The BackBeat

Electronic Music Instrument Design

Spring 2018 Semester

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May 9th, 2018

Introduction

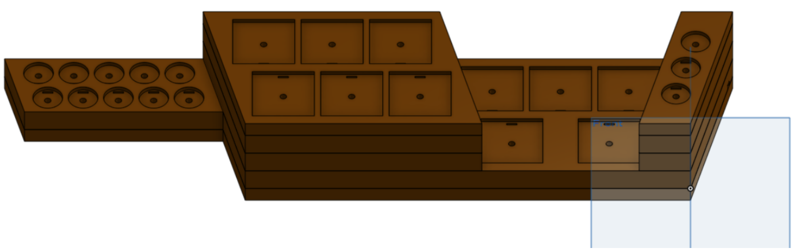
Drumming on a kit requires coordinating both legs and both arms to play even the simplest of rock beats. This skill takes lots of practice to feel natural, and even longer to sound good. However, it limits the ability of drummers to make other, more melodic sounds. The BackBeat addresses that issue by putting the entire drum kit in one hand. With the clever placement of a suite of sensors, one hand is now capable of replicating the sounds that used to take an entire body to produce. This new arrangement gives drummers a whole new level of freedom to be creative and expressive.

The instrument is divided into two different segments, one intended to create percussive sounds and the other intended for melodic sounds. The percussive section has square force triggered regions for the standard bass, snare, toms, and crash cymbal. To make it simpler to play than a drum kit, the hi-hat sound is triggered by breaking a horizontal line with either a drumstick or finger. This allows one hand to play the hi-hat at the same time as the bass or snare. On the upstroke, the line can be broken again which would play the hi-hat again. Once the musician gets the feel for playing beats with just one hand, that leaves them able to manipulate the remaining pads on the instrument. On the other side, the instrument has a neck that is reminiscent of a bass or guitar which allows the user to play a bass line or chord structures. These two separate regions can each be manipulated with just one hand, so a single person can play both a melody and a drum beat.

The instrument is configured so it can be played in multiple modes. Our group coded four distinct playing modes into the instrument. The first mode is hybrid mode, which is set up so that one side acts as a drum kit and the other acts like a bass. The second mode is bass mode. This makes the entire instrument into a laser bass, so that pressing the buttons on the neck does not produce sounds except for when the laser is strummed. This replicates how a guitar or bass is played. The third mode sets the whole instrument up to play percussive sounds. Lastly, the fourth mode is known as music box mode, and is programmed unlike any existing instrument to create a range of ephemeral and surprising musical sounds.

Design and Construction

The instrument was designed to be portable and durable, so it is entirely enclosed with just a USB cord emerging. The BackBeat was made of slices of white oak that were stacked and wood glued together. The material selection was made because of its durability to withstand drumstick hits and for its ease of workability. Each slice was designed in CAD software and then created with the use of an X-Carve CNC router. When stacked, the slices created an internal cavity with enough room to house an Arduino MEGA, a breadboard, and two lasers along with the wiring to attach everything together.



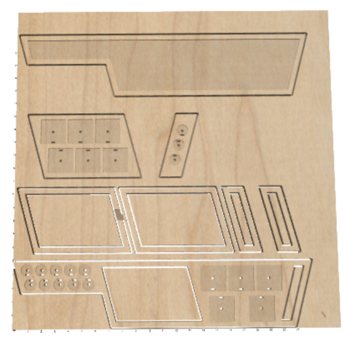


Figure 1: Initial CAD model on the left, and the individual cutouts shown on the right

On the top surface of the instrument there is a grid of force sensing resistors (FSRs) which are each covered by a thin layer of neoprene rubber. They are glued in place between the neoprene and wood surface, and the wires are routed through the wooden face to the internal opening. The two lasers were then mounted and calibrated so that they shine directly on the opposing photoresistors. Underneath the instrument there is a patch of neoprene to prevent it from sliding or rocking on the table during use. Lastly, a guitar strap was added so that the instrument can be played while standing, in addition to being laid flat on a tabletop.

Figure 2: Top view of the final assembly

The ergonomics of the BackBeat were a central focus of the design, so everything is laid out in positions that are easy to reach. On the neck, the sensors are round and positioned where fingers can rest on them naturally. The thickness and width of the neck were modelled based on the dimensions of an electric guitar neck, which are already designed for the comfort of the player. The height of the lasers was decided iteratively after testing multiple possible heights.

