## **Pulse Width Modulation**

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#### **Pulse Width Modulation**

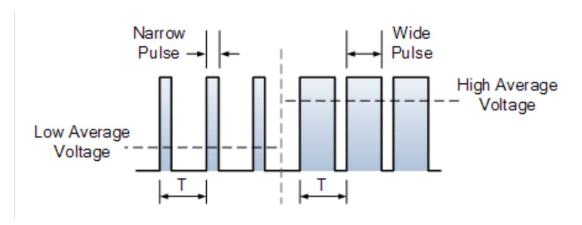
- PWM is a way to control analog devices with a digital output
  - O Motors, actuators, speakers, ...
- PWM is not a true output analog signal
- PWM fakes an analog-like result by applying power in pulses

#### **PWM Characteristics**

A PWM signal is characterized by:

- Duty Cycle: The percentage of high voltage in a period T
- Frequency: Depends on the application

Average voltage = Duty Cycle x High voltage level



#### **PWM Generation in STM32F40xxx**

- PWM signals are generated using the MCU timers
- Our STM32F407VG has a total of 14 timers as follows:
  - 2 advanced timers: (TIM1, TIM8)
  - o 10 general purpose timers: (TIM2, 3, 4, 5, 9, 10, 11, 12, 13, 14)
  - o 2 basic timers: (TIM6, TIM7)
- Except basic timers, All other timers can be used to generate PWM output
- Each timer has a number of independent channel to be used

## **PWM Generation in STM32F40xxx**

PWM channels are not dedicated to fixed GPIO port pins

Timer type	Timer	Number of independent channels
Advanced	1, 8	4
General Purpose	2, 3, 4, 5	4
	9, 12	2
	10, 11, 13, 14	1

- Facilitates the use of timers for PWM generation
- Can be included as we included the Button library before
- Has mainly four functions to deal with timers for PWM
  - o PWM\_TIMn\_Init
  - PWM\_TIMn\_Set\_Duty
  - o PWM\_TIMn\_Start
  - o PWM\_TIMn\_Stop

unsigned int PWM\_TIMn\_Init(unsigned long freq\_hz);

- Initializes timer n in PWM mode
- Takes as input the PWM frequency in Hz
- Returns the calculated timer period

#### Example:

unsigned int period = 0;

period = PWM\_TIM1\_Init(25000); // initializes timer 1 in PWM mode with 25 kHz frequency

void PWM\_TIMn\_Set\_Duty(unsigned int duty, char inverted, char channel);

- Changes duty ratio for Timer module in PWM mode for ST MCUs.
- Inputs:
  - duty: PWM duty ratio, takes values from 0 to timer period returned by PWM TIMn Init
  - o inverted: inverted and non inverted PWM signals
  - o channel: desired PWM channel

#### Example:

// sets timer 8 duty ratio to 200, non inverted signal, channel 4 PWM\_TIM8\_Set\_Duty(200, \_PWM\_NON\_INVERTED, \_PWM\_CHANNEL4);

Inverted parameter		
Description	Predefined library const	
Inverted PWM signal	_PWM_INVERTED	
Non-inverted PWM signal	_PWM_NON_INVERTED	

Channel parameter		
Description	Predefined library const	
Channel 1	_PWM_CHANNEL1	
Channel 2	_PWM_CHANNEL2	
Channel 3	_PWM_CHANNEL3	
Channel 4	_PWM_CHANNEL4	

void PWM\_TIMn\_Start(char channel, const module\_Struct \*module);

- Starts Timer n in PWM mode
- Inputs:
  - channel: desired PWM channel
  - module: mapping the channel to a GPIO port pin

```
GPIO MODULE TIM2 CH1 PA0
_GPIO_MODULE_TIM2_CH1_PA15
GPIO MODULE TIM2 CH1 PA5
GPIO_MODULE_TIM2_CH2_PA1
GPIO MODULE TIM2 CH2 PB3
GPIO MODULE TIM2 CH3 PA2
GPIO MODULE TIM2 CH3 PB10
GPIO_MODULE_TIM2_CH4_PA3
GPIO MODULE TIM2 CH4 PB11
GPIO MODULE TIM3 CH1 PA6
GPIO MODULE TIM3 CH1 PB4
GPIO_MODULE_TIM3_CH1_PC6
GPIO MODULE TIM3 CH2 PA7
GPIO MODULE TIM3 CH2 PB5
GPIO MODULE TIM3 CH2 PC7
_GPIO_MODULE_TIM3_CH3_PB0
GPIO_MODULE_TIM3_CH3_PC8
GPIO MODULE TIM3 CH4 PB1
_GPIO_MODULE_TIM3_CH4_PC9
_GPIO_MODULE_TIM4_CH1_PB6
GPIO_MODULE_TIM4_CH1_PD12
GPIO MODULE TIM4 CH2 PB7
GPIO MODULE TIM4 CH2 PD13
GPIO MODULE TIM4 CH3 PB8
_GPIO_MODULE_TIM4_CH3_PD14
```

#### Example:

```
// starts timer 3 PWM generation to channel 2 and maps the output to PC7 PWM_TIM3_Start(_PWM_CHANNEL2, &_GPIO_MODULE_TIM3_CH2_PC7);
```

void PWM\_TIMn\_Stop(char channel);

- Stops timer n in PWM mode
- Takes channel as input

#### Example:

// stops timer 4 channel 1 from generating PWM output PWM\_TIM4\_Stop(\_PWM\_CHANNEL1);

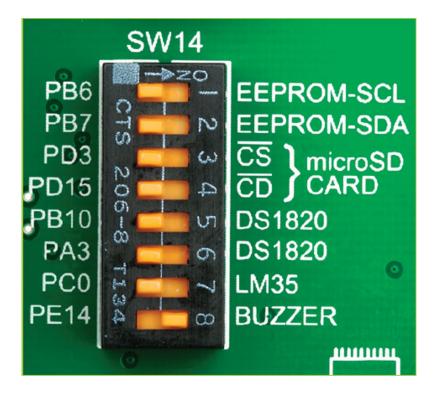
#### EasyMx Pro Buzzer

- Create sound when provided analog signal
- Connected to pin PE14
- Can be used by generating PWM output to PE14



#### **Enable the Buzzer**

To enable the Buzzer you need to push SW14.8 to ON position



# Requirements

#### Requirement 1

It is required to to generate a fixed non inverted 500 Hz PWM signal with 20% duty ratio on PE14 and enable the Buzzer.

#### Hints:

- Don't forget to include the PWM library from library manager
- To find out what timer and channel to work with you can use code assistant
  - Type \_GPIO\_MODULE\_TIM
  - O Press CTRL + SPACE
  - O Search for PE14

## **Requirement 2**

It is required to fade PE14 LED (and hence the Buzzer). Use timer 1 to output a 3.8 kHz PWM signal with a duty ration that goes from 0 to 100% then from 100% to zero and so on.

#### Hint:

Use Delay\_us(time\_in\_microseconds) in your loop.

## **Requirement 3**

It is required to use timer 4 to generate 4 kHz PWM signals. Use the 4 channels of timer 4 and map them to PD12, PD13, PD14, PD15. The LEDs should fade from OFF to ON sequentially then from ON to OFF in the same order and so on.