

## ELEC2208 Power Electronics and Drives

# Phase-Controlled Thyristor Converter

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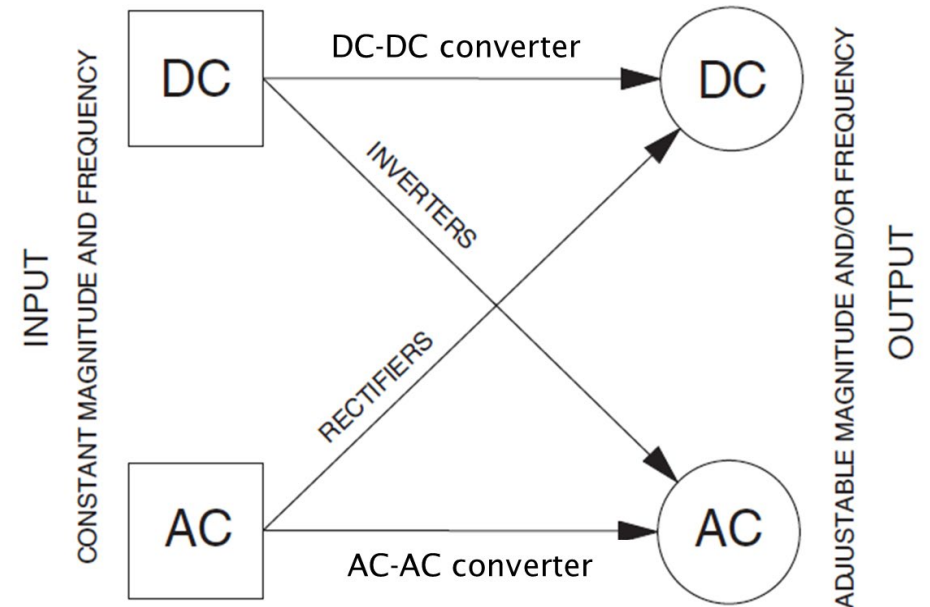
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# Classification

