Bryan Takemoto

CPE301 – SPRING 2018

Design Assignment 2

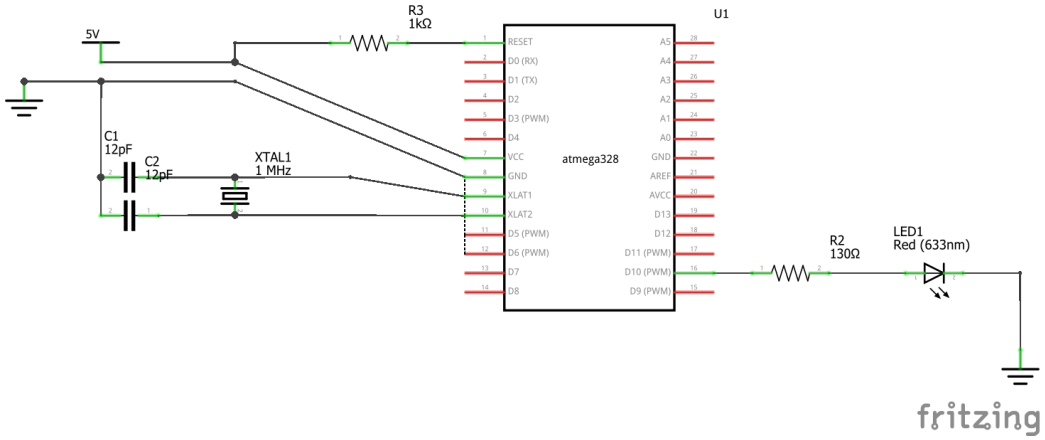
DO NOT REMOVE THIS PAGE DURING SUBMISSION:

The student understands that all required components should be submitted in complete for grading of this assignment.

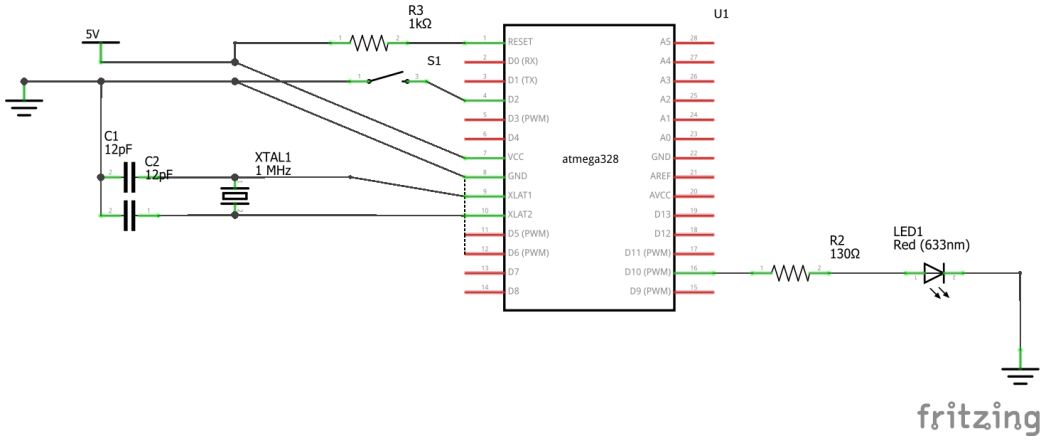
NO	SUBMISSION ITEM	COMPLETED (Y/N)	MARKS (/MAX)
1	COMPONENTS LIST, SCHEMATICS, AND BREADBOARD		
2.	TASK #1 ASSEMBLY CODE		
3.	TASK #1 C CODE		
4.	TASK #1 SIMULATION PICTURES		
5.	TASK #2 ASSEMBLY CODE		
6.	TASK #2 C CODE		
7.	TASK #2 SIMULATION PICTURES		
8.	TASK #3 ASSEMBLY CODE		
9.	TASK #3 C CODE		
10.	TASK #3 SIMULATION PICTURES		
11.	TASK #4 ASSEMBLY CODE		
12.	TASK #4 C CODE		
13.	TASK #4 SIMULATION PICTURES		
14.	TASK #5 ASSEMBLY CODE		
15.	TASK #5 C CODE		
16.	TASK #5 SIMULATION PICTURES		
17.	YouTube Links		

1. COMPONENTS LIST AND SCHEMATICS

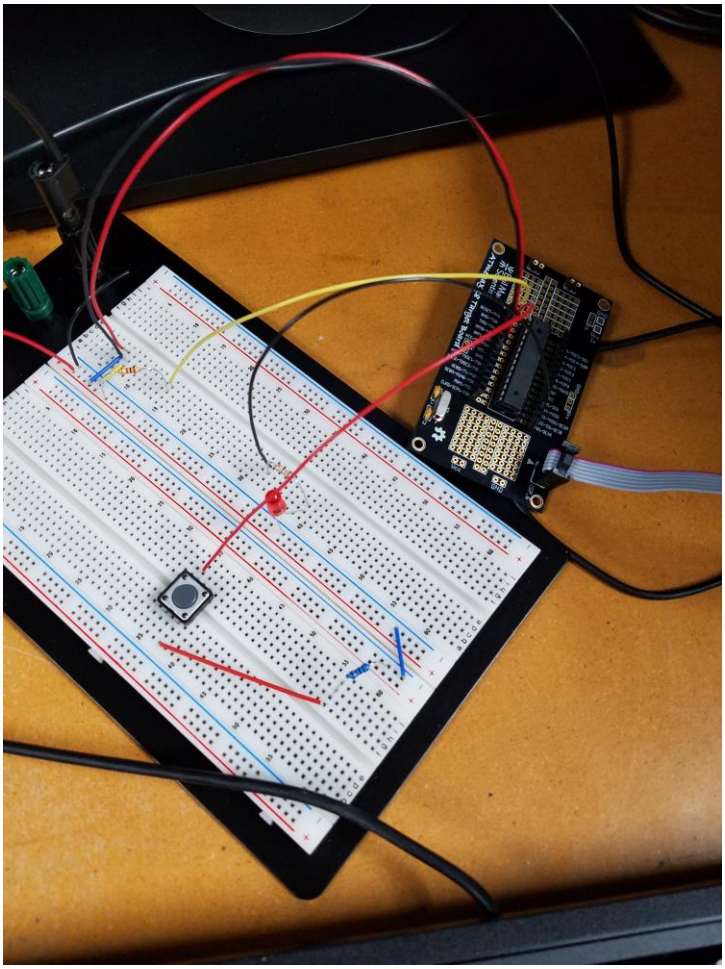
Components:
Red LED
Switch



Schematic for Task #1, #3, and #4



Schematic for Task #2 and #5



Breadboard overview

2. Task #1 Assembly Code

```
.ORG 0
       ; Initialize the stack
       LDI           R16, HIGH(RAMEND)
       OUT           SPH, R16
       LDI           R16, LOW(RAMEND)
       OUT           SPL, R16

       SBI           DDRB, 2       ; Set PORTB as output
       LDI           R16, (1<<2)   ; Output signal of PORTB
       LDI           R17, 0x0
       OUT           PORTB, R17    ; Clear PORTB

       ; Toggle PB2 port
BEGIN:
       RCALL  DELAY
       EOR           R17, R16      ; Toggle logic
       OUT           PORTB, R17    ; Output the toggled signal
       RJMP   BEGIN
```

```
        ; Delay for 0.25 second
        ; Delay subroutine using Timer1 (F = 0.5 MHz)
DELAY:
        ; Set the TCNT1 = 65536-15625 = 49911
        LDI             R20, HIGH(-15625)
        STS             TCNT1H, R20
        LDI             R20, LOW(-15625)
        STS             TCNT1L, R20
        ; Start the timer with a prescalar of 8
        LDI             R20, 0x00
        STS             TCCR1A, R20
        LDI             R20, 0x02
        STS             TCCR1B, R20
        ; Delay for 31250 cycles
LOOP:
        IN              R20, TIFR1
        SBRS    R20, TOV1
        RJMP    LOOP
        ; Stop timer and reset TOV flag
        LDI             R20, 0x0
        STS             TCCR1B, R20
        LDI             R20, (1<<TOV1)
        OUT             TIFR1, R20
        RET
```

3. Task #1 C Code

```
#include <avr/io.h>

void T1Delay();

int main(void)
{
        DDRB |= 0x04;         // Set PORTB.2 as output
        PORTB = 0x00;         // Clear PORTB
        while(1)
        {
                T1Delay();            // Call delay
                PORTB ^= 0x04;        // Toggle the LED
        }
        return 0;
}

// Function that uses Timer1 [Delay for 0.25 second]
// F = 0.5 MHz
void T1Delay()
{
        // Set the TCNT1 = 0xC2F7 [65536-15625 = 49911]
        TCNT1H = 0xC2;
        TCNT1L = 0xF7;
        // Start clock using prescalar 8
        TCCR1A = 0x00;
        TCCR1B = 0x02;
        while((TIFR1&0x01) == 0); // Loop until TOV flag is set
        TCCR1B = 0x00;                          // Stop the timer
        TIFR1 |= 0x01;                          // Reset TOV flag
}
```

4. Task #1 Simulation Pictures

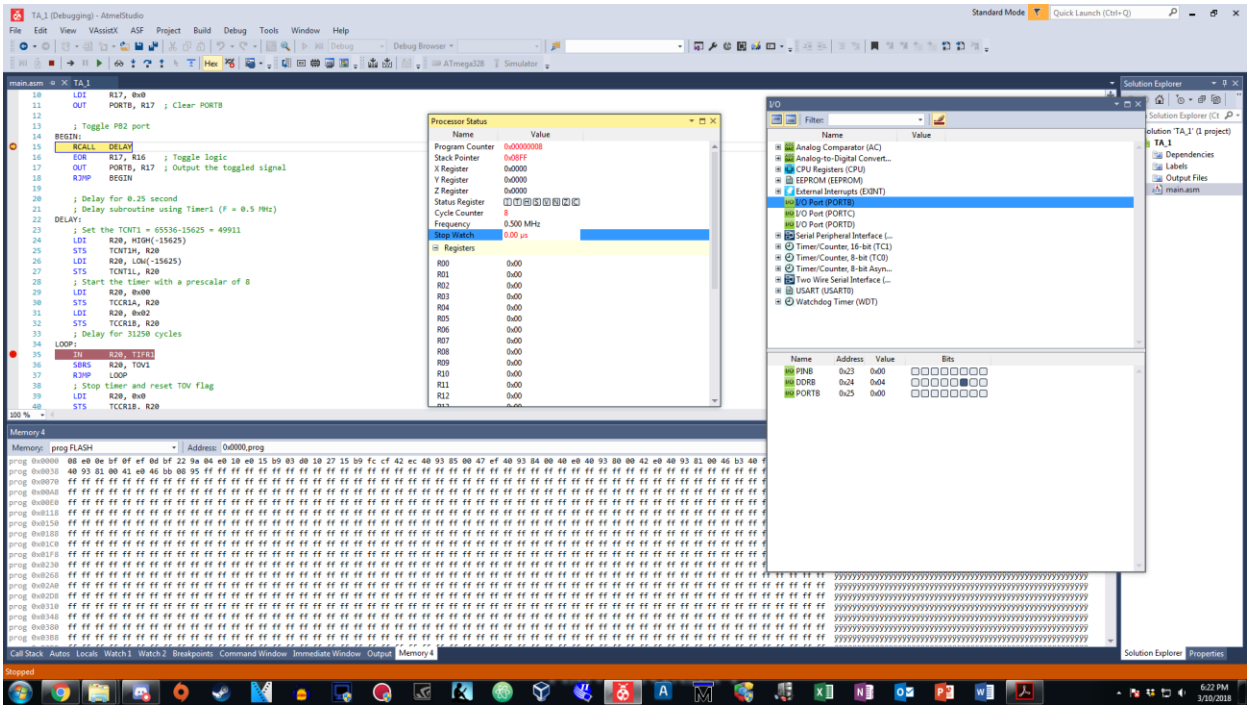


Figure 1: Before the call of delay, PB.2 is cleared and stopwatch ready (ASM)

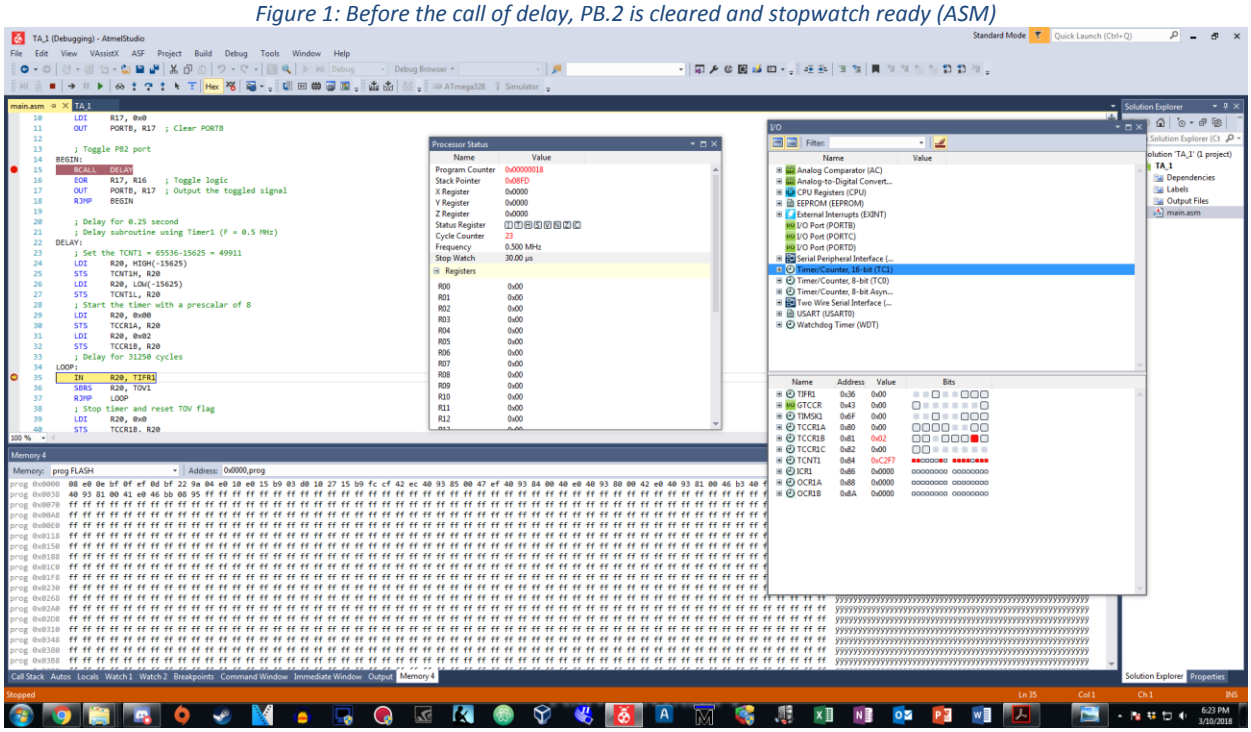


Figure 2: TIMER1 registers are set to count in the delay subroutine (ASM)

