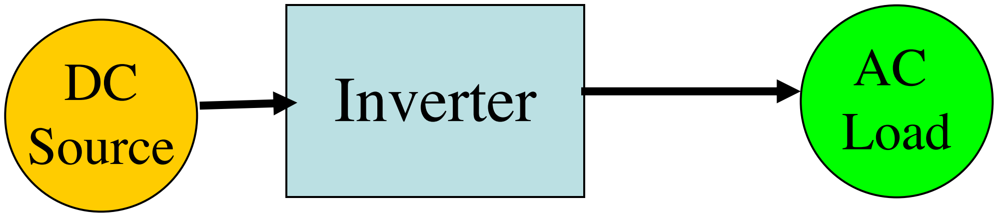
Inverters

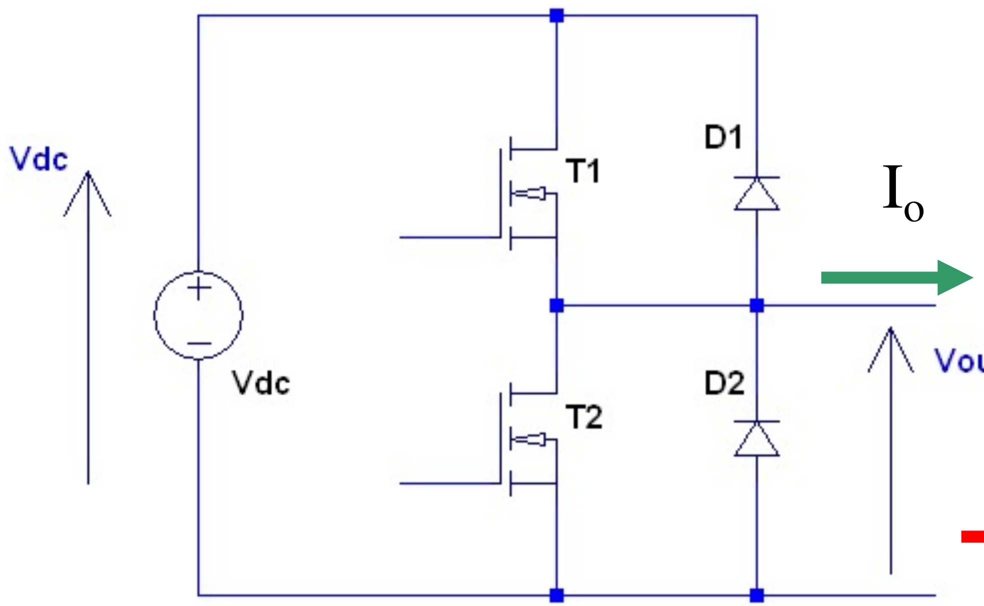
Voltage Source Inverters Basics

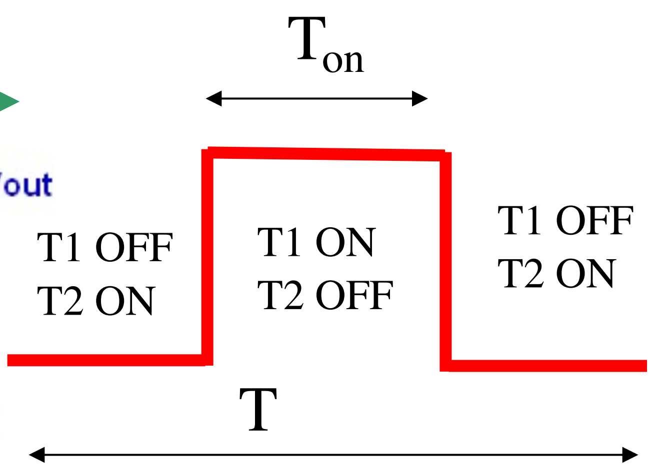


- Inverters are DC to AC converters
- Voltage source inverters synthesise an AC voltage from a DC supply voltage
- https://www.youtube.com/watch?v=qVeERT4nyz8
- Inverters operate by controlling the duty cycle of the power devices.
- Inverters can generate:
    - Single-phase AC supply
    - Three-phase AC supply
- The basic building block is the two ‘Bridge’ circuit
- https://www.youtube.com/watch?v=QNyoak45MSY

