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CPE301 – SPRING 2018

Design Assignment 4

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)**
0.	COMPONENTS LIST AND CONNECTION BLOCK DIAGRAM w/ PINS		
1.	INITIAL CODE OF TASK 1/A		
2.	INCREMENTAL / DIFFERENTIAL CODE OF TASK 2/B		
3.	INCREMENTAL / DIFFERENTIAL CODE OF TASK 3/C		
4.	INCREMENTAL / DIFFERENTIAL CODE OF TASK 4/D		
5.	INCREMENTAL / DIFFERENTIAL CODE OF TASK 5/E		
6.	SCHEMATICS		
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0.	COMPONENTS LIST AND CONNECTION BLOCK DIAGRAM w/ PINS		

- Atmega328P
- DC motor
- Servo motor
- Stepper motor
- ULN2003
- PC
- 5V power supply

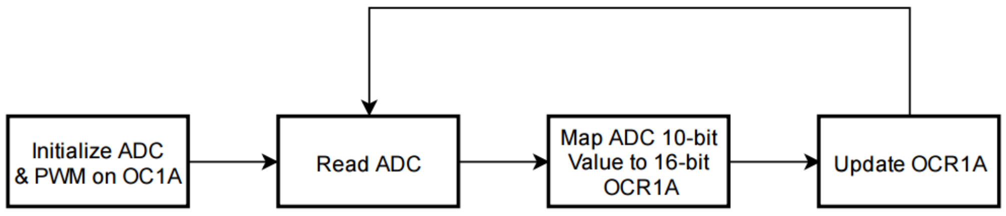
See schematics for block diagrams

1.	INITIAL CODE OF TASK 1		

Write an AVR C program to control the speed of the DC Motor using a potentiometer connected to any of the analog-in port.

The speed of a DC motor can be modulated by mapping the value of a potentiometer output voltage to a PWM output to the DC motor.

Flow chart of Task 1


Initialize ADC & PWM on OC1A
Read ADC
Map ADC 10-bit Value to 16-bit OCR1A
Update OCR1A

Code

```
#define F_CPU 8000000UL // XTAL = 8MHZ

#include <stdio.h>
#include <avr/io.h>
#include <util/delay.h>

#define BAUDRATE        9600    // Define baudrate
#define ASYNCH_NORM_PRESCALER (F_CPU/16/BAUDRATE - 1) // Calculate prescaler for USART0

void ADC0init();                        // Initialize ADC0 input
void PWM_OC1A_init();                   // Initialize PWM on OC1A at 50Hz
unsigned short readADC();               // read ADC0 analog input and return it
void updateDC_OC1A(unsigned char);      // Change duty cycle on OC1A
int USART0_sendChar(char, FILE*);       // Send character on USART0
void usart0_init (void);                // Initialize USART0

// reset stream pointer
// http://www.gnu.org/savannah-checkouts/non-gnu/avr-libc/user-manual/group__avr__stdio.html
FILE USART0_stream = FDEV_SETUP_STREAM(USART0_sendChar, NULL, _FDEV_SETUP_WRITE);
```

```c
int main()
{
	unsigned short adcVal; // Variable to store input ADC Value
	unsigned char  dc;     // Store calculated DC value based on adcVal

	stdout = &USART0_stream;// change standard output to point to a USART stream

	PWM_OC1A_init();       // initialize pwm  on OC1A
	ADC0init();            // Initialize ADC0 input
	usart0_init();         // Initialize USART0 for debugging and monitoring

	while (1)
	{
		adcVal = readADC();    // read ADC0;
		dc = (unsigned short)(100.0*adcVal / 1023); // get percentage of input voltage from
Vcc.
		updateDC_OC1A(dc);     // Update OCR1A to update duty cycle of OC1A
		printf("ADC Value = %u\n", adcVal);            // Monitoring output
		printf("\tDuty cycle = %u%%\n", dc);   // Monitoring output
		_delay_ms(100);        // Have an imperceivable delay
	}
}

void usart0_init (void)
/*
 * Procedure to initialize USART0 asynchronous with enabled RX/TX, 8 bit data,
 * no parity, and 1 stop bit.
*/
{
	UCSR0B = (1<<TXEN0)  | (1<<RXEN0);     // enable transmit/receive
	UCSR0C = (1<<UCSZ01) | (1<<UCSZ00);    // asynchronous, 8N1
	UBRR0L = ASYNCH_NORM_PRESCALER;        // Set prescaler based on desired baudrate
}

int USART0_sendChar(char data, FILE *stream)
/*
 * Procedure to send a single character over USART0. If character is linefeed, reset
 * line.
 * Assumes ASCII code.
 */
{
	if(data == '\n')       // If character is linefeed,
	{                      // First send return.
		while(! (UCSR0A & (1<<UDRE0)) );
		UDR0 = '\r';
	}
	while(! (UCSR0A & (1<<UDRE0)) ); // Wait for last data to be transmitted.
	UDR0 = data;    // send data.
	return 0;
}

void updateDC_OC1A(unsigned char DC)
// Procedure to update PWM duty cycle on OC1A. Given an unsigned character DC, this
// procedure will calculate the appropriate OCR1A value based on the top value of
// Timer1.
{
	OCR1A = (unsigned short)(DC * 2499.0 / 100);
}


unsigned short readADC()
// readADC will read the adcValue after it has been calculated.
{
	ADCSRA |= (1<<ADSC);                   // Begin conversion
	while((ADCSRA & (1<<ADIF)) == 0 );     // Wait for conversion to finish.
```

