Embedded System on AVR Microcontroller (ATMEGA32)

Exp8: ADC in ATMEGA32

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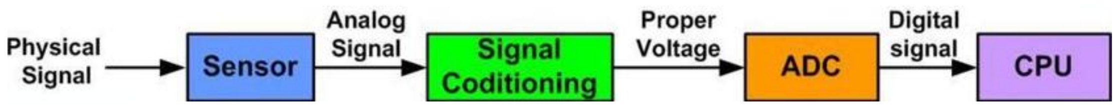
Introduction to ADC

Analog-to-digital converters are among the most widely used devices for data acquisition. Digital computers use binary (discrete) values, but in the physical world everything is analog (continuous).



Temperature, pressure (wind or liquid), humidity and velocity are a few examples of physical quantities that we deal with every day. A physical quantity is converted to electrical (voltage, current) signals using a device called a transducer. Transducers are also referred to as sensors. Sensors for temperature, velocity, pressure, light, and many other natural quantities produce an output that is voltage (or current). Therefore, we need an analog-to-digital converter to translate the analog signals to digital numbers so that the microcontroller can read and process them.

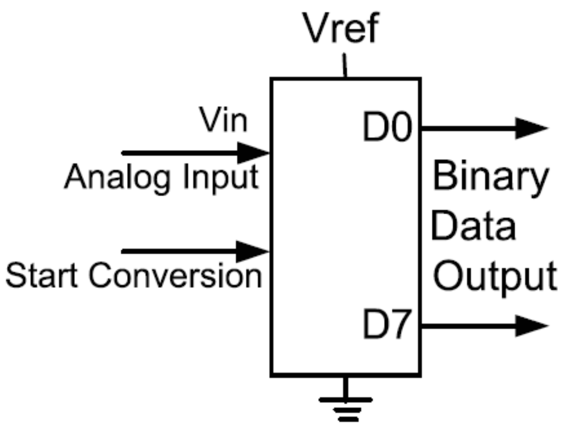
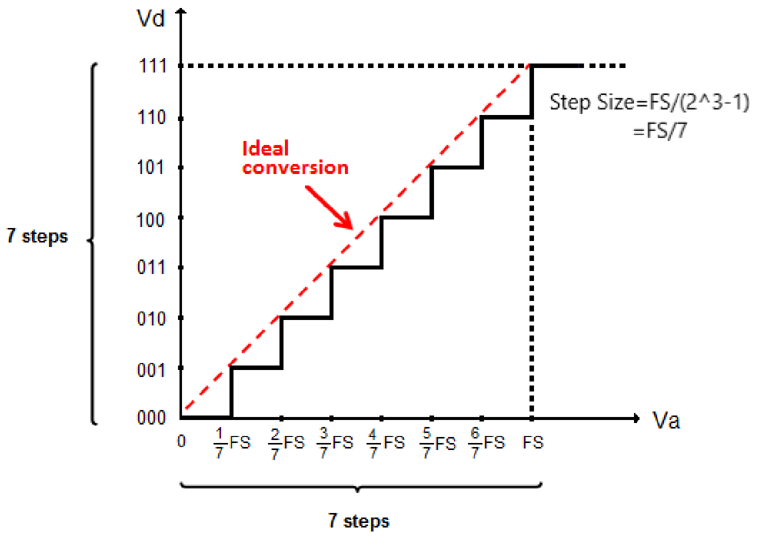


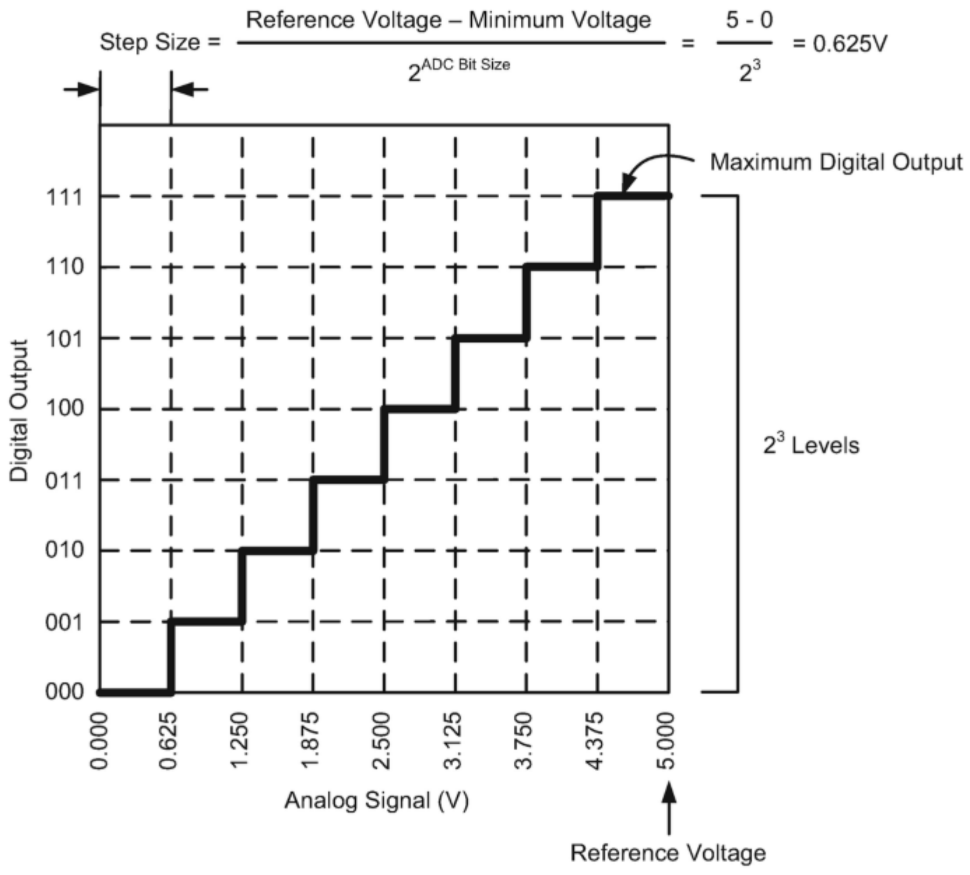
Fig. An 8-bit ADC Block Diagram

Some of the major characteristics of the ADC

I. **Resolution:** Step size (resolution) is the smallest change that can be discerned by an ADC.



The above figure is the ideal conversion with step size for ADC. Here, Vref=FS and resolution is FS/(2^n-1). For 3-bit ADC, the ideal resolution is FS/7. We all know that we cannot apply analog voltage more than reference voltage of the ADC. So, here if we apply exactly FS as analog voltage then only we can achieve 111 as digital conversion bits.
To overcome this situation, the resolution of n-bit ADC is defined as Vref/2^n. The below figure represents the practical 3-bit ADC resolution with corresponding analog voltage with converted digital bits.