- Phase-Controlled Thyristor Converter

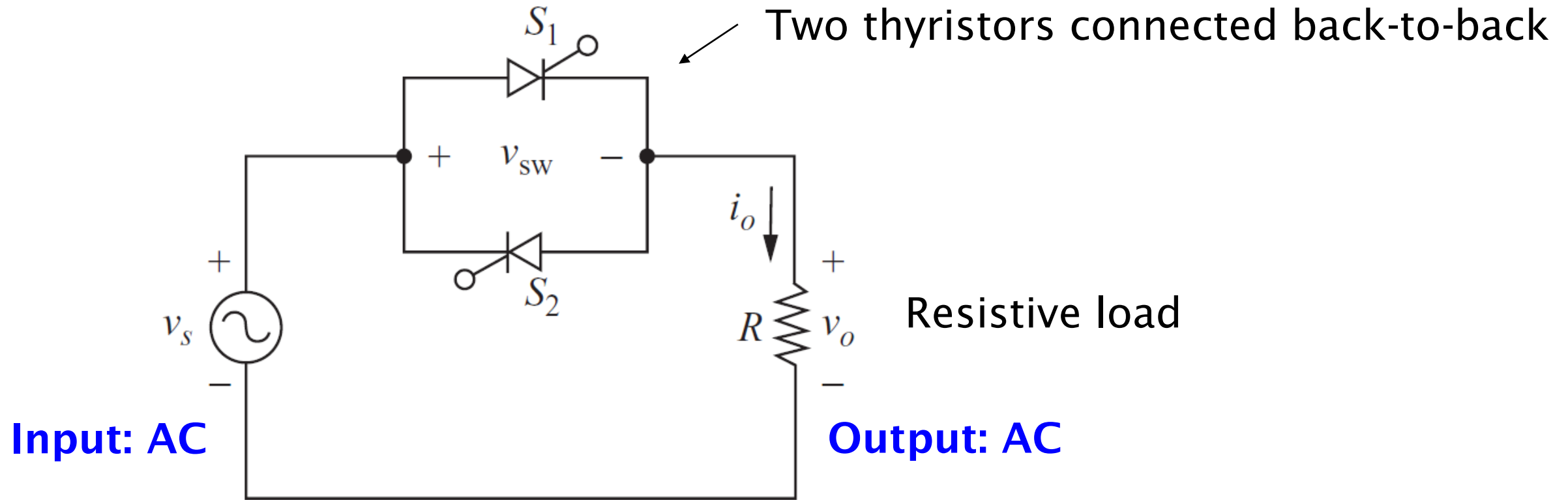
**AC-AC, Voltage**

- Rectifier **AC-DC**
- Cycloconverter **AC-AC, Frequency**
