

E85: Digital Design and Computer Engineering

Lab 5: Music Keyboard

Objective

The purpose of this lab is to independently design a nontrivial digital system. Specifically, you will design a 4-key music keyboard that plays notes onto an amplified speaker.

1. Connecting the Speaker

Connect an amplified speaker to the GPIO0 headers using one of the custom connectors in the lab that has a speaker jack on one end and two female headers on the other. Plug the red or orange header into pin D0 (upper left corner, FPGA PIN_N16) and the black or gray header into ground (6th row, right side). Make sure the speaker is plugged in and powered on.

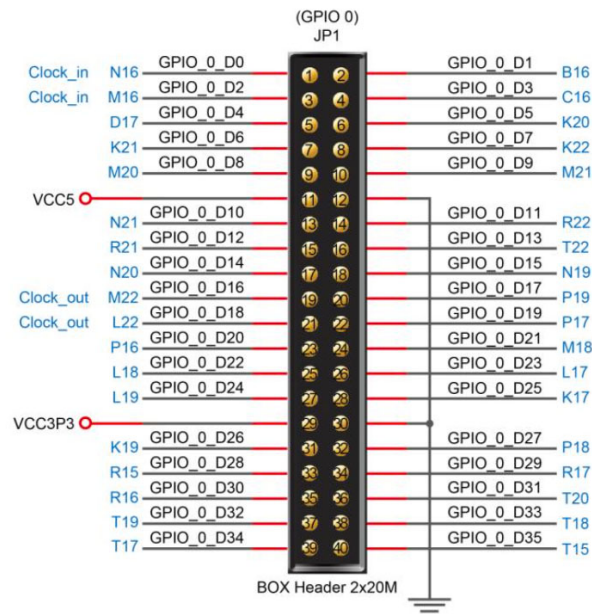


Figure 1: GPIO Conn. From DE0-CV User Manual

2. Generating Tones

Design a digital system with four inputs from KEY_{3:0} and one output to GPIO D0. It should generate a square wave of a frequency that varies with the key pressed, as given below. Set the output frequencies within 1% of the given frequencies. Measure the output frequency for each key pressed with an oscilloscope. Fill out the following table. Note that the keys read 1 when not pressed and 0 when pressed. If more than one key is pressed, you can choose what should happen. Sketch a schematic at the level of registers, adders, multiplexers, and gates.

| Key | Note | Desired Frequency (Hz) | Actual Frequency (Hz) |
|------|------|------------------------|-----------------------|
| KEY3 | C | 261.6 | |
| KEY2 | E | 329.6 | |
| KEY1 | G | 392 | |
| KEY0 | A | 440 | |

Write behavioral SystemVerilog to implement your design. Program it onto the DE2 board and test it.

To generate tones, you may want to use one of the DE0 board's clock signals. There are buffered 50MHz clock signals connected to PIN_M9, PIN_H13, PIN_E10, and PIN_V15. If you are using a reset signal, you can assign reset to a toggle switch, e.g., SW0, PIN_U13.

3. A Happy Song

Play a tune by tapping the following keys.

1120 12 1120 12 12 12 11 3

Can you name the tune?

4. Extra Credit

Invent another song for your keyboard or modify the hardware to create another interesting feature, such as the ability to add more notes, change octaves, play more than one note at a time, or play a tune automatically. Test your invention.

What to Turn In

1. Please indicate how many hours you spent on this lab. This will be helpful for calibrating the workload for next time the course is taught.
2. Schematic
3. Behavioral SystemVerilog code

4. Table of actual output frequencies

| Key | Note | Desired Frequency (Hz) | Actual Frequency (Hz) |
|------------|-------------|-------------------------------|------------------------------|
| KEY3 | C | 261.6 | |
| KEY2 | E | 329.6 | |
| KEY1 | G | 392 | |
| KEY0 | A | 440 | |

5. Does your system play music? Can you name the tune (ok if you don't recognize it)?

6. Extra credit, if applicable

If you have suggestions for further improvements of this lab, you're welcome to include them at the end of your lab.