Diode Matrix MIDI Controller and Router

Jan Kučera
Newcastle University
Newcastle upon Tyne, UK
jan.kucera@newcastle.ac.uk

***Abstract*—This paper proposes a user programmable device for connecting peripheral keyboards and pedals into a single instrument such as organ. It can also be used as a generic device mapping MIDI protocol onto custom I/O signals for stage production and other applications. The challenge lies mostly in supporting USB connectivity in modern devices.**

I. Introduction

When a young person wants to become an organist, access to an instrument can pose a significant challenge. The price of organ for home or school can range anywhere from £5,000 to £60,000 [1, 2, 3], which is prohibitive for many. However, most digital keyboards and pianos are equipped with a MIDI interface [4], allowing to just connect an external pedal unit to them.

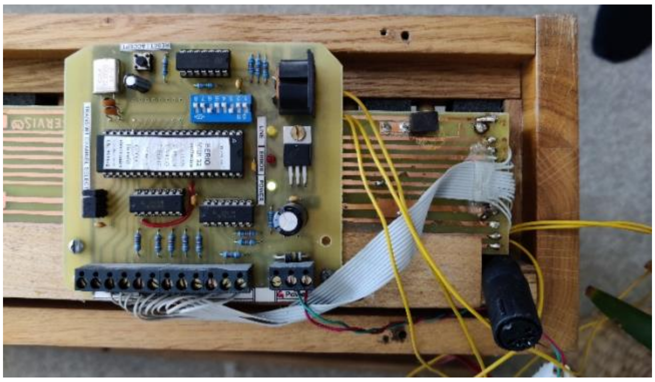
In theory, providing input to the piano should be trivial. MIDI is a relatively slow serial protocol with baud rate of 31250, and reading out 29 binary contacts can easily be done on an 8-bit microcontroller, such as PIC16F15274 with £0.66 per 5k pricing and minimal support components (2 resistors and 2 capacitors). The physical interface is usually done by 5-pin DIN connectors.

Unfortunately, except for high-end professional instruments, the traditional UART interface for MIDI protocol has been replaced by MIDI over USB [5]. This imposes several complications to any device trying to interface with it. First, as the most common use case is to connect the keyboard to a computer, the keyboard acts as a USB client. Second, the MIDI input and output lines are conflated into different endpoints through a single physical USB connection, making it impossible for the input and output connect to different hardware.

II. Related Work

The need for merging MIDI signals is well understood and addressed by the commercial sector, as the market is saturated with such devices using the DIN physical interface. In contrast, the availability of devices merging MIDI over USB is contrastively minimal. The only commercially products available seem to be two HxMIDI products by CME [6]. However, these devices cannot be used with generic I/O signals on their own.

Converting diode matrix input as is the one coming from a pedal or keyboard board into MIDI has been done as a commercially available DIY product Berio MIDI, which uses closed source, pre-programmed ATmega controllers, with price ranging from £130 to £260 per assembled unit [1]. Pedal and organ builders use it in their products [8]. A limited configuration is possible on some models using hardware jumpers, which are not accessible once the MIDI controller is built into the final product.

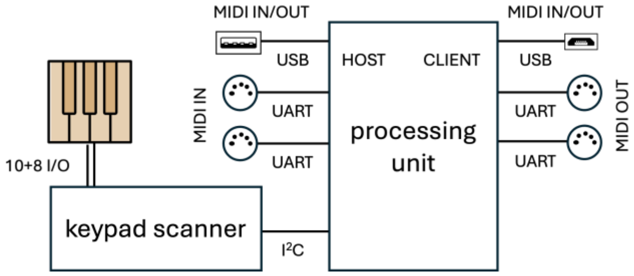


Berio MIDI has no USB connectivity, only standard DIN output connector. Moreover, while it may fit the needs of closed systems with central processing unit, it is unfit to be connected with other devices such as digital pianos, as usually extra MIDI communication is required, such as selecting an appropriate music instrument etc. This must be addressed by injecting a and modifying the data on a separate device and routing it back to the piano or merging the streams and have a separate audio rendering system.

III. Proposed Device

The proposed solution is to create a new, open-source and programmable device serving all the functions described above. Such device needs to provide both USB host and USB client interfaces and consequently secure a specified 5V power supply to any USB devices connected to it. Having to focus on the serving the USB functions, the input scanning loop needs to be outsourced to a separate component to ensure low and consistent latency.

The proposed device design is as follows:



A. Component selection

For keypad scanning, **TCA8418** I²C controlled keypad scan circuit has been selected. With integrated ESD protection and built-in debounce, it can continuously scan up to 80 keys connected using a diode matrix. Furthermore, it can be configured as a general I/O expander, providing both inputs and outputs to the device, or any combination thereof.

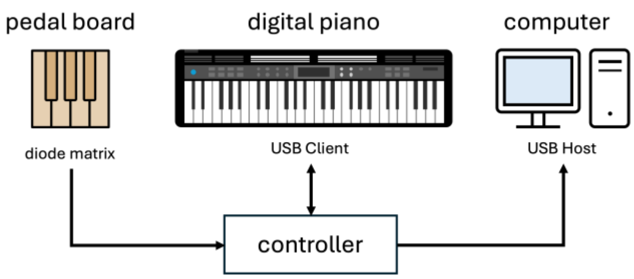
The diode matrix should be external to the device to meet the common keypad designs and to allow the device work as general input and output interface.

Finding a controller that supports both USB host and USB client is quite challenging. The only option for this market seems to be **Teensy 4.0** or Teensy 4.1, which is a 600 MHz Cortex-M7 board. It comes with 7 UART ports and an example setup for MIDI applications. However, with around £18 per piece, it might not be appropriate for larger production runs.

B. Functionality

The device has 5 MIDI IN and OUT endpoints (1 from I/O, 2 from DIN, 2 from USB host and client respectively). Users should be able to configure the device to route any input to any output, allowing both merging and duplicating capability. During the routing, message transforms could be defined, allowing to transpose notes, adjust MIDI channels and velocity, filter out undesired or inject new messages. Finally, startup messages can be defined to automatically establish the right configuration of connected devices.

An example use for the device with the scenario described above:



The controller uses diode matrix scanning to convert signals from pedal board into a MIDI stream with appropriate velocity and sends it to the digital piano for playback. The piano sends MIDI data to controller, which is filtered for instrument change messages and injected back to the pedal data stream going to piano. This allows the pedals to play using the same instrument as selected on the piano by the user at any point. In addition, signals from both piano and pedals are combined and sent to a personal computer for recording.

IV. Responsible innovation

The device is designed as a multi-purpose tool that can be reused in various different configurations. When the designed I/O specification are not enough for a particular secnario, multiple devices can be daisy chained to expand e.g. to more keys. The components have been chosen with low power requirements in mind and the device itself shouldn't need more than about 100 mA and offers power saving modes. This should minimize the environmental impact.

Inspired by real needs of the author, it also provides value to aspiring musicians, not only by significantly lowering the costs of persuing interests in organ playing and organ building, but also by expanding the paradigm of musical instruments by allowing new combinations.

V. Author bio

I am currently a post-doc researcher in human vision and colour science at Newcastle University. I enjoy bringing technical and prototyping skills into fields where they are often overlooked, including humanities and natural sciences. I have experience with both hardware and software prototyping, soldering, PCB design, laser cutters and 3D printers, and I have contributed to both .NET Micro Framework and .NET Gadgeteer prototyping platforms.

VI. References

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