- Inverter **DC-AC**
- DC-to-DC Converter **DC-DC**

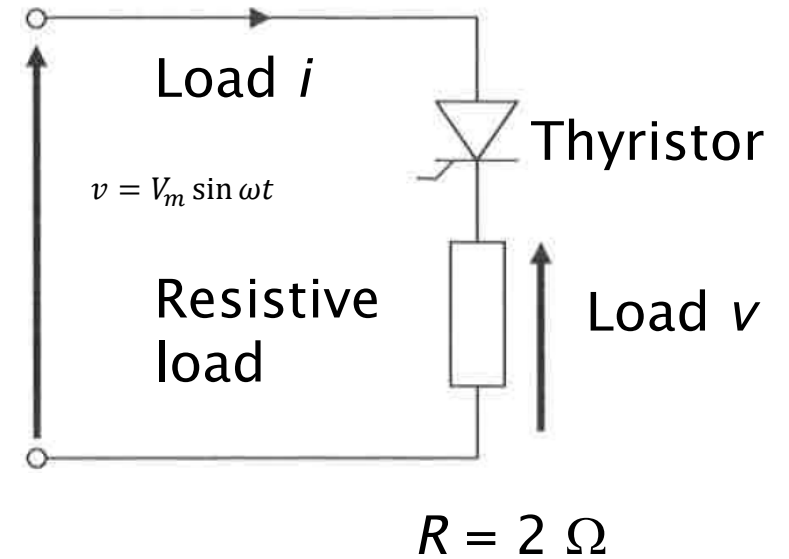
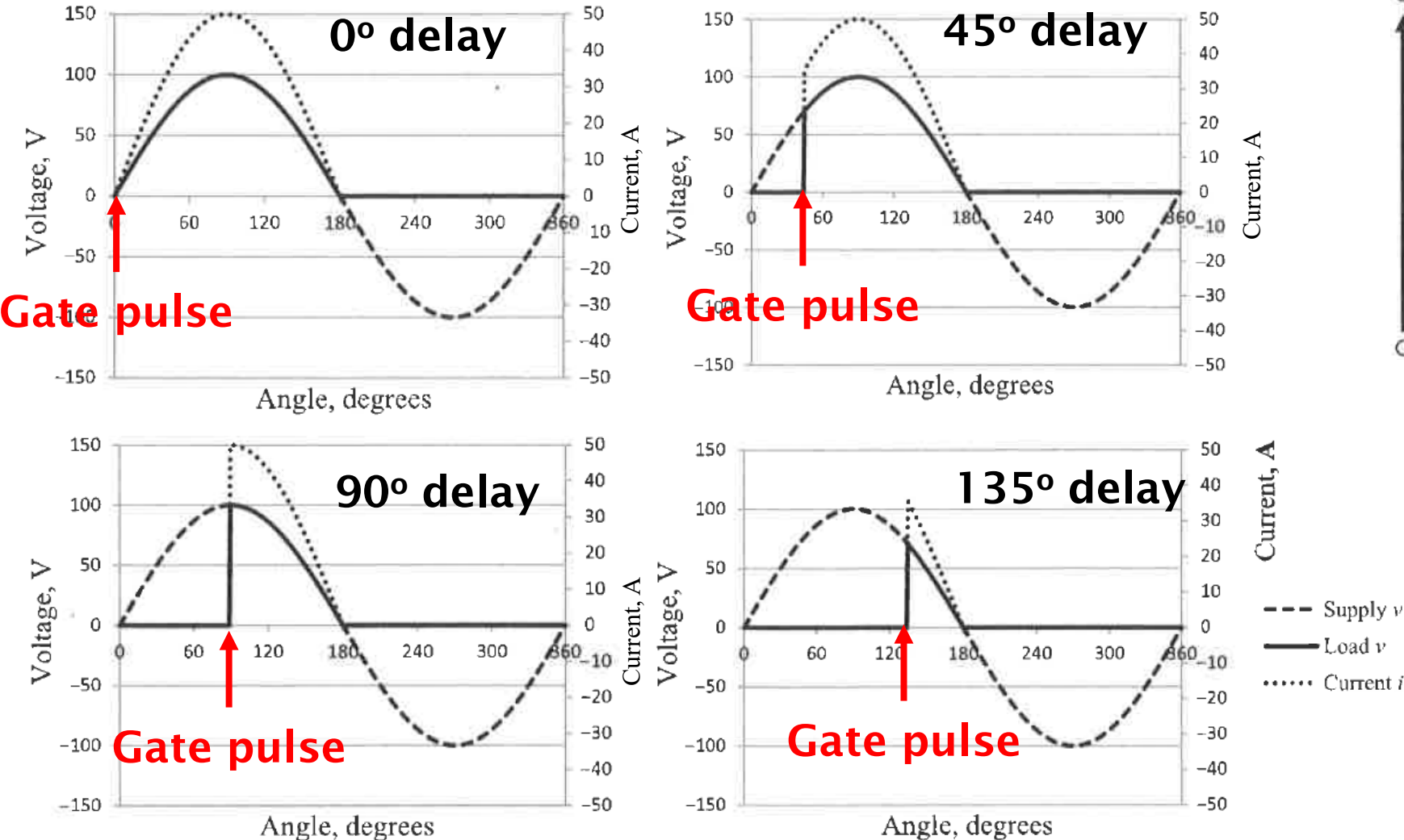


