Designing Feedback Controllers for Motor Drives

- Objective
- Definitions
- Cascaded Control
- Steps in Design
- Average Representation of PPU
- Example of a DC Motor Drive
- PI Control

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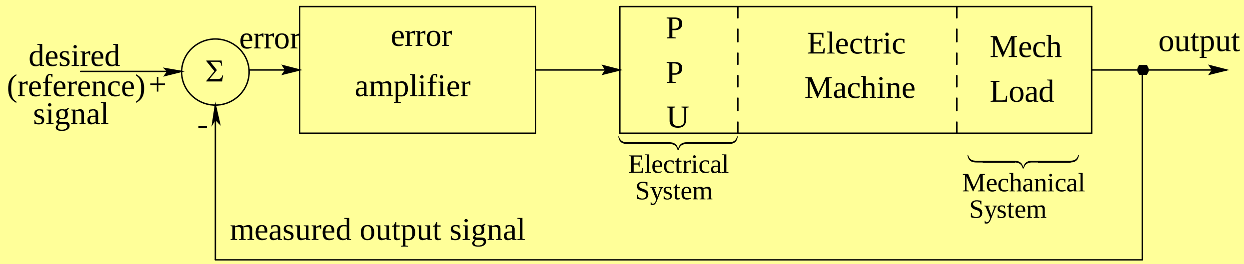
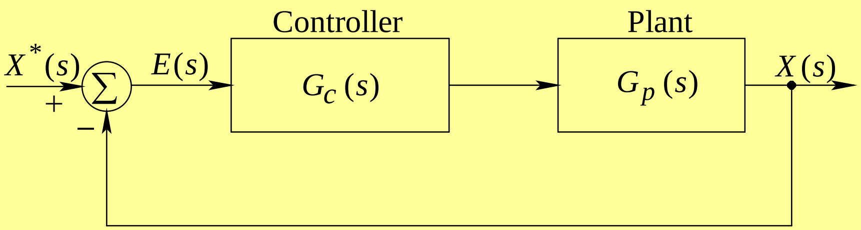
Feedback Control Objectives



- Feedback control
  - makes system insensitive to disturbances and parameter variation

- Control Objectives
  - Zero steady-state error
  - Good dynamic response
    - fast
    - small overshoot



