EE 5314 Embedded Microcontroller System Design
Low-Cost Programmable Pulse Generator with Automatic Level Control and Network Gain Calculation
Fall 2019 Project

1 Overview

The goal of this project is to design a low cost (<$10) system capable of generating various waveforms on two analog outputs while also providing two analog inputs allow measurement of the amplitude of a signal, providing feedback for automatic level control and load impedance estimation

This project has a command line interface capable of controlling the system and providing measurement data back to the user.

This project can be used for several subsequent purposes, including a complex baseband modulation source for the RF systems engineering course (EE 5331).

A collection of most major parts will be provided.. The pc boards, tools, and any optional items are not included in this collection of parts.

2 Hardware Description

The circuit and PSPICE simulation will be provided in class for the analog processing stages.

Microcontroller:
An ARM M4F core (TM4C123GH6PMI microcontroller) is required. It is recommended that the 2x10 header mated with J1/3 be mounted near the edge of the breadboard so that sufficient room exists for the 4 ICs.

Serial interface:
If using the EK-TM4C123GXL evaluation board, then the UART0 tx/rx pair is routed to the ICDI that provides a virtual COM port through a USB endpoint.

Analog output processing:
The system uses an MCP4822 DAC with an internal 2.048V reference to create a two separate waveforms with a voltage range of +/-5V at frequencies up to 40 kHz. The DAC is connected to SSI2TX/CLK/FSS and a GPIO pin for ~LDAC. After a reconstruction filter is applied to each DAC output (a PCM signal), an op amp (1/2 of TLC072) is used to level shift and gain up the DAC output signal to a +/-5V range. The DAC and op amp are bypassed with 0.1uF capacitors.

Analog input processing:
The system is capable of measuring two analog signals with a voltage range of +/- 5V. The input is sent to an op amp that is used to form an ideal rectifier. The input and rectified signal are then sent to an op amp that is configured to both full-wave rectifier the signal and to act as a leaky integrator to measure the amplitude of the signal. These inputs are presented to the microcontroller on AIN0 and AIN1.

All four op amps are part of a TLV2374 rail-to-rail input/output quad op amp powered from +/-5V supplies. This device is bypassed with a 0.1uF capacitor.

+/- 5V supply:
The 5V supply is derived from the USB bus. A -5V power rail is created using a MAX660 charge pump. 22uF capacitors provide the switched energy element and the output storage capacitor and a 1uF capacitor and 0.1uF capacitor are connected to the positive rail.

Connections:
Five connections will be provided to allow access to the 2 outputs and 2 inputs and provide a method to connect the 2-port device under test.

3 Suggested Parts List

Part	Quantity
TM4C123G evaluation board (ARM M4F)	1
MCP4822 SPI DAC with internal reference	1
MAX660 (analog negative rail charge pump)	1
TLV2374 (quad rail-to-rail input/output op amp)	1
TLC072 (dual high current op amp)	1
47ohm, 1% resistor (DAC reconstruction filter)	2
49.9ohm resistor (output series resistor)	2
1k, 1% resistor (DAC signal conditioning)	2
10k, 1% resistor (DAC signal conditioning)	4
12k, 1% resistor (ADC signal conditioning)	2
23.7k, 1% resistor (ADC signal conditioning)	4
47k, 1% resistor (ADC signal conditioning)	8
49.9k, 1% resistor (DAC signal conditioning)	2
52.3k, 1% resistor (DAC signal conditioning)	2
0.1uF capacitor (bypassing, reconstruct filter)	6
1 uF capacitor (leaky integrator, dc-to-dc converter positive rail)	3
22 uF capacitor (dc-to-dc converter commutation and negative rail)	2
1N914 diode (ideal rectifier)	4
2x10 double-row header, unshrouded	1
14pin 300mil socket (for quad op amp)	1
8pin 300mil socket (charge pump, DAC, op amp amp)	3
Wire (22-24 AWG solid wire, 3+ colors)	1
PC board (approx 4.5x6”)	1
ST-7565R based graphics LCD and parts	Optional
Tools, safety glasses, …	1 each

4 Software Description

A virtual COM power using a 115200 baud, 8N1 protocol with no hardware handshaking shall be provided with support to the following commands.

General:

If “reset” is received, the hardware shall reset.

Signal Generation:

If “dc OUT, VOLTAGE” is received, the output will be configured to be a DC signal with a voltage (V) on the requested output (OUT).

If “cycles N” is entered, then the cycle count for the waveform will be limited to N cycles.
If “cycles continuous” is entered, then the waveform will be continuous. This is the default setting.

If “sine OUT, FREQ, AMP, [OFS]” is received, the output will be configured to be a sinusoidal signal with a frequency of FREQ (Hz), an amplitude of AMP (V) on the requested output (OUT), and an average of OFS (V), default OFS is 0V.

