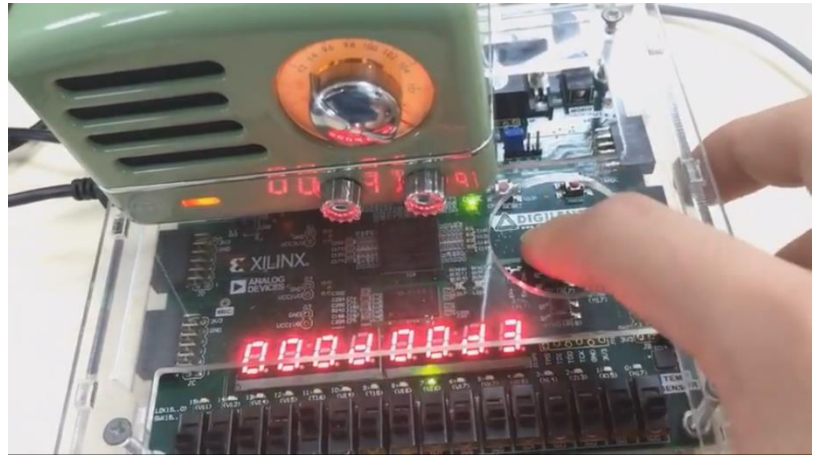


# 16-Step FPGA Music Sequencer and Synthesizer | Digital System Design Project

2018

Music sequencer is a device that can edit, record, and play back music notes for a certain period. For example, for a 16-step sequencer, we can edit the music notes at each step, record our editing, and then the sequencer would play the 16 notes again and again.

In this project, my teammate and I made a hardware music sequencer on Nexys 4 DDR FPGA board using VHDL as programming language. I was responsible for the sequencer circuit, implementing functions of counting step progression, music notes selection and memorization, and a "play & pause" button.



The picture beside is the features and layout of the board.

## Counting 16-step Progression

Our music sequencer used No.8 switches as the main control. There were 16 switches in total, with each one represented a music note or a beat, so 16 switches corresponded to the 16 steps in the sequencer. Turning a certain switch up meant that the corresponding step was activated, then the music note on this step could be edited.

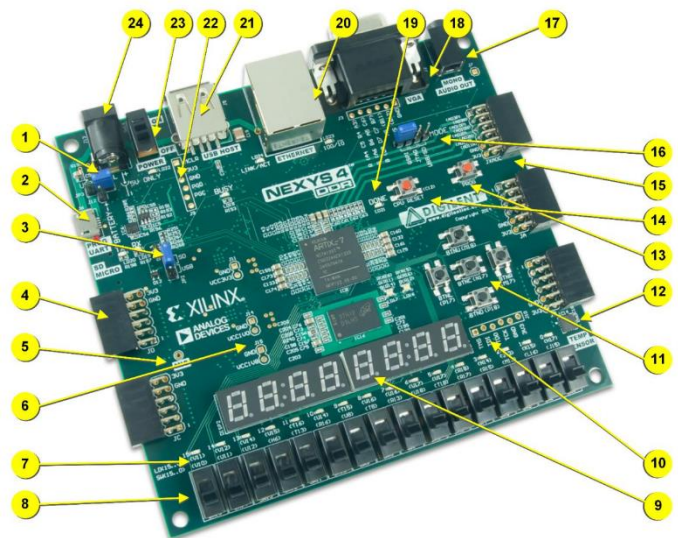


Figure 1. Nexys4 DDR board features.

No.7 are LEDs. It showed the beat that was currently playing. If there was a sound on the current step, the corresponding LED would be on.

The 16-step progression was implemented with a 4-bit T flip-flop. The 4-bit T flip-flop could count from 0 to 15 and then came back to 0, so I used it as a 4-bit counter to keep track of the step progression. 16 switches corresponded to the 16 values in 4-bit counter, so the speaker output could know which switch was on and played out its music note.

## Selecting And Memorizing Music Notes

No. 11 the five buttons were used to edit the beats. Every beat had 16 available pitches preset in the program, selected by pressing the up button. After selection, we could press right button to save the pitch. I used 16 D flip-flops to remember the chosen pitches for

each step respectively. Same as counting the progression, I used a 4-bit T flip flop to store the 16 preset pitches in the circuit. They were in a pentatonic scale, with three octaves of C, D, E, G, A, and a C in the fourth octave.

### Play & Pause Button

The center button of No.11 was utilized as a play & pause button. Since we could not press and release the button so rapidly that only one trigger was given to the button under the hardware clock signal, the sequencer would switch between play and pause. In order to overcome this problem, I designed and implemented a finite state machine into the circuit, so that I could toggle between play and pause states in finite state machine exactly once when the button was pressed.

### Synthesizer circuit

The Nexys 4 DDR FPGA board could only generate square wave, which was not as musically favored as sine wave, so we converted square wave to sine wave using pulse width modulation.

