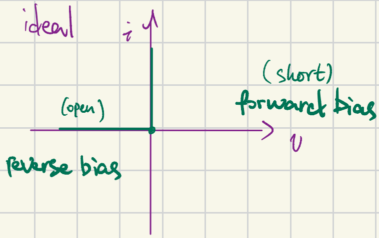
Diodes

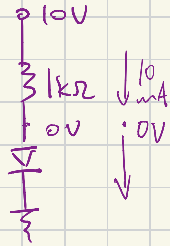
$A\cos(\omega t)$ $\omega = 2\pi f$

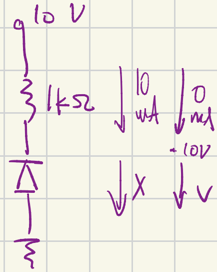


ideal

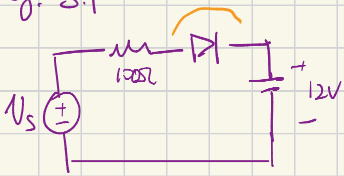


Eg.





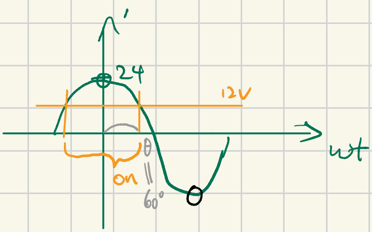
Eg. 3.1



using a diode circuit to charge a 12-V battery

$V_s = 24\cos\omega t$

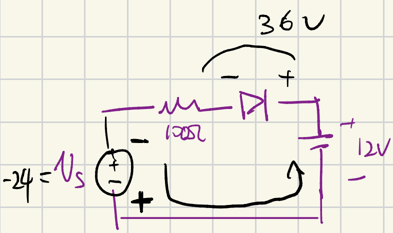
a) Find the fraction of each cycle during which the diode conducts



$$\frac{120^\circ}{360^\circ} = \frac{1}{3}$$

b) the peak value of the diode current

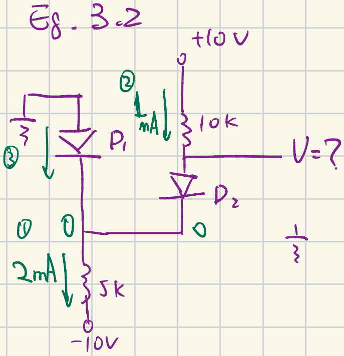
$$i_D = \frac{24-12}{100} = 0.12A$$



c) the maximum reverse-bias voltage that appears across the diode

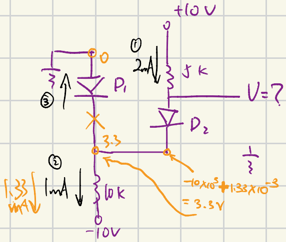
$$-24-(12) = -36V$$

Eg. 3.2



step 1: 猜 D 導通 or 不導通

$I③ = 2-1 = 1mA$



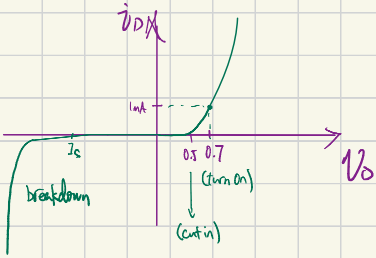
step 1: Assume

I ③ ✗ 1-2

step 2: open D_1

$$I_0 = \frac{20}{15} = 1.33\ mA$$

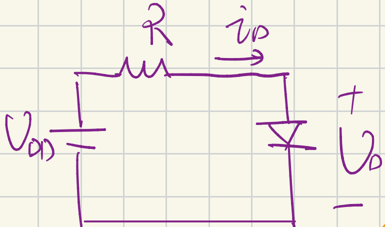
a real diode



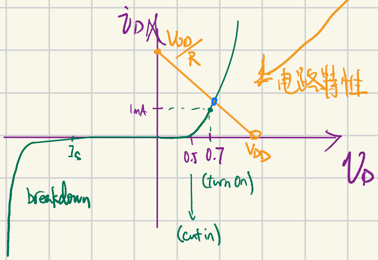
$$i = I_S\left(e^{V/nV_T} - 1\right) \qquad V_T = \frac{kT}{q} = 25\,mV \text{ at RT}$$

