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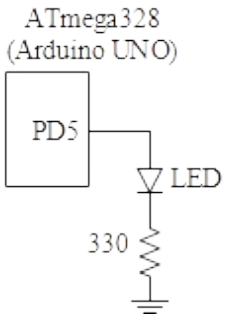
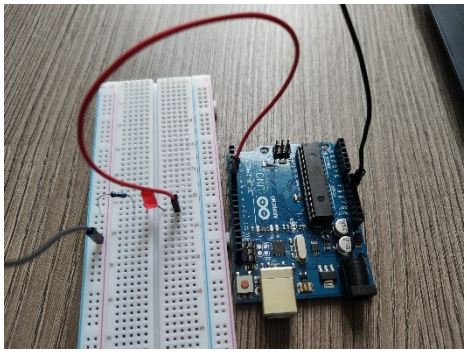
SIIT SINCE 1992	**School of ICT** **Sirindhorn International Institute of Technology**
CSS332 Microcontrollers and Applications	**Lab 6: AVR Timer Programming**

Instructions: Answer the following exercises. During the lab class, please feel free to ask the instructor, the TAs, or other students if there is a question. When finishing all of them, the students can ask a TA to check the answers. The students submit this lab sheet with the answers to the Google Classroom (no submission, no score). (In the Google Classroom, do not forget to press the Confirm button to submit the work.)

Exercise 1: Connect an LED to the pin PD5 as shown below.





850,000 / 3500 → 0xf2

The following assembly program will turn the LED on and off, every 0.85 second (approximately), where Timer0 used in the DELAY subroutine is set as follows.

- normal mode, 0x00 (100)
- pre-scaling number = 256, 0x04
- the time delay generated by this DELAY subroutine = 3500 μs (approximately).

Specifically, there are two parts in the assembly program here that the students must determine.

1) In the DELAY subroutine, the students must determine the Timer0 setup to achieve the Timer0 requirement above.
2) In the main program, since the DELAY subroutine will generate around 3500 μs, the initial value in R16 before the HERE1 and HERE2 loops must be set such that, in overall, each loop will produce 0.85 second (approximately).

Note that the crystal frequency of the ATmega328 is 16 MHz.

a) Fill in the blank specified in this assembly program.

```
1            .ORG    0
2            LDI     R16, HIGH(RAMEND)
3            OUT     SPH, R16
4            LDI     R16, LOW(RAMEND)
5            OUT     SPL, R16
6            SBI     DDRD, 5      ;Set the pin PD5 as the output
7
8    LOOP:   CBI     PORTD, 5     ;Set the pin PD5=0
9            LDI     R16, 0xF2
10   HERE1:  CALL    DELAY
11           DEC     R16
12           BRNE    HERE1
13
14           SBI     PORTD, 5     ;Set the pin PD5=1
15           LDI     R16, 0xF2
16   HERE2:  CALL    DELAY
17           DEC     R16
18           BRNE    HERE2
19           RJMP    LOOP
20
```

```
21   DELAY:  ;DELAY subroutine
22           LDI     R20, 0x25    -> A
23           OUT     TCNT0, R20   ;Set the initial value of Timer0
24           LDI     R20, 0x00
25           OUT     TCCR0A, R20  ;Set the normal mode,
26           LDI     R20, 0x04    <- 256  1 0 0
27           OUT     TCCR0B, R20  ;Pre-scaling :          start the clock
28   AGAIN:  SBIS    TIFR0, 0     ;Check if TOV0 flag = 1?
29           RJMP    AGAIN
30           LDI     R20, 0x00
31           OUT     TCCR0B, R20  ;Stop the clock
32           LDI     R20, 0x01
33           OUT     TIFR0, R20   ;Clear the TOV0 flag
34           RET                  ;Return to the main program
```

b) Upload your assembly program to your Arduino UNO board. Take a video to demonstrate your result. Name it "Ex1" and submit to the Google Classroom.

3500 256 f

$$\text{Time delay } (\mu s) = \left[\left(\left\lceil\frac{(255-A+1)\times P}{3}\right\rceil \times 3\right) + 2 + 14\right] \times 0.0625,$$

$$\left[\left(\left\lceil\frac{(255-A+1)\times 256}{3}\right\rceil \times 3\right) + 2 + 14\right] \times 0.0625$$

16

$$\left[\left(\left\lceil\frac{(256-A)\times 256}{3}\right\rceil \times 3\right) + 16\right] \times 0.0625 = 3500$$

$A = (37)_{10} = (0x25)_{16}$

Exercise 2: Connect an LED to the pin PD5 as shown in Example 1. The following assembly program will turn the LED on and off, every 0.5 second (approximately), where Timer0 used in the DELAY subroutine is set as follows.

