Lab6 STM32 Clock and Timer

實驗六 STM32 Clock and Timer

1. Lab objectives 實驗目的

Understand the various clock source usage and modification of STM32

Understand the principle of using STM32 timer

Understand the principle and application of PWM for STM32

瞭解 STM32 的各種 clock source 使用與修改

瞭解 STM32 的 timer 使用原理

瞭解 STM32 的 PWM 使用原理與應用

2. Lab principle 實驗原理

2.1. Timer and Counter

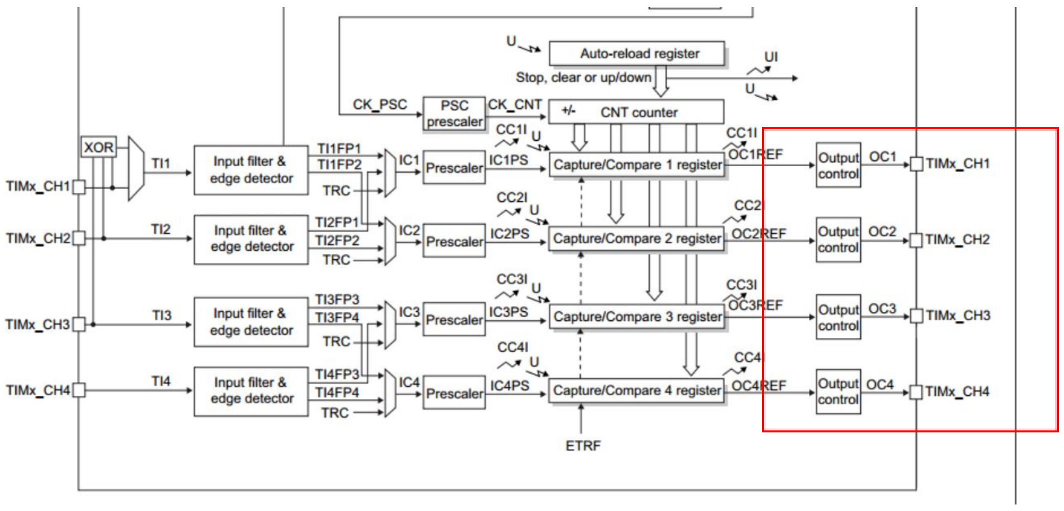
Please refer to 009-MCSL-CounterTimer lecture slide.

請參考上課 009-MCSL-CounterTimer 講義。

2.2. Timer PWM output mode

In the STM32 system, the Timer is used to generate the PWM output, which is mainly set by the capture/compare mode register (TIMx_CCMR1) and TIMx_CCRx registers and enabled by TIMx_CCER.

在 STM32 中利用 Timer 產生 PWM 輸出，主要通過 capture/compare mode register(TIMx_CCMR1) 與 TIMx_CCRx registers 設定並利用 TIMx_CCER 啟動。



The general PWM has two modes, mode1 and mode2, and the corresponding output is in the counter mode.

而一般 PWM 有分 mode1 與 mode2 兩種模式，而在計數器上數模式時其對應的輸出為

- PWM mode1: Channel is active as long as TIMx_CNT < TIMx_CCRx else inactive.
- PWM mode2: Channel is inactive as long as TIMx_CNT < TIMx_CCRx else active.

