CMPEN 472, The Pennsylvania State University

Homework 11: Analog Signal Acquisition with HCS12

Due: Nov. 29, 2023 11:30pm

Objective

To learn Analog Signal Acquisition programming with timer module interrupt.

Textbook Reading:

1. MC9S12C Family Data Sheet: Chapters 5, 8, 13, and 15

Instruction

1. Write a program to **generate** (Homework 10) and **aquire** analog signal through the HCS12 board (simulation) and display the analog signal values on a Terminal window while the digital clock is running on the background. That is, add a new command "adc" to Homework 10.

2. The analog signal acqusition function is based on the Timer Interrupt OC3 at the rate of 125usec (8000Hz). The Homework 11 program prints aquired analog wave data on the terminal connected to the HCS12, by sending the signal value in 8-bit unsigned integer numbers. One number is printed every 125usec and total 2048 numbers are printed for each analog wave acquisition command. At the same time, the digital clock is running and displayed on the 7-segment displays connected to the PORTB of the HCS12 board (same as Homework 10).

3. Copy the HW11 sample program file. Study it, assemble it, and run it on the HCS12 simulator. This program converts analog signal to digital data and transmits it in ASCII characters. This program is used to test the signal connections and ADC operation. You may use some parts of this program. Click here for the HW11 sample program - hw11samp4gSim.asm file. Also you will need to save the following two files [right click and select 'Save Link As...' option] to your **project folder** for simulating ADC: ADCcon7.cmd and WAVEsn10.cmw files. These are the files for the CodeWarrior Debugger/Simulator analog signal generator - to be virtually connected to the ADC input pin. Please follow the Additional Simulation Guide to connect the ADC input pin to a signal generator.)

4. Additional analog signal acqusition rules to the previous Homework 10 are:

    1. Command adc: analog signal acqusition, for total 2048 points
    2. Print one signal sample (an 8-bit unsigned integer) every 125usec (8000Hz sampling rate)
    3. Capture the terminal output into a file, so the wave can be plotted with Excel or MATLAB
    4. Show 'HW11> ' prompt and echo print user keystrokes until the Enter/Return key
    5. In case of an invalid input format, print error message on the next line: 'Invalid input format'
    6. 24 hour digital clock (same as Homework 8), with h, m, and s commands to display hour, minutes, or second
    7. Clock commands ("t", "q", "h", "m", and "s" commands) entered on the terminal screen (same as Homework 8)
    8. Time display: ONLY on the 7-segment displays on PORTB, UPDATE the time display every one second
    9. Use Real Time Interrupt (RTI) feature to keep the time
    10. Waveform display: on the terminal screen (ASCII text print, decimal integer number)

11. Clock **must** be running during the analog signal acqusition or signal generation
12. Acquired signal data display: on the terminal screen (ASCII text print, decimal number)

5. The Terminal display should look something like the following:

```
HW11>
HW11> adc
      analog signal acqusition ....

HW11> gw
      sawtooth wave generation ....

HW11> gw2
      sawtooth wave 100Hz generation ....

HW11> gt
      triangle wave generation ....

HW11> gq
      square wave generation ....

HW11> gq2
      square wave 100Hz generation ....

HW11> ab
      Invalid input format

HW11> gtx
      Invalid input format

HW11> $gw
      Invalid input format

HW11> gw 2
      Invalid input format

HW11>
HW11> t 12:34:56
HW11>
HW11> t 00:00:00
HW11>
HW11> t 23:59:59
HW11>
HW11> t 25:09:30
      Error> Invalid time format. Correct example => 00:00:00 to 23:59:59
HW11>
HW11> t 00:25:75
      Error> Invalid time format. Correct example => 00:00:00 to 23:59:59
HW11>
HW11> t 1:A2
      Error> Invalid time format. Correct example => 00:00:00 to 23:59:59
HW11>
HW11> s 3:33
      Error> Invalid command. ("s" for 'second display' and "q" for 'quit')
HW11>
HW11> m 0
      Error> Invalid command. ("m" for 'minute display' and "q" for 'quit')
HW11>
HW11> q
      Analog to Digital Conversion, Wave Generator, and Clock stopped and
      Typewrite program started.  You may type below.
```

6. The program is outlined as follows:

    1. Initialize.
    2. Your program starts from memory location $3100, data at $3000.
    3. The SCI port Terminal baud rate set to 1.5M baud (assuming 24MHz BUS CLOCK).
    4. Print the user guiding messages:
       (1) saving Terminal output to file,
       (2) run analog signal command - connect an analog signal to ADC pin 7,
       (3) when ready, enter 'adc' command to start the 2048 point ADC data capture.
    5. For the analog signal acqusition, start the **Timer Module Channel 3 Output Compare** interrupt generation at every 125usec (8KHz rate).
       Each time the Output Compare interrupt occurs, carry out the following tasks:

        1. Service the Output Compare (OC) register (update the counter-compare number) for the next interrupt.
           Also clear the OC interrupt flag.
        2. Pick up the ADC result (from previous conversion) from the ADC result register.
           Only the lower 8-bit of the ADC result should be picked up as the ADC result data.
           Start another single Analog-to-Digital conversion of the signal on the AN7 pin.
           The picked up result data must be converted to the ASCII characters in decimal number.
        3. Send the data (number) to the Terminal (SCI Port).

