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RENESAS

M16C/60, M16C/Tiny

High Speed High Resolution PWM Using IAR C-Compiler

Introduction

The M32C and M16C family provides PWM (Pulse Width Modulation) functionality through timer A modes. Up to five timer A's are available for PWM mode with 8bit or 16bit resolution selectable. These timers use internal clock divider from Xin (or internal PLL output) signal to create the modulation signal. The maximum PWM frequency is achieved when using divide by 1 (also called f1 inside the device).The maximum PWM frequency is equal to f1 divided by 2 to the power of the PWM resolution in number of bits.

As example when 13bit resolution the maximum frequency would be 2.929KHZ with 24MHZ timer clock ($24 \times 10^6 / (2^{13}) = 2{,}929$)

For some applications it is required to have higher frequencies in order to avoid audible switching frequencies and/or to filter more easily the PWM signal. The purpose of this application note is to show how a high frequency PWM with a high resolution can be implemented. The example outputs a 20KHZ or higher frequency PWM with a 13 bits resolution.

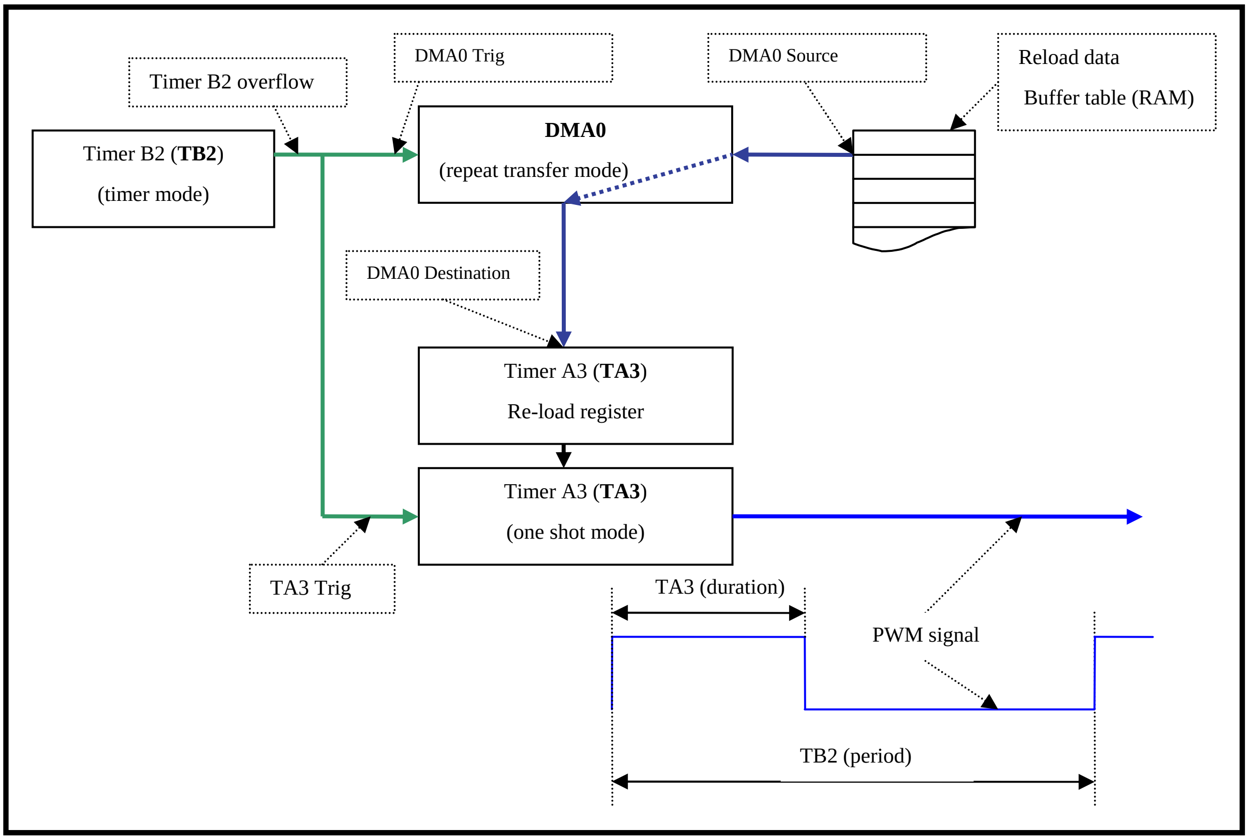
Contents

Peripheral usage and settings.

