LAB 5-1
PROGRAMMING USING ADC

OBJECTIVE:

- Understand and use the ADC of AVR.
- Understand how to use the ADC for measurement.

REFERENCES:

- Experiment Experiment guide, chapters 11
- AN2538-ADC-of-megaAVR-in-SingleEnded-Mode-00002538A.pdf
- AVR120: Characterization and Calibration of the ADC on an AVR

EXPERIMENT 1: MEASURING SINGLE-ENDED SIGNALS

a) Connect the ADC_VR1 and ADC_VR2 signals from header J86 to the ADC0 and ADC1 inputs. Connect UART0 to the RS232 module and connect the USB-Serial cable to the computer. Connect ADC_VR1 and ADC_VR2 to the test points on header J56. Make sure not to connect them to the GND pins on the header. Write a program to perform the following tasks:

b) Select the V_{REF} voltage as the internal V_{CCA} voltage. Initialize UART with self-selected configuration. (Note: configure the Hercules software on the computer in a similar way). Right-click on the Hercules screen to select HEX Enable.

c) Write a program to sample the signal input to ADC0 and send it to the computer using UART0 with the following transmission frame every 1 second. The 1-second delay can be achieved using either a delay function or a timer.

   0x55 ADCH ADCL 0xFF

d) Change the voltage applied to ADC0, measure it using a VOM, and compare it with the sampled ADC result. Fill in the table in the report.

e) Connect an LCD to one of the AVR ports. Add to the existing program the functionality to calculate the input voltage and display it on the LCD.

f) Change the reference voltage to the internal 2.56V reference. Repeat steps c, d, and e, assuming the reference voltage is accurately set to 2.56V.

g) Measure the voltage on the VREF pin (header J57) using a VOM.

EXPERIMENT 2: MEASURING OFFSET ERROR AND GAIN ERROR

a) Calculate the offset error and gain error of the ADC.
b) Rewrite the program with the requirements mentioned in question e of exercise 1, using the calibrated ADC. Vref = VCCA. Send the calibrated ADC values to the computer and display the measured voltage values on the LCD.
(Note: Please refer to the documentation "AVR120: Characterization and Calibration of the ADC on an AVR" for detailed instructions and guidelines on the calibration process.

EXPERIMENT 3: MEASURING ADC IN BIAS MODE

a) Calibrate channel VR1 to a voltage level of 2.5V and connect it to ADC0.
b) Write a program to initialize the ADC in bias mode with two input channels, ADC0 and ADC1, amplification factor of 10, and a reference voltage of 2.56V. Start the ADC in FreeRunning mode.
c) Write a program to display the voltage value of VR1 on the LCD and send the ADC measurement results to the computer every 1 second, as described in experiment 1.

EXPERIMENT 4:MEASURING OFFSET ERROR AND GAIN ERROR IN BIAS MODE

a) Connect both ADC1 and ADC0 to the voltage ADC_VR1. Adjust this voltage to 1V and record the measured ADC value. This value represents the offset error.
b) From the offset error value, calculate the gain error using Table 4.
c) Rewrite the program from question c in exercise 3, using the calibrated ADC value.

EXPERIMENT 5: MEASURING TEMPERATURE USING MCP9701

a) Connect the sensor to header J73.
b) Connect the voltage signal V_TEMP on header J18 to ADC0.
c) Write a program to measure the voltage value of V_TEMP with the calibration parameters as in experiment 1, calculate the temperature value, and display it on the LCD.

LAB REPORT

Class group: *Group:*
Subject:

EXPERIMENT 1:

1. Answering the questions:
   a. In Single Conversion mode, how do you start a sampling cycle and check when it completes?
   b. How do you select an ADC channel?
   c. Does Atmega324 have an internal temperature measurement channel?
   d. What is the formula to calculate the input voltage from the ADC when $V_{REF}=V_{CCA}$?
   e. What is the formula to calculate the input voltage from the ADC when $V_{REF}=2.56V$?
   f. Record the ADC value compared to the measurement result from the measuring instrument. Calculate the voltage value based on the ADC value with $V_{REF}=V_{CCA}$.

V_{ADC0} (V)	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
ADCH-ADCL											
ADCH-ADCL (Theoretical)											
Error (LSB)											

Bảng 1

   g. Repeat step f with $V_{REF}=2.56V$. Compare the calculation formula and the error with step e.

V_{ADC0} (V)	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
ADCH-ADCL											
ADCH-ADCL (Theoretical)											
Error (LSB)											

Bảng 2

   h. Repeat step g with V_{REF} being the value measured from a VOM.

LAB REPORT

Class group: *Group:*
Subject:

V_{REF} = ...

V_{ADC0} (V)	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
ADCH-ADCL											
ADCH-ADCL (Theoretical)											
Error (LSB)											

Bảng 3

2. Program source code with comments

EXPERIMENT 2:

1. Answering the questions:
   a. What are the types of errors for an ADC?
   b. What is offset error?
   c. What is gain error?
   d. What are the units of measurement for offset error and gain error?
   e. Using the results from Table 1, taking two measurement points at V_{in} = 1 V and V_{in} = 4.5V, calculate the offset error and gain error.
2. Measurement and Calculation:
   a. The measured ADC values corresponding to the input channels.

V_{ADC0} (V)	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
ADCH-ADCL (calibrated)											
ADCH-ADCL (Theoretical)											
Error (LSB)											

Bảng 4

   b. Program source code with comments

.....

EXPERIMENT 3:

1. Answering the questions:

a. In differential mode, what is the voltage range within which the input voltages of the ADC oscillate?
b. When selecting the signal pair ADC0, ADC1 with a gain of 10, V_{REF}=2.56V, and V_{ADC0} = 2.5V, what is the measurement range for ADC1?
c. Fill in the measured values and calculate the input voltage based on the theoretical information.

$V_{ADC1} - V_{ADC0}$ (mV)	0	50	100	150	200	250	-50	-100	-150	-200	-250
ADCH-ADCL											
Values											

Bảng 5

2. Program source code with comments

.....

EXPERIMENT 4:

1. Answering the questions:
   a. How to measure offset error in differential mode?
   b. Results obtained after calibration.chỉnh

$V_{ADC1} - V_{ADC0}$ (mV)	0	50	100	150	200	250	-50	-100	-150	-200	-250
ADCH-ADCL											
Values											

2. Program source code with comments

.....

EXPERIMENT 5:

1. Answering the questions:
   a. According to the datasheet, what is the thermal coefficient of the MCP9701 sensor ?
   b. If $V_{REF} = V_{CCA}$ is used, what is the measurement range of the circuit? What is the resolution of the measurement circuit in degrees Celsius ?
   c. If V_{REF} = 2.56V is used, what is the measurement range of the circuit? What is the resolution of the measurement circuit in degrees Celsius ?

d. If we use the ADC in differential mode, input a voltage of 400 + 19.53*20 (mV) to ADC0, and connect the output of MCP9751 to ADC1, with a gain of 10 and V_{REF}=2.56V, what is the measurement range and resolution of the measurement circuit ?

2. Program source code with comments

.....