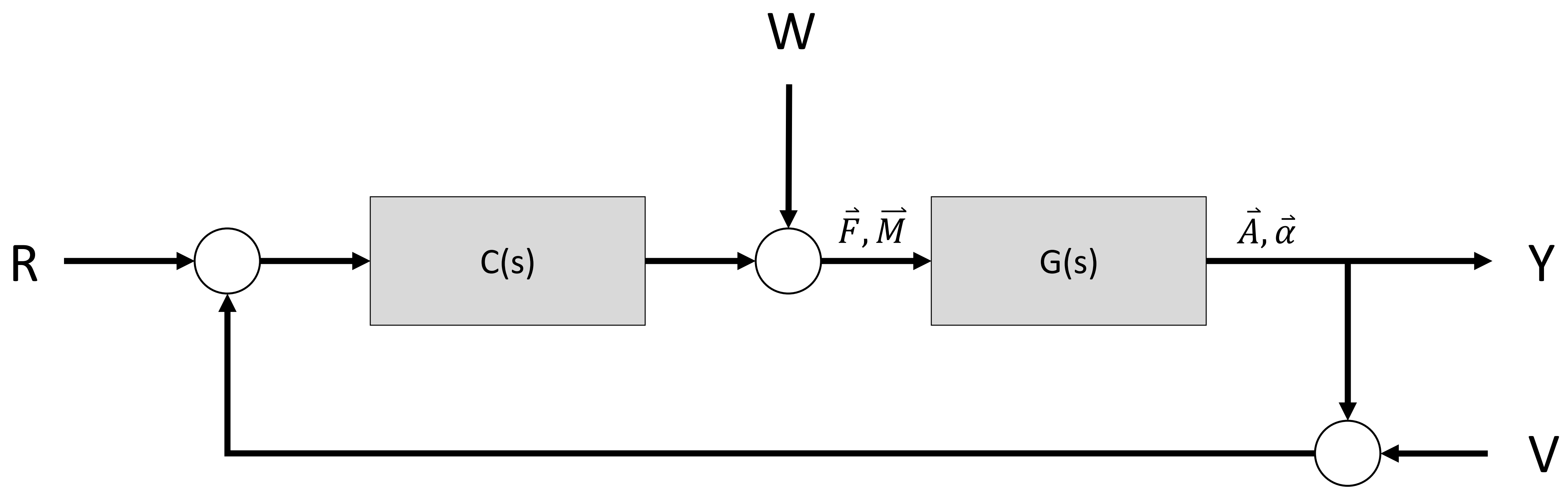
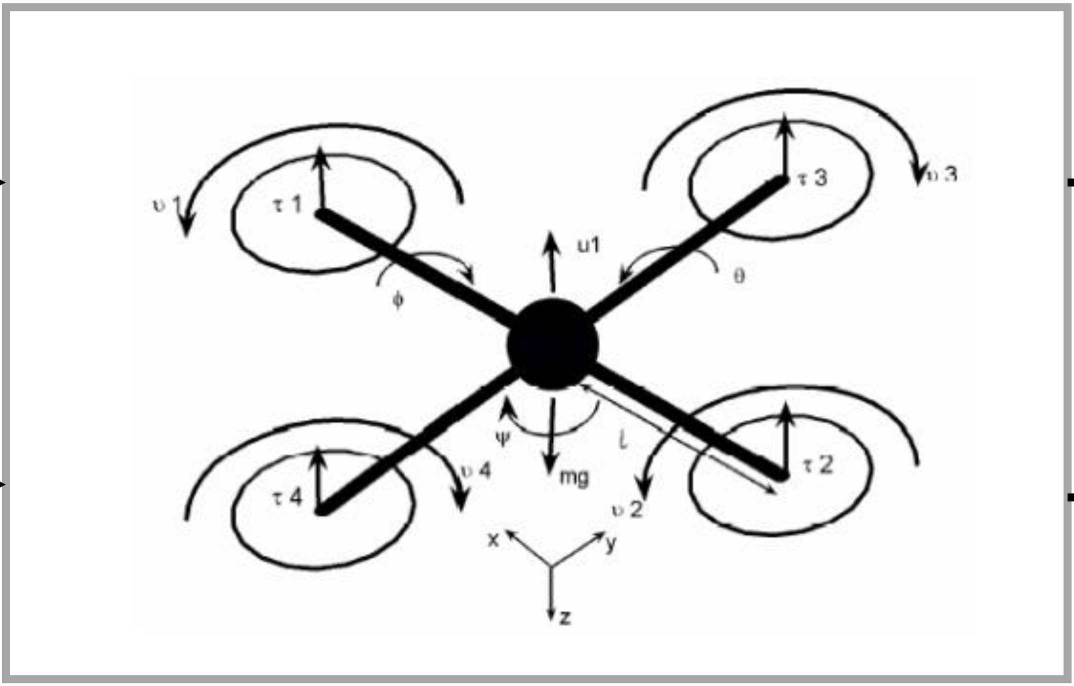

