About the post

In my last post I have explained the 8 bit timers of the Arduino UNO (or ATmega328P), namely Timer0 and Timer2. In this second part I would like to go into the details of the 16 bit Timer1. Theoretically, it is very similar to the two 8-bit timers, but has greater flexibility and additional functions.
You don't necessarily have to read part 1, but I'm going to explain fewer details in this part. The following is covered in this post:

- Structure and components of the Timer1
- Normal Mode
- CTC Mode
- PWM Modes
  - Fast PWM
  - Phase Correct PWM
  - Phase and Frequency Correct PWM
- Using the Input Capture Pin
- External clock

Structure and components of the Timer1

The registers of Timer1

Timer/Counter1 Register TCNT1

The Timer/Counter1 Register TCNT1 is 16 bits. The register counts corresponding to the system clock or it can be slowed down with a prescaler. The lower limit is Bottom (zero), the upper limit is Top. Top is fixed or can be defined variably, depending on the mode.

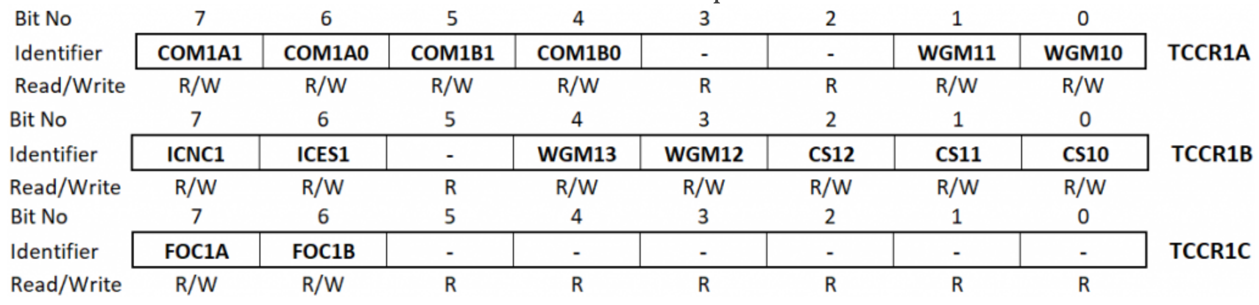
Output Compare Register OCR1x

In the two Output Compare Registers OCR1A and OCR1B you can define values that are permanently compared with the TCNT1 register. Depending on the setting and mode, a match (Compare Match) triggers certain actions. In certain WGM1 modes, OCR1A is Top. The registers are of course 16 bits like TCNT1.

Timer/Counter1 Control Register TCCR1x

The main settings are made in the Timer/Counter1 Control Registers TCCR1A, TCCR1B and TCCR1C. These include:

- Choice of Wave Form Generation Mode via the WGM1 Bits
- Determination of what happens in case of a Compare Match (COM1xy Bits)
- Prescaler or external clock via the Chip Select Bits CS1x



Bit No	7	6	5	4	3	2	1	0	
Identifier	COM1A1	COM1A0	COM1B1	COM1B0	-	-	WGM11	WGM10	TCCR1A
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W	
Bit No	7	6	5	4	3	2	1	0	
Identifier	ICNC1	ICES1	-	WGM13	WGM12	CS12	CS11	CS10	TCCR1B
Read/Write	R/W	R/W	R	R/W	R/W	R/W	R/W	R/W	
Bit No	7	6	5	4	3	2	1	0	
Identifier	FOC1A	FOC1B	-	-	-	-	-	-	TCCR1C
Read/Write	R/W	R/W	R	R	R	R	R	R	

Timer/Couter1 Control Register TCCR1A/B/C

ICES1, the Input Capture Edge Select Bit in TCCR1B, will be discussed together with the Input Capture function. For all other bits please look at the data sheet of the ATmega 48 / 88 / 168 / 328 family.

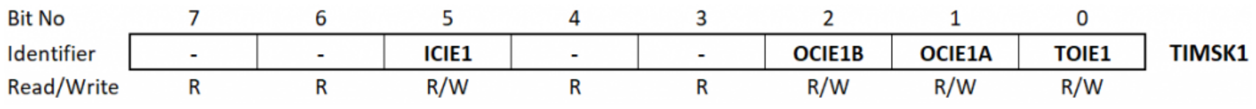
Input Capture Register ICR1

This Timer1 register has two functions.

1. If there is an event on ICP1, the counter reading of TCNT1 is written to ICR1. The ICES1 bit mentioned above determines whether this should happen with the rising (ICES1 = 1) or falling edge (ICES1 = 0).
2. Like OCR1A, ICR1 is the Top value in some WGM1 modes. In these cases, the Input Capture Register function is disabled. Unlike OCR1A, ICR1 is not buffered, but is immediately overwritten. We discuss the consequences of this when we get to the PWM modes.

Timer/Counter1 Interrupt Mask Register TIMSK1

In TIMSK1, you enable the interrupts for the Input Capture function (ICIE1), the Output Compare Matches (OCIE1B, OCIE1A), and the Timer Overflow (TOIE1). The “IE” stands for “Interrupt Enable”.



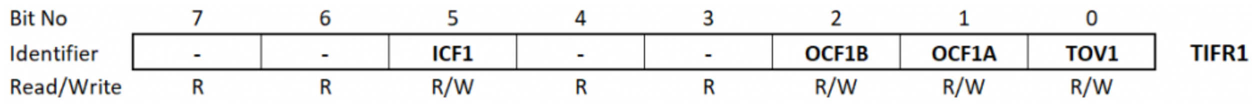
Bit No	7	6	5	4	3	2	1	0	
Identifier	-	-	ICIE1	-	-	OCIE1B	OCIE1A	TOIE1	TIMSK1
Read/Write	R	R	R/W	R	R	R/W	R/W	R/W	

Timer/Counter1 Interrupt Mask Register
If the respective interrupts are enabled, you can use them in Interrupt Service Routines (ISRs). For this, you pass the corresponding interrupt vectors to the ISR:

- TIMER1_CAPT_vect for Input Capture
- TIMER1_COMPA_vect / TIMER1_COMPB_vect for Compare Match
- TIMER1_OVF_vect for Timer Overflow

Timer/Counter1 Interrupt Flag Register TIFR1

If the interrupts are enabled, the corresponding bits are set in TIFR1 if an interrupt is triggered. Executing an interrupt vector deletes the bit. Alternatively, you delete the bits by overwriting them with 0.