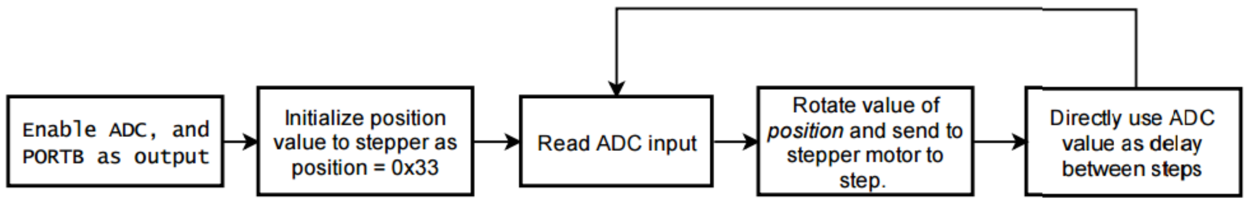
```
        return ADC;
}

void PWM_OC1A_init()
{
        //Set PORTB1 pin as output
        DDRB |= (1<<DDB1);     // make OC1A as output.
        // Output compare mode on OC1A. Fast PWM with top = ICR1.
        // Clear OC1A on Compare match and set at bottom.
        TCCR1A |=
(1<<COM1A1)|(0<<COM1A0)|(0<<COM1B1)|(0<<COM1B0)|(0<<FOC1A)|(0<<FOC1B)|(1<<WGM11)|(0<<WGM10);
        // Start timer with prescaler 64
        TCCR1B |= (0<<ICNC1)|(0<<ICES1)|(1<<WGM13)|(1<<WGM12)|(0<<CS12)|(1<<CS11)|(1<<CS10);
        ICR1 = 2499;  // F_CPU / (N * F_pwm) - 1, where N is the prescaler = 64, and F_pwm is the
desired 50Hz frequency.
}

void ADC0init()
// ADC0init will initialize analog input on ADC0, set voltage reference to Vcc, with
// data right justified on data register.
{
        DDRC    &= ~(0<<DDC0);
        ADCSRA  = 0x87;         // Make ADC enable and select ck/128
        ADMUX   = (1<<REFS0);   // VCC reference, ADC0 single ended input
                                // data will be right-justified
}
```

2.	INITIAL CODE OF TASK 2		

Write an AVR C program to control the speed of the Stepper Motor using a potentiometer connected to any of the analog-in port.

Similarly, to task 1, the value read from the potentiometer can be simply used as the delay between steps of the stepper motor.

Flow chart of task 2


Enable ADC, and PORTB as output
Initialize position value to stepper as position = 0x33
Read ADC input
Rotate value of *position* and send to stepper motor to step.
Directly use ADC value as delay between steps

Code

```
#define F_CPU 8000000UL // XTAL = 8MHZ

#include <stdio.h>
#include <avr/io.h>
#include <util/delay.h>

#define BAUDRATE        9600
#define ASYNCH_NORM_PRESCALER (F_CPU/16/BAUDRATE - 1)

void ADC0init();                    // Initialize ADC0 input
unsigned short readADC();           // read ADC0 analog input and return it
void delay_ms(unsigned int);        // shell procedure to call _delay_ms on variable input
void step_clockwise(unsigned int, unsigned int);      // step stepper motor desired number of times
with delay
unsigned char rotateLeft(unsigned char);      // rotate bits of input to the left.
int USART0_sendChar(char, FILE*);      // Write character to USART0
void usart0_init (void);               // Initialize USART0

// reset stream pointer
// http://www.gnu.org/savannah-checkouts/non-gnu/avr-libc/user-manual/group__avr__stdio.html
FILE USART0_stream = FDEV_SETUP_STREAM(USART0_sendChar, NULL, _FDEV_SETUP_WRITE);

// Current position signal of stepper motor
unsigned char positionSig = 0x33;

int main()
{
        unsigned short adcVal;
        DDRB = 0xFF; // make portB output pins.

        stdout = &USART0_stream;       // change standard output to point to a USART stream

        usart0_init();                 // Initialize USART0 for debugging and monitoring
        ADC0init();                    // Initialize ADC0 input

        while (1)
        {
                adcVal = readADC();            // read ADC0;
                step_clockwise(1, adcVal);     // Step stepper motor 1 step with an adcVal delay
                // print monitoring message
                printf("ADC Value: %u | Position signal: 0x%X\n", adcVal, positionSig);
        }
}

void usart0_init (void)
/*
 * Procedure to initialize USART0 asynchronous with enabled RX/TX, 8 bit data,
 * no parity, and 1 stop bit.
*/
{
        UCSR0B = (1<<TXEN0)  | (1<<RXEN0);     // enable transmit/receive
        UCSR0C = (1<<UCSZ01) | (1<<UCSZ00);    // asynchronous, 8N1
        UBRR0L = ASYNCH_NORM_PRESCALER;        // Set prescaler based on desired baudrate
}

int USART0_sendChar(char data, FILE *stream)
/*
 * Procedure to send a single character over USART0. If character is linefeed, reset
 * line.
 * Assumes ASCII code.
 */
{
        if(data == '\n')       // If character is linefeed,
        {                      // First send return.
                while(! (UCSR0A & (1<<UDRE0)) );
                UDR0 = '\r';
        }
        while(! (UCSR0A & (1<<UDRE0)) ); // Wait for last data to be transmitted.
        UDR0 = data;    // send data
        return 0;
}

unsigned char rotateLeft(unsigned char x)
/*
 * Given an unsigned character x, rotateLeft will do a logic rotatation of
 * the bits of x to the right.
 */
```

