Building a Highly-Customized, Wireless MIDI Controller

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Introduction

The ability to combine data collection, FPGAs, test instruments, and sensors provide engineers with innovative new approaches to developing solutions for a wide variety of applications. And one such application is building a wireless MIDI controller.

Figure 1. MIDI controllers are a staple of modern electronic music, and creating your own can be overwhelming. Image courtesy of Digilent.

This article will discuss an innovative example of building a wireless MIDI controller, including a detailed discussion of the hardware and software required and links to additional details for circuitry and implementation.

MIDI Controllers

As many of you may know, a MIDI controller is a piece of equipment used to produce electronic music. Because of their capabilities and the design involved, off-the-shelf MIDI controllers are usually quite expensive.

However, building your own customizable MIDI controller can be a valuable alternative and provide just as powerful capabilities. One innovative approach to developing a custom, wireless MIDI controller combines a test and measurement device with a PC, physical controls, and some passive electronic components.

MIDI and DAW

MIDI refers to a technical standard with specifications to support electronic music production. MIDI controllers send commands to devices (including instruments) or specialized software. DAW (Digital Audio Workstation) packages, such as BandLab (free) or Serato, are commonly used. The commands sent by the MIDI controller contain the data required by DAW to create that sound or apply an effect.

One of the problems with using MIDI controllers with DAW is the specific type of connectors required -- and most laptops do not have a MIDI connector. A MIDI connector can be built on the prototype board for a project such as this. However, sending MIDI commands wirelessly via Wi-Fi or over Ethernet is much more efficient. To do so requires the RTP-MIDI (Real-time Transfer Protocol) network protocol to a receiver. The DAW software receives the MIDI commands and then produces the desired audio.

Customized MIDI Controller

For the approach presented here, a test and measuring device (e.g.., portable mixed signal oscilloscope) receives data from hardware user interface elements (e.g., think buttons, sliders, switches, piezoelectric pads) configured on an FPGA development board. Then, the data is converted into MIDI commands transmitted via RTP-MIDI to an instrument or system with DAW installed. Once the instrument/system has received it, the DAW software implements those commands, producing the desired audio.

What makes this approach to creating a MIDI controller different from others lies in (1) its use of a test/measurement instrument to process the control data and (2) avoiding issues with finding a MIDI connector by using RTP-MIDI.

Why Build This Customized MIDI Controller?

When designing or creating a custom MIDI controller, there are multiple considerations to weigh against each other. Cost, time invested in prototyping and assembly, and customizability are three traditional concerns that all designers will want to account for early on in a project's life cycle. Following the build described in this article, this custom MIDI controller will likely cost over $1,000, which is similar in price to those used in recording studios. Many other MIDI controllers are available online for $200 or less, and they come fully assembled - so what are tradeoffs other than cost are seen with this particular controller?

When writing custom software, designers have complete control over the MIDI controller, which is simply not possible when purchasing an assembled one online. There is also profound flexibility introduced with a bespoke product: an Arty S7, for example, can be reconfigured to do something completely different, and the ADP3250 oscilloscope can analyze a wide variety of systems. It is a voltmeter and data logger as well as a network, protocol, impedance, spectrum, and logic analyzer. The ADP high-resolution digital oscilloscope is also a power supply, waveform generation, and pattern generator.

