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CPE301 – SPRING 2018

Design Assignment 02

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 AND CONNECTION BLOCK DIAGRAM w/ PINS		
2.	INITIAL CODE OF TASK 1/A		
3.	INCREMENTAL / DIFFERENTIAL CODE OF TASK 2/B		
3.	INCREMENTAL / DIFFERENTIAL CODE OF TASK 3/C		
3.	INCREMENTAL / DIFFERENTIAL CODE OF TASK 4/D		
3.	INCREMENTAL / DIFFERENTIAL CODE OF TASK 5/E		
4.	SCHEMATICS		
5.	SCREENSHOTS OF EACH TASK OUTPUT		
5.	SCREENSHOT OF EACH DEMO		
6.	VIDEO LINKS OF EACH DEMO		
7.	GOOGLECODE LINK OF THE DA		

Task 1/A: Design a delay subroutine to generate a waveform on PORTB.2 with 50% DC and 0.5 sec period. (I was told that just having the LED light turn on/off every 0.25s would suffice.)

a) C code

```c
/*
    1) toggle LED light on
    2) delay 0.25s
    3) toggle LED light off
    4) delay 0.25s
    5) repeat
*/

#define F_CPU 8000000UL
#include <avr/io.h>
#include <util/delay.h>

#define LEDPORT PORTB
#define LED_PIN PORTB2
#define LED_DDR DDRB

int main(void)
{
    LED_DDR |= (1 << LED_PIN);  // Set LED to output
    LEDPORT &= ~(1 << LED_PIN); // Initial state of OFF

    while (1)   // Loops forever
    {
        LEDPORT |= (1 << LED_PIN);  // turn LED on
        _delay_ms(250); // 0.25 sec delay
        LEDPORT &= ~(1 << LED_PIN); // turn LED off
        _delay_ms(250); // 0.25 sec delay
    }
}
```

b) Assembly code

```
.org 0

    LDI R16, 4 ;needed to toggle LED
    SBI DDRB, 2 ;PB2 as output
    LDI R17,0  ;needed to toggle led

    ;OUT PORTB,R17
    LDI R20,5 ;to set prescaler
    STS TCCR1B,R20 ;Prescaler: 1024

begin:
    RCALL delay ;calling timer to wait for 0.25 sec
    EOR R17,R16 ;XOR to toogle led
    OUT PORTB,R17 ;display LED
    RJMP begin ;repeating i.e, while(1)
delay:
    LDS R29, TCNT1H ;loading upper bit of counter to R29
    LDS R28, TCNT1L ;loading lower bit of counter to R28
    CPI R28, 0xA1 ;comparing if lower is 0xA1
    BRSH body
    RJMP delay
body:
    CPI R29,0x07 ;comparing if higher is 0x07
    BRSH done ;if equal, branch to "done"
    RJMP delay ;if not, loop back
done:
    LDI R20,0x00
    STS TCNT1H,R20 ;resetting the counter to 0 for next round
    LDI R20,0x00
    STS TCNT1L,R20 ;resetting the counter to 0 for next round
    RET
```

c) Timing Proof
In /da02_screenshots/TimingProof folder, under the names:
Assembly code: *ASM_T1.PNG*
C code: *C_T1.PNG*

Task 2/B: Connect a switch to PORTD.2 (active high - turn on the pull up transistor) to poll for an event to turn on the led at PORTB.2 for 1 sec after the event. (There were no further instructions of what to do after, so I made the LED light toggle on/off 1 second after pressing the button.)

a) C code

```
/*
    1) push button is initially off
    2) push button
    3) toggle LED light
*/

#define F_CPU 8000000UL
#include <avr/io.h>
#include <util/delay.h>

#define LEDPORT PORTB
#define LED_PIN PORTB2
#define LED_DDR DDRB

#define BUTTONPORT PORTD
#define BUTTONDDR DDRD
#define BUTTON_PIN PORTD2
#define BUTTONPIN PIND

short checkButton(); // prototype

int main(void)
{
    LED_DDR |= (1 << LED_PIN);  // Set LED to output
    LEDPORT &= ~(1 << LED_PIN); // Initial state of OFF

    BUTTONPORT |= (1 << BUTTON_PIN);    // pull-up

    while (1)   // Loops forever
    {
        short pressed = checkButton(); // branch to
        if(pressed) // if button is pressed,
        {
            _delay_ms(900); // 0.9 sec delay
            // (0.9 sec + 0.1 sec makes 1 sec delay)
            LEDPORT ^= (1 << LED_PIN);  // turn LED on
        }
    }
}

short checkButton()
{
    short count = 0; // counter

    while(!(BUTTONPIN & (1 << BUTTON_PIN)) && // check if button is stayed
            count < 20)
    {
        // counter to make sure button is being pressed for 0.1 sec
        count++;
        _delay_ms(5);
    }

    return (count == 20);
    // return true if button has been held for 0.1 sec
}
```

