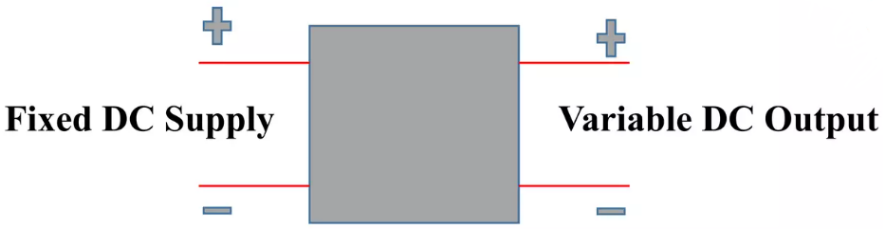
DC CHOPPER : DC TO DC CONVERTER

4.1 Introduction

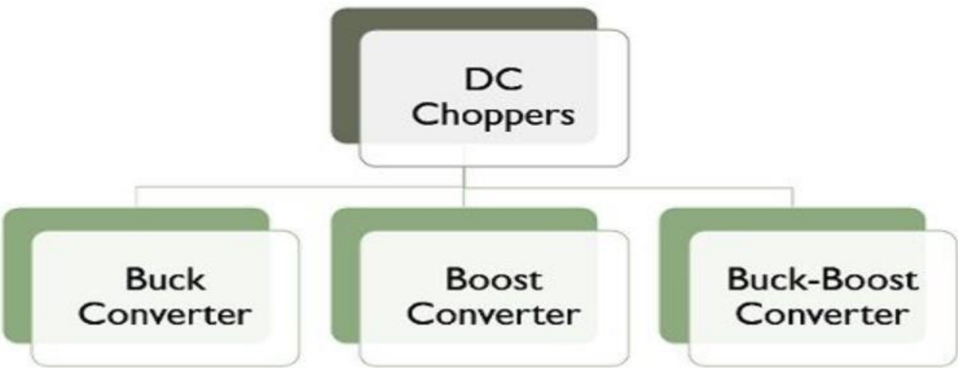


1- In many industrial applications, it is required to converter a fixed-voltage dc source into a variable-voltage dc source.

2-A dc chopper converters directly from dc to dc and is also known as dc to dc converter.

3- The classification of dc chopper circuits is based on the type of operation performed by the converter.

- Buck Converters (also known as Step-up Choppers)
- Boost Converters (also known as Step-down Choppers)
- Buck-Boost Converters (also known as Step-up/Step-down Choppers)



4- Choppers are widely used for traction motor control in electric automobiles, trolley cars, marine hoists, forklift trucks, and mine haulers.

5- They provide smooth acceleration control, high efficiency, and fast dynamic response.

6- Choppers can be used in regenerative braking of dc motors to return energy back into the supply, and this feature results in energy savings for transportation systems with frequency stops.

7-Choppers are used in dc voltage regulators, and also used, in conjunction with an inductor, to generate a dc current source, especially for the current source inverter.

8- The voltage source driven dc-dc converters are more popular than the current driven converters.

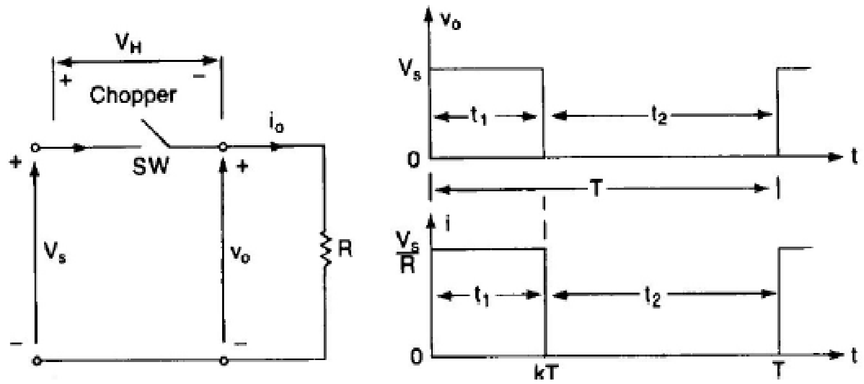
9- All converters use effective filtering on both the input and output to reduce the ac components from going outside the converters.