$$I_S \doteq 10^{-15} A$$

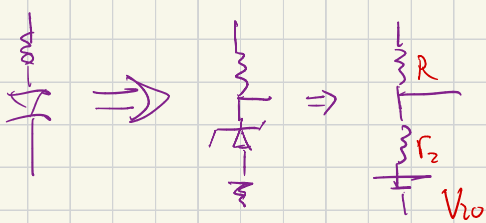
$$i = 10^{-15}\left(e^{0.7/0.025} - 1\right) = 1\,mA$$



$$\boxed{V_{DD} = i_D R + V_D}$$

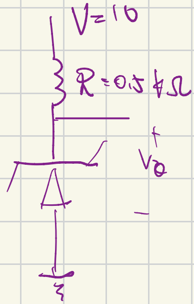


Zener diode

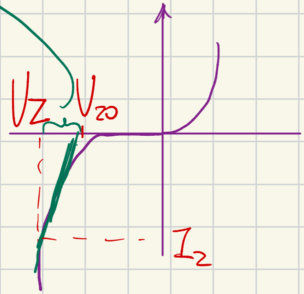


$$I_Z = \frac{V_S - V_{Z0}}{R + r_Z}$$

Eg.



$V_Z = V_{Z0} + I_Z r_Z \Rightarrow 6.8 = V_{Z0} + 5 \times 0.02$

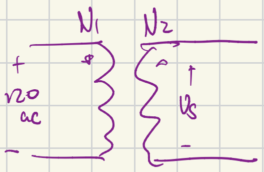


find V_0

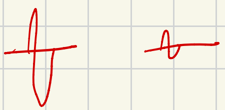
$I_Z = \dfrac{10-6.7}{0.5+20} = 6.35\,mA$

$V_0 = 6.7 + 6.35\,mA \cdot 20\,\Omega$

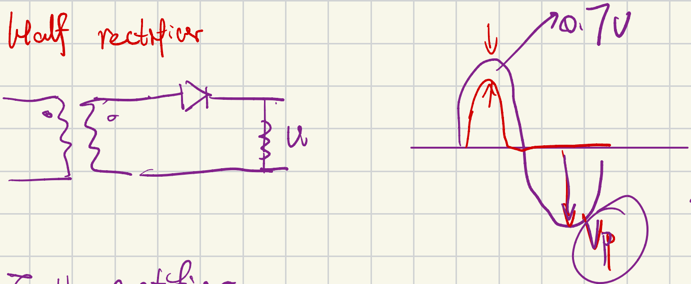
Peak rectifiers



$\dfrac{V_2}{V_1} = \dfrac{N_2}{N_1}$

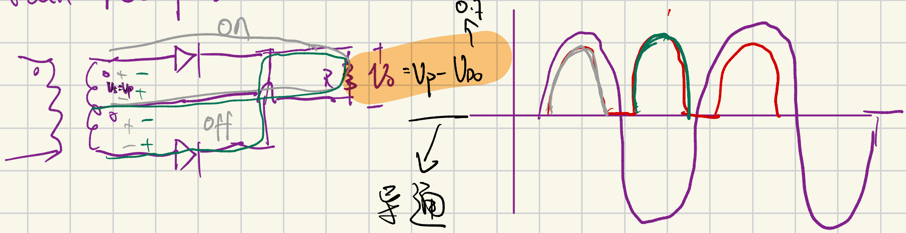


Half rectifier



Peak inverse Voltage

Full rectifier

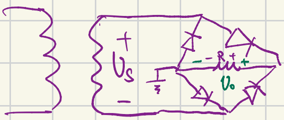


$V_0 = V_p - V_{D0}$

导通

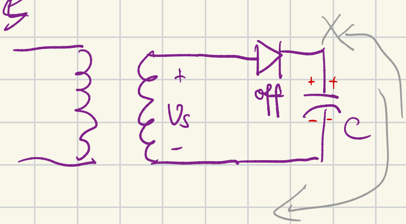
(不导通时：$V_p + V_p - V_{D0} = 2V_p - V_{D0}$)

