Tampere University of Technology **DEE-34106 Converter Dynamics and EMC** 31.10. 2017
Electrical Energy Engineering
Teuvo Suntio Programmable calculator allowed 5 questions/ á 6 pts

Question 1. Fig. 1 shows an electrical equivalent circuit representing the dynamics of DDR-controlled second-order switched-mode converters operating in CCM. Define symbolically based on Fig. 1 **a)** $Z_{o\text{-}o}$ (i.e., $\hat{v}_o / \hat{i}_o$), **b)** $Z_{in\text{-}o}$ (i.e., $\hat{v}_{in} / \hat{i}_{in}$), and **c)** $G_{io\text{-}o}$ (i.e., $\hat{v}_o / \hat{v}_{in}$). Each correct answer gives 2 pts.

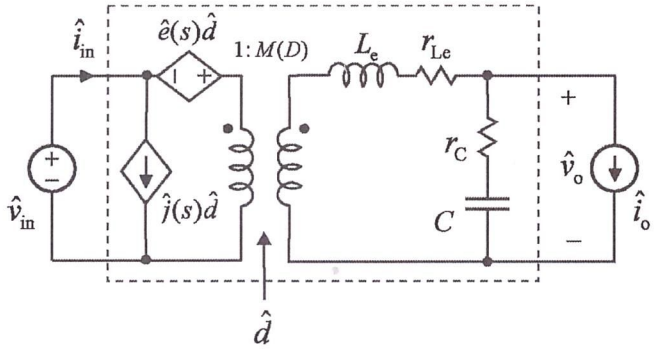

Fig. 1

Question 2. Fig. 2 shows the measured input impedances of a DDR-controlled buck converter equipped with an LC input filter (Z_s).

a) Is the converter stable? (Justify your answer)
b) What is the approximate crossover frequency of the output-voltage feedback loop?
c) The open-loop input impedance ($Z_{in\text{-}o}$), and the LC-filter output impedance (Z_s) overlaps as visible in the figure. What effect this overlap has in the converter?

Each correct answer gives 2 pts.

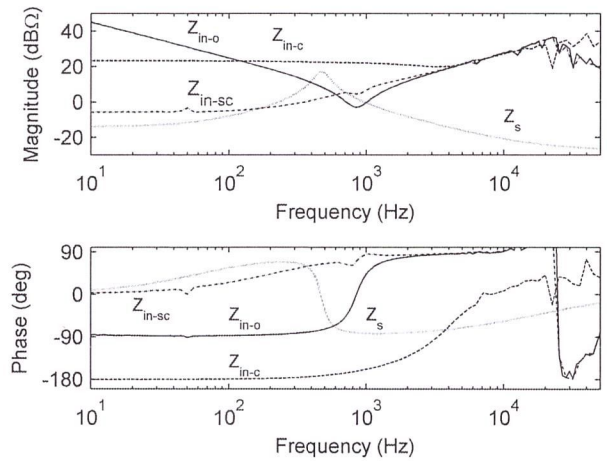

Fig. 2

Question 3. A typical complementary sensitive function ($T(s)$) of a closed-loop system can be given by according to Eq. (1).

$$T(s)=\frac{\omega_n^2}{s^2+s2\zeta\omega_n+\omega_n^2} \tag{1}$$

a) Explain the meaning of ζ and ω_n.
b) Derive the expression for the loop gain $L(s)$ based on Eq. (1).
c) If $2\zeta\omega_n<0$ then how many RHP poles will exist in the system?

Each correct answer will give 2 pts.