This application note uses the internal DMA channel in repeat mode to modulate the content of the PWM generation timer. The basic operations for variable PWM resolution are described in the application note *"How to generate variable resolution PWM with M16C family processors"*, it is recommended to read this application note before starting with current one.

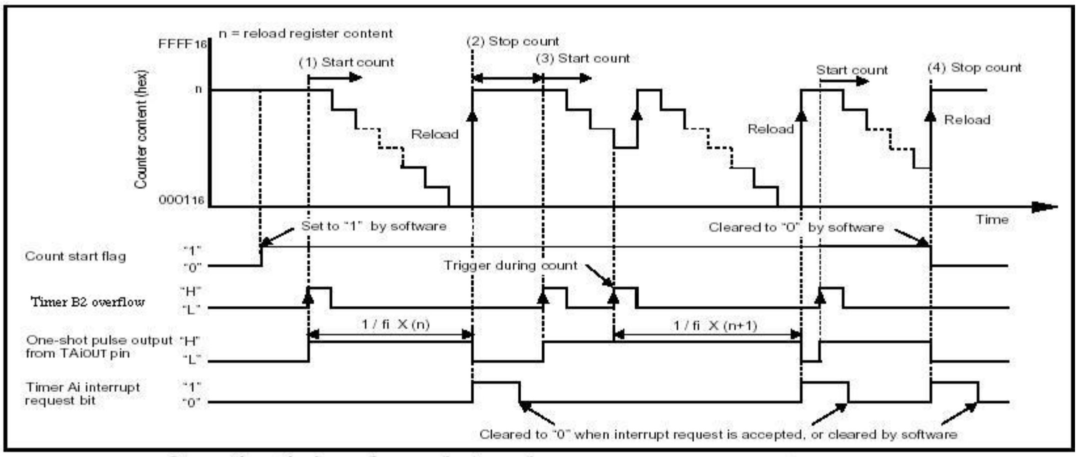
Timer B2 (TB2) is used as trigger source for DMA0 channel as well as for the Timer A3 (TA3). TA3 is set in one shot mode trigged by TB2. The PWM frequency is defined by TB2 settings and contents. TA3 contents define the output pulse high duration. DMA0 transfers data from a RAM table, which is updated by the MCU application software, to the TA3 register.

Such operation can also be used to generate specific signals (sinus, triangular, noise…) in an automatic manner.



1. Operation timing of Timer A one-shot mode

In this mode Timer A outputs a high level pulse with a duration time defined by Timer A reload register contents.