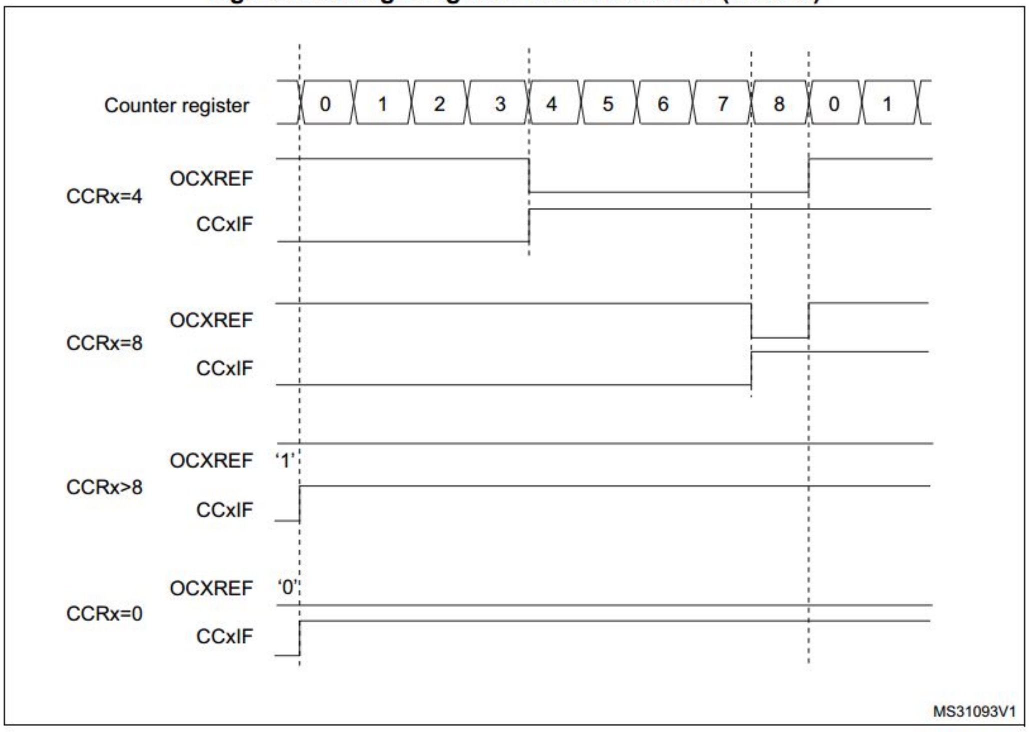
In addition, according to different special purposes, it can be divided into Combined PWM mode and Asymmetric PWM mode.

另外依不同特殊用途又可分 Combined PWM mode 與 Asymmetric PWM mode。

When ARR is set to 8, the signal output corresponding to OCxREF is set for different CCR values.

在 ARR 設定為 8 時，不同 CCR 值設定下 OCxREF 所對應的訊號輸出

Figure 279. Edge-aligned PWM waveforms (ARR=8)



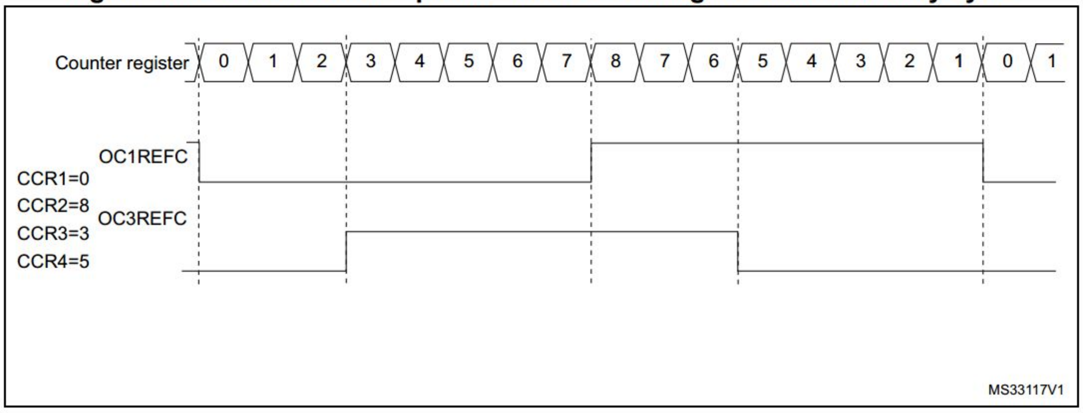
In the example above, when CCRx=4, ARR=8, the waveform of the duty cycle (the ratio of 1 level to 0 level in unit time) is 50%, CCRx=8, ARR=8 can get duty cycle= 1-1/8=87.5% waveform.

