System Control

6-1. Electrical Motor

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Electrical Motor

Development of Integrated Vehicle Control System of "Fine-X" Which Realized Freer Movement.

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Toyota Motor Corporation.

TOYOTA

TOYOTA Freer Movement Control System

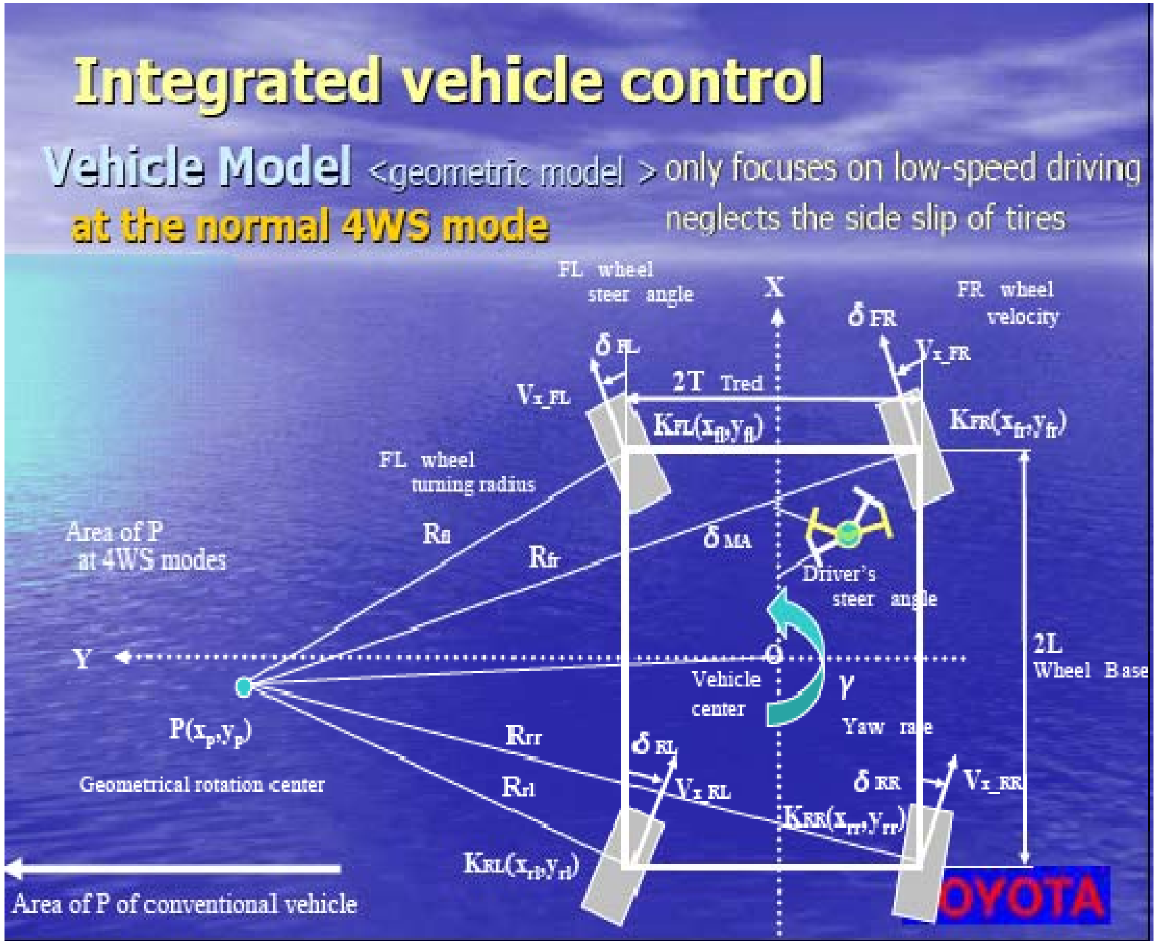
4Wheel independent drive

4wheel independent steering

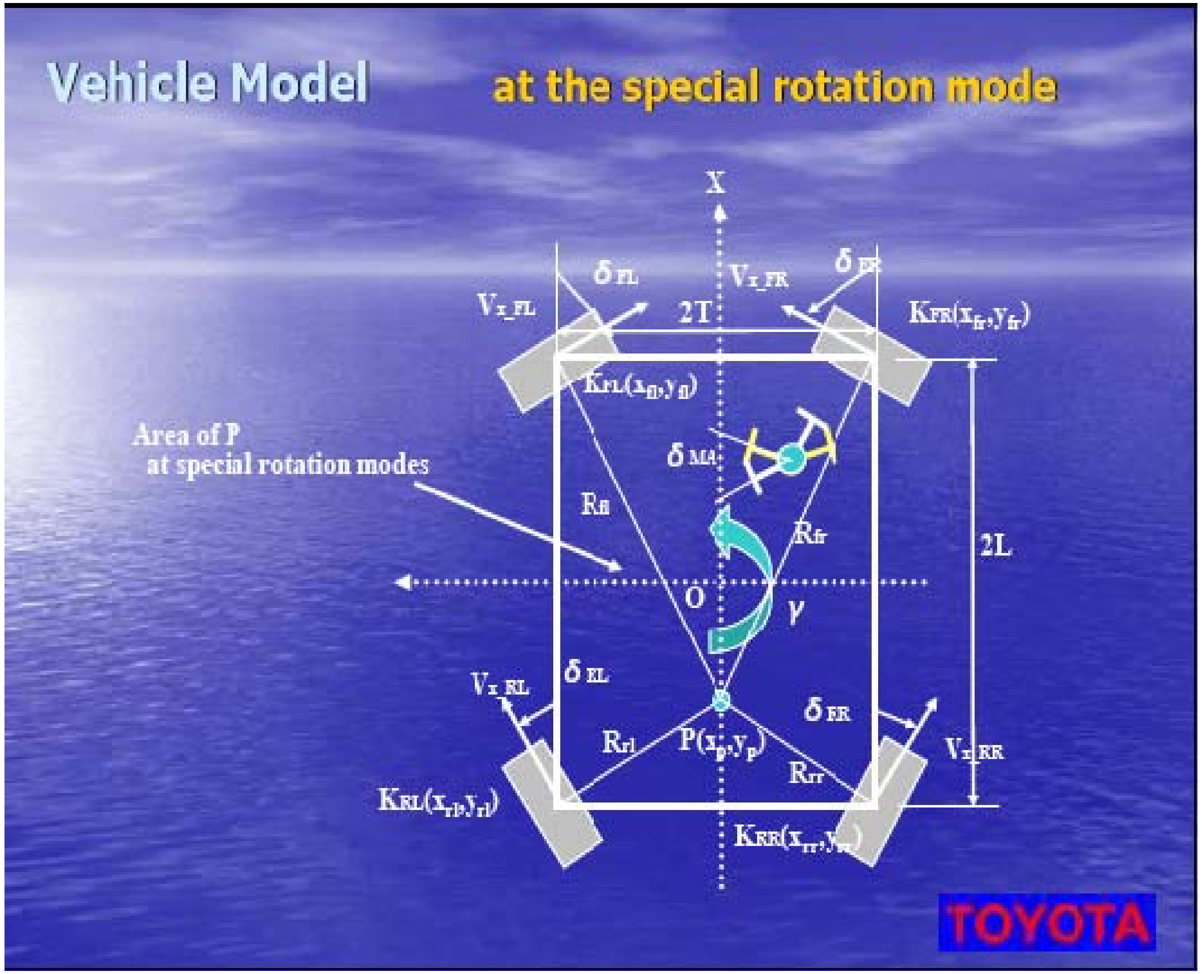
4wheel independent braking

By 'wheel-in-motor'

