BEAT STARTER

ECE 445 Design Review — Spring 2020

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3/3/20

1 Introduction

1.1 Objective

One issue in today's society is about how communities throughout America have a wide range of opportunities that they offer. For example, one environment could have thousands of available resources and opportunities whereas another area might only have a handful of those resources. In order to help bridge this gap in opportunity, the Hip Hop Xpress is a bus that will travel to different communities throughout the US to educate people on both music and technology to show people the resources that are available to them [1]. We want people, of all ages, to come together and become a part of the bus and their community in an educational way. By adding an easy-to-understand, interactive device that anyone could pick up and use would drastically help reach this goal by having them interact with some of the resources their environment does not currently offer. In order to meet this objective, we will design our own flat board, similar to a drum board, that would sit on top of a table. The board would have a wide variety of different sounds to select and combine in a loop to create personal beats. It would be portable in order to be set up outside the bus, so people can use our board without having to get on the bus. The board's instruments would be organized into several, color-coded sections.

1.2 Background

For many adolescents growing up in today's society, they are immensely impacted by their surrounding environment. For instance, some individuals have a lot fewer opportunities than others purely due to their surroundings. However, for many kids in America, their certain circumstances do not exhibit all the possible resources that exist around the world. If we are able to show kids something that they find very cool or interesting, we have a chance at changing those individuals' futures, quite possibly for the better. One method that is able to be reached and understood by many young people is music [1]. With the help of the Hip Hop Xpress, our idea is to present some of the simple yet interesting aspects of music and technology to kids that have never seen or even knew of devices like these existing. Overall, we want to help spark interest in the musical and technological industries in hopes that one day, someone finds their true passion from some of the resources that were not previously offered to them from their environment.

Our solution, Beat Starter, is not the first solution to teaching kids about music and technology. Some other methods that try to solve this issue involve using music the kids enjoy, downloading musical apps, and encouraging collaboration on music between children [2]. It has also been found that creativity is an extremely powerful tool for teaching which is why some games have been tied with music. For instance, a drumboard was used as a chess board where each time the players moved a piece, it would result in a different button being pressed which led to a different sound being made [2]. We believe our solution combines most of the above techniques into one user-friendly device. When Beat Starter is being played, the adolescents would be creating their very own beats which inspires creativity and incorporates styles of music the kids appreciate. Making our device multiple-user-friendly stimulates collaboration between the users which teaches them how to work as a team in order to reach a goal. We believe the combination of these methods makes Beat Starter an unique, teaching tool.

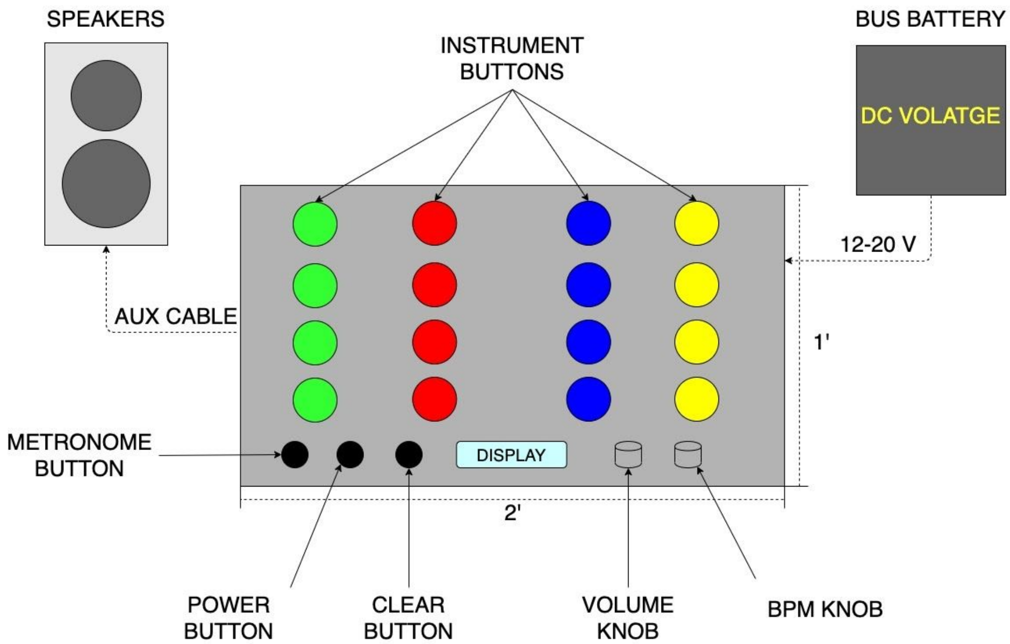


Figure 1. High-level 2D design displaying basic layout and use.

