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PID Control of a DC Position Servo Drive

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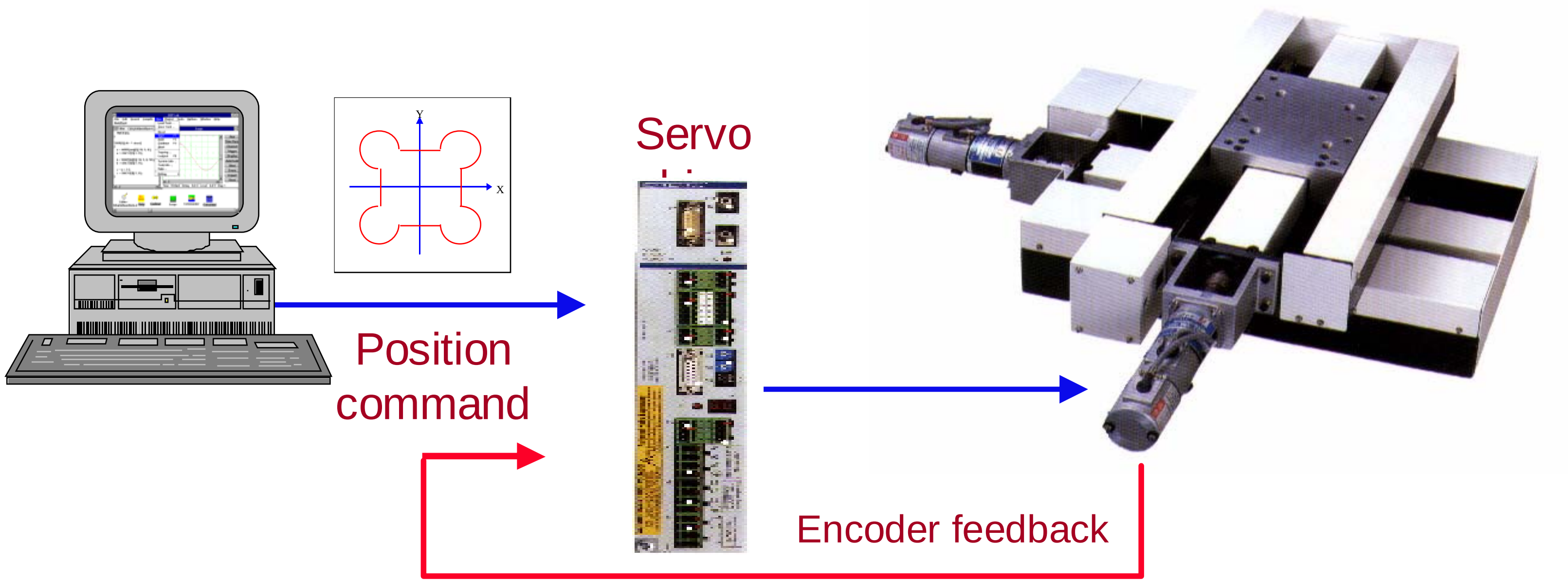
Position Control of a DC Servo Drive for a Motion Table



How to synthesize the PID control law for a DC position servo drive?

- Block Diagram Construction and Modeling
- Parameterization
- Control Architecture or Controller Configuration
- Control Laws or Control Equations
- Determination of Control Parameters
- Controller Realization

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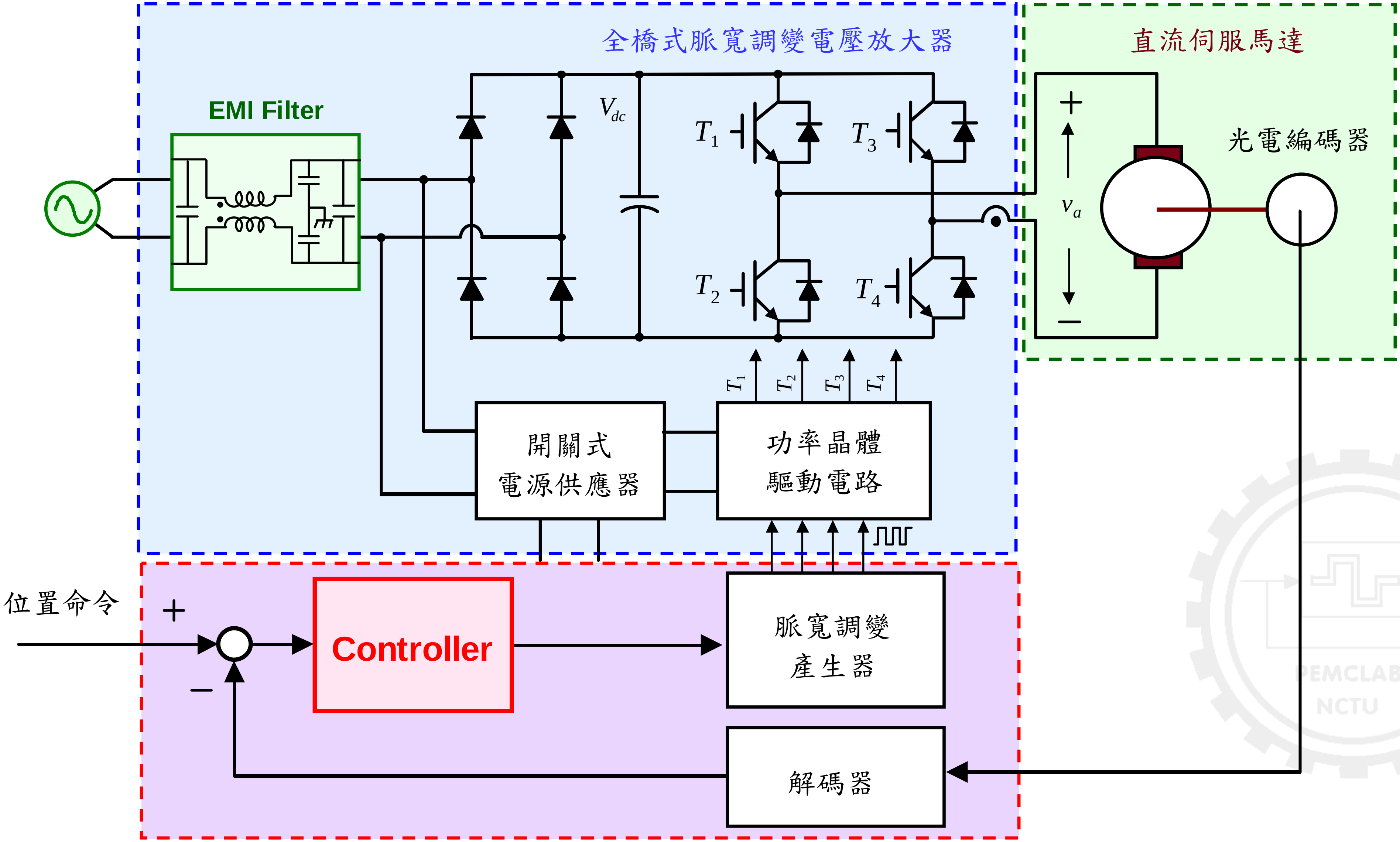
Block Diagram of PID Control of a DC Position Servo