b) Assembly code

```
.INCLUDE "M328pDEF.INC"

.org 0

    LDI R16, 4 ;needed to toggle LED
    SBI DDRB, 2 ;PB2 as output
    CBI DDRD, 2 ;PD2 as input
    LDI R17, 0  ;needed to toggle led

    ;OUT PORTB,R17
    LDI R20,5 ;to set prescaler
    OUT TCCR0B,R20 ;Prescaler: 1024

button:
    SBIS PIND, 2 ;prompts for button
    JMP begin ;jumps to LED toggle function
    RJMP button ;loop back to prompt for button

begin:
    RCALL delay ;calling timer to wait for 1 sec
    EOR R17,R16 ;XOR to toogle led
    OUT PORTB,R17 ;display LED
    RJMP button ;jump to prompt for button again
delay:
    IN R28, TCNT0 ;loading lower bit of counter to R28
    CPI R28, 0xFF ;check for overflow
    BREQ HIGHINC ;jump to increment overflow count

cont:
    CPI R28, 0xA0 ;comparing if timer is 0xA0
    BREQ body ;if equal, check for OVF_count
    RJMP delay ;if not, loop back

HIGHINC:
    INC R21 ;increment overflow count
    LDI R20, 0
    OUT TCNT0, R20 ;reset TCNT
    RJMP cont ;loop back to check timer bits

body:
    CPI R21,0x1E ;comparing if OVF_count is 0x1E
    BRSH done ;if equal, branch to "done"
    RJMP delay ;if not, loop back
done:
    LDI R21, 0 ;reset overflow count
    LDI R20, 0
    OUT TCNT0,R20 ;resetting the counter to 0 for next round
    RET
```

c) Timing Proof

In /da02_screenshots/TimingProof folder, under the names:

Assembly code: *ASM_T2.PNG*

C code: *C_T2.PNG*

Task 3/C: Implement Task 1 using Timer 0. Count OVF occurrence if needed. Do not use interrupts.

a) C code

```c
/*
    1) USE TIMER0 (TCNT0) TO CHECK FOR OVF
    2) ONCE OVF == 1, TOGGLE LED LIGHT
    3) RESTART TIMER0
    4) REPEAT
*/
#include <avr/io.h>

#define LEDPORT PORTB
#define LED_PIN PORTB2
#define LED_DDR DDRB

int main(void)
{
    volatile int count = 0; // initialize overflow count
    LED_DDR |= (1 << LED_PIN);  // Set LED to output
    LEDPORT &= ~(1 << LED_PIN); // Initial state of OFF

    TCCR0A = 0; // normal mode
    TCCR0B = (1 << CS02) | (1 << CS00); // Clock divided by 1024

    while (1)   // Loops forever
    {
        if(TCNT0 >= 255)
        {
            // using this check and the two for loops inside
            //with cause the LED to toggle for 0.25 sec
            if(count == 6)
            {
                for(volatile unsigned int i=0; i<38; i++)
                for(volatile unsigned int j=0; j<255; j++);
                LEDPORT ^= (1 << LED_PIN); //toggle LED light
                count = 0; //reset count to continuously toggle LED
            }
            else
                count++; // overflow occurred
        TCNT0 = 0; // reset timer
        }
    }
}
```

b) Assembly code

```
.org 0

    LDI R16, 4 ;needed to toggle LED
    LDI R21, 0 ;OVF count
    SBI DDRB, 2 ;PB2 as output
    LDI R17,0  ;needed to toggle led

    OUT PORTB,R17
    LDI R20,5 ;to set prescaler
    OUT TCCR0B,R20 ;Prescaler: 1024

begin:
    RCALL delay ;calling timer to wait for 0.25 sec
    EOR R17,R16 ;XOR to toogle led
    OUT PORTB,R17 ;display LED
    RJMP begin ;repeating i.e, while(1)
delay:
    IN R28, TCNT0 ;loading lower bit of counter to R28
    CPI R28, 0xFF ;check for overflow
    BREQ HIGHINC ;jump to increment overflow count
```

