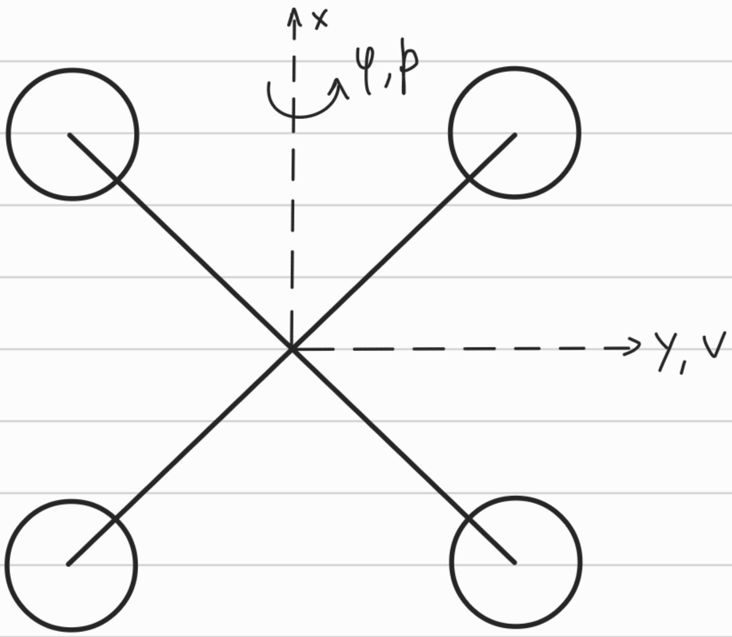
ACS EXAM PROJECT 22/23

LATERAL DYNAMICS OF MULTIROTOR UAV



QUADROTOR IN X-CONFIG.

FRD CONVENTION FOR BODY AXES

$$x = \begin{bmatrix} v \\ p \\ \varphi \end{bmatrix}$$

$$\dot{v} = Y_p p + Y_v v + Y_\delta \delta + g\varphi$$
$$\dot{p} = L_p p + L_v v + L_\delta \delta$$
$$\dot{\varphi} = p$$

DERIVATIVES: NOMINAL VALUES AND STANDARD DEVIATIONS

$$y = [p \;\; \varphi \;\; a_y]^T \qquad a_y = Y_v v + Y_p p + Y_\delta \delta$$

$$y = Cx + Dw$$

$$C = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ Y_v & Y_p & 0 \end{bmatrix} \qquad D = \begin{bmatrix} 0 \\ 0 \\ Y_\delta \end{bmatrix}$$

Control - Oriented Assumptions

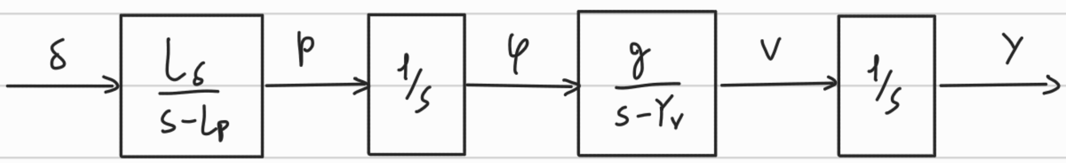
① $Y_\delta = 0$
② $Y_p = 0$
③ $Y_v = 0$

$$\Longrightarrow \quad \dot\varphi = p \qquad \dot p = L_p p + L_\delta \delta \qquad \dot v = Y_v + g\varphi$$

