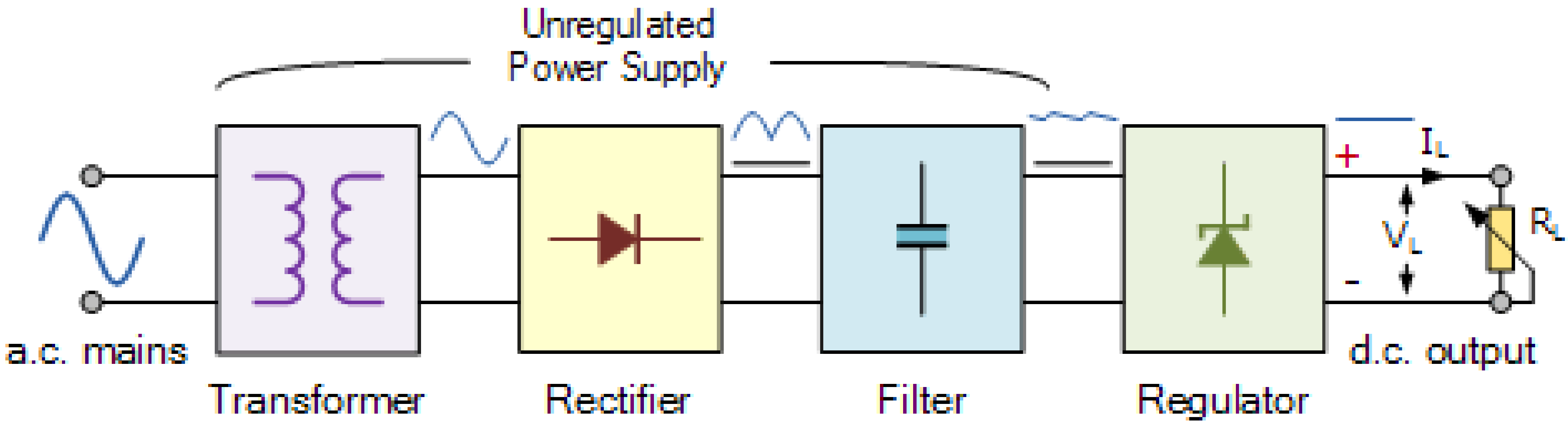
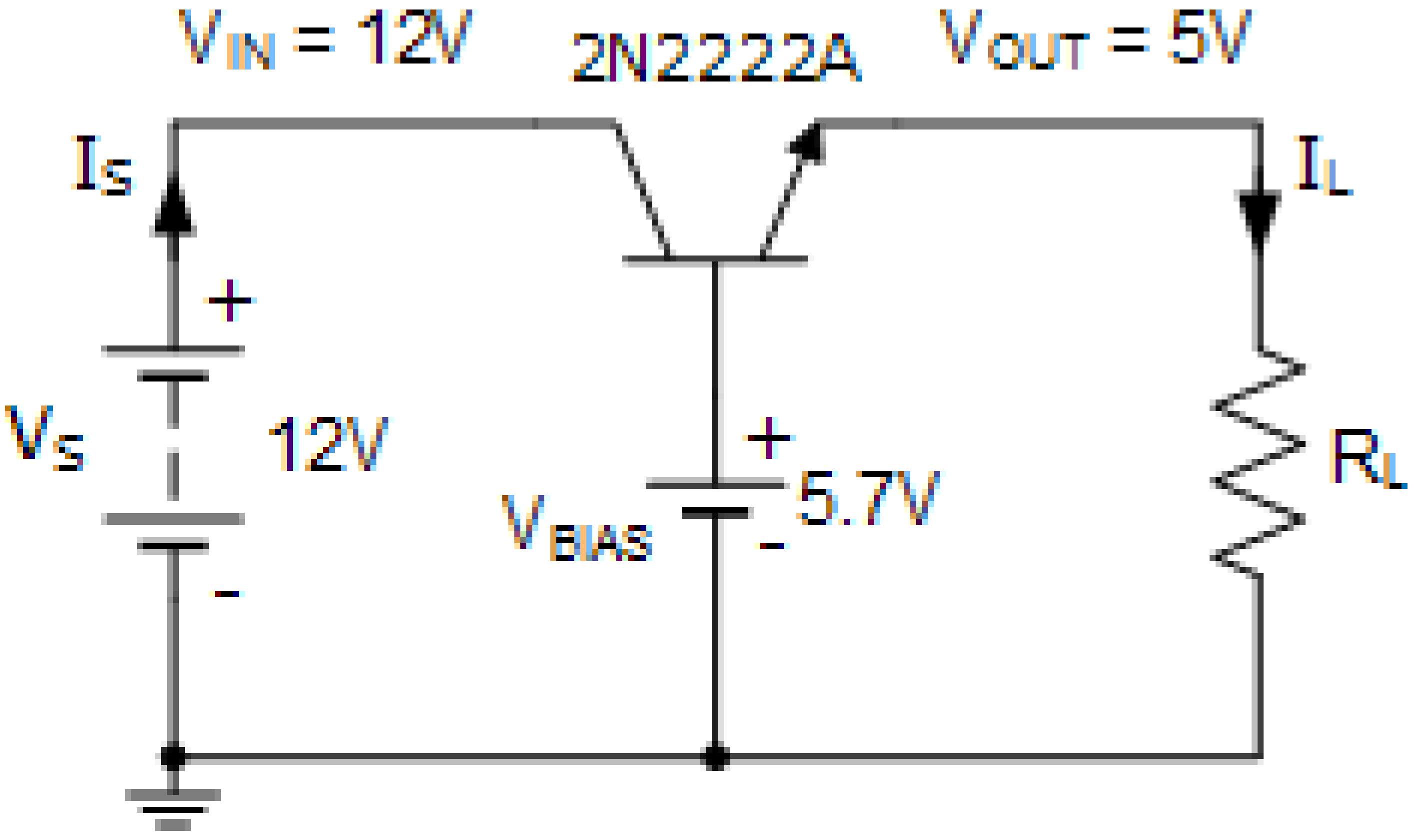
Electronic Circuits

Lecture 5.4: Switch-Mode Power Supply (SMPS)

