Voltage Loop and Compensator Design

ECE 482 Lecture 9

February 10, 2014

Compensated Loop Gain

Current Loop Gain

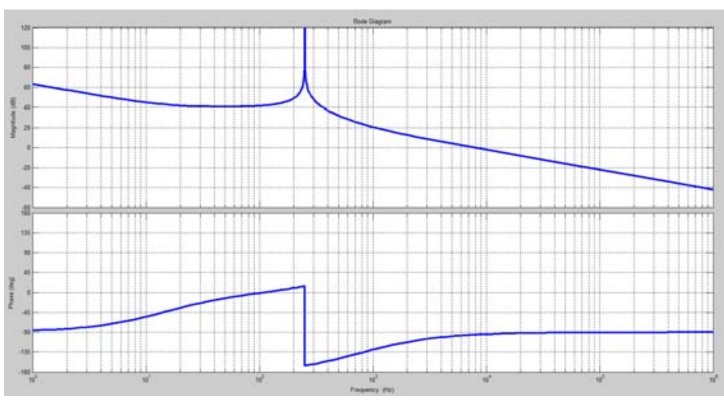
$$T_i = G_{ci} \frac{1}{V_m} G_{id} R_s$$

Open Loop d-to-i_l TF

$$G_{ido} = \frac{I_L}{D'} = \frac{I_{bus}}{(D')^2}$$

$$f_{zi} = \frac{1}{2\pi} \frac{1}{C} \frac{I_{bus}}{V_{bus}}$$

$$f_o = \frac{1}{2\pi} \frac{D'}{\sqrt{LC}}$$

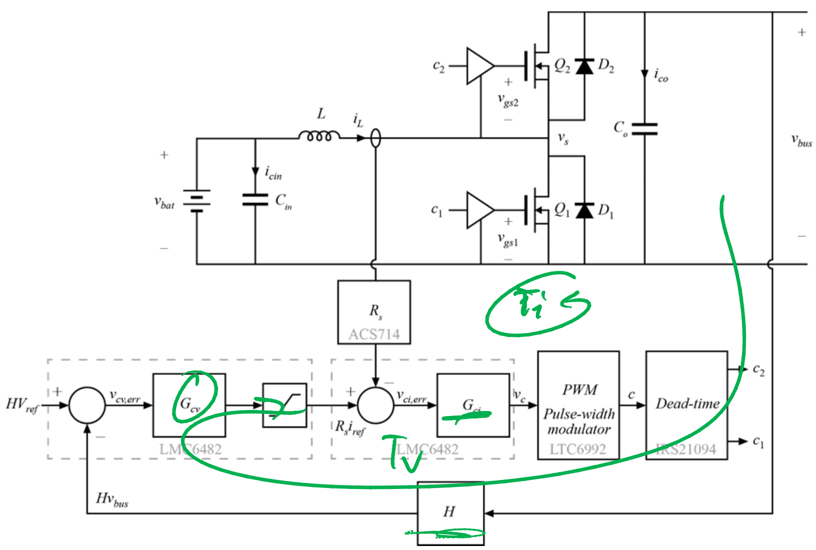


Compensator

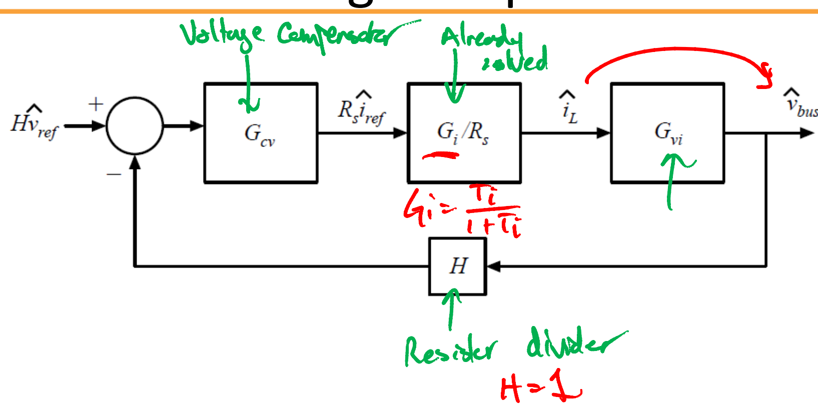
$$G_{ci} = \frac{1}{10}\left(1 + \frac{\omega_{zi}}{s}\right)$$