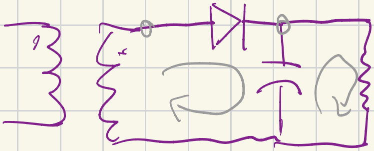
§ Bridge rectifier

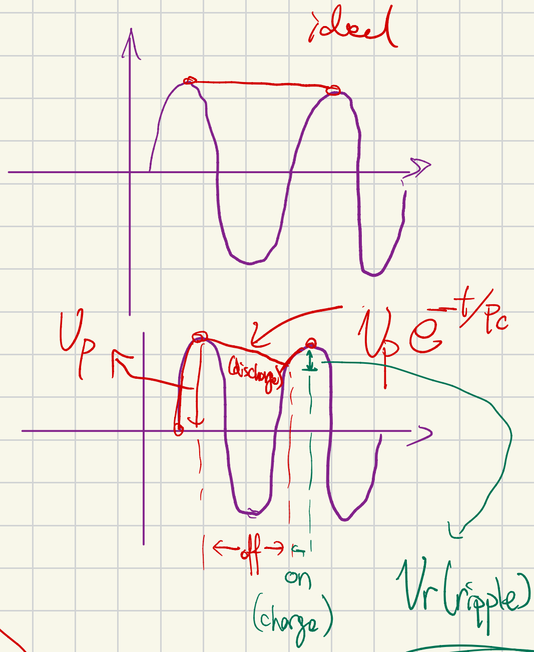


$V_o = V_s - 2V_{D0}$

§







$$V_p \cdot e^{-T/RC} = V_p - V_r$$

$$\Downarrow$$

$$V_p\left(1-\frac{T}{RC}\right) \cong V_p - V_r$$

$$V_r = V_p \frac{T}{RC}$$

$RC \gg T$

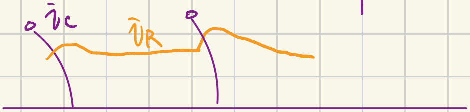
一个周期：放电V=充电V

ΔQ (discharge) = ΔQ (charge)

$$\frac{V_p}{R} T = C V_r$$

电流

$$i_D = i_C + i_R = C V_p(-\omega)\sin(\omega t) + \frac{V_p}{R}$$



$$i_{D(max)} = C V_p(\omega)\,\omega\Delta t + \frac{V_p}{R}$$

$$= \frac{V_p}{R}\,\frac{T}{V_r}\,V_p\,\omega\sqrt{2V_r/V_p}$$

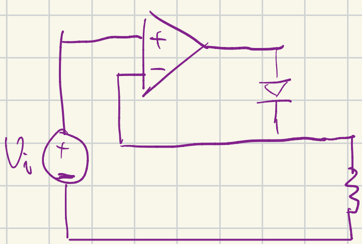
$$\omega = 2\pi f = \frac{2\pi}{T}$$

$$\approx \frac{V_p}{R}\left(1+2\pi\sqrt{2V_p/V_r}\right)$$

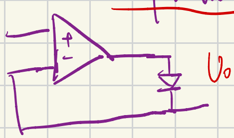
$$i_{D(Ave)} \approx \frac{V_p}{R}\left(1+\pi\sqrt{2V_p/V_r}\right)$$