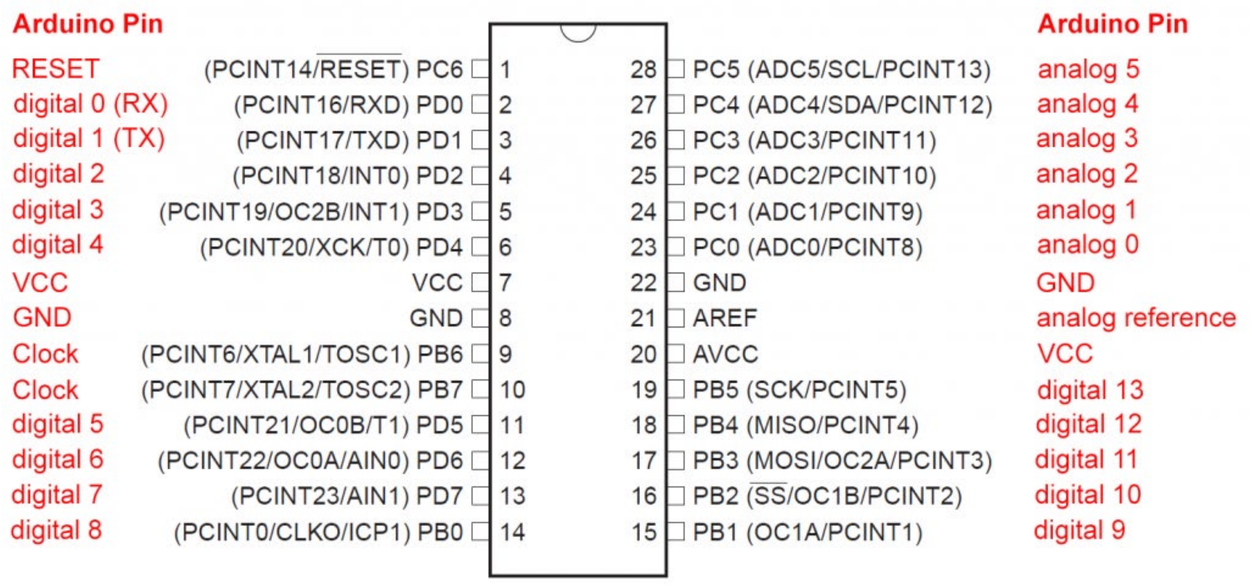


Bit No	7	6	5	4	3	2	1	0	
Identifier	-	-	ICF1	-	-	OCF1B	OCF1A	TOV1	TIFR1
Read/Write	R	R	R/W	R	R	R/W	R/W	R/W	

Output Compare Pins OC1x

The Timer1 has two Output Compare pins assigned to it, OC1A (PB1, Arduino UNO Pin 9) and OC1B (PB2, Arduino UNO Pin 10). When I speak of Arduino Pins below, I am referring to the Arduino UNO. Besides, I always refer to digital pins when I’m not writing anything else.

Pin designations ATmega328P vs. Arduino UNO



The behavior of the Output Compare pins depends on the setting of the WGM1 bits and the Compare Output bits in TCCR1A and TCCR1B.

Input Capture Pin ICP1

The Input Capture pin corresponds to PB0 (Arduino Pin 8). Thanks to the Input Capture function, the time sequence of fast events can be measured elegantly. I will come back to this towards the end of this article.

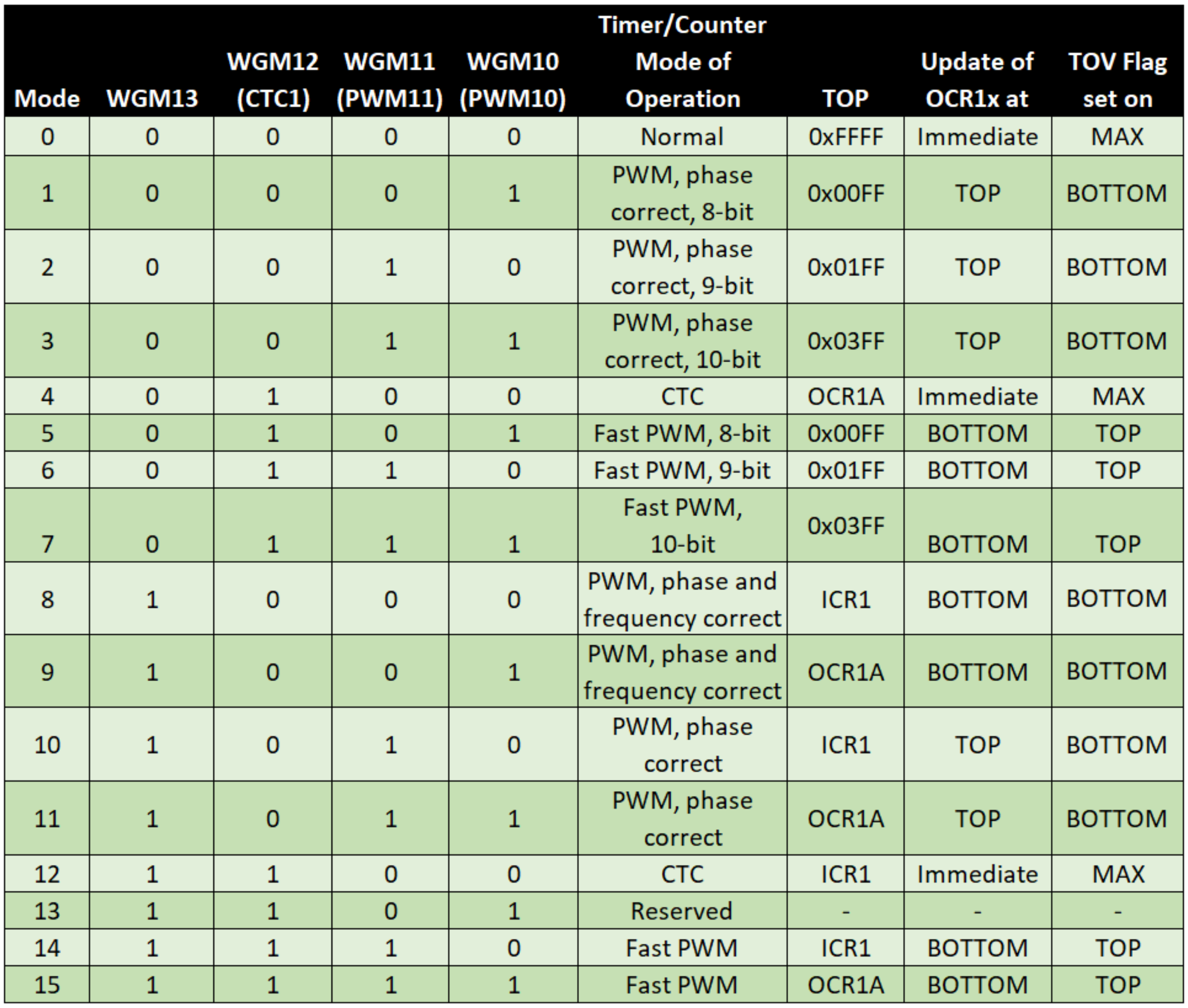
External Clock Pin T1

As an alternative to the internal clock, you can attach an external clock to T1 (PD4, Arduino Pin 4).

