# Homework 4: Packaging Specifications and Design

**Team Code Name: Beat Square** **Group No. 01**

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**Evaluation:**

| SEC | DESCRIPTION | MAX | SCORE |
|---|---|---|---|
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| 2.0 | Commercial Product Packaging | - | |
| 2.1 | <Product #1> | 10 | |
| 2.2 | <Product #2> | 10 | |
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| | TOTAL | 100 | |

**Comments:**

## 1.0 Introduction

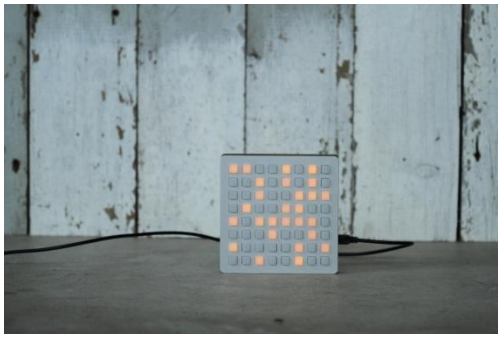
The BeatSquare is a music creation device featuring an 8 x 8 grid of LED-illuminated pushbuttons. The user can play with the pushbutton grid to create a simple repeating melody, and control several parameters such as the volume and BPM. Users may also store device configurations to the device's memory, or save the created melody into a simple MIDI file output on an SD card.

The shape of the device will be a simple flat, rectangular plastic box. The box should be small enough to be portable, yet large enough to be ergonomic and durable enough to withstand occasional knocks or hard button presses. The button-LED grid will be centered prominently at the bottom of the box, and the parameter controls, LCD interface, and speakers will be located at the top. The power jack, SD card slot, and power and reset buttons will be located on the back side. The PCB will be located inside the box in order to be as close to these controls as possible, so the packaging should be tall enough to accommodate it.

## 2.0 Commercial Product Packaging

In the following section two commercial designs ware detailed and contrasted with the Beatsquare. The following two products are similar in design however they do however differ significantly in functionality. Both products feature designs that would be difficult to reproduce with the available tools and materials.

### 2.1 Product #1: Monome



The monome is a product that has been detailed in previous homeworks. It is an 8x8 grid of buttons that light when pressed. The effect of these buttons presses is up to the application interfacing with the monome. Most of the applications on the monome website are musical in nature and utilize the monome device as a sort of sequencer. The monome website details the

exact materials used in the packaging. "Pennsylvania black walnut, 6061 anodized aluminum, custom silicone keypads, custom encoder knobs. bright yellow leds." [1] The choice of materials leads the monome to have a premium look and feel. The contrast between the anodized aluminum and black walnut results in a very modern look and feel. The black walnut exterior is only broken by the USB port and four anti-slip rubber pads located on the four bottom corners. All of these packaging choices lead to a very sleek looking device. The trade-off of these these choices include functionality and mainly cost. The monome was not designed to have many of the functionality that the BeatSquare will contain and thus could design sleeker packaging. The BeatSquare will feature nonslip rubber pads on the bottom of the device.

### 2.2 Product #2: Ableton Push

The Ableton Push was also detailed in previous assignments. The Ableton Push also includes an 8x8 grid of illuminated buttons but this product also has features such as an LCD display for user interaction, multiple twist knobs in order to adjust parameters, and other features. The Push is made of black plastic and metal. The front and side exteriors are black plastic while the bottom is black painted metal. [2] This gives the Push a less premium look when compared to the Monome. One result of the plastic enclosure design choice is that despite the far greater feature set the Push is only $100 more than the Monome with software included. The software Ableton produces to interface with the Push is called Live 9 and is sold separately for $99 bringing the hardware price on par with the monome. [3] The Monome does not include software and relies on users to create applications. The Push's packaging includes the I/O on the side of the device. The BeatSquare will use a similar system with the I/O devices located along

one edge of the device. Unlike the Push the BeatSquare will have the LCD and user controls located below the 8x8 button grid so that the user may interact with them more readily.

