Lab 2 Lecture Notes Clean

Monday, January 31, 2022 5:12 PM

Agenda:

- Inner current / outer voltage control (Background)
- week 1: controller design
- week 2: implementation and HIL
- week 3: work-time and wrap-up.

1) Background.

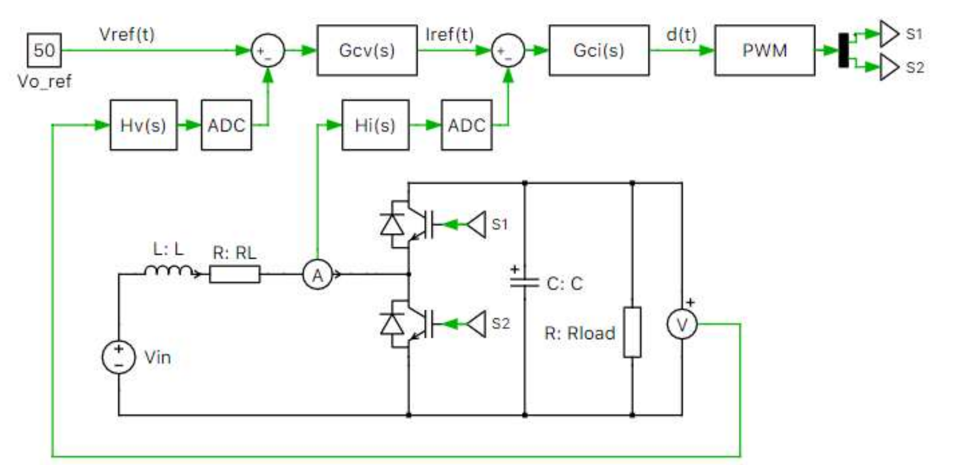


Figure 1: Conceptual diagram of ICOV control for a synchronous boost

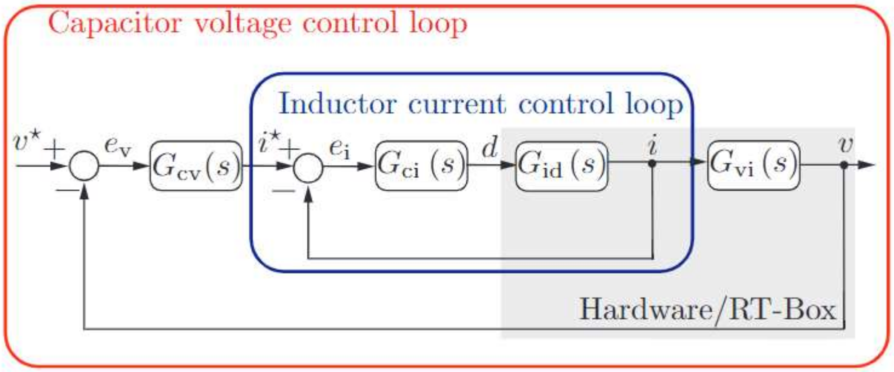


Figure 2: Transfer function diagram of ICOV control

ω_{bw} for IC loop 10x HIGHER than ω_{bw} for OV loop

Why?

2) Controller Design: (week 1)

- similar process for IC and OV
  - specific to this problem
  - general solution discussed in lecture.

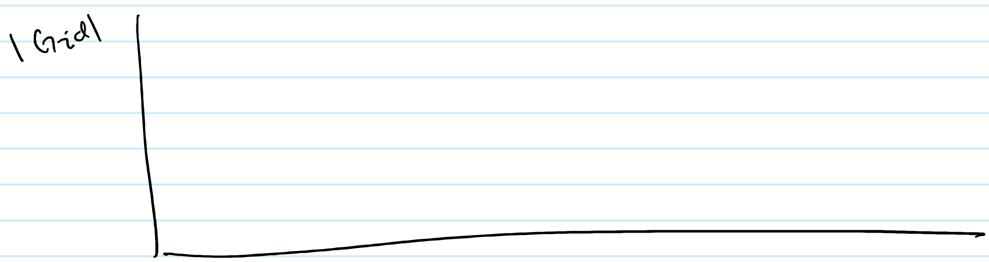
- IC controller design:

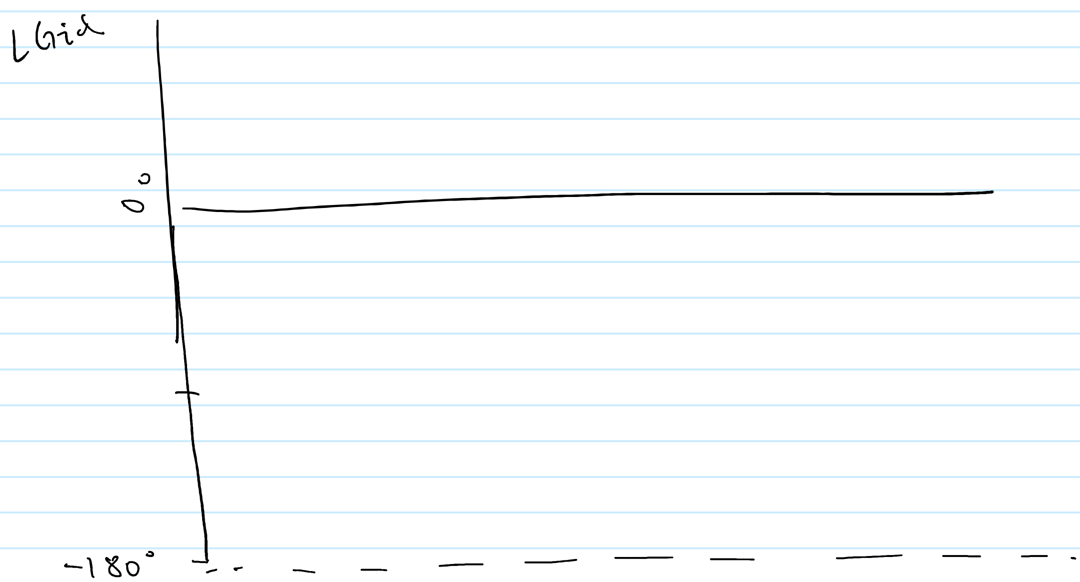
  input: i_{ref} output: d

  1) select f_{ci}, ϕ_m

  2) find gain / phase of uncompensated loop

  approx: $G_{id}(s) \approx \frac{V_{out}}{sL}$ at high frequency.





3.) use PI controller: $C(s) = \left(k_p + \frac{k_i}{s}\right)$

$l_i(s) = C(s)\,P(s) = C(s)\,G_{id}(s)$

$\approx \left(k_p + \frac{k_i}{s}\right)\left(\frac{V_{out}}{sL}\right)$

$\|l_i(s)\|\Big|_{\omega=\omega_{bw}} = 1$

$\angle l_i(s)\Big|_{\omega=\omega_{bw}} = -180^\circ + \phi_m$

use this to get k_p and k_i

$\left\| \frac{V_{out}}{sL}\left(k_p + \frac{k_i}{s}\right) \right\|$

$\angle l_i = \angle \left(k_p + \frac{k_i}{s}\right) \frac{V_{out}}{sL} = -180^\circ + \phi_m$

note: $k_p + \frac{k_i}{s} = G_{PI_\infty}\left(1 + \frac{\omega_{PI}}{s}\right) = G_c$

note: $k_p + \frac{k_i}{s} = G_{PI\infty}\left(1 + \frac{\omega_{PI}}{s}\right) = G_c$

Use (1) and (2) to get $G_{PI\infty}$, ω_{PI}

- Simulate current control.
  - Starter file for control in Canvas
    - this is a transfer function model
    - also need to implement w/ switched model

- OV controller design:

  input: v_{ref} output: i_{ref}

  select $\omega_{c,v} \leq \frac{\omega_{ci}}{10}$

  $\left\|\left(k_p + \frac{k_i}{s}\right) G_{vi}\right\| = 1 \rightarrow \boxed{\sqrt{k_p^2 + \left(\frac{k_i}{\omega_c}\right)^2}\left[\frac{D'R}{2} - \frac{R_L}{2D'}\right]}$ (3)

  $\angle\left(k_p + \frac{k_i}{s}\right) G_{vi} = -180° + \phi_m$

  $\angle k_p + \frac{k_i}{s} + \angle G_{vi}$
  ↳ approx 0 at low frequency.

  $-\arctan\left(\frac{k_i}{\omega_c k_p}\right) = -180° + \phi_m$

  $\therefore \arctan\left(\frac{k_i}{\omega_c k_p}\right) - \cancel{180°} = \cancel{-180°} + \phi_m$

  $\boxed{\arctan\left(\frac{k_i}{\omega_c k_p}\right) = \phi_m}$ (4)

- use (3) (4) to get k_p / k_i for voltage controller.

3) Implementation (week 2)

- Set up RT BOX (see auxilliary video)

- scaling
  - scale in PLECS, send to MCU
  - read in ADC pin
  - scale to actual numerical value

  scale: $\frac{3.3V}{\text{max value + safety}}$ → max ADC voltage

- you can choose these based on your design last quarter

- implement PI in code:

  - same idea for V

- saturation
  - saturate $y_{i_{int}}$ [-0.95, 0.95]
  - saturate y_i on max/min duty
  - saturate y_V on max/min current

Code structure: (suggested)

Globals / const defines
- state variables for at least 1 previous cycle
- reference variables
- saturation values
- controller gains
- scalings

ADC interrupt:

// voltage control

$$V_{err} = V_{ref} - V_o$$

$$\left.\begin{aligned} Y_{V_{pr}} &= V_{err} \cdot k_{p,V} \\ Y_{int,V} &= (Ts*0.5)(V_{err} + V_{err\,prev})\,ki_V + Y_{V_{int}\,prev} \end{aligned}\right\} \text{PI calculation}$$

if $y_{int,V}$ too high/low:
saturate.

update y_{prev}, $y_{V,int}$ prev, V_{err} prev, etc.

$Y_V = Y_{int} + Y_{pr}$

if Y_V too high/low //yv is current ref!
saturate

if Y_V too high/low //yv is current ref!
saturate

// current control.

$i_{ref} = Y_V$

repeat PI calculations but for IC loop

saturate y_i if needed // y_i = duty.

update PWM duty register (CMPA)