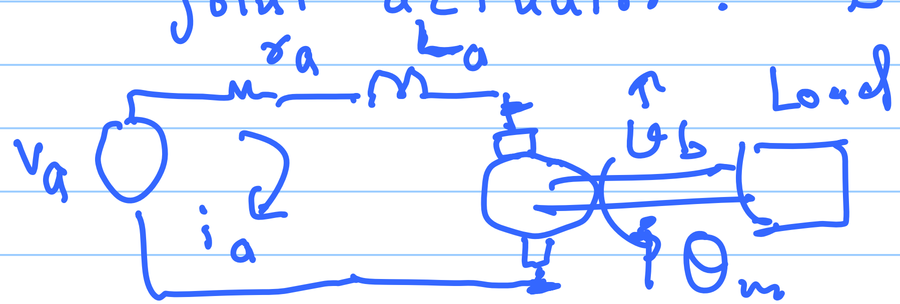
Lecture 36+37

Note Title 11/30/2005

|| "Independent joint control"

each joint of the manipulator is controlled independently and the robot dynamics are essentially treated as a disturbance.

joint actuator : "DC servomotor"



$$v_a = i_a r_a + L_a \frac{di_a}{dt} + v_b$$

$$v_b = k_e \dot{\theta}_m$$

Our simplifying assumptions:

1. ignore L_a
2. current amplifier that can supply a demanded current i_a

Can show:

$$\boxed{\tau = k_m i_a}$$

$$\tau_L = \eta\,\tau_m$$

$$\dot{\theta}_L = \frac{\dot{\theta}_m}{\eta}$$

$$\ddot{\theta}_L = \frac{\ddot{\theta}_m}{\eta}$$

$$\theta_L = \frac{\theta_m}{\eta}$$

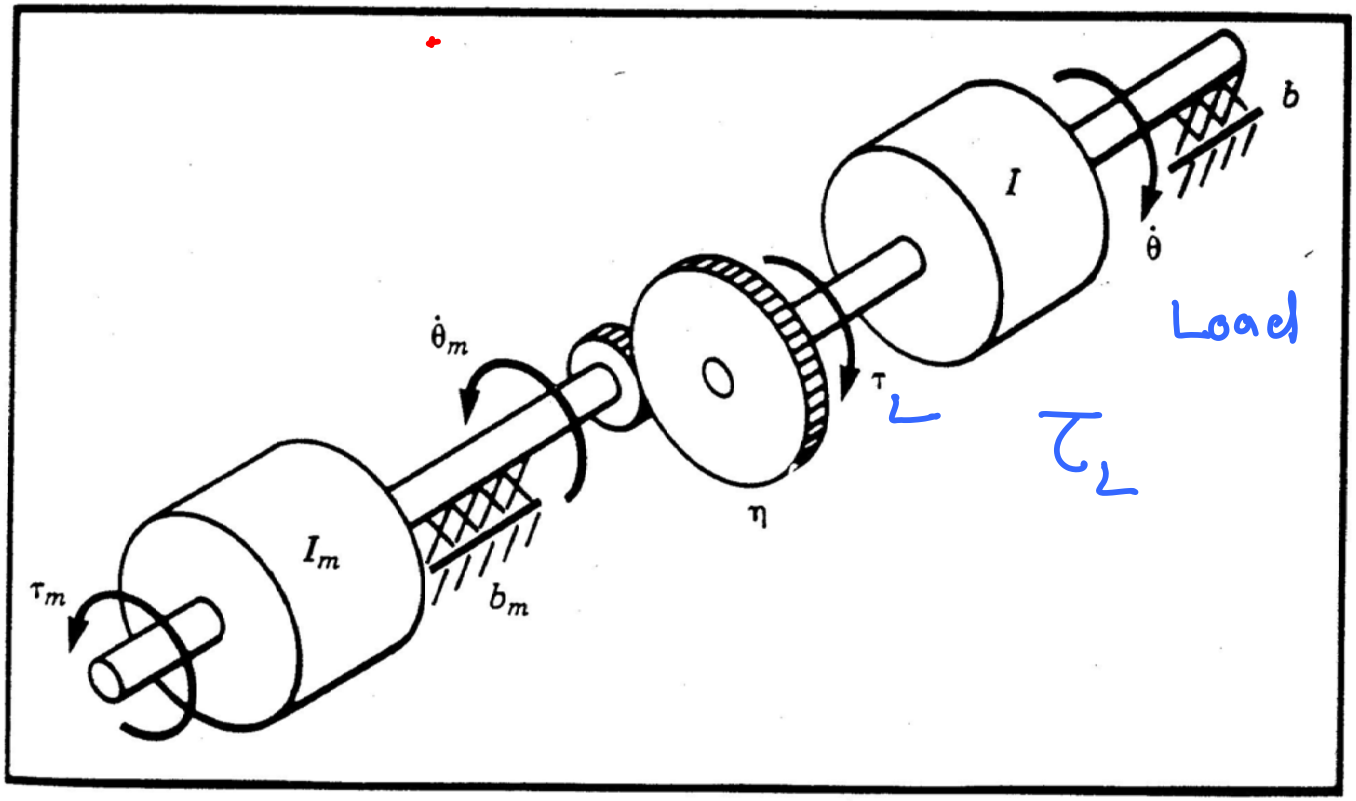


FIGURE 9.12 Mechanical model of a DC torque motor connected through gearing to an inertial load.

$$\tau_m = I_m\ddot{\theta}_m + b_m\dot{\theta}_m + \frac{1}{\eta}\left(I_L\ddot{\theta}_L + b_L\ddot{\theta}_L\right)$$

$\eta = 20$ to 50

$$= \underbrace{\left(I_m + \frac{I_L}{\eta^2} \right)}_{I_{eff}} \ddot{\theta}_m + \underbrace{\left(b_m + \frac{b_L}{\eta^2} \right)}_{b_{eff}} \dot{\theta}_m$$

with max or ave values often exp. det.

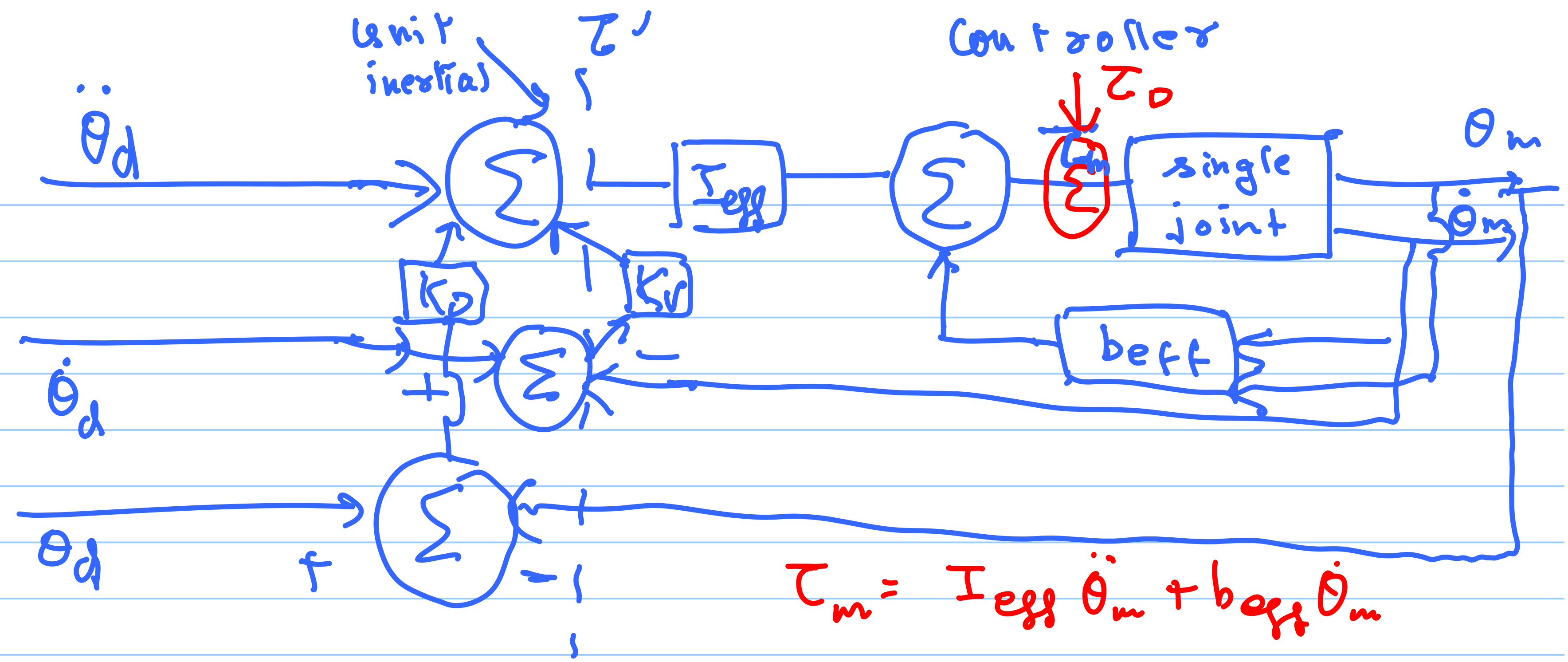
Gearing ratios reduces the effect of varying loads / and the coupling effect due to other joints.