## 3.0 Project Packaging Specifications

Several constraints for the project's packaging must be met. First, the device must be small enough to be portable and easy to handle, yet large enough to be ergonomic without giving the user interface a cluttered feeling. Second, the product must accommodate a PCB board and cabling to connect the peripheral controls to the PCB without sacrificing compactness. Third, the device's packaging must be durable enough to withstand typical usage.

A simple box shape was chosen for the base layout of the product due to the need for a simple form factor. This will provide each set of controls with a flat surface. From a top-down perspective, the 8x8 LED pushbutton matrix will be situated at the bottom of the front panel. This is the component that will be most utilized during operation, so this position on the packaging reduces the need for the user to reach or stretch. This part is also the largest, measuring 200 cm square, so the box must be at least 200 cm wide (plus some additional margin) to accommodate this. The speakers are located in the corners at the back of the front panel, away from the user, so that the user will not be covering them while reaching for other controls. This will allow the sound to travel more freely. This leaves room for the LCD to sit between the speakers, and for the buttons and knobs used to interface with the device's parameters to sit in a line between the speakers/LCD and the LED button matrix. An option that has been considered is to angle the area containing the controls, LCD, and speakers up at a slight angle between 20 and 30 degrees, so that the controls and screen are more accessible and visible. Finally, the SD card interface, power jack, and power and reset switches will reside on the back panel due to this face's proximity to the PCB, and because at least two of these four controls will be mounted directly to the PCB.

As of yet, the height of the product's packaging box is undetermined, but is estimated to be in the ballpark of 10 cm. This is small enough for the device to retain a flat shape while still granting enough room for the PCB and the cabling that will attach the exterior controls to the PCB. This also allows for some standoff spacers to be used to suspend the PCB between the top and bottom of the box, keeping the heat from the electronics away from the packaging's exterior.

The box itself will be made of plastic, probably acrylic due to its durability. Assuming a height of 10 cm, the box will require a surface area of about 410 square inches, not accounting for holes for the peripherals. This totals about 4.4 lbs. in weight for the acrylic. The front face and back faces will measure 23 x 33 cm, or roughly 9 x 13 in. Each side face will measure 33 x 10 cm, or 13 x 4 in. The top and bottom faces will measure 23 x 10 cm, or 9 x 4 in. Custom cut acrylic sheets may be ordered from sites such as TAP Plastics, where two 1/4 in. thick sheets of opaque acrylic - one measuring 13 x 26 in. and two each measuring 9.1 x 7.9 in. – may be ordered for about $42.27. [4] The large sheet will have to be cut by hand into four separate faces for the top, bottom, and sides. The smaller sheet will also have to be cut by hand to form the front and back faces.

## 4.0 PCB Footprint Layout

The PCB itself does not require any particular shape and, similar to the physical packaging, is constrained in two ways: it must be large enough to hold all of the components required, but small enough to fit into the compact shape of the device. The location of the PCB was chosen to be close to the back of the device, nearest to the control buttons and LCD, and also nearest to the power source. Another constraint is that the PCB must fit between the speakers in the corners, to minimize magnetic interference. The speakers are rated at 12W and 8 Ohms, so they are not so powerful as to fully disrupt the PCB's operation, but it is best to be safe. Additionally, trying to place the PCB below the speakers would result in increasing the height of the box and adding unused space to the packaging's interior.

A majority of the components used for this design feature an SOIC or SSOP footprint type. An obvious exception to this is the TM4C123GH6PM microcontroller, which features an LQFP type. These types of footprints are easy to solder, and thus were chosen for this design. Utilizing the maximum areas recommended for all of the parts listed in Appendix B, the total area required for ICs and the micro comes to a total of 2193.2 $mm^2$, or roughly 3.4 $in^2$. This does not include footprints for pin headers that will connect via cable to the LED button matrix breakout boards, the pushbuttons, the rotary encoders, or the LCD. Nor does this measurement account for any area for space, traces, or passive components.

One interesting point is that the specified voltage regulator has two packaging options that both look promising: the standard SOIC, which will tentatively be used, and a SIP style that

is designed to be mounted so that the three pins are flat against the board. This package type would likely save space, but may have additional issues not yet identified, such as heat or power dissipation that should be investigated before making the final choice.

