Choppers

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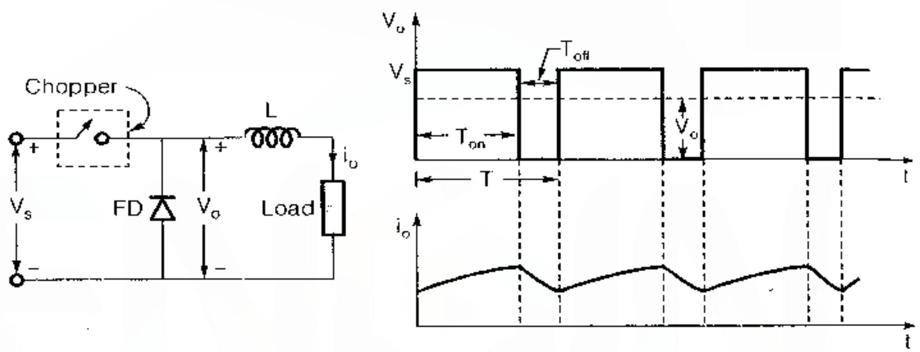
A chopper is a high speed on/off semiconductor switch. Chopper is a static device that converters fixed dc input voltage to a variable dc output voltage directly.

Remember:

For medium power application we use IGBT and GTO, in chopper.

Step Down Chopper

Average output voltage V_o is always less than the input voltage V_s.



- Duty cycle

$$\alpha = \frac{T_{ON}}{T} = \frac{T_{ON}}{T_{ON} + T_{OFF}} \quad ; \; \alpha < 1$$

- Average load voltage

$$V_o = \alpha V_s$$

- RMS load voltage

$$V_{RMS} = \sqrt{\alpha}\, V_s$$

- Average load current

$$I_o = \frac{V_o}{R} = \frac{\alpha V_s}{R}$$

- RMS load current

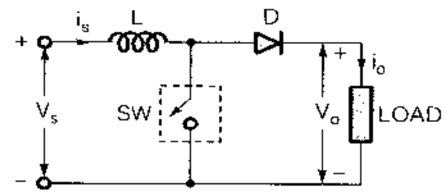
$$I_{RMS} = \frac{\sqrt{\alpha}\, V_s}{R}$$

Note:

- Above formulae valid only for continuous conduction.
- Inductor connected in series with load is used to reduce the ripple content in output current.

Step Up Chopper

Average output voltage V_o is more than input DC voltage V_s.



- Average load voltage

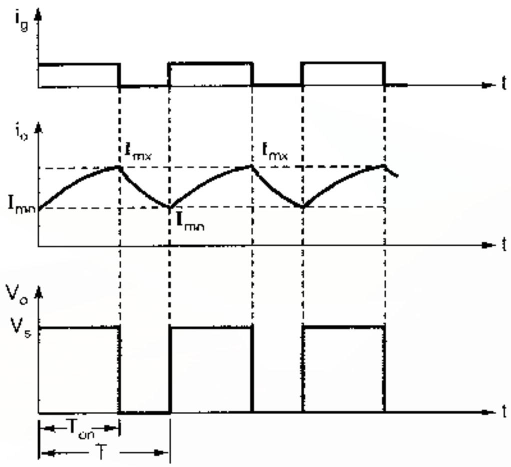
$$V_o = \frac{1}{1-\alpha} V_s$$

- For a basic DC to DC converter, the critical inductance of the filter circuit is given by

$$L = \frac{V_o^2 (V_s - V_o)}{2 f V_s P_o}$$

where, V_o = Load voltage
V_s = Source voltage
P_o = Load power
f = Chopping frequency

Steady State Time-Domain Analysis of Type-A Chopper



- Maximum value of current

$$I_{mx} = \frac{V_s}{R}\left[\frac{1-e^{-T_{on}/T_a}}{1-e^{-T/T_a}}\right] - \frac{E}{R}$$

- Minimum value of current

$$I_{mn} = \frac{V_s}{R}\left[\frac{e^{T_{on}/T_a}-1}{e^{T/T_a}-1}\right] - \frac{E}{R}$$

where, $T_a = \frac{L}{R}$

- Per unit ripple current

$$\text{p.u. ripple current} = \frac{(I_{mx} - I_{mn})}{V_s/R} = \frac{(1-e^{-\alpha T/T_a})(1-e^{-(1-\alpha)T/T_a})}{(1-e^{-T/T_a})}$$

Note:

The peak to peak ripple current has maximum value ΔI_{mx} when duty cycle $\alpha = 0.5$.

- For $\alpha = 0.5$

$$\Delta I_{mx} = \frac{V_s}{R}\tanh\frac{R}{4fL}$$

- If 4 fL >> R then $\tanh\frac{R}{4fL} \approx \frac{R}{4fL}$

$$\Delta I_{mx} = \frac{V_s}{4fL}$$

Remember:

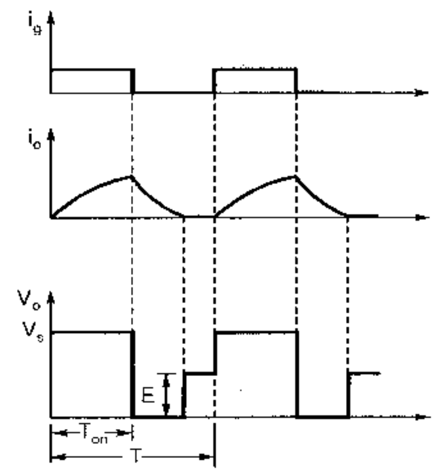
Higher the inductance, ripple is minimum.

- The value of duty cycle at the limit of continuous conduction

$$\alpha' \geq \frac{T_a}{T} \ln\left[1 + \frac{E}{V_s}\left(e^{T/T_a} - 1\right)\right]$$

where, α' measures the limit of continuous conduction.

Load Current Discontinuous



- Minimum value of current

$$I_{mn} = 0$$

- Maximum value of current

$$I_{mx} = \frac{V_s - E}{R}\left(1 - e^{-T_{on}/T_a}\right)$$

- Extinction time (t_x)

$$t_x = T_{on} + T_a \ln\left[1 + \frac{V_s - E}{E}\left(1 - e^{-T_{on}/T_a}\right)\right]$$

- Average output voltage

$$V_o = \alpha V_s + \left(1 - \frac{t_x}{T}\right)E$$

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