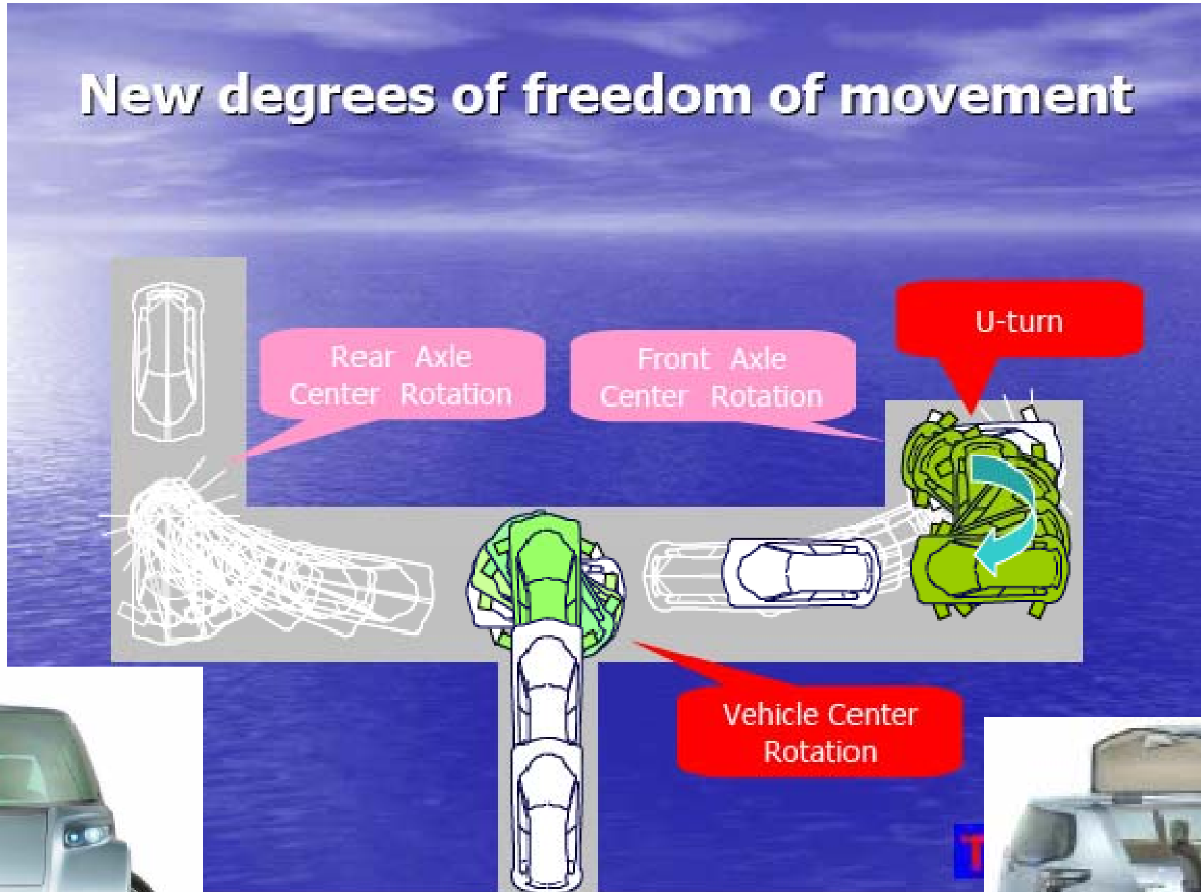
TOYOTA Freer Movement Control System



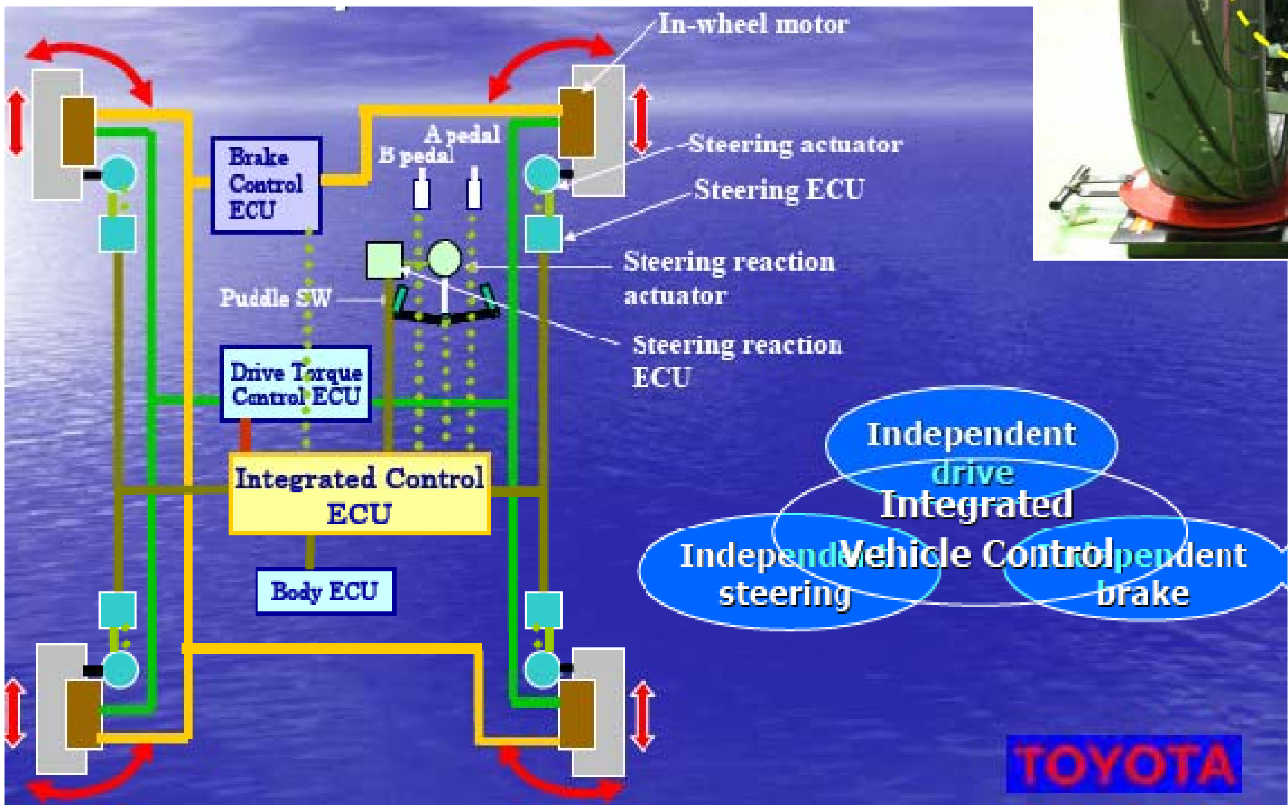
TOYOTA Freer Movement Control System

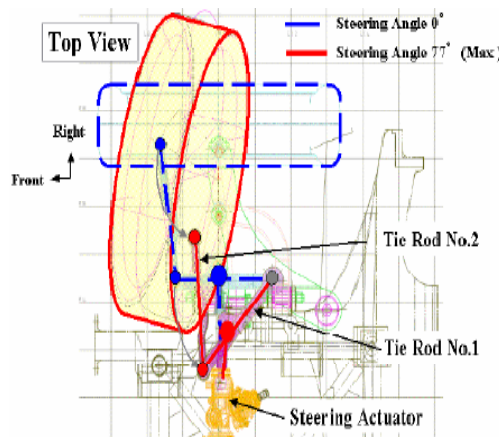


