Homework Assignment #4

Transformer Design

Chapter 12

Magnetics for Power Electronic Converters

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Design of an Isolation Transformer for a Full-Bridge Converter

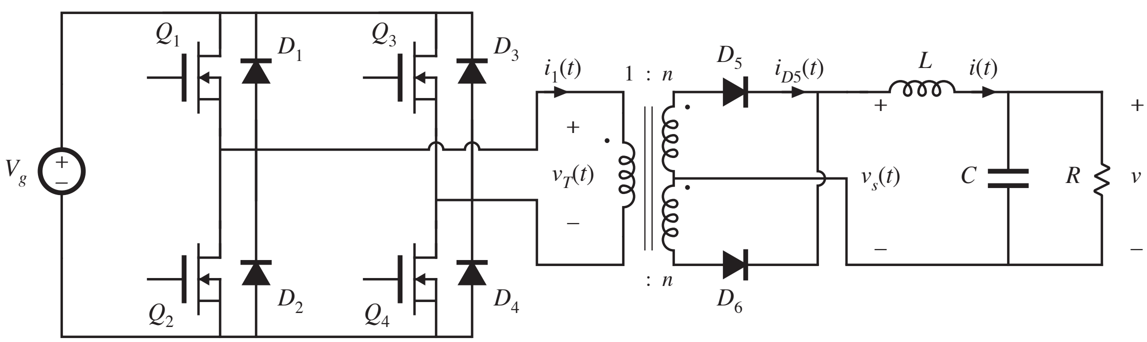

Figure 1 Full-bridge isolated converter.

An isolated buck-derived full-bridge converter (Fig. 1) operates at the following quiescent point:

- Input voltage $V_g = 400\text{V}$
- Output voltage $V = 48\text{V}$
- Load power $P_{load} = 750\text{W}$

The switching frequency of the voltage $v_s(t)$ is 200 kHz, and hence the transformer operating frequency is 100 kHz.

This assignment concerns the design of the transformer for this converter and operating point, including a primary winding and a center-tapped secondary winding as shown. Each half of the center-tapped secondary winding can be treated as a separate winding, such that this becomes a three-winding transformer.

The desired turns ratio is 6:1 (so in the figure above, $n = 1/6$). The empirical core loss equation parameters at 100 kHz are $K_{fe} = 10\,\text{W/T}^{\beta}\text{cm}^3$ and $\beta = 2.7$. Assume a fill factor of $K_u = 0.3$, and design for a winding temperature of 100°C, where copper wire has resistivity $\rho = 2.3 \cdot 10^{-6}\,\Omega\,\text{cm}$. Neglect converter losses, and assume that the output inductor current $i(t)$ has negligible switching ripple. Allow a total transformer copper loss of 1.8 W based on the winding dc resistances (*i.e.*, not including skin and proximity losses), and use a ferrite EC core.

1. What is the $v_s(t)$ duty cycle D? Enter your result accurate to $\pm 1\%$.
2. Compute the rms current of the primary winding. Enter your result accurate to $\pm 1\%$.
3. Compute the rms current of one of the secondary windings. Enter your result accurate to $\pm 1\%$.
4. Compute the applied primary winding volt-seconds λ_1. Enter your result in units of (volt $\cdot\,\mu$s), accurate to $\pm 1\%$.
5. Compute the geometric constant K_{gfe} required for this transformer. Enter your result accurate to $\pm 2\%$.
6. Use the magnetics design tables to select an appropriate ferrite EC core. You should choose the smallest core having K_{gfe} greater than your answer to Question 5.
7. Evaluate the peak ac flux density ΔB. Enter your result in Tesla, accurate to $\pm 2\%$.
8. Determine the number of primary and secondary turns needed. Round your answers to the nearest integers that preserve the desired turns ratio of 6:1. Enter your choice for primary turns n_1 below.
9. Enter your choice for secondary turns n_2 (*i.e.*, for each half of the center-tapped secondary) below.
10. Determine the required primary wire size. You should use the magnetics tables, and select the largest wire size having a bare area less than the wire area that you compute. Enter the AWG number in the field below. Your entry should be a numeric integer, without other characters.
11. Determine the required secondary wire size. You should use the magnetics tables, and select the largest wire size having a bare area less than the wire area that you compute. Enter the AWG number in the field below. Your entry should be a numeric integer, without other characters.
12. For your design, what total copper loss is predicted by the dc wire resistances? Enter your result in watts (W), accurate to $\pm 2\%$.
13. For your design, what is the predicted core loss? Enter your result in watts (W), accurate to $\pm 2\%$.