- CTC mode, 0x02
- initial value of TCNT0 is 0x40,
- pre-scaling number = 256, → 0x04
- the time delay generated by this DELAY subroutine = 2500 μs (approximately).

Specifically, there are two parts in the assembly program here that the students must determine.

1) In the DELAY subroutine, the students must determine the Timer0 setup to achieve the Timer0 requirement above.

2) In the main program, since the DELAY subroutine will generate around 2500 μs, the initial value in R16 before the HERE1 and HERE2 loops must be set such that, in overall, each loop will produce 0.5 second (approximately).

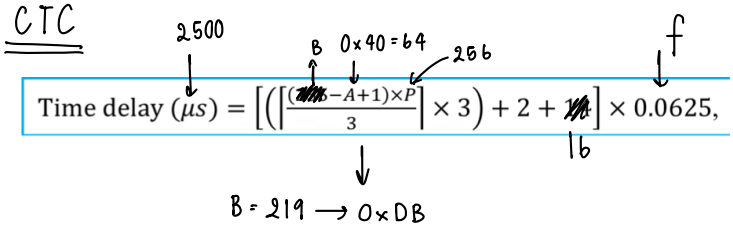
Note that the crystal frequency of the ATmega328 is 16 MHz.

a) Fill in the blank specified in this assembly program.

```
1           .ORG    0
2           LDI     R16, HIGH(RAMEND)
3           OUT     SPH, R16
4           LDI     R16, LOW(RAMEND)
5           OUT     SPL, R16
6           SBI     DDRD, 5     ;Set the pin PD5 as the output
7
8   LOOP:   CBI     PORTD, 5    ;Set the pin PD5=0
9           LDI     R16, 0xC8
10  HERE1:  CALL    DELAY
11          DEC     R16
12          BRNE    HERE1
13
14          SBI     PORTD, 5    ;Set the pin PD5=1
15          LDI     R16, 0xC8
16  HERE2:  CALL    DELAY
17          DEC     R16
18          BRNE    HERE2
19          RJMP    LOOP
20
```

```
21  DELAY:  ;DELAY subroutine
22          LDI     R20, 0x40
23          OUT     TCNT0, R20  ;Set the initial value of Timer0
24          LDI     R20, 0xDB
25          OUT     OCR0A, R20  ;Set the max value of Timer0
26          LDI     R20, 0x02
27          OUT     TCCR0A, R20 ;Set the CTC mode,
28          LDI     R20, 0x04
29          OUT     TCCR0B, R20 ;Pre-scaling 256 and start the clock
30  AGAIN:  SBIS    TIFR0, 1    ;Check if OCF0A flag = 1?
31          RJMP    AGAIN
32          LDI     R20, 0x00
33          OUT     TCCR0B, R20 ;Stop the clock
34          LDI     R20, 0x02
35          OUT     TIFR0, R20  ;Clear the OCF0A flag
36          RET                 ;Return to the main program
```

b) Upload your assembly program to your Arduino UNO board. Take a video to demonstrate your result. Name it "Ex2" and submit to the Google Classroom.



$\frac{2,100,000}{10,000} = 0x\,D2$

Exercise 3: Revise the assembly program in Exercise 1 such that the LED will be on and off, every 2.1 seconds (approximately), where Timer0 used in the DELAY subroutine is set as follows.

- normal mode, 0x00
- pre-scaling number = 1024, 0x05, 101
- the time delay generated by this DELAY subroutine = $10000\,\mu s$ (approximately).

Specifically, there are two parts in the assembly program in Exercise 1 must be revised.

1) In the DELAY subroutine, the students must revise the Timer0 setup to achieve the Timer0 requirement above.
2) In the main program, since the DELAY subroutine will generate around $10000\,\mu s$, the initial value in R16 before the HERE1 and HERE2 loops must be revised such that, in overall, each loop will produce 2.1 seconds (approximately).

a) What are the initial values stored in the register TCNT0, TCCR0A, TCCR0B (those specified before the AGAIN loop in the DELAY subroutine)?

TCNT0 = 0x63
TCCR0A = 0x00 → Normal
TCCR0B = 0x05 → 101 = pre clock

b) What is the initial value of R16 before the HERE1 and HERE2 loops?