Typical DC Power Supply

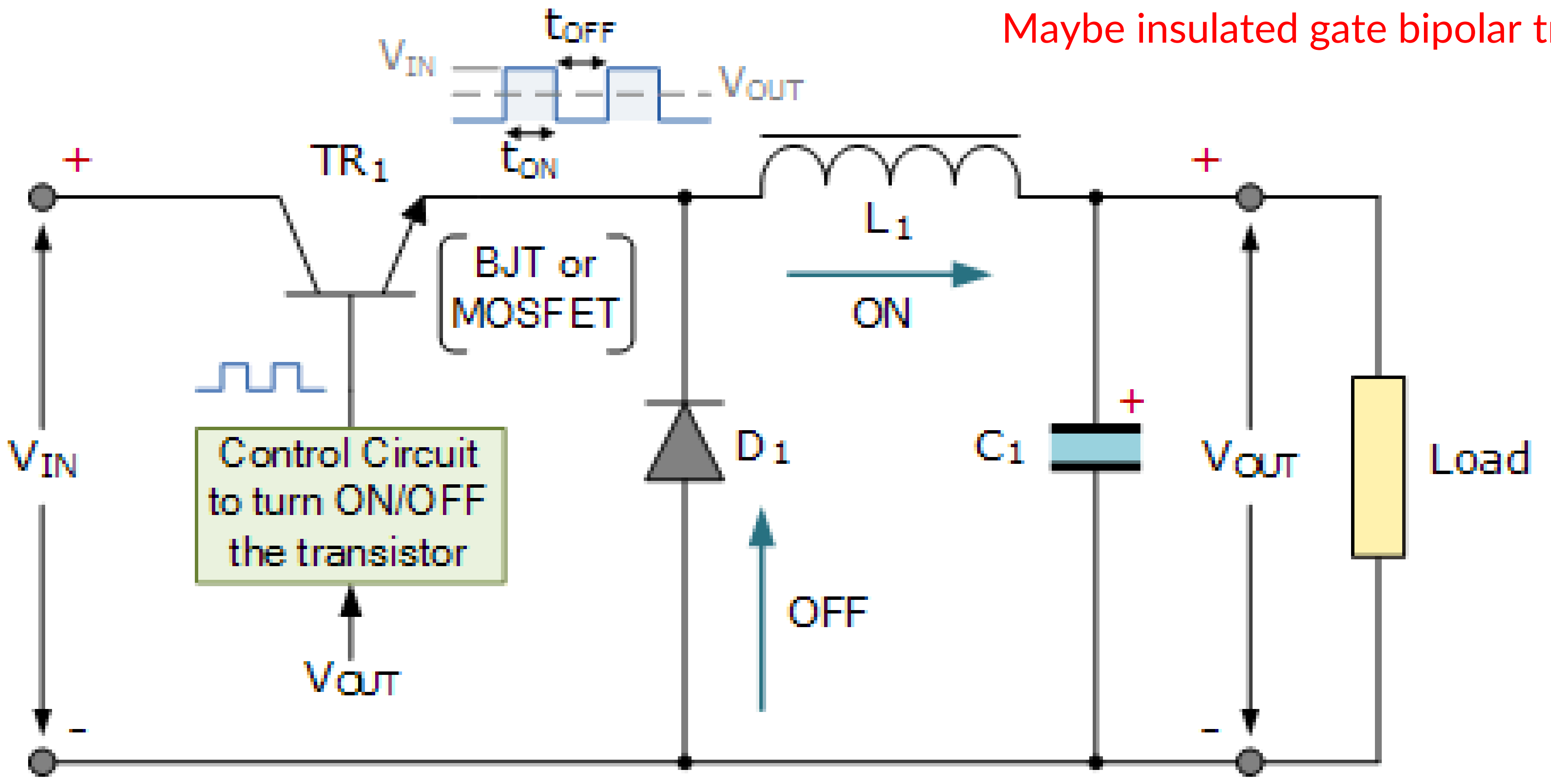


Series Transistor Regulator Circuit



Buck Switching Regulator Circuit

Maybe insulated gate bipolar transistor (IGBT)



Buck Converter Duty Cycle

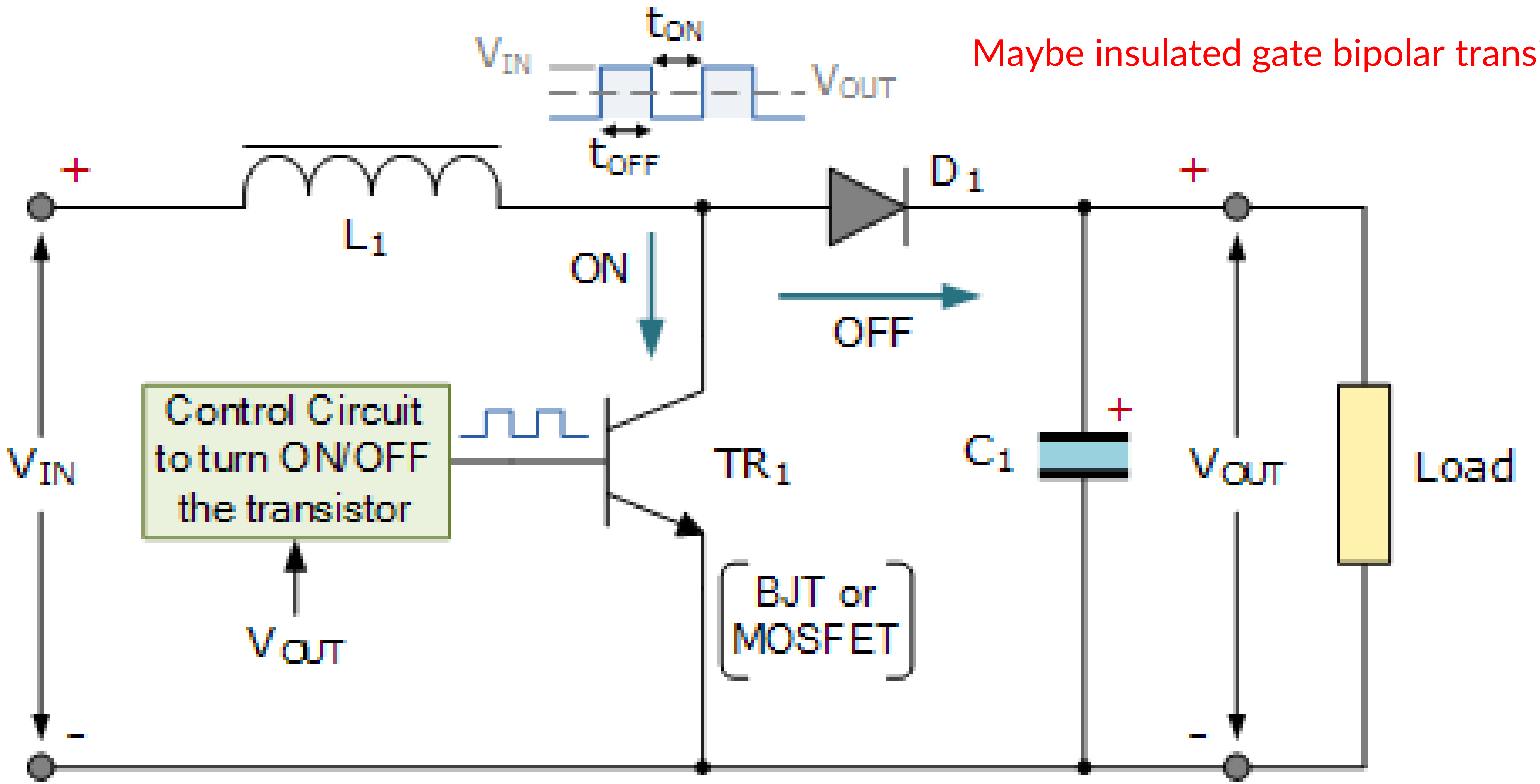
$$V_{OUT} = \frac{t_{ON}}{(t_{ON} + t_{OFF})} \times V_{IN}$$

$$D = \frac{t_{ON}}{(t_{ON} + t_{OFF})} = \frac{t_{ON}}{\text{Total Time}} = \frac{t_{ON}}{T}$$

$$\therefore\ D \approx \frac{V_{OUT}}{V_{IN}} \quad \text{or} \quad V_{OUT} = D V_{IN}$$