The bus battery will be powering our device so we will be running a cord from the battery to our board. We will have several different knobs and buttons to allow the user/users to create their own beat. The board will have a display panel which will allow the user to see useful information such as volume or BPM to adjust each to their own desire. Our device will also be AUX compatible, so an AUX cable will be needed in order for the user to listen to their newly created beat.

1.3 High-level requirements list

- We want at least two people to be able to use our device at the same time. In order to be considered a multiple-user device, we could make the physical board big enough for two people to stand side by side and use it simultaneously. Also, the board will have different features dispersed across the board to encourage a collaborative effort.
- Our device has at least four instrumental sounds, with three different pitches each. The four instruments of choice are drum sounds such as: kick, snare, hi-hat, and clap. We decided on these because they are fundamental hip hop instruments. The three pitches would be at the notes C, E, and G to stay in C major chord progression, one of the most popular hip hop chords.
- Our device will have a regular range of 60-120 beats per minute (BPM). For advanced users, we would also provide the option to double the BPM allowing for an even larger range of 60-240 beats per minute. We decided on these options and these ranges because adolescents who do not have a very concrete understanding of music might find using a higher BPM more challenging, but we also did not want to turn away the more advanced music kids by having a too simple of device. These ranges in BPM also give enough room to make plenty of completely different styles of beats. We wanted our product to appease both rookie and advanced music listeners which is why we will provide the option of doubling the rate.

2 Design

Our device will be powered by the bus's battery which is DC power. A three-prong outlet cord will be connected to a voltage regulator to drop the voltage in order for the PCB to function. Our design will consist of a flat board, similar to a drum board, that would sit on top of a table. The board would have a wide variety of different sounds to select and combine in a loop to create personal beats. The board's face will have various buttons and switches to receive user input. We will have buttons to control the instruments, power, and clear function and turn knobs to adjust volume and BPM. The created beats that are running in a loop will be stored and accessed in memory. For the display, the device will have a simple display panel to indicate the current settings. This includes volume level and beats per minute (BPM) count. The LCD panel will display the content provided by the PCB.

