Lecture 19

HW 6 (final HW) is due Thursday 10^{th} March

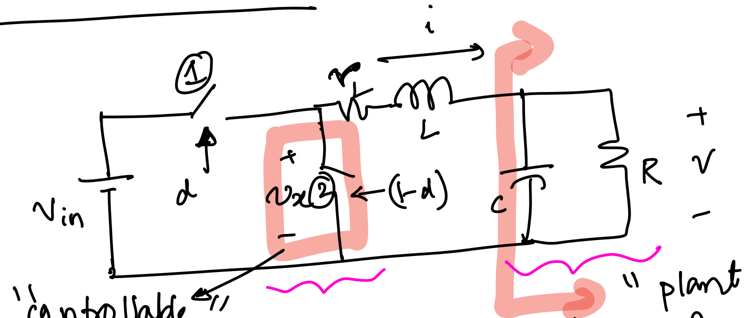
finals will be released after that.

Suggestion: Use the HW solution - simulation, derivation etc for finals.

① Circuit Equivalents for controller.

Buck converter

$$\frac{1}{sL+r_L}$$



"controllable"   "plant"

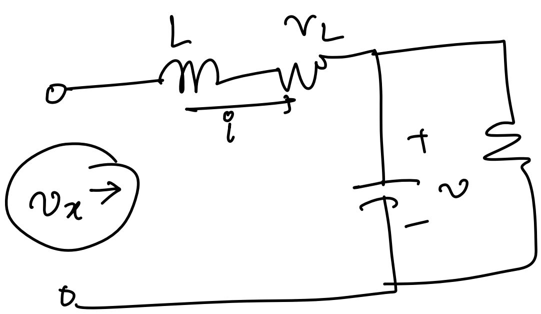
∘ objective : control current through inductor.

(L, r_L)

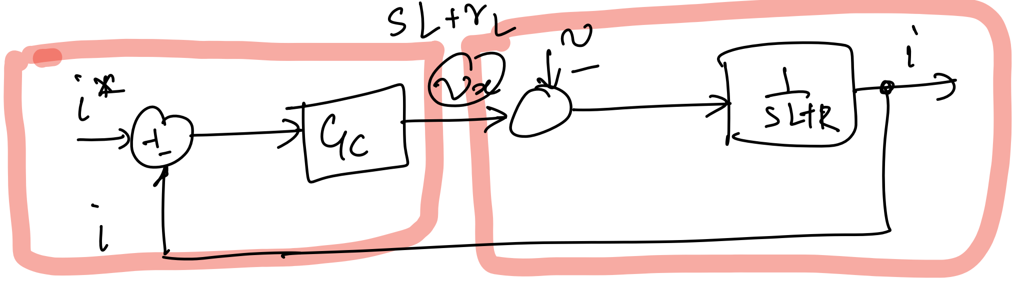
$v_x = V_{in} \quad (d=1) \leftarrow$ during ① ON

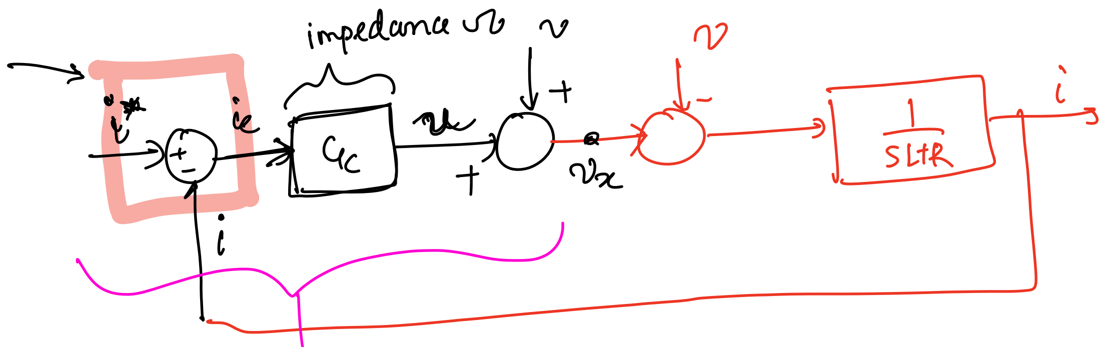
$v_x = 0 \quad (d=0) \leftarrow$ during ② ON

$\therefore \langle v_x \rangle = V_{in} \cdot d + 0 \cdot d' = V_{in} \cdot d$

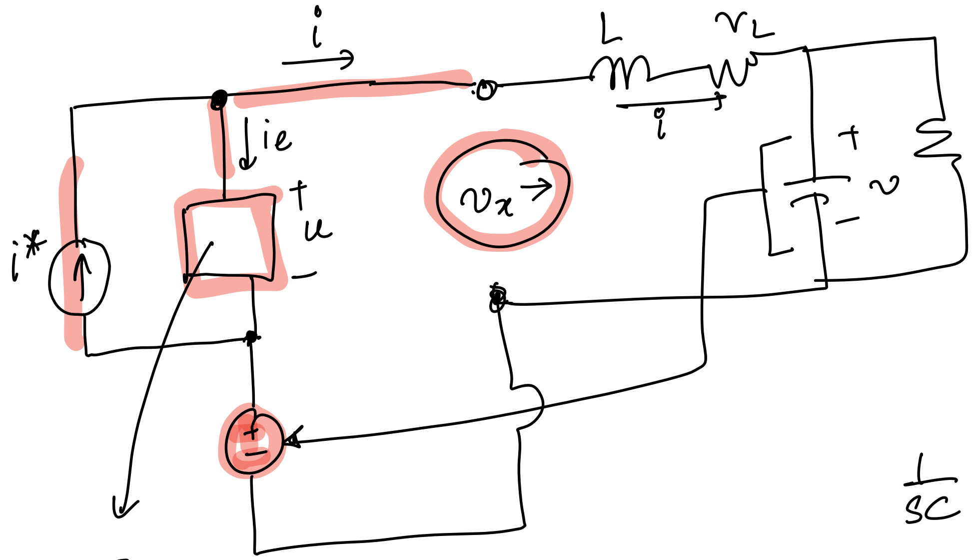


$$\frac{v_x - v}{sL+r_L} = i$$





controller implementation.



$\frac{1}{SC}$

$$\underbrace{\overset{i \cdot R}{\left(K_p + \frac{K_i}{S}\right)} i_e}_{\text{voltage}} = \underbrace{u}_{\text{voltage}}$$

$\underbrace{\frac{K_i}{S}}$ = impedance

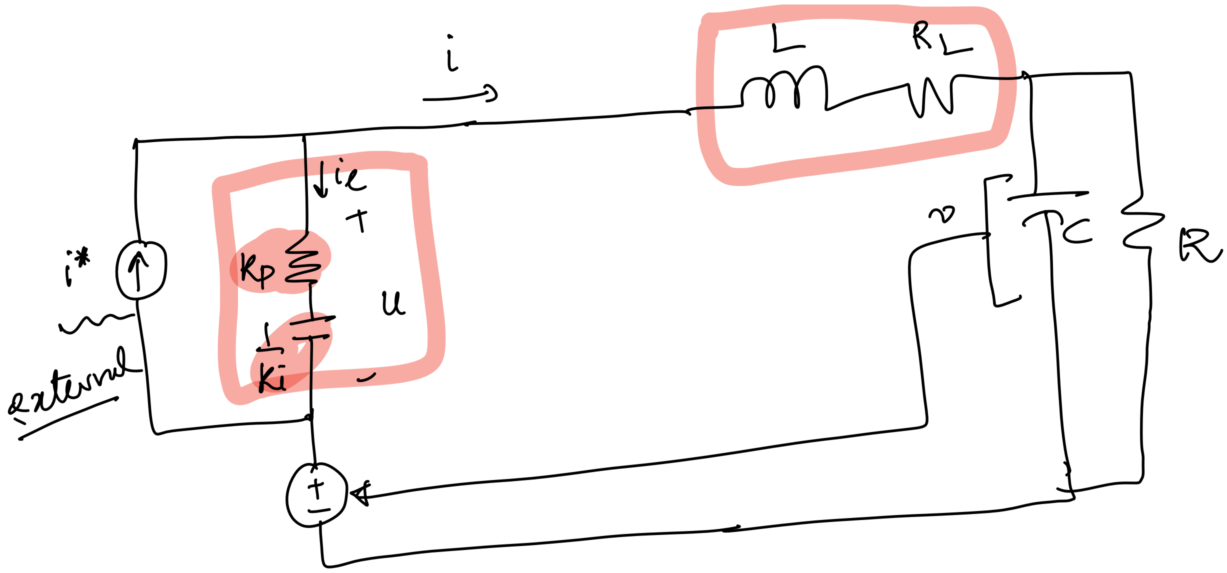
$K_p \equiv$ resistor

$I = C\frac{dV}{dt}$

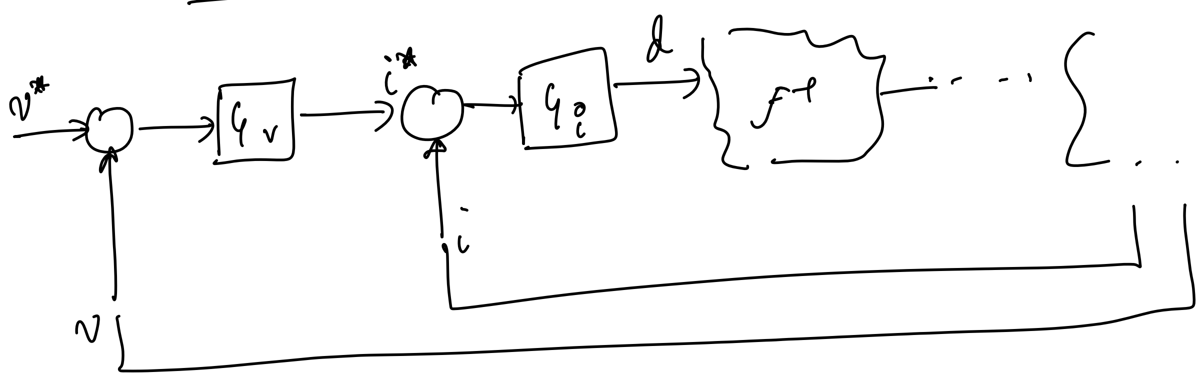
$\frac{K_i}{S} i_e$ = voltage

$I = SC\,v$

$$\frac{K_i}{S} \cdot i_e = u_i \Rightarrow \qquad i_e = S \cdot \underbrace{\left(\frac{1}{K_i}\right)}_{C} \cdot u_i$$

