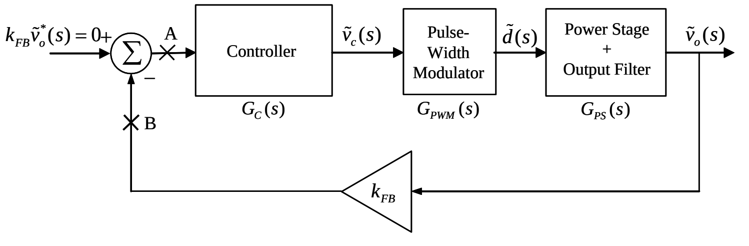
Feedback Control Design in Regulated DC Power Supplies

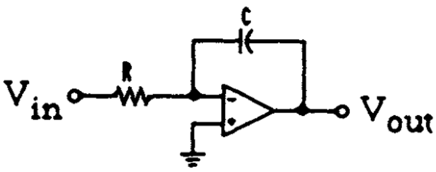
- Peak-Current-Mode Control

Voltage feedback - Summary

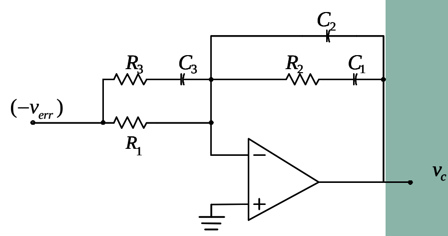


$$G_c(s)=\frac{k_c}{s}\frac{\left(1+s/\omega_z\right)^2}{\left(1+s/\omega_p\right)^2}$$

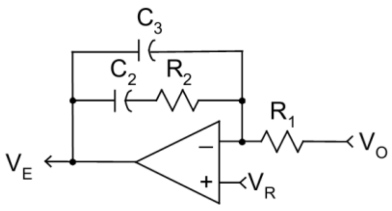
Three General Amplifier types



Type 1



Type 3



Type 2

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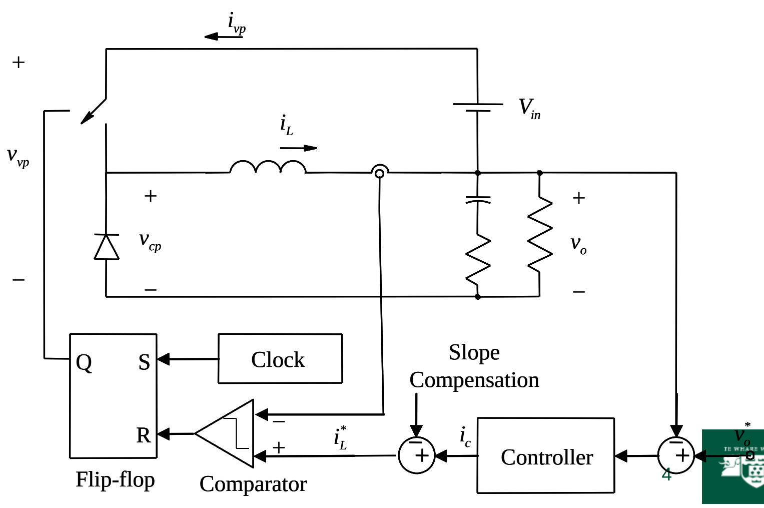
PEAK-CURRENT MODE CONTROL

- Peak-Current-Mode Control, and
- Average-Current-Mode Control. ← In PFC Lecture



4

Current Mode Control

- Difference I mode vs V mode
  - Current mode has two feedback loops; one to control the inductor current, the other to control the capacitor (output) voltage
  - Control system can be same as V mode; but for practical reasons, in inner loop, controlling the inductor current acts to remove its effect in the power stage.
  - Hence no resonant tank to worry about.
  - So only a single pole of output cap at high frequencies

5

5

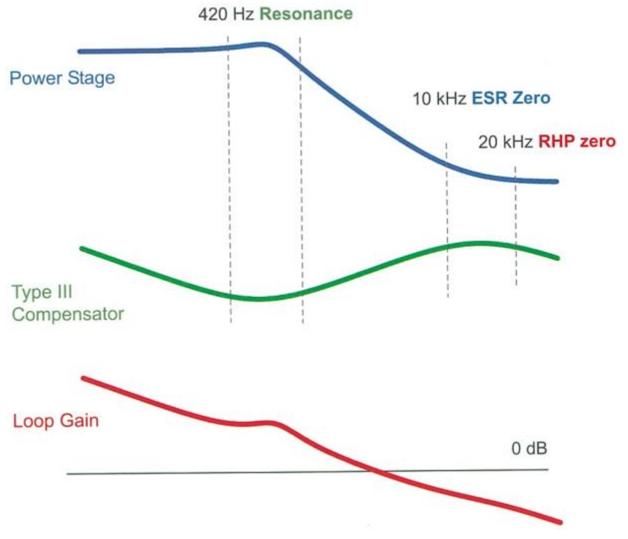
Limitation of Current Mode

- Sense a current using a resistor (CT going to a resistor)
- Feed it into PWM IC
- However as load current decreases the magnitude of the signal must naturally decrease.
- If load is light the current signal will be negligible and the current feedback loop has no effect on the system. So, **current mode control becomes voltage mode control at light loads.**

6

6

RHPZ



7

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7

Solutions?

- Bandwidth of the converter to be designed such that RHPZ occurs at much higher frequencies than the bandwidth
- Beware that zeros moves with loads
- I mode Compensator design:
  - First pole at origin
  - Zero at 1/5 the selected crossover frequency
  - Second pole at ESR zero of cap or RHP Zero whichever is lower

8

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8

PEAK-CURRENT MODE CONTROL

- Peak-Current-Mode Control, and
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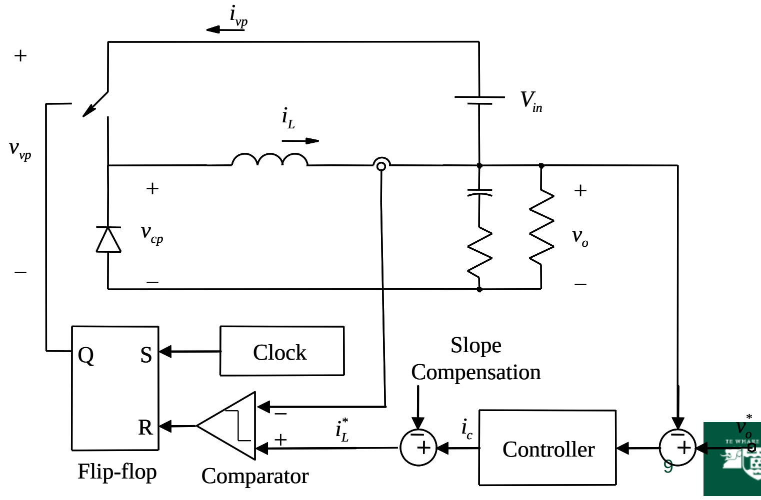
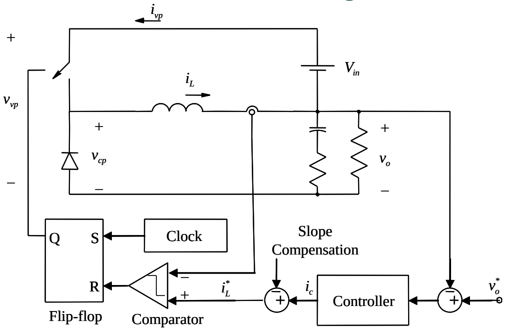
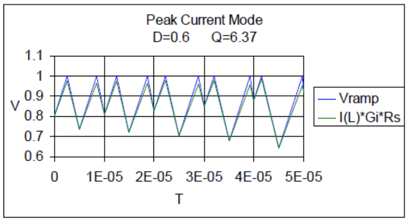


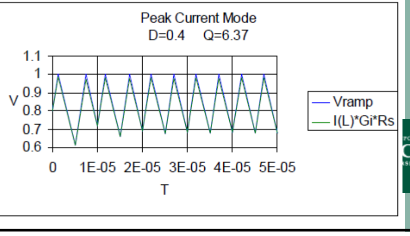
Slope Compensation

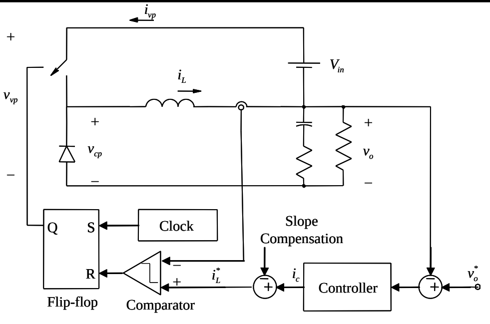
- When the duty cycle of the current mode converter exceeds 50%, the converter will oscillate at a subharmonic of the switching frequency
- Similar to the effect of RHP zero effect but at subharmonics
- This happens when we try to compare average inductor current and the dc value of the sampled inductor current.

