Sinusoidal Pulse Width Modulation

Capstone II Technical Presentation

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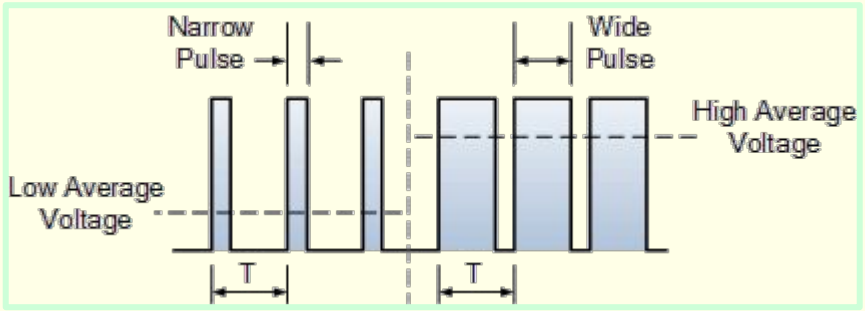
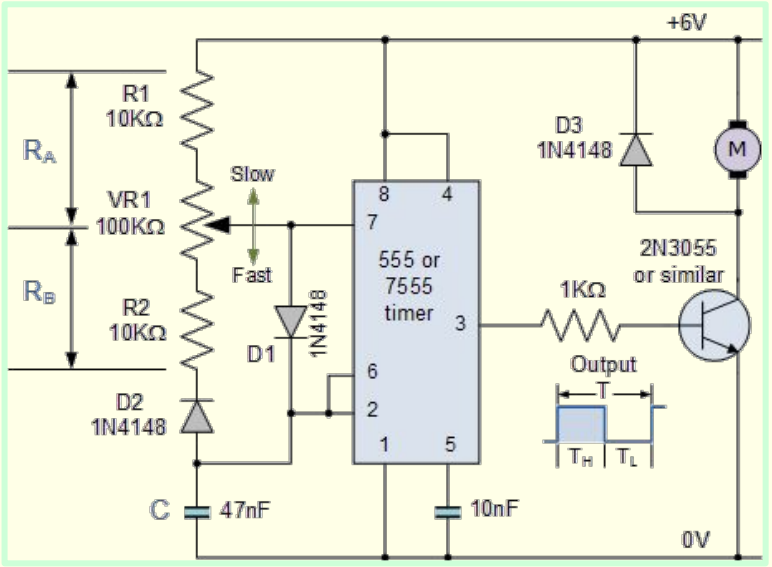
Traditional Pulse Width Modulation

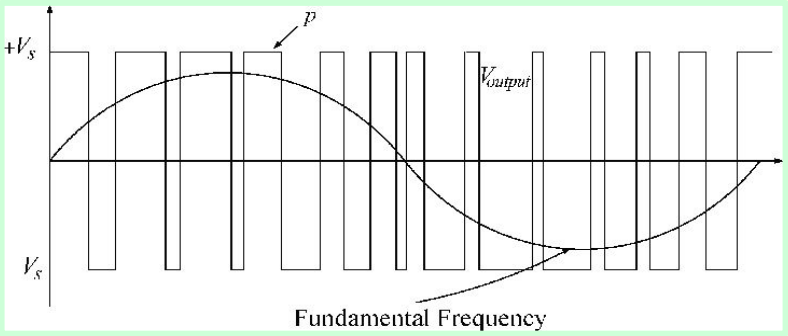
- A square wave is formed from quick switching of a transistor
- Controls speed based on the duty cycle
- Useful in hardware and software implementations

