Introduction:

This demo gives you an idea about internal on-chip ADC in 10 bit mode with variable reference. A 2 line by 16 characters LCD is used to display the digital value of the input analog voltage.

Hardware:

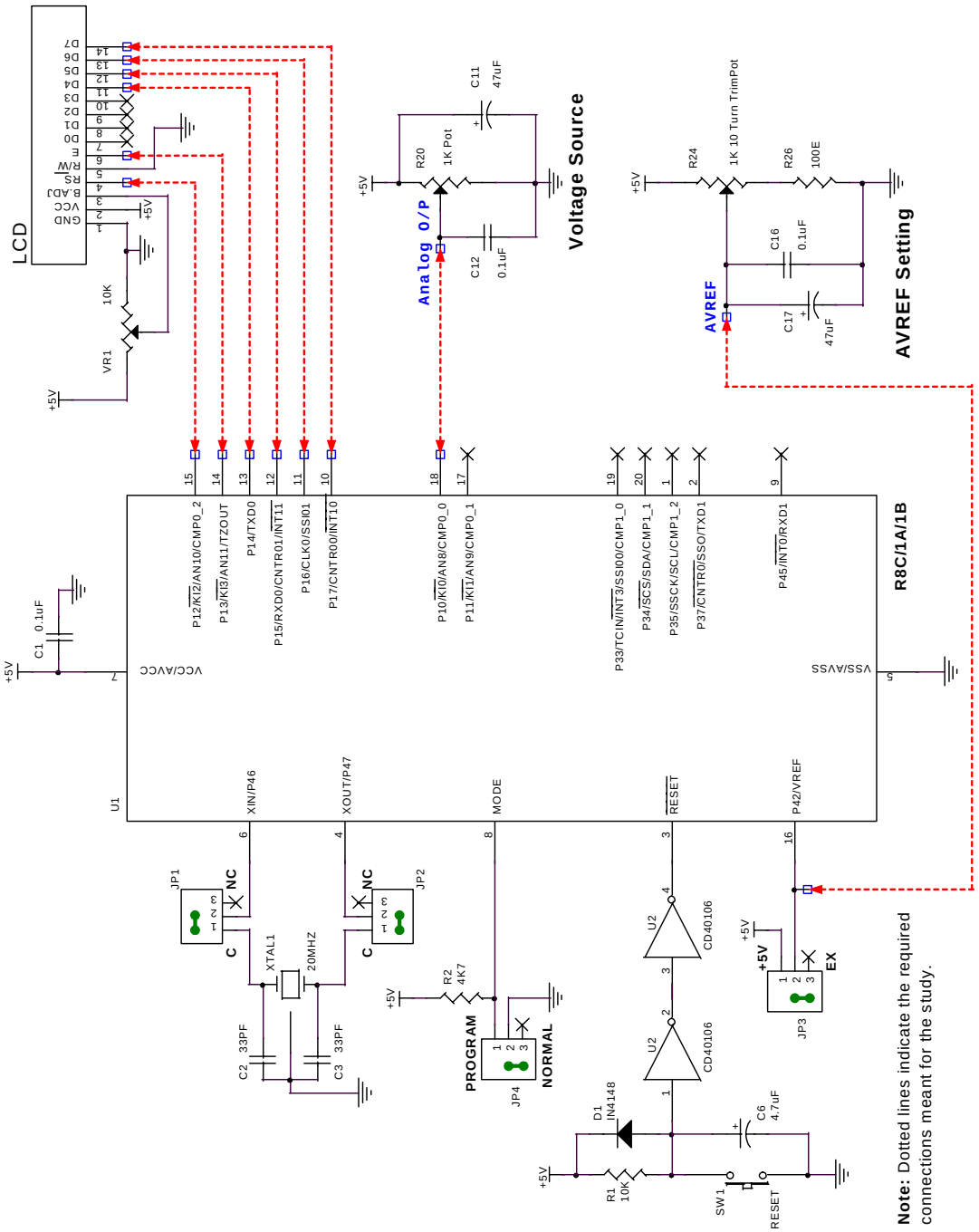
A 2 line by 16 characters LCD is used to display the 10 bit digital value read from the ADC. A variable reference voltage is used to give either 3V or 5V to Vref pin of the micon. Another variable analog voltage source is used to give a variable analog voltage to channel 8 of ADC from 0 to 3V or 0 to 5V.

Port lines P12 and P13 are used to control LCD and connected to RS and E pins of LCD. The R/W pin of LCD is connected to ground to select always write operation. The port lines P14 to P17 are connected to upper data bus D4 to D7 of LCD to send both data and command.

The first variable analog voltage source with the name "AVREF SETTING" is used to give variable reference voltage to Vref pin.

