AVR1501: Xplain training – XMEGA Timer/Counter

8-bit AVR® Microcontrollers

Application Note

Prerequisites

- **Required knowledge**
  Completed AVR1500: XMEGA™ Basics training
- **Software prerequisites**
  Atmel® AVR® Studio® 4.18 SP2 or later
  WinAVR/GCC 20100110 or later
- **Hardware prerequisites**
  - **Xplain evaluation board**
  - **JTAGICE mkII**
- **Estimated completion time:**
  - **2 hours**

1 Introduction

Atmel XMEGA has a set of high-end and very flexible 16-bit Timer/Counters (TC). Their basic capabilities include accurate program execution timing, frequency and waveform generation, event management, and time measurement of digital signals.

In this hand-on we will learn more about the XMEGA timers, PWM generation, High resolution Extension and Advanced Waveform extension.

Rev. 8309A-AVR-06/10

2 Overview

Atmel XMEGA has a set of high-end and very flexible 16-bit Timer/Counters (TC). Their basic capabilities include accurate program execution timing, frequency and waveform generation, event management, and time measurement of digital signals.

The Timer/Counter consists of a Counter (COUNT) and a set of Compare and Capture (CC) channels. It has direction (DIR) control and period (PER) settings that can be used for timing.

The Hi-Resolution Extension (Hi-Res) and Advanced Waveform Extension (AWeX) can be used together with a Timer/Counter to ease implementation of more advanced and specialized frequency and waveform generation features.

Here is a short overview of the tasks in this training:

Task 1: Starting the Timer/Counter

In the first task you will be guided through initial setup to start the Timer/Counter, including the prescaler and period settings.

Task 2: Compare Match

In this task you will learn how to use the Capture/Compare (CCx) registers for compare checking.

Task 3: Waveform Generation

The CC channels and compare match can be used for waveform generation output on the I/O pins, and in this task you will learn how to configure this.

Task 4: AWeX and Pattern Generation

The Timer/Counter extensions can be used to enable more specialized features. In this task we will look at the Common Waveform and Pattern Generation modes.

Good luck!

3 Task 1: Starting the Timer/Counter

The Timer/Counter needs a clock source to run. The available clock sources are the (pre-scaled) Peripheral Clock and the Event System. In this task we will only use the Peripheral Clock, but setting up the TC to use the Event System is equally easy.

The goal for this task is that you know how to:

- Start the Timer/Counter using the prescaler (CLKSEL bits) in the CTRLA register
- Use the PER register, to set how far the counter should count

Todo

TASK:

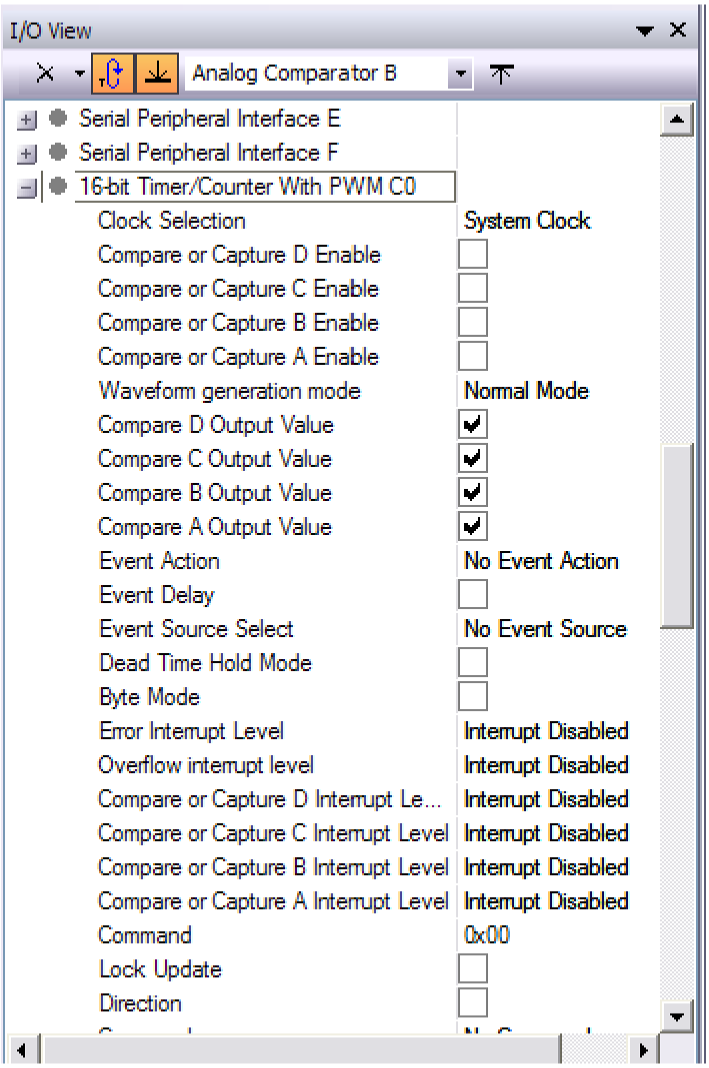
1. Locate the Atmel XMEGA-TimerCounter folder, find the Task 1 folder and open the `StartingTheTimer.aps` project file in Atmel AVR Studio