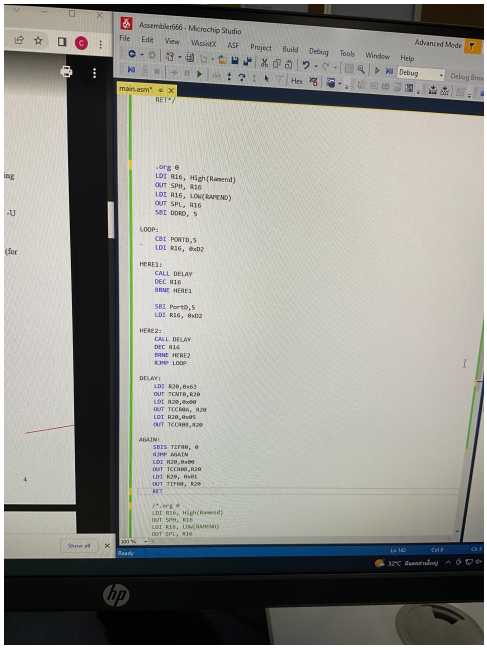
R16 = 0xD2

c) Copy the screenshot of your assembly program and put it here.

Normal, 0xFF, 10,000, 1024

$$\text{Time delay } (\mu s) = \left[\left(\left\lceil\frac{(255-A+1)\times P}{3}\right\rceil \times 3\right) + 2 + 14\right] \times 0.0625,$$

= 99 → 0x63



d) Upload your assembly program to your Arduino UNO board. Take a video to demonstrate your result. Name it "Ex3" and submit to the Google Classroom.

$$\text{Time delay } (\mu s) = \left[\left(\left\lceil\frac{(OCR0A-A+1)\times P}{3}\right\rceil \times 3\right) + 2 + 16\right] \times 0.0625,$$

7000 0xE9 1024 16

1.3 sec / 7000 μs → 1,300,000 / 7000 = B9

= 129 → 9C

Exercise 4: Revise the assembly program in Exercise 2 such that the LED will be on and off, every 1.3 seconds (approximately), where Timer0 used in the DELAY subroutine is set as follows.

- CTC mode, 0x02
- the value stored in the register OCR0A is 0xE9, B
- pre-scaling number = 1024, → 0x05
- the time delay generated by this DELAY subroutine = 7000 μs (approximately).

Specifically, there are two parts in the assembly program in Exercise 2 must be revised.

1) In the DELAY subroutine, the students must revise the Timer0 setup to achieve the Timer0 requirement above. Here, the students must also determine the initial value in the register TCNT0.

2) In the main program, since the DELAY subroutine will generate around 7000 μs, the initial value in R16 before the HERE1 and HERE2 loops must be revised such that, in overall, each loop will produce 1.3 seconds (approximately).

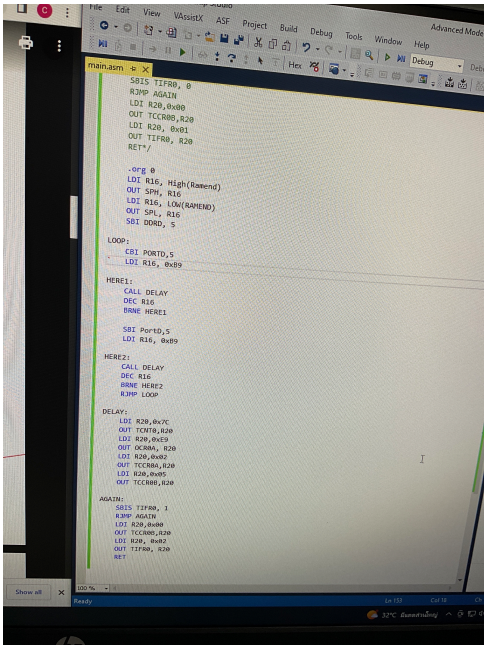
a) What are the initial values stored in the register TCNT0, TCCR0A, TCCR0B (those specified before the AGAIN loop in the DELAY subroutine)?

TCNT0 = 0x7C
OCR0A = 0xE9 (B)
TCCR0A = 0x02 → mode
TCCR0B = 0x05 → prescail

b) What is the initial value of R16 before the HERE1 and HERE2 loops?

R16 = 0xB9

c) Copy the screenshot of your assembly program and put it here.



d) Upload your assembly program to your Arduino UNO board. Take a video to demonstrate your result. Name it "Ex4" and submit to the Google Classroom.