M480 PLC Pulse Ramp

Example Code Introduction for 32-bit NuMicro® Family

Information

Application	本範例代碼使用 M480 EPWM 與 PDMA Scatter-gather 模式來自動產生 PLC pulse ramp 梯形圖的波形圖
BSP Version	M480 Series BSP CMSIS V3.03.000
Hardware	NuMaker-PFM-M487 V3.0

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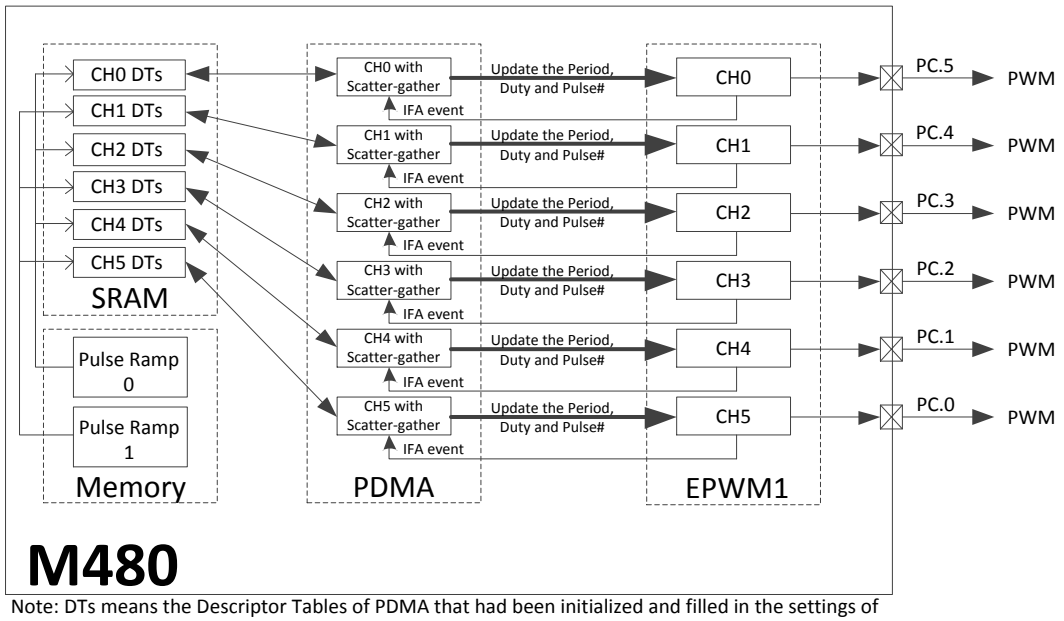
1 功能描述

1.1 介紹

本範例代碼使用 M480 EPWM 模塊與 PDMA 的 Scatter-gather 模式來產生 PLC 的 pulse ramp 梯形圖，並以示波器來觀測 PWM 的輸出波形。

1.2 原理

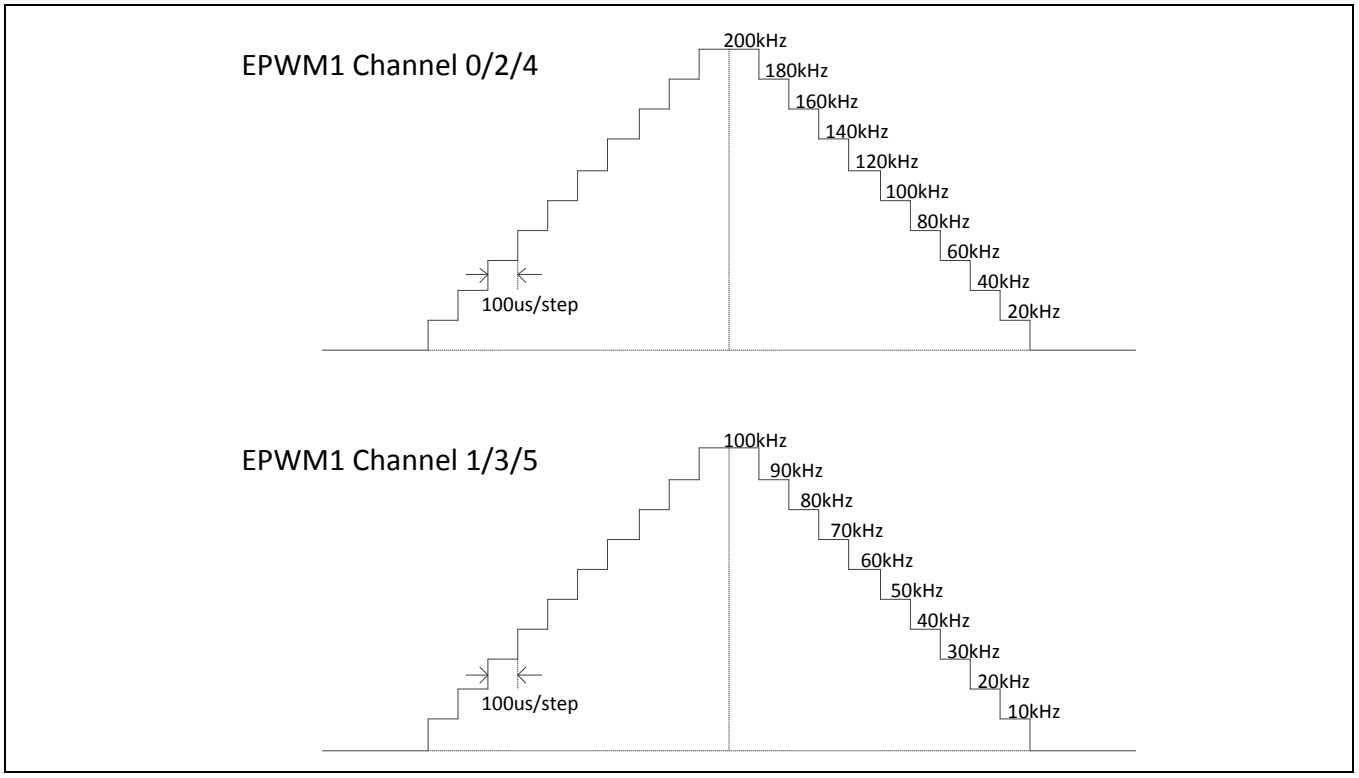
範例代碼中使用了 EPWM1 模塊的 6 個通道，分別為通道 0~5 (PC.5~PC.0)，並利用 EPWM 模塊內的 Interrupt Flag Accumulator (IFA) 中斷旗標計數的事件分別來觸發 PDMA 模塊的通道 0~5，而 PDMA 與其對應的每個通道都已事先規劃成 Scatter-gather 模式並已初始化它的描述表 (Descriptor Tables)，每個 PDMA 通道再利用這些描述表來自動更新下一個步驟 (step) 與其對應的 PWM 通道所要輸出的 period (週期 = 頻率的倒數)、duty (佔空比) 與 pulse 數 (脈衝數) 來達到自動產生 PLC 應用常見的 pulse ramp 梯形圖的 PWM 波形，M480 MCU 的 PDMA 與 EPWM1 功能方塊示意圖如下圖所示。



Note: DTs means the Descriptor Tables of PDMA that had been initialized and filled in the settings of Pulse Ramp 0 or Pulse Ramp 1 from memory by CPU at the initialization of sample code.

M480 PDMA 與 EPWM1 功能方塊示意圖

在此範例代碼中，規劃了兩種 pulse ramp 的梯形圖分別輸出在 EPWM1 的通道 0/2/4 與通道 1/3/5，每個梯形圖上升與下降分別分割成 10 個步驟 (step)，每個步驟 (step) 時間預設值為 100us，頻率差值為最高頻率的十分之一，如下圖所示。



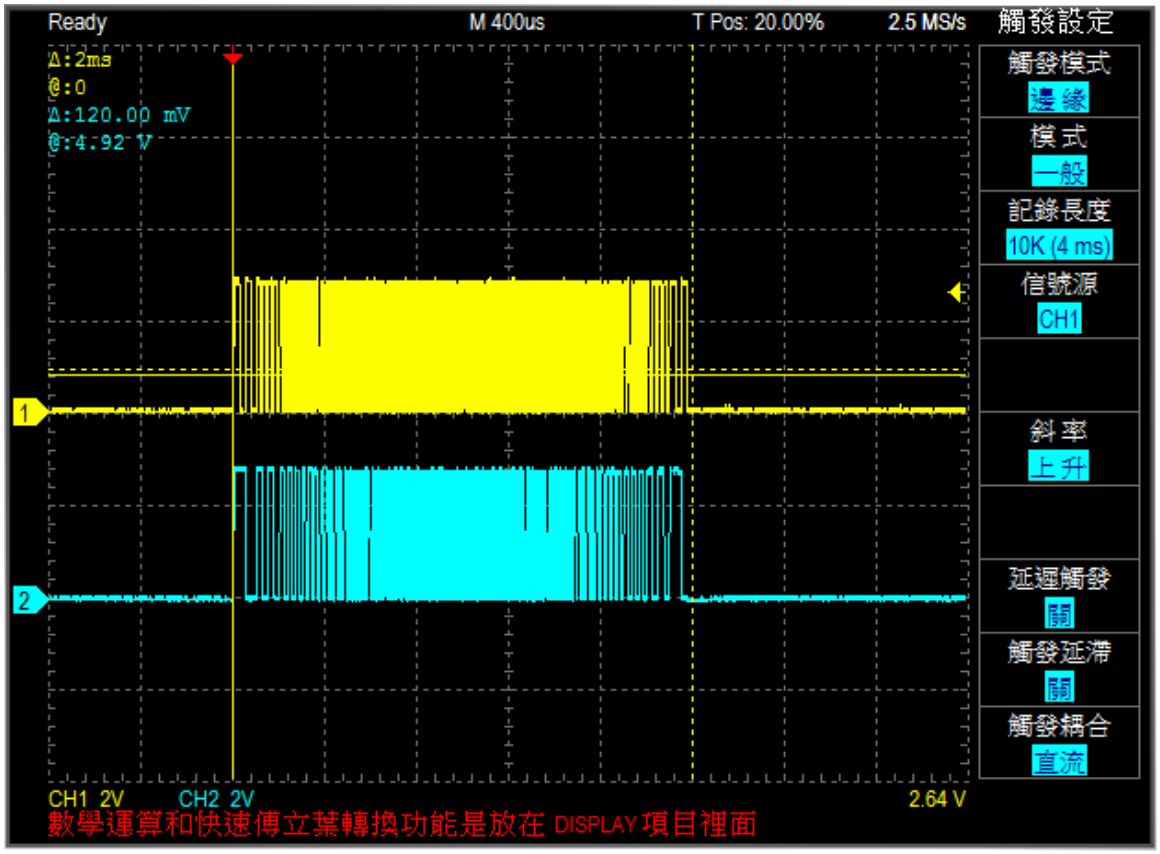
PLC Pulse Ramp 梯形圖

1.3 執行結果

執行代碼後，示波器顯示 EPWM 輸出 pulse ramp 梯形圖的波形圖。

CH1 (黃色) : EPWM1 通道 0 (or 2 or 4)

CH2 (藍色) : EPWM1 通道 1 (or 3 or 5)


Ready
M 400us
T Pos: 20.00%
2.5 MS/s
觸發設定
Δ:2ms
@:0
Δ:120.00 mV
@:4.92 V
觸發模式
邊緣
模式
一般
記錄長度
10K (4 ms)
信號源
CH1
斜率
上升
延遲觸發
關
觸發延滯
關
觸發耦合
直流
CH1 2V
CH2 2V
2.64 V
數學運算和快速傅立葉轉換功能是放在 DISPLAY 項目裡面

示波器顯示的波形圖

2 代碼介紹

Init_PDMA_CHx() 函式主要是對 PDMA 的通道 (0~5) 致能 Scatter-gather 模式與其對應的 Descriptor Tables 做初始化的設定。每一次 EPWM 模塊內的 Interrupt Flag Accumulator (IFA) 中斷旗標計數的事件發生時，就會觸發 PDMA 的通道做下一個步驟 (step) 對應的 EPWM 通道輸出的 period (頻率的倒數)、duty (佔空比) 與 pulse 數 (脈衝數) 做一次性的更新，直到最後的一個步驟 (step) 的 Descriptor Table 設定條件發生時，即產生 PDMA Transfer Done 事件觸發 PDMA 中斷，當進入 PDMA 中斷服務程式後，立即關閉 PWM 的輸出來結束此通道的 pulse ramp 梯形圖。

```
/**
 * @brief       Initial PDMA Channels
 *
 * @param       DMA_CHx: PDMA channel number (0~5)
 *              EPWMx: EPWM0 or EPWM1 module
 *              DescTable: Descriptor Table struct
 *              PeriodTable: Period table
 *              DutyTable: Duty table
 *              PulseTable: Pulse number table
 *
 * @return      None
 *
 * @details     To initial the PDMA channel 0~5 with Scatter-gather mode and their
descriptor tables
 */
void Init_PDMA_CHx(uint32_t DMA_CHx, EPWM_T *EPWMx, DMA_DESC_T *DescTable, uint32_t
*PeriodTable, uint32_t *DutyTable, uint32_t *PulseTable)
{
    uint8_t i;


    /* Enable Scatter Gather mode, assign the first scatter-gather descriptor table is
DescTable 0, and set transfer mode as memory to peripheral */
    if(EPWMx == EPWM0){
        if(DMA_CHx == 0)
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM0_CH0_TX, 1, (uint32_t)&DescTable[0]);
        else if(DMA_CHx == 1)
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM0_CH1_TX, 1, (uint32_t)&DescTable[0]);
        else if(DMA_CHx == 2)
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM0_CH2_TX, 1, (uint32_t)&DescTable[0]);
        else if(DMA_CHx == 3)
```

```
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM0_CH3_TX, 1, (uint32_t)&DescTable[0]);
        else if(DMA_CHx == 4)
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM0_CH4_TX, 1, (uint32_t)&DescTable[0]);
        else if(DMA_CHx == 5)
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM0_CH5_TX, 1, (uint32_t)&DescTable[0]);
    }else{
         if(DMA_CHx == 0)
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM1_CH0_TX, 1, (uint32_t)&DescTable[0]);
        else if(DMA_CHx == 1)
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM1_CH1_TX, 1, (uint32_t)&DescTable[0]);
        else if(DMA_CHx == 2)
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM1_CH2_TX, 1, (uint32_t)&DescTable[0]);
        else if(DMA_CHx == 3)
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM1_CH3_TX, 1, (uint32_t)&DescTable[0]);
        else if(DMA_CHx == 4)
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM1_CH4_TX, 1, (uint32_t)&DescTable[0]);
        else if(DMA_CHx == 5)
            PDMA_SetTransferMode(PDMA, DMA_CHx, EPWM1_CH5_TX, 1, (uint32_t)&DescTable[0]);
    }

    /* Inital the Descriptor Tables */
    for(i=0; i<=18; i++){
        /*--- Descriptor Table 0 ---*/
        DescTable[i*3].ctl =
            ((PDMA_TEST_LENGTH - 1) << PDMA_DSCT_CTL_TXCNT_Pos) | /* Transfer count is
PDMA_TEST_LENGTH */ \
            PDMA_WIDTH_32 |   /* Transfer width is 32 bits(one word) */ \
            PDMA_SAR_FIX |    /* Source increment size is 32 bits(one word) */ \
            PDMA_DAR_FIX |    /* Destination increment size is 32 bits(one word) */ \
            PDMA_REQ_BURST |  /* Transfer type is single transfer type */ \
            PDMA_BURST_1 |    /* Burst size is 1. No effect in single transfer type */ \
            PDMA_TBINTDIS_DISABLE |/* Disable transfer done and table empty interrupt */ \
            PDMA_OP_SCATTER;  /* Operation mode is scatter-gather mode */

        /* Configure source address */
        DescTable[i*3].src = (uint32_t)&(PeriodTable[i]);
        /* Configure destination address */
