PWM System (Part 2)
There are 6 PWM channels. Each can be independently controlled.

Figure 12-1. PWM8B6CV1 Block Diagram

from MC9S12C Family Reference Manual
PWM signals come out to Port P (PP0:PP5)

However, some chips don’t have any Port P pins. So PWM signals can be routed to Port T (PT0:PT4)

This multiplexer can route PWM signals to Port T

from MC9S12C Family Reference Manual
PWM Clock / Channel

- There are two sets of clocks: A, B, SA (scaled A), SB (scaled B)
  - Clocks A, B are the system clock divided by M, where M=1,2,4,8, ..., 128
  - Clocks SA, SB are generated by an additional division by N*2, for N=1 through 256

- Channels
  - Clock A, SA used for channels 0, 1, 4, 5
  - Clock B, SB used for channels 2, 3
Note: there is an option to concatenate two PWM channels into a single channel. This allows for a 16-bit counter and 16-bit duty and period registers.

from MC9S12C Family Reference Manual
PWM Clock Registers

- **PWMSCLA, PWMSCLB**
  - These contain the number N to use for the clock divider, for SA and SB

- **PWMCLK**
  - Selects which clock to use for each channel:

    | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
    |---|---|---|---|---|---|---|---|
    | PCLK7 | PCLK6 | PCLK5 | PCLK4 | PCLK3 | PCLK2 | PCLK1 | PCLK0 |

  reset: 0 0 0 0 0 0 0 0

  PCLKx: PWM channel x clock select (x = 7, 6, 3, 2)
  0 = clock B as the clock source
  1 = clock SB as the clock source
  PCLKy: PWM channel y clock select (y = 5, 4, 1, 0)
  0 = clock A as the clock source
  1 = clock SA as the clock source

  Figure 8.42 PWM clock select register (PWMCLK)

  - How to select clock SA for channel 0?
PWM Clock Registers (continued)

- **PWMPRCLK**
  - Used to set the value of M (prescalar value):

    ```
    | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
    |---|---|---|---|---|---|---|---|
    | 0 | PCKB2 | PCKB1 | PCKB0 | 0 | PCKA2 | PCKA1 | PCKA0 |
    reset: | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
    ```

  - Example: to make the frequency of clock A equal to the E-clock divided by 64, what should we write to PWMPRCLK?

    - Table 8.3 Clock B prescaler selects
      ```
      | PCKB2 | PCKB1 | PCKB0 | value of clock B |
      |-------|-------|-------|-----------------|
      | 0     | 0     | 0     | E clock         |
      | 0     | 0     | 1     | E clock/2       |
      | 0     | 1     | 0     | E clock/4       |
      | 0     | 1     | 1     | E clock/8       |
      | 1     | 0     | 0     | E clock/16      |
      | 1     | 0     | 1     | E clock/32      |
      | 1     | 1     | 0     | E clock/64      |
      | 1     | 1     | 1     | E clock/128     |
      ```

    - Table 8.4 Clock A prescaler selects
      ```
      | PCKA2 | PCKA1 | PCKA0 | value of clock A |
      |-------|-------|-------|-----------------|
      | 0     | 0     | 0     | E clock         |
      | 0     | 0     | 1     | E clock/2       |
      | 0     | 1     | 0     | E clock/4       |
      | 0     | 1     | 1     | E clock/8       |
      | 1     | 0     | 0     | E clock/16      |
      | 1     | 0     | 1     | E clock/32      |
      | 1     | 1     | 0     | E clock/64      |
      | 1     | 1     | 1     | E clock/128     |
      ```
Other PWM registers

- **PWMPER0, PWMPER1, ... PWMPER5**
  - One register for each channel (0..5)
  - Put your desired period (in clock ticks) here

- **PWMDTY0, PWMDTY1, ... PWMDTY5**
  - One register for each channel (0..5)
  - Put your desired duty time (in clock ticks) here

- **PWMPOL**
  - Determines polarity of pulse (1=high, 0=low)
  - Usually we want the duty pulse high

![Figure 8.43 PWM polarity register (PWMPOL)]

<table>
<thead>
<tr>
<th>PPOL7</th>
<th>PPOL6</th>
<th>PPOL5</th>
<th>PPOL4</th>
<th>PPOL3</th>
<th>PPOL2</th>
<th>PPOL1</th>
<th>PPOL0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Reset: 0 0 0 0 0 0 0 0

PPOLx: PWM channel x polarity

- 0 = PWM channel x output is low at the start of a period, then goes high when the duty count is reached.
- 1 = PWM channel x output is high at the start of a period, then goes low when the duty count is reached.
Other PWM registers (continued)

• **PWME**
  
  – Enable PWM system for each channel

  ![PWM enable register diagram](image)

  **Figure 8.45** PWM enable register (PWME)

  **PWMEx:** PWM channel x enable
  
  0 = PWM channel x disabled.
  
  1 = PWM channel x enabled.