2. Look through the code and ensure that you understand how things are set up

3. Build the project; ensure that there are no errors

4. Start the debugging session

5. In the I/O-view locate the 16-bit Timer/Counter with PWM C0, and expand it, so you can see the settings change as you start debugging



Serial Peripheral Interface E	
Serial Peripheral Interface F	
16-bit Timer/Counter With PWM C0	
Clock Selection	System Clock
Compare or Capture D Enable	□
Compare or Capture C Enable	□
Compare or Capture B Enable	□
Compare or Capture A Enable	□
Waveform generation mode	Normal Mode
Compare D Output Value	☑
Compare C Output Value	☑
Compare B Output Value	☑
Compare A Output Value	☑
Event Action	No Event Action
Event Delay	□
Event Source Select	No Event Source
Dead Time Hold Mode	□
Byte Mode	□
Error Interrupt Level	Interrupt Disabled
Overflow interrupt level	Interrupt Disabled
Compare or Capture D Interrupt Le...	Interrupt Disabled
Compare or Capture C Interrupt Level	Interrupt Disabled
Compare or Capture B Interrupt Level	Interrupt Disabled
Compare or Capture A Interrupt Level	Interrupt Disabled
Command	0x00
Lock Update	□
Direction	□

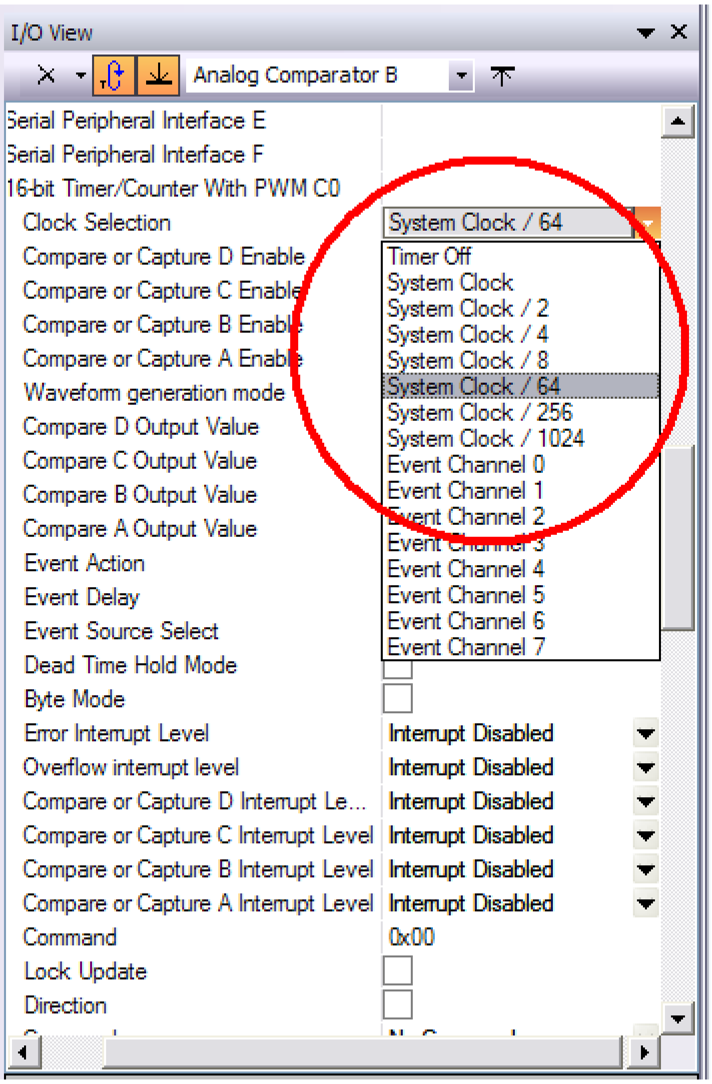
6. Single step through the code until you reach the while (1) statement