TOYOTA Freer Movement Control System for Auto-Parking

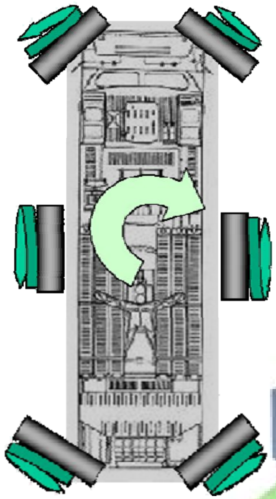


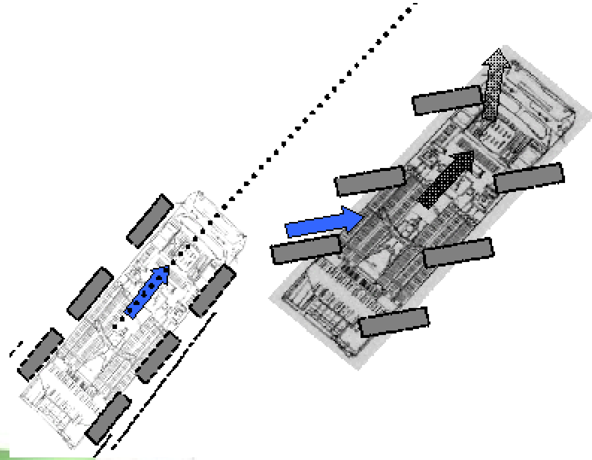
TOYOTA Freer Movement Control System for Auto-Parking