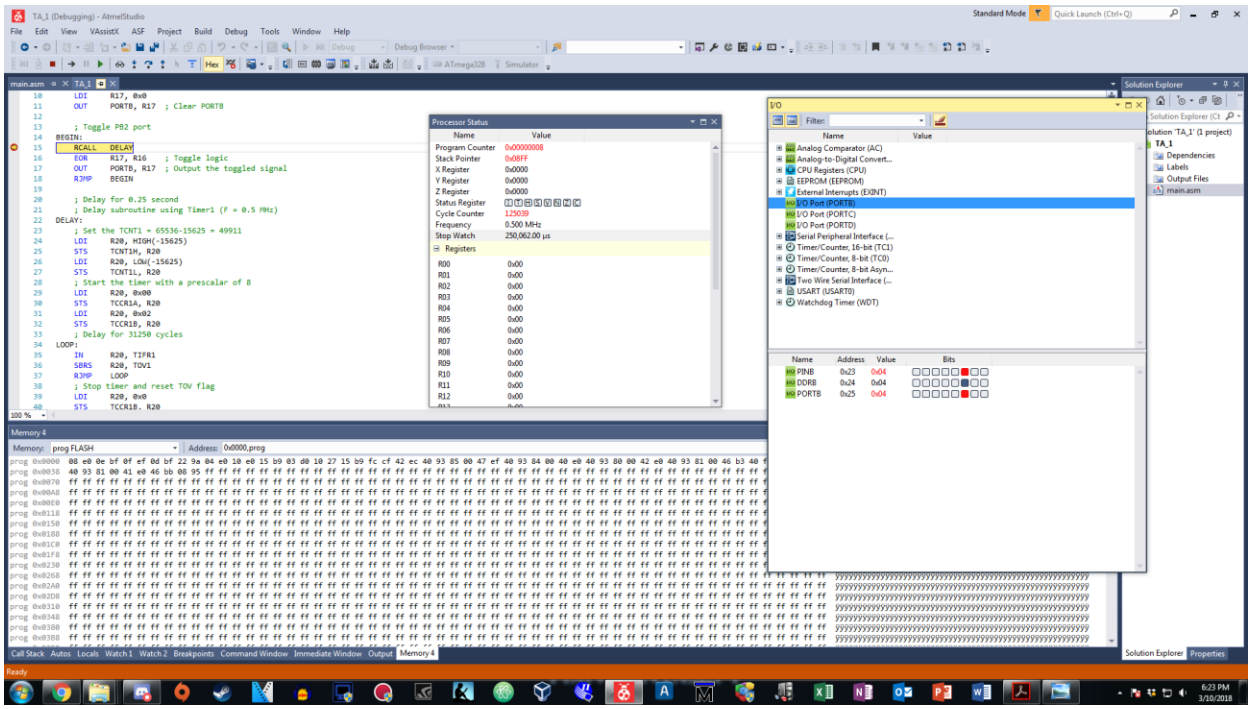


Figure 3: After 0.25 second delay, PB.2 toggles high (ASM)

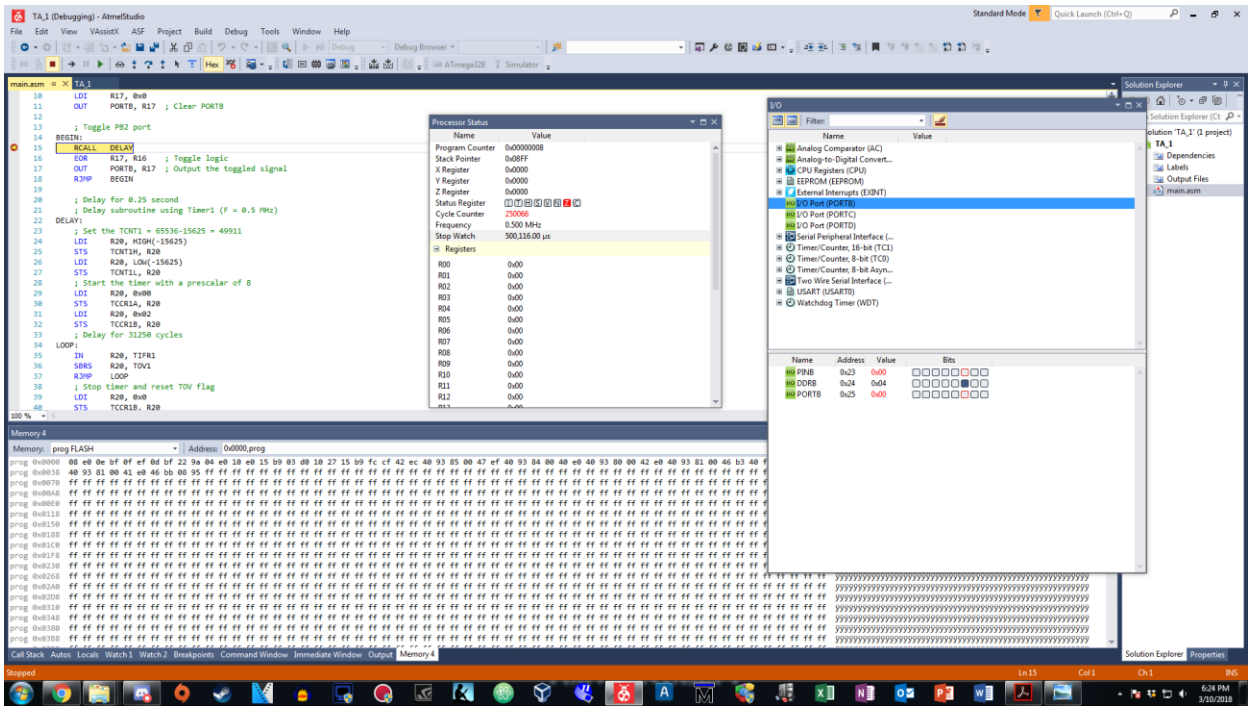


Figure 4: Another 0.25 second of delay, PB.2 toggles to low again (ASM)

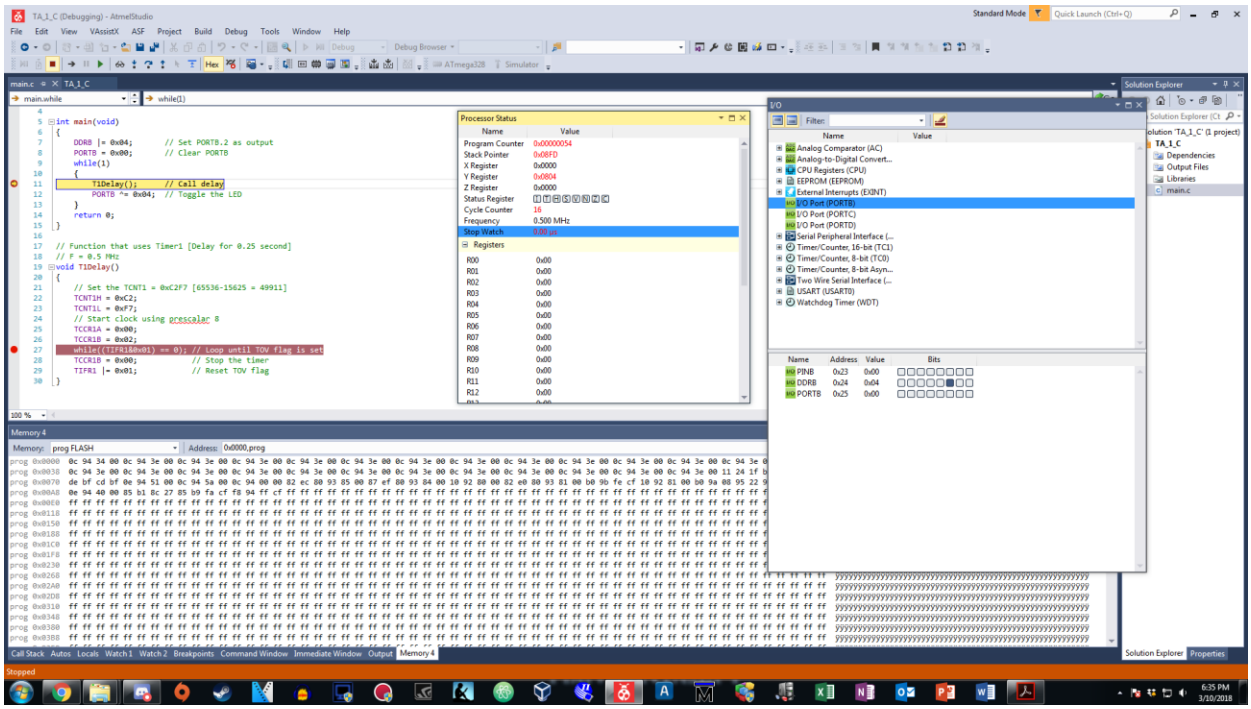


Figure 5: Before the call of delay, PB.2 is cleared and stopwatch ready (C)

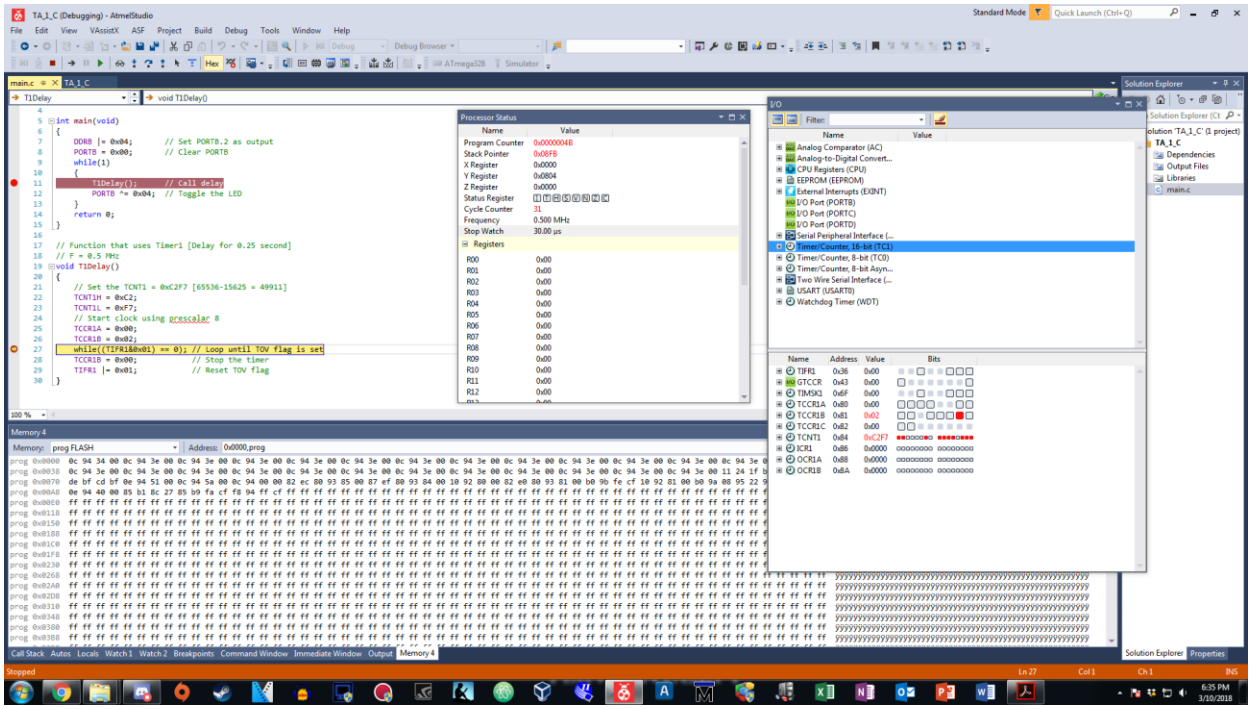


Figure 6: TIMER1 registers are set to count in the delay subroutine (C)

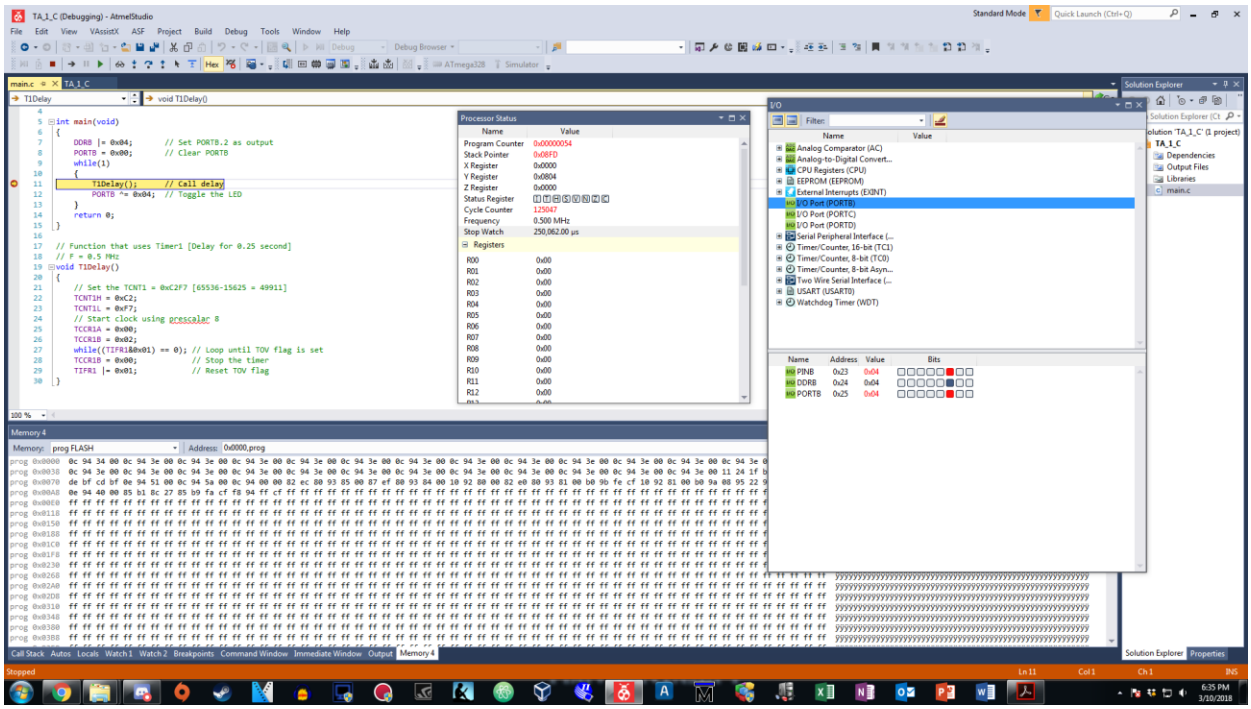


Figure 7: After 0.25 second delay, PB.2 toggles high (C)

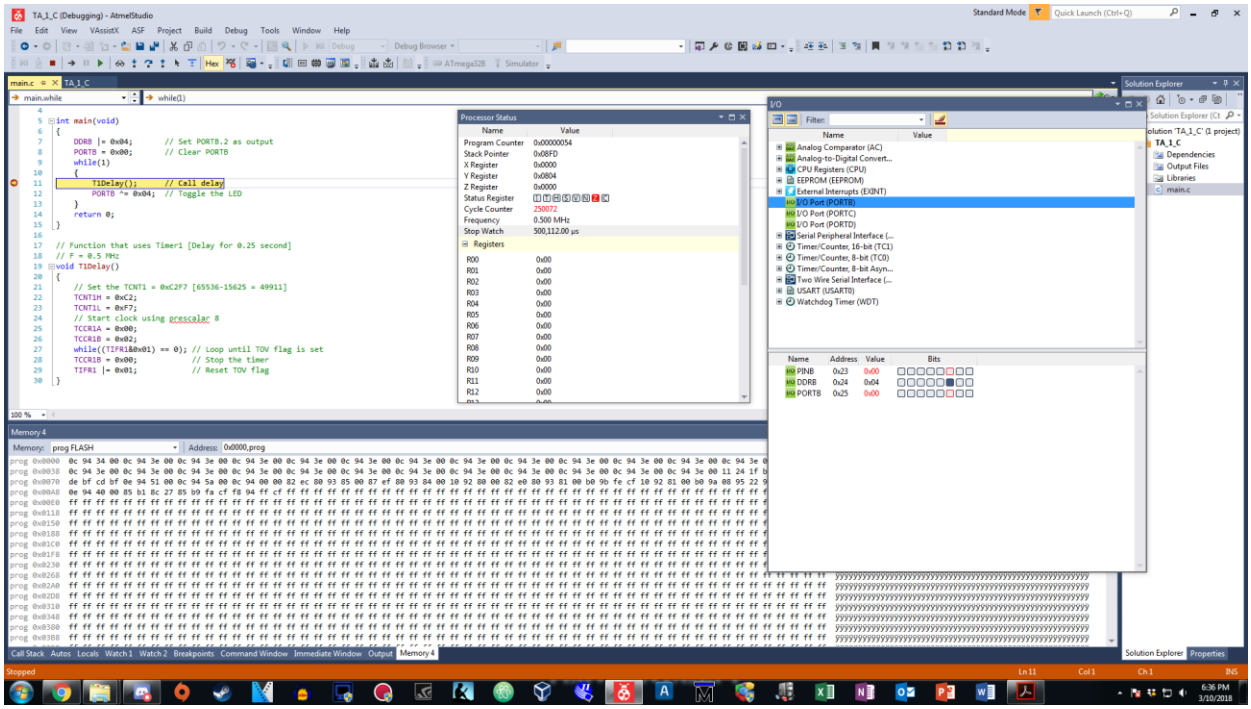


Figure 8: Another 0.25 second of delay, PB.2 toggles to low again (C)