以上圖範例來說當 CCRx=4, ARR=8 可以得到 duty cycle (在單位時間內 1 準位與0 準位的比例)為 50% 的波形，CCRx=8,ARR=8 可得 duty cycle = 1 - ⅛ = 87.5% 的波形。

To output a more complex PWM and different duty cycle waveforms can also be achieved using Asymmetric PWM mode.

要輸出比較複雜的 PWM 與不同 duty cycle 波形也可以利用 Asymmetric PWM mode 來達成。

Figure 281. Generation of 2 phase-shifted PWM signals with 50% duty cycle



For details on other PWM settings, please refer to STM32L4x6-Advanced-Arm®-based-32bitMCUs-Reference-Manual chapter 30.3.11 PWM mode

其他PWM設定細節用途請參閱 STM32L4x6-Advanced-Arm®-based-32bitMCUs-Reference-Manual chapter 30.3.11 PWM mode

3. Steps 實驗步驟

3.1. Lab6.1: Modify system initial clock (20%)

- Please use the GPIO_init and Delay1sWith4MHz implemented by the previous lab to call the previous assembly function or re-implement with C to initialize GPIO and delay.
- Modify the clock source of SYSCLK and the associated prescaler so that the CPU frequency (HCLK) is 1MHz.
- Observe the frequency at which the LEDs flash before and after modification.
- **When the user presses the user button**, the CPU system clock (HCLK) is changed in the following order,
  1MHz -> 6MHz -> 10MHz -> 16MHz -> 40MHz -> 1MHz ->...

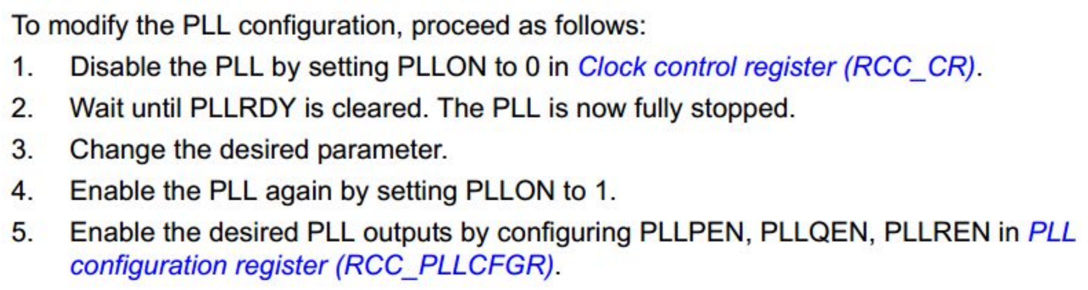
- 請利用先前 lab 所實作的 GPIO_init 與 Delay1sWith4MHz，可呼叫之前的 assembly function 或是用 C 重新實作，初始化 GPIO 與 delay。
- 修改 SYSCLK 的 clock source 以及相關的 prescaler 使得 CPU frequency(HCLK) 為 1MHz。
- 觀察修改前後 LED 燈閃爍的頻率。
- **當使用者按下 user button** 便依以下順序改變 CPU system clock(HCLK), 1MHz -> 6MHz -> 10MHz ->16MHz -> 40MHz ->1MHz ->…

main.c
```c
void GPIO_init();
void Delay1sWith4MHz();
void SystemClock_Config(){
    //TODO: Change the SYSCLK source and set the corresponding
Prescaler value.
}

int main(){
   SystemClock_Config();
   GPIO_init();
   while(1){
      // make LED light
      Delay1sWith4MHz();
      // make LED dark
      Delay1sWith4MHz();
   }
}
```

Note: Some CPU frequency settings must be made by the multiplier and divider in PLLCLK. In this case, change the SYSCLK source to PLLCLK and set the RCC_PLLCFGR register setting according to the following procedure.