$$\omega_{zi} = 5\,\frac{\text{krad}}{\text{sec}}, \varphi_m = 84^\circ$$

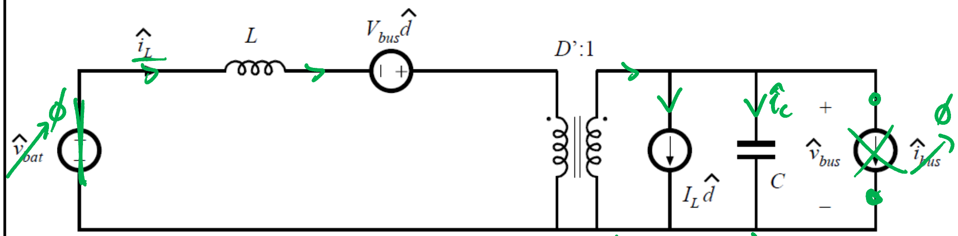
Voltage Loop



Voltage Loop Gain



Solving G_{vi}



$$G_{vi} = \left.\frac{\hat{v}_{bus}}{\hat{i}_L}\right|_{\hat{v}_{bat}=0,\,\hat{i}_{bus}=0}$$

$$\hat{v}_{bus} = \frac{1}{sC}\hat{i}_c = \frac{1}{sC}\left(\hat{i}_L D' - I_L\hat{d}\right)$$

$$G_{id} = \frac{\hat{i}_L}{\hat{d}} \rightarrow \hat{d} = \frac{\hat{i}_L}{G_{id}}$$

$$\hat{v}_{bus} = \frac{1}{sC}\left(\hat{i}_L D' - \frac{I_L}{G_{id}}\hat{i}_L\right)$$

$$G_{vi} = \frac{\hat{v}_{bus}}{\hat{i}_L} = \frac{1}{sC}\left(D' - \frac{I_L}{G_{id}}\right)$$

Solving G_{vi}

Open Loop d-to-i_L TF

$$G_{ido} = \frac{I_L}{D'} = \frac{I_{bus}}{(D')^2}$$

$$f_{zi} = \frac{1}{2\pi}\frac{1}{C}\frac{I_{bus}}{V_{bus}}$$

$$f_o = \frac{1}{2\pi}\frac{D'}{\sqrt{LC}}$$

$$G_{vi} = \frac{1}{sC}\left(D' - \frac{I_L}{G_{id}}\right)$$

$$G_{vi} = \frac{1}{sC}\left(D' - I_L\frac{D'}{I_L}\frac{\left(1+\frac{s^2LC}{D'^2}\right)}{\left(1+\frac{sCV_{bus}}{I_{bus}}\right)}\right)$$

$$= \frac{D'}{sC}\left(\frac{1+\frac{sCV_{bus}}{I_{bus}} - 1 - \frac{s^2LC}{D'^2}}{1+\frac{sCV_{bus}}{I_{bus}}}\right)$$

$$= D'\left(\frac{\frac{V_{bus}}{I_{bus}} - \frac{sL}{D'^2}}{1+\frac{sCV_{bus}}{I_{bus}}}\right)$$

$$G_{vi} = D'\frac{V_{bus}}{I_{bus}}\frac{\left(1-\frac{sLI_{bus}}{D'^2V_{bus}}\right)}{1+\frac{sCV_{bus}}{I_{bus}}} = G_{vio}\frac{1-\frac{s}{\omega_{zv}}}{1+\frac{s}{\omega_{zi}}}$$