7. The TCC0 is now running in Normal Mode with no pre-scaling, and you can see the TCC0 setup details by using the IO view

8. Continue to single step and you will see that the Count (CNT) value is changing and that the OVVIF in INTFLAGS is set when the Count (CNT) register reach 0x30 and wraps around. The LED will toggle

9. Run the code (F5). You will notice that both LED0 and LED1 will be on. This is because the code runs too fast for you to see the LEDs toggle

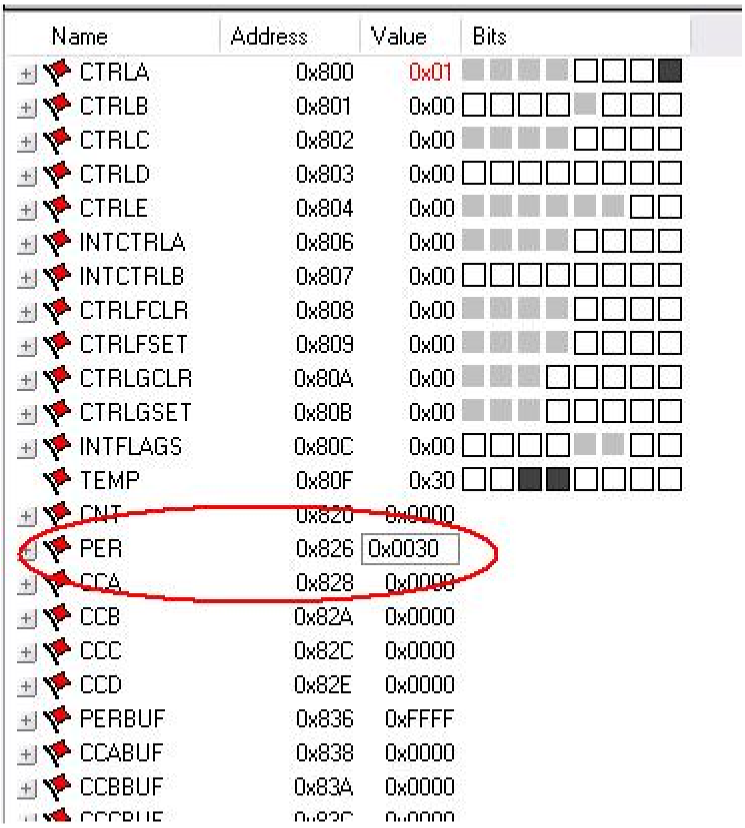
10. Break the execution (Ctrl+F5). Change the Clock Selection so that the TC runs from the Peripheral Clock divided by 64 using the I/O view in Atmel AVR Studio



Serial Peripheral Interface E	
Serial Peripheral Interface F	
16-bit Timer/Counter With PWM C0	
Clock Selection	System Clock / 64
Compare or Capture D Enable	
Compare or Capture C Enable	
Compare or Capture B Enable	
Compare or Capture A Enable	
Waveform generation mode	
Compare D Output Value	
Compare C Output Value	
Compare B Output Value	
Compare A Output Value	
Event Action	
Event Delay	
Event Source Select	
Dead Time Hold Mode	□
Byte Mode	□
Error Interrupt Level	Interrupt Disabled
Overflow interrupt level	Interrupt Disabled
Compare or Capture D Interrupt Le...	Interrupt Disabled
Compare or Capture C Interrupt Level	Interrupt Disabled
Compare or Capture B Interrupt Level	Interrupt Disabled
Compare or Capture A Interrupt Level	Interrupt Disabled
Command	0x00
Lock Update	□
Direction	□

