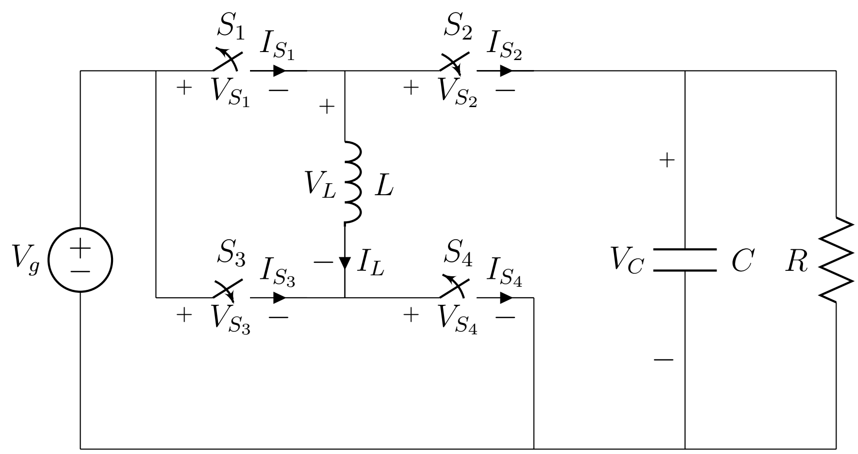
ECEN 4797 Fall 2014	Homework #3	**Vince Coghlan**

3.1: The input voltage V_g is dc an positive with the polarity shown. Specify how to implement the switches using a minimal number of diodes and transistors, such that the converter operates over the entire range of duty cycles $0 \le D \le 1$. THe switch states should vary as shown. You may assume that the inductor current ripples and capacitor voltage ripples are small.

(a) Realize the switches using SPST ideal switches, and explicitly define the voltage and current of each switch.

The new circuit would look like:



(b) Express the on-state current and off-state voltage of each SPST switch in terms of the converter inductor currents, capacitor voltages, and/or input source voltage.

In position 1, S_2 and S_3 are both closed and S_1 and S_4 are both open. This is the inverse in position 2. We can find the voltages and currents, in position 1:

$$V_{S_2} = 0,\ V_{S_3} = 0,\ I_{S_1} = 0,\ I_{S_4} = 0$$

$$V_{S_4} = V_g,\ V_{S_1} = V_L = V_g - V_C,\ I_{S_3} = I_{S_2} = -I_L$$

In position two:

$$V_{S_1} = 0,\ V_{S_4} = 0,\ I_{S_2} = 0,\ I_{S_3} = 0$$

$$V_{S_2} = V_g - V_C,\ V_{S_3} = V_g,\ I_{S_1} = I_{S_4} = I_L$$

(c) Solve the converter to determine the inductor currents and capacitor voltages, as in chapter 2.

To do this we must use KVL and KCL, in position 1:

$$V_L = V_C - V_G,\ I_C = -\frac{V}{R} - I_L$$

In position 2:

$$V_L = V_G,\ I_C = -\frac{V}{R}$$

We then use our knowledge of the inductor current balance:

$$(-\frac{V}{R})DT_S + (-\frac{V}{R} - I_L)(1-D)T_S = 0$$

$$I_L = \frac{V}{R(D-1)}$$

And capacitor charge balance:

$$(V_g)D + (V_G - V_C)(1-D) = 0$$

$$2V_GD - V_g + V_C - V_CD = 0$$

$$V_C = \frac{(1-2D)V_g}{1-D}$$

Combining these we find that:

$$I_L = \frac{(1-2D)V_g}{R(1-D)(D-1)} \text{ and } V_C = \frac{(1-2D)V_g}{1-D}$$

(d) Determine the polarities of the switch on-state currents and off-state voltages. Do the polarities vary with duty cycle?