The second variable analog voltage source with the name "VOLTAGE SOURCE" is used to give variable voltage to input of ADC at the channel 8.

Circuit:


LCD
GND
VCC
R/S
R/W
E
D0
D1
D2
D3
D4
D5
D6
D7
10K
VR1
+5V
Analog O/P
R20
1K Pot
C11
47uF
C12
0.1uF
Voltage Source
R24
1K 10 Turn TrimPot
R26
100E
C16
0.1uF
C17
47uF
AVREF
AVREF Setting
C1
0.1uF
U1
R8C/1A/1B
VCC/AVCC
VSS/AVSS
XIN/P46
XOUT/P47
MODE
RESET
P42/VREF
P12/KI2/AN10/CMP0_2
P13/KI3/AN11/TZOUT
P14/TXD0
P15/RXD0/CNTR01/INT11
P16/CLK0/SSI01
P17/CNTR00/INT10
P10/KI0/AN8/CMP0_0
P11/KI1/AN9/CMP0_1
P33/TCIN/INT3/SSI00/CMP1_0
P34/SCS/SDA/CMP1_1
P35/SSCK/SCL/CMP1_2
P37/CNTR0/SSO/TXD1
P45/INT0/RXD1
JP1
JP2
NC
C
XTAL1
20MHZ
C2
33PF
C3
33PF
R2
4K7
PROGRAM
NORMAL
JP4
U2
CD40106
JP3
EX
D1
IN4148
R1
10K
C6
4.7uF
SW1
RESET
Note: Dotted lines indicate the required connections meant for the study.

Connections:

1. Connect port lines P12 and P13 to RS and E pins of LCD. Connect “GND” to R/W pin of LCD. Connect port lines P14 to P17 to D4 to D7 of LCD.
2. Connect the variable analog voltage reference (AVREF) to Vref pin of micon.
3. Connect the output of the variable analog voltage source (ANALOG O/P) to channel 8 (port line P10) of micon.

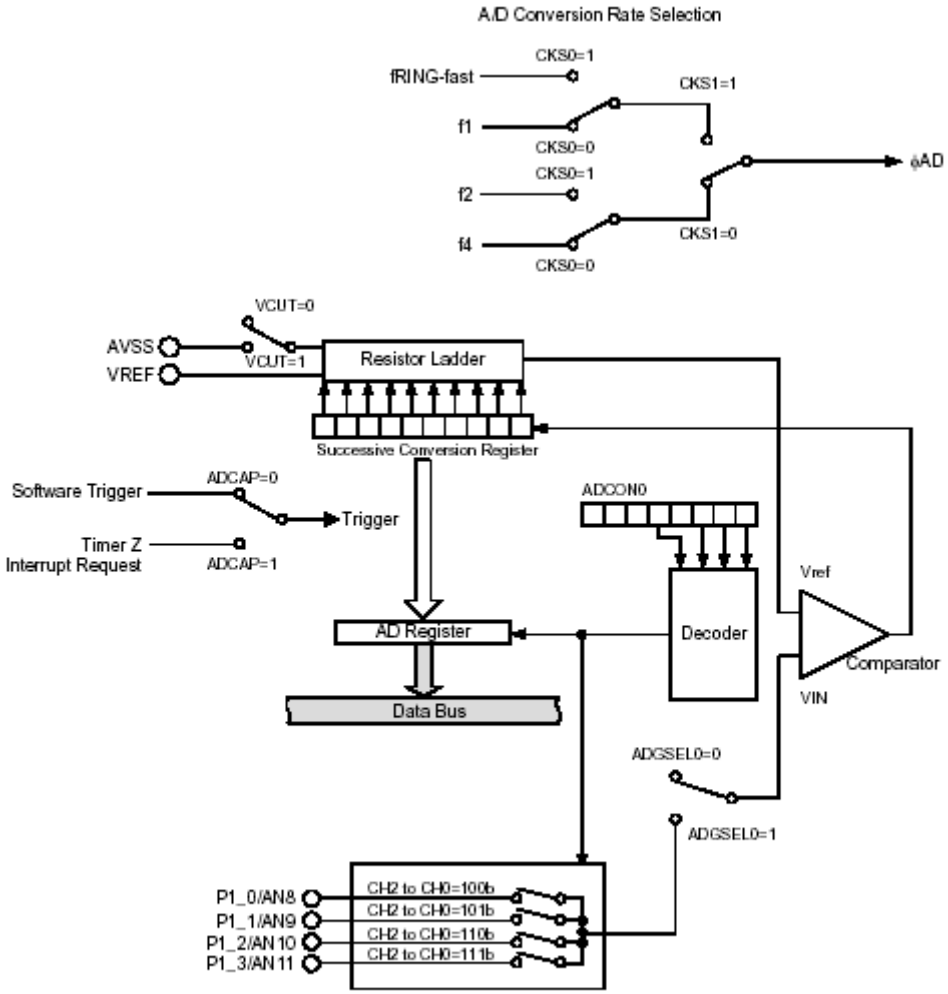
Functional Description:

