

PHASE-SHIFT FULL BRIDGE (PSFB) PART II

USING MATHCAD AND MATLAB / SIMULINK TOOLS

I. PARAMETERS AND CALCULATIONS

1. SYSTEM PARAMETERS:

Input voltage (V_{in}):	350-450 V
Output voltage (V_{out}):	24 V
Output current (I_{out}):	50 A
Switching Frequency (f_{sw}):	100 kHz

2. ASSUMPTIONS:

$$V_{RDSON} = 0.3 \text{ V}$$

$$C_{OSS,avg} = 2 \text{ nF}$$

3. SELECTION OF TURN-RATIO (N):

Select transformer turns based on 70% duty cycle (D_{max}) at minimum specified input voltage.

$$n = \frac{(V_{in,min} - 2V_{RDSON})D_{max}}{V_{out} + V_{RDSON}} = \frac{(350 - 0.6) \times 0.7}{24 + 0.3} \approx 10$$

4. MAGNETIZING INDUCTANCE (L_M):

Calculate typical duty cycle (D_{typ}) based on average input voltage.

$$D_{typ} = \frac{(V_{out} + V_{RDSON})n}{(V_{in} - 2V_{RDSON})} = \frac{(24 + 0.3) \times 10}{(400 - 2 \times 0.3)} = 0.6$$

To keep the RMS current in the output capacitance to a minimum LOUT will be selected so the inductor ripple, current ($\Delta I_{L_{out}}$) will be 20% of the DC output current.

$$\Delta I_{L_{out}} = 0.2I_{out} = 0.2 \times 50 = 10 \text{ A}$$

$$L_M \geq \frac{V_{in}(1 - D_{typ})}{\frac{0.5\Delta I_{L_{out}}}{n} f_s} \geq \frac{400(1 - 0.6)}{\frac{0.5 \times 10}{10} \times 100,000} = 3.2 \text{ mH}$$

5. LEAKAGE INDUCTANCE (L_{lkg}):

Calculating the leakage inductor (L_{lkg}) is based on the amount of energy required to achieve zero voltage switching.

$$L_{lkg} \geq \frac{2C_{OSS,avg}V_{in,max}^2}{\left(\frac{I_{PP}}{2} - \frac{\Delta I_{Lout}}{2n}\right)^2} \geq 101 \text{ nH}$$

where

$$I_{PP} = \frac{1}{n} \left(\frac{P_{out}}{V_{out}\eta} + \frac{\Delta I_{Lout}}{2} \right) + \Delta I_{mag}$$

$$\Delta I_{mag} = \frac{V_{in,min}D_{max}}{2L_M f_{sw}}$$

6. OUTPUT FILTER INDUCTOR (L_o):

$$L_o = \frac{\left(\frac{V_{in}}{n} - V_{out}\right) \times V_{out}}{0.01 I_{out,max} \Delta I_{ripple} \frac{V_{in}}{n} F_c \eta} = 4.7 \mu\text{H}$$

7. OUTPUT FILTER CAPACITOR (C_o):

$$C_o = \frac{0.9 t_{HU} P_{out}}{0.1 V_{out} V_{trans}}$$

$$t_{HU} = \frac{0.9 L_{out} P_{out}}{V_{out}^2}$$

Ref: Phase-Shift Full Bridge (PSFB) AC-DC Power Supply Basic Simulation Circuit (Reference Guide) - Toshiba

