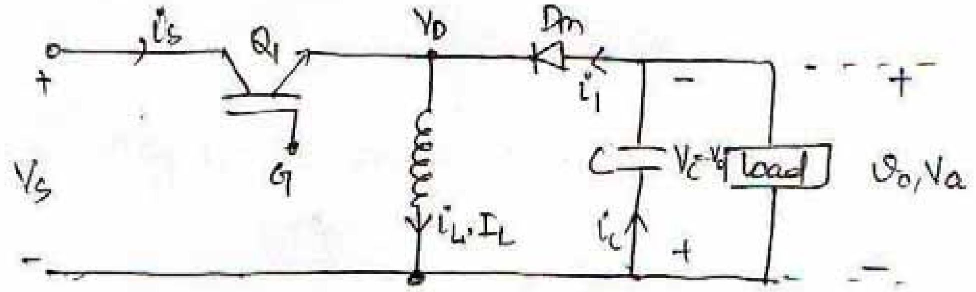
Buck-Boost Converter

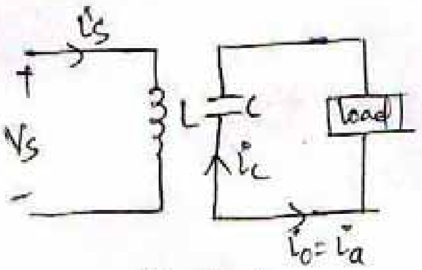
→ A Buck-Boost Converter provides an o/p voltage that may be less than or greater than the input voltage.

→ The output voltage polarity ~~being~~ opposite to that of input voltage so this converter is also known as inverting regulator

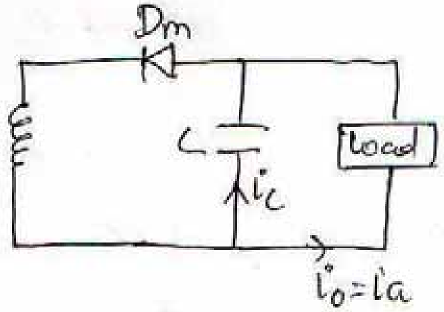


Circuit Diagram

Equivalent Circuits



Mode-1



Mode-2

Operation

During mode-1, transistor Q_1 is turned on and diode D_m is reverse biased. The i/p current, which rises linearly (assumed) flows through the inductor L and transistor Q_1.

During mode-2, transistor Q_1 is switched off and the load current which was flowing through L, would flow through L, C, D_m and the load. The energy stored in inductor L would be transferred to the load and the inductor current would fall until transistor Q_1 is switched on again in the next cycle.

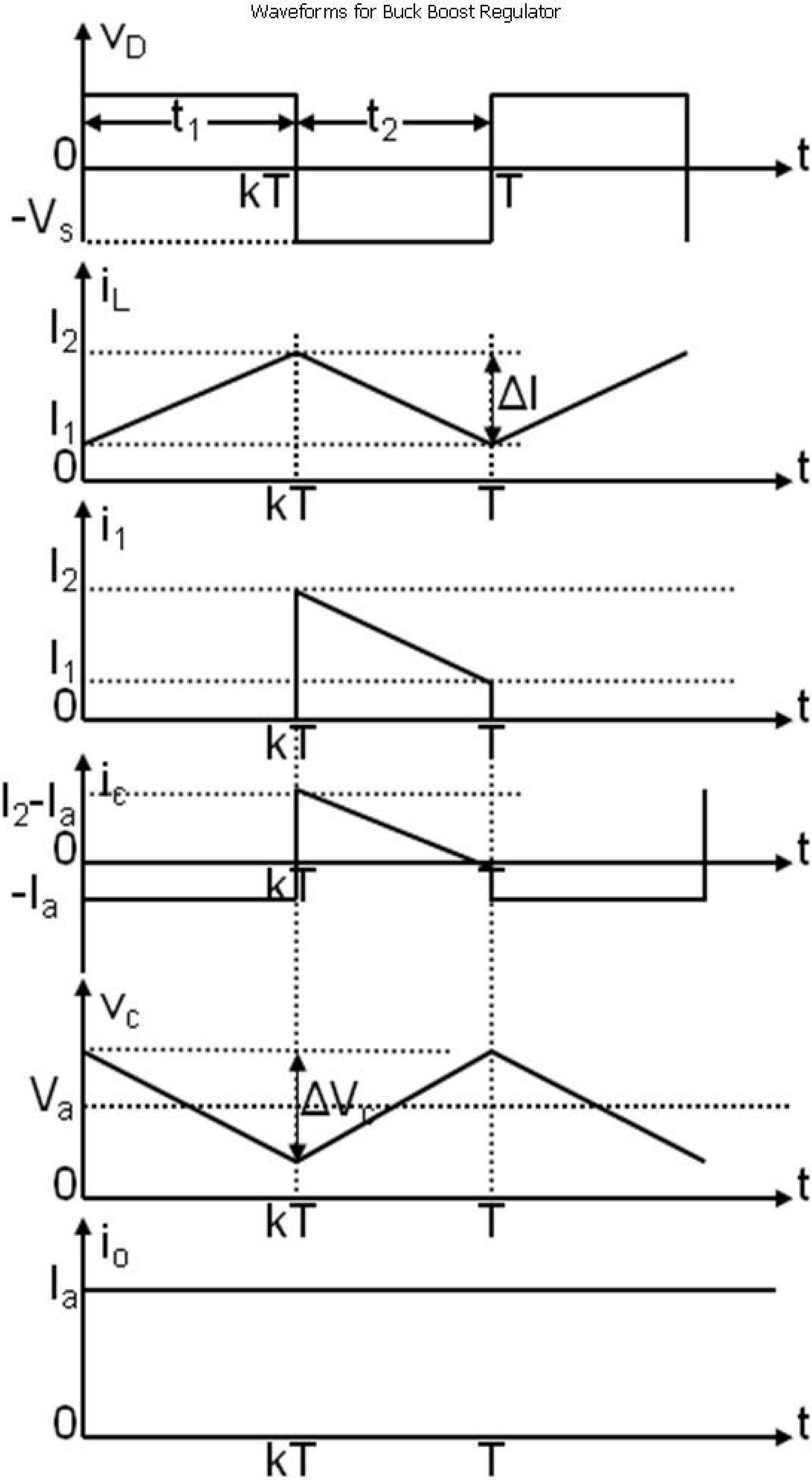
Assuming that the inductor current that rises during time t is linear, we get

