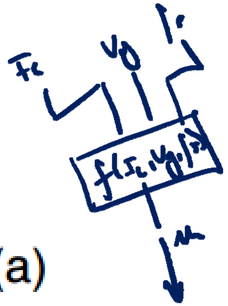
SSM, PWM Case

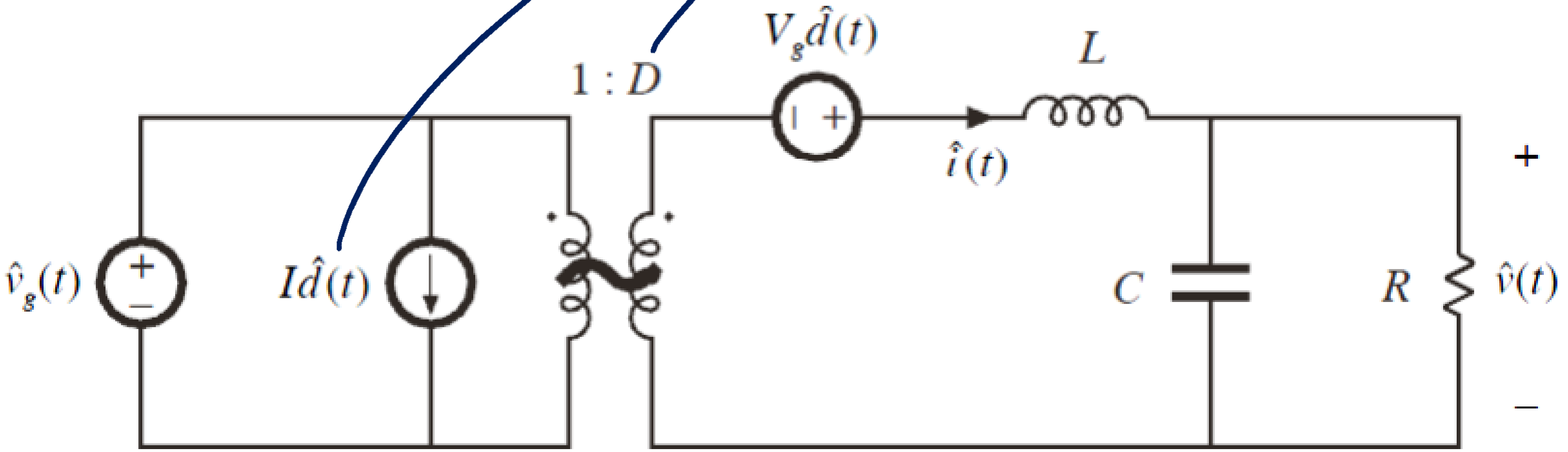


Textbook, Fig.7.17(a)

for resonant case, replace

$D \rightarrow M$

$\hat{d} \rightarrow \hat{m}$



ZVS-QR Switch Cell SSM

$$\mu = 1 - F \cdot \frac{1}{2\pi}\left[\frac{1}{2J_L} + \pi + \sin^{-1}\left(\frac{1}{J_L}\right) + \sqrt{J_L^2 - 1} + J_L\right] = 1 - F \cdot P_{1/2}\left(\frac{1}{J_L}\right)$$

$$= 1 - \frac{f_s}{f_o} P_{1/2}\left(\frac{V_g}{I_L R_o}\right)$$

$$F = \frac{f_s}{f_o} \qquad J_L = \frac{I_L R_o}{V_g}$$

$$\mu = f(I_L, V_g, f_s)$$

$$\frac{\partial \mu}{\partial I_L} = -\frac{f_s}{f_o}\frac{\partial P_{1/2}}{\partial J_L} \cdot \left(\frac{-V_g}{I_L^2 R_o}\right)$$

$$\frac{\partial \mu}{\partial V_g} = -\frac{f_s}{f_o} \cdot \frac{\partial P_{1/2}}{\partial V_g} \cdot \left(\frac{1}{I_L R_o}\right)$$

$$\frac{\partial \mu}{\partial f_s} = -\frac{1}{f_o} P_{1/2}\left(\frac{1}{J_L}\right)$$