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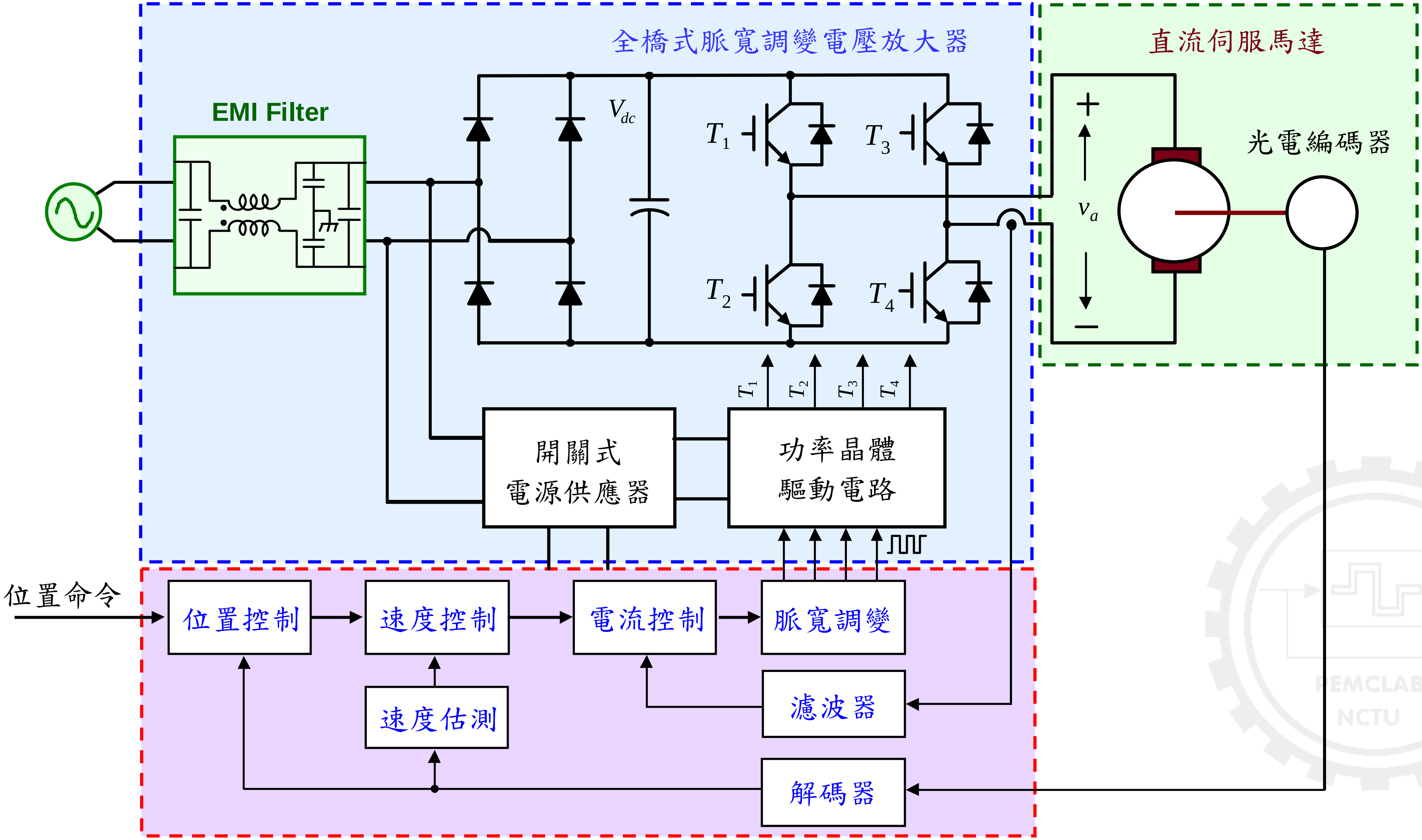
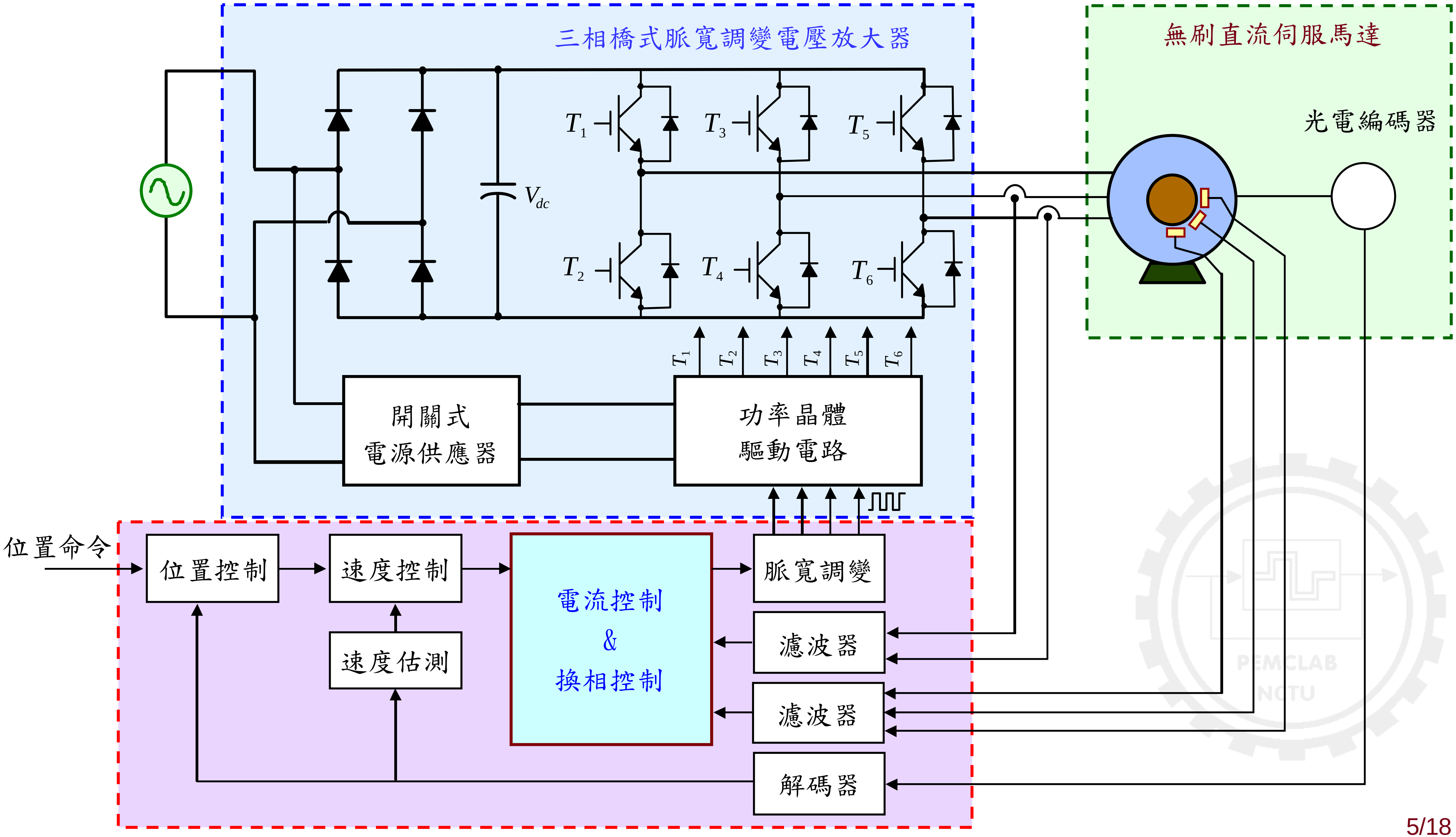
Block Diagram of a Practical DC Position Servo Drive