The ADC has n-bit resolution, where n can be 8, 10, 12, 16, or even 24 bits. Higher-resolution ADCs provide a smaller step size, where step size is the smallest change that can be discerned by an ADC. Some widely used resolutions for ADCs are shown in below Table.

n-bit	Number of Steps	Step Size (mV)
8	256	19.53
10	1024	4.88
12	4096	1.22
16	65536	0.076

Table: Resolution versus Step Size for ADC (V_{ref}= 5V)

II. **Conversion time:** In addition to resolution, conversion time is another major factor in judging an ADC. Conversion time is defined as the time it takes the ADC to convert the analog input to a digital (binary) number. The conversion time is dictated by the clock source connected to the ADC in addition to the method used for data conversion and technology used in the fabrication of the ADC chip such as MOS or TTL technology.

III. **V_{ref}:** V_{ref} is an input voltage used for the reference voltage. The voltage connected to this pin, along with the resolution of the ADC chip, dictate the step size. For an 8-bit ADC, the step size is $V_{ref}/256$ because it is an 8-bit ADC, and 2 to the power 8 gives us 256 hence 256 steps.
For example, if the analog input range needs to be 0 to 4volts, V_{ref} is connected to 4 volts. That gives 4V/256 = 15.625mV for the step size of an 8-bit ADC. In another case, if we need a step size of 10mV for an 8-bit ADC, then V_{ref} =2.56V, because 2.56V/256=10mV.

V_{ref}(V)	**V_{in}(V)**	**Step Size (mV)**
5.00	0 to 5	5/1024= 4.88
4.096	0 to 4.096	4.096/1024= 4
3.3	0 to 3.3	3.3/1024= 3.22
2.56	0 to 2.56	2.56/1024= 2.5

Table: V_{ref} Relation to V_{in} Range for an 10-bit ADC

IV. **Digital Data Output:** In an 8-bit ADC we have an 8-bit digital data output of D0–D7, while in the 10-bit ADC the data output is D0–D9. To calculate the output voltage, we use the following formula:

$$D_{out} = \frac{V_{in}}{step\ size}$$

Where D_{out}= digital data output (in decimal), V_{in}= analog input voltage, and step size (resolution) is the smallest change, which is $V_{ref}/1024$ for an 10-bit ADC.

• ADC Programming in the ATMEGA32

Because the ADC is widely used in data acquisition, in recent years an increasing number of microcontrollers have had an on-chip ADC peripheral, just like timers and USART. An on-chip ADC eliminates the need for an external ADC connection, which leaves more pins for other I/O activities. The vast majority of the AVR chips come with ADC. In this section we discuss the ADC feature of the ATmega32 and show how it is programmed in Assembly.

ATmega32 ADC features:

The ADC peripheral of the ATmega32 has the following characteristics:

a. It is a 10-bit ADC.

b. 0 - V_{CC} ADC Input Voltage Range.
c. It has 8 analog input channels, 7 differential input channels, and 2 differential input channels with optional gain of 1x, 10x and 200x.
d. The converted output binary data is held by two special function registers called ADCL (A/D Result Low) and ADCH (A/D Result High).
e. Because the ADCH:ADCL registers give us 16 bits and the ADC data out is only 10 bits wide, 6 bits of the 16 are unused. We have the option of making either the upper 6 bits or the lower 6 bits unused. When the lower 6 bits are unused then it is called 8bit ADC mode and the converted data will be stored in ADCH.
f. We have three options for V_{ref}. V_{ref} can be connected to AVCC (Analog V_{cc}), internal 2.56 V reference, or external AREF pin.
g. The conversion time is dictated by the crystal frequency connected to the XTAL pins (Fosc) and ADPS0:2 bits. 13 µs - 260 µs Conversion Time and up to 15 kSPS at Maximum Resolution.

• ADC Registers in the ATMEGA32

In the AVR microcontroller five major registers are associated with the ADC that we deal with in this experiment. They are **ADMUX (ADC multiplexer selection register), ADCSRA (ADC Control and Status Register), ADCH (high data), ADCL (low data), and SPIOR (Special Function I/O Register)**. We examine each of them in this section.

i. ADMUX (ADC Multiplexer Selection Register)

Bit	7	6	5	4	3	2	1	0	
	REFS1	REFS0	ADLAR	MUX4	MUX3	MUX2	MUX1	MUX0	ADMUX
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	

REFS1,REFS0 (Bit 7,Bit 6): Reference Selection Bits
These bits select the reference voltage for the ADC.