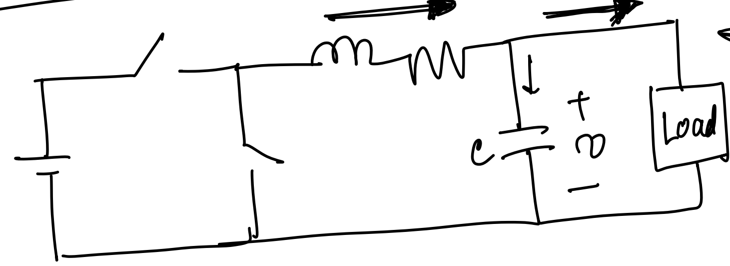


voltage control



Buck Converter

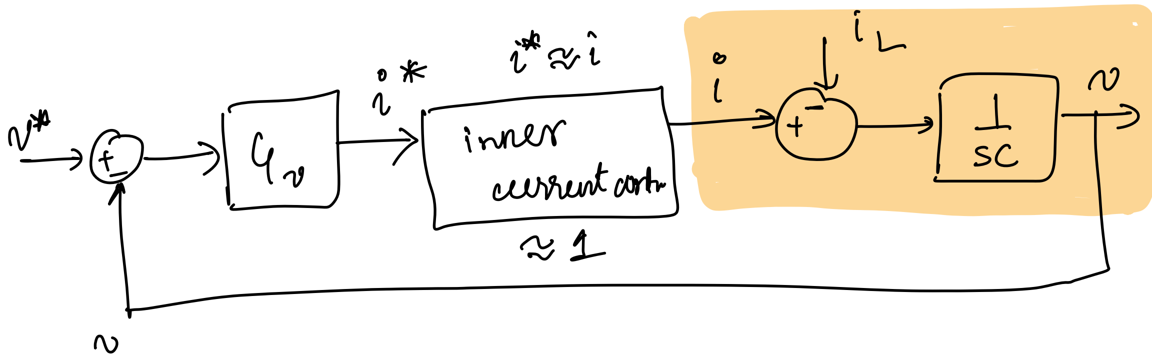
$i_x = i$ $\quad$ i_L = load current



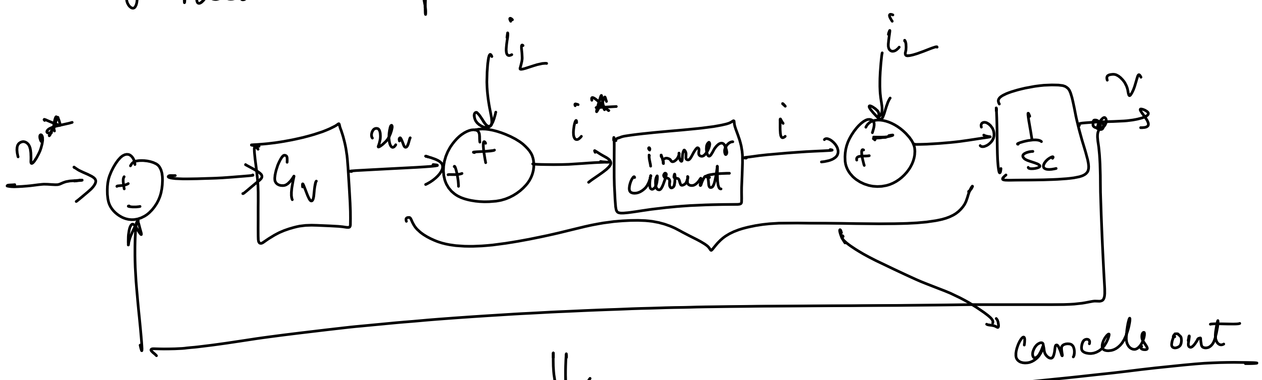
you can measure this current by a sensor.

$$i - i_L = sCv$$

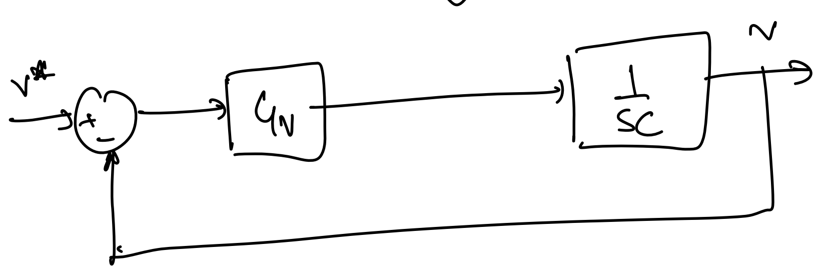
$$\boxed{v = \frac{i - i_L}{sC}}$$



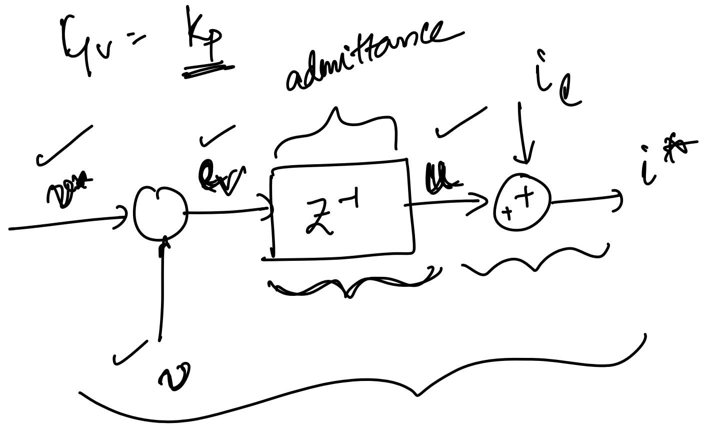
If I want my plant transfer function to be $\frac{1}{sC}$ I need to implement Feedforward to cancel i_L