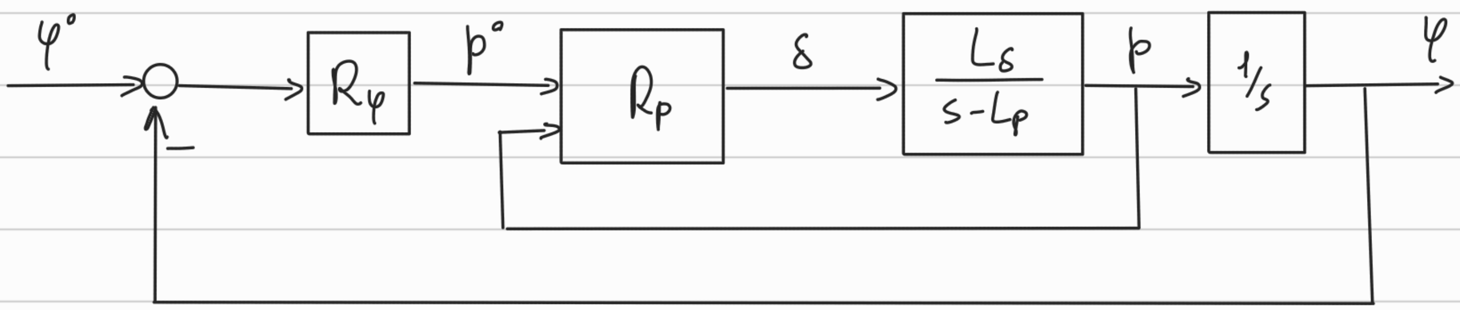
$$\varphi = \frac{1}{s} p$$

$$p = \frac{L_\delta}{s - L_p}\delta$$

$$v = \frac{g}{s - Y_v}\varphi$$



Task 1: Attitude Control

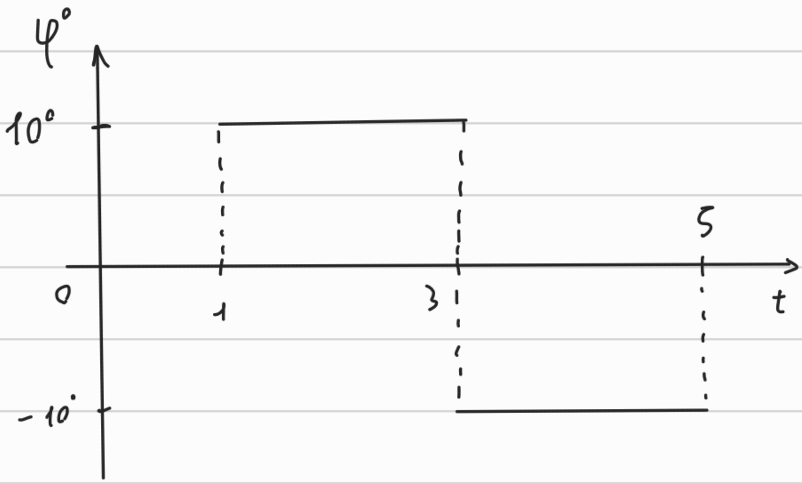


R_φ : Proportional $\qquad$ R_p : 2 dof PID controller

Requirements:

- Performance: Response of φ to a variation of φ° must be equivalent to a second order system with $\omega_n \geq 10$ rad/s and $\xi \geq 0{,}9$

- CONTROL EFFORT LIMITATION :



$|\delta| \leq 5\%$

(IN THE MODEL φ IS IN RADIANS)

CONTROLLER STRUCTURES

P: $u = K_p e$

PID2: $u = K_p e + \frac{K_I}{s} e + \frac{K_D s}{T_f s + 1}(-y)$

(OUTPUT FEEDBACK IMPLEMENTATION OF DERIVATIVE FUNCTION)

MATLAB FUNCTIONS

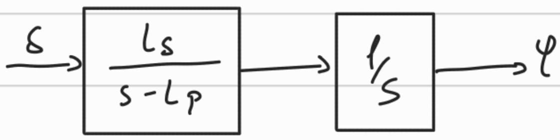
- tunable PID
- tunable PID2

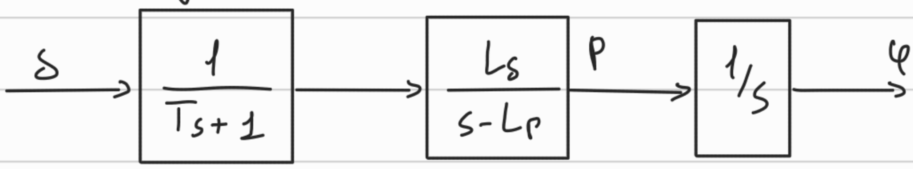
FIXED T_f : $T_f = 0{,}01\ s$

TASK 2: ROBUSTNESS ANALYSIS

- RESIDUALS FROM SYSTEM IDENTIFICATION
  (TREAT $\pm 3\sigma$ BOUNDS AS UNCERTAINITY INTERVALS)

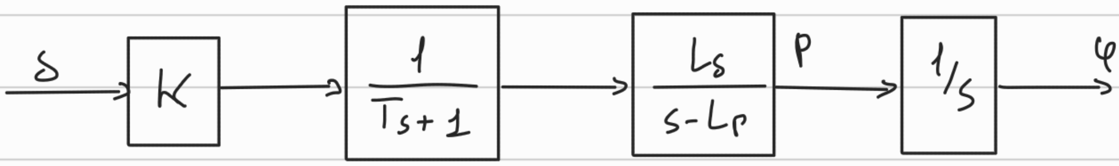
- DYNAMICS OF THE MOTORS:





$T_s = 0{,}02\,s$

Battery Voltage Drop



K: $\bar{K} = 1 \longrightarrow$ CAN DECREASE DOWN TO 0,75

BASELINE: RS AND RP ANALYSIS ON THIS BLOCK DIAGRAM

EXTRA: RS AND RP ANALYSIS WITH INITIAL ASSUMPTIONS

TASK 3: DYNAMICS OF THE OBSERVER

REAL SYSTEM: ABLE TO MEASURE p AND a_y

- DESIGN AN OBSERVER FOR THE STATE (GOAL: ESTIMATE φ)

- DEFINE A SUITABLE TUNING SO THAT THE OBSERVER DOES NOT AFFECT PREVIOUS CONCLUSIONS ON NP, RS AND RP

TASK 4: MONTE CARLO VALIDATION OF COMPLETE SYSTEM

CONSIDER:

- INITIAL MODEL (W/O ASSUMPTIONS)

- INCLUDE MOTOR DYNAMICS, GAIN UNCERTAINTY AND OBSERVER

CARRY OUT A MONTECARLO STUDY TO VALIDATE PERFORMANCE REQUIREMENTS AND CONTROL EFFORT MODERATION REQUIREMENTS.

STEP RESPONSE

- % OVERSHOOT
- SETTLING TIME

(STEPINFO MATLAB)

DOUBLET RESPONSE

- MAXIMUM OF δ

→ MEAN VALUE STANDARD DEVIATION

EXPECTED OUTPUT

- A POWERPOINT PRESENTATION
  - PROBLEM FORMULATION
  - SOLUTION APPROACH
  - RESULTS

- MATLAB CODE PRODUCED FOR THE PROJECT