

Introduction to Collidoscope

(v0.2)

Collidoscope is a table-top granular synthesizer unit that allows users to create impromptu whimsical sounds and play with them straight away. It is a collaborative instruments and it sports two independent synthesis engines so that multiple users can play together and share their experience. Each engine comes with a visual wave on the screen, that displays the sound and gives feedback on the user actions.

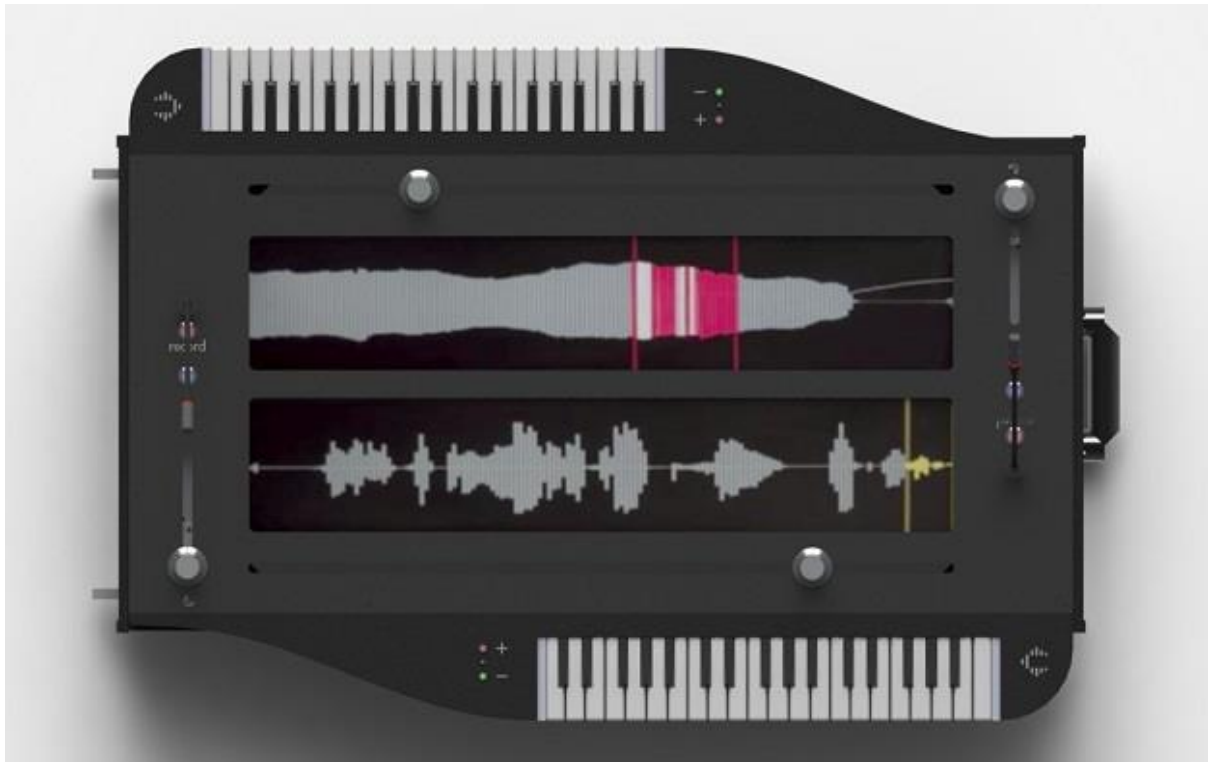


Figure 1: The new version of Collidoscope

Recording new sound

You start by recording some sound using the embedded microphone. When you press the record button a 2 seconds sample is recorded in the unit. As you record, a waveform with your sound is displayed on the screen. If you want to record a new sound just press the record button again and a new 2 seconds wave will be recorded and will replace the old one.

The waveform is your raw material to create new timbres but first you need to select the bit of sound you want to work with.

Making a Selection

In Collidoscope you make sound by playing a selection of the recorded wave. By moving the big horizontal knob left and right along the wave, you can set the selection start. By turning the knob, you can set the size of the selection: clockwise to increase the size and anticlockwise to shrink it. The maximum size of the selection is 37 bars (or chunks); the minimum size is 1 chunk.

