ECE692

Small Signal Discrete Time Modeling of a DAB Converter

In this problem, you will investigate the control-to-output transfer function of the 200-to-12V, 120 W dual active bridge converter.

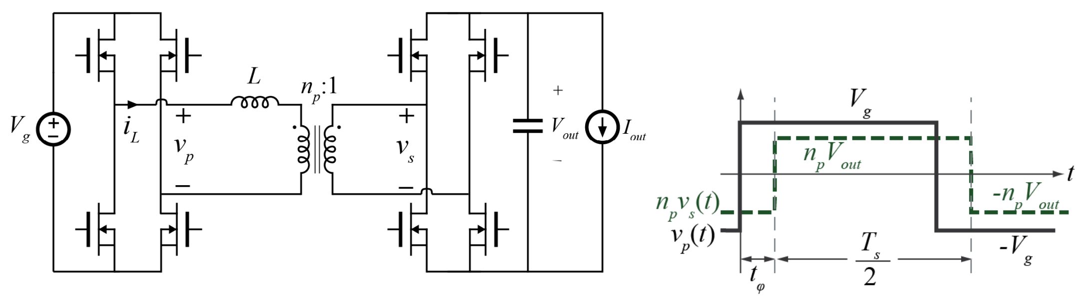

Fig. 1: DAB converter schematic and waveform timing.

Table I: Converter design specification

$r_{on,p}$	$r_{on,s}$	f_s	R_L	L	n_p	V_g	I_{load}	C_{out}
1 Ω	5 mΩ	500 kHz	0.4 Ω	20 µH	17	200 V	10 A	20 µF

Device C_{ds} capacitances and transformer core losses may be neglected.

Derive the control-to-output transfer function $G_{v\varphi}(z)$ from $\varphi = t_\varphi \cdot (2\pi/T_s)$ to V_{out}. An ADC samples the output voltage; in order to accommodate ADC conversion time, the ADC samples the output voltage t_r = 500 ns before the rising edge of $v_p(t)$.

a) Find the steady-state phase shift φ which results in 120 W output power with V_{out} = 12 V.
b) Assuming the ADC samples at rate $f_r = f_s$, derive an expression for $G_{v\varphi}(z)$, and generate a bode plot of the transfer function
c) Assuming the ADC samples at rate $f_r = 2 \cdot f_s$, with each sample occurring t_r = 500 ns prior to the primary-side switching action, derive an expression for $G_{v\varphi}(z)$, and generate a bode plot of the transfer function. Comment on any differences between the results of parts (b) and (c)
d) Repeat (c) for t_r = 250 ns and 0 ns. Plot all three bode plots on a single axis. Comment on any differences.
e) Using the same approach, derive an expression and generate a bode plot for the output impedance $Z_{out}(z) = -\hat{V}_{out}(z)/\hat{I}_{out}(z)$. Logically, we expect the high-frequency output impedance of this converter to be dominated by the output capacitance. Comment on the characteristics of the bode plot.

Note: in all subparts, you may use the default MATLAB mapping built into the `bode()` function to convert between discrete and continuous systems. `z = tf('z', Ts)` will create a variable `z` which is the z-transform variable, with sampling time `Ts`. Then, `bode(z)` will produce a bode plot of $G(z) = z$ with the built in (exponential) mapping.