The aesthetics of the instrument were also important to us, which is why we took steps to ensure it looked clean and high quality. To guarantee the neoprene cutouts were perfect circles and squares, we cut them using the X-Carve, and then placed them in laser-cut acrylic. This made sure that all of the edges were perfectly smooth and that each sensor was evenly spaced.

Electronics

The sounds are triggered by hitting the FSRs along the instrument, or by breaking the laser beams which illuminate photoresistors. Each of the 27 sensors are wired in voltage divider circuits and measured rapidly by the input pins on the Arduino MEGA. The Arduino power pins are also used to supply voltage to the 5mW laser diodes that are integrated into the instrument. Lots of care was put into the wire management inside of the BackBeat so that all the wiring fits inside of the instrument to create a clean aesthetic, and to make the instrument portable and durable. The entire body is sealed shut with the exception of a single hole through which the USB cable emerges and supplies power to the instrument.

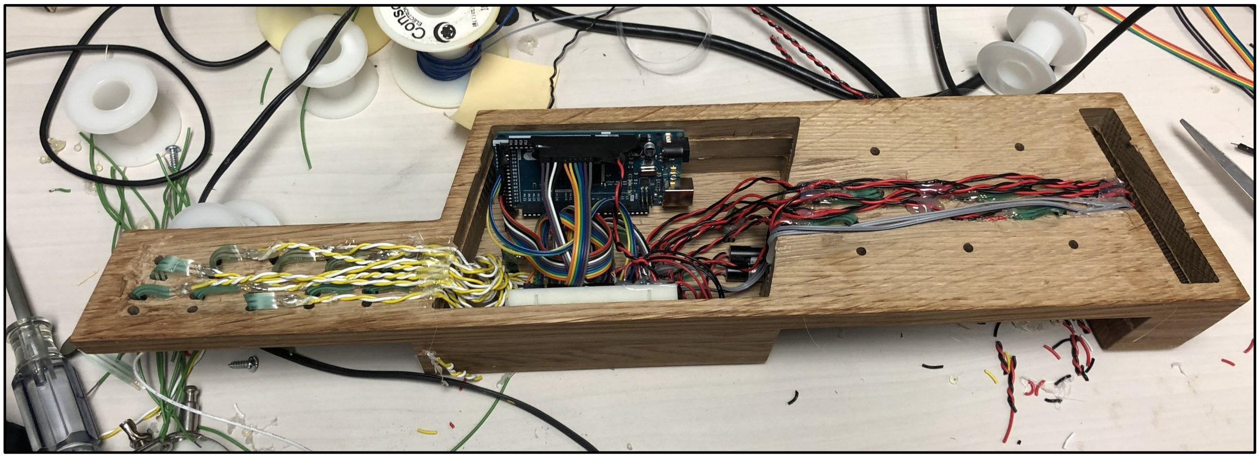


Figure 3: Bottom view of the instrument without the bottom cover attached, showing the wiring. The Arduino MEGA is mounted on the upper wall and a breadboard on the lower wall

Programming

The Arduino uses a supplied code to continuously output the pin readings to a MIDI manipulation software called Max. Within the Max patch, each of the analog readings is then parsed and coded to send a MIDI note-on signal at the appropriate times. The incoming data from the FSR pins is a nominal reading of 0, which changes between roughly 100 and 900 when being pressed, depending on the applied force. Max interprets this signal and sends the corresponding note-on signal with a velocity reading. The velocity of each hit is measured by averaging the first three sensor readings after a hit is detected and dividing that number by an appropriate scaling factor. Each FSR corresponds to a distinct note number. There are also three toggle buttons that allow the user to switch between playing modes and accent sounds.

The photoresistors which detect the laser beams have the opposite reading: a large number when the laser beam is unbroken, and a lower value when the beam is blocked. Using appropriate thresholds, the code determines when a laser beam is broken, and then calculates the amount of time until the next laser beam is broken. Depending on the delay, the velocity of the note is computed. A small delay indicates that the user is strumming hard, so the velocity is high. When the delay is longer, that means the user is playing a softer hit so the velocity is lower.

