Gizmo
An Arduino MIDI Tool
By Sean Luke sean@cs.gmu.edu *For Aric*

Gizmo is a small MIDI device intended to be inserted between the MIDI OUT of one device and the MIDI IN of one or more other devices. There are a number of tools like this, such as the esteemed MIDIPal[1] or a variety of tools from MIDISolutions.[2]

Gizmo is the unholy union of an Arduino Uno or Arduino Mega 2560,[3] an Adafruit 16x8 I2C LED matrix[4], and a SparkFun MIDI Shield[5] to perform a variety of helpful MIDI tasks. Gizmo has several built-in applications, and assuming there's space[6] you can develop additional applications for it.

This is a software project: the hardware is just three off-the-shelf boards and four wires. There's no enclosure, no custom board. If you'd like to make an enclosure, I'd love to see it.

Gizmo comes built-in with the following applications and other capabilities:

Applications

- **Arpeggiator.** Gizmo's arpeggiator has built-in up, down, up/down, repeated chord, note-assign, and random arpeggios spanning one to three octaves. Additionally, you can define up to ten additional arpeggiator patterns, each up to 32 notes long, involving up to 15 different chord notes, plus rests. Arpeggios can be *latched* (or not), meaning that they may continue to play even after you have released the keys. You can specify the note value relative to the tempo (ranging from eighth triplets to double whole notes), the note length as a percentage of the note value (how legato or staccato a note is), whether or not the velocity is fixed, the output MIDI channel, and the degree of swing (syncopation). Gizmo will show the arpeggio on-screen.

- **Step Sequencer.** Gizmo's step sequencer can be organized as 12 16-note tracks, 8 24-note tracks, or 6 32-note tracks. Each note in a track can have its own unique pitch and velocity, or be a rest, or continue (lengthen, tie) the previous note. You can also fix the velocity for an entire track, mute tracks, fade their volume, specify their independent output MIDI channels, specify the note value relative to the tempo (again ranging from eighth triplets to double whole notes), the note length as a percentage of the note value (how legato or staccato a note is), and the degree of swing (syncopation). The step sequencer lets you edit in two modes: either by triggering independent steps like a classic drum sequencer, or by playing a sequence of notes. The Arduino Uno can store up to two sequences in its slots (shared with the Recorder, discussed next). The Mega can store up to nine sequences. Gizmo will show and edit sequences on-screen.

- **Recorder.** The Arduino doesn't have a lot of memory, but we provide a note recorder which records and plays back up to 64 notes (pitch and velocity) played over 21 measures. The recorder has 16-voice polyphony. It's enough to record a very short ditty. You can also set the recorder to loop the recording while playing, and to provide a click track. The Arduino Uno can store up to two recordings in its slots (shared with the Step Sequencer). The Mega can store up to nine recordings.

[1] Though they share nothing in common, MIDIPal is quite similar to Gizmo in functionality and goals. But I wasn't even aware of the existence of MIDIPal when I started building Gizmo. And besides, re-inventing the wheel is fun! I've since ripped off a few of MIDIPal's features. MIDIPal's page is http://mutable-instruments.net/midipal This device has been discontinued, but its open source software lives on in other hardware clones, such as the MIDIGal (https://midisizer.com/midigal/) or MIDIBro (http://www.audiothingies.com/product/midibro/)

[2] http://www.midisolutions.com/

[3] http://arduino.cc

[4] https://www.adafruit.com/categories/326 I use the 1.2-inch 16x8 matrix with red round LEDs, which works well. This particular model can be found at https://www.adafruit.com/products/2037

[5] https://www.sparkfun.com/products/12898

[6] As of this writing, Gizmo on the Arduino Uno uses 32,252 bytes out of 32,256 available. So if you're like to extend Gizmo on the Uno, you'll need to make sure your extension fits within 4 bytes :-) Instead: get a Mega.

- **MIDI Gauge.** The gauge will display all incoming MIDI information on one or all channels. Note on, note off, and polyphonic aftertouch are shown with pitch and velocity (or pressure). Channel aftertouch is shown with the appropriate pitch. Program changes indicate the number. Pitch bends indicate the value in full 14-bit. Control Change, NRPN, and RPN messages display the number, value, and whether the value is being set, incremented, or decremented. Sysex, song position, song select, tune request, start, continue, stop, and system reset are simply noted. Rapid-fire MIDI signals such as MIDI clock, active sensing, and time code just turn on individual LEDs.
- **MIDI Control Surface.** Gizmo has two potentiometers and two buttons. Each can be configured to send a unique Program Change, Control Change, NRPN, or RPN commands, or (Arduino Mega only) control voltage values via either of two DACs. The potentiometers can only send MSB values.
- ***Mega Only:*** **Keyboard Splitter.** You can split incoming MIDI notes by pitch and route them to different MIDI out channels. You can also fade notes between two channels depending on note velocity.
- ***Mega Only*** **Midi Thru: Distributing and Layering Notes, and Chord Memory.** Gizmo can *distribute* notes to different MIDI channels as you play: this lets you play multiple mono synths as if they were polyphonic, for example. Gizmo can also *layer* notes: when you play a note, Gizmo will send some $N > 1$ note-on messages instead of one. This lets you use a polyphonic synthesizer to play a note with more than one voice, making it fatter, but not going all the way to unison. Finally, Gizmo can perform *chord memory*, playing a transposed chord of your choosing starting at a note you are currently playing. And yes, you can do all three simultaneously.
- ***Mega Only:*** **Measure Counter.** You can count elapsed beats, measures (bars), and phrases; and alternatively count eighths of a second, seconds, and minutes. The counter also responds to external MIDI clock directives.

Other Cool Stuff As if this weren't enough, Gizmo also comes with the following capabilities. All of these settings are automatically saved permanently in memory.

- **Tempo and the MIDI Clock.** Gizmo can sync to an external MIDI clock, can ignore it and use its own internal clock, and can emit the same as a MIDI clock. Gizmo can also pass the external MIDI clock through or block it. When using its own internal clock, Gizmo supports tempos ranging from 1 to 999 BPM, settable numerically or via tapping. You can start, pause/un-pause, and stop this clock (sending the appropriate MIDI Start, Stop, or Continue signals). Gizmo can also divide the MIDI clock, thereby outputting a slower clock than it is inputting.

  Gizmo applications can also be set with a *note value* (or *note speed*) to play their notes relative to this clock, ranging from eighth triplets (1/24 beat) to double whole notes (8 beats). At any time, Gizmo pulses on-screen LEDs indicating the clock and note speed pulses. Finally, Gizmo can be configured to vary the degree of *swing* or *syncopation*.
- **In and Out MIDI Channels** Gizmo can be configured with input and output MIDI channels (some applications will use these: others will have multiple channels and will treat these as defaults). Both channels can be turned off, and the input channel can be OMNI. Gizmo pulses on-board LEDs indicating incoming and outgoing MIDI data.
- **Remote Control via MIDI NRPN.** Gizmo can be controlled remotely via NRPN rather than using its on-board controls. If you start using the controls, Gizmo's onboard potentiometers are locked out so their noise will not interfere with your remote control. You can unlock the potentiometers by pressing a button on-board Gizmo, or by sending Gizmo's *Release* NRPN message.
- **Bypass.** You can quickly put Gizmo in Bypass mode, to pass through all MIDI signals and generate no new ones (with the exception of the Controller, see Section 9). Putting Gizmo in Bypass mode will also send an All Notes Off message, so toggling Bypass is also a useful way to hush your synthesizer.

- **Screen Brightness.** You can change the screen brightness.
- ***Mega Only* Control Voltage / Gate.** You can configure Gizmo to output control voltage (CV) values from 0–5V, as well as trigger a 5V gate, and output 0–5V in response to another signal, either velocity or aftertouch, all in response to notes being played.
- ***Mega Only* Transposition and Volume Control.**[7] You can transpose all of Gizmo's MIDI output pitch by anywhere from $-60...60$ steps. Additionally you can multiply the MIDI output velocity (volume) by multiples of two ranging from $1/8$ to 8.
- ***Mega Only* Menu Delay.** Many of Gizmo's menus display the first few letters of a menu item, then pause for some interval of time before they start scrolling the full item. You can change this interval.

Future Stuff (on the Arduino Mega) I have written but not tested some additional code. It won't appear on the Uno version (not enough space) but may show up on the Mega version. This stuff includes:

- **Per-MIDI Device Options.** There will be an area for specific kinds of MIDI devices. For example, I have written code to convert NRPN values into the unusual sysex messages required by the Kawai K4 Synthesizer so it can be manipulated easily via a standard MIDI controller.

Hopefully there'll be more than this. Message filtering? A MIDIPal-style CC LFO? Longer note recorder songs? And so on.

1 Building Gizmo

1. **Assemble the Hardware** Gizmo consists of an Arduino Uno or Arduino Mega, a SparkFun MIDI Shield[8], and an Adafruit 16x8 LED Matrix[9] attached via four wires (I2C). The SparkFun MIDI Shield does not come with headers to plug into the Arduino, and you'll need to get those too: it's assumed you'll either use plain headers, or use stackable headers. I use stackable headers as it makes it easy for me to plug my four test wires into it. See Section 16 for a warning about the low-quality buttons supplied with the MIDI Shield and what to do about it.

   Attach the four wires for SDA, SCL, 5V (VCC), and GND between the MIDI Shield and the LED Matrix.

2. **Modify your Arduino Software** You will need a pretty recent version of the Arduino software, as newer versions have better compilers which compile more compact code. I developed Gizmo on Arduino 1.6.12 for MacOS X. You will want to modify the source code files for the Arduino libraries in two spots:

   Add Nonblocking I2C Writes This will dramatically speed up I2C for our purposes.