Note: 有些 CPU 頻率設定須由 PLLCLK 內的倍頻器與除頻器達成，此時須將 SYSCLK source 改成 PLLCLK 並依以下流程設定 RCC_PLLCFGR register 設定。



To modify the PLL configuration, proceed as follows:

1. Disable the PLL by setting PLLON to 0 in *Clock control register (RCC_CR)*.
2. Wait until PLLRDY is cleared. The PLL is now fully stopped.
3. Change the desired parameter.
4. Enable the PLL again by setting PLLON to 1.
5. Enable the desired PLL outputs by configuring PLLPEN, PLLQEN, PLLREN in *PLL configuration register (RCC_PLLCFGR)*.

The PLL clock frequency is calculated as f(VCO clock) = f(PLL clock input) × (PLLN / PLLM)
The final output to the system clock frequency is f(PLL_R) = f(VCO clock) / PLLR

其中 PLL clock 頻率計算為 f(VCO clock) = f(PLL clock input) × (PLLN / PLLM)
最終可輸出給 system clock 頻率為 f(PLL_R) = f(VCO clock) / PLLR

3.2. Lab6.2: Timer 計時器 (30%)

Complete Timer_init() and Timer_start() in main.c below and use STM32 timer to do a timer that counts up from 0 (Upcounting) for TIME_SEC seconds. The second digit below the decimal point is displayed, and the 7-SEG LED stays at the TIME_SEC number at the end. (It is recommended to use TIM2~TIM5 timer with higher counter resolution). Please use polling to get the timer CNT register value and convert it into time display to 7-SEG LED.

0.01 ≤ TIME_SEC ≤ 10000.00 (Please display 0.00 directly beyond the range)

Note: The 7-SEG LED driver should be rendered using the GPIO_init(), max7219_init() and Display () functions previously implemented by Lab (which must be changed to render 2 decimal places).

完成以下的 main.c 中的 Timer_init() 與 Timer_start(); 並使用 STM32 timer 實做一個計時器會從 0 上數(Upcounting) TIME_SEC 秒的時間。顯示到小數點以下第二位，結束時 7-SEG LED 停留在 TIME_SEC 的數字。(建議使用擁用比較高 counter resolution 的 TIM2~TIM5 timer)，請使用 polling 的方式取得 timer CNT register 值並換算成時間顯示到 7-SEG LED 上。

0.01 ≤ TIME_SEC ≤ 10000.00 (超過範圍請直接顯示0.00)

Note: 7-SEG LED 驅動請利用之前 Lab 所實作的 GPIO_init()、max7219_init() 與 Display () 函式呈現(須改成可呈現 2 個小數位)。

main.c

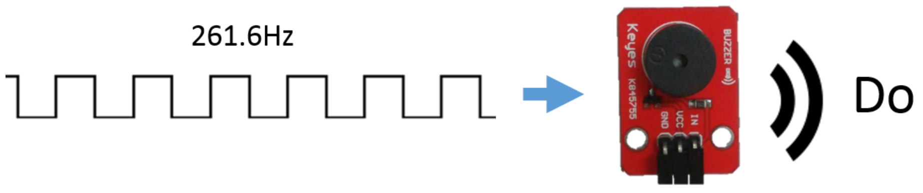
```c
#include "stm32l476xx.h"-
// You can use your way to store TIME_SEC. Maybe it is `int` or
`float` or any you want
#define TIME_SEC 12.70
extern void GPIO_init();
extern void max7219_init();
extern void Display();
void Timer_init( TIM_TypeDef *timer)
{
    //TODO: Initialize timer
}
void Timer_start(TIM_TypeDef *timer){
    //TODO: start timer and show the time on the 7-SEG LED.
}
int main()
{
   GPIO_init();
   max7219_init();
   Timer_init();
   Timer_start();
   while(1)
   {
     //TODO: Polling the timer count and do lab requirements
   }
}
```

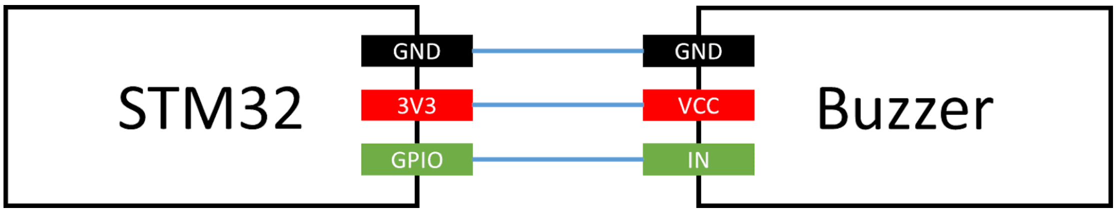
e.g. Demo video with TIME_SEC = 12.7 : https://goo.gl/F9hh35

