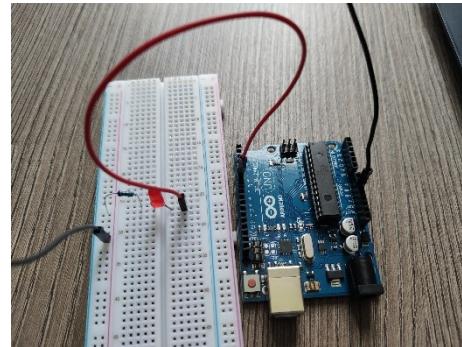
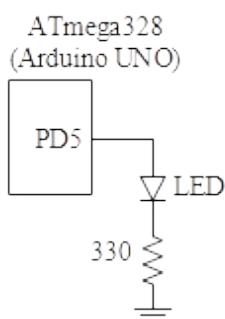


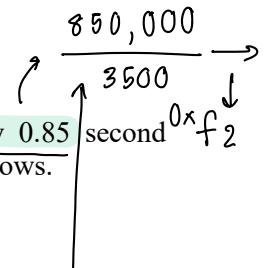
Instructions: Answer the following exercises. During the lab class, please feel free to ask the instructor, the TAs, or other students if there is a question. When finishing all of them, the students can ask a TA to check the answers. The students submit this lab sheet with the answers to the Google 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.



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, 0×00 100
- pre-scaling number = 256, 0×04
- the time delay generated by this DELAY subroutine = $3500 \mu\text{s}$ (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 $3500 \mu\text{s}$, 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 ← 256 100
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.

$$\begin{aligned}
 & \text{Time delay } (\mu\text{s}) = \left[\left(\left(\frac{(255-A+1) \times P}{3} \right) \times 3 \right) + 2 + 14 \right] \times 0.0625, \\
 & \quad \left[\left(\left(\frac{(255-A+1) \times 256}{3} \right) \times 3 \right) + 2 + 14 \right] \times 0.0625 \\
 & \quad \left[\left(\left(\frac{(256-A) \times 256}{3} \right) \times 3 \right) + 16 \right] \times 0.0625 = 3500 \\
 & \quad A = 34_{10} = 0x25_{16}
 \end{aligned}$$

$$\frac{500,000}{2500} \rightarrow C8$$

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 , $\rightarrow 0x04$
- the time delay generated by this DELAY subroutine = $2500\ \mu s$ (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 $2500\ \mu s$, 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

```

A

```

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  0 1 0
27    OUT   TCCR0A, R20 ;Set the CTC mode,
28    LDI    R20, 0x04  1 0 0
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.

CTC

$$\text{Time delay } (\mu\text{s}) = \left[\left(\frac{(256 - A + 1) \times P}{3} \right) \times 3 \right] + 2 + M \times 0.0625,$$

\downarrow

$B = 219 \rightarrow 0xDB$

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

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, 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 =	<u>$0x63$</u>
TCCR0A =	<u>$0x00$</u> \rightarrow Normal
TCCR0B =	<u>$0x05$</u> \rightarrow 101 = pre clock

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

R16 =	<u>$0xD2$</u>
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- c) Copy the screenshot of your assembly program and put it here.

$$\text{Time delay } (\mu s) = \left[\left(\frac{(255 - A + 1) \times P}{3} \right) \times 3 \right] + 2 + 14 \times 0.0625, \\ = 99 \rightarrow 0x63$$

The screenshot shows the Microchip Studio interface with the assembly code for `main.asm`. The code includes instructions for setting port D pins 5 and 6 high, then low, followed by a loop that toggles port D pin 5, calls a `DELAY` function, and then loops back. It also includes a `HERE2` label, a `CALL DELAY` instruction, and a `KMP LOOP` label. The assembly code ends with a `MAIN` section that initializes port D pin 0 to high, then loops back to the start of the main code.

```
    ORG $0
    OUT R16, High(Sound)
    OUT SPW, R16
    LDZ R16, Low(Sound)
    OUT SPW, R16
    SIE Sound, 5

LOOP:
    CBI PORTD, 5
    LDZ R16, R4D2
    HERE1:
    CALL DELAY
    DEC R16
    BRNE HERE1
    SBI PORTD, 5
    LDZ R16, R4D2

HERE2:
    CALL DELAY
    DEC R16
    BRNE HERE2
    KMP LOOP

DELAY:
    OUT R29,R4D3
    OUT TCON, R29
    LDZ R29, R4D0
    OUT TCON, R29
    LDZ R29,R4D5
    OUT TCON, R29
    LDZ R29, R4D0

MAIN:
    SMC, TCON, 0
    BTFSP R4D0, 0
    LDZ R29,R4D0
    OUT TCON, R29
    LDZ R29, R4D1
    OUT TCON, R29
    LDZ R29, R4D2
    RET
```

- 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.

$$\frac{1.35\text{sec}}{7000\mu\text{s}} \rightarrow \frac{1300000}{7000} = B9$$

Time delay (μs) = $\left[\left(\left(\frac{(R16 - A + 1) \times P}{3} \right) \times 3 \right) + 2 + 16 \right] \times 0.0625$

$= 124 \rightarrow 1C$

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,
- the value stored in the register **OCR0A** is **0xE9**,
- pre-scaling number = **1024**, $\rightarrow 0x05$
- 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	<u>0x7C</u>
OCR0A	<u>0xE9</u>
TCCR0A	<u>0x02</u> \rightarrow mode
TCCR0B	<u>0x05</u> \rightarrow prescal

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

R16	<u>0xB9</u>
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- c) Copy the screenshot of your assembly program and put it here.

```
mainchain:
    SBI$ T1FB0, 0
    R3P0 AGA1n
    LD$ R28, R9D0
    OUT$ TCCR0B, R28
    LD$ R20, 0x01
    OUT$ TIFR0, R28
    RET$V

    .DATA
    LD$ R16, High(RAMEND)
    OUT$ SPL, R16
    LD$ R16, Low(RAMEND)
    OUT$ SPL, R16
    SBT DDRD, 5

    .CODE
    CBT PORTD, 5
    LD$ R16, 0xb9

    .LOOP:
    CALL DELAY
    DCF R16
    BRNE HERE1

    SBT Portd, 5
    LD$ R16, 0xb9

    .HERE2:
    CALL DELAY
    DCF R16
    BRNE HERE2
    RMPH LOOP

    .DELAY:
    LD$ R29, 0x00
    LD$ R28, 0x00
    LD$ R29, 0x79
    OUT$ OCRA1, R29
    OUT$ OCRA1, R29
    OUT$ OCRA1, R29
    OUT$ OCRA1, R29
    LD$ R29, 0x00
    OUT$ OCRA1, R29

    .AGU:
    SBI$ T1FB0, 1
    R3P0 AGA1n
    LD$ R28, R9D0
    OUT$ TCCR0B, R28
    LD$ R20, 0x01
    OUT$ TIFR0, R28
    RET$V
```

- 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.

For more information about the study, please contact Dr. John Smith at (555) 123-4567 or via email at john.smith@researchinstitute.org.