GOAL

The goal of this lab is to understand the concept of Analog to Digital Converter and use this peripheral of AVR atmega328p.

BACKGROUND

REFERENCE VOLTAGE $V_{ref}$

$V_{ref}$ It is the input voltage used for reference for ADC conversion. Reference voltage along with ADC resolution dictates the step size of ADC.

STEP SIZE

Step Size is the smallest change that can be recognized by ADC.

$$\text{Step Size} = \frac{V_{ref}}{\text{number of steps}}$$

- number of steps = $2^n$
- $n$ – resolution of ADC
- $V_{ref}$ – reference voltage

CONVERSION TIME

Time taken by ADC to convert analog input to digital output.
**Digital Data Output** \( D_{out} \)

\( D_{out} \) It is the digital data converted by ADC.

\[
D_{out} = \frac{V_{in}}{\text{Step Size}}
\]

- \( V_{in} \) – input to ADC for conversion

Example:
For 8 bit ADC with 2.56v reference, 1.7v input will be:

\[
\text{Step Size} = \frac{2.56}{2^8} = 10mV
\]

\[
D_{out} = \frac{1.7V}{10mV} = 170
\]

170 decimal = 10101010 in binary.

**Code: ADC Polling**

```c
#include <avr/io.h>

int main(void)
{
    DDRD = 0xFF;
    DDRB = 0xFF;
    DDRC = 0;
    ADMUX=0x60;
    ADCSRA=0xE6;
    while (1)
    {   while(!((ADCSRA & (1<<ADIF))));
        ADCSRA|(1<<ADIF);
        PORTD = ADCH;
    }
}
```
**CODE: ADC INTERRUPT**

```c
#include <avr/io.h>
#include <avr/interrupt.h>

ISR (ADC_vect)
{
    PORTD = ADCH;
    ADCSRA |= (1<<ADSC);
}

int main(void)
{
    DDRD = 0xFF;
    DDRB = 0xFF;
    DDRC = 0;
    sei();
    ADMUX = 0x60;
    ADCSRA=0x8F;
    ADCSRA |= (1<<ADSC);
    while (1)
    {
    }
}
```

Fig. 1. Schematic for ADC
**CODE: HC-SR04**

```c
#define F_CPU 800000UL
#include <avr/io.h>
#include <util/delay.h>

int main(void)
{
    DDRB = 0xFF;  //trigger
    DDRC = 0xFF;  //o/p
    DDRD = 0x00;  //echo

    while (1)
    {
        int a=0;
        PORTC = 0x00;
        PORTB =0x00;
        _delay_us(2);
        PORTB =0xff;
        _delay_us(10);
        PORTB =0x00;

        TCCR1A=0x00;
        TCCR1B |= (1<< CS11);

        while((PIND & 0b00000100)==0b00000000);
        TCNT1 = 0;

        while((PIND & 0b00000100)==0b00000100);
        a= TCNT1+1;
        TCCR1B = 0x00;

        if((a/148)<14)
        {
            PORTC = 0xFF;
            _delay_ms(100);
        }
    }
}
```
PRELAB

1. Answer the questions
   1. What effects step size of ADC and how?
   2. Name one serial ADC IC and one parallel ADC IC commercially available.
   3. Find step size for 8-bit ADC with $V_{ref} = 1.28\text{V}$.
   4. What is digital output for analog input 1V and 0.8V?
   5. Expand each bit of ADMUX with value 96 and explain the effect.
   6. Expand each bit of ADCSRA with value 230 and explain the effect.
   7. Read the datasheet of HC-SR04 and explain the function of the following pins: $V_{cc}$, $Trig$, $Echo$ and $GND$.

EXPERIMENTS

1. Implementing ADC
   a) Use given ADC polling code and show the working experiment.
   b) Modify the code with different ADC Channel.
   c) Find input for digital output to be 128 for 10-bit ADC with reference 5v and verify that with given formula.

2. LED Sequence
   a) Write the code for a led sequence.
   b) Use the given ADC interrupt code and modify it to verify the ADC interrupt operation.

3. Distance sensor
   a) Interface HC-SR04 and verify the operation of the sensor.
POSTLAB

Include the following elements in the report document:

<table>
<thead>
<tr>
<th>Section</th>
<th>Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Theory of operation</td>
</tr>
</tbody>
</table>

Include a brief description of every element and phenomenon that appears during the experiments.

| 2       | Prelab report |

| 3       | Results of the experiments |

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Experiment Results</th>
</tr>
</thead>
</table>
| 1          | a. Modified code with comments  
b. Picture of the circuit wired  
c. Description of your modification |
| 2          | a. Code with comments  
b. Picture of the circuit wired  
c. Description of your modification |
| 3          | a. Code with comments  
b. Picture of the circuit wired |

| 4       | Answer the questions |

<table>
<thead>
<tr>
<th>Question no.</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>What is the principle of operation of the HC-SR04 sensor?</td>
</tr>
<tr>
<td>2</td>
<td>List all the parameters of the ADC used in the lab.</td>
</tr>
<tr>
<td>3</td>
<td>What is the accuracy of ADC used in the lab?</td>
</tr>
</tbody>
</table>

| 5       | Conclusions |

Write down your conclusions, things learned, problems encountered during the lab and how they were solved, etc.