Applications of DC Chopper :

- DC choppers are used in subway cars, trolley buses, and battery-operated vehicles.
- DC choppers can offer regenerative braking of dc motors, resulting in energy saving.
- Used in speed-controlling of dc motors.
- The unregulated dc voltage from solar photovoltaic cells can be regulated using dc choppers.

- Circuits are used in switched-mode power supplies, onboard regulated dc power supplies, and various domestic and commercial electronic appliances.
- Airplanes and spaceships.

4.2 Principle of Step-Down Operation with R load



Step-down chopper with resistive load

Chopper switch: BJT; MOSFET, GTO forced-commutated thyristor.

The average output voltage,

$$V_a = \frac{1}{T}\int_0^{t_1} v_0\,dt = \frac{t_1}{T}V_s = f\,t_1 V_s = kV_s$$

The average load curent, $I_a = \frac{V_a}{R} = \frac{kV_s}{R}$

T *: chopping period*

$k = t_1/T$ *: duty cycle of chopper*

f *: chopping frequency*

The rms output voltage, $V_o = \left(\frac{1}{T}\int_0^{kT} v_0^2\,dt\right)^{1/2} = \sqrt{k}\,V_s$

The ripple factor RF

$$RF = \sqrt{\frac{1-k}{k}}$$

Assuming a lossless chopper, the input power to the chopper is the same as the output power,

$$P_i = \frac{1}{T}\int_0^{kT} v_0 i \, dt = \frac{1}{T}\int_0^{kT} \frac{v_0^2}{R} dt = k\frac{V_s^2}{R}$$

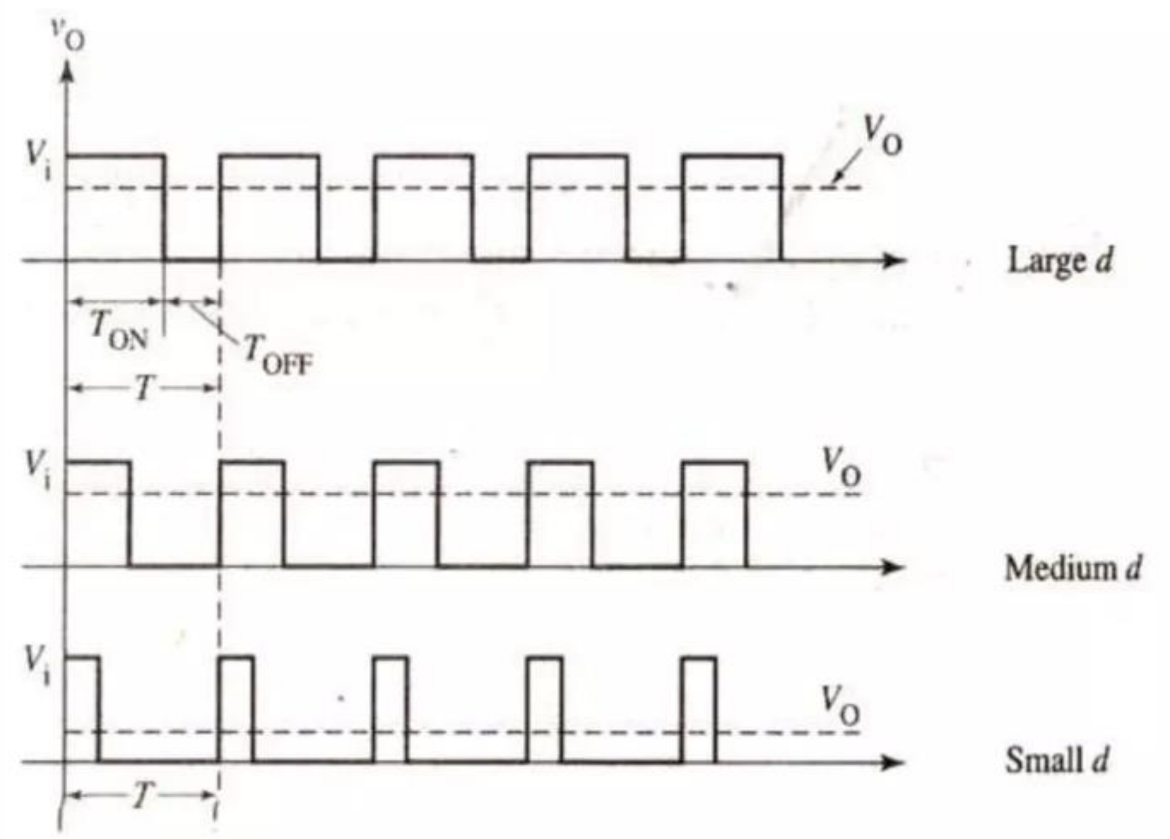
The effective input resistance seen by the source,

