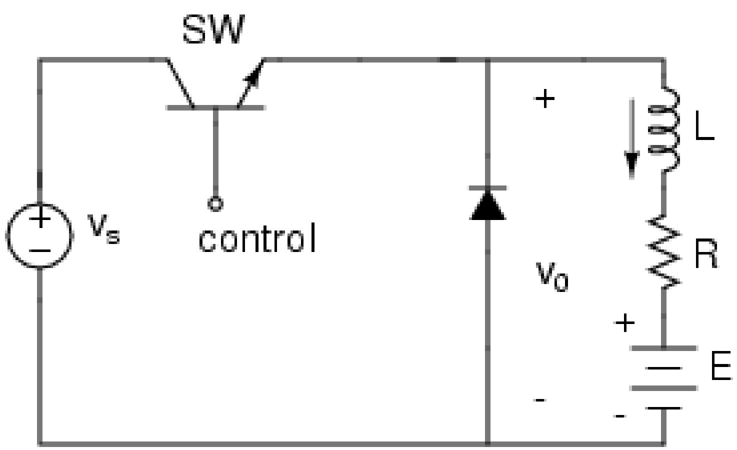
DC-DC Converters (choppers)

- The objective is to convert a fixed DC voltage to a variable DC voltage
- It is possible to step up and step down voltage.

Voltage step down (buck converter)



First, suppose L=0, E=0.

The diode is not needed.

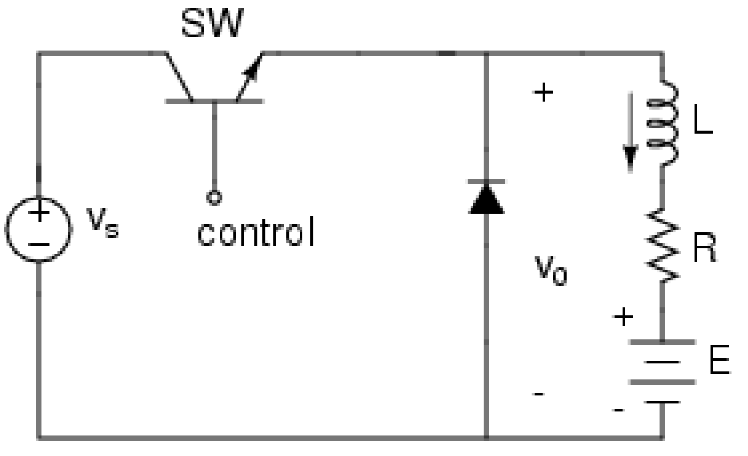
$V_a=(t_{on}/T)V_s$

$k=t_{on}/T$ is the duty cycle

$V_{RMS}=k^{1/2}V_s$

$P_{out}=(kV_s^{\,2})/R$

Step down converter with RL load



Mode 1 (On)

$$i_1(t) = I_1 e^{-tR/L} + \frac{V_s - E}{R}(1 - e^{-tR/L}), \quad 0 \le t \le kT$$

Mode 2 (Off): $I_2 = i_1(kT)$, and

$$i_2(t) = I_2 e^{-(t-kT)R/L} + \frac{V_s - E}{R}(1 - e^{-(t-kT)R/L}), \quad kT \le t \le T.$$