Bridge Circuit

$$V_{out} = V_{dc} \frac{t_{1,on}}{T_s}$$





$I_0 > 0$ T1 and D2 are active

$I_o < 0$ D1 and T2 are active

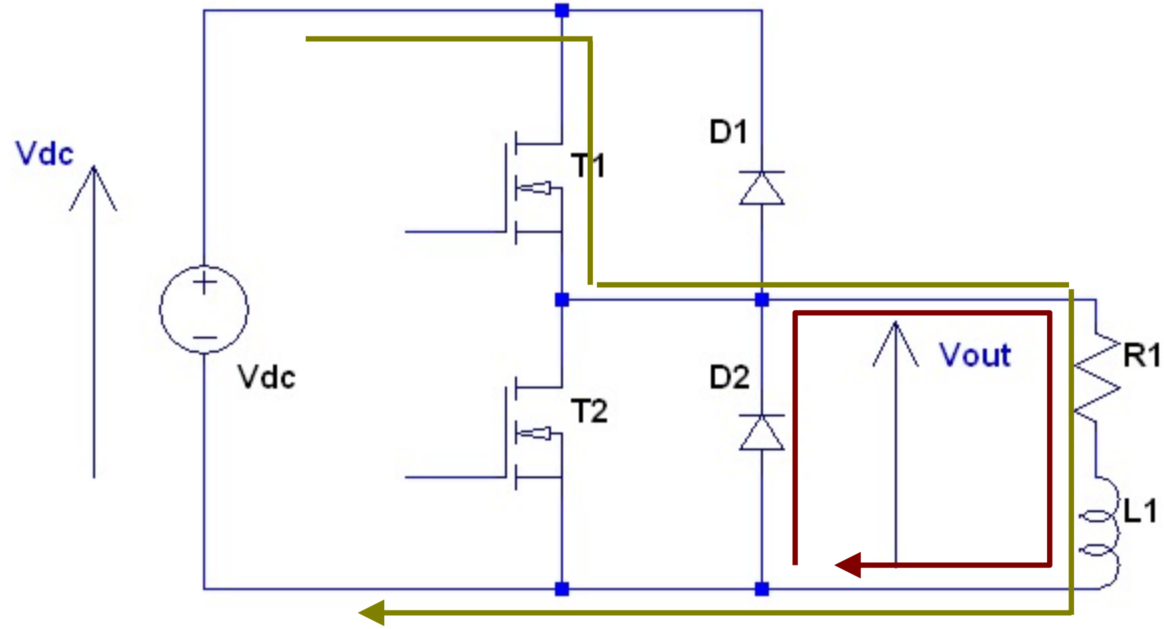
Current Paths

• Two switches with freewheel diodes provides uni-directional voltage and bi-directional current control.

• Only when T1 is ON is energy supplied from the source.

• When T2 ON, a zero voltage loop is applied.