5. Task #2 Assembly Code

```
.ORG 0
        ; Initialize stack
```

```
        LDI             R16, HIGH(RAMEND)
        OUT             SPH, R16
        LDI             R16, LOW(RAMEND)
        OUT             SPL, R16

        ; Port initialization
        CBI             DDRD, 2         ; Set PORTD.2 as an input
        SBI             PORTD, 2        ; Pull up the resistor of PORTD.2
        SBI             DDRB, 2         ; Set PORTB.2 as an output

POLL:
        SBIC            PIND, 2         ; Poll until PIND.2 is low
        RJMP            POLL
        SBI             PORTB, 2        ; Light up the LED
HOLD:
        SBIS            PIND, 2         ; Poll until the user lets go of the switch
        RJMP            HOLD
        CALL            DELAY           ; Delay for 1 second after switch is off
        CBI             PORTB, 2        ; Turn off the LED
        RJMP            POLL

        ; Delay subroutine (F = 0.5 MHz) [Delay for 1 second]
DELAY:
        ; Set the TCNT1 = 65536-62500 = 3036
        LDI             R20, HIGH(-62500)
        STS             TCNT1H, R20
        LDI             R20, LOW(-62500)
        STS             TCNT1L, R20
        ; Set timer control register
        LDI             R20, 0x00
        STS             TCCR1A, R20
        LDI             R20, 0x02
        STS             TCCR1B, R20     ; Start the timer with a prescalar of 8
LOOP:
        IN              R20, TIFR1      ; Check for the TOV flag
        SBRS            R20, TOV0
        RJMP            LOOP
        ; Stop timer and clear TOV flag
        LDI             R20, 0x0
        STS             TCCR1B, R20
        LDI             R20, (1<<TOV0)
        OUT             TIFR1, R20
        RET
```

6. Task #2 C Code

```
#include <avr/io.h>

void T1Delay();

int main(void)
{
        DDRD = 0x00;            // Set PORTD.2 as input
        PORTD |= (1<<2);        // Pull up the resistor of PORTD.2
        DDRB = 0xFF;            // Set PORTB.2 as output
        PORTB = 0x00;           // Clear PORTB
```

```
        // Poll until switch is pressed
        while(1)
        {
                if((PIND&0x04) == 0x00)
                {
                        PORTB = (1<<2);         // Turn on LED
                        while((PIND&0x04) == 0x00); // Poll until switch is turned off
                        T1Delay();              // Call the delay after switch is turned off
                }
                PORTB = 0x00;                   // Turn off LED
        }
        return 0;
}

// Delay subroutine for Timer1 [Delay for 1 second]
// F = 0.5 MHz
void T1Delay()
{
        // Set the TCNT1 = 65536-62500 = 3036 [0xBDC]
        TCNT1H = 0x0B;
        TCNT1L = 0xDC;
        // Start Timer1 with prescalar 8
        TCCR1A = 0x00;
        TCCR1B = 0x02;
        while((TIFR1&(1<<TOV1)) == 0x00);       // Check TOV flag
        TCCR1B = 0x00;                          // Stop Timer1
        TIFR1 |= (1<<TOV1);                     // Reset TOV flag in TIFR1 register
}
```

7. Task #2 Simulation Pictures

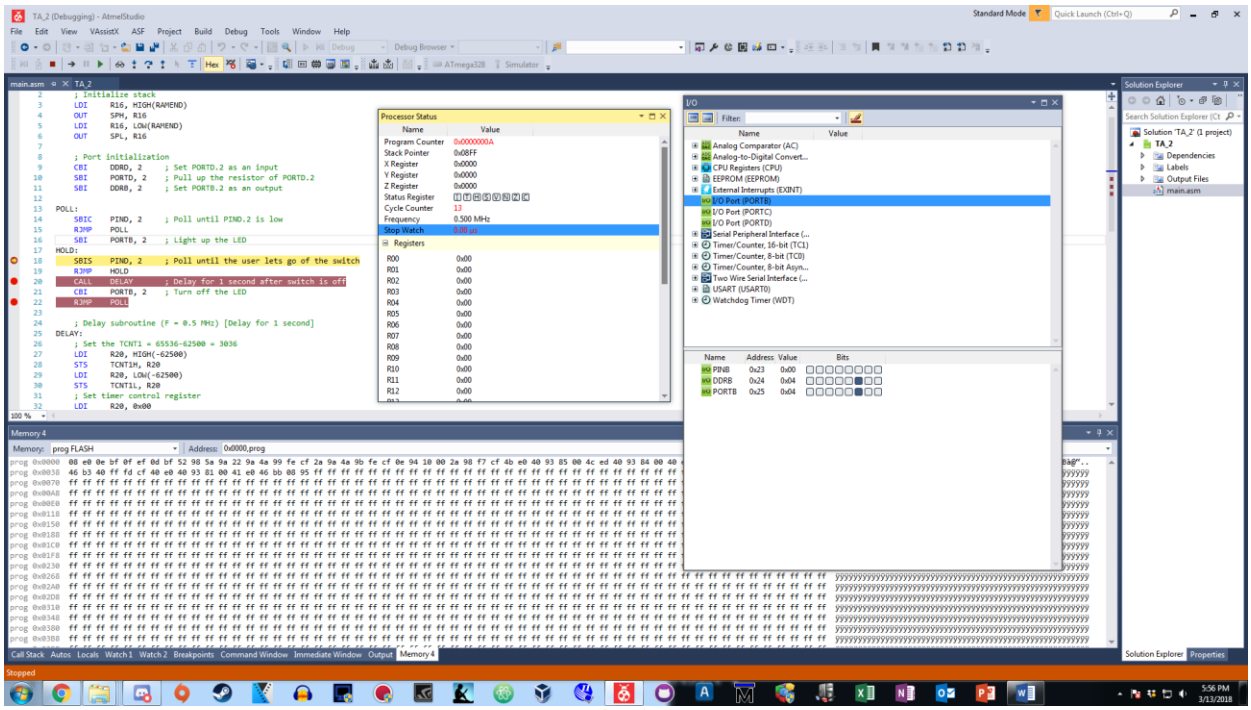


Figure 1: LED turns on at PORTB.2 and stopwatch set to measure the 1 second delay (ASM)

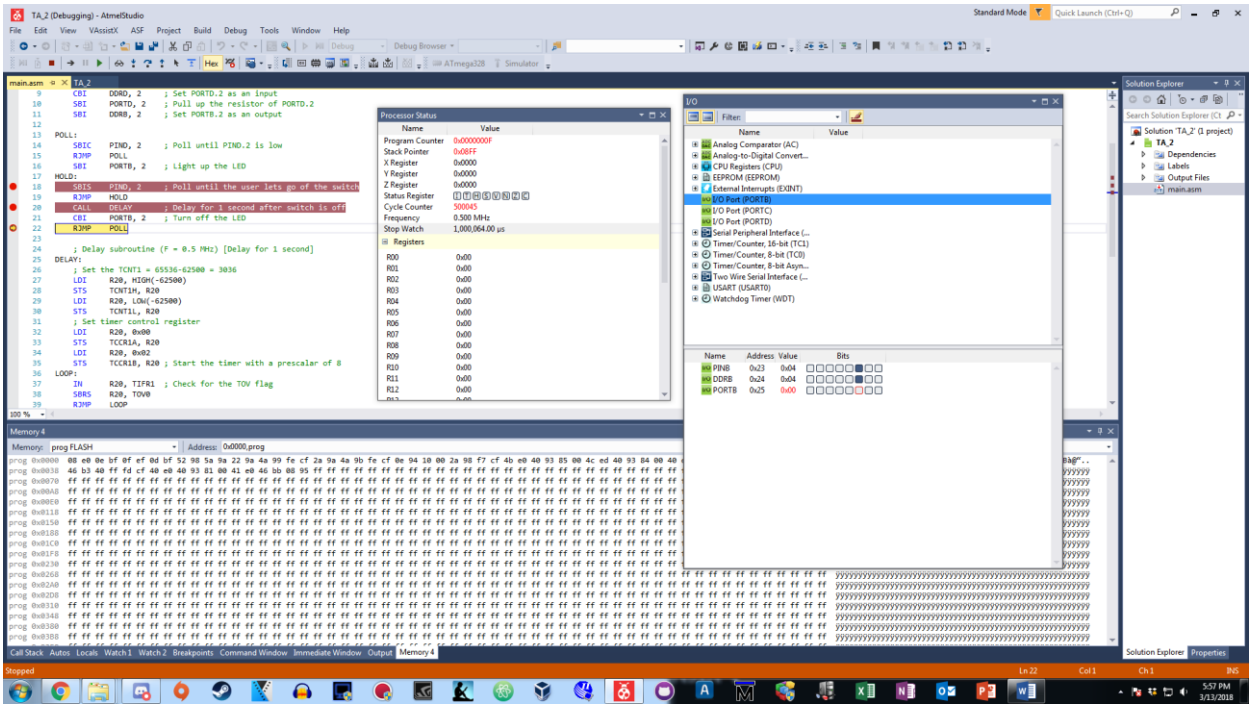


Figure 2: After 1 second delay, LED turns off at PORTB.2 (ASM)

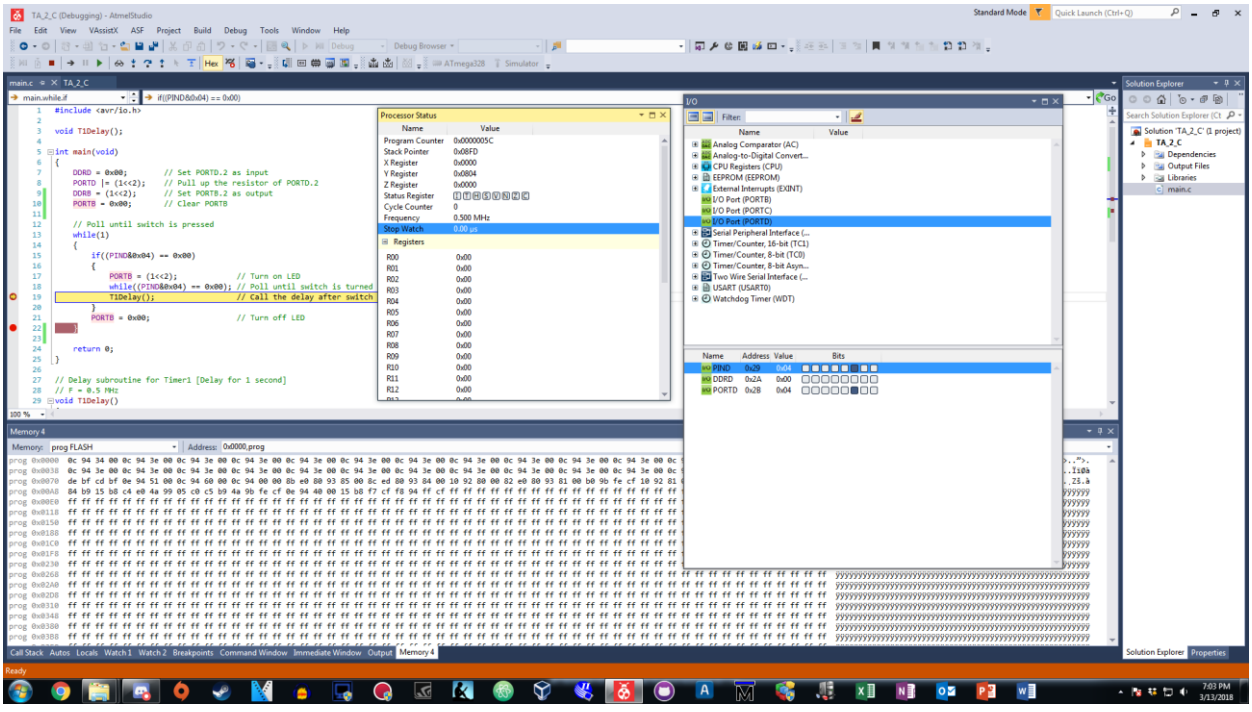


Figure 3: LED turns on at PORTB.2 and stopwatch set to measure the 1 second delay (C)

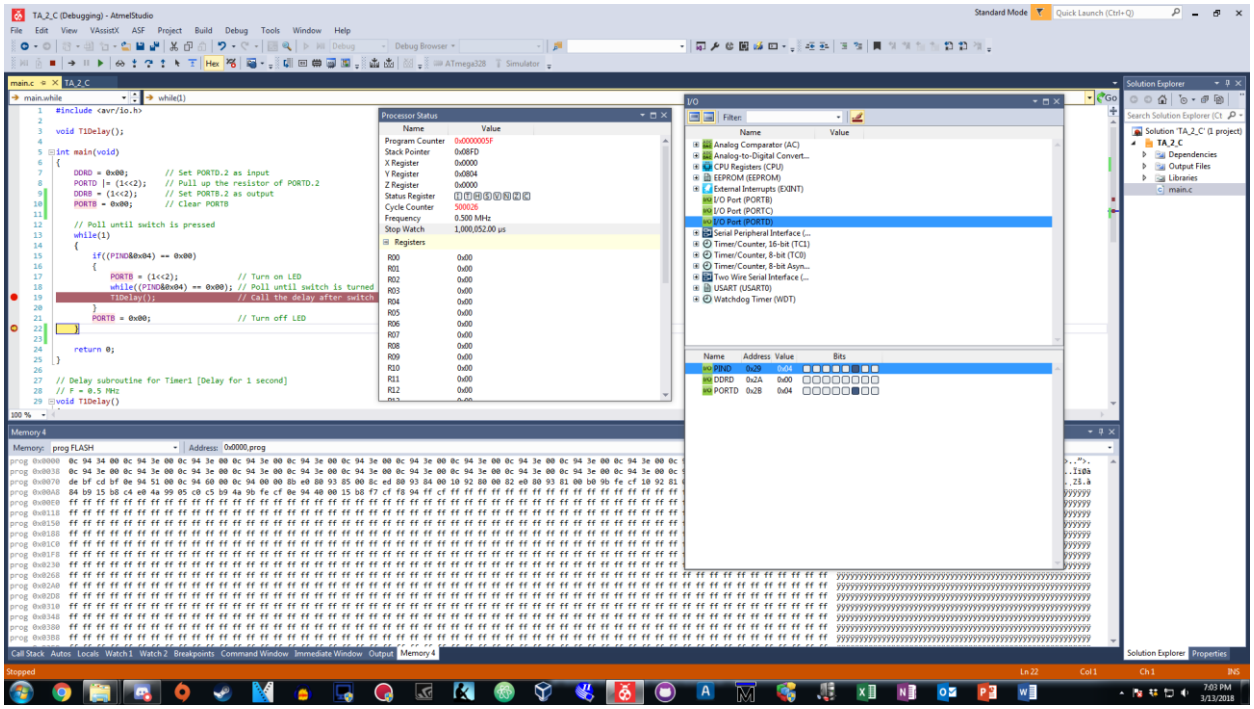


Figure 4: After 1 second delay, LED turns off at PORTB.2 (C)