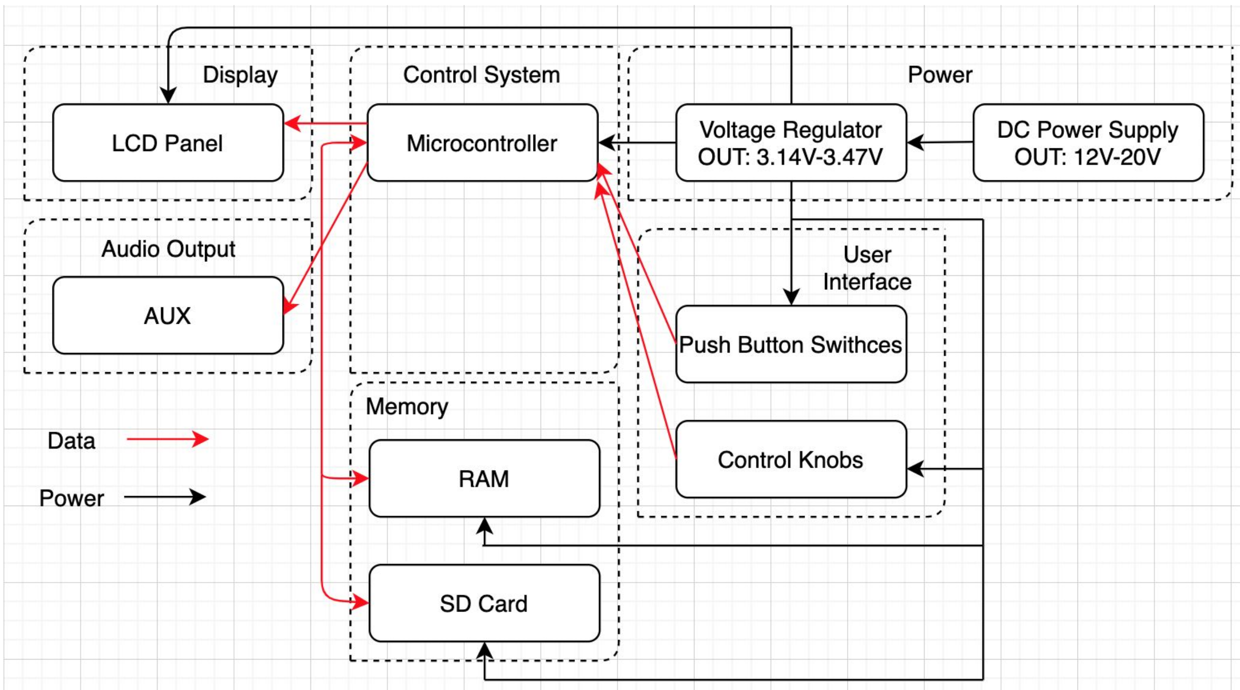


Figure 2. Modular Block Diagram of System.

The power supply will be connected to the voltage regulator to turn the voltage down in order to use all our other components which require a lower voltage. The switches and knobs will send digital data to the microcontroller. This digital data will be sent to the microcontroller which will then read and write memory from the digital information. The new information from memory will be sent to AUX in order to play the newly created beat. The microcontroller will also update the new input to the display panel.

2.1 Power

The power supply is needed to ensure all components of the device remain functional. Power from the bus battery must be regulated down to 3.3V to apply to our system [3].

2.1.1 DC Power Supply

We plan on using the bus's battery to supply power to our device.

Requirement: If we are not able to use the bus's battery to power our device, then we'll need to supply our own. This will need to be at least a 4V 500mAh battery.

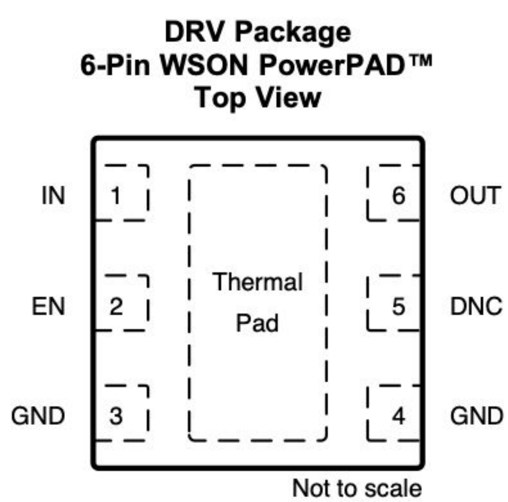
2.1.2 Voltage Regulator

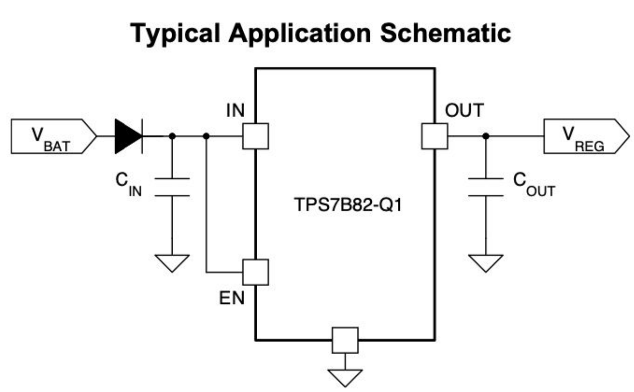
Part: TPS7B8233QDRVRQ1 300mA High-Voltage Ultra-Low IQ Low-Dropout Regulator
Input: 12-20V from bus battery
Output: 3.3V to switches, knobs, microcontroller, raspberry pi, and LCD panel [4]

The bus battery supplies power at a much higher voltage than we need. Due to this, we need to be able to step down the voltage to a level our system can handle.