Question 4. If we know that the set of transfer functions (i.e., G parameters) of the converter in Fig. 3a can be given by

$$\begin{bmatrix}\hat{i}_{in}\\ \hat{v}_o\end{bmatrix}=\begin{bmatrix}Y_{in}^G & T_{oi}^G & G_{ci}^G\\ G_{io}^G & -Z_o^G & G_{co}^G\end{bmatrix}\begin{bmatrix}\hat{v}_{in}\\ \hat{i}_o\\ \hat{d}\end{bmatrix} \tag{2}$$

then compute the corresponding set of transfer functions (i.e., Y parameters) representing the dynamics of the converter in Fig. 3b according to

$$\begin{bmatrix}\hat{i}_{in}\\ \hat{i}_o\end{bmatrix}=\begin{bmatrix}Y_{in}^Y & T_{oi}^Y & G_{ci}^Y\\ G_{io}^Y & -Y_o^Y & G_{co}^Y\end{bmatrix}\begin{bmatrix}\hat{v}_{in}\\ \hat{v}_o\\ \hat{d}\end{bmatrix} \tag{3}$$

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

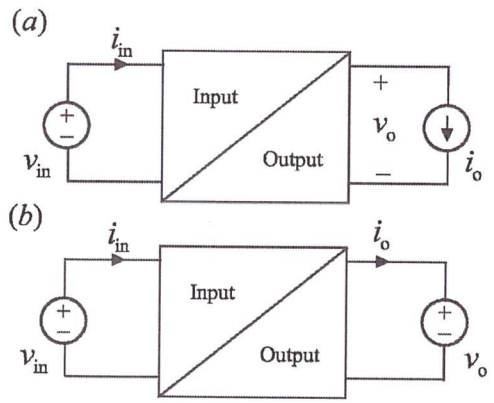

Fig. 3 VF-converter (a) voltage-output mode, and (b) current-output mode.

Each correct transfer function will give 1 pt.

Question 5. Fig. 4 shows the Bode plot of the open-loop output impedance of a buck converter. Its analytic form is given in Eq. (4).

a) Estimate the values of L, C, r_L, and r_C based on Fig. 4 (Each correct value gives 1 pt)
b) What is the characteristic impedance of this circuit and what is its value? (2 pts)

$$Z_{o\text{-}o} = \frac{1}{LC} \cdot \frac{(r_L + sL)(1 + sr_C C)}{s^2 + s\frac{r_L + r_C}{L} + \frac{1}{LC}} \tag{4}$$

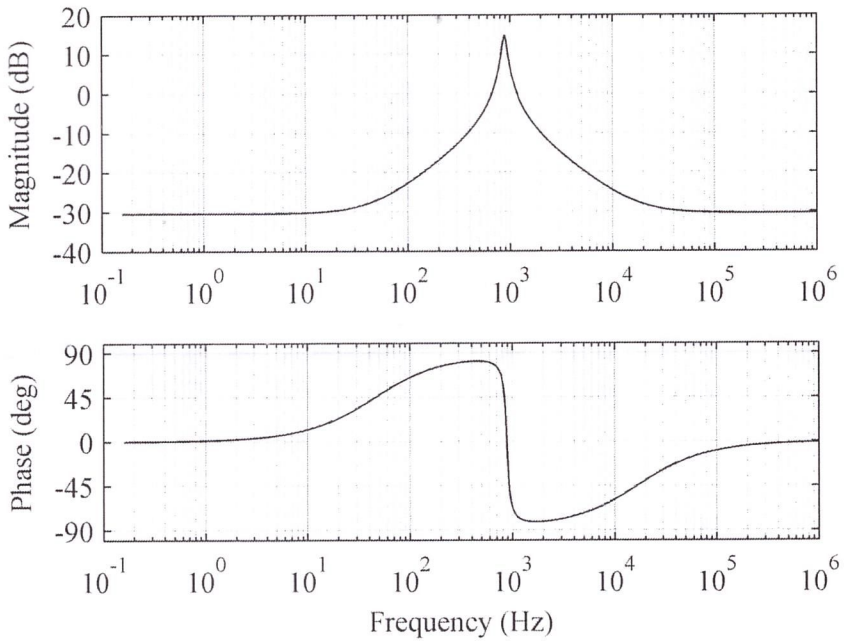

Fig. 4