11. Change the Period (PER) register to a higher value so you can see that the LED toggles when you run the code

12. A higher PER setting gives a longer period for the timer, hence the LED will toggle with a slower frequency



Name	Address	Value	Bits
CTRLA	0x800	0x01	▨▨▨▨□□□■
CTRLB	0x801	0x00	□□□□▨□□□
CTRLC	0x802	0x00	▨▨▨▨□□□□
CTRLD	0x803	0x00	□□□□□□□□
CTRLE	0x804	0x00	▨▨▨▨▨▨□□
INTCTRLA	0x806	0x00	▨▨▨▨□□□□
INTCTRLB	0x807	0x00	□□□□□□□□
CTRLFCLR	0x808	0x00	▨▨▨▨□□□□
CTRLFSET	0x809	0x00	▨▨▨▨□□□□
CTRLGCLR	0x80A	0x00	▨▨▨□□□□□
CTRLGSET	0x80B	0x00	▨▨▨□□□□□
INTFLAGS	0x80C	0x00	□□□□▨▨□□
TEMP	0x80F	0x30	□□■■□□□□
CNT	0x820	0x0000	
PER	0x826	0x0030	
CCA	0x828	0x0000	
CCB	0x82A	0x0000	
CCC	0x82C	0x0000	
CCD	0x82E	0x0000	
PERBUF	0x836	0xFFFF	
CCABUF	0x838	0x0000	
CCBBUF	0x83A	0x0000	
CCCBUF	0x83C	0x0000	

4 Task 2: Compare Match in Normal Mode

Task1 showed how to set up a basic timer function. Task2 will show how to use the Compare Match feature.

In addition to the counter and the period settings, the Atmel XMEGA timers/counters of type TC0 has 4 Capture and Compare (CC) channels that can be used for compare match, Waveform Generation (WG) or input capture. XMEGA timer/counters of type TC1 have 2 Capture channels available. The ATxmega128A1 has 4 timers of type 0 (TCC0, TCD0, TCE0, TCF0), and 4 timers of type 1 (TCC1, TCD1, TCE1, TCF1).

In task2 we will use the TC in Normal Mode as in task1, but use compare match to check when the Counter has reached a specific value. We will use one CC channel to detect when the counter has reached a specific value. This can be used for interrupt and event generation, but for now we will use polled software to detect the compare match condition.

The goal for this task is that you know:

- How to use the CCx register for compare checking
- How the double buffering work

Todo

TASK:

1. Locate the XMEGA-TimerCounter folder, find the Task 2 folder and open the `CompareMatch.aps` project file in AVR Studio. Spend some time to understand the code

2. Notice how we in this task use a function from the `TC_driver.c` file to configure the clock source. In the TC driver files you can see the basic functions that are available for using the XMEGA TC

3. In `task2.c` we need to set a compare value for the CC channel to use for compare match. Add code that sets the CCA register to the value to compare the counter to for example 0x0300

4. Build the project; ensure there are no errors and run the code. You should see the LED toggle, and that the on and off time changes as we increase the compare value for each overflow

5. Why is the LED having a different on and off time now? (Recall from task1 that the on and off time was the same)

6. Leave debug mode by (press Ctrl+Shift+F5). Change the code where you update the CCABUF register, to instead update the CCA register directly: CCA += 0x1000;

7. Recompile the code, start a new debug session and run the code

The LED is not blinking as before. This has to do with the double buffering, why?

5 Task 3: Waveform Generation Modes

In task1 and task2 we used Normal Mode to run the timer and toggle LEDs in software on overflow or compare match.

In addition to Normal Mode, the TC has different Waveform Generation (WG) modes that can be used to output a frequency or waveform on the port pins directly.

