

# AVRAssist - AVR Helpers

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# Table of Contents

|                                      |    |
|--------------------------------------|----|
| 1. Introduction .....                | 1  |
| 2. Timer 0 .....                     | 3  |
| 2.1. Timer Initialisation .....      | 3  |
| 3. Timer 1 .....                     | 9  |
| 3.1. Timer Initialisation .....      | 9  |
| 4. Timer 2 .....                     | 17 |
| 4.1. Timer Initialisation .....      | 17 |
| 5. Analogue Comparator .....         | 23 |
| 5.1. Comparator Initialisation ..... | 23 |
| Appendix A: Foibles .....            | 27 |
| A.1. Timer 0 .....                   | 27 |
| A.2. Timer 1 .....                   | 27 |
| A.3. Timer 2 .....                   | 29 |
| A.4. Analogue Comparator .....       | 29 |
| A.5. ??? .....                       | 29 |



# Chapter 1. Introduction

**AVRAssist** is a *first attempt* at making (my) life easier when it comes to trying to remember what bits in which registers need to be set to enable/initialise certain features on my Arduino boards' Atmega328P micro controller. After all, which of these is easier to remember, this:

```
#include <timer0.h>

using namespace AVRAssist;

...

Timer0::initialise(Timer0::MODE_FAST_PWM_255,    // Timer mode;
                   Timer0::CLK_PRESCALE_64,      // Prescaler;
                   Timer0::OC0X_DISCONNECTED,     // Don't touch OC0A or OC0B;
                   Timer0::INT_COMP_MATCH_A |    // Interrupt(s) to enable;
                   Timer0::INT_COMP_MATCH_B);

...
```

or this:

```
TCCR0A = (1 << WGM00) | (1 << WGM01);
TCCR0B = (1 << CS01) | (1 << CS00);
TIMSK0 = (1 << OCIE0A) | (1 << OCIE0B);
```

And it gets worse when I decide to add in more features and have to look up the additional bits and set them correctly. Get the computer to do it for you is my motto - or one of them!

At the moment, each header file creates a namespace and you (or I) can use that namespace to initialise one feature - timer, comparator, watchdog, ADC etc - of the micro-controller. At the moment, everything lives in the **AVRAssist::<feature>** namespace, **AVRAssist::Timer0** for example, but if, as I might, I decide to add my ATtiny85s into the mix, it is possible that some future update will break things and add another level - **AVRAssist::<chip>::<feature>** namespace, **AVRAssist::atmega328::Timer0** and **AVRAssist::attiny85::Timer0** perhaps. Stay tuned.



It *should* be a simple edit to change one line, **using namespace AVRAssist;** to something like **using AVRAssist::atmega328;** instead, to use the micro-controller specific later versions of the code. Hey, I have to change my code as well, so the easier the better.

At the moment, I'm working mostly with ATmega328P devices, so the whole thing is designed (for certain values of *designed*) exclusively for that micro controller.

It could be that I extend this code to make actual objects out of the current namespaces, so that I can do other things, without needing the bit names and registers all the time. Time will tell, that's its job after all.

It is intended that this code will work in the Arduino IDE as well as with other development systems, such as PlatformIO or even AVR Studio etc, however, the Arduino IDE does a lot of jiggery-pokery in the background, setting up timers and PWM and such like, that some things might not be fully compatibly with the Arduino. Hopefully, this will be pointed out in the documentation.

# Chapter 2. Timer 0

This AVR Assistant allows the simple setup and configuration of Timer/Counter 0 on your AVR (specifically, ATmega328) micro controller. This code works in the Arduino IDE or free standing for use with some other development system, such as PlatformIO. It has not been tested on other micro controllers. (Although the ATmega168 should work.)

To use the assistant, you must include the `timer0.h` header file:

```
#include "timer0.h"
```

Following this, you may, optionally, use the `AVRAssist` namespace:

```
using namespace AVRAssist;
```



The spelling of `AVRAssist` must be as shown above.

If you choose not to do this, you must prefix everything with `AVRAssist::` or the code will not work.

## 2.1. Timer Initialisation

Once the header file has been included, timer/counter 0 can be initialised as follows:

```
#include <timer0.h>

using namespace AVRAssist;

...

Timer0::initialise(Timer0::MODE_FAST_PWM_255,           // Timer mode;
                   Timer0::CLK_PRESCALE_64,             // Clock source;
                   Timer0::OC0X_DISCONNECTED,            // OCOA, OCOB actions on
compare match;
                   Timer0::INT_COMPARE_MATCH_A |        // Interrupt(s) to enable;
                   Timer0::INT_COMPARE_MATCH_B,
                   Timer0::FORCE_COMPARE_NONE           // Force Compare required?
                   );

...
```

The above sets Timer/Counter 0 into fast PWM mode with `TOP` = to 255, with a clock prescaler of 64. When `OCR0A` and `OCR0B` match `TCNT0` nothing happens to pins `OC0A` or `OC0B` but an interrupt will be fired when the comparison happens to match.

### 2.1.1. Initialisation Function

The header file exposes a single `initialise` function which is defined as follows:

```
void initialise(const uint8_t timerMode,
               const clockSource_t clockSource,
               const compareMatch_t compareMatch = OCOX_DISCONNECTED,
               const interrupt_t enableInterrupts = INT_NONE
               const forceCompare_t forceCompare = FORCE_COMPARE_NONE) {
```

### 2.1.2. Timer Modes

Timer/counter 0 can be initialised to run in one of 6 modes, as follows.

| Mode | Parameter           | Description                                     |
|------|---------------------|---|
| 0    | MODE_NORMAL         | Normal mode.                                    |
| 1    | MODE_PC_PWM_255     | Phase Correct PWM with TOP at 255.              |
| 2    | MODE CTC_OCR0A      | Clear Timer on Compare (CTC) with TOP at OCR0A. |
| 3    | MODE_FAST_PWM_255   | Fast PWM with TOP at 255.                       |
| 4    | MODE_RESERVED_4     | Reserved, do not use.                           |
| 5    | MODE_PC_PWM_OCR0A   | Phase Correct PWM with TOP at OCR0A.            |
| 6    | MODE_RESERVED_6     | Reserved, do not use.                           |
| 7    | MODE_FAST_PWM_OCR0A | Fast PWM with TOP at OCR0A.                     |

You use this parameter to define the mode that you wish the timer/counter to run in. It should be obvious, I hope, that only one of the above modes can be used, however, if you wish to `or` them together, be it on your own head!

```
Timer0::initialise(Timer0::MODE_FAST_PWM_255,           ①
                   Timer0::CLK_PRESCALE_64,
                   Timer0::OCOX_DISCONNECTED,
                   Timer0::INT_COMPARE_MATCH_A |
                   Timer0::INT_COMPARE_MATCH_B,
                   Timer0::FORCE_COMPARE_NONE
                   );
```

① The timer mode parameter in action enabling the timer/counter in fast PWM mode with TOP defined by the value 255.