• With positive current flow →



Current path if T2 ON, or T1 and T2 OFF

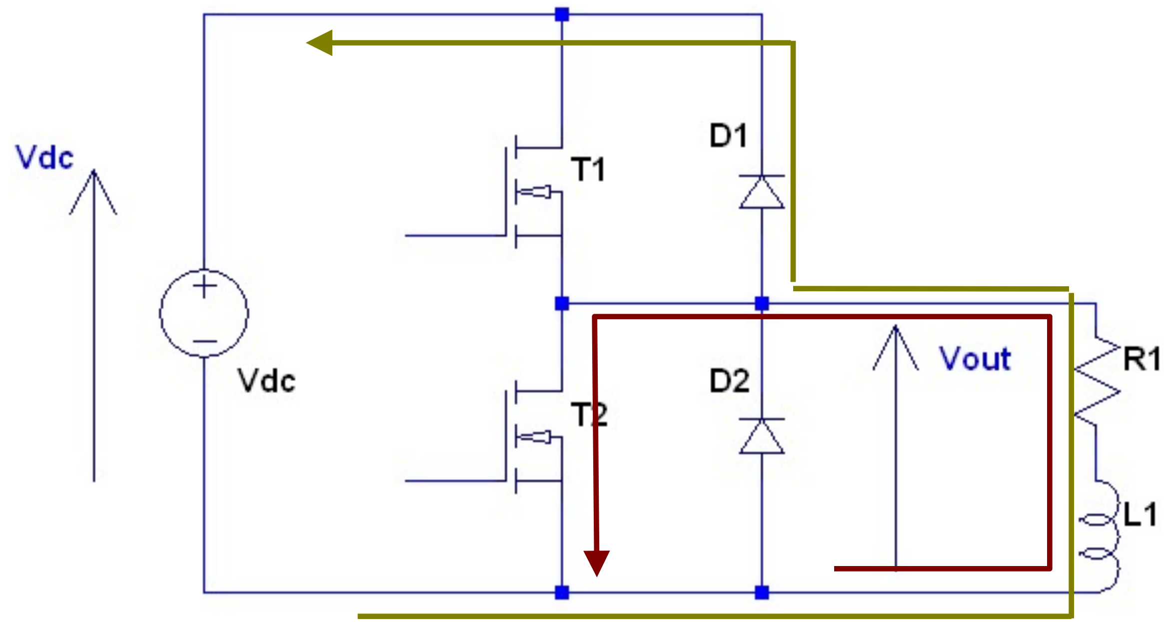
Current path if T1 ON

Current Paths

- When T1 is ON (or T1 and T2 OFF) energy has to be absorbed by the source.

- When T2 ON, a zero voltage loop is applied.

- With negative current flow →



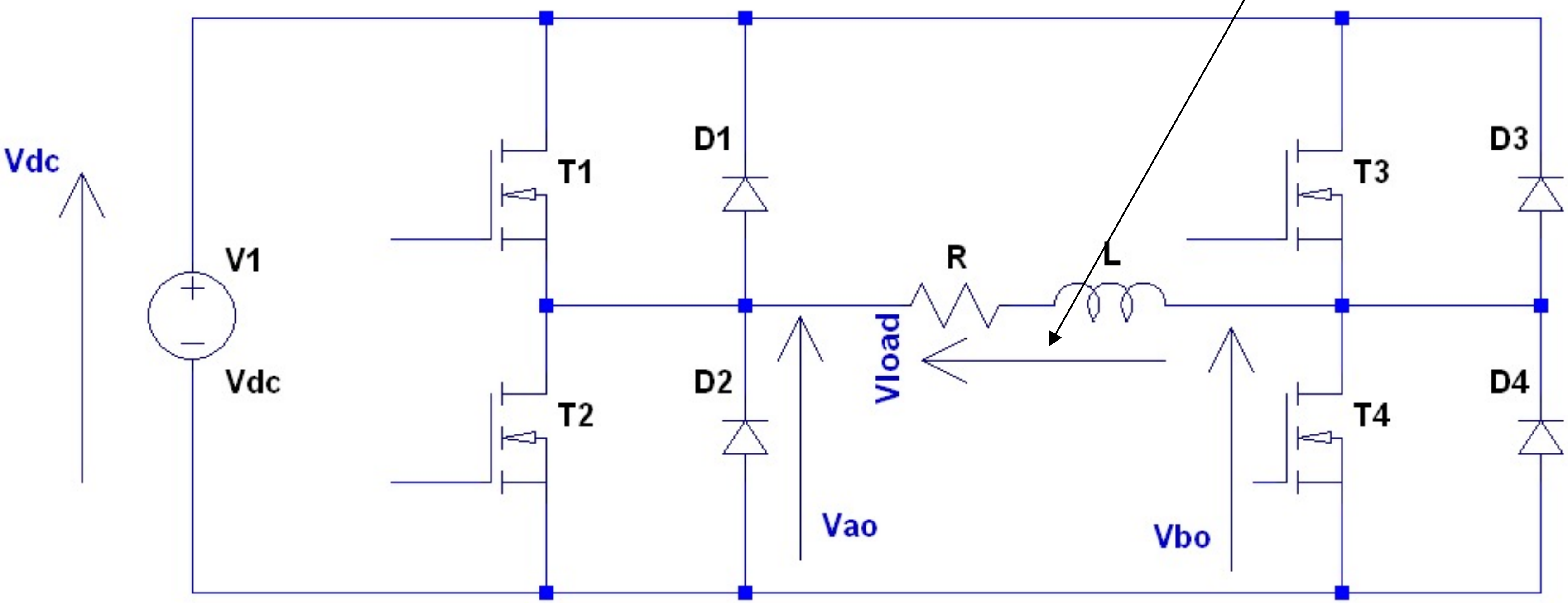
Current path if T2 ON

Current path if T1 ON, or T1 and T2 OFF

Single-phase H-bridge

- Two inverter legs connected in parallel.
- Bi-directional load voltage and current.