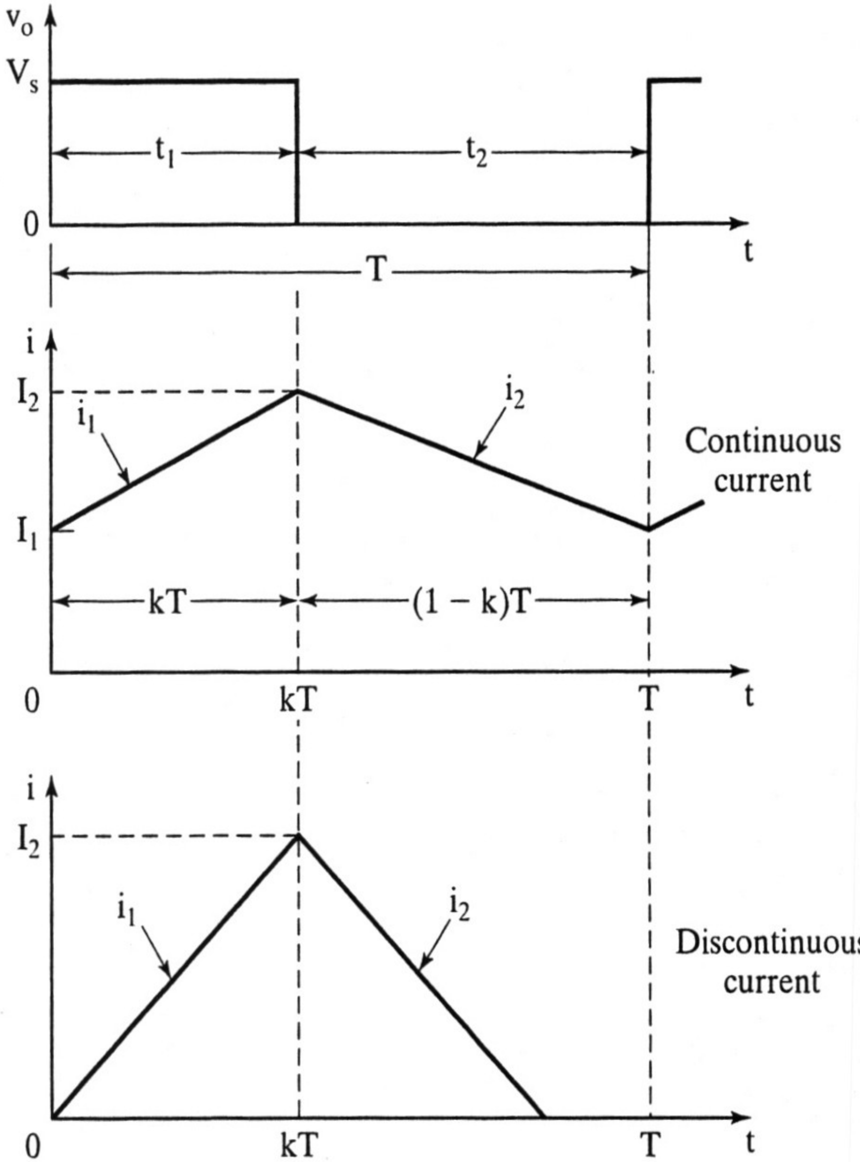
For a steady state current

$$i_1(0) = i_2(T),$$

$$I_1 = \frac{V_s}{R}\left(\frac{1 - e^{kT(R/L)}}{1 - e^{T(R/L)}}\right) - \frac{E}{R} = \frac{V_s}{R}\left(\frac{1 - e^{kz}}{1 - e^{z}}\right) - \frac{E}{R}$$

$$I_2 = \frac{V_s}{R}\left(\frac{1 - e^{-kz}}{1 - e^{-z}}\right) - \frac{E}{R}, \qquad z = T\frac{R}{L},$$

$$\frac{E}{V_s} \le \frac{1 - e^{kz}}{1 - e^{z}} \quad \text{for cont. current}$$



