ECE 271 Microcomputer Architecture and Applications
Lab 6: Pulse Width Modulation
Instructor: Prof. Yifeng Zhu
Spring 2015

Goals

1. Understand the concept of Pulse Width Modulation (PWM)
2. Use PWM to control the LED brightness

Pre-Lab Assignment

1. Read Chapter 15
2. Complete the pin and timer configuration tables

Lab Demo

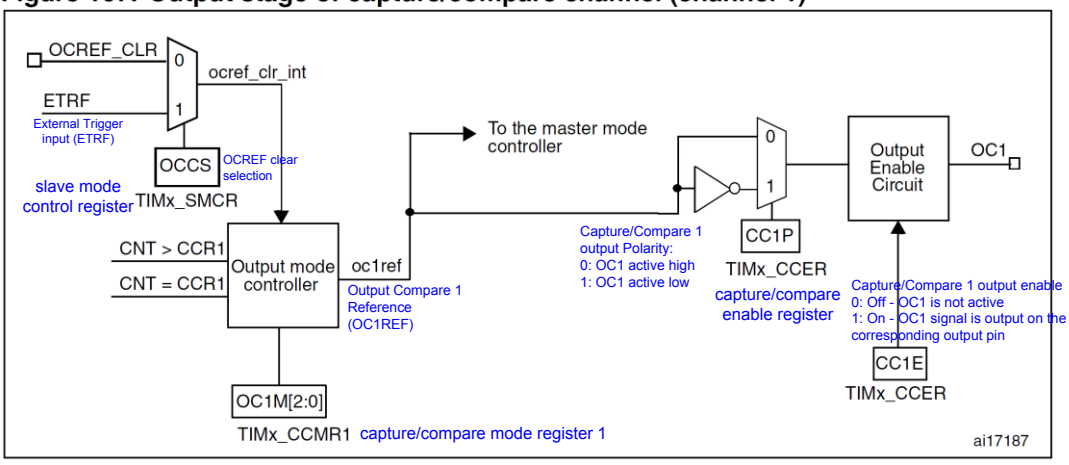
1. Periodically dimming a LED
2. Use an oscilloscope to measure duty cycles.
3. Something cool. Note that dimming another LED does not count as something cool. The following gives a few example of something cool.
    a. Use PWM to control stepper motors to perform micro-stepping
    b. Use PWM to generate a music tone (a 440-Hz sine wave, tone A)
    c. Adjust PWM accuracy by calibrating the accuracy of MSI.

Post-Lab Assignment

1. Complete the post lab report and write your answer in Readme.md

Timer Control for Channel 1 of Timer X:

Figure 107. Output stage of capture/compare channel (channel 1)



Output compare 1 mode
000: Frozen
001: Toggle
100: Force inactive level
101: Force active level
110: PWM mode 1:
Up counting: active if CNT < CCR1, else inactive
Down counting: active if CNT > CCR1, else inactive
111: PWM mode 2
Up counting: inactive if CNT < CCR1, else active
Down counting: inactive if CNT > CCR1, else active

TIMx PWM Mode
- TIMx_APR (Auto-Reload register): frequency
- TIMx_CCRx (Capture/Compare register): duty
- TIMx_CCMRx (Capture/Compare Mode register):
  OCxM for PWM mode 1 or 2
  OCxPE to enable preload
- TIMx_EGR (Event Generation register):
  UG to Re-initialize the counter and generates an update of the registers
- TIMx_CCER (Capture/Compare Enable register):
  CCxP for polarity and CCxE for enabling
- TIMx_CR1 (Control register 1):
  ARPE: Auto-reload enable:
  CMS for edge-align mode or center-aligned mode
- TIMX_DIER (DMA/Interrupt Enable register)

