Switch Realization Problems

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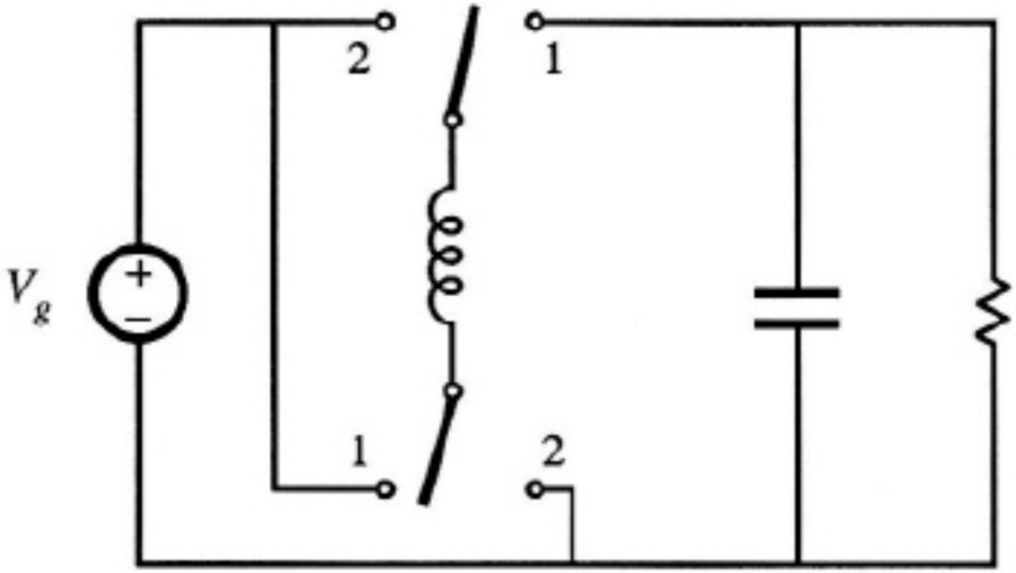
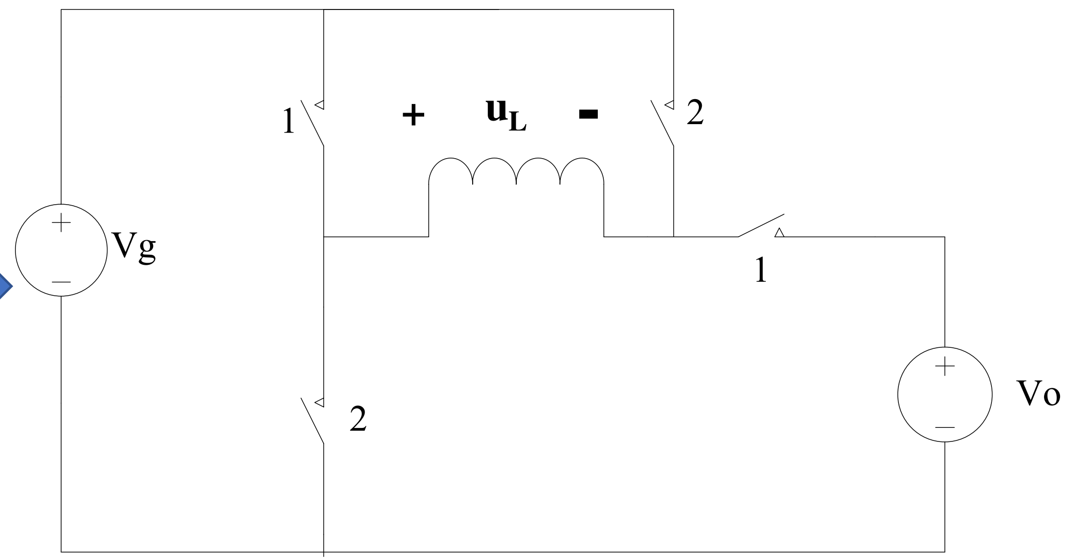
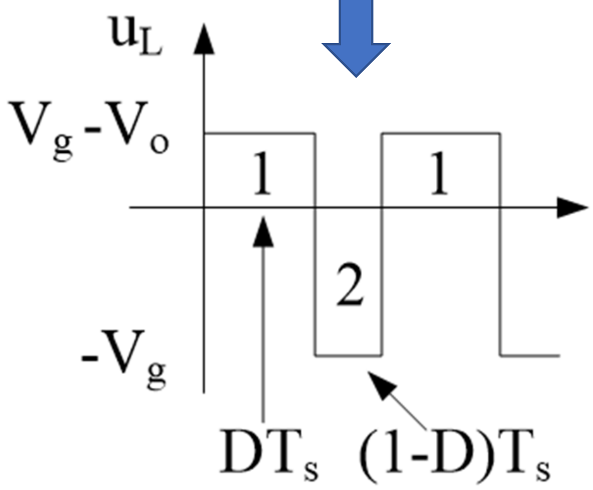
Associate Professor, DUTH

Problem 1



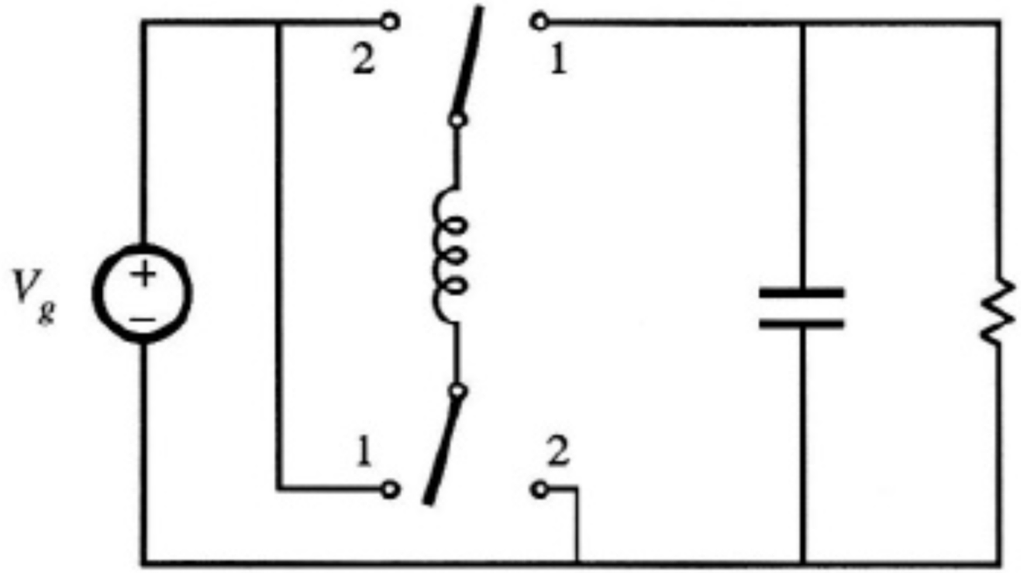


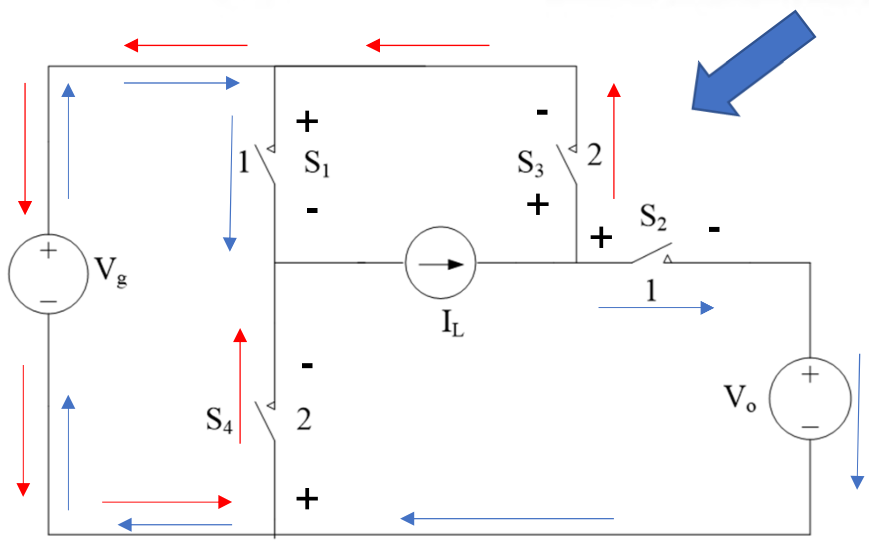


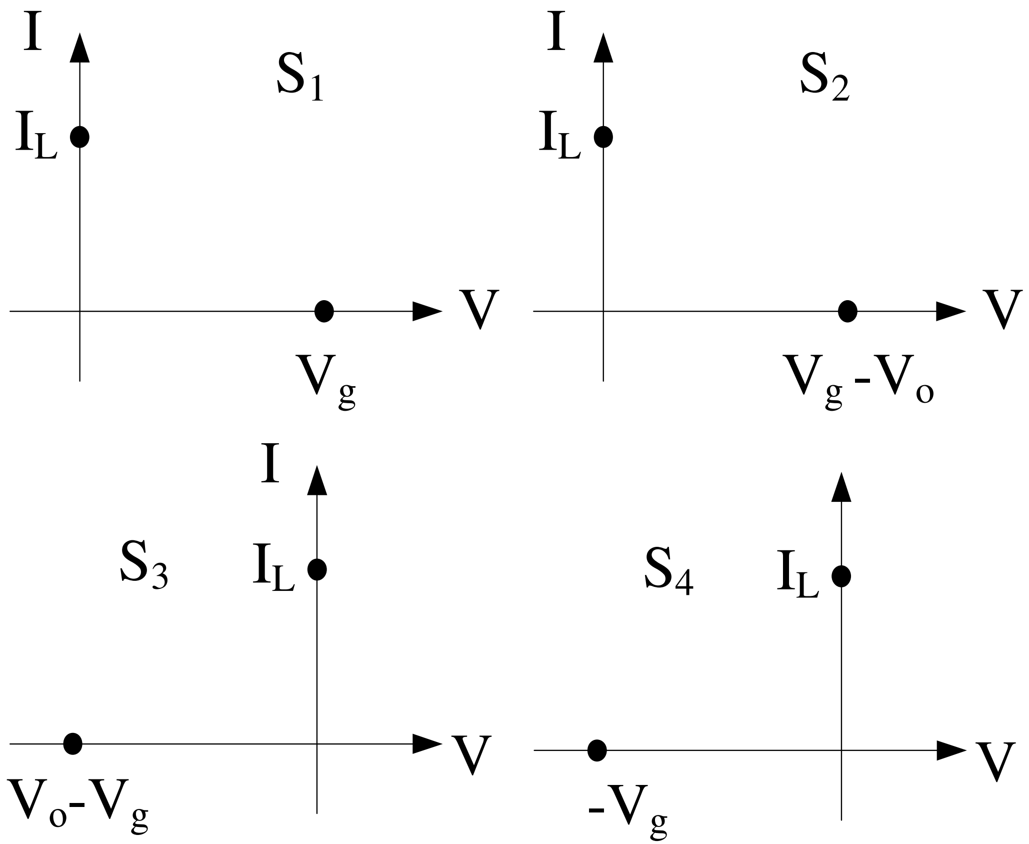
$$\left(V_g - V_o\right)D - V_g\left(1-D\right) = 0 \Rightarrow V_g\left(D-1+D\right) + V_o\left(-D\right) = 0 \Rightarrow$$

$$\Rightarrow V_g\left(2D-1\right) = V_o D \Rightarrow \frac{V_o}{V_g} = \frac{2D-1}{D}, \qquad D \geq 0.5$$

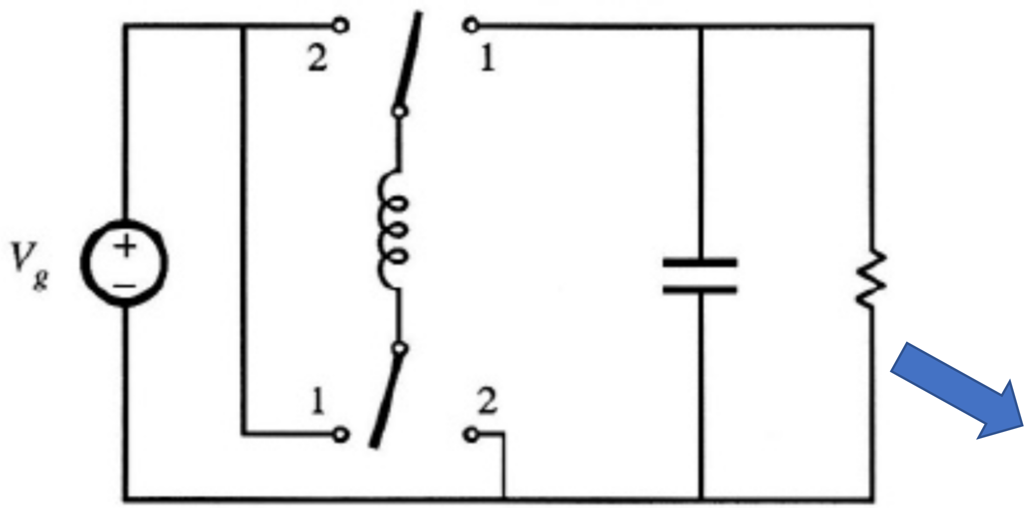
Problem 1 (cont.)