The goal for this task is that you know how to:

- Enable and use a waveform generation mode
- Enable the individual CC channels to override the corresponding port pin output register and output the waveform
- Use port pin to invert the output signal from the TC

Todo

TASK:

1. Locate the Atmel XMEGA-TimerCounter folder, find the Task 3 folder and open the `WaveformGeneration.aps` project file in AVR Studio. Spend some time to understand how the code works

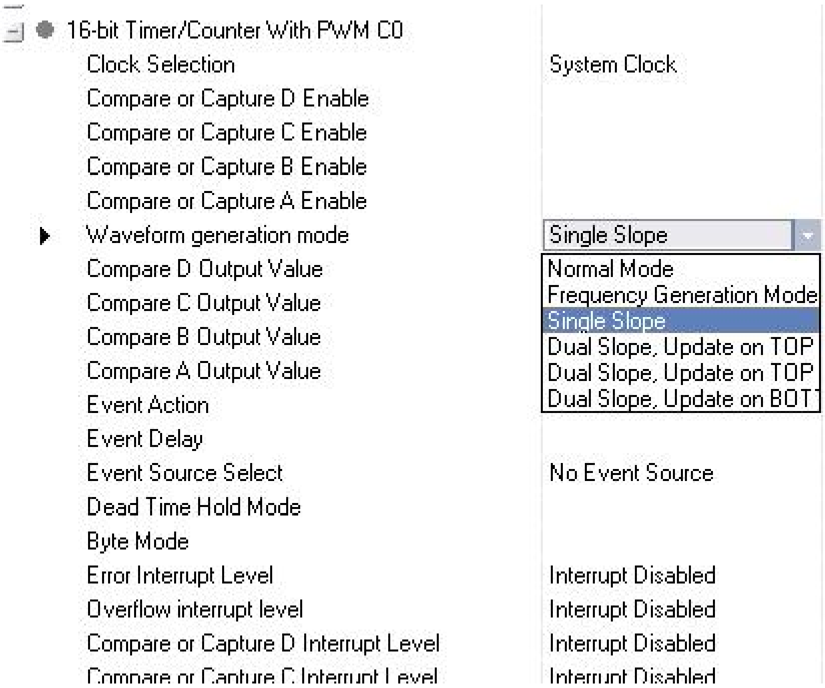
2. The basic time function is already set up as in task1 and task2, but we need to enable the correct WG mode and set the override enable signals

3. At the top of the `main()` function, locate the place where the code is missing, and add the missing code as described. Use the Atmel XMEGA Manual or the `ATxmega128A1.h` header file to find the group configurations for the WG modes

4. Build the project; ensure that there are no errors, and enter debug mode in AVR Studio

5. Start debugging, and step over the initialization until the whole loop

6. If you open the IO view for the TCEO you can now see the mode of the timer, and the modes available. Try changing the configuration, and see how it affects the output



16-bit Timer/Counter With PWM C0

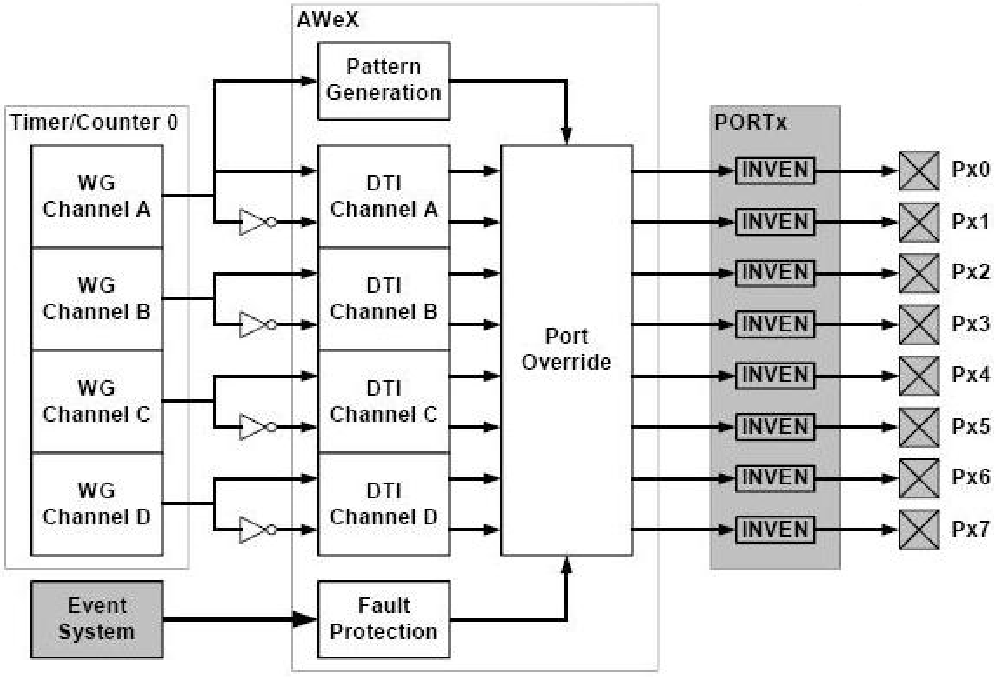
Clock Selection	System Clock
Compare or Capture D Enable	
Compare or Capture C Enable	
Compare or Capture B Enable	
Compare or Capture A Enable	
Waveform generation mode	Single Slope
Compare D Output Value	
Compare C Output Value	
Compare B Output Value	
Compare A Output Value	
Event Action	
Event Delay	
Event Source Select	No Event Source
Dead Time Hold Mode	
Byte Mode	
Error Interrupt Level	Interrupt Disabled
Overflow interrupt level	Interrupt Disabled
Compare or Capture D Interrupt Level	Interrupt Disabled
Compare or Capture C Interrupt Level	Interrupt Disabled