Looping/playing the selection

If you flick the loop switch/button, the selection will start looping. You will see a white cursor that goes from left to right and indicates the play position at the current time. If you press the middle C of the keyboard you will get the same result as the looping. However, the other keys will play the selection with higher or lower pitch according to the chromatic scale of the piano. You can use the octave up/down button of the keyboard to play all the notes of the piano.

The looper is meant to allow the user to fiddle with the controls without having to hold the keyboard keys; however, the keyboard and the looper are independent. That is, the piano will play regardless of whether the looper is on or off.

Note that you can move the selection and change its size as you play, so as to experiment with the sound of other parts of the wave in real time.

Filter

If you tweak the **filter cut-off parameter**, a low-pass filter effect will be applied to the output of Collidoscope. A low-pass filter cuts the high frequencies of the sound and makes the output darker and in general lower in volume. All the frequencies above the filter cut-off frequency are cut. The cut-off parameter ranges from 22050Hz (no cut) to 200Hz (maximum cut).

As you turn the filter up and down you'll see that the selection colour will become respectively brighter or darker, to reflect visually what's happening to the sound.

Granular engine

By tweaking the **grain duration parameter**, you actually trespass to the granular domain.

We can indeed define the wave selection more properly as a grain. A grain is a piece of sound, to which a particular amplitude envelope is applied: a bell-shaped curve called Hann envelope, that makes it fade in and out smoothly when the grain is played.

Once a grain is triggered, it plays from the beginning to the end. There can be many grains playing together at the same time.

The selection start defines where the grain starts, whereas the selection size defines:

- The grain duration: how long a grain is or how much audio it is made of, if you like;
- The trigger rate of the grain: normally a new grain is triggered exactly as soon as the previous one has finished playing. This is what gives the repetitive looping effect.

However, when the grain duration parameter is cranked up, the duration of the grain is increased by multiplying it by a coefficient. So for instance, if the coefficient is 2, then the grain will last twice as long as the selection size. The coefficient ranges from 1 to 8.

Note though that the trigger rate is only affected by the selection size and it stays the same regardless of the duration parameter. This means that, when the duration parameter is greater than 1, a new grain is triggered before the previous one has finished playing and many grains (up to eight in fact) start overlapping with each other.

Thanks to the bell shaped envelope the grains overlap in a way that they do not go on each other's way too much. They rather start building up an eerie sound that's very characteristic of granular synthesis.

The best way to achieve such eerie sound is to set the selection size very small and to crank up the grain duration to the maximum.

When the grain duration is cranked up, the visual wave starts to emit particles, to convey visually what's happening in audio.

Versions of Collidoscope

There are two versions of Collidoscope: the **new version** (in Figure 1) and the **original version** (Figure 2).

The main difference in terms of functionality is that the filter and grain duration parameters are controlled by two faders in the original version and by another “mobile knob” laid out vertically in the new version.

In the new version moving the vertical knob up and down sets the filter cut-off frequency respectively up and down in the frequency spectrum. Turning the knob clockwise and anticlockwise turns the grain duration respectively up and down.



Figure 2: Original version of Collidoscope

Building Collidoscope

This paragraph gives an overview of all the electrical components of Collidoscope. Figure 3 shows how they are connected together.

