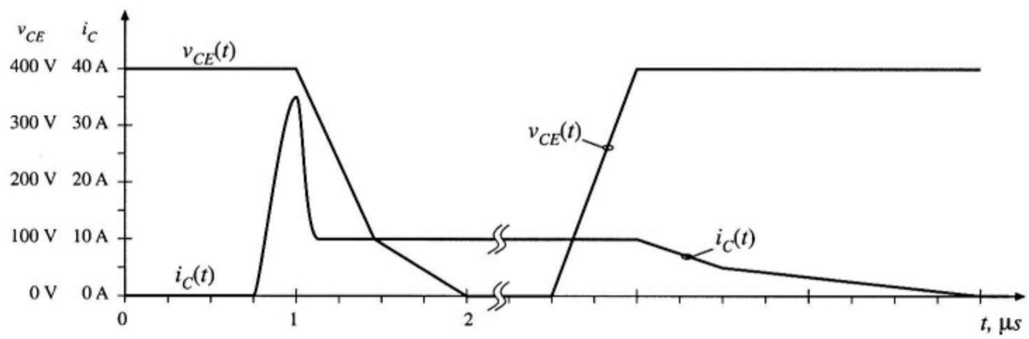
ECEN 4797 Fall 2014	Homework #4	Vince Coghlan

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



(a) Estimate the total energy lost during the switching transitions
power loss is going to be voltage times current. Energy will be power times time. I will devide the graph into 7 sections, treating the begining of the waveform as a linear line: This means that we can easily estimate the total energy for the first section.

$$E = 2.5 \cdot 10^{-7} \cdot (400 \cdot 17.5) = 1.75mJ$$

Finding the rest of them shows that:

$$E_{\text{loss}} = 1.75mJ + 1.06mJ + 0.23mJ + 0.25mJ + 1mJ + 1.5mJ + 1.5mJ = 7.29mJ$$

(b) The forward voltage drop of the IGBT is 2.5V, and the diode has forward voltage drop 1.5V. All other sources of conduction loss and fixed loss can be neglected. Estimate the semiconductor conduction loss.
The semiconductor loss will be the power lost when the load current is on (all of the diode currents will go through the load). This looks like (remember only one of the devices will conduct at a time):

$$P = I \cdot V = D \cdot 10 \cdot 2.5 + D' \cdot 10 \cdot 1.5 = 25D + 15D'$$

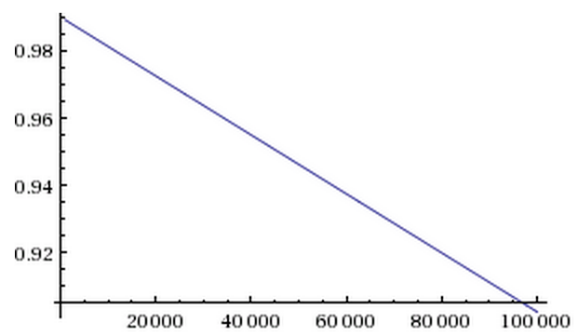
With this information, we can solve for D. If this is an ideal Buck Converter, than the ratio of voltage out over voltage in will be equal to the duty cycle. This means that our duty cycle is 0.5, and our power lost is 20W.

(c) Sketch the converter efficiency over the range of switching frequencies 1kHz $\leq f_g \leq$ 100kHz, and label numerical values.
Efficiency is defined as $\frac{P_{\text{out}}}{P_{\text{in}}}$ and can be calculated as:

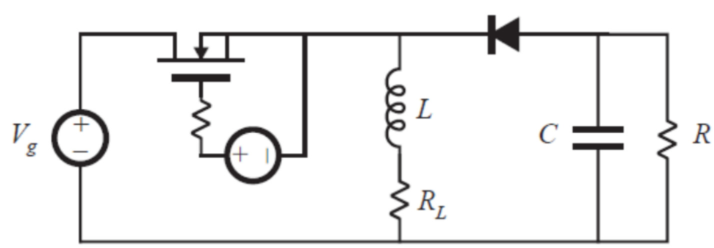
$$\eta = \frac{P_{\text{out}}}{P_{\text{out}} - P_{\text{loss}} - P_{\text{switch}-P_{\text{switch}}}}$$

$$\eta = \frac{200 \cdot 10}{200 \cdot 10 - 20 - 0.00175 \cdot f}$$

This looks like:



4.2: The buck-boost converter shown below is implemented with a MOSFET and a diode. The MOSFET can be modeled as ideal, but the diode exhibits snappy reverse-recovery characteristics, with reverse recovery time t_r and recovered charge Q_r. In addition, the inductor has winding resistance R_L. The converter operates with small inductor current ripple and small capacitor voltage ripple. Derive an equivalent circuit that models the dc components of the converter waveforms and that accounts for the loss elements described above.



We can begin by finding the average currents and voltages:

$$V_L = V_g - i_L R_L$$

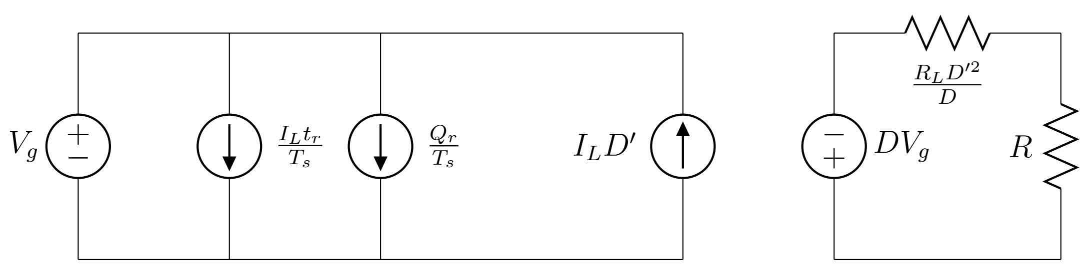
$$V_L = V - i_L R_L$$
$$i_C = \frac{-V}{R}$$
$$i_C = -i_L - \frac{V}{R}$$

These make (including the equation for i_g):

$$0 = V_g D + V D' - I_L R_L$$

$$0 = \frac{-V}{R} - I_L D'$$
$$0 = D I_L + \frac{I_L t_r}{T_S} + \frac{Q_r}{T_s}$$

Our equivalent circuit will look like this:



With a transformer: