PWM正弦波

NuMicro® 32 位系列微控制器範例代碼介紹

文件資訊

代碼簡述	使用 M031 的 PWM0 通道和 RC 濾波器，產生 60 Hz 的正弦波。
BSP 版本	M031_Series_BSP_CMSIS_V3.02.000
開發平台	NuMaker-M032SE V1.3

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1 功能介紹

1.1 簡介

範例程式使用M031的PWM0通道0，產生60 Hz的正弦波。為了產生高解析的正弦波，將單一正弦波分成360點。並基於正弦數值以及PWM週期值，各點有不同的PWM佔空比數值。然後PWM會依照正弦波的頻率，根據各點的數值改變佔空比的數值。藉由使用外部RC濾波器，PWM輸出將形成平滑的正弦波。

1.2 原理

為了獲得360點的PWM佔空比數值，範例程式使用各點的正弦數值和PWM週期值相乘。這些數值會形成查找表陣列，供PWM要改變佔空比時使用。由於正弦數值的範圍在-1到1之間，因此需要加上偏移值1，將正弦值移到0和2之間。接著除以2，讓正弦值最後壓縮在0到1之間。
範例程式同時使用Timer0，並且使能Timer0中斷，用來改變PWM的佔空比數值。Timer0使用週期模式，使Timer0能夠自動重載Timer數值，達到週期中斷。
Timer0的超時週期計算公式，如下所示：

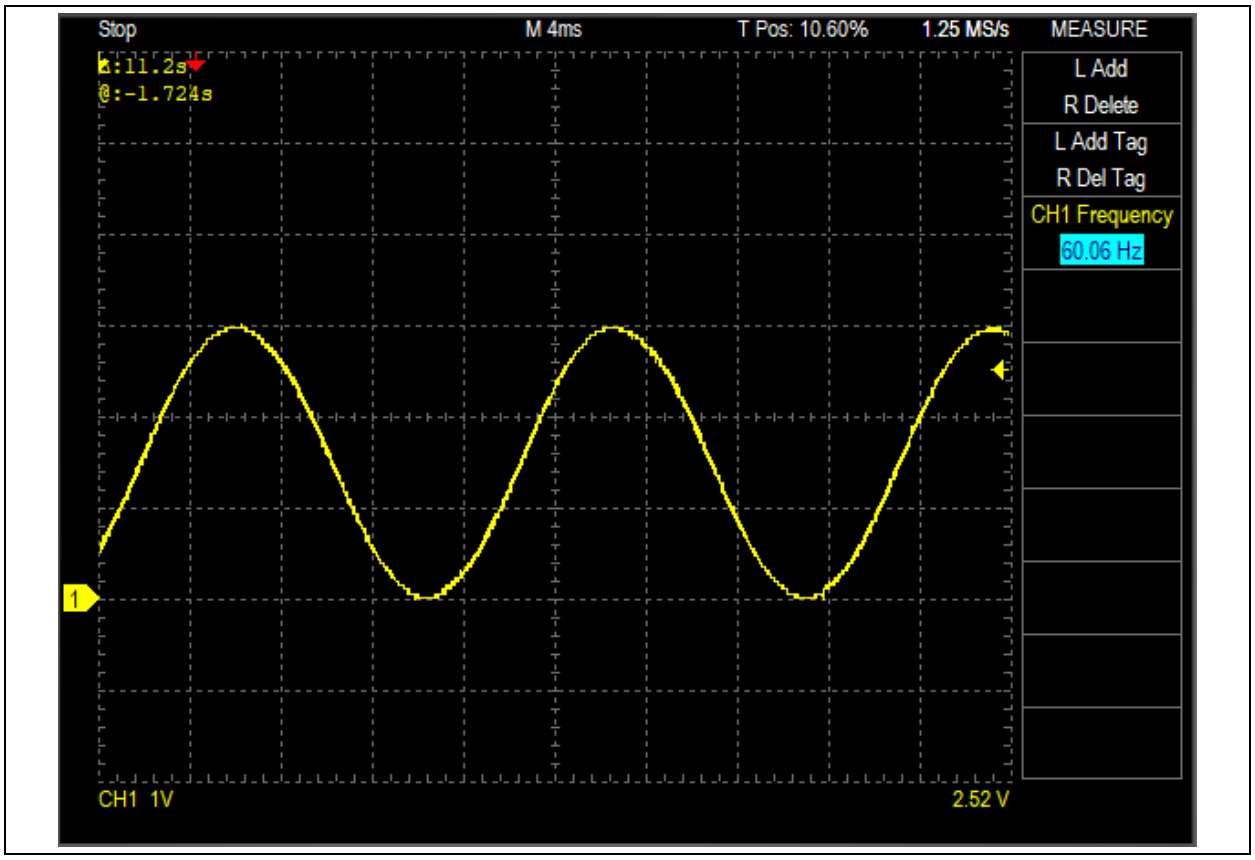
$$\text{超時週期} = \frac{1}{\text{TMR0_FREQ}} = \frac{1}{\text{正弦波頻率} * \text{正弦波解析度}}$$

由於正弦波頻率為60 Hz，且正弦波解析度為360時，TMR0_FREQ經由公式可以得到21600。另外若藉由於使用高頻率PWM以及外部RC濾波器，可使輸出的正弦波會更平滑。
PWM頻率的計算公式，如下所示：

$$\text{PWM頻率} = \frac{\text{Fsys}}{\text{PWM_PERIOD}}$$

根據計算公式，當Fsys為48 MHz，並且PWM頻率為20 kHz時，PWM_PERIOD的值將會是2400。使用者需要對PWM通道輸出，使用100 Ω電阻以及4.7 μF電容，作為外部RC濾波器。

1.3 執行結果


Stop
M 4ms
T Pos: 10.60%
1.25 MS/s
MEASURE
L Add
R Delete
L Add Tag
R Del Tag
CH1 Frequency
60.06 Hz
CH1 1V
2.52 V

2 代碼介紹

基於正弦數值以及PWM週期值，計算PWM佔空比數值的查找表。

```
    /* Create sine table for lookup */
    for (i = 0; i < 360; i++)
        /* Add 1.0 to offset sine result from [-1, 1] to [0, 2],
        and divide with 2.0 to compress to [0, 1] */
        g_au16Sine[i] = ((sin((i * Pi_Value) / 180.0) + 1.0) / 2.0) * PWM_PERIOD;
```

設定Timer0以及始能中斷，以改變PWM佔空比數值。

```
    /* Set timer frequency to 21600Hz */
    TIMER_Open(TIMER0, TIMER_PERIODIC_MODE, TMR0_FREQ);
    /* Enable timer interrupt */
    TIMER_EnableInt(TIMER0);
    NVIC_EnableIRQ(TMR0_IRQn);
```

設定PA.5為PWM0通道0，並且設定PWM頻率為20 kHz。

```
    /* Set PA5 multi-function pin for PWM0 Channel 5 */
    SYS->GPA_MFPL = (SYS->GPA_MFPL & ~(SYS_GPA_MFPL_PA5MFP_Msk)) |
                    (SYS_GPA_MFPL_PA5MFP_PWM0_CH0);
    …
    …
    …
    /* PWM0 channel 0 frequency and duty configuration are as follows */
       PWM_ConfigOutputChannel(PWM0, 0, PWM_FREQ, 50);
    /* Enable output of PWM0 channel 0 */
       PWM_EnableOutput(PWM0, 0x01);
```

開始Timer0和PWM。

```
    /* Start Timer0 counter */
    TIMER_Start(TIMER0);
    /* Start PWM counter */
    PWM_Start(PWM0, 0x01);
```

在Timer0中斷處理中，改變PWM的佔空比數值，以及將指標移往下一個數值。如果指標等於360，則重新歸零。然後再次開始PWM。

```
void TMR0_IRQHandler(void)
{
    if(TIMER_GetIntFlag(TIMER0) == 1)
    {
        /* Clear Timer0 time-out interrupt flag */
```

```
        TIMER_ClearIntFlag(TIMER0);
        /* Set PWM new setting according to sine phase from lookup table */
        PWM_SET_CMR(PWM0, 0, g_au16Sine[g_u16Sine_Count]);

        /* Add sine array pointer */
        g_u16Sine_Count++;

        /* Reset sine array pointer */
        if (g_u16Sine_Count == 360)
        {
            g_u16Sine_Count = 0;
        }
    }
}
```

3 軟體與硬體環境

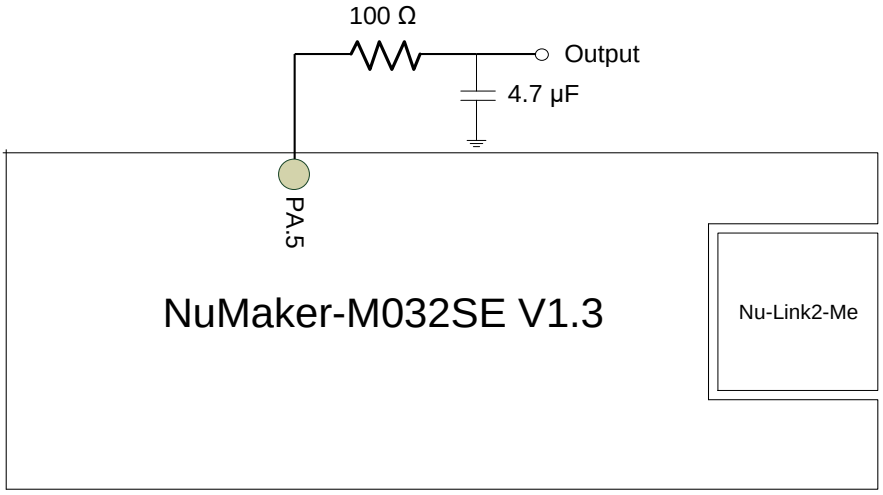
● 軟體環境

- ■ BSP 版本
  - ◆ M031_Series_BSP_CMSIS_V3.02.000
- ■ IDE 版本
  - ◆ Keil uVersion 5.28

● 硬體環境

- ■ 電路元件
  - ◆ NuMaker-M032SE V1.3
- ■ 示意圖

M031使用PWM0通道0來產生60 Hz的正弦波，還有PWM通道的輸出需要使用100 Ω電阻以及4.7 μF電容，作為外部RC濾波器。



4 目錄資訊

- EC_M031_PWM_Sine_Wave_V1.00
  - Library — Sample code header and source files
    - CMSIS — Cortex® Microcontroller Software Interface Standard (CMSIS) by Arm® Corp.
    - Device — CMSIS compliant device header file
    - StdDriver — All peripheral driver header and source files
  - SampleCode
    - ExampleCode — Source file of example code

5 如何執行範例程式

1. 根據目錄資訊章節進入 ExampleCode 路徑中的 KEIL 資料夾，雙擊 EC_M031_PWM_Sine_Wave.uvprojx。
2. 進入編譯模式介面
   a. 編譯
   b. 下載代碼至記憶體
   c. 進入 / 離開除錯模式
3. 進入除錯模式介面
   a. 執行代碼

6 修訂紀錄

Date	Revision	Description
Nov. 22, 2019	1.00	1. 初始發布.

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