Boost Switch Mode Circuit

Maybe insulated gate bipolar transistor (IGBT)

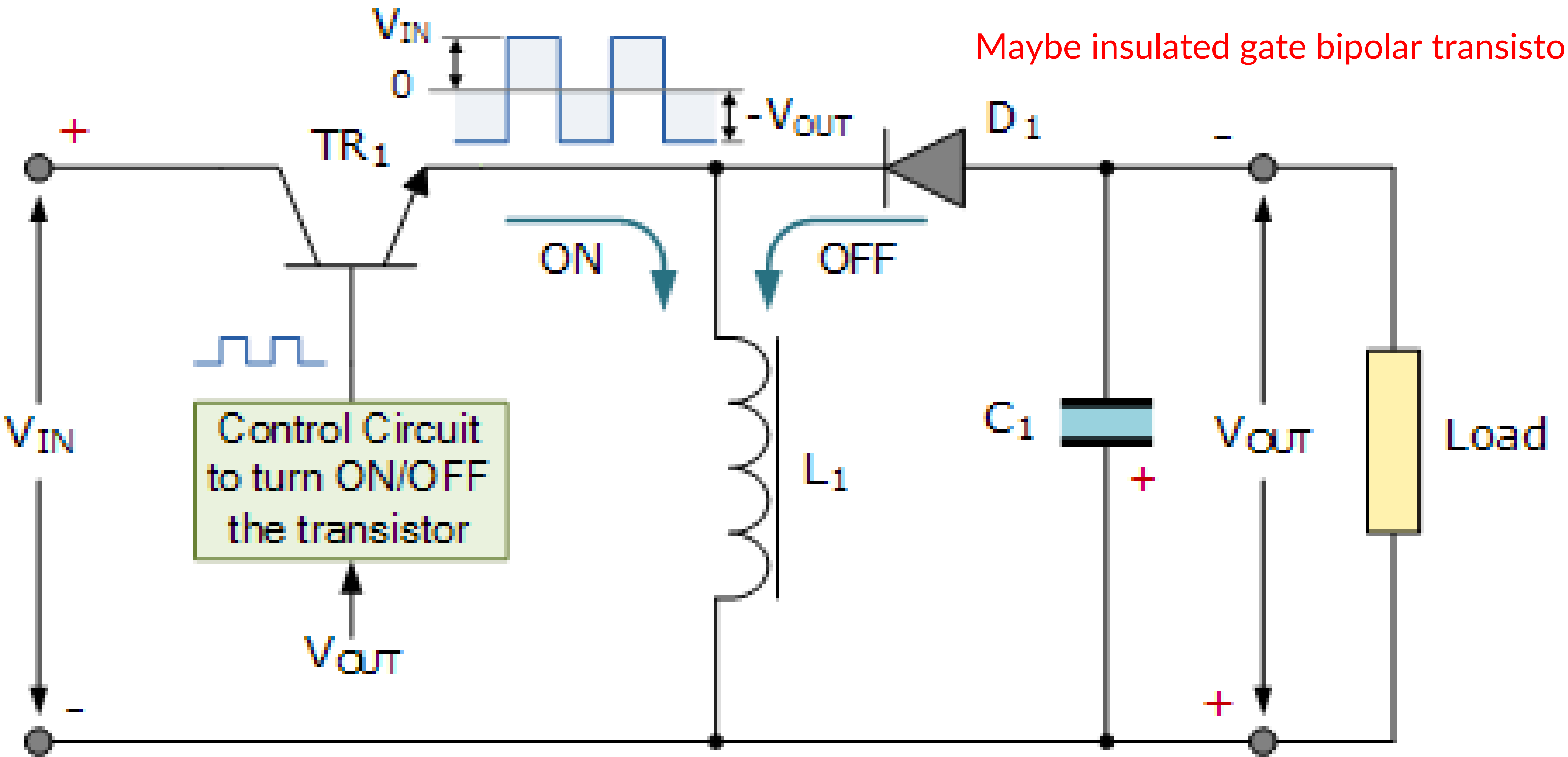


Boost Mode Duty Cycle

$$V_{OUT} = V_{IN} \frac{1}{(1 - \text{duty cycle})} = V_{IN}\left(\frac{1}{1 - D}\right)$$

Buck-Boost Switching Regulator Circuit

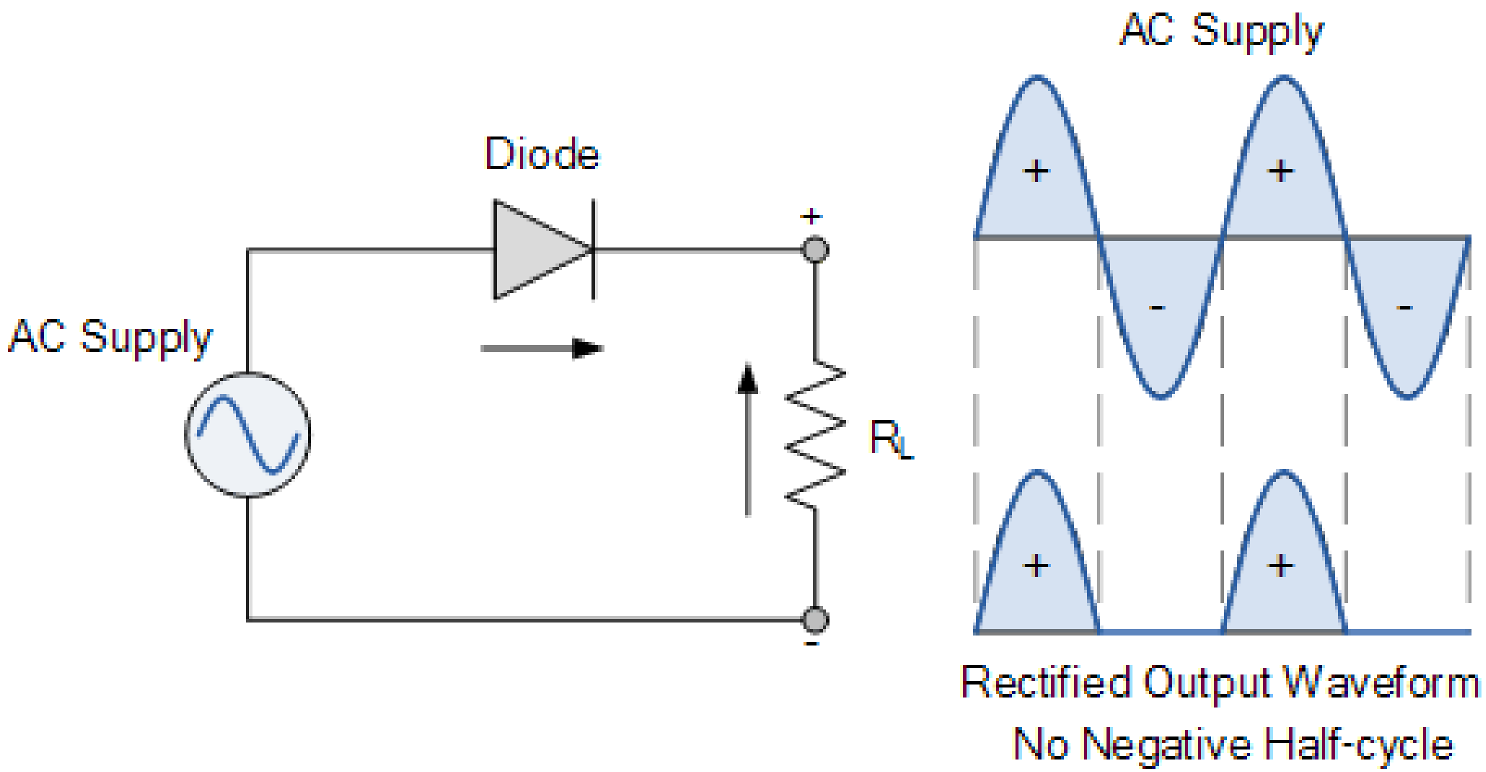
Maybe insulated gate bipolar transistor (IGBT)



