Tampere University of Technology **DEE-34106 Converter dynamics and EMC** 9.5. 2017
Electrical Engineering
Teuvo Suntio — Programmable calculator allowed — 5 questions/ á 6 pts

Question 1. The transfer function of the typical PI controller (Type 2) in power electronics is given in Eq. (1). Sketch its magnitude and phase behavior (i.e., Bode plot) in logarithmic x-scale by using the asymptotic behavior of its magnitude and phase according to the zeros and poles as they are typically placed in power electronics.

$$G_{\text{cc-PI}} = \frac{K_{\text{cc}}(1+s/\omega_{\text{z}})}{s(1+s/\omega_{\text{p}})} \tag{1}$$

Correct magnitude and phase behavior will yield 3 pts each.

Question 2. Two different control-to-output-voltage transfer functions are of the form

$$G_{\text{co}}^{1} = K\frac{1-s/\omega_{\text{z}}}{(1+s/\omega_{\text{p1}})(1+s/\omega_{\text{p2}})} \tag{2}$$

and

$$G_{\text{co}}^{2} = K\frac{1+s/\omega_{\text{z}}}{(1-s/\omega_{\text{p1}})(1+s/\omega_{\text{p2}})} \tag{3}$$

where $\omega_{\text{z}} = 2\pi\cdot 10^{4}\frac{\text{rad}}{\text{s}}$, $\omega_{\text{p1}} = 2\pi\cdot 10^{3}\frac{\text{rad}}{\text{s}}$, $\omega_{\text{p2}} = 2\pi\cdot 10^{5}\frac{\text{rad}}{\text{s}}$ and $K = 10$.

a) Which one of G_{co}^{i} indicates unstable system and why? (2 pts)
b) Can you stabilize the unstable system by control design and how? (2 pts)
c) Does the stable system contain any control design limitation? Justify your answer (2 pts).

Question 3. Fig. 1 shows $G_{\text{co-o}}$ of a certain switched-mode converter at the minimum and maximum input voltages. Each of the subquestions gives 2 points.

a) Which of the transfer function shall be used as the base for the control design and why?
b) What kind of controller type you have to use and why (P, I, PI, PID)?
c) What is the theoretical factor limiting the achievable control bandwidth?

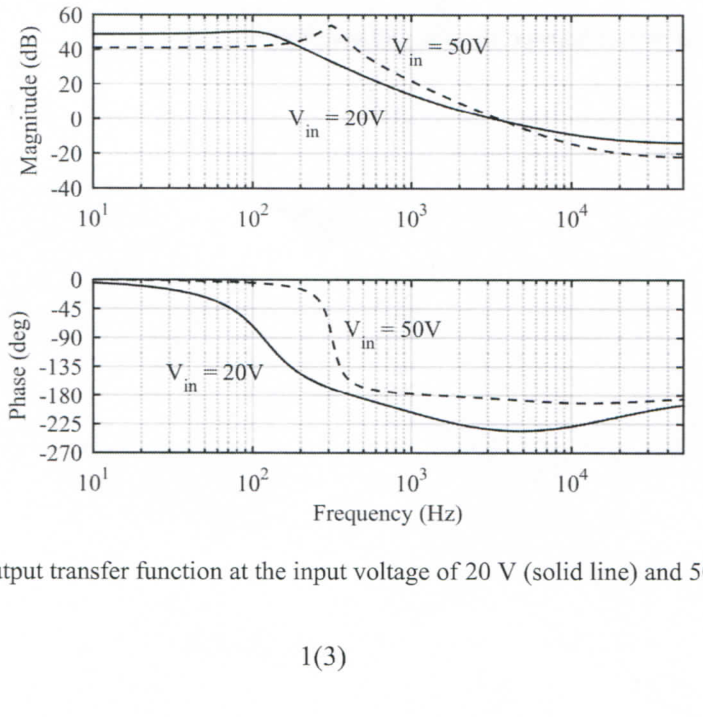

Fig. 1 Control-to-output transfer function at the input voltage of 20 V (solid line) and 50 V (dashed line).

