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# **AVR Interfacing**

## **ADC**

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# Agenda

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- Introduction to ADC.
  - AVR ADC.
  - AVR ADC Registers.
  - AVR ADC Programming.
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# Introduction to ADC

- In the Real World, a **sensor** senses any physical parameter and converts into an equivalent analog electrical signal this analog signal is converted into a digital signal using an Analog to Digital Converter (ADC).
- ADC can be defined by
  - The ADC **precision** is the number of **distinguishable ADC inputs** that ADC can measure (e.g. **1024** alternatives for 10 bits ADC).
  - The ADC **range** is the maximum and minimum ADC input (e.g. 0 to +5V).
  - he ADC **resolution** is the smallest distinguishable change in input voltage that can be sensed by ADC. The resolution is the change in input that causes the digital output to change by 1.

$$\text{Resolution(volts)} = \frac{\text{Range(volts)}}{\text{Precision(alternatives)}} = \frac{5V-0}{1024} = 4.88\text{mv}$$

$$\text{ADC} = \frac{V_{\text{IN}} \times 1024}{V_{\text{REF}}}$$

# Introduction to ADC

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## ➤ ADC Prescaler

- ❑ The ADC of the AVR converts analog signal into digital signal at some regular **interval**. This interval is determined by the **clock frequency**.
  - ❑ The prescaler acts as **frequency division factor**.
  - ❑ There are some predefined division factors 2, 4, 8, 16, 32, 64, and 128.
  - ❑ For example, a prescaler of 128 implies  
 $F_{\text{ADC}} = F_{\text{CPU}}/8$ . For  $F_{\text{CPU}} = 16\text{MHz}$ ,  $F_{\text{ADC}} = 16\text{M}/128 = 125\text{kHz}$ .  
so time required to convert the analog signal to digital is  $1/125 \text{ ms}$ .
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# AVR ADC Registers

- ADMUX - ADC Multiplexer Selection Register

Bit	7	6	5	4	3	2	1	0	ADMUX
(0x7C)	REFS1	REFS0	ADLAR	–	MUX3	MUX2	MUX1	MUX0	
Read/Write	R/W	R/W	R/W	R	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

- **Bits 7:6 – REFS1:0 – ADC  $V_{ref}$  Reference Selection Bits**  
These bits select the voltage reference for the ADC. The internal voltage reference options may not be used if an external reference voltage is being applied to the AREF pin

REFS1	REFS0	Voltage Reference Selection
0	0	AREF, internal $V_{REF}$ turned off
0	1	$AV_{CC}$ with external capacitor at AREF pin
1	0	Reserved
1	1	Internal 1.1V voltage reference with external capacitor at AREF pin

# AVR ADC Registers

## ➤ Bit 5 – ADLAR – ADC Left Adjust Result

The ADLAR bit affects the presentation of the ADC conversion result in the ADC Data Register. Write one to ADLAR to left adjust the result. Otherwise, the result is right adjusted.

ADLAR = 0															
Bit															
15	14	13	12	11	10	9	8								
-	-	-	-	-	-	-	-								
ADC7								ADC8							
ADC6								ADC9							
ADC5								ADC0							
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# AVR ADC Registers

- **ADCSRA – ADC Control and Status Register A**

Bit	7	6	5	4	3	2	1	0
(0x7A)	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Initial Value	0	0	0	0	0	0	0	0

- **Bit 7 – ADEN – ADC Enable**

This is enabled, ADC operations. Otherwise the pins behave as GPIO ports.

- **Bit 6 – ADSC – ADC Start Conversion**

1 is written as long as the conversion is in progress, When the conversion is complete, it returns to zero.

- **Bit 5 – ADATE – ADC Auto Trigger Enable**

1 enables auto trigger where the ADC will start a conversion on a positive edge of the selected trigger signal.

- **Bit 4 – ADIF – ADC Interrupt Flag**

This bit is set when an ADC conversion completes and the Data Registers are updated.