$$V_s = L\frac{di_L}{dt} = L\frac{(I_2 - I_1)}{t_1}$$

$$\therefore t_1 = \frac{L\Delta I}{V_s} \quad \text{---(1)}$$

where, ΔI is the peak to peak ripple current.

Waveforms for Buck Boost Regulator



During time t_2, inductor current falls linearly from I_2 to I_1.

$$\text{i.e. } V_a = -L\frac{\Delta I}{t_2}$$

$$\therefore t_2 = -\frac{L\Delta I}{V_a} \quad \text{——(2)}$$

From eqⁿ (1) and (2)

$$\Delta I = \frac{t_1 V_s}{L} = -\frac{t_2 V_a}{L} \quad \text{——(3)}$$

Substituting $t_1 = KT$ and $t_2 = (1-K)T$, we get,

$$\frac{K\cancel{T}V_s}{\cancel{L}} = -\frac{(1-K)\cancel{T}V_a}{\cancel{L}}$$

$$\text{or, } KV_s = -(1-K)V_a$$

$$\therefore V_a = \frac{-KV_s}{1-K} \quad \text{——(4)}$$

Further, $t_1 = KT = \left(\frac{-V_a}{V_s - V_a}\right)T = \frac{V_a}{V_a - V_s}\cdot T$

$$\therefore t_1 = \frac{V_a}{f(V_a - V_s)} \quad \text{——(5)} \quad \left[\because T = 1/f\right]$$

For lossless circuit, $V_s I_s = -V_a I_a$

$$\therefore V_s I_s = -\left(\frac{-KV_s}{1-K}\right)I_a$$

$$\text{or, } I_s = \frac{KI_a}{1-K} \quad \text{——(6)}$$

$$T = t_1 + t_2 = L\Delta I\left(\frac{1}{V_s} - 1/V_a\right) = \frac{L\Delta I}{V_s V_a}(V_a - V_s)$$

$$\text{or, } T = 1/f = \frac{L\Delta I}{V_s V_a}(V_a - V_s)$$

$$\therefore \Delta I = \frac{V_s V_a}{fL(V_a - V_s)} = \frac{V_s}{fL}\left(\frac{V_a}{V_a - V_s}\right) = \frac{V_s K}{fL} \quad \text{——(7)}$$

When Q_1 is on, the capacitor supplies the load current for $t = t_1$. The average discharging current of the capacitor is $I_C = I_a$ and the peak to peak ripple voltage of the capacitor is,

$$\Delta V_C = \frac{1}{C}\int_0^{t_1} I_C\,dt = \frac{1}{C}\int_0^{t_1} I_a\,dt = \frac{1}{C} I_a t_1 \quad \text{--- (8)}$$

from eqn (5),

$$t_1 = \frac{V_a}{f(V_a - V_s)}$$

$$\therefore \Delta V_C = \frac{1}{C} I_a \cdot \frac{V_a}{f(V_a - V_s)} = \frac{I_a K}{fC} \quad \text{--- (9)}$$

<u>Condition for Continuous Inductor Current and Capacitor Voltage</u>

If I_L is the average inductor current, the inductor ripple current $\Delta I = 2I_L$.

$$\Delta I = 2I_L$$

or, $$\frac{V_s \cdot K}{fL} = 2I_a$$

~~[illegible]~~

or, $$\frac{KV_s}{fL} = 2\left(-\frac{V_a}{R}\right) = -2\cdot\left(-\frac{KV_s}{1-K}\right)\cdot\frac{1}{R}$$

or, $$\frac{KV_s}{fL} = \frac{2KV_s}{(1-K)R}$$

Which gives the critical value of inductor L_c as,

$$L_c = L = \frac{(1-K)R}{2f}$$

If V_c is the average capacitor voltage, then, the capacitor ripple voltage $\Delta V_C = 2V_a$.

$$\frac{I_a K}{fC} = 2V_a = 2I_a \cdot R$$

Which gives the critical value of capacitor C_c as,

$$\boxed{C_c = C = \frac{K}{2fR}}$$