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Definitions

- Open loop

$$G_{OL}(s) = G_c(s) G_p(s)$$

- Closed loop

$$G_{CL}(s) = G_{OL}(s) / (1 + G_{OL}(s))$$

- Crossover frequency

$$f_c, \omega_c$$

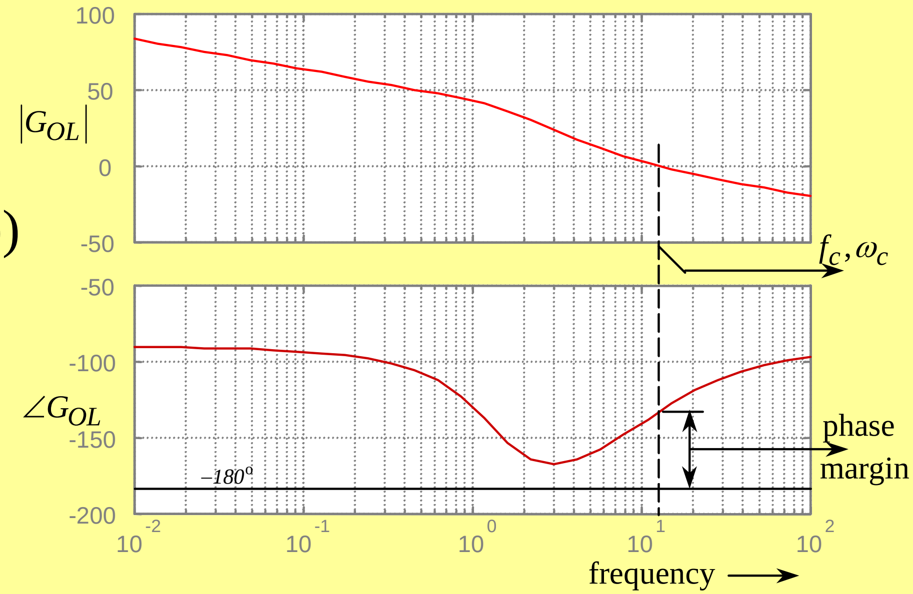
- Gain Margin
- Phase Margin

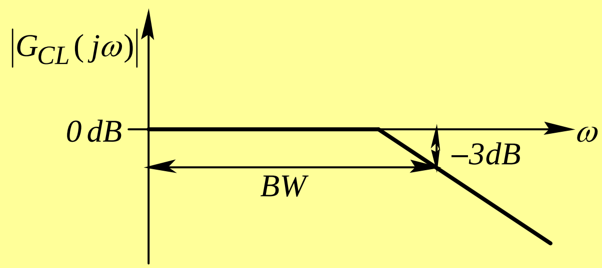
  > 45° for no oscillations

  60° preferable

- Closed loop bandwidth $\simeq f_c$

  desired high for fast response





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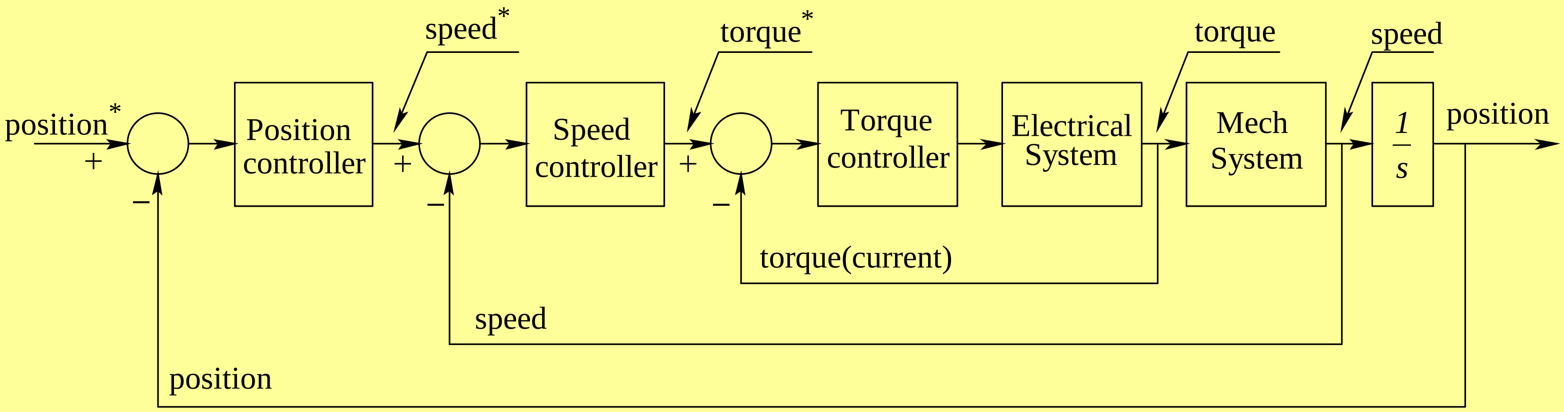
Cascaded Control



- Torque loop : fastest
- Speed loop : slower
- Position loop : slowest

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Steps in Designing the Controller

- Assume system is linear about the steady state operating point; design controller using Linear Control Theory
- Simulate design under large signal conditions and "tweak" controller as necessary

System representation for small signal analysis

- Assume
  - Steady state system operating point
  - Highest bandwidth at least an order of magnitude lower than switching frequency ; neglect switching frequency components

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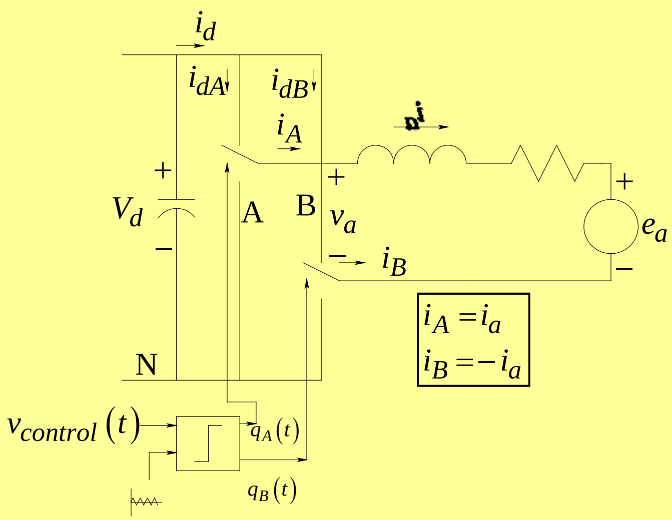
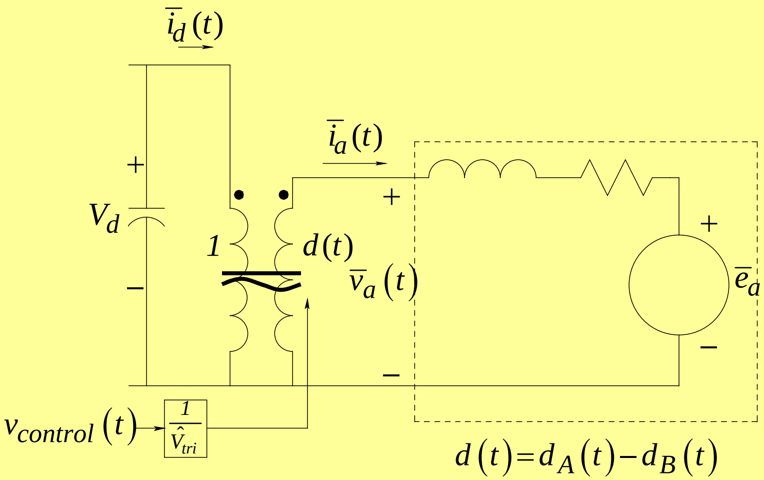
Averaged Representation of the PPU





$$\bar{v}_a(t) = k_{PWM} v_c(t)$$

$$V_a(s) = k_{PWM} V_c(s)$$

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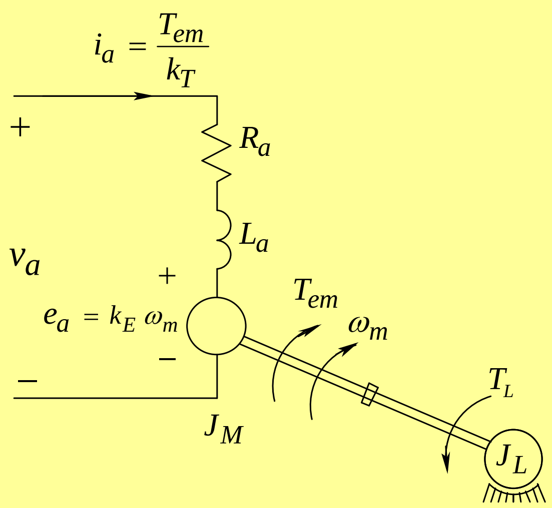
Modeling of DC Machines and Mechanical Load Combinations



$$\bar{v}_a(t) = e_a(t) + R_a \bar{i}_a(t) + L_a \frac{d\,\bar{i}_a(t)}{dt}$$

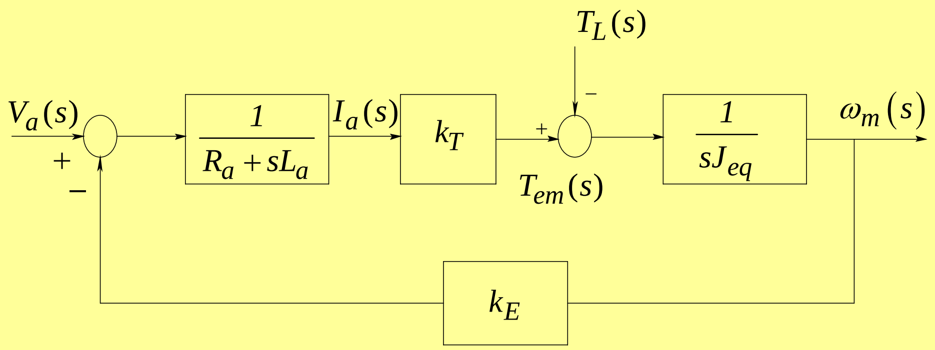
$$e_a\,(t) = k_E\,\omega_m(t)$$

$$V_a(s) = E_a(s) + (R_a + s\,L_a)\,I_a(s)$$

$$\Rightarrow I_a(s) = \frac{V_a(s) - E_a(s)}{(R_a + s\,L_a)} \qquad ;\; E_a(s) = k_E\,\omega_m(s)$$

$$T_{em}\,(s) = k_T I_a(s)$$

$$\omega_m(s) = \frac{T_{em}(s)}{sJ_{eq}}$$



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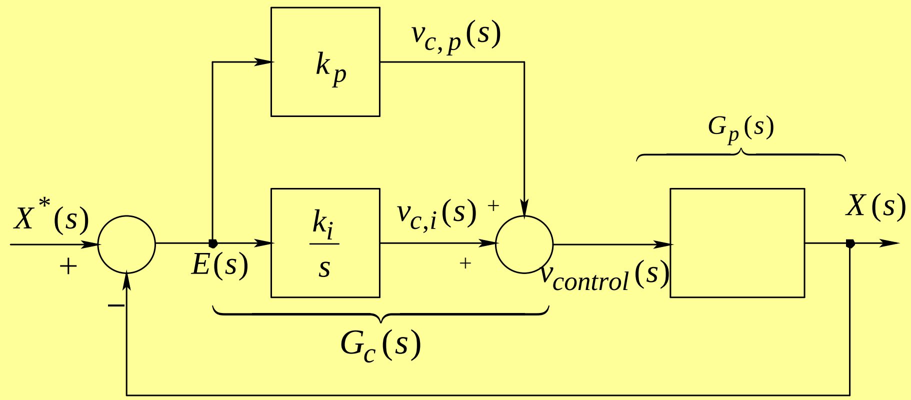
PI Controller



$$\frac{v_c(s)}{E(s)} = k_p + \frac{k_i}{s} = \frac{k_i}{s}\left(1 + \frac{s}{k_i / k_p}\right)$$

- Proportional-Integral (PI) Controller
  - In the torque and speed loops, proportional control without integral control input leads to steady-state error

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Summary

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