# Phase Controlled AC Thyristor Converter

Single-phase AC voltage controller

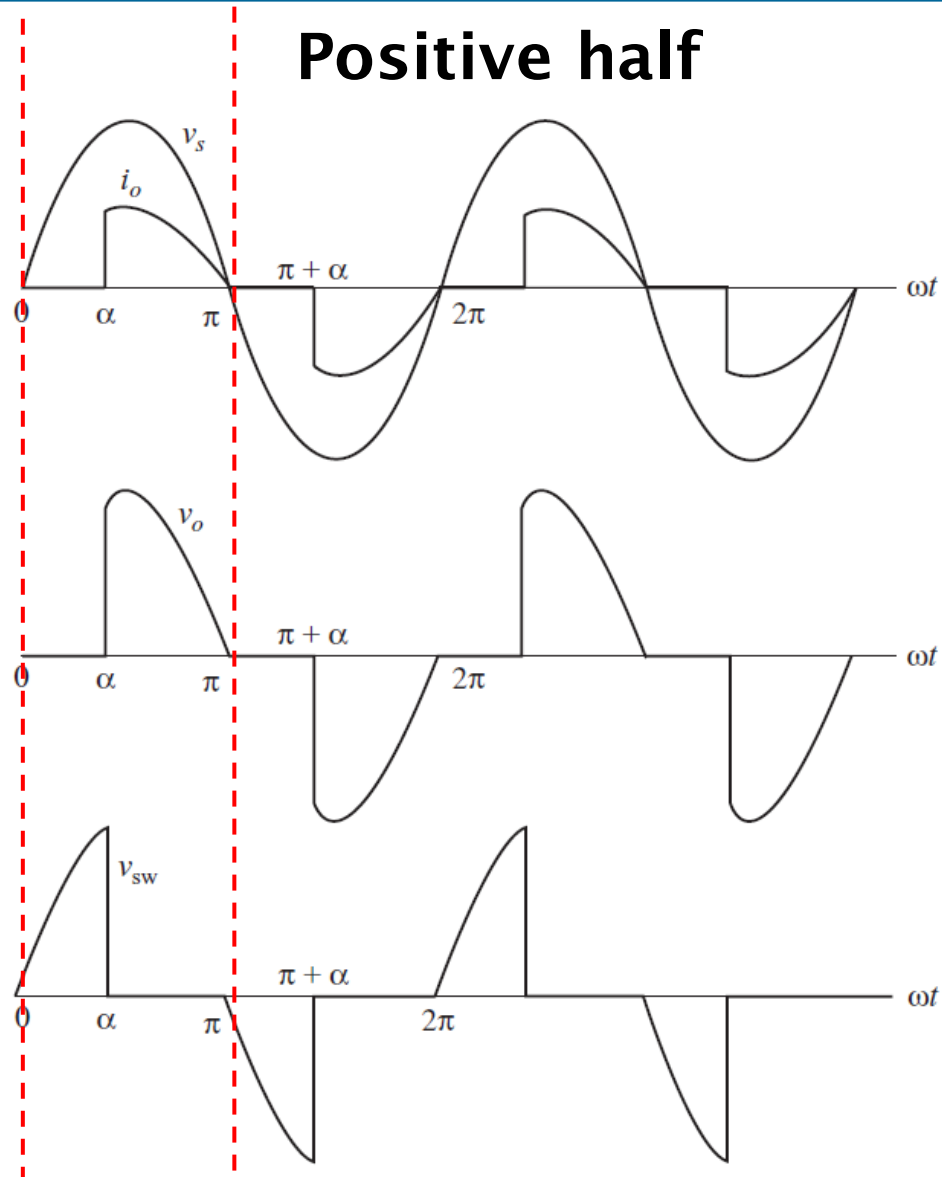


# Revision – Phase control in Thyristor

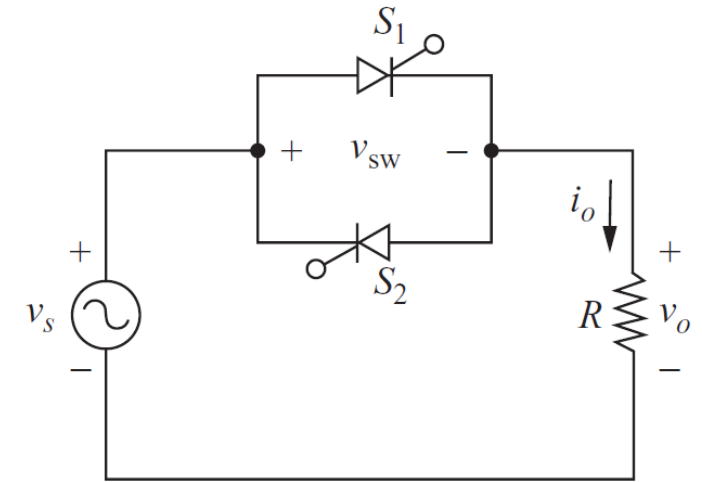


- Voltage adjusted

# AC voltage controller - Waveforms



$\alpha$ : Delay angle  
or Firing angle

