AVR1504: Xplain training - XMEGA Event system

8-bit AVR® Microcontrollers

Application Note

Prerequisites

- **Required knowledge**
  Basic knowledge of microcontrollers and the C programming language
  Completed AVR1500: Xplain training – XMEGA™ Basics
  Recommended to have finished AVR1501: Xplain training – XMEGA Timer/Counter
- **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

The Event System is a set of features for inter-peripheral communication. It enables the possibility for a change of state in one peripheral to automatically trigger actions in other peripherals. What change of state in a peripheral, that will trigger actions in other peripherals is configurable in software. It is a simple, but powerful system as it allows for autonomous control of peripherals without any use of interrupts or CPU and DMA resources.

The indication of a change of state in a peripheral is referred to as an event. The events are passed between the peripherals using a dedicated routing network called the Event Routing Network. This consists of eight multiplexers, where all events are routed into all multiplexers.

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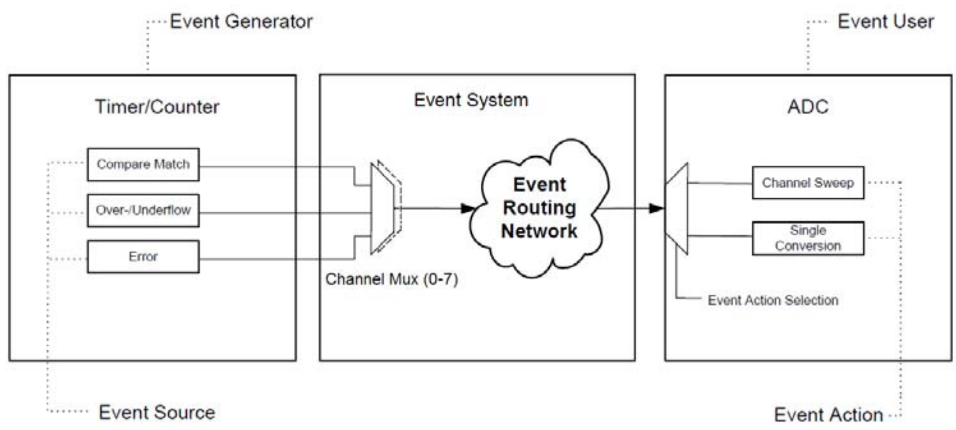
2 Introduction to the Event System

This introduction is intended to give you a basic overview of the terminology and behavior which is needed to understand the Event System and the tasks in this training. The tasks in this training will show you how the Event System works in more detail.

The figure below illustrates the Event System. The figure shows the different parts that makes it operate; the event sources, the channel MUX's and the event action selection in the event user/peripheral.

The figure shows a simplified version with one timer/counter as event generator and one ADC as an event user. The event channel MUX's can select one of three available sources to be routed though the corresponding event channel.



Events can be generated by the following peripherals:

- Timer/Counters (TCxn)
- Real Time counter (RTC)
- Analog to Digital converters (ADCx)
- Analog Comparators (ACx)
- Ports (PORTx)
- System clock (clksys)

Each of these peripherals has several sources for events. Examples of sources are timer/counter overflow, pin change on a port or A/D conversion completed. The full list of available event sources is shown in the register description for the Event System in the Atmel XMEGA A manual.

The channel multiplexers (MUX) selects what source is routed into each of the 8 event system channels available. Each event system channel allows *one source* that generates events to that channel. The EVSYS.CHxMUX registers controls the event source for each channel.

Events can be used by the following peripherals:

- Timer/Counters
- Analog to Digital Converters
- Digital to Analog Converters
- Direct Memory Access Controller (DMAC)

Usage of events is controlled on the individual peripherals. Configuration registers on the individual peripheral allows you to select what event channel to use as input and what the event action is for that channel. Several peripherals can be using the same event channel as input. This is convenient for allowing several actions start at the same time.

For example: starting input capture of a Timer/Counter at the same time as starting a conversion in an ADC. The available event actions are shown in the register description for each peripheral.

3 Overview

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

Task 1: 32-bit Timer/Counter

This task shows the basic Event System setup with event user and event generator and how this can be used for making a 32-bit timer.

Task 2: Input capture with filtering

Input capture with a Timer/Counter is controlled with events in Atmel XMEGA, and this task shows you how flexible this is.