Block Diagram of a Practical BLDC Servo Drive



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Motion Profile of a Position Servo System

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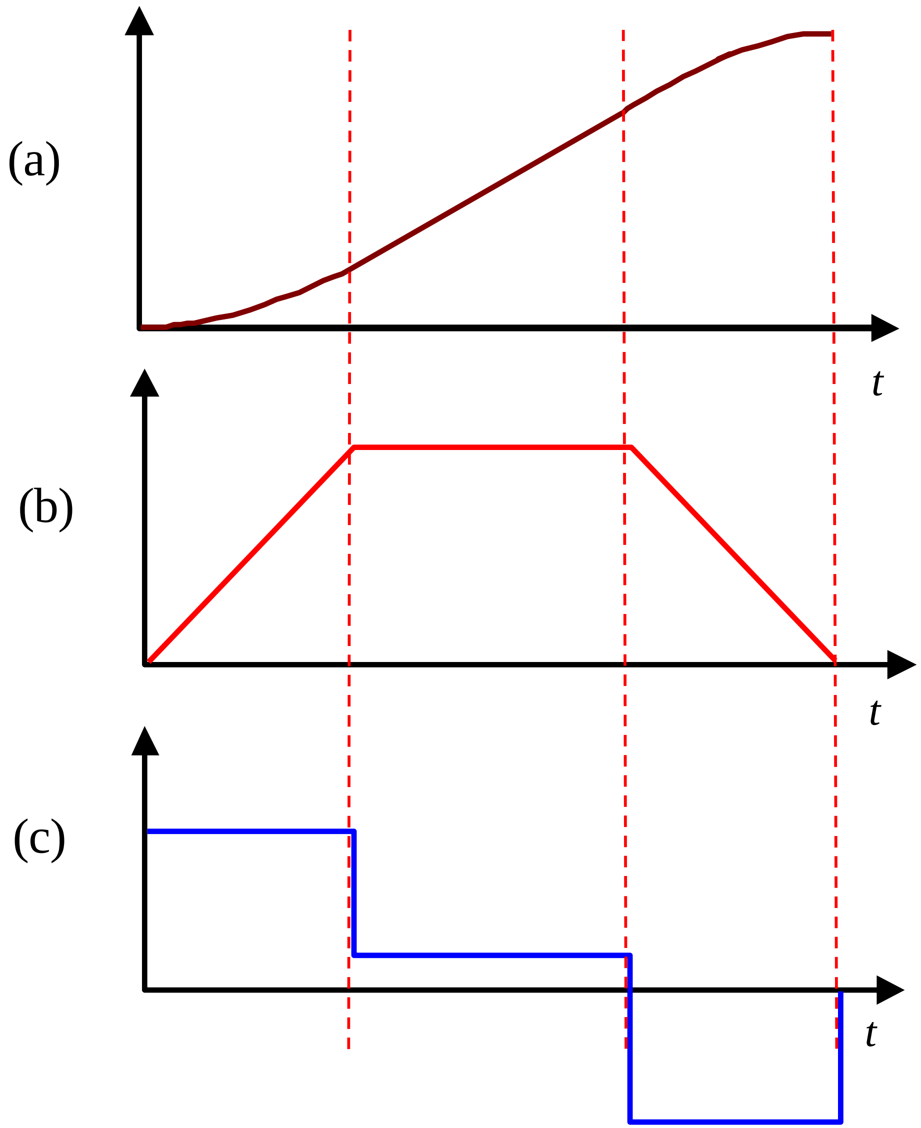
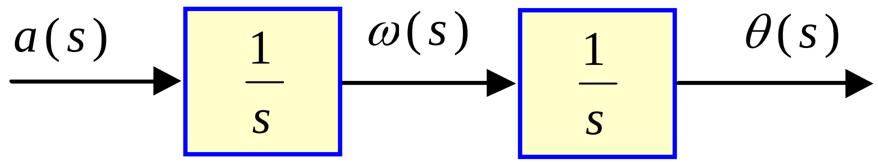
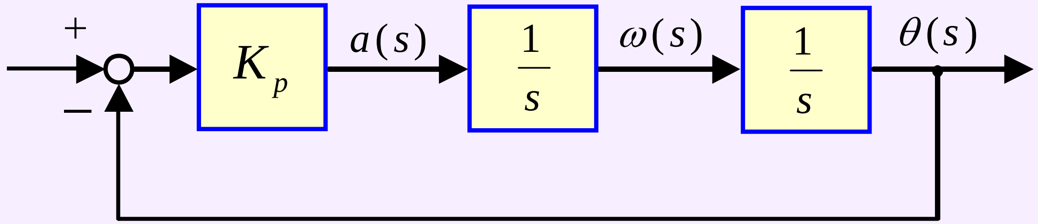




