Principles of Embedded Software: Final Project Proposal

ARMusical

Author: Surya Kanteti

Overview:

The idea of the project is to use the FRDM-KL25Z development board to play musical tones, based on inputs from the user through the UART command processor.

Functionality:

The command line interface is enabled (powered by UART) for the user to enter musical notes to be played, along with their durations. The supported command to achieve this is “play”.

Ex**:** When the user enters “play A300, G500, F300”, the board plays the note ‘A’ for 300 mill-seconds followed by note ‘G’ for 500 milli-seconds followed by note ‘F’ for 300 milli-seconds.

The inputted command is then parsed and each note’s duration is obtained. The code relates the note to its equivalent frequency and generates the analog signal, which is then passed as an input to the speaker. The speaker then plays out the tone based on the signal it receives, which constitutes the basic functionality.

Additionally, the user gets to enter another command “echo” which creates the DSP effect of an echo.

Ex**:** When the user enters “echo 200 0.5”, the echo mode is turned on with a delay of 200 milliseconds and an amplitude scaling factor of 0.5.

The tones followed by this command are echoed according to the parameters inputted by the user. When the user enters the command “echo off”, the echo mode is turned off and the tones following it are played normally.

Technologies Used:

The technologies used for this project are:

- Circular buffers: For UART data buffering, command queueing
- UART: To communicate serially with the console on the PC
- Command processing: To perform lexical analysis of the user-inputted command
- Digital to Analog Converter: To convert a digital input to an analog output signal
- Direct Memory Access (DMA): To copy sample values into the DAC
- Timer PWM Module (TPM): To trigger DMA to achieve the required sampling rate

The challenge would be to integrate all of the above-mentioned technologies to work seamlessly in one single application.

The output of this application, residing on the board, will drive a peripheral outside of the board. It is different compared to the assignments done so far, in which values were read from the peripherals on the board.

Learnings and Implementation Ideas:

To implement this project, the signal processing mechanism of the “echo” sound effect will have to be learned in order to replicate it using software.

The idea is to use another buffer which will be populated with the tone’s sample values scaled by a factor and delayed by a certain time period, both of which are provided by the user. Both the buffers will have to be mixed in such a way that it replicates modulation of two signals. The exact implementation of this process is yet to be figured out. Also, a flag will be used to determine if the current mode of operation is in echo mode or not.

Another challenge is to maintain UART responsiveness in such a way that the user can enter commands over the command-line interface even when the tones are being played over the speaker.

Since the modules used in the project are interrupt-based, the main loop contains only the logic to play the tones by copying the samples in the buffer to the DAC module through DMA. In order to achieve greater UART responsiveness, we can use a queue (circular buffer) which is enqueued by the command line processor with the tones and durations, dequeued by the main logic to fill the buffer with samples for DAC.

Learning to interface the board with a speaker and also checking the output signal using an oscilloscope is required.

References:

The references used for implementation would be:

- KL25Z datasheet and reference manual
- Adafruit Stemma Speaker 3885 datasheet
- ECEN 5813: Principles of Embedded Software (PES) lectures and slides
- Code from previous assignments of PES
- The “Embedded Systems Fundamentals with ARM Cortex-M based Microcontrollers” textbook by Alexander Dean
- The “Making Embedded Systems” textbook by Elicia White

Additional Hardware:

The project requires a speaker to play the musical notes. Since it is not a part of the development board, it will have to be interfaced separately through jumper cables.

The speaker used for the project is “Adafruit Stemma Speaker 3885”. It can take input voltages of the range 3V to 5V peak-to-peak, which is quite compatible with output voltage of KL25Z (0V – 3.3V).

Testing Strategy:

Based on the nature of the project and the technologies used, a mixture of automated and manual tests will be used.

- Automating test cases for testing multiple instances of cbfifo (circular buffer).
- Manually checking the inputs and outputs from UART through the command line interface. The input given by the user should be reflected back to him on the console.
- Manually passing known and unknown commands to check the functionality of the command line processor.
- Manually verifying the analog signal generated by the DAC on an oscilloscope.
- Manually verifying that the sound from the speaker resembles the command inputted by the user.