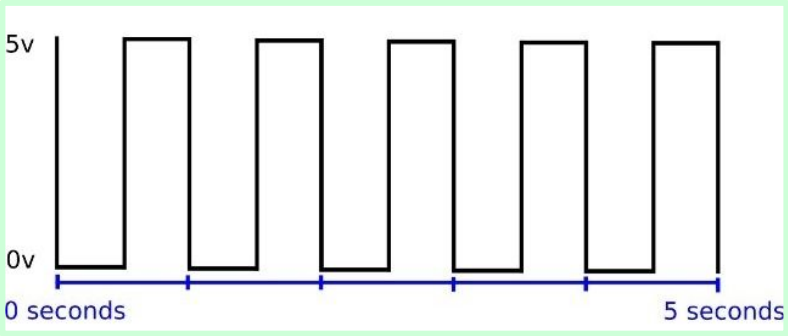




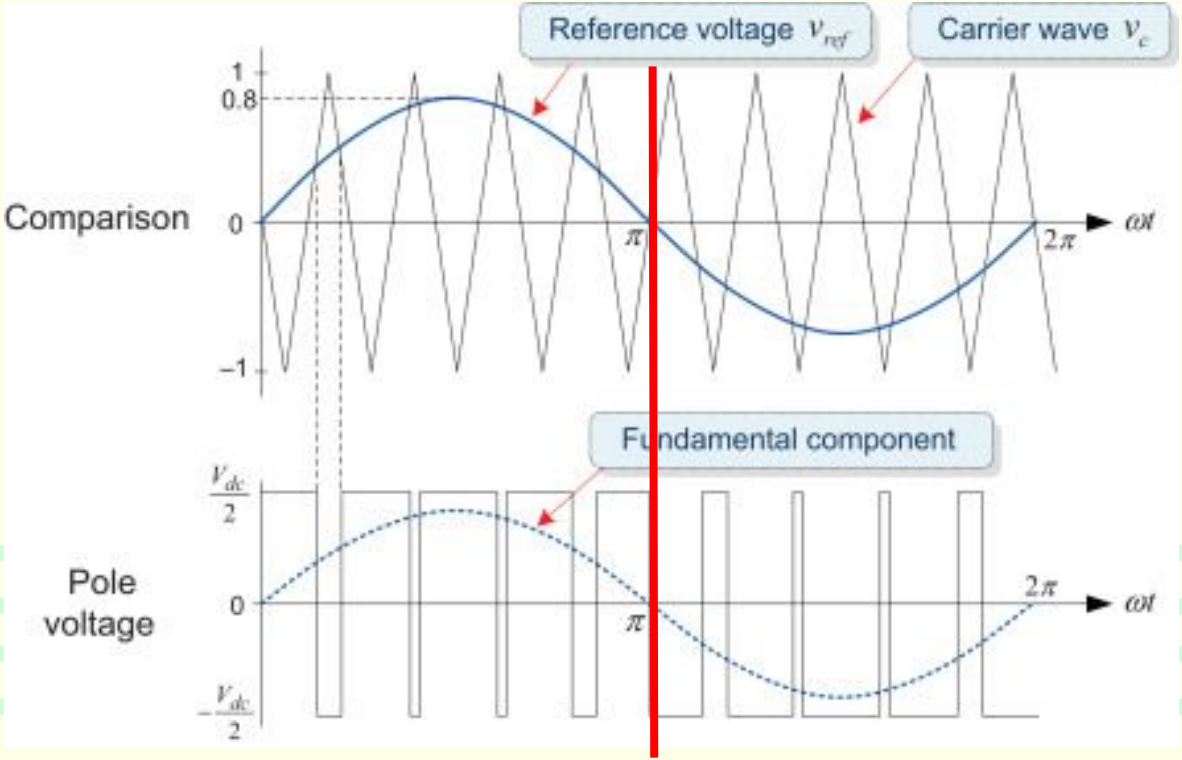
Sinusoidal PWM vs Traditional PWM

Lower harmonic distortion	Simplicity and efficiency
Smoothing effect	Faster switching frequencies
More ideal in hardware	Flexibility in control