$a(t)$: angular acceleration

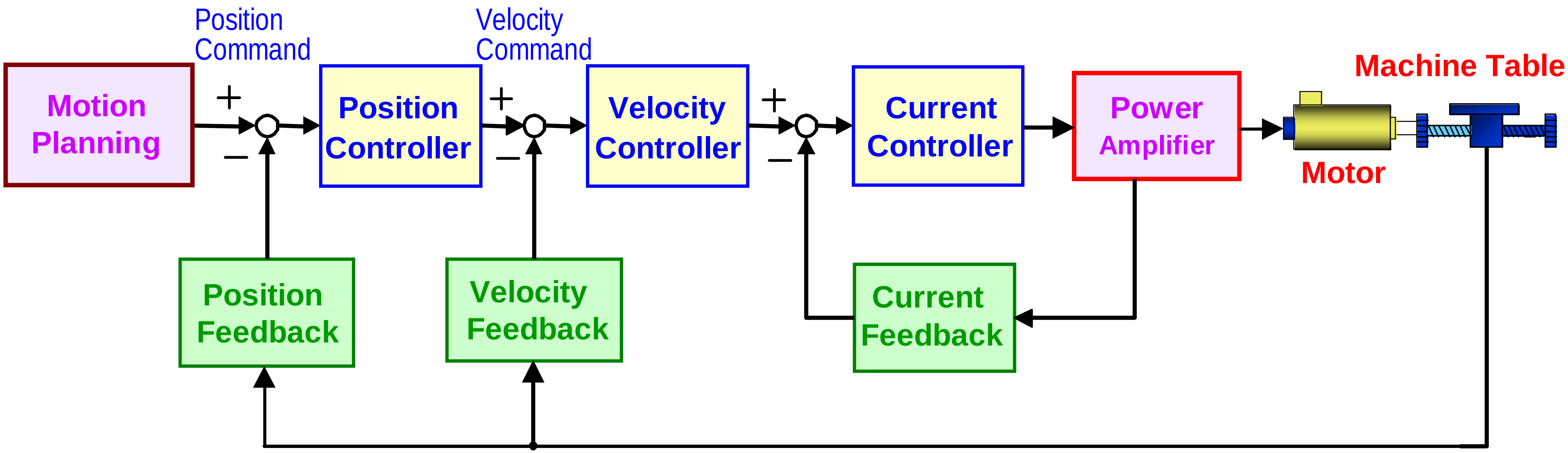
$\omega(t)$: angular velocity

$\theta(t)$: angular position



The proportional control of an double integrator plant is inherently unstable!

Multi-Loop Control Architecture



- The purpose of the control loop is to eliminate the loop dynamics.
- Cascaded control loop design is inherent robust for practical applications.
- Inner loop must be designed with higher bandwidth than outer loop.
- The loop controllers design should be designed from inside out.
- Each controller can be design with a PID controller with possibile necessary phase leading compensation.

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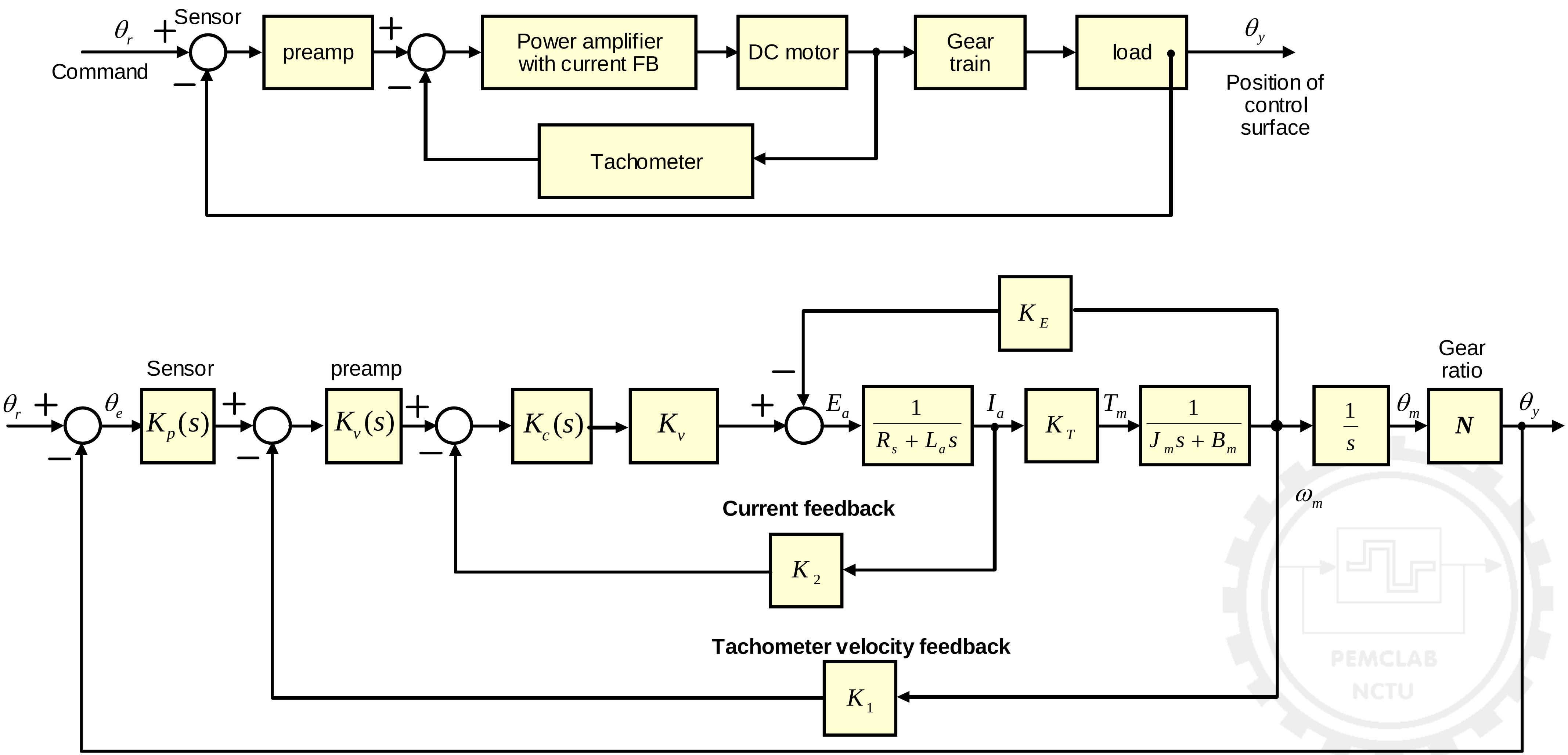
PID Control of a DC Position Servo



Ref: Benjamin C. Kuo and Farid Golnaraghi, **Automatic Control Systems**, Wiley Text Books, 8th Ed., Aug. 2002. pp. 402-436.