$$V_{load} = V_a - V_b$$



Single Phase AC Output

Basic AC Waveform Generation

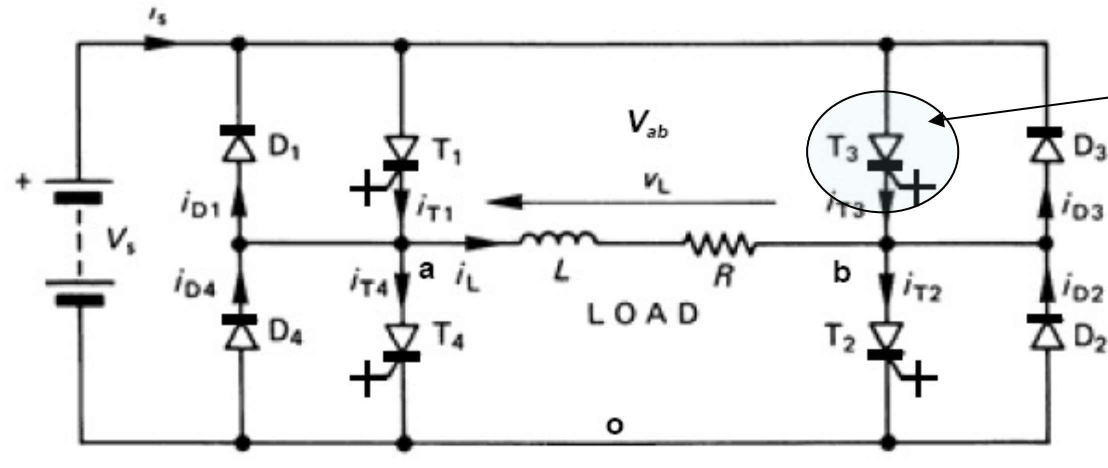
A simple AC waveform may be generated by switching the bridge legs at the fundamental frequency.

The converter gives square wave output at the desired power frequency.

The maximum output corresponds to a $-V_{dc}$ to $+V_{dc}$ square-wave.

It is possible to vary the magnitude of the fundamental component of the AC output by introducing zero output voltage regions where $V_a=V_b$

Single Phase H-Bridge **Inverter**

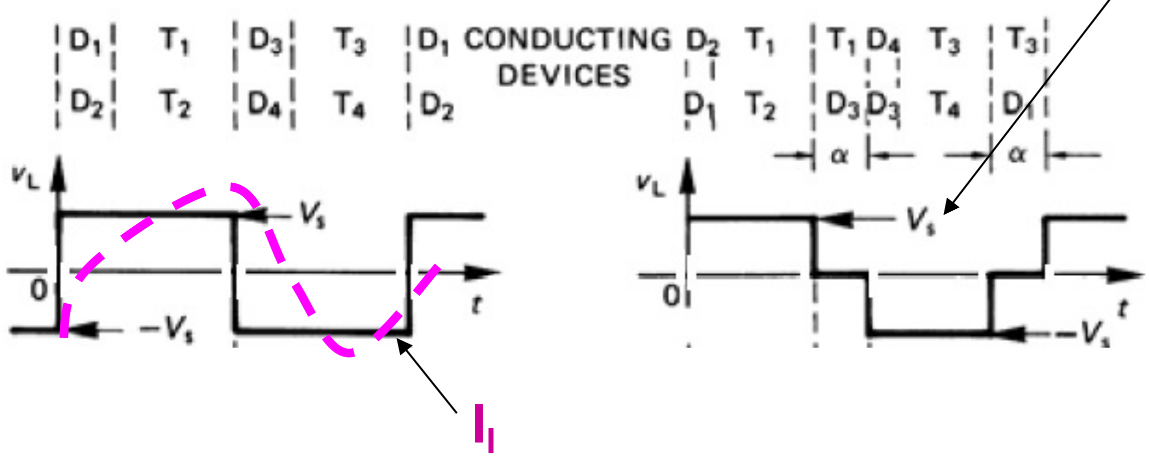


GTO switch

(a)