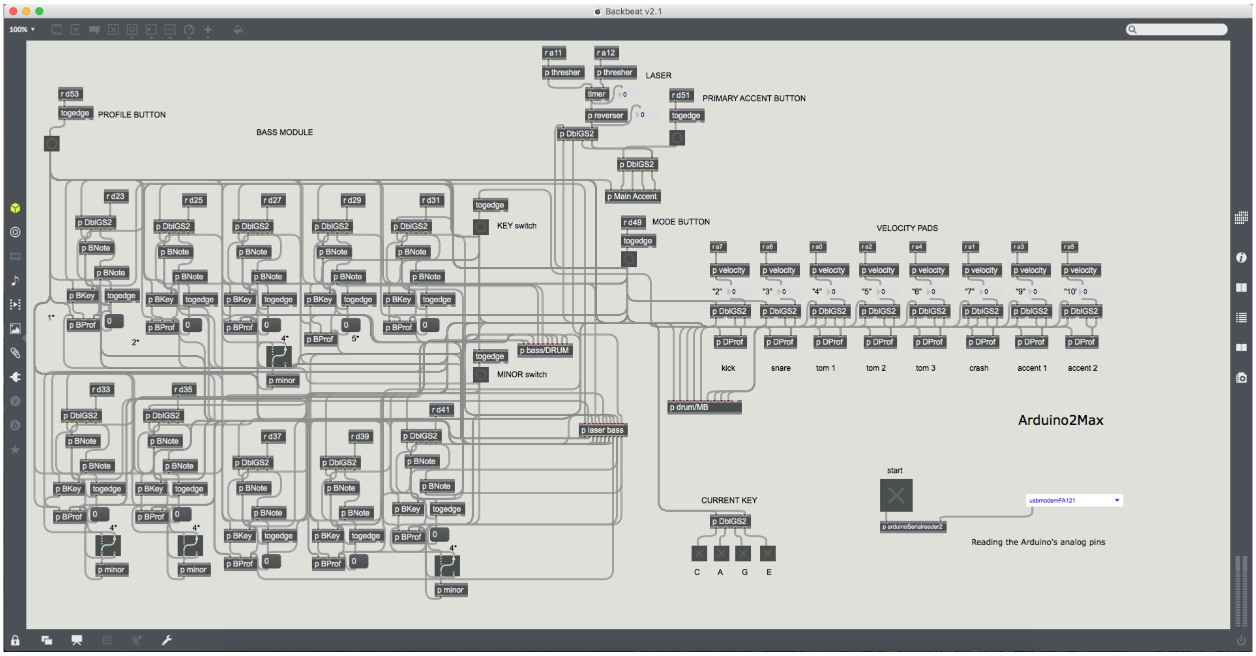


Figure 4: Max program front panel

Once the MIDI data is sent from Max, a separate program called Reason interprets the signals. A variety of modules within Reason determine which sounds are made. Depending on the mode that the instrument is set to, the MIDI data is either routed to synthesizers, percussion modules, or samplers. The group jointly decided which drum samples and bass sound we wanted to use so that the instrument has the intended feel. The setups are further supplemented with different profiles, so for instance the instrument can switch between jazz, rock, or disco sounds with the press of a button.

Moving Forward

The BackBeat was designed iteratively and the second version drastically improved on the first prototype. The biggest improvements were adding velocity readings for both the FSRs and the dual laser beams. The second version of the instrument also included the melodic neck section. The ability to switch modes and profiles was also a huge improvement. All of these updates drastically increased the expressiveness of the instrument. In addition, the design and construction of the instrument was a huge step forward in terms of aesthetics and ergonomics. These changes all compounded to create a much more engaging and dynamic playing experience, and are one step closer to what could one day be a final product.

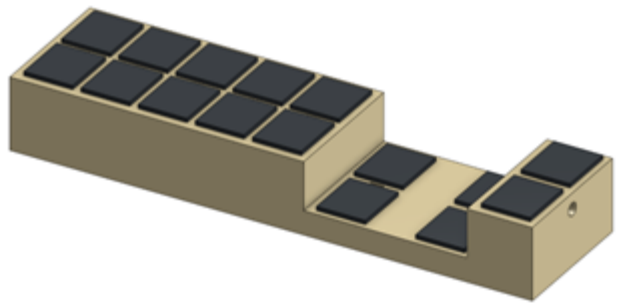


Figure 5: CAD model of the first BackBeat prototype

Two prototypes is almost never enough iterations to create a perfect product, however, and there are certainly improvements that we would make if there were to be a third version. To begin with, the internal wiring of the instrument is tedious and would be more robust if a custom PCB was used for the final wiring. Our group designed a PCB that would solve this problem, but the endmill we used to manufacture the board broke and a replacement was not available in time to pursue that aspect of the product for this version. In the future, making this PCB would hugely reduce the amount of time and energy that goes into final assembly, and would also make the instrument more durable.