8. Task #3 Assembly Code

```
.ORG 0
        ; Initialize the stack
        LDI             R16, HIGH(RAMEND)
        OUT             SPH, R16
        LDI             R16, LOW(RAMEND)
        OUT             SPL, R16

        SBI             DDRB, 2         ; Set PORTB as output
        LDI             R16, (1<<2)     ; Output signal of PORTB
        LDI             R17, 0x00
        OUT             PORTB, R17      ; Clear PORTB

        ; Toggle PB2
BEGIN:
        RCALL           DELAY
        EOR             R17, R16        ; Toggle logic
        OUT             PORTB, R17      ; Output the toggled signal
        RJMP            BEGIN

        ; Delay for 0.25 second
        ; Delay subroutine using Timer0 (F = 0.5 MHz)
DELAY:
        ; Set TCNT0 = 256-122 = 134
        LDI             R20, -122
        OUT             TCNT0, R20
        ; Start the timer with a prescalar of 1024
        LDI             R20, 0x00
        OUT             TCCR0A, R20
```

```
        LDI             R20, 0x05
        OUT             TCCR0B, R20
        ; Delay for 134 cycles by checking the TOV0 flag
LOOP:
        IN              R20, TIFR0
        SBRS            R20, TOV0
        RJMP    LOOP
        ; Stop timer and reset TOV flag
        LDI             R20, 0x00
        OUT             TCCR0B, R20
        LDI             R20, (1<<TOV0)
        OUT             TIFR0, R20
        RET
```

9. Task #3 C Code

```
#include <avr/io.h>

void T0Delay();

int main(void)
{
        DDRB |= 0x04;                   // Set PORTB.2 as output
        PORTB = 0x00;                   // Clear PORTB
        while(1)
        {
                T0Delay();              // Call delay
                PORTB ^= 0x04;          // Toggle the LED
        }
        return 0;
}

// Delay for 0.25 second
// Delay subroutine using Timer0 (F = 0.5 MHz)
void T0Delay()
{
        TCNT0 = 0x86;                   // Set TCNT0 = 256-122 = 134
        TCCR0A = 0x00;
        TCCR0B = 0x05;                  // Start the timer0 with a prescalar of 1024
        while((TIFR0&0x01) == 0);
        TCCR0B = 0x00;                  // Stop timer0
        TIFR1 |= (1<<TOV0);             // Reset TOV flag
}
```

10. Task #3 Simulation Pictures

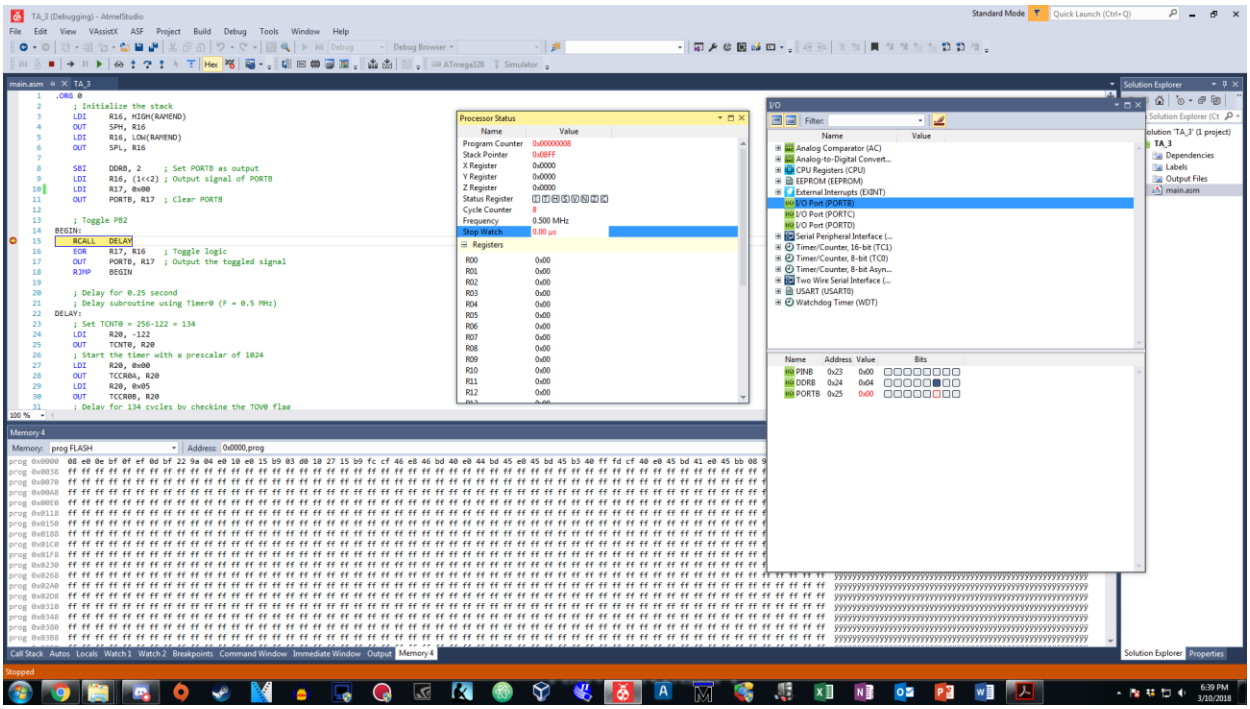


Figure 1: Before the call of delay, PB.2 is cleared and stopwatch ready (ASM)

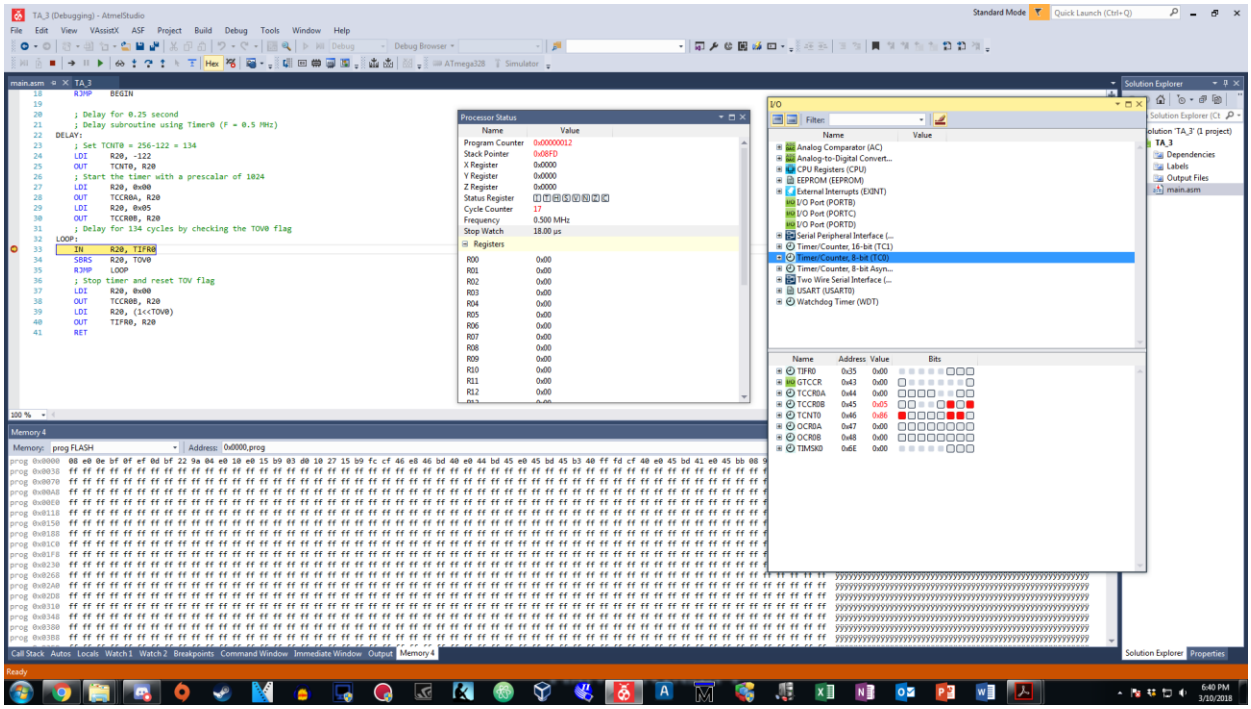


Figure 2: TIMER0 registers are set to count in the delay subroutine (ASM)

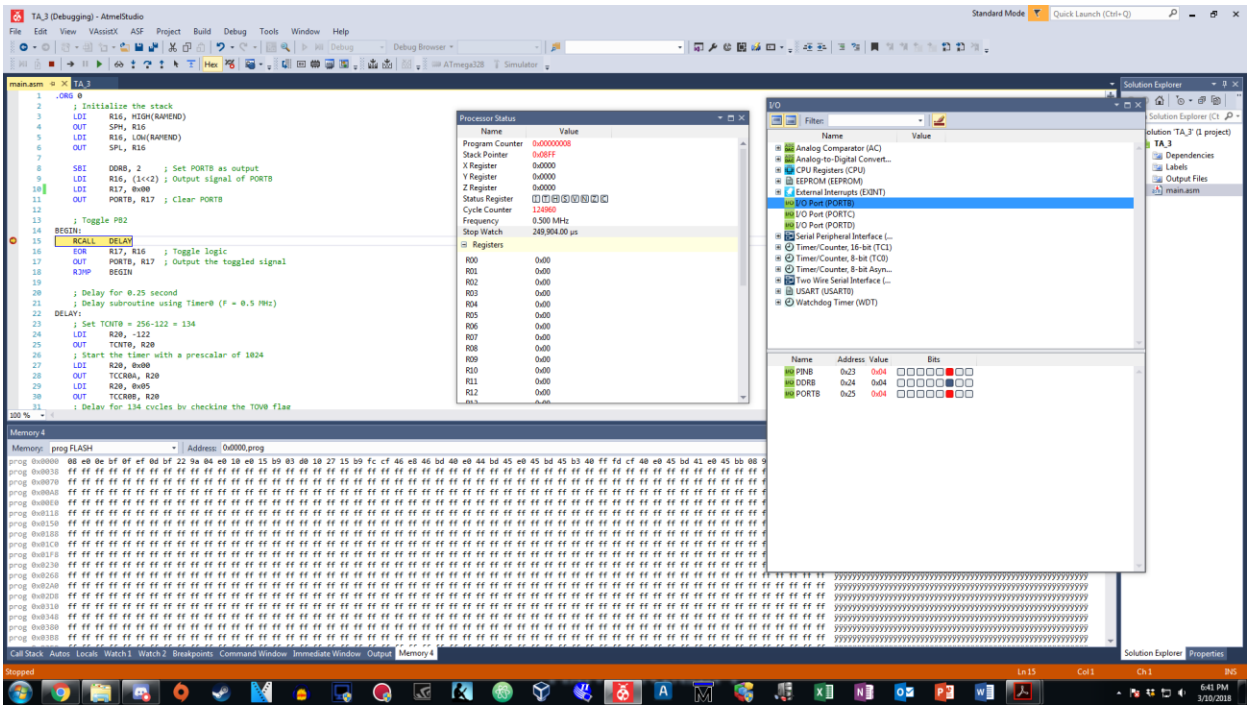


Figure 3: After 0.25 second delay, PB.2 toggles high (ASM)

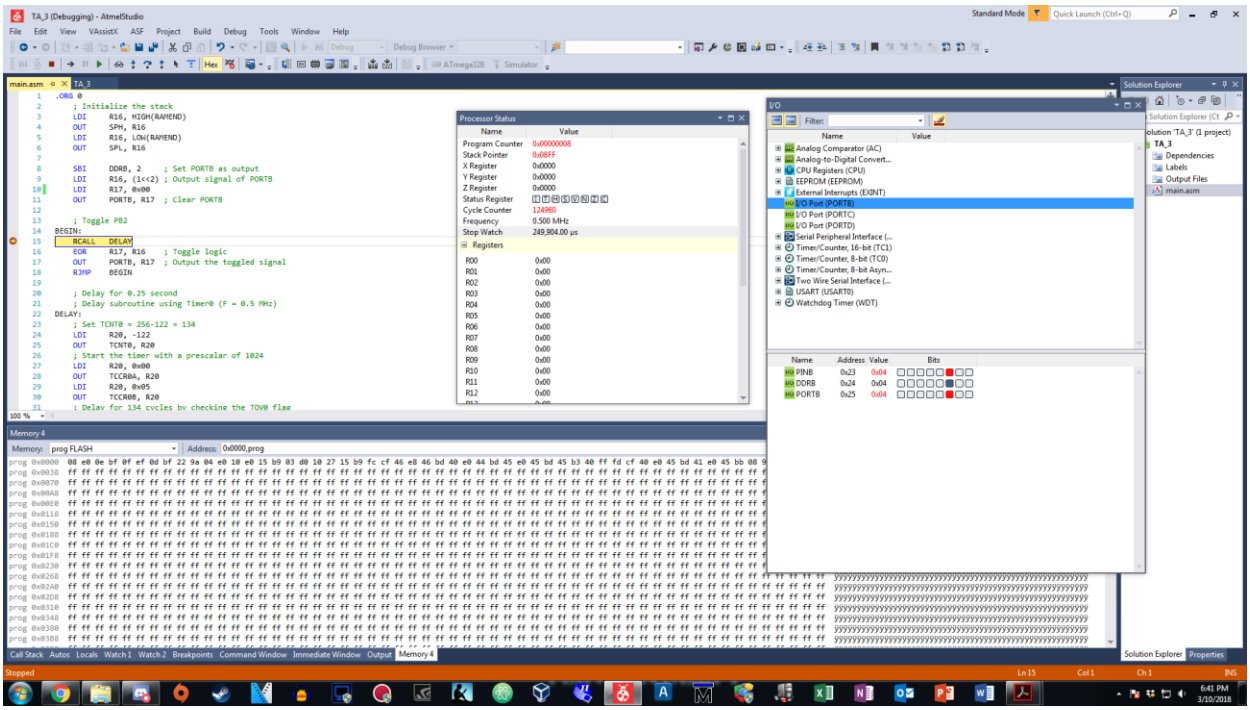


Figure 4: Another 0.25 second of delay, PB.2 toggles to low again (ASM)

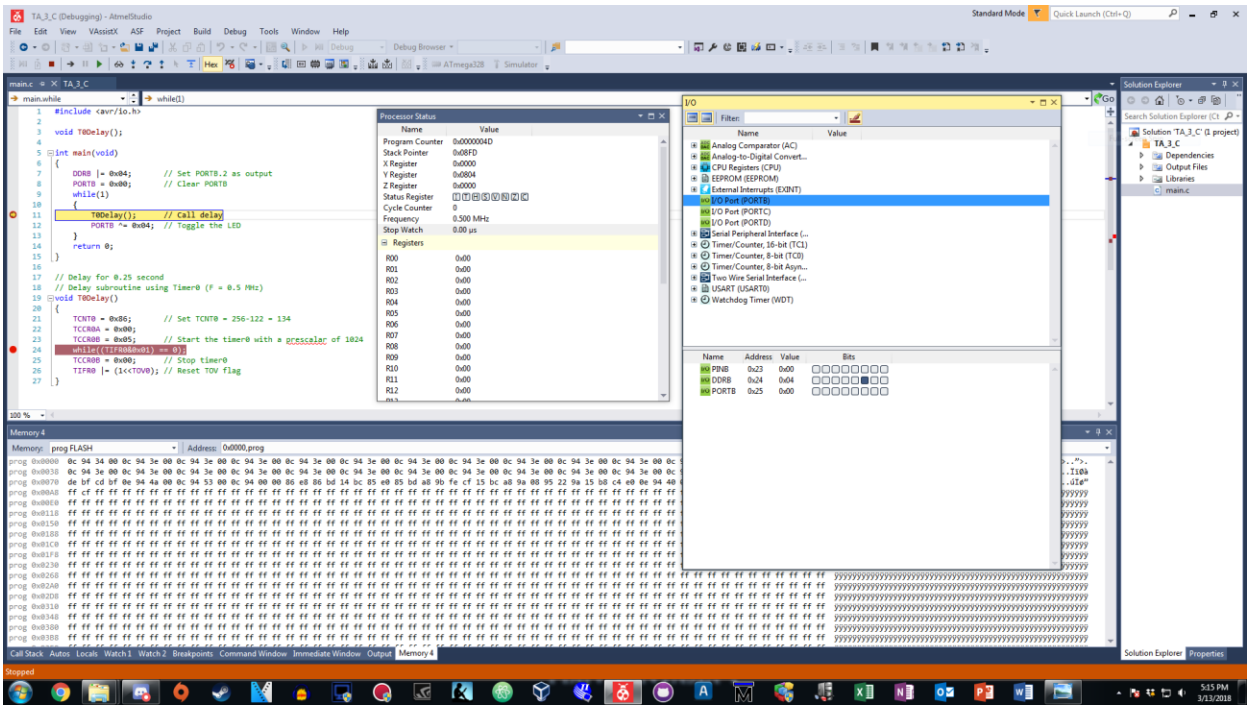


Figure 5: Before the call of delay, PB.2 is cleared and stopwatch ready (C)