        DescTable[i*3].dest = (uint32_t)&(EPWMx->PERIOD[DMA_CHx]);
        /* Configure next descriptor table address */
        DescTable[i*3].offset = (uint32_t)&DescTable[i*3+1] - (PDMA->SCATBA); /* next
descriptor table is table 1 */
```

```
        /*--- Descriptor Table 1 ---*/
        DescTable[i*3+1].ctl =
            ((PDMA_TEST_LENGTH - 1) << PDMA_DSCT_CTL_TXCNT_Pos) | /* Transfer count is
PDMA_TEST_LENGTH */ \
            PDMA_WIDTH_32 |   /* Transfer width is 32 bits(one word) */ \
            PDMA_SAR_FIX |    /* Source increment size is 32 bits(one word) */ \
            PDMA_DAR_FIX |    /* Destination increment size is 32 bits(one word) */ \
            PDMA_REQ_BURST |  /* Transfer type is single transfer type */ \
            PDMA_BURST_1 |    /* Burst size is 1. No effect in single transfer type */ \
            PDMA_TBINTDIS_DISABLE |/* Disable transfer done and table empty interrupt */ \
            PDMA_OP_SCATTER;  /* Operation mode is scatter-gather mode */

        /* Configure source address */
        DescTable[i*3+1].src = (uint32_t)&(DutyTable[i]);
        /* Configure destination address */
        DescTable[i*3+1].dest = (uint32_t)&(EPWMx->CMPDAT[DMA_CHx]);
        /* Configure next descriptor table address */
        DescTable[i*3+1].offset = (uint32_t)&DescTable[i*3+2] - (PDMA->SCATBA); /* next
descriptor table is table 2 */

        /*--- Descriptor Table 2 ---*/
        DescTable[i*3+2].ctl =
            ((PDMA_TEST_LENGTH - 1) << PDMA_DSCT_CTL_TXCNT_Pos) | /* Transfer count is
PDMA_TEST_LENGTH */ \
            PDMA_WIDTH_32 |   /* Transfer width is 32 bits(one word) */ \
            PDMA_SAR_FIX |    /* Source increment size is 32 bits(one word) */ \
            PDMA_DAR_FIX |    /* Destination increment size is 32 bits(one word) */ \
            PDMA_REQ_SINGLE | /* Transfer type is single transfer type */ \
            PDMA_BURST_1 |    /* Burst size is 1. No effect in single transfer type */ \
            PDMA_TBINTDIS_DISABLE |/* Disable transfer done and table empty interrupt */ \
            PDMA_OP_SCATTER;  /* Operation mode is scatter-gather mode */

        /* Configure source address */
        DescTable[i*3+2].src = (uint32_t)&(PulseTable[i]);
        /* Configure destination address */
        DescTable[i*3+2].dest = (uint32_t)&(EPWMx->IFA[DMA_CHx]);
        /* Configure next descriptor table address */
        DescTable[i*3+2].offset = (uint32_t)&DescTable[i*3+3] - (PDMA->SCATBA); /* next
descriptor table is table 3 */
    }
```

```
    /*--- The last Descriptor Table ---*/
    DescTable[i*3].ctl =
        ((PDMA_TEST_LENGTH - 1) << PDMA_DSCT_CTL_TXCNT_Pos) | /* Transfer count is
PDMA_TEST_LENGTH */ \
        PDMA_WIDTH_32 |   /* Transfer width is 32 bits(one word) */ \
        PDMA_SAR_FIX |    /* Source increment size is 32 bits(one word) */ \
        PDMA_DAR_FIX |    /* Destination increment size is 32 bits(one word) */ \
        PDMA_REQ_SINGLE | /* Transfer type is single transfer type */ \
        PDMA_BURST_1 |    /* Burst size is 1. No effect in single transfer type */ \
        PDMA_OP_BASIC;    /* Operation mode is Basic mode */

    /* Configure source address */
    DescTable[i*3].src = (uint32_t)&(PeriodTable[i]);
    /* Configure destination address */
    DescTable[i*3].dest = (uint32_t)&(EPWMx->PERIOD[DMA_CHx]);
    /* Configure next descriptor table address */
    DescTable[i*3].offset = 0;

    /* Enable PDMA Transfer Done interrupt */
    PDMA_EnableInt(PDMA, DMA_CHx, PDMA_INT_TRANS_DONE);

    printf("Initial PDMA Channel %d done.\n", DMA_CHx);

}
```