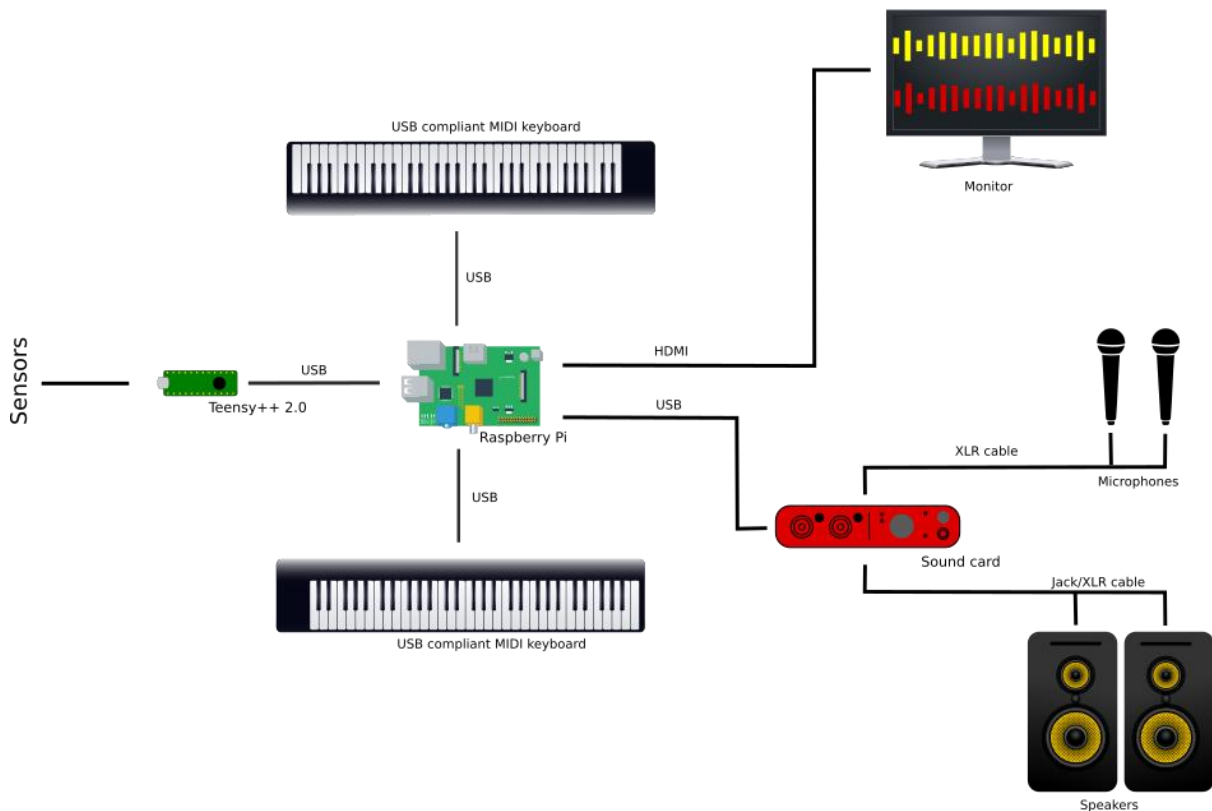


Figure 3: Architecture of Collidoscope

Components

Collidoscope was built with relatively cheap set of components. Let's see them in details.

Raspberry Pi 3, running *Raspbian Jessie* operating system

The Raspberry Pi runs all the visuals and sounds and is exclusively controlled via MIDI. See the document *Collidoscope Software Instruction* for installing and running the *CollidoscopeApp* software on the Raspberry Pi.

Link: <https://www.raspberrypi.org>

Teensy++ 2.0 microcontroller

The Teensy gathers all the sensor information (knobs, buttons etc.) and sends it as MIDI messages to the Pi. It is connected to the Raspberry Pi via USB cable. Note that the Teensy can be configured to become a class-compliant USB MIDI device and so doesn't need any additional driver to work with the Pi.

See the document *Collidoscope Software Instruction* for installing and running the *CollidoscopeTeensy* software on the Teensy

Link: <https://www.pjrc.com/store/teensypp.html>

Focusrite scarlett 2i2 audio interface

The audio interface is connected to the Raspberry Pi via USB cable. It receives audio via the microphones and it outputs audio through the connected speakers. Possibly other interfaces can be used as well, as long as they have two microphone inputs and two outputs. The Scarlett 2i2 though is proven to work seamlessly with the Raspberry Pi.

Link: <http://focusrite.com>

IMG Stage Line DMG700 Dynamic Gooseneck Microphone (XLR connection)

These are cardioid microphones, so the sound is picked up mostly from the front. You can try different types of microphones of course and see if the recording is satisfying enough.

Speakers

Any speakers will do as long as they can be connected to the audio interface.

Monitor

Collidoscope uses one single monitor, overlaid with a sheet of acrylic to separate it in two different parts, with one wave each. Both waves are drawn by the CollidoscopeApp. The yellow wave is drawn upside-down to accommodate the instrument for two players standing in front of each other.

The monitor is connected to the Raspberry Pi through an HDMI cable. Any monitor with an HDMI input can be used. Write down the resolution of your monitor in pixel, as this will be needed when launching the CollidoscopeApp on the Raspberry Pi. (See *Collidoscope Software Instructions* for more info on this)

For the original Collidoscope we used an [LG 21:9 UltraWide 25UM65](#).

For the new Collidoscope we tried both an [Asus MX299Q 29 inch Widescreen](#) and a [Dell 29 UltraSharp Monitor](#). The latter turned out to be a much better choice for the unit.