(assembly code cont.)

```
cont:
    CPI R28, 0xA0 ;comparing if timer is 0xA0
    BREQ body ;if equal, check for OVF_count
    RJMP delay ;if not, loop back

HIGHINC:
    INC R21 ;increment overflow count
    LDI R20, 0
    OUT TCNT0, R20 ;reset TCNT
    RJMP cont ;loop back to check timer bits

body:
    CPI R21,0x07 ;comparing if higher is 0x07
    BRSH done ;if equal, branch to "done"
    RJMP delay ;if not, loop back
done:
    LDI R21, 0 ;reset overflow count
    LDI R20, 0
    OUT TCNT0,R20 ;resetting the counter to 0 for next round
    RET
```

c) Timing Proof
In /da02_screenshots/TimingProof folder, under the names:
Assembly code: *ASM_T3.PNG*
C code: *C_T3.PNG*

Task 4/D: Implement Task 1 using TIMER0_OVF_vect interrupt mechanism.

a) C code

```
/*
    1) HAVE A 0.5 PERIOD, TOGGLE LED EVERY 0.25s
    2) ONCE OVF == 1, TURN LED ON FOR 1 SEC
    3) AFTER 1 SEC, CONTINUE 0.5 PERIOD LIKE NORMAL
*/
#include <avr/io.h>
#include <avr/interrupt.h>

#define LEDPORT PORTB
#define LED_PIN PORTB2
#define LED_DDR DDRB

volatile int count;

int main(void)
{
    volatile int count = 0;
    LED_DDR |= (1 << LED_PIN);  // Set LED to output

    TCCR0A = 0;
    TCCR0B |= (1 << CS02) | (1 << CS00);    // clock divided by 1024

    TCNT0 = 0;
    TIMSK0 |= (1 << TOIE0); // enable interrupt on overflow

    sei(); // turn on interrupts

    while (1);
}
```

(c code cont.)

```
// called after overflow of timer.
// toggle LED on/off
ISR(TIMER0_OVF_vect)
{
    if(count == 6){
        for(volatile unsigned int i=0; i<36; i++)
            for(volatile unsigned int j=0; j<255; j++);
                LEDPORT ^= (1 << LED_PIN);  //turn LED on
    count = 0;
    }
    else
        count++;
}
```

b) Assembly code

```
.org 0
    jmp  main
.org 0x20
    jmp  TIM0_OVF ;Timer0 overflow interrupt vector

main:
    LDI R16, 4 ;needed to toggle LED
    LDI R21, 0 ;OVF count
    SBI DDRB, 2 ;PB2 as output
    LDI R17,0  ;needed to toggle led

    ;OUT PORTB,R17
    LDI R20,5 ;to set prescaler
    OUT TCCR0B,R20 ;Prescaler: 1024

    LDI R20, 0x01 ;can also use (1<<TOIE0)
    STS TIMSK0,R20 ;enable overflow interrupt
    SEI ;enable global interrupts
Loop:
    RJMP Loop ;infinite loop

TIM0_OVF:

delay:
    IN R28, TCNT0 ;loading timer0 to R28
    CPI R28, 0xFF ;check for overflow
    BREQ HIGHINC ;jump to increment overflow count

cont:
    CPI R28, 0xB6 ;comparing if timer is 0xB6
    BREQ body ;if equal, check for OVF_count
    RJMP delay ;if not, loop back

HIGHINC:
    INC R21 ;increment overflow count
    LDI R20, 0
    OUT TCNT0, R20 ;reset TCNT
    RJMP cont ;loop back to check timer bits

body:
    CPI R21,0x06 ;comparing if OVF_count is 0x06
    BRSH done ;if equal, branch to "done"
    RJMP delay ;if not, loop back
done:
    EOR R17,R16 ;XOR to toogle led
    OUT PORTB,R17 ;display LED
    LDI R21, 0 ;reset overflow count
    LDI R20, 0
    OUT TCNT0,R20 ;resetting the counter to 0 for next round
    LDI R20, 5 ;Timer0: enabled, prescaler = 1024
    OUT TCCR0B, R20 ; prescaler = 1024
    RETI ;return from interrupt, interrupts enabled
```

c) Timing Proof
In /da02_screenshots/TimingProof folder, under the names:
Assembly code: *ASM_T4.PNG*
C code: *C_T4.PNG*

Task 5/E: Implement Task 2 using INT0 interrupt mechanism.