NAME	PIN	I/O	DESCRIPTION
IN	1	I	Input power-supply pin
EN	2	I	Enable input pin
GND	3, 4	---	Ground reference
DNC	5	---	Do not connect this pin to a biased voltage. Tie this pin to GND or leave floating
OUT	6	O	Regulated output voltage pin

Table 1: Pin Configuration





2.2 Control System

The control system needs to take in information from the buttons, knobs, and RAM to write to memory, display the proper readings, and output the created audio signals.

2.2.1 Microcontroller

Input: 3.3V from voltage regulator

The microcontroller needs to be able to detect the correct button, corresponding to an exact instrument and pitch, that was pressed by the user from the signal that came from the respective push button switch. Then, we will be using the raspberry pi to read memory on the RAM to send that audio signal to output while at the same time write memory to keep repeating that sound in the loop. If the BPM or volume knobs are turned, it needs to adjust the rate of the beats and the volume level on the speaker itself accordingly. It also needs to be able to output these new changes to BPM or volume on the display. When the user hits the clear button, it needs to be able to write memory to erase all of the previously created beats.

2.3 User Interface

The board's instruments would be organized into several, color-coded sections. Each instrument based section would contain several different buttons. We would also include BPM and volume knobs that would also be sending data to the PCB.

2.3.1 Push Button Switches

Input: 3.3V from voltage regulator
Output: 1-bit code to raspberry pi

Instrumental Buttons: large, color-coded buttons organized by instrument and pitch.
Power Button: allows the user to turn the device on and off.
Clear Button: removes existing sounds from the loop to start a new session.

2.3.2 Control Knobs

Part: PEC11-4215F-S24
Input: 3.3 V from voltage regulator
Output: 2-bit code to raspberry pi [5]

BPM Knob: gives users the ability to adjust BPM of the loop playing.
Volume Knob: allows for volume adjustment.

2.4 Memory

The memory needs to be able to be read and written.

2.4.1 RAM

The RAM, on the raspberry pi, will contain our data of the current loop. It needs to constantly be read and written to update with new sounds and keep the previous sounds repeating in the loop. When the clear button is pressed, the memory of the sounds in the loop are erased.

2.4.2 SD Card
The SD Card will contain our library of samples. It will only need to be read. Based on which button is pressed, we need to be able to access memory and send that data over to the microcontroller to update the current loop.

2.5 Display
A small panel located on the face of the board used to provide the user with information and status of settings.

2.5.1 LCD Panel
A small panel located on the face of the device to display settings such as BPM and volume. [6]

Requirement 1: Panel must be visible in daylight.
Requirement 2: Panel must receive a maximum of 1 mA.

2.6 Requirements and Verifications

VOLTAGE REGULATOR	
REQUIREMENT	VERIFICATION
1. Must provide 3.3V +/- 5% from a 12-20V. 2. Must provide voltage at a minimum current of 100 mA.	1A. Use a DMM to measure open-circuit voltage to ensure it is within desired range 1B. Provide a resistive load such that the voltage drop is 3.14 V (minimum desired voltage). 2. Use a DMM to measure current through the load and make sure it is at least 100 mA.

USER INTERFACE	
REQUIREMENT	VERIFICATION
1. Buttons and knobs must have a maximum latency of 0.2 seconds. 2. Buttons are debounced to limit one register per press.	1A. Use an oscilloscope to measure response time after individual button presses (knob turns). We will do this by probing the signal from the button (knob) and compare it to the signal sent by the micro-controller due to the action. 2A. Observe signal from buttons with an oscilloscope. 2B. If output signal from button is bouncing, then apply a debouncing circuit.

MICRO-CONTROLLER	
REQUIREMENT	VERIFICATION
1. Operates within range of 3.3V +/- 5%. 2. Must drive a minimum of 100 mA.	1. While running micro-controller probe input and output voltage with DMM/ oscilloscope. Confirm difference between Vin and Vout is within 3.135-3.465 V 2. While running micro-controller probe with DMM to confirm minimum current is at least 100 mA.