   (a) Locate your `Wire.cpp` and `Wire.h` files. On the Mac they're located in `Arduino.app/Contents/Java/hardware/arduino/avr/libraries/Wire/src/`

   (b) Add the following line inside the "public" method region in `Wire.h`:

   ```
   uint8_t endTransmissionNonblocking();
   ```

   (c) Add the following method to `Wire.cpp`:

[7] *Didn't this used to be available for the Uno?* Yeah. Ran out of space fixing bugs.

[8] https://www.sparkfun.com/products/12898

[9] This matrix comes in various colors LED shapes (round, square), and matrix sizes (0.8 inch, 1.2 inch). I personally use a 1.2 inch round red matrix. The URL for my model is https://www.adafruit.com/products/2037

```
uint8_t TwoWire::endTransmissionNonblocking()
    {
    uint8_t ret = twi_writeTo(txAddress, txBuffer, txBufferLength, 0, 1);
    return ret;
    }
```

Reduce the I2C Buffer Size from 32 to 20 This gives us some extra static RAM space.

(a) Locate your `Wire.h` file. Again, on the Mac it's located in `Arduino.app/Contents/Java/hardware/arduino/avr/libraries/Wire/src/`

(b) Change the `BUFFER_LENGTH` constant in the `Wire.h` file as follows:

```
#define BUFFER_LENGTH 20   // Was 32
```

(c) Identify your `twi.h` file. On the Mac it's located in `Arduino.app/Contents/Java/hardware/arduino/avr/libraries/Wire/src/utility/`

(d) Change the `TWIBUFFER_LENGTH` constant in the `twi.h` file as follows:

```
#define TWI_BUFFER_LENGTH 20    // Was 32
```

3. **Install the FortySevenEffects MIDI Library** But not straight off of its website.[10] The MIDI library is in a state of flux and is having some significant additions being made. The Gizmo code is extremely sensitive to code size (at least on the Uno). Thus for now, use the version I include in Gizmo's Github repository.

4. **Install the SoftReset Library** A copy of it is in Gizmo's Github repository.

5. **Switch the MIDI Shield to "Prog"**

6. **Build and Upload Gizmo's Code to the Arduino** It should compile cleanly for either an Arduino Uno or an Arduino Mega 2560. On the Uno it'll complain of Low Memory.

7. **Switch the MIDI Shield to "Run"** You can plug in MIDI cables now.

8. **Reset Gizmo** Power up the Arduino. Then hold down all three pushbuttons on the MIDI Shield. While doing so, press and release the reset button on the MIDI Shield. Continue to hold down the three push buttons until the two LEDs on the MIDI Shield light up. Let go of the pushbuttons.

   This procedure initializes the memory, options, and files in the device. Now you're ready to go!

1.1 Starting Gizmo Headless

Gizmo normally targets the SparkFun MIDI Shield, but you might be able to use its code with some other MIDI shield, as long as the shield just intercepts Serial to do its MIDI and doesn't interfere with I2C. Such MIDI shields are unlikely to have the button, pots, or LEDs that the SparkFun shield has. But that's okay, you can control the buttons and pots virtually via NRPN, and just do without the two LEDs.

To do this you'll need to reset Gizmo's options without needing to press any buttons (as you won't have any). You can do it like this:

1. In the `All.h` file, change the line

```
//#define HEADLESS_RESET
```

[10] https://github.com/FortySevenEffects/arduino_midi_library

...to...

```
#define HEADLESS_RESET
```

2. Compile and download the code, and run it once. Gizmo will show its opening screen, then display `RSET` and not do anything else.

3. In the `All.h` file, change the line back, that is, to

```
//#define HEADLESS_RESET
```

Gizmo's options have now been reset in a slightly different way than usual: specifically, the **Control MIDI** option (see "Control MIDI" in Section 13) has been set to MIDI channel 16, rather than to OFF.

Now you need to modify Gizmo's code to run headless, so it doesn't bother lighting up the on-board LEDs or reading the buttons and pots. You can do this as follows:

1. In the `All.h` file, change the line

```
//#define HEADLESS
```

...to...

```
#define HEADLESS
```

2. Compile and download the code, and run it.

3. You should now be able to control Gizmo via NRPN (see "Control MIDI" in Section 13) on channel 16.

4. In the `All.h` file, you might wish to change the line back, that is, to

```
//#define HEADLESS
```

I make no guarantees that this will work: but it might.

2 User Interface

Gizmo has a modest interface: a 16x8 LED display, two additional on-board LEDs (red and green), three buttons, and two potentiometers (dials): but it strives hard to make good use of these.

Gizmo's top-level interface layout is a menu hierarchy. You select menu items, which may take you deeper into the hierarchy, or you can go back up towards the top of the hierarchy. The top level menu chooses between different **applications**. Once you have entered an application, its **application number** is displayed in the **current application region** (see Figure 1).

The current application LEDs light up right-to-left in a certain pattern with increasing application numbers, as shown in Figure 2. Gizmo's interface can presently support up to eleven top-level applications.

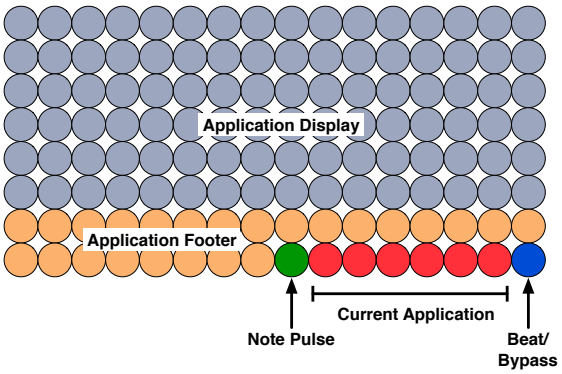


Figure 1: High-Level Gizmo Layout

Also shown in Figure 1 are the **Beat/Bypass** light and the **Note Pulse** light. The Beat/Bypass turns on and off every *beat* (quarter note). This shows the current **tempo**.[11] The Note Pulse light turns on and off every *note pulse*: this is the speed you have chosen for the arpeggiator, step sequencer, etc. Note pulses are defined in terms of note value: for example, if the note pulse is presently in sixteenth notes, then this light will turn on and off four times faster than the beat light, which is in quarter notes. The note pulse light is also affected by the degree of swing (syncopation) you have defined.

If Gizmo's clock is presently **stopped**, either because you have stopped it internally or because Gizmo is being driven by an external MIDI clock which is currently stopped, then **both the Beat/Bypass and the Note Pulse lights will be off** (though if Bypass mode is on, then Beat/Bypass will still blink rapidly). See Section 14 for more information about starting and stopping the clock.

The reset of the screen is given over to the application. In many cases an application will display text and other data in the **Application Display** region, while lighting up certain status LEDs in the **Application Footer**.

You wend your way through menus, choose applications, and manipulate them using Gizmo's three buttons and two potentiometers as follows:

Buttons The left button is called the **back button**. The right button is called the **select button**. The center button is called (unsurprisingly) the **middle button**. The buttons respond to being **pressed** and immediately released, and also respond to **long presses**: holding a button down for a long time (presently one-half second) and then releasing it.

Buttons do different things. Here are certain common items:

- **Pressing the Back Button** This is the "escape" or "cancel" button: it **always goes back up the menu hierarchy.** Thus you can't ever get lost — just keep pressing the Back button and you'll eventually find yourself at the root menu.
- **Long-Pressing the Back Button** This toggles **bypass mode**, where Gizmo tries hard to act as if it's just a MIDI THRU coupler between its input and output MIDI wires: it passes through all the MIDI it receives, and with one exception (the Controller, see Section 9) it doesn't output any new data. In bypass mode, the **Beat/Bypass** light (Figure 1) will stop beating and instead will flash rapidly.
- **Pressing the Select Button** If you're being presented with a menu of options, or a number to choose, or a glyph to choose, the Select button will select the currently-displayed option. In some applications (such as the Step Sequencer, Arpeggiator, and Recorder) the Select Button is assigned other tasks.

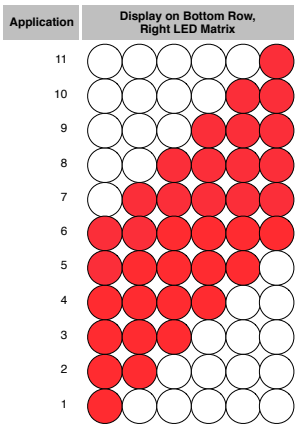


Figure 2: Application Values

- **Pressing the Middle Button** Likewise if you're being presented with a menu of options, or a number to choose, or a glyph to choose, the Middle button will increment the current display (but not select it).

Potentiometers Gizmo's potentiometers (or **pots**) do a number of tasks, including scrolling through menu options, moving a cursor horizontally or vertically, or choosing a number. The left pot does primary tasks, and the right pot assists when appropriate. Note that these are potentiometers, not encoders: if you start turning one, you may experience a big jump initially. The potentiometers have a limited range (0...1023), and a significant degree of noise, so realistically they can only choose numbers between 0...256 or so. If asked to select a *big* number, the **left pot** will act as a coarse-level selector, and the **right pot** will fine-tune the number.

[11] A beat occurs every 24 *pulses* of a MIDI Clock or Gizmo's internal clock.

On-Board LEDs There are two LEDs on-board the SparkFun MIDI Shield. The **red LED** is toggled on and off to reflect incoming MIDI data. The **green LED** is toggled on and off to reflect outgoing MIDI data.