(b) Waveforms

Example 5.2

$$I_a = \frac{1}{2}(I_1 + I_2)$$

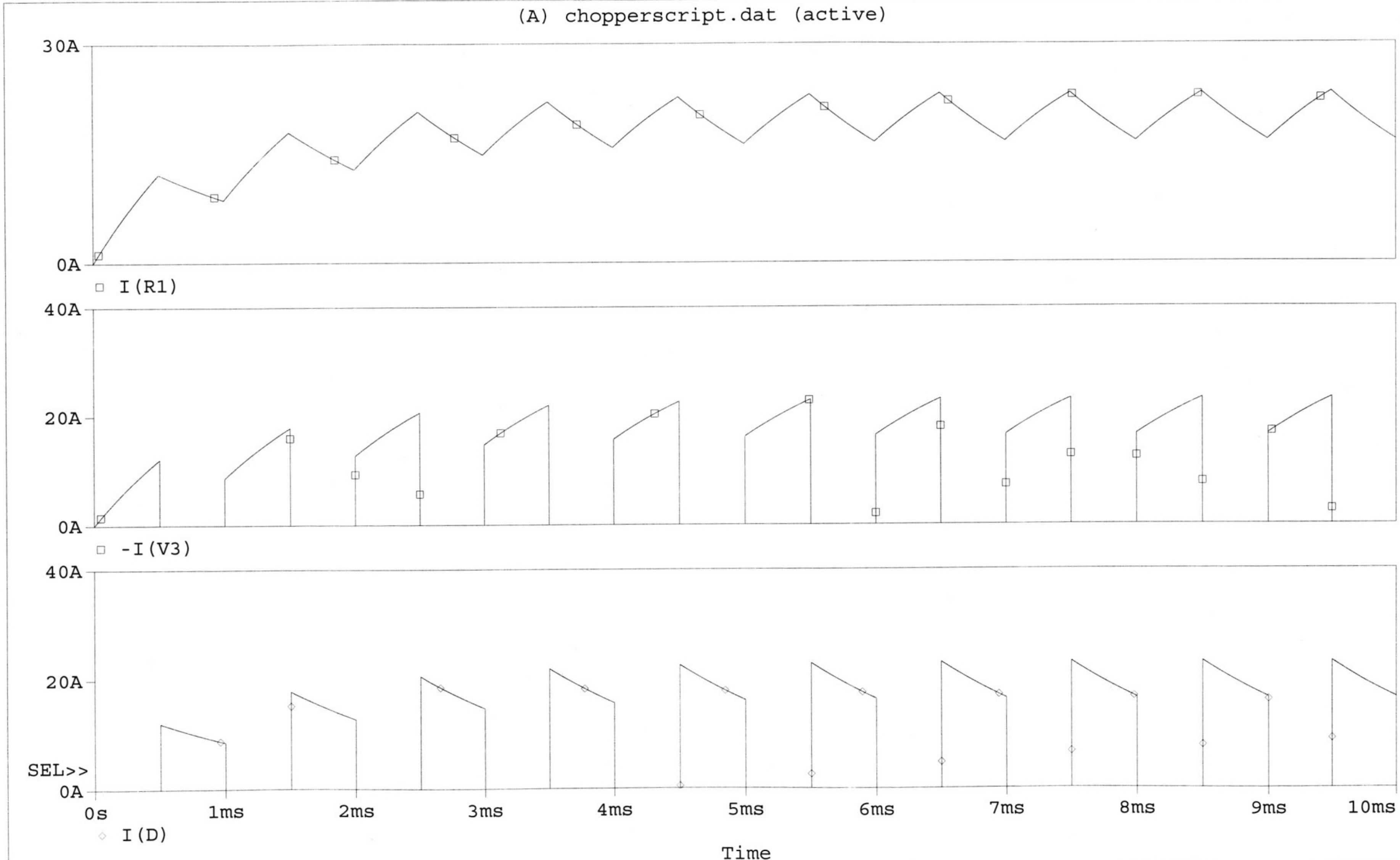
$$I_o = (I_1^2 + \frac{1}{3}\Delta I^2 + I_1 \Delta I)^{1/2}$$