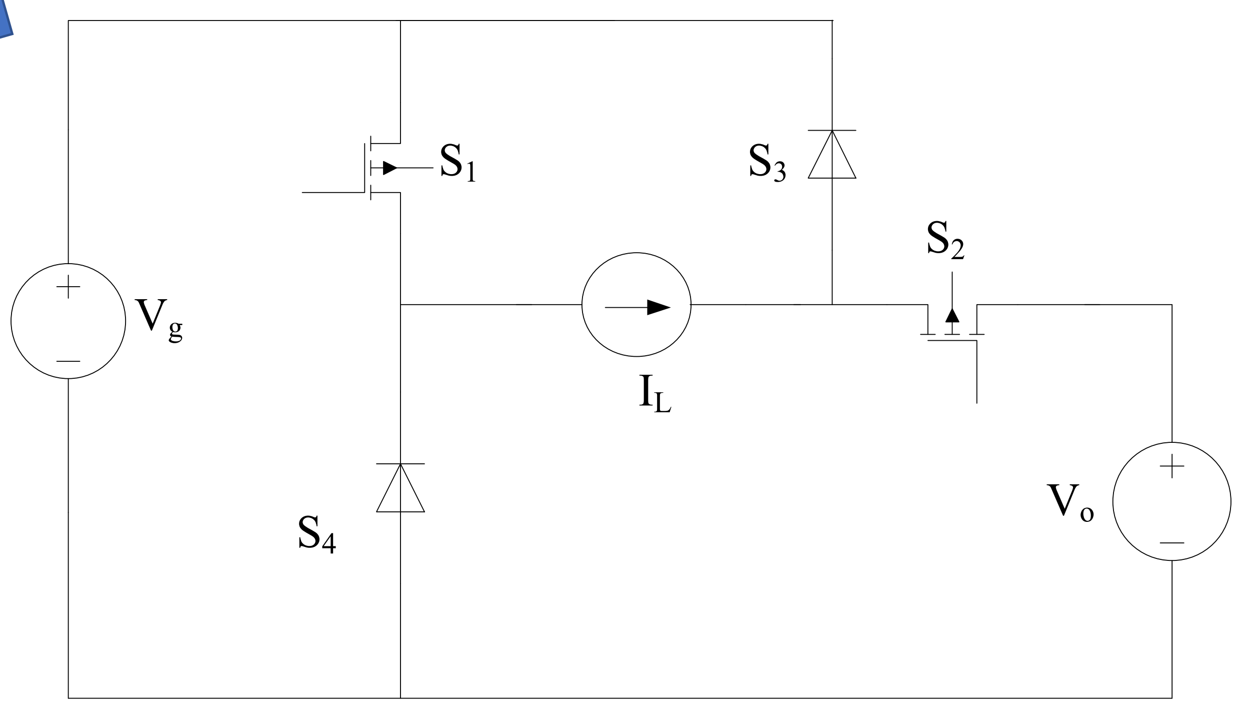




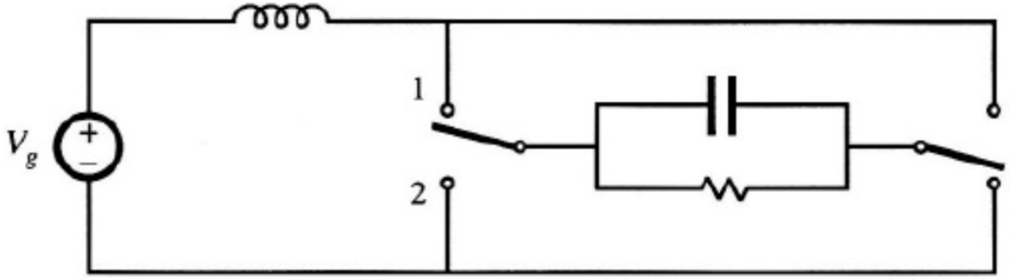


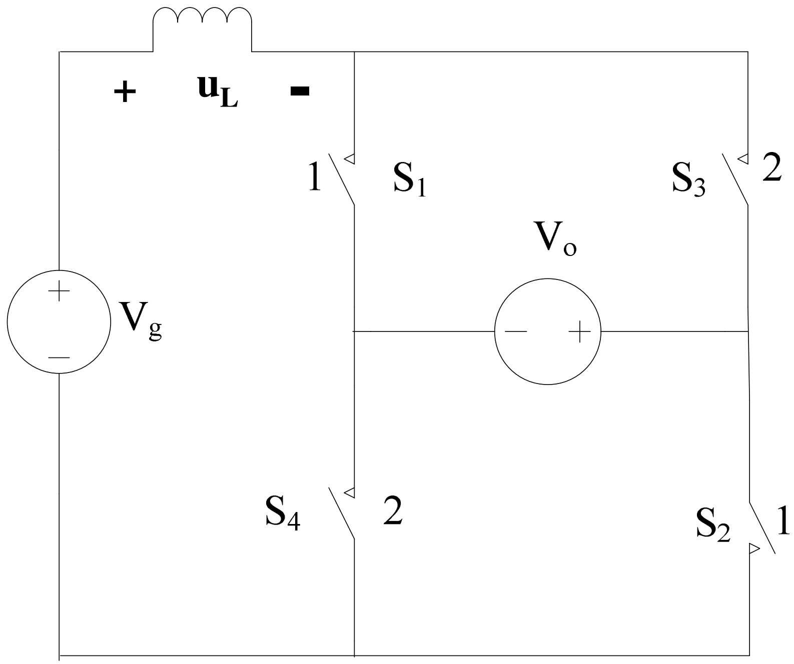
Problem 1 (cont.)





