EE128: Data Acquisition, Instrumentation and Process Control
University of California, Riverside

Lab 4: Analog to Digital Conversion and Display

Spring 2019

Objective

To get familiar with the concept of A/D conversion and 7-segment displays.

References

- Dragon12-JR Trainer User's Manual
- Freescale MC9S12DG256 Device User Guide
- Freescale HCS12 Core User Guide
- Reference Guide for D–Bug12 Version 4.x.x
- ATmega328 datasheet
- Online Arduino Reference (https://www.arduino.cc/reference/en/)

Equipment

- PC running MS Windows
- Digital Multi-Meter (DMM)
- Dragon12-JR 9S12DG256 EVB
- Arduino Uno
- **Breadboard** (you need to bring one)

Parts

- 2 each 7-segment display, common cathode
- 1 each 10 kΩ potentiometer (or equivalent to create an adjustable voltage divider circuit)
- 2 each 390Ω x 8, independent resistor network (DIP)

Software

- Freescale CodeWarrior for HC12 v5.1
- Arduino IDE
- RealTerm (terminal emulation program)
    - If you don't like RealTerm, try TeraTerm, which is another serial terminal with a file transmission capability.

Background

In this lab, we will be working with the 9S12DG256 A/D converter. Please read the appropriate background material on this module, like the Lecture Note of Analog to Digital and Digital to Analog Conversion and the MC9S12DG256 reference manual.

Lab Exercise

In this experiment, we will create a simple voltage divider circuit using the potentiometer, and then measure the voltage with the ADC module on the 9S12DG256. The ADC module should be configured for a range of 0 to 5 volts. Dedicated power supply and ground are required for the ADC in order to isolate the sensitive analog circuitry from the normal levels of noise present on the MCU. **V_{DDA}** (Pin 83) and **V_{SSA}** (Pin 86) are the power supply and ground input pins for the ADC. These pins can also provide the reference for the internal voltage regulator.

In your code, make sure to wait for at least 10 msec after turning on the A/D converter to allow the analog circuitry to settle.

1. The 9S12 microcontroller will translate the voltage and output the results. The voltage should be displayed on two 7-segment LED displays, where the voltage reading will range from **0.0** to **5.0** volts.

   Make sure your program is accurate and concise, and is a similar implementation of the following pseudo-code:

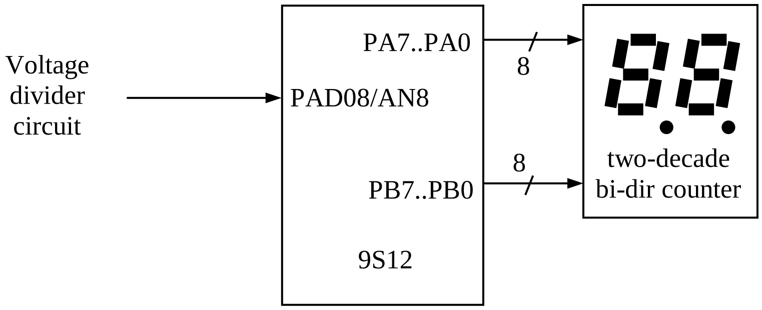
   ```
   Configure Port A to be an 8-bit output port;
   Configure Port B to be an 8-bit output port;

   Initialize Port A;
   Initialize Port B;

   Turn on ADC;
   Wait at least 10 milliseconds for initialization;
   Configure ADC for 8-bit resolution;

   While (1)
   {
       Wait for the A/D conversion completion flag in status register;
       Read the corresponding A/D result register;
       Send the result to the corresponding LED display;
   }
   ```

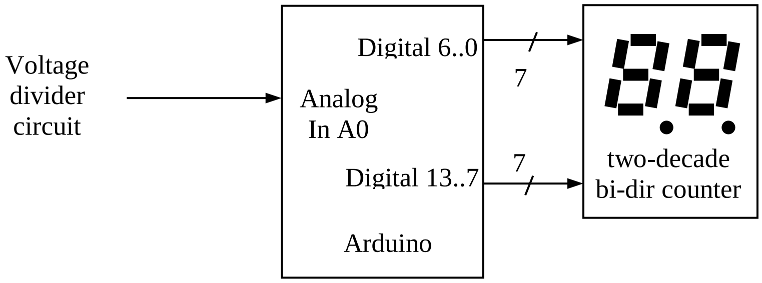
2. Repeat Step 1, but at this time configure the A/D converter to **10-bit resolution** mode. How much precision was gained in your output?

3. Repeat Step 1, but at this time, use the **Arduino** board. The Arduino has 14 digital input/output pins and has an ADC with 10-bit resolution. Details can be found on page 250 of the datasheet of the ATmega328, which is the microcontroller chip of the Arduino board (the datasheet is available at ilearn). Since there are only 14 digital input pins and we do not use any hardware decoder, we can use 7 digital I/O pins for each 7-segments LED display.

   For the schematic drawing with Cadence, you will need a library for ATmega328 (ATMEGA328P-AU.OLB). You can find it from the zipped library uploaded in the course website. Download and unzip it, and copy the library files to a relevant directory (e.g., the PSpice library folder: <cadence_directory>\tools\capture\library\pspice), and reload all PSpice libraries in Cadence Capture CIS.

Block Diagram





Questions

1. What is the resolution (minimum distinguishable input voltage) of a 10-bit ADC with $V_{RH} = 8V$ and $V_{RL} = 2V$?

2. Suppose that there is a 10-bit A/D converter with $V_{RL} = 2V$ and $V_{RH} = 8V$. Find the corresponding voltage values for the A/D conversion results of 5, 110, 250 and 800.

3. Assume that we have a 12-bit Successive Approximation ADC, driven by a 4 KHz clock. What is the minimum conversion time of one sample with this ADC? Express your answer in seconds.

Demonstration

Show Steps 1, 2, and 3 by changing the potentiometer by hand.

Lab Demo (50 points)

Demonstrate your working system to the TA and get a confirmation of completion

Lab Report (50 points)

Make sure you include the following in your report:

1. Abstract (a short paragraph stating the objectives and accomplishments)
2. Experiment system specification (what has been designed and implemented) – **10 points**
   - Flowchart diagram (show how your system works)
   - Photos of your boards and circuits

3. Hardware design – **10 points**
    - Draw schematics of your own; do not copy and paste from the handout
4. Software design – **10 points**
    - High level description of the software
    - Program listing (including comments)
5. Technical problems encountered, and how they are solved
6. Answers to the questions – **10 points**
7. Conclusion
    - A very short concluding remark
    - Summary of the contributions of each member