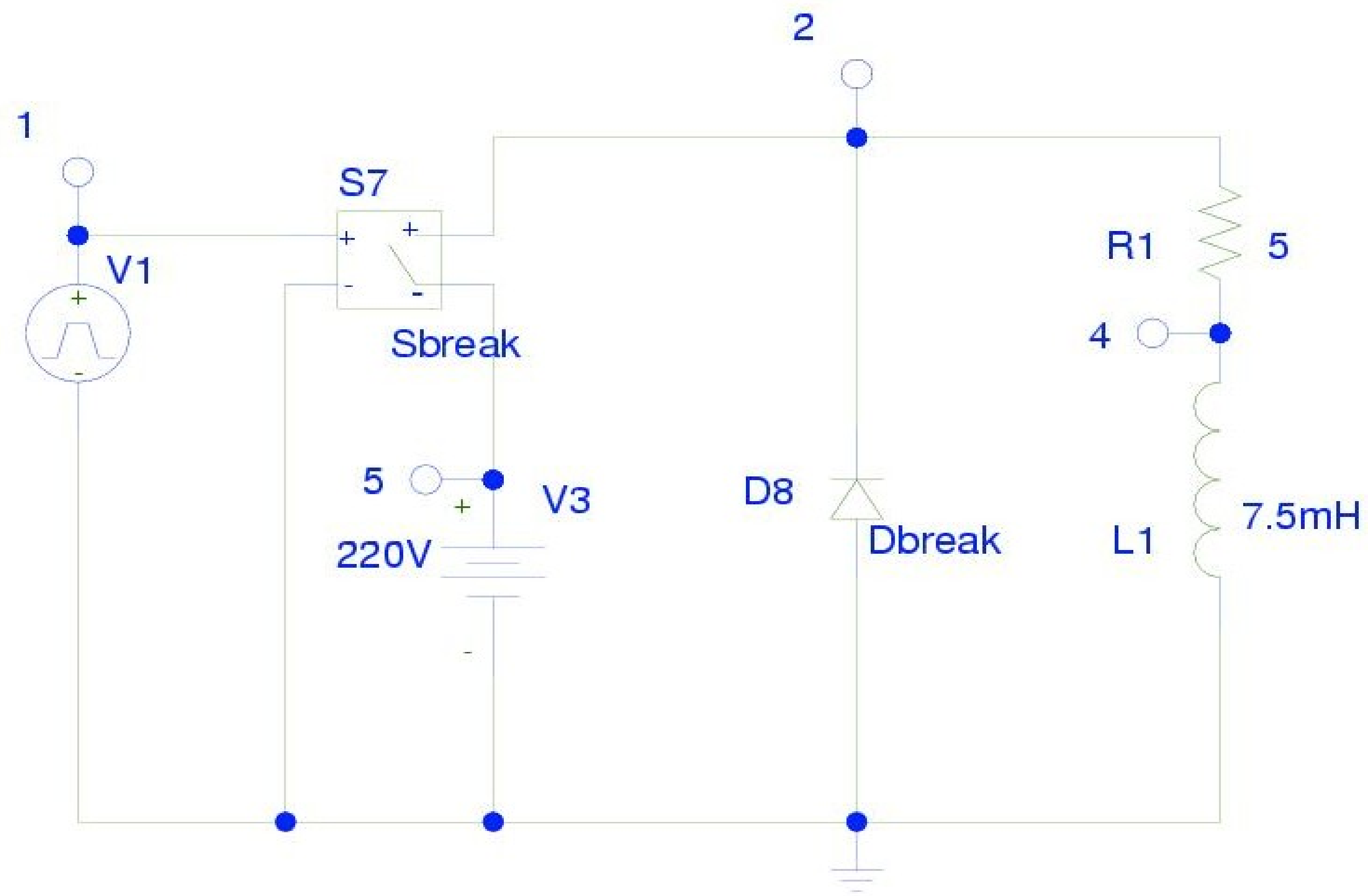
$$I_s = kI_a$$

$$I_R = \sqrt{k} I_o$$

* Dc to Dc step-down converter

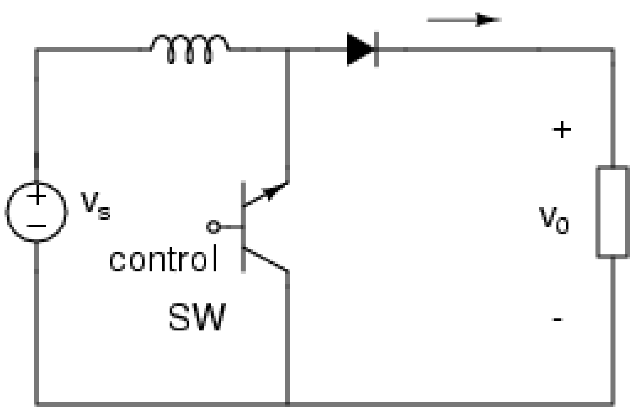
Date/Time run: 07/17/06 00:05:04 Temperature: 27.0