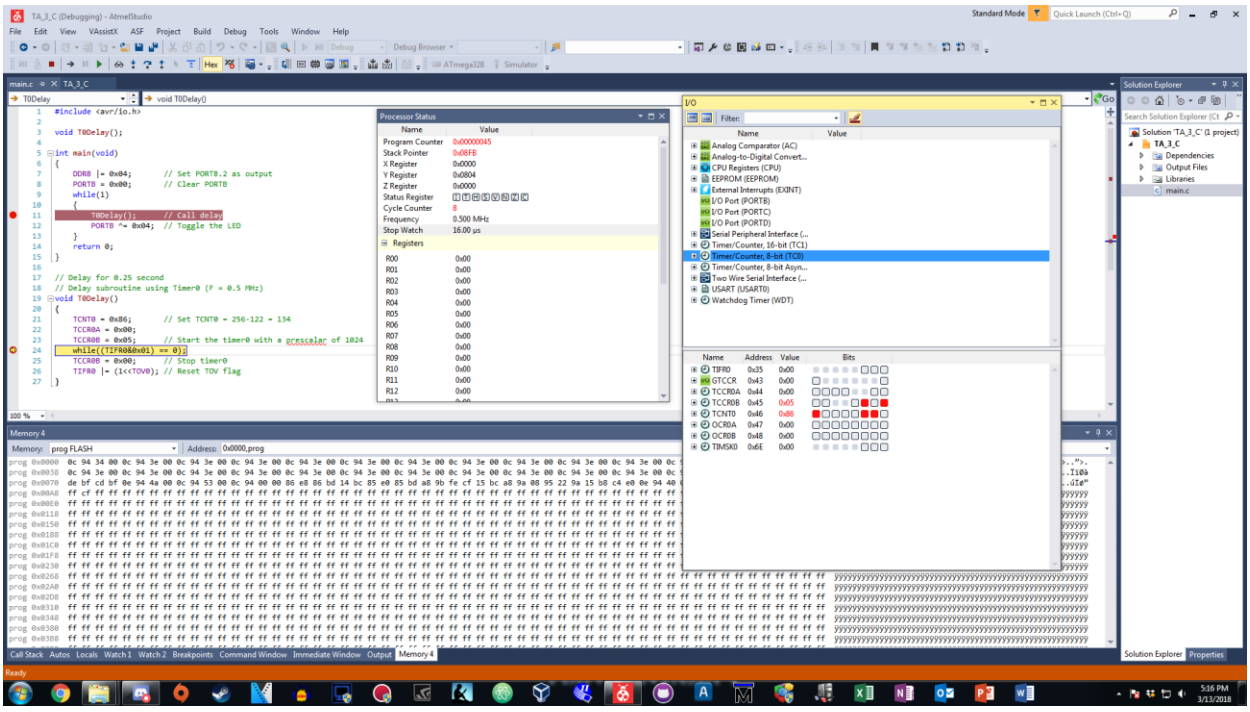


Figure 6: TIMER0 registers are set to count in the delay subroutine (C)

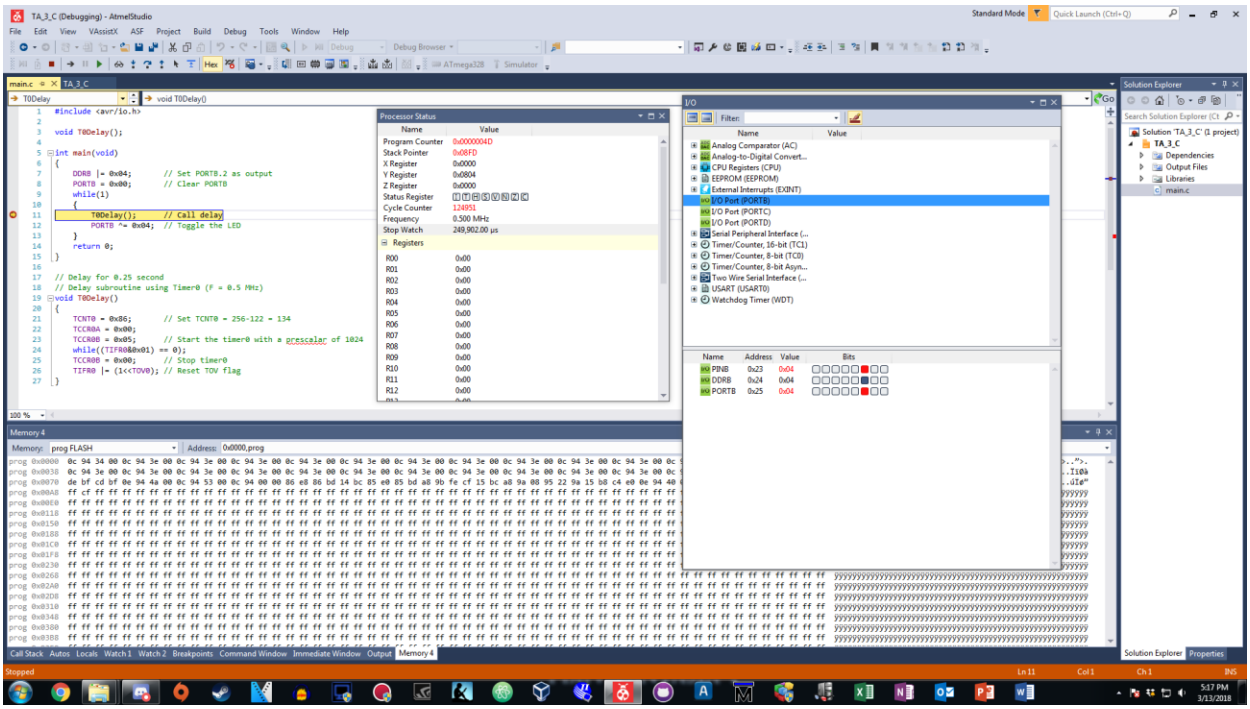


Figure 7: After 0.25 second delay, PB.2 toggles high (C)

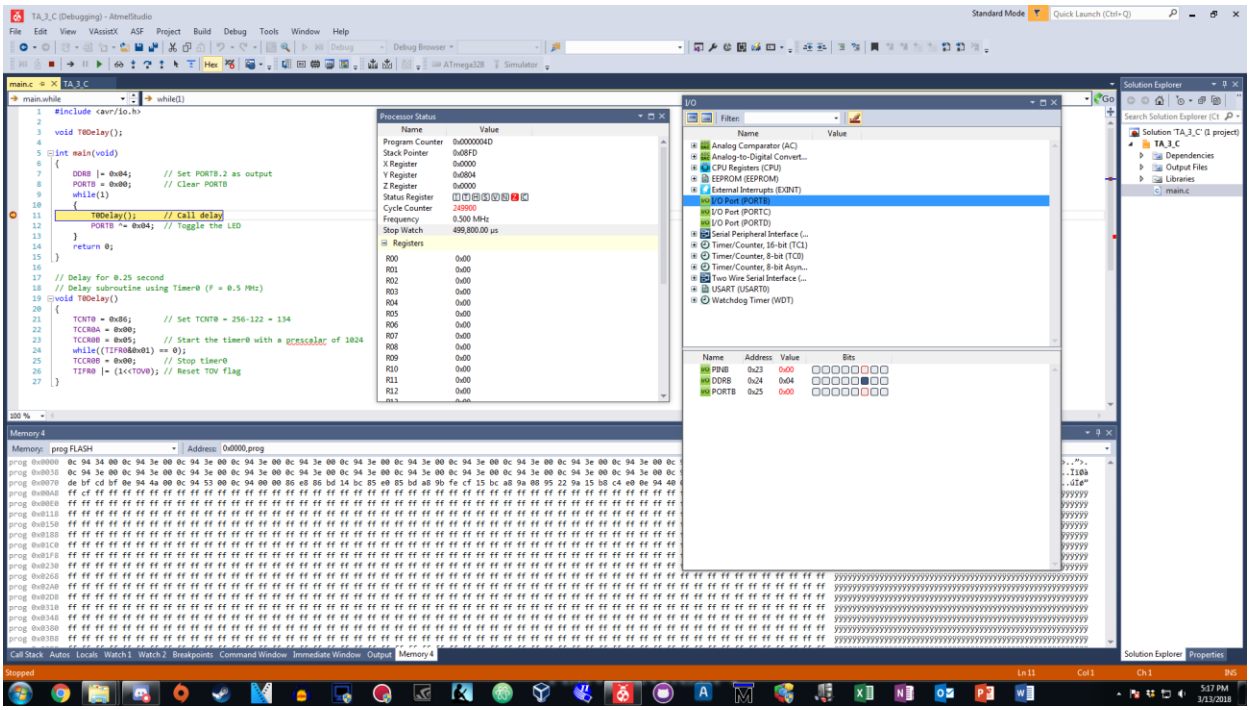


Figure 8: Another 0.25 second of delay, PB.2 toggles to low again (C)

11. Task #4 Assembly Code

```
.ORG 0x0000
```

```
        JMP             MAIN
.ORG 0x0020
        JMP             TIMER0_OVF_ISR

.ORG 0x0100
MAIN:
        ; Initialize the stack
        LDI             R16, HIGH(RAMEND)
        OUT             SPH, R16
        LDI             R16, LOW(RAMEND)
        OUT             SPL, R16

        SBI             DDRB, 2         ; Set PORTB.2 as output
        LDI             R16, (1<<2)     ; Value for toggling the LED
        LDI             R17, 0x00
        OUT             PORTB, R17      ; Clear PORTB register
        LDI             R20, -122       ; 256-122 = 134 cycles (DELAY)
        OUT             TCNT0, R20      ; Load 134 into TCNT0
        LDI             R20, (1<<TOIE0)
        STS             TIMSK0, R20     ; Enable TIMER0 interrupt for OVF
        SEI                             ; Enable interrupts
        LDI             R20, 0x00
        OUT             TCCR0A, R20
        LDI             R20, 0x05
        OUT             TCCR0B, R20     ; Start TIMER0 with a prescalar of 1024 (F = 0.5 MHz)
LOOP:
        RJMP    LOOP                    ; Infinite loop (Wait until TIMER0_OVF interrupts)

.ORG 0x0200
        ; ISR for toggling PORTB.2
TIMER0_OVF_ISR:
        LDI             R20, (1<<TOV0)          ; Clear TOV flag
        OUT             TIFR0, R20
        EOR             R17, R16                ; Toggle PORTB.2
        OUT             PORTB, R17
        LDI             R20, -122
        OUT             TCNT0, R20              ; Reset TCNT0
        RETI
```

12. Task #4 C Code

```
#include <avr/io.h>
#include <avr/interrupt.h>


int main(void)
{
        DDRB = (1<<2);          // Set PORTB.2 as output
        TCNT0 = 0x86;           // Set TCNT0 = 134 (DELAY)
        TIMSK0 = (1<<TOIE0); // Enable TIMER0 interrupt for OVF
        sei();                  // Enable global interrupts
        TCCR0A = 0x00;
        TCCR0B = 0x05;          // Start TIMER0 with a prescalar of 1024 (F = 0.5 MHz)
        PORTB = 0x00;           // Clear PORTB
        // Poll until the interrupt occurs
    while(1)
        {
```

```
        }
        return 0;
}

// Subroutine to handle the TIMER0 OVF interrupt
// Clear TOV, toggle PB.2, and reset TCNT0
ISR(TIMER0_OVF_vect)
{
        TIFR0 = (1<<TOV0);   // Clear TOV flag
        PORTB ^= (1<<2);     // Toggle PORTB.2
        TCNT0 = 0x86;        // Reset TCNT0 count back to 134
}
```

13. Task #4 Simulation Pictures

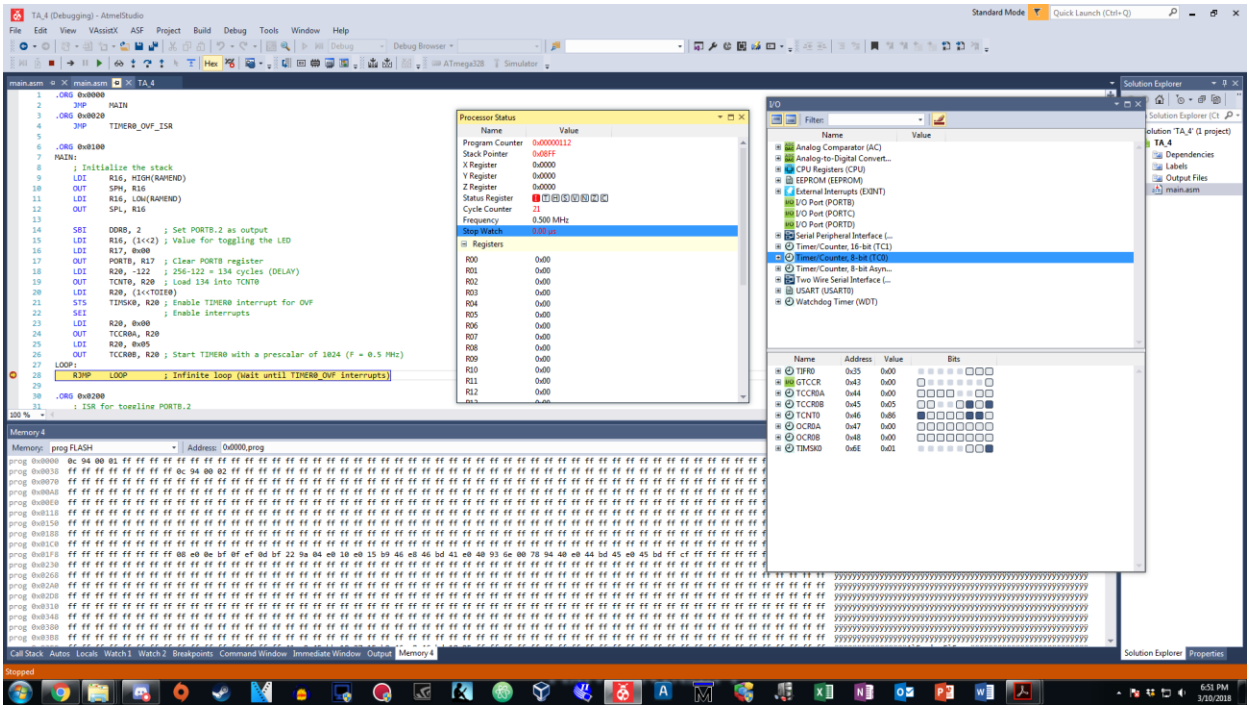


Figure 1: Before the interrupt, Timer0 interrupt registers are set (ASM)