3.3. Lab6.3: Music keypad (35%)

The buzzer is divided into an active (self-excited) buzzer and a passive (excited) buzzer. The active buzzer directly designs the drive circuit into the buzzer, so it is only necessary to provide a DC voltage to make a sound, but the disadvantage is that the frequency of the sound cannot be changed. The external buzzer needs to provide an oscillating waveform to make a sound, and the frequency of the sound is the frequency of the input wave. Our LAB is using a passive buzzer.

蜂鳴器分為有源(自激式)蜂鳴器和無源(他激式)蜂鳴器。有源蜂鳴器將驅動電路直接設計到蜂鳴器中，因此只需提供直流電壓就可以發出聲音，但其缺點是聲音的頻率無法更改。無源蜂鳴器外部需提供震盪波形才會發出聲音，其聲音的頻率就是輸入波的頻率。我們這次 LAB 使用的是無源蜂鳴器。





The buzzer's VCC is connected to 3.3V, GND is connected to GND, and IN is connected to the GPIO pin.
蜂鳴器的VCC接3.3V、GND接GND、IN接GPIO腳位。

Please use the timer to generate and output the PWM signal with 50% Duty cycle, and use the keypad in Lab6 as the keyboard. When the user presses the different keypad buttons, the PWM square wave of the specific frequency (refer to the following table) is given to the buzzer. Do not make a sound when there is no button or press to a button that has no function. This lab will need to set registers such as GPIOx_AFRH, GPIOx_AFRL, TIMx_CCER, TIMx_CCMR1, TIMx_CCR1...

Note: Refer to STM32L4x6-Advanced-Arm®-based-32bitMCUs-Reference-Manual to understand the functions of these registers to complete the lab. Use STM32L476XX-DataSheet-Production-Data to find the pin corresponding to the timer channel.

請利用 timer 產生並輸出Duty cycle為 **50% 的 PWM 訊號**，並以 Lab5 中的 keypad 為鍵盤，當使用者在按下不同 keypad 按鍵時產生特定頻率(參考下表)的 PWM 方波給蜂鳴器，沒按鍵或按到沒功能的鍵時請不要發出聲音。本次實驗

會需要設定 GPIOx_AFRH、GPIOx_AFRL、TIMx_CCER、TIMx_CCMR1、TIMx_CCR1…等 registers。

Note: 參考 STM32L4x6-Advanced-Arm®-based-32bitMCUs-Reference-Manual 瞭解這些register的功能完成此次實驗。並利用 STM32L476XX-DataSheet-Production-Data 找到timer channel所對應的腳位。