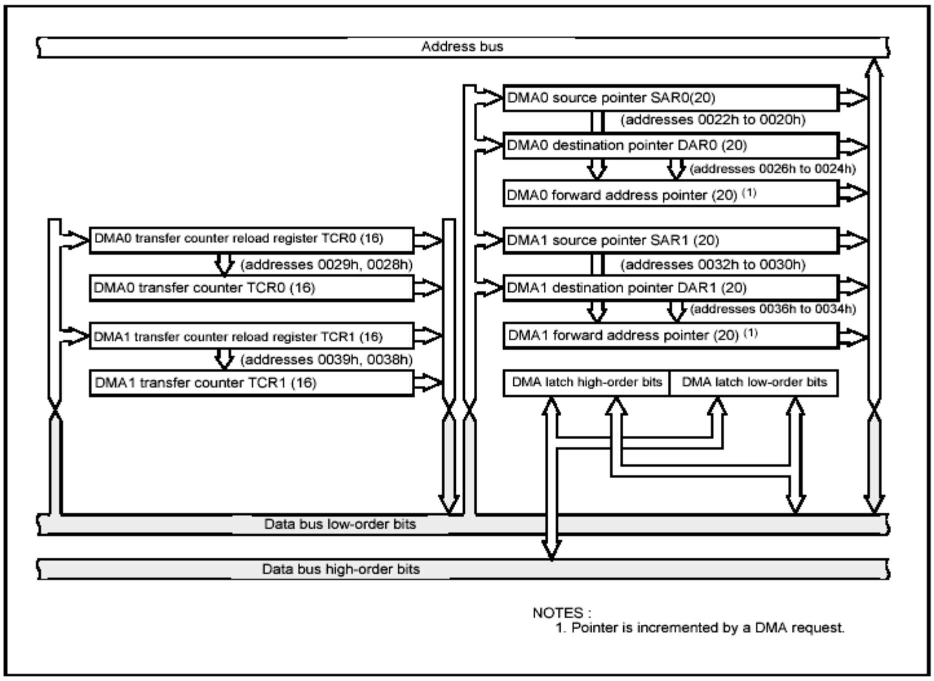
Operation timing of one-shot mode

2. M16C DMA operation.

All M16C devices have at least two DMA channels (DMA0 and DMA1). DMA's role is to transfer a certain amount of data (defined by software) from a source to a destination trigged by some event. To achieve this each DMA channel has its own source register (20bit address), destination register (also 20bits) and count register (16bits) along with configuration registers.

The DMA source and/or destination can be any location inside the M16C, it could be either RAM or Flash or SFR register. DMA block diagram is bellow.

The DMA channel only accepts source or destination increment (not both at same time).



3. DMA configuration.

Either DMA0 or DMA1 can be used to achieve this application; DMA0 has been selected for this application.

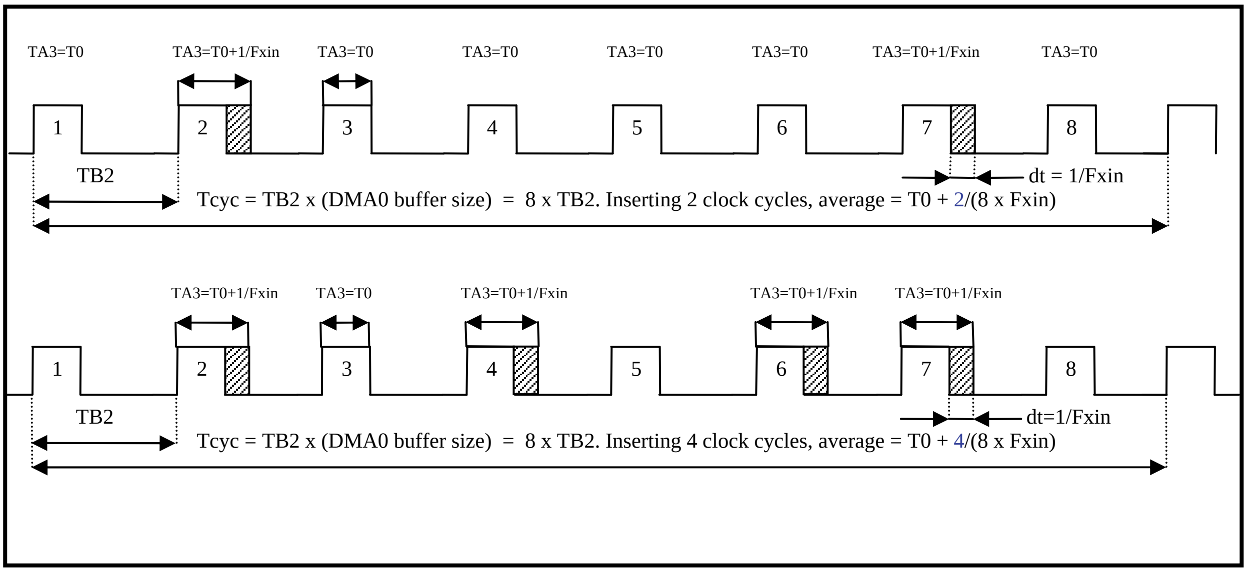
DMA0 is used in repeat mode with fixed destination and forward source which means that the source pointer is incremented after each DMA transfer. When the transfer counter (TCR0) reaches zero the source pointer and the transfer counter are automatically reloaded with their SFR reload register values and process continues.