### 2.1.3. Clock Sources

The timer/counter needs a clock source to actually start it running as a timer, or as a counter. The following options are available for Timer/counter 0:

| Parameter | Description |
|-----------|-------------|
|-----------|-------------|



|                   |   |
|-------------------|---|
| CLK_DISABLED      | The timer/counter will stopped.   |
| CLK_PRESCALE_1    | The timer/counter will be running at F_CPU/1  |
| CLK_PRESCALE_8    | The timer/counter will be running at F_CPU/8  |
| CLK_PRESCALE_64   | The timer/counter will be running at F_CPU/64   |
| CLK_PRESCALE_256  | The timer/counter will be running at F_CPU/256  |
| CLK_PRESCALE_1024 | The timer/counter will be running at F_CPU/1024   |
| CLK_T0_FALLING    | The timer/counter will be clocked from pin 6, aka T0, Arduino pin D4 on a falling edge. |
| CLK_T0_RISING     | The timer/counter will be clocked from pin 6, aka T0, Arduino pin D4 on a rising edge.  |

You use this mode to define how fast the timer/counter will count, or, to disable the timer.

```

Timer0::initialise(Timer0::MODE_FAST_PWM_255,
                   Timer0::CLK_PRESCALE_64,           ①
                   Timer0::OC0X_DISCONNECTED,
                   Timer0::INT_COMPARE_MATCH_A |
                       Timer0::INT_COMPARE_MATCH_B,
                   Timer0::FORCE_COMPARE_NONE
                   );

```

- ① The clock source parameter in action showing that the timer/counter will be running at a speed defined by the system clock, F\_CPU, divided by 64.

### 2.1.4. Compare Match Options

This parameter allows you to indicate what actions you want the AVR micro controller to perform on pins OC0A (pin 12, Arduino pin D6) and/or OC0B (pin 11, Arduino pin D5) when the value in TCNT0 matches OCR0A or OCR0B. The allowed values are:

| Parameter         | Description   |
|-------------------|---|
| OC0X_DISCONNECTED | The two OC0x pins will not be affected when the timer count matches either OCR0A or OCR0B.                      |
| OC0A_TOGGLE       | Pin OC0A will toggle when TCNT0 matches OCR0A.  |
| OC0A_CLEAR        | Pin OC0A will be reset LOW when TCNT0 matches OCR0A.  |
| OC0A_SET          | Pin OC0A will be reset HIGH when TCNT0 matches OCR0A.   |
| OC0B_TOGGLE       | Pin OC0B will toggle when TCNT0 matches OCR0B. You cannot use OC0B_TOGGLE in anything but NORMAL and CTC modes. |
| OC0B_CLEAR        | Pin OC0B will be reset LOW when TCNT0 matches OCR0B.  |
| OC0B_SET          | Pin OC0B will be reset HIGH when TCNT0 matches OCR0B.   |

An example of initialising the timer/counter using this parameter is:

```

Timer0::initialise(Timer0::MODE_FAST_PWM_255,
                  Timer0::CLK_PRESCALE_64,
                  Timer0::OC0X_DISCONNECTED, ①
                  Timer0::INT_COMPARE_MATCH_A |
                  Timer0::INT_COMPARE_MATCH_B,
                  Timer0::FORCE_COMPARE_NONE
                  );

```

① The compare match parameter in action showing that when **TCNT0** matches **OCR0A** or **OCR0B**, that no special effects take place. The pins **OC0A** (pin 12, Arduino **D6**) and **OC0B** (pin 11, Arduino **D5**) are not affected.

## 2.1.5. Interrupts

Timer/counter 0 has three interrupts that can be enabled. Sadly though, if you are using the Arduino IDE to write your code, it will sneakily use the overflow interrupt on this timer/counter, to facilitate the **millis()** function, and from that **delay()** etc are defined. You cannot define the Timer/counter 0 overflow interrupt *handler* in your own code if you compile within the Arduino IDE.

The various interrupt options are:

| Parameter           | Description   |
|---------------------|---|
| INT_NONE            | No interrupts are required on this timer/counter. This is the default.  |
| INT_COMPARE_MATCH_A | The <b>TIMER0 COMPA</b> interrupt is to be enabled. You are required to create an ISR function to handle it.  |
| INT_COMPARE_MATCH_B | The <b>TIMER0 COMPB</b> interrupt is to be enabled. You are required to create an ISR function to handle it.  |
| INT_OVERFLOW        | The <b>TIMER0 OVF</b> interrupt is to be enabled. You are required to create an ISR function to handle it. This interrupt's handler cannot be defined in your own code in an Arduino IDE development system as the handler, <b>ISR(TIMER0_OVF_vect)</b> has been created internally and added to your code behind the scenes. |

An example of initialising the timer/counter with interrupts enabled, would be:

```

ISR(TIMER0_COMPA_vect) {
    ...
}

ISR(TIMER0_COMPB_vect) {
    ...
}

Timer0::initialise(Timer0::MODE_FAST_PWM_255,
                   Timer0::CLK_PRESCALE_64,
                   Timer0::OC0X_DISCONNECTED,
                   Timer0::INT_COMPARE_MATCH_A | ①
                   Timer0::INT_COMPARE_MATCH_B, ②
                   Timer0::FORCE_COMPARE_NONE
                   );

```

- ① The interrupts parameter in action showing that the 'compare match A' and 'compare match B' interrupts are to be enabled, while the other interrupt, the timer/counter overflow interrupt, is not to be enabled here.