Solving G_{vi}

$$G_{vi} = \frac{\hat{v}_{bus}}{\hat{i}_L}\bigg|_{\hat{v}_{bat}=0,\,\hat{i}_{bus}=0} = G_{vio}\frac{1-\frac{s}{\omega_z}}{1+\frac{s}{\omega_{zi}}}$$

$$G_{vio} = D'\frac{V_{bus}}{I_{bus}}$$

$$f_z = \frac{1}{2\pi}\frac{D'^2}{L}\frac{V_{bus}}{I_{bus}}$$

$$f_{zi} = \frac{1}{2\pi}\frac{1}{C}\frac{I_{bus}}{V_{bus}}$$

Example Values

$I_{bus} = 5\text{A}$

$V_{bus} = 50\text{V}$

$V_{bat} = 26\text{V}$

$L = 100\mu\text{H}$

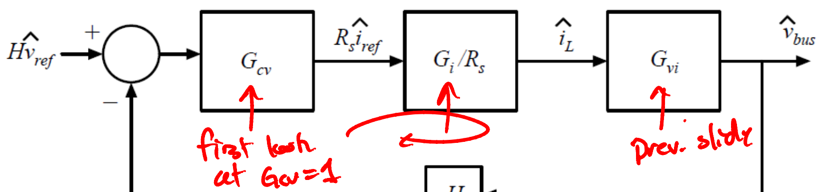
$C = 4 \times 270\mu\text{F}$