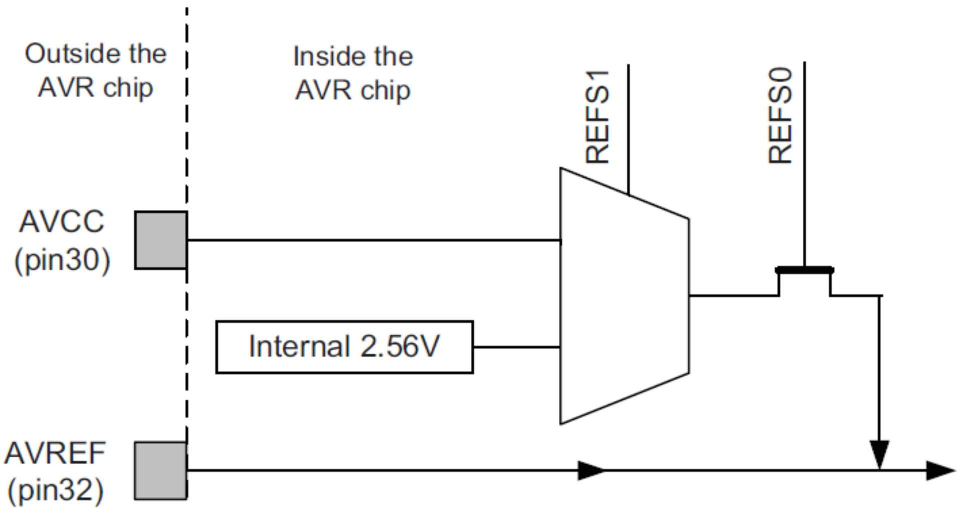


Fig. ADC Reference Source Selection

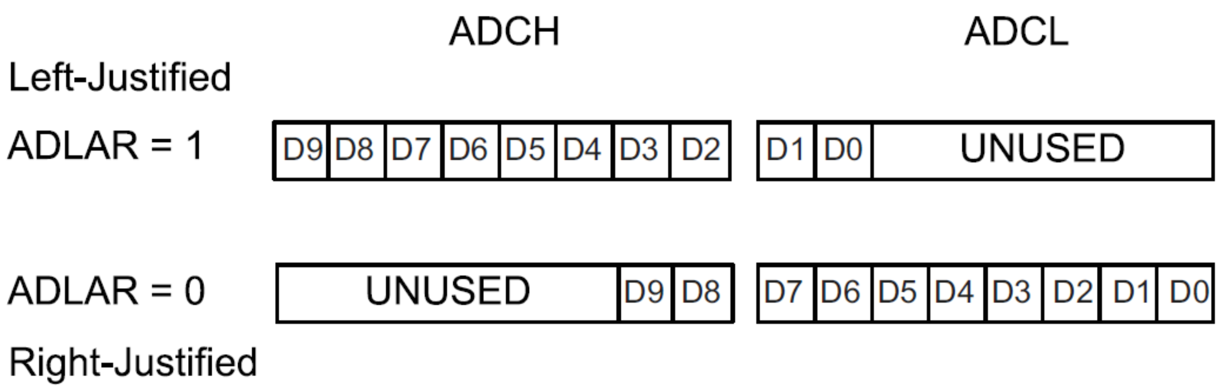
Above figure shows the block diagram of internal circuitry of V_{ref} selection. As we can see that we have three options: (a) AREF pin, (b) AVCC pin, or (c) internal 2.56V. The below table shows how REFS1 and REFS0 bits of the ADMUX register can be used to select the V_{ref} source.

REFS1	REFS0	Voltage Reference Selection
0	0	AREF, Internal Vref turned off
0	1	AVCC with external capacitor at AREF pin
1	0	Reserved
1	1	Internal 2.56V Voltage Reference with external capacitor at AREF pin

Table: Voltage Reference Selections for ADC

ADLAR (Bit 5): ADC Left Adjust Results

The AVRs have a 10-bit ADC, which means that the result is 10 bits long and cannot be stored in a single byte. In AVR two 8-bit registers are dedicated to the ADC result, but only 10 of the 16 bits are used and 6 bits are unused. You can select the position of used bits in the bytes. This ADLAR bit dictates either the left bits or the right bits of the result registers ADCH:ADCL that are used to store the result. If we write a one to ADLAR, the result will be left adjusted; otherwise, the result is right adjusted.



MUX4:0 (Bit 4:0): Analog Channel and Gain Selection Bits

The value of these bits selects the gain for the differential channels and also selects which combination of analog inputs are connected to the ADC.

MUX4...0	Single-ended Input
00000	ADC0
00001	ADC1
00010	ADC2
00011	ADC3
00100	ADC4
00101	ADC5
00110	ADC6
00111	ADC7

ii. ADCSRA (ADC Control and Status Register A)

Bit	7	6	5	4	3	2	1	0	
	ADEN	ADSC	ADATE	ADIF	ADIE	ADPS2	ADPS1	ADPS0	ADCSRA
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	

The ADCSRA register is the status and control register of ADC. Bits of this register control or monitor the operation of the ADC.

ADEN (Bit 7): ADC Enable

This bit enables or disables the ADC. Setting this bit to one will enable the ADC, and clearing this bit to zero will disable it even while a conversion is in progress.

ADSC (Bit 6): ADC Start Conversion

To start each conversion, you have to set this bit to one.

ADATE (Bit 5): ADC Auto Trigger Enable

When this bit is written to one, Auto Triggering of the ADC is enabled. The ADC will start a conversion on a positive edge of the selected trigger signal. The trigger source is selected by setting the ADC Trigger Select bits, ADTS in SFIOR.

ADIF (Bit 4): ADC Interrupt Flag

This bit is set when an ADC conversion completes and the Data Registers are updated. The ADC Conversion Complete Interrupt is executed if the ADIE bit and the I-bit in SREG are set. ADIF is cleared by hardware when executing the corresponding interrupt handling vector. Alternatively, ADIF is cleared by writing a logical one to the flag.

ADIE (Bit 3): ADC Interrupt Enable

When this bit is written to one and the I-bit in SREG is set, the ADC conversion Complete Interrupt is activated.

ADPS2:0 (Bit 2:0): ADC Prescaler Select Bits

These bits determine the division factor between the oscillator frequency of the microcontroller and the input clock to the ADC.

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

A/D conversion time

By using the ADPS2:0 bits of the ADCSRA register we can set the A/D conversion time. To select the conversion time, we can select any of Fosc/2, Fosc/4, Fosc/8, Fosc/16, Fosc/32, Fosc/64, or Fosc/128 for ADC clock, where Fosc is the speed of the crystal frequency connected to the AVR chip. For the AVR, the ADC requires an input clock frequency less than 200KHz for the maximum accuracy.

Example: An AVR is connected to the 8 MHz crystal oscillator. Calculate the ADC frequency for (a) ADPS2:0 = 001 (b) ADPS2:0 = 100 (c) ADPS2:0 = 111

Solution:

(a) Because ADPS2:0 = 001 (1 decimal), the ck/2 input will be activated; we have 8 MHz / 2 = 4 MHz (greater than 200 kHz and not valid)

(b) Because ADPS2:0 = 100 (4 decimal), the ck/8 input will be activated; we have 8 MHz / 16 = 500 kHz (greater than 200 kHz and not valid)

(c) Because ADPS2:0 = 111 (7 decimal), the ck/128 input will be activated; we have 8 MHz / = 62 kHz (a valid option since it is less than 200 kHz)

A timing factor that we should know about is the acquisition time. After an ADC channel is selected, the ADC allows some time for the sample-and-hold capacitor (C hold) to charge fully to the input voltage level present at the channel.

In the AVR, the first conversion takes 25 ADC clock cycles in order to initialize the analog circuitry and pass the sample-and-hold time. Then each consecutive conversion takes 13 ADC clock cycles.

Below table lists the conversion times for some different conditions. Notice that sample-and-hold time is the first part of each conversion.