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Modeling of a DC Position Servo Drive

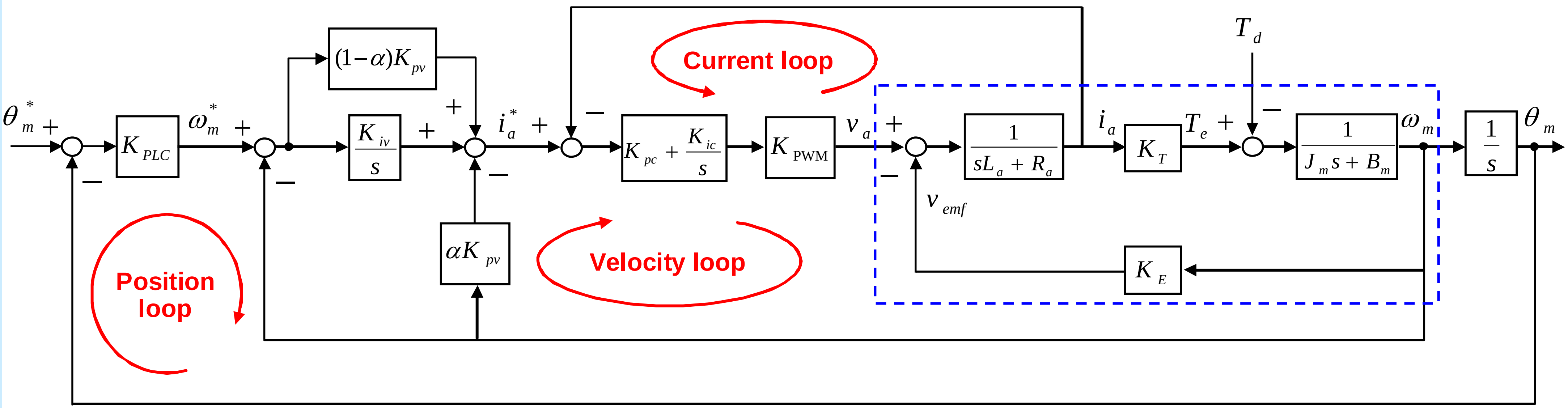

Table 1. Parameters of a 1HP dc position servo drive.

POSITION LOOP CONTROLLER	VELOCITY LOOP CONTROLLER	CURRENT LOOP CONTROLLER	SENSORS & AMP	DC SERVO MOTOR
$K_{PLC} = 30$	$G_v(s)$ $K_v = 25$ $p_1 = 5.6$ $z_1 = 35$ **CUR. CMD LIMITER** $\text{gain} = 1$ $\text{max.} = 8.0$ $\lvert v_i^* \rvert \le 8.0$	$G_c(s)$ $K_c = 0.6$ $z_2 = 220$ **DUTY-RATIO LIMITER** $\text{gain} = 1$ $D_{max} = 80\%$ $\lvert d \rvert \le 80\%$	**CURRENT SENSOR** $K_I = 0.4$ (V / A) **PWM AMP** $V_{dc} = 150V$ $f_s = 2kHz$ **TACHOGENERATOR** $K_\omega = 10V / 2000$ rpm $= 0.04775$ V / (rad / s)	$L_a = 0.011$ (H) $R_a = 4.7$ (ohm) $J_m = 0.00098$ (Kg m) $B_m = 0.0015$ Nm / (rad / s) $K_T = 0.4511$ (Nm / A) $K_E = 0.4511$ V / (rad / s)

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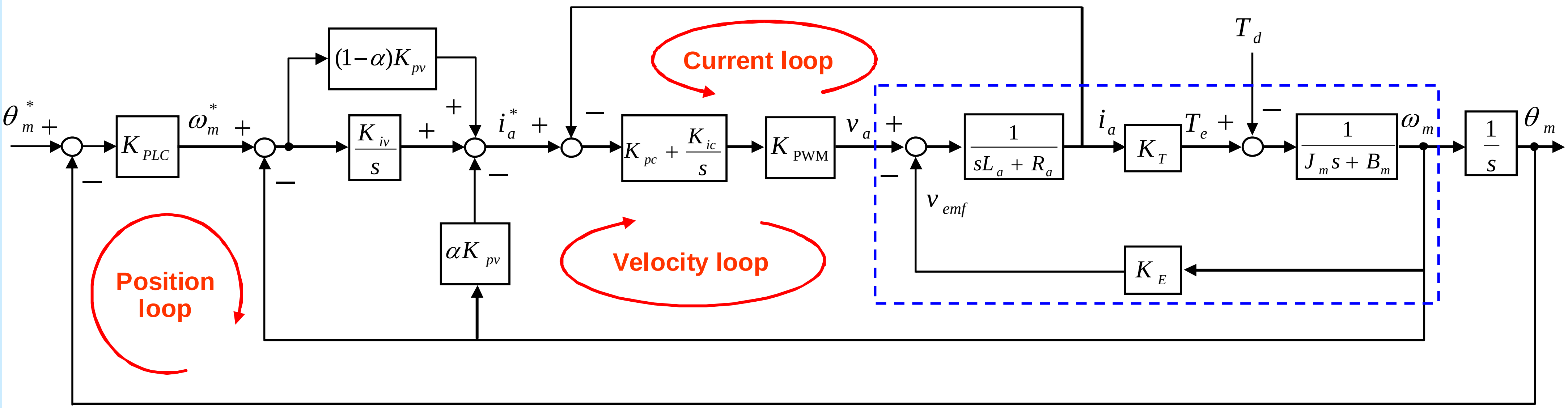
Simplification with Intrinsic Property



- For study purpose, we can eliminate the current loop!

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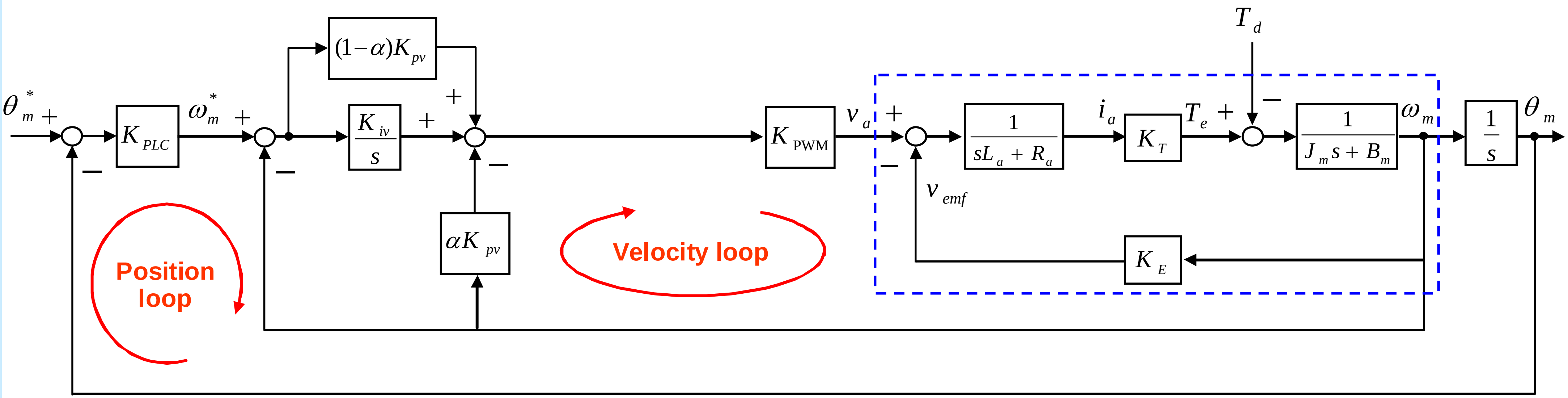
Position Servo Without Current Loop



- What about to eliminate the velocity loop?