W
R
C(s)
$\vec{F}, \vec{M}$
G(s)
$\vec{A}, \vec{\alpha}$
Y
V

Thrust, T
Drag, F_D
Gravity, F_g

$\overrightarrow{F}$

Roll Torque
Pitch Torque
Yaw Torque

$\overrightarrow{M}$



$$\overrightarrow{A_i} = \begin{bmatrix} \ddot{x} \\ \ddot{y} \\ \ddot{z} \end{bmatrix}_{inertial}$$

$$\overrightarrow{\alpha_b} = \begin{bmatrix} \ddot{\phi} \\ \ddot{\theta} \\ \ddot{\psi} \end{bmatrix}_{body}$$

<u>Forces</u>

$$T = \sum T_i = k_t \omega^2$$

$$F_D = -k_d \dot{\vec{x}}$$

$$F_g = m\ddot{z}$$

<u>Moments</u>

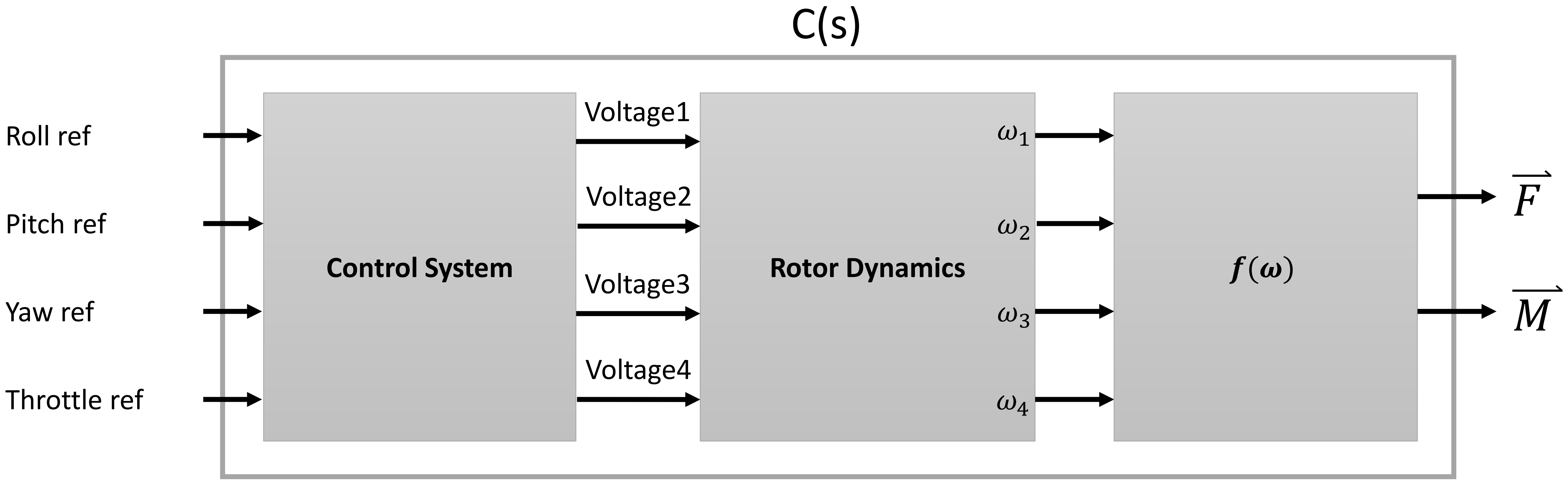
$$\tau_\phi = k_t L\ (\omega_3^2 - \omega_4^2)$$