Condition	Sample & Hold (Cycles from Start of Conversion)	Conversion Time (Cycles)
First conversion	13.5	25
Normal conversions, single ended	1.5	13
Auto Triggered conversions	2	13.5
Normal conversions, differential	1.5/2.5	13/14

Table: ADC Conversion Time

If the conversion time is not critical in your application and you do not want to deal with calculation of ADPS2:0 you can use ADPS2:0 = 111 to get the maximum accuracy of ADC.

iii. ADCH: ADCL registers

After the A/D conversion is complete, the result sits in registers ADCL(A/D Result Low Byte) and ACDH (A/D Result High Byte).

As we mentioned before, the ADLAR bit of the ADMUX is used for making it right-justified or left-justified because we need only 10 of the 16 bits.

iv. SFIOR (Special Function IO Register – SFIOR)

Bit	7	6	5	4	3	2	1	0	
	ADTS2	ADTS1	ADTS0	–	ACME	PUD	PSR2	PSR10	SFIOR
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	

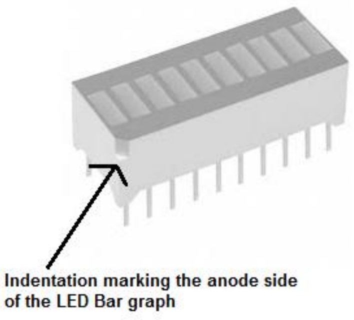
ADTS2:0 (Bit 7:5): ADC Auto Trigger Source
If ADATE in ADCSRA is written to one, the value of these bits selects which source will trigger an ADC conversion. If ADATE is cleared, the ADTS2:0 settings will have no effect.

ADTS2	ADTS1	ADTS0	Trigger Source
0	0	0	Free Running mode
0	0	1	Analog Comparator
0	1	0	External Interrupt Request 0
0	1	1	Timer/Counter0 Compare Match
1	0	0	Timer/Counter0 Overflow
1	0	1	Timer/Counter1 Compare Match B
1	1	0	Timer/Counter1 Overflow
1	1	1	Timer/Counter1 Capture Event

Reserved Bit (Bit4): This bit is reserved for future use in the ATmega32. For ensuring compatibility with future devices, this bit must be written zero when SFIOR is written.
The remaining SFIOR bits are not used in ADC experiment.

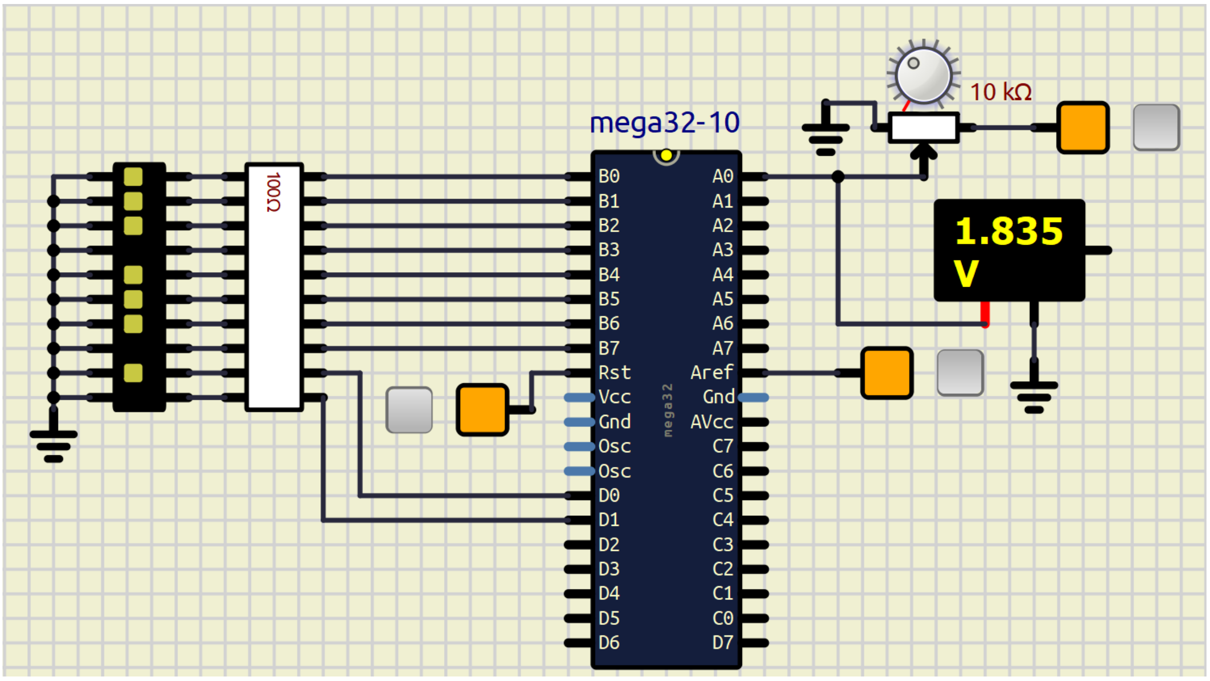
Since the General Purpose GPIO is covered, so to display the digital conversion the LED bar graph is used or 10 LEDs can be used instead of the LED bar graph.

How to know which sides pins are anode and cathode respectively?



```
Experiment1: /* Analog to Digital conversion with Right Justified and display
the digital conversion on LED bar graph */

.INCLUDE "M32DEF.INC"
.ORG 0x0000

//Data direction register of PORTB and PORTD
LDI R16,0xFF
OUT DDRB,R16
OUT DDRD,R16

//stack declaration
LDI R16,HIGH(RAMEND)
OUT SPH,R16
LDI R16,LOW(RAMEND)
OUT SPL,R16

// ADC Initialization
LDI R16,0x00
OUT ADMUX,R16

LDI R16,0xC3
OUT ADCSRA,R16

MAIN:  SBI ADCSRA,ADSC
              CONV:  SBIC ADCSRA,ADSC
                            RJMP CONV //Jump over next instruction if portbit clear
              IN R16,ADCL
              //IN R17,ADCH
              OUT PORTB,R16
              OUT PORTD,R17
              JMP MAIN
```

Make the below circuit for simulation on SimulIDE.