a) C code

```c
#define F_CPU 8000000UL
#include <avr/io.h>
#include <avr/interrupt.h>
#include <util/delay.h>

#define LEDPORT PORTB
#define LED_PIN PORTB2
#define LED_DDR DDRB

#define BUTTONPORT PORTD
#define BUTTONDDR DDRD
#define BUTTON_PIN PORTD2
#define BUTTONPIN PD2

ISR(INT0_vect)
{
    unsigned char temp; // Saves current state of LED light
    EIFR |= (1 <<INTF0); // clear flag
    temp = LEDPORT; // Save the LED light state
    LEDPORT |= (1 << LED_PIN);  // Turn LED on
    _delay_ms(1000);    // Keep LED on for 1 sec
    LEDPORT = temp; // Restore state
}

int main(void)
{
    LED_DDR |= (1 << LED_PIN);  // Set LED to output
    LEDPORT &= ~(1 << LED_PIN); // Initial state of OFF

    BUTTONPORT = (1 << BUTTONPIN);  // pull-up
    BUTTONDDR = (1 << BUTTONPIN);   // set PD2 as input (using for interrupt INT0)

    EIMSK = (1 << INT0);                    // Enable INT0
    EICRA = (1 << ISC01) | (1 << ISC00);    // Trigger INT0 on rising edge

    sei(); // enables interrupt

    while (1)   // Loops forever
    {
        LEDPORT |= (1 << LED_PIN);  // turn LED on
        _delay_ms(250); // 0.25 sec delay
        LEDPORT &= ~(1 << LED_PIN); // turn LED off
        _delay_ms(250); // 0.25 sec delay
    }
}
```

b) Assembly code

```
.INCLUDE "M328pDEF.INC"

.org 0
    jmp main
.org 0x02
    jmp INT0_v ;external interrupt vector

main:
    LDI R16, 4 ;needed to toggle LED
    SBI DDRB, 2 ;PB2 as output
    CBI DDRD, 2 ;PD2 as input
    LDI R17, 0  ;needed to toggle led

    LDI R20,5 ;to set prescaler
    OUT TCCR0B,R20 ;Prescaler: 1024

    LDI R20, (1 << INT0)
    OUT EIMSK, R20 ;set bits for EIMSK
    LDI R20, (1 << ISC11) | (1 << ISC01)
    STS EICRA, R20 ;set bits for EICRA
    SEI

button:
    SBI PIND, 2 ;prompts for button
    RJMP begin ;toggle LED if != button

begin:
    RCALL delay ;delay function
    EOR R17,R16 ;XOR to toogle led
    OUT PORTB,R17 ;display LED
    RJMP button ;jump to prompt for button again
delay:
    IN R28, TCNT0 ;loading lower bit of counter to R28
    CPI R28, 0xFF ;comparing if lower is 0x41
    BREQ HIGHINC

cont:
    CPI R28, 0xA0 ;comparing if timer is 0xA0
    BREQ body ;if equal, check for OVF_count
    RJMP delay ;if not, loop back

HIGHINC:
    INC R21 ;increment overflow count
    LDI R20, 0
    OUT TCNT0, R20 ;reset TCNT
    RJMP cont ;loop back to check timer bits

body:
    CPI R21,0x07 ;comparing if higher is 0x07
    BRSH done ;if equal, branch to "done"
    RJMP delay ;if not, loop back
done:
    LDI R21, 0 ;reset overflow count
    LDI R20, 0
    OUT TCNT0,R20 ;resetting the counter to 0 for next round
    RET

INT0_v:
begin2:
    LDI R22, (1 << INTF0)
    OUT EIFR, R22 ;clear flag
    SBI PORTB, 2 ;turn LED light on
    RCALL delay2 ;delay function
    LDI R22, 5 ;Timer0: enabled, prescaler = 1024
    OUT TCCR0B, R22 ; prescaler = 1024
    RETI ;return from interrupt, interrupts enabled
delay2:
    IN R28, TCNT0 ;loading timer0 to R28
    CPI R28, 0xFF ;check for overflow
    BREQ HIGHINC2 ;jump to increment overflow count

cont2:
    CPI R28, 0x84 ;comparing if timer is 0x84
    BREQ body2 ;if equal, check for OVF_count
    RJMP delay2 ;if not, loop back

HIGHINC2:
    INC R23 ;increment overflow count
    LDI R22, 0
    OUT TCNT0, R22 ;reset TCNT
    RJMP cont2 ;loop back to check timer bits

body2:
    CPI R23,0x1E ;comparing if OVF_count is 0x1E
    BRSH done2 ;if equal, branch to "done2"
    RJMP delay2 ;if not, loop back
done2:
    LDI R23, 0 ;reset overflow count
    LDI R22, 0
    OUT TCNT0,R22 ;resetting the counter to 0 for next round
    RET
```

c) Timing Proof

In /da02_screenshots/TimingProof folder, under the names:
Assembly code: *ASM_T5a.PNG* and *ASM_T5b.PNG*
C code: *C_T5.PNG*