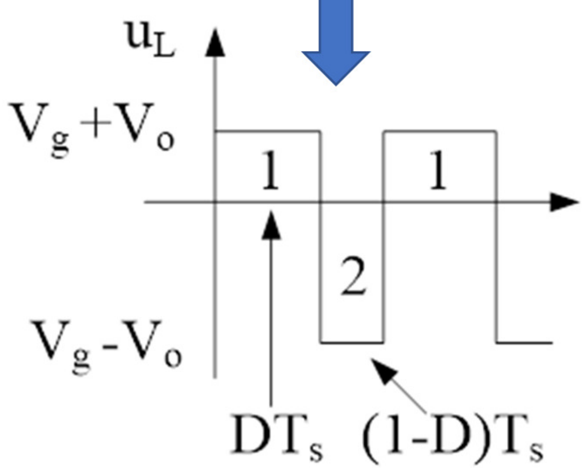
Problem 2



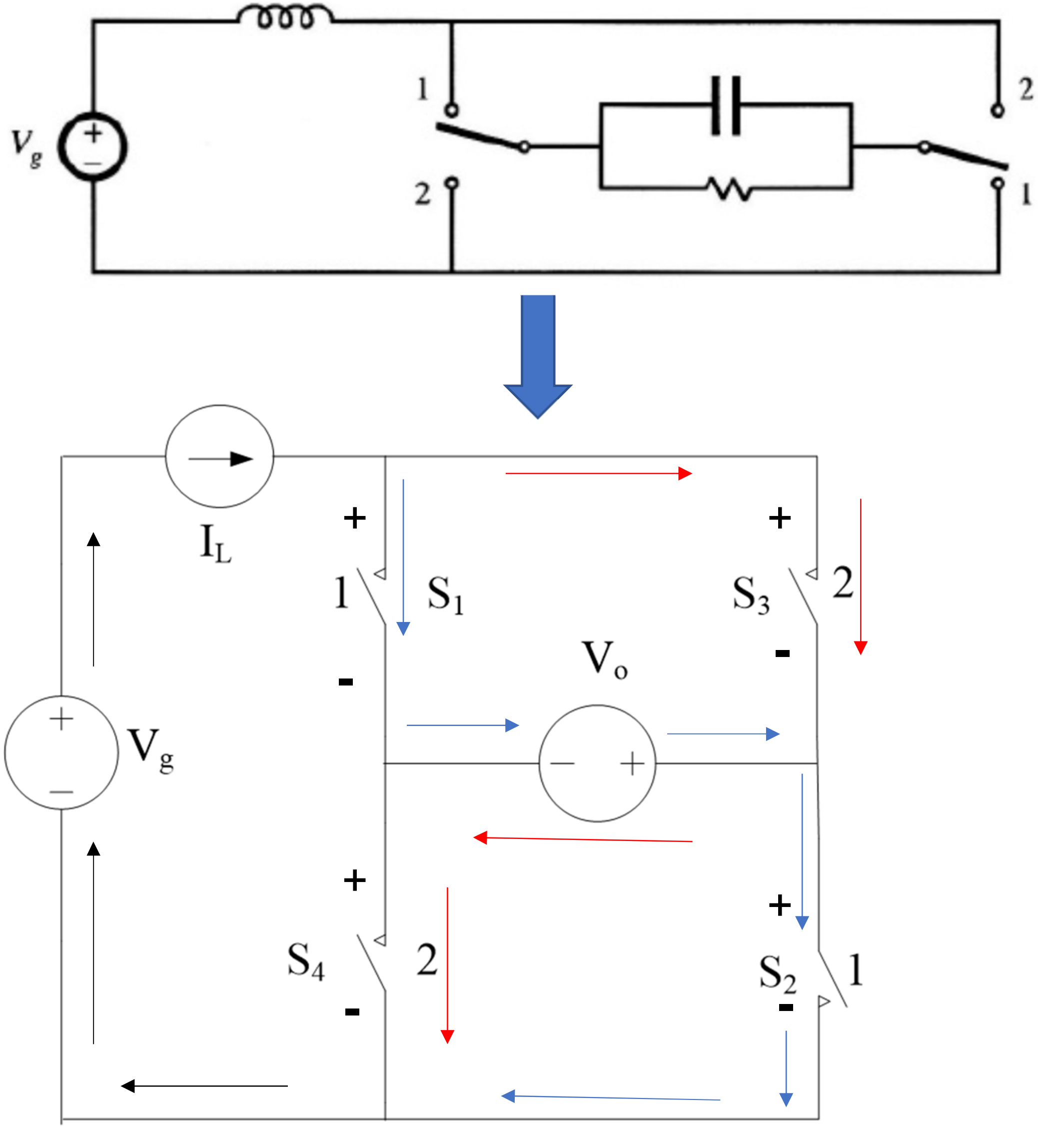


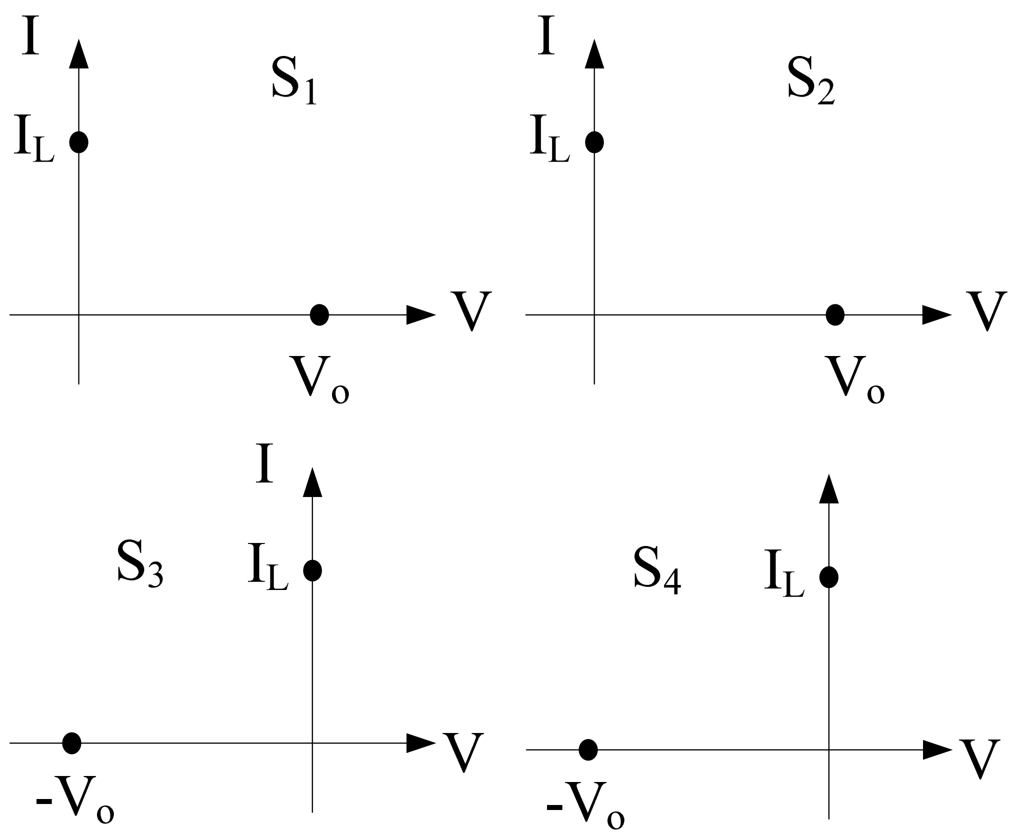
$$\left(V_g+V_o\right)D+\left(V_g-V_o\right)(1-D)\Rightarrow V_g\left(D+1-D\right)+V_o\left(D-1+D\right)=0\Rightarrow$$

$$\Rightarrow V_g=-V_o\left(2D-1\right)\Rightarrow\frac{V_o}{V_g}=\frac{1}{1-2D},\qquad D\le 0.5$$