3 Initializing Gizmo

Gizmo must be initialized before it can be used. You can also do a factory reset on Gizmo with this procedure:

1. Hold down all three buttons
2. Press the reset button
3. Continue to hold down all three buttons until both on-board LEDs have lit.
4. Let go of the buttons.

Gizmo will reset all of its flash RAM and reboot. This means that all options will be set to their default state, and all file storage (including arpeggios) will be emptied.

4 Starting Gizmo

If you power up Gizmo, or press its reset button, it will display its **boot screen**, which includes the version number (at right, the version number is "1").

Gizmo will then show the **root menu**. Use the left potentiometer to scroll to any of the following applications, and use the select button to select an application. Available applications are:

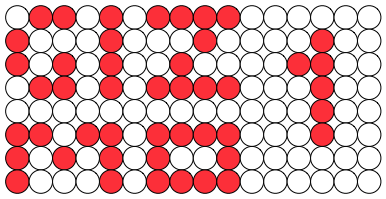


Figure 3: Boot Screen

5 The Arpeggiator

The arpeggiator allows you to play different kinds of arpeggios, and also to create and save up to ten of them. The arpeggiator's main menu lets you choose to play five different kinds of pre-set arpeggios, or to select an arpeggio from user-created arpeggio slots 1–10, or finally to create an arpeggio.

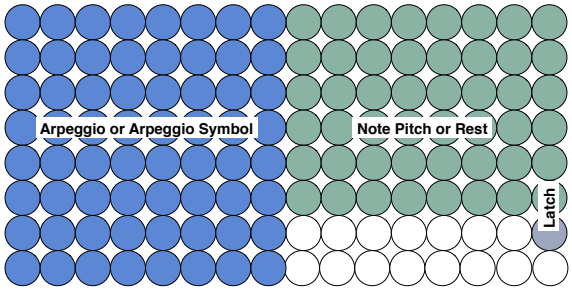


Figure 4: The Arpeggiator Display

An arpeggio is a pattern for repeatedly playing the notes in a chord. When you hold down a chord on the keyboard, the arpeggiator uses this pattern to play the notes, typically one at a time, according to the pattern selected. Patterns do not specify exact notes, but rather note orderings. For example, an arpeggio might be defined as 1, 2, 2, 3, 4, 2, 3: if 1 is set to be the root (lowest) note of your chord, then if you play a C7 chord (C E G B♭), then the arpeggiator will repeat the sequence C E E G B♭ E G. This pattern will repeat as long as you hold down the keys in the chord.

Alternatively if you toggle the **latch**, then the playing will continue after you have released the keys, and will only shift to a new chord when you release all notes and then hold down an entirely new chord. Latch mode is toggled by pressing the Middle button while playing an arpeggio. When Latch mode is engaged, an LED will light as shown in Figure 4.

Also, normally you toggle **bypass mode** by Long-Pressing the back button. But that's not fast enough to turn arpeggiation on and off in performance. So the arpeggiator also lets you toggle bypass by pressing the **select** button. (Of course you can also toggle bypass via NRPN if you like).

Playing Preset Arpeggios There are six preset arpeggios: *up*, *down*, *up-down*, *random*, *chord repeat*, and *assign*. They work as follows:

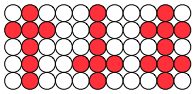


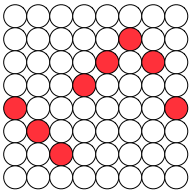
Figure 5: Up, Down, and Up-Down Symbols

- **Up**. Each note in your chord is played in turn, lowest note first. When all notes are exhausted, the pattern is repeated.
- **Down**. Each note in your chord is played in turn, highest note first. When all notes are exhausted, the pattern is repeated.
- **Up-Down**. Each note in your chord is played in turn, lowest note first, up to but not including the highest note. When all notes are exhausted, all notes in the chord are played in turn, highest note first, down to but not including the lowest note. When all notes are again exhausted, this pattern repeats.
- **Random**. Chord notes are played at random. Gizmo tries not to play the same note twice in a row.
- **Chord Repeat**. The entire chord is repeatedly played in its entirety.
- **Assign**. Each note in your chord is played in turn, in the order in which you had pressed the keys when you formed the chord. When all notes are exhausted, the pattern is repeated.

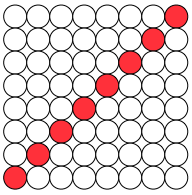
As you play a preset arpeggio, the notes played by the arpeggio will appear at right. The symbol representing the preset will appear at left.

While playing a preset arpeggio, you can select the number of octaves by choosing calling up the menu by Long-Pressing the Select button, then choosing **Octaves**. If you have an octaves value ≥ 0, then when the arpeggiator exhausts its notes, it will repeat them again one octave higher, then another octave higher, and so on, up to the number of octaves chosen. You an select any value from 0–6 octaves.[12]

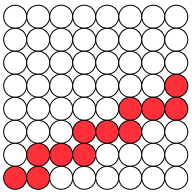
By default the key velocity[13] that *all* notes in the track will use (as a value 0...127). If you would instead prefer that each note in the track use its own indepof an arpeggio is determined by the **first note** you press when you hold down a chord. This strategy usually works well, but if you can instead fix the velocity to a specific value by (once again) calling up the menu by Long-Pressing the Select button, then choosing **Velocity**. At the far highest end of the velocity options is `FREE`, which means that the velocity is determined by your fingers again (this is the default).



Example Arpeggio



Ascending Notes in Sparse Mode



Ascending Notes in Dense Mode

Figure 6: Example Arpeggio Editing Displays

Creating an Arpeggio The last menu option in the top-level Arpeggiator menu is **Create**. If you choose this, you can create an Arpeggio. To do this you enter notes one by one. These won't be the *actual* notes that are played when you hold down a chord. Rather, after you save the result, the Arpeggiator will compact these notes into a sequence of consecutive numbers. For example, if you play C3 E3 G3 E3 G2, then the Arpeggiator will compact these into 2 3 4 3 1. Then when you play this as an arpeggio, the Arpeggiator will assign each of these numbers, in order, to the notes in your chord.

The first question you will be asked is `NOTE`: the Arpeggiator is asking you to specify the note in your arpeggio pattern which will correspond to the root (lowest) note in a played chord. This allows you to make a pattern which plays

[12]Note that this means that if your chord is larger than one octave, you may not get what you expected. For example, if you are playing UP with C5 E5 G5 D6, and with octaves=1, then the arpeggiator will play C5 E5 G5 D6 C6 E6 G6 D7. Note that C6 is played after D6 is played. That's the current behavior right now anyway.

[13]By velocity we mean in the MIDI sense: how fast the key is struck; this basically translates to loudness.

notes both above and below the played chord. For example, if the Root is C3, then the above pattern will instruct the Arpeggiator to play its final note *below* the chord root.

After you have entered the root, the Arpeggiator will wait for you to start playing notes. You can enter a sequence of up to 32 notes, including 15 unique notes. You can also enter rests by pressing the Middle button. If you enter more than 15 unique notes, or more than 32 notes in total, the Arpeggiator will simply refuse to accept the next note.

As you enter notes, they are displayed in the left half of the LED, and the latest note pitch is displayed in the right half. Figure 6 shows different arpeggio patterns. If you have eight or fewer unique notes in your pattern, then they will be displayed in *sparse mode* as shown at right. If you have over eight notes, they will be displayed in *dense mode* in order to show all of the notes. The LEDs don't show the notes per se, but rather the consecutive numbers that the notes represent. For example, the ascending notes shown at right could be C, D, E, F, G, A, B, C, or they could be C, C♯, D, D♯, E, F, F♯, B.

If you don't like the latest portion of your arpeggio, you can scroll the cursor back to an earlier section by turning the right knob. Then if you start playing, the later notes will be discarded and the arpeggio pattern will continue from where the cursor was. You can also scroll to view your past notes, then scroll all the way back to continue.

An **important note regarding the scrolling.** The cursor is always located at the position where new notes will be entered. But as you scroll back and forth, you'll hear the notes of your arpeggio. When you scroll and hear a note, that note is the note *immediately before* the cursor position. It's the last note in the arpeggio before you start adding new notes. It is *not* the note that you'll replace when you start entering notes.

Anyway, when you are satisfied with your arpeggio, Long-Press the Select button to save. You'll be asked for a slot to save in, and after that, you'll be back in the main Arpeggiator menu.

Playing a User-Created Arpeggio To play a user-created arpeggio, from the main Arpeggiator menu, choose one of the numbers 0–9, each of which represents the arpeggiator slot you had saved your arpeggio in (these options appear after the preset options). Then hold down a chord! As you play a user-created arpeggio, the notes played by the arpeggio will appear at right. The arpeggio pattern will scroll by at left.

The preset arpeggio patterns (such as Up-Down) vary with the number of notes in your chord: if you hold down five notes for example, and octaves=0, then five notes will be played in the arpeggio pattern. This isn't the case for user-created arpeggios, which have a fixed user-specified number of notes.

What happens if your arpeggio is designed for three notes but you hold down five notes in your chord? Only three of your five notes will be played.

What happens if your arpeggio is designed for five notes but you hold down only three notes in your chord? Then notes from the bottom (or top, as appropriate) of your chord will be transposed up/down one octave to make up the remaining notes.

Also, because they are fixed in size, user-created arpeggios do not respond to the octaves option.

More Arpeggiator Options In addition to Octaves, the arpeggiator menu (Long-Press the select button) also includes the Options Menu as a submenu.[14] See Section 13 for detailed information on each of the options. The Arpeggiator responds to the following options:

Tempo	Note Speed	Swing	Note Length	Transpose (on Mega)
In MIDI	Out MIDI	Control MIDI	MIDI Clock	Volume (on Mega)

Of particular interest to you may be Length and Tempo. And Swing!