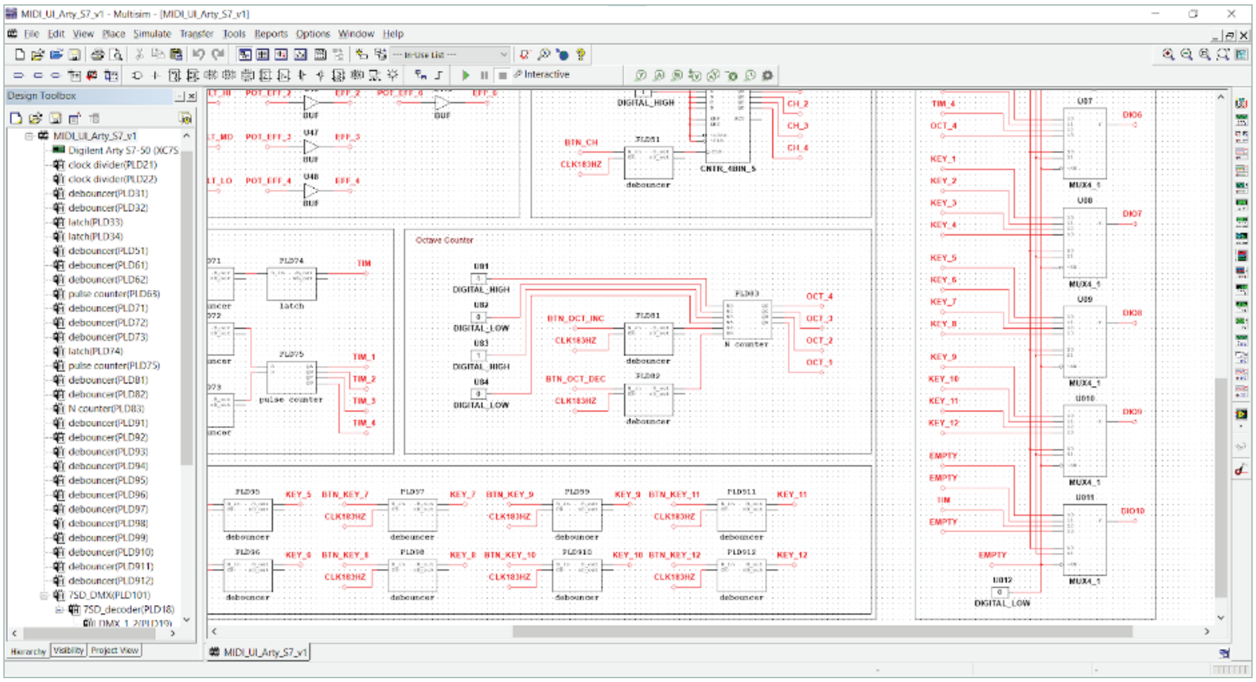

Figure 2. While there are many driver circuits required, they are not excessively complex.

