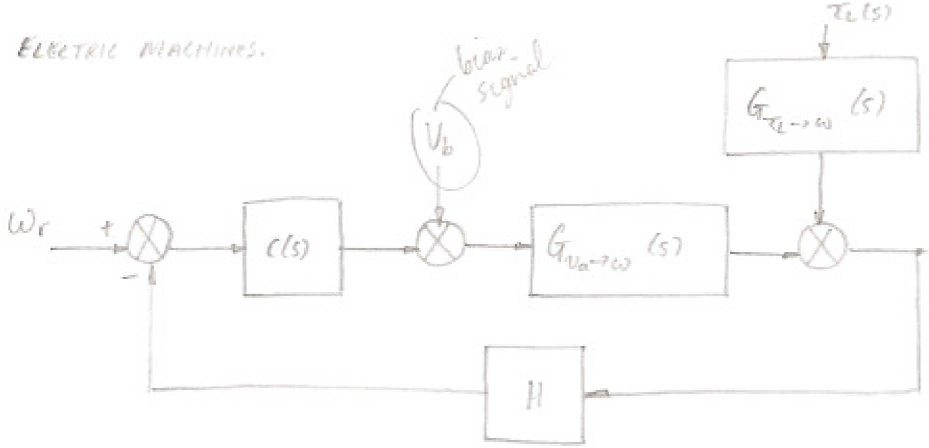
ELECTRIC MACHINES. OCT. 11

#2 ASS'T DUE

DATE: 17/10.

@ 1300.




$$G_{V_a \to \omega}(s) = \frac{k_e I_f}{(Js+D)(L_a s+R_a)+(k_e I_f)^2}$$

$$f = -\frac{\partial W(\lambda, x)}{\partial x} = \frac{\partial W'(i,x)}{\partial x}$$

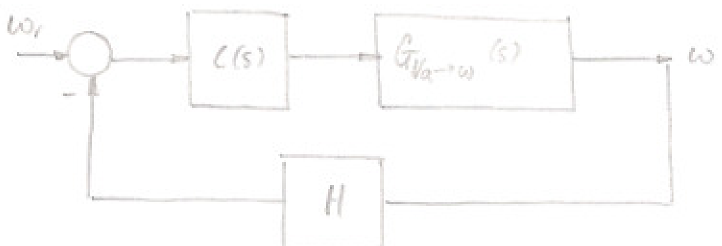
energy

co-energy

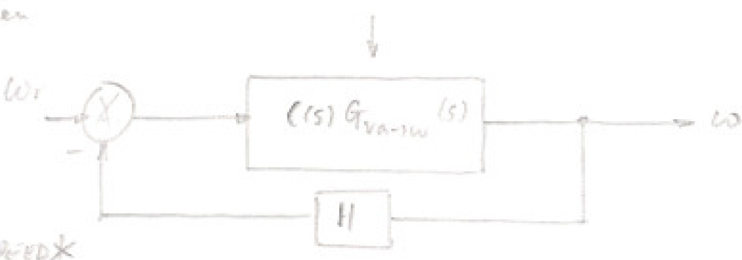
$$C(s) = k_p + \frac{k_I}{s} + k_D s = \frac{k_D s^2 + k_p + k_I}{s}$$

→ Let $\boxed{V_b = 0 \ , \ \tau_L(s) = 0}$ for controller design.

* During testing, if $V_b = 0$, the zero voltage resulting from $\omega_r = \omega$ will force the controller to apply 0V to the motor armature ⇒ motor speed will drop. Applying $V_{bias} = V_{nom, \text{full speed}}$ will ensure that when error = 0, motor runs @ full speed *




* IF MOTOR IS TOO SLOW WE NEED A +VE ERROR, WHICH WILL BE "PROCESSED" TO INCREASE MOTOR SPEED *




$$G_c(s) = \frac{C(s)\,G_{V_a \to \omega}(s)}{1 + H\,C(s)\,G_{V_a \to \omega}(s)}$$

$$= \frac{\left(\frac{k_D s^2 + k_p s + k_I}{s}\right)\left(\frac{k_e I_f}{(Js+D)(L_a s+R_a)+(k_e I_f)^2}\right)}{1 + H\left(\frac{k_D s^2 + k_p s + k_I}{s}\right)\left(\frac{k_e I_f}{(Js+D)(L_a s+R_a)+(k_e I_f)^2}\right)}$$

$$\to G_{equiv}(s) = \frac{(k_e I_f)(k_D s^2 + k_p s + k_I)}{s(Js+D)(L_a s+R_a)+(k_e I_f)^2 + H k_e I_f (k_D s^2 + k_p s + k_I)}$$

closed loop TF

For controller design we need only consider the denominator of $G_c(s)$

$$G_c(s) = \frac{\frac{k_e I_f}{J \cdot L_a}\left(k_D s^2 + k_p s + k_I\right)}{\underbrace{s^3 + \left(\frac{JR_a + DL_a}{JL_a}\right)s^2 + \frac{DR_a}{JL_a}s + \frac{(k_e I_f)^2}{JL_a}s}_{1^{ST}} + \underbrace{\frac{Hk_eI_f k_D s^2 + Hk_eI_f k_p s + Hk_eI_f k_I}{JL_a}}_{2^{ND}}}$$

$$G_c(s) = \frac{\frac{k_e I_f}{J \cdot L_a}\left(k_D s^2 + k_p s + k_I\right)}{s^3 + \left(\frac{JR_a + DL_a + Hk_eI_f k_D}{JL_a}\right)s^2 + \left(\frac{DR_a + (k_eI_f)^2 + Hk_eI_f k_p}{JL_a}\right)s + Hk_eI_f k_I}$$

## CONTROLLER:

$1^{ST}$ ORDER:

$$C(s) = \frac{K}{Ts+1}$$

* $2^{ND}$ ORDER: *

$$C(s) = \frac{k\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$t_s = \frac{3}{\zeta\omega_n}, \quad 0.5 = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$$

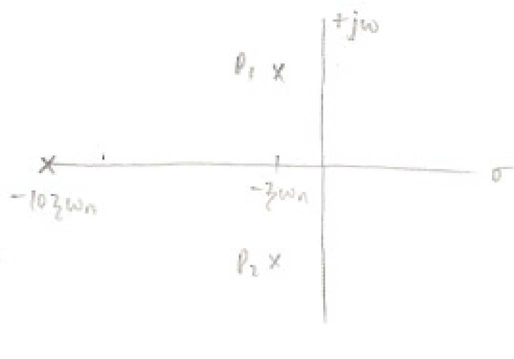
$3^{RD}$ ORDER:

$$\frac{N(s)}{\underbrace{(s^2 + 2\zeta\omega_n s + \omega_n^2)}(s+P_3)}$$

$$P_{1,2} = -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2} \qquad (\zeta \leq 1)$$

$P_3$ is placed further away from origin, make it a real pole, $P_3 = -10\zeta\omega_n$

* $P_{1,2}$ should be dominant *




$e^{P_3(t)}$ → should be quick to "fade out" → large -ve pole → $e^{-\infty t}$: quick to end.

$$\left.\begin{array}{l} e^{\mathrm{Re}(P_1)t} \\ e^{\mathrm{R}(P_2)t} \end{array}\right\} \text{DOMINANT}$$

* $G_{equiv}(s)$ is made to match $G_c(s)$ so that we can solve for $k_I, k_P$ & $k_D$. *

$$G_{equiv}(s) = \frac{N(s)}{s^3 + (P_3 + 2\zeta\omega_n)s^2 + (2\zeta\omega_n P_3 + \omega_n^2)s + P_3\omega_n^2}$$

Match the two denominators and equate coefficients:

$$P_3 + 2\zeta\omega_n = \frac{JR_a + DL_a + Hk_eI_f k_D}{JL_a}$$

$$2\zeta\omega_n P_3 + \omega_n^2 = \frac{DR_a + (k_eI_f)^2 + Hk_eI_f k_P}{JL_a}$$

$$P_3\omega_n^2 = Hk_eI_f k_I.$$

→ First we must select settling time, $t_s$, and overshoot, o.s:

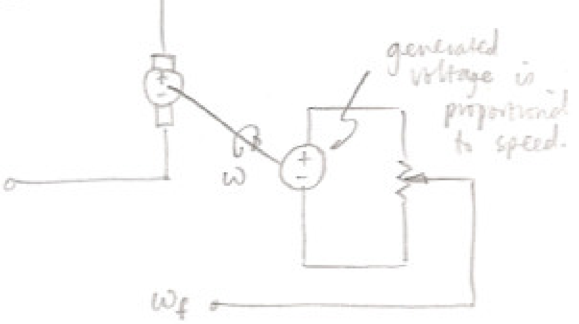
$$t_s = \frac{3}{\zeta\omega_n}, \quad o.s. = \exp\left(\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}\right)$$

These equations give $\omega_n$ and $\zeta$.