Buck-Boost Mode Duty Cycle

$$V_{OUT} = V_{IN}\left(\frac{D}{1-D}\right)$$

Half-Wave Single-Phase Rectifier



Half-Wave Single-Phase Rectifier Example

A single phase half-wave rectifier is connected to a 50V RMS 50Hz AC supply. If the rectifier is used to supply a resistive load of 150 Ohms. Calculate the equivalent DC voltage developed across the load, the load current and power dissipated by the load. Assume ideal diode characteristics.

First we need to convert the 50 volts RMS to its peak or maximum voltage equivalent (its not necessary but it helps).

a) Maximum Voltage Amplitude, V_M

$$V_M = 1.414 * V_{RMS} = 1.414 * 50 = 70.7 \text{ volts}$$

b) Equivalent DC Voltage, V_{DC}

$$V_{DC} = 0.318 * V_M = 0.318 * 70.7 = 22.5 \text{ volts}$$

c) Load Current, I_L

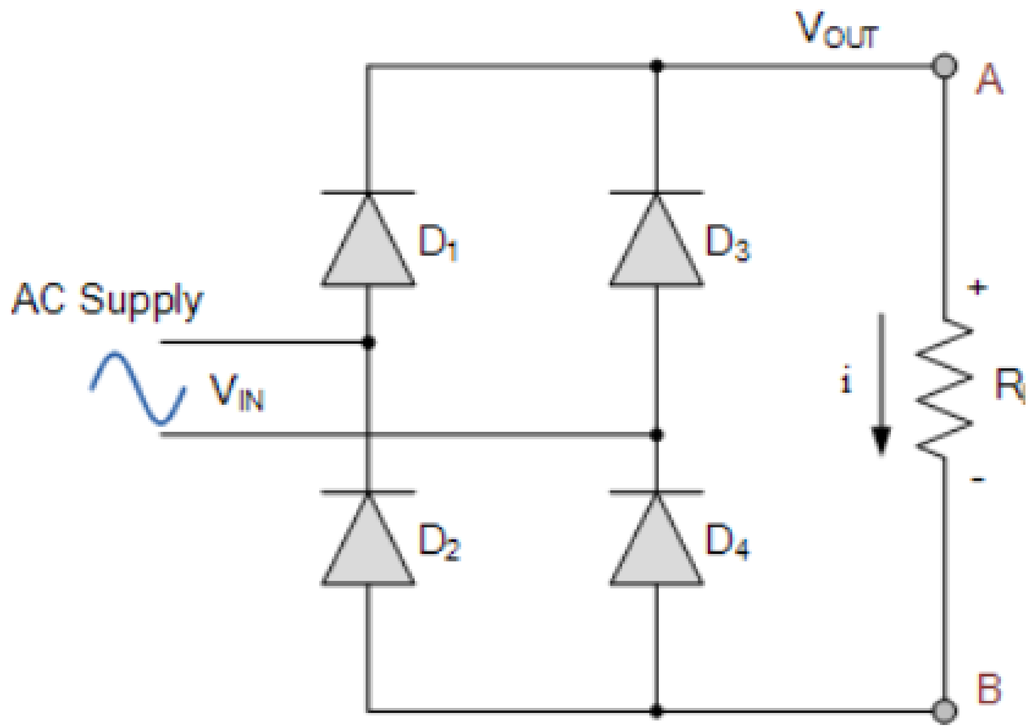
$$I_L = V_{DC} \div R_L = 22.5/150 = 0.15\text{A or } 150\text{mA}$$