Pspice schematics Step down dc-dc converter

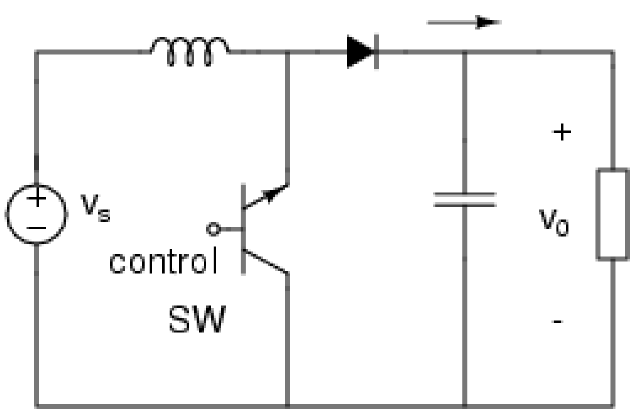
Voltage step up (boost) converter



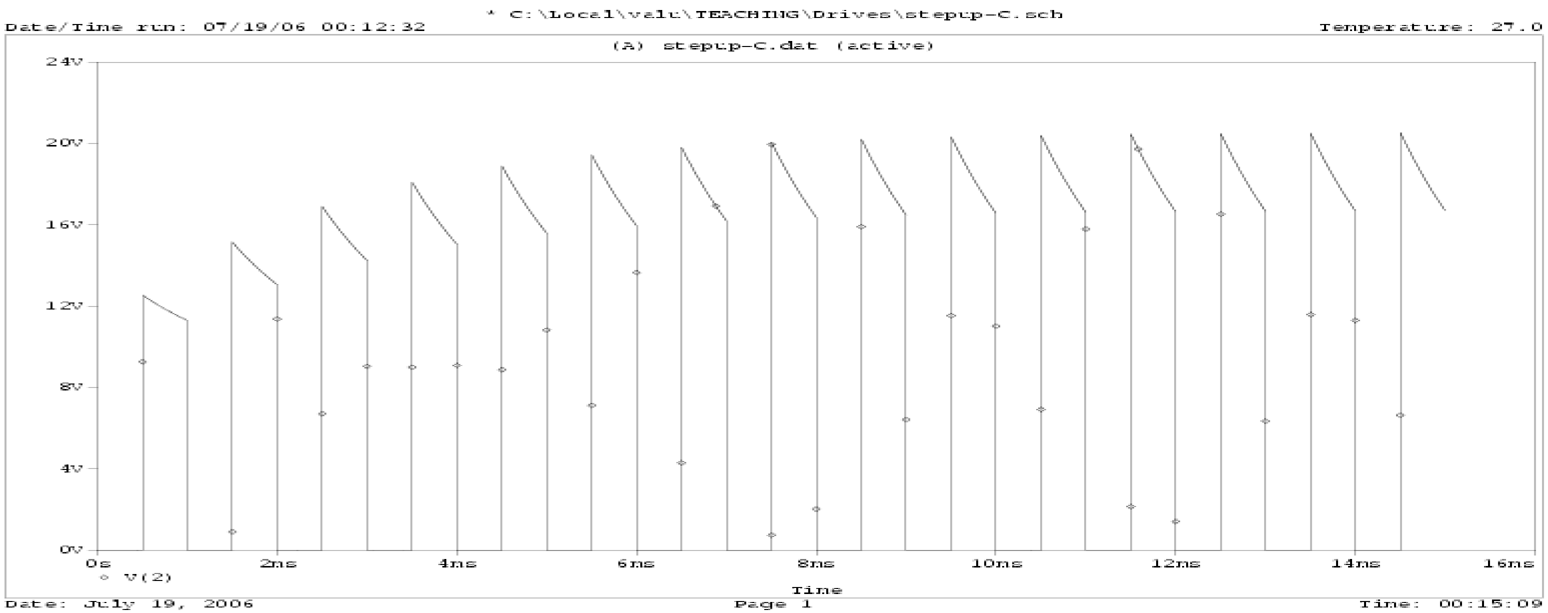
"On" mode: V_L=L(di/dt)