# AVR ADC Registers

- Bit 3 – ADIE – ADC Interrupt Enable
- Bits 2:0 – ADPS2:0 – ADC Prescaler Select Bits

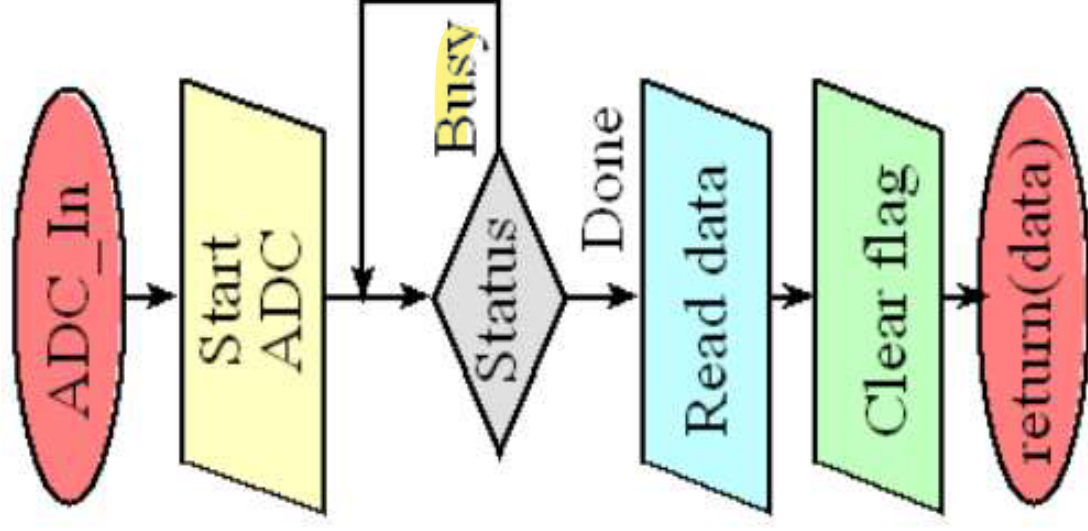
ADPS2	ADPS1	ADPS0	Division Factor
0	0	0	2
0	0	1	2
0	1	0	4
0	1	1	8
1	0	0	16
1	0	1	32
1	1	0	64
1	1	1	128

- ADCL and ADCH – ADC Data Registers

The result of the ADC conversion is stored here.



# AVR ADC Programming



as long as it is busy, this implies that it didn't finish conversion.

# AVR ADC Programming

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## *ADC Initialization*

The following code segment initializes the ADC

```
void adc_init()
{
    // AREF = AVCC
    ADMUX = (1<<REFS0);

    // ADC Enable and prescaler of 128
    // 16000000/128 = 125000
    ADCSRA = (1<<ADEN) | (1<<ADPS2) | (1<<ADPS1) | (1<<ADPS0);
}
```

---

# AVR ADC Programming

## *Reading ADC Value*

The following code segment reads the value of the ADC

```
uint16_t adc_read(uint8_t ch) one of the 6 adc channels
{
    // select the corresponding channel 0~5
    // ANDing with '7' will always keep the value
    // of 'ch' between 0 and 5
    ch &= 0b00000111; // AND operation with 7
    ADMUX = (ADMUX & 0xF8) | ch; // clears the bottom 3 bits before ORing

    8 = 1000 bsafrom
    // start single conversion bsafrom el awl 34an a7ot kemt el channel fehom, el channel msh b 111 laa hya b3mlha
    // write '1' to ADSC and m3 111 34an akhly kolo 0 w aseeb el 1's el fl channel zy mana 3auz
    ADCSRA |= (1<<ADSC);

    // wait for conversion to complete
    // ADSC becomes '0' again
    // till then, run loop continuously
    while(ADCSRA & (1<<ADSC));

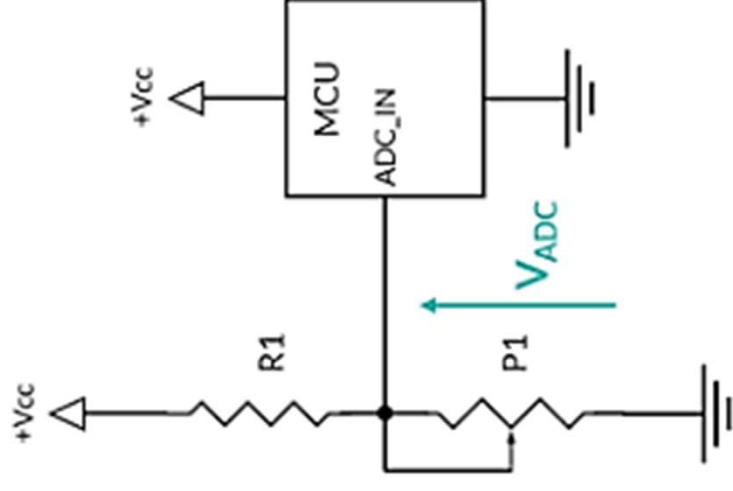
    return (ADC);
}
```