II. CLOSED-LOOP CONTROL DESIGN:

8. REQUIREMENTS:

Cross-over frequency = 1 kHz

Phase margin = 60°

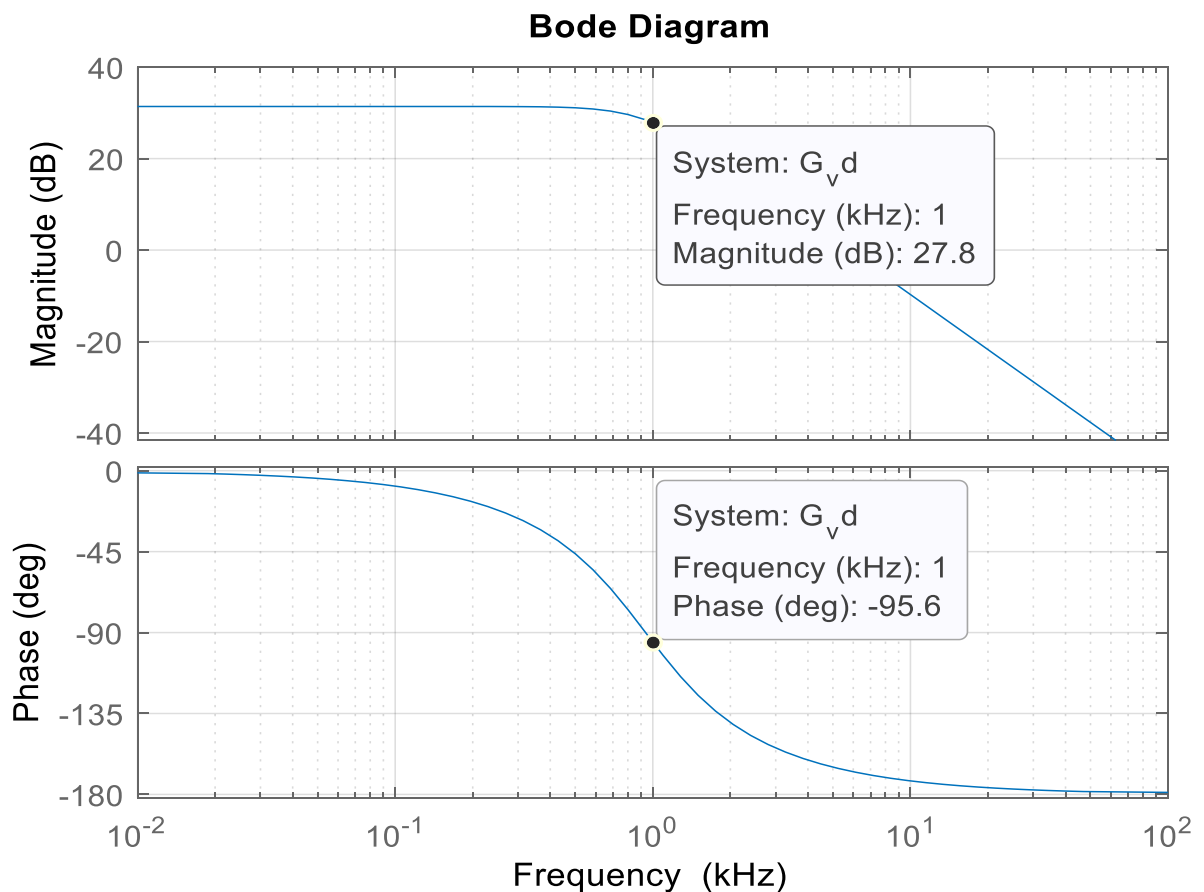
$$G_{v\phi} = \frac{\frac{1}{n} V_{in}}{L_f C_f s^2 + \left(\frac{L_f}{R_{out}} + R_d C_f \right) s + \frac{R_d}{R_{out}} + 1},$$

From the open-loop bode plot of the system, it can be noted that no need for phase boosting at the required cross-over frequency; consequently, PI regulator is sufficient.