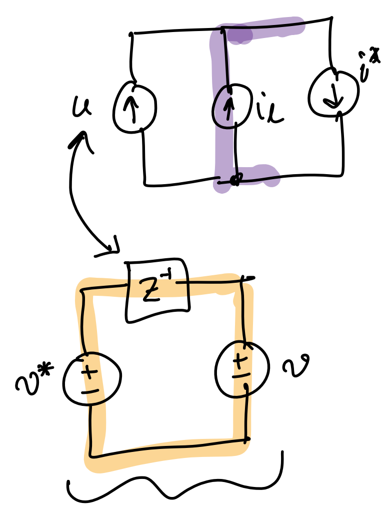


$\Downarrow$

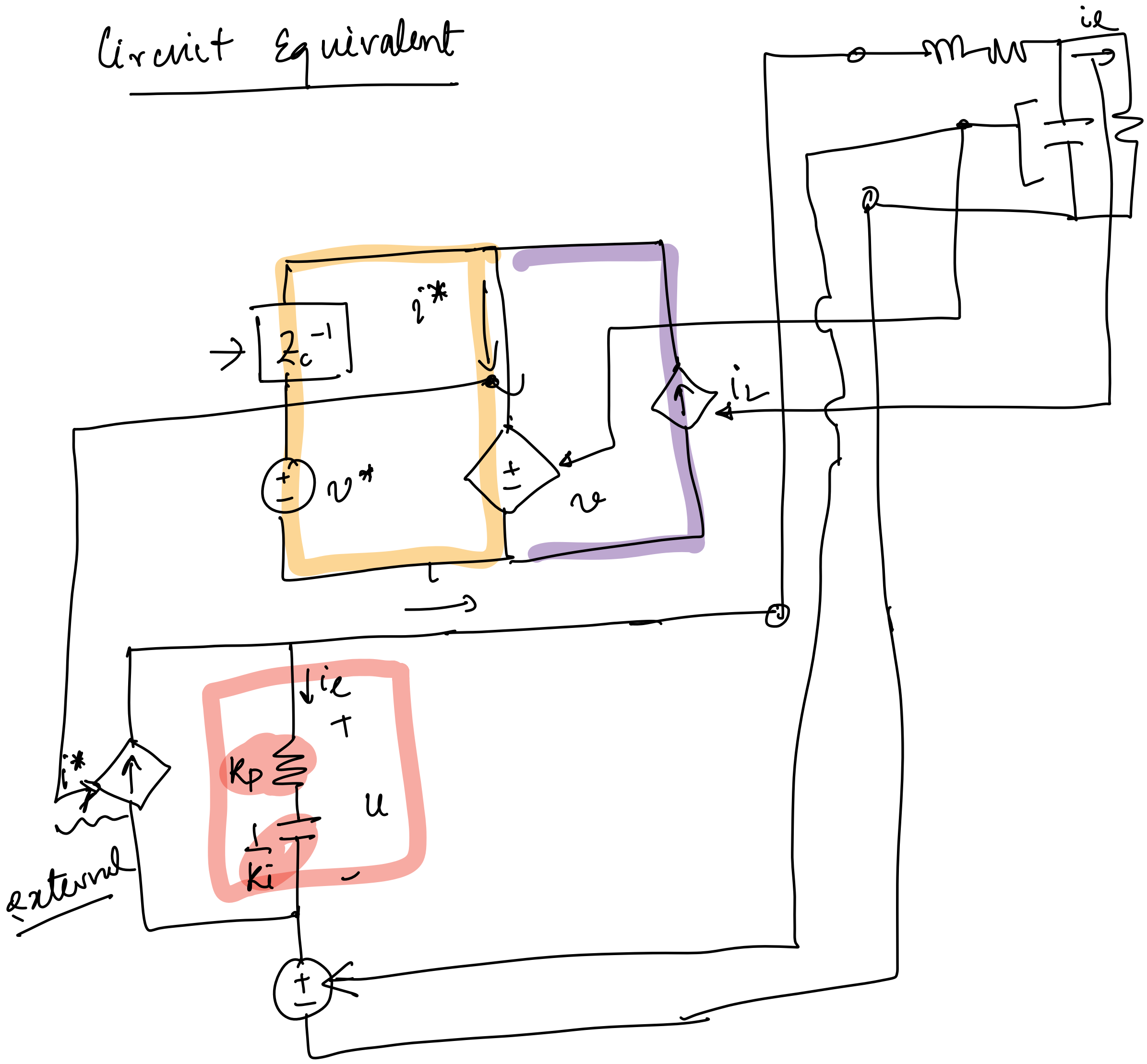


$G_v = K_p$





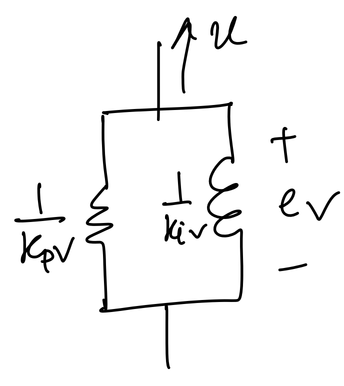
Circuit Equivalent

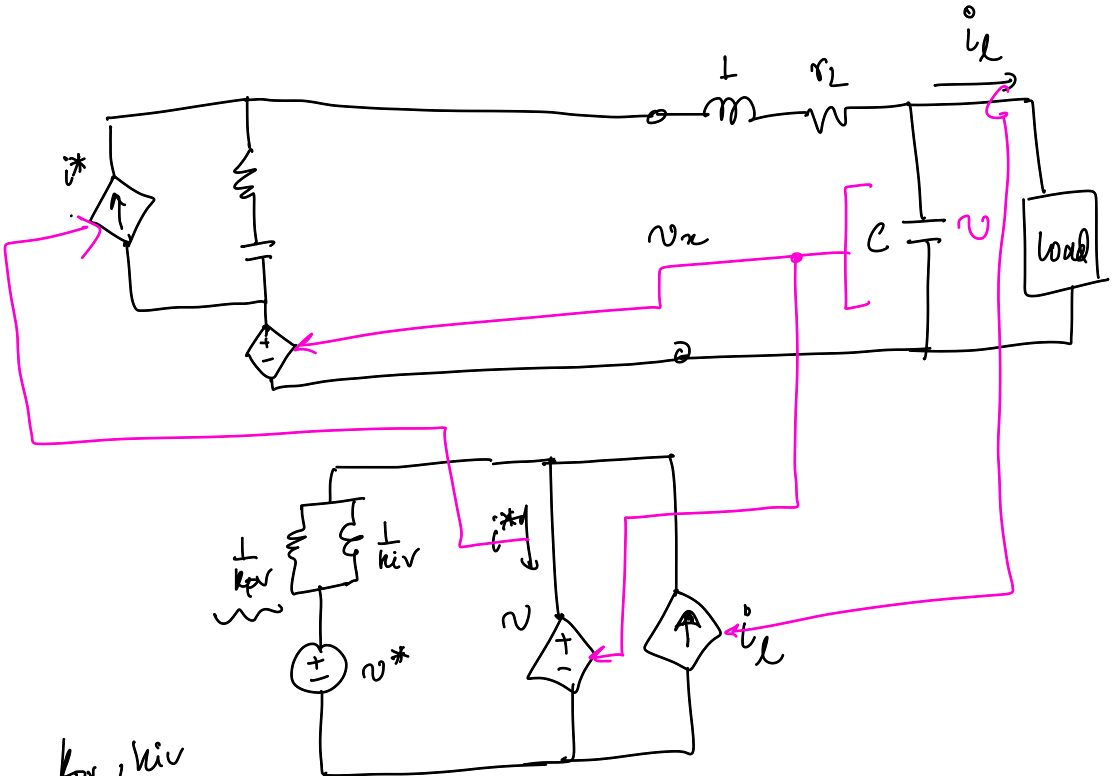


$$u = Z^{-1} \cdot e_v$$

$$u = \underbrace{\left(K_{pv} + \frac{k_{iv}}{s}\right)}_{\text{admittances}} e_v$$