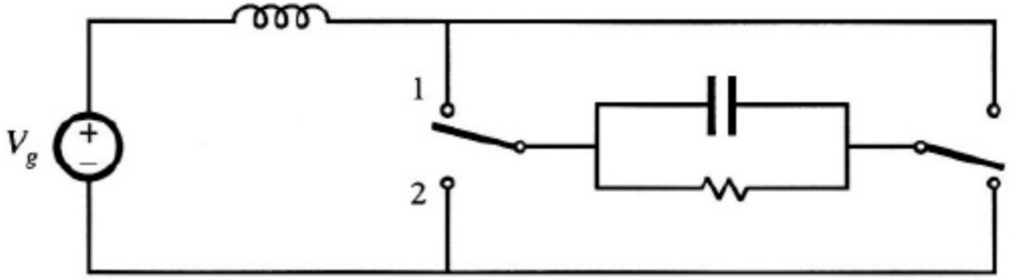


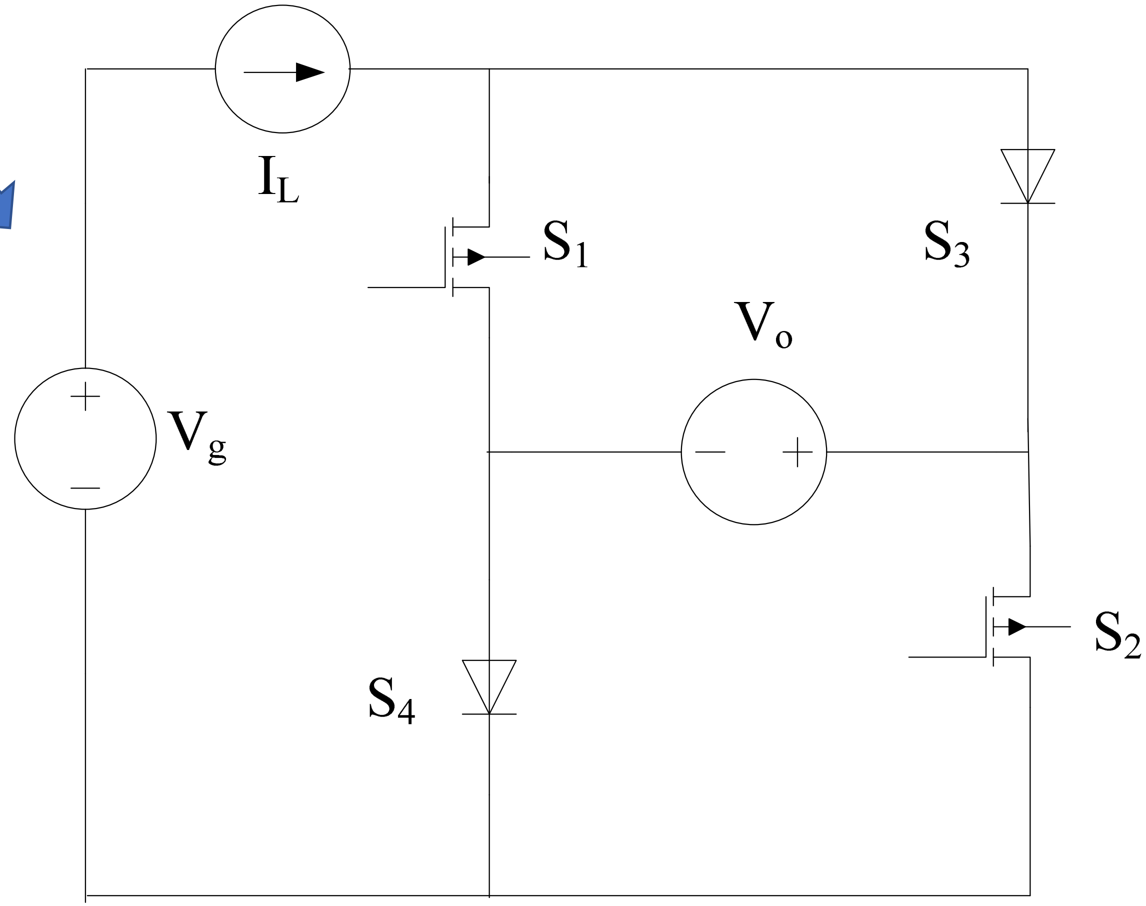
Problem 2 (cont.)



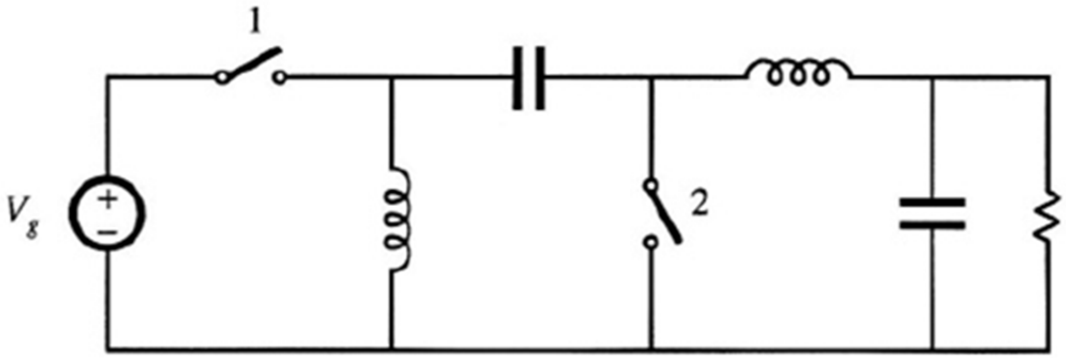


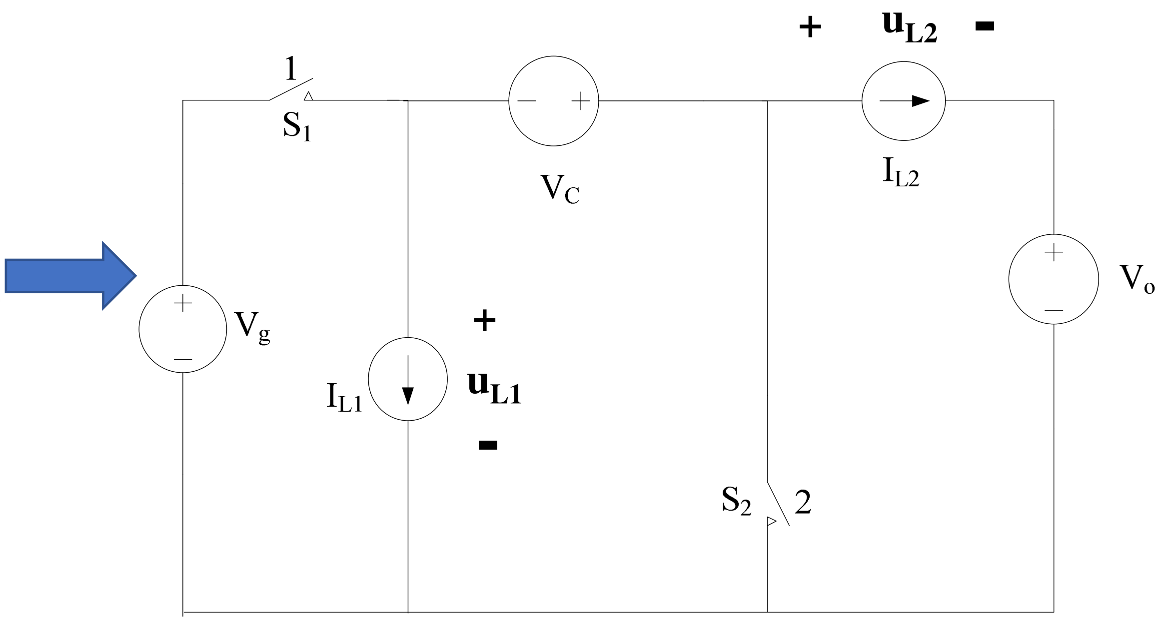
Problem 2 (cont.)





Problem 3





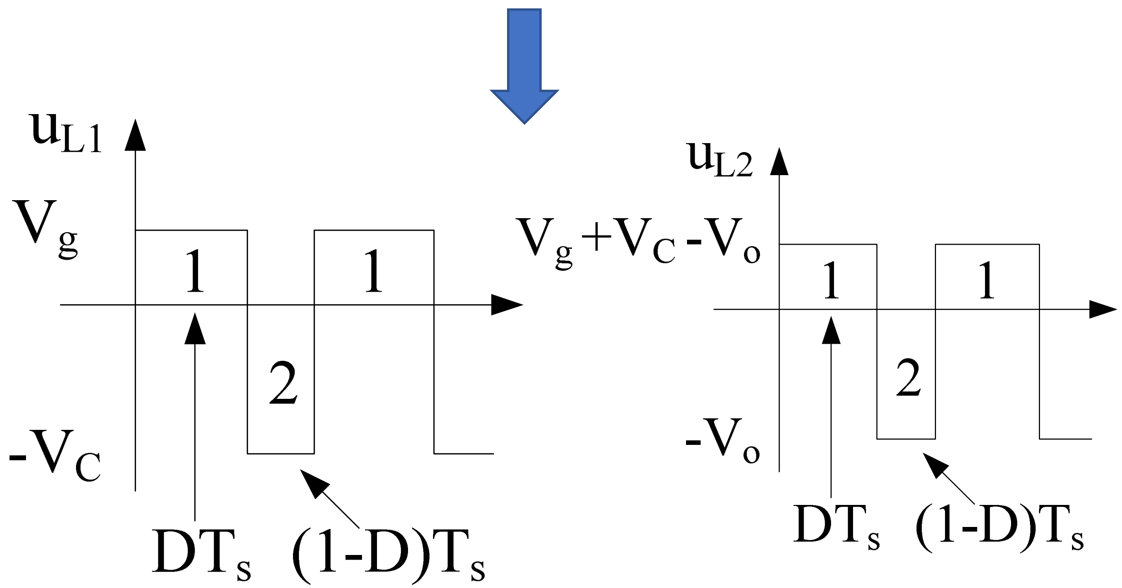
$$V_g D - V_C(1-D) = 0 \Rightarrow V_C = V_g \frac{D}{1-D}$$

