TB3143

Angular Timer Implementation

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INTRODUCTION

The angular timer module is a timer that subdivides periodic signals into smaller intervals and translates time-based signals into angle/phase-based signals. This technical brief describes briefly how the module works, how to use this module in users' applications, and what is important to observe.

BASIC PRINCIPLE

The angular timer module is very useful when an event is needed at a certain angle/phase in a periodic signal. For example, a good application for this module is motor control. If the sensor of the DC motor gives a pulse for every revolution of the motor, and in the user's application, an event needs to be fired at 30 degrees and 90 degrees of every revolution. If so, then the angular timer is the right module to use.

The basic operation of this module is to subdivide a periodic input signal into small intervals. The module is able to give an interrupt at every degree based on how many degrees (resolution) the user wants each period of the input signal to be divided into, or give an interrupt at a certain degree in Capture/Compare mode. For the module to accomplish this, several counters are used to do a hardware divide and trigger the interrupt at the right time.

FIGURE 1: SIMPLIFIED BLOCK DIAGRAM OF THE ANGULAR TIMER MODULE

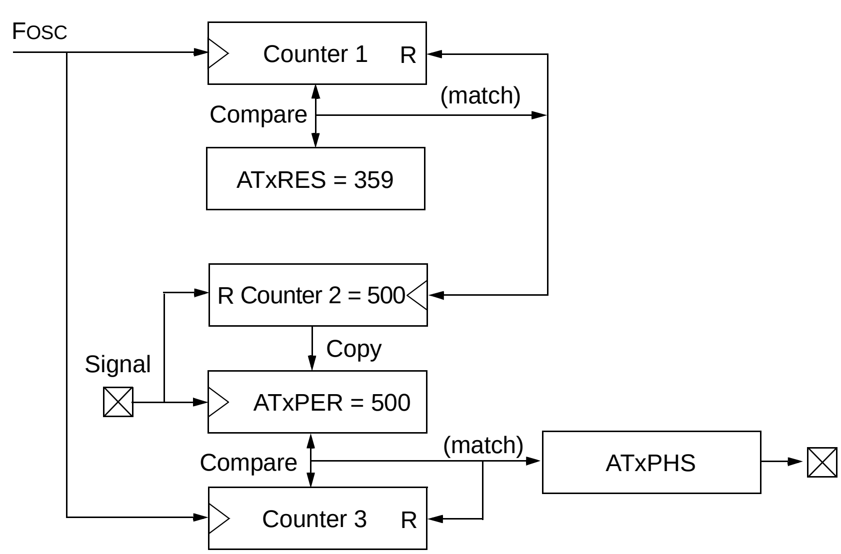
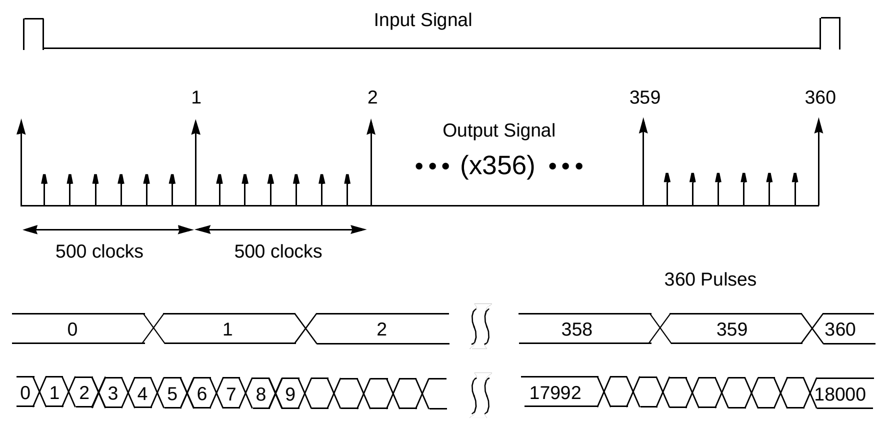


