基於ADC 輸入電壓來調整PWM 占空比

NuMicro® 8位系列微控制器範例代碼介紹

文件資訊

應用簡述	本範例代碼使用 MS51 依據 0~3V ADC 輸入電壓來輸出占空比為 0~100%且頻率為 10 kHz 的 PWM 波形。
BSP 版本	MS51_Series_BSP_Keil_V1.00.004
開發平台	NuTiny-MS51DA V1.1

The information described in this document is the exclusive intellectual property of Nuvoton Technology Corporation and shall not be reproduced without permission from Nuvoton.

Nuvoton is providing this document only for reference purposes of NuMicro microcontroller and microprocessor based system design. Nuvoton assumes no responsibility for errors or omissions.

All data and specifications are subject to change without notice.

For additional information or questions, please contact: Nuvoton Technology Corporation.

www.nuvoton.com

1. 概述

本範例代碼使用 MS51 依據 0~3V ADC 輸入電壓輸出占空比為 0~100% 且頻率為 10 kHz 的 PWM 波形。後續章節會介紹如何使用 ADC 採樣輸入電壓並將其轉換為 12 位二進制數據，也會介紹如何透過 ADC 轉換結果來改變 PWM 占空比。

1.1 原理

MS51 內嵌 12 位 ADC，ADC 會將引腳上的輸入電壓轉換為 12 位二進制數據，12 位解析度意味 ADC 轉換結果的範圍為 0~4095。其轉換結果會對應到 PWM 輸出占空比為 0~100% 的波形。使用下列公式來表示 ADC 轉換結果與 PWM 占空比的轉換關係式。

$$\text{PWM 占空比} = \frac{\text{ADC 轉換結果 x100}}{4095}$$

1.2 執行結果

本範例代碼執行的結果如圖 1-1 與圖 1-2 示波器截圖所示。其表示 ADC 輸入電壓與 PWM 占空比的關係。當 ADC 輸入電壓為 1.02 V 與 1.5 V 時，其 PWM 占空比分別為 34 % 與 50%。