# AVR ADC Programming

The following circuit describes the connection of potentiometer.

The following code reads ADC value and checks if the reading is above 500, the led will be turned on. Otherwise, the led will be turned off.

```
void main()  
{  
    uint16_t adc_result0;  
    DDRB = 0x20;           // to connect led to PB5  
  
    // initialize adc  
    adc_init();  
    while(1)  
    {  
        adc_result0 = adc_read(0); // read adc value at PC0  
  
        // condition for led to turn on or off  
        if (adc_result0 > 500)  
            PORTB = 0x20;  
        else  
            PORTB = 0x00;  
    }  
}
```



# AVR ADC Programming

Using ADC interrupt:

we don't use the interrupts unless the logic to be applied in the ISR is small and short

- Replacing conversion waiting to be completed with firing a flag or signal that called “ADC interrupt”.
- The main difference that will happen in the previous code to be adopted with the ADC interrupt, will be as following;
  - In *ADC Initialization*, global interrupt and ADC interrupt enable have to be set.
  - In *Reading ADC Value*, while loop which waiting for the conversion ending will be remove and global flag will checked if it comes high or not, In case of the flag comes high the ADC read will be ready to be returned from the function.
  - This flag is controlled in the interrupt function (ISR).

# AVR ADC Programming

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## *ADC Initialization*

The following code segment initializes the ADC

```
void adc_init()
{
    // AREF = AVCC
    ADMUX = (1<<REFS0);

    // ADC Enable and prescaler of 128
    // 16000000/128 = 125000
    // (1<<ADIE)=1 → set ADC interrupt enable
    ADCSRA = (1<<ADEN) | (1<<ADPS2) | (1<<ADPS1) | (1<<ADPS0)
              | (1<<ADIE);

    // Set global interrupt
    sei();
}
```

---

# AVR ADC Programming

## Reading ADC Value

```
uint8_t ADC_endconversion_Flag=0;
int16_t adc_read(uint8_t ch)
{
    // select the corresponding channel 0~5
    // ANDing with '7' will always keep the value
    // of 'ch' between 0 and 5
    ch &= 0b00000111; // AND operation with 7
    ADMUX = (ADMUX & 0xF8) | ch; // clears the bottom 3 bits before ORing
    // start single conversion
    // write '1' to ADSC
    ADCSRA |= (1<<ADSC);

    // wait for conversion to complete
    // ADSC becomes '0' again
    // till then, run loop continuously
    if(ADC_endconversion_Flag==1){
        ADC_endconversion_Flag=0;
        return (ADC);
    }
    // pre-defined word in the adc library contains the result of the conversion of ADC
    else
        return (-1);
}
```

```
ISR(ADC_vect)
{
    ADC_endconversion_Flag=1;
}
```

# AVR ADC Programming

## *Main function:*

we use the potentiometer to simulate the sensor

```
void main()
{
    uint16_t adc_result0;
    DDRB = 0x20;           // to connect led to PB5

    // initialize adc
    adc_init();
    while(1)
    {
        adc_result0 = adc_read(0); // read adc value at PA0

        // condition for led to turn on or off
        if(adc_result0!=--1){
            if (adc_result0 > 500)
                PORTB = 0x20;
            else if ( )
                PORTB = 0x00;
        }
    }
}
```