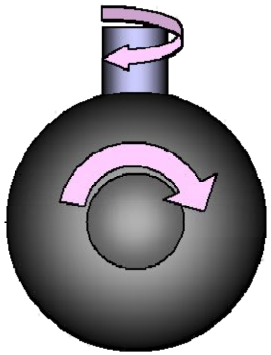


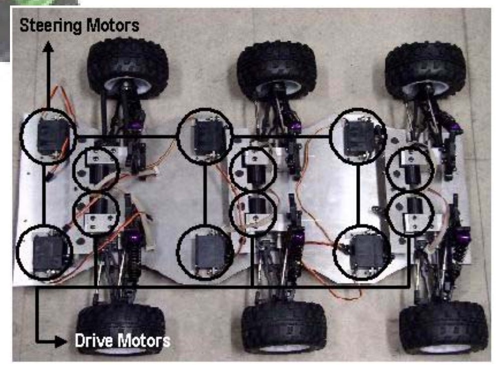


6WD6WS Vehicle

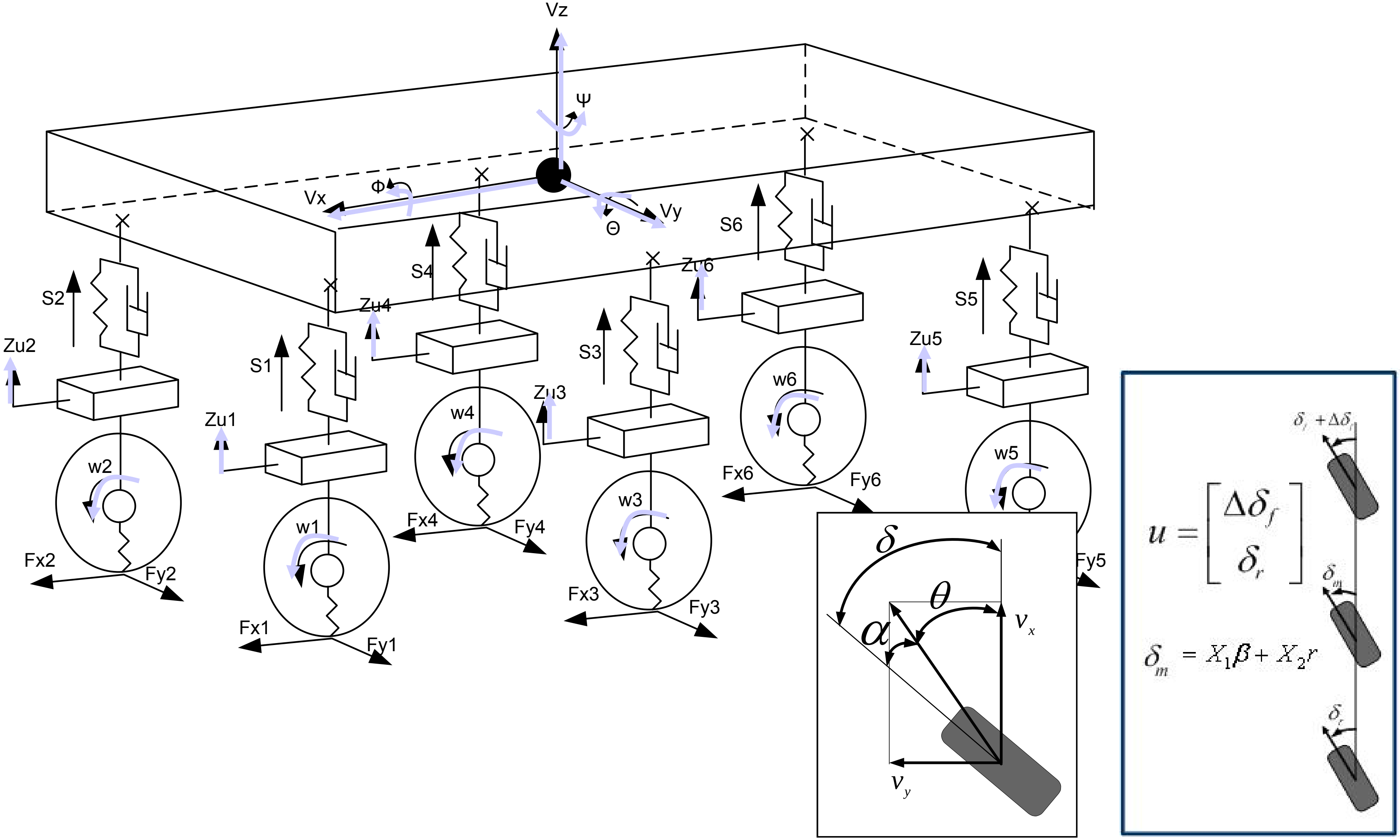




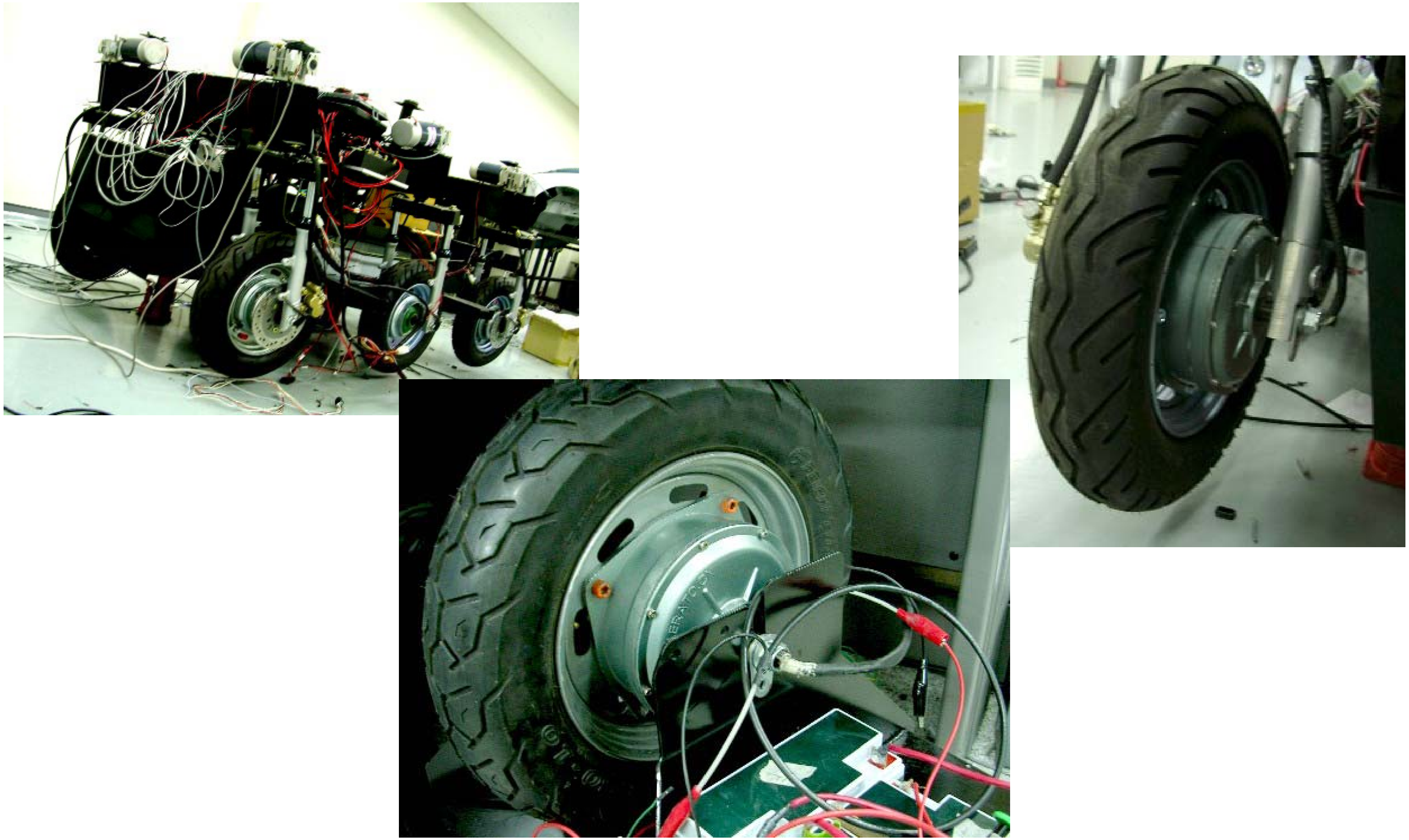




6WD6WS Vehicle



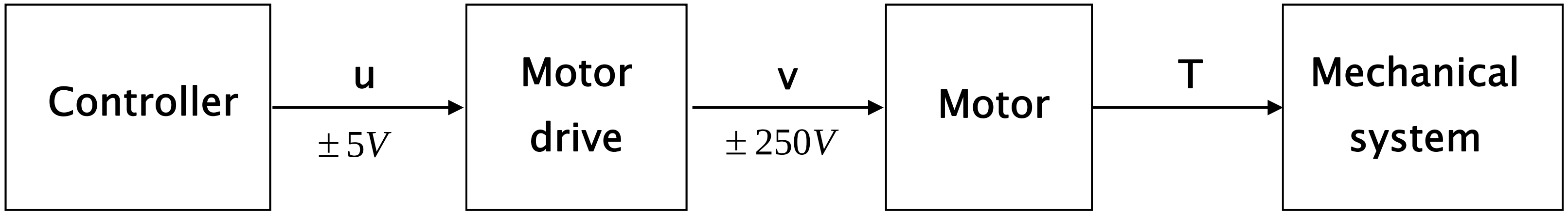