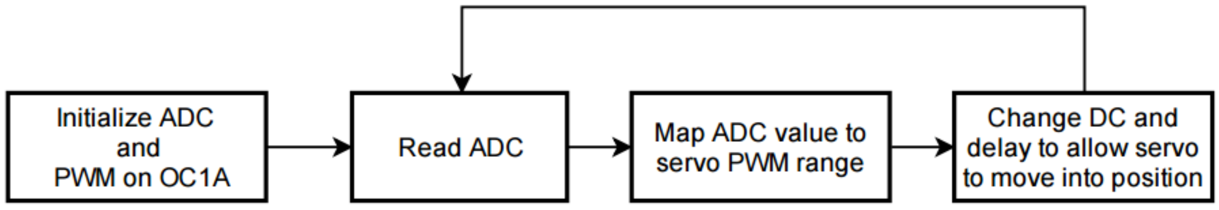
```
{
	unsigned char shiftIn = 0;
	if ((x & 0x80) == 0x80)
		shiftIn = 0x01;
	return ((x<<1) | shiftIn);
}

void step_clockwise(unsigned int steps, unsigned int delay)
/*
 * Given the unsigned integers steps, and delay, step_clockwise will send the appropriate
 * signal to PORTB[7:0] to step a stepper motor in the clockwise direction.
 * A global variable positionSig must be initialized to 0x33.
 */
{
	for (; steps > 0; steps--)     // loop steps times.
	{
		positionSig = rotateLeft(positionSig); // Rotate value of positionSig
		PORTB = positionSig;                   // send data to PORTB
		delay_ms(delay);                       // Delay a given value of milliseconds.
	}
}

unsigned short readADC()
// readADC will read the adcValue after it has been calculated.
{
	ADCSRA |= (1<<ADSC);                    // Begin conversion
	while((ADCSRA & (1<<ADIF)) == 0 );     // Wait for conversion to finish.
	return ADC;
}

void ADC0init()
// ADC0init will initialize analog input on ADC0, set voltage reference to Vcc, with
// data right justified on data register.
{
	DDRC    &= ~(0<<DDC0);
	ADCSRA  = 0x87;         // Make ADC enable and select ck/128
	ADMUX   = (1<<REFS0);   // VCC reference, ADC0 single ended input
	// data will be right-justified
}

void delay_ms(unsigned int count)
/*
 * Procedure to perform a delay based on an unsigned short
 * since the _delay_ms macro will not accept parameters
 * other than constant values.
 */
{
	int i;
	for(i = 0; i < count; i++)
		_delay_ms(1);
}
```

3.	INITIAL CODE OF TASK 3		

Write an AVR C program to control the position of the Servo Motor using a potentiometer connected to any of the analog-in port. When pot value is 0 the servo is at position 0 deg. and when pot value is max (approx. 5V) the servo is at position 180 deg.

Similarly to task 1, the 10 bit value read from the potentiometer can be mapped to the 16 bit value on OCR1A to control the duty cycle of the PWM signal fed to the servo motor. Since the servo motor's positions between 0 degrees and 180 degrees were between OCR1A values of 65 to 285, the potentiometer value was mapped to a value from 0 to 285. However, OCR1A was set to 65 if value after mapping was lower than 65.

Flow chart of task 3


Initialize ADC and PWM on OC1A
Read ADC
Map ADC value to servo PWM range
Change DC and delay to allow servo to move into position

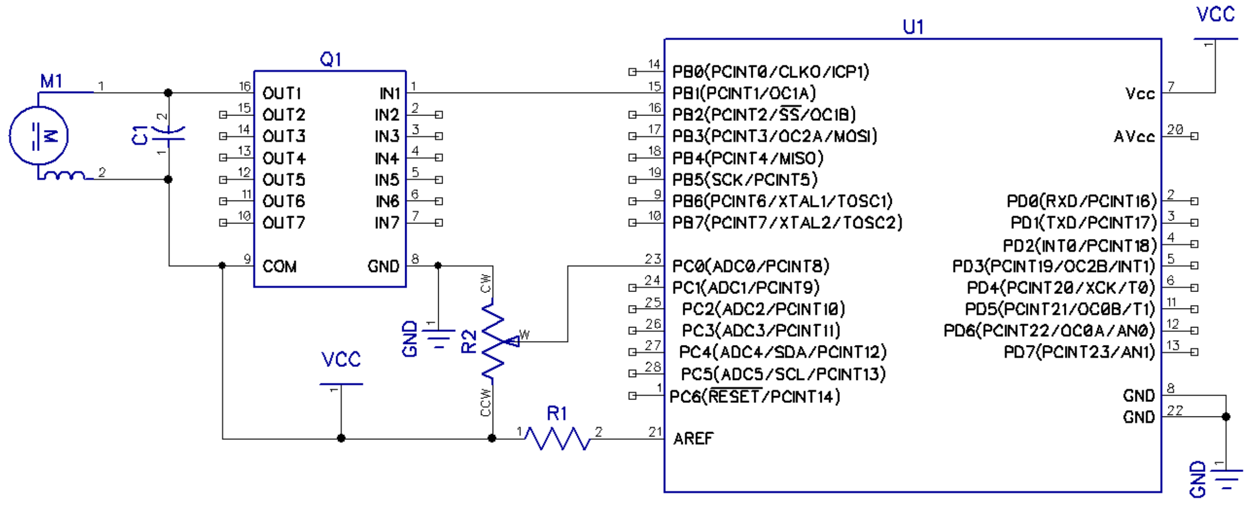
Code

```
#define F_CPU 8000000UL // XTAL = 8MHZ

#include <stdio.h>
#include <avr/io.h>
#include <util/delay.h>

#define SERVO_MIN       65
#define SERVO_MAX       285
#define BAUDRATE        9600
#define ASYNCH_NORM_PRESCALER (F_CPU/16/BAUDRATE - 1)

void ADC0init();                        // Initialize ADC0 input
unsigned short readADC();               // read ADC0 analog input and return it
void delay_ms(unsigned int);            // shell procedure to call _delay_ms on variable input
void PWM_OC1A_init();                   // Initialize PWM on OC1A at 50Hz
int USART0_sendChar(char, FILE*);       // Send character on USART0
void usart0_init (void);                // Initialize USART0

// reset stream pointer
// http://www.gnu.org/savannah-checkouts/non-gnu/avr-libc/user-manual/group__avr__stdio.html
FILE USART0_stream = FDEV_SETUP_STREAM(USART0_sendChar, NULL, _FDEV_SETUP_WRITE);

int main()
{
        unsigned short adcVal; // Variable to store input ADC Value
        unsigned short newVal; // new value calculated based on a range for servo
        DDRB = 0xFF; // make portB output pins.

        ADC0init();             // Initialize ADC0 input
        PWM_OC1A_init();        // initialize pwm  on OC1A
        usart0_init();          // Initialize USART0 for debugging and monitoring

        stdout = & USART0_stream;// change standard output to point to a USART stream

        while (1)
        {
                adcVal = readADC();             // read ADC0;
                // Map ADC value to a range from 0 to SERVO_MAX
                newVal = (unsigned short)((float)adcVal / ((1UL<<10) - 1) * SERVO_MAX);
                printf("adcVal = %u\n", adcVal);        // Print monitoring data
                printf("\tnewVal = %u\n", newVal);
                if (newVal <= SERVO_MIN)        // If newVal is less than minimum servo value (0
degrees)
                        OCR1A = SERVO_MIN;      // then set OCR1A to minimum value.
                else
                {
                        OCR1A = newVal;         // else, update OCR1A to change duty cycle.
                }
                _delay_ms(50);                  // Delay to allow servo to move
        }
}

int USART0_sendChar(char data, FILE *stream)
/*
 * Procedure to send a single character over USART0. If character is linefeed, reset
 * line.
 * Assumes ASCII code.
 */
{
        if(data == '\n')
        {
                while(! (UCSR0A & (1<<UDRE0)) );
                UDR0 = '\r';
        }
        while(! (UCSR0A & (1<<UDRE0)) );
        UDR0 = data;
        return 0;
}

void usart0_init (void)
/*
 * Procedure to initialize USART0 asynchronous with enabled RX/TX, 8 bit data,
 * no parity, and 1 stop bit.
*/
{
        UCSR0B = (1<<TXEN0)  | (1<<RXEN0);      // enable transmit/receive
        UCSR0C = (1<<UCSZ01) | (1<<UCSZ00);     // asynchronous, 8N1
        UBRR0L = ASYNCH_NORM_PRESCALER;         // To set 9600 baud rate with 8MHz clock
}

unsigned short readADC()
/*
 * Procedure to send a single character over USART0. If character is linefeed, reset
 * line.
 * Assumes ASCII code.
 */
{
        ADCSRA |= (1<<ADSC);                    // Begin conversion
        while((ADCSRA & (1<<ADIF)) == 0 );      // Wait for conversion to finish.
        return ADC;
}

void ADC0init()
// ADC0init will initialize analog input on ADC0, set voltage reference to Vcc, with
// data right justified on data register.
{
        DDRC    &= ~(0<<DDC0);
        ADCSRA  = 0x87;         // Make ADC enable and select ck/128
        ADMUX   = (1<<REFS0);   // VCC reference, ADC0 single ended input
        // data will be right-justified
}
void delay_ms(unsigned int count)
/*
 * Procedure to perform a delay based on an unsigned short
 * since the _delay_ms macro will not accept parameters
 * other than constant values.
 */
{
        int i;
        for(i = 0; i < count; i++)
```