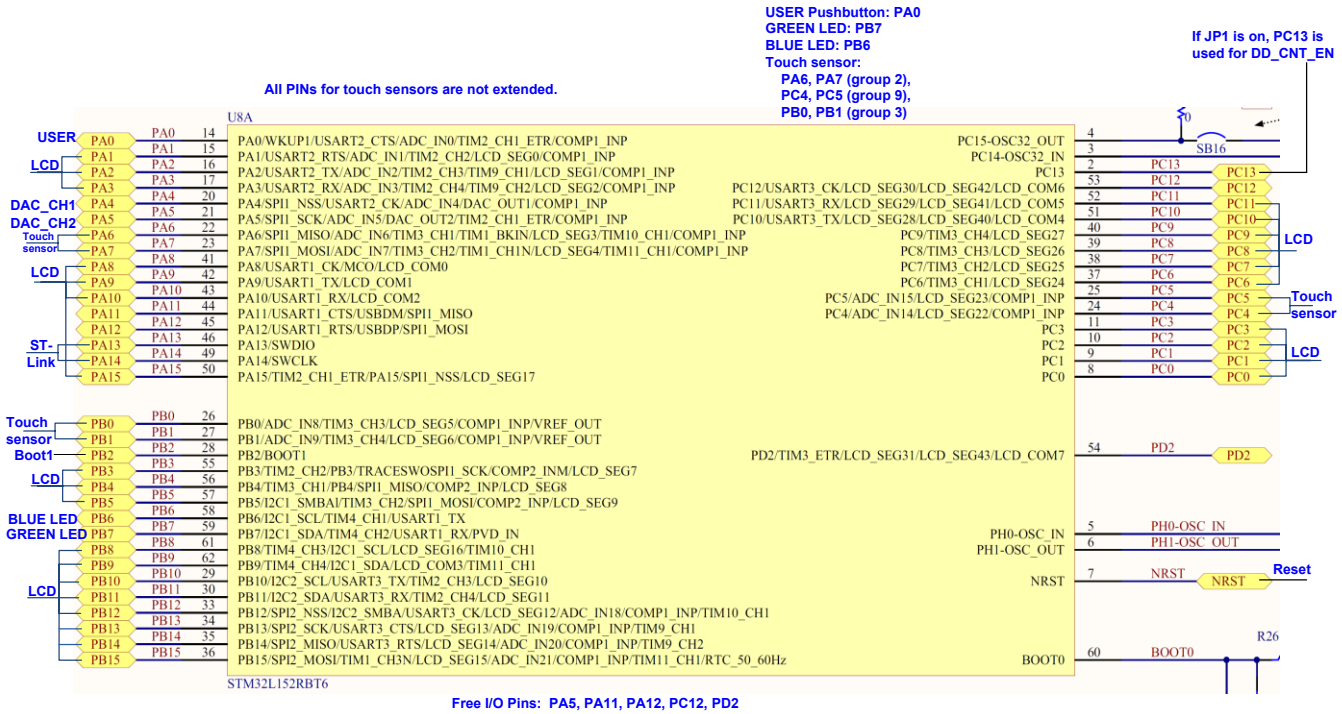


Figure 2. PIN Connection of STML-Discovery Board

The above diagram shows the functions of each pin. The blue and green LED is connected to the PB 6 pin and the PB 7 pin, respectively. The following table shows the alternative functions available for these two pins.

LED	Pin	Available Alternative Functions
Blue	PB 6	I2C1_SCL/**TIM4_CH1**/USART1_TX
Green	PB 7	I2C1_SDA/**TIM4_CH2**/USART1_RX/PVD_IN

This shows:

- *PB 6 pin can be programmed to connect to Channel 1 of Timer 4*, and
- *PB pin 7 can be connected to Channel 2 of Timer 4*.

Comments about comments

Properly documenting is especially important for assembly programs.

Thumb of Rule: "*If you are able to easily and quickly modify your codes one year after your initial development, then your code comments are excellent.*"

When writing comments, you can assume that readers of your codes know the assembly syntax but do not know your program goals, logic, and methodology.

- Give meaningful name to registers
- Recommend to using corresponding C code to make comment

Instruction	Bad comment	Good comment
add r2, r2, #1	; add one to a register	; array_index++
sub r2, r2, #1	; r2 = r2 - 1	; counter++
mul r3, r2, r1	; r3 = r2 * r1	; distance = speed * time

Specific Requirements

For each subroutine (also called function or procedure), your program should have a comment header. Your program should include a register usage page. Give each register a meaningful name. Here is an example.

```
; Name: strcat
; Description: Concatenate two strings
; Input: r0 – pointer to the first string
;        r1 – pointer to the second string
; Returns: r0 – pointer to the resulting string
; Register usage:
;        r3 – array index i of the second string
;        r4 – array index j of the resulting string
;        r5 – temporary value to hold a char loaded from memory

strcat   PROC
         ...
         ENDP
```

Lab 6: Pre-Lab Assignment

Student Name: _____

NOTE:

- The Blue LED (PB 6) is connected to the Channel 1 of Timer 4.
- The Green LED (PB 7) is connected the Channel 2 of Timer 4.

1. Configure RCC_AHBENR to enable the clock of GPIO Port B

Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AHBENR	Reserved	FSMCEN	Reserved		AESEN	Reserved	DMA2EN	DMA1EN	Reserved								FLITFEN	Reserved		CRCEN	Reserved				GPIOPGEN	GPIOPFEN	GPIOPHEN	GPIOPEEN	GPIOPDEN	GPIOPCEN	GPIOPBEN	GPIOPAEN
Mask																																
Value																																

Write your assembly code below to enable the GPIO B clock:

2. Configure RCC_APB1ENR to enable the clock of Timer 4

Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
APB1ENR	COMPEN	Reserved	DACEN	PWREN	Reserved				USBEN	I2C2EN	I2C1EN	USART5EN	USART4EN	USART3EN	USART2EN	Reserved	SPI3EN	SPI2EN	Reserved		WWDGEN	Reserved	LCDEN	Reserved			TIM7EN	TIM6EN	TIM5EN	TIM4EN	TIM3EN	TIM2EN
Mask																																
Value																																

Write your assembly code below to enable the Timer 4 clock:

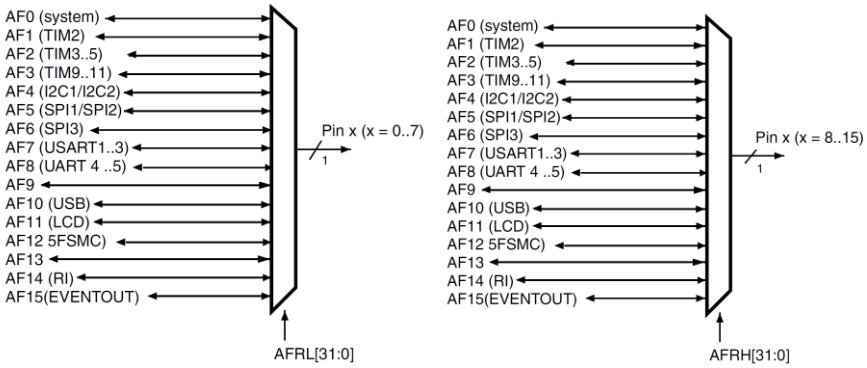
3. Configure PB 6 (Blue LED), PB 7(Green LED) as Alternative Function Mode

GPIO Mode: Input (00, reset), Output (01), AlterFunc (10), Analog (11)

Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
GPIOB MODER	MODER15[1:0]		MODER14[1:0]		MODER13[1:0]		MODER12[1:0]		MODER11[1:0]		MODER10[1:0]		MODER9[1:0]		MODER8[1:0]		MODER7[1:0]		MODER6[1:0]		MODER5[1:0]		MODER4[1:0]		MODER3[1:0]		MODER2[1:0]		MODER1[1:0]		MODER0[1:0]	
Mask																																
Value																																

GPIOB Mode Register MASK Value = 0x_____ (in HEX)
GPIOB Mode Register Value = 0x_____ (in HEX)

4. Configure and Select the Alternative Function for PB 6 (Blue LED), PB 7(Green LED)



GPIOx_AFRL[31:00] defines the alternate function for pins 0 to 7, and GPIO_AFHL for pins 8 to 15.

Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
GPIOB AFR[0]	AFRL7[3:0]				AFRL6[3:0]				AFRL5[3:0]				AFRL4[3:0]				AFRL3[3:0]				AFRL2[3:0]				AFRL1[3:0]				AFRL0[3:0]			
MASK																																
VALUE																																
GPIOB AFR[1]	AFRH15[3:0]				AFRH14[3:0]				AFRH13[3:0]				AFRH12[3:0]				AFRH11[3:0]				AFRH10[3:0]				AFRH9[3:0]				AFRH8[3:0]			
MASK																																
VALUE																																

GPIOB Alternative Function Register [0] MASK = 0x_____ (in HEX)
GPIOB Alternative Function Register [0] = 0x_____ (in HEX)
GPIOB Alternative Function Register [1] MASK = 0x_____ (in HEX)
GPIOB Alternative Function Register [1] = 0x_____ (in HEX)

5. Complete the following table to configure the PWM output for Channel 1 of Timer 4

Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TIMx_CR1	Reserved																						CKD [1:0]		ARPE	CMS [1:0]		DIR	OPM	URS	UDIS	CEN
Value																																
TIMx_CR2	Reserved																								TI1S	MMS[2:0]			CCDS	Reserve d		
Value																																
TIMx_CCMR1 *Output Compare mode*	Reserved																OC2CE	OC2M [2:0]			OC2PE	OC2FE	CC2S [1:0]		OC1CE	OC1M [2:0]			OC1PE	OC1FE	CC1S [1:0]	
Value																																
TIMx_CCMR2 *Output Compare mode*	Reserved																O24CE	OC4M [2:0]			OC4PE	OC4FE	CC4S [1:0]		OC3CE	OC3M [2:0]			OC3PE	OC3FE	CC3S [1:0]	
Value																																
TIMx_CCER	Reserved																CC4NP	Reserved	CC4P	CC4E	CC3NP	Reserved	CC3P	CC3E	CC2NP	Reserved	CC2P	CC2E	CC1NP	Reserved	CC1P	CC1E
value																																
TIMx_CCR1	CCR1[32:16] (TIM5 only, reserved on the other timers)																CCR1[15:0]															
value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																
TIMx_PSC	Reserved																PSC[15:0]															
value																																
TIMx_ARR	ARR[32:16] (TIM5 only, reserved on the other timers)																ARR[15:0]															
value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0																

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Lab Demo

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Demo 1: Diming an LED
Demo 2: Use an oscilloscope to measure duty cycles.

Keep TIM4_ARR fixed but set TIM4_CCR1 to three different values.

TIM4_ARR = _____
TIM4_PSC = _____

Case		TIM4_CCR1	Pulse Width Measured	Pulse Period Measured	Duty Cycle Measured
#1	TIM4_CCR1 = 1/6* TIM4_ARR				
#2	TIM4_CCR1 = 1/3* TIM4_ARR				
#3	TIM4_CCR1 = 1/2* TIM4_ARR				

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Post-Lab Assignment

1. Suppose the HSE (high-speed external clock) of 16 MHz is selected the clock of a timer. In order to generate 1 Hz square wave with duty cycle of 50%, how would set up the timer? Indicate your counting mode and show the value of ARR, CRR, and PSC registers.
2. Do you have any suggestions or comments for this lab, the textbook or the lab?