## 5.0 Summary

In summary, the major packaging constraints of this project are that it be large enough to fit all of the interface components and the PCB, yet small enough to be portable and ergonomic. Several design choices must still be made concerning the height of the box and the angled elevation of the control panel section, but these are fairly trivial. The PCB will rest in the back lower corner of the device, closest to the power source and a majority of the functional controls. The size of the PCB is constrained by the location of the speakers, as well as the size of the packaging itself. The components on the PCB feature footprint types that are both small and easy to solder onto the PCB. Finally, the physical packaging of the device will be an opaque acrylic box that will both hold up well to everyday wear and tear, and also give the product a sleek look and feel.

## 6.0 List of References

[1] devices | monome, Monome.org, [Online] 2014 http://monome.org/devices/ (Accessed: 29 January 2014)

[2] James, Trew "Ableton Push review: a dedicated controller for the Live faithful" (Engadget), [Online] 2013, http://www.engadget.com/2013/03/24/ableton-push-review/ (Accessed: 13 February 2000).

[3] Ableton Push, ableton.com [Online] 2014 https://www.ableton.com/en/push/ (Accessed: 29 January 2014)

[4] "Translucent and Opaque Colored Acrylic Sheets" [Online] http://www.tapplastics.com/product/plastics/cut_to_size_plastic/acrylic_sheets_color/341 2014 (Accessed: 14 February 2014)

[5] “LM317L” [Online] http://www.ti.com/product/lm317l 2014 (Accessed: 14 February 2014)