BLDC Wheel-in-Motor of 6WD6WS Vehicle



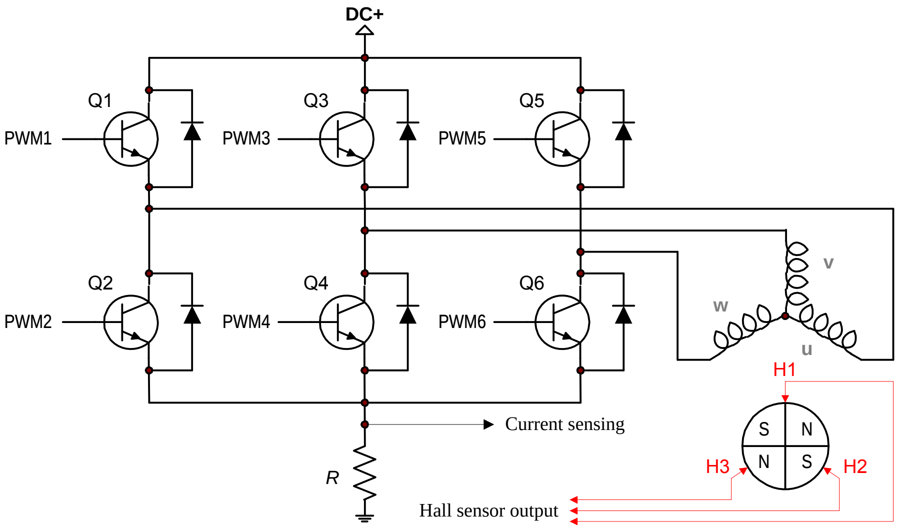
Sectional View of BLDC Motor

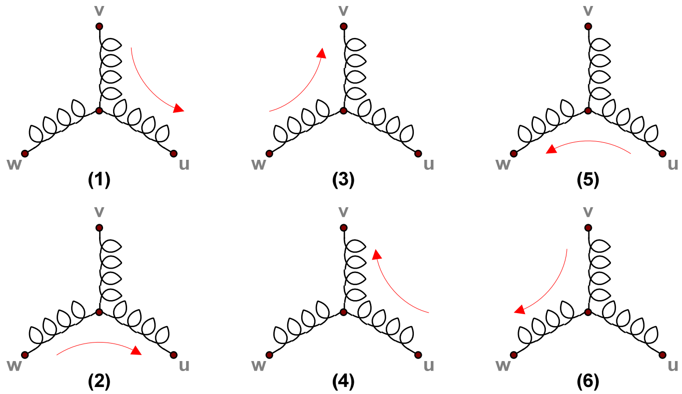
Constitution of DC Servomotor System

Motor drive system :