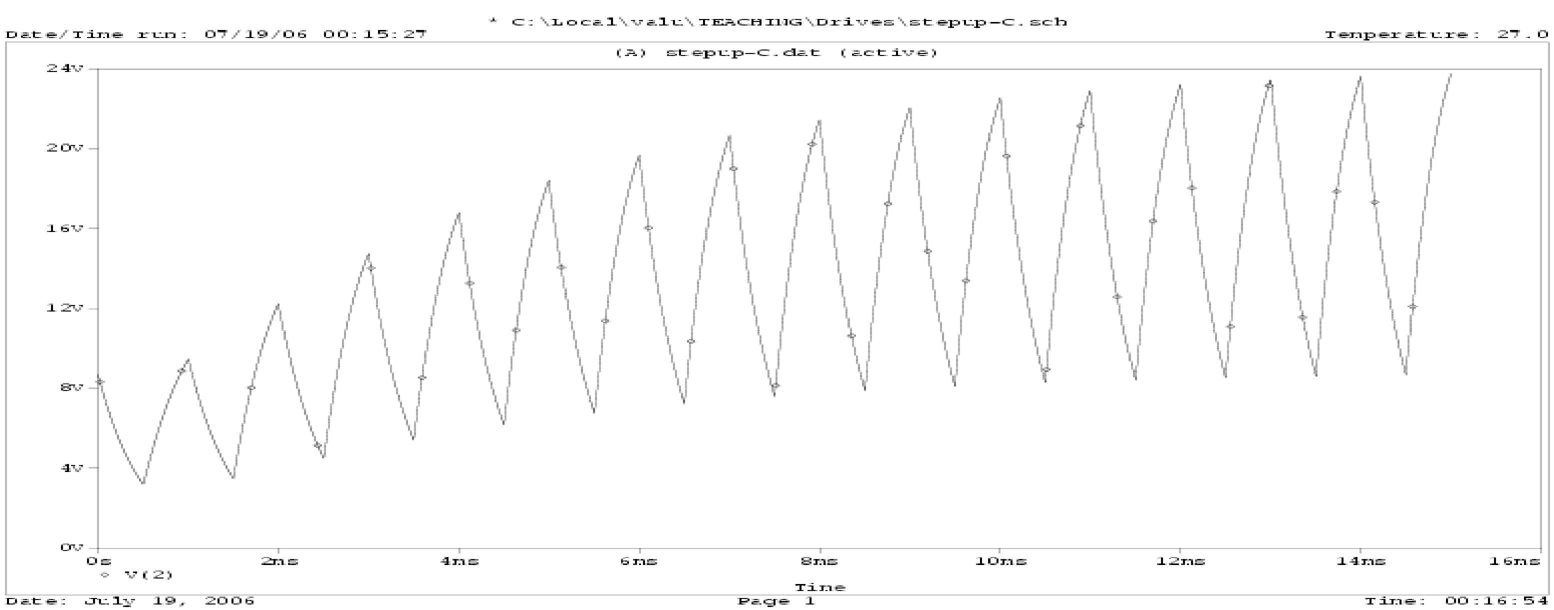
"Off" mode: Assume current decreases at a constant rate. Then

$V_o=V_s+V_L$



To ensure continuous current flow, a capacitor is included.


* C:\Local\valu\TEACHING\Drives\stepup-C.sch
Date/Time run: 07/19/06 00:12:32
Temperature: 27.0
(A) stepup-C.dat (active)
24V
20V
16V
12V
8V
4V
0V
0s
2ms
4ms
6ms
8ms
10ms
12ms
14ms
16ms
V(2)
Time
Date: July 19, 2006
Page 1
Time: 00:15:09


* C:\Local\valu\TEACHING\Drives\stepup-C.sch
Date/Time run: 07/19/06 00:15:27
Temperature: 27.0
(A) stepup-C.dat (active)
24V
20V
16V
12V
8V
4V
0V
0s
2ms
4ms
6ms
8ms
10ms
12ms
14ms
16ms
V(2)
Time
Date: July 19, 2006
Page 1
Time: 00:16:54

Performance of a step up converter with resistive load (C=0).

Mode 1 (On)

$$i_1(t) = \frac{V_s}{L}t + I_1, \quad 0 \le t \le kT$$

Mode 2 (Off): , and

$$I_2 = i_1(kT) = \frac{V_s}{L}kT + I_1 \quad \text{and}$$

$$i_2(t) = I_2 e^{-(t-kT)R/L} + \frac{V_s - E}{R}(1 - e^{-(t-kT)R/L}), \quad kT \le t \le T.$$

At steady state $i_1(0) = i_2(T)$,

$$I_1 = \frac{V_s}{R}\left(\frac{kze^{(k-1)z}}{1-e^{(k-1)z}}\right) + \frac{V_s - E}{R}$$

$$I_2 = \frac{V_s}{R}\left(\frac{kz}{1-e^{(k-1)z}}\right) + \frac{V_s - E}{R}, \qquad z = T\frac{R}{L},$$

$$\Delta I = \frac{V_s}{L}kT, \quad I_{a,\text{load}} = \frac{I_1 + I_2}{2}(1-k)$$

$$\frac{E}{V_s} \le 1 \quad \text{for continuous inductor current}$$