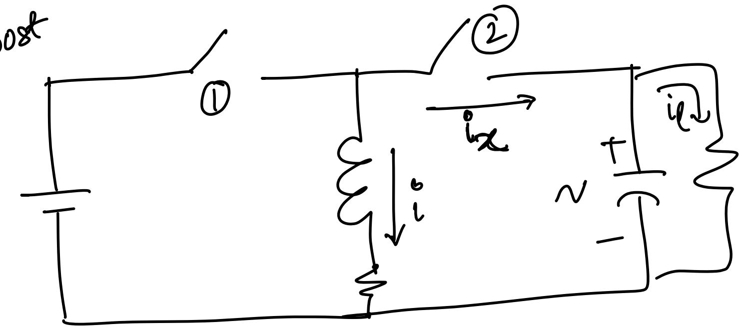
current





k_{pv}, k_{iv}

Buck-boost



$$\boxed{\frac{i_x - i_\ell}{sC} = v}$$

when ① is ON, $i_x = 0$

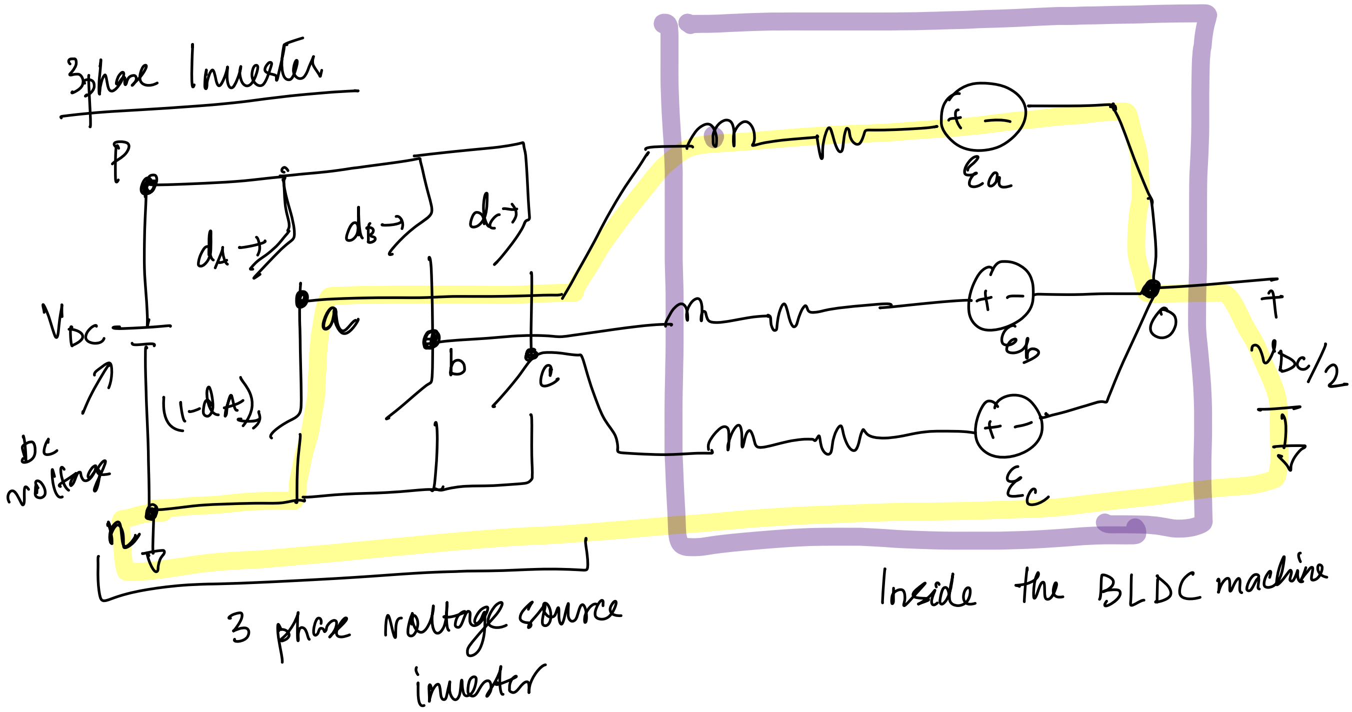
② is ON, $i_x = -i_L$

$$\therefore \langle i_x \rangle = 0 \cdot d + (-i_L) \cdot d'$$

$$= -i_L d'$$

$$\underbrace{\frac{-i_L d' - i_\ell}{sC} = v}$$

3phase Inverter



$$d_A = \underbrace{0.5 + 0.5\, \overbrace{m \sin\omega t}}$$ $0 < d_A < 1$

$$d_B = 0.5 + 0.5\, m \sin(\omega t - 2\pi/3)$$ $-1 < m < 1.$

$$d_C = 0.5 + 0.5\, m \sin(\omega t - 4\pi/3)$$

$$\langle v_{an} \rangle = d_A \cdot V_{dc} + (1-d_A) \cdot 0$$

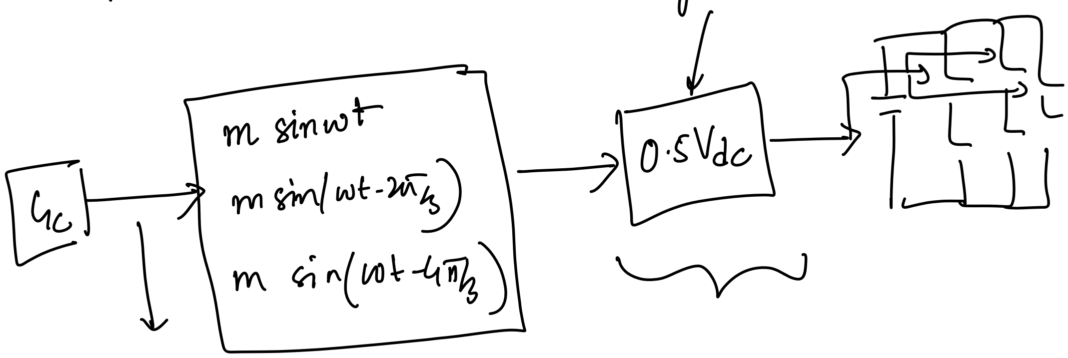
$$= (0.5 + 0.5\, m \sin\omega t)\, v_{dc}$$

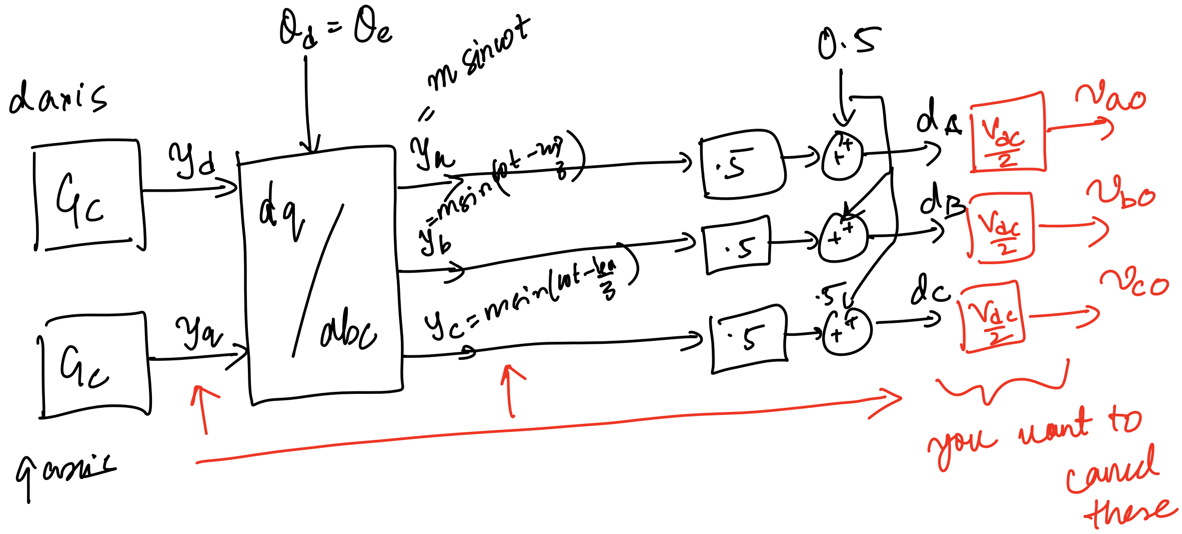
$$= \underbrace{0.5\, v_{dc}} + \underbrace{0.5\, m \sin\omega t\, v_{dc}}$$

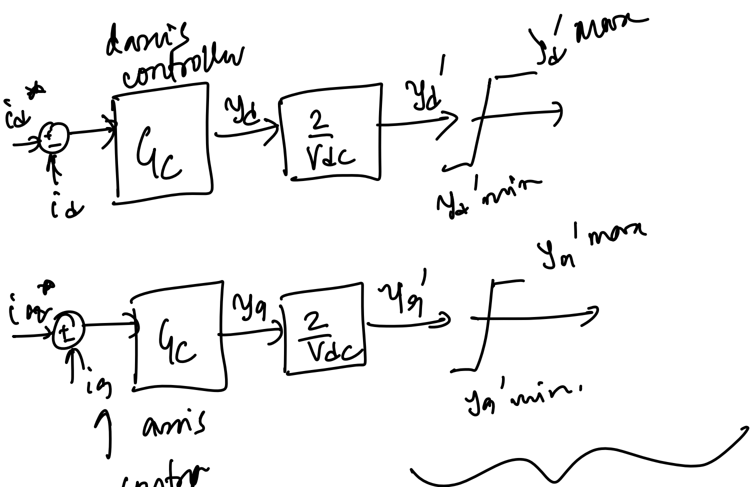
$$\langle v_{an} \rangle = \underbrace{\langle v_{ao} \rangle} + \underbrace{\langle v_{on} \rangle}$$

$\langle v_{ao}\rangle = 0.5 m \sin\omega t \, V_{dc}$

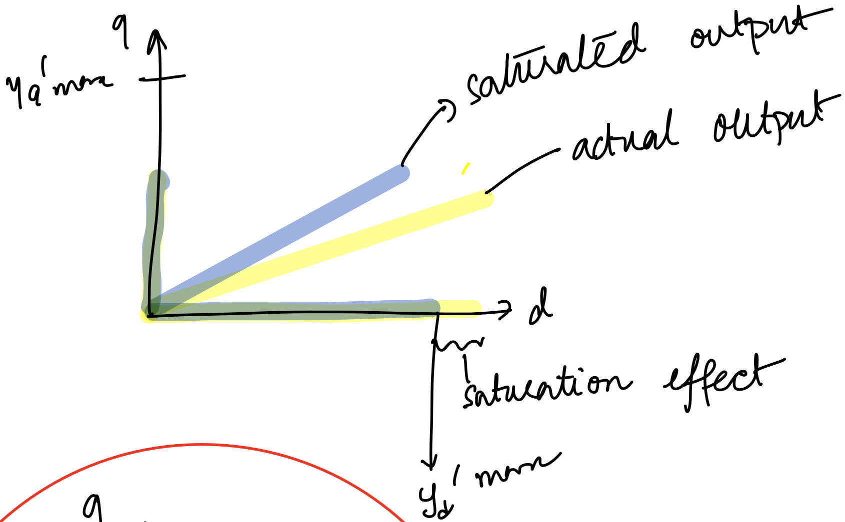
gain due to inverter

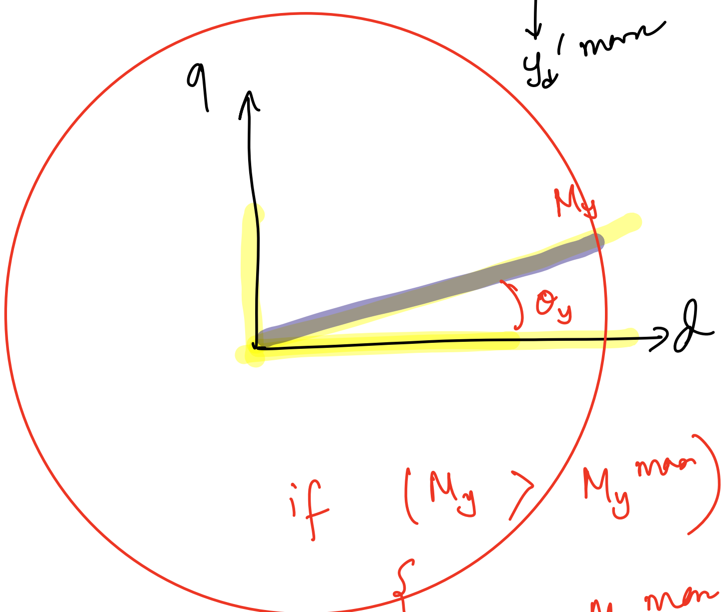






(1) Saturation.