Calculations:

For the purpose of obtaining the correct values for the delays, I used the TCNT formula to get the proper numbers for each task.

a) TCNT formula

$$TCNT = \left(\frac{clock\_speed}{prescaler\_value} * desired\_time\_in\_seconds\right) - 1$$

b) Plugging in values:
1st formula: 8000000 represents clock speed (in Hz), 1024 represents prescaler value, desired time is 0.25 seconds; the output value is 1952

2nd formula: 8000000 represents clock speed (in Hz), 1024 represents prescaler value, desired time is 1 second; the output value is 7812

$$\left(\frac{8000000}{1024} \cdot 0.25\right) - 1 = 1952.125$$

$$\left(\frac{8000000}{1024} \cdot 1\right) - 1 = 7811.5$$

c) converting 1952 to hex

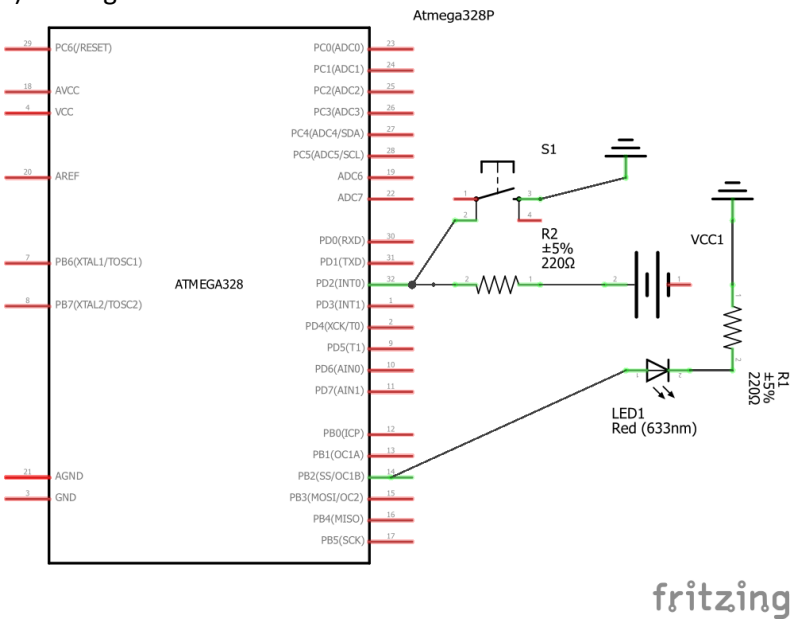
Enter decimal number:
1952 10
Convert Reset Swap
Hex number:
7A0 16
Hex signed 2's complement:
07A0 16
Binary number:
11110100000 2

d) converting 7812 to hex

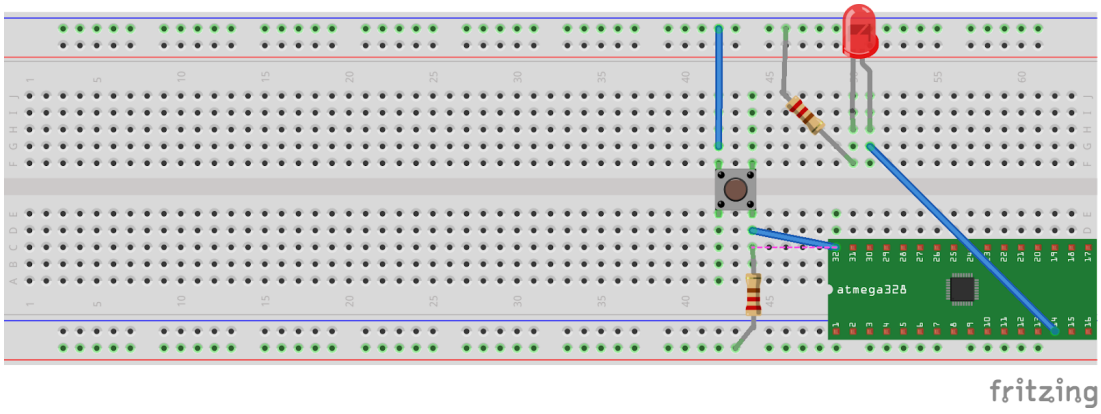
Enter decimal number:
7812 10
Convert Reset Swap
Hex number:
1E84 16
Hex signed 2's complement:
1E84 16
Binary number:
1111010000100 2