One note regarding the **Note Length** option. If the Note Length is set to 100 (and *only* 100), the Arpeggiator behaves specially: each note will extend until the next note (or rest) is played, regardless of how long that is. Thus if you have Swing turned on, notes will extend until the next syncopated (delayed) note even if their time is up. This provides a fully legato feel.

[14] Recall that the Options Menu is for options shared among several applications: that's why it's a separate menu. That and code space issues.

6 The Step Sequencer

The Step Sequencer makes it easy to create 16-note, 24-note, or 32-note multitrack loops common on devices such as drum machines. 16-note loops have up to twelve tracks. 24-note loops have up to eight. 32-note loops have up to six tracks.

When you choose the Step Sequencer from the root menu, you will be asked to load a sequence from a slot. You can do this, or you can create a new empty sequence by choosing `- - - -` (meaning *none*). Slots are displayed by number, plus an `R` (for Recorder) or `S` (for Step Sequencer) if the slot is filled with a file by one of the two applications. This letter blinks if the file isn't the type of your current application.

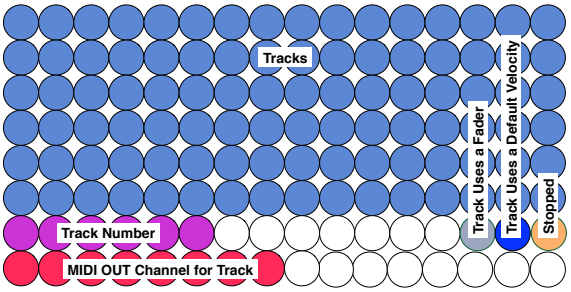


Figure 7: Step Sequencer Display

If you have chosen *none*, or have chosen an empty slot or one presently filled by the Recorder, you have to initialize the slot first: you'll be asked to choose between 16, 24, or 32 notes per track. After this you are taken to the main Step Sequencer display.

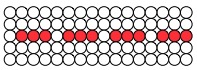


Figure 8: None

Figure 7 shows the general step sequencer display structure. The *Tracks* region is where sequencer tracks are displayed and edited. The *Track Number* area tells you the number of the currently-edited track. Figure 9 explains how to interpret this. The *Stopped* LED tells you if the step sequencer is currently stopped (or playing). The *Track Uses a Default Velocity* LED tell you if all notes in the current track are fixed to the same velocity, or permitted to use different velocities. The *Track Uses a Fader* LED is lit when the pre-track fader (volume) is set to something other than maximum volume for the current track. Finally, the *MIDI Out Channel for Track* tells you what channel the current track is playing. The patterns for the MIDI Out Channel for Track are the same as those in Figure 15, except that MIDI Out does not support ALL (OMNI).

Each track has a blinking *edit cursor* which determines, normally, where notes are entered if you play them. The location of this cursor is determined by the potentiometers. You select your current track by turning the left knob. In a given track, you choose the current note position by turning the right knob. The Tracks region also displays a blinking vertical set of LEDs which indicate which notes in the tracks the Step Sequencer is currently playing. As the Step Sequencer plays notes, this vertical group heads to the right, eventually wrapping around. This is the *play position cursor*.

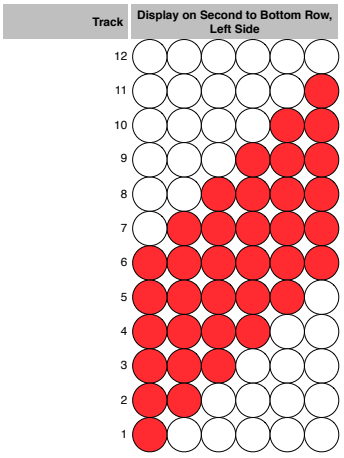


Figure 9: Track Numbers

Each track takes up one or two rows in the Tracks area: 16-note tracks take a single row, and 24-note and 32-note tracks take two rows. There can be up to twelve tracks, yet the tracks display region is only six LEDs high. This of course means that the Tracks region scrolls as you turn the left knob.

You enter notes by moving the edit cursor to the a location, then pressing keys. You can also press the Middle Button to enter a rest, or Long Press the Middle Button to enter a *tie* (or *continuation*. A tie just means "keep playing the previous note": it essentially lengthens the previous note. You can enter multiple ties in series to make a note as long as you like.

Pressing the Select button will toggle whether the Step Sequencer is playing. When you start playing the Step Sequencer, it waits for the clock to reach a measure boundary before beginning. Furthermore, even if you start playing the Step Sequencer, if the clock isn't running it won't play at all.

Play Position Mode If you turn the right knob fully to the left, you will find that the cursor scrolls right off the left side of the screen. At this point you are in **play position mode**. Here, if you press a key, it is entered at the play position cursor.

In play position mode, the function of the Middle Button changes. Now if you press the Middle Button, it will toggle muting the current track. You can tell a track is muted because the LEDs at each end of the track are blinking. Additionally, if you Long Press the Middle Button, it will erase all the notes on the current track (but not change its settings).

You can tell you're in play position mode because the play position cursor has changed to include two dots which indicate the current track, as shown in Figure 10.

Play position mode isn't all that easy to enter notes, particularly if there is any degree of swing: I'd stick with the normal mode. You can get out of play position mode just by turning the right knob so that the edit cursor is once again on-screen.

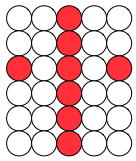


Figure 10: The Play Position Mode Cursor. The current track is marked by the two dots.

Menu Options If you Long Press the Select button, you'll call up the Step Sequencer's menu. The Step Sequencer has a number of options:

- **Reset Track** This wipes out and resets the track. Unlike Long-Pressing the Middle Button while in Play Position mode, this doesn't just clear the track of notes: it also resets all of its settings to their defaults.
- **Length** This specifies the note length of notes in the track, as a percentage (0 is fully staccato and 100 is fully legato). You can choose numerical values, or choose `DFLT`, which tells the Step Sequencer to use the default note length specified in the Options menu (see Section 13).
- **Out MIDI (Track)** This specifies the MIDI Out Channel for notes in the track, You can choose a value 1...16, or choose `DFLT`, which tells the Step Sequencer to use the default MIDI Out Channel specified in the Options menu (see Section 13).
- **Velocity** This lets you specify a key velocity[15] that *all* notes in the track will use (as a value 0...127). If you would instead prefer that each note in the track use its own independent key velocity as you had entered them, you can choose `FREE`.
- **Fader** This lets you specify a volume modifier which is multiplied against the velocities of the notes in the track. Possible values are 0...127, where 0 completely hushes the notes, and 127 lets them play at their specified velocities.
- **Save** This saves the sequence. You then choose the slot to save in. Slots are again displayed by number, plus an `R` (for Recorder) or `S` (for Step Sequencer).
- **Options** This brings up the Options menu.

More Step Sequencer Options Beyond the settings above, the step sequencer responds to a number of options in the Options Menu. See Section 13 for detailed information on each of the options. The Step Sequencer responds to the following options:

Tempo	Note Speed	Swing	Note Length	Transpose (on Mega)	Click
In MIDI	Out MIDI	Control MIDI	MIDI Clock	Volume (on Mega)	

Of particular use are Tempo, Note Speed, Swing, and especially Click.

[15] By velocity we mean in the MIDI sense: how fast the key is struck; this basically translates to loudness.

7 The Note Recorder

The Note Recorder lets you record and play back approximately 64 notes[16] spread over 21 measures.[17] You can save up to two recordings on an Arduino Uno and nine recordings on a Mega.

The Note Recorder screen has two major parts. The *Note Display* section indicates the current note number being played (and hints at the remaining notes available). The *Measure Display* section indicates the current measure being played (and again hints at the remaining measures available). When recording a song, each of these sections will contain a single lit LED indicating the current note or measure position. When playing a song, the Note Display and Measure Display will each also contain an additional lit LED indicating the position of the end of the song.

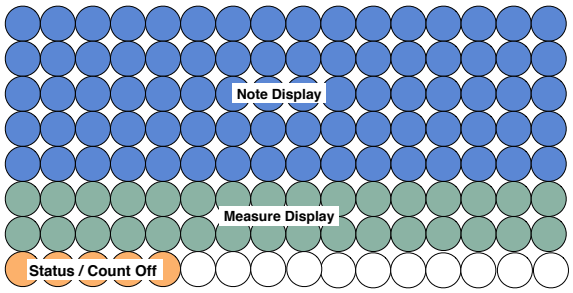


Figure 11: Recorder Display

When you choose the Note Recorder from the root menu, you will be asked to load a recording from a slot. You can do this, or you can create a new empty recording by choosing `- - - -` (meaning *none*). Slots are displayed by number, plus an `R` (for Recorder) or `S` (for Step Sequencer) if the slot is filled with a file by one of the two applications. This letter blinks if the file isn't the type of your current application.

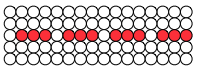


Figure 12: None

After this you will enter the Note Recorder. The Note Recorder is always in one of four states, indicated the patterns at right:

- Stopped
- Playing
- Counting off beats prior to Recording
- Recording

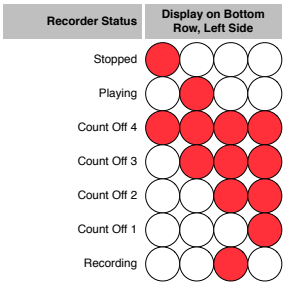


Figure 13: Recorder Status LEDs

When you enter the Note Recorder, the state is initially Stopped. To start playing a song, press the middle button. To stop playing (or stop recording), you also press the middle button. To start recording a song, Long Press the middle button. The recorder will count off four beats for you, then start recording.

