ECE 492 - Computer Engineering Design Project
# Voice Manipulator

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Project Overview

The Voice Manipulator allows you to modify your voice and either send it to speakers or a Bluetooth-paired device. It allows you to apply a frequency shift to your voice and add an echo of variable volume and delay.

The Voice Manipulator can be used in Direct Mode, in which the voice signal is sent to Line Out, or in Bluetooth mode, in which the output is sent via Bluetooth to a paired cellular phone, effectively allowing for the Voice Manipulator to be used as a Bluetooth headset.
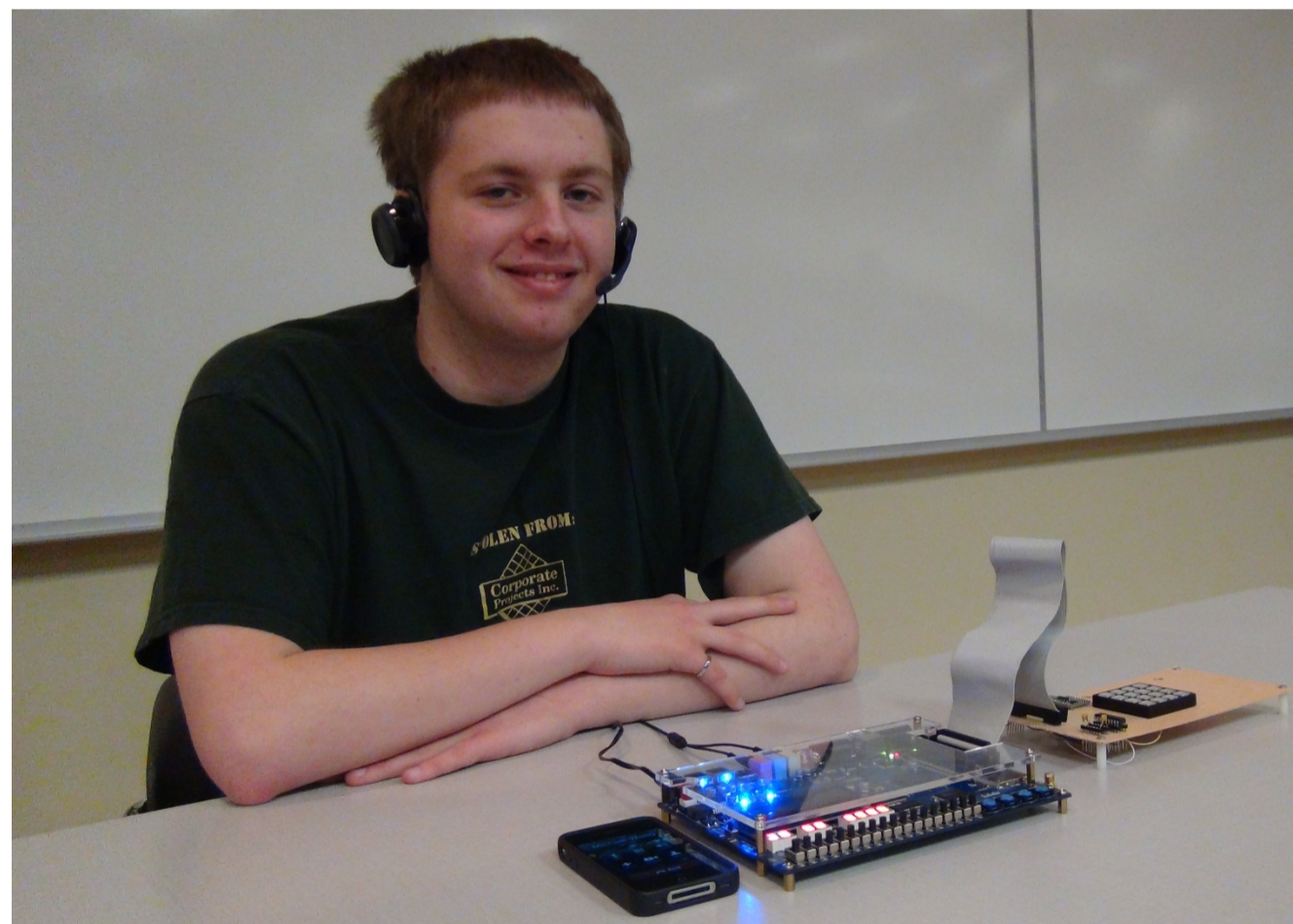
Audio Codec