$$R_i = \frac{V_s}{I_a} = \frac{V_s}{kV_s / R} = \frac{R}{k}$$

4.2.1 Method of control

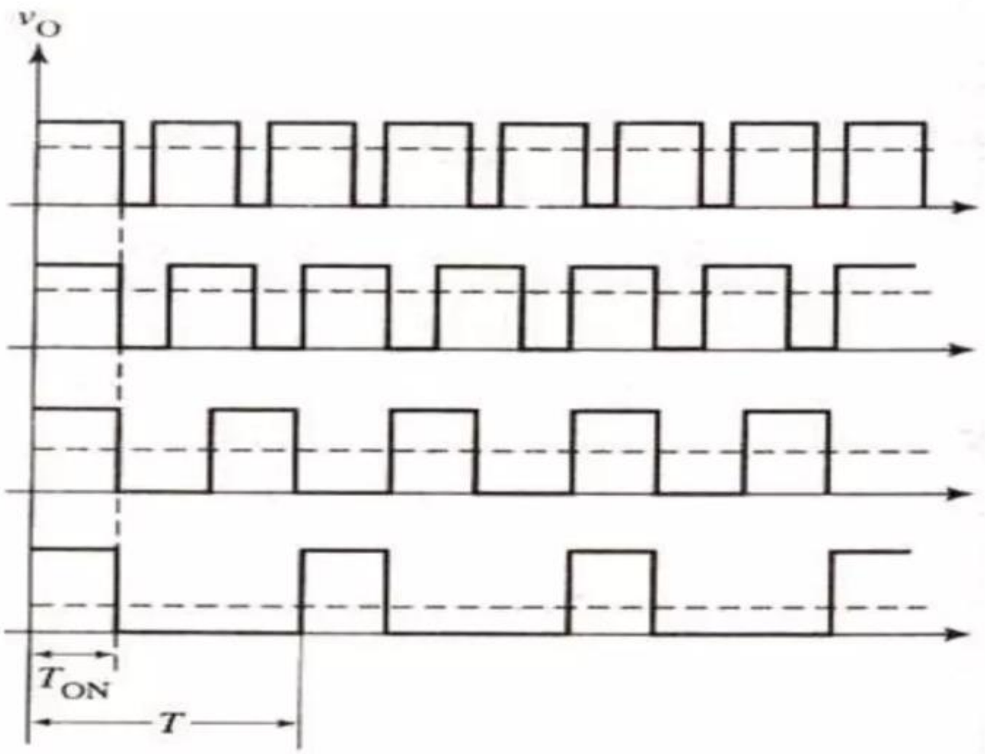
1. Constant-frequency operation

The chopping frequency f (or chopping period T) is kept constant and the on-time t_1 is varied. The width of the pulse is varied and this type of control is known as pulse-width-modulation (PWM) control.



2. Variable-frequency operation

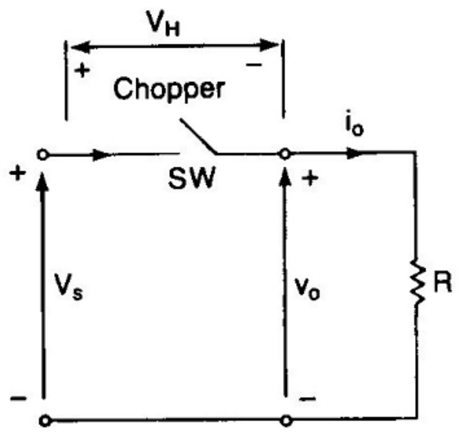
The chopping frequency f is varied. Either on-time t_1 or off-time t_2 is kept constant. This is called frequency modulation. The frequency has to be varied over a wide range to obtain the full output voltage range. This type of control would generate harmonics at unpredictable frequencies and the filter design would be difficult.