You can choose **Repeat Mode** from a menu by Long-Pressing the Select (right) Button. When in repeat mode, the recorder repeats the song it is playing at the measure boundary after it has finished playing the song. Repeat mode also toggles an LED (see Figure 11).

You can save your recorded song by pressing the Select Button. Gizmo will ask you to select a slot to save in, then it will exit the Recorder. Slots are again displayed by number, plus an `R` (for Recorder) or `S` (for Step Sequencer).

More Recorder Options You can also choose the Options Menu from inside the Note Recorder: it's part of the menu brought up by Long-Pressing the Select button. The Recorder responds to a number of options:

Tempo	Transpose (on Mega)	Volume (on Mega)	Click
In MIDI	Out MIDI	Control MIDI	MIDI Clock

[16] Why *approximately* 64? Because the recorder is recording MIDI NOTE ON and NOTE OFF messages. If you provide 64 pairs of these messages, it'll take up exactly all the available memory. But you could plausibly send a few more NOTE ON than NOTE OFF messages, in which case at the end of the recording all the remaining outstanding notes will be terminated. This would allow you to squeeze in a few (perhaps 16) more notes in rare circumstances. But I'd not rely on it. BTW, if you looked carefully you would have noted that the Note Display in Figure 11 has space for 16 more notes too.

[17] Why 21? Because notes are stored with a timestamp of eleven bits, resulting in $2^11 = 2048$ timesteps. A single timestep is $1/24$ of a quarter note, and a quarter note is $1/4$ of a measure, so we have $2048/24/4 = 211/3$ measures. We round that down to 21.

Of particular use to you will be Tempo and Click. Click gives you an audible click track: and the count-in is also clicked for you.

Recording and Quantization The Recorder records nothing but MIDI NOTE ON and NOTE OFF messages. It presently quantizes these messages, rounding them up or down to the nearest MIDI Clock pulse, that is, 1/24 of a quarter note.[18]

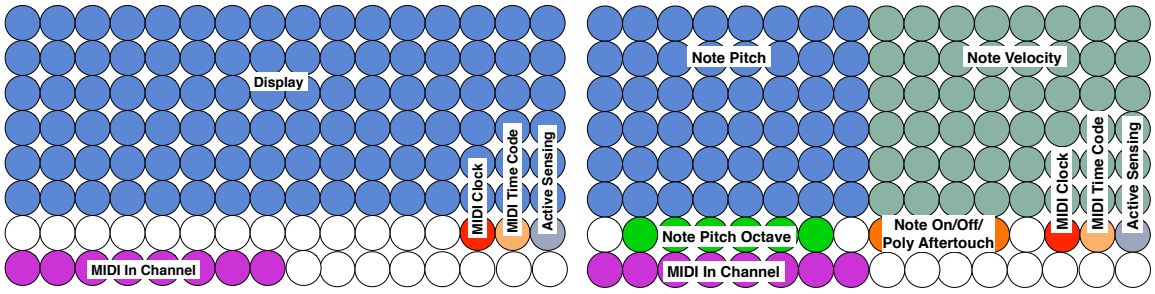


Figure 14: (Left) General Gauge Display, and (Right) Note Gauge Display

8 The MIDI Gauge

The MIDI gauge listens to incoming MIDI messages and displays them on-screen. This only occurs if the MIDI IN channel is something other than NO CHANNEL (See **Options→ In MIDI**, in Section 13).

There are three kinds of MIDI messages for purposes of display. *General* messages take up the whole screen with a single message. *Note* messages split the screen between pitch and velocity of the given note (on, off, polyphonic aftertouch). Finally *Frequent* messages are simply displayed by lighting a specific LED to indicate their presence.

Messages that are associated with a MIDI channel will have their channel number displayed at bottom left (see Figure 14 [Left]). Note that if the MIDI IN channel is something other than OMNI (ALL Channels), then only messages associated with the MIDI IN channel will be displayed.

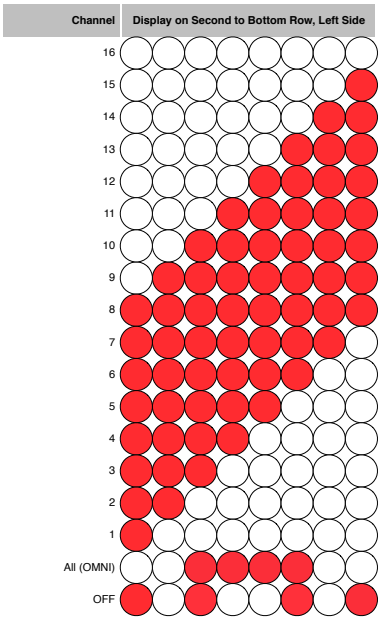


Figure 15: MIDI Channel Values

General Gauge Display These are simple displays which take up the entire screen.

- **Pitch Bend** The 14-bit value is displayed
- **Channel Aftertouch**. `AT` is displayed, followed by the value.
- **Program Change** `PC` is displayed, followed by the value.
- **Control Change (CC)** If the CC parameter is for 7-bit values, then the value is shown first, then text is scrolled with the value, then `CC`, then the parameter. If the CC parameter is for 14-bit values, the MSB of the value is shown first, then text is scrolled with the value, then `CC`, then the parameter, then in parentheses the 14-bit (MSB+LSB) value.

[18] This is pretty low-resolution, but there you have it.

- **Registered Parameter Number (RPN)** The value (7-bit MSB only) is shown first, then text is scrolled with the value (MSB), then `RPN`, then the parameter (14-bit), then in parentheses the 14-bit (MSB+LSB) value.
- **Non-Registered Parameter Number (NRPN)** The value (7-bit MSB only) is shown first, then text is scrolled with the value (MSB), then `NRPN`, then the parameter (14-bit), then in parentheses the 14-bit (MSB+LSB) value.
- **Channel Mode** The value is shown first, then text is scrolled with the value, then `CHANNEL MODE`, then the parameter. Channel Mode parameters are:[19]

Parameter	*Value*	*Meaning*
120	Normally 0	All Sound Off
121	Normally 0	Reset All Controllers
122	0=Off, 1=On	Local Control (On/Off)
123	Normally 0	All Notes Off
124	Normally 0	Omni Mode Off
125	Normally 0	Omni Mode On
126	*C*	Mono Mode On, with *C* channels total
127	Normally 0	Poly Mode On

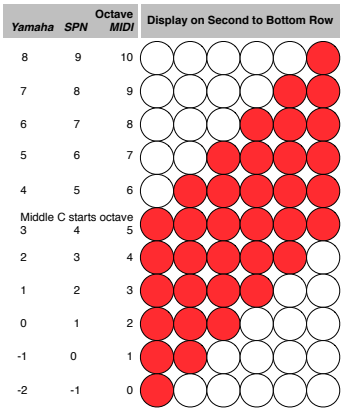


Figure 16: Octave Values. Three common octave numbering schemes shown: Yamaha, SPN (so-called *Scientific Pitch Notation*), and MIDI. SPN is the most common on keyboards.

- **System Exclusive** `SYSX` is displayed.[20]
- **Song Position** `SPOS` is displayed.
- **Song Select** `SSEL` is displayed.
- **Tune Request** `TREQ` is displayed.
- **Start** `STRT` is displayed.
- **Continue** `CONT` is displayed.
- **Stop** `STOP` is displayed.
- **System Reset** `RSET` is displayed.

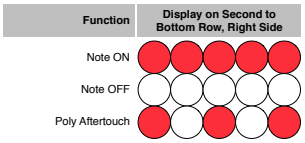


Figure 17: Note Function

Note Display Note messages are displayed with both the **pitch** (at left) and the **velocity** (at right) of the note value, plus the particular kind of message in question: **Note On, Note Off,** and **Polyphonic Aftertouch**.

How exactly do you distinguish between a Note On, Note Off, or Polyphonic Aftertouch message then? Figure 14 [Right] shows a four-LED region, in orange, where a certain pattern is displayed to indicate this. The patterns are shown in Figure 17.

Note pitches are displayed by showing the note (such as B♭), with the octave value directly below it. MIDI has eleven different octaves (0–10): Middle C is the bottom note of octave 5. The octave number is displayed as shown in Figure 16. As usual, the MIDI In Channel is shown below that.

Frequent MIDI Display These are messages which are too fast to display usefully in most cases. In each case, a specific LED will be toggled (see Figure 14). The messages are:

[19] Why no text to describe these things? Because the Arduino Uno is out of space. And they're not that common.

[20] Note that the version of the MIDI library on which Gizmo relies presently doesn't handle large System Exclusive messages well.

- **Active Sensing**
- **MIDI Time Code**
- **MIDI Clock**

9 The Controller

The Controller allows you to assign to each of two buttons and two potentiometers any NRPN, RPN, Control Change (CC), or Program Change (PC) value, or (on the Mega) Pitch Bend, Channel Aftertouch, or control voltage. These assignments are stored in Flash memory and survive reboots and power cycling.

The Controller interacts with Bypass mode differently than other applications. In bypass mode, the Controller passes all the incoming MIDI data to MIDI out as usual. But it will still emit values when you press the buttons or more the knobs. This is because it's typical that you'd want to use Controller to (for example) manipulate the VCF on an analog synthesizer while playing it via a remote keyboard. To do this, you'd plug the keyboard into Gizmo, plug Gizmo into the synthesizer, and turn on bypass mode.