Right Adjusted Video Demonstration: https://drive.google.com/file/d/1TnfWoh-2xP3MBVLOudyClAutnYd8aPBo/view?usp=sharing

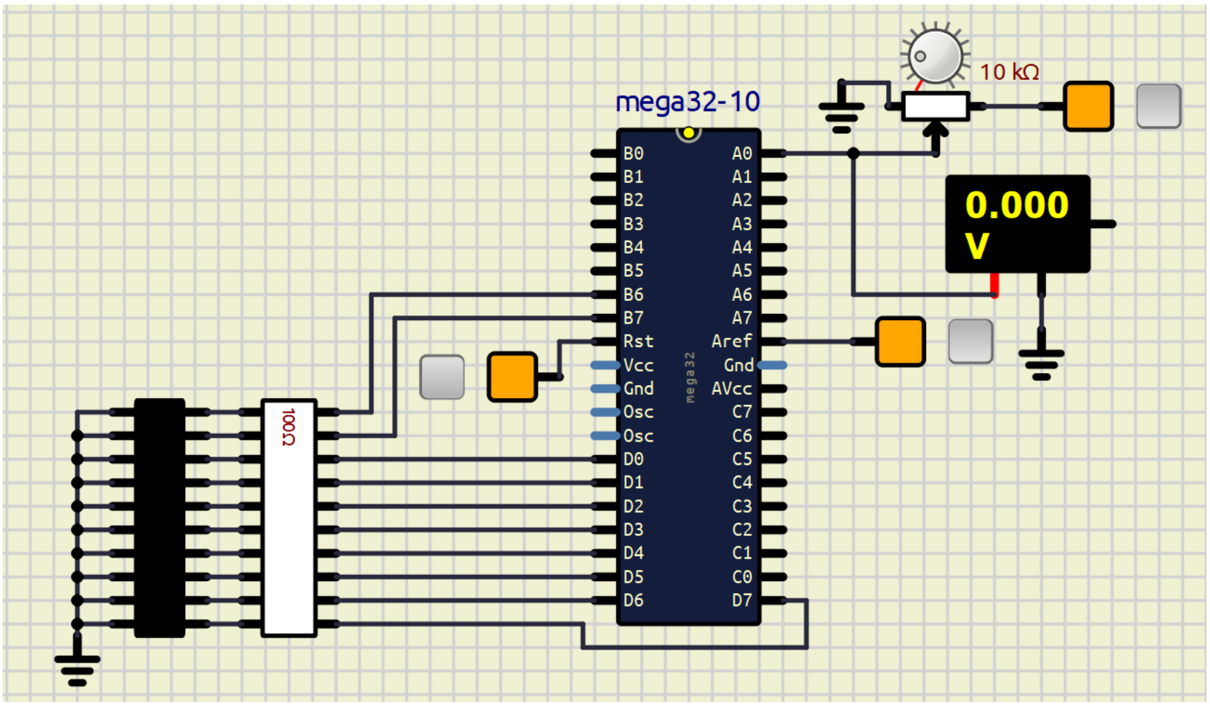
Verify the digital conversion with corresponding analog voltage by hand calculation.

Vref=5Volt, ADC Bits=10bit, Analog Applied Voltage=1.835Volt

ADC Value= (1024/5)*1.835=375.808
Since the ADC follows the floor converted digital value. Hence,
ADC Value= int(375.808)=375
The corresponding 10-bit binary value is 0101110111

Note: ***The resolution of te ADC is 4.88mV. To show this minimum analog input change the 4-decimal Voltmeter will be required. Since here 3-decimal voltmeter is present so we cannot verify the LSB value of the analog input. After hand conversion there may be 1-bit error due to this.***

Class Assignment 1: Write Assembly Code for Analog to Digital conversion with Left Justified and display the digital conversion on LED bar graph as shown in the below figure. Verify the digital conversion with corresponding analog voltage by hand calculation.



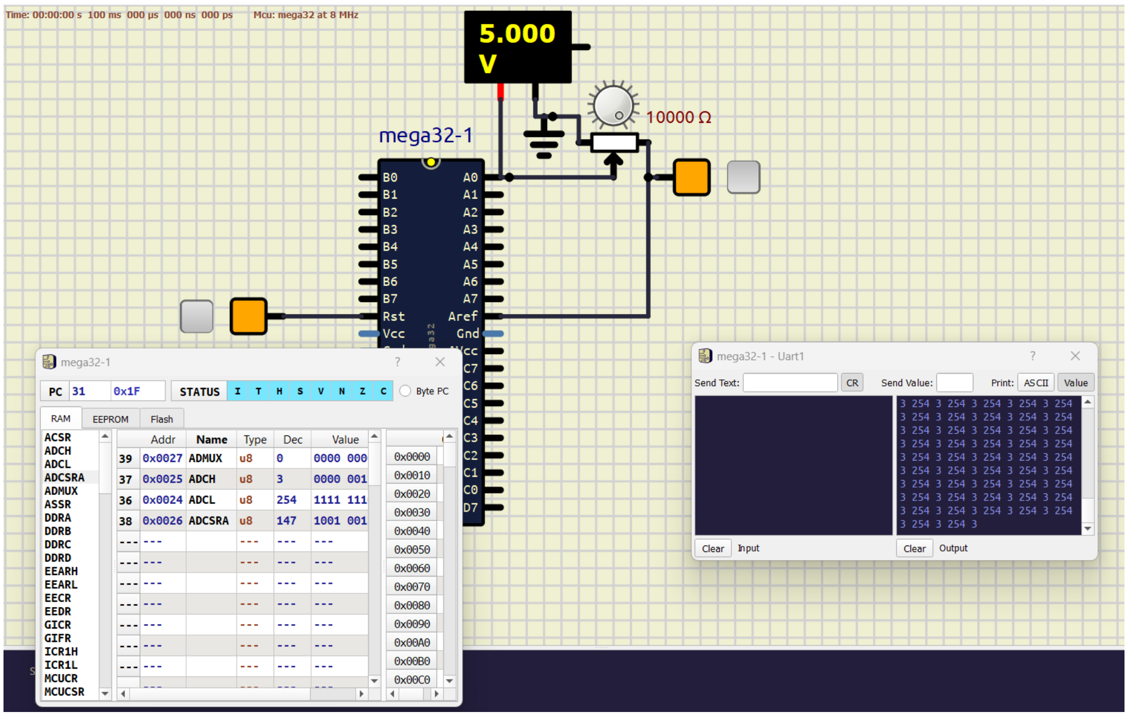
Left Adjusted Video Demonstration:
https://drive.google.com/file/d/1CsWjE2xZg3AN0T4JI4BznG-l2zKvf4wc/view?usp=sharing

After simulation, make the above two circuits on Hardware and verify these.