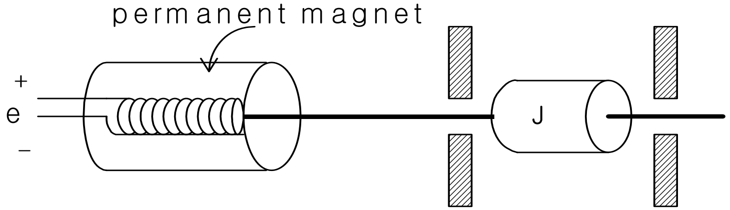
3 phase BLDC motor driver :





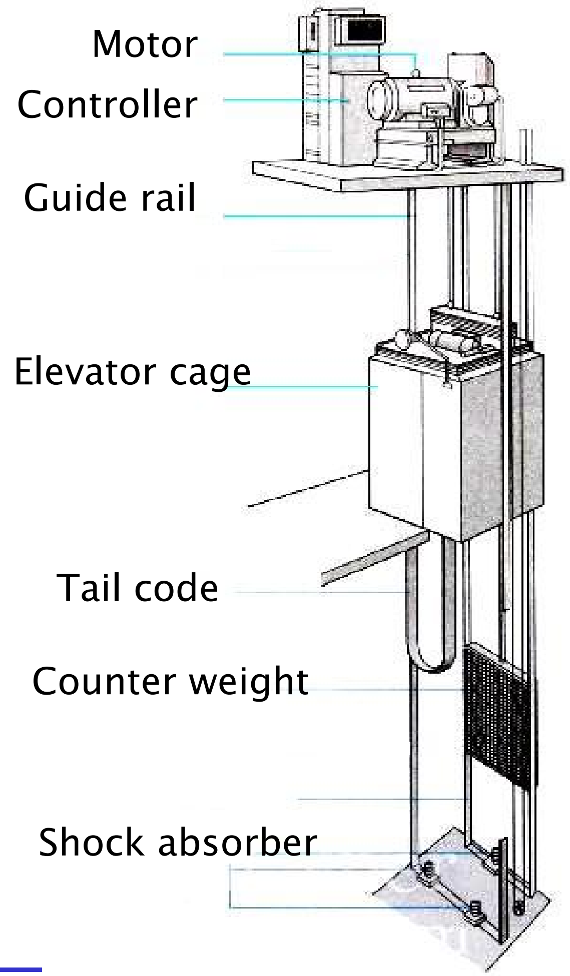
Constitution of DC Servomotor System

DC servo motor :

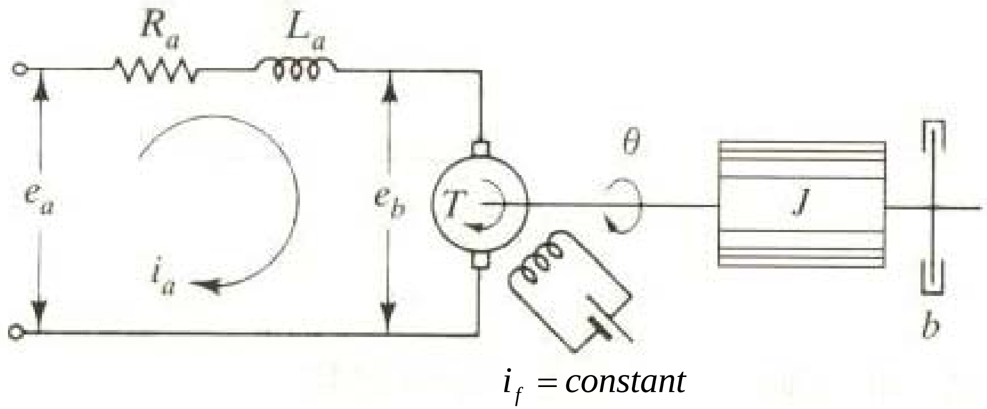


Electric Energy → Mechanical energy

ex) Elevator structure :



Armature Control of DC Servomotors



Variables :

R_a : armature resistance, Ω

L_a : armature inductance, H

i_a : armature current, A

i_f : field current, A

e_a : applied armature voltage, V

e_b : back emf , V

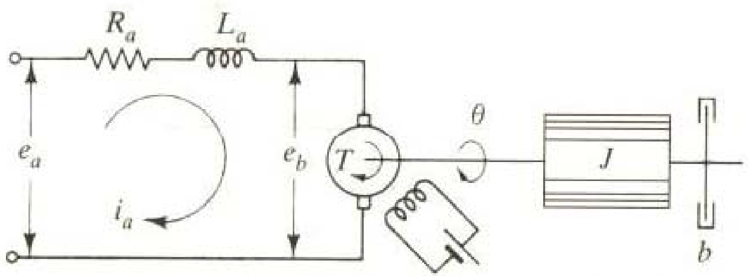
θ : angular displacement of the motor shaft, rad