Task 3: Synchronized triggering

More than one peripheral can use events from one event channel, and this can be used to synchronize event actions in the peripherals.

Task 4: Manually generating events

Events can be generated from software, and this task gives you a basic example on how to do this.

GOOD LUCK!

4 Task 1: 32-bit Timer/Counter

By using the overflow event from one Timer/Counter as the clock input/source to another Timer/Counter, it is possible to use the Event System for making a 32-bit Timer/Counter. In this setup it is also possible to do input capture in order to have 32-bit input capture. In the Timer/Counter hands-on session we use the Peripheral Clock as input to the timer/counter TCC0, and the event system will be used as input to timer/counter TCC1. The following figure shows this conceptually:

The AVR1001 – using the Atmel XMEGA event system application note contains a code example on how to implement a 32-bit Timer/Counter with input capture.

The goal for this task is that you:

- Understand the basics of using the Event System, and how to configure an event channel
- Know how to use an event channel in a peripheral module
- Understand how to use an event channel to clock a timer

Todo

TASK:

1. Locate the Atmel XMEGA-EventSystem folder and open the 32bitTimerCounter.aps project file in AVR Studio
2. Spend some time to understand the code, how it works, and ensure you know the basics of how the Event System is set up
3. Build the project, ensure there are no errors (you can ignore the warning) and start a debug session
4. Run the code, and you will see that the LEDs are counting upwards with the clock tick rate of the most significant TC which is clocked from the event system
5. Break and place a breakpoint as indicated below:

```
if(TCC0.CNT >= 0xFFF0)
{
  nop();
}
```

6. Run the code again and see that it breaks when the least significant timer is close to overflow. If you single step a few times, the timer will overflow, and you will see that the LED is counting. If you expand the IO view for TCC1, you can see how CNT increase when TCC0 overflows

7. If you wish to write some code in this task, you can add code to make a 48- or 64-bit timer ☺

5 Task 2: Input Capture with Filtering

In Task 1 we used the Event System to trigger events that were the clock source to a Timer/Counter (TC). In general, a peripheral may perform different actions when receiving an event. For instance, for the TC, see the timer event action list in the CTRLD register shown in the register description of the Timer counter in the Atmel XMEGA A Manual. Take a look at this table to understand what event actions the timer can use.

By having the Event System able to trigger input capture is much more flexible than having one or a few capture pins. Because a pin change on any I/O pin can be used to generate an event, this means that any I/O pin can be used as an input capture pin.

In fact, any event can trigger an input capture, not just pin changes. In this task we will stick to the basics and we will use a pin change event to do input capture. To make this work we need to configure the following:

- Timer TCC0 to perform input capture on capture channel A (CCA) when getting an event on channel 0
- Event System routing to route PORTE pin 0 events into event channel 0
- Input sensing on PORTE pin 0 to specify if rising edge, falling edge, both edges or the level of the pin generates events

The goal for this task is that you:

- Understand how to set up input capture using a timer and the Event System
- Know how filtering on the I/O pins is handled by the Event System

Todo

TASK:

1. Locate the InputCapture.aps Atmel AVR Studio project file. Open the task2.c file and familiarize yourself with the code

2. The code is almost done, but you need to configure the event channel 0 MUX to use pin 0 of PORTF as input to this event channel. If you need help, see how this is done in Task 1

3. Build the project, ensure there are no errors (you may ignore the warning) and open the debug file in AVR Studio

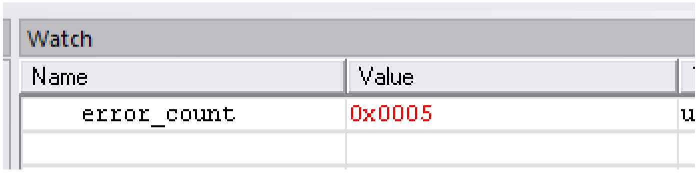
4. Run the code; press the switch a few times

5. Each press will generate an event (or in fact two events) that trigger the input capture. The capture values are continuously read and output to the LEDs

Why does each press generate two events?