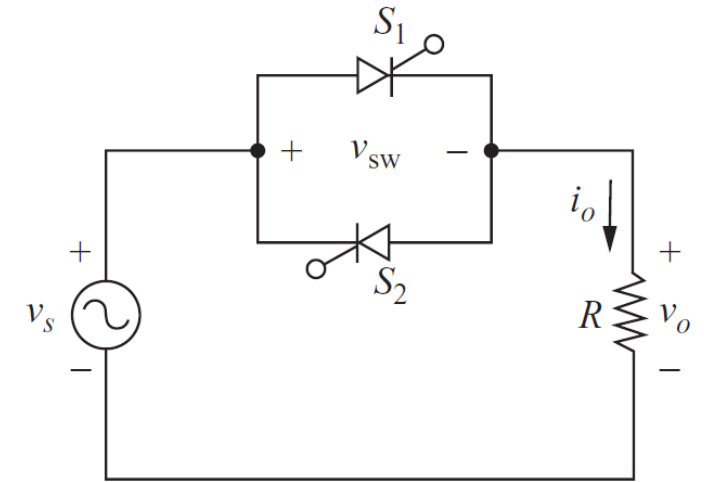
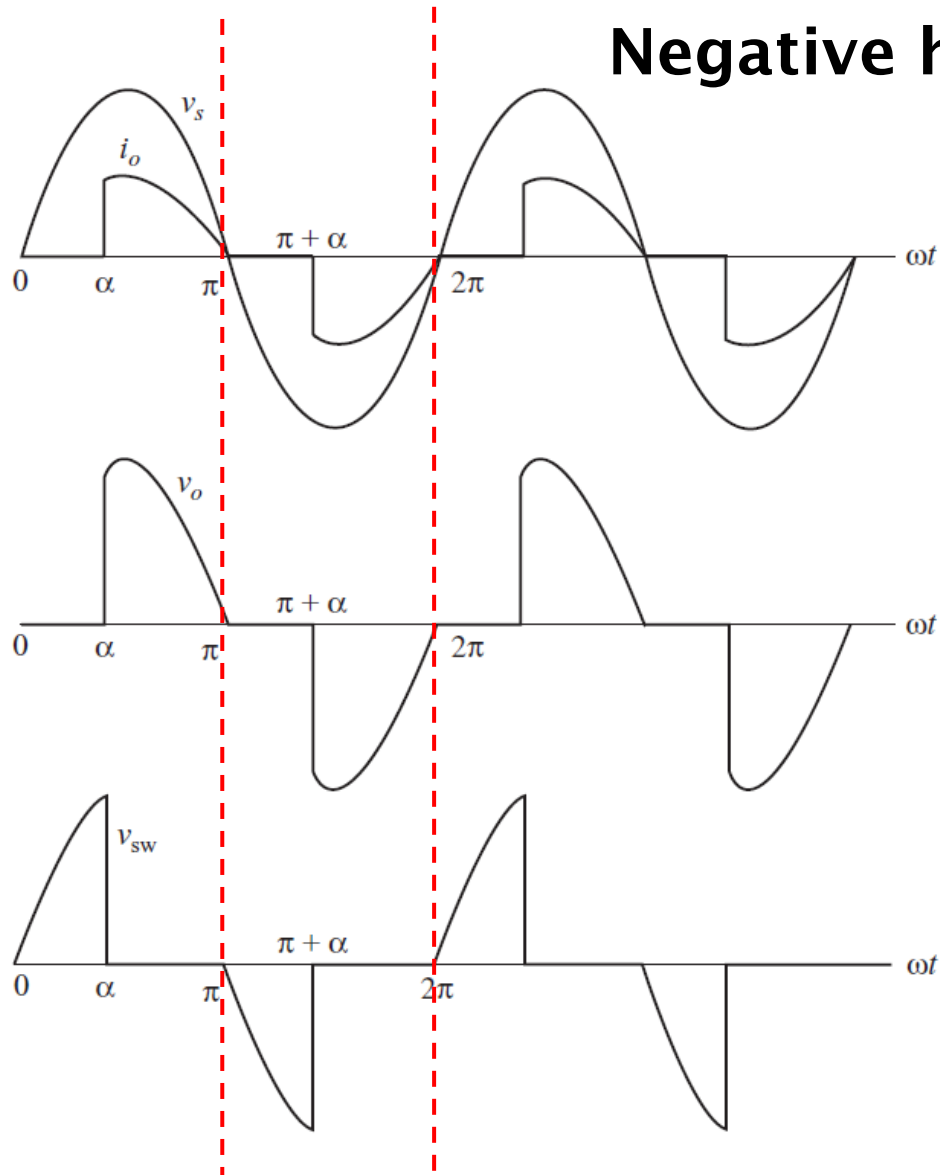


- In positive half cycle,  $S_1$  is forward biased.
- It starts conducting at firing angle  $\alpha$  after being triggered.
- $S_1$  is reverse biased and turns off naturally at  $\pi$  due to the load current falls below holding value.