Example 1:

The dc chopper has a resistive load of R=10Ω and the input voltage is V_s=220V. When the chopper switch remains on, its voltage drop is v_{ch}=2V and the chopping frequency is f=1kHz. If the duty cycle is 50%, determine,

(a) The average output voltage V_a
(b) The *rms* output voltage V_o
(c) The chopper efficiency
(d) The effective input resistance R_i of the chopper



Sol:

$$R = 10\Omega,\ V_s = 220\,\text{V},\ k = 0.5,\ v_{ch} = 2\,\text{V}$$

$$(a)\quad V_a = \frac{1}{T}\int_0^{t_1} v_0\,dt = \frac{t_1}{T}V_s = f\,t_1 V_s = kV_s$$
$$= 0.5\times(220-2) = 109\,\text{V}$$

$$(b)\quad V_o = \left(\frac{1}{T}\int_0^{kT} v_0^2\,dt\right)^{1/2} = \sqrt{k}\,V_s = \sqrt{.5}\times(220-2) = 154.15\ \text{V}$$

(c) *output power,*

$$P_o = \frac{1}{T}\int_0^{kT}\frac{v_0^2}{R}\,dt = \frac{1}{T}\int_0^{kT}\frac{(V_s - v_{ch})^2}{R}\,dt = k\frac{(V_s - v_{ch})^2}{R}$$
$$= 0.5\times\frac{(220-2)^2}{10} = 2376.2\,\text{W}$$

input power,

$$P_i = \frac{1}{T}\int_0^{kT} V_s i\, dt = \frac{1}{T}\int_0^{kT} \frac{V_s(V_s - v_{ch})}{R}\, dt = k\frac{V_s(V_s - v_{ch})}{R}$$

$$= 0.5 \times 220 \times \frac{220-2}{10} = 2398\ \text{W}$$

the chopper efficiency, $\frac{P_o}{P_i} = \frac{2376.2}{2398} = 99\ .09\%$

$$(d)\ \ R_i = \frac{V_s}{I_a} = \frac{V_s}{kV_s / R} = \frac{R}{k} = \frac{10}{0.5} = 20\Omega$$

Example 2 : A transistor dc chopper circuit (Buck converter) is supplied with power form an ideal battery of 100 V. The load voltage waveform consists of rectangular pulses of duration 1 ms in an overall cycle time of 2.5 ms. Calculate, for resistive load of 10 Ω.

(a) The duty cycle .

(b) The average value of the output voltage .

(c) The ripple factor *RF*.

(d) The output d.c. power.

Sol:

Ans: a) K= 0.4

b) Va= 40V

c) RF= 1.225

d) Idc= 4A, Pdc=160w

Example 3: A Chopper circuit is operating at a frequency of 2 kHz on Vs= 460 V supply. If the Va= 350 volts, calculate the conduction period of the thyristor in each cycle.

Solution:

Chopping period $T = \frac{1}{f}$

$$T = \frac{1}{2\times10^{-3}} = 0.5\ m\sec$$

Output voltage Va = kVs =(ton/T)Vs

Conduction period of thyristor

$$t_{ON} = \frac{T\times \text{Va}}{\text{Vs}}$$

$$t_{ON} = \frac{0.5\times10^{-3}\times350}{460}$$

$$t_{ON} = 0.38 \text{ msec}$$

Example 4: In a dc chopper, the average load current is 30 Amps, chopping frequency is 250 Hz, supply voltage is 110 volts. Calculate the ON and OFF periods of the chopper if the load resistance is 2 ohms.

Sol:

Ans: ton= t1= 2.18 msec , toff= t2=1.82 msec