$$(V_g + V_C - V_o)D - V_o(1-D) = 0 \Rightarrow$$

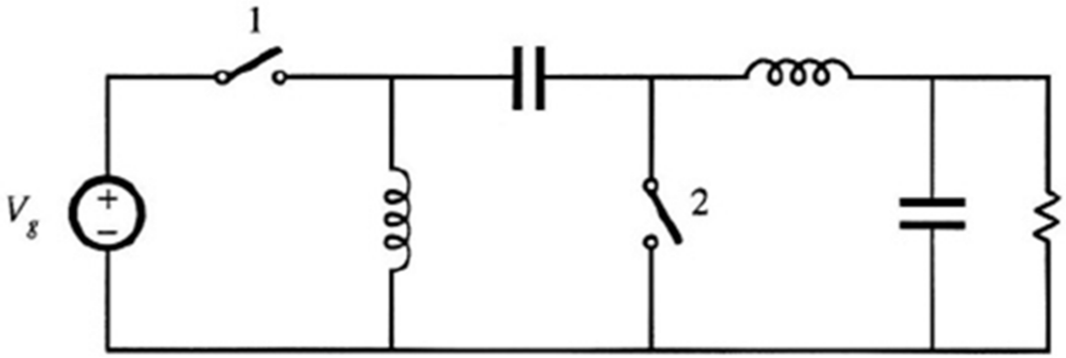
$$\Rightarrow \left(V_g \frac{1-D+D}{1-D} - V_o\right)D - V_o(1-D) = 0 \Rightarrow$$

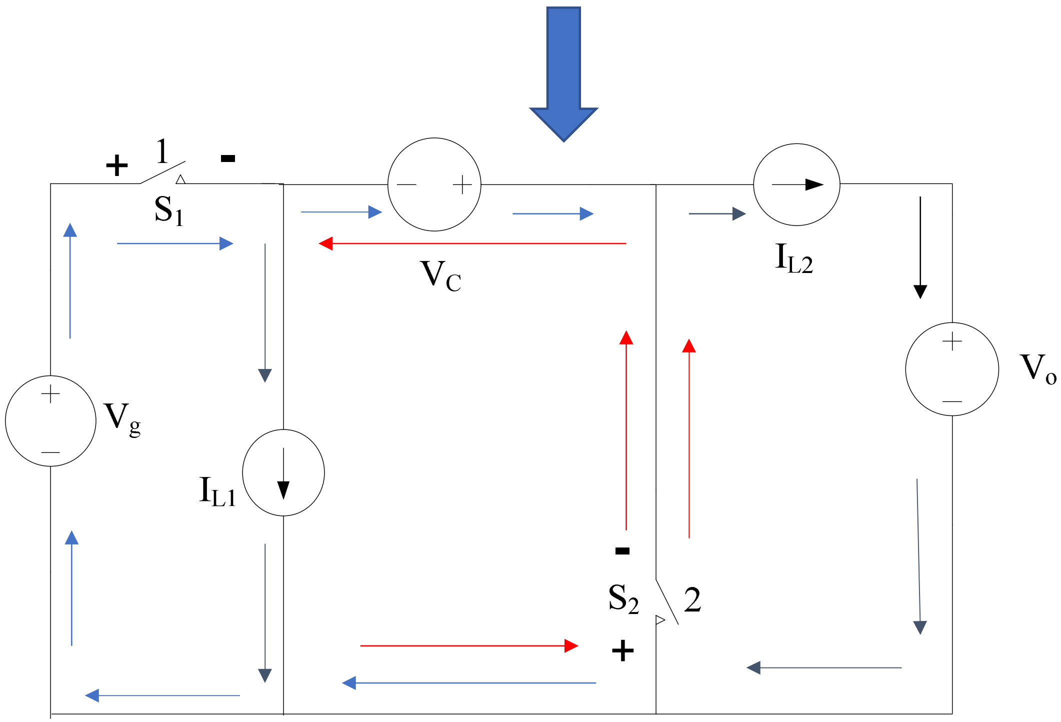
$$\Rightarrow V_g \frac{D}{1-D} - V_o D - V_o(1-D) = 0 \Rightarrow V_C = V_o$$

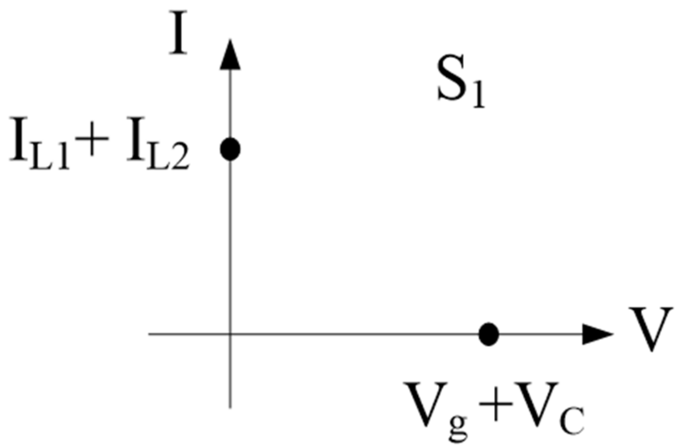
$$\frac{V_o}{V_g} = \frac{D}{1-D}$$

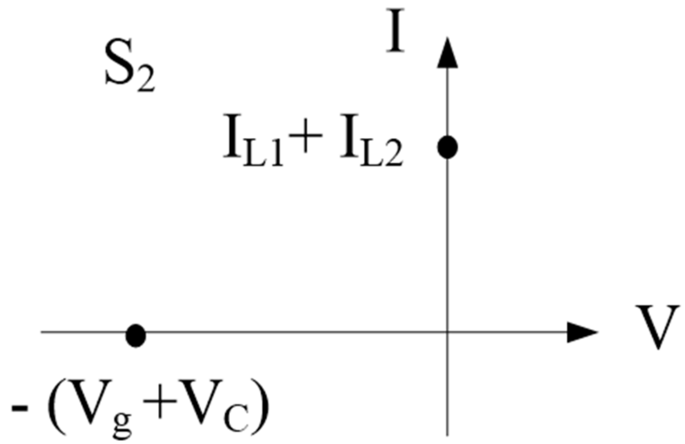


Problem 3 (cont.)