Settings in TCCR1x

Wave Form Generation Modes

In contrast to the Timer0 and Timer2, four WGM bits are available for the Timer1, i.e. there are 16 different settings. The choice of the WGM is always the basis for all further settings.

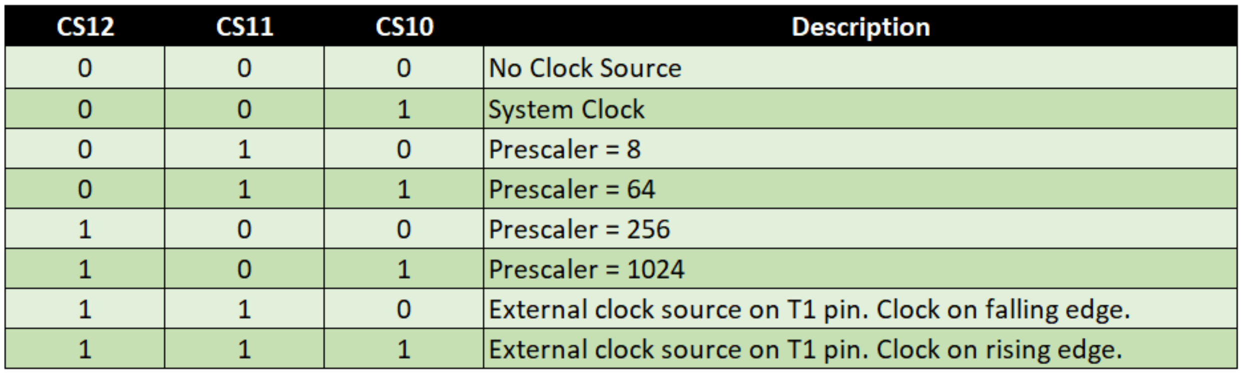


Mode	WGM13	WGM12 (CTC1)	WGM11 (PWM11)	WGM10 (PWM10)	Timer/Counter Mode of Operation	TOP	Update of OCR1x at	TOV Flag set on
0	0	0	0	0	Normal	0xFFFF	Immediate	MAX
1	0	0	0	1	PWM, phase correct, 8-bit	0x00FF	TOP	BOTTOM
2	0	0	1	0	PWM, phase correct, 9-bit	0x01FF	TOP	BOTTOM
3	0	0	1	1	PWM, phase correct, 10-bit	0x03FF	TOP	BOTTOM
4	0	1	0	0	CTC	OCR1A	Immediate	MAX
5	0	1	0	1	Fast PWM, 8-bit	0x00FF	BOTTOM	TOP
6	0	1	1	0	Fast PWM, 9-bit	0x01FF	BOTTOM	TOP
7	0	1	1	1	Fast PWM, 10-bit	0x03FF	BOTTOM	TOP
8	1	0	0	0	PWM, phase and frequency correct	ICR1	BOTTOM	BOTTOM
9	1	0	0	1	PWM, phase and frequency correct	OCR1A	BOTTOM	BOTTOM
10	1	0	1	0	PWM, phase correct	ICR1	TOP	BOTTOM
11	1	0	1	1	PWM, phase correct	OCR1A	TOP	BOTTOM
12	1	1	0	0	CTC	ICR1	Immediate	MAX
13	1	1	0	1	Reserved	-	-	-
14	1	1	1	0	Fast PWM	ICR1	BOTTOM	TOP
15	1	1	1	1	Fast PWM	OCR1A	BOTTOM	TOP

Overview of the WGM settings of the timer1

Clock Select Bits / Prescaler The counting frequency of TCNT1 is determined by the

$$f_{count} = \frac{system\_clock}{prescaler}$$



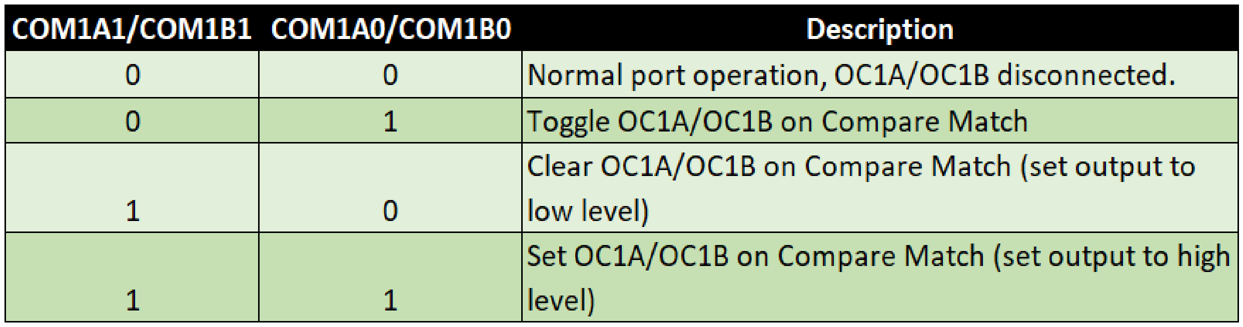
CS12	CS11	CS10	Description
0	0	0	No Clock Source
0	0	1	System Clock
0	1	0	Prescaler = 8
0	1	1	Prescaler = 64
1	0	0	Prescaler = 256
1	0	1	Prescaler = 1024
1	1	0	External clock source on T1 pin. Clock on falling edge.
1	1	1	External clock source on T1 pin. Clock on rising edge.

system clock and the prescaler:

Prescaler selection via the Clock Select Bits of the Timer1

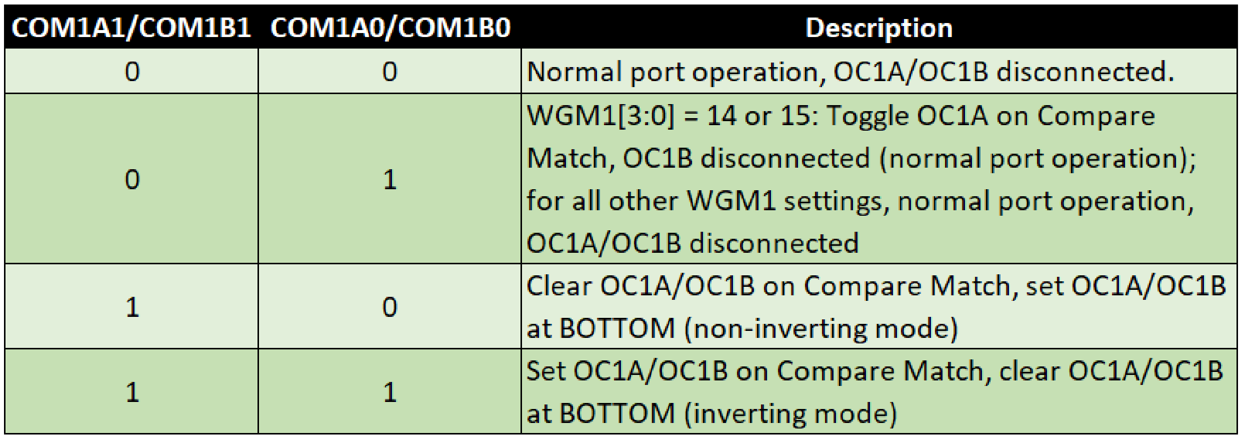
Compare Output Mode Bits The effect of the COM1xy bits depends on which mode is chosen:

1. Compare Output Mode for non-PWM Modes



COM1A1/COM1B1	COM1A0/COM1B0	Description
0	0	Normal port operation, OC1A/OC1B disconnected.
0	1	Toggle OC1A/OC1B on Compare Match
1	0	Clear OC1A/OC1B on Compare Match (set output to low level)
1	1	Set OC1A/OC1B on Compare Match (set output to high level)

2. Compare Output Mode for Fast PWM Modes



COM1A1/COM1B1	COM1A0/COM1B0	Description
0	0	Normal port operation, OC1A/OC1B disconnected.
0	1	WGM1[3:0] = 14 or 15: Toggle OC1A on Compare Match, OC1B disconnected (normal port operation); for all other WGM1 settings, normal port operation, OC1A/OC1B disconnected
1	0	Clear OC1A/OC1B on Compare Match, set OC1A/OC1B at BOTTOM (non-inverting mode)
1	1	Set OC1A/OC1B on Compare Match, clear OC1A/OC1B at BOTTOM (inverting mode)

3. Compare Output Mode for Phase Correct and Phase and Frequency Correct Modes

COM1A1/COM1B1	COM1A0/COM1B0	Description
0	0	Normal port operation, OC1A/OC1B disconnected.
0	1	WGM1[3:0] = 14 or 15: Toggle OC1A on Compare Match, OC1B disconnected (normal port operation); for all other WGM1 settings, normal port operation, OC1A/OC1B disconnected
1	0	Clear OC1A/OC1B on Compare Match when up-counting; set OC1A/OC1B on Compare Match when down-counting.
1	1	Set OC1A/OC1B on Compare Match when up-counting; clear OC1A/OC1B on Compare Match when down-counting.

The Normal Mode

In Normal Mode, Top is always 0xFFFF (65535). A complete pass consists of 65536 steps, since the 0 is counted as well. After reaching Top, TNCT1 is set to 0 again. The frequency for the timer overflow is determined by the system clock and the prescaler. In addition, you can provide TCNT1 with a starting value and thus – within the scope of the resolution and the limits – generate arbitrary frequencies for the overflow. However, you must write the starting value again in TCNT1 after each overflow. The frequency $f_{desired}$ is calculated according to the formula:

$$f_{desired} = \frac{system\_clock}{prescaler \cdot (65536 - start\_value)}$$

$$start\_value = 65536 - \frac{system\_clock}{prescaler \cdot f_{desired}}$$

System clock and frequency are known variables. But still, it's an equation with two unknowns. I have already discussed this in more detail in Part 1 of the article. That is why I do not want to repeat this here. However, I would like to point out once again the helpful AVR Timer calculators in the net, e.g. here or here.

Normal Mode example sketch

An LED shall turn on and off every second. We do this by overflowing TCNT1 in exactly this frequency and using the Overflow Interrupt to invert the pin to which the LED is connected.

With Timer0 and Timer2 we had to introduce an additional scale factor for this application (see last article). Because TCNT1 is 16 bit, this is not necessary here. The Arduino UNO has a clock speed of 16 MHz. This results in two possible combinations: 1) prescaler 256 / start value 3036 or 2) prescaler 1024 / start value 49911.
The bits to be set in TCCR1A and TCCR1B are derived from the tables above. TOIE1 must be set to get an overflow interrupt. The LED is attached to PD7 (Arduino Pin 7). In the ISR, the LED pin is inverted and the timer is set back to the starting value.

T1_normal_mode_1Hz_toggle.ino

```
unsigned int counterStart = 3036; // alternative: 49911
void setup(){
TCCR1A = 0x00; // OC2A and OC2B disconnected; Wave Form Generator: Normal Mode
TCCR1B = (1<<CS12); // prescaler = 256; alternative: 1024 (set CS12 and CS10)
TIMSK1 = (1<<TOIE1); // interrupt when TCNT1 is overflowed
TCNT1 = counterStart;
DDRD |= (1<<PD7);
}
void loop() {
// do something else
}
ISR(TIMER1_OVF_vect){
TCNT1 = counterStart;
PORTD ^= (1<<PD7);
}
```

One advantage of working with timers is that the processes run in the background. The main loop of the sketch is still empty. Normally you would probably have created the flashing LED with a delay construction. It can always be a challenge to build additional code around it, especially if it contains additional time-critical functions. In the last post I had two LEDs flash asynchronously as an example.

CTC Mode

CTC stands for “Clear Timer on Compare Match” and that’s what you do in this mode. Instead of 0xFFFF, Top is either OCR1A (WGM 4) or ICR1 (WGM 12). Top determines the frequency.

Also in CTC mode, counting is only upwards. After peaking, TCNT1 is reset to zero.

CTC Mode Sample Sketch

We do the same as in Normal Mode: an LED should flash every second. For the calculation of the prescaler and Top:

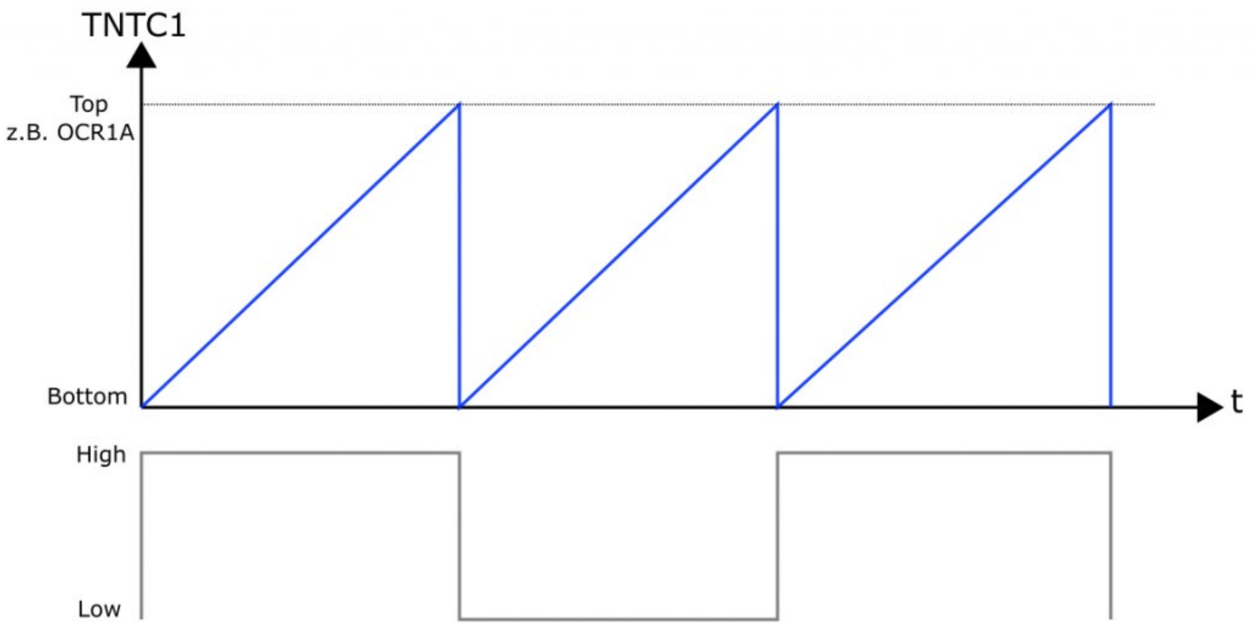
$$f_{desired} = \frac{system\_clock}{prescaler \cdot (1 + Top)}$$