	X0	X1	X2	X3
Y0	Do	Re	Mi	
Y1	Fa	So	La	
Y2	Si	HDo		
Y3				

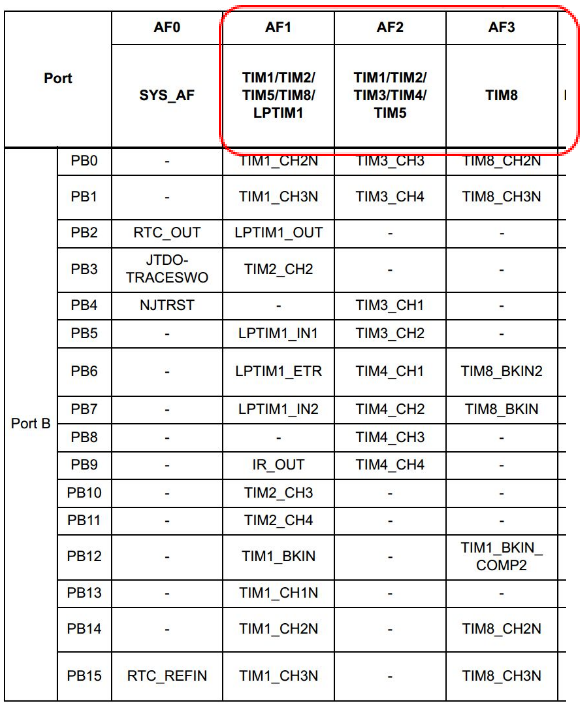
Keypad corresponds to the phonetic name

音名	Do	Re	Mi	Fa	So	La	Si	HDo
頻率(Hz)	261.6	293.7	329.6	349.2	392.0	440.0	493.9	523.3

Phonetic frequency correspondence table

Note: When the GPIO pin is set to PWM output, it needs to be set to the alternate function (AF) Mode, and set the AFRH and AFRL register according to the timer used. For details of the setting method, please refer to reference manual and datasheet.

Note: GPIO Pin 設為 PWM output 時需設定為 alternate function(AF) Mode, 並根據根據所對應使用的 timer 設定 AFRH 與 AFRL register, 設定方式細節請參考 reference manual 與 datasheet。



Port		AF0	AF1	AF2	AF3
		SYS_AF	TIM1/TIM2/TIM5/TIM8/LPTIM1	TIM1/TIM2/TIM3/TIM4/TIM5	TIM8
Port B	PB0	-	TIM1_CH2N	TIM3_CH3	TIM8_CH2N
	PB1	-	TIM1_CH3N	TIM3_CH4	TIM8_CH3N
	PB2	RTC_OUT	LPTIM1_OUT	-	-
	PB3	JTDO-TRACESWO	TIM2_CH2	-	-
	PB4	NJTRST	-	TIM3_CH1	-
	PB5	-	LPTIM1_IN1	TIM3_CH2	-
	PB6	-	LPTIM1_ETR	TIM4_CH1	TIM8_BKIN2
	PB7	-	LPTIM1_IN2	TIM4_CH2	TIM8_BKIN
	PB8	-	-	TIM4_CH3	-
	PB9	-	IR_OUT	TIM4_CH4	-
	PB10	-	TIM2_CH3	-	-
	PB11	-	TIM2_CH4	-	-
	PB12	-	TIM1_BKIN	-	TIM1_BKIN_COMP2
	PB13	-	TIM1_CH1N	-	-
	PB14	-	TIM1_CH2N	-	TIM8_CH2N
	PB15	RTC_REFIN	TIM1_CH3N	-	TIM8_CH3N

PortB AF mode selection table

```
extern void GPIO_init();
void GPIO_init_AF(){
//TODO: Initial GPIO pin as alternate function for buzzer. You can
choose to use C or assembly to finish this function.
}
void Timer_init(){
    //TODO: Initialize timer
}
void PWM_channel_init(){
    //TODO: Initialize timer PWM channel
}
int main(){
   GPIO_init();
    GPIO_init_AF();
   Timer_init();
    PWM_channel_init();
     //TODO: Scan the keypad and use PWM to send the corresponding
frequency square wave to buzzer.
}
```

Example video： https://goo.gl/4MuIFv

3.4. Lab6.4: Modify LED brightness 調整 LED 亮度 (15%)

In the previous lab, the keypad adds two function buttons to adjust the Duty cycle of the PWM output (range 10%~90%, 5% adjustment per button).

Use LED to replace buzzer. If successful, you should see that the LED’s brightness changes with the duty cycle.

Note: Pay attention to the relationship between frequency and duty cycle to set timer ARR and CCR registers.

在前一實驗中的 keypad 增加 2 個功能按鈕用以調整 PWM 輸出的 Duty cycle (範圍10%~90%，每按一次鍵調整5%)。

使用 LED 去替換蜂鳴器。如果成功應會看到 LED 亮度隨著 duty cycle 不同而有變化。

Note: 須注意頻率與 duty cycle 的關係來設定 timer ARR 與 CCR registers。