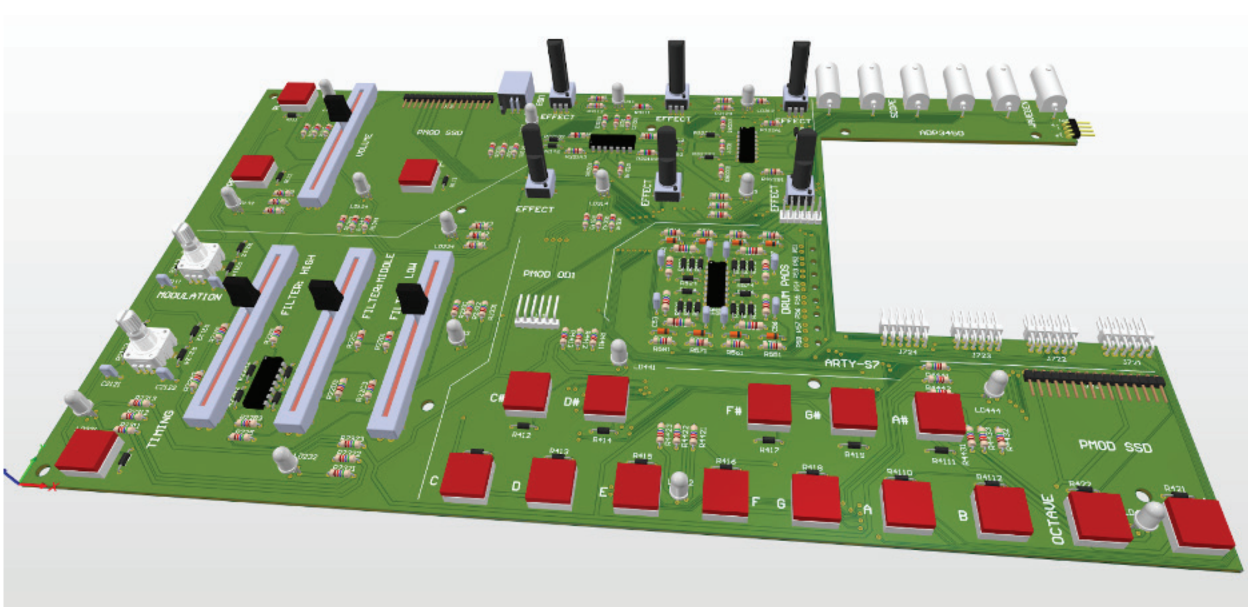

Figure 3. Hardware components and circuitry are laid out on a custom PCB.

Another valuable outcome of making this product is an increased understanding of MIDI technology and MIDI controller systems at large. More robust, customizable ecologies are only possible when designers have learned the intricacies of various subsystems, and constructing a custom MIDI controller is a first step for many designers in moving away from off-the-shelf solutions to truly understanding the inner workings of this subsystem. This knowledge is easily leveraged and transferred to other, more intricate and further individualized projects.

Building a MIDI Controller

To start, you will need the following hardware:

- Portable high-resolution mixed signal oscilloscope
- FPGA development board for prototyping
- Hardware user interface elements (e.g., buttons, switches, sliders, LEDs)
- Passive electronic components

The design under discussion will support three control signals via the hardware user interface components. The controls are for (1) slowly changing analog signals, (2) fast-changing analog signals, and (3) digital signals. And each type of control has human-interface components and circuitry. A portion of the driver circuitry for this MIDI controller is shown in **Figure 2**.

Here are the specific hardware user interface components:

- Potentiometers and sliders for making adjustments to slowly changing signals
- Pressure-sensitive pads are for adjusting the fast-changing signals
- Switches, buttons, and rotary encoders for adjusting digital signals

The answer is simple for those wondering why hardware interface components such as switches, buttons, and sliders are used: many MIDI controller users are more comfortable with physical interaction and the tactile feedback that goes with it than using a mouse or touch-screen controls. And this is more feasible as some manufacturers can supply quality hardware at highly competitive prices. An illustration of what such an approach can look like is shown in **Figure 3**.

The filter block includes low, middle, and high-level filters along with an analog-to-PWM converter for the volume slider, filters, and incremental rotary encoders to set the attack, modulation, or release time of the sounds. The control block also includes piezoelectric drum pads.

This project also requires various types of software, such as a network MIDI driver, DAW, terminal emulator, code editor, and SPICE simulation and circuit design.

Conclusion: The Digilent Solution

You can review Building a MIDI Controller with Analog Discovery Pro (ADP3450/3250 for all the details behind this build, including software configuration and recommended board designs. This design can be implemented with Digilent products, starting with the Analog Discovery Pro (ADP3450/ADP3250) portable high-resolution mixed signal oscilloscope. And one of the best development boards for this application is the Arty A7 or the new Arty S7 FPGA development board (**Figure 4**).