$$Top = \frac{system\_clock}{prescaler \cdot f_{desired}} - 1 \quad with \quad Top < 65536$$

Again, there are two possible combinations for the prescaler and Top. We take the 1024 as prescaler 1024 and 15624 as Top. The alternative would be prescaler 256 and Top 62499. Whether we use Mode 4 or 12 makes no difference, except in the definition of Top. We choose Mode 4, so OCR1A is Top. In the TCCR1A register we set COM1A0. This allows us to define “Toggle OC1A on Compare Match” according to the table. So we do not use the interrupt by means of an ISR, but directly control an Output Compare Pin. And in this case, it is OC1A = PB1 = Arduino Pin 9. OC1A must be set to output because this does not happen automatically. This step should always be done after all other settings.

```
T1_CTC_mode_1Hz_toggle.ino
void setup(){
TCCR1A = (1<<COM1A0); // Toggle OC1A on Compare Match; Wave Form Generator: CTC Mode 4, Top =
OCR1A
TCCR1B = (1<<WGM12) + (1<<CS12) + (1<<CS10); // prescaler = 1024;
OCR1A = 15624;
DDRB |= (1<<PB1);
}
void loop() {
// do something else
}
```

Graphically, this looks like this:



Graph 1: CTC – "Toggle Mode" with Timer1

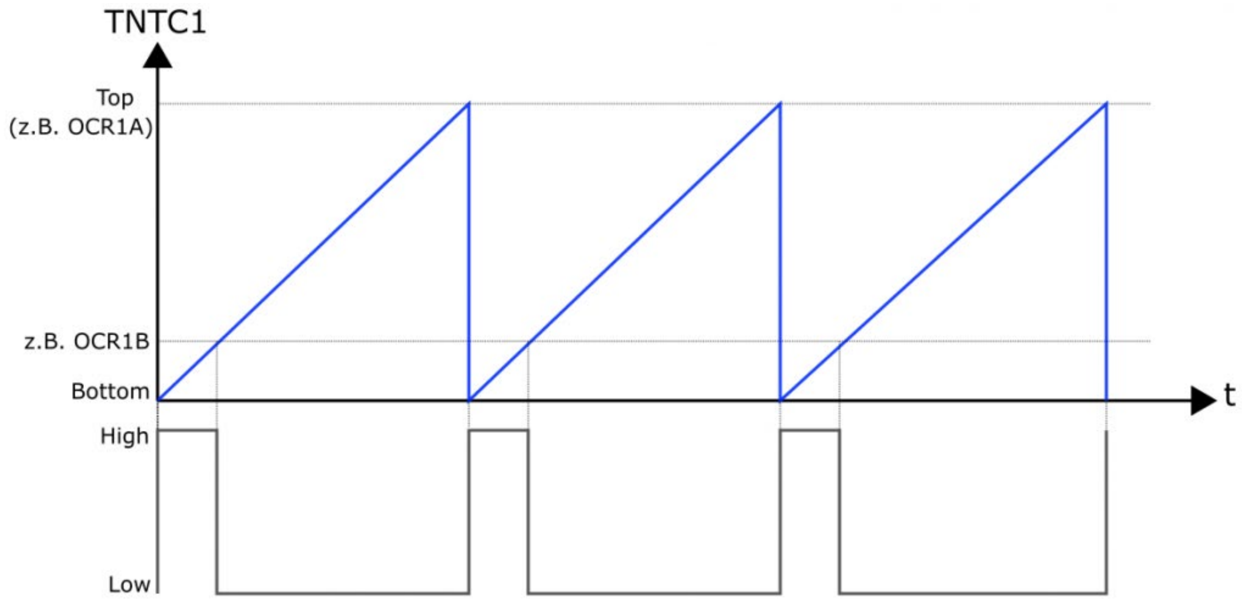
Fast PWM

In Fast PWM mode, as well as in all other PWM modes, Top determines the frequency. TCNT1 counts from Bottom to Top and is then reset to zero (one edge per period). In contrast to Timer0 and Timer2 there is an extended selection for Top for Timer1. Depending on the WGM1 bit combination, this is:

- 0x00FF, 0x01FF, 0x03FF – Mode 5 to 7
- ICR1 (Input Capture Register 1) – Mode 14
- OCR1A – Mode 15

Normally, in the PWM modes, you control the Output Compare pins OC1A (PB1, Arduino Pin 9) and OC1B (PB2, Arduino Pin 10) associated with the respective timer. Alternatively, you can also use the Compare Match interrupts.

In the Compare Output Mode table for Fast PWM, you choose the desired behavior of the Output Compare Pins. In the next graphic, OCR1A is chosen as Top. For OCR1B, the option "Clear OC1B at Compare Match, set OC1B at Bottom" was selected. OCR1B therefore determines the duty cycle, OCR1A determines the frequency. In Mode 5 to 7, the frequency is set only by a fixed Top and the prescaler. Accordingly, you cannot choose any desired frequencies in mode 5 to 7.



Graph 2: TNTC1 vs. OC1x at Fast PWM

If you change OCR1A while the program is executed, Top will not be updated until the previous Top has been reached. This delayed update happens because the OCR1x registers are buffered, i.e. there is, so to speak, a clipboard for the values to be updated.

ICR1 does not have a buffer and this has an important consequence. Imagine using ICR1 as your Top and assigning it a new value that is smaller than the current TCNT1 counter reading. In this case, TCNT1 can no longer match Top in the current cycle and counts up to 0xFFFF. And this can take quite a long time depending on the prescaler and counter reading. Therefore, if you want to change the frequency during the program, use OCR1A as the top (Mode 15). Or even better: choose the Phase and Frequency Correct Mode 9.