After learning LCD and UART, you can verify the ADC conversion through these.

```
Experiment2: /* Write a program for the AVR for ADC and transfer the ADC Value
serially through UART at 9600 baud, continuously. Oscillator Frequency=8MHz, U2X=0,
StopBit=1, No Parity Bit. The data will be printed on realterm horizontally. */

.INCLUDE "M32DEF.INC"
.ORG 0x0000

LDI R16,HIGH(RAMEND)
OUT SPH,R16
LDI R16,LOW(RAMEND)
OUT SPL,R16
// ADC Initialization

LDI R16,0x00
OUT ADMUX,R16

LDI R16,0xC3
OUT ADCSRA,R16

//UART Initialization

SBI DDRD,PIND1 // Set Tx as Output Pin
SBI PORTD,PIND1

//UART Initialization
LDI R16,0x08// Enabling Tx Rx
OUT UCSRB,R16
LDI R17,0x86// 8 bit data mode
OUT UCSRC,R17
//9600bps Baud-Rate Settings for 8MHz Oscillator
LDI R16,51
OUT UBRRL,R16

MAIN:         SBI ADCSRA,ADSC
              CONV: SBIC ADCSRA,ADSC
              RJMP CONV     //Jump over next instruction if portbit clear
              IN R16,ADCL
              IN R17,ADCH
              OUT UDR,R17
              AGAIN1:       SBIS UCSRA, UDRE
                            RJMP AGAIN1
              OUT UDR,R16
              AGAIN2:       SBIS UCSRA, UDRE
                            RJMP AGAIN2
              JMP MAIN
```

Make the below circuit for simulation on SimulIDE.


Time: 00:00:00 s 100 ms 000 µs 000 ns 000 ps
Mcu: mega32 at 8 MHz
5.000 V
10000 Ω
mega32-1
B0 B1 B2 B3 B4 B5 B6 B7 Rst Vcc
A0 A1 A2 A3 A4 A5 A6 A7 Aref Gnd AVcc C7 C6 C5 C4 C3 C2 C1 C0 D7
mega32-1 - Uart1
Send Text: CR Send Value: Print: ASCII Value
Clear Input Clear Output

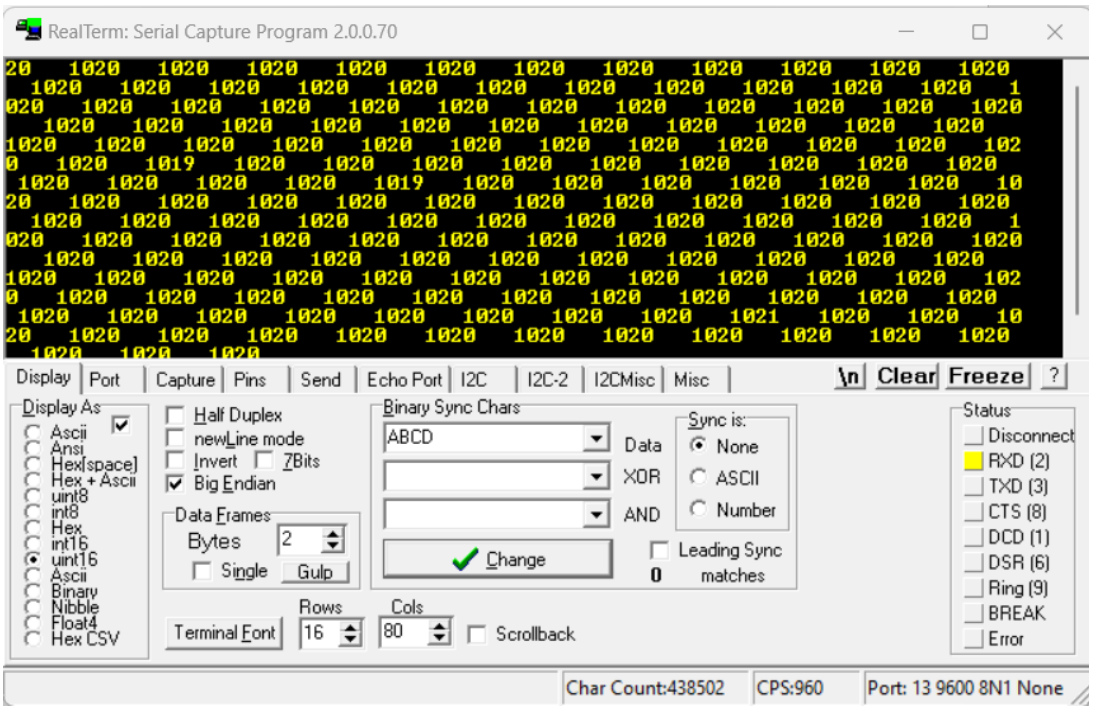
mega32-1

PC 31 0x1F STATUS I T H S V N Z C Byte PC

	Addr	Name	Type	Dec	Value
39	0x0027	ADMUX	u8	0	0000 000
37	0x0025	ADCH	u8	3	0000 001
36	0x0024	ADCL	u8	254	1111 111
38	0x0026	ADCSRA	u8	147	1001 001

```
3 254 3 254 3 254 3 254 3 254
3 254 3 254 3 254 3 254 3 254
3 254 3 254 3 254 3 254 3 254
3 254 3 254 3 254 3 254 3 254
3 254 3 254 3 254 3 254 3 254
3 254 3 254 3 254 3 254 3 254
3 254 3 254 3 254 3 254 3 254
3 254 3 254 3 254 3 254 3 254
3 254 3 254 3 254 3 254 3 254
3 254 3 254 3
```

Make the above hardware and UART hardware connection to display the result on realterm as shown in below figure. Set the display as unsigned int16 and verify the 10-bit ADC value ranging from 0 to 1023.