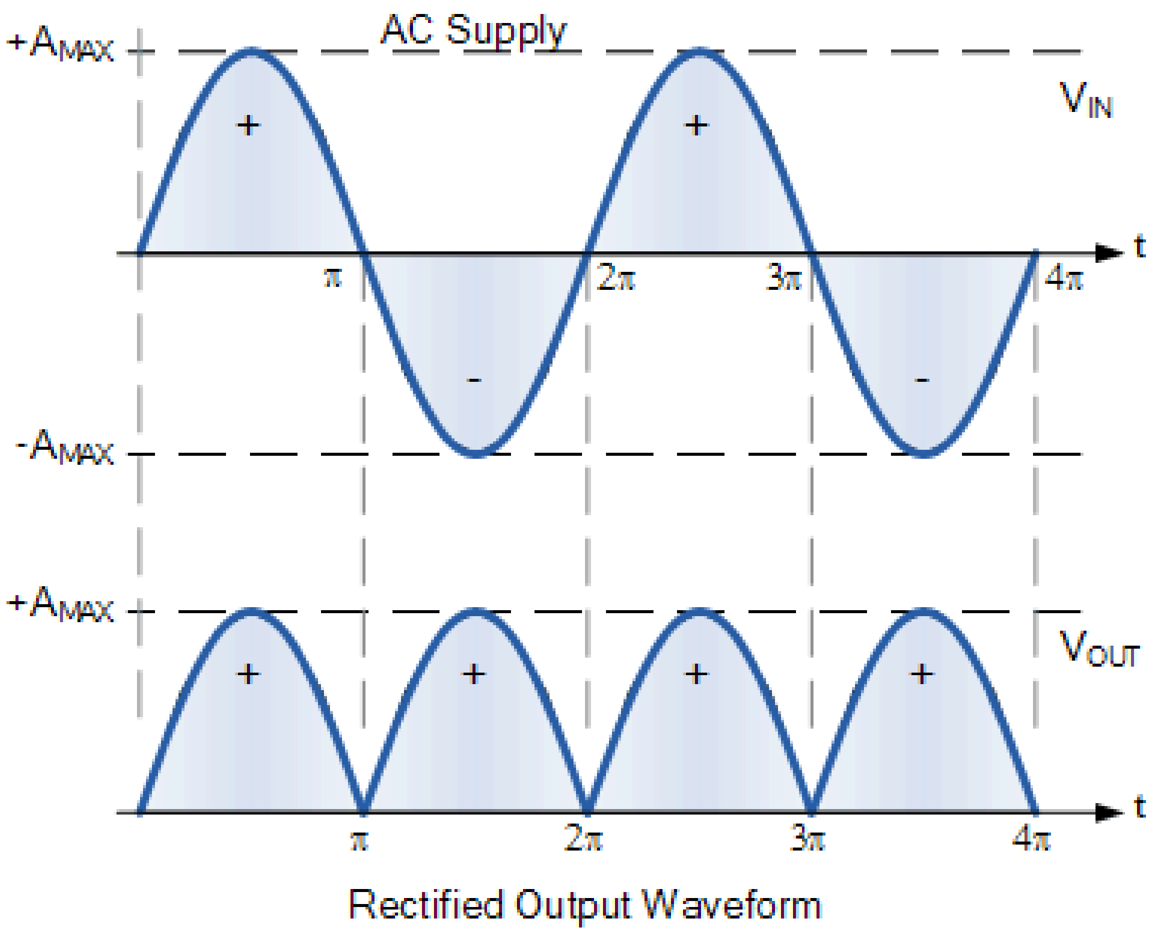
d) Power Dissipated by the Load, P_L

$$P_L = V * I \text{ or } I^2 * R_L = 22.5 * 0.15 = 3.375\text{W} \cong 3.4\text{W}$$

In practice, V_{DC} would be slightly less due to the forward biased 0.7 volt voltage drop

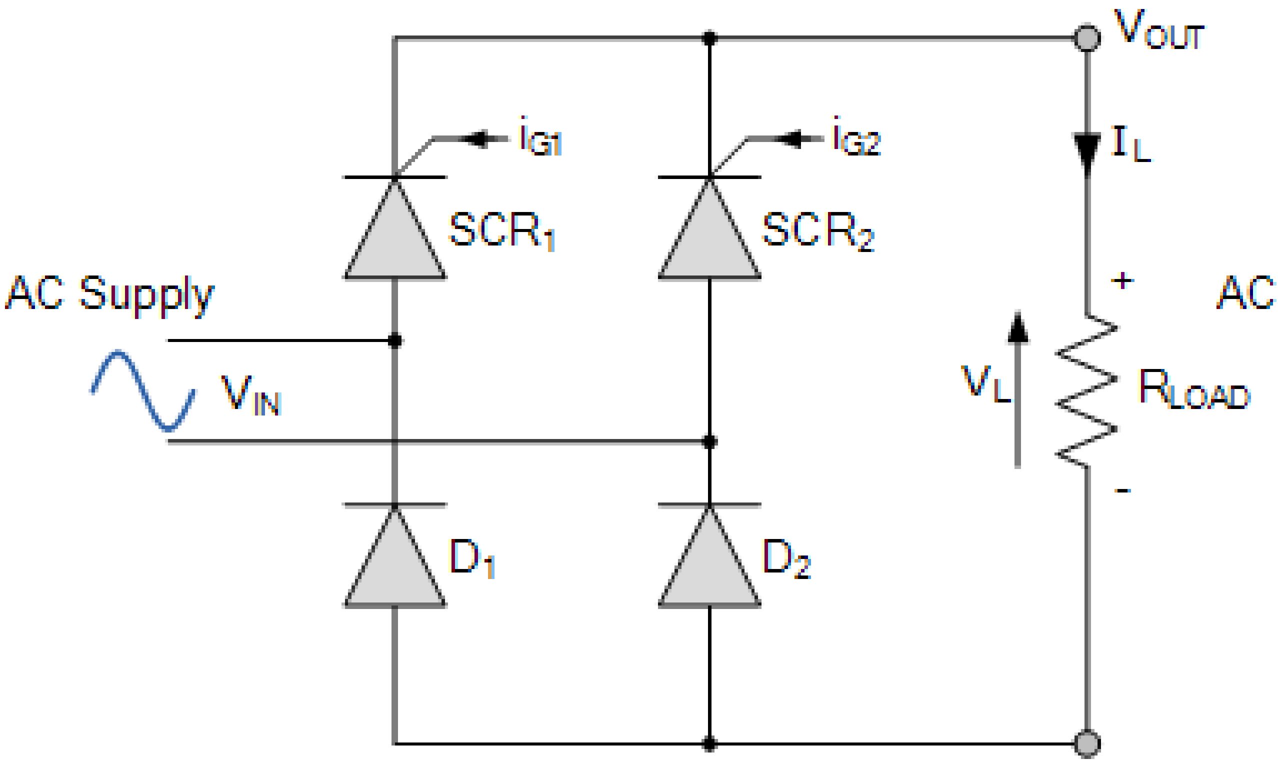
Full-Wave Single-Phase Rectifier



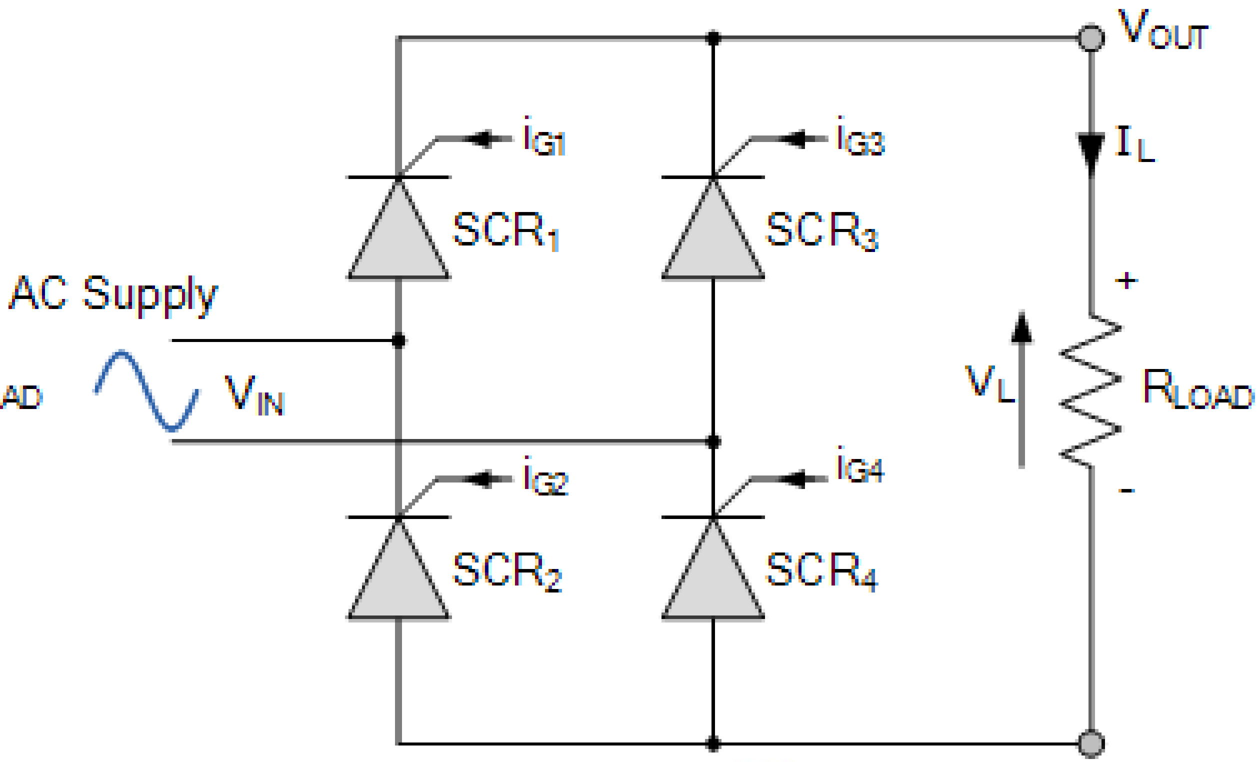


$$A_{AVE} = \frac{2 \times A_{MAX}}{\pi} = \frac{2}{\pi} A_{MAX} = 0.637 A_{MAX}$$