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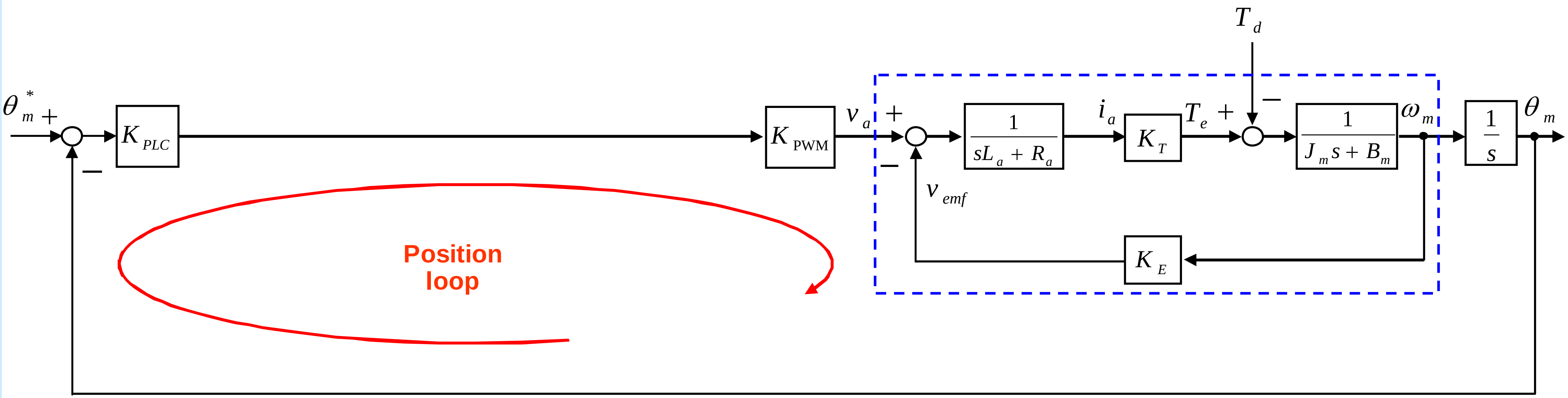
Position Servo Without Velocity Loop



- Now, we have a very simple P-controller!
- What about its performance for practical applications?

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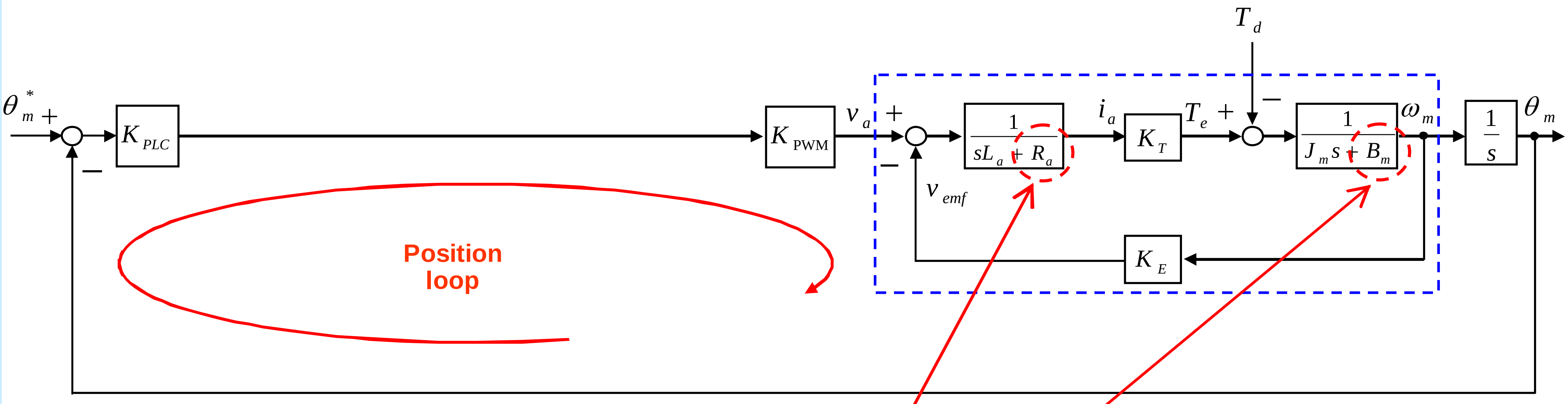
Position Servo with Small R_a and B_m



- In practical applications:
- The armature resistance is very small
- The friction constant is also very small

Neglect these parameters!