Schematics:
This schematic is the basic setup for this assignment. PORTB2 was used in all 5 tasks (website used to build this schematic did not let me connect the resistor and ATmega to the led, so the connection in the picture below was the best I could do). PORTD2 was used in task 2 and 5. The ATmega328p was connected to the ISR cable to my laptop and a VCC and GND source, which connected to the power supply (delivering a fixed 5V to microcontroller).

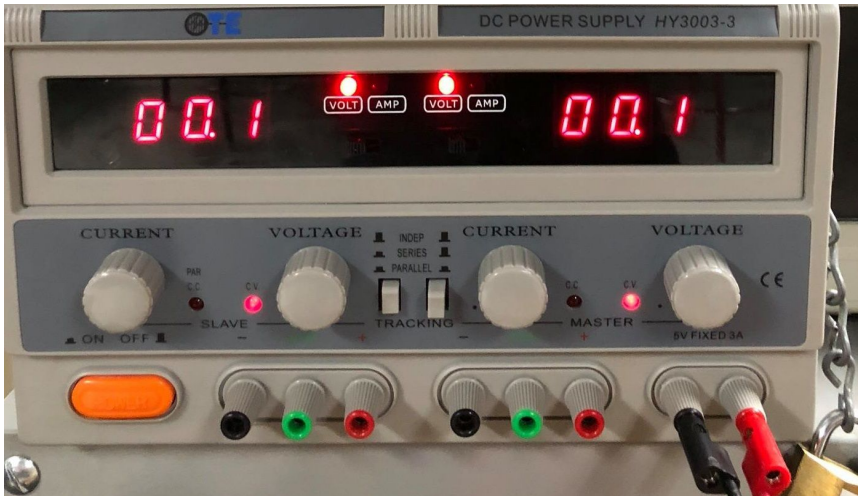
a) Fritzing schematics



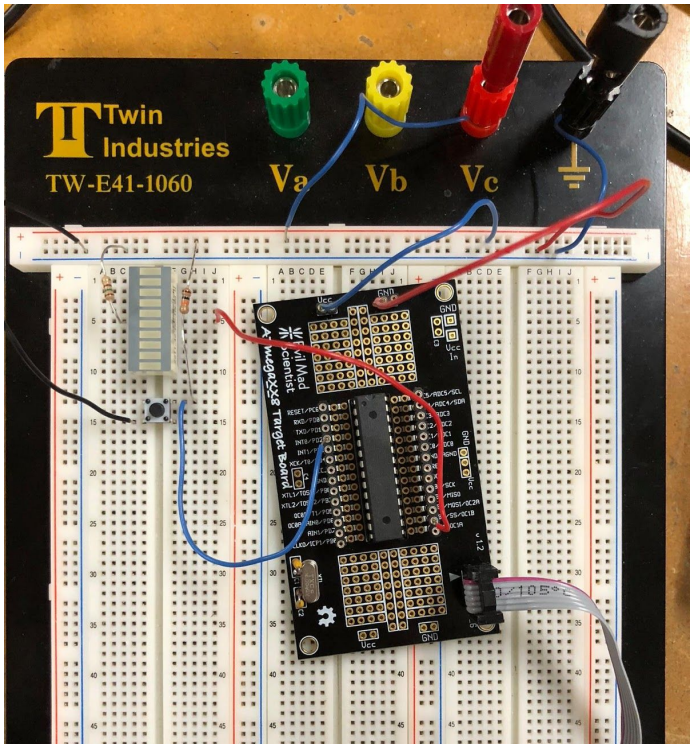
b) Fritzing breadboard



Physical Set-Up:
b) the power supply (using fixed 5V)



a) the breadboard set-up



Other notes:
da02_screenshots in the repository contains the photos of the timing proof, schematics, physical setup, and screenshots of all of my code for this assignment.
Brief explanations of the timing proof are in **TP_README.txt** in the same folder.
Outputs of each demo are shown in the Youtube videos. (It's difficult to prove with screenshots)

GITHUB LINK: https://github.com/JeffinVegas/EmbSys.git
YOUTUBE LINK: In the videos_DA02.txt file

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

"*This assignment submission is my own, original work*".
Jeffrey Razon