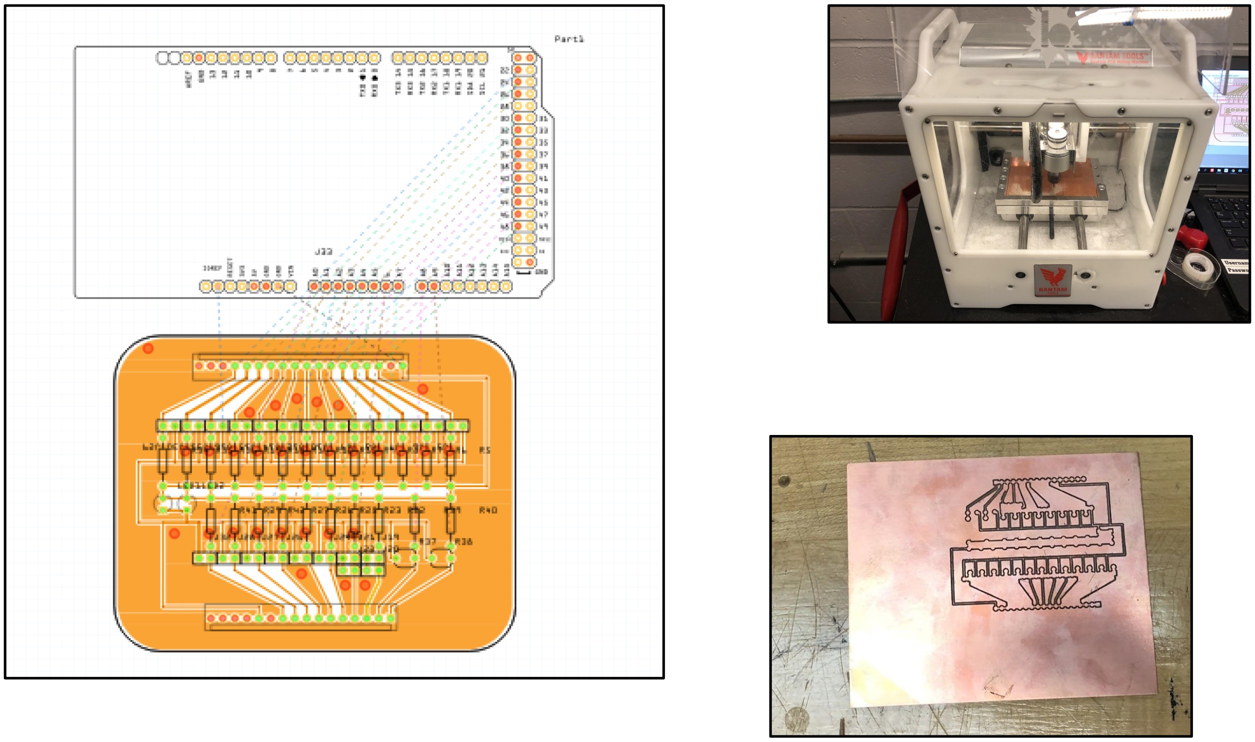


Figure 6: Steps of the PCB creation attempt

The next improvement we would like to see would be more visual feedback from the instrument, especially from the toggle switches which control the current play mode. Embedded LEDs which change color with each touch of the toggle switches would make the BackBeat easier to play. The team also had a design that would allow for this feature, but the LEDs tested were not bright enough to illuminate the acrylic faces as intended. Finding brighter lights or rethinking their placement would solve this problem and make for an even better user experience.

Conclusion

The BackBeat is a new type of instrument and was fun to build. It is something that the entire group is excited to use outside of the classroom and to add to their collections of instruments. The first proof of concept demonstrated that the idea is realistic, and the next version brought the concept even closer to its ultimate potential. Just like any instrument, with practice it has become more playable and useful, and it will be exciting to see what can be done by someone who truly masters the BackBeat.

Appendix

Bill of Materials				
Material	**Use**	**Source**	**Quantity**	**Cost**
White oak boards	Body of instrument	Wood supply store	8 board-feet	$50.00
Laser diode	Create laser beam	adafruit.com	2	$5.95
Photoresistor	Detect laser presence	Bray lab	2	-
0.5” circular FSR	Create small triggers	sparkfun.com	13	$6.95 ea
1.75” x 1.5” rectangular FSR	Detect stick hits for larger triggers	sparkfun.com	10	$9.95 ea
Neoprene	Covering for FSRs	Music Lab	4 sq ft	-
Clear acrylic, 1/8in thick	Hold neoprene in place	Bray lab	1 sheet	-
Various Wires, resistors, and breadboard	Wiring	Bray lab	-	-
Drumsticks	For playing	Already acquired	1	-
Arduino MEGA	Interpret sensors	Music Lab	1	-