On Arduino systems, disabling the overflow interrupt for timer/counter 0 will stop `millis()` etc from working. The `delay()` function will also fail to work. In addition, attempting to define the timer/counter 0 overflow interrupt handler in your own (Arduino) code will fail to compile as the Arduino system already defines a handler for that interrupt. You need to write your code in something like *Atmel Studio* or *PlatformIO* to be able to use that interrupt as those development systems do not interfere with the code that you write!

You *can* obviously still enable the interrupts with `INT_OVERFLOW` enabled, you just cannot control what happens in the interrupt handler for it. The Arduino IDE has full control, you have none, but if your code relies on the Arduino `millis()` or calls `delay()` then you should always enable that interrupt.

Of course, if you change this timer/counter's initialisation away from that of the Arduino, you will affect those functions anyway.

- ② You can **or** various values together to create the full set of required interrupts, as in this example.

### 2.1.6. Force Compare Options

Timer/counter 0 can be forced to run a compare of `TCNT0` against `OCR0A` and/or `OCR0B` at any time. However, it is unlikely that this will be useful (Famous last words?) - the output pins `OC0A` (pin 12, Arduino **D6**) and `OC0B` (pin 11, Arduino **D5**) will be toggled or set according to the [compare match options](#) as long as that parameter is not set to `OC0X_DISCONNECTED` and the pin(s) in question are set to toggle, clear or set.

When the forced comparison is carried out, no interrupts will fire, if configured, and `TCNT0` will not be cleared in CTC mode with `OCR0A` as **TOP**. (Timer mode `MODE_CTC_OCR0A`.)

Setting these bits at timer initialisation is perhaps not so useful, but at least the option is there. These bits are cleared after the forced compare has taken place.

The options are:

| Parameter             | Description   |
|-----------------------|---|
| FORCE_COMPARE_NONE    | No forced comparisons will take place. This is the default.   |
| FORCE_COMPARE_MATCH_A | A forced compare of <b>TCNT0</b> against <b>OCR0A</b> will be carried out. You cannot use any force compare modes in anything but NORMAL and CTC modes. |
| FORCE_COMPARE_MATCH_B | A forced compare of <b>TCNT0</b> against <b>OCR0B</b> will be carried out. You cannot use any force compare modes in anything but NORMAL and CTC modes. |

While the default for this parameter is to have no force compares enabled, **FORCE\_COMPARE\_NONE**, you can be explicit if you wish, and call the **initialise()** function as follows:

```
Timer0::initialise(Timer0::MODE_FAST_PWM_255,  
                  Timer0::CLK_PRESCALE_64,  
                  Timer0::OC0X_DISCONNECTED,  
                  Timer0::INT_COMPARE_MATCH_A |  
                    Timer0::INT_COMPARE_MATCH_B,  
                  Timer0::FORCE_COMPARE_NONE ①  
                );
```

① The force compare parameter in action showing that we are not requiring a force compare as soon as the timer is initialised.

You can, of course, initialise the timer as above, and then, in your code at any time, simply set one or other of the **FOC0A** and **FOC0B** bits in register **TCCR0B** to force a compare to affect the output pins at that point, but remember, no interrupts will fire for the compare match in that case.

# Chapter 3. Timer 1

This AVR Assistant allows the simple setup and configuration of the 16 bit Timer/counter 1 on your AVR (specifically, ATmega328) micro controller. This code works in the Arduino IDE or free standing for use with some other development system, such as PlatformIO. It has not been tested on other micro controllers. (Although the ATmega168 should work.)

To use the assistant, you must include the `timer1.h` header file:

```
#include "timer1.h"
```

Following this, you may, optionally, use the `AVRAssist` namespace:

```
using namespace AVRAssist;
```



The spelling of `AVRAssist` must be as shown above.

If you choose not to do this, you must prefix everything with `AVRAssist::` or the code will not work.

## 3.1. Timer Initialisation

Once the header file has been included, Timer/counter 1 can be initialised as follows:

```
#include <timer1.h>

using namespace AVRAssist;

...

Timer1::initialise(Timer1::MODE_CTC_OCR1A,           // Timer mode;
                  Timer1::CLK_PRESCALE_1024,        // Clock source;
                  Timer1::OC1A_TOGGLE,              // OC1A, OC1B actions on
compare match;
                  Timer1::INT_NONE,
                  Timer1::FORCE_COMPARE_NONE,        // Force Compare required?
                  Timer1::INPCAP_NOISE_CANCEL_OFF_FALLING_EDGE // Disable input
capture.
                  );

...
```

The above sets Timer/counter 1 into Clear Timer on Compare match mode with **TOP** at **OCR1A**, with a clock prescaler of 1,024. When **OCR1A** matches **TCNT1** pin **OC1A** will toggle but when **OCR1B** matches **TCNT1** nothing happens to pin **OC1B**. No interrupts will be fired for this timer.

### 3.1.1. Initialisation Function

The header file exposes a single `initialise` function which is defined as follows:

```
void initialise(const uint8_t timerMode,
               const clockSource_t clockSource,
               const compareMatch_t compareMatch = OC1X_DISCONNECTED,
               const interrupt_t enableInterrupts = INT_NONE,
               const forceCompare_t forceCompare = FORCE_COMPARE_NONE,
               const inputCapture_t inputCapture =
INPCAP_NOISE_CANCEL_OFF_FALLING_EDGE)
```

### 3.1.2. Timer Modes

Timer/counter 1 can be initialised to run in one of 15 modes, as follows.

| Mode | Parameter            | Description  |
|------|----------------------|--|
| 0    | MODE_NORMAL = 0      | Normal mode.                                       |
| 1    | MODE_PC_PWM_255      | 8 bit Phase Correct PWM with TOP at 255.           |
| 2    | MODE_PC_PWM_511      | 9 bit Phase Correct PWM with TOP at 511.           |
| 3    | MODE_PC_PWM_1023     | 10 bit Phase Correct PWM with TOP at 1023.         |
| 4    | MODE_CTC_OCR1A       | Clear Timer on Compare (CTC) with TOP at OCR1A.    |
| 5    | MODE_FAST_PWM_255    | 8 bit Fast PWM with TOP at 255.                    |
| 6    | MODE_FAST_PWM_511    | 9 bit Fast PWM with TOP at 511.                    |
| 7    | MODE_FAST_PWM_1023   | 10 bit Fast PWM with TOP at 1023.                  |
| 8    | MODE_PC_FC_PWM_ICR1  | Phase and Frequency Correct PWM with TOP at ICR1.  |
| 9    | MODE_PC_FC_PWM_OCR1A | Phase and Frequency Correct PWM with TOP at OCR1A. |
| 10   | MODE_PC_PWM_ICR1     | Phase Correct PWM with TOP at ICR1.                |
| 11   | MODE_PC_PWM_OCR1A    | Phase Correct PWM with TOP at OCR1A.               |
| 12   | MODE_CTC_ICR1        | Clear Timer on Compare (CTC) with TOP at ICR1.     |
| 13   | MODE_RESERVED_13     | Reserved, do not use.                              |
| 14   | MODE_FAST_PWM_ICR1   | Fast PWM with TOP at ICR1.                         |
| 15   | MODE_FAST_PWM_OCR1A  | Fast PWM with TOP at OCR1A.                        |