Fast PWM Sample Sketch

As an example, we generate a 1 kHz signal with 25% DutyCycle at OC1A. ICR1 is intended to serve as Top. First, we have to calculate:

$$f_{desired} = \frac{system\_clock}{prescaler \cdot (1 + Top)}$$

$$Top = \frac{system\_clock}{prescaler \cdot f_{desired}} - 1$$

$$Top = \frac{1600000}{1 \cdot 1000} - 1 = 15999 \quad with \quad prescaler = 1$$

Top is 15999 and that’s 16000 steps. 25% is 4000 steps, which are completed with 3999. We choose the WGM1 bits for Mode 14 because it defines ICR1 as a top. By setting CS10, we select the prescaler 1, i.e. no prescaler. OC1A is PB1 (Arduino Pin 9) and must be set to output.

T1_FastPWM_Mode14_DutyCycle25.ino

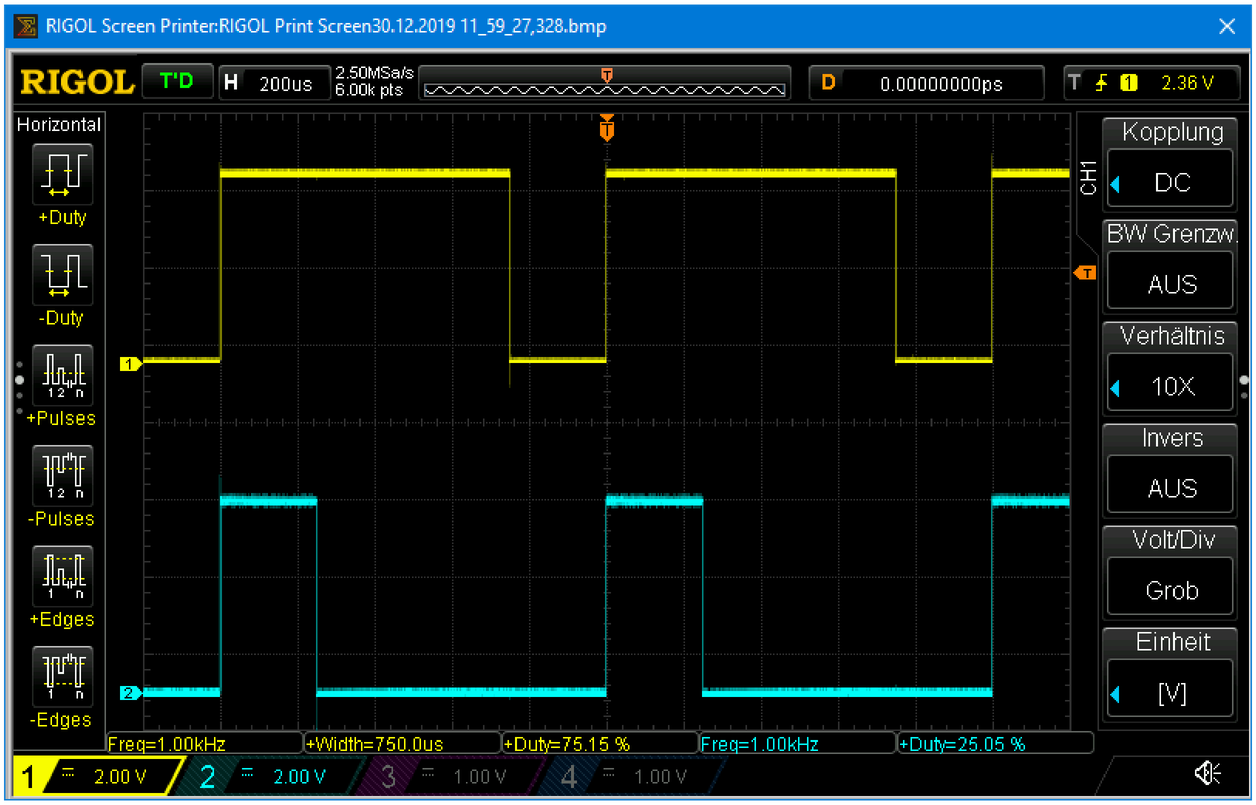
```
void setup(){
// Clear OC1A on Compare Match / Set OC1A at Bottom; Wave Form Generator: Fast PWM 14, Top = ICR1
TCCR1A = (1<<COM1A1) + (1<<WGM11);
TCCR1B = (1<<WGM13) + (1<<WGM12) + (1<<CS10); // prescaler = none;
ICR1 = 15999;
OCR1A = 3999;
DDRB |= (1<<PB1);
}
void loop() {
// do something else
}
```

The beauty of the fact that the Timer1 allows ICR1 to be TOP is that we have both OCR1A and OCR1B available as a Compare Match for controlling the output pins. We extend the sketch with a signal to OC1B with 75% Duty Cycle:

T1_FastPWM_Mode14_DutyCycle25_and_75.ino

```
void setup(){
// Clear OC1A and OC1B on Compare Match / Set OC1A and OC1B at Bottom;
// Wave Form Generator: Fast PWM 14, Top = ICR1
TCCR1A = (1<<COM1A1) + (1<<COM1B1) + (1<<WGM11);
TCCR1B = (1<<WGM13) + (1<<WGM12) + (1<<CS10); // prescaler = 1 (none)
ICR1 = 15999;
OCR1A = 3999;
OCR1B = 11999;
DDRB |= (1<<PB1)|(1<<PB2);
}
void loop() {
// do something else
}
```

This is what it looks like on the oscilloscope:



As an exercise, you can slow down the settings so that you can make the PWM signal visible on two LEDs. If you don't have an oscilloscope, it's more satisfying. As in the last article, however, I would like to refer once again to the DSO 138, an oscilloscope for less than 30 euros. As a start, I highly recommend this. At Amazon, ebay and Co it's available in many shops.