Init_EPWM_CHx() 函式主要是對 EPWM 模塊內的通道 (0~5) 做初始化的設定。此初始化須先給定每個 EPWM 通道在 pulse ramp 梯形圖中第一個步驟 (step) 所要輸出的 period (頻率的倒數)、duty (佔空比) 與 pulse 數 (脈衝數)，並致能 EPWM 模塊內的 Interrupt Flag Accumulator (IFA) 中斷旗標計數的功能來觸發 PDMA 對應通道的 Scatter-gather 模式下的 Descriptor Tables 所要執行的相對動作。

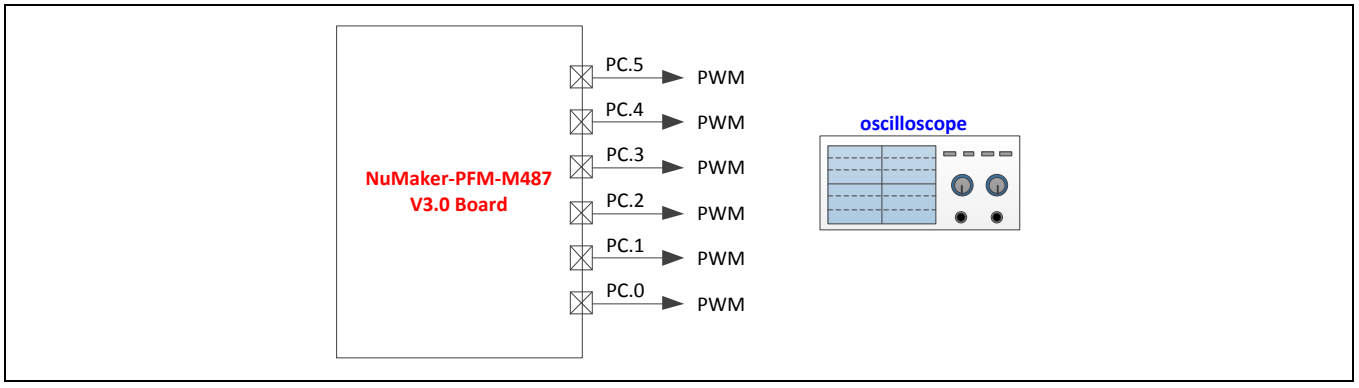
```
/**
 * @brief       Initial EPWM Channels
 *
 * @param       EPWMx: EPWM0 or EPWM1 module
 *              PWM_CHx: PWM channel number (0~5)
 *              Freq_1st: The frequency at the first step
 *              Duty_1st: The duty at the first step (In generally, it is 50%.)
 *              Pulse_1st: The pulse number at the first step
```

```
 *
 * @return      None
 *
 * @details     To initial frequency, duty and pulse number of EPWM channel 0~5 for the first step
 */
void Init_EPWM_CHx(EPWM_T *EPWMx, uint32_t PWM_CHx, uint32_t Freq_1st, uint32_t Duty_1st, uint32_t Pulse_1st)
{
    /* Set EPWMx channel x output configuration */
    EPWM_ConfigOutputChannel(EPWMx, PWM_CHx, Freq_1st, Duty_1st);

    /* Enable EPWM Output path for EPWMx channel x */
    EPWM_EnableOutput(EPWMx, 1 << PWM_CHx);

    /* Enable EPWMx channel x accumulator, interrupt count 1, accumulator source select to period point */
    EPWM_EnableAcc(EPWMx, PWM_CHx, Pulse_1st, EPWM_IFA_ZERO_POINT);

    /* Enable EPWMx channel x accumulator interrupt */
    EPWM_EnableAccInt(EPWMx, PWM_CHx);

    /* Enable EPWMx channel x accumulator interrupt trigger PDMA */
    EPWM_EnableAccPDMA(EPWMx, PWM_CHx);

#ifdef EN_EPWM_INDEP
    /* Enable Timer for EPWMx channel x */
    EPWM_Start(EPWMx, 1 << PWM_CHx);
#endif

    printf("Initial EPWM%d Channel %d done.\n", (EPWMx == EPWM1 ? 1 : 0), PWM_CHx);

}
```

3 軟體和硬體環境

- **軟體環境**
  - BSP 版本
    - M480 Series BSP CMSIS V3.03.000
  - IDE 版本
    - Keil uVersion 4.74
- **硬體環境**
  - 電路元件
    - NuMaker-PFM-M487 V3.0 開發板
  - 示意圖

M480 EPWM1 的通道 0~5 (亦即 PC.5~PC.0) 輸出 PLC pulse ramp 梯形圖的 PWM 波形，利用示波器來檢測 PWM 的波形。



硬體示意圖

4 目錄資訊

- EC_M480_PLC_PulseRamp_V1.00
  - Library — Sample code header and source code files
    - CMSIS — Cortex® Microcontroller Software Interface Standard (CMSIS) by Arm® Corp.
    - Device — CMSIS compliant device header files
    - StdDriver — All peripheral driver header and source code files
  - SampleCode
    - ExampleCode — Source code files of this 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 M480_PLC_PulseRamp.uvproj
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
June 28, 2019	1.00	1. 初始發布.

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