You use this parameter to define the mode that you wish the timer/counter to run in. It should be obvious, I hope, that only one of the above modes can be used, however, if you wish to `or` them together, be it on your own head!

```

Timer1::initialise(Timer1::MODE_CTC_OCR1A,
                  Timer1::CLK_PRESCALE_1024,
                  Timer1::OC1A_TOGGLE,
                  Timer1::INT_NONE,
                  Timer1::FORCE_COMPARE_NONE,
                  Timer1::INPCAP_NOISE_CANCEL_OFF_FALLING_EDGE
                );

```

① The timer mode parameter in action enabling the timer/counter in CTC mode with TOP at OCR1A.

### 3.1.3. Clock Sources

The timer/counter needs a clock source to actually start it running as a timer, or as a counter. The table below lists the available options for Timer/counter 1.

| Parameter         | Description  |
|-------------------|--|
| CLK_DISABLED      | The timer/counter will stopped.  |
| CLK_PRESCALE_1    | The timer/counter will be running at F_CPU/1   |
| CLK_PRESCALE_8    | The timer/counter will be running at F_CPU/8   |
| CLK_PRESCALE_64   | The timer/counter will be running at F_CPU/64  |
| CLK_PRESCALE_256, | The timer/counter will be running at F_CPU/256   |
| CLK_PRESCALE_1024 | The timer/counter will be running at F_CPU/1024  |
| CLK_T1_FALLING    | The timer/counter will be clocked from pin 11, aka T1, Arduino pin D5 on a falling edge. |
| CLK_T1_RISING     | The timer/counter will be clocked from pin 11, aka T1, Arduino pin D5 on a rising edge.  |

You use this mode to define how fast the timer/counter will count, or, to disable the timer.

```

Timer1::initialise(Timer1::MODE_CTC_OCR1A,
                  Timer1::CLK_PRESCALE_1024,
                  Timer1::OC1A_TOGGLE,
                  Timer1::INT_NONE,
                  Timer1::FORCE_COMPARE_NONE,
                  Timer1::INPCAP_NOISE_CANCEL_OFF_FALLING_EDGE
                );

```

① The clock source parameter in action showing that the timer/counter will be running at a speed defined by the system clock, F\_CPU, divided by 1,024.

### 3.1.4. Compare Match Options

This parameter allows you to indicate what actions you want the AVR micro controller to perform on pins OC1A (pin 15, Arduino pin D9) and/or OC1B (pin 16, Arduino pin D10) when the value in TCNT1 matches OCR1A or OCR1B. The allowed values are:

| Parameter         | Description   |
|-------------------|---|
| OC1X_DISCONNECTED | The two OC1x pins will not be affected when the timer count matches either OCR1A or OCR1B. This is the default. |
| OC1A_TOGGLE       | Pin OC1A will toggle when TCNT1 matches OCR1A.  |
| OC1A_CLEAR        | Pin OC1A will be reset LOW when TCNT1 matches OCR1A.  |
| OC1A_SET          | Pin OC1A will be reset HIGH when TCNT1 matches OCR1A.   |
| OC1B_TOGGLE       | Pin OC1B will toggle when TCNT1 matches OCR1B.  |
| OC1B_CLEAR        | Pin OC1B will be reset LOW when TCNT1 matches OCR1B.  |
| OC1B_SET          | Pin OC1B will be reset HIGH when TCNT1 matches OCR1B.   |

An example of initialising the timer/counter using this parameter is:

```
Timer1::initialise(Timer1::MODE CTC_OCR1A,
                  Timer1::CLK_PRESCALE_1024,
                  Timer1::OC1A_TOGGLE,
                  Timer1::INT_NONE,
                  Timer1::FORCE_COMPARE_NONE,
                  Timer1::INPCAP_NOISE_CANCEL_OFF_FALLING_EDGE
                  );
```

- ① The compare match parameter in action showing that when TCNT1 matches OCR1A, pin OC1A (pin 15, Arduino D9) will toggle while OC1B (pin 16, Arduino D10) will not be affected when TCNT1 matches OCR1B.

### 3.1.5. Interrupts

Timer/counter 1 has four interrupts that can be enabled and these are:

| Parameter           | Description  |
|---------------------|--|
| INT_NONE            | No interrupts are required on this timer/counter. This is the default.   |
| INT_CAPTURE         | The TIMER1 CAPT (input capture) interrupt is to be enabled. You are required to create an ISR function to handle it. |
| INT_COMPARE_MATCH_A | The TIMER1 COMPA interrupt is to be enabled. You are required to create an ISR function to handle it.                |
| INT_COMPARE_MATCH_B | The TIMER1 COMPB interrupt is to be enabled. You are required to create an ISR function to handle it.                |
| INT_OVERFLOW        | The TIMER1 OVF interrupt is to be enabled. You are required to create an ISR function to handle it.                  |

An example of initialising the timer/counter with one interrupt enabled, would be:



```

Timer1::initialise(Timer1::MODE CTC_OCR1A,
                  Timer1::CLK_PRESCALE_1024,
                  Timer1::OC1A_TOGGLE,
                  Timer1::INT_NONE,
                  Timer1::FORCE_COMPARE_NONE,
                  Timer1::INPCAP_NOISE_CANCEL_OFF_FALLING_EDGE
                  );

```

① The interrupts parameter in action showing that there are no interrupts to be enabled for this timer. If required, you can **or** various values together to create the full set of required interrupts.



You don't have to activate the input capture interrupt (**INT\_CAPTURE**) if you don't wish to, you can poll (not always a good idea) bit **ICF1** in register **TIFR1** and when it is set, an event has occurred.