The A/D converter consists of one 10-bit successive approximation A/D converter circuit with a capacitive coupling amplifier. The analog inputs share the pins with P10 to P13. Therefore, when using these pins, make sure the corresponding port direction bits are set to “0” (input mode). When not using the A/D converter, set the VCUT bit to “0” (Vref unconnected), so that no current will flow from the VREF pin into the resistor ladder, helping to reduce the power consumption of the chip. The result of A/D conversion is stored in the AD register. Performance of the A/D converter is tabulated below:

Item	Performance
A/D Conversion Method	Successive approximation (with capacitive coupling amplifier)
Analog Input Voltage(1)	0V to Vref
Operating Clock ϕAD(2)	4.2V ≤ AVCC ≤ 5.5V f1, f2, f4 2.7V ≤ AVCC < 4.2V f2, f4
Resolution	8 bit or 10 bit is selectable
Absolute Accuracy	AVCC = Vref = 5V • 8-bit resolution ±2 LSB • 10-bit resolution ±3 LSB AVCC = Vref = 3.3 V • 8-bit resolution ±2 LSB • 10-bit resolution ±5 LSB
Operating Mode	One-shot and repeat modes(3)
Analog Input Pin	4 pins (AN8 to AN11)
A/D Conversion Start Condition	• Software trigger Set the ADST bit in the ADCON0 register to “1” (A-D conversion starts) • Capture Timer Z interrupt request is generated while the ADST bit is set to “1”
Conversion Rate Per Pin	• Without sample and hold function 8-bit resolution: 49ϕAD cycles, 10-bit resolution: 59ϕAD cycles • With sample and hold function 8-bit resolution: 28ϕAD cycles, 10-bit resolution: 33ϕAD cycles

Notes: (1) Does not depend on use of sample and hold function. (2) The frequency of ϕAD must be 10 MHz or less. When Vcc is less than 4.2V, ϕAD must be fAD/2 or less by dividing fAD. Without sample and hold function, the ϕAD frequency should be 250 kHz or more. With the sample and hold function, the ϕAD frequency should be 1 MHz or more. (3) In repeat mode, only 8-bit mode can be used.

Block Diagram of ADC:



CH0 to CH2, CKS0 : Bits in ADCON0 register
CKS1, VCUT: Bits in ADCON1 register

One-shot Mode:

In one-shot mode, the input voltage on one selected pin is data converted once. The specifications of one-shot mode are listed below:

Item	Specification
Function	The input voltage on one selected pin by the CH2 to CH0 bits is A/D converted once
Start Condition	• When the ADCAP bit is set to "0" (software trigger), set the ADST bit to "1" (A-D conversion starts) • When the ADCAP bit is set to "1" (capture), Timer Z interrupt request is generated while the ADST bit is set to "1"
Stop Condition	• A/D conversion completes (ADST bit is set to "0") • Set the ADST bit to "0"
Interrupt Request Generation Timing	A/D conversion completes
Input Pin	Select one of AN8 to AN11
Reading of A/D Conversion Result	Read AD register

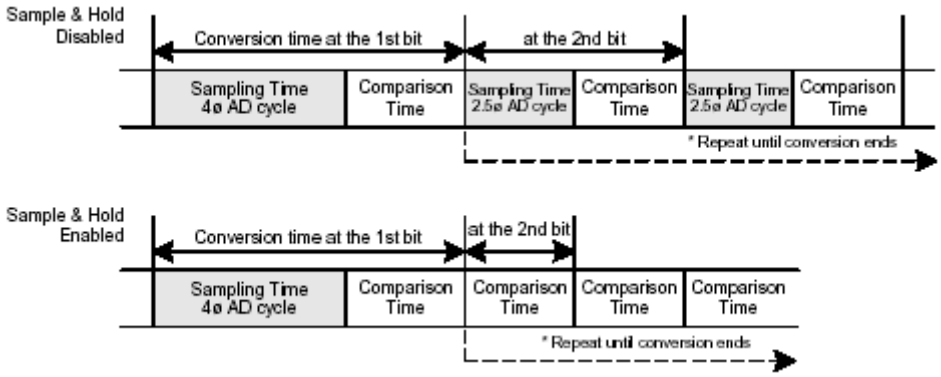
Repeat Mode:

In repeat mode, the input voltage on one selected pin is data converted repeatedly. The specifications of repeat mode are listed below:

Item	Specification
Function	The Input voltage on one pin selected by CH2 to CH0 and ADGSEL0 bits is A/D converted repeatedly
Start Condition	• When the ADCAP bit is set to "0" (software trigger) Set the ADST bit to "1" (A-D conversion starts) • When the ADCAP bit is set to "1" (capture) Timer Z interrupt request is generated while the ADST bit is set to "1"
Stop Condition	Set the ADST bit to "0"
Interrupt Request Generation Timing	Not generated
Input Pin	Select one of AN8 to AN11
Reading of A/D Conversion Result	Read AD register

Sample and Hold:

If the SMP bit in the ADCON2 register is set to “1” (with sample-and-hold), the conversion speed per pin is increased to 28 ØAD cycles for 8-bit resolution or 33 ØAD cycles for 10-bit resolution. Sample and-hold is effective in all operation modes. Select whether or not to use the sample-and-hold function before starting A/D conversion. When performing the A/D conversion, charge the comparator capacitor inside the microcomputer. The A/D conversion timing diagram is shown below:



Registers Used:

PD1 - Port 1 Direction Register
ADCON0 - ADC Control register 0
ADCON1 - ADC Control register 1
ADCON2 - ADC Control register 2

Port Direction Register:

Symbol	Address	After Reset
PD1	00E3h	00h
PD3	00E7h	00h
PD4	00EAh	00h

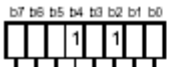
Bit Symbol	Bit Name	Function	RW
PDi_0	Port Pi0 Direction Bit	0 : Input mode (Functions as an input port)	RW
PDi_1	Port Pi1 Direction Bit		RW
PDi_2	Port Pi2 Direction Bit	1 : Output mode (Functions as an output port)	RW
PDi_3	Port Pi3 Direction Bit		RW
PDi_4	Port Pi4 Direction Bit		RW
PDi_5	Port Pi5 Direction Bit		RW
PDi_6	Port Pi6 Direction Bit		RW
PDi_7	Port Pi7 Direction Bit		RW

NOTES :

1. Nothing is assigned to the PD3_0 to PD3_2 and PD3_6 bits in the PD3 register. When writing to the PD3_0 to PD3_2 and PD3_6 bits , write "0" (input mode). When read, its content is "0".
2. Nothing is assigned to the PD4_0 to PD4_4, PD4_6 and PD4_7 bits in the PD4 register. When writing to the PD4_0 to PD4_4, PD4_6 and PD4_7 bits in the PD4 register, write "0" (input mode). When read, its content is "0".

PD1 is set to H'FC to select the port lines P12 to P17 as output lines to control the LCD.

AD Control Register 0:



Symbol	Address	After Reset
ADCON0	00D6h	00000XXXb

Bit Symbol	Bit Name	Function	RW
CH0	Analog Input Pin Select Bit(2)	b2 b1 b0 1 0 0 : AN8 1 0 1 : AN9 1 1 0 : AN10 1 1 1 : AN11 Other than above : Do not set	RW
CH1			RW
CH2			RW
MD	A/D Operation Mode Select Bit(3)	0 : On-shot mode 1 : Repeat mode	RW
ADGSEL0	A/D Input Group Select Bit	0 : Disabled 1 : Enabled (AN8 to AN11)	RW
ADCAP	A/D Conversion Automatic Start Bit	0 : Starts in software trigger (ADST bit) 1 : Starts in capture (Requests Timer Z interrupt)	RW
ADST	A/D Conversion Start Flag	0 : Disabes A/D conversion 1 : Starts A/D conversion	RW
CKS0	Frequency Select Bit 0	[When CKS1 in ADCON1 register = 0] 0 : Select f4 1 : Select f2 [When CKS1 in ADCON1 register = 1] 0 : Select f1(4) 1 : fRING-fast	RW

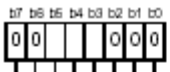
NOTES :

1. If the ADCON0 register is rewritten during A/D conversion, the conversion result is indeterminate.
2. CH0 to CH2 bits are enabled when the ADGSEL0 bit is set to "1". After setting the ADGSEL0 bit to "1", write to the CH0 to CH2 bits.
3. When changing A/D operatio mode, set the analog input pin again.
4. Set øAD frequency to 10MHz or below.

The register ADCON0 is loaded with the data H'84 to select one shot mode, channel 8 and clock as fad/2

.

