Brief Project Report

Jackson Spray
May 2, 2022
Embedded Systems II
CSE 4342

Objective:

The goal of this project is to design a low cost (<$20) system capable of generating various waveforms on two analog outputs while also providing two analog inputs allowing measurement of the amplitude of a signal, providing feedback for automatic level control and load impedance estimation.
The project includes a graphical user interface (GUI) to connect and control the system through serial connection using a computer. This GUI controls the system and provides measurement data back to the user.
This project can be used for several subsequent purposes.

Hardware:

Microcontroller:
An ARM Cortex-M4F Based MCU LaunchPad (TM4C123GH6PM)

Serial Interface:
The TM4C123GH6PM is connected to a computer via USB endpoint to provide a virtual COM port using a 115200 baud, 8N1 protocol with no hardware handshaking.

Analog Output Processing:
The system uses an MCP4822 DAC with an internal 2.048V reference to create 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 AIN8 and AIN9.
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.
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.

Software:

The GUI provides easy access to all possible commands to the system.

System Buttons:
The “RUN” command is used to start the output of voltages.
The “STOP” command is used to stop the output of voltages.
The “RESET” command is used to reset the microcontroller and restart the program.

Arbitrary:
The canvas at the top of the GUI is where you can draw your own waveform cycle. The canvas has a horizontal line at 0V to give a reference of that axis. The top and bottom of the canvas are +4.5V and -4.5V respectively. After drawing the waveform, input the requested frequency in the correlating text field and press the “Arbitrary” button to send the data to the microcontroller, then press “RUN” to begin.
Notes: The user can use the “Clear Canvas” button to clear the canvas of waveforms created. The program will use the most recently created voltage (Y-axis value) for each position in the lookup table (X-axis value). After sending the data to the microcontroller, the drawn waveform will stay on the canvas so the user can compare it to the actual output waveform, however the data points will be cleared so the user must draw a new waveform to use another arbitrary wave.

Standard Waveforms:
The rest of the waveforms work the same way as each other. Just input the requested parameters in the text fields on the left, select the desired wave type, and “RUN”.

Toggleable Options:
The “Differential” option will output on channel B the inverse waveform of channel A.
The “Hilbert” option will output on channel B the Hilbert transform of a sine wave of channel A.
The “Voltage IN” option will read the input RMS voltage on the requested channel to the Universal Asynchronous Receiver-Transmitter (UART) field at the bottom of the GUI.
The “Level” option requires the source voltage of the external circuit to be input into Channel B and the voltage after the load of the external circuit to be input into Channel A. Selecting this option will display back in the UART field the voltage difference.

Cycles Command:
The “Cycles” command will constrain the output on the desired channel to only output the number of cycles specified in the corresponding text field when the waveform is run.

Gain Function:
The “Gain” function assumes the user is using an external frequency filter circuit. To use this function, the user must power the external filtering circuit using channel A of the system. Then, input the unfiltered voltage into channel B and the filtered voltage into channel A. Finally, the user can input beginning and ending frequencies for the analysis and select “Gain”. The system will then sweep through a logarithmic set of frequencies, record the gain at each frequency, and display to the user a bode plot diagram in a separate window of the GUI.

Part 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