$$M_y = \sqrt{y_d'^2 + y_q'^2}$$

$$\theta_y = \tan^{-1} \frac{y_q'}{y_d'}$$

if $(M_y > M_y^{max})$

{

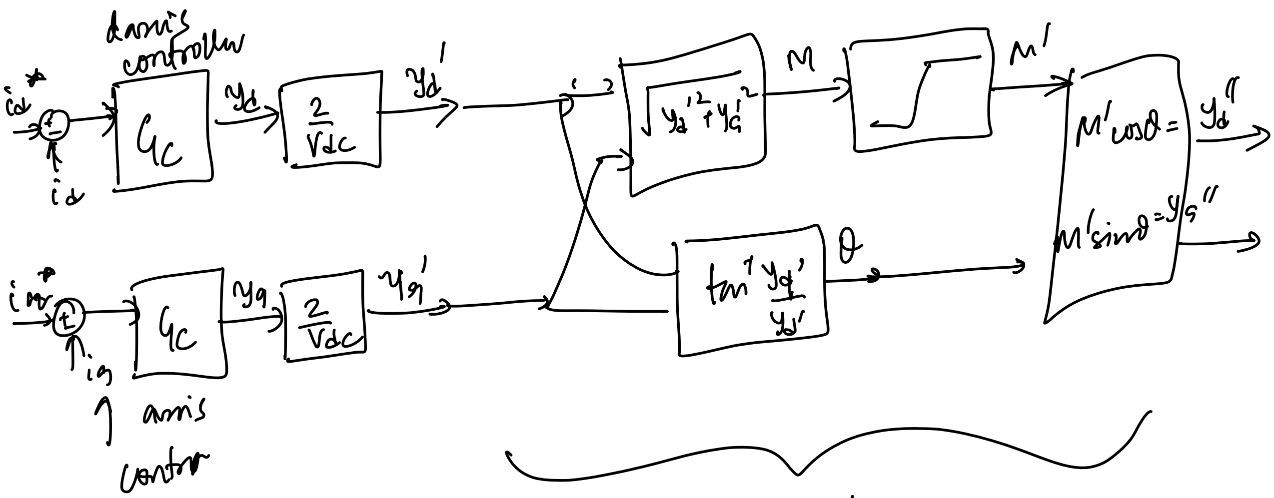
$M_y = M_y^{max}$;

}

O/P:

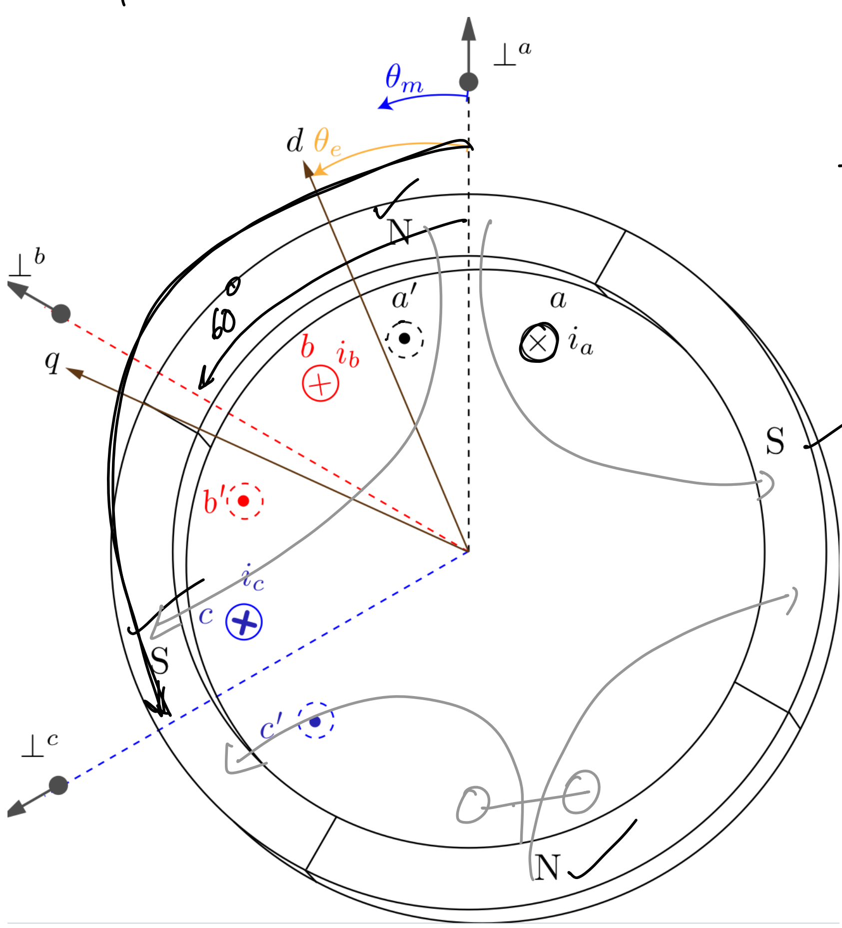
$$y_d'' = M_y \cdot \cos\theta_y$$

$$y_q'' = M_y \sin\theta_y$$



② saturation

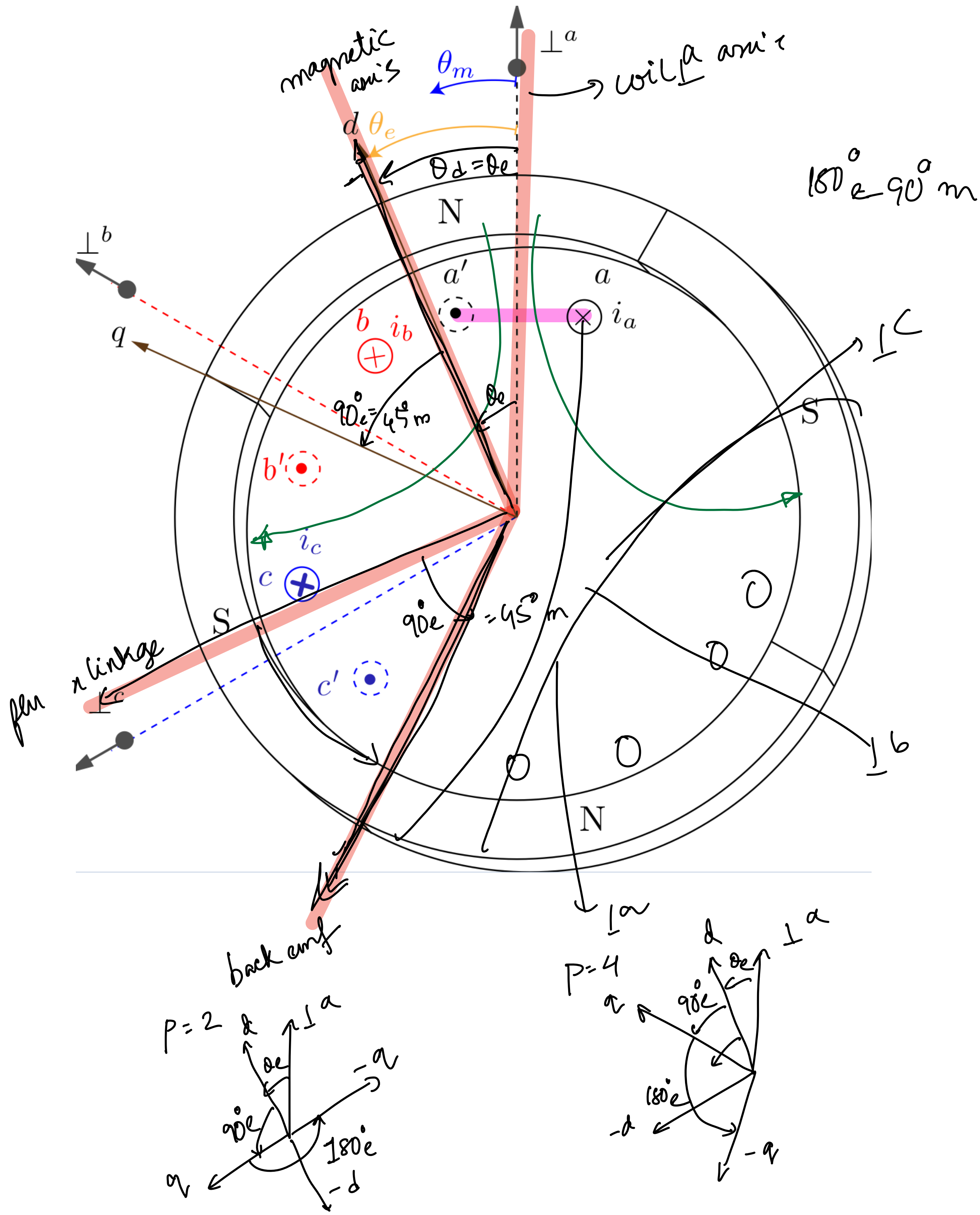
5:40 pm



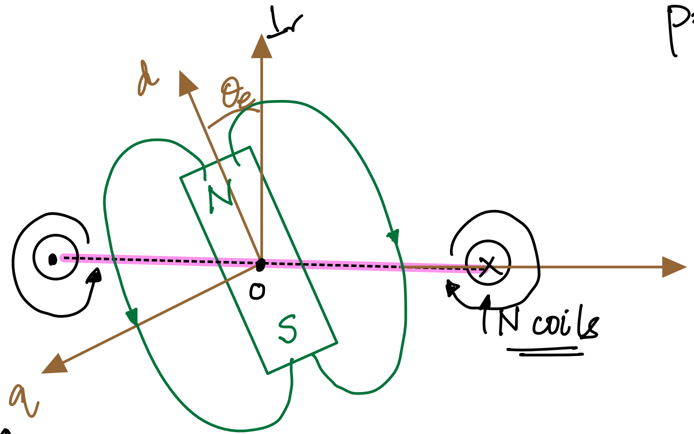
$P = 4$

$b - 120^\circ e = 60^\circ m$

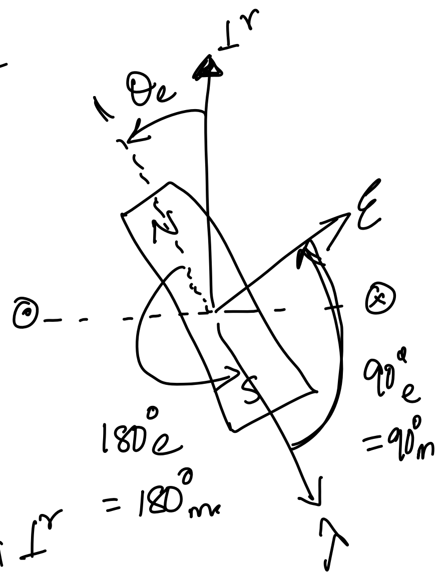
$c \to 240^\circ e = 120^\circ m$

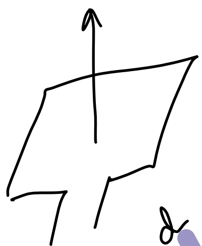


magnetic axis
coil a axis
180°e - 90°m
N
S
a
a'
b
b'
c
c'
d
q
90°e = 45°m
90°e = 45°m
flux linkage
back emf
P = 2
P = 4
90°e
180°e
-q
-d