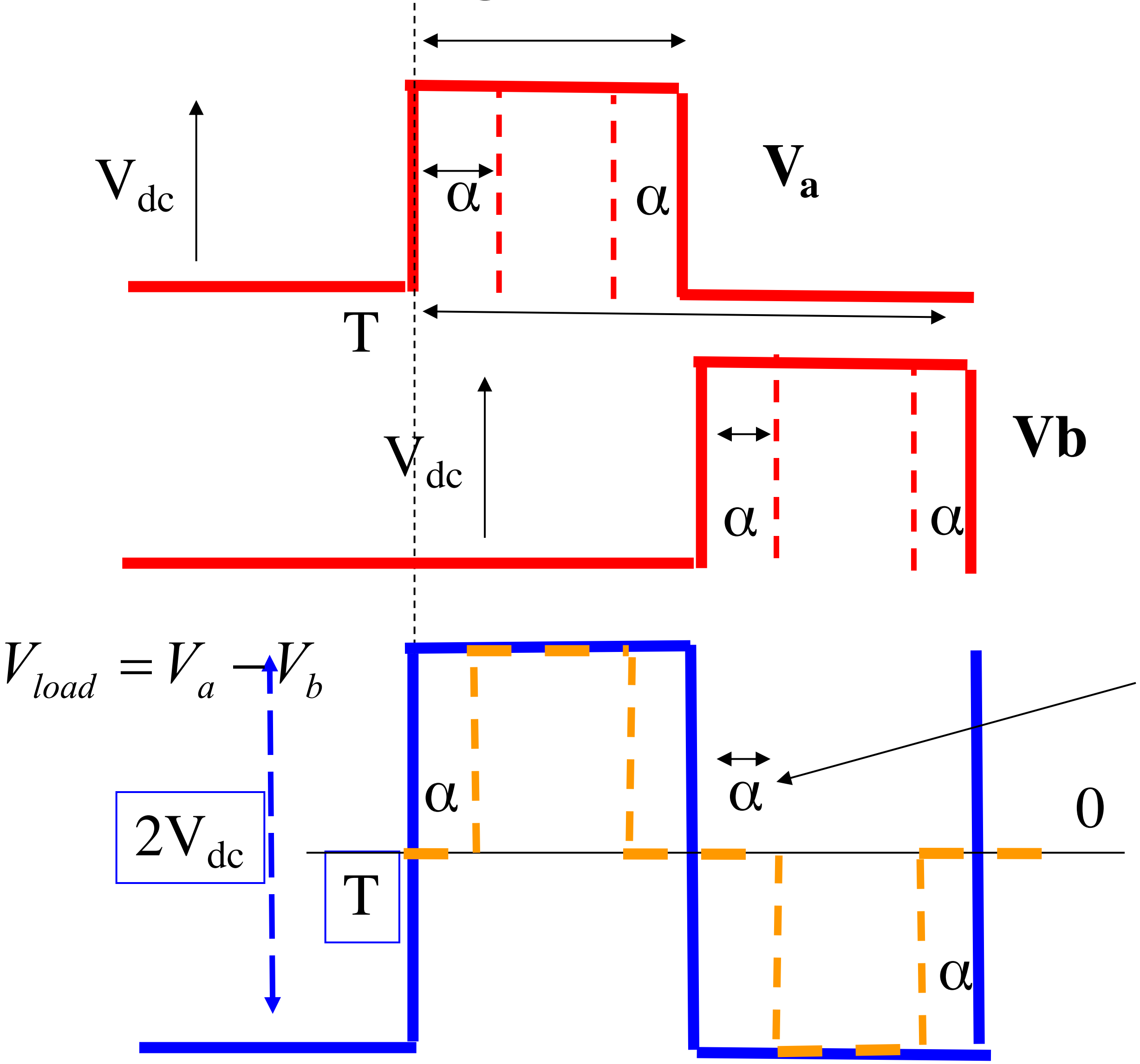
Fundamental frequency switching

Magnitude of Fundamental can be controlled



Load Voltage

Load Voltage



The common DC Component a_0 is cancelled.