# AC voltage controller - Waveforms

Negative half

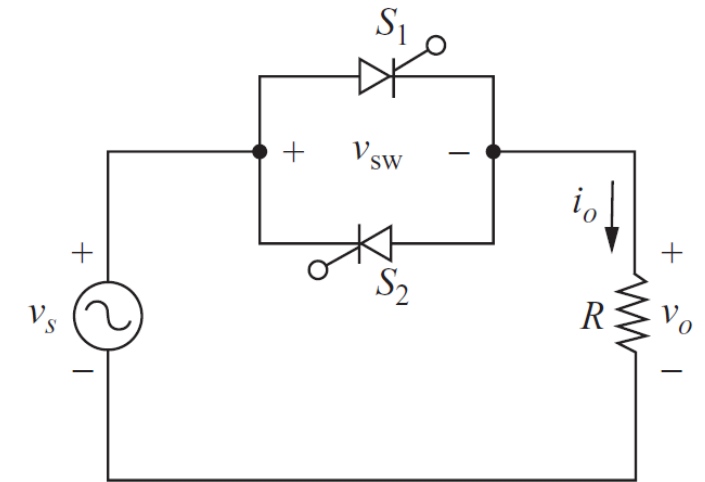
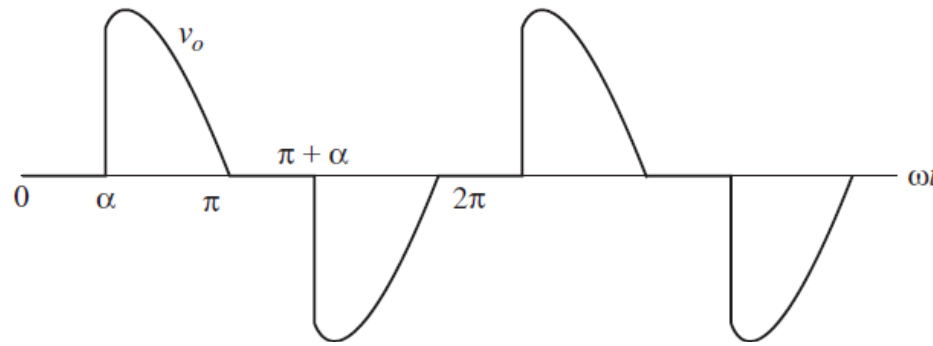
$\alpha$ : Delay angle  
or Firing angle



- In negative half cycle,  $S_2$  is forward biased.
- It starts conducting at  $\pi + \alpha$  after being triggered.
- $S_2$  is reverse biased turns off naturally at  $2\pi$  due to the load current falls below holding value.