Half- and Full-Controlled Single-Phase Bridge Rectifier

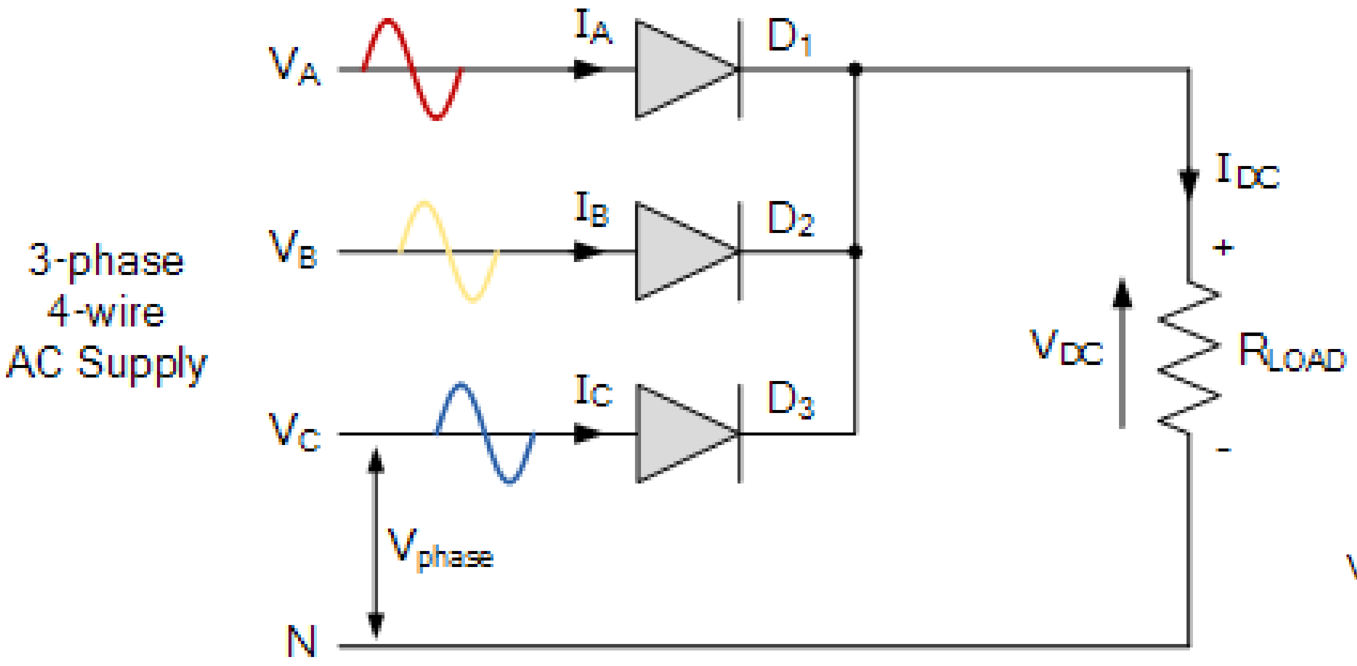


$$V_{AVE} = \frac{V_{MAX}}{\pi} \times (1 + \cos\alpha)$$

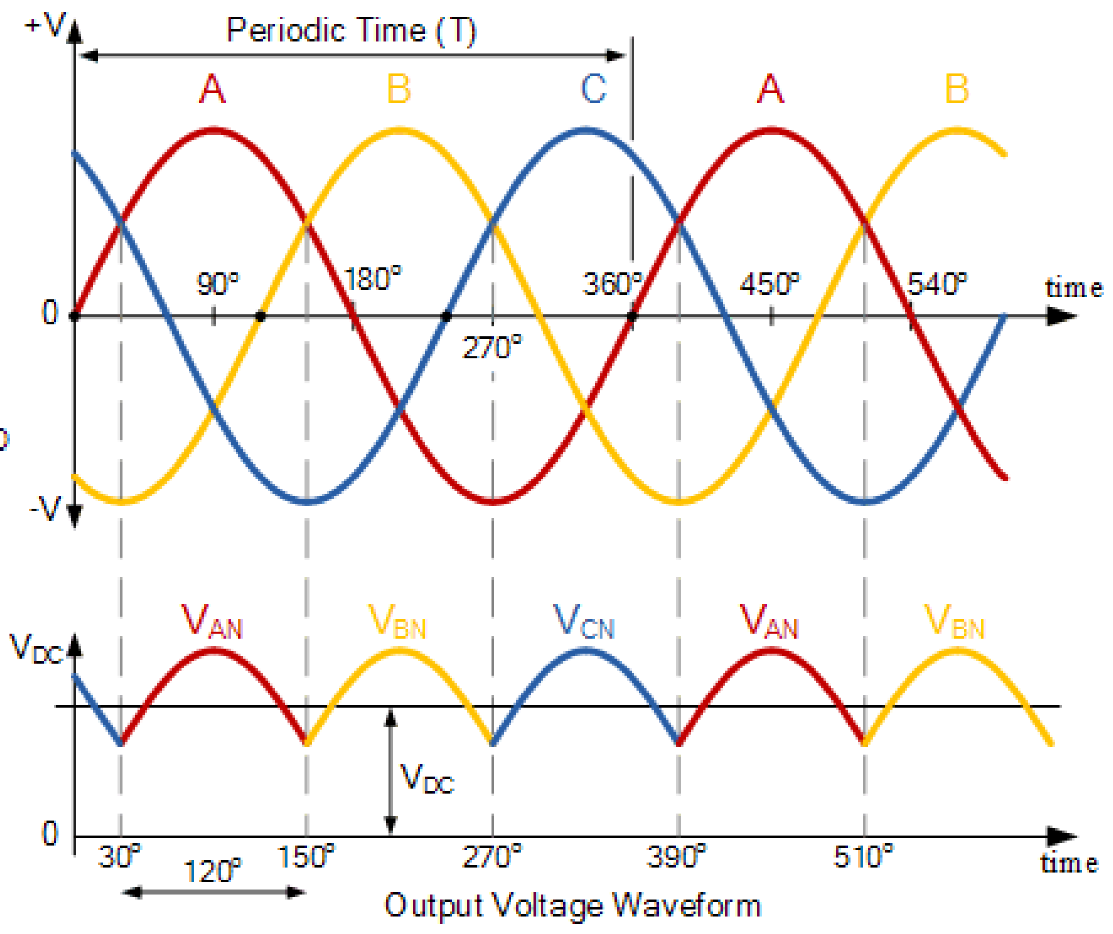


$$V_{AVE} = \frac{V_{MAX}}{\pi} \times \cos(\alpha)$$