AD Control Register 1:



Symbol: ADCON1 | Address: 00D7h | After Reset: 00h

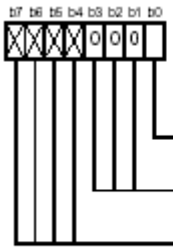
Bit Symbol	Bit Name	Function	RW
— (b2-b0)	Reserved Bit	Set to "0"	RW
BITS	8/10-bit Mode Select Bit(2)	0 : 8-bit mode 1 : 10-bit mode	RW
CKS1	Frequency Select Bit 1	Refer to a description of the CKS0 bit in the ADCON0 register function	RW
VCUT	Vref Connect Bit(3)	0 : Vref not connected 1 : Vref connected	RW
— (b6-b7)	Reserved Bit	Set to "0"	RW

NOTES :

1. If the ADCON1 register is rew ritten during A/D conversion, the conversion result is indeterminate.
2. Set the BITS bit to "0" (8-bit mode) in repeat mode.
3. When the VCUT bit is set to "1"(connected) from "0" (not connected), w ait for 1µs or more before starting A/D conversion.

The data H'28 is moved to ADCON1 register to select 10 bit mode and external Vref.

AD Control Register 2:



Symbol: ADCON2 | Address: 00D4h | After Reset: 00h

Bit Symbol	Bit Name	Function	RW
SMP	A/D Conversion Method Select Bit	0 : Without sample and hold 1 : With sample and hold	RW
— (b3-b1)	Reserved Bit	Set to "0"	RW
— (b7-b4)	Nothing is assigned. When write, set to "0". When read, its content is "0".		—

NOTES :

1. When the ADCON2 register is rew ritten during A/D conversion, the conversion result is indeterminate.

The register ADCON2 is initialized with the data H'01 to enable sample and hold function.

Software Description:

ADC channel 8 is used to convert the given analog voltage and the generated digital value is displayed on the LCD.

After reset, the LCD is configured in 4 bit mode and ADC is initialized in one shot mode with 10 bits and also sample and hold function enabled. Afterwards the program will read the input analog voltage from channel 8 of ADC and display the results on LCD. After waiting for small delay the process is repeated from reading channel 8 of ADC.

We can study the ADC in two possibilities. One is with 5V reference and other one is with 3V reference as discussed below:

Case 1:

Keeping the reference voltage at 5.00V, the ADC generates a digital equivalent range from H'000 to H'3FF for the input variation of 0 to 5V.

The Voltage sensitivity is 4.88mV per bit. (5V/1024)

Case 2:

When the reference, Vref, is made equal to 3.00V, the digital output value for the input range of 0 to 3.00V is H'000 to H'3FF.

The Voltage sensitivity is 2.92mV per bit. (3V/1024)

The files used in this module are listed below:

Files	*Description*
Demo12.C	Main file for this module, will read and display the equivalent digital data for the input analog voltage.
R8C1A1B_FE_LCD_4Bit.C	LCD routines to initialize LCD, cursor on/off, display a message etc.
R8C1A1B_FE_LCD_4Bit.H	Declarations of functions in R8C1A1B_FE_LCD_4Bit.C

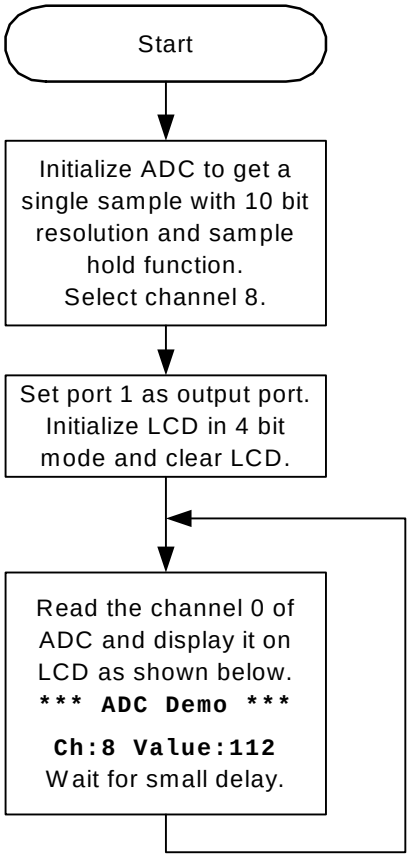
The functions in the file "**Demo12.C**" and short descriptions are listed below:

Functions	*Description*
main	Reads the digital data from channel 8 of ADC and displays the results on LCD. **Input**: None. **Output** : None.
MCUInitialize	Selects the external crystal oscillator as clock source for the CPU and other peripherals. **Input**: None. **Output** : None.
InitializeADC	Initializes the ADC in one shot mode with sample and hold function and 10 bit mode.Channel 8 is also selected. **Input**: None. **Output** : None.
ReadADC	Reads the 8th channel and returns the 10 bit digital value. **Input**: None. **Output** : Digital value.

