

### 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,  $010 \rightarrow 0x02$   $\nearrow 64_{10}$
- initial value of TCNT0 is  $0x40$ ,
- pre-scaling number = 256,  $\rightarrow 100 \rightarrow 0x04$
- 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).

$$\begin{aligned} \#loops &= \frac{0.5}{2500 \times 10^{-6}} \\ &= 200 \\ &= 0xC8 \end{aligned}$$

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

```

### General Formula for Time Delay in CTC Mode

To calculate the time delay in CTC Mode, use:

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

where:

- A = Initial TCNT0 value
- B = Max OCR0A value
- P = Pre-scaling factor (1, 8, 64, 256, or 1024)
- $\lceil \rceil$  = Ceiling function

$$\begin{aligned} 2500 &= \left[ \left( \left\lceil \frac{(B - 64 + 1) \times 256}{3} \right\rceil \times 3 \right) + 2 + 16 \right] \times 0.0625 \\ B &\approx 219.17 \\ &= 219 \\ &= 0xDB \end{aligned}$$

```

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.

[https://drive.google.com/drive/folders/1ArMlIRSdYMutnvNb38b\\_iAMAcT8tyJkD?usp=share\\_link](https://drive.google.com/drive/folders/1ArMlIRSdYMutnvNb38b_iAMAcT8tyJkD?usp=share_link)