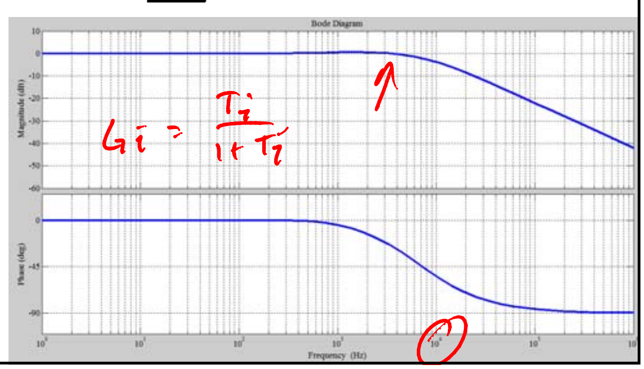
$G_{vi0} = 5.2 = 14dB$

$f_z = 4.3kHz$ → RHP zero

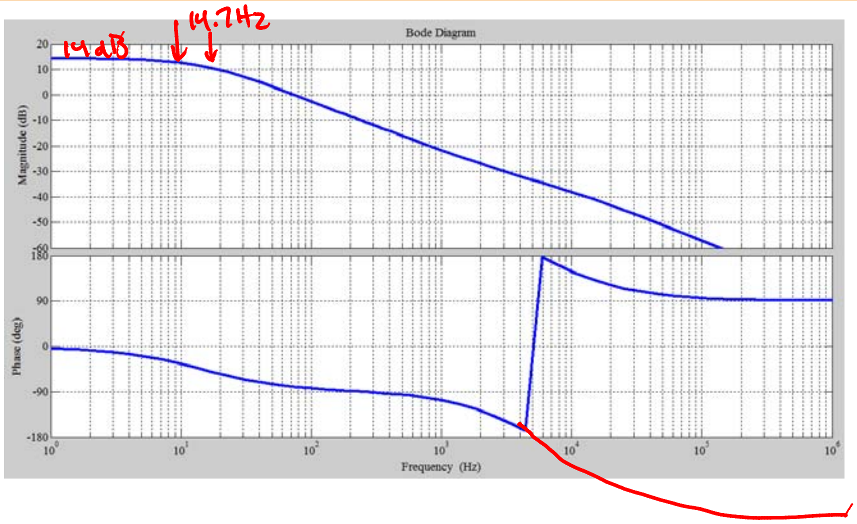
$f_{zi} = 14.7Hz$ → pole

Voltage Loop Gain

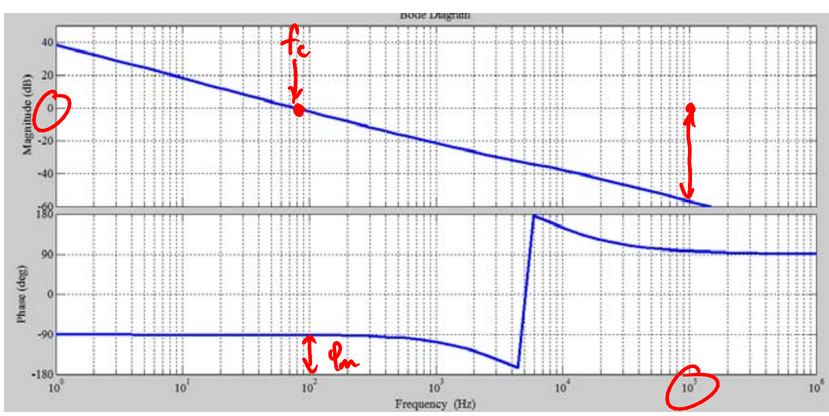




Uncompensated Voltage Loop Gain



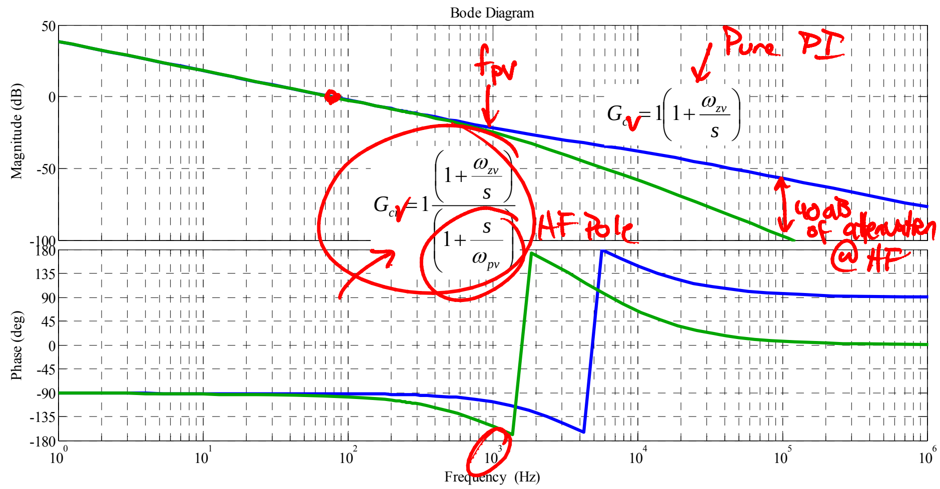
Compensated Loop Gain



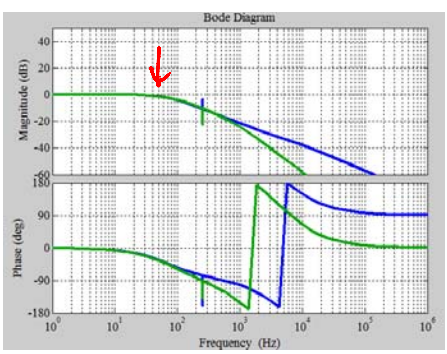
$$G_{ci} = 1\left(1+\frac{\omega_{zv}}{s}\right)$$

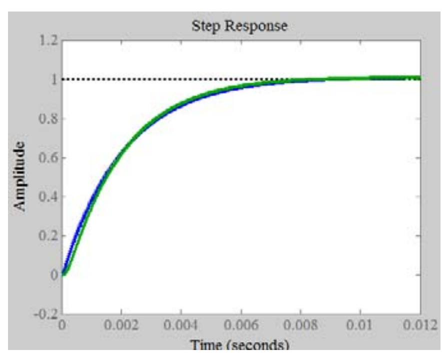
$$\omega_{zv} = 100\,\frac{\text{rad}}{\text{sec}},\ \varphi_m = 88^\circ$$