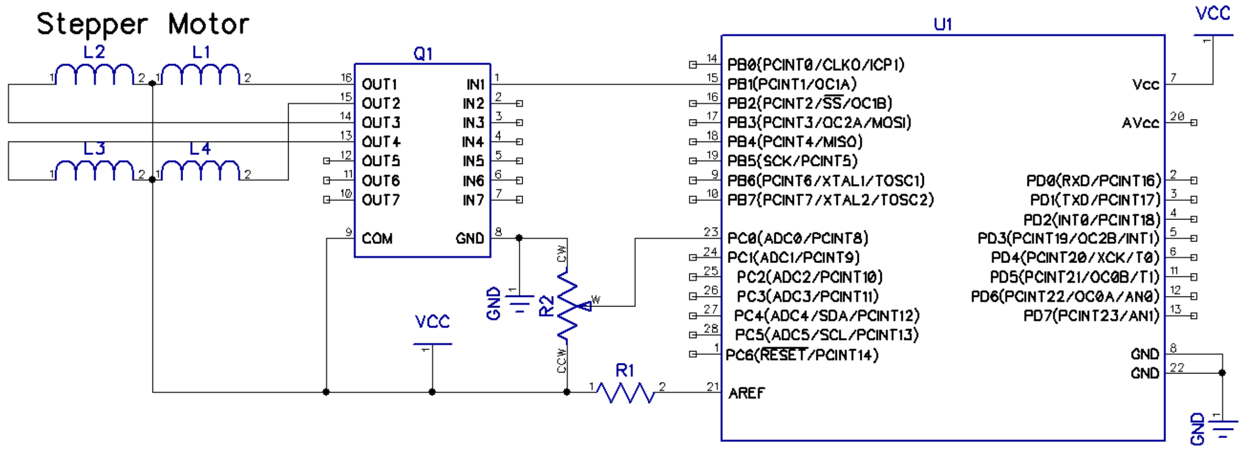
```
                _delay_ms(1);
}

void PWM_OC1A_init()
{
        //Set PORTB1 pin as output
        DDRB |= (1<<DDB1);     // make OC1A as output.
        // Output compare mode on OC1A. Fast PWM with top = ICR1.
        // Clear OC1A on Compare match and set at bottom.
        TCCR1A |=
(1<<COM1A1)|(0<<COM1A0)|(0<<COM1B1)|(0<<COM1B0)|(0<<FOC1A)|(0<<FOC1B)|(1<<WGM11)|(0<<WGM10);
        // Start timer with prescaler 64
        TCCR1B |= (0<<ICNC1)|(0<<ICES1)|(1<<WGM13)|(1<<WGM12)|(0<<CS12)|(1<<CS11)|(1<<CS10);
        ICR1 = 2499;  // F_CPU / (N * F_pwm) - 1, where N is the prescaler = 64, and F_pwm is the
desired 50Hz frequency.
}
```