DISPLAY	
REQUIREMENT	VERIFICATION
1. Panel displays correct settings as user toggles BPM and volume.	1A. Observe display panel as volume and BPM knobs are turned. 1B. Ensure setting increase and decrease with corresponding turns.

AUDIO OUTPUT	
REQUIREMENT	VERIFICATION
1. Audio is outputted with a signal to noise ratio of at least 25 dB.	1A. Using an oscilloscope measure the RMS of the noise output alone. 1B. Output an audio signal measure its RMS and calculate the SNR 1C. Ensure SNR is at a minimum of 25 dB

2.7 Tolerance Analysis

The control system is a great risk to the success of our project. This is where software meets hardware. Every subsystem of our device connects to the PCB. Significant programming will have to go into our control system in order to meet our deliverables. We at least need code that can modify BPM of our audio signal in real time. The PCB will be connected to our memory system. Time discrepancy between memory access and looping will be something challenging we must overcome. Due to our device being able to support multiple users, our system will also have to recognize simultaneous button presses. The overall amount of input that can be done at once, along with correct timing of every button press, causes our biggest problem due to the amount of simultaneous data that must be processed [7].

Therefore, we want a signal-to-noise ratio as high as possible. **The ratio between the signal power and the noise power is the Signal-Noise Ratio** and be calculated as:

$$SNR = \frac{P_{signal}}{P_{noise}}$$

SNR is also usually represented in decibels (dB)

$$SNR = 10\log\left(\frac{P_{signal}}{P_{noise}}\right)(dB)$$

or if working with the amplitudes of signal and noise

$$SNR = 10\log\left(\left(\frac{A_{signal}}{A_{noise}}\right)^2\right) = 20\log\left(\frac{A_{signal}}{A_{noise}}\right)(dB)$$

We will have to find the most adequate quantization of button presses to stay on beat so that the learning curve of our product stays low, without taking away from the uniqueness and desired result given by the user. If the quantizing value is too high, then the user will notice a delay from their input to the produced sound. If the quantizing value is too low, a new user will struggle to make a beat that sounds desiring.

3 Cost and Schedule

3.1 Cost Analysis

PARTS					
DESCRIPTION	QUANTITY	MANUFACTURER	VENDOR	COST/UNIT	TOTAL COST
Voltage Regulator	1	Texas Instruments	ti.com	$1.28	$1.28
15 pc Push Buttons	1	Awpeye	amazon.com	$13.99	$13.99
Raspberry Pi	1	Raspberry Pi	amazon.com	$42.00	$42.00
Rotary Encoder	2	Adafruit	adafruit.com	$4.50	$9.00
16 GB microSD Card	1	SanDisk	amazon.com	$6.50	$6.50
LCD Display	1	Adafruit	newark.com	$19.95	$19.95
TOTAL					$92.72

Table 2: Parts Cost

LABOR			
NAME	HOURLY RATE	HOURS	TOTAL
Individual Labor	$50	150	$7500
Team Labor	$50	150	$7500
Parts	$50	150	$7500
TOTAL			$22,500

Table 3: Labor Cost

GRAND TOTAL	
SECTION	TOTAL
Labor	$22,500
Parts	$92.72
TOTAL	$22,600

Table 4: Grand Total Cost

3.2 Weekly Schedule

SCHEDULE		
WEEK	TASK	RESPONSIBILITY
3/2/20	**Design Review**	ALL
	PCB design	Kevin
	Machine shop design	Collin, John
3/9/20	**Solder Assignment (3/13)**	ALL
	Teamwork Eval I (3/10)	ALL
	Order parts	Collin
	Order PCB	Kevin
3/16/20 (SPRING BREAK)	Revise machine shop design	Collin
	Playback module	John
3/23/20	Finalize machine shop design (3/27)	Kevin
	Finish playback module	John
3/30/20	**Individual Progress Report (3/30)**	ALL
4/6/20	Assemble and test PCB	Kevin
4/13/20	Testing individual modules	Kevin
	Prepare mock demo	John
4/20/20	**Mock Demo**	ALL
	Finalize assembly	Collin
	Prepare demo	John
4/27/20	**Demo**	ALL
	Prepare mock presentation	Collin
	Mock Presentation	ALL
	Prepare presentation	Kevin
5/4/20	**Presentation**	ALL
	Final Report (5/6)	ALL
	Lab Notebook Due (5/7)	ALL
	Teamwork Eval II (5/7)	ALL

Table 5: Week by Week Schedule

4 Ethics and Safety

It is important to us to not break any of the Ethic Codes set before us by IEEE. We plan on accomplishing this by taking diligence during the development of our project. According to Code 1 of the IEEE Code of Ethics, we will paramountly hold the safety and health of the public by making the device durable and easy to use [8]. We will ensure that the electronic wiring, the only hazardous part of our design, is wired correctly and not accessible by the user.