### 3.1.6. Force Compare Options

Timer/counter 1 can be forced to run a compare of **TCNT1** against **OCR1A** and/or **OCR1B** at any time. However, it is unlikely that this will be particularly useful - Famous last words? When actioned, the output pins **OC1A** (pin 15, Arduino **D9**) and **OC1B** (pin 16, Arduino **D10**) will be toggled or set according to the **compare match options** as long as that parameter is not set to **OC1X\_DISCONNECTED** and the pin(s) in question are set to toggle, clear or set.

These options, if enabled, are only ever actioned when the timer/counter is running in a mode other than any of the PWM modes.

When a forced comparison is carried out, no interrupts will fire, even if configured, and **TCNT1** will not be cleared in CTC mode with **OCR1A** as **TOP**. (Timer mode **MODE CTC\_OCR1A**.)

Setting these bits at timer initialisation is perhaps not so useful, but at least the option is there. These bits are cleared immediately after the forced compare has taken place.

The options are:

| Parameter             | Description  |
|-----------------------|--|
| FORCE_COMPARE_NONE    | No forced comparisons will take place. This is the default.                |
| FORCE_COMPARE_MATCH_A | A forced compare of <b>TCNT1</b> against <b>OCR1A</b> will be carried out. |
| FORCE_COMPARE_MATCH_B | A forced compare of <b>TCNT1</b> against <b>OCR1B</b> will be carried out. |

While the default for this parameter is to have no force compares enabled, **FORCE\_COMPARE\_NONE**, you can be explicit if you wish, and call the **initialise()** function as follows:

```

Timer1::initialise(Timer1::MODE_CTC_OCR1A,
                  Timer1::CLK_PRESCALE_1024,
                  Timer1::OC1A_TOGGLE,
                  Timer1::INT_NONE,
                  Timer1::FORCE_COMPARE_NONE,
                  Timer1::INPCAP_NOISE_CANCEL_OFF_FALLING_EDGE
                );

```

① The force compare parameter in action showing that we are not requiring a force compare as soon as the timer is initialised.

You can, of course, initialise the timer as above, and then, in your code at any time, simply set one or other of the **FOC1A** and **FOC1B** bits in register **TCCR1C** to force a compare to affect the output pins at that point, but remember, no interrupts will fire for the compare match in that case.

### 3.1.7. Input Capture

Timer/counter 1 has an input capture facility which allows it to record a 'timestamp' when an event happens on pin 14, **ICP1**, Arduino pin **D8**. This parameter allows the timer to be configured as required, or for the input capture to be disabled - the default setting.

The permitted values are shown in the following table.

| Parameter                            | Description   |
|--------------------------------------|---|
| INPCAP_NOISE_CANCEL_OFF_FALLING_EDGE | The input capture is running with no noise cancelling and will be triggered on a falling edge on <b>ICP1</b> .      |
| INPCAP_NOISE_CANCEL_OFF_RISING_EDGE  | The input capture is running with no noise cancelling and will be triggered on a rising edge on <b>ICP1</b> .       |
| INPCAP_NOISE_CANCEL_ON_FALLING_EDGE  | The input capture is running with noise cancelling enabled and will be triggered on a falling edge on <b>ICP1</b> . |
| INPCAP_NOISE_CANCEL_ON_RISING_EDGE   | The input capture is running with noise cancelling enabled and will be triggered on a rising edge on <b>ICP1</b> .  |



When **ICR1** is used as the **TOP** value in timer mode **MODE\_PC\_FC\_PWM\_ICR1**, **MODE\_PC\_PWM\_ICR1**, **MODE\_CTC\_ICR1** or **MODE\_FAST\_PWM\_1CR1**, then the **ICP1** (pin 14, Arduino pin **D8**) is disconnected from the input capture circuitry meaning that the input capture function is disabled.

You can still set the bits in *any* timer mode, obviously, but they won't work if the mode is one of the PWM modes.

Yes, I know, they *are* long names!

```
Timer1::initialise(Timer1::MODE CTC_OCR1A,  
                  Timer1::CLK_PRESCALE_1024,  
                  Timer1::OC1A_TOGGLE,  
                  Timer1::INT_NONE,  
                  Timer1::FORCE_COMPARE_NONE,  
                  Timer1::INPCAP_NOISE_CANCEL_OFF_FALLING_EDGE ①  
                  );
```

- ① The input capture parameter in action showing that we wish to have input capture noise cancelling turned off, and the input to be triggered on a falling edge on **ICP1**. As no interrupts have been enabled for the input capture, the code is assumed to be polling bit **ICF1** in register **TIFR1** to determine when an event occurred.



# Chapter 4. Timer 2

This AVR Assistant allows the simple setup and configuration of the 8 bit Timer/Counter 2 on your AVR (specifically, ATmega328) micro controller. This code works in the Arduino IDE or free standing for use with some other development system, such as PlatformIO. It has not been tested on other micro controllers. (Although the ATmega168 should work.)

To use the assistant, you must include the `timer2.h` header file:

```
#include "timer2.h"
```

Following this, you may, optionally, use the `AVRAssist` namespace:

```
using namespace AVRAssist;
```



The spelling of `AVRAssist` must be as shown above.

If you choose not to do this, you must prefix everything with `AVRAssist::` or the code will not work.

## 4.1. Timer Initialisation

Once the header file has been included, Timer/counter 2 can be initialised as follows:

```
#include <timer2.h>

using namespace AVRAssist;

...

Timer2::initialise(Timer2::MODE_FAST_PWM_255,           // Timer mode;
                  Timer2::CLK_PRESCALE_64,              // Clock source;
                  Timer2::OC2X_DISCONNECTED,             // OC2A, OC2B actions on
compare match;
                  Timer2::INT_COMPARE_MATCH_A |         // Interrupt(s) to enable;
                  Timer2::INT_COMPARE_MATCH_B,
                  Timer2::FORCE_COMPARE_NONE            // Force Compare required?
                  );

...
```

The above sets Timer/counter 2 into fast PWM mode with `TOP` = to 255, with a clock prescaler of 64. When `OCR2A` and `OCR2B` match `TCNT2` nothing happens to pins `OC2A` or `OC2B` but an interrupt will be fired when the comparison happens to match.