$$\hat{\mu} = \underbrace{\frac{\partial \mu}{\partial I_L}}_{K_i}\hat{i}_L + \underbrace{\frac{\partial \mu}{\partial V_g}}_{K_v}\hat{v}_g + \underbrace{\frac{\partial \mu}{\partial f_s}}_{K_c}\hat{f}_s$$

$$P_{1/2}\left(\frac{1}{J_c}\right) = \frac{1}{2\pi}\left[\frac{1}{2J_c} + \pi + \sin^{-1}\left(\frac{1}{J_c}\right) + \sqrt{J_c^2-1} + J_c\right]$$

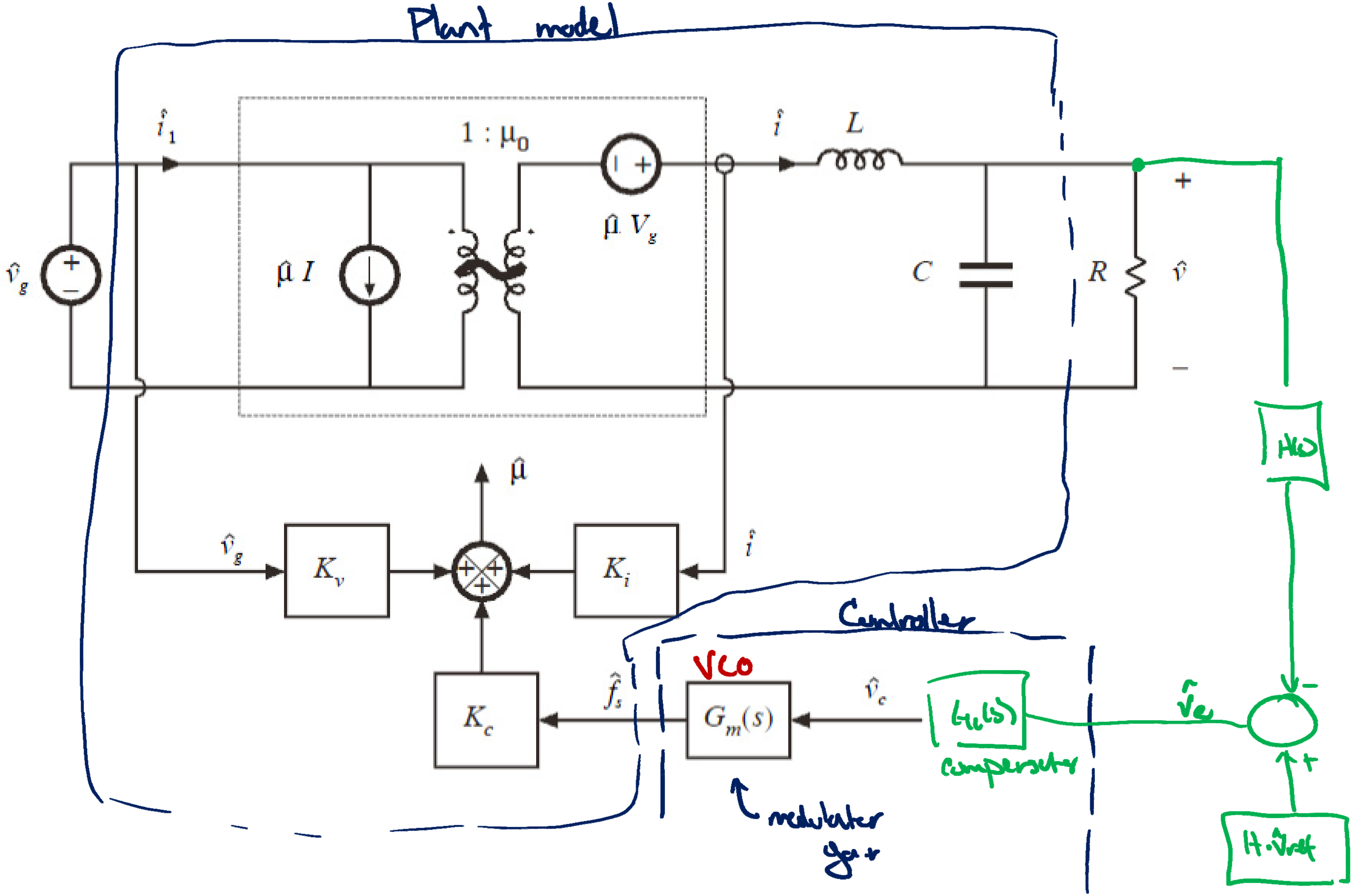
$$\frac{\partial P_{1/2}\left(\frac{1}{J_c}\right)}{\partial J_c} = \frac{1}{2\pi}\left[\frac{-1}{2J_c^2} + \left(\frac{-1}{J_c^2}\right)\cdot\frac{1}{\sqrt{1-\left(\frac{1}{J_c}\right)^2}} + \frac{1/2}{\sqrt{J_c^2-1}}(2J_c) + 1\right]$$

