# PWM ON TIVAC

## TM4C123GH Tiva C Board

Dr. Munesh Singh

Indian Institute of Information Technology Design and Manufacturing
Kancheepuram, Chennai, Tamil Nadu

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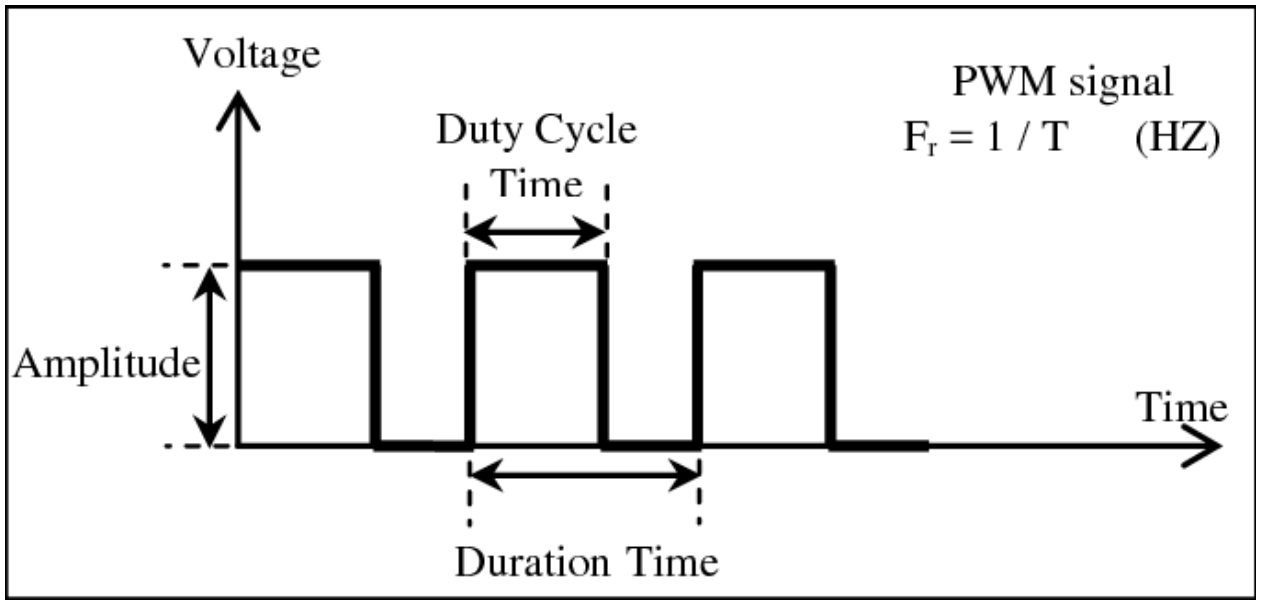
# What is Pulse Width Modulation (PWM)?