### 4.1.1. Initialisation Function

The header file exposes a single `initialise` function which is defined as follows:

```
void initialise(const uint8_t timerMode,
               const clockSource_t clockSource,
               const compareMatch_t compareMatch = OC2X_DISCONNECTED,
               const interrupt_t enableInterrupts = INT_NONE
               const forceCompare_t forceCompare = FORCE_COMPARE_NONE) {
```

### 4.1.2. Timer Modes

Timer/counter 2 can be initialised to run in one of 6 modes, as follows.

| Mode | Parameter           | Description                                     |
|------|---------------------|---|
| 0    | MODE_NORMAL         | Normal mode.                                    |
| 1    | MODE_PC_PWM_255     | Phase Correct PWM with TOP at 255.              |
| 2    | MODE CTC_OCR2A      | Clear Timer on Compare (CTC) with TOP at OCR2A. |
| 3    | MODE_FAST_PWM_255   | Fast PWM with TOP at 255.                       |
| 4    | MODE_RESERVED_4     | Reserved, do not use.                           |
| 5    | MODE_PC_PWM_OCR2A   | Phase Correct PWM with TOP at OCR2A.            |
| 6    | MODE_RESERVED_6     | Reserved, do not use.                           |
| 7    | MODE_FAST_PWM_OCR2A | Fast PWM with TOP at OCR2A.                     |

You use this parameter to define the mode that you wish the timer/counter to run in. It should be obvious, I hope, that only one of the above modes can be used, however, if you wish to `or` them together, be it on your own head!

```
Timer2::initialise(Timer2::MODE_FAST_PWM_255,           ①
                   Timer2::CLK_PRESCALE_64,
                   Timer2::OC2X_DISCONNECTED,
                   Timer2::INT_COMPARE_MATCH_A |
                   Timer2::INT_COMPARE_MATCH_B,
                   Timer2::FORCE_COMPARE_NONE
                   );
```

① The timer mode parameter in action enabling the timer/counter in fast PWM mode with TOP defined by the value 255.

### 4.1.3. Clock Sources

The timer/counter needs a clock source to actually start it running as a timer, or as a counter. The following options are available for Timer/counter 2 and are slightly different from Timer/counter 0, the other 8 bit timer/counter, as there are no facilities to clock this timer/counter externally. It also has an additional two prescaler options over Timer/counter 0.

| Parameter         | Description                                     |
|-------------------|---|
| CLK_DISABLED      | The timer/counter will stopped.                 |
| CLK_PRESCALE_1    | The timer/counter will be running at F_CPU/1    |
| CLK_PRESCALE_8    | The timer/counter will be running at F_CPU/8    |
| CLK_PRESCALE_32   | The timer/counter will be running at F_CPU/32   |
| CLK_PRESCALE_64   | The timer/counter will be running at F_CPU/64   |
| CLK_PRESCALE_128  | The timer/counter will be running at F_CPU/128  |
| CLK_PRESCALE_256, | The timer/counter will be running at F_CPU/256  |
| CLK_PRESCALE_1024 | The timer/counter will be running at F_CPU/1024 |

You use this mode to define how fast the timer/counter will count, or, to disable the timer.

```

Timer2::initialise(Timer2::MODE_FAST_PWM_255,
                  Timer2::CLK_PRESCALE_64,           ①
                  Timer2::OC2X_DISCONNECTED,
                  Timer2::INT_COMPARE_MATCH_A |
                    Timer2::INT_COMPARE_MATCH_B,
                  Timer2::FORCE_COMPARE_NONE
                  );

```

① The clock source parameter in action showing that the timer/counter will be running at a speed defined by the system clock, **F\_CPU**, divided by 64.

#### 4.1.4. Compare Match Options

This parameter allows you to indicate what actions you want the AVR micro controller to perform on pins **OC2A** (pin 17, Arduino pin **D11**) and/or **OC2B** (pin 5, Arduino pin **D3**) when the value in **TCNT2** matches **OCR2A** or **OCR2B**. The allowed values are:

| Parameter         | Description  |
|-------------------|--|
| OC2X_DISCONNECTED | The two <b>OC2x</b> pins will not be affected when the timer count matches either <b>OCR2A</b> or <b>OCR2B</b> . This is the default.        |
| OC2A_TOGGLE       | Pin <b>OC2A</b> will toggle when <b>TCNT2</b> matches <b>OCR2A</b> .   |
| OC2A_CLEAR        | Pin <b>OC2A</b> will be reset <b>LOW</b> when <b>TCNT2</b> matches <b>OCR2A</b> .  |
| OC2A_SET          | Pin <b>OC2A</b> will be reset <b>HIGH</b> when <b>TCNT2</b> matches <b>OCR2A</b> .   |
| OC2B_TOGGLE       | Pin <b>OC2B</b> will toggle when <b>TCNT2</b> matches <b>OCR2B</b> . You cannot use <b>OC2B_TOGGLE</b> in anything but NORMAL and CTC modes. |
| OC2B_CLEAR        | Pin <b>OC2B</b> will be reset <b>LOW</b> when <b>TCNT2</b> matches <b>OCR2B</b> .  |
| OC2B_SET          | Pin <b>OC2B</b> will be reset <b>HIGH</b> when <b>TCNT2</b> matches <b>OCR2B</b> .   |

An example of initialising the timer/counter using this parameter is:

```

Timer2::initialise(Timer2::MODE_FAST_PWM_255,
                  Timer2::CLK_PRESCALE_64,
                  Timer2::OC2X_DISCONNECTED,           ①
                  Timer2::INT_COMPARE_MATCH_A |
                  Timer2::INT_COMPARE_MATCH_B,
                  Timer2::FORCE_COMPARE_NONE
                );

```

- ① The compare match parameter in action showing that when **TCNT2** matches **OCR2A** or **OCR2B**, that no special effects take place. The pins **OC2A** (pin 17, Arduino **D11**) and **OC2B** (pin 5, Arduino **D3**) are not affected.