$$\tau_\theta = k_t L\ (\omega_1^2 - \omega_2^2)$$

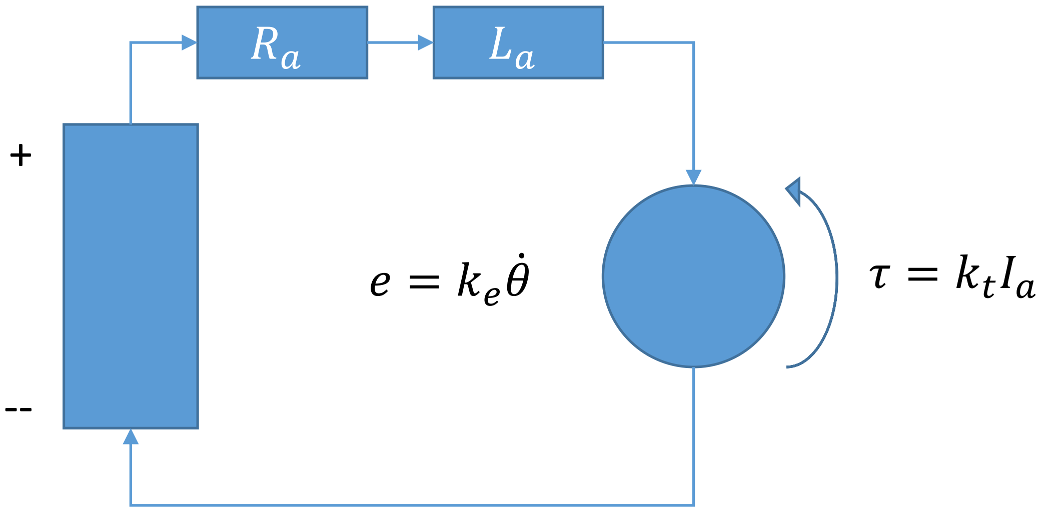
$$\tau_\psi = k_\psi L\ (\omega_1^2 - \omega_2^2 + \omega_3^2 - \omega_4^2)$$

Assuming body and propeller gyroscopic moments are small

$\dot{\theta}\dot{\psi}(I_y - I_z)$	$J_r \dot{\theta} \Omega_r$
$\dot{\phi}\dot{\psi}(I_z - I_x)$	$J_r \dot{\phi} \Omega_r$
$\dot{\phi}\dot{\theta}(I_x - I_y)$	$J_r \dot{\Omega}_r$


C(s)
Roll ref
Pitch ref
Yaw ref
Throttle ref
Control System
Voltage1
Voltage2
Voltage3
Voltage4
Rotor Dynamics
ω_1
ω_2
ω_3
ω_4
$\boldsymbol{f(\omega)}$
$\overrightarrow{F}$
$\overrightarrow{M}$

Rotor Dynamics



$$J_m\ddot{\theta} + b\dot{\theta} = k_t I_a$$
$$L_a\frac{di_a}{dt} + R_a i_a = V_a - k_e\dot{\theta}$$