Normal Mode
Frequency Generation Mode
Single Slope
Dual Slope, Update on TOP
Dual Slope, Update on TOP
Dual Slope, Update on BOT

6 Task 4: AWeX and Pattern Generation

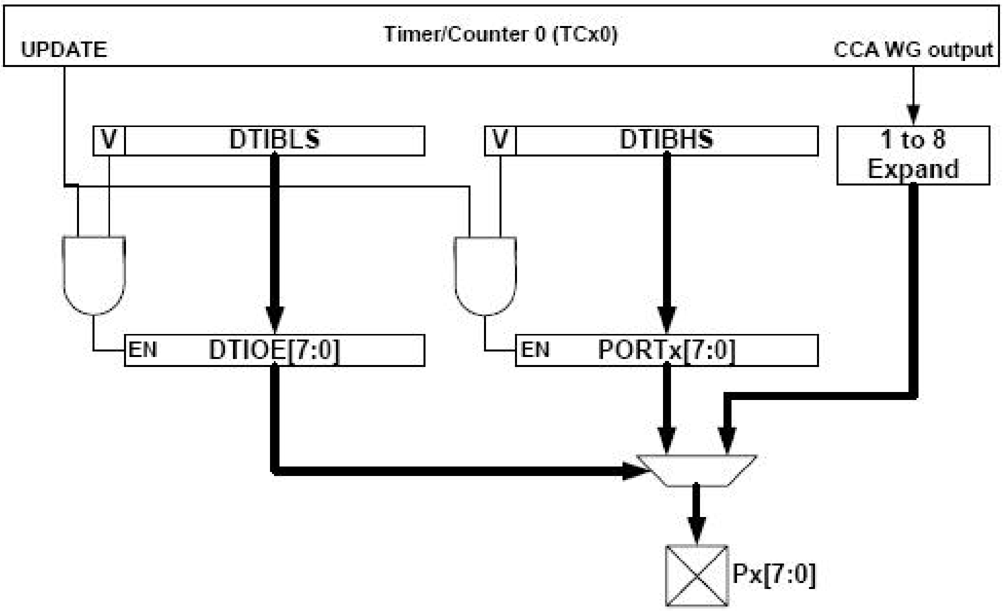
The Advanced Waveform Extension (AWeX) provides extra features to the TC when using WG (Waveform Generation) modes. The AWeX enables easy and robust implementation of advanced motor control (AC, Brushless DC, Switched Reluctance, and Stepper motors) and power control applications.

Each of the waveform generator outputs from the Timer/Counter0 is split into a complimentary pair of outputs when any AWeX features are enabled.



In this task we will use the Pattern Generation Mode (PGM), which is used to generate a synchronized bit pattern on the port (PORTE) to which TCE0 is connected. In addition, the waveform generator output from the CCA channel is distributed to and overriding all the port pins. The PGM is ideal for DC motor control and similar applications, but since no motor is available for this training, we use a more simple approach and use a switch to control the pattern. In a motor control application, the commutation sequence will control the pattern.