The functions in the file "**R8C1A1B_FE_LCD_4Bit.C**" and short descriptions are listed below:

Functions	*Description*
DisplayLCD	Displays a message (16 Characters) on LCD on the given line number. **Input**: Line number and message string. **Output** : None.
DisplayLCD2Digit	Displays the given 2 digit number on LCD at given location. **Input**: Line number, character position and data. **Output** : None.
CursorON	Makes the cursor visible on LCD. **Input**: None. **Output** : None.
CursorOFF	Hides the cursor. **Input**: None. **Output** : None.
InitializeLCD	Initializes the I/O lines used by LCD and LCD in 4 bit mode. Clears the LCD. **Input**: None. **Output** : None.
WriteDataLCD	Write a data byte to LCD. **Input**: Data Byte. **Output** : None.
WriteCommandLCD	Write a command byte to LCD. **Input**: Command Byte. **Output** : None.

Program Flow:



Execute Demo:

After reset, the program will read and display the digital value of the analog voltage given at channel 8 on LCD as shown below:

"***** ADC Demo *****

Ch:8 Value:112 "

Study 1:

Set the reference (Vref) as 5.00V. The converted digital value for the input analog variation of 0 to 5V will be H'000 to H'3FF.

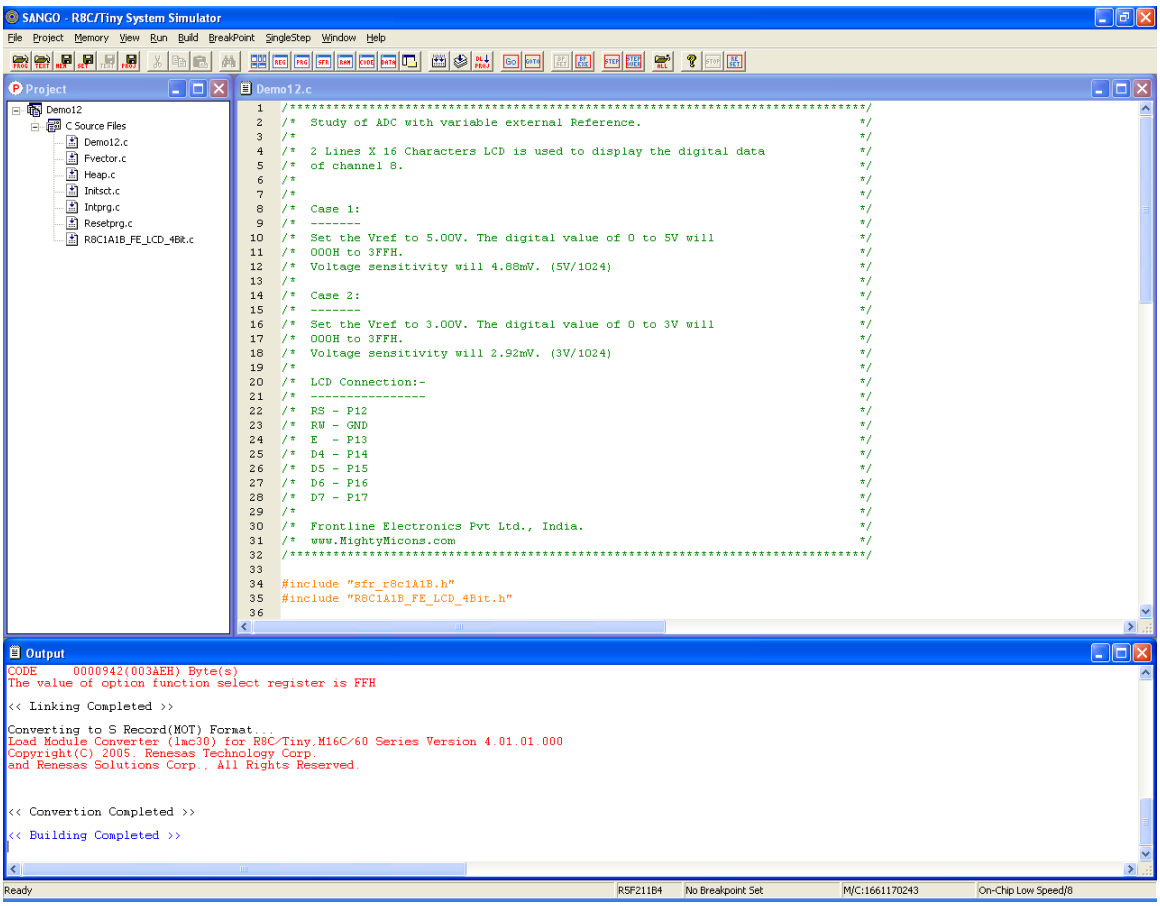
Study 2:

With the reference, Vref, as 3.00V the converted digital value meant for analog variation of 0 to 3V will H'000 to H'3FF.