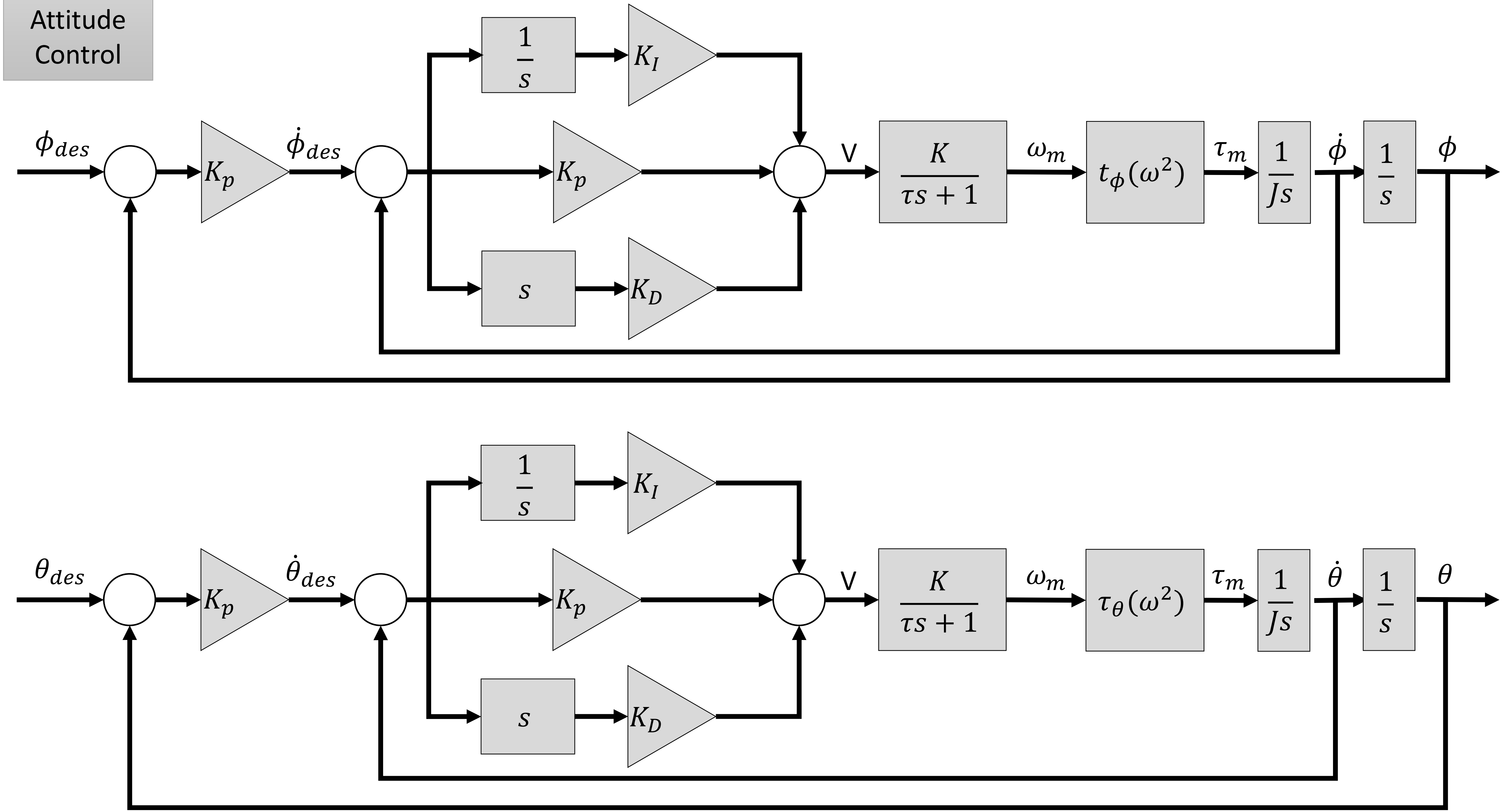
$$\xrightarrow{\mathcal{L}(s)}$$

$$J_m\,\Theta s^2 + b\,\Theta s = k_t \mathbb{I}_a$$
$$L_a\mathbb{I}_a s + R_a\mathbb{I}_a = \mathbb{V}_a - k_e\Theta s$$

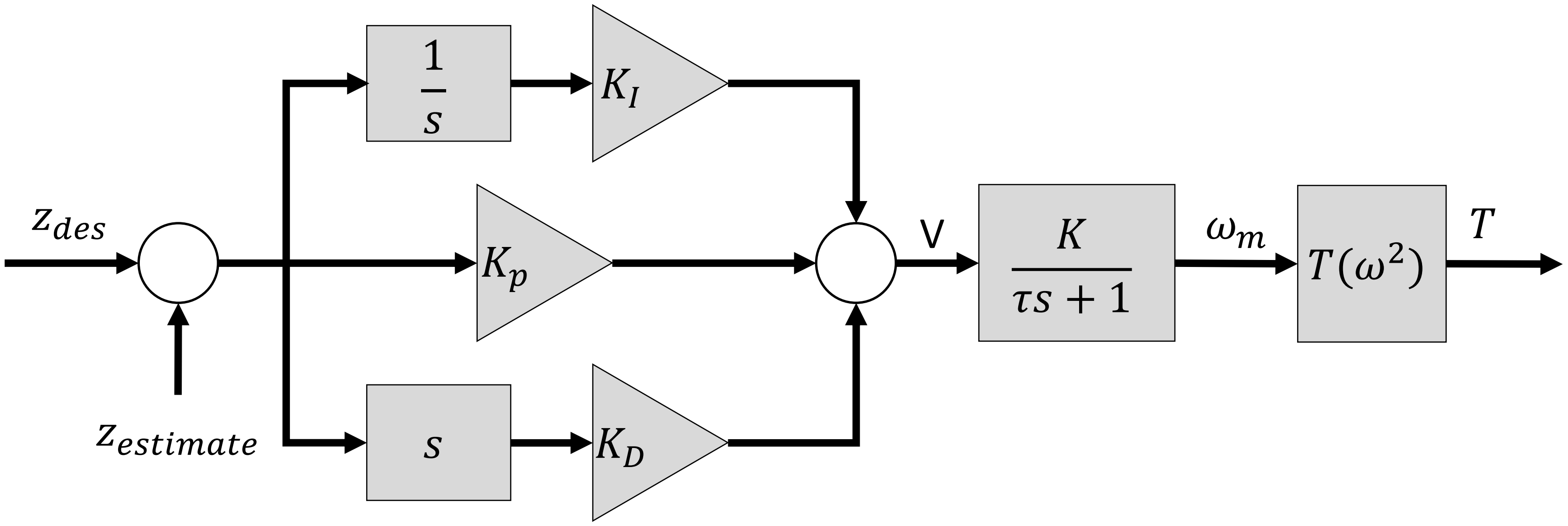
$$\Longrightarrow$$

$$\frac{\Theta}{\mathbb{V}} = \frac{K}{s(\tau s + 1)}$$
$$\frac{\Omega}{\mathbb{V}} = \frac{K}{\tau s + 1}$$