    6. Repeat for 2048 ADC result data - until the ADC conversion count to be 2048
    7. Print 'Finished' when the 2048 data transmission completes.

7. Additional comments on the Homework 11 program are as follows:

    1. The 'adc' command of the Homework 11 program must send the 8-bit number in decimal (with ASCII conversion) to Terminal (SCI port).
    2. The sample program uses busy ADC wait for ADC completion. But your Homework 11 program
       must use the Timer Module Channel 3 Output Compare interrupt. Set 125usec (8KHz) interrupt rate for each ADC operation.
    3. Your Homework 11 program must do one ADC conversion at the rate of exactly 8KHz, 125usec a part. If the conversion rate (sampling time) is not consistent or missed, the acquired analog signal becomes distorted - this is very important.
    4. The sample program converts ADC input channel 7 signal. Also your Homework 11 program must convert ADC input channel 7 signal.
    5. The sample program does one conversion per Enter key hit, your Homework 11 program must do 2048 conversions per each 'adc' commend issued.

8. Check the plot and verify the signal frequency and any distortion. Use magnify feature to see the signal wave details. Identify one cycle of signal wave, check how many points are plotted. (for plotting, one may also use MS Excel)

9. Program Homework 11 such that the program allows you to aquire another set of 2048 point ADC data as follows:

    1. Open Terminal output file.
    2. Attache analog signal to AN7 pin
    3. Enter the 'adc' command.
    4. New set of data will be recorded into the 'RxData3.txt' file.

10. Once your Homework 11 program is finished, run it many times to test that it works. Change the analog signal wave frequency as well as the wave type as you test your Homework 11 program. Repeat the data acquisition and plotting.

11. Write a report of your Homework 11 program and your experiments. Your report must include the followings in addition to that of Homework 10:

    1. Cover sheet with course and your information.
    2. Sine wave plots. (Signal files: AWAVE100S.cmd and AWAVE100S.cmw for 100Hz)
    3. Square wave plots. (Signal files: AWAVE100Q.cmd and AWAVE100Q.cmw for 100Hz)
    4. Triangle wave plots. (Signal files: AWAVE100T.cmd and AWAVE100T.cmw for 100Hz)
    5. Mixed frequency sine wave plots. (Signal files: AWAVE200S.cmd and AWAVE200S.cmw for ?Hz and ??Hz)
    6. For each signal wave, plot full 2048pts and plot magnified 2 signal cycles. Note the signal shape difference among square, sign, triangle, and mixed waves. Identify one cycle of signal wave, and verify correct signal frequency by counting how many points are plotted in one cycle.
    7. Run FFT on the 2048 point signal wave data (each of Sine [S], Square [Q], Triangle [T], and Mixed [M] signal waves), and plot the FFT results. You will need to add X axis, the time of each sample point. You may use MATLAB (SciLab) FFT command. You should expect one frequency peak for S, Q, and T signals and multiple peaks for M (Mixed) signal. Use proper horizontal and vertical axis, and label them on your plots.
    8. Write the detailed explanation of each plot, and each experiments/operations.
    9. Be sure to include complete Homework 10 results too.

12. Create your report file. (You can capture any window on the screen by pressing 'Alt' and 'Print Screen' keys together. Once captured, you can paste the window picture into the .doc file by pressing 'Ctrl' and 'v' keys together.)

13. You will be sending both the report file and program source file for this homework.

14. Make your program user friendly by giving directions as to how to correctly use your program. Once your program is running, everything must be self explanatory to user at the Terminal.

15. Also, make your program 'fool-proof', never crash or stop based on wrong user response.

16. Be sure to put much comments so that grader and others can clearly and quickly understand your program. Comments are very important in assembly language programs.

17. You may want to see and check the Sample Grading Sheet for this homework.

18. Copy your 'main.asm' **program** file to 'cmpen472hw11_YourLastName.asm'. For example, mine will be 'cmpen472hw11_choi.asm'.
    Do not ZIP your 'cmpen472hw11_YourLastName.asm' file.

19. Name your Homework 11 **report** file to 'cmpen472hw11_YourLastName_RPT.doc'. For example, mine will be 'cmpen472hw11_choi_RPT.doc'.
    Do not ZIP your 'cmpen472hw11_YourLastName_RPT.doc' file.

20. Turn-in your Homework 11 program file and report file through Penn State CANVAS. Upload your files into the CANVAS Assignment's Homework submission. Be sure to select CMPEN 472 class and correct Homework number, and with correct file names.

Congratulations on your 11th CMPEN 472 homework completion!