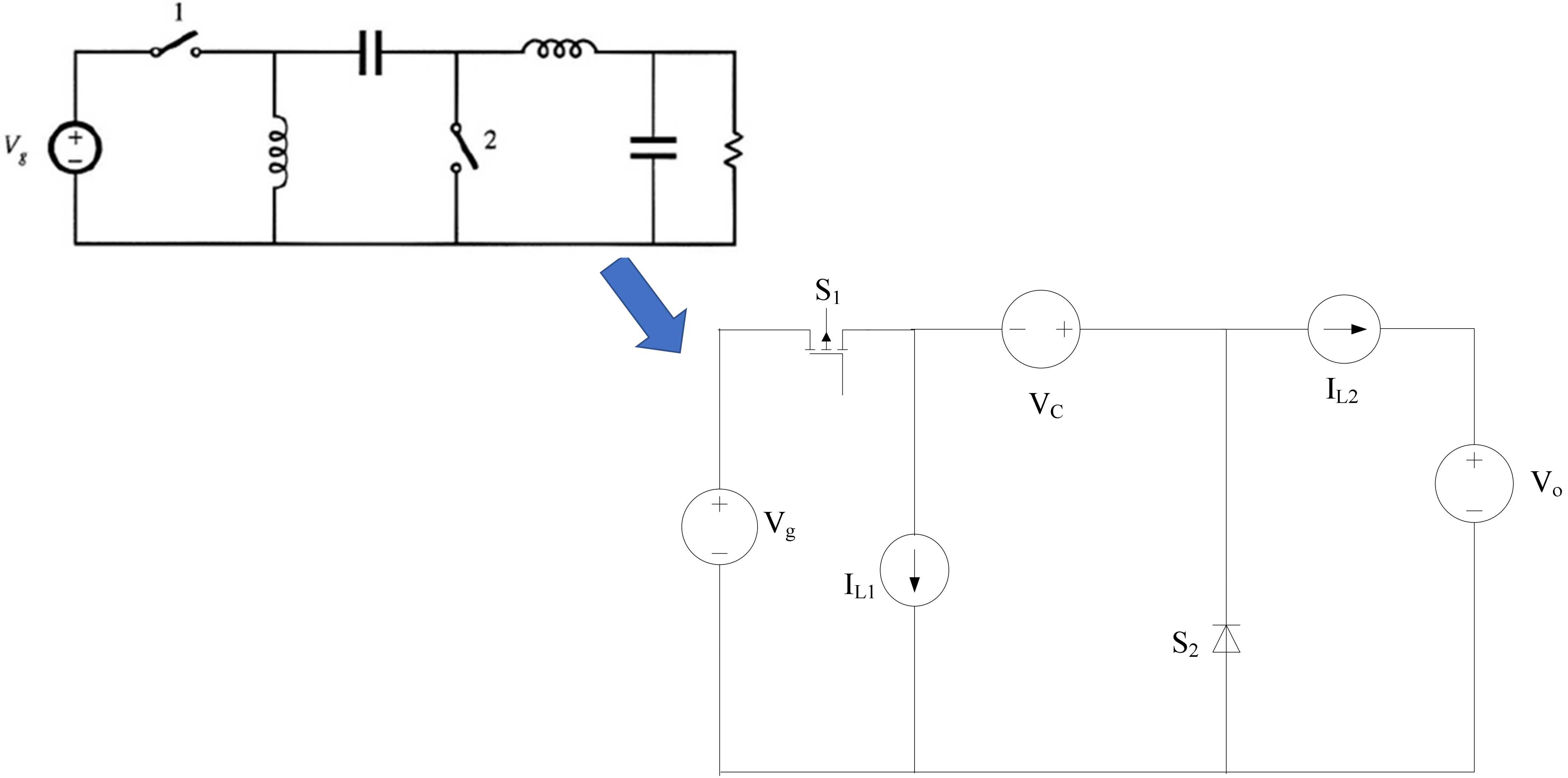






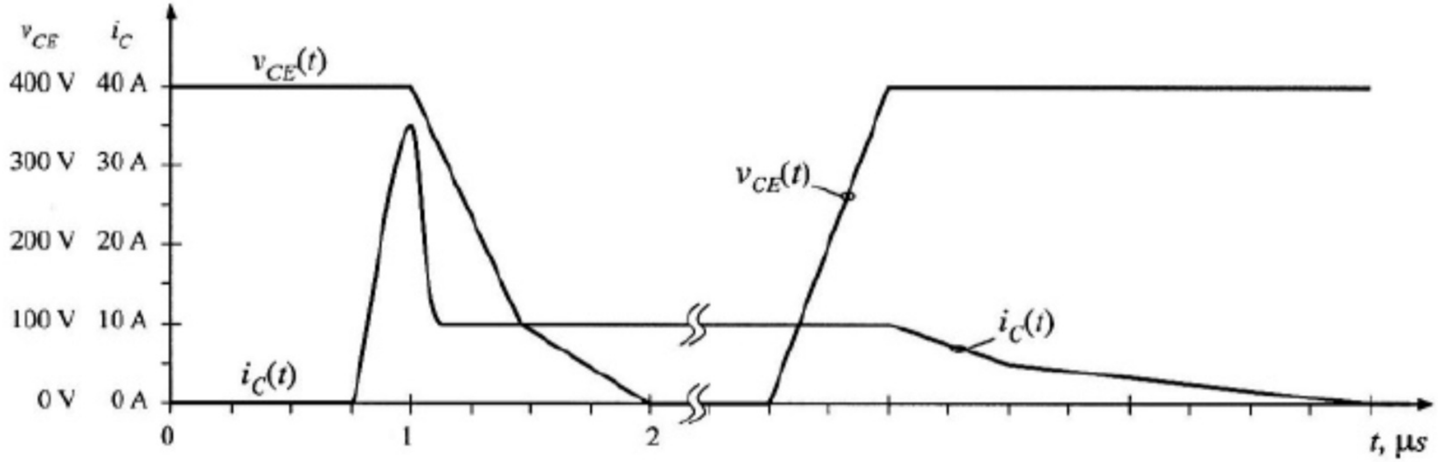


Problem 3 (cont.)



Problem 4

An IGBT and a silicon diode operate in a buck converter, with the IGBT waveforms illustrated in Fig. 4.57. The converter operates with input voltage $V_g = 400$ V, output voltage $V = 200$ V, and load current $I = 10$A.



(a) Estimate the total energy lost during the switching transitions.

$$Q_r \approx \frac{1}{2}(35A - 10A)(1{,}1\mu\sec - 0{,}8\mu\sec) = 3{,}75\mu Cb$$

$$W_{on} \approx Q_r V_t + 10A\left[400V(1\mu\sec - 0{,}8\mu\sec) + \left(\frac{1}{2}\{400V - 100V\}\{1{,}5\mu\sec - 1\mu\sec\}\right) + \left(\frac{1}{2}\{100V - 0V\}\{2\mu\sec - 1{,}5\mu\sec\}\right)\right]$$

