ECE 362 Lab Verification / Evaluation Form

Experiment 9

Evaluation:

IMPORTANT! You must complete this experiment during your scheduled lab period. All work for this experiment must be demonstrated to and verified by your lab instructor *before the end* of your scheduled lab period.

STEP	DESCRIPTION	MAX	SCORE
DP 1	Function generator/oscilloscope setup	**1**	
DP 2	Demo program load/run, potentiometer verification	**1**	
DP 3	LPF cutoff frequency calculation/verification	**1**	
DP 4	Input waveform type/frequency trials	**4**	
SW 1	Software (completed during your scheduled lab period)	**8**	
SW 2	Input/output sampling frequency trials	**4**	
SW 3	Submission (completed following demonstration)	**4**	
TQ	Thought questions	**2**	
Bonus	Carefully print and label oscilloscope displays from trials	**5**	
	TOTAL	**25+**	

Signature of Evaluator: ____

Academic Honesty Statement:

IMPORTANT! Please carefully read and sign the Academic Honesty Statement, below. *You will not receive credit for this lab experiment unless this statement is signed in the presence of your lab instructor.*

"In signing this statement, I hereby certify that the work on this experiment is my own and that I have not copied the work of any other student (past or present) while completing this experiment. I understand that if I fail to honor this agreement, I will receive a score of ZERO for this experiment and be subject to possible disciplinary action."

Printed Name: ______________________ Class No. __ __ __ __ - __

Signature: ____________________________________ Date: _______

Experiment 9: Analog Signal Sampling and Reconstruction

Instructional Objectives

- To illustrate how analog signals can be sampled using the ATD and reconstructed using the PWM (used in conjunction with a low-pass filter)
- To illustrate the effects of input sampling rate and output sampling rate on the quality of signal reconstruction

Parts Required

- 2 x 16 LCD and 16-pin single-row header (previous experiment)
- GAL22V10 programmed as 8-bit shift register (previous experiment)
- One 10 KΩ potentiometer
- Breadboard and wire

Preparation

- Read this document in its entirety
- Review material on the ATD, PWM, TIM, and SPI
- Complete interface wiring on your breadboard

NOTE: All "C" code for this experiment must be written and debugged ***during your scheduled lab period***.

Introduction

In lecture you have been introduced to the concept of data acquisition using a microcontroller. Here, the analog-to-digital converter (ATD) can be used to uniformly sample a continuous-time input signal, an encoding process referred to as *pulse code modulation* (PCM). Recall that the minimum frequency at which a continuous time signal should be sampled (Fs) is twice the highest frequency component that signal contains (referred to as the Nyquist frequency). Traditionally, PCM data can be reconstructed using a digital-to-analog (DTA) converter, the output of which is low-pass filtered (to remove "images" of the reconstructed signal centered at integer multiples of Fs). In the absence of an integrated DTA, another peripheral that can be used for signal reconstruction is the PWM unit. Here, the uniformly sampled data from the ATD is converted into a time-varying PWM duty cycle. The resulting "naturally sampled" square wave is then "transformed" into a continuous time signal by low-pass filtering it. One of the goals of this experiment is for you to witness this seemingly "magical transformation" first hand, as well as qualitatively compare the effects of input and output sampling frequencies on the reconstructed waveform.

Demo Program

A simple demo program is provided to help you get started as well as test your low-pass filter and function generator setup. This program initializes the TIM, ATD, and PWM modules to sample an analog input at 10,000 Hz and sample the PWM output signal at 47,059 Hz. It also includes provisions for a "digital volume control".

DP Step 1: Set the function generator to produce a **1000 Hz, 5.0 V *peak-to-peak*** sine wave that is **<u>offset</u>** by **+2.5 V DC** (*carefully verify this with the oscilloscope before connecting the function generator output to your board!*).

DP Step 2: Connect the function generator output to **PAD0** (ATD input channel 0) and to oscilloscope channel 1. Connect the wiper of your potentiometer (with the legs connected to +5V and GND) to **PAD1** (ATD input channel 1). Connect channel 2 of the oscilloscope to **PT0** (PWM channel 0). Assemble, load, and run the demo program provided on the course web site. Verify that the potentiometer works as expected (i.e. as a "digital volume control") and set it to its maximum output. *Print the display obtained for* ***one period of the input sine wave*** (show both channels: the input sine wave and the "raw" PWM output signal).

DP Step 3: Using a **1 KΩ** resistor and a **0.1 μF** capacitor, construct a single-pole low-pass filter (LPF) for the PWM output and connect it between the PWM output pin and the oscilloscope input (channel 2). Leave channel 1 of the oscilloscope connected to the function generator. Calculate the -3 dB *cutoff frequency* ($f_{-3\text{ dB}}$) of the LPF. Vary the sine wave input frequency from 0.5 $f_{-3\text{ dB}}$ to 2 $f_{-3\text{ dB}}$ and *print the LPF output waveforms obtained for the cases* 0.5 $f_{-3\text{ dB}}$, $f_{-3\text{ dB}}$, and 2 $f_{-3\text{ dB}}$.