FIGURE 2: TIMING DIAGRAM FOR THE INPUT AND OUTPUT OF THE ANGULAR TIMER



For example, the user needs a 360° resolution in each period of the input signal. FOSC is selected as the module clock, which is 16 MHz. The frequency of the input signal is around 90 Hz (5400 RPM). Then the input signal takes around 180k module clocks per period. This calculates to 180,000/360 = 500, which in this case means that the module needs to insert an interrupt every 500 clocks to get 360° per period. Equation 1 shows the operation of the module:

EQUATION 1:

$$\mathrm{ATxPER} = \frac{\dfrac{F(ATxCLK)}{F(ATxSIG)}}{(ATxRES + 1)} - 1$$

In Equation 1, the ATxRES register represents how many interrupts the user wants in between each period, which in this example is 360 - 1 = 359. The frequency of the module clock, divided by the frequency of the input signal, is how many module clocks are in each period, which is 180k. The ATxPER register records how many module clocks are needed between each to insert one interrupt, which is 500.

This example is shown in Figure 1 as a simplified block diagram. The only register in the figure that needs to be set is ATxRES. All other values are calculated in the hardware. Counter 1 increments each module clock and compares itself with the ATxRES register. When Counter 1 matches the number in ATxRES, Counter 2 is incremented by one. In this period, there are 180k module clocks, so Counter 2 is increased to 500. The number in Counter 2 is copied to the ATxPER register at the end of this period. So far, the module has finished the calculation in this period and is ready to output the interrupts for the next period. When the next period begins, Counter 3 is increased each module clock and compared with ATxPER. When those two match, an interrupt flag is set and the ATxPHS register is increased by one. Therefore, the module triggers an interrupt every 500 module clocks and ATxPHS records how many interrupts have occurred so far. In the meantime, the upper part of the block diagram is calculating ATxPER for the next period. The input and output signals of this example are shown in Figure 2 as a timing diagram.

IMPLEMENTATION

Initialization

To set up the module in the user's own application, the first step is to initialize registers. There are three major inputs that need to be initialized in order to get the module to work:

- module clock
- input signal
- resolution

ATxCLK is used to select the clock source for the module. Either Fosc or HFINTOSC (16 MHz) can be selected as the module clock. A prescaler can also be applied by setting the ATxCON0 register. This is useful in low-speed/frequency applications to avoid overflow in the ATxPER register.

ATxSIG is used to select the input signal. Several sources can be selected as the input signal, such as the Configurable Logic Cell (CLC) output, the Zero-Cross Detect (ZCD) output, the internal comparators output, and ATxINPPS, which can be routed to any digital pins with Peripheral Pin Select (PPS).

ATxRES is used to set the resolution for the user's application. Recall the "+1" in the equation. If the user wants a 360° resolution, the ATxRES register should be set to 359.

There are other registers that can be set according to the user's preference such as the operating mode and the polarity bit for the input signal. Those can be found in the data sheet and can be easily set.

Choosing ATxRES

The resolution chosen could affect the error of the angular timer module. Since the basic principle of the module is a hardware divide, there is usually a remainder of the calculation. This remainder appears as extra module clocks in the last degree/phase in each period. This error becomes larger when there is a larger ATxRES value. The larger the divider (ATxRES +1), the larger the remainder could be. Thus, choosing a comparatively smaller ATxRES value can reduce the error of the module. For instance, if the user wants four interrupts when the motor runs at 90°, 180°, 270° and 360°, ATxRES can be set to 3 instead of 359. However, with the same dividend (number of module clocks per period), a smaller divider leads to a bigger result, which is saved in ATxPER. Therefore, be aware that ATxPER could overflow if the resolution is too small and the frequency of the input signal is too low.

Figure of Merit

Calculating the figure of merit is a way to get an idea of how much error there could be in the user's own application.

The figure of merit can be calculated by Equation 2.

EQUATION 2:

$$FOM\% = \frac{ATxRES}{\frac{f(ATxCLK)}{f(ATxSIG)}} \bullet 100$$

The result represents the maximum possible error of a single degree. If the FOM is small, it means the user's design has less margin for error.

Missing Pulse Register

A missing pulse register ATxMISS can be used for fault detection. It is useful to detect sudden speed changes in the motor control application.