The load sees a fundamental of: $4V_{dc}/\pi$

Fundamental magnitude may be controlled by a delay angle: α

Voltage Harmonics

The simplest modulation technique is to use a square wave approximation with devices switched at the fundamental frequency.
This has the problem of a large low frequency harmonic content.
Fourier series of single phase gives:

$$a_0 = \frac{V_s}{2}$$

DC component

$$a_n = \frac{1}{\pi}\int_0^{\pi} V_a \sin n\theta . d\theta$$

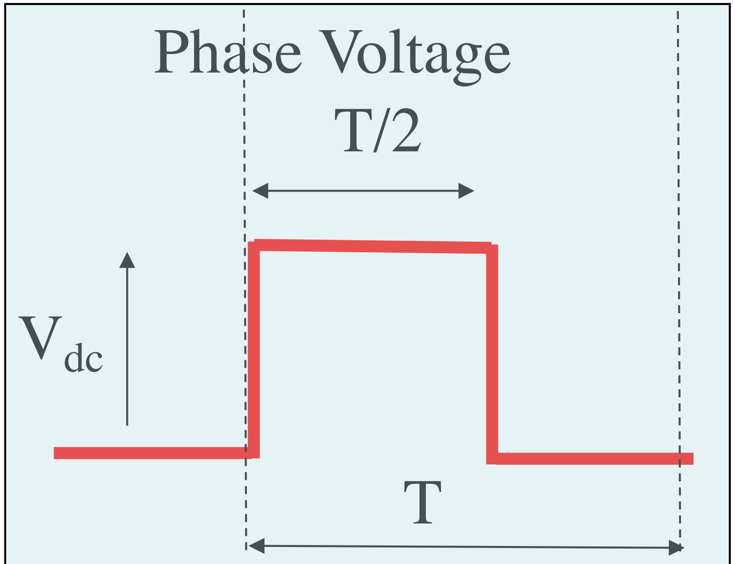
$$0 < \theta < \pi \Rightarrow V_a = V_{dc} \qquad \pi < \theta < 2\pi \Rightarrow V_a = 0$$

$$\mathrm{a_n} = \frac{V_{dc}}{\pi}\left[\frac{-\cos\theta n}{n}\right]_0^{\pi}$$

Harmonics

$$\left|\mathrm{a_n}\right| = \frac{2V_{dc}}{n\pi} \qquad \mathrm{n : odd}$$

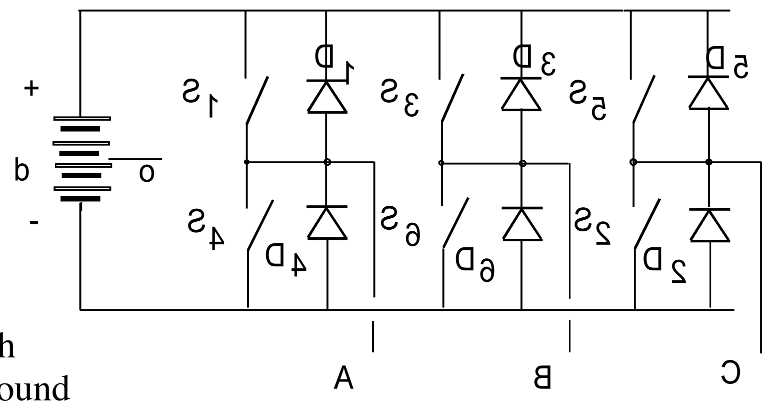
Integral in angular base where θ=2π(t/T)*



Switched at desired fundamental
(Maximum output)

