Lab 5: Digital Audio

1 Learning Objectives

By the end of this lab you will have…

- Built a circuit to enable an I/O pin from your MCU to drive a speaker
- Implemented the timer functionality available on the MCU by reading the datasheet and writing your own library in C from scratch

2 Requirements

Build a system to play music on a speaker. Use your µMudd MkVI, an LM386 audio amplifier, and an 8-ohm speaker. The µMudd should read a list of notes specifying the pitch (in Hz) and duration (in ms) of each note. It should generate a corresponding sequence of square waves. A frequency of 0 indicates a rest (silence for the given duration). A duration of 0 indicates the end of the song. Your system should play accurate pitches regardless of the frequency. Test your system on the score of Für Elise, which is provided.

3 Discussion

You can find `lab5_starter.c` on the class web page with the Für Elise score provided as an array of ordered pairs of pitch frequencies and durations.

A goal of this lab is for you to learn to interpret a datasheet and figure out how the timer works. Write your own code from scratch to use the system timer.

The GPIO pins don't generate enough output current to play satisfactory music directly on the speaker, so use an LM386 audio amplifier between the µMudd MkVI and the speaker. Do not connect the µMudd directly to the speaker, as the current draw could damage it. The datasheet shows AC coupling from the amplifier to the speaker, but you can leave out the capacitors and resistors and produce an acceptable square wave. Volume control is optional (but recommended for your own sanity and that of your roomates and labmates). There are only a limited number of speakers available in the lab so please leave the speakers in the supply cabinet when you leave lab. Do not leave them attached to your breadboard when you are done working. If you kill a speaker, throw it away rather than putting it back in the cabinet for your unfortunate classmates.

4 Extra Credit

Up to one point of extra credit can be earned if you compose and play a different tune. The following information may help as you compose your music.

The duration depends on an arbitrary choice of tempo (speed at which the piece is played). If a whole note is chosen to be 1/2 a second long, other notes follow accordingly:

Duration	Seconds
Sixteenth	0.03125
Eighth	0.0625
Quarter	0.125
Half	0.25
Whole	0.5

Table 1: Note durations for a 0.5 second whole note

Recall that the A above middle C (called A4) is 440 Hz (at least in the United States) and that an octave spans a factor of 2 in frequency. There are twelve notes in an octave spaced evenly on a geometric scale, so each is separated in frequency by a factor of $2^{(1/12)}$.

Note	Frequency (Hz)
A3	220
A sharp / B flat	233.1
B3	246.9
C3 (middle C)	261.6
C sharp / D flat	277.2
D3	293.7
D sharp / E flat	311.1
E3	329.6
F3	349.2
F sharp / G flat	370.0
G3	392.0
G sharp / A flat	415.3
A4	440
A sharp / B flat	466.2
B4	493.9
C4	523.3
C sharp / D flat	554.4
D4	587.3
D sharp / E flat	622.2
E4	659.2
F4	698.4
F sharp / G flat	740.9
G4	784.0
G sharp / A flat	830.6
A5	880

Table 2: Note pitches

5 What to Turn In

When you are done, have your lab checked off by the instructor. You should thoroughly understand how it works and what would happen if any changes were made. Turn in your lab writeup including the following information:

- Schematics of the breadboarded circuit.
- Your source code.
- How many hours did you spend on the lab? This will not count toward your grade.

6 Credits

This lab was original developed in 2015 by Alex Alves '16, redesigned for the µMudd Mark 5.1 in 2019 by Caleb Norfleet '21, and redesigned for the µMudd MkVI in Fall 2021 by Prof. Josh Brake.