Our project uses the Wolfson Microelectronics WM8731 Audio Codec present on the DE2. Volume control is performed by writing to the audio codec registers.
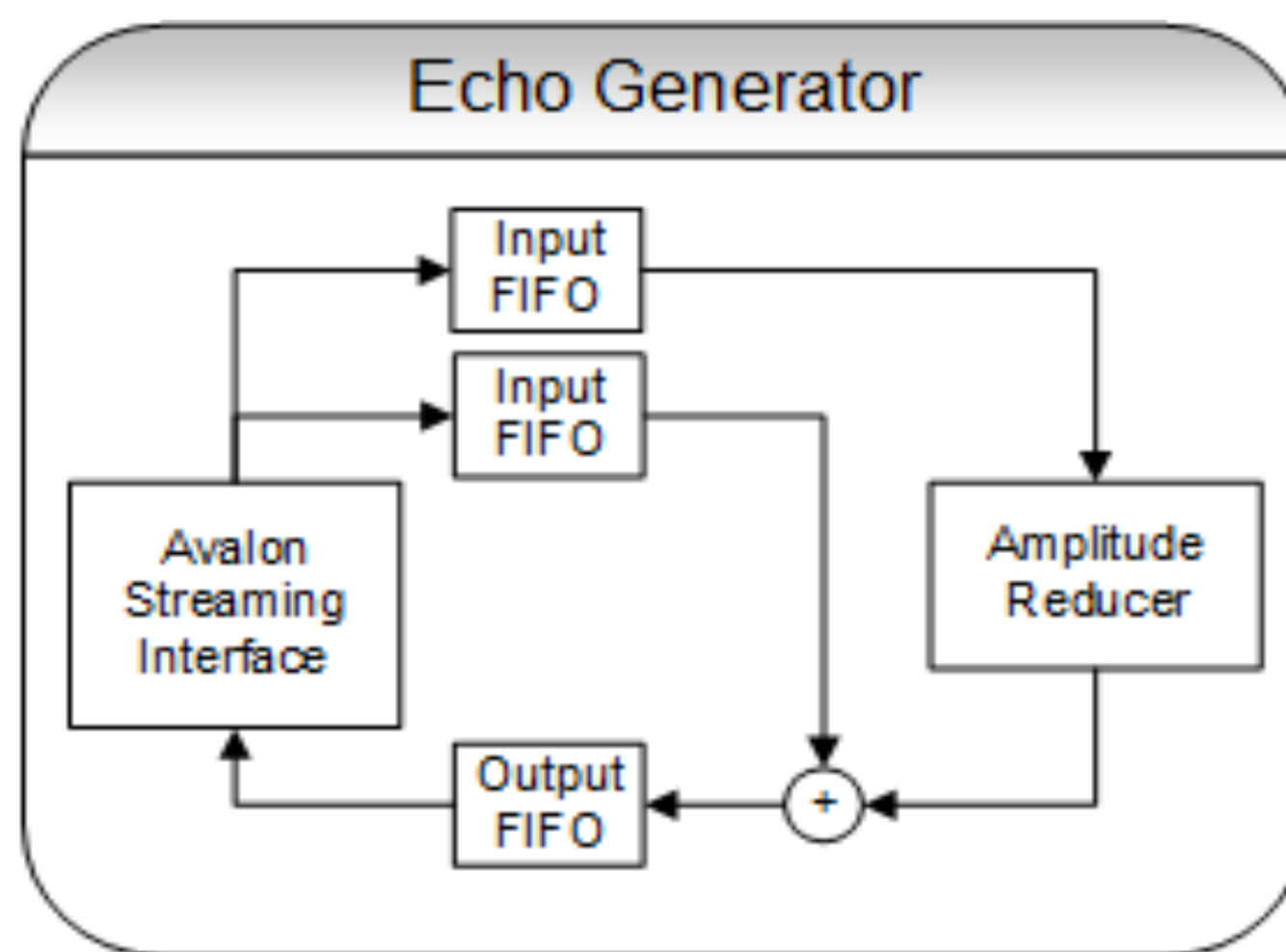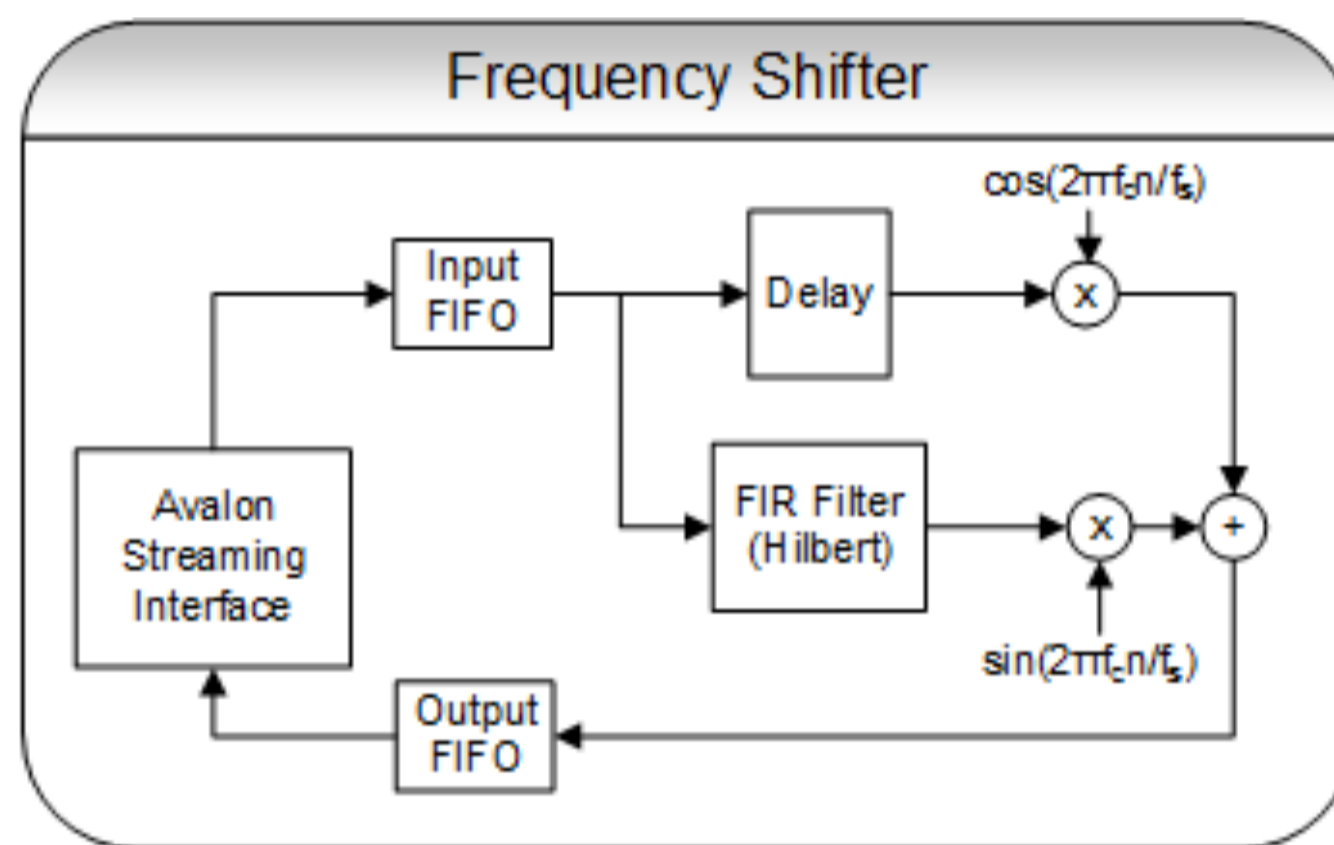
Incoming data is sampled at 32kHz using 16 bits per sample, meaning we have a very high quality audio stream for signal processing. The output data is downsampled to 8kHz due to timing constraints and Bluetooth protocol requirements, so the output sound is transmitted at 8kHz using 16 bits per sample.