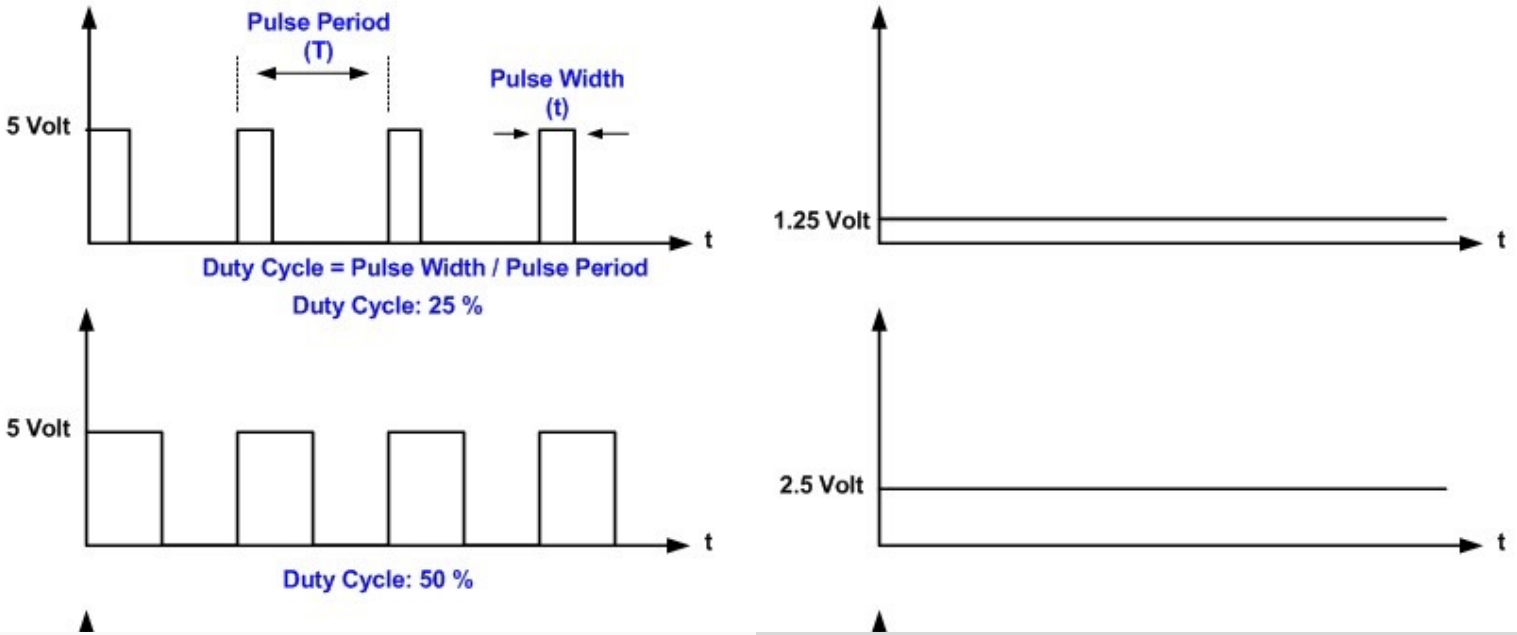
- PWM is a simple method of using a rectangular digital waveform to control an analog variable.
  - The on-off behavior changes the average power of the signal.
  - Output signal alternatives between ON and OFF with a specific time period.
- PWM control is used in a variety of applications, ranging from communications to automatic control.
- It can also be used to encode information for data transmission.

# How it works?

- The period is normally kept constant, and the pulse width (or ON time) is varied.
- Duty Cycle: it is defined as the proportion of time the pulse is ON, expressed as a percentage.
  Duty Cycle = (pulse ON time)/(pulse period)*100%
  $=t_{on}$/T*100%

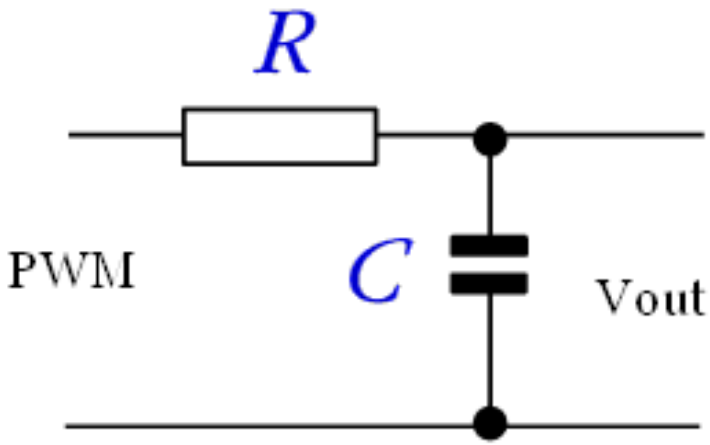


- Whatever duty cycle a PWM has, there is an average value, as indicated by the dooted line.
  - If the ON time is small, the average value is low; if it is large, the average value is high.
  - By controlling the duty cycle, we can control the average value.
- Average value of the signal $= \frac{1}{T}\int_0^T f(t)dt = t_{on} * V_H + (1 - t_{on}) * V_L$
- In general, $V_L$ is taken as 0V for ease of calculation
  - Average value become $t_{on} * V_H$



# How to Extract the Average Value?

- The average value can be extracted from the PWM stream using a low-pass filter.
- If the PWM frequency and the values of R and C are appropriately chosen, $V_{out}$ becomes an analog output.
  - Can be used in place of a digital-to-analog converter