• **MODRR**
  
  – Set to 1 to route the PWM channel to the corresponding Port T pin

  ![Port T Module Routing Register diagram](image)

  **Figure 2-9. Port T Module Routing Register (MODRR)**
Example

• Generate a PWM signal with period = 20 ms. We did this example before, and found that any of these are ok:

<table>
<thead>
<tr>
<th>M</th>
<th>clock A freq</th>
<th>1 Clk A tick</th>
<th>256 ticks</th>
<th>N</th>
<th>SA freq</th>
<th>1 Clk SA tick</th>
<th>256 ticks</th>
<th># SA ticks in 0.02 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>6000000</td>
<td>1.67E-07</td>
<td>4.27E-05</td>
<td>240</td>
<td>12500</td>
<td>8.00E-05</td>
<td>2.05E-02</td>
<td>250.0</td>
</tr>
<tr>
<td>8</td>
<td>3000000</td>
<td>3.33E-07</td>
<td>8.53E-05</td>
<td>120</td>
<td>12500</td>
<td>8.00E-05</td>
<td>2.05E-02</td>
<td>250.0</td>
</tr>
<tr>
<td>16</td>
<td>1500000</td>
<td>6.67E-07</td>
<td>1.71E-04</td>
<td>60</td>
<td>12500</td>
<td>8.00E-05</td>
<td>2.05E-02</td>
<td>250.0</td>
</tr>
</tbody>
</table>

• Assume we should use PWM channel 0.
  – Pick M=8, N=120.
  – Tell the system to use clock SA (instead of clock A)
  – The period register PWMPER0 gets the value 250

• If say, we want to generate PWM with a 50% duty cycle
  – The duty cycle register PWMDTY0 gets the value 125

• Don’t forget to route PWM channel 0 to PT0, if our chip doesn’t have Port P pins
Example

- **C code:**

```c
PWMCLK = 0x01;       // select clock SA for channel 0
PWMPRCLK = 0x03;     // set clock A prescaler (M=8)
PWMSCLA = 120;       // divider for clock SA (N=120)
PWMPOL = 0x01;       // positive going pulse, channel 0
PWMDTY0 = 125;       // pulse width for channel 0
PWMPER0 = 250;       // period for channel 0
PWME = 0x01;         // enable channel 0
MODRR = 0x01;        // route PWM channel 0 to PT0
```
Example

- Generate a 2 KHz PWM signal with 40% duty cycle, on pin PT2.

Solution:
- A 2 kHz waveform has a period of $\frac{1}{2000} = 0.0005$ sec.
- For channel 2, we have to use clock B or clock SB

<table>
<thead>
<tr>
<th>M</th>
<th>clock B freq</th>
<th>1 Clk B tick</th>
<th>256 ticks</th>
<th>N</th>
<th>SB freq</th>
<th>1 Clk SB tick</th>
<th>256 ticks</th>
<th>in 0.0005 s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24000000</td>
<td>4.17E-08</td>
<td>1.07E-05</td>
<td>24</td>
<td>500000</td>
<td>2.00E-06</td>
<td>5.12E-04</td>
<td>250.0</td>
</tr>
<tr>
<td>2</td>
<td>12000000</td>
<td>8.33E-08</td>
<td>2.13E-05</td>
<td>12</td>
<td>500000</td>
<td>2.00E-06</td>
<td>5.12E-04</td>
<td>250.0</td>
</tr>
<tr>
<td>4</td>
<td>6000000</td>
<td>1.67E-07</td>
<td>4.27E-05</td>
<td>6</td>
<td>500000</td>
<td>2.00E-06</td>
<td>5.12E-04</td>
<td>250.0</td>
</tr>
</tbody>
</table>

- Should we use clock B or clock SB?
- Values for M, N?
- What is the period (in clock ticks)?
- What is the duty time (in clock ticks)?
Example

- C code:

```c
PWMCLK = 0x04;          // select clock SB as the source of PWM2
PWMPRCLK = 0x0;         // set clock prescaler (value for M)
PWMSCLB = 24;           // set divider for clock SB (value of N)
PWMPOL = 0x04;          // positive going pulse, channel 2
PWMDTY2 = 100;          // pulse width for channel 2
PWMPER2 = 250;          // period for channel 2
PWME = 0x04;            // enable channel 2
MODRR = 0x04;           // route PWM channel 2 to PT2
```
Example

- C code:

```c
PWMCLK = 0x04;  // select clock SB as the source of PWM2
PWMPRCLK = 0x0;  // set clock prescaler (value for M)
PWMSCLB = 24;  // set divider for clock SB (value of N)
PWMPOL = 0x04;  // positive going pulse, channel 2
PWMDTY2 = 100;  // pulse width for channel 2
PWMPER2 = 250;  // period for channel 2
PWME = 0x04;  // enable channel 2
MODRR = 0x04;  // route PWM channel 2 to PT2
```
Servo Motor

- A servo motor is a small motor with feedback control
- A PWM signal specifies the desired angular rotation angle of the shaft
- As the duty cycle changes, the angular position of the shaft changes
- Servos are commonly used in radio controlled airplanes to position control surfaces like the elevators and rudders
- They are also used in radio controlled cars, puppets, and robots

- Typically a period of 20 ms is used
- The neutral position corresponds to duty = 1.5 ms

from http://acroname.com
Servo motors on the SSMI board

- There are two connectors designed to connect to servo motors
- Each connector has 3 wires: power (Vservos), ground, and the control (PWM) signal
- The PWM signal wires are hardwired to Port T
Servo motor power

- $V_{servos}$ is produced by voltage regulator LM1066T-ADJ
Summary / Questions

• The HCS12 has how many PWM channels?

• What is the resolution of the PWM system (ie, how finely can you change the duty cycle)?

• Why is it ok to connect a servo motor directly to an output pin of your microcontroller?