$$\begin{cases} \tau_m = I_{eff}\, \ddot{\theta}_m + b_{eff}\, \dot{\theta}_m \\ \tau_m = k_m\, i_a \end{cases}$$

given this eqn., I Could use my partitioned control law to develop the joint

$$\tau_m = \alpha \tau' + \beta$$

$$\tau' = \ddot{\theta}_m$$



$$\tau_m = I_{eff}\,\ddot{\theta}_m + b_{eff}\,\dot{\theta}_m$$

$$\Rightarrow \quad \ddot{e} + k_v\dot{e} + k_p e = 0$$

$$s^2 + 2\xi\omega_n s + \omega_n^2 = 0$$

$$k_p = \omega_n^2 \qquad k_v \xrightarrow{\xi=1} 2\sqrt{k_p}$$

upper limit on k_p : comes due to "resonances" in the mechanical system → (flexibility)

open loop

→ mech.

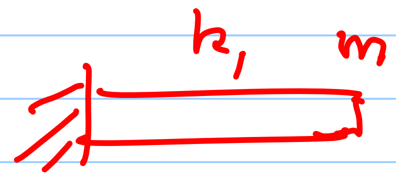
$$m\ddot{x} + b\dot{x} + kx = f \quad \rightsquigarrow \quad I\ddot{\theta} + b\dot{\theta} + k\theta = \tau$$

$$\omega_{res} = \omega_n = \sqrt{\frac{k}{m}}$$

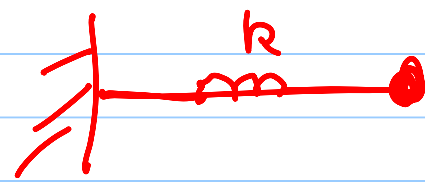
closed loop natural freq. $\omega_n \boxed{\leq \frac{1}{2}\,\omega_{res}}$

$$\Rightarrow \quad k_p = \omega_n^2 \leq \frac{1}{4}\,\omega_{res}^2$$

Take them as recipes :