The latched value of the ATxPERH/L register pair is continuously subtracted from the current value of the period counter. The result is compared to either the value of the ATxMISSH/L register pair or half of the previously latched-in measured period (ATxPER/2), depending on the mode. If there is a match, a pulse is output on the missing pulse output, and the MISSIF interrupt flag bit of the AT1IR0 register is set. In addition, in certain modes, the missing pulse output determines when period clock pulses are set. Please note that AT1MISSH is latched until AT1MISSL is written. In the user's code, AT1MISSH and AT1MISSL should be set separately, and AT1MISSH should be set before AT1MISSL.

Operating Modes

The angular timer has four basic operating modes, which are described below. Note that all descriptions are written assuming that the POL bit of the ATxCON0 register is cleared. If POL is set, the events will be triggered from falling edges, instead of rising edges.

- Single-Pulse per Revolution with fixed missing pulse
- Multi-Pulse per Revolution with fixed missing pulse
- Single-Pulse per Revolution with adaptive missing pulse
- Multi-Pulse per Revolution with adaptive missing pulse

When the MODE bits (of the ATxCON0 register) = `00`, the angular timer is in Single-Pulse per Revolution mode. In this mode, every rising edge on the input signal after the VALID bit of the ATxCON register is set latches the current period counter value into the ATxPERH/L register pair and resets the period counter. The missing pulse output triggers if the difference between the latched value of the ATxPERH/L register pair and the current value of the period counter equals the ATxMISSH/L register pair.

When the MODE bits (of the ATxCON0 register) = `01`, the angular timer module is in Multi-Pulse with Fixed Time Missing Pulse mode. In this mode, each input latches the period count until a missing pulse occurs. After that, the following input edges set the VALID bit, but will not latch-in the period counter value. Then, after a missing pulse occurs and while VALID = `1`, the period clock will wait for the next input edge after the missing pulse, and output a pulse and an interrupt at that input edge. This continues until a missing pulse output occurs. After this point, the next rising edge on the input signal will output a period clock pulse, but will not latch-in the period counter value until the following rising edge. Please note that in the two modes with fixed missing pulse, ATxMISS needs to be set by the user, but in the two adaptive missing pulse modes below, ATxMISS is ignored by the module and there is no need to set it.

The Single/Multi-Pulse per Revolution with adaptive missing pulse are very similar to the two modes with fixed missing pulse. The exception is that the missing pulse output triggers if the difference between the latched value of the ATxPERH/L register pair and the current value of the period counter equal half of the latched value of the ATxPERH/L register pair (ATxPER/2). In this way, it adapts the missing pulse detection to the current motor speed.

Capture/Compare Mode

The angular timer contains multiple built-in capture/compare modules. These are controlled by their respective ATxCCONy registers.

The Capture mode can help the user read out the current angle/phase value at a certain moment. In this mode, the capture unit looks for an input edge and captures the current value of the Angle/Phase timer in the instantaneous phase counter value and stores it in the respective ATxCCy registers. It also outputs a pulse that can be used to trigger the ADC module or in combinational logic in the CLC, and triggers an interrupt.

The Compare mode can be used when a high resolution is needed for the application. In this mode, the ATxCCONy compares its value with the current angle/phase value. If they are the same, it triggers an interrupt.

Interrupts

The major usage of the angular timer is to trigger interrupts at certain angles/phases. The most commonly used interrupts are the angular timer phase interrupt and period interrupt. The phase interrupt flag ATxPHSIF is set at every angle/phase in between the two rising/falling edge of the input signal. The period interrupt flag ATxPERIF is set at every rising/falling edge of the input signal. Therefore, by using a logical “or” with those two flags, the user can get an interrupt at every angle/phase of the input signal.

Other useful interrupts such as missing pulse and capture/compare interrupts can be chosen to use, based on the user’s own application.

CONCLUSION

The angular timer module can be used in many motor control applications. Since the module uses a hardware divide to translate a time-based signal into an angle-based signal, it is more time efficient and allows the user to trigger events based on angles or phases.