### 4.1.5. Interrupts

Timer/counter 2 has three interrupts that can be enabled and these are:

| Parameter           | Description  |
|---------------------|--|
| INT_NONE            | No interrupts are required on this timer/counter. This is the default.                                       |
| INT_COMPARE_MATCH_A | The <b>TIMER2 COMPA</b> interrupt is to be enabled. You are required to create an ISR function to handle it. |
| INT_COMPARE_MATCH_B | The <b>TIMER2 COMPB</b> interrupt is to be enabled. You are required to create an ISR function to handle it. |
| INT_OVERFLOW        | The <b>TIMER2 OVF</b> interrupt is to be enabled. You are required to create an ISR function to handle it.   |

An example of initialising the timer/counter with interrupts enabled, would be:

```

ISR(TIMER2_COMPA_vect) {
    ...
}

ISR(TIMER2_COMPB_vect) {
    ...
}

Timer2::initialise(Timer2::MODE_FAST_PWM_255,
                  Timer2::CLK_PRESCALE_64,
                  Timer2::OC2X_DISCONNECTED,
                  Timer2::INT_COMPARE_MATCH_A |           ①
                  Timer2::INT_COMPARE_MATCH_B,           ②
                  Timer2::FORCE_COMPARE_NONE
                );

```

- ① The interrupts parameter in action showing that the 'compare match A' and 'compare match B' interrupts are to be enabled, while the other interrupt, the timer/counter overflow interrupt, is not to be enabled.
- ② You can **or** various values together to create the full set of required interrupts, as in this



example.

### 4.1.6. Force Compare Options

Timer/counter 2 can be forced to run a compare of **TCNT2** against **OCR2A** and/or **OCR2B** at any time. However, it is unlikely that this will be particularly useful - Famous last words? When actioned, the output pins **OC2A** (pin 17, Arduino **D11**) and **OC2B** (pin 5, Arduino **D3**) will be toggled or set according to the [compare match options](#) as long as that parameter is not set to **OC2X\_DISCONNECTED** and the pin(s) in question are set to toggle, clear or set.

When the forced comparison is carried out, no interrupts will fire, if configured, and **TCNT2** will not be cleared in CTC mode with **OCR2A** as **TOP**. (Timer mode **MODE\_CTC\_OCR2A**.)

Setting these bits at timer initialisation is perhaps not so useful, but at least the option is there. These bits are cleared immediately after the forced compare has taken place.

The options are:

| Parameter             | Description   |
|-----------------------|---|
| FORCE_COMPARE_NONE    | No forced comparisons will take place. This is the default.   |
| FORCE_COMPARE_MATCH_A | A forced compare of <b>TCNT2</b> against <b>OCR2A</b> will be carried out. You cannot use any force compare modes in anything but NORMAL and CTC modes. |
| FORCE_COMPARE_MATCH_B | A forced compare of <b>TCNT2</b> against <b>OCR2B</b> will be carried out. You cannot use any force compare modes in anything but NORMAL and CTC modes. |

While the default for this parameter is to have no force compares enabled, **FORCE\_COMPARE\_NONE**, you can be explicit if you wish, and call the **initialise()** function as follows:

```
Timer2::initialise(Timer2::MODE_FAST_PWM_255,  
                  Timer2::CLK_PRESCALE_64,  
                  Timer2::OC2X_DISCONNECTED,  
                  Timer2::INT_COMPARE_MATCH_A |  
                    Timer2::INT_COMPARE_MATCH_B,  
                  Timer2::FORCE_COMPARE_NONE    ①  
                  );
```

① The force compare parameter in action showing that we are not requiring a force compare as soon as the timer is initialised.

You can, of course, initialise the timer as above, and then, in your code at any time, simply set one or other of the **FOC2A** and **FOC2B** bits in register **TCCR2B** to force a compare to affect the output pins at that point, but remember, no interrupts will fire for the compare match in that case.



# Chapter 5. Analogue Comparator

This AVR Assistant allows the simple setup and configuration of the Analogue Comparator on your AVR (specifically, ATmega328) micro controller. This code works in the Arduino IDE or free standing for use with some other development system, such as PlatformIO. It has not been tested on other micro controllers. (Although the ATmega168 should work.)

The comparator output will be **HIGH** whenever the reference voltage is higher than the sampled voltage, and will be **LOW** when the reference voltage is lower or equal to the sampled voltage. The comparator output is simply bit **ACO** in register **ACSR**.

To use this assistant, you must include the **comparator.h** header file:

```
#include "comparator.h"
```

Following this, you may, optionally, use the **AVRAssist** namespace:

```
using namespace AVRAssist;
```



The spelling of **AVRAssist** must be as shown above.

If you choose not to do this, you must prefix everything with **AVRAssist::** or the code will not work.

## 5.1. Comparator Initialisation

Once the header file has been included, the comparator can be initialised as follows:

```
#include <comparator.h>

using namespace AVRAssist;

...

comparator::initialise(comparator::REFV_EXTERNAL,
                      comparator::SAMPLE_AIN1,
                      comparator::INT_TOGGLE);

...
```

The above sets the comparator to use **AIN0**, pin 12, Arduino pin **D6** as the reference voltage, **AIN1**, pin 13, Arduino pin **D7** as the voltage to be sampled and compared, and an interrupt to fire whenever the comparator output toggles.

### 5.1.1. Initialisation Function

The header file exposes a single **initialise** function which is defined as follows:

```
void initialise(const reference_t referenceSource,
               const sample_t sampleSource,
               const interrupt_t interruptMode = 0);
```

### 5.1.2. Reference Voltage

The comparator can be configured to use one of two separate voltage sources as the reference voltage, these being:

| Parameter     | Description  |
|---------------|--|
| REFV_EXTERNAL | Pin 12, <b>AIN0</b> , Arduino pin <b>D6</b> will be used as the reference voltage. |
| REFV_INTERNAL | The internal 1.1 volt bandgap reference voltage will be used.                      |



The data sheet advises strongly, that you do not change to **REFV\_INTERNAL** if the **AREF** pin is connected to any external source of voltage. You will let the magic blue smoke out if you do.

Many of the 'breadboard Arduinos' on the internet, show the **AREF** pin connected to 5V - this is a bad thing if you ever configure the Analogue Comparator or the ADC to use the internal voltage as a reference.

The only thing you should connect to the **AREF** pin is a 100nF capacitor to ground.

You use this parameter to define the reference voltage to be used, as follows:

```
comparator::initialise(comparator::REFV_EXTERNAL, ①
                       comparator::SAMPLE_AIN1,
                       comparator::INT_TOGGLE);
```

① The comparator will be set up using the **AIN0** pin as its reference voltage.