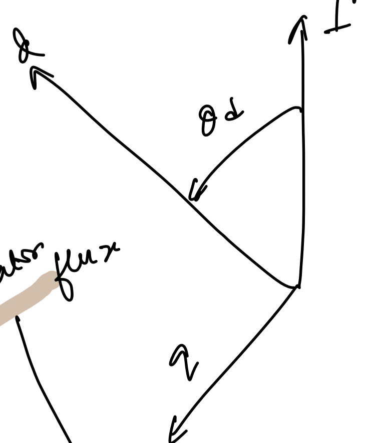


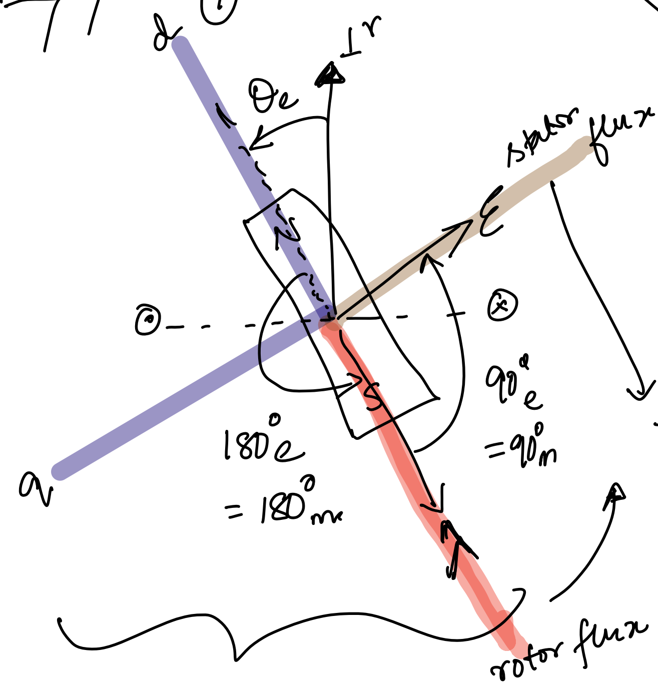
$p=2$





① $\theta_d = \theta_e$

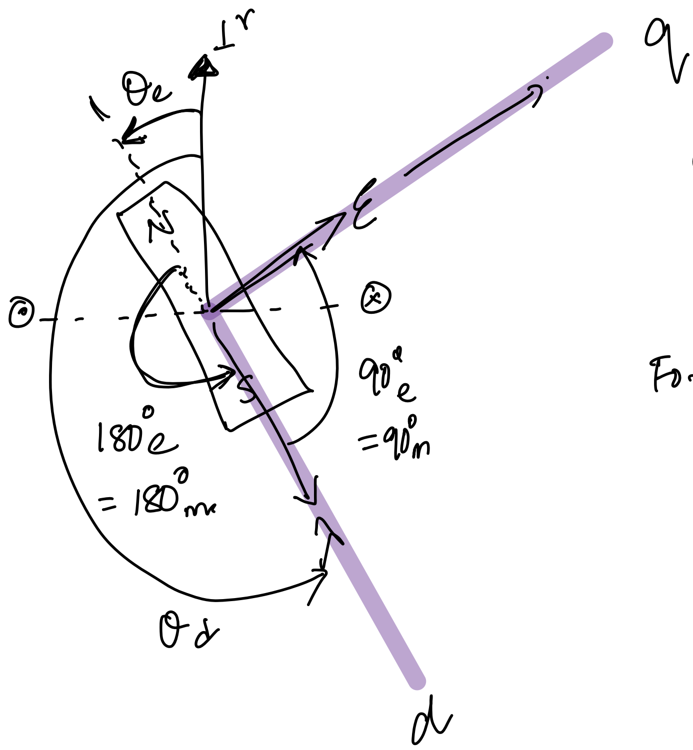




you have to excite -ve i_q currents

$i_q^* < 0$

$i_d = 0$

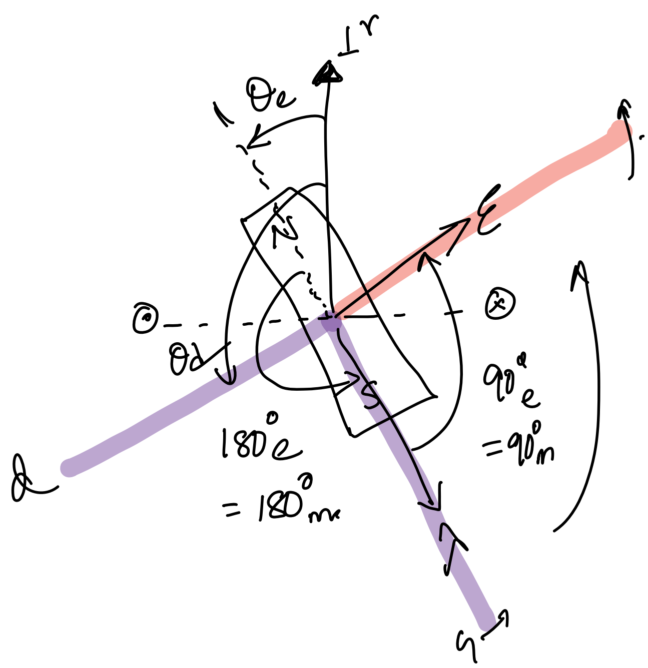


$$\underbrace{\theta_d = \theta_e + 180^\circ_e}$$

For this case,

i_q needs to be +ve

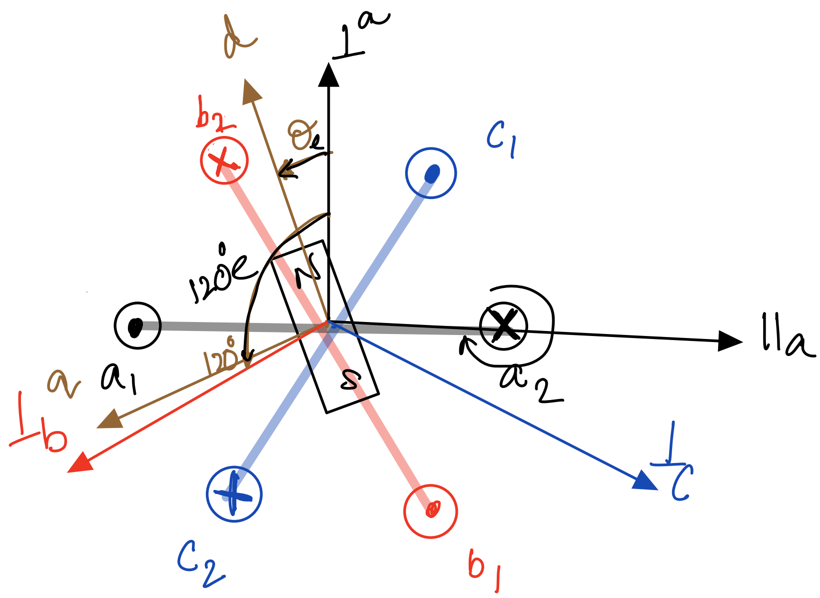
$i_d = 0$

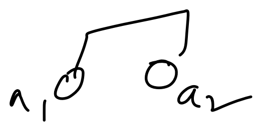


$$\theta_d = \theta_e + 90^\circ_e$$

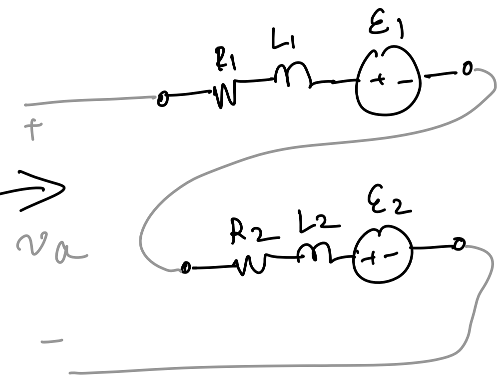
i_d^* -ve

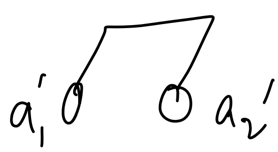
$i_q^* = 0$



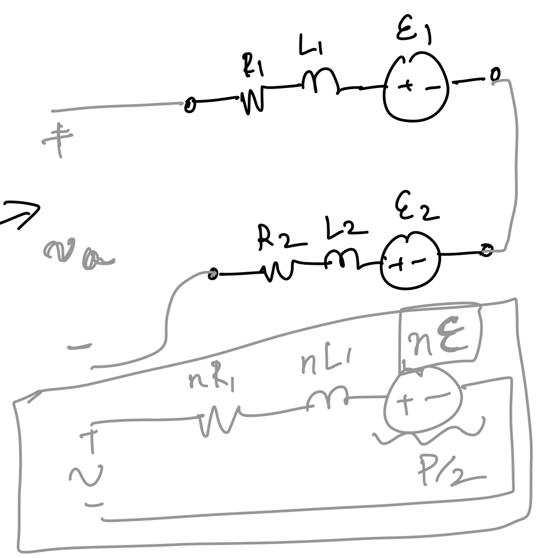