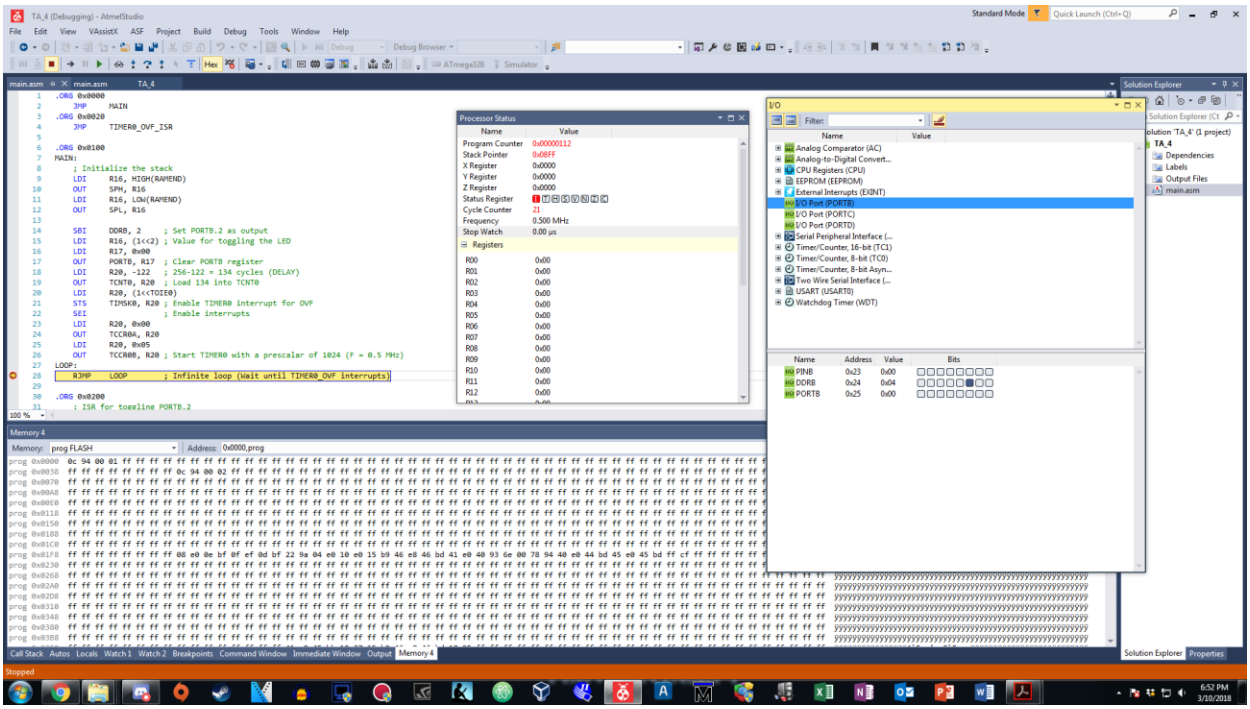


Figure 2: Before the interrupt, stopwatch is set and PB.2 is cleared (ASM)

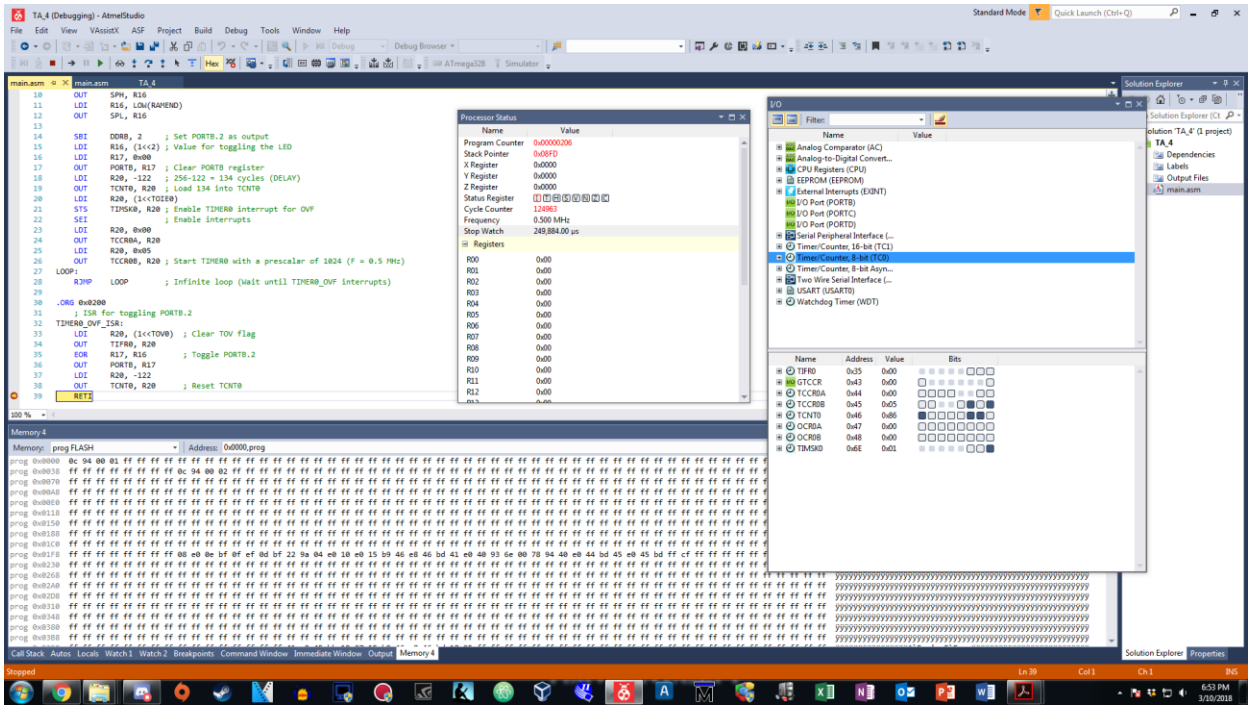


Figure 3: Interrupt occurred and serviced in the ISR by clearing the flag (ASM)

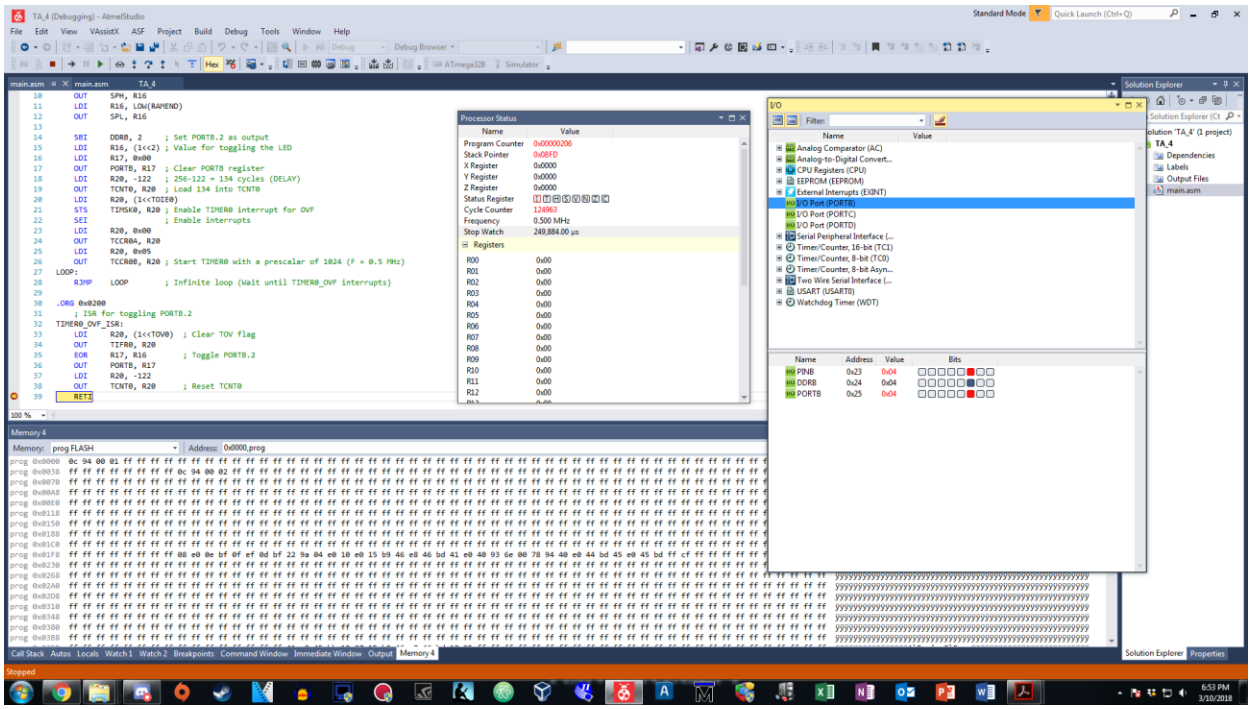


Figure 4: PB.2 is toggled in the ISR after 0.25 second of delay (ASM)

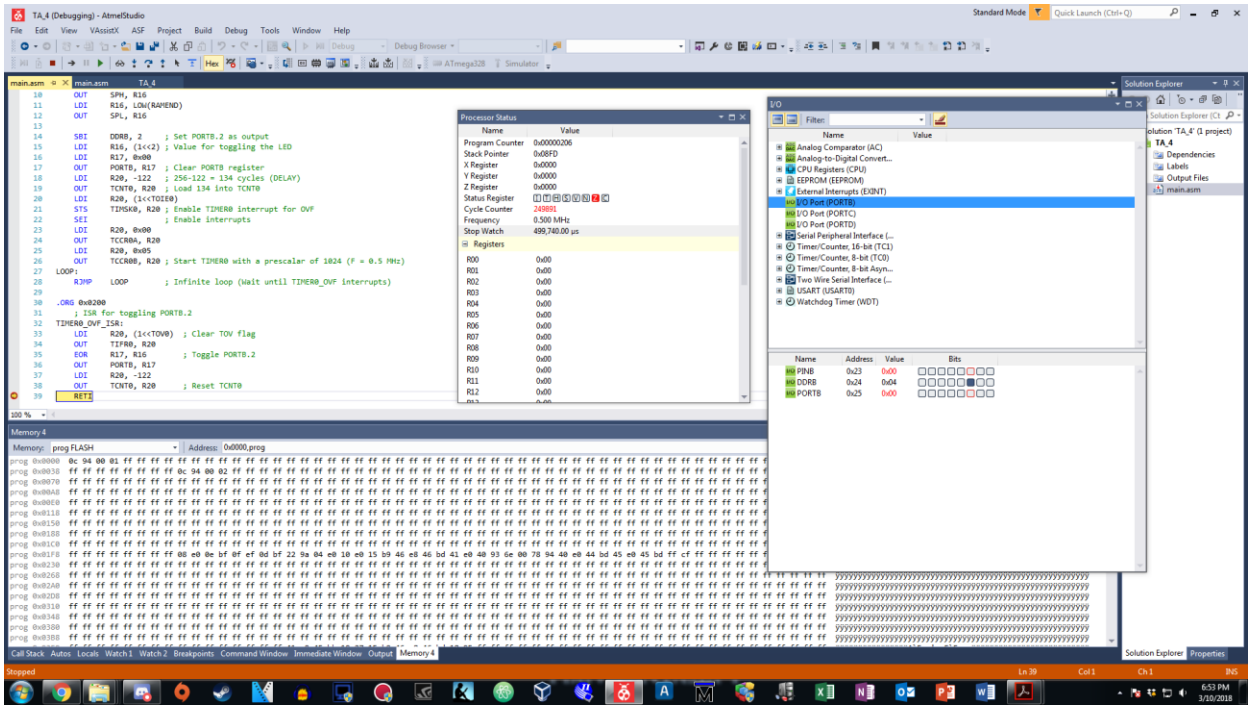


Figure 5: PB.2 is toggled in the ISR again after 0.25 second of delay (ASM)

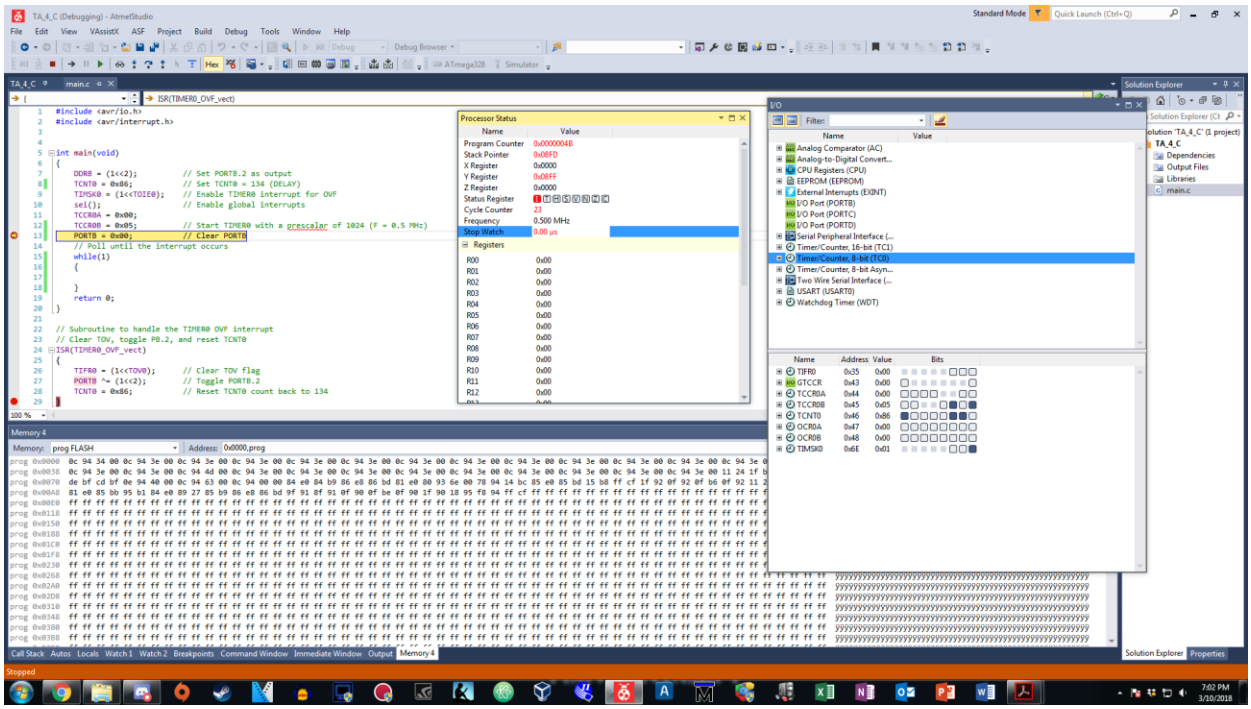


Figure 6: Before the interrupt, Timer0 interrupt registers are set (C)

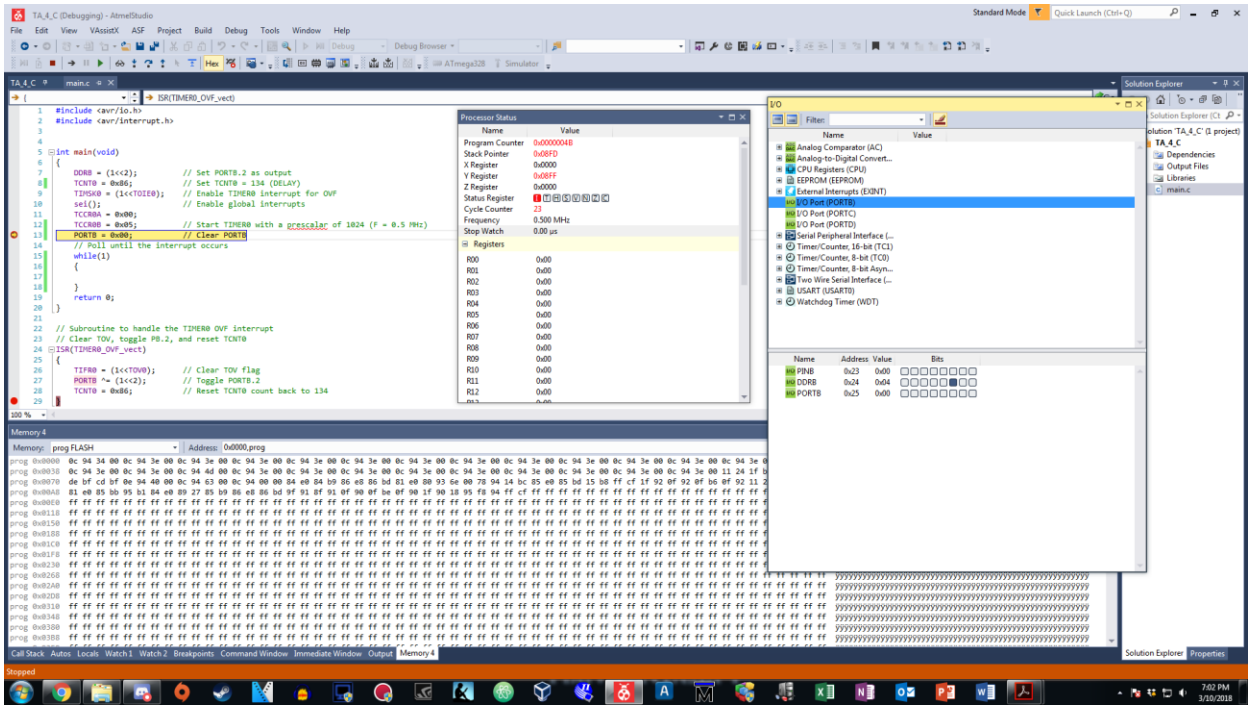


Figure 7: Before the interrupt, stopwatch is set and PB.2 is cleared (C)