Optional control voltage is sent out one of two Digital-to-Analog Converters or DACs you may have attached, which it refers to as DAC A (I2C address 0x62) or DAC B (I2C address 0x63).[21]

Go

This enters the controller proper. Turning the left or right knobs, or pressing the Select or Middle buttons, will cause them to issue MIDI messages as assigned (below). If you press the Back button, you can exit the controller.

When you turn a knob or press a button, and the knob/button has had its control type set to something other than OFF, then the appropriate MIDI message is sent, and the value of the message is displayed as a number on-screen. Messages are only sent if the MIDI OUT channel is something other than NO CHANNEL (See **Options→ Out MIDI**, in Section 13).

Several protocols (NRPN, RPN, some CC) can accept 14-bit numbers, that is, values in the range 0...16383. However Gizmo's potentiometers have a maximum resolution of 10 bits, that is, 0...1023. The potentiometers in fact send 10 bits of data: their top 7 bits are the MSB, and their bottom 3 bits become the upper 3 bits of the LSB (the bottom 4 bits are padded with zeros). While only the MSB is displayed on-screen, this partial LSB is being sent as well to give you a bit more control. For control voltage, all ten bits will be mapped to 0–5V.[22] For Pitch Bend, the ten bits will be mapped to $-8192...8191$.

Left Knob and **Right Knob**

These submenus let you select your control type and parameter number for the left and right potentiometers.

In each, you are first given the option of what kind of **control type** (OFF, CC, NRPN, RPN, PC, or (on the Mega) Pitch Bend, Aftertouch, A Voltage, or B Voltage) you would like to manipulate with the left knob. If OFF, then turning the knob will not do anything.

After you have selected a control type, if you have selected CC, NRPN, or RPN, you will be then asked to select a **controller parameter number**. (Otherwise ,for PC and OFF, you will go back to the top-level Controller Menu). CC parameter numbers may range 0 ... 119. NRPN and RPN parameter numbers may range 0 ... 16383. When you have completed this, you will be sent back to the top-level Controller menu.

[21] Gizmo assumes you're DACs of this kind: https://www.adafruit.com/product/935 These DACs can be connected via I2C, send 0–5V, and can be set to either I2C address 0x62 or 0x63. If you need more than 5V, you'll need to wire up your own op-amp.

[22] The DACs are actually 12-bit, but what can you do: the pots are only 10 bit.

Middle Button and **Select Button**

Thees submenus let you select your control type, parameter number, and on/off values for the middle and select buttons.

In each, you are first given the option of what kind of **control type** (OFF, CC, NRPN, RPN, PC, or (on the Mega) Pitch Bend, Aftertouch, A Voltage, or B Voltage) you would like to manipulate with the middle button. If OFF, then pressing the button will not do anything.

After you have selected a control type, if you have selected CC, NRPN, or RPN, you will be then asked to select a **controller parameter number**. (Otherwise ,for PC and OFF, you will go back to the top-level Controller Menu). CC parameter numbers may range 0 ... 119. NRPN and RPN parameter numbers may range 0 ... 16383.

When you have completed this, you will be then asked to enter the value sent when the button is **pressed**. This value must be 0...127 (the Controller does not send 14-bit values). Afterwards, you will be similarly asked to enter the value sent when the button is **pressed again** (the buttons act as toggles). When you have completed this, you will be sent back to the top-level Controller menu.

10 The Keyboard Splitter

[Mega Only] The Splitter allows lets you (1) split your keyboard into two zones, each controlling a different MIDI channel; or (2) split your keyboard into *three* zones, two controlling different MIDI channels and the third (middle) zone playing both MIDI channels simultaneously[23]; or (3) fade or balance your entire keyboard such that if you play a note quietly, one channel will predominate, but if you play loudly, the other channel will predominate.

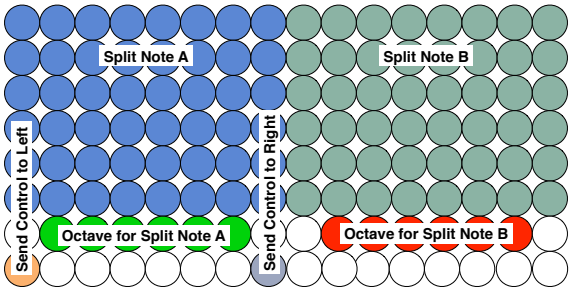


Figure 18: Splitter Layout

The two MIDI channels in question are the Default MIDI Out Channel (defined in the Options, see Section 13), and an Alternative MIDI Out Channel which you specify in the Splitter. If you're splitting your keyboard, you'll also specify up to two notes, **Split Note A** and **Split Note B** (Split Note B is optional), and whether Control Change, Aftertouch, and the like go to the left split region or the right split region.

- If you want to just split your keyboard, specify only Split Note A at the split point. Notes in the left (lower) region will go our the Alternative MIDI Channel, and notes in the right (upper) region will go out the Default MIDI Channel.
- If you want your keyboard to play **both** channels, make Split Note A be the lowest note on your keyboard, and Split Note B be the highest note on your keyboard. Notes played on the keyboard will be sent out both the Alternative MIDI and Default MIDI Channels.
- If you want your keyboard to have **three regions**, a left-only region, a right-only region and a middle region where both are played, make Split Note A be the lower note in the middle region and Split Note B be the higher note. Notes in the left (lower) region will go our the Alternative MIDI Channel, notes in the right (upper) region will go out the Default MIDI Channel, and notes in the middle region will go out both channels.
- Note that it is possible to also give you keyboard three regions where in the middle region **neither** channel is played. This is probably not very useful. But it happens when you define Split Note A to be *above* (to the right of) Split Note B.

[23] This is commonly known as *layering*.

- Finally, if you want to fade or balance your keyboard so that notes on the two channels are played with opposite velocities, you simply choose this option (see below). You don't need to specify either Split Note A or B, but you will need to define the alternative MIDI Channel.

Fade Behavior The current fade behavior function is:

$$\begin{aligned} \textit{Default MIDI Velocity} &= \textit{Velocity} - \textit{Velocity} \times (\textit{Velocity} + 1) \,/128 \\ \textit{Alternative MIDI Velocity} &= \textit{Velocity} \times (\textit{Velocity} + 1) \,/128 \end{aligned}$$

This is a fancy way of saying that the total velocity of both channels is the same as the input velocity, and that the ratio of the Alternative velocity versus the Default velocity increases linearly as you get closer to 127. I don't know if this is the right approach, and certainly different keyboards synthesizers have different and often nonlinear velocity mappings. But there you have it. If you'd like to play with it, it's in the function `handleNoteOn(...)` in `TopLevel.cpp`.

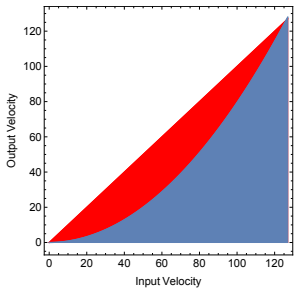
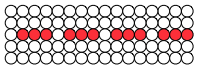


Figure 19: Cumulative Velocity the MIDI Out Channels when fading. Default is red, and Alternative is blue.

Defining Notes and Channels If you press the Select Button, you'll be asked to enter a note. This note will be Split Note A. By default this note is Middle C. You can back out if you don't want to enter the note.

If you press the Middle Button you'll be asked to enter a note. This note will be Split Note B. By default this note is off. You can back out if you don't want to enter the note. You can also turn Split Note B off again by once again pressing the Middle Button, at which point you'll be presented with `- - - -`. You can also back out if you don't want remove Split Note B.



You define the Alternative MIDI Out channel by Long-Pressing the Select Button. The Alternative MIDI Channel must be a value 1–16 (you can't choose Off).

The Splitter will display your two Split Notes, as shown in Figure 19.

Routing and Fading Long-pressing the Middle Button cycles through three options:

- Split/Layer the Keyboard, and route all CC, PC, Channel Aftertouch, and NRPN/RPN to the *right* (upper) split channel, that is, to the Default MIDI Out channel. Pitch Bend is also routed to the right channel if you're doing a simple split, but if you're layering, it's routed to both channels. Polyphonic Aftertouch is always routed to the channel handling the note in question, as are all Note On and Note Off messages. The screen will show the Split A note, and will light the "left" LED (see Figure 19)..
- Split/Layer the Keyboard, and route all CC, PC, Channel Aftertouch, and NRPN/RPN to the *left* (upper) split channel, that is, to the alternative MIDI Out Channel. Pitch Bend is also routed to the left channel if you're doing a simple split, but if you're layering, it's routed to both channels. Polyphonic Aftertouch is always routed to the channel handling the note in question, as are all Note On and Note Off messages. The screen will show the Split A note at left and the Split B note at right, and will light the "left" LED (see Figure 19).
- Fade/Balance the Keyboard. All CC, PC, Channel Aftertouch, and NRPN/RPN if routed to the alternative MIDI Out Channel. Pitch Bend is routed to both channels, as is Polyphonic Aftertouch and all Note On and Note Off messages (though with inverted velocities as discussed earlier). The screen will display `FADE`.