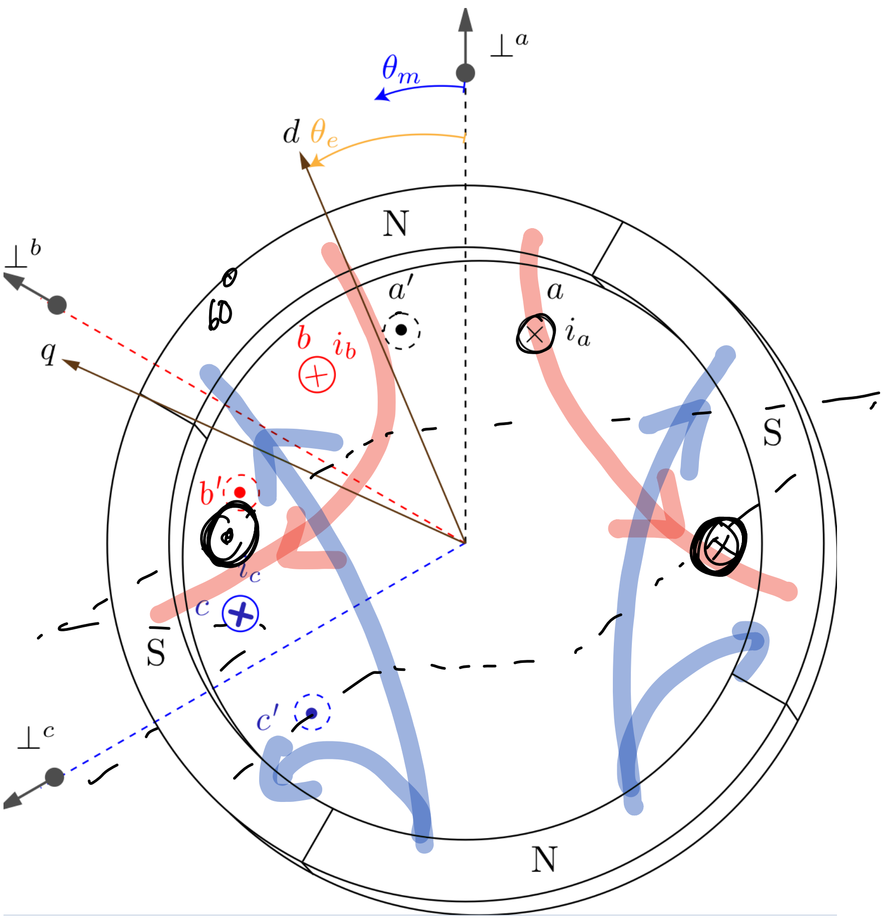
correct connection





Wrong connection





$\perp^a$
θ_m
d θ_e
N
$\perp^b$
q
a'
a
b i_b
i_a
S
b'
i_c
c
S
$\perp^c$
c'
N

Effect of right half zeros

Minimum phase s/s = s/s that does not have
- delay (e^{-2s})
- Right half zero
- Right half pole

Non minimum phase s/s →

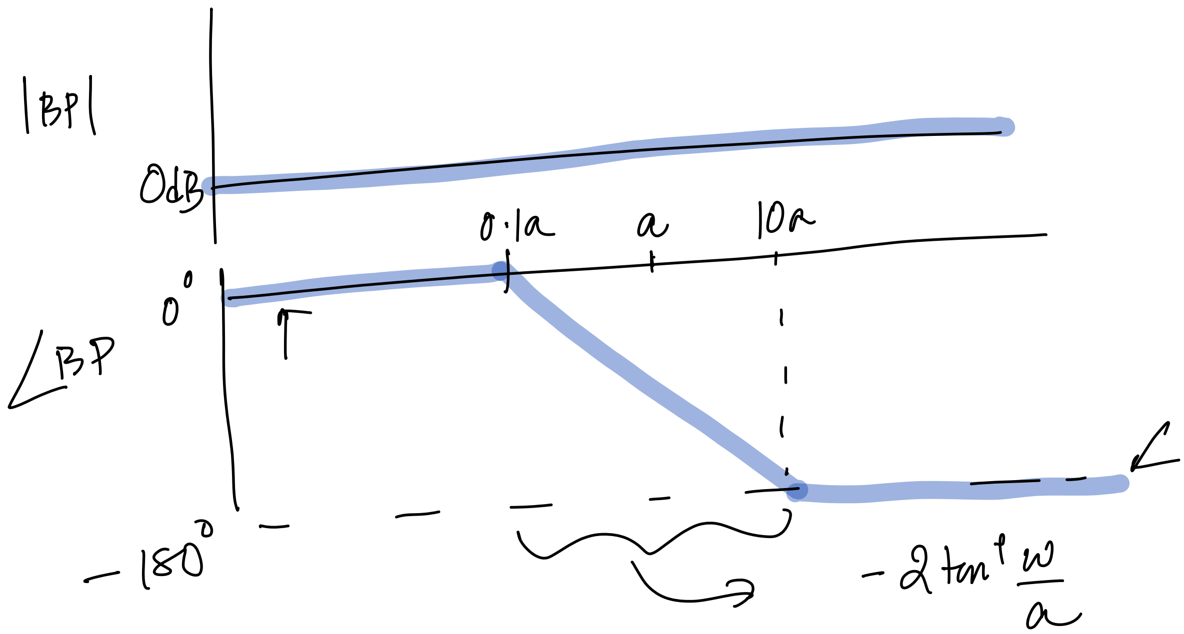
$$P_{NMP}(s) = \underbrace{(a-s)}_{\text{right half zero}} \; \underbrace{P_1(s)}_{\text{minimum ph. transfer func.}}$$

$$= \frac{a-s}{a+s} \cdot \underbrace{(a+s)\, P_1(s)}$$

$$P_{NMP}(s) = \underbrace{\frac{a-s}{a+s}}_{\text{Blaschke Product}} \cdot \underbrace{P_{MP}(s)}$$

Blaschke Product.