[註] 通道 1 用來量測 ADC 輸入電壓；通道 2 用來量測 PWM 輸出波形。

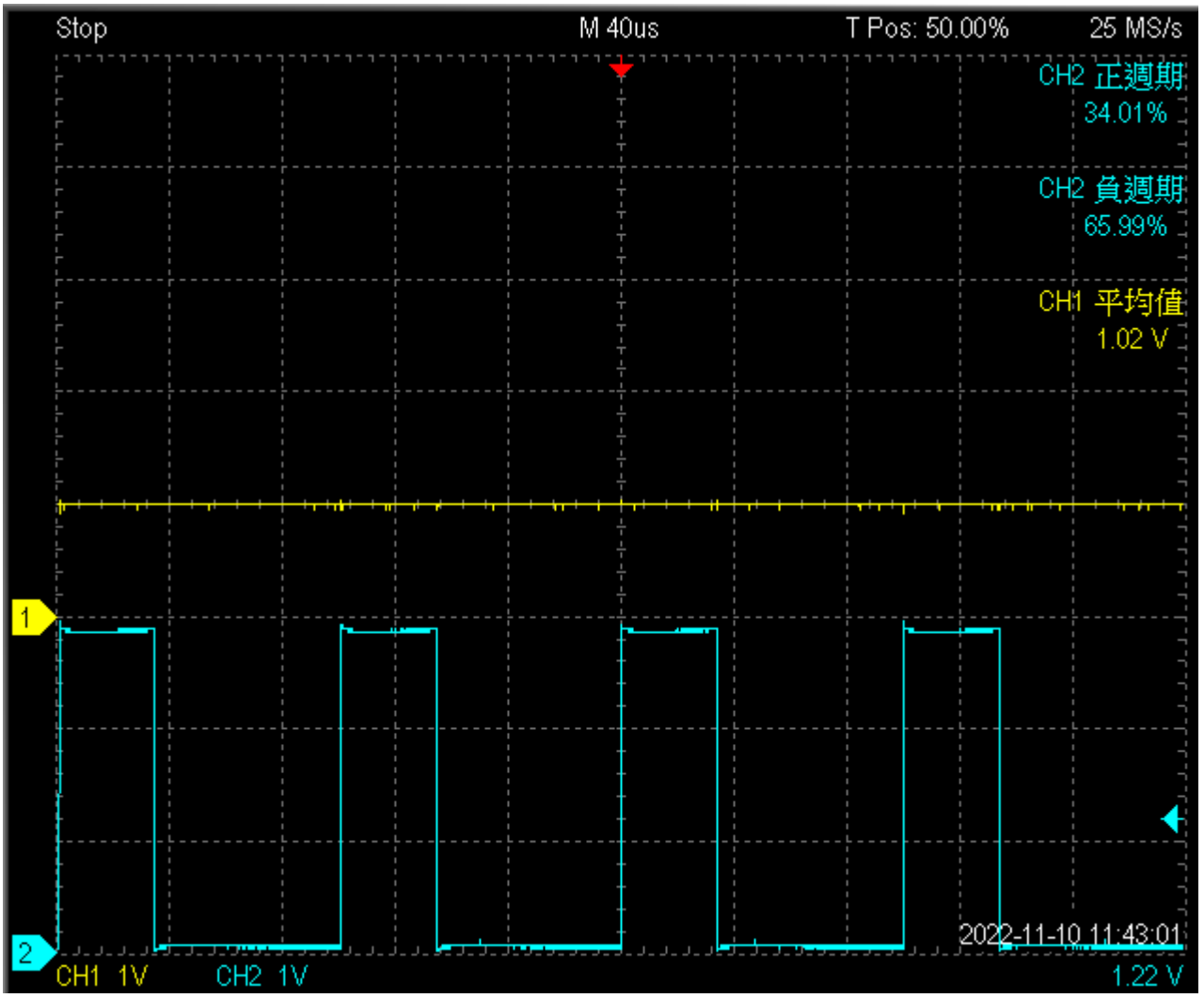

圖 1-1 PWM 占空比 V.S. ADC 輸入電壓為 1.02 V

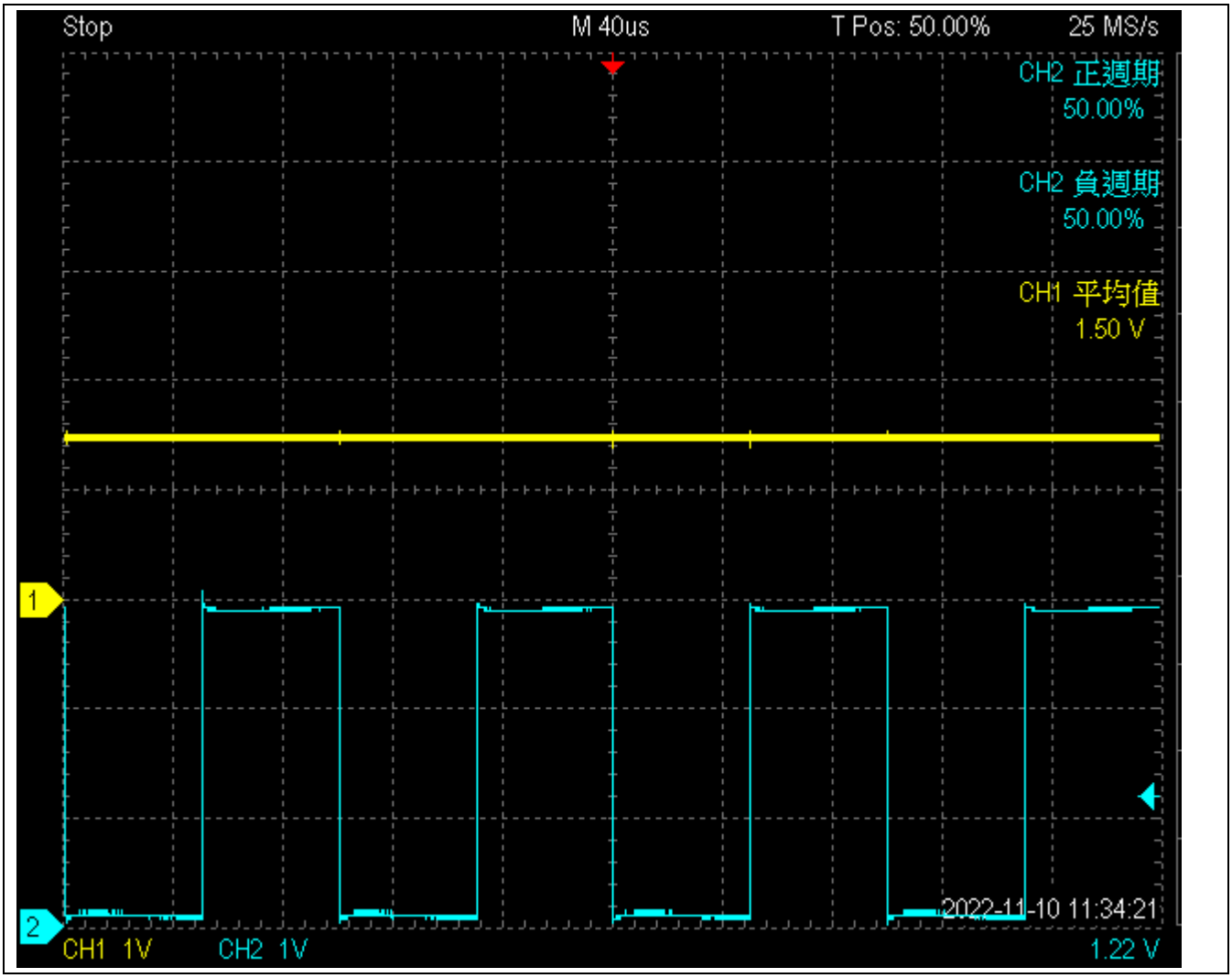

圖 1-2 PWM 占空比 V.S. ADC 輸入電壓為 1.5V

2. 代碼介紹

main() 函式可分為三個部分，第一部分為系統初始化，包含設定 HIRC 為 24 MHz 且初始化相關外設。PWM 與 ADC 相關設定請分別參考章節 2.1 與章節 2.2。 第二部分為在 *IDLE_STATE* 條件中啟動 ADC 轉換程序，且當 ADC 中斷發生時獲取 ADC 轉換結果。最後，在 *ADC_UPDATE_STATE* 條件中依據 ADC 轉換結果計算並更新 PWM 占空比。

```
void main(void)
{
    unsigned char state = IDLE_STATE;

    /* FSYS = 24MHz */
    MODIFY_HIRC(HIRC_24);
    PWM0_Init();
    ENABLE_GLOBAL_INTERRUPT;

    while (1)
    {
        switch (state)
        {
            case IDLE_STATE:
            default:

                ADC_Convert();
                state = ADC_UPDATE_STATE;
                break;


            case ADC_UPDATE_STATE:

                if (g_bADC_Flag == 1)
                {
                    g_bADC_Flag = 0;

                    i64_ADCdataConvert = u32_ADCdataAIN;
                    i64_ADCdataConvert = i64_ADCdataConvert * 100 / 4095;
                    /* Integer value */
                    i64_ADCdataConvert = (2 * i64_ADCdataConvert -
(int)(i64_ADCdataConvert));

                    PWM0_Reload((unsigned int)i64_ADCdataConvert);
                    DISABLE_ADC;
                    state = IDLE_STATE;
                }

                break;
        }
    }
}
```