---

§ precision peak rectifier

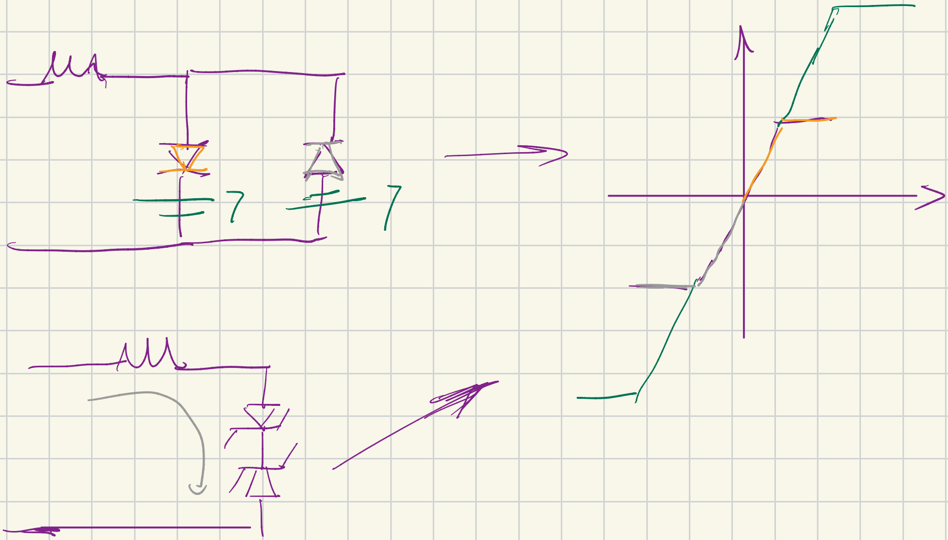


super diode → 去 0.7



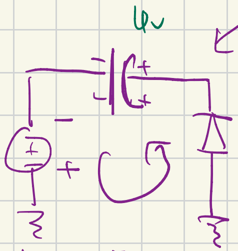
$v_i > 0$, Assume D "on" ⇒ $v_o = v_i$

$V_i < 0$, Assume D "off" ⇒ $v_o = 0$



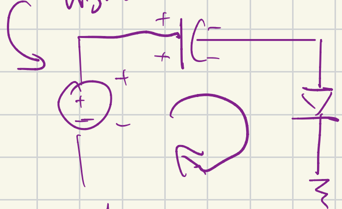
Clamping Circuit

The circuit clamps the lowest peak at 0 V

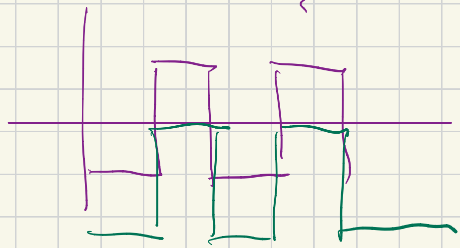


$V_o = V_i + 6$

light



$V_o = V_i - 4$



§ Intrinstic Si $\rightarrow n_i$

$i = $ (free electron) + (movement of hole)

$\quad\quad\quad\quad n \quad\quad\quad\quad\quad\quad\quad\quad p$

$n_i = p = n = 10^{10}\,cm^{-3}$

$np = n_i^2 = 10^{20}\,cm^{-3}$ at RT

§ Doped Si

n-type Si

§ current

drift (under E)

$j = \underset{\text{密度}}{\rho}\,\underline{v}$ Carrier Volcity $\rightarrow$ $v \propto E$

$v = \mu E$

mobility

$j_n = q\,n\,\mu_n E$

电流 $1.6\times10^{-19}C$

$j = q\,p\,\mu_p E$

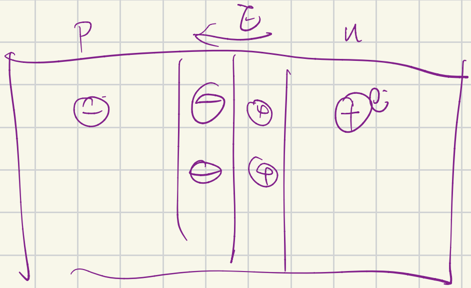
Diffusion

$j \propto \frac{dn}{dx} \Rightarrow j_n = qD_n\frac{dn}{dx}$

Diffusion constant

$j_p = -qD_p\frac{dp}{dx}$

Current $j = qD_n\frac{dn}{dx} - qD_p\frac{dp}{dx}$



steady state

$$j_n = q n \mu E + q D_n \frac{dn}{dx} = 0$$

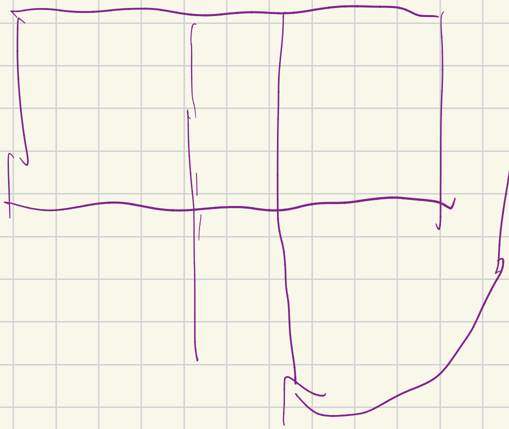
$(j_p = 0)$

$$\frac{V_t}{T} \ln \frac{n(x_2)}{n(x_1)} = V(x_2) - V(x_1)$$

$$25\,\text{mV} \ln \frac{10^{16}}{10^{5}} = V_0 = 0.64$$

built-in

$(E = 0)$



$$j_p = q D_p \frac{dp}{dx}$$

$$= q D_p \frac{p_{n0}}{L_p} \left(e^{V/V_t} - 1\right)$$

$$j_n = q D_n \frac{n_{p0}}{L_n} \left(e^{V/V_t} - 1\right)$$

$$j = I_s \left(e^{V/V_t} - 1\right)$$

$$q D_p \frac{p_{n0}}{L_p} + q D_n \frac{n_{p0}}{L_n}$$