Using Fast PWM

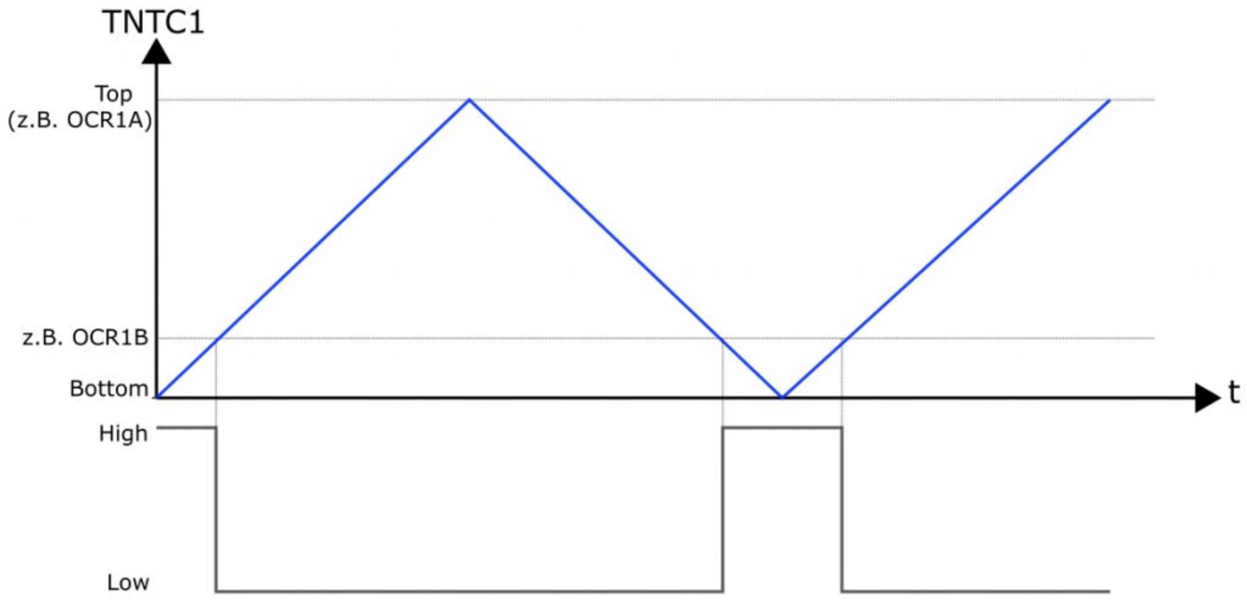
The name already suggests that Fast PWM is fast. Therefore, this mode is mainly used where this property is important. You will learn soon why it is twice as fast as the other PWM modes. The limitations of Fast PWM compared to the other PWM modes are more understandable, if you look at them in comparison.

Phase-Correct PWM

In the Phase-Correct PWM, TCNT1 counts up from Bottom to Top and then down again (two flanks per period). Top values are again

- 0x00FF, 0x01FF, 0x03FF – Mode 1 to 3
- ICR1 – Mode 10
- or OCR1A – Mode 11

to choose from. In the following I would like to explain the special features of this mode using a concrete example. OCR1A is defined as Top and OCR1B as Compare Match:



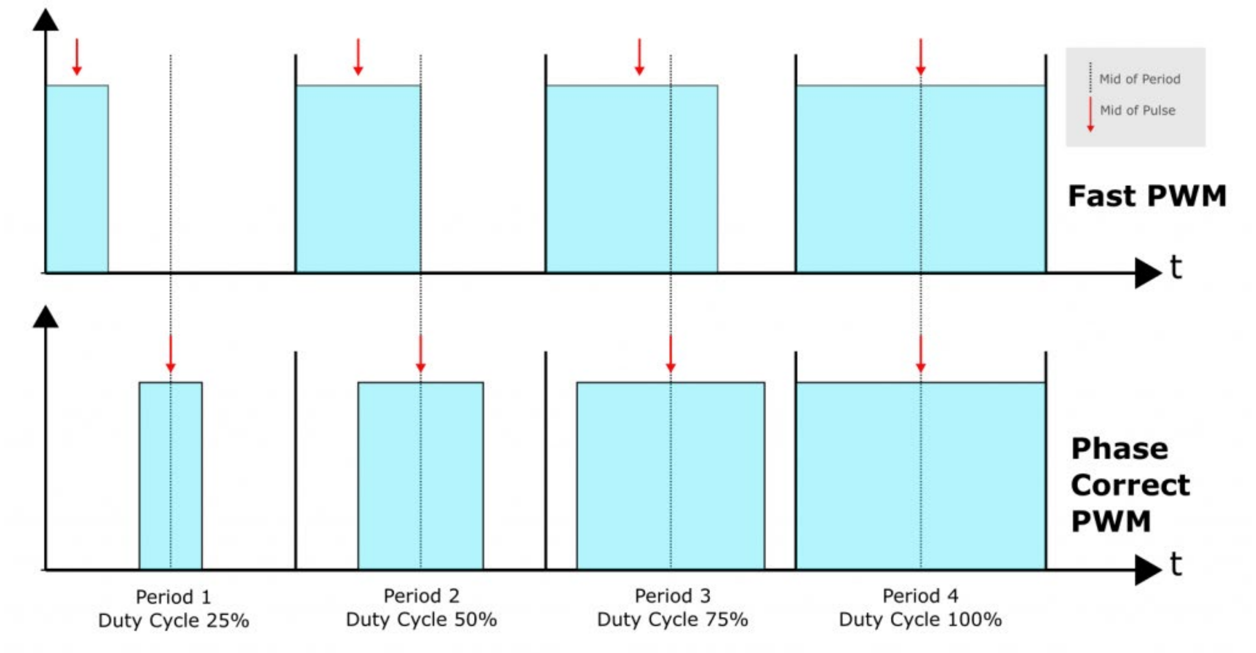
Graph 3: TNTC1 vs. OC1x at Phase Correct PWM

The period doubles compared to Fast PWM, or the frequency halves. A Compare Match with OCR1B takes place both when counting up and down.

Since you should be able to make the settings yourself, and because the article should not be longer, I have omitted further example sketches.

Phase-Correct PWM at constant frequency

OCR1A and OCR1B are updated when TCNT1 reaches Top. This ensures that the center of the pulse is always in the middle of the period, as long as only OCR1B is varied. In Fast PWM, the center of the pulse wanders through the period as the pulse width changes. Sounds complex, but it is not:



Graph 4: Fast PWM vs. Phase Correct PWM when changing pulse width and constant frequency

A nice animation can be found here.

A typical application for Phase-Correct PWM is the control of servo motors, as they like a symmetrical signal. I will perhaps write something about servo motors separately.

Phase-Correct PWM at varying frequency

If the Top changes, i.e. a frequency change, we still have the update problem when using ICR1 as the top. If ICR1 is updated as a Top while you're counting and it is less than the current TCNT1 value, there will be no "Top Match" in the current cycle.

With OCR1A as Top, there is another problem if you change this value in the running program. Imagine you're updating Top while TCNT1 is counting down. The length of the falling edge is then still determined by the old TOP. The length of the rising edge, on the other hand, is determined by the new Top. Again, this makes the signal asymmetrical. You can prevent this by switching to Phase and Frequency Correct PWM mode.

Phase and Frequency Correct PWM

Also in the phase and frequency correct PWM, TCNT1 counts from Bottom to Top and then down to Bottom. The same scheme applies as for the phase-correct PWM (Graph 3). The difference is that OCR1A and OCR1B are updated at Bottom. This ensures that there are always two symmetrical edges. You find more graphics related to this In the data sheet of the ATmega 48 / 88 / 168 / 328 family.

Summary: which PWM mode is appropriate?

- **Fast PWM**: with constant frequency and pulse width or applications that are not allergic to the migration of the pulse center associated with the pulse width change
- **Phase Correct PWM**: with variation of pulse width and constant frequency
- **Phase and Frequency Correct PWM**: with variation of frequency

Using the Input Capture Pin

As promised above, I would like to return to the Input Capture function. It would be a pity to reduce it simply to having another TOP available with ICR1.

The Input Capture Pin allows you to measure events conveniently in the background in terms of their chronological sequence. The following example illustrates the principle. It’s not very nicely programmed with its many global variables, but that’s not what matters here.