11 The Thru Facility

[Mega Only] The **Thru Facility** passes MIDI through the box, but if MIDI data comes in via the MIDI In channel, it applies various transformations to it and then routes it out specially. There are three transformations at present:

- First, you can *distribute* incoming notes, one by one, to separate MIDI channels, round-robin. Thus if you have multiple copies of the same monosynth, you could distribute notes to the various synths and basically treat them as if they were a polysynth[24]
- Second, you can have Gizmo add *extra notes*, that is, repeat notes you're playing multiple times extremely rapidly. For example, if you play the note G, Gizmo might send four G notes out essentially at the same time. This is useful for fattening up a synth but not making it fully unison (mono). For example, I have an Oberheim Matrix 1000 with six voices. If I instruct Gizmo to provide two extra notes, then every time I press a note, Gizmo emits *three* copies of that note to the Oberheim, causing three voices to play together. This basically turns the Matrix into a fatter two-voice polysynth.
- Third, you can perform *chord memory*. Here you first specify a chord, and then afterwards, every time you play a note, Gizmo will instead emit that chord, transposed so that its lowest note corresponds with the note you played. This is a classic facility available on a number of synthesizers, including early ones such as the Oberheim OB-Xa, Sequential Circuits Prophet 600, Korg PolySix, and so on.[25]

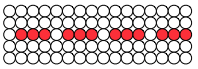
You can do all three of these at the same time. I might add more unusual transformers later. Anyway, here's how it works:

Go

Once you have set up your Thru options (see below), if you choose **Go**, the Thru facility starts and you can start playing. You'll see the word `PLAY` on the LED.

Extra Notes

This lets you select how many *additional* simultaneous note-on (and note-off) messages Gizmo should send down a given channel in response to you playing a note.

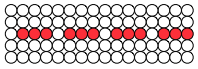


Choose: No Extra Notes, or 1...31

Distribute Notes

This lets you select the number of MIDI channels, beyond the Default MIDI Out channel, over which to distribute notes. Let's say you selected 2, and the Default MIDI Out channel was M. This means that three MIDI channels will be used: M, $M+1$, and $M+2$. This wraps around: if, say, $M = 15$, then it wraps around: the channels used would be 15, 16, and 1).

If you played the five notes A, B, C, D, E, Gizmo would send A down channel M, then send B down channel $M+1$, then send C down channel $M+2$, then send D down channel M again (wrapping around), then E down channel $M+1$ again, and so on. This would let you essentially use Mono devices listening in on the three MIDI Channels as a 3-voice polyphonic device.



Choose: No Extra Channels, or 1...15

Chord Memory or **No Chord Memory**

This will show the text `CHRD`, and you can then specify a chord (of up to eight notes). Thereafter if you play a single note, the chord will be played instead, transposed so that its root note corresponds with the note you play. (If you play more than one note, more than one chord will be played). If you have already chosen a chord, then selecting this option a again will turn off chord memory.

Choose: a chord of up to eight notes.

[24] This is an idea directly stolen from the MIDIPal.
[25] This idea was also directly stolen from the MIDIPal.

12 The Measure Counter

The measure counter is basically a stopwatch which counts elapsed beats, measures (bars), and phrases (up to 127 phrases). Alternatively if can count eighths of a second,[26] seconds, and minutes (up to 127 minutes) via the internal clock or external MIDI clock. If the minutes or phrases exceed 127, then `HI` is displayed in that space instead.[27]

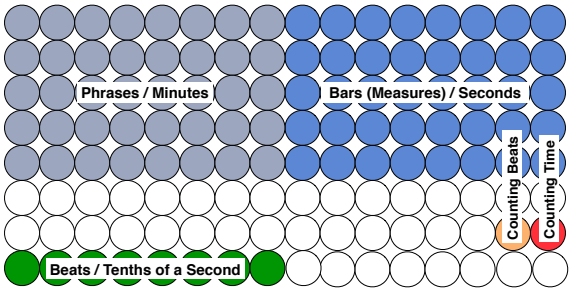


Figure 20: Measure Counter Layout

By default, Measure counts beats, measures (bars), and phrases. Long-press the Select button to bring up the Menu. Here you can choose the **Beats Per Bar** (a value from 1...16)[28] and the **Bars per Phrase** (a value from 1...32), and as usual, call up the **Options Menu** to change the **Tempo**, etc.

Pressing the Middle Button starts and and restarts the stopwatch. Long-pressing the Middle Button pauses the stopwatch (pressing the Middle Button afterwards will continue). Additionally, external MIDI Start, Stop, and Continue commands will affect the stopwatch: Stop will pause it, Continue will continue from last pause, and Start will reset the stopwatch and start it fresh.

If you press the Select button, this shifts Measure into counting time, so it's basically a stopwatch. Rather than counting beats, measures (bars), and phrases, Measure will count tenths of a second, seconds, and minutes. The response to buttons is the same, as is the response to MIDI clock directives.

13 Options

Options sets global parameters for the device. These parameters are stored in Flash memory and survive a power cycle. Some options can be also accessed from certain other applications as a convenience.

Tempo

If Gizmo is following its own internal clock rather than relying on an external MIDI clock , this specifies how fast a quarter note is. (See **Options→MIDI Clock**). When not in **Bypass Mode**, the tempo is shown by the pulsing on/off of the **Beat / Bypass Light** (see Figure 1).

Choose: 1 ... 999 Beats Per Minute. Note that this is a large number, and so may require you to choose it with the left potentiometer, then fine-tune it with the right potentiometer.[29]

Alternatively: Tap the Middle Button. The BPM will be set to the rate you tap.

Note Speed

Various applications (arpeggiators, step sequencers) produce notes at a certain rate relative to the tempo. For example, though the tempo may specify that a quarter note is set to 120 Beats Per Minute, the arpeggiator might be generating eighth notes and so is producing notes at twice that speed. You specify the note speed here.

Note speed is shown by pulsing the **Note Pulse Light** (Figure 1).

[26] Why not tenths of a second? Because $10 \times 60 \times 128$ is larger than 2^{16}, so it won't fit in a 16-bit integer.

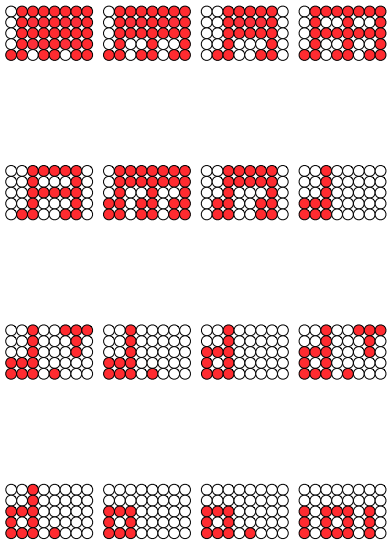
[27] The Measure Counter was added to Gizmo at the request of `Inkog`, a member of http://gearslutz.com and early adopter of Gizmo.

[28] Why not 32 like Bars Per Phrase? Because $32 \times 32 \times 128 > 2^{16}$. So basically for the same reason as Footnote 26.

[29] Gizmo can go lots faster than 999: in theory it could go clear to 31200 or so. But then your synthesizer would explode and we wouldn't want that.

Choose:

Eighth Triplet (Triplet 64th Note)	1/24	Beat
Quarter Triplet (Triplet 32nd Note)	1/12	Beat
Thirty-Second Note	1/8	Beat
Half Triplet (Triplet 16th Note)	1/6	Beat
Sixteenth Note	1/4	Beat
Triplet	1/3	Beat
Eighth Note	1/2	Beat
Quarter Note	1	Beat (duh)
Quarter Note Tied to Triplet	1 1/3	Beats
Dotted Quarter Note	1 1/2	Beats
Half Note	2	Beats
Half Note Tied to Two Triplets	2 2/3	Beats
Dotted Half Note	3	Beats
Whole Note	4	Beats
Dotted Whole Note	6	Beats
Double Whole Note	8	Beats



Swing

Swing, or **syncopation**, is the degree to which every other note is delayed. 0% means no swing at all. 100% means so much swing that the odd note plays at the same time as the next even note. That's a lot.

Choose: 0% ... 100% (larger percentages are more swing, that is, longer delay every other note)

Swing is only applied if the Note Speed is set to thirty-second, sixteenth, eighth, quarter, or half-notes.

Mega Only: **Transpose**

Here you can state that any notes generated by Gizmo be **transposed** up or down by as much as 60 notes. If a note is transposed to the point that it exceeds the MIDI range, it is not played. When appropriate, some applications (such as the MIDI Gauge) ignore this option.

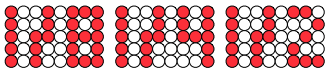
Choose: -60 ... 60

Mega Only: **Volume**

Like Transpose, here you can state that any notes generated by Gizmo have their volume changed by multiplying their MIDI note velocity by some value. If a resulting MIDI note velocity exceeds the maximum (127), it is bounded to 127.

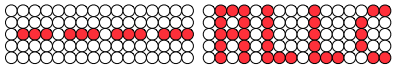
Choose:

1/8
1/4
1/2
1 (default)
2
4
8



In MIDI[30]

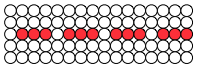
Many applications expect notes and other controls to come in via a specific input MIDI channel. You specify it here.



Choose: No Channel, Channels 1...16, or ALL Channels (OMNI)

Out MIDI

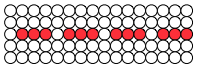
Many applications emit notes etc. via a specific output MIDI channel. You specify it here. Other applications can emit notes on several different channels, in which case this value determines the default channel used.