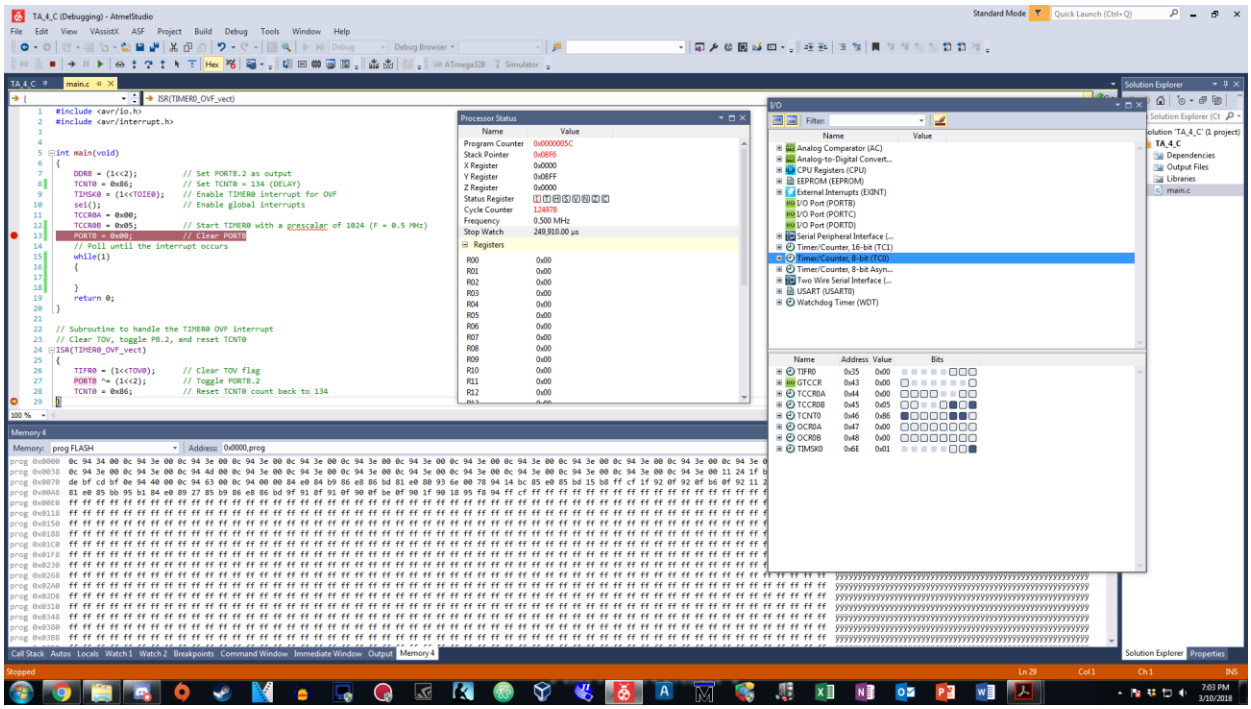


Figure 8: Interrupt occurred and serviced in the ISR by clearing the flag (C)

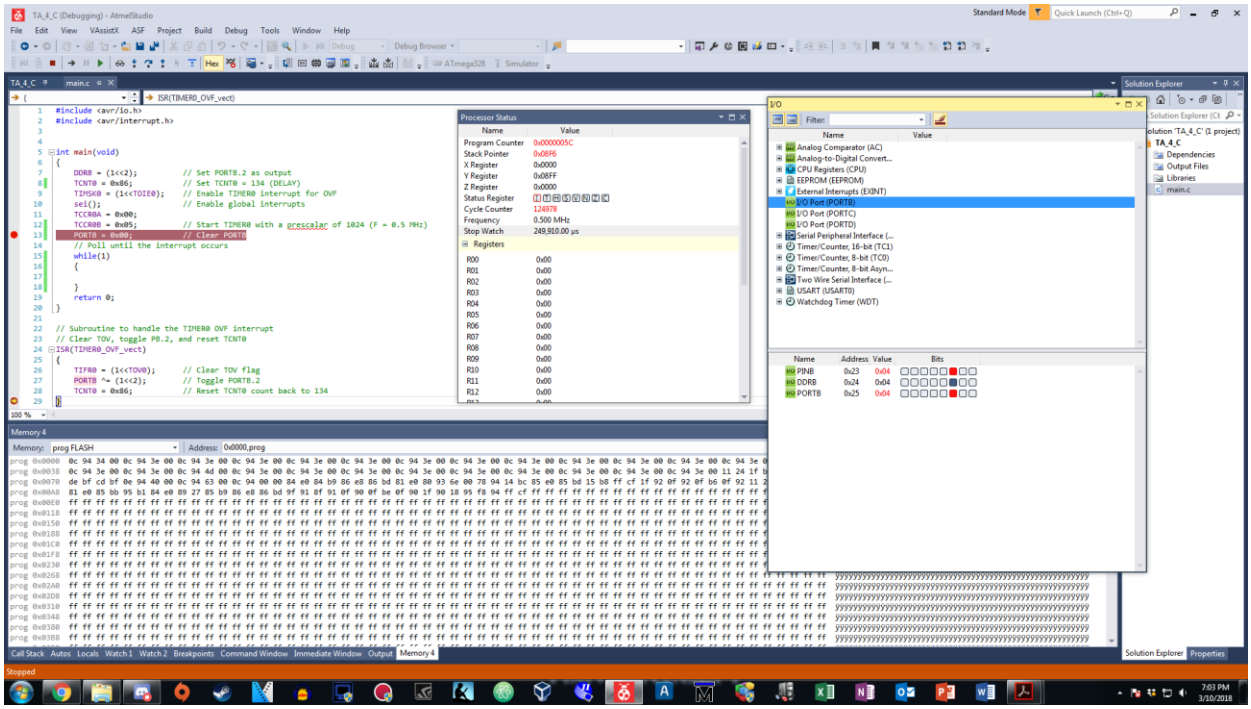


Figure 9: PB.2 is toggled in the ISR after 0.25 second of delay (C)

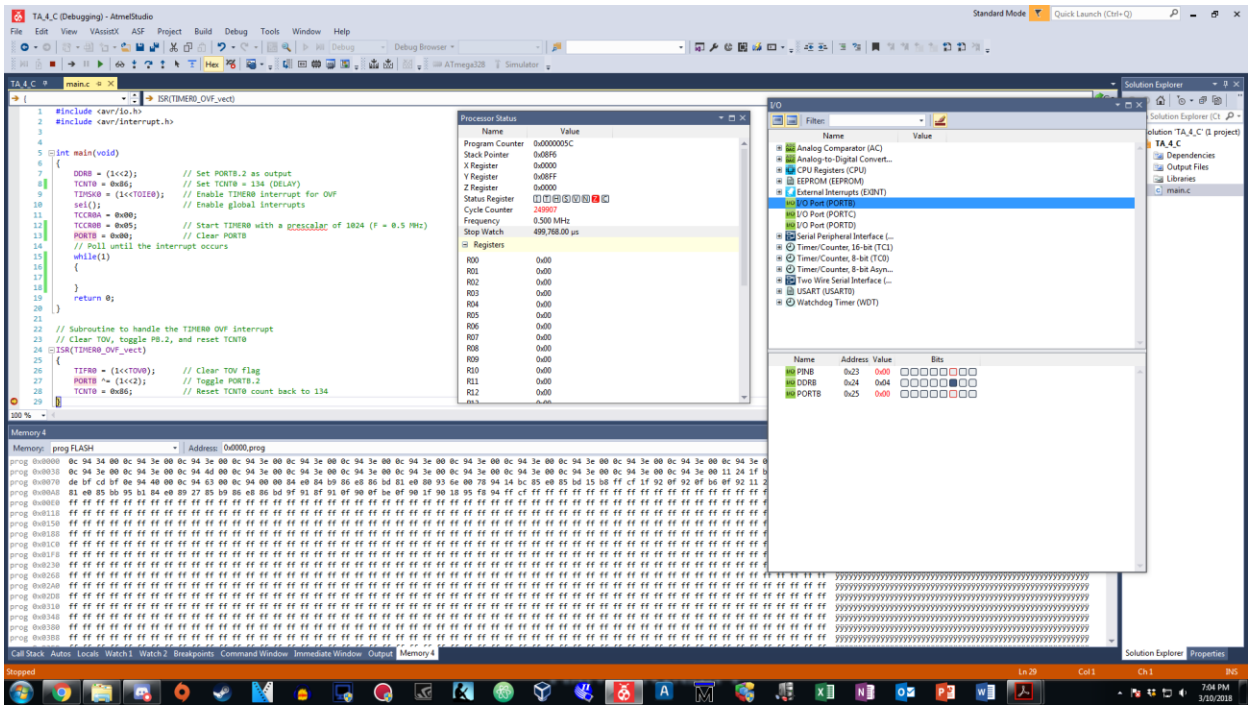


Figure 5: PB.2 is toggled in the ISR again after 0.25 second of delay (C)

14. Task #5 Assembly Code

```
.ORG 0x0000
	JMP MAIN
.ORG 0x0006
	JMP ISR_INT0
.ORG 0x0100
MAIN:
	; Initialize stack
	LDI		R16, HIGH(RAMEND)
	OUT		SPH, R16
	LDI		R16, LOW(RAMEND)
	OUT		SPL, R16
	; PORT initialization
	CBI		DDRD, 2			; Set PORTD.2 as input
	SBI		PORTD, 2		; Pull the resistor of PORTD.2
	SBI		DDRB, 2			; Set PORTB.2 as output
	CBI		PORTB, 2		; Clear PORTB.2
	; Interrupt register initialization
	LDI		R16, (1<<INT0)
	OUT		EIMSK, R16		; Enable INT0 interrupt
	LDI		R16, 0x02
	STS		EICRA, R16		; INT0 interrupt occurs on the falling edge
	SEI
LOOP:
	RJMP	LOOP			; Infinite loop until INT0 interrupt occurs

.ORG 0x0200
ISR_INT0:
	SBI		PORTB, 2		; Light up the LED
HOLD:
```

```
        SBIS    PIND, 2                     ; Poll until the user lets go of the switch
        RJMP    HOLD
        CALL    DELAY                       ; Delay for 1 second
        CBI             PORTB, 2            ; Turn off the LED
        LDI             R21, (1<<INTF0)
        STS             EIFR, R21           ; Clear interrupt flag
        RETI

        ; Delay subroutine (F = 0.5 MHz) [Delay for 1 second]
DELAY:
        LDI             R20, HIGH(-62500)
        STS             TCNT1H, R20
        LDI             R20, LOW(-62500)
        STS             TCNT1L, R20
        ; Set timer control register
        LDI             R20, 0x00
        STS             TCCR1A, R20
        LDI             R20, 0x02
        STS             TCCR1B, R20     ; Start the timer with a prescalar of 8
DLOOP:
        IN              R20, TIFR1      ; Check for the TOV flag
        SBRS    R20, TOV0
        RJMP    DLOOP
        ; Stop timer and clear TOV flag
        LDI             R20, 0x0
        STS             TCCR1B, R20
        LDI             R20, (1<<TOV0)
        OUT             TIFR1, R20
        RET
```

15. Task 5 C Code

```
#include <avr/io.h>
#include <avr/interrupt.h>

void T1Delay();

int main(void)
{
        // Port initialization
        DDRD = 0x00;          // Set PORTD as inputs
        PORTD |= (1<<2);      // Pull up the resistor of PORTD.2
        DDRB |= (1<<2);       // Set PORTB.2 as output
        PORTB = 0x00;         // Clear PORTB
        // Interrupt register initialization
        EIMSK |= (1<<INT0);  // Enable INT0 interrupt
        EICRA |= 0x02;              // INT0 interrupt occurs on the falling edge
        sei();                      // Enable global interrupt
    while (1)
    {

    }
        return 0;
}

ISR(INT0_vect)
{
```

```
        PORTB |= (1<<2);     // Light up the LED
        while((PIND&(1<<2))&0x00);
        T1Delay();
        PORTB = 0x00;        // Turn off LED
        EIFR = (1<<INTF0);   // Clear interrupt flag
}

// Delay subroutine for Timer1 [Delay for 1 second]
// F = 0.5 MHz
void T1Delay()
{
        // Set the TCNT1 = 65536-62500 = 3036 [0xBDC]
        TCNT1H = 0x0B;
        TCNT1L = 0xDC;
        // Start Timer1 with prescalar 8
        TCCR1A = 0x00;
        TCCR1B = 0x02;
        while((TIFR1&(1<<TOV1)) == 0x00);  // Check TOV flag
        TCCR1B = 0x00;                              // Stop Timer1
        TIFR1 |= (1<<TOV1);                         // Reset TOV flag in TIFR1 register
}
```

16. Task #5 Simulation Pictures

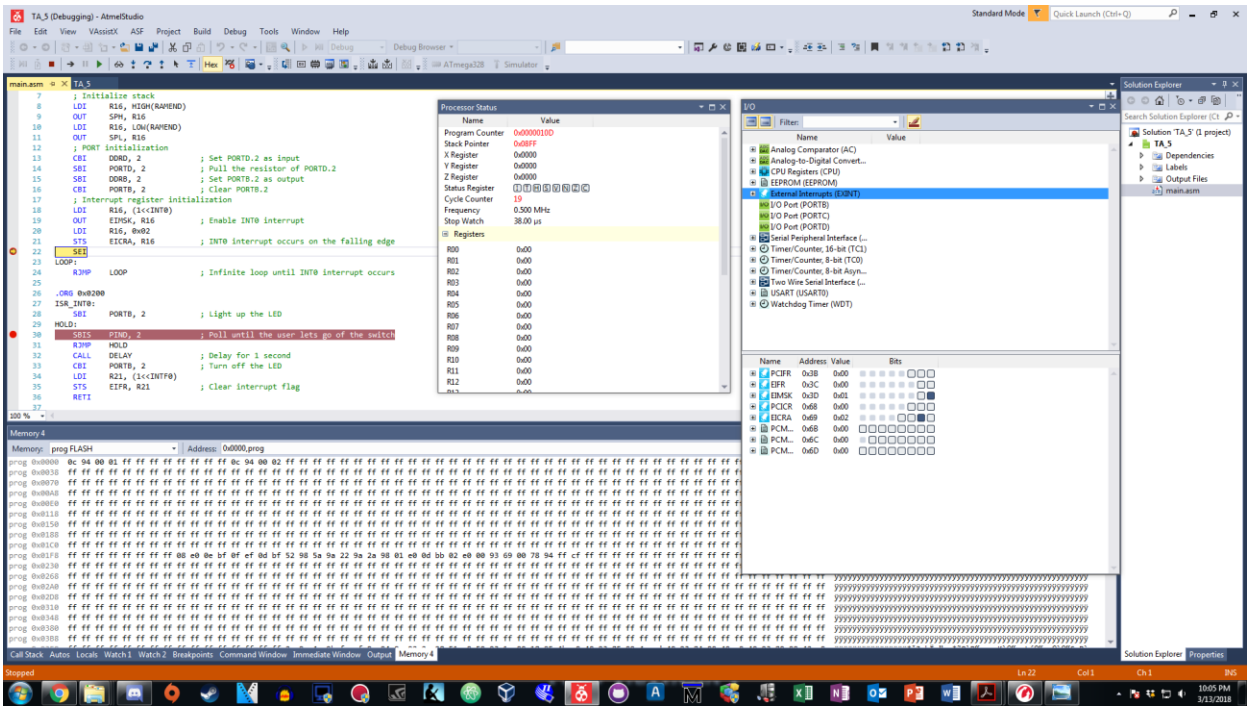


Figure 1: Appropriate interrupt registers are set: INT0 interrupt on falling edge (ASM)