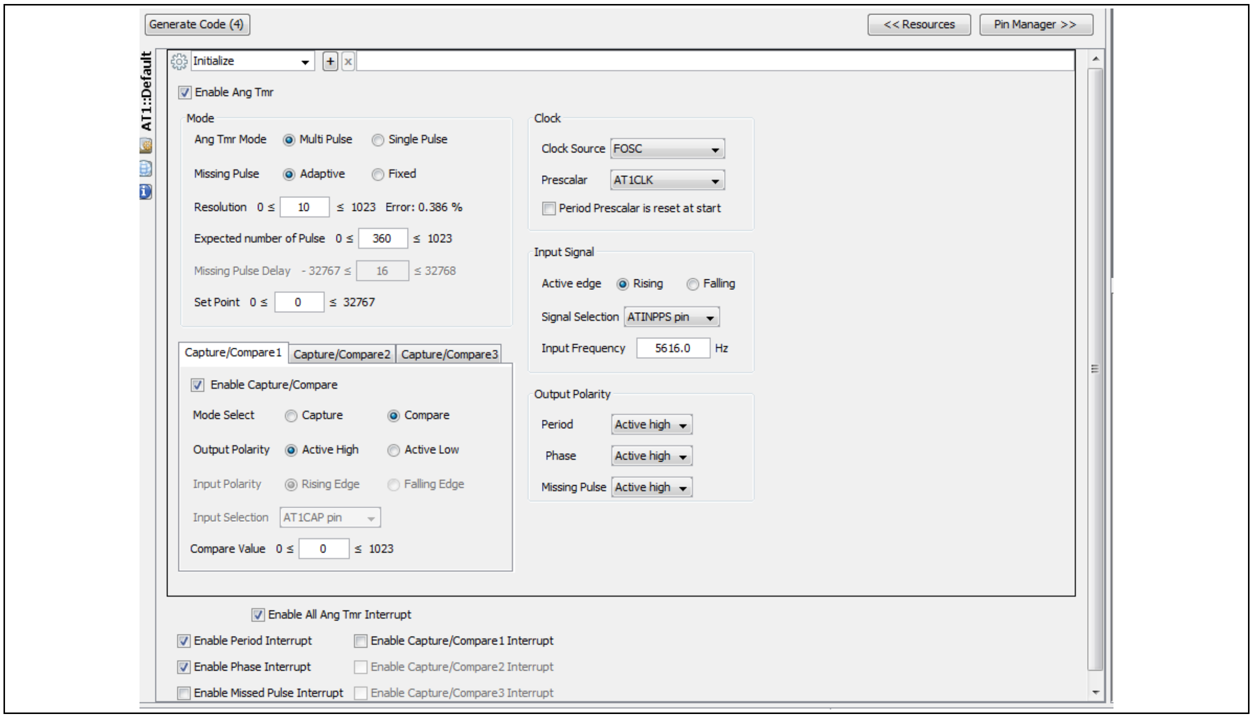
APPENDIX A: CODE FOR INITIALIZATION AND USING THE PHASE AND PERIOD INTERRUPT

```
    // enable interrupts
    AT1IE = 1;                  // the same ISR handles both phase and period interrupts
    AT1IE0 = 0x05;
    // Angular Timer initiallization
    ATINPPS = 0b00100;          // RA4 as input
    AT1CLK = 0;                 // Fosc as system clock (ATxCLK)
    AT1RES = res - 1;           // Set a resolution of 360 degrees. Recall the "-1" (ATxRES)
    AT1CON0bits.PS = 0b11;      // Prescaler set to ATxCLK/8
    AT1CON0bits.PREC = 1;       // Period prescaler is reset at the start of every period
                                   (ATxCON0)
    AT1CON0bits.MODE = 0b00;    // Angular Timer is in Single Pulse mode (ATxCON0)
    AT1SIG = 0b000;             // Input signal is ATxINPPS (ATxSIG)
    AT1CON0bits.AT1EN = 1;      // Angular Timer is enabled (ATxCON0)



// Angular Timer interrupt
void interrupt ISR(void){
    if (AT1IF)
    {
        // write your own application here
        AT1IF0 = 0;            // The ATxIF flag in PIR is read-only, and the only way to clear
                                  it is to clear the bits in AT1IF0
    }
 }
```

APPENDIX B: SCREEN SHOT OF HOW TO INITIALIZE THE ANGULAR TIMER MODULE BY USING MPLAB™ CODE CONFIGURATOR



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