# Output voltage calculation

$v_o$  wave form



$$v_s = V_m \sin \omega t$$

Resistive load

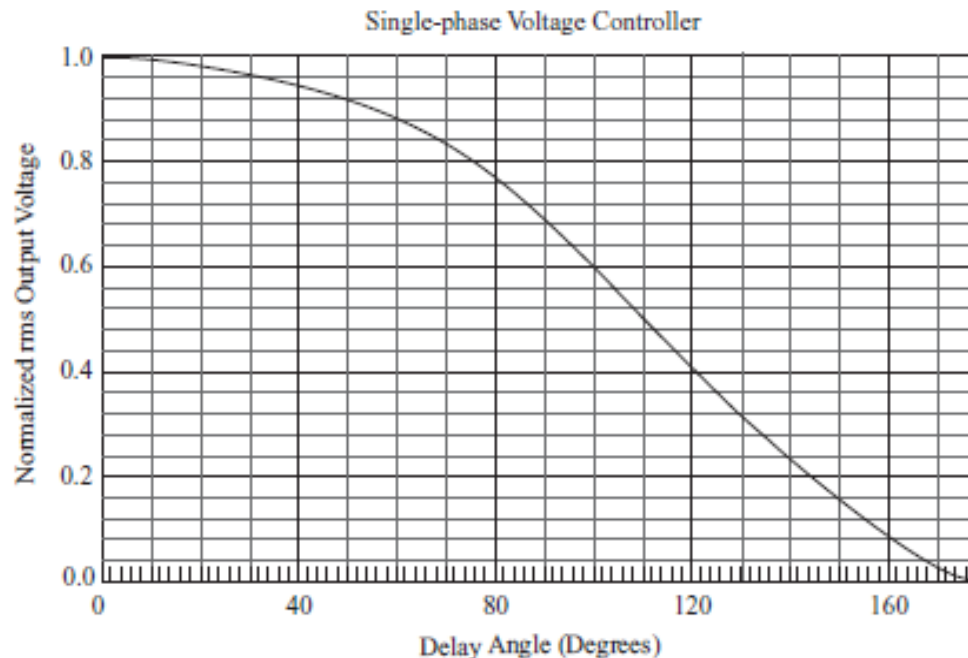
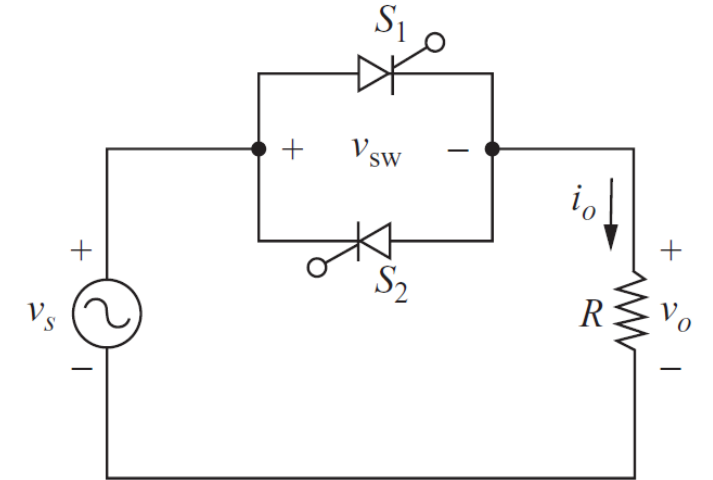
Thanks to positive and negative symmetry, the RMS load voltage is calculated from a half period.

$$\begin{aligned} V_{o,rms} &= \sqrt{\frac{1}{\pi} \int_{\alpha}^{\pi} [V_m \sin(\omega t)]^2 d(\omega t)} = \sqrt{\frac{V_m^2}{\pi} \int_{\alpha}^{\pi} \frac{1 - \cos 2\theta}{2} d\theta} = \sqrt{\frac{V_m^2}{2\pi} \int_{\alpha}^{\pi} (1 - \cos 2\theta) d\theta} \\ &= \sqrt{\frac{V_m^2}{2\pi} \left[ \theta - \frac{\sin 2\theta}{2} \right]_{\alpha}^{\pi}} = \sqrt{\frac{V_m^2}{2\pi} \left( \pi - \frac{\sin 2\pi}{2} - \alpha + \frac{\sin 2\alpha}{2} \right)} = \frac{V_m}{\sqrt{2}} \sqrt{1 - \frac{\alpha}{\pi} + \frac{\sin 2\alpha}{2\pi}} \end{aligned}$$