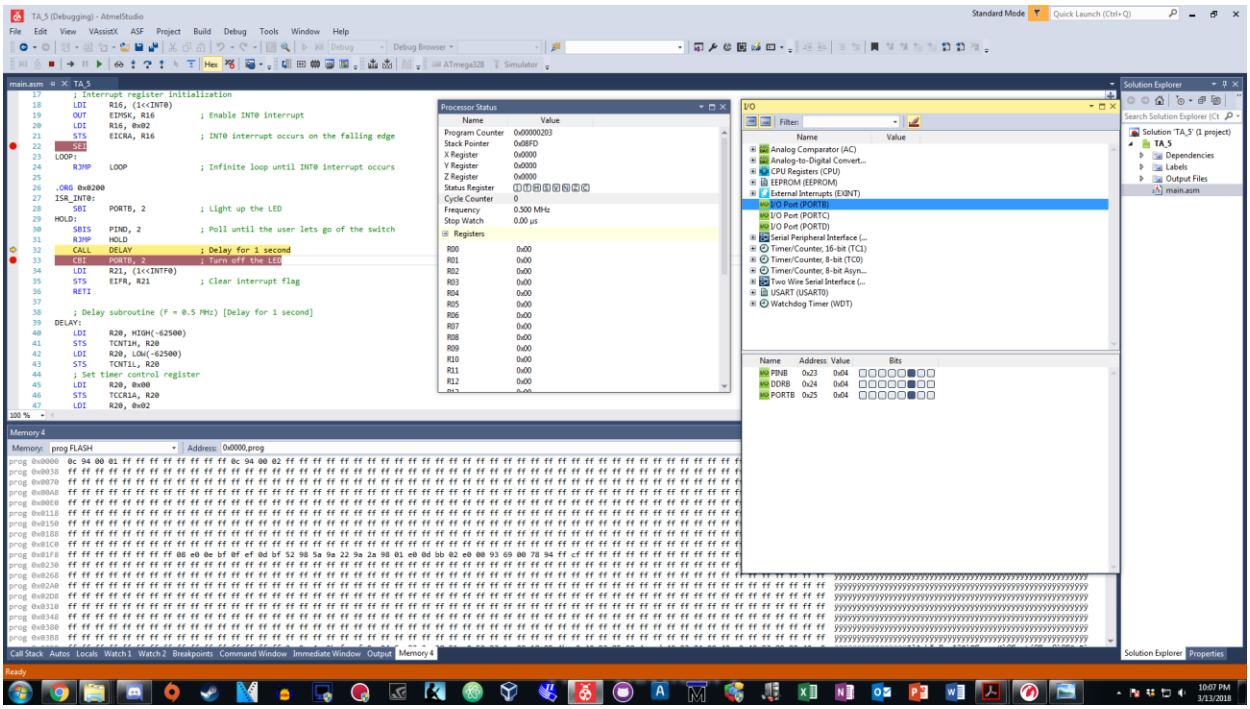


Figure 2: LED turns on at PORTB.2 and stopwatch set to measure the 1 second delay (ASM)

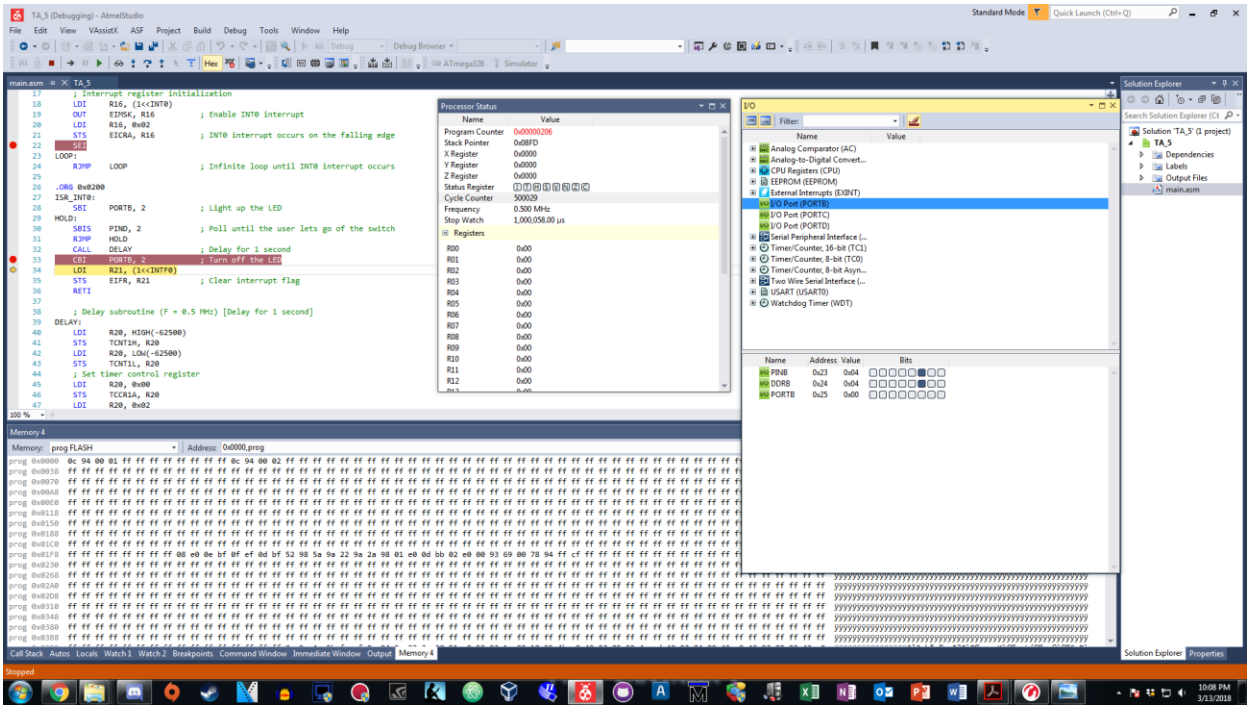


Figure 3: After 1 second delay, LED turns off at PORTB.2 (ASM)

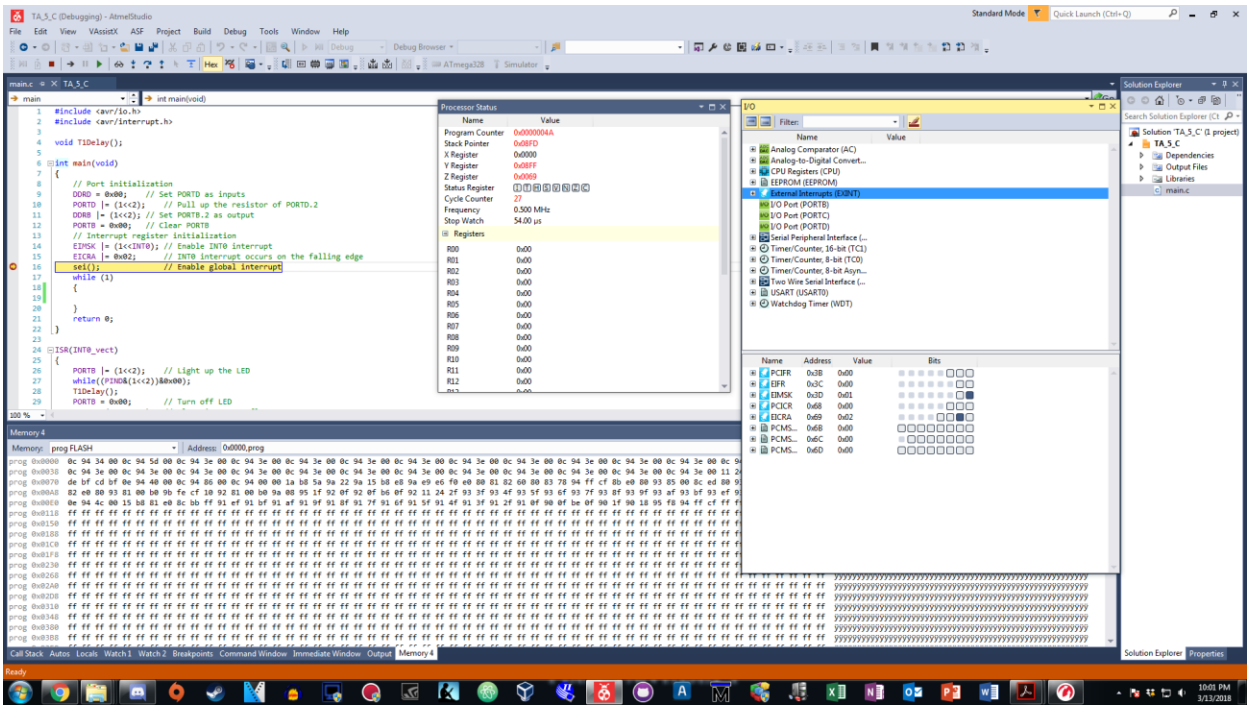


Figure 4: Appropriate interrupt registers are set: INT0 interrupt on falling edge (C)

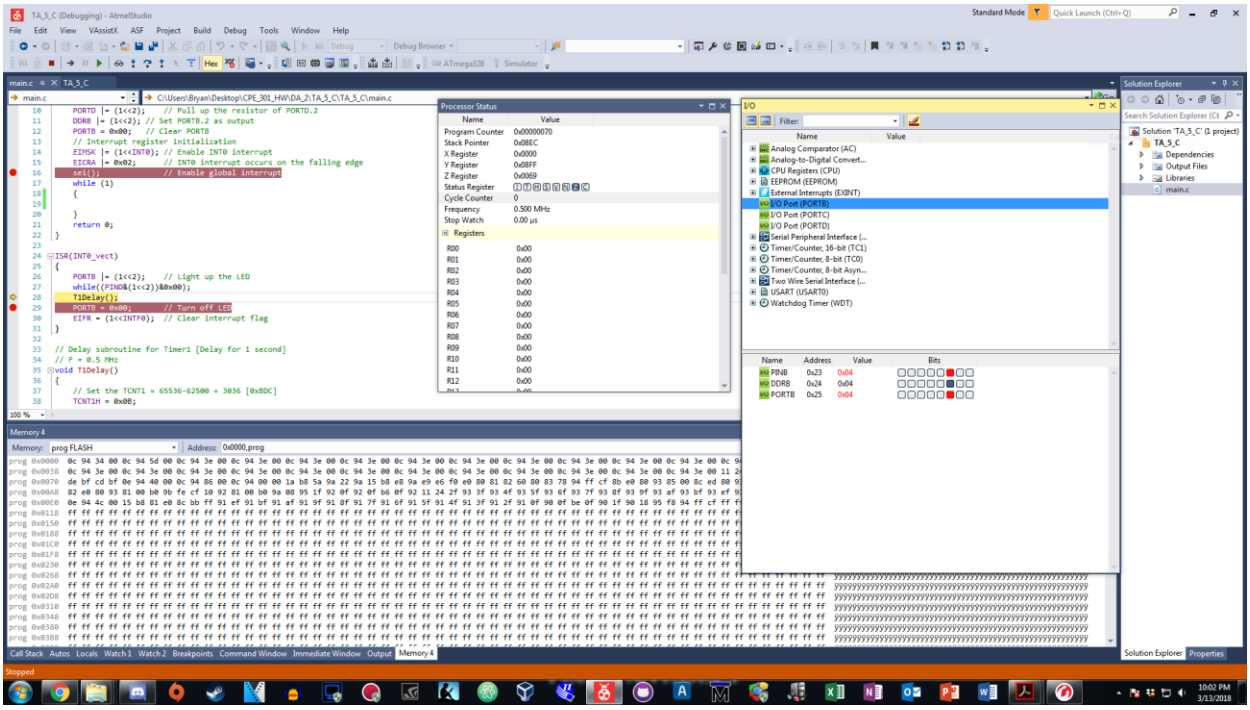


Figure 5: LED turns on at PORTB.2 and stopwatch set to measure the 1 second delay (C)

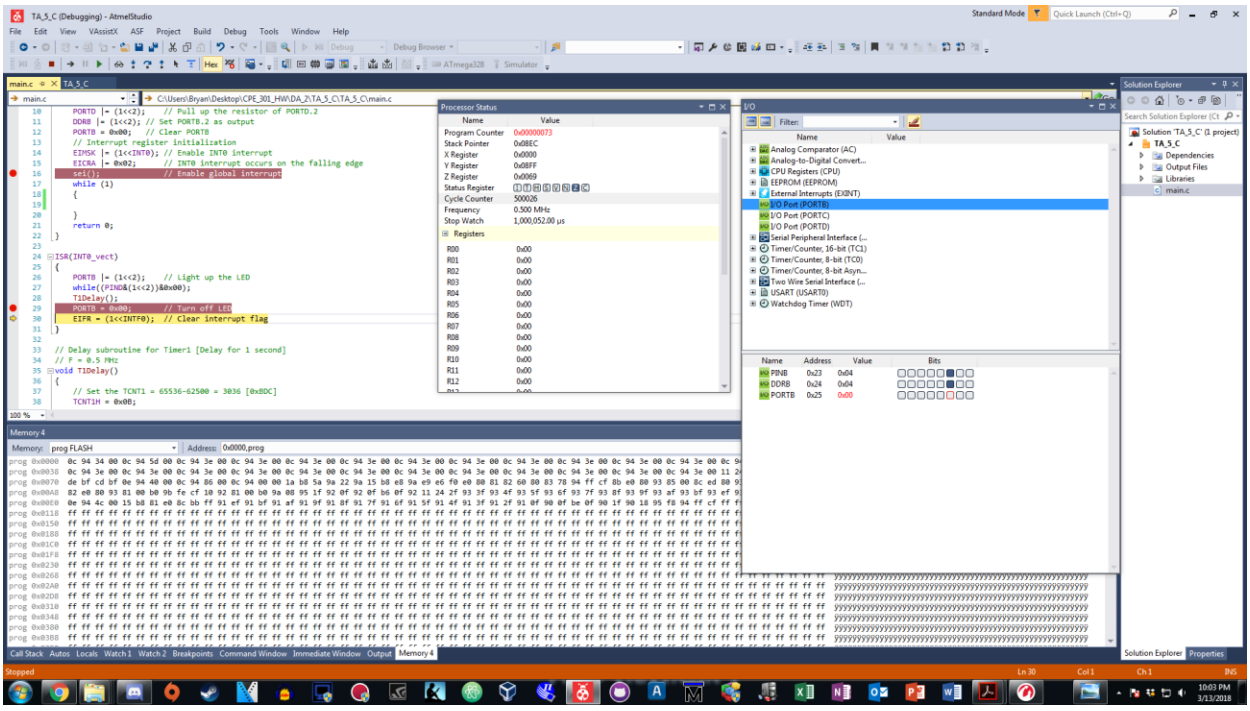


Figure 6: After 1 second delay, LED turns off at PORTB.2 (C)

17. YouTube Links

Task #1: https://youtu.be/kM3ICCMPzmo
Task #2: https://youtu.be/AVIxueKxSqc

Student Academic Misconduct Policy
http://studentconduct.unlv.edu/misconduct/policy.html

"*This assignment submission is my own, original work*".
Bryan Takemoto