If “square OUT FREQ, AMP, [OFS]” is received, the output will be configured to be a square wave with frequency of FREQ (Hz), an amplitude of AMP (V) on the requested output (OUT), and an average of OFS (V), default OFS is 0V.

If “sawtooth OUT, FREQ, AMP, [OFS]” is received, the output will be configured to be a sawtooth wave with a frequency of FREQ (Hz), an amplitude of AMP (V) on the requested output (OUT), and an average of OFS (V), default OFS is 0V.

If “triangle OUT, FREQ, AMP, [OFS]” is received, the output will be configured to be a triangle wave with a frequency of FREQ (Hz), an amplitude of AMP (V) on the requested output (OUT), and an average of OFS (V), default OFS is 0V.

Optional: Modify square wave to add duty cycle support as follows:
If “square OUT, FREQ, AMP, [OFS], [DC]” is received, the output will be configured to be a square wave with frequency of FREQ (Hz), an amplitude of AMP (V), and an average of OFS (V), and DC is 0-100%. Note that the DC if not the average of Vmax and Vmin in this case so this causes ALC operation to work differently.

Optional: Support an “arb” command that plays a previously downloaded arbitrary waveform. A “download” command and mechanism is also needed to send the LUT to the device.

Optional: If “differential ON|OFF” is active (ON), then output 2 will be the inverse of output 1. This mode can be supported when the offset = 0.

Optional: If “hilbert ON|OFF” is active (ON), then output 2 will match the Hilbert transform of output 1. The sine at minimum should be supported.

If “run” is entered, the waveforms on the two outputs should start as last configured. If an output is not configured, the output should be 0V.

If “stop” is entered, then the waveform play should stop and 0V should be output from both outputs.

The system should be able to drive both outputs at the same time, with DAC sample updates at the same time to prevent a phase offset. The amplifier is designed to reach amplitudes of +/- 5V with no load connected if the USB bus voltage is sufficient. In practical use, voltages of +/- 4.5V are typically available.

The project should be manually calibrated to output the correct amplitude and offset with a high-impedance load (such as a scope probe) attached to the outputs.

Voltage measurement:
If “voltage IN” is received, the hardware shall display the average of the absolute voltage on input IN on the UART.

Automatic level control:
if output N is connected to input N, then auto-leveling control (ALC) can be enabled. If ALC is enabled, the circuit will attempt to compensate for various load impedances.

If “alc ON|OFF” is entered, then the ALC will be turned on or off. If ALC is on, the hardware should measure the amplitude of the output and attempt to determine the correct scaling for the varying load.

Two-port gain calculation:
Although limited by charge pump current, output impedance, signal bandwidth, and scalar (no phase) measurements, it is possible to make a number of primitive swept frequency measurements. By sweeping the frequency over a range of frequencies, the transfer function of the hardware can be calculated using the following commands: For this mode to operation, OUT1 drive a two-port network under test, IN1 is connected to OUT1, and IN2 is connected to the output of the two-port network under test. OUT2 is not used for this mode.

If “gain FREQ1, FREQ2” is received, the system shall sweep a sinusoidal output from FREQ1 to FREQ2 and capture IN1 and IN2 to calculate the gain. The calculated gain at each frequency should be presented in a tabular format on UART. A log(f) sweep should be used to quicken the calculation.

5 Testing

Your hardware will be tested in the NH 148 lab.

Computers and lab equipment will be provided on campus in NH 148 for you to work on this project. If you do plan on plugging your project into your own machine, do so at your own risk and only after having the hardware tested. Again, you are responsible for anything that happens to your personal machine. Do not connect your project to any machines in the UTA computing labs or in other EE labs.

6 Deadlines

You should complete construction of the hardware by Friday, 10/11. After 10/11, a 25% deduction to the hardware portion of the project will be assessed for each class period that the hardware is late. The project hardware may be inspected by the GTAs at any date prior to and including this date.

The project is due on the date and at the time indicated in the syllabus, with an oral defense, electronic copy of your code and report, hard copy of your code, and demonstration of hardware and software (including compilation on site). The project is an individual project and no work (code or hardware) should be shared.

7 Safety Issues

While far beyond the scope of this document, it is important to use tools safely. Safety goggles are a good idea, since you can cause yourself injury if a wire that is being cut flies into your eye. Similarly, if wires being unsoldered are placed under some strain, the solder can be fling toward you. Soldering entails some care to prevent burning yourself or a burning down a building if you forget to turn it off. If you choose to use solder containing lead, then care shall be taken to dispose of lead properly (don’t cool off the iron in a drinking fountain, etc.). Always wash your hands after using solder to prevent the build-up of heavy metals in your body. These are a few helpful suggestions and are a very incomplete listing. Please read and understand all safety labels and exercise caution.

Please utilize the supervised lab resources in NH 148 when working on the project for your safety. You may only use the resources in the labs when the GTA, Grader, or other E.E. staff is present and only after taking the online safety training.

Have fun!