T : torque developed by the motor, N-m

J : equivalent moment of inertia of the motor and load referred to the motor shaft, kg-m^2

b : equivalent viscous-friction coefficient of the motor and load referred to the motor shaft, N-m/rad/s

Armature Control of DC Servomotors



$i_f = constant$

The torque of motor : $T = K i_a$ $\quad K: motor-torque \ \ constant$

For a constant flux, the induced voltage : $e_b = K_b \dfrac{d\theta}{dt}$ $\quad K_b: back\ emf \ \ constant$

Armature circuit D.E : $L_a \dfrac{di_a}{dt} + R_a i_a + e_b = e_a$

Inertia and friction : $J \dfrac{d^2\theta}{dt^2} + b\dfrac{d\theta}{dt} = T = K i_a$

Armature Control of DC Servomotors

Laplace transforms of equations :

$$e_b = K_b \frac{d\theta}{dt} \qquad\qquad K_b s\Theta(s) = E_b(s)$$

$$L_a \frac{di_a}{dt} + R_a i_a + e_b = e_a \quad \longrightarrow \quad (L_a s + R_a) I_a(s) + E_b(s) = E_a(s)$$

$$J\frac{d^2\theta}{dt^2} + b\frac{d\theta}{dt} = T = K\,i_a \qquad\qquad (Js^2 + bs)\Theta(s) = T(s) = KI_a(s)$$

$$T.F = \frac{\Theta(s)}{E_a(s)} = \frac{K}{s(R_a Js + R_a b + KK_b)} = \frac{\dfrac{K}{R_a J}}{s\left(s + \dfrac{R_a b + KK_b}{R_a J}\right)}$$

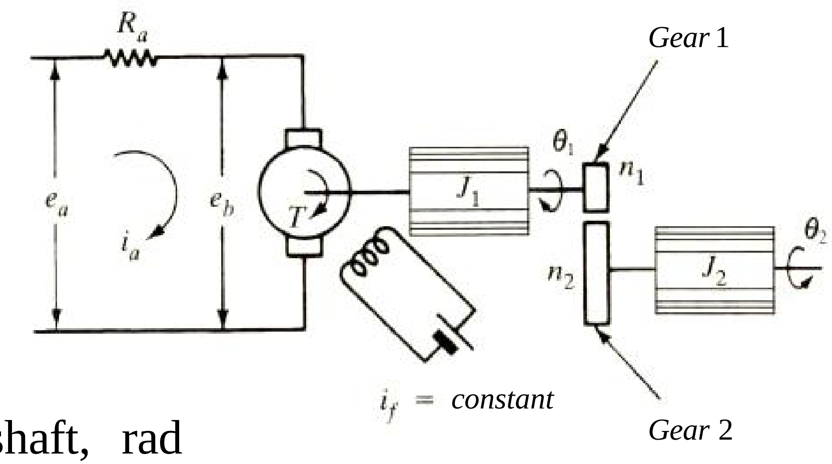
$$= \frac{K_m}{s(T_m s + 1)}$$

$$K_m = K/(R_a b + KK_b) = motor\ gain\ constant$$

$$T_m = R_a J/(R_a b + KK_b) = motor\ time\ constant$$

Example of a DC Servomotor System

ex) servo-motor system



R_a : armature resistance, Ω

i_a : armature current, A

i_f : field current, A

e_a : applied armature voltage, V

e_b : back emf, V

θ_1 : angular displacement of the motor shaft, rad

θ_2 : angular displacement of the load shaft, rad

T : torque developed by the motor, N-m

J_1 : equivalent moment of inertia of the motor, kg-m^2

J_2 : equivalent moment of inertia of the load, kg-m^2

The torque of motor : $T = K i_a$

For a constant flux, the induced voltage : $e_b = K_b \dfrac{d\theta}{dt}$ $\quad K_b$: *back emf constant*

Example of a DC Servomotor System

Armature circuit D.E : $R_a i_a + e_b = e_a$

Inertia and friction : $J_{1eq} = J_1 + \left(\frac{n_1}{n_2}\right)^2 J_2$

Laplace transforms of these equations :

$$K_b s\Theta(s) = E_b(s), \quad (L_a s + R_a) I_a(s) + E_b(s) = E_a(s), \quad (Js^2 + bs)\Theta(s) = T(s) = K I_a(s)$$

$$T.F = \frac{\Theta(s)}{E_a(s)} = \frac{K}{s(R_a Js + R_a b + K K_b)} = \frac{\frac{K}{R_a J}}{s\left(s + \frac{R_a b + K K_b}{R_a J}\right)}$$

$$= \frac{K_m}{s(T_m s + 1)}$$