Using the same knowledge from part (b), we only need V_C and I_L. In position 1 we can see that:

$$V_{S_1} = V_g - V_C = V_g - \frac{(1-2D)V_g}{1-D}$$

Which is always positive, additionally:

$$I_{S_3} = I_{S_2} = -I_L = -\frac{(1-2D)V_g}{R(1-D)(D-1)}$$

Which is positive for $D < 0.5$ and negative for $D > 0.5$. we know from before:

$$V_{S_2} = 0,\ V_{S_3} = 0,\ I_{S_1} = 0,\ I_{S_4} = 0$$

In position two:

$$V_{S_2} = V_g - V_C = V_g - \frac{(1-2D)V_g}{1-D}$$

which is positive, and:

$$I_{S_1} = I_L = \frac{(1-2D)V_g}{R(1-D)(D-1)}$$

Which is positive for $D > 0.5$ and negative for $D < 0.5$. In all this tells us that in position 1:

$$V_{S_2} = 0,\ V_{S_3} = 0,\ I_{S_1} = 0,\ I_{S_4} = 0$$

$$V_{S_4} = \text{positive},\ V_{S_1} = \text{positive},\ I_{S_3} = I_{S_2} = \text{positive for } D < 0.5, \text{ negative for } D > 0.5$$

And in position two:

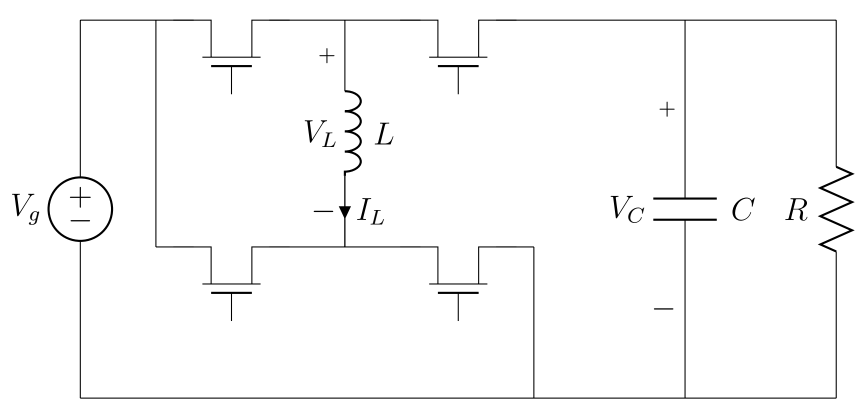
$$V_{S_1} = 0,\ V_{S_4} = 0,\ I_{S_2} = 0,\ I_{S_3} = 0$$

$$V_{S_2} = \text{positive},\ V_{S_3} = \text{positive},\ I_{S_1} = I_{S_4} = \text{positive for } D > 0.5, \text{ negative for } D < 0.5$$

(e) State how each switch can be realized using transistors and/or diodes, and whether the realization requires single-quadrant, current-bidirectional two-quadrant, coltage-bidirectional two-quadrant, or four-quadrant switches.

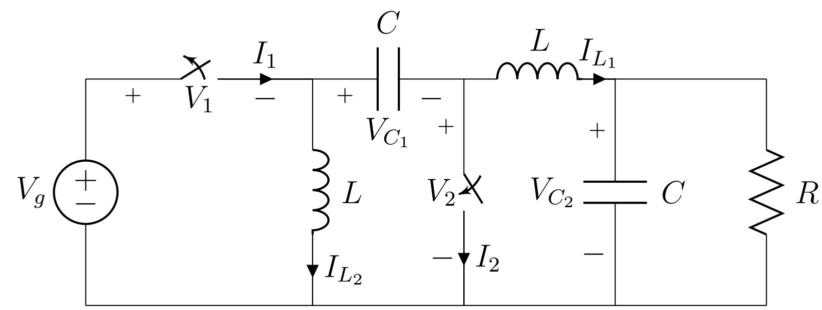
We need voltage to only go in one direction (positive) but current must be able to go in both directions in all switches. That means current-bidirectional two-quadrant switches. The component that best realizes this is a MOSFET. We would need four of them.

(f) draw the converter circuit, including your realization of the switch elements using MOSFETs and diodes.



