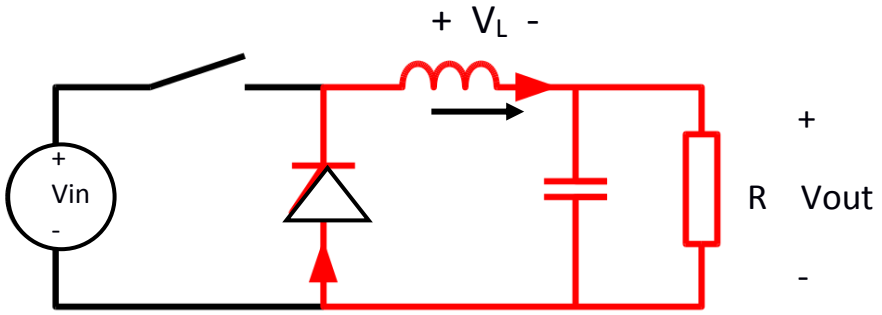
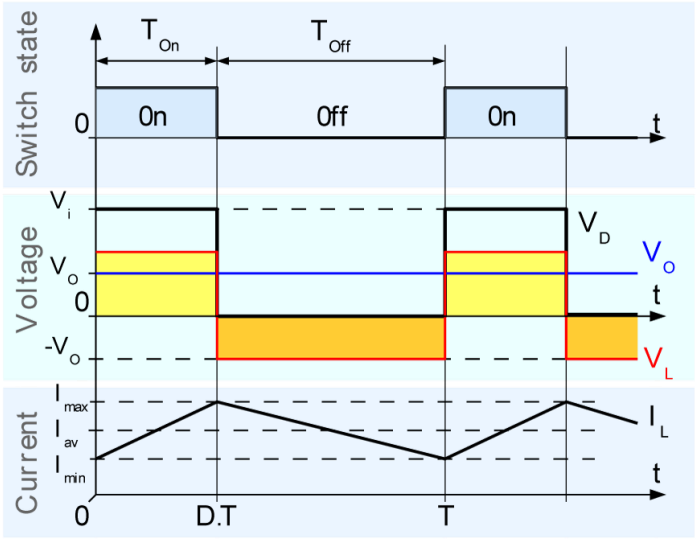
Buck Converter (draft 2/20/2017) v2



- Output voltage is less than input voltage



For simplicity, assume i_L goes from i_{max} to i_{min} in a linear fashion in time T_{off}, with a change of $\Delta i = i_{max} - i_{min}$ (>0). Also assume V_{out} is approximately constant. During T_{off} the instantaneous power delivered to the capacitor and load from the inductor in series with V_{in} is $p(t)= -i_L(t)V_L(t)$. (Note V_L is negative during off, so $-V_L = V_{out}$, for ideal diode.)
The inductor voltage during T_{off} is assumed constant: $V_L(t) = -L\,\Delta i / T_{off}$. Also $i_{av} \sim V_{out}/R$.

When switch is open, the work delivered per cycle from inductor to load is (assuming $i_L = i_{av}$), and $V_L<0$:

$$W_{off} = -i_L V_L T_{off} = -i_L (L\,\Delta i / T_{off}) T_{off} = i_L L\,\Delta i$$

When switch is closed, $\Delta i = i_{max} - i_{min}$ (>0), and $V_L>0$ the work delivered through inductor per cycle is:

$$W_{on} = i_L (V_{in}-V_L)T_{on} = i_L (V_{in}-\Delta i\, L/T_{on})T_{on} = -i_L L\,\Delta i + i_L V_{in} T_{on}$$

The time average power delivered to the load (through the inductor) is W/T=

$$P_{ave} = (W_{off} + W_{on}) / (T_{on} + T_{off}) = i_L (L\,\Delta i - L\,\Delta i + V_{in} T_{on}) / (T_{on} + T_{off}) = i_L V_{in} T_{on} / (T_{on} + T_{off}) = V_{out}^2 / R$$

Note that there is a contribution from energy stored in the inductor and the power provided by battery.

Note that L is chosen based frequency. Consider V_{in} =10V, V_{out} = 2V, R=1 ohm. Then i_{av} = 2 amps, and V_L = 8V with switch on and V_L = -2V with switch off. Thus $4T_{on} = T_{off}$. For switching period $T = T_{on} + T_{off}$ = 4 us (LM2678), we might choose L = 33 uH (bigger L means smaller di/dt). Then $\Delta i = T_{on}$ (8V)/L = 0.2 amps. Thus i_{max} = 2.1 amps and i_{min} = 1.9 amps.