Loop Gain with of HF Pole

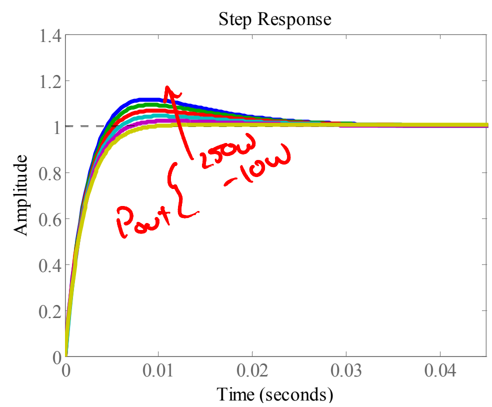


Closed Loop G_v

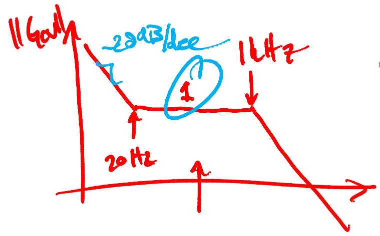


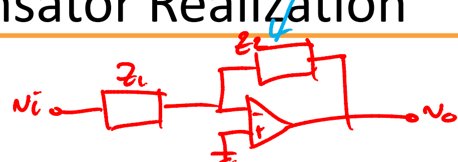


Variations in DC Operation Point



Compensator Realization

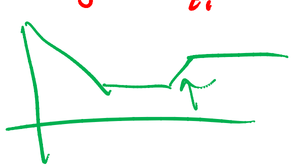


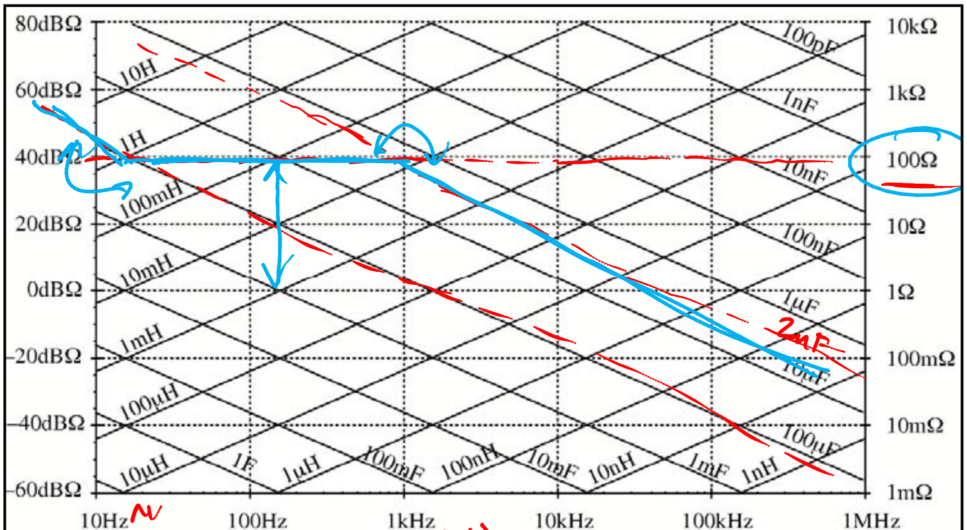


$$\|G\| = \frac{V_o}{V_i} = \frac{-Z_2}{Z_1}$$

$$\|G\| = \left\| \frac{-Z_2}{Z_1} \right\| = \|Z_2\| - \|Z_1\|$$

Construct Z_2 & Z_1 out of R's & C's to get $-\frac{Z_2}{Z_1} = G_{cv}$





$\|Z_1 + Z_2\| \simeq \mathrm{Max}(\|Z_1\|, \|Z_2\|)$

$\|Z_1 \| Z_2\| \simeq \mathrm{Min}(\|Z_1\|, \|Z_2\|)$