2.1 PWM 相關函式

PWM0_Init() 函式用來初始化 PWM 模組與相關設定，包含時鐘源、輸出通道、PWM 輸出頻率與 PWM 占空比等。

PWM0_Reload() 函式用來計算並更新 PWM 占空比。

```
/**
* @brief Initialize the PWM module with specified configurations. It could be clock source, PWM channel and frequency.
*        The default duty cycle is 50%.
*
* @param[in] None
*
* @return None
*
* @details None
*/
void PWM0_Init(void)
{
    /* Define PWM0 clock source and divider. */
    PWM0_ClockSource(PWM_FSYS, 1);

    /* Setting PWM0 channel 2 */
    ENABLE_PWM0_CH2_P10_OUTPUT;
    P10_PUSHPULL_MODE;
    PWM0_ConfigOutputChannel(2, Independent, EdgeAligned, PWM_FREQ, 50);

    PWM0_RUN();
}

/**
* @brief Update PWM duty cycle.
*
* @param[in] u16PWM0Duty Set PWM default duty cycle. The range is 0%~100%
*
* @return None
*
* @details The formula is:
*          PWM duty cycle = PWM duty register /  (PWM period register + 1)
*          -> PWM duty register = PWM duty cycle * (PWM period register + 1)
*/
void PWM0_Reload(unsigned int u16PWM0Duty)
{
    /* Reload PWM duty */
    unsigned int u16PWM0DutyCycleTemp = 0;
    u16PWM0DutyCycleTemp = ((PWM_FREQ + 1) / 100) * u16PWM0Duty;

    PWM2H = u16PWM0DutyCycleTemp >> 8;
    PWM2L = u16PWM0DutyCycleTemp;

    set_PWMCON0_LOAD;
}
```

2.2 ADC 相關函式

ADC_Convert() 函式用來初始化 ADC 模組與相關設定，包含時鐘除頻值、輸入通道與 ADC 採樣時間。 當轉換完成後，可在 ADC_ISR() 函式中獲取 ADC 轉換結果。

```
/**
* @brief ADC interrupt service routine
*
* @param[in] None
*
* @return None
*
* @details Get ADC conversion result.
*/
void ADC_ISR(void) interrupt 11
{
    _push_(SFRS);

    clr_ADCCON0_ADCF;//Clear ADC interrupt flag

    u32_ADCdataAIN = ADCRH << 4;
    u32_ADCdataAIN |= ADCRL;
    g_bADC_Flag = 1;
    _pop_(SFRS);
}

/**
* @brief Initialize the ADC module with specified configurations and start ADC convert.
*
* @param[in] None
*
* @return None
*
* @details None
*/
void ADC_Convert(void)
{
    /*Enable channel 5 */
    ENABLE_ADC_CH5;
    ADCCON1 |= 0x30;          /* clock divider */
    ADCCON2 |= 0x0E;          /* AQT time */
    AUXR1 |= SET_BIT4;        /* ADC clock low speed */
    clr_ADCCON0_ADCF;
    set_ADCCON0_ADCS;

    /* Enable ADC interrupt */
    set_IE_EADC;
}
```

3. 軟體與硬體需求

3.1 軟體需求

- BSP 版本
  - MS51_Series_BSP_Keil_V1.00.004
- IDE 版本
  - Keil uVersion 5.26

3.2 硬體需求

- 電路元件
  - NuTiny-MS51DA V1.1
- 示意圖
  - 將 ADC_CH5(P0.4) 腳位連接到外部電源供應器，用以得到不同的電壓轉換結果。
  - 將 PWM0_CH2(P1.0) 腳位連接到示波器，用以觀察 PWM 輸出訊號。