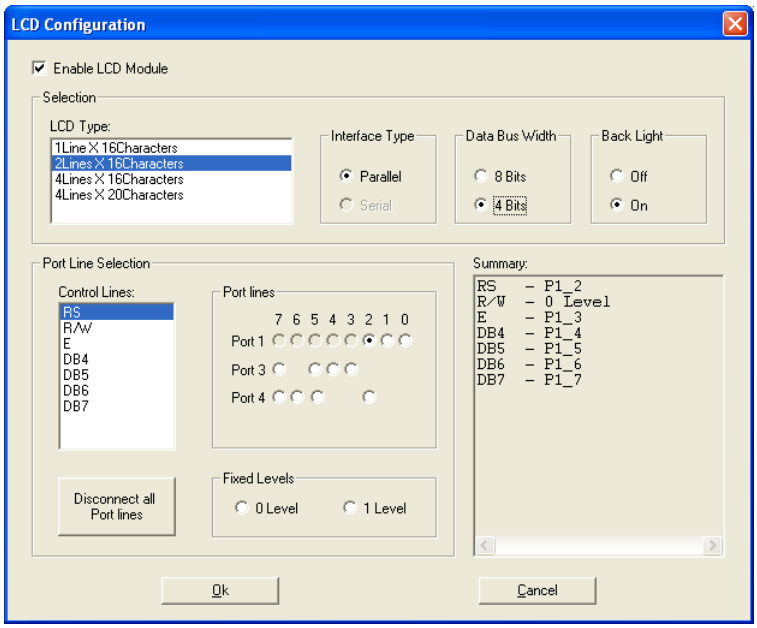
Use Topview Simulator to Verify the Design.

Open the project Demo12 in the R8C/Tiny System Simulator using **Open Project** option from **Project menu**. The project window opens up along with the Demo12.c file. Use **Build** option from **Build** menu to compile the project. An output window captures the compiler ouput.

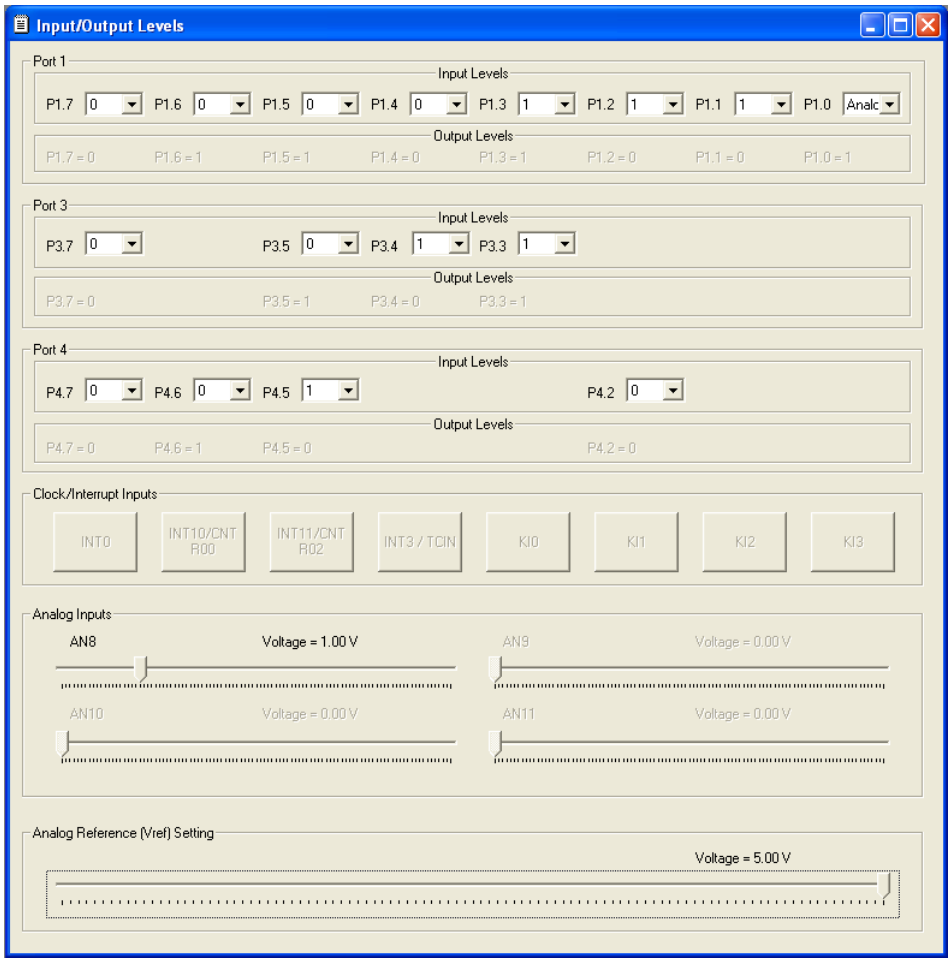
Use **Project** -> **Download Project** from main menu to download the .mot file into the simulator's memory for simulation.