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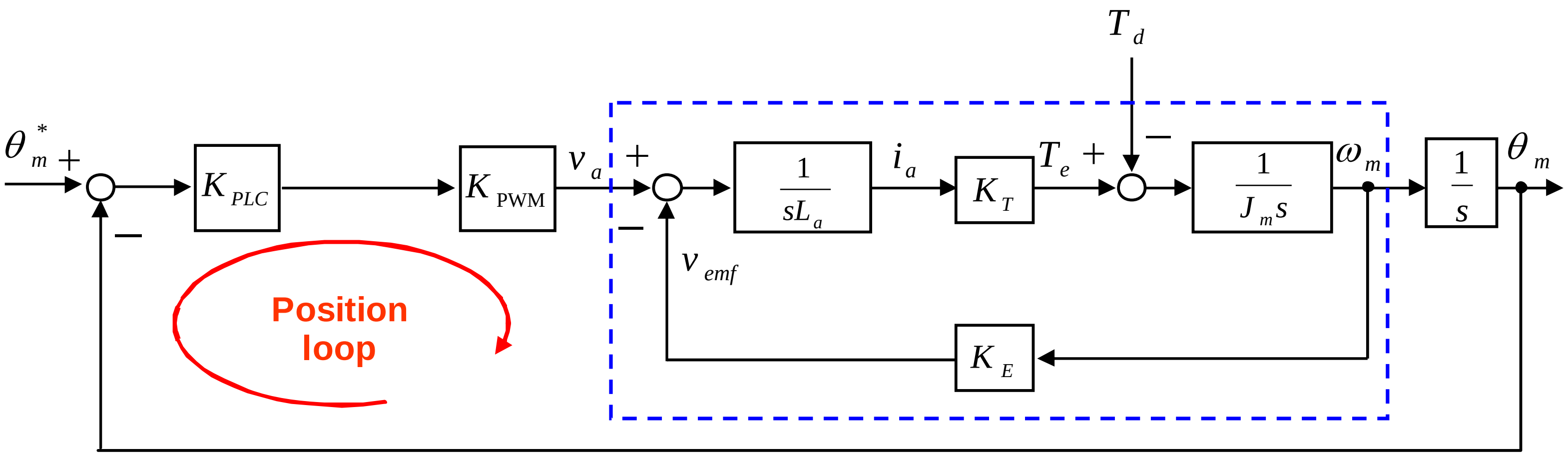
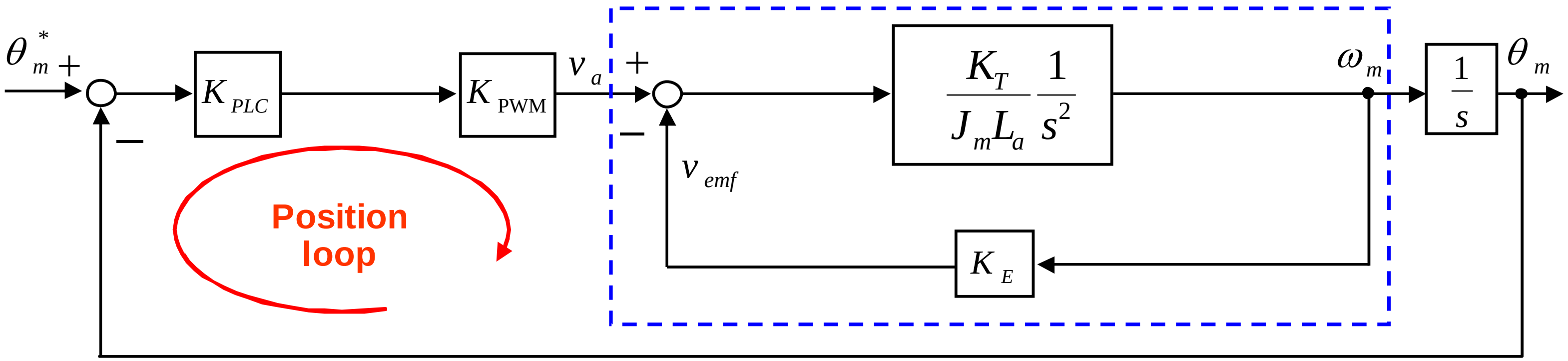
A Pair of Complex Poles and a Pole at the Origin



Under zero disturbance condition:



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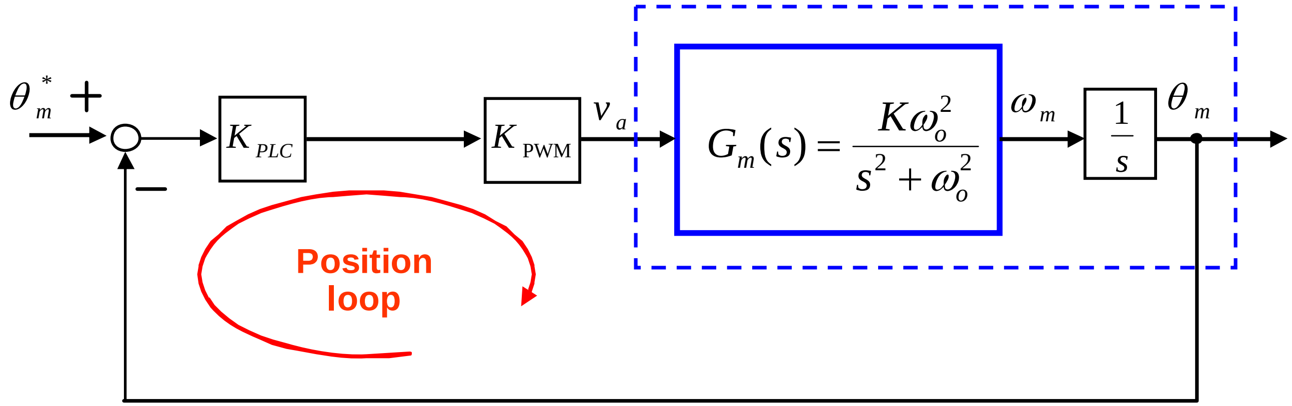
Deduction of the Motor Plant

$$G_m(s) = \frac{\frac{K_T}{J_m L_a}\frac{1}{s^2}}{1+\frac{K_E K_T}{J_m L_a}\frac{1}{s^2}} = \frac{K_T}{J_m L_a s^2 + K_E K_T} = \frac{\frac{K_T}{J_m L_a}}{s^2 + \frac{K_T K_E}{J_m L_a}} = \frac{K\omega_o^2}{s^2+\omega_o^2}$$