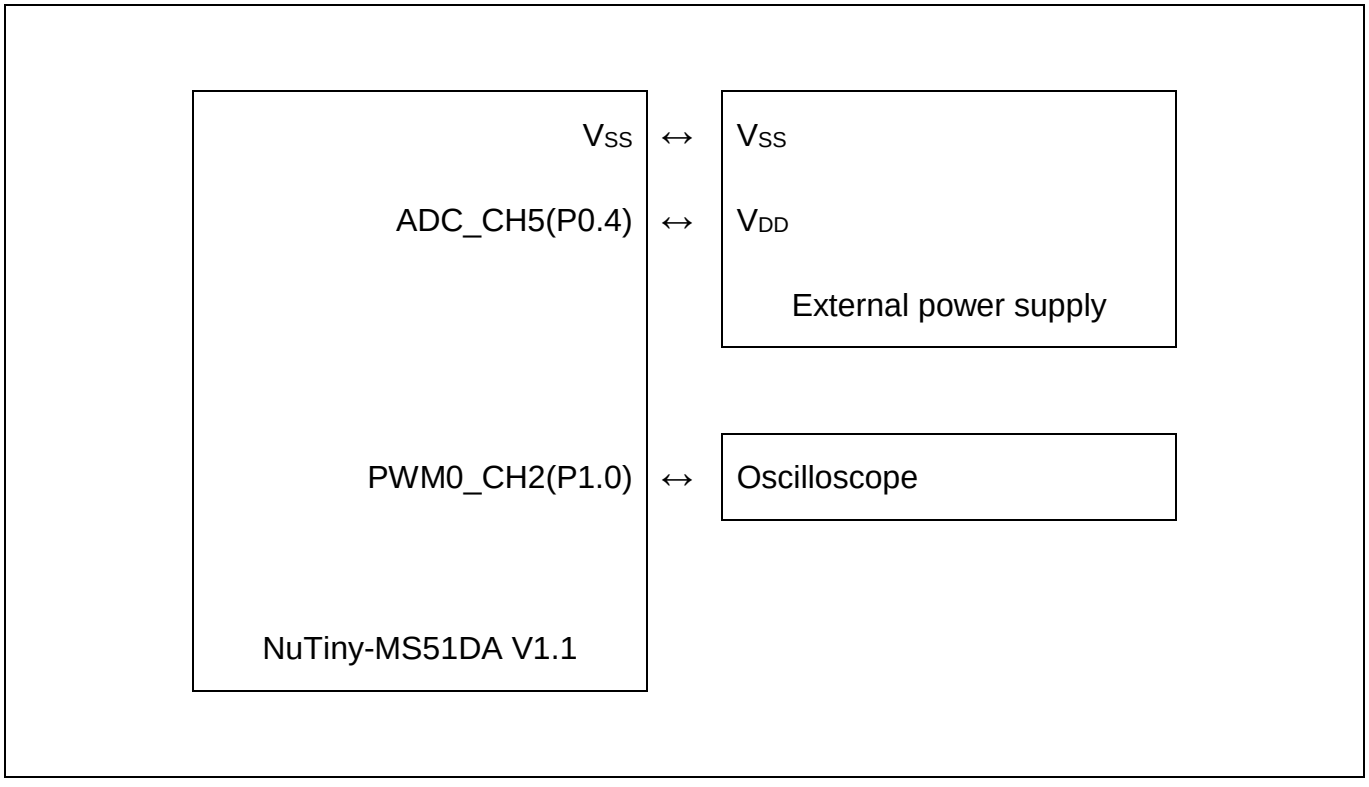

圖 3-1 腳位連接

4. 目錄資訊

EC_MS51_ADC_PWM_V1.00	
Library	Sample code header and source files
Device	MS51 series flash device header file
Startup	A51 startup file and executable file
StdDriver	All peripheral driver header and source files
SampleCode	
ExampleCode	Source file of example code

圖 4-1 目錄資訊

5. 範例程式執行

1. 根據目錄資訊章節進入 ExampleCode 路徑中的 KEIL 資料夾，雙擊 *MS51_ADC_PWM.uvproj*。
2. 進入編譯模式介面
   - 編譯
   - 下載代碼至記憶體
   - 進入 / 離開除錯模式
3. 進入除錯模式介面
   - 執行代碼

6. 修訂紀錄

Date	Revision	Description
2022.11.10	1.00	初始發布。

Important Notice

Nuvoton Products are neither intended nor warranted for usage in systems or equipment, any malfunction or failure of which may cause loss of human life, bodily injury or severe property damage. Such applications are deemed, "Insecure Usage".

Insecure usage includes, but is not limited to: equipment for surgical implementation, atomic energy control instruments, airplane or spaceship instruments, the control or operation of dynamic, brake or safety systems designed for vehicular use, traffic signal instruments, all types of safety devices, and other applications intended to support or sustain life.

All Insecure Usage shall be made at customer's risk, and in the event that third parties lay claims to Nuvoton as a result of customer's Insecure Usage, customer shall indemnify the damages and liabilities thus incurred by Nuvoton.

Please note that all data and specifications are subject to change without notice.
All the trademarks of products and companies mentioned in this datasheet belong to their respective owners.