$$= \frac{1}{2\pi}\left[1 - \frac{1}{2J_c^2} - \frac{1/J_c}{\sqrt{J_c^2-1}} + \frac{J_c}{\sqrt{J_c^2-1}}\right]$$

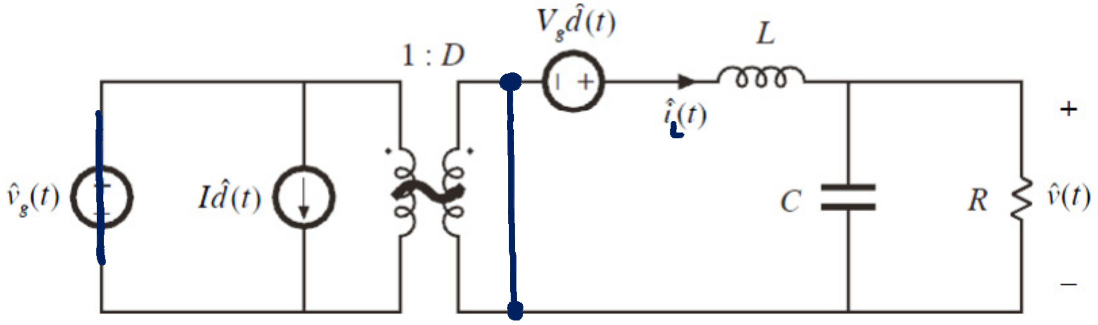
$$= \frac{1}{2\pi}\left[1 - \frac{1}{2J_c^2} + \frac{1}{J_c}\frac{J_c^2-1}{\sqrt{J_c^2-1}}\right]$$

$$\boxed{\frac{\partial P_{1/2}\left(\frac{1}{J_c}\right)}{\partial J_c} = \frac{1}{2\pi}\left[1 - \frac{1}{2J_c^2} + \frac{1}{J_c}\sqrt{J_c^2-1}\right]}$$