DSP Functionality

Our Digital Signal Processing consists of two main elements: the frequency shifter, and the echo generator. The audio data stream is routed through these DSP blocks, implemented in hardware on the DE2's FPGA.

The frequency shifter employs single sideband modulation in order to shift the frequency content of the input voice signal. The implementation is shown in the block diagram below.

Single sideband modulation requires that we apply the Hilbert transform to the audio signal. This is accomplished using a finite impulse response filter. The original signal and Hilbert-transformed signal are then multiplied by sinusoidal signals with some frequency f_c and then summed to yield the original signal shifted up by f_c. A delay is introduced in order to ensure that the two components of the signal add in phase.

Ultimately, the frequency shifter implements the following expression:

$$x(t)cos(2\pi f_c t) + H\{x(t)\}sin(2\pi f_c t)$$

The echo generator uses a second buffer that stores sound data as it returns from the frequency shifter. A delayed copy of the audio signal is added to the real-time sound signal to produce an echo effect. This delayed signal can be made quieter via an amplitude reduction if desired by the user.

Frequency Shifter

Echo Generator

Bluetooth Connectivity

Our project uses a LinkMatik LM20 module, which contains 2 interfaces – an RS-232 compliant serial data interface, and a Pulse Code Modulation (PCM) audio interface.

The serial data interface is used to configure the LM20 module and communicate messages indicating the status of the Bluetooth link with the board.

The PCM interface carries the audio data, which is serialized into a 16-bit frame format. The LM20 module generates a 256 kHz bit clock, and an 8 kHz frame synchronization signal. Successive bits of the audio signal are sent along a single data line according to the bit clock, with the start of each sample being denoted by the frame synchronization signal.

User Interface

The DE2 on which our project is implemented contains 3.5 mm audio jacks for the MIC IN and LINE OUT which are connected to the Audio Codec. An external microphone and speakers can be attached through these standard connectors.

The DSP functionality is configured using the 4 push buttons mounted on the DE2. Two buttons allow the user to select a DSP parameter: volume, echo delay, echo decay, or frequency shift. The remaining 2 buttons allow the user to set the parameter value. The onboard LCD displays the currently selected parameter and its value.

A single switch is used to select between Direct Mode and Bluetooth Mode.

Future Work

Given additional time, we would be interested in improving the Voice Manipulator by adding additional DSP functionality such as volume levelling, noise cancellation, and true pitch shifting.

Other potential avenues for expansion are creating a more inqtuitive user interface, as well as implementing additional Bluetooth functionality, including the ability to place and answer calls from the device.

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