RealTerm: Serial Capture Program 2.0.0.70
Display Port Capture Pins Send Echo Port I2C I2C-2 I2CMisc Misc
\n Clear Freeze ?
Display As
Ascii Ansi Hex[space] Hex + Ascii uint8 int8 Hex int16 uint16 Ascii Binary Nibble Float4 Hex CSV
Half Duplex newLine mode Invert 7Bits Big Endian
Data Frames Bytes Single Gulp
Terminal Font Rows Cols Scrollback
Binary Sync Chars Data XOR AND Change
Sync is: None ASCII Number Leading Sync matches
Status Disconnect RXD (2) TXD (3) CTS (8) DCD (1) DSR (6) Ring (9) BREAK Error

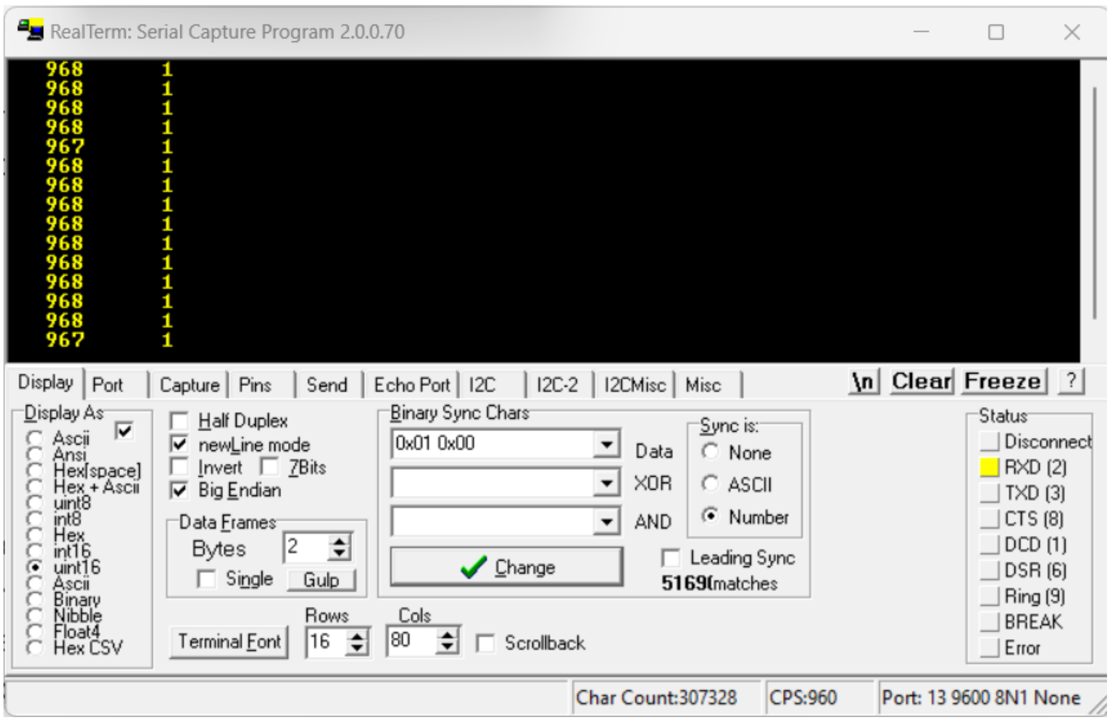
```
20   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020
  1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1
020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020
   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020
1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   102
0   1020   1019   1020   1020   1020   1020   1020   1020   1020   1020   1020
 1020   1020   1020   1020   1019   1020   1020   1020   1020   1020   1020   10
20   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020
  1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1
020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020
   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020
1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   102
0   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020
 1020   1020   1020   1020   1020   1020   1020   1020   1021   1020   1020   10
20   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020   1020
  1020   1020   1020
```

Display As: [✓ uint16]; Big Endian [✓]; Bytes 2; Rows 16; Cols 80; Binary Sync Chars: ABCD; Sync is: [✓ None]; Leading Sync 0 matches

Char Count:438502 CPS:960 Port: 13 9600 8N1 None

```
Experiment3: /* Write a program for the AVR for ADC and transfer the ADC Value
serially through UART at 9600 baud, continuously. Oscillator Frequency=8MHz, U2X=0,
StopBit=1, No Parity Bit. The data will be printed on realterm vertically i.e. new
line program. */

.INCLUDE "M32DEF.INC"
.ORG 0x0000

LDI R16,HIGH(RAMEND)
OUT SPH,R16
LDI R16,LOW(RAMEND)
OUT SPL,R16
// ADC Initialization

LDI R16,0x00
OUT ADMUX,R16

LDI R16,0xC3
OUT ADCSRA,R16

//UART Initialization

SBI DDRD,PIND1 // Set Tx as Output Pin
SBI PORTD,PIND1

//UART Initialization
LDI R16,0x08// Enabling Tx Rx
OUT UCSRB,R16
LDI R17,0x86// 8 bit data mode
OUT UCSRC,R17
//9600bps Baud-Rate Settings for 8MHz Oscillator
LDI R16,51
OUT UBRRL,R16

MAIN:         SBI ADCSRA,ADSC
              CONV: SBIC ADCSRA,ADSC
              RJMP CONV     //Jump over next instruction if portbit clear
              IN R16,ADCL
              IN R17,ADCH
              OUT UDR,R16
              AGAIN1:       SBIS UCSRA, UDRE
                            RJMP AGAIN1
              OUT UDR,R17
              AGAIN2:       SBIS UCSRA, UDRE
                            RJMP AGAIN2
              LDI R18,0x01
              OUT UDR,R18
              AGAIN3:       SBIS UCSRA, UDRE
                            RJMP AGAIN3
              LDI R18,0x00
              OUT UDR,R18
              AGAIN4:       SBIS UCSRA, UDRE
                            RJMP AGAIN4
              JMP MAIN
```

Set the display as unsigned int16, then select new line mode and select binary sync characters to verify the 10-bit ADC value ranging from 0 to 1023 vertically.