### 5.1.3. Sample Voltage

The comparator needs a second voltage source, this one is to be compared with the reference voltage described above. The following values are permitted:

| Parameter   | Description  |
|-------------|--|
| SAMPLE_ADC0 | Compare the voltage on pin <b>PC0</b> (Arduino <b>A0</b> ) with the reference voltage. |
| SAMPLE_ADC1 | Compare the voltage on pin <b>PC1</b> (Arduino <b>A1</b> ) with the reference voltage. |
| SAMPLE_ADC2 | Compare the voltage on pin <b>PC2</b> (Arduino <b>A2</b> ) with the reference voltage. |
| SAMPLE_ADC3 | Compare the voltage on pin <b>PC3</b> (Arduino <b>A3</b> ) with the reference voltage. |
| SAMPLE_ADC4 | Compare the voltage on pin <b>PC4</b> (Arduino <b>A4</b> ) with the reference voltage. |
| SAMPLE_ADC5 | Compare the voltage on pin <b>PC5</b> (Arduino <b>A5</b> ) with the reference voltage. |

|             |  |
|-------------|--|
| SAMPLE_ADC6 | Compare the voltage on pin <b>ADC6</b> with the reference voltage. (SMD version only.) |
| SAMPLE_ADC7 | Compare the voltage on pin <b>ADC7</b> with the reference voltage. (SMD version only.) |
| SAMPLE_AIN1 | Compare the voltage on pin <b>AIN1</b> with the reference voltage.                     |



The various dual inline versions of the ATmega328 do not have pins **ADC6** and **ADC7**, those two are only present on the surface mount versions. Some Arduino Uno clones have been built with a surface mount version of the ATmega328, and on those boards, *some* manufacturers have connected these two pins to a header while others leave them unconnected.

You use this parameter to define which pin will be use to source the voltage to be compared with the reference voltage.

```
comparator::initialise(comparator::REFV_EXTERNAL,
                       comparator::SAMPLE_AIN1,
                       comparator::INT_TOGGLE);
```

① The comparator will be set up using the **AIN1** pin as its sample voltage source.

#### 5.1.4. Interrupts

The comparator has a single interrupt, but it has thee separate manners of firing it. These are:

| Parameter    | Description  |
|--------------|--|
| INT_DISABLED | The comparator will not raise any interrupts. The code is assumed to be monitoring bit <b>ACO</b> in register <b>ACSR</b> .          |
| INT_TOGGLE   | When bit <b>ACO</b> in register <b>ACSR</b> toggles, the <b>ANALOG_COMP</b> interrupt will be fired.                                 |
| INT_FALLING  | When bit <b>ACO</b> in register <b>ACSR</b> changes from <b>HIGH</b> to <b>LOW</b> , the <b>ANALOG_COMP</b> interrupt will be fired. |
| INT_RISING   | When bit <b>ACO</b> in register <b>ACSR</b> changes from <b>LOW</b> to <b>HIGH</b> , the <b>ANALOG_COMP</b> interrupt will be fired. |

An example of initialising the comparator using this parameter is:

```
comparator::initialise(comparator::REFV_EXTERNAL,
                       comparator::SAMPLE_AIN1,
                       comparator::INT_TOGGLE);
```

① The comparator will be set up so that the interrupt will be fired whenever the **ACO** bit changes.



# Appendix A: Foibles

The following foibles have been detected with the `AVRAssist` code. Some of these *may* be able to be fixed in future, and if so, this appendix will be updated to show that such a thing has happened. Some might not be fixable.

## A.1. Timer 0

### A.1.1. Timer 0 Overflow

The ISR for this timer 0 overflow *cannot* be used when compiling code within the Arduino IDE. This is down to the fact that the Arduino IDE sets up it's own ISR for this interrupt and if you (or I) define one for our own code, it will cause duplicate definition errors and as the IDE got it's version in first, we will be up that famous creek.

This problem cannot be fixed in the `AVRAssist` code as it is caused by the Arduino IDE. The problem does not occur in PlatformIO, for example, where you can define your own ISR for this interrupt without any problems.



Redefining this interrupt in the Arduino IDE, if it actually was possible, would lead to all sorts of problems as you would be messing with the interrupt that works the `millis()` function, and from that, the `delay()` and all the other functions that depend upon `millis()`.

## A.2. Timer 1

Setting up Timer 1, to automatically toggle `OC1A` or Arduino pin `D9` does not work in the Arduino IDE. The following code:

```

#include <timer1.h>

using namespace AVRAssist;

int main() {
    // Make OC1A an output pin.
    DDRB |= (1 << DDB1);

    // Set up the required flash rate.
    OCR1A = whatever;

    // Initialise Timer 1.
    Timer1::initialise(Timer1::MODE_CTC_OCR1A,    // Timer mode;
                       Timer1::CLK_PRESCALE_1024, // Clock source;
                       Timer1::OC1A_TOGGLE       // Toggle OC1A on compare match;
                       );

    while (1) {
        ; // do nothing.
    }
}

```

Works perfectly in PlatformIO, and the LED attached to the pin does indeed flash at the required rate. So far, so good. Converting the above for the Arduino IDE, as follows, simply toggles the LED attached to D9 on, and leaves it on. It never flashes.



```

#include <timer1.h>

using namespace AVRAssist;

void setup() {
    // D9 is required to be an output pin.
    pinMode(9, OUTPUT);

    // Set up the required flash rate.
    OCR1A = whatever;

    // Initialise Timer 1.
    Timer1::initialise(Timer1::MODE_CTC_OCR1A,    // Timer mode;
                       Timer1::CLK_PRESCALE_1024, // Clock source;
                       Timer1::OC1A_TOGGLE,      // Toggle OC1A on compare match;
                       );
}

void loop() {
    // Nothing to do here...
    // Timer 1 should take care of flashing the LED on D9.
}

```

This is an interesting foible because the **AVRAssist** code takes over the timer completely and reinitialises it to the mode given from the ground up, overwriting everything set up by the Arduino IDE. I've even gone so far as to examine the compiled assembly language for the sketch and compared it with the code in the output from PlatformIO, and they are, to all intents, identical - at least, the assembly language generated by the **AVRAssist** code are identical.

Time will tell if this foible can be fixed by the **AVRAssist** code or not. Watch this space.

## A.3. Timer 2

## A.4. Analogue Comparator

## A.5. ???