$$\omega_o = \sqrt{\frac{K_T K_E}{J_m L_a}} \qquad K = \frac{1}{K_E}$$



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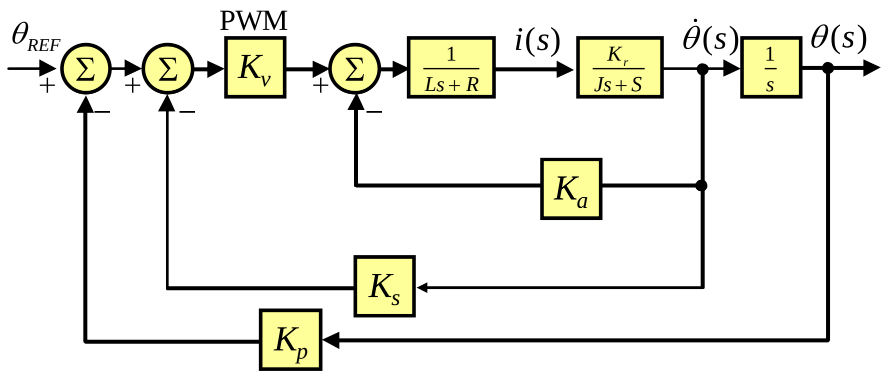
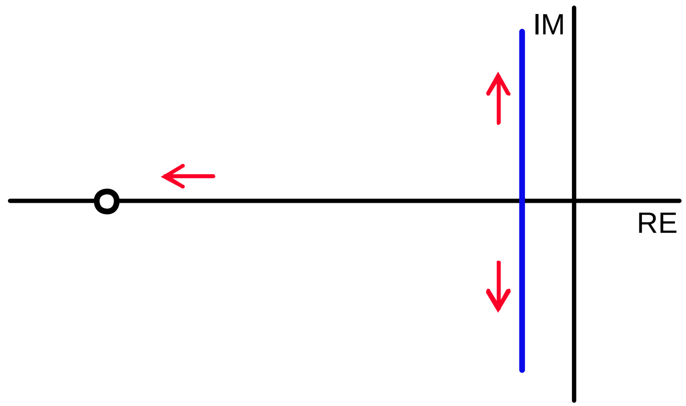
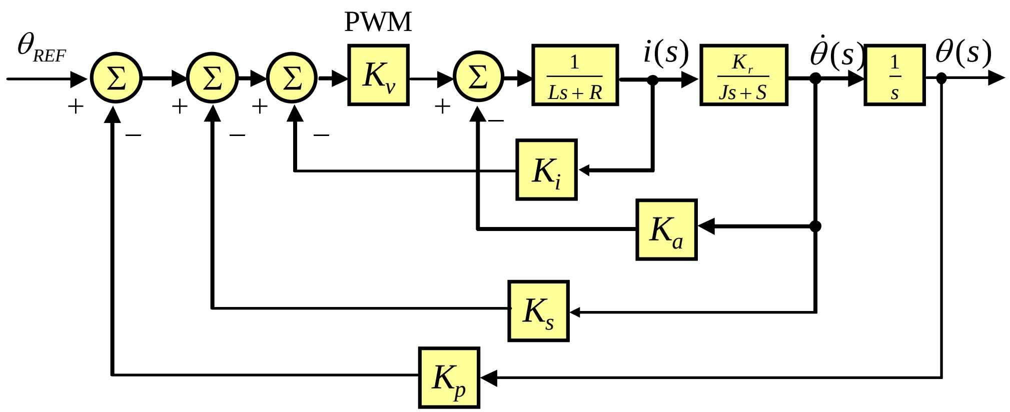
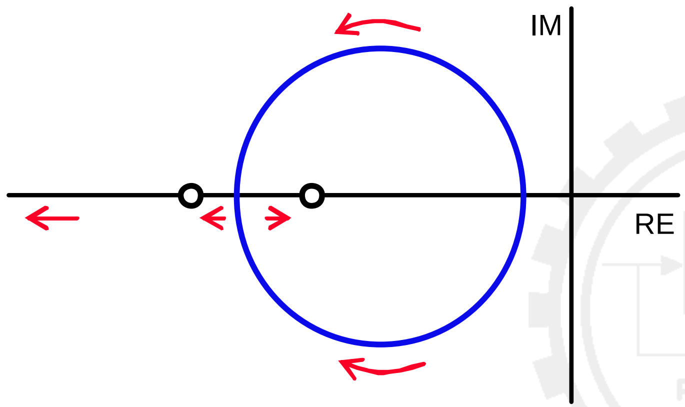
Effect of Inner Current Loop









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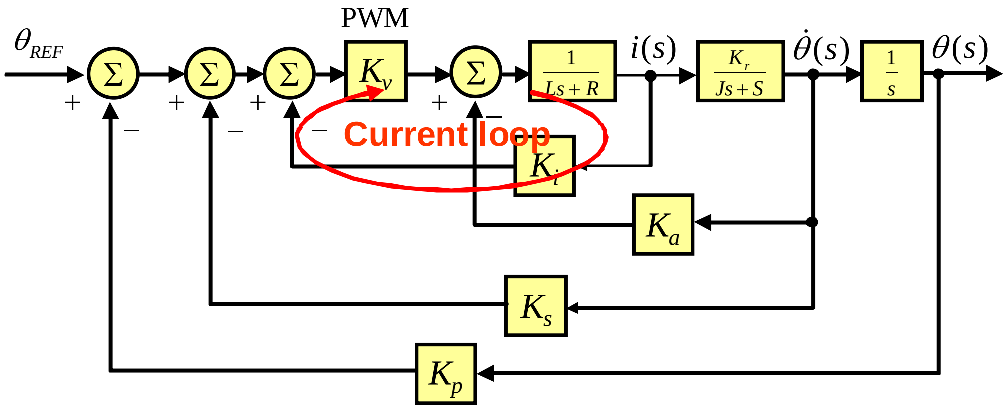
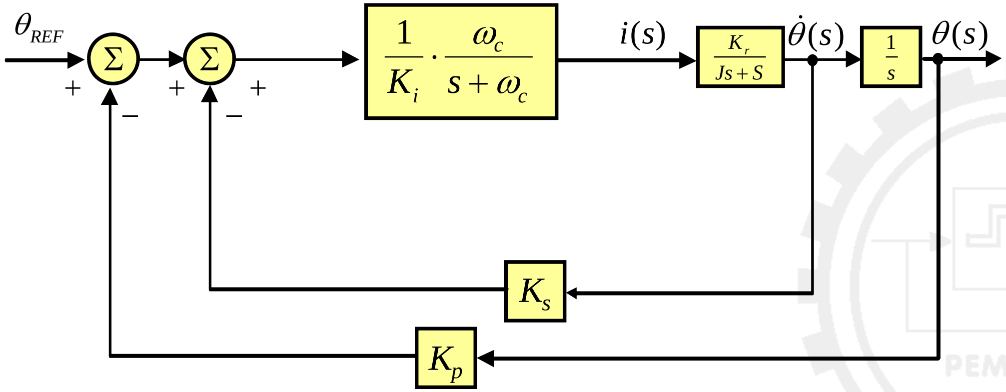
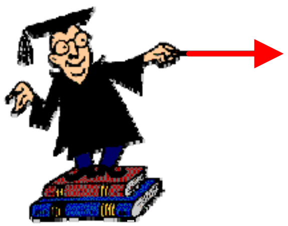
Model Reduction of a Current Controlled Drive







The current control can be reduced to a first-order system with an equivalent bandwidth of ω_{cl}. The back emf can be considered as an external disturbances within the current loop.

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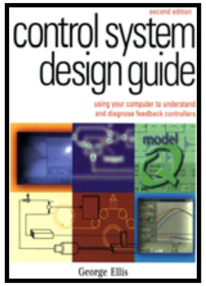
Extended Readings



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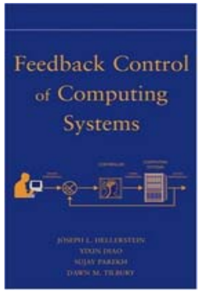

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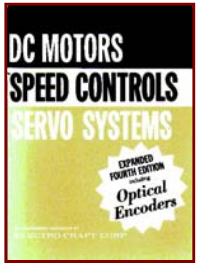

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