Question 4. If we know that the set of transfer functions (i.e., G parameters) of the converter in Fig. 2a can be given by

$$\begin{bmatrix} \hat{i}_{in} \\ \hat{v}_{o} \end{bmatrix} = \begin{bmatrix} Y_{in}^{G} & T_{oi}^{G} & G_{ci}^{G} \\ G_{io}^{G} & -Z_{o}^{G} & G_{co}^{G} \end{bmatrix} \begin{bmatrix} \hat{v}_{in} \\ \hat{i}_{o} \\ \hat{d} \end{bmatrix} \tag{4}$$

then compute the corresponding set of transfer functions (i.e., Y parameters) representing the dynamics of the converter in Fig. 2b according to

$$\begin{bmatrix} \hat{i}_{in} \\ \hat{i}_{o} \end{bmatrix} = \begin{bmatrix} Y_{in}^{Y} & T_{oi}^{Y} & G_{ci}^{Y} \\ G_{io}^{Y} & -Y_{o}^{Y} & G_{co}^{Y} \end{bmatrix} \begin{bmatrix} \hat{v}_{in} \\ \hat{v}_{o} \\ \hat{d} \end{bmatrix} \tag{5}$$

The power stage of the converter is the same all the time.

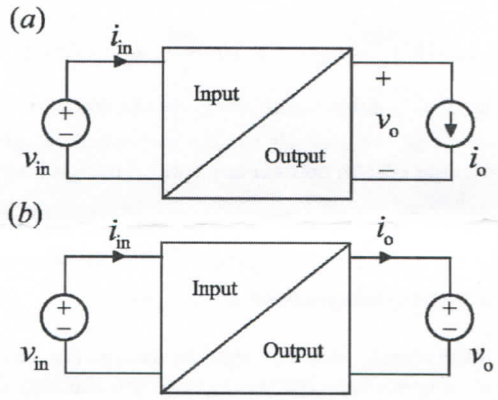

Fig. 2 VF-converter (a) voltage-output mode, and (b) current-output mode.

Each correct transfer function will give 1 pt.

Question 5. Fig. 3 shows the Bode plot of an impedance composing of L and C and their internal ohmic loss components (i.e., r_L and r_C). The characteristic impedance of the circuit equals $0.58\ \Omega$. a) What is the name of the circuit?, b) What is the approximate value of the corresponding inductance?, c) What is the approximate value of corresponding capacitance, d) What is the approximate value of $r_L + r_C$?, e) What is the approximate value of $1/\sqrt{LC}/2\pi$?, f) What is the value of the phase of the circuit at $1/\sqrt{LC}/2\pi$? Each subquestion gives 1 pt.

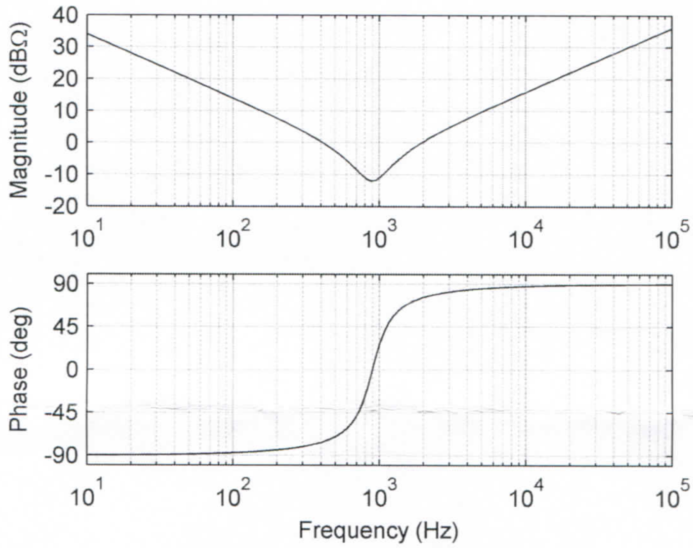

Fig. 3 The frequency response of a specific impedance circuit.