SSM, Soft-Switching Buck

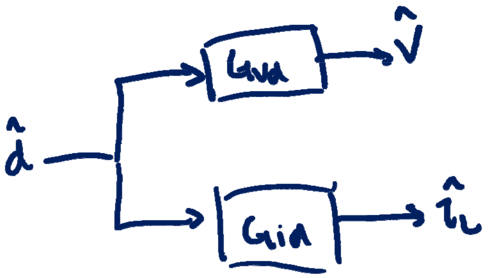


PWM Transfer Functions



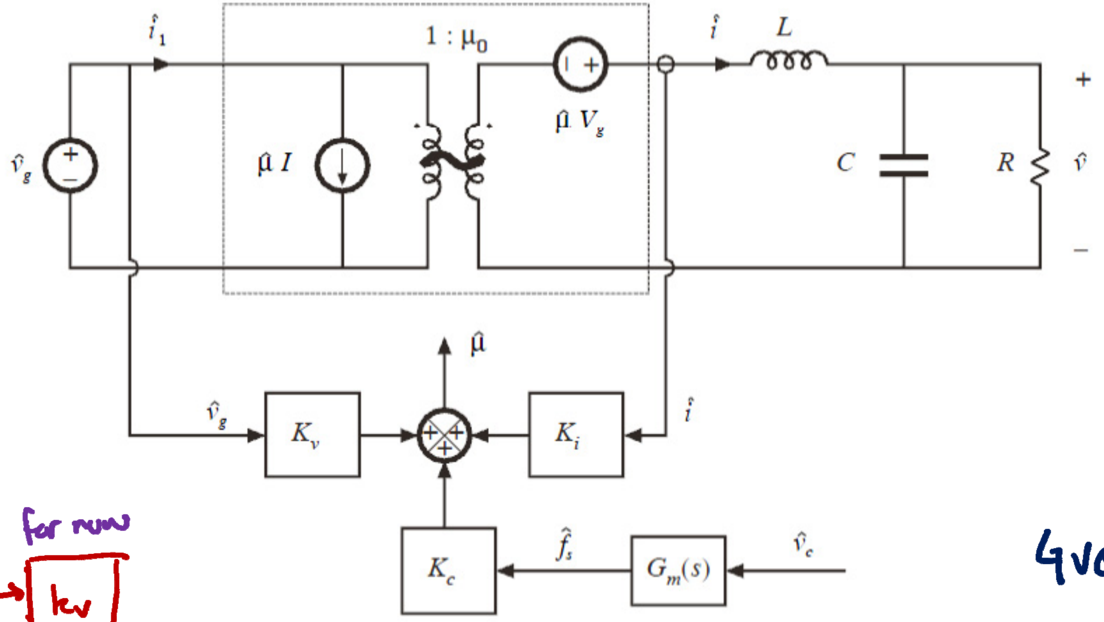
$$G_{vd} = \frac{\hat{v}}{\hat{d}}\Bigg|_{\hat{v}_g=0} = V_g \frac{R\|\frac{1}{sC}}{sL + R\|\frac{1}{sC}} = \frac{V_g}{s^2LC + s\frac{L}{R} + 1}$$

$$G_{id} = \frac{\hat{i}_L}{\hat{d}}\Bigg|_{\hat{v}_g=0} = V_g \frac{1}{sL + R\|\frac{1}{sC}} = \frac{V_g(1 + sCR)}{s^2LC + s\frac{L}{R} + 1}$$



model w/ only $\hat{d}$ as varying indep. input

QR Transfer Functions



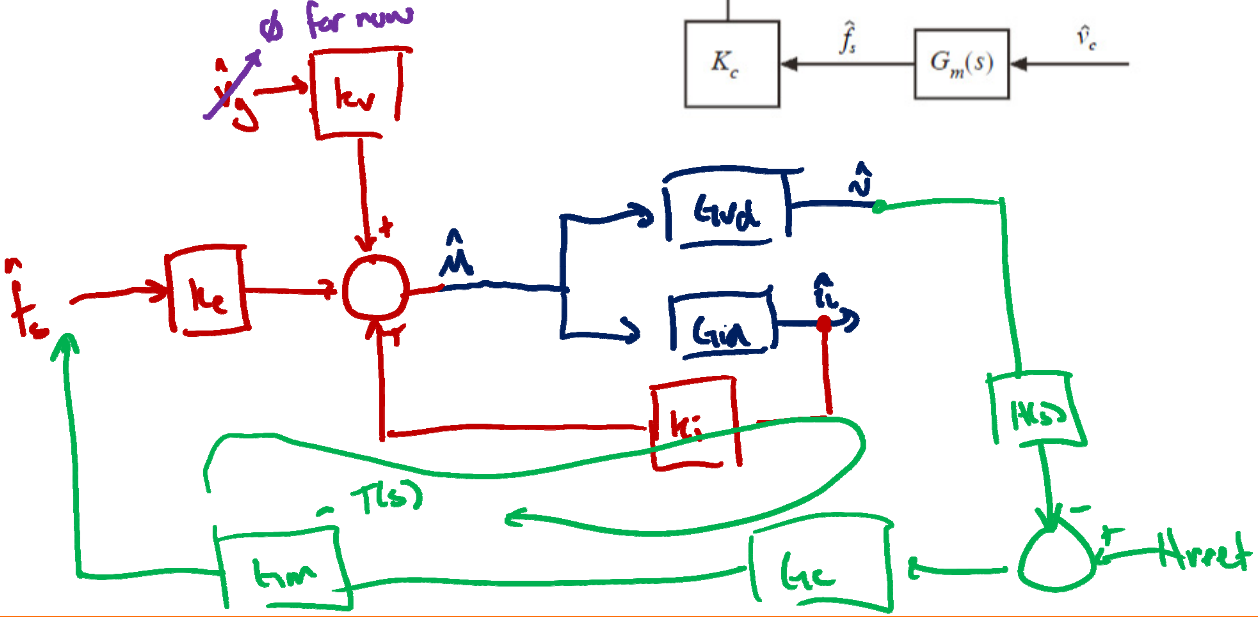
$$G_{v\mu} = \frac{\hat{v}}{\hat{\mu}} = G_{vd} \text{ in PWM case}$$