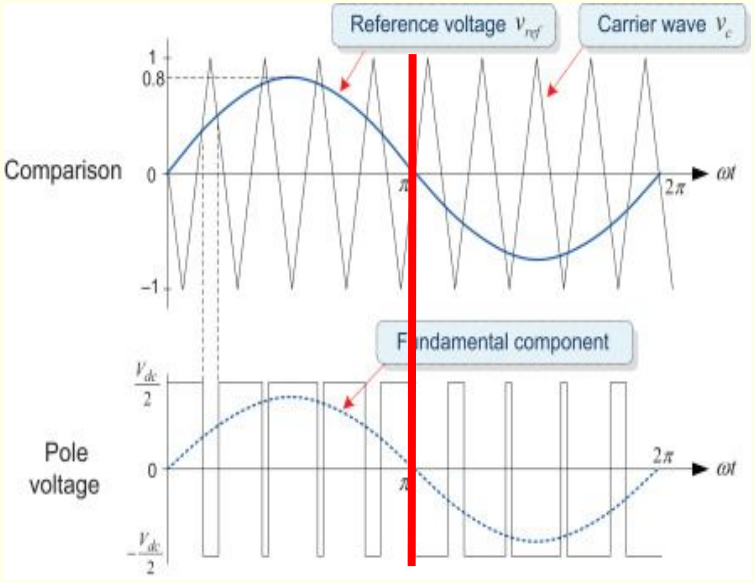


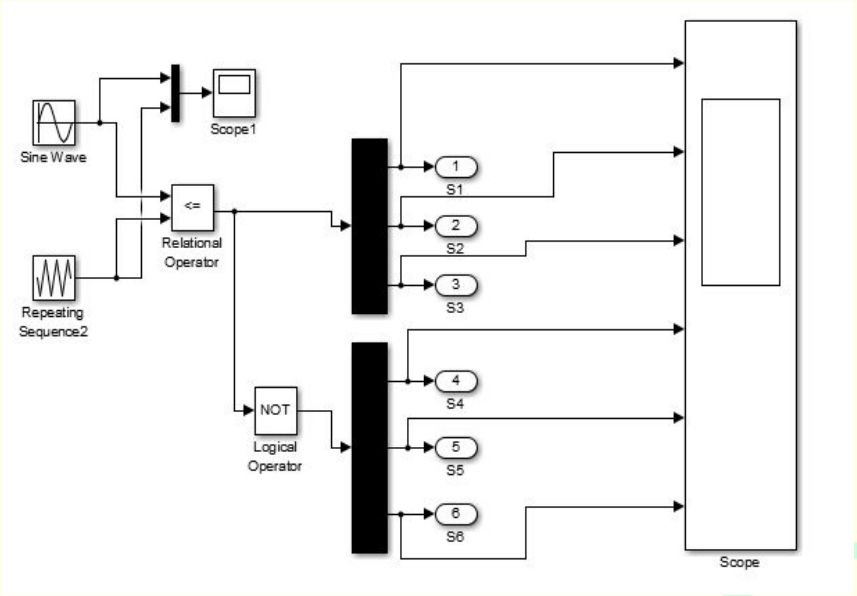


What is sinusoidal pulse width modulation?



The Circuitry





When $v_{ref} > v_c$, the pole voltage is high.
When $v_{ref} < v_c$, the pole voltage is low.

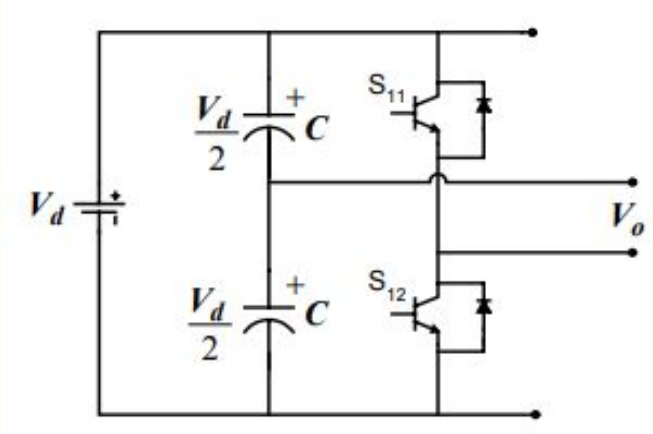
The Math Behind It

Modulation Index (m_i): $\frac{V_{ref}}{V_{c,\,peak}}$

The output (v_o) is the pole voltage from before, and it is the output from the corresponding bridge.