MIDI keyboards

Any USB compliant MIDI keyboard can be used

Spectra Symbol SP-L-0200-103-3%-ST, Industrial Motion & Position Sensors SoftPot 200mm



Figure 4: Strip sensor

The strip sensor reads the position of the knob on the rail and send it to the Teensy analog input. The sensor is used for the selection start position and, in the new version of Collidoscope, for the filter cut-off frequency.

Link: <http://www.spectrasymbol.com/potentiometer/softpot>

Bourns PEC11R-4025F-N0024, Encoders 25mm SHAFT NO SWITCH



Figure 5: rotary encoder

The rotary encoder is mounted on a rail on top of the strip sensor. It holds the wiper (see next items) and, when turned, it sends [interrupt signals](#) to the Teensy to set the selection size.

Link: <http://www.bourns.com/docs/Product-Datasheets/PEC11R.pdf>

Spectra Symbol WP-M1-01-03-014-DI wiper



Figure 6: wiper

The wiper exerts pressure on the strip sensor for it to sense the position of the knob.

Silver aluminium knob Straw hat type, 38mm



Figure 7: aluminium knob

The aluminium knob is placed on the shaft of the rotary encoder.

Metal Pushbutton - Momentary (16mm, Red)



Figure 8: push button

Button to start recording. The button is also connected to a digital output of the teensy for the led ring to be lit.

12V Heavy Duty HD On / Off Metal Toggle Flick Switch Car Dash K875



Figure 9: toggle flick switch

Switches the loop play on/off in the original version of Collidoscope.

Series 48m-ss (solid-state) panel sealed metal pushbutton switch



Figure 10: 48m-ss Push button

Switches the loop play on/off in the new version of Collidoscope.

Link: <http://www.itwswitches.com/S48M-SS.shtml>

Bourns Motorized Slide Potentiometer



Figure 11: Slide Potentiometer

In the original version the sliders control the filter cut-off frequency parameter and the grain duration parameter. The motor is not used in Collidoscope so you can use non-motorized sliders as well.

Link: <https://www.bourns.com/data/global/pdfs/PSM.pdf>

Connecting the Sensors to the Teensy board

The sensors need to be connected to specific analog and interrupt pins in order for the Collidoscope software running on the Teensy to work properly (See *Collidoscope Software Instructions* for more info on the Teensy software).

The table below reports to which pin each sensor must be connected.

See [this link](#) for Teensy++ 2.0 pin assignment (scroll down in the page for Teensy 2.0). The codes used in the table below (F0, F2 etc.) are actually on the board; except the interrupts codes, which are listed on the side.

Wave 1 (red)

Sensor	Teensy Pin
Strip Sensor for selection start	F0
Strip Sensor for filter cut-off (new Collidoscope only)	F2
Fader for filter cut-off (orig. Collidoscope only)	F2
Fader for grain duration (orig. Collidoscope only)	F3
Knob for selection size	INT0/INT1
Knob for grain duration (new Collidoscope only)	INT4/INT5
Loop on/off switch	B0
Record Button	B1
Record Button Led	D4

Wave 2 (yellow)

Sensor	Teensy Pin
Strip Sensor for selection start	F1
Strip Sensor for filter cut-off (new Collidoscope only)	F4
Fader for filter cut-off (orig. Collidoscope only)	F4
Fader for grain duration (orig. Collidoscope only)	F5
Knob for selection size	INT2/INT3
Knob for grain duration	INT6/INT7
Loop on/off switch	B3
Record Button	B4
Record Button Led	D5