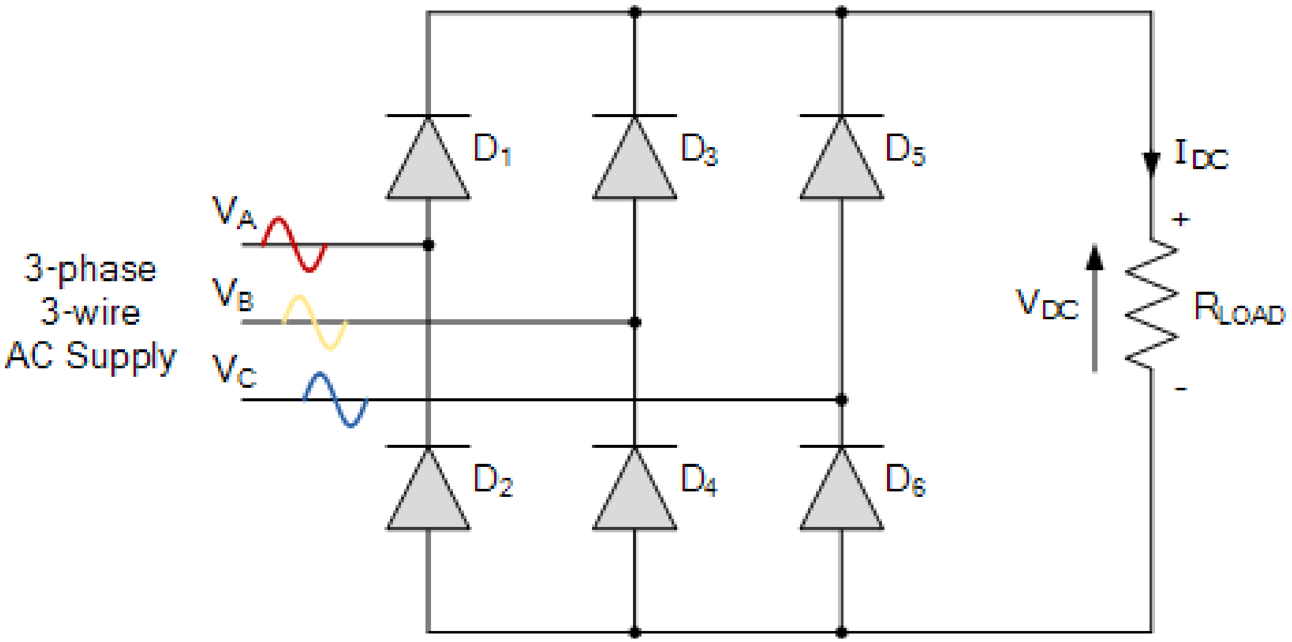
Half-Wave Three-Phase Rectifier



$$V_{DC} = \frac{3\sqrt{3}}{2\pi} V_P = 0.827 * V_{PEAK}$$

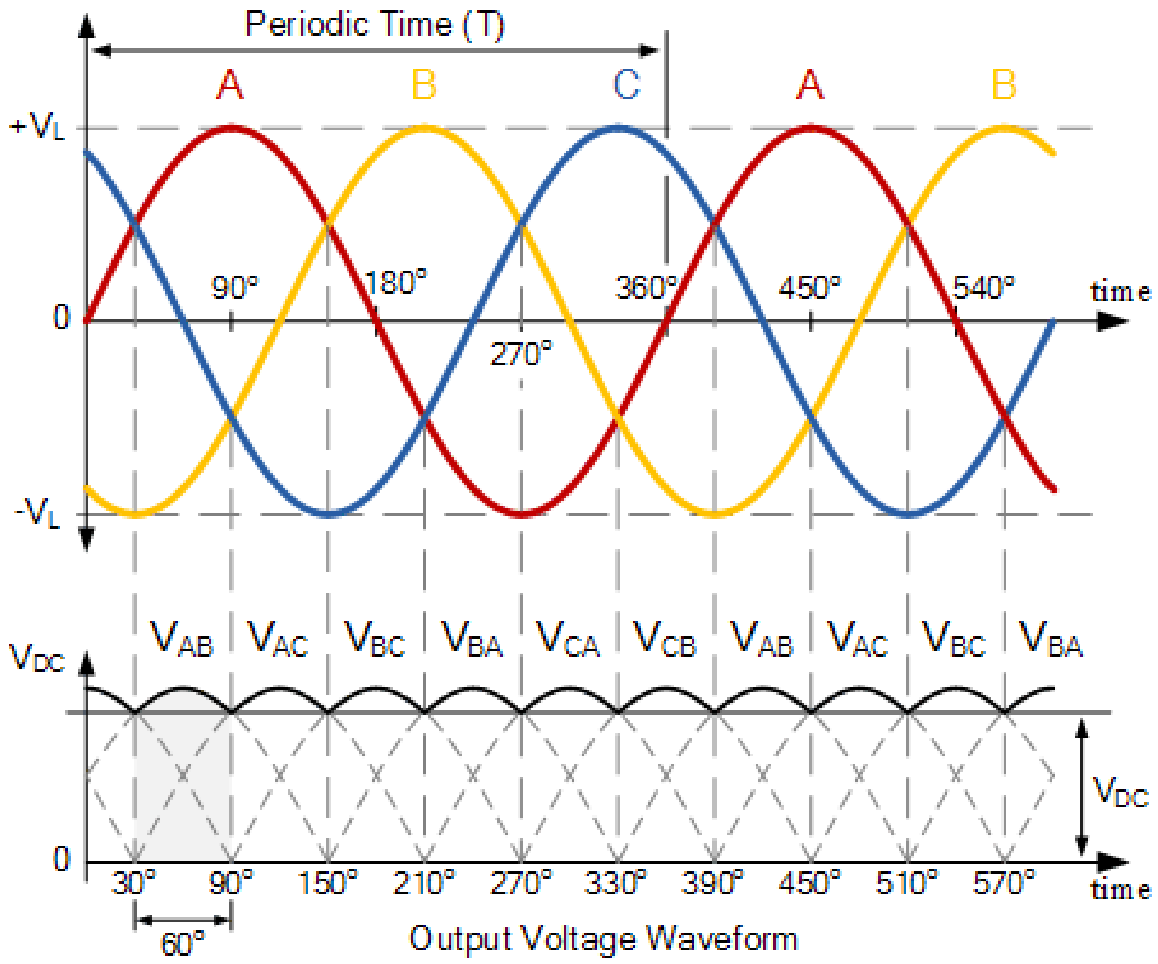


Full-Wave Three-Phase Rectifier

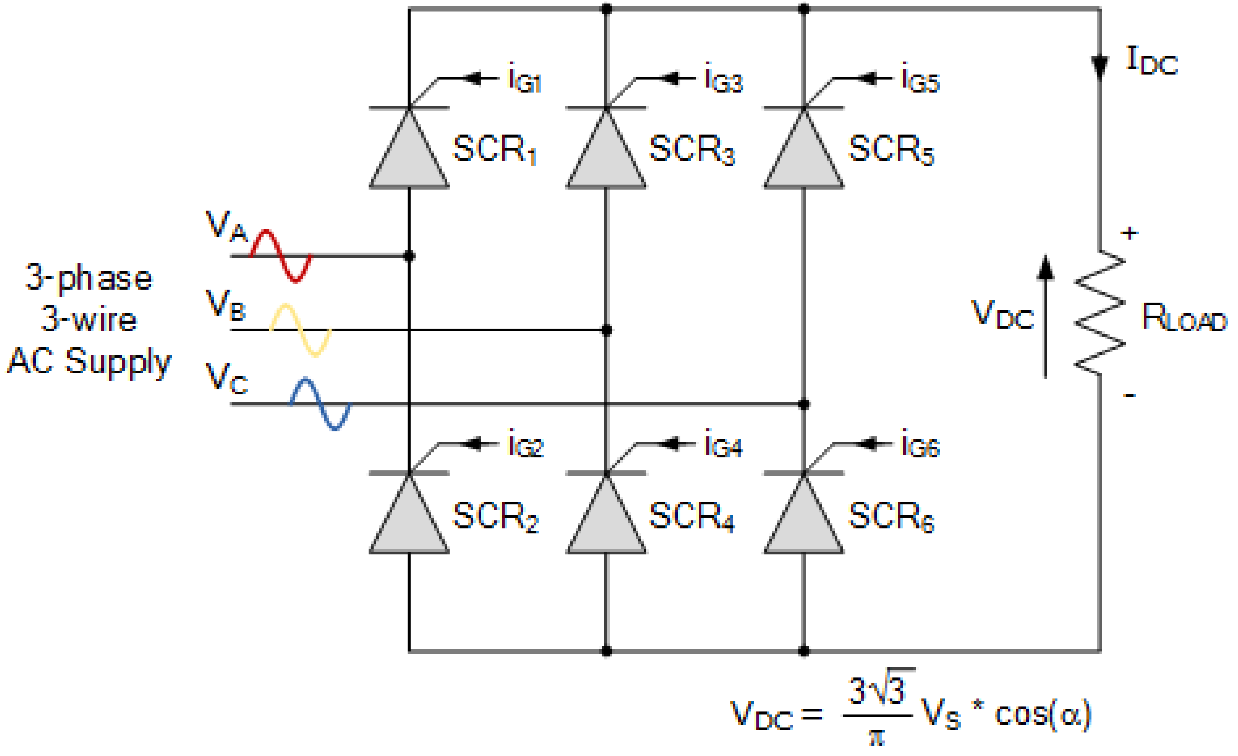


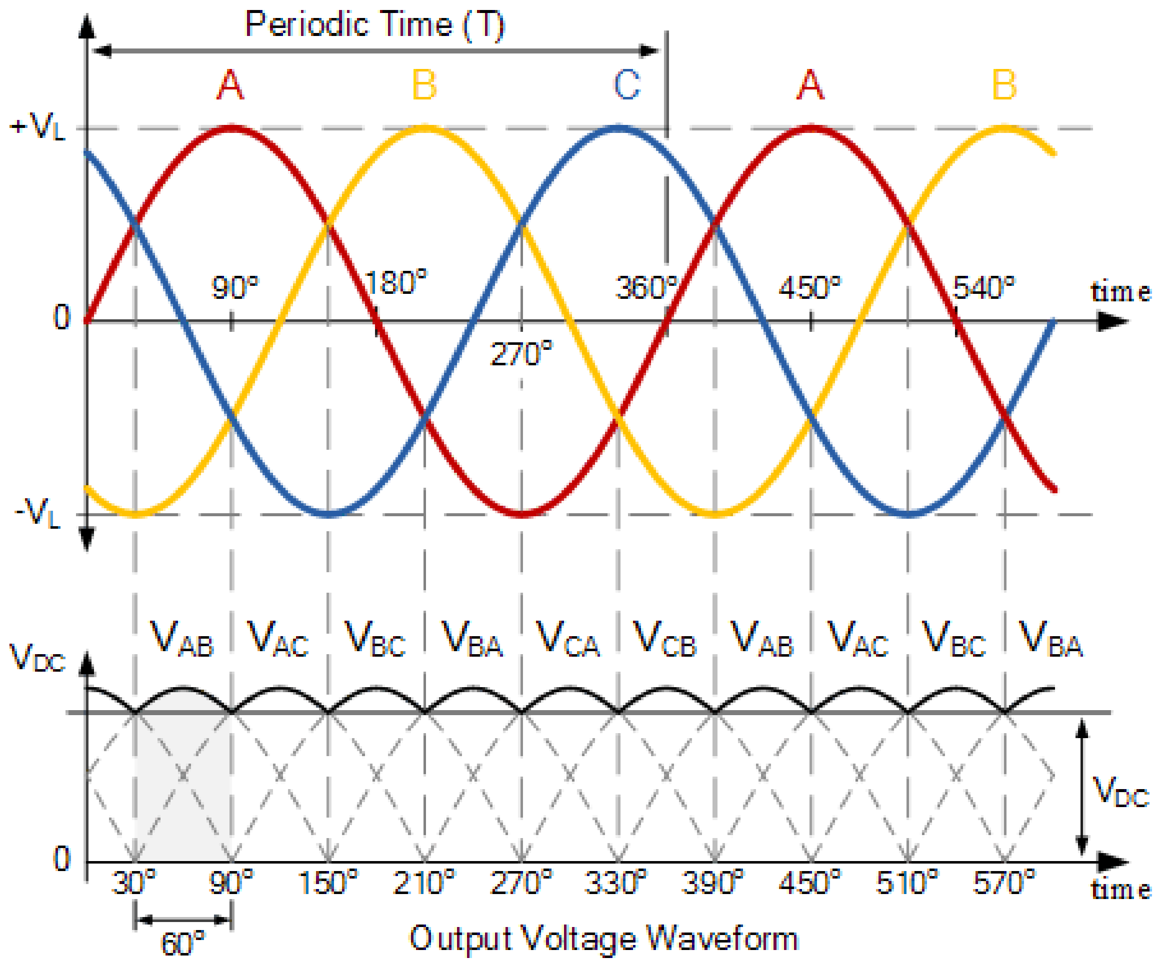
$$V_{DC} = \frac{3\sqrt{3}}{\pi} V_S = 1.65 * V_S$$

Where: V_S is equal to ($V_{L(PEAK)} \div \sqrt{3}$) and $V_{L(PEAK)}$ is the maximum line-to-line voltage (V_L*1.414).



Fully-Controlled Three-Phase Bridge Rectifier





Thanks for listening ☺

YALÇIN İŞLER

Assoc. Prof.