LPF -3 dB cutoff frequency ($f_{-3\text{ dB}}$) =

DP Step 4: Vary the input signal frequency and the waveform type. Set the function generator to produce sine, triangle, and square waves at 100 Hz, 1000 Hz, and 2000 Hz (total of 9 cases). Note which waveforms are produced with the greatest accuracy, and which are produced with the least.

BONUS CREDIT: *Print and carefully label each LPF output waveform obtained.*

Waveform comparison notes:

Software Description

Write an application program in C that allows the input and output sampling frequencies to be changed, thus facilitating an efficient comparison of signal reconstruction quality. Similar to the demo program provided, ATD Ch 0 will be used to input the analog signal from the function generator, ATD Ch 1 will be interfaced to a 10 KΩ potentiometer (“digital volume control”), and PWM Ch 0 (output on PT0) will be used to provide the output signal. The left and right pushbuttons on the docking module will be used to “cycle” among the input and output sampling frequency choices available, respectively. Pushing the left pushbutton will allow the user to cycle through the choices available for input sampling frequency: 5000 Hz, 10,000 Hz, and 20,000 Hz. Note that the input sampling frequency can be controlled by changing the value loaded in TC7. Pressing the right pushbutton will allow the user to cycle through the choices available for output sampling frequency: 23,529 Hz, 47,059 Hz, and 94,118 Hz. Note that the output sampling frequency can be controlled by the PWM clock pre-scalar.

Use the LCD to display the current input sampling frequency (ISF) and output sampling frequency (OSF) settings, as illustrated in the example.

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ISF: 5000
OSF: 47059
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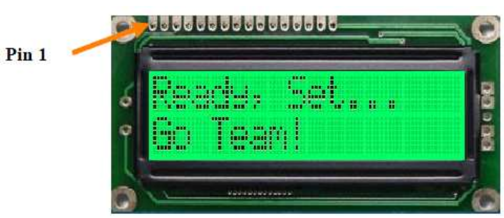
The RTI will be used to sample the pushbuttons on the docking board every 2.048 milliseconds. Data for the LCD display will be shifted out to an external shift register (GAL22V10) and will be interfaced to the SPI module through Port M (PTM). The description of the LCD interface used previously is reproduced below for your convenience.

An external 8-bit shift register (GAL22V10) will be used to interface LCD to the microcontroller via the SPI module (MOSI, port pin PM[4]; and SCK, port pin PM[5]). The LCD will be interfaced as described to the microcontroller module as described in the table below:



LCD Pin #	LCD Pin Description	Connected to Microcontroller
1	Vss (ground)	Vss (ground)
2	Vcc (+5V)	Vcc (+5V)
3	VEE (contrast adjust)	Vss (ground)
4	R/S (register select)	PTT[2]
5	R/W′ (LCD read/write)	PTT[3]
6	LCD Clock	PTT[4]
7	DB[0] (LSb)	Q[0]
8	DB[1]	Q[1]
9	DB[2]	Q[2]
10	DB[3]	Q[3]
11	DB[4]	Q[4]
12	DB[5]	Q[5]
13	DB[6]	Q[6]
14	DB[7] (MSb)	Q[7]
15	Not connected	
16	Not connected	

NOTE: DB[#] are the LCD data inputs and Q[#] are the data outputs of the shift register.

Some of the LCD pins require a bit more explanation:

Mnemonic	Name	Description
RS	Register select	This pin is logic 0 when sending an instruction command over the data bus and logic 1 when sending a character.
R/W'	Read/write	This pin is logic 0 when writing to the LCD, logic 1 when reading from it. For this lab, we will only write to the LCD.
LCDCLK	LCD clock	This pin latches in the data on the data[7:0] bus on the falling edge. Therefore, this line should idle as logic 1.

SW Step 1:
Complete the "C" skeleton file provided on the course website ***during your scheduled lab period.*** Note that the "finished product" should work in a "turn key" fashion, i.e., your application code should be stored in flash memory and begin running upon power-on or reset. After completing your C program, test its operation by selecting an input sampling frequency of 10,000 Hz and an output sampling frequency of 47,059 Hz. Verify that the results obtained (LPF output waveforms) with a 1000 Hz sine wave as input are identical to those produced by the demo program.

SW Step 2: With a 1000 Hz sine wave as input, cycle through each possible combination of input and output sampling frequencies (total of 9 cases). Note which waveforms are produced with the greatest accuracy, and which are produced with the least.

BONUS CREDIT: *Print and carefully label each LPF output waveform obtained.*

Waveform comparison notes:

SW Step 3.
Submit your ".C" solution file on-line <u>after</u> demonstrating it to your lab T.A. (but <u>before</u> leaving lab). ***Be sure identifying information*** (i.e., name, class number, and lab division) ***is included in the files you submit – credit will not be awarded if identifying information is omitted.***

Thought Questions

Answer the following thought questions in the space provided below:

(a) In your own words, describe the difference between *uniform* sampling (PCM encoding) and *natural* sampling.

(b) Provided Nyquist-related input sampling constraints have been met, what is the most important parameter that influences the quality (accuracy) of the reconstructed output signal? What is a “good working value” for this parameter?

(c) Describe what you would expect to observe if the value of R and/or C in the LPF were changed (thus changing the cut-off frequency).

(d) Describe what you would expect to observe if a *higher order* LPF were used in place of the single-pole filter.