$$G_{v\mu} = V_g \frac{1}{s^2LC + s\frac{L}{R} + 1}$$

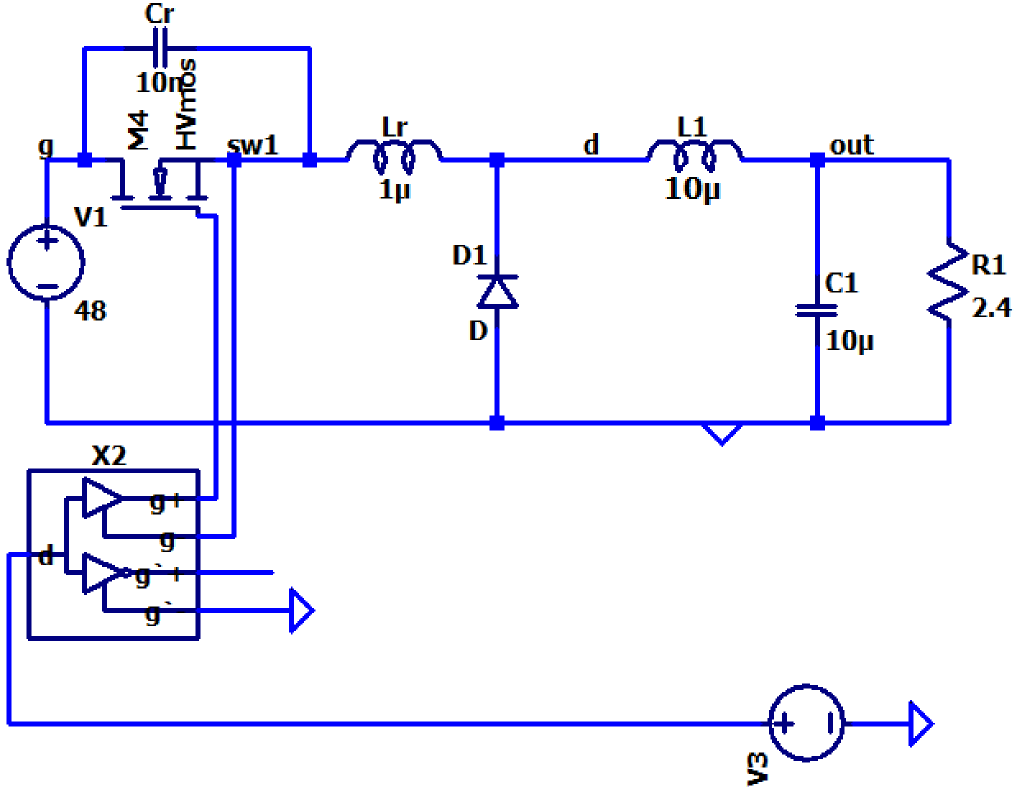
$$G_{i\mu} = \frac{\hat{i}}{\hat{\mu}} = G_{id} \text{ in PWM case}$$

$$G_{i\mu} = V_g \frac{1 + sRC}{s^2LC + s\frac{L}{R} + 1}$$

$$G_{vc} = \frac{\hat{v}}{\hat{f}_s} = k_c G_{vd} \cdot \frac{1}{1 - G_{i\mu} k_i}$$