6. Let's look at the Error flag. The Error flag is set when there is a buffer overflow for the input captures registers in the TC. You can study Section 14.5 (double buffering) in the Atmel XMEGA A manual to see how this works

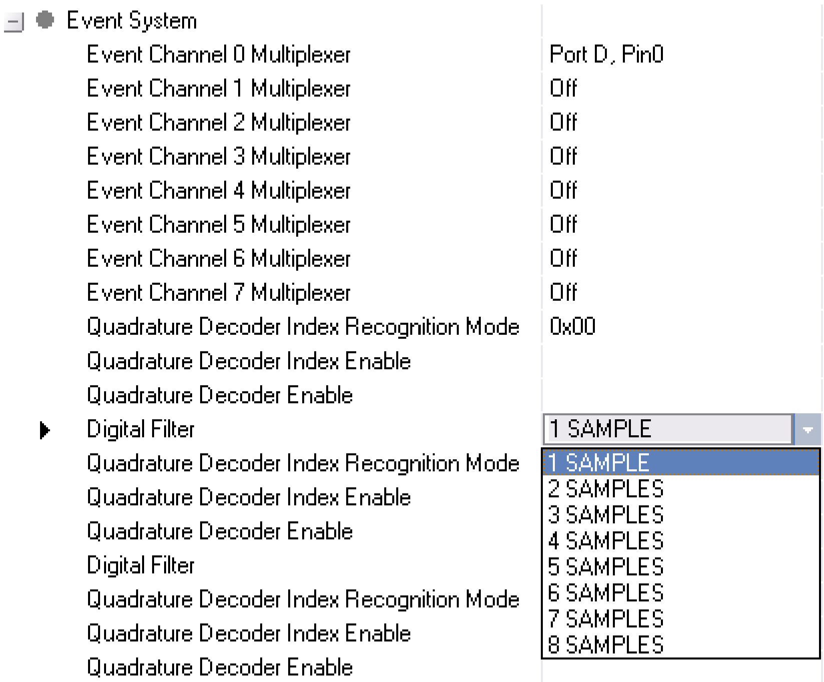
7. Add error_count to the Watch window so you can follow the number of overflow errors



8. Run the code, press the switch many times with short intervals, break and see if any errors occurred. You should be able to generate some

9. We are using noise from the buttons to generate quickly enough to get a buffer overflow. If it is difficult to press the switch to generate overflow, you can add a delay (for example _delay_ms(200);) in the while(1) loop so the CCA register is not read that often

10. While the debug session is still stopped, locate the Event System in the IO view and expand it to see the current configuration



11. The first instance of the Digital Filter, represents the filter for event channel 0

12. Change the digital filter to set how many pin change events must be sampled by the peripheral clock before the event is passed through

13. Run the code again, press the switch and see how the different filter value is able to reduce the error_count

6 Task 3: Synchronized Triggering

It is possible to let different peripherals use the same event channel as input, and by doing this several peripherals can use the same event. This can for example be used to synchronize actions. Here are a few examples where this is useful:

- For doing an input capture and start an ADC conversion at the same time, in order to give the conversion a time stamp
- For starting conversions on two ADCs at the same time
- Other combinations of ADC, DAC, Timer/counter and DMA

In this task we are going to keep it simple and use the Event System to initiate input capture on 3 timers (TCC0, TCD0 and TCE0) simultaneously. Timer/counter TCF0 overflow is used as the event trigger source (generator).

The goal for this task is that you:

- Are able to configure the Event System
- Understand synchronized Triggering

TASK:

1. Locate the folder for Task 3 and open the SynchronizedTriggering.aps project. Look at the task3.c file and familiarize yourself with the code

2. The code is almost complete, but we need to do some changes:
    a. Add code that sets up the timer/counter TCD0 and TCE0 in the same way as TCC0
    b. Set up overflow of timer/counter TCF0 as input to event channel 0
    c. Build the project, ensure there are no errors, and start debugging in Atmel AVR Studio

3. Let's run the code and make sure that the event is triggered as expected, and that the input capture happens

4. Break the execution, and place a breakpoint as indicated below:

```
    capture_values[0] = TCC0.CCA;
    capture_values[1] = TCD0.CCA;
    capture_values[2] = TCE0.CCA;
    LEDPORT.OUT = capture_values[0];
}
```

5. Add a watch on the `capture_values` variable by right clicking on the variable and selecting *“Add watch : “capture_values”*. This array contains capture values from all three timers

6. Run the code and observe that the `capture_values` variable gets updated

You can notice that all the capture values are almost the same. Why are they not exactly the same?