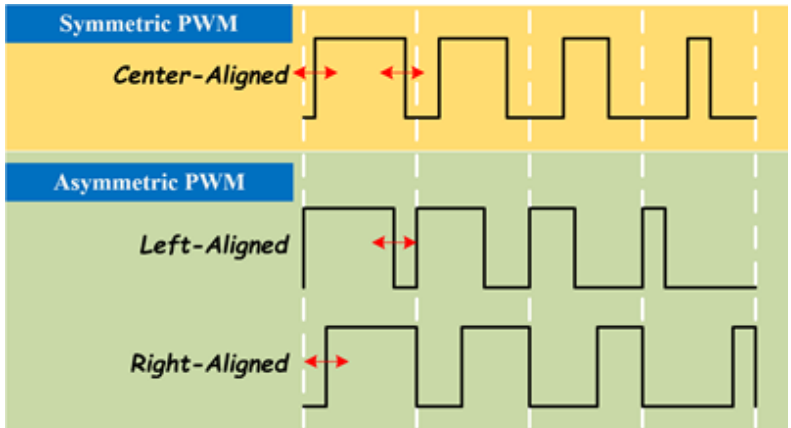



- In practice, the filter is not always required.
- Many physical systems have response characteristics that act like low-pass filters.

# Types of PWM

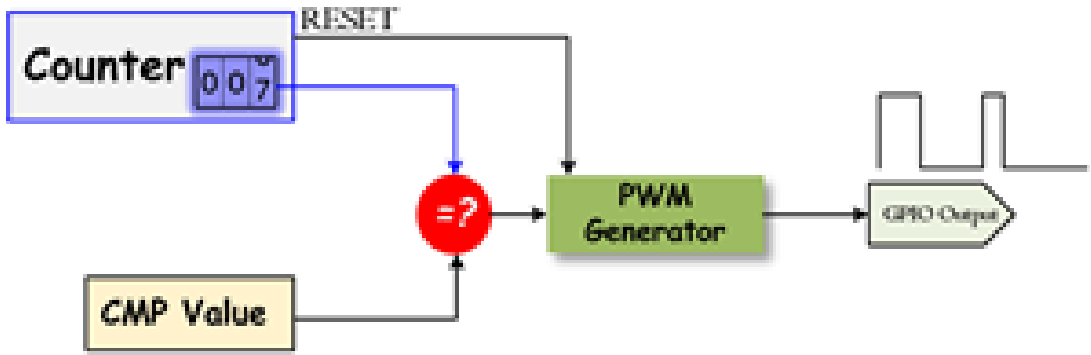
## Classify PWM Signal by Methods: Symmetric and Asymmetric

- Symmetric PWM:
  - The pulses of a symmetric PWM signal are always symmetric with respect to the center of each PWM period.
  - Symmetric PWM are often used for three-phase AC induction and brushless DC motors.
- Asymmetric PWM:
  - The pulses of an asymmetric PWM signal always have the same side aligned with one end of each PWM period.
  - Asymmetric PWM can be used for stepper motors and other variable-reluctance motors.



# Generating PWM with Microcontroller using Timer/Counter

- The basic idea to generate PWM signal is using a counter (or timer), a CMP (compare) value, and a digital output pin
- The counter continuously counts to up or down, and is compared with CMP value.
- The digital output (PWM) will be changed when the counter matches the CMP value, or when counter resets



# PWM Timer

- The PWM timer in the microcontroller runs in one of two modes:
- Count-Down mode:
  - the timer counts from the Period (LOAD) value to zero, goes back to the Period (LOAD) value, and continues counting down.
- Count-Up/Dow mode:
  - the timer counts from zero up to the Period (LOAD) value, back down to zer, back up to the Period (LOAD) value, and so on.

# PWM Calculation

## TM4C123GH PWM

- Calculate the frequency of the PWM timer based on the system clock frequency and the PWM divisor.

$$f_{PWMTimer} = \frac{SysClk}{PWMDivisor}$$

- Calculate the count value for the PWM signal.
- The count value you calculated is over 65535 ($= 2^{16}$-1)

$$LOAD = Count_{PWM} = \frac{T_{PWM}}{T_{PWMTimer}} = \frac{f_{PWMTimer}}{f_{PWM}} \leq 65535$$

- Changing the CMP value in the PWM module will change the duty cycle of the PWM signal