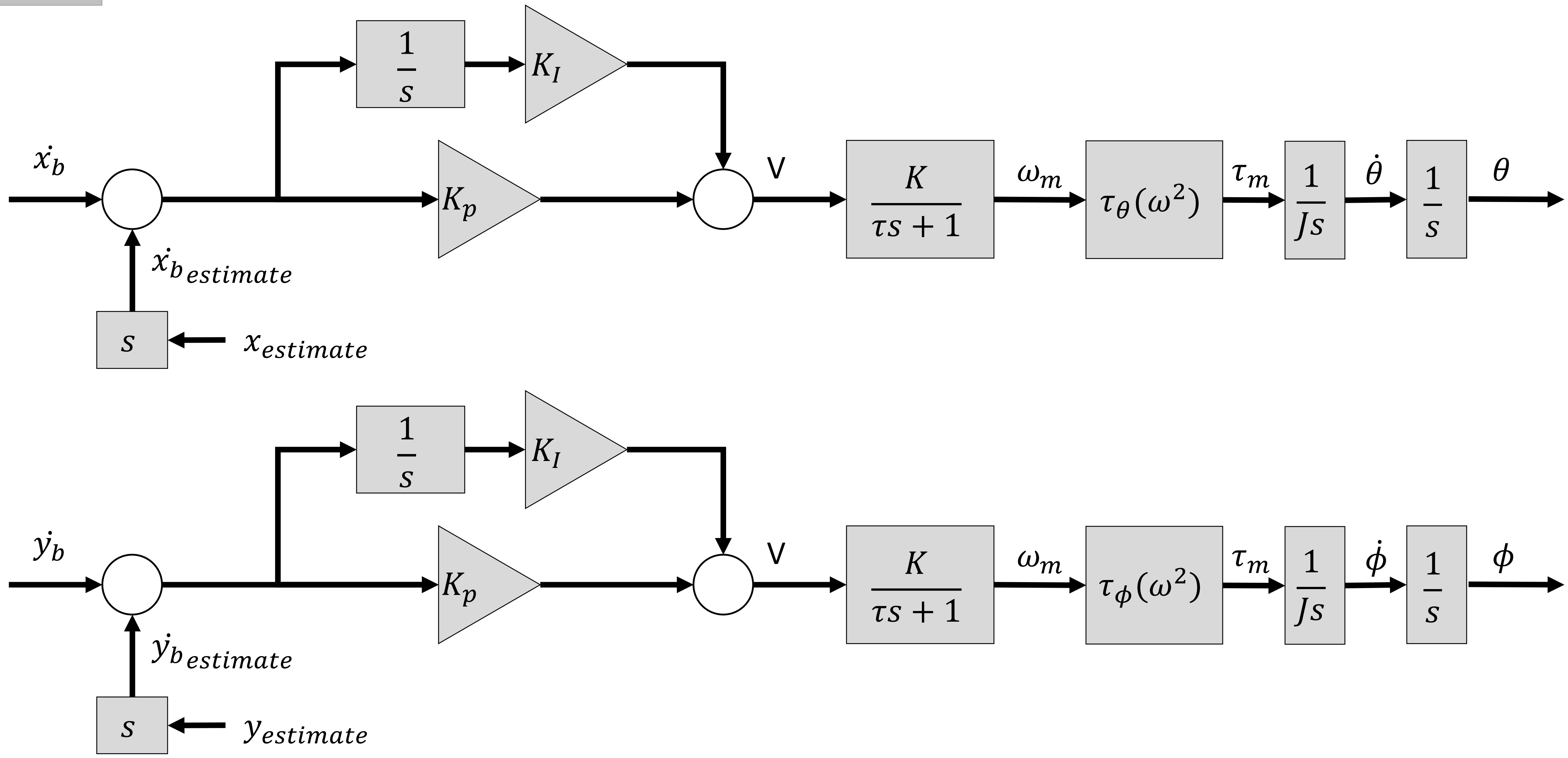
Attitude Control



Altitude Control



Velocity Control



Position Control