beam of mass m



point mass $.23m$

$$\omega_{res} = \sqrt{\frac{k}{.23m}}$$

I will give ω_{res} or even k_p directly

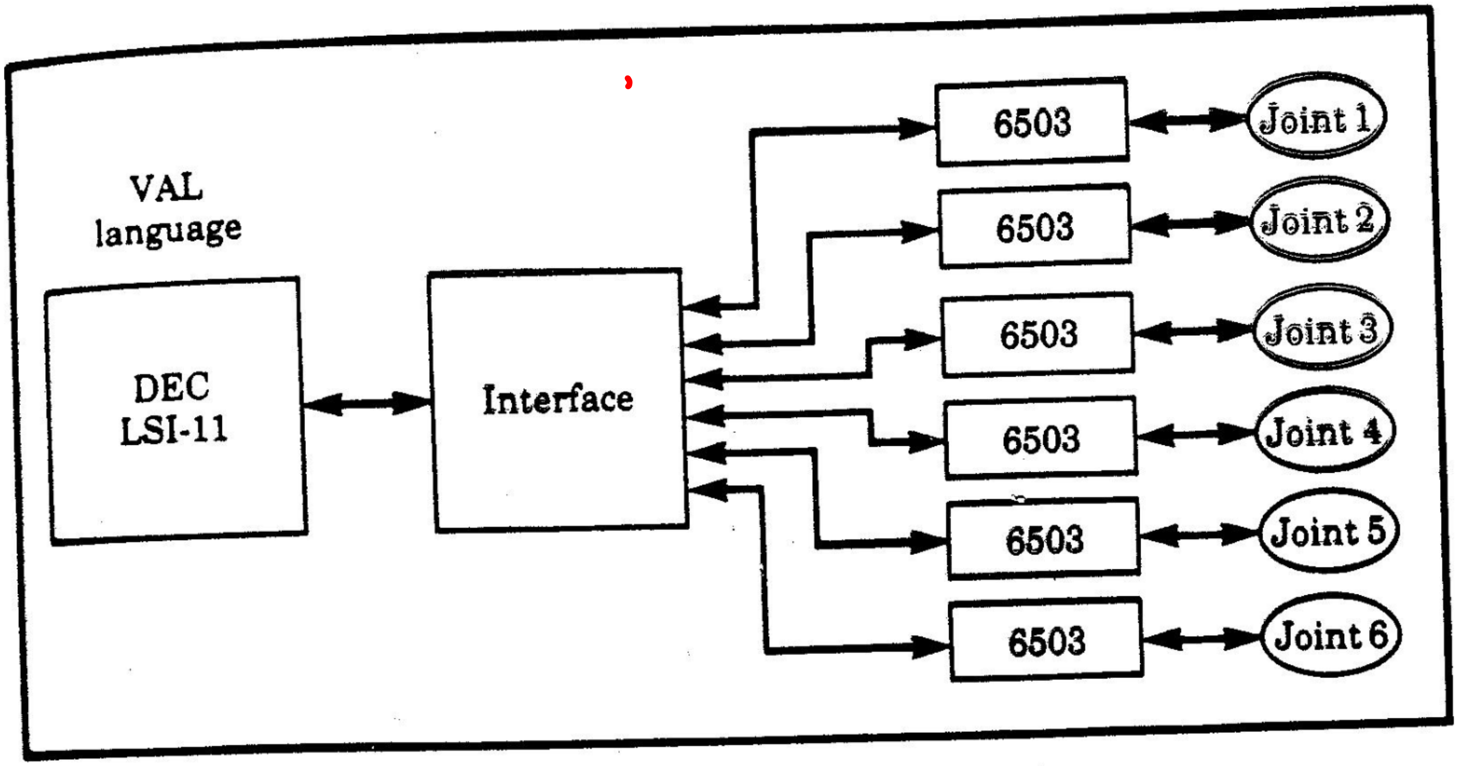


FIGURE 9.14 Hierarchical computer architecture of the PUMA 560 robot control system.