Due to KVL, only S_{11} or S_{12} can be turned on at once.

$$S_{11}+S_{12}=1$$



Half-Bridge PWM Inverter

Modulation Index

Modulation Index (m_i): $\frac{V_{ref}}{V_{c,\,peak}}$

- Defines the duty cycle of the PWM signal

  $D=m_i/(2\pi)$

While the modulation index indicates the influence of the modulating signal on the pulse width, the duty cycle determines the relative duration of the high and low states within one period.

Modulation Index

Modulation Index (m_i): $\frac{V_{ref}}{V_{c,\,peak}}$

m=0 : the modulating signal has no effect on the output

0<m<1 : linear modulation range

m=1 : the modulating signal and output mimic each other

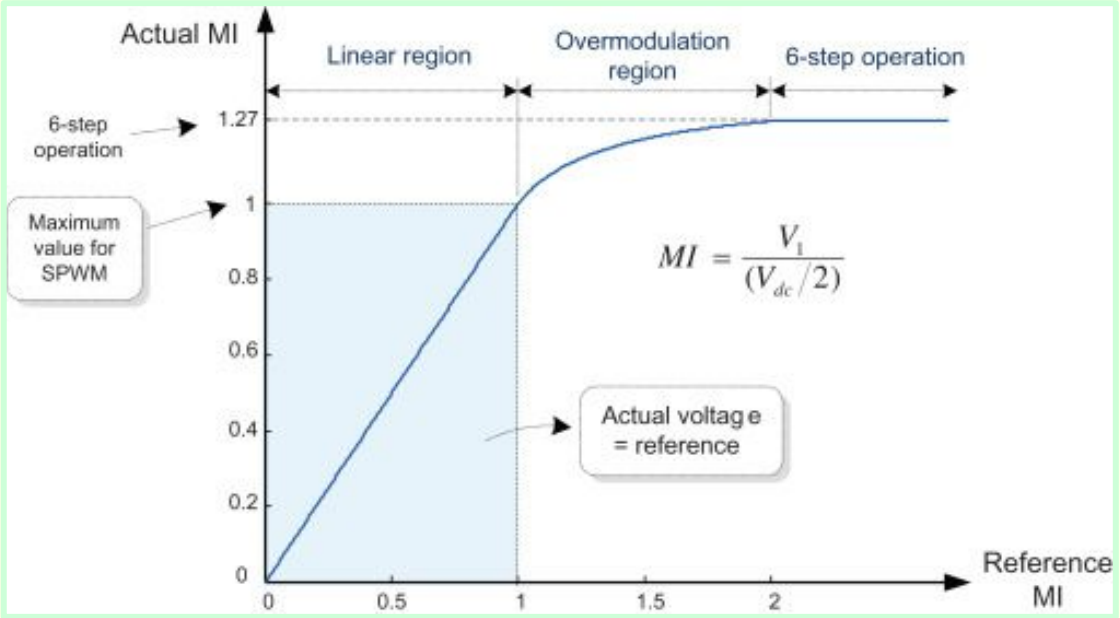
m>1 : leads to distortion and nonlinear behavior

Higher m_i	Lower m_i
Wider pulse widths, more distortion from modulating signal	Restricted pulse widths, resembles the carrier signal
Lower harmonic distortion	Higher harmonic distortion

