Tampere University of Technology **DEE-34106 Converter dynamics and EMC** 9.5. 2016
Electrical Engineering
Teuvo Suntio Programmable calculator allowed 5 questions/ á 6 pts

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Question 1. Fig. 1 shows an ideal PWM shunt regulator widely applied in space application. The MOSFET is turned on during the off-time. Solve the transfer functions representing the dynamics of the converter according to

$$\begin{bmatrix} \hat{v}_{in} \\ \hat{i}_o \end{bmatrix} = \begin{bmatrix} Z_{in\text{-}o} & T_{oi\text{-}o} & G_{ci\text{-}o} \\ G_{io\text{-}o} & -Y_{o\text{-}o} & G_{co\text{-}o} \end{bmatrix} \begin{bmatrix} \hat{i}_{in} \\ \hat{v}_o \\ \hat{d} \end{bmatrix} \tag{1}$$

Each correct transfer function will give 1 pt.

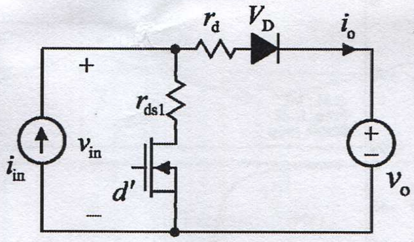


Fig. 1 Ideal PWM shunt regulator.

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

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

and

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

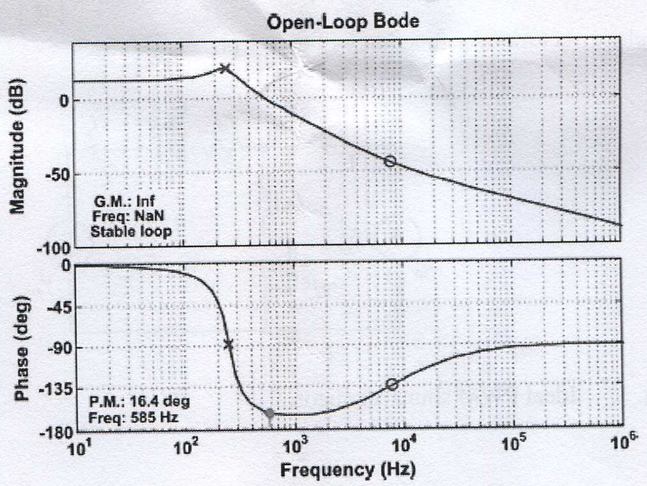
where $\omega_z = 2\pi \cdot 10^4 \frac{\text{rad}}{\text{s}}$, $\omega_{p1} = 2\pi \cdot 10^3 \frac{\text{rad}}{\text{s}}$, $\omega_{p2} = 2\pi \cdot 10^5 \frac{\text{rad}}{\text{s}}$ and $K = 10$.

a) Which one of G_{co}^{i} indicates unstable system and why? (2 pts)

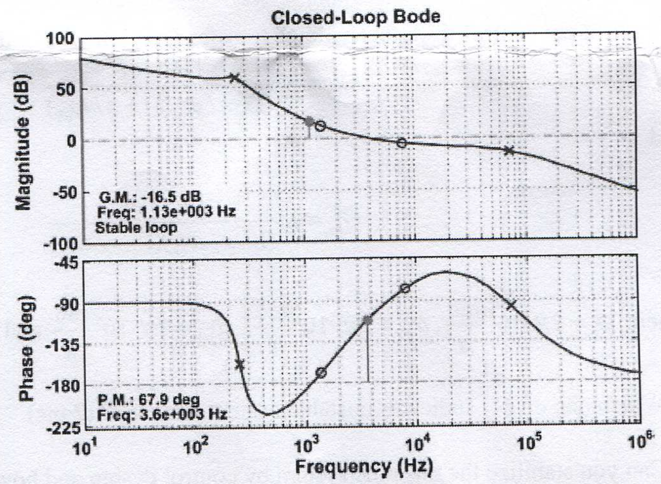
b) Can you stabilize the unstable system by control design and how? (2 pts)

c) Does the stable system contain any control design limitation? Justify your answer (2 pts).

Question 3. Fig. 3 shows $G_{\text{co-o}}$ (a) and the corresponding final loop gain L_{out} (b). **a)** What type of controller is used in the design (P, I, PI, or PID). Justify your answer (2 pts). b) Is the closed-loop converter stable? Justify your answer (1 pts), and c) What kind of controller would suit better for this purpose and how its zeros and poles should be placed (3 pts).



(a)



(b)

Fig. 3 Buck converter: (a) $G_{\text{co-o}}$, and (b) L_{out}

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Question 4. Fig. 4 shows the measured input impedances of a buck converter equipped with an input LC filter. The output impedance of the LC filter in Fig. 4 shows the typical frequency-domain behaviour of a parallel resonant circuit.

a) Estimate the output-voltage-loop crossover frequency based on the frequency-domain behaviour of the closed-loop and open-loop input impedances in Fig. 4 (2pts).
b) Is the converter-LC-filter system stable? Justify your answer based on the impedance behaviour in Fig. 4 (2 pts).
c) What is the approximate value of the converter ideal input impedance ($Z_{in-\infty}$) according to Fig. 4. Justify your answer (2 pts).

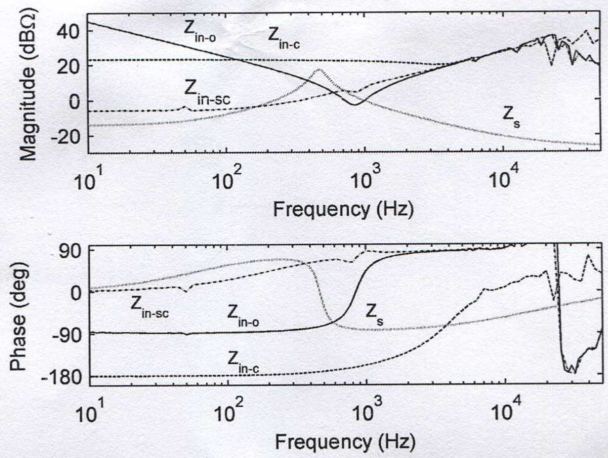

Fig. 4 The measured input impedances of a buck converter.

Question 5. Fig. 5 shows the typical input filter structure of the voltage-fed converters, which is characterized by four transfer functions. Compute those transfer functions by utilizing only circuit theory. Each correct transfer functions will give 1 pts and the identification of the correct set would give 2 pts. Only the named method would give the points. If other techniques are used then the outcome would be zero.

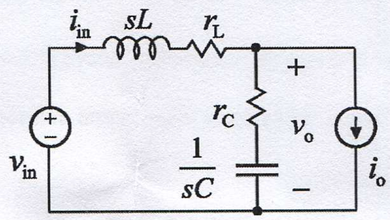

Fig. 5 Input LC filter