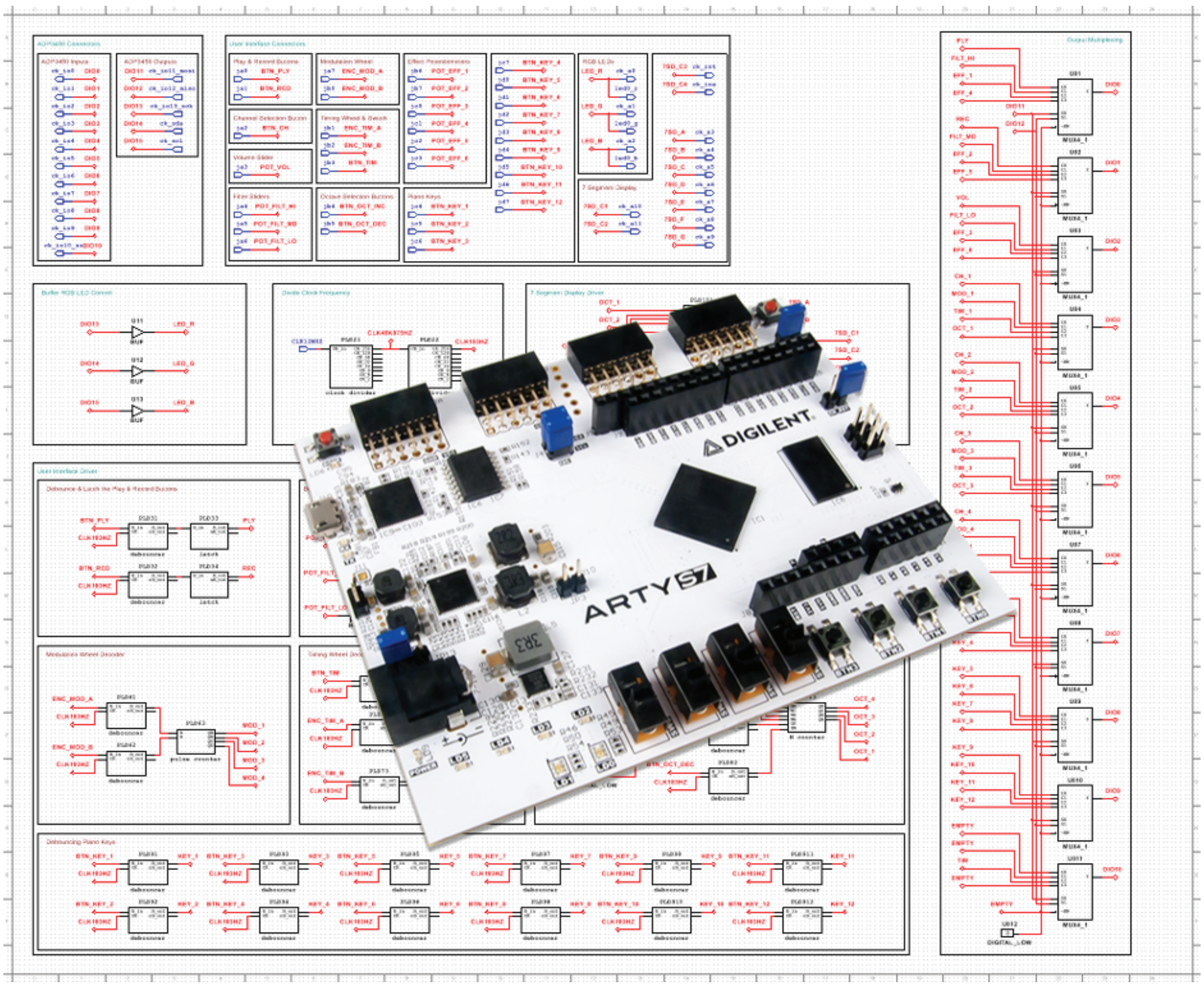

Figure 4. The ARTY S7 is a development board for developing a range of products.

All hardware user interface elements can be found in the PMOD series, including the Pmod OD1 for the open-drain MOSFET driver module and Pmod SSD for the seven-segment displays.

In addition, Digilent also provides the software needed to configure and program the system or provides information on free or low-cost sources. For example, the FPGA development board uses RaveloxMIDI, Python 3, WaveForms SDK, and Adept Utilities.

There are also different FPGA board designs, USB-based test and measurement devices, and DAQ and data-logging devices. This includes their most popular development boards/FPGA, the Zybo Z7 and Arty A7, and their dependable, accurate Analog Discovery Pro ADP3450/3250 and ADP5250 high-resolution oscilloscopes. To see Digilent's entire line of development boards, pc-based test devices, and DAQ tools, visit **Digilent.com**.

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