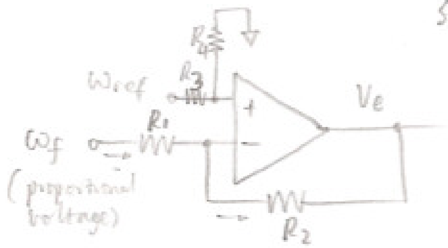
eg. $k_I = \dfrac{P_3\omega_n^2}{Hk_eI_f}$ ...

PROCESS REQUIRES KNOWLEDGE OF MOTOR MODEL, INCLUDING J and D.
TRIAL & ERROR REQUIRED IF THE MODEL IS NOT KNOWN.

TACHOGENERATOR.




SUBTRACTOR

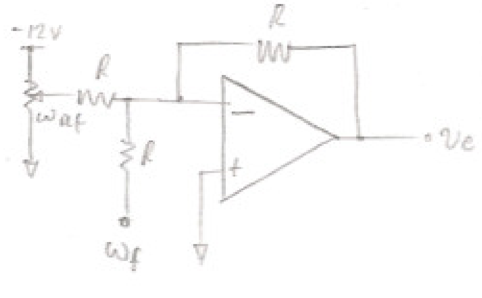



$$V^+ = \frac{\omega_r}{R_3 + R_4} \cdot R_4$$

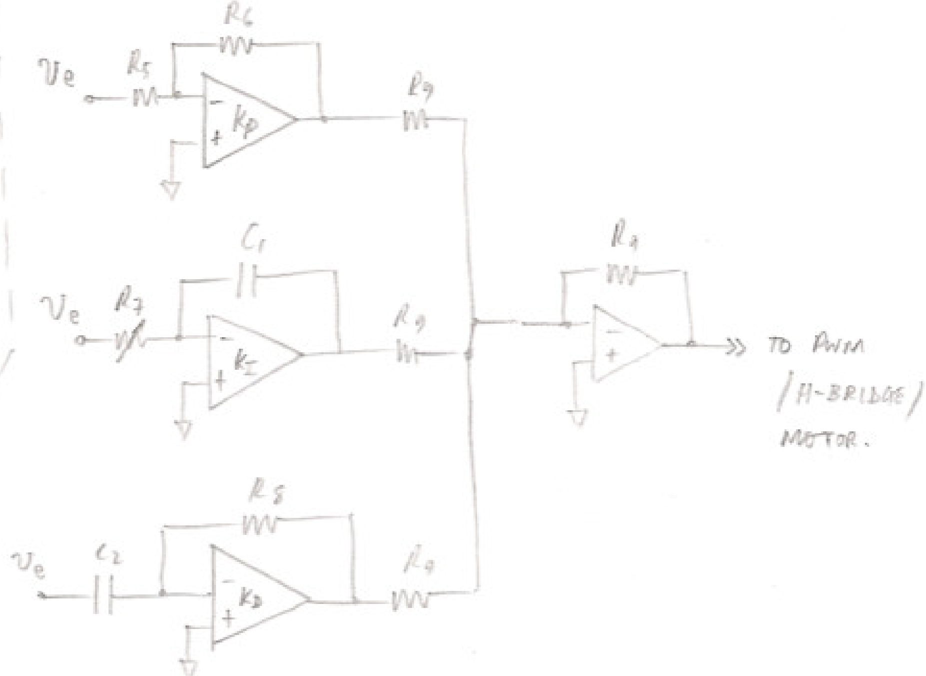
$$\frac{\omega_f - V^+}{R_1} = \frac{V_+ - V_e}{R_2}$$

$$V_e = \omega_r - \omega_f$$

OR: SUMMING AMP.




CONTROLLER:




μ PROCESSOR CONTROLLER.