Example



$f_s = 1\,\text{MHz}$

$J_L \approx 1$

$P_o = 60\,W$

$V = 12V$

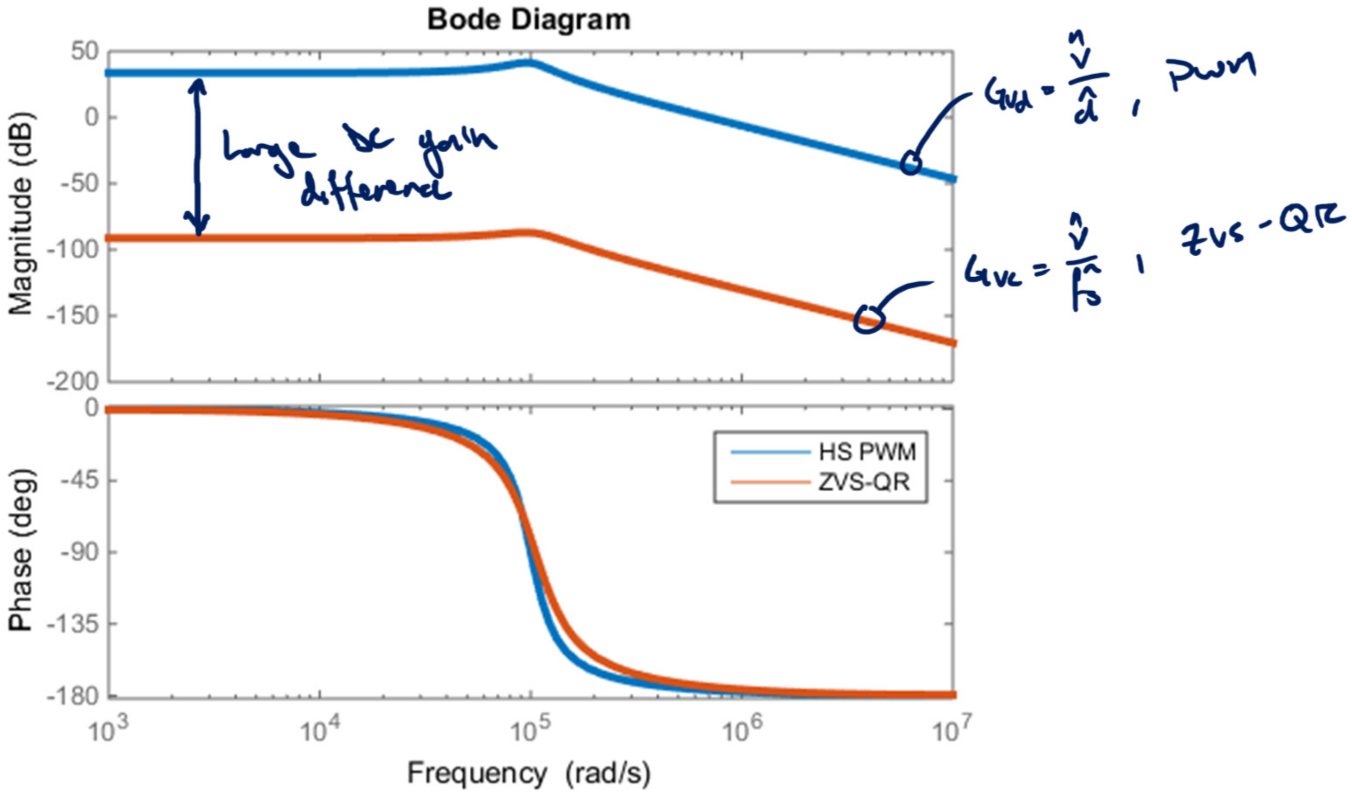
$F = 0.6$

$k_c = 6.24e^{-12}$

$k_i = -0.005$

$k_v = 5.6e{-4}$

Control-to-Output Transfer Function



Control-to-Output Transfer Function