6.	SCHEMATICS		

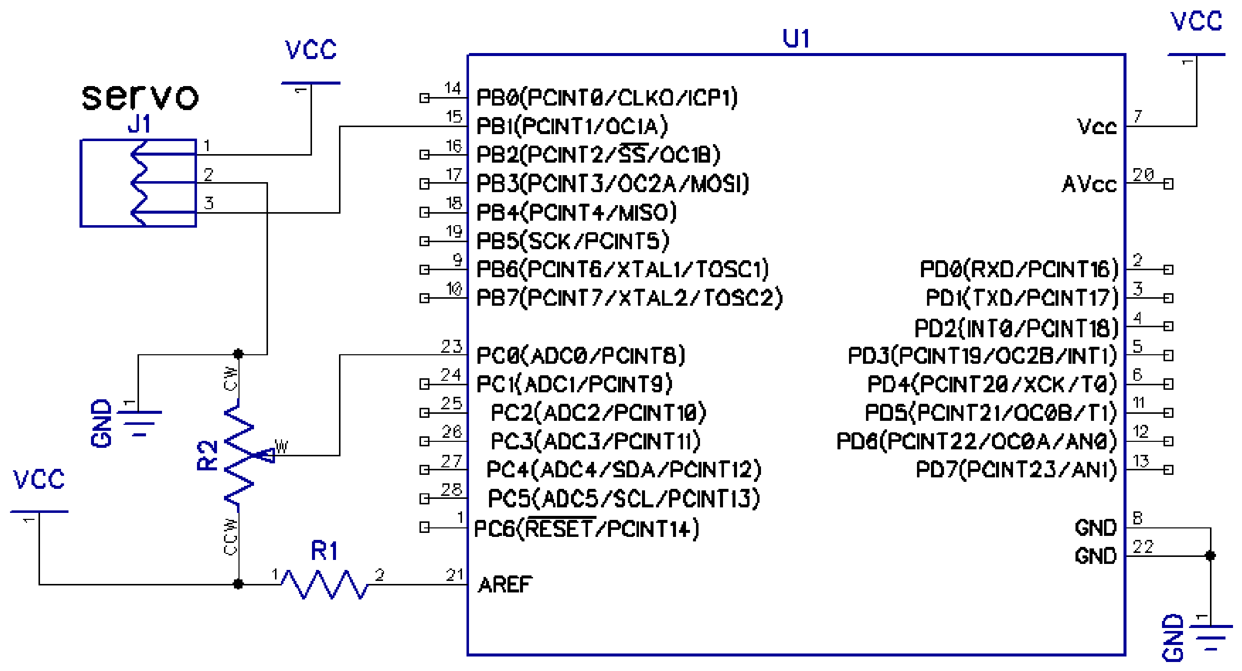
Task 1



Task 2



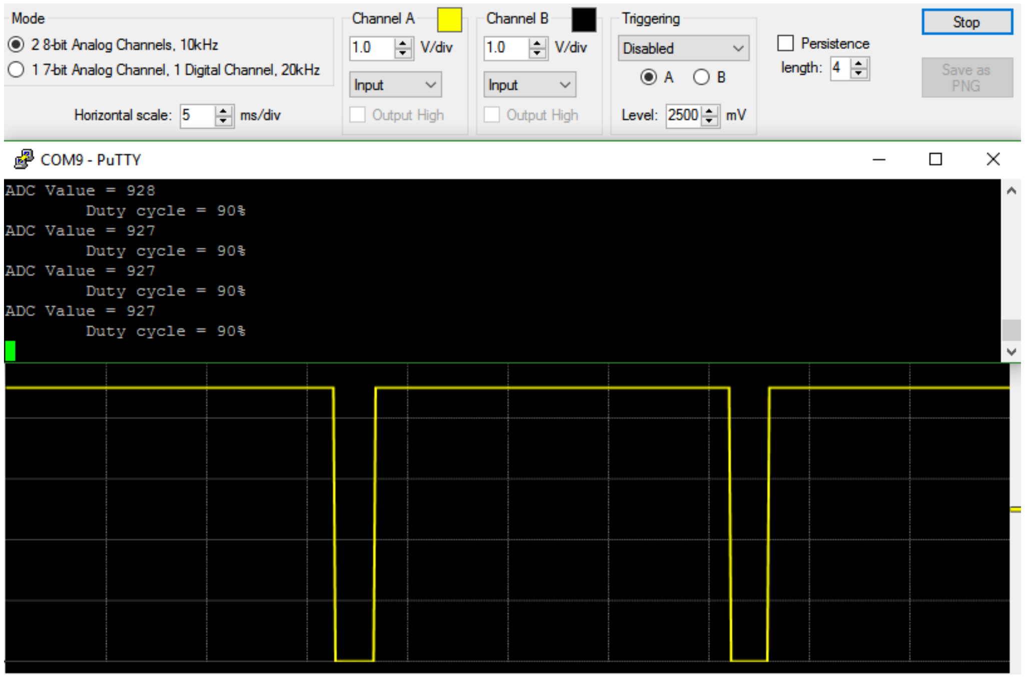
Task 3


servo
J1
VCC
U1
VCC
PB0(PCINT0/CLKO/ICP1)
PB1(PCINT1/OC1A)
PB2(PCINT2/SS/OC1B)
PB3(PCINT3/OC2A/MOSI)
PB4(PCINT4/MISO)
PB5(SCK/PCINT5)
PB6(PCINT6/XTAL1/TOSC1)
PB7(PCINT7/XTAL2/TOSC2)
PC0(ADC0/PCINT8)
PC1(ADC1/PCINT9)
PC2(ADC2/PCINT10)
PC3(ADC3/PCINT11)
PC4(ADC4/SDA/PCINT12)
PC5(ADC5/SCL/PCINT13)
PC6(RESET/PCINT14)
AREF
Vcc
AVcc
PD0(RXD/PCINT16)
PD1(TXD/PCINT17)
PD2(INT0/PCINT18)
PD3(PCINT19/OC2B/INT1)
PD4(PCINT20/XCK/T0)
PD5(PCINT21/OC0B/T1)
PD6(PCINT22/OC0A/AN0)
PD7(PCINT23/AN1)
GND
GND
GND
R2
CW
W
CCW
VCC
R1
GND