I have a push button attached to ICP1 (PB0, Arduino Pin8). Pressed it is HIGH, otherwise LOW. After pressing ten times, the time at which the button was pressed is output.

Using the Timer1 in Normal Mode, the sketch registers the seconds. For this, I have chosen the prescaler 256 and the starting value 3036. The frequency is 1 Hz and 1 second corresponds to 62500 steps. For each timer overflow, the seconds are incremented. By setting ICES1, the rising edge of the signal on ICP1 is selected. ICIE1 and TOIE1 enable the required interrupts.

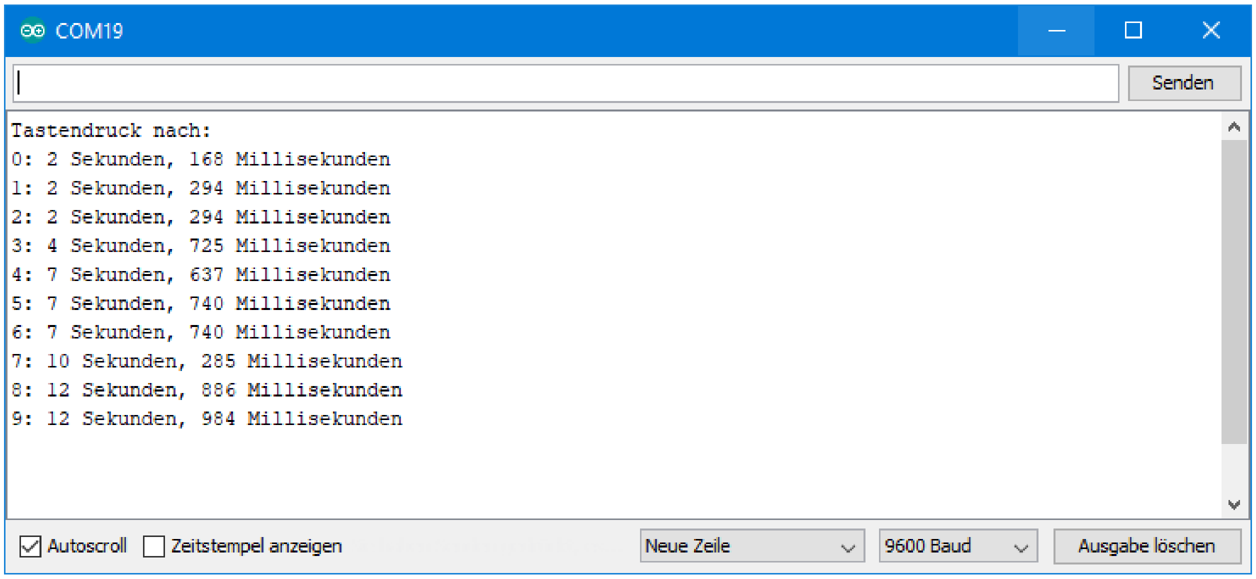
When pressing a button, the TCNT1 counter reading is stored in ICR1. Subtracting the start value and dividing by 62.5 provides the milliseconds. The push-button presses are stored in an array.

T1_input_capture.ino

```
unsigned int counterStart = 3036;
unsigned int eventTime[10][2];
volatile unsigned int seconds = 0;
unsigned int ms = 0;
unsigned int eventCounter = 0;
volatile bool event = false;
const float ms_const = 62.5;
void setup(){
Serial.begin(9600);
TCCR1A = 0; // Normal Mode
TCCR1B = (1<<ICES1) + (1<<CS12);
TIMSK1 = (1<<ICIE1) + (1<<TOIE1);
TCNT1 = counterStart;
}
void loop() {
if(event){
eventTime[eventCounter][1] = seconds;
eventTime[eventCounter][2] = round((ICR1 - 3036) / ms_const);
eventCounter++;
if(eventCounter==10){
ausgabeZeiten();
eventCounter=0;
}
event=false;
}
}
void ausgabeZeiten(){
Serial.println("Tastendruck nach: ");
for(int i=0; i<10; i++){
Serial.print(i);
Serial.print(": ");
Serial.print(eventTime[i][1]);
Serial.print(" Sekunden, ");
Serial.print(eventTime[i][2]);
Serial.println(" Millisekunden");
}
}
ISR(TIMER1_OVF_vect){
TCNT1 = counterStart;
seconds++;
}
ISR(TIMER1_CAPT_vect){
event = true;
}
```

Output of the Input Capture example sketch

I pressed the button every 2-3 seconds. In the output you can see the push-button bounce. Of course, this example could have been easily programmed with a digitalRead / millis combination. The beauty of the Input Capture method, however, is that you don't have to query the time of the event immediately. It is stored safely in ICR1. In addition, the time of the event can be determined in very high resolution, namely precisely to the system clock.



```
Tastendruck nach:
0: 2 Sekunden, 168 Millisekunden
1: 2 Sekunden, 294 Millisekunden
2: 2 Sekunden, 294 Millisekunden
3: 4 Sekunden, 725 Millisekunden
4: 7 Sekunden, 637 Millisekunden
5: 7 Sekunden, 740 Millisekunden
6: 7 Sekunden, 740 Millisekunden
7: 10 Sekunden, 285 Millisekunden
8: 12 Sekunden, 886 Millisekunden
9: 12 Sekunden, 984 Millisekunden
```

External clocks on T1

As can be seen from the Clock Select Bit table, you can attach an external clock to T1 (PD5, Arduino Pin 5). You have the choice whether the rising or falling edge serves as the clock signal. In part 1 of this article I had attached a push button to T0 as a clock and I switched an LED with it. I was all the more astonished that it didn't work with T1 on the Arduino. The following sketch was used:

T1_external_clock.ino

```
// geht nicht!!!!
void setup(){
TCCR1A |= (1<<COM1A0) + (1<<WGM11) + (1<<WGM10);
TCCR1B |= (1<<WGM13) + (1<<WGM12) + (1<<CS12) + (1<<CS11) + (1<<CS10);
OCR1A = 10;
DDRB |= (1<<PB1);
}
void loop() {
// do something else
}
```

Actually, the LED and OC1A (PB1, Arduino Pin9) should turn on or off with every tenth press of the push button. I do not know why this is not happening. Does anyone have an idea? But it seems to be due to the setup of the Arduino, because the same sketch, translated into C, worked with Atmel Studio on the "naked" ATmega328P without any problems:

timer1_external_clock_an_T1.cpp

```
#include <avr/io.h>
#include <util/delay.h>
int main(void)
{
TCCR1A |= (1<<COM1A0) + (1<<WGM11) + (1<<WGM10);
TCCR1B |= (1<<WGM13) + (1<<WGM12) + (1<<CS12) + (1<<CS11) + (1<<CS10);
OCR1A = 10;
DDRB |= (1<<PB1);
while (1)
{
}
}
```