## Appendix A: Project Packaging Illustrations

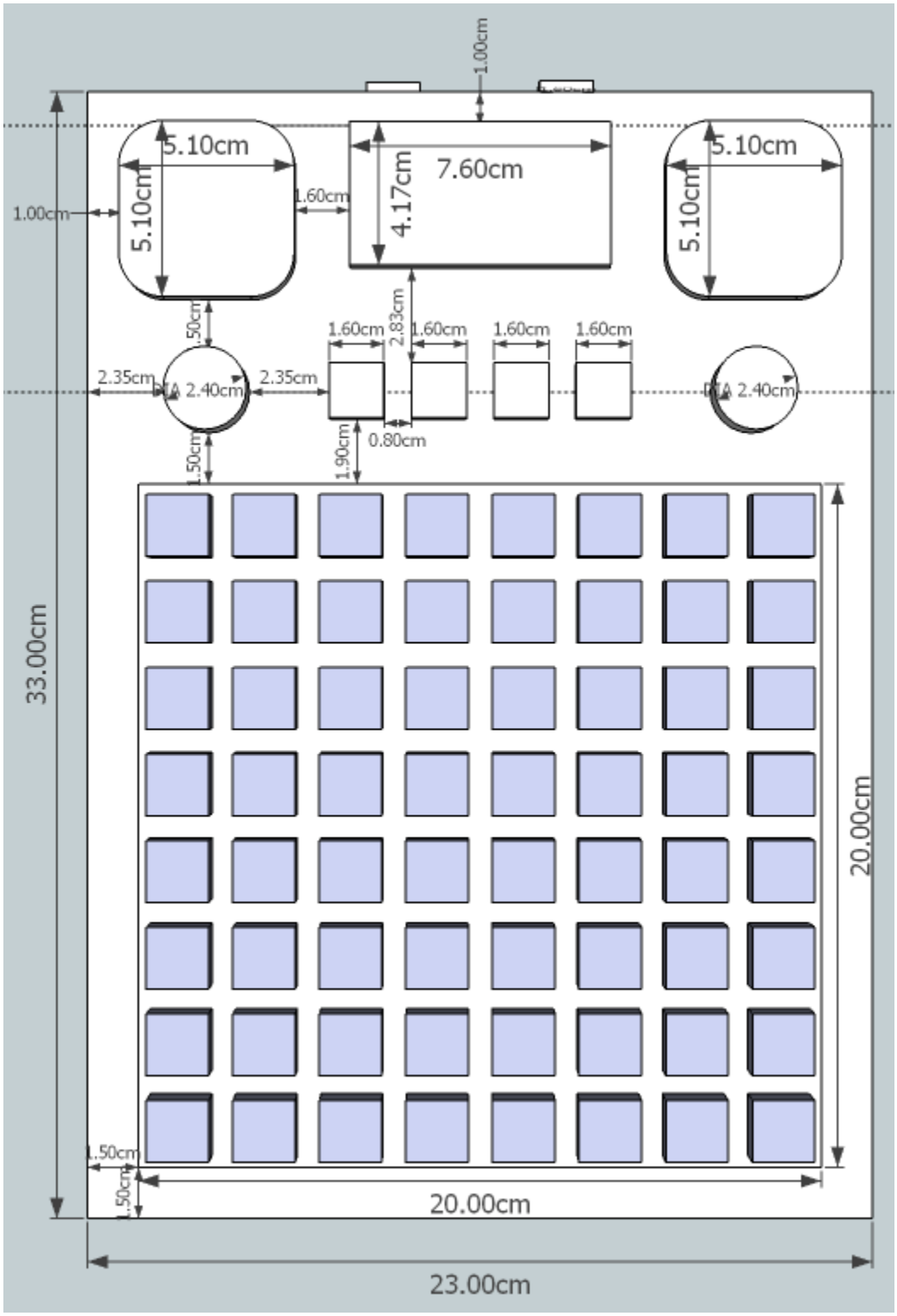



**Figure 1. Top view with main interface**

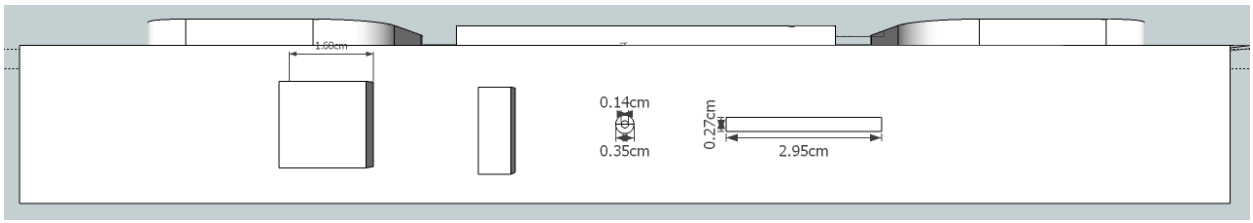



**Figure 2. Back view with SD card interface, reset switch, power jack, and power switch**

## Appendix B: Project Packaging Specifications

| Material | Tooling | Weight | Size | Cost |
|---|---|---|---|---|
| Acrylic | Table Saw, Drill | 3.60 lbs | 13 x 26 x 0.25 in | $ 32.27 |
| Acrylic | Table Saw, Drill | 0.77 lbs | 9.1 x 7.9 x 0.25 in | $ 10.00 |

**Table 1. Estimated Material Specifications**

| Part | Name/Number | Package | Dimensions (mm) | Count | Total Area ($mm^2$) |
|---|---|---|---|---|---|
| DC Power Jack | PJ-014DH-SMT | Surface Mount | 10.8 x 9.3 | 1 | 100.44 |
| Voltage Regulator | LM317L | SOIC | 6.2 x 5.0 | 1 | 31.00 |
| Step-Down Converter | LM2675 | SOIC | 6.2 x 5.0 | 1 | 31.00 |
| Microcontroller | TM4C123GH6PM | LQFP | 12.2 x 12.2 | 1 | 148.84 |
| SD Card Connector | 67913-0002 | Surface Mount | 30.6 x 29.3 | 1 | 896.58 |
| DAC | DAC8571 | VSSOP | 3.1 x 5.05 | 1 | 15.655 |
| Op-Amps | LM324 | SOIC | 6.2 x 8.75 | 1 | 54.25 |
| SIPO Shift Register | 74HC595 | SOIC | 6.2 x 10.00 | 5 | 310.00 |
| PISO Shift Register | 74HC165 | TSSOP | 5.1 x 6.6 | 1 | 33.66 |
| Switch Debouncers | MAX6818 | SSOP | 7.3 x 7.9 | 1 | 57.67 |
| Transistors Array | ULN2803A | SOIC | 11.75 x 10.63 | 1 | 124.90 |
| Level Shifter | 74LVC245 | SOIC | 13.0 x 10.63 | 2 | 276.38 |