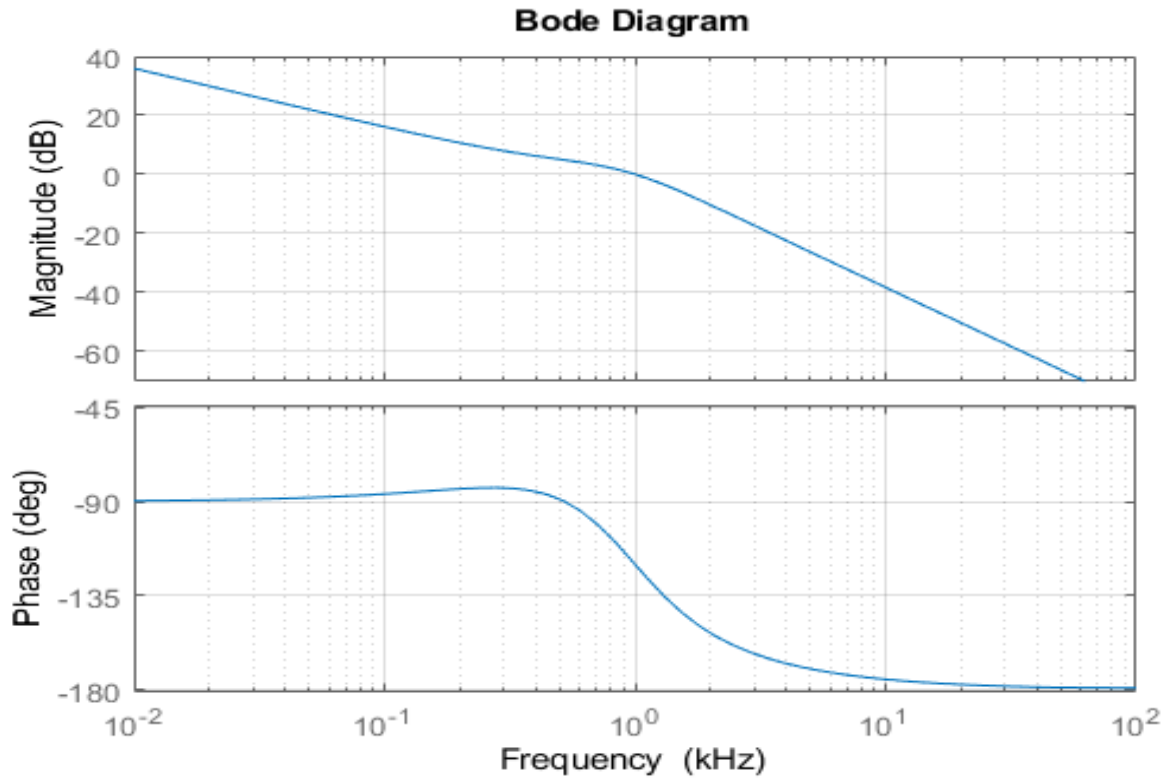
$$PI = k_p + \frac{k_i}{s}$$

$$k_p = 0.037, \quad k_i = 106$$

9. OPEN-LOOP BODE PLOT OF THE SYSTEM, NOT COMPENSATED



10. OPEN-LOOP BODE PLOT OF THE SYSTEM WITH PI COMPENSATION

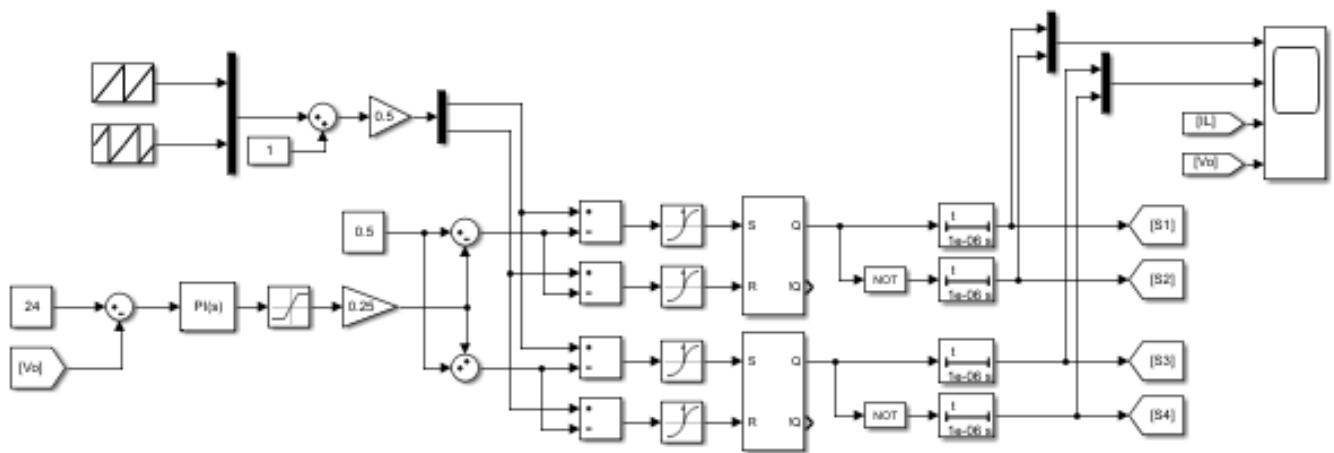


III. PHASE SHIFTED BRIDGE SIMULATION IN MATLAB

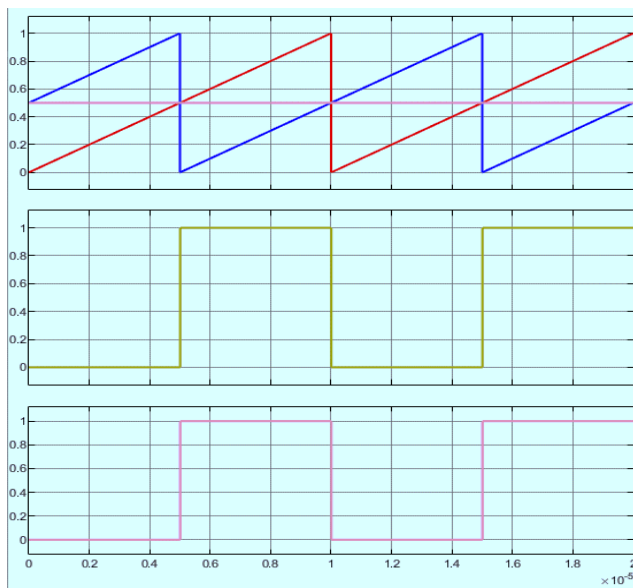
BUILDING MODULATOR OF PHASE SHIFT BRIDGE CONTROL SIGNALS:

The modulator described below is just of the ways the phase shifted modulation can be created. It is done by moving saw-tooth signals up and down on amplitude scale.