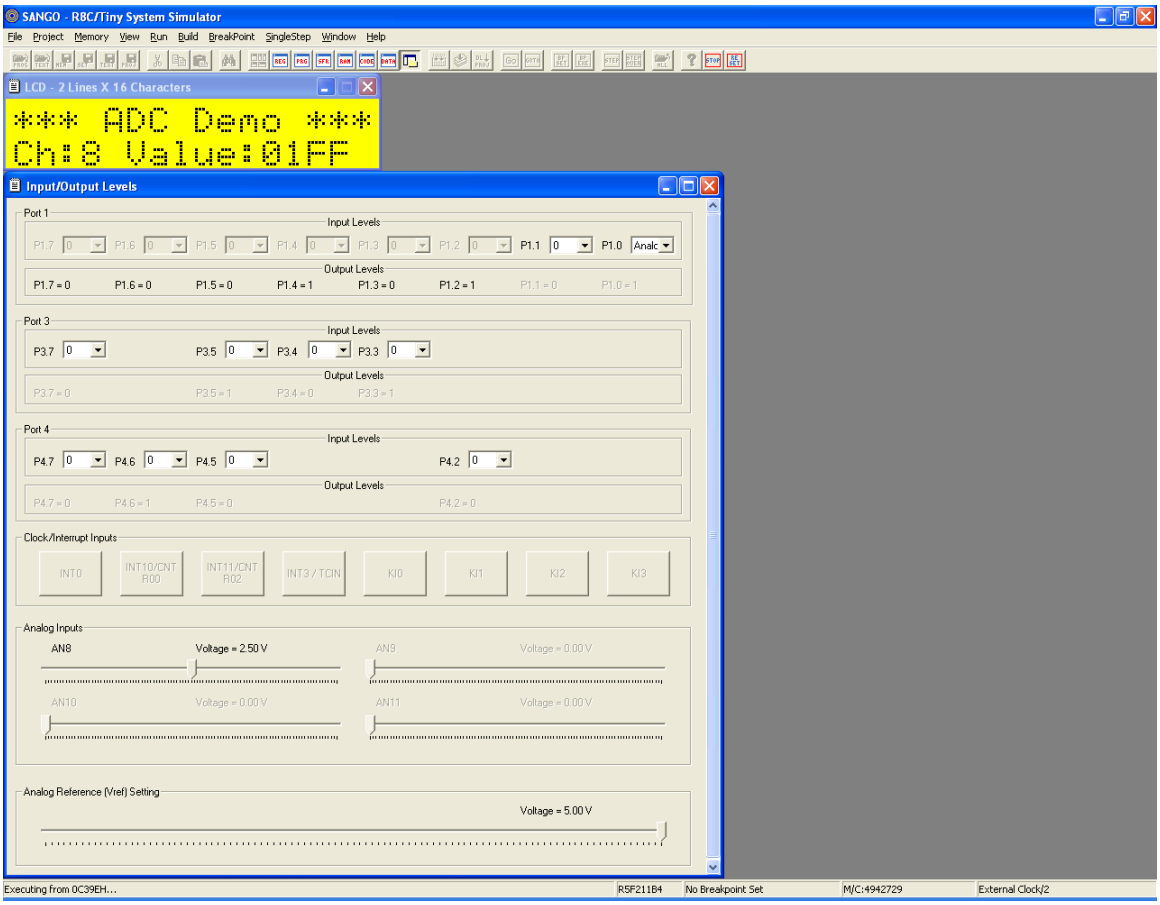
Do the settings to the LCD modules as shown. Connect LCD control and data lines to port lines P12 to P17.



Open I/O Window and connect the variable analog voltage source to P10(AN8) by setting “Analog” option in input level setting. Set Vref to 5V using “Analog Reference(Vref) Setting”.



Then open the LCD window and arranage the LCD window and I/O window as shown below.



Down load the program using **Download Project** command in **Project** menu.

Run the program using **Go** command in **Run** menu. The message,

"* ADC Demo ***
Ch:8 Value:01FF "**

will be displayed in LCD.

You can change the analog input voltage to AN8 and also the Vref using I/O Window.