The DMA0 channel source points to the buffer table that contains the data to be set for each PWM cycle, the destination is the TA3 reload register and the number of transfers is defined as source buffer table size (8 in this example).

Increasing PWM resolution keeping frequency.

As explained in the introduction chapter, the maximum PWM frequency is limited by the requested resolution and operating frequency of the timers. In this example the requested 20KHZ PWM frequency using 20MHZ clock frequency leads to have TB2=1000 (which can also achieve 24KHZ PWM for same TB2 value and Xin=24MHZ). In order to make things easier to calculate and understand it has been chosen to select TB2= 1024 which is the power of 2 value closest to 1000. This will lead to have a PWM frequency of 19.531KHZ with Xin=20MHZ or 23.437KHZ with Xin=24MHZ.

In normal operation for a fixed PWM value the duration at high level and low level are fixed from period to period. The principle implemented here is to change dynamically, using the DMA0, the PWM value in order to create an average result (over 8 PWM periods in this application note example) which increase the resolution compared to standard drive. Bellow figure explains the operation for 2 different PWM values.



If Th1 is the duration at high level for first period in the cycle and Th2 the same for second period and so on, the average value over 8 periods is equal to (Th1+Th2+…+Th8)/8.

Software

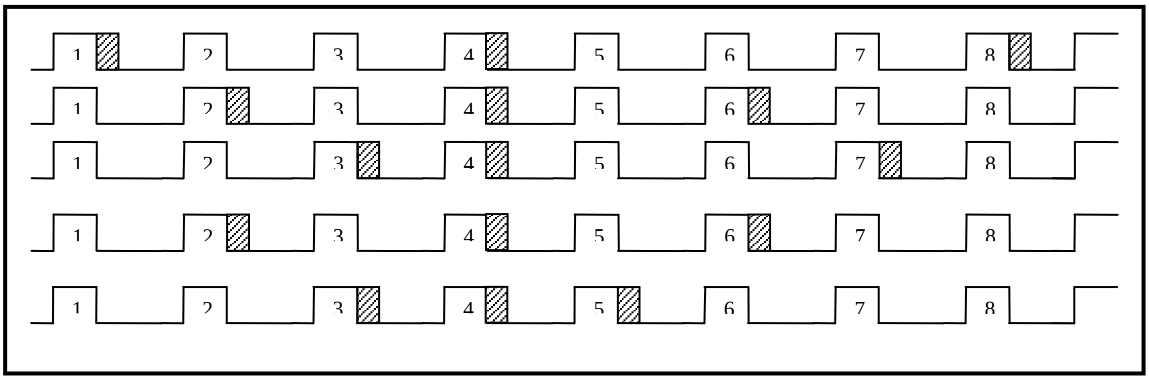
Software Algorithm

The main calculation function is *Filling_Dma*, it gets as parameter the PWM value (with 13 representative bits), splits the value in *MSB* (10bits) and *LSB* (3bits) and uses a constant look-up table to fill-in the *Pwm_Table* buffer. *MSB* is the default value for TA3, the *LSB* parameter indicates how many periods in a 8 period frame will have one additional unit in duration high of the PWM signal (*MSB*+1).

The *Pwm_Table* contents are sent automatically every TB2 overflow to TA3 by the DMA0.