7.	SCREENSHOTS OF EACH TASK OUTPUT		

TASK 1:

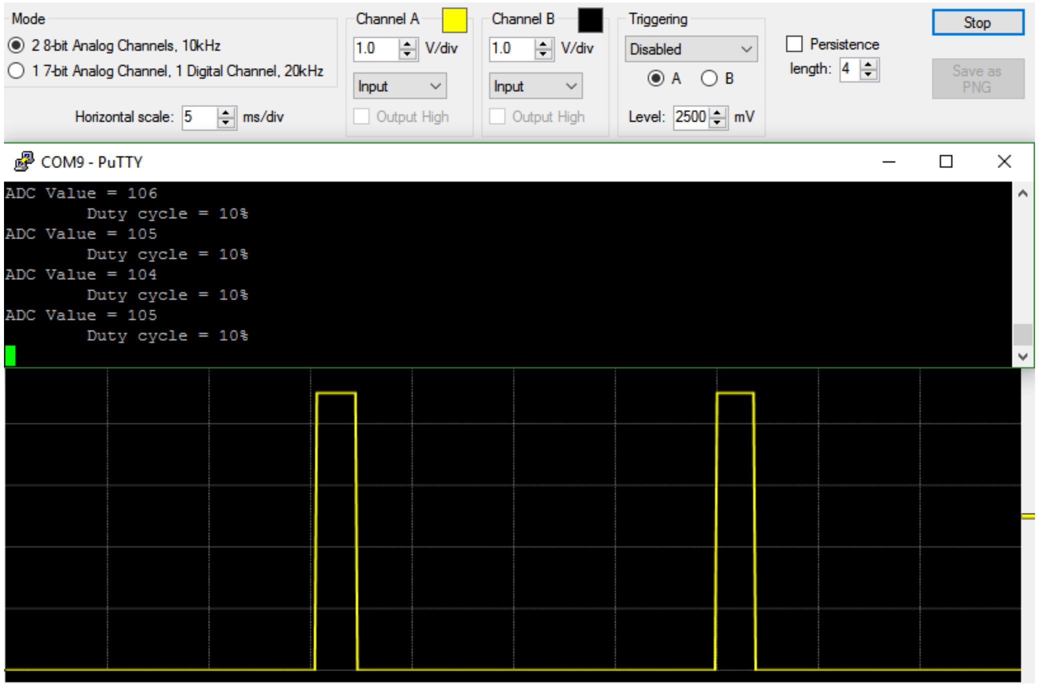
The figure below illustrates where the potentiometer was at a 90% position. Output duty cycle is displayed with the Pololu monitoring software for Pololu USB AVR Programmer.



Mode: (●) 2 8-bit Analog Channels, 10kHz ( ) 1 7-bit Analog Channel, 1 Digital Channel, 20kHz
Horizontal scale: 5 ms/div
Channel A: 1.0 V/div, Input, Output High
Channel B: 1.0 V/div, Input, Output High
Triggering: Disabled, (●) A ( ) B, Level: 2500 mV
Persistence length: 4

```
ADC Value = 928
        Duty cycle = 90%
ADC Value = 927
        Duty cycle = 90%
ADC Value = 927
        Duty cycle = 90%
ADC Value = 927
        Duty cycle = 90%
```

And then with 10% duty cycle

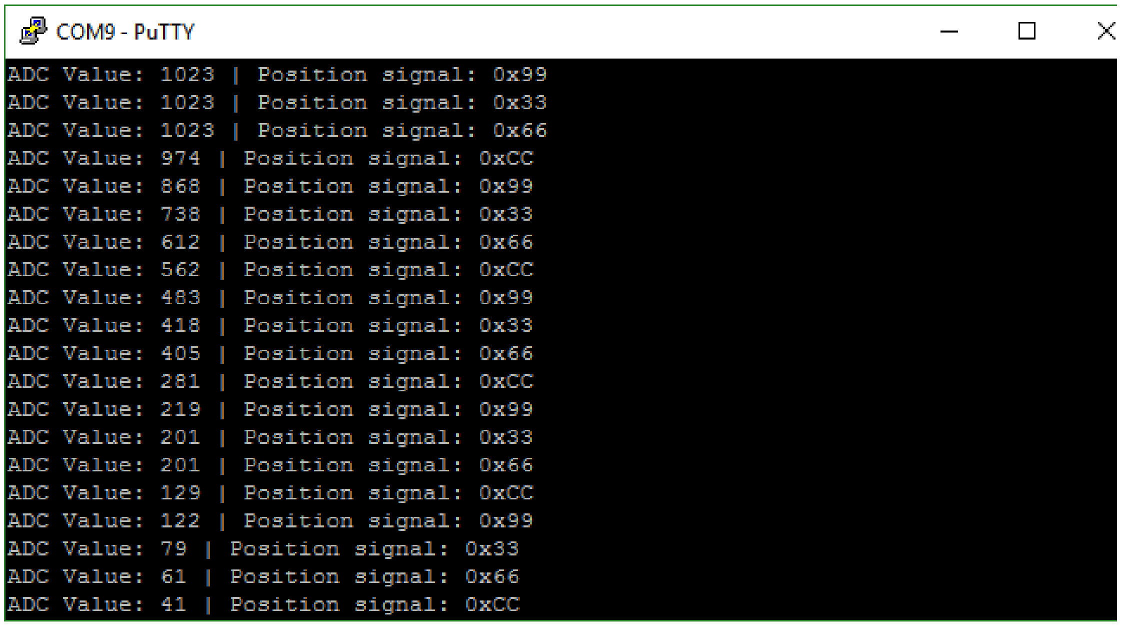


Mode: (●) 2 8-bit Analog Channels, 10kHz ( ) 1 7-bit Analog Channel, 1 Digital Channel, 20kHz
Horizontal scale: 5 ms/div
Channel A: 1.0 V/div, Input, Output High
Channel B: 1.0 V/div, Input, Output High
Triggering: Disabled, (●) A ( ) B, Level: 2500 mV
Persistence length: 4

```
ADC Value = 106
        Duty cycle = 10%
ADC Value = 105
        Duty cycle = 10%
ADC Value = 104
        Duty cycle = 10%
ADC Value = 105
        Duty cycle = 10%
```