Choose: No Channel, or Channels 1...16

Control MIDI

The arduino can be controlled via NRPN messages. You specify the channel here on which it will listen for them



Choose: No Channel, or Channels 1...16

The NRPN Messages are:

NRPN Parameter	*Min Value*	*Max Value*	*MSB/LSB*	*Description*
0	0 (released)	1 (pressed)	MSB	Press/Release the Back Button
1	0 (released)	1 (pressed)	MSB	Press/Release the Middle Button
2	0 (released)	1 (pressed)	MSB	Press/Release the Select Button
3	0	1023	MSB + LSB	Turn the Left Potentiometer
4	0	1023	MSB + LSB	Turn the Right Potentiometer
5	0 (un-bypass)	1 (bypass)	MSB	Toggle Bypass
6	Any Value	Any Value	MSB	Unlock Potentiometers. When an NRPN message is received, normally the on-board potentiometers are locked so that turning them has no effect. Pressing an on-board button unlocks them: so does sending this NRPN message.
7	Any Value	Any Value	MSB	Start Clock. If Gizmo's clock is stopped, resets and starts it. When appropriate, sends a MIDI START message.
8	Any Value	Any Value	MSB	Stop Clock. If Gizmo's clock is playing, stops it. When appropriate, sends a MIDI STOP message.
9	Any Value	Any Value	MSB	Continue Clock. If Gizmo's clock is stopped, continues it. When appropriate, sends a MIDI CONTINUE message.

You can also start/stop/continue the clock via by pressing the Middle button while in the Options menu (see **Starting, Stopping, and Continuing the Clock** at the end of this section).

MIDI Clock

Gizmo can respond to a MIDI clock, ignore it, or emit its own MIDI clock. The use of the **Options→Tempo** setting will depend on the setting chosen here.

[30] *Why aren't these called MIDI In and MIDI Out?* Because then they'd be indistinguishable on the menu screen before the text started scrolling.

Choose:

Ignore	Use an internal clock but let any external MIDI clock pass through.
Use	Use an external MIDI clock and also let it pass through.
Divide	Use an external MIDI Clock. Don't pass it through, but instead send out MIDI clock messages whenever a Note Pulse occurs.
Consume	Use an external MIDI clock but don't let it pass through.
Generate	Use an internal clock and emit it as a MIDI clock. Don't let any external MIDI clock pass through.
Block	Use an internal clock but don't emit as a MIDI clock. Don't let any external MIDI clock pass through.

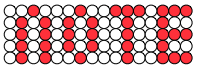
The **Divide** option is special: instead of sending MIDI clock every pulse, it sends MIDI clock every note pulse, thus slowing down (dividing) the clock signal. To set the Note Pulse, see the **Note Speed** option earlier. The division is as follows:

Note Speed	*Divisor*
Eighth Triplet (Triplet 64th Note)	1
Quarter Triplet (Triplet 32nd Note)	2
Thirty-Second Note	3
Half Triplet (Triplet 16th Note)	4
Sixteenth Note	6
Triplet	8
Eighth Note	12
Quarter Note	24
Quarter Note Tied to Triplet	32
Dotted Quarter Note	36
Half Note	48
Half Note Tied to Two Triplets	64
Dotted Half Note	72
Whole Note	96
Dotted Whole Note	144
Double Whole Note	192

You can also start/stop/continue the clock via by pressing the Middle button while in the Options menu (see **Starting, Stopping, and Continuing the Clock** at the end of this section), or by sending an appropriate NRPN message (see **Control MIDI** earlier).

Click or **No Click**

This toggles the note played by Gizmo to provide a click track for applications such as the Step Sequencer or Recorder. If you select **Click**, you will be asked to play a **note**. The note pitch and velocity form the click. If you select **No Click**, this turns off the click track.



Screen Brightness

This changes the brightness of the LED matrix.

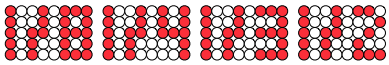
Choose: 1...16 (higher values are brighter)

Mega Only: **Menu Delay**

Gizmo often will display text (such as `SWING`) by filling the screen with the first few letters (in this case, `SWI`), then *delaying* for a certain interval, then scrolling through the whole word horizontally. You can specify how long that delay is.

Choose:

0	Seconds	(scroll immediately)
1/8	Seconds	
1/4	Seconds	
1/3	Seconds	
1/2	Seconds	
1	Second	(default)
2	Seconds	
3	Seconds	
4	Seconds	
8	Seconds	
∞	Seconds	(never scroll)



Mega Only: **CV+Velocity *or* CV+Aftertouch *or* No CV**

Toggles whether Gizmo will send control voltage and gate information. If **CV+Velocity**, then control voltage will be sent out DAC A (I2C address 0x62), velocity will be sent out DAC B (I2C address 0x63), and digital pin 8 will be set HIGH (5V) when a note is played (or LOW (0V) when a note is released), thus acting as a Gate.[31] If **CV+Aftertouch**, then the same is done except that aftertouch will be sent out DAC B instead of velocity. If **No CV**, then nothing is sent. Pitch Bend at present has no effect. [32]

The About Screen

Presently says: `GIZMO V1 (C) 2016 BY SEAN LUKE`

14 Starting, Stopping, and Continuing the Clock

You can start, stop, and continue the clock via NRPN as discussed earlier (see **Control MIDI** in Section 13). But there's another "secret" way to do it using Gizmo's buttons. If you are in the Options menu, long-press the Middle Button: this toggles **starting** or **stopping** the clock. Furthermore, on the Mega, if you long-press the Select button, you can toggle **continuing** or **stopping** the clock. Remember that you can also get to the Options menu from inside the Arpeggiator, Step Sequencer, or Recorder.

Neither long-pressing the Middle Button, nor using NRPN to start/stop/continue, will do anything if the MIDI Clock is set to **Use, Divide,** or **Consume** (in which case the MIDI Clock is out of your control). See **MIDI Clock** in Section 13.

Note that starting and stopping the clock doesn't mean that an application starts or stops playing. However, the Start message *will* cause applications to reset themselves to the beginning when appropriate. This means that if you want to start/stop/pause/continue the Step Sequencer (for example), you can do it as follows: first stop the clock, then start the sequencer playing. Note that it won't play because there's no clock pulses. But now you can start, stop, and pause/continue the sequencer by controlling the Start/Stop/Continue clock messages directly.

15 The Internal Clock

The Arduino has an internal clock with 32 bits, yielding a maximum of 42,949,672,95 ticks (one tick per microsecond) before it rolls back over to 0. This sounds like a lot, but it's not: it's a bit over an hour.[33] This means that once an hour, Gizmo might do something odd, if you're using the internal clock. Most likely it could drop a single pulse (1/24 of a quarter note), so it might be off by that much with respect to other instruments synced to it. You've been warned.

[31] As mentioned in an earlier footnote, Gizmo assumes you're DACs of this kind: https://www.adafruit.com/product/935

[32] Note that at present if you have set either knob in the Controller to control voltage, that DAC will be unavailable even outside the Controller. I'll fix that soon.

[33] 71.5827882666 minutes to be exact.

16 Buttons, Shield Quality, and Debouncing

The SparkFun MIDI Shield uses poor quality buttons. You can push down on the button and wiggle it and it'll think it's been pressed multiple times. As a result occasionally pressing a button may send two or more button-presses to Gizmo.

Gizmo has a debounce mechanism built-in: it ignores secondary apparent button-presses if they occurred within *N* milliseconds of an earlier button release. At present *N* is set to 100ms. If you need to press buttons faster than ten times a second (and it's possible) set the `BUTTON_PRESSED_COUNTDOWN_DEBOUNCE` constant (in `TopLevel.h`) to something smaller.

After about four months of extremely heavy use, my select and back buttons began to fail: if I pressed either the right way it wouldn't indicate that it's been pressed. If you reach this state you may have to replace the buttons, though that's kind of hard to do: I just built a new board with different, better-quality low-profile buttons (just look on Adafruit for 12mm pushbutton switches). Fingers crossed.

17 Space on the Arduino Uno

Gimzo uses nearly all available space on the Arduino Uno, and whenever I need to fix a bug I have to go on a hunting expedition to squeeze out a little more space somewhere. You don't want to do that. If you want to do any serious development, you should get an Arduino Mega instead, which has lots of available space. But if you *insist* on extending Gizmo on the Uno with some tiny application, you can remove the Note Recorder to make space. In `All.h` just uncomment the line that says `NO_RECORDER` and you'll get about 1.5K of code space. It's not a lot but should be enough to write a small app. Note that "Recorder" will still appear in the Menu: it just won't do anything. To get rid of that you need to modify the state machine a bit. I'd not bother.

18 Development Status

		Testing		
Item	*Coded*	*Cursory*	*Significant*	*Known Bugs and Issues*
Arpeggiator	✓	✓	✓	
Step Sequencer	✓	✓	✓	Occasionally the beat doesn't match up with the play cursor; this particularly happens under Swing. I've not been able to track it down.
Recorder	✓	✓	✓	Rarely a note will get stuck after recording: appears that a NOTE OFF message isn't getting matched with the ID of the corresponding NOTE ON message when entered into memory. I also think there may be a bug causing chords near the start of the song to be rushed a bit. Perhaps timing is being delayed for some reason?
Gauge	✓	✓		
Controller	✓	✓		Voltage and Aftertouch untested. Pitch Bend displays correctly but MIDI output is untested.
NRPN Control	✓	✓	✓	
Transposition / Volume	✓	✓	✓	
Brightness / Delay	✓	✓	✓	
Tempo / Note Speed	✓	✓	✓	
MIDI In/Out Channels	✓	✓		No test of OMNI yet
Bypass	✓	✓	✓	
Display Subsystem	✓	✓	✓	
Timing Subsystem	✓	✓	✓	
Interface Utilities	✓	✓	✓	
Storage Facility	✓	✓	✓	
MIDI Clock Control	✓	✓		
Keyboard Splitting	✓	✓		Works well but the fade option is perhaps a bit unnecessary and weird.
Thru Facility	✓	✓		
Control Voltage	✓			Untested
Tap Tempo	✓	✓		Seems to work, but might be better to average in tempos. This would require floating point probably, which would be too big for the Uno.
Measure Counter	✓	✓		Seems to work. MIDI clock response has not been tested.