If you have time, add code to set all the count (CNT) values of the timer/counter to zero before the while loop. Are the capture values the same now? Why?

7 Task 4: Manually Generating Events

Events can be generated manually from software. This is done by STROBE registers or by accessing the registers directly during on-chip debugging. Writing the STROBE register triggers the operation.

It is possible to generate events on several channels at the same time by writing to several bit locations at once. This can be useful for synchronizing event actions, for on-chip debug or using events to keep track of program execution status.

Manually generated events last for one clock cycle and will overwrite events from other event sources during that clock cycle.

The goal for this task is that you:

- Know how to generate events from software
- Understand when generating events from software can be useful
- Know how to synchronize several timer/counters

TASK:

1. Locate the ManuallyGeneratingEvent.aps project and open it in Atmel AVR Studio

2. Open the task4.c file and familiarize yourself with the code. The code is similar to task3, but notice that timer/counter TCC0, TCD0 and TCE0 are now running with a clock prescaler/divider of 1 (same speed as the CPU). In addition the timer/counters are now configured to RESTART when an event is received

3. Build the project, ensure there are no errors, and start debugging the project

4. Place a breakpoint in the main loop

5. Add a watch to `capture_values` so you can keep track of the compare values

```
while (1)
{
    // Wait for capture interrupt to update capture values
    do {} while ((TCC0.INTFLAGS & TC0_CCAIF_bm) == 0);

    TCC0.INTFLAGS = TC0_CCAIF_bm;
```

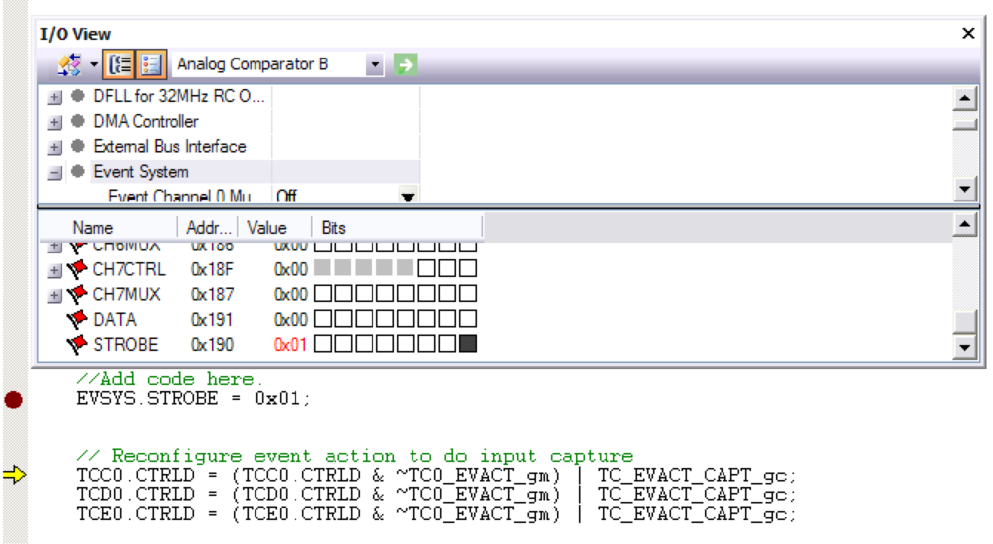
6. Notice that the `capture_values` are now different values even if the input capture happens on the exact clock cycle. This is like in Task 3 because the timers are started at different clock cycles

7. The code is almost done, but you need to add code to generate events from software on event channel 0

8. Place a breakpoint in the code so you can single step after the software events are generated

9. Run the code and ensure that it stops at the breakpoint

10. Open the Event System in the IO view and single step to see that the STROBE register is being written, and cleared again in the next cycle



11. Use “Run to cursor” to see that the compare_values are updated with new values after the event triggered the input capture. *Notice that all the timers are now perfectly synchronized*

12. The STROBE register can be written during on-chip debug, for example by using the IO view to set the bits. The bits that are written will be cleared in the next cycle. You can test this, but keep in mind that the capture values for the timer are not kept if the buffer is full. Instead you will get an error

8 Summary

In this hands-on we have learned how the Event System operates, how to configure it and we have shown you potential uses for the Event System.

9 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/

10 Atmel Technical Support Center

Atmel has several support channels available:

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

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

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