3.2: The input voltage V_g is dc an positive with the polarity shown. Specify how to implement the switches using a minimal number of diodes and transistors, such that the converter operates over the entire range of duty cycles $0 \leq D \leq 1$. THe switch states should vary as shown. You may assume that the inductor current ripples and capacitor voltage ripples are small.

(a) Realize the switches using SPST ideal switches, and explicitly define the voltage and current of each switch.
The new circuit would look like:



(b) Express the on-state current and off-state voltage of each SPST switch in terms of the converter inductor currents, capacitor voltages, and/or input source voltage.
In position 1, we can see that:

$$V_1 = V_g - V_{C_1} \text{ and } V_2 = 0$$

$$I_1 = 0 \text{ and } I_2 = I_{L_1}$$

In position 2:

$$V_1 = 0 \text{ and } V_2 = V_g - V_{C_1}$$

$$I_1 = I_{L_2} \text{ and } I_2 = 0$$

(c) Solve the converter to determine the inductor currents and capacitor voltages, as in chapter 2.
First we can use KVL when we are in state 1:

$$V_{L_1} = V_{C_2} \text{ and } V_{L_2} = -V_{C_1}$$

$$I_{C_1} = -I_{L_2} \text{ and } I_{C_2} = I_{L_1} - \frac{V_{C_2}}{R}$$

in state 2:

$$V_{L_1} = V_g - V_{C_1} - V_{C_2} \text{ and } V_{L_2} = V_g$$

$$I_{C_1} = I_{L_1} \text{ and } I_{C_2} = I_{L_1} - \frac{V_{C_2}}{R}$$

We can solve these:

$$D(V_{C_2}) + (1-D)(V_g - V_{C_1} - V_{C_2}) = 0$$

$$(2D-1)V_{C_2} + (D-1)V_{C_1} + (D-1)V_g = 0$$

$$D(-V_{C_1}) + (1-D)(V_g) = 0$$

$$V_{C_1} = \frac{1-D}{D}V_g$$

$$D(-I_{L_2}) + (1-D)(I_{L_1}) = 0$$

$$I_{L_2} = \frac{1-D}{D}I_{L_1}$$

$$I_{L_1} = \frac{V_{C_2}}{R}$$

Thats a lot of unknowns and a lot of equations, but I think we can do this. Plugging in our equation for V_{C_1} into the first equation we find that:

$$V_{C_2} = \frac{D-1}{D}V_g$$

That means that:

$$I_{L_1} = \frac{D-1}{DR}V_g$$

and

$$I_{L_2} = \frac{(D-1)(1-D)}{D^2R}V_g$$

and as we know:

$$V_{C_1} = \frac{1-D}{D}V_g$$

(d) Determine the polarities of the switch on-state currents and off-state voltages. Do the polarities vary with duty cycle?
Going back to part (b) we find that in position 1:

$$V_1 = V_g - \frac{1-D}{D}V_g \text{ and } V_2 = 0$$

$$I_1 = 0 \text{ and } I_2 = \frac{D-1}{DR}V_g$$

In position 2:

$$V_1 = 0 \text{ and } V_2 = V_g - \frac{1-D}{D} V_g$$

$$I_1 = \frac{(D-1)(1-D)}{D^2 R} V_g \text{ and } I_2 = 0$$

Which, it can be easily shown, that in position 1:

$$V_1 = \text{positive for } D > 0.5, \text{ negative for } D < 0.5 \text{ and } V_2 = 0$$

$$I_1 = 0 \text{ and } I_2 = \text{negative}$$

In position 2:

$$V_1 = 0 \text{ and } V_2 = \text{positive for } D > 0.5, \text{ negative for } D < 0.5$$

$$I_1 = \text{positive and } I_2 = 0$$

(e) State how each switch can be realized using transistors and/or diodes, and whether the realization requires single-quadrant, current-bidirectional two-quadrant, voltage-bidirectional two-quadrant, or four-quadrant switches.

Both switches myst have bidirectional voltage two quadrant switches, but only require one direction of current. This can be realized with each switch consisting of a MOSFET and a diode, as shown in the next part.

(f) draw the converter circuit, including your realization of the switch elements using MOSFETs and diodes.