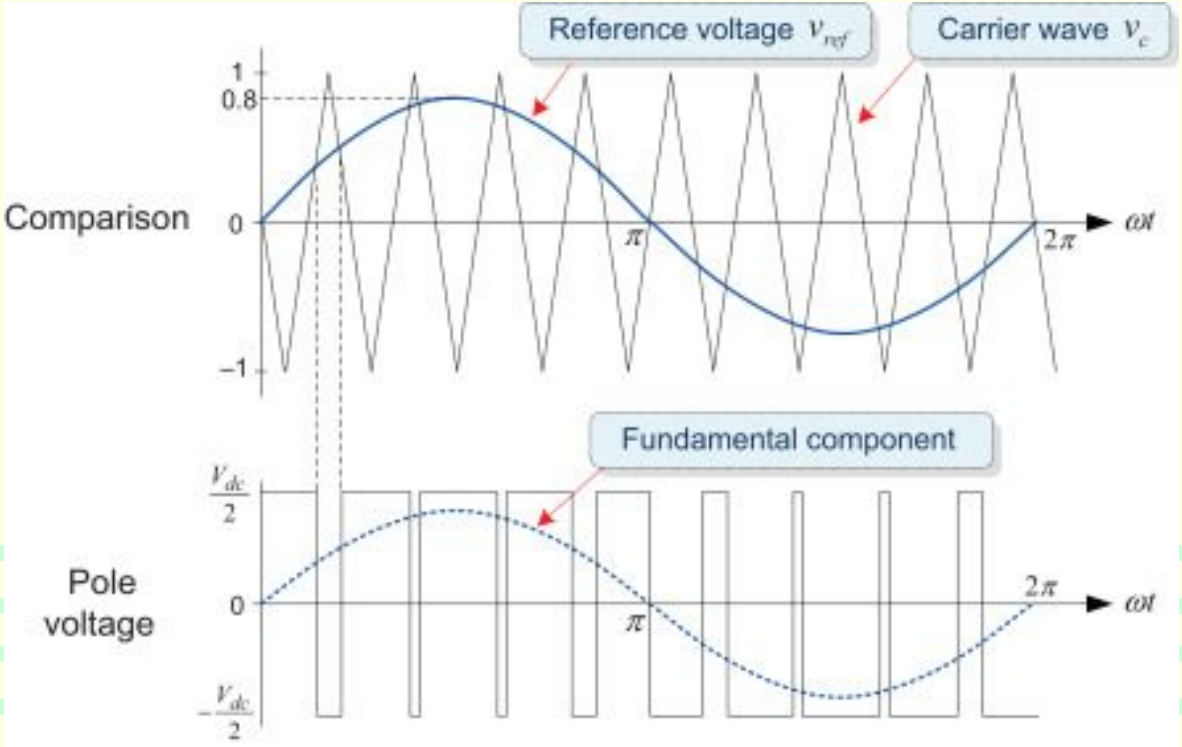
Linear Modulation Range

$0<m_i<1$ is the **linear modulation range**

- the inverter generates an output linearly proportional to the reference voltage
- essentially a voltage amplifier with a unit gain



Conclusion


Reference voltage v_{ref}
Carrier wave v_c
Comparison
1
0.8
0
−1
π
2π
ωt
Fundamental component
$\frac{V_{dc}}{2}$
$-\frac{V_{dc}}{2}$
Pole voltage
0
π
2π
ωt

Citations

[1] W. Storr, “Pulse width modulation used for motor control,” Basic Electronics Tutorials, https://www.electronics-tutorials.ws/blog/pulse-width-modulation.html#:~:text=As%20its%20name%20suggests%2C%20pulse,while%20keeping%20the%20frequency%20constant (accessed Mar. 18, 2024).

[2] Sang-Hoon Kim, “Sinusoidal pulse width modulation,” Sinusoidal Pulse Width Modulation - an overview | ScienceDirect Topics, https://www.sciencedirect.com/topics/engineering/sinusoidal-pulse-width-modulation (accessed Mar. 18, 2024).

[3] Ojo, Chapter 2 single phase pulse width modulated inverters, https://www.tntech.edu/engineering/pdf/cesr/ojo/asuri/Chapter2.pdf (accessed Mar. 18, 2024).

[4] S. Mohammad Irshad & P. G. “High Gain Power Generation Based On Hybrid Renewable Energy for AC Load Application,” Indonesian Journal of Electrical Engineering and Computer Science, https://www.researchgate.net/publication/329467258_High_Gain_Power_Generation_Based_On_Hybrid_Renewable_Energy_for_AC_Load_Application (accessed Mar. 18, 2024).