Task 2:

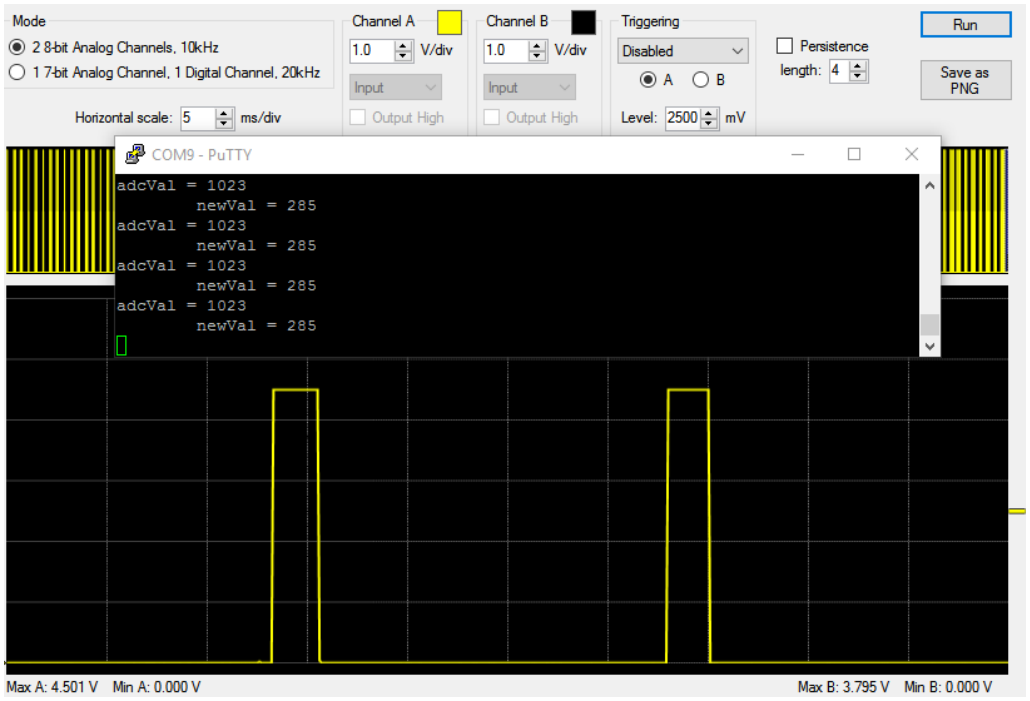
The following screenshot simply illustrates the monitoring of the potentiometer value as it is rotated and the position signal being sent to the stepper motor. Each line represents one step. Notice that the position signal is being rotated at each iteration.



```
ADC Value: 1023 | Position signal: 0x99
ADC Value: 1023 | Position signal: 0x33
ADC Value: 1023 | Position signal: 0x66
ADC Value: 974 | Position signal: 0xCC
ADC Value: 868 | Position signal: 0x99
ADC Value: 738 | Position signal: 0x33
ADC Value: 612 | Position signal: 0x66
ADC Value: 562 | Position signal: 0xCC
ADC Value: 483 | Position signal: 0x99
ADC Value: 418 | Position signal: 0x33
ADC Value: 405 | Position signal: 0x66
ADC Value: 281 | Position signal: 0xCC
ADC Value: 219 | Position signal: 0x99
ADC Value: 201 | Position signal: 0x33
ADC Value: 201 | Position signal: 0x66
ADC Value: 129 | Position signal: 0xCC
ADC Value: 122 | Position signal: 0x99
ADC Value: 79 | Position signal: 0x33
ADC Value: 61 | Position signal: 0x66
ADC Value: 41 | Position signal: 0xCC
```

Task 3:

The following image illustrates the monitoring of the PWM signal and the mapping of values from potentiometer to OCR1A.