$B.P = \frac{a-s}{a+s}$



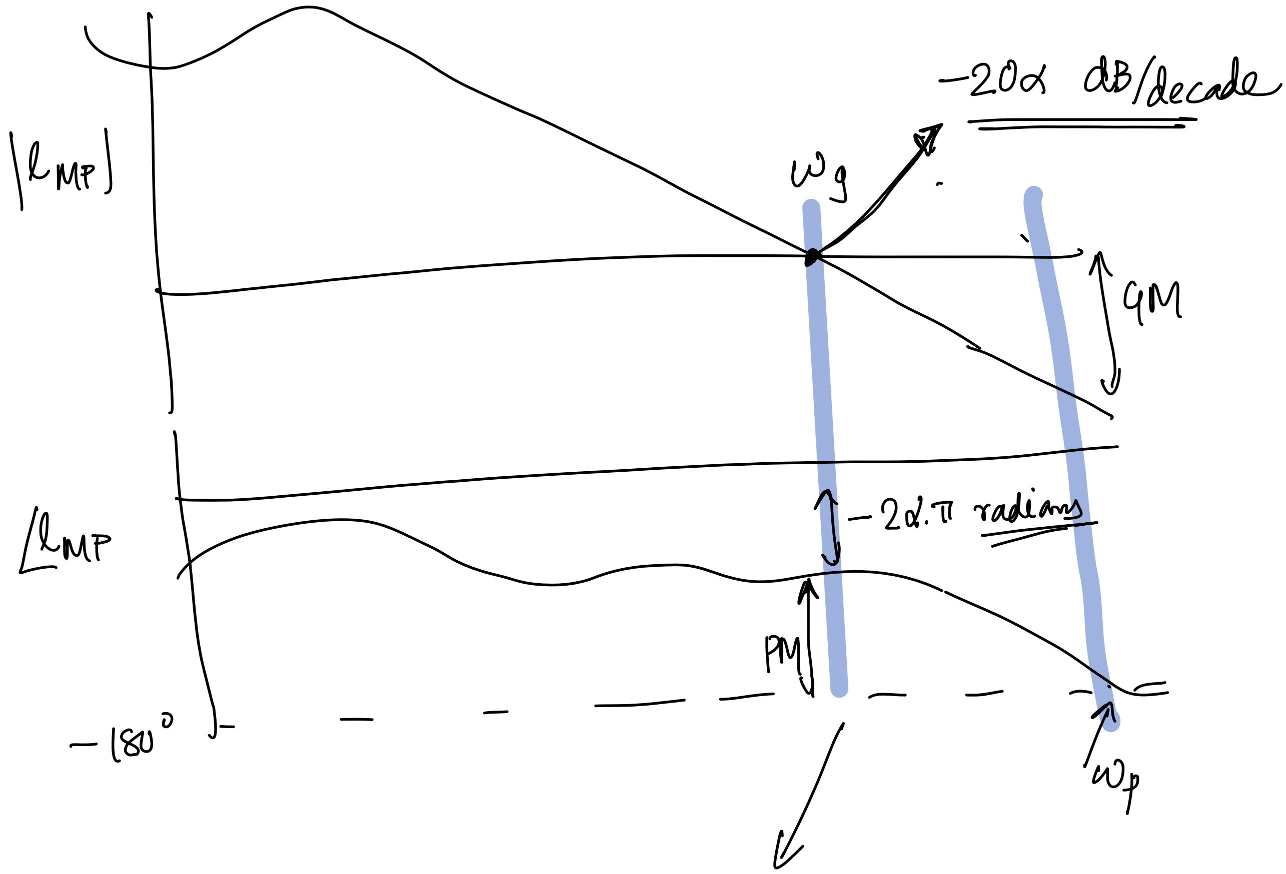
Lets say you have a plant

$$\underbrace{\frac{G_0 \boxed{\left(\frac{s}{\omega_z}-1\right)}}{\frac{s^2}{\omega_0^2}+\frac{s}{Q\omega_0}+1}}_{P_1}$$

1. $P_{MP} = \left(\frac{s}{\omega_z}+1\right)\cdot P_1$

2. Design controller for P_{MP}, lets call that controller $= C_{MP}$

$$l_{MP} = C_{MP} P_{MP}.$$



$$\angle L_{NMP} = \angle L_{MP} - 2\tan^{-1}\frac{\omega}{a}$$

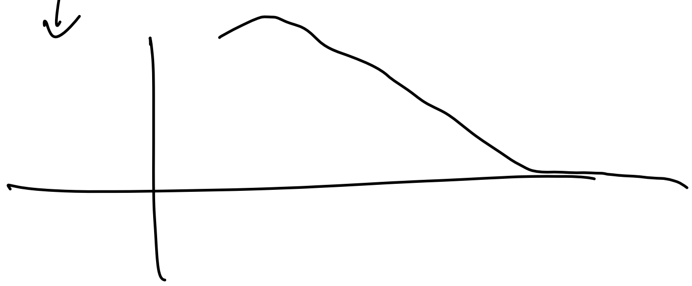
At gain cross over freq

$$\angle L_{NMP}(\omega_{gc}) = -2\alpha\pi - 2\tan^{-1}\frac{\omega_{gc}}{a}$$

$$= -\pi + PM$$

$$\therefore \tan^{-1}\left(\frac{\omega_{gc}}{a}\right) = \frac{(1-2\alpha)\pi - PM}{2}$$

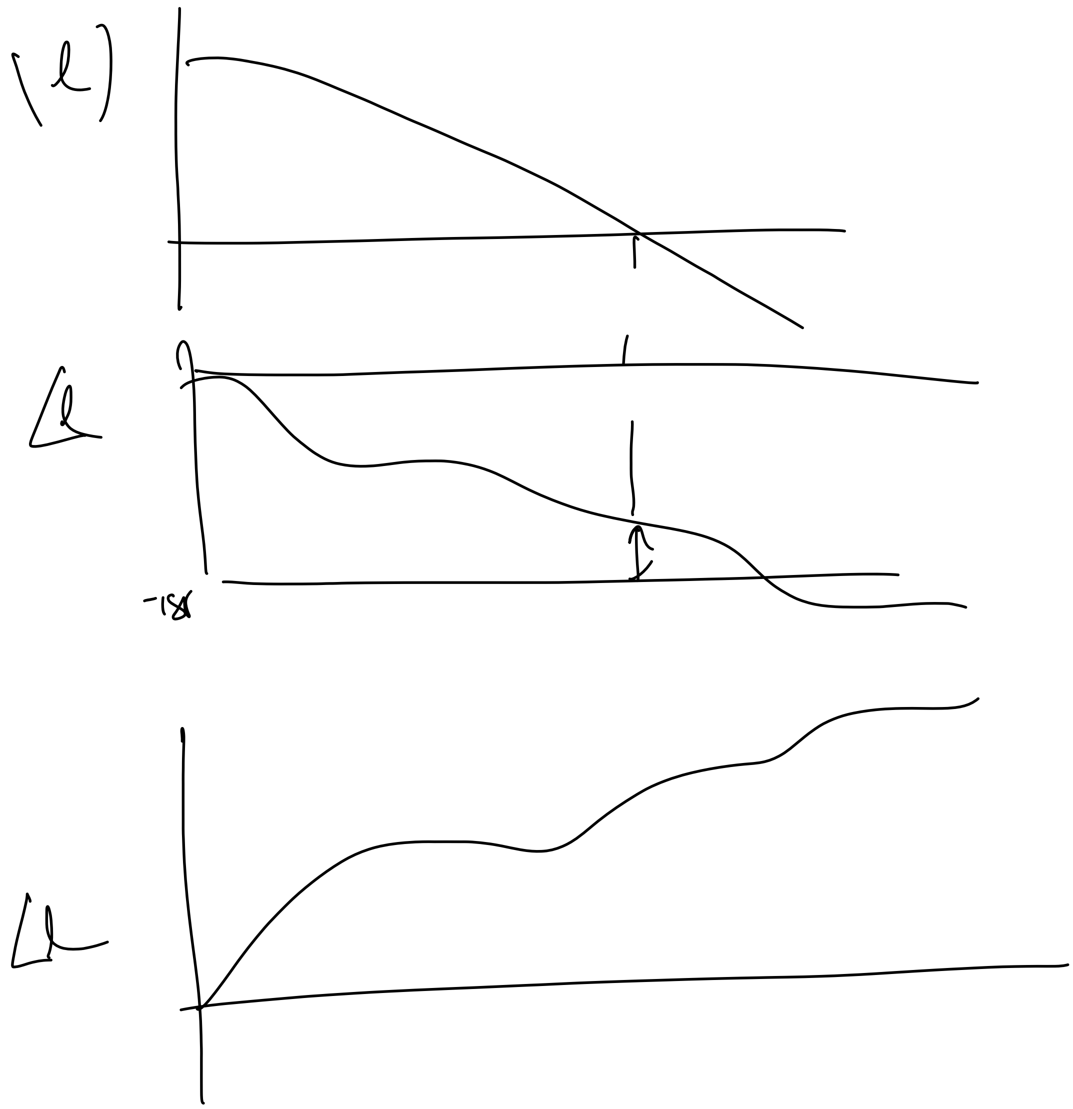
$$\therefore \frac{\omega_{gc}}{a} = \cot\left[\frac{2\alpha\pi + PM}{2}\right]$$



$\underline{\underline{\alpha = 0}}$

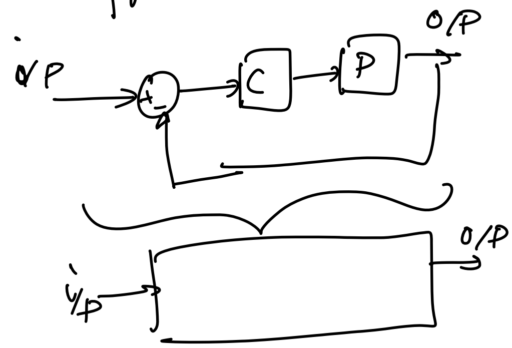
$$\underbrace{\omega_{gc} = a \cot\left[\frac{PM}{2}\right]}$$

maximum gain crossover freq that you can get for a certain PM.


|l|
∠l
-180
∠L

$\underbrace{C}_{\text{controller}}$ $\underbrace{P}_{\text{plant}}$

$\underline{l} = C \cdot P$ $\longrightarrow$ use this for bode plot, nyquist

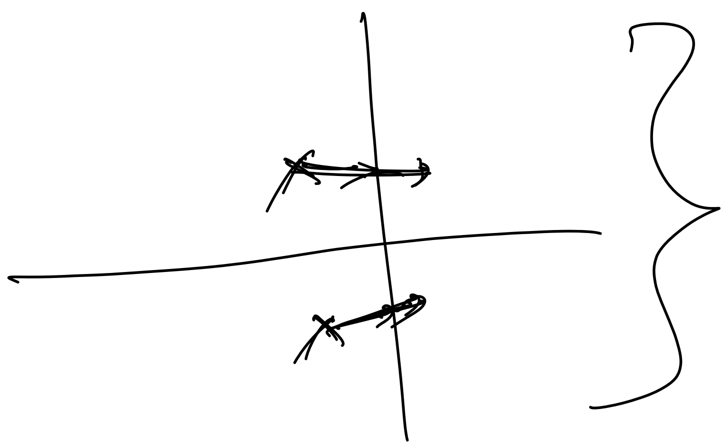


$$CLTF = \frac{O/P}{i/P} = \frac{l}{1+l}$$

$$CLTF = \frac{l}{1+l}$$

If $(1+l)$ has any right half pole

pzmap(CLTF) Sanity check



$$l = \frac{n(s)}{\boxed{d(s)}}$$

$$\frac{l}{1+l} = \frac{n/d}{1+n/d} = \frac{n(s)}{\boxed{n(s)+d(s)}}$$