**Table 2. Estimated PCB Component Specifications**

## Appendix C: PCB Footprint Layout

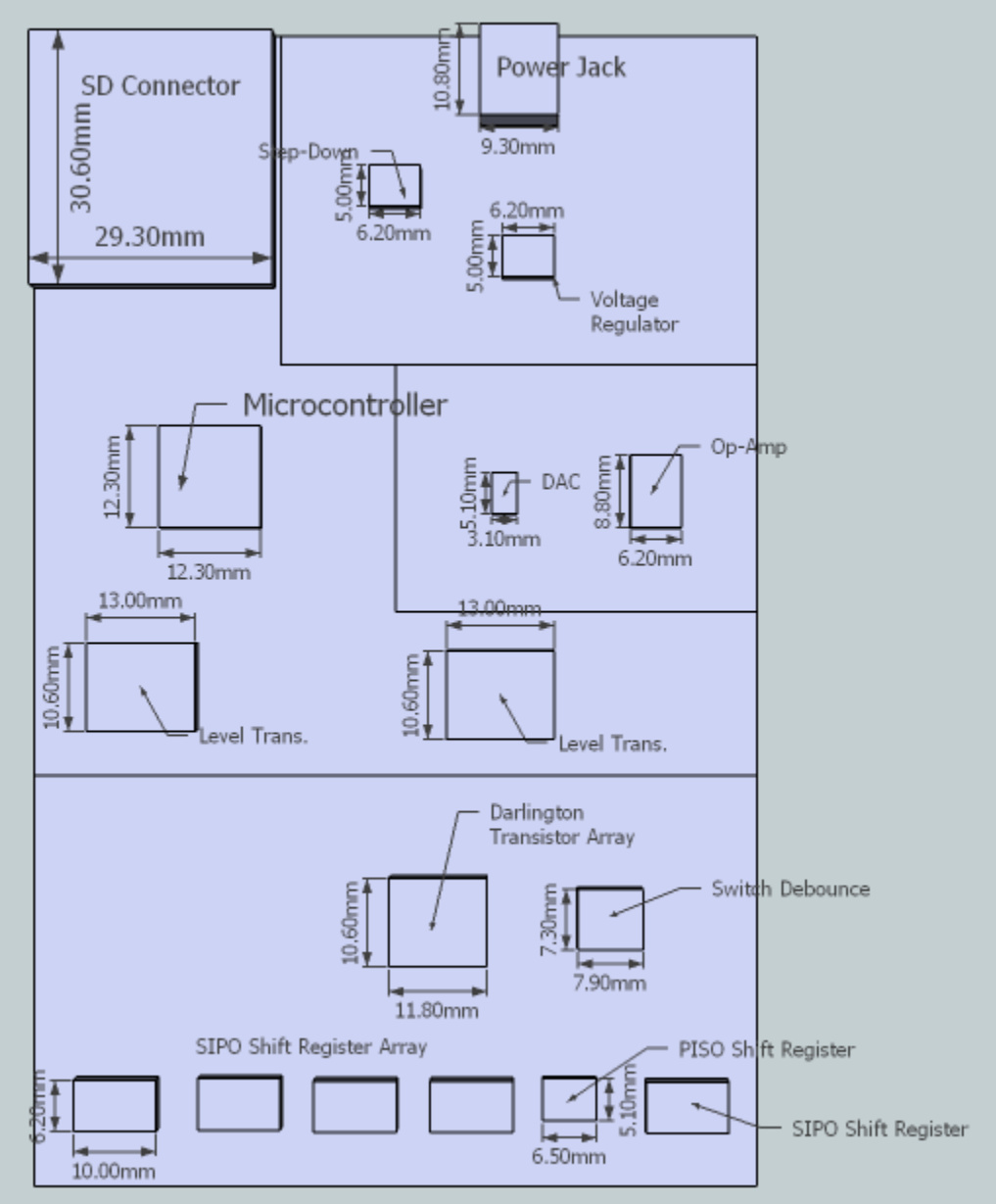



**Figure 3. Estimated PCB Layout**