

Homework Assignment #10

Chapter 9

Introduction to Power Electronics

ECEN 4797/5797

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Feedback system analysis

A forward converter with feedback system is illustrated in Fig. 1.

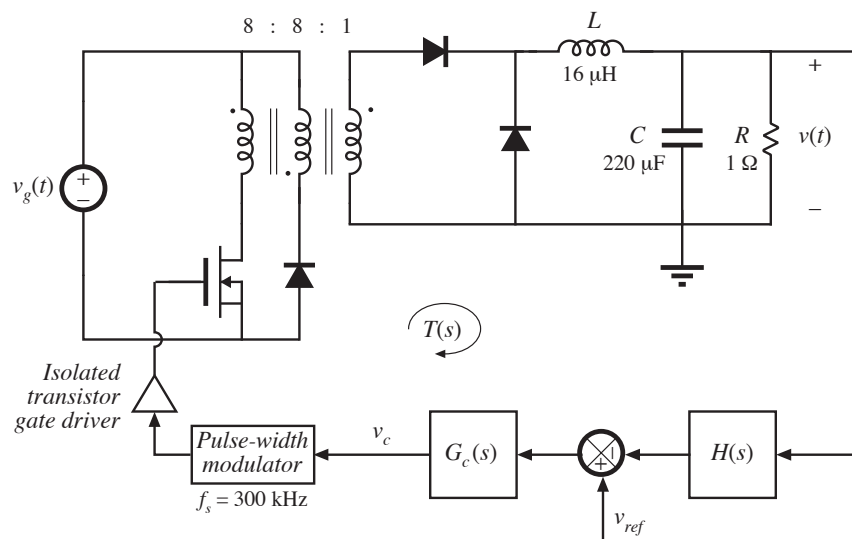


Figure 1 Forward converter with feedback controller.

The small-signal ac model of the forward converter is essentially that of a buck converter plus an additional factor equal to the transformer turns ratio. The relevant parameter values for this system are specified below.

- $H = 0.125$
- $v_{ref} = 1.5 \text{ V}$
- $v_g = 330 \text{ V}$

The compensator transfer function is

$$G_c(s) = G_{c0} \frac{\left(1 + \frac{s}{\omega_z}\right) \left(1 + \frac{\omega_L}{s}\right)}{\left(1 + \frac{s}{\omega_p}\right)} \quad (1)$$

with

$$f_z = \omega_z/2\pi = 4 \text{ kHz} \quad (2)$$

$$f_p = \omega_p/2\pi = 56 \text{ kHz} \quad (3)$$

$$f_L = \omega_L/2\pi = 1 \text{ kHz} \quad (4)$$

$$G_{c0} = 3 \quad (5)$$

The pulse-width modulator is realized by a comparator and sawtooth generator, as discussed in an earlier lecture. The peak-to-peak amplitude of the sawtooth waveform is $V_M = 2 \text{ V}$.

Unless otherwise specified, your numerical results should be entered with an accuracy of $\pm 0.1\%$. Treat all components as ideal and hence neglect losses.

1. What is the value of the steady-state output voltage V ?
2. What is the value of the steady-state duty cycle D ?
3. What is the resonant frequency of the power stage poles? Express your answer in Hz and do not round.
4. What is the Q -factor of the power stage poles? Express your answer as a numerical value, not in dB.
5. Sketch a Bode diagram of the loop gain $T(s)$ for this system. Use the magnitude asymptotes to estimate the crossover frequency f_c of the loop gain, and enter the numerical value in Hz below (do not round your answer).
6. Compute the phase of $T(s)$ at the crossover frequency you estimated above, and use this value to compute the phase margin φ_m . Express your result in degrees, and enter your result below. Use the exact expression for phase (rather than the phase asymptotes) when computing φ_m .
7. Estimate the Q -factor of the closed-loop poles at the crossover frequency, using the relationship between φ_m and Q discussed in lecture, and using your result for φ_m calculated above. Express your result in dB, and enter your result below. Round to the nearest dB.

For Questions 8 to 10, the input voltage contains a dc component of 330 V, plus an ac sinusoid of frequency 100 Hz and peak-to-peak amplitude 20 V.

8. Compute the magnitude asymptote of the open-loop transfer function G_{vg} at 100 Hz. Express your result in dB, and round your answer to the nearest dB. Enter your answer below.

9. Compute the magnitude asymptote of the loop gain T at 100 Hz. Express your result in dB, and round your answer to the nearest dB. Enter your answer below.
10. Compute the peak-to-peak magnitude of the 100 Hz output voltage variation for this system, using your results from Questions 8 and 9. Express your result in millivolts (mV), and round your answer to the nearest mV.