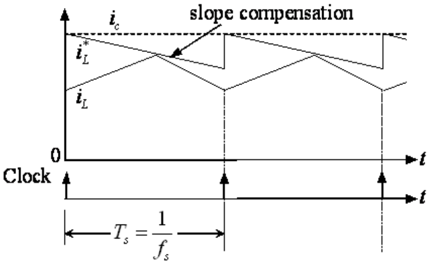
Effect of Line Voltage and Duty Cycle changes

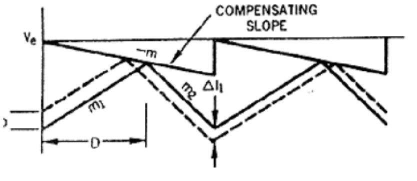


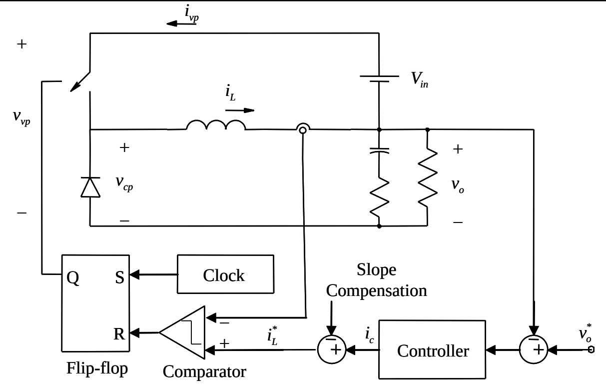


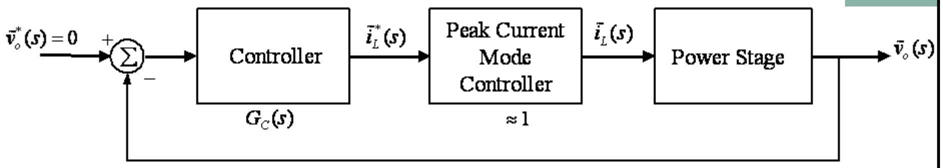






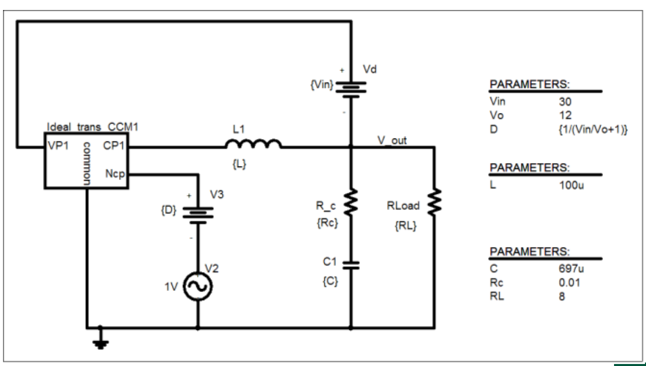






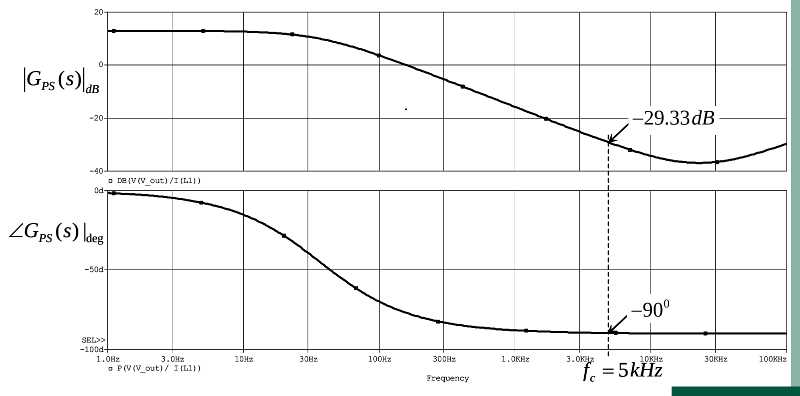
15

In this example, we will design a peak-current-mode controller for a Buck-Boost converter that has the following parameters and operating conditions: $L = 100\,\mu\text{H}$, $C = 697\,\mu\text{F}$, $r = 0.01\Omega$, $f_s = 100$ kHz, $V_{in} = 30\,\text{V}$. The output power $P_o = 18\,\text{W}$ in CCM and the duty-ratio D is adjusted to regulate the output voltage $V_o = 12\,\text{V}$. The phase margin required for the voltage loop is 60^0. Assume that in the voltage feedback network, $k_{FB} = 1$.



16

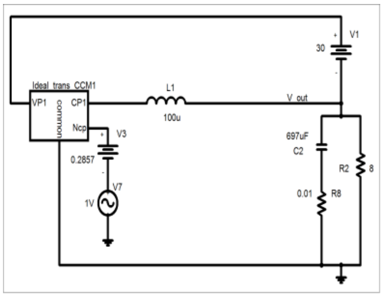
$$\frac{\tilde{v}_O}{\tilde{i}_L}(s) = \frac{R(1-D)\left(1 - \dfrac{sLD}{R(1-D)^2}\right)(1 + srC)}{(1+D)\left(1 + \dfrac{sRC}{1+D}\right)}$$