The reason for the look-up table is to reduce the ripple noise due to the value averaging over 8 samples. The same average value can be reached with different *Pwm_Table* values as shown in bellow drawing example.

The drawing bellow shows some possible combinations when lsb = 3 (which means that 3 periods in a frame of 8 will have one unit more in pulse duration while the other 5 periods remain non modified).



Conclusion.

This piece of software allows expanding system performance without any extra cost.

The CPU usage is limited to the *Pwm_Table* calculation, when no change to PWM value is required the peripherals are set so that they run automatically which results on an almost zero cpu load.

As well the code size is very limited; the main routine with initialization and push button scan uses only 315 bytes of code.

Appendix

Code listing

```
#define uint unsigned int
#define uchar unsigned char
// defines definition
#define RESOLUTION_INCREASE 3 //number of bits increased in resolution
#define RECURRENCE_SIZE       8 // 2 to the power 3 (number of bits to increase the
resolution
#define SW_INT0             (P8&0x04)
#define SW_INT1             (P8&0x08)
#define SW_INT2             (P8&0x10)
#define LED4                P2_bit.P2_3
#define LED6                P2_bit.P2_5
```

```
#define LED8                P2_bit.P2_7
#define TEMPO               100
#define PWM_TIME              1024  // Value stored in TB2 and max value to be stored in
TA3
#define TMAX                (PWM_TIME*8-10)
#define TMIN                10
#define T0                  514*8
// Constant table (for bit timming insertion).
const uchar Stuffing[]={0,0x8,0x24,0x25,0xaa,0xab,0xbb,0xfb};
// Global variables definition
uint Pwm_Table[RECURRENCE_SIZE];  // Holds PWM values to be transfered to one shot timer
uchar tempo;  // Used to slow down push switches scanning code .
// -----------------------------------------------------------------------------
void Filling_Dma(value)
{
unsigned char lsb,i;
unsigned int  msb;

lsb = value & 0x07;         // store the 3 lsb bits for table update
msb = (value>>3) & 0x03ff;  // Limit the number to 10bits
lsb = Stuffing[lsb] ;        // Use the lsb bits to address the look-up table
for(i=0;i!= RECURRENCE_SIZE;i++)
  {
  if((lsb & 1)==1)
    Pwm_Table[i] = msb +1;
  else
    Pwm_Table[i] = msb;
  lsb = lsb>>1;
  }
}

void main (void)
{
unsigned int t; // Timer Period

  init();
  tempo = TEMPO;
  t = T0;
  Filling_Dma(T0);              // Initialise DMA table with default value
  timer_a3_init_one_shot_timer_mode ();
  timer_a3_set(Pwm_Table[0]); // Set first PWM value in One Shot timer (Timer A3)
  dma0_init_repeated_transfer_mode(Pwm_Table,(void *)&TA3,8);
  dma0_start();                 // Allow DMA
  timer_b2_init_timer_mode ();
  timer_b2_set (PWM_TIME-1);  // BCLK = 24MHZ => 24KHZ periodic pulse
  timer_b2_start ();          // Start Timer B2 (trig source for Timer A3)
  timer_a3_start ();          // Start Timer A3 (One shot timer)
  for(;;)         // Never ending loop
    {
// Increase duty cycle
```

```
  if(!SW_INT2)
    {
    LED4 = 1; // Light ON LED to show push button is pressed.
    tempo--;
    if(tempo == 0)      // Slow down loop
      {
      tempo = TEMPO;
      if(t<TMAX)  t++;  // Increase duty cycle by one unit
      }
    }
    else LED4 = 0;
// Decrease duty cycle
  if(!SW_INT0)
    {
    LED8 = 1;
    tempo--;
    if(tempo == 0)
      {
      tempo = TEMPO;
      if(t>TMIN) t--;
      }
    }
    else LED6 = 0;
// restore default duty cycle
  if(!SW_INT1)
    {
    LED6 = 1;
    t = T0 ;
    }
    else LED8 = 0;
  Filling_Dma(t);
  };
}
```

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