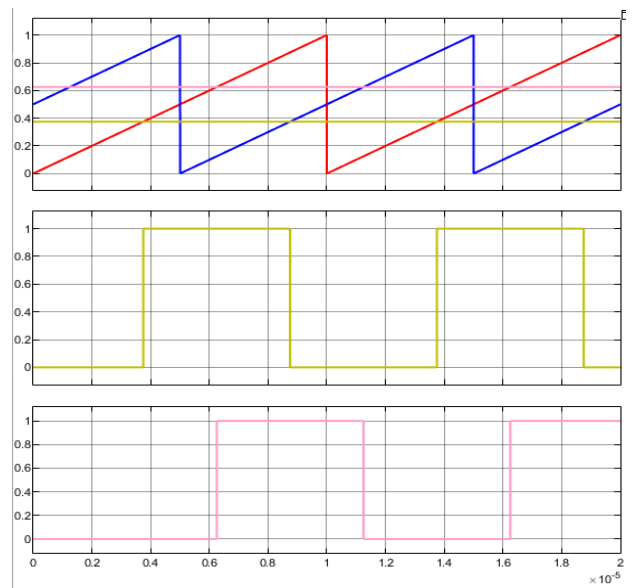
To have two pulses with a controllable phase-shift, two sawtooth carriers are used. The phase-shift between the two carriers represents the duty-cycle of the switches (fixed to 50%). The modulation signal of one switch moves from 0 to 0.5 while the other moves from 0.5 to 1 proportional to the required phase-shift between the two gate signals. Below are three conditions for the phase-shift



$\Phi = 0$



$\Phi = 90^\circ$



$$\Phi = 180^\circ$$