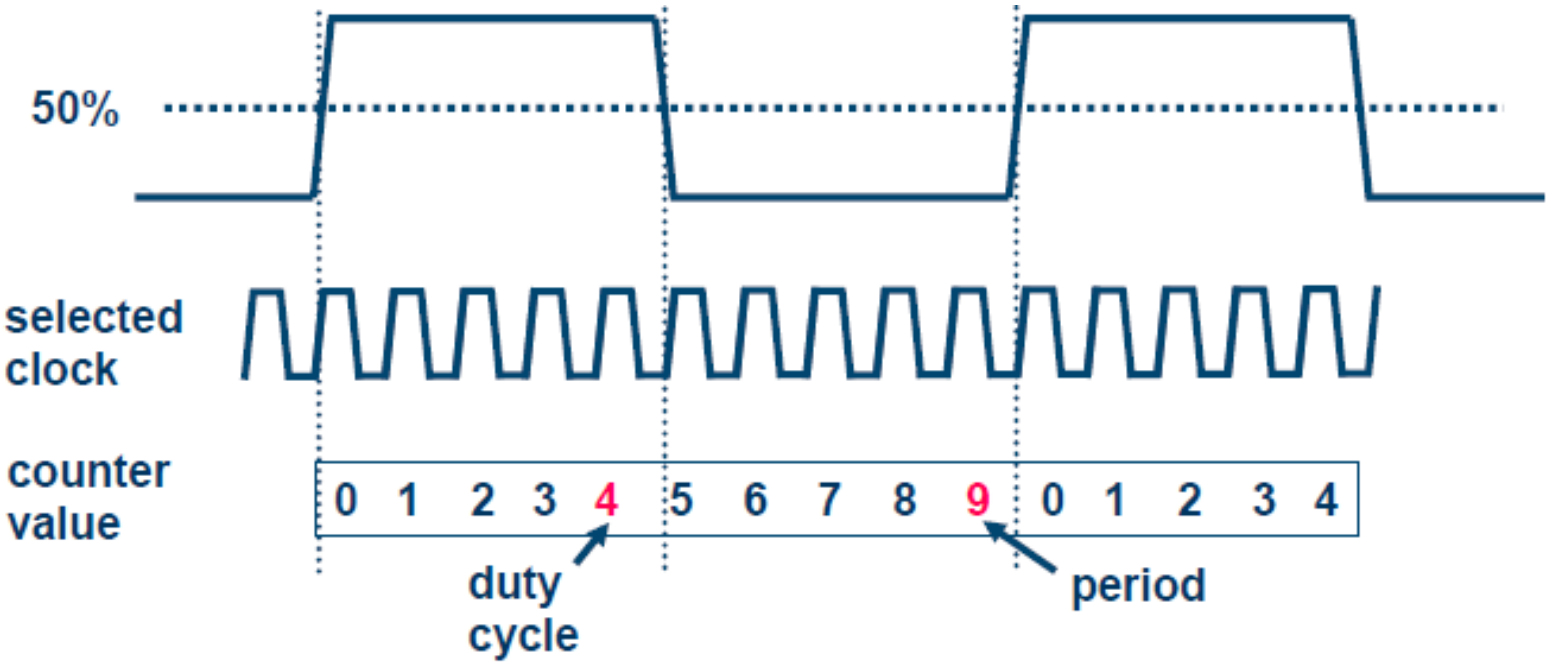
# PWM Calculation

## TM4C123GH PWM

- To calculate the CMP value, you have to know the type of PWM signal that you used:
  - Left-aligned
  - Right-aligned PWM
- For Left-Aligned PWM:
  - If the CMP value is closing to the LOAD value, it will decrease the duty cycle of the PWM signal.
  - If the CMP value is closing to zero, it will increase the duty cycle of the PWM signal.
- For Right-Aligned PWM:
  - If the CMP value is closing to the LOAD value, it will increase the duty cycle of the PWM signal.
  - If the CMP value is closing to zero, it will decrease the duty cycle of the PWM signal.
- The range of the duty cycle is from 0% to 100%, and the relationship between CMP and LOAD is: $0 <= CMP <= LOAD$

# Some Typical Applications

1. Control of DC motor.
   - The voltage supplied to the motor is proportional to the duty cycle.
2. Controlling the brightness of LED.
   - The duty cycle of the voltage source determines the brightness.
3. Control the temperature (heater).
   - Switch ON and OFF the heater with an appropriate duty cycle.
4. Many more...




PWM frequency = $F_{sc}$ / (period)
= 100KHz / 10 = 10 KHz

PWM duty cycle = ((period – duty cycle) / (period)) * 100%
= ((10 – 5) / 10) * 100% = 50%

*Thank You*