Independent joint control for Puma 560 architecture

$\tau = k_m i_a$

$\tau = I_{eff}\ddot{\theta} + b_{eff}\dot{\theta}$

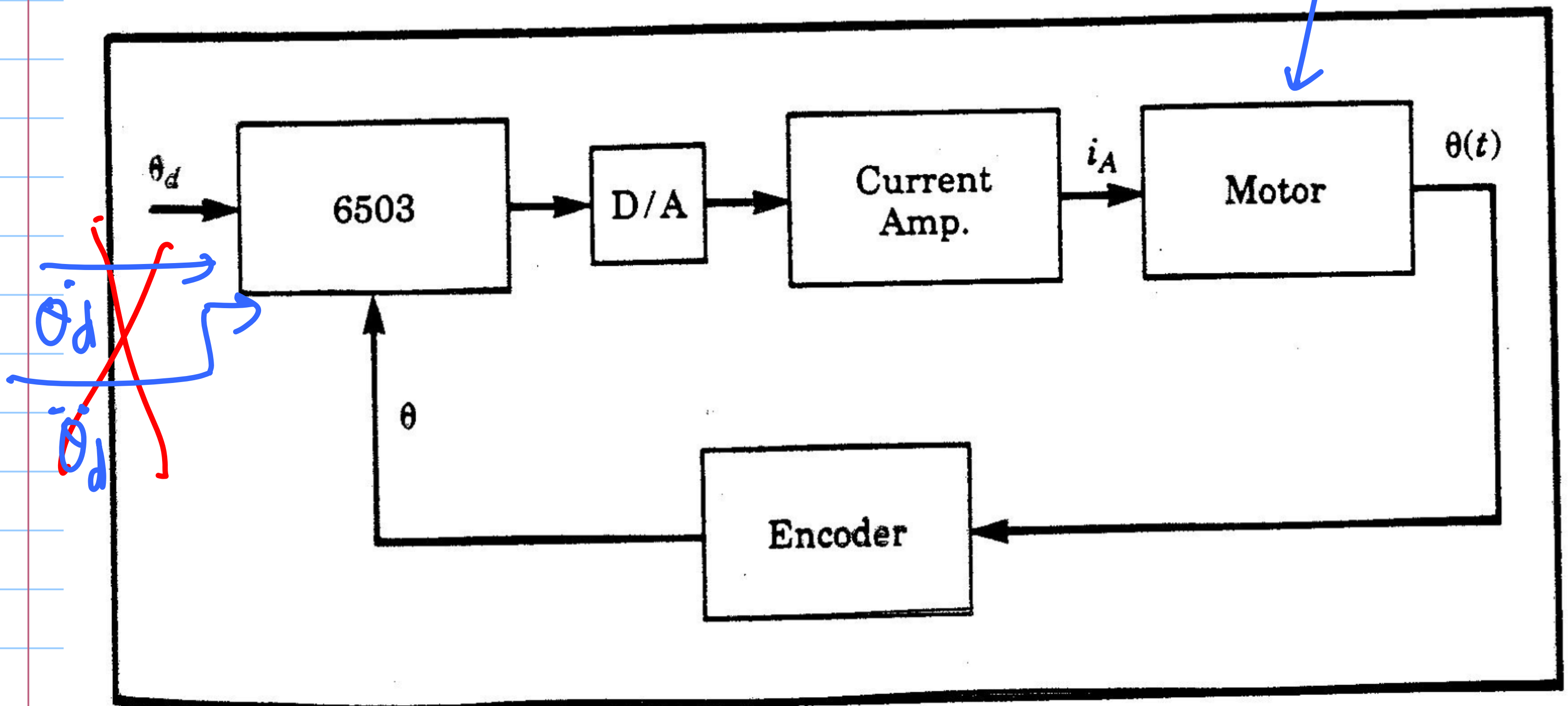
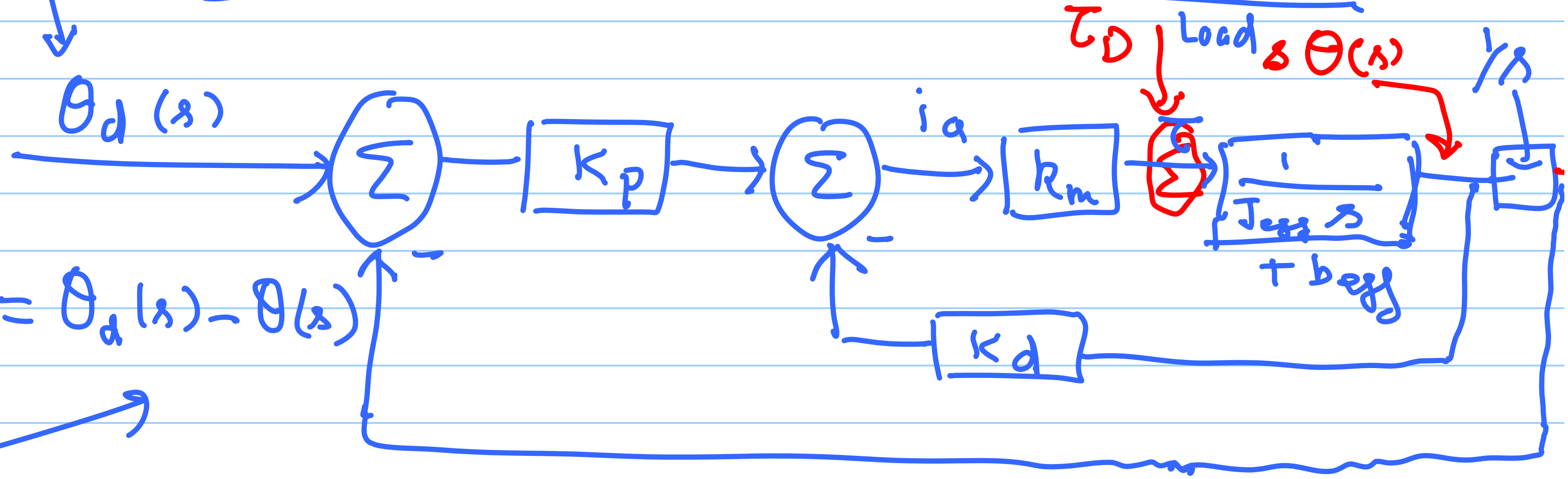