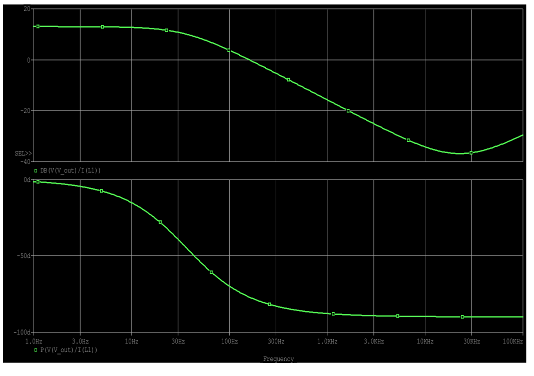


17

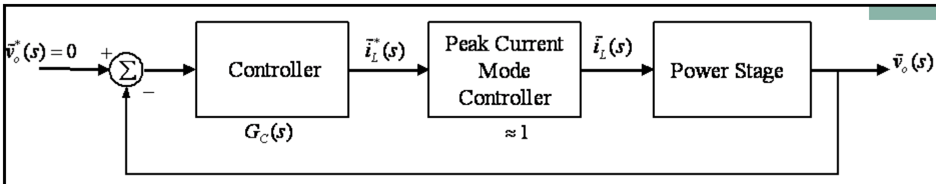
17

PSpice Modeling:





19



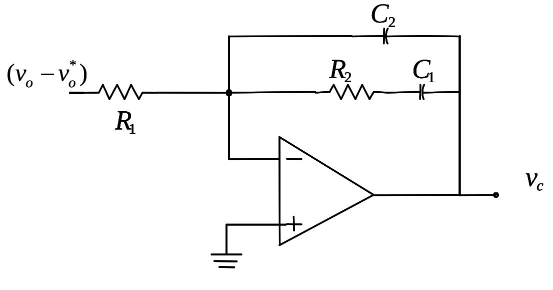
$$G_c(s)=\frac{k_c}{s}\frac{(1+s/\omega_z)}{(1+s/\omega_p)} \qquad f_c=\sqrt{f_z f_p} \qquad \sqrt{\frac{f_p}{f_z}}=\tan\left(45^o+\frac{\phi_{boost}}{2}\right)$$

$$\left|G_C(s)\right|_{f_c}\times\left|G_{PS}(s)\right|_{f_c}=1$$

All other equations from voltage mode are valid

20

20



$$R_1=10k\Omega$$

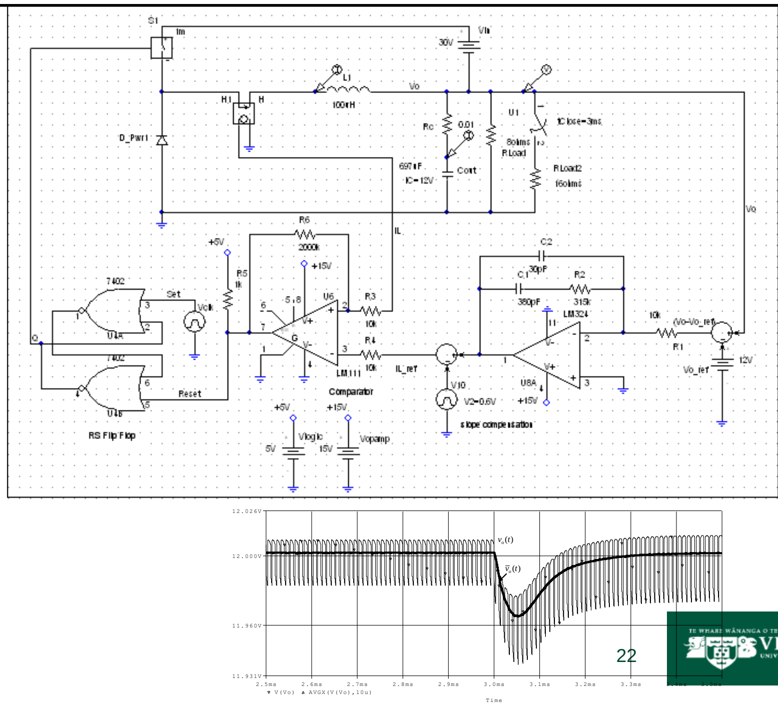
$$C_2=\frac{\omega_z}{\omega_p R_1 k_c}=30\ p\mathrm{F}$$

$$C_1=C_2\left(\omega_p/\omega_z-1\right)=380\ p\mathrm{F}$$

$$R_2=1/(\omega_z C_1)=315k\Omega$$

21

21



22

22

Summary

Feedback Control Design in Regulated DC Power Supplies

- RHP Zero
- Peak-Current-Mode Control

25

25

Concept Quiz

The crossover frequency in the peak-current-mode control can be selected to be higher than that in the voltage-mode control, because of the phase angle of the power stage in the control bock-diagram below?

A. True

B. False