Three Phase Output

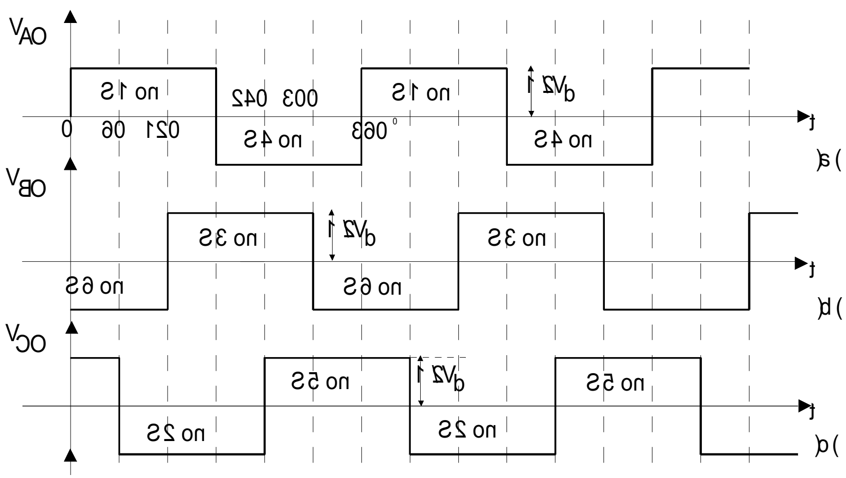
Three Phase Inverters



Note V_{dc} with mid point ground

Three bridge leg circuits can be modulated with a 120° phase shift.

Phase Voltage



Simple fundamental frequency switching may be used

Six-step Line Voltages

- Line voltages are stepped

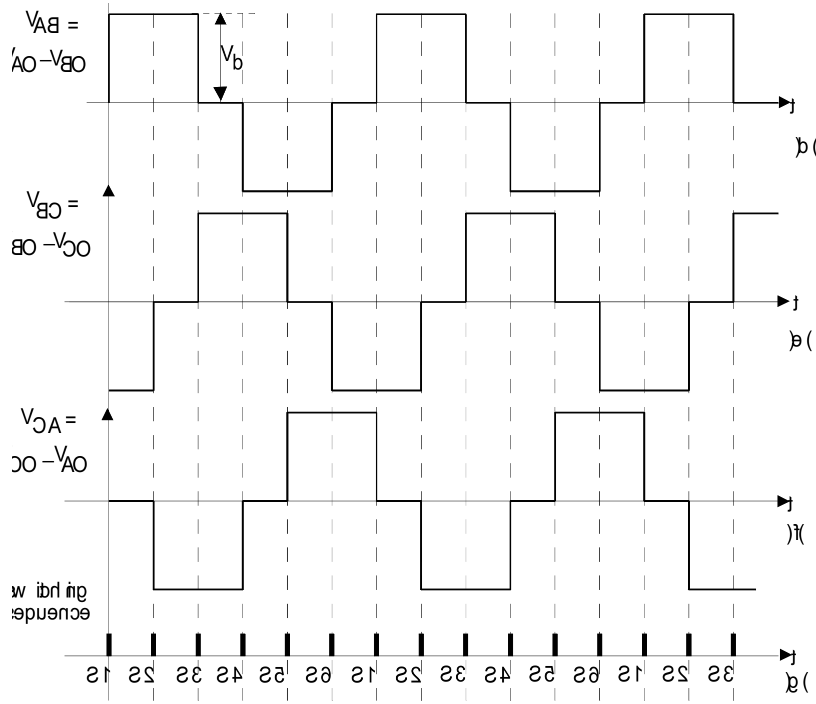
- Fourier analysis of output voltages gives

$$V_{AO} = \frac{4}{\pi} \cdot \frac{V_d}{2} \left[\sin \omega t + \frac{1}{3} \sin 3\omega t + \frac{1}{5} \sin 5\omega t + ... \right]$$

- and line voltages

$$V_{AB} = \frac{2\sqrt{3}}{\pi} V_d \left[\sin \omega t + \frac{1}{5} \sin 5\omega t - \frac{1}{7} \sin 7\omega t + \frac{1}{11} \sin 11\omega t + ... \right]$$

Line Voltage



Six-step Inverter Currents

- Inverter currents are obviously non-sinusoidal. (Note: this load is inductive)
- Result from the harmonic voltages in the output line voltage.
- Harmonic currents causes additional loss components.
- And also torque ripple if the load is a machine.