# Output voltage vs Phase

RMS load voltage

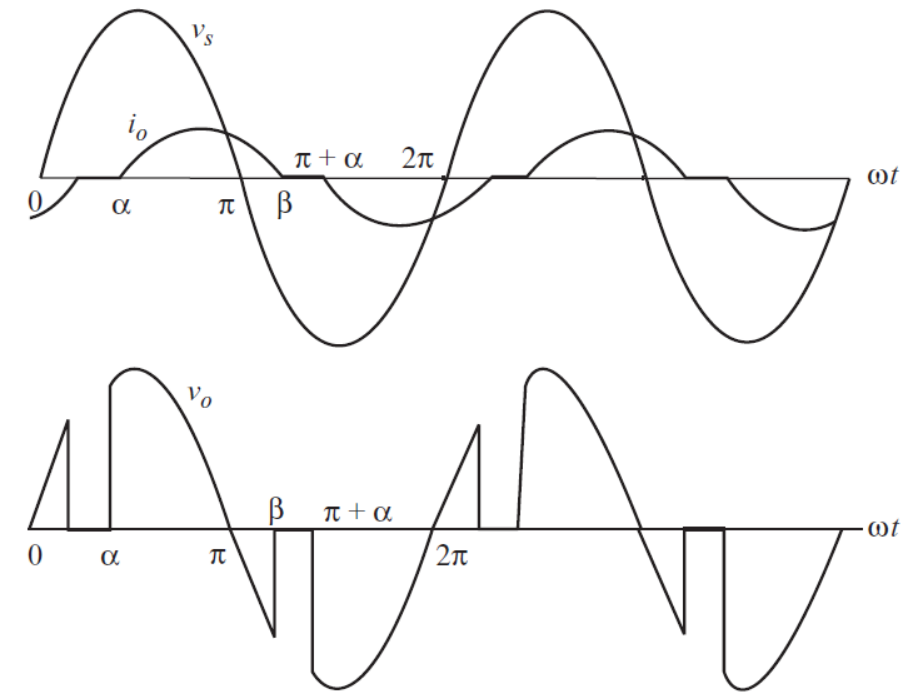
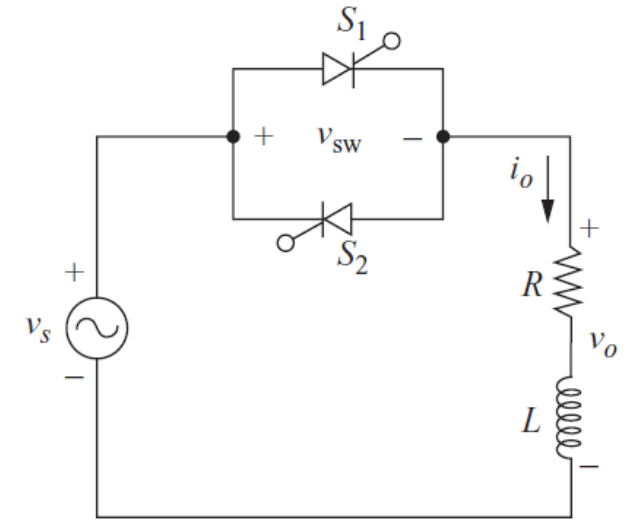
$$V_{o,rms} = \frac{V_m}{\sqrt{2}} \sqrt{1 - \frac{\alpha}{\pi} + \frac{\sin(2\alpha)}{2\pi}}$$



- For  $\alpha = 0$ ,  $V_{o,rms} = \frac{V_m}{\sqrt{2}}$
- Output voltage can be controlled with delay angle.
- Output voltage decreases with increasing delay angle

# Inductive load

- The rms of output voltage can be regulated by controlling the firing angle.
- The firing angle for both half cycles should be equal to avoid the presence of dc component at the load.
- For inductive load, the current will take time to rise and fall to zero.



# Summary – AC voltage controller

- AC-AC voltage controller consists of two thyristors connected back-to-back.
- Output voltage is controlled by the delay angle of the thyristors.

$$V_{o,rms} = \frac{V_m}{\sqrt{2}} \sqrt{1 - \frac{\alpha}{\pi} + \frac{\sin(2\alpha)}{2\pi}}$$