The purpose of our project is to be able to teach and bring people of all ages in a community together through the creation of their own hip-hop music. Adhering to Code 5 of the IEEE Code of Ethics, we will "improve the understanding by individuals and society…" of music and the effect it has on communities, through our technology [8]. We will be able to tell if the understanding of the community and individual has improved, based on the ability to use our device.

Our device will use sampled noises and sounds from libraries constructed by other users and companies. We will ensure the correct citing and give credit based on the specific guidelines of the chosen resource. This adheres to Code 7 of the IEEE Code of Ethics [8].

Our device will be powered from a 12-20V source courtesy of the bus. This is too much voltage for our system to handle, so we will use a voltage regulator to allow for 3.14-3.47V to pass to our system. This will prevent the circuit from erupting and causing possible harm to any user. The design of our device is simple and easy to understand as to reduce the possibility of misuse and harm. The corners of our design could harm a user and the device if it was dropped so we could add rubber protectors on the sides to prevent this.

One potential hazard we have considered for our project is potentially blowing out the speakers connected to the device. The speaker receiver can usually handle at max +16dB, but keeping it below -6dB will almost always prevent the receiver from being over-driven [9]. Therefore, our volume knob will keep a range from -infinity(mute) to -6dB. The gain and drive of our sample will be universal so that there are no discrepancies between the volume of each sound.

References

[1] The Hip Hop Xpress, publish.illinois.edu/hiphopxpress/.

[2] “10 Tips For Teaching Music to Kids More Effectively.” Solfeg.io, 11 Dec. 2019, solfeg.io/teaching-kids-music/.

[3] “Tips to Ensure Your PCB Power Distribution Requirements Are Satisfied.” Tempo, 19 June 2019, www.tempoautomation.com/blog/tips-to-ensure-your-pcb-power-distribution-requirements-are-satisfied/.

[4] “TPS7B82-Q1 High-Voltage Regulator.” TPS7B82-Q1 High-Voltage Regulator, 2019, www.ti.com/lit/ds/symlink/tps7b82-q1.pdf.

[5] “1115 - LCD and Keypad Kit, 16x2, Blue and White, Raspberry Pi.” Newark, 2013, www.newark.com/adafruit/1115/blue-white-16x2-lcd-keypad-kit/dp/52W9087?gclid=CjwKCAiA-vLyBRBWEiwAzOkGVB21kUl8MNlk4OeSHvBa310C7OyhkwStpmyih1BgG71GVpLRYe_lVxoCcwMQAvD_BwE&mckv=sWQjBbKH2_dc%7Cpcrid%7C81605889141%7Cplid%7C%7Ckword%7C%7Cmatch%7C%7Cslid%7C%7Cproduct%7C52W9087%7Cpgrid%7C20389674261%7Cptaid%7Cpla-294357559827%7C&CMP=KNC-GUSA-GEN-SHOPPING-AllProducts.

[6] Adafruit Industries. “Rotary Encoder + Extras.” *Adafruit Industries Blog RSS*, www.adafruit.com/product/377.

[7] Gonçalves, Hugo. “Signal-Noise Ratio (SNR).” OnMyPHD, www.onmyphd.com/?p=snr.signal.noise.ratio.

[8] Ieee.org, "IEEE IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html.

[9] Heyne, Cliff. “AV Tip: How to Avoid Blowing Out Your Speakers.” Audioholics Home Theater, HDTV, Receivers, Speakers, Blu-Ray Reviews and News, 16 Oct. 2013, www.audioholics.com/home-theater-connection/avoid-blowing-speakers.