RealTerm: Serial Capture Program 2.0.0.70

```
968        1
968        1
968        1
968        1
967        1
968        1
968        1
968        1
968        1
968        1
968        1
968        1
968        1
968        1
967        1
```

Display As: uint16 selected; newLine mode ✓; Big Endian ✓; Half Duplex, Invert, 7Bits unchecked

Data Frames: Bytes 2; Single unchecked

Binary Sync Chars: Data 0x01 0x00; Sync is: Number; Leading Sync unchecked; 5169(matches

Rows 16; Cols 80; Scrollback unchecked

Status: RXD (2) active

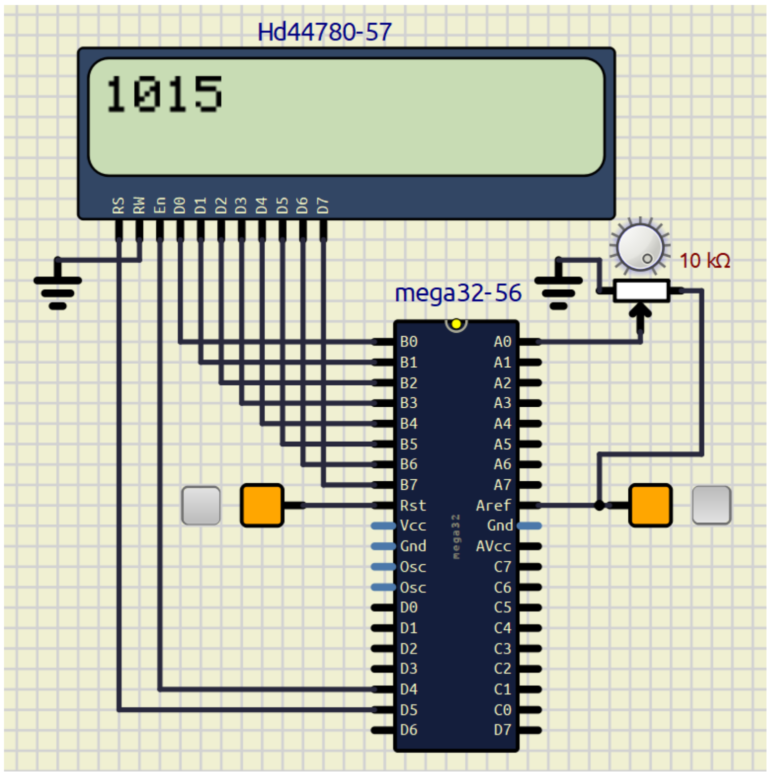
Char Count:307328 | CPS:960 | Port: 13 9600 8N1 None

```
Experiment4: /* Print ADC data on LCD. Oscillator frequency=8MHz*/

.INCLUDE "M32DEF.INC"
.ORG 0x0000

LDI R16,HIGH(RAMEND)
OUT SPH,R16
LDI R16,LOW(RAMEND)
OUT SPL,R16

MAIN:  //Data Direction Register of LCD
             LDI R16,0xFF
             OUT DDRB,R16
             SBI DDRD,PIND4 //Falling Edged Enable
             SBI DDRD,PIND5 //Register Select

             // LCD Initialization
             CBI PORTD,PIND5 // Command Register Enable
             LDI R16,0x38 //2 lines and 5x7 matrix
             OUT PORTB,R16
             CALL ENABLE
             LDI R16,0x02 // Return Home
             OUT PORTB,R16
             CALL ENABLE
             LDI R16,0x01 // Clear display screen
             OUT PORTB,R16
             CALL ENABLE
             LDI R16,0x0C //Display on, cursor off
             OUT PORTB,R16
             CALL ENABLE
             LDI R16,0x06 // Shift Cursor to right after print on LCD
             OUT PORTB,R16
             CALL ENABLE
```

```
//Set Cursor Coordinate
LDI R16,0x80 //Set Cursor at beginning of 1st Line
OUT PORTB,R16
CALL ENABLE

//ADC Initialization
LDI R16,0x00
OUT ADMUX,R16
LDI R16,0xC3
OUT ADCSRA,R16

Infinite_Loop:       SBI ADCSRA,ADSC
                            ADC_CONV:     SBIC ADCSRA,ADSC
                                                 RJMP ADC_CONV
                            IN R24,ADCL
                            IN R25,ADCH

                            //Digit separation to print on LCD
                            LDI R21,0
                            LOOP_Digit3:  INC R21
                                          LDI R23,19
                            THOUSAND:     SBIW R25:R24,50
                                          DEC R23
                                          BRNE THOUSAND
                                          SBIW R25:R24,50
                                          BRPL LOOP_Digit3
                            DEC R21
                            LDI R23,20
                            THOUSAND_ADD: ADIW R25:R24,50
                                          DEC R23
                                          BRNE THOUSAND_ADD
                            LDI R19,0
                            LOOP_Digit2:  INC R19
                                          SBIW R25:R24,50
                                          SBIW R25:R24,50
                                          BRPL LOOP_Digit2
                            DEC R19
                            ADIW R25:R24,50
                            ADIW R25:R24,50

                            LDI R20,0
                            LOOP_Digit1:  INC R20
                                          SBIW R25:R24,10
                                          BRPL LOOP_Digit1
                            DEC R20
                            ADIW R25:R24,10

                            //Digit to Ascii Digit conversion
                            LDI R22,48
                            ADD R21,R22
                            ADD R19,R22
                            ADD R20,R22
                            ADD R24,R22

                            //Clear LCD Screen
                            CBI PORTD,PIND5
                            LDI R16,0x01 // Clear display screen
                            OUT PORTB,R16
                            CALL ENABLE
                            //Print on LCD
                            SBI PORTD,PIND5
                            OUT PORTB,R21
```

```
                                        CALL ENABLE
                                        OUT PORTB,R19
                                        CALL ENABLE
                                        OUT PORTB,R20
                                        CALL ENABLE
                                        OUT PORTB,R24
                                        CALL ENABLE
                                        //Wait for few times
                                        CALL DELAY
                                        JMP Infinite_Loop


ENABLE:             SBI PORTD,PIND4
                    LDI R18,0xFF
                    LOOP2_EN:     LDI R17,0x00
                                  LOOP1_EN:    NOP
                                               DEC R17
                                               BRNE LOOP1_EN
                                  DEC R18
                                  BRNE LOOP2_EN
                    CBI PORTD,PIND4
                    RET

DELAY:              LDI R16,0x0F
LOOP3_DL:           LDI R18,0xFF
                    LOOP2_DL:    LDI R17,0xFF
                                 LOOP1_DL:     NOP
                                               DEC R17
                                               BRNE LOOP1_DL
                                 DEC R18
                                 BRNE LOOP2_DL
                    DEC R16
                    BRNE LOOP3_DL
                    RET
```

Make the below circuit and simulate it then make the hardware to realize practically.


Hd44780-57
1015
RS RW En D0 D1 D2 D3 D4 D5 D6 D7
10 kΩ
mega32-56
B0 B1 B2 B3 B4 B5 B6 B7 Rst Vcc Gnd Osc Osc D0 D1 D2 D3 D4 D5 D6
A0 A1 A2 A3 A4 A5 A6 A7 Aref Gnd AVcc C7 C6 C5 C4 C3 C2 C1 C0 D7
mega32