The bit pattern (which pins should output the waveform) is stored in the DTLSBUF register when PGM is enabled. This means that bit 0 in DTLSBUF register, control the output on pin 0, and so on. Setting bit 0 in DTLSBUF will enable the waveform output on pin0. The High Side register holds the default PORT output that would be used when the corresponding Low Side bit is not set to override the port value. On UPDATE condition and if there are valid data (V) in the DTLSBUF register, the bit pattern is updated with the correct pattern.



The goal for this task is that you:

- Know how to enable features in the AWeX and use this
- Understand how Common Waveform Channel mode is working
- Know what Pattern Generation is
- Know that the AWeX has separate output override enable bits (just like the TC)

Todo

TASK:

1. Locate the Atmel XMEGA-TimerCounter folder, find the Task 4 folder and open the `AWex.aps` project file in Atmel AVR Studio. Spend some time to understand the code

We need to enable the Common Waveform Mode (CGM) to enable the CCA waveform output to all the pins. This is done by setting the CWCM. We also need to enable Pattern Generation Mode by setting the PGM mode in the CTRL register

2. Locate the top of the `main()`, and find the parts where code is missing. Insert the two missing lines to enable AWEX correctly

3. In the code, notice how the AWEX_DTICCxEN bits must be set in order to enable port override for the CC channel when the AWEX is enabled. This is the same as for the override enable bits for the Timer/Counter

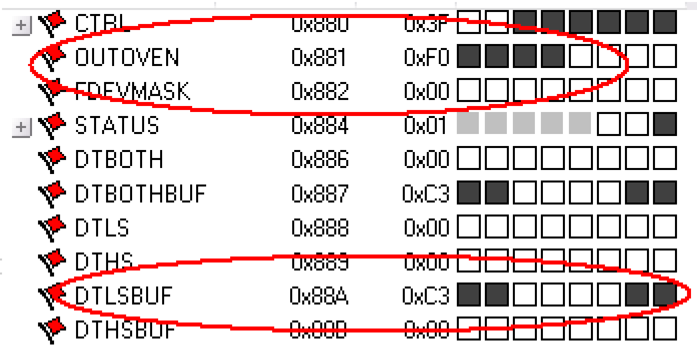
4. Build the project; ensure that there are no errors and open the debug file in AVR Studio

5. Run the code and see how the pattern changes when the switch is pressed. To prevent multiple changes, keep the switch pressed only for a short time

6. Break the debug session, and add a breakpoint on the line:

```
AWEXC.DTLSBUF =  new_pattern;
```

7. Single step a few times, expand the I/O-view to look at the Advanced Waveform Extension E, and verify how the OUTOVEN and DTLSBUF register now have different values



CTRL	0x880	0x3F	□□■■■■■■
OUTOVEN	0x881	0xF0	■■■■□□□□
FDEVMASK	0x882	0x00	□□□□□□□□
STATUS	0x884	0x01	▨▨▨▨▨□□■
DTBOTH	0x886	0x00	□□□□□□□□
DTBOTHBUF	0x887	0xC3	■■□□□□■■
DTLS	0x888	0x00	□□□□□□□□
DTHS	0x889	0x00	□□□□□□□□
DTLSBUF	0x88A	0xC3	■■□□□□■■
DTHSBUF	0x88B	0x00	□□□□□□□□

8. Remove the breakpoint, run the code again before you break. Notice how the OUTOVEN and DTLSBUF have the same value

When is OUTOVEN updated, and what is the Timer/Counter condition that causes this?

7 Summary

In this training you have learned about the Atmel XMEGA timers, the PWM generation and Advanced Waveform extension, and how they are configured and used in an application.

8 Resources

- Atmel XMEGA Manual and Datasheets
    - http://www.atmel.com/xmega
- Atmel AVR Studio with help files
    - http://www.atmel.com/products/AVR
- WINAVR GCC compiler
    - http://winavr.sourceforge.net/
- Atmel IAR Embedded Workbench® compiler
    - http://www.iar.com/

9 Atmel Technical Support Center

Atmel has several support channels available:

• Web portal:	http://support.atmel.no/	All Atmel microcontrollers
• Email:	avr@atmel.com	All Atmel AVR products
• Email:	avr32@atmel.com	All 32-bits AVR products

Please register on the web portal to gain access to the following services:

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