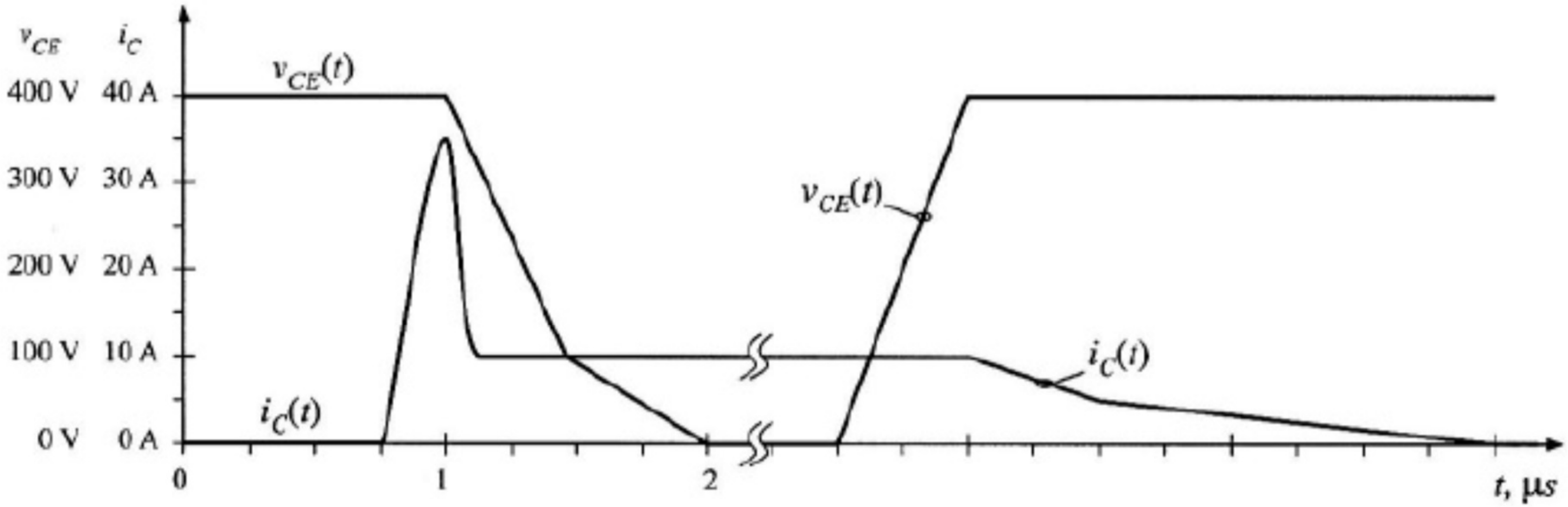
$$W_{on} \approx \{3{,}75 \cdot 400 + 10[80 + 75 + 25]\}\mu J = \{1500 + 1800\}\mu J = 3300\mu J$$

$$W_{off} \approx \left[10A\frac{1}{2}400V\,0{,}5\mu\sec + \left(400V\frac{1}{2}\{10A + 5A\}\,0{,}5\mu\sec\right) + \left(400V\frac{1}{2}5A \cdot 1{,}5\mu\sec\right)\right]$$

$$W_{off} \approx [1000 + 1500 + 1500]\mu J = 4000\mu J$$

$$W_{SW} = W_{on} + W_{off} = 7300\mu J = 7{,}3mJ$$

Problem 4 (cont.)



(b) The forward voltage drop of the IGBT is 2.5 V, and the diode has forward voltage drop 1.5 V. All other sources of conduction loss and fixed loss can be neglected. Estimate the semiconductor conduction loss.

$$P_{Cond,SW} = \Delta V_{SW} I_{SW}$$

$$I_{SW} = DI$$

$$D = \frac{V_o}{V_i} = \frac{200V}{400V} = 0,5$$

$$I_{SW} = DI = 0,5 \cdot 10A = 5A$$

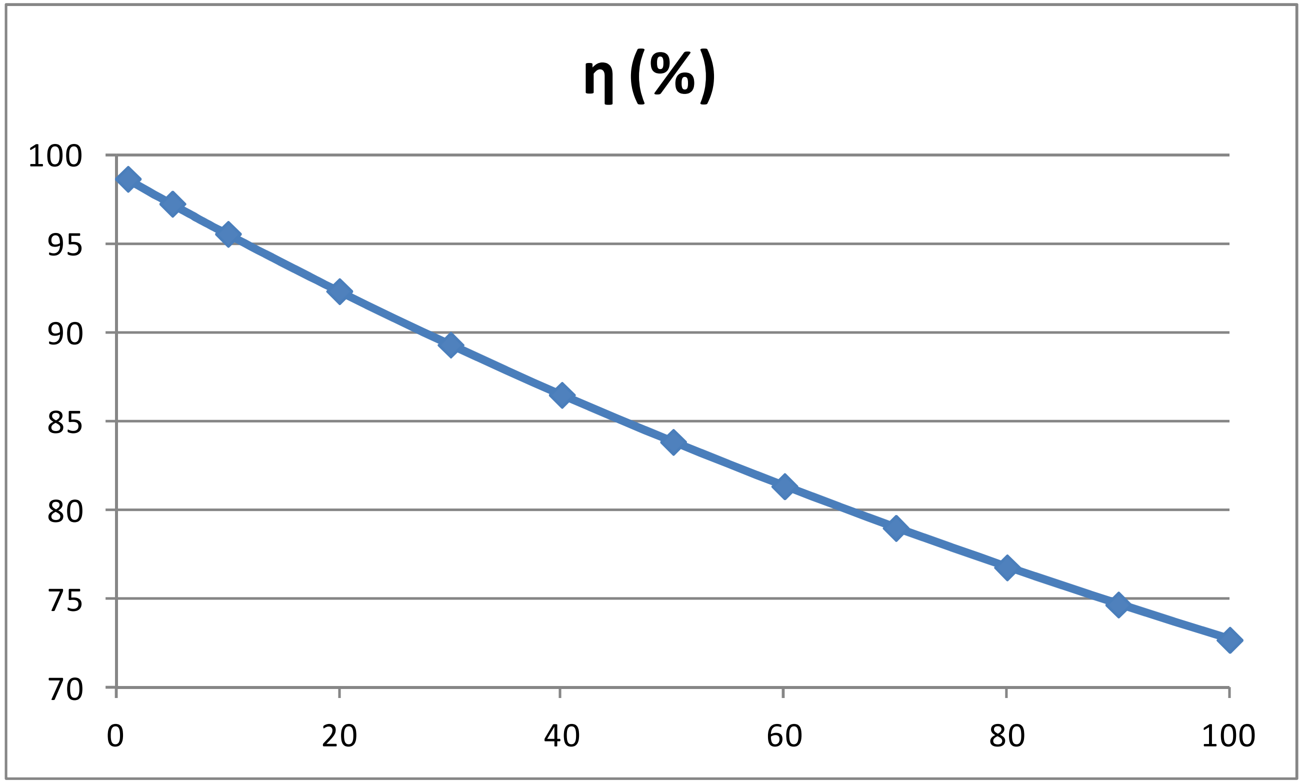
$$P_{Cond,SW} = \Delta V_{SW} I_{SW} = 2,5V \cdot 5A = 12,5W$$

$$P_{Cond,D} = \Delta V_D I_D = \Delta V_D \left(1-D\right) I = 1,5V \cdot 0,5 \cdot 10A = 7,5W$$

$$P_{Cond} = 20W$$

Problem 4 (cont.)

(c) Sketch the converter efficiency over the range of switching frequencies 1 kHz $\le f_s \le$ 100 kHz, and label numerical values.



$$P_{loss}(W) = P_{Cond} + W_{SW} f_S \Rightarrow$$

$$\Rightarrow P_{loss}(W) = 20 + 7{,}3 \cdot f_S(kHz)$$

$$P_o(W) = V_o I_o = 2000W$$

$$\eta(\%) = \frac{P_o}{P_{in}} 100\% = \frac{P_o}{P_o + P_{loss}} 100\% =$$

$$= \frac{1}{1 + P_{loss}/P_o} 100\% = \frac{1}{1 + \left[(20 + 7{,}3 f_S)/2000\right]} 100\%$$