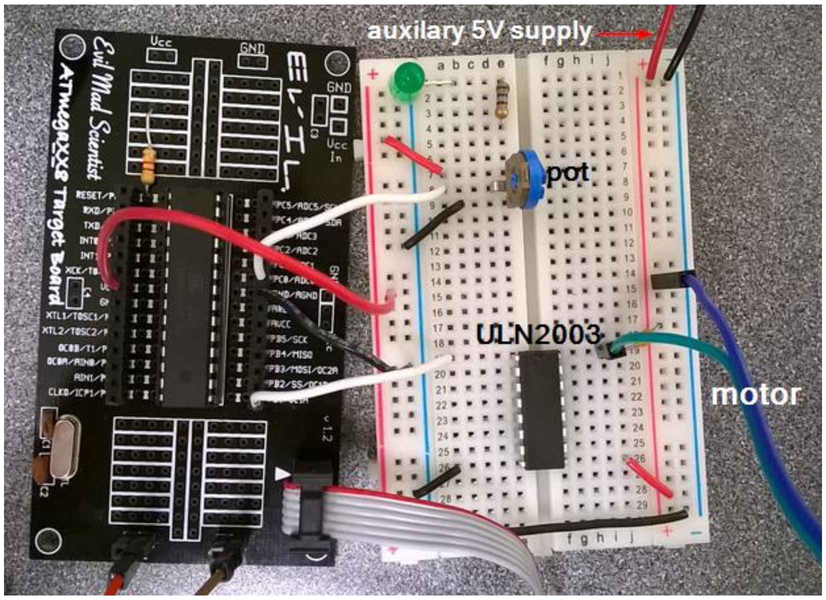


Mode
2 8-bit Analog Channels, 10kHz
1 7-bit Analog Channel, 1 Digital Channel, 20kHz
Horizontal scale: 5 ms/div
Channel A 1.0 V/div
Input
Output High
Channel B 1.0 V/div
Input
Output High
Triggering
Disabled
A B
Level: 2500 mV
Persistence
length: 4
Run
Save as PNG
COM9 - PuTTY
Max A: 4.501 V Min A: 0.000 V
Max B: 3.795 V Min B: 0.000 V

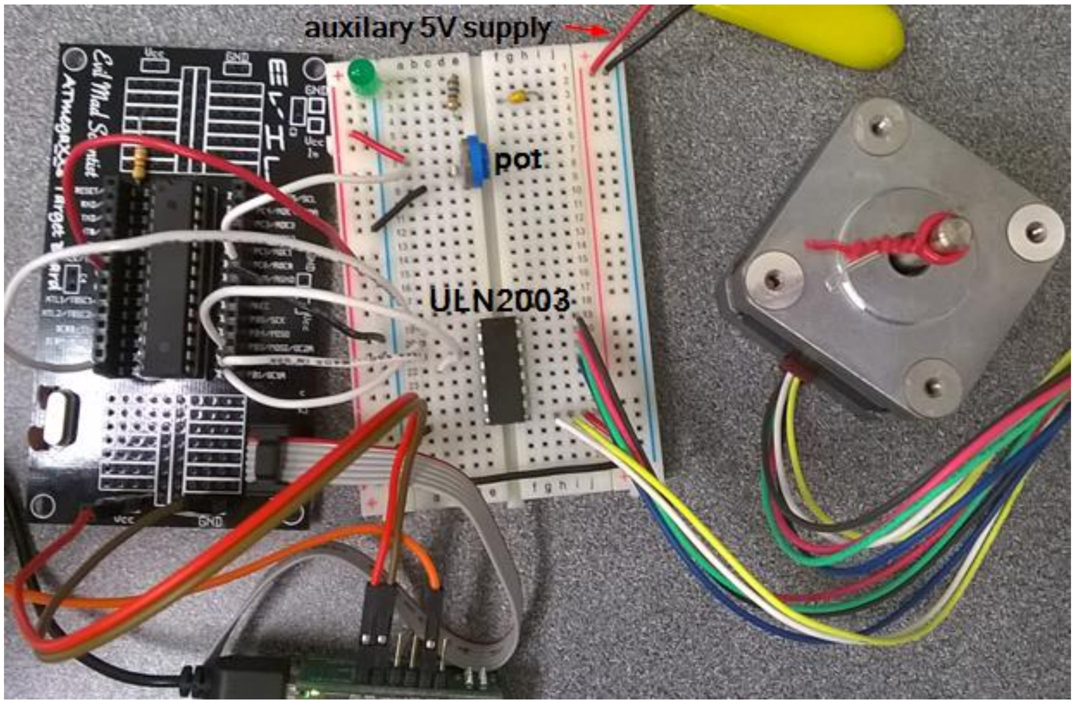
```
adcVal = 1023
          newVal = 285
adcVal = 1023
          newVal = 285
adcVal = 1023
          newVal = 285
adcVal = 1023
          newVal = 285
```

8.	SCREENSHOT OF EACH DEMO		

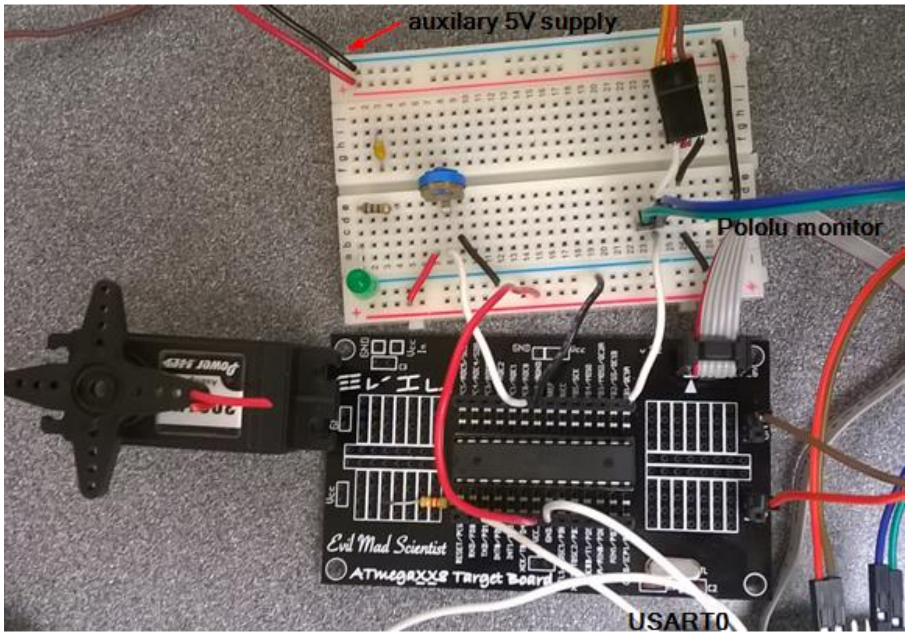
TASK 1:



Task 2:



Task 3:



9.	VIDEO LINKS OF EACH DEMO		
10.	GITHUB REPOSITORY		
https://github.com/Vasty1995/CPE301			

Student Academic Misconduct Policy
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"This assignment submission is my own, original work".
Yannick Kengne Tatcha