FIGURE 9.15 Functional blocks of the joint control system of the PUMA 560.

step, ramp.

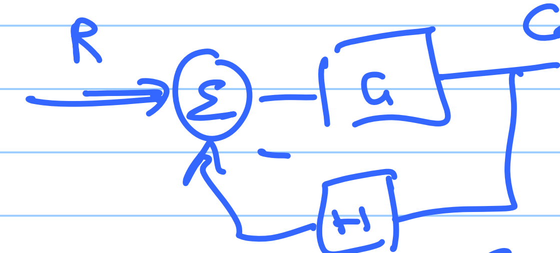
Classical linear Control (a la 383)



$$E(s) = \theta_d(s) - \theta(s)$$

$$e_{ss} = \boxed{\lim_{s \to 0} sE(s)} =$$

F.V.T.

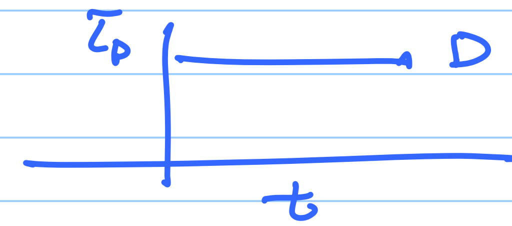


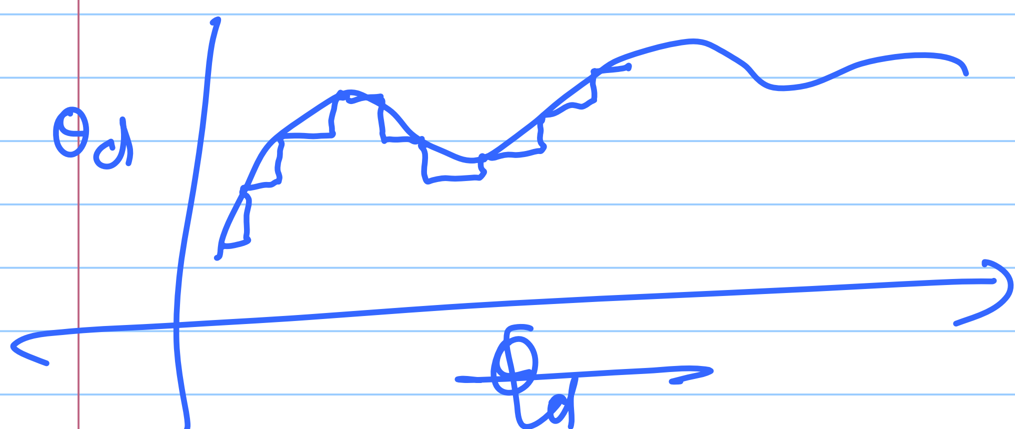
$$T(s) = \frac{C(s)}{R(s)} = \frac{G}{1+GH}$$

Can show (leave it as exercise)

$$e_{ss} = \boxed{\frac{\eta D}{K_m K_p}}$$

D = size of const dist. (mg.)





official

End of course material

Off-line Robot programs:

Robot language:

① joint-level command

② Cartesian space commands (for/inv kin. / Dynamics)

③ WORLD Model → pick up object A (blah)

Computer lang.

m/c an.

high level c/c++

place it at
location X.

1. How to grasp

2. How to avoid collisions
with obstacles ...

GAVE DEMO OF MPK (Motion Plng Kernel)
and path planners for obstacle avoidance.