The Teensy PCB board

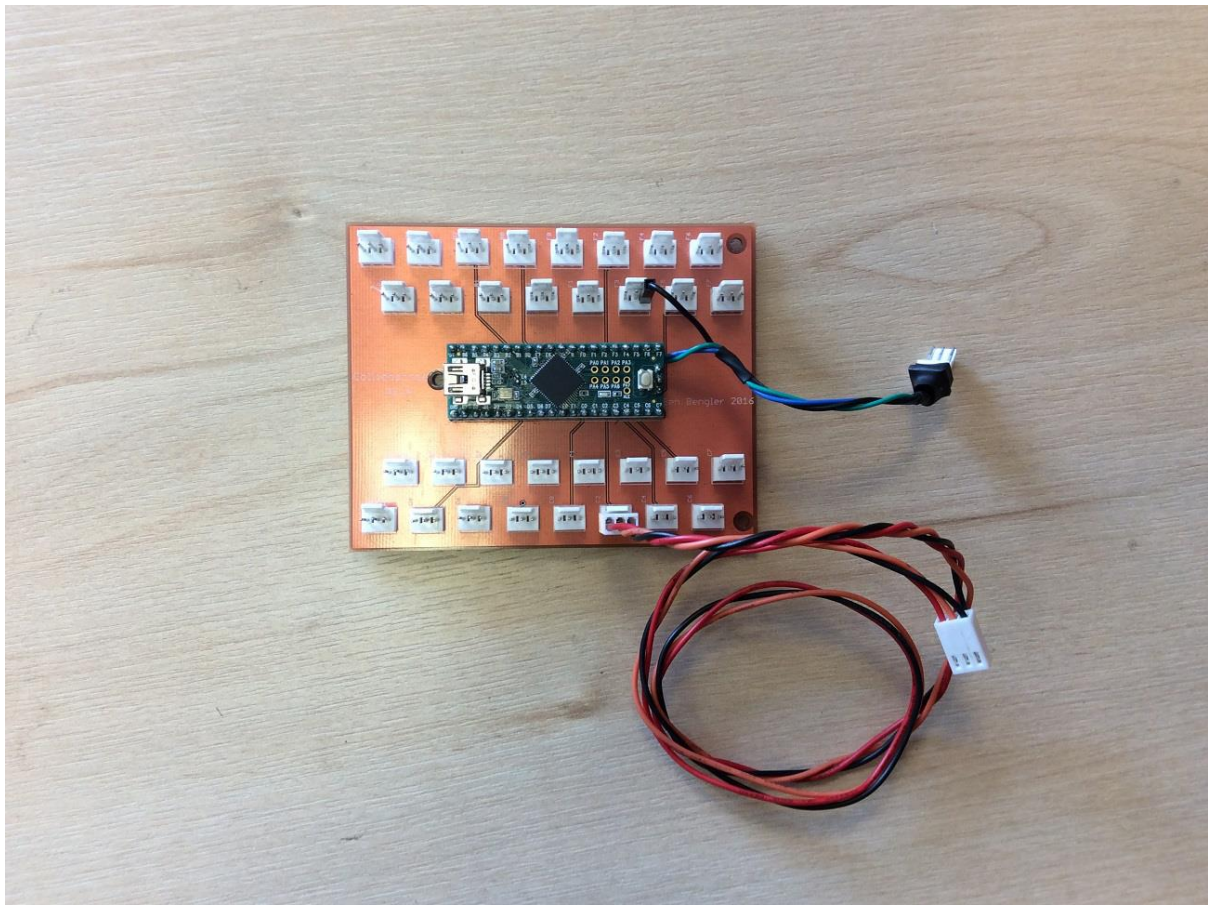


Figure 12: Collidoscope pcb for Teensy

The Collidoscope pcb (printed circuit board) for the Teensy makes it easy to plug and unplug sensors to the Teensy inputs and output without the need of breadboards or solder iron.

Besides the pcb itself, you will also need two additional types of components to use it:

1. **Molex KK 2.54mm Pitch PCB Headers with Straight Friction Lock, 6410 Series**
The three headed pins mounted on the board in Figure 12 and 13.
2. **TinkerKit Cable**
The orange/red/black cable in Figure 12.

The PCB headers that you see in the Figure 12 and 13 feature three pins: one for power, voltage and ground and map to the related Teensy pins. Each header has the same code as the Teensy pins (F1, F2, C1 etc.)

The interrupts of the Teensy are mapped to the pcb header in pairs: INT0/INT1, INT2/INT3, INT4/INT5 and INT6/INT7. The codes of each header are engraved in the pcb as you can see in Figure 13.

The INT4/INT5 interrupt is mapped to a header through the small blue and green TinkerKit cable that you see on Figure 12. This is because on the Teensy this very interrupts sit on top of the board and not on the side. You'll need to solder this cable to the Teensy yourself.

As shown in Figure 12, TinkerKit cables can be plugged in and out on one end, with the other end being soldered or attached to the sensor. In Figure 14 you can see a close-up image of the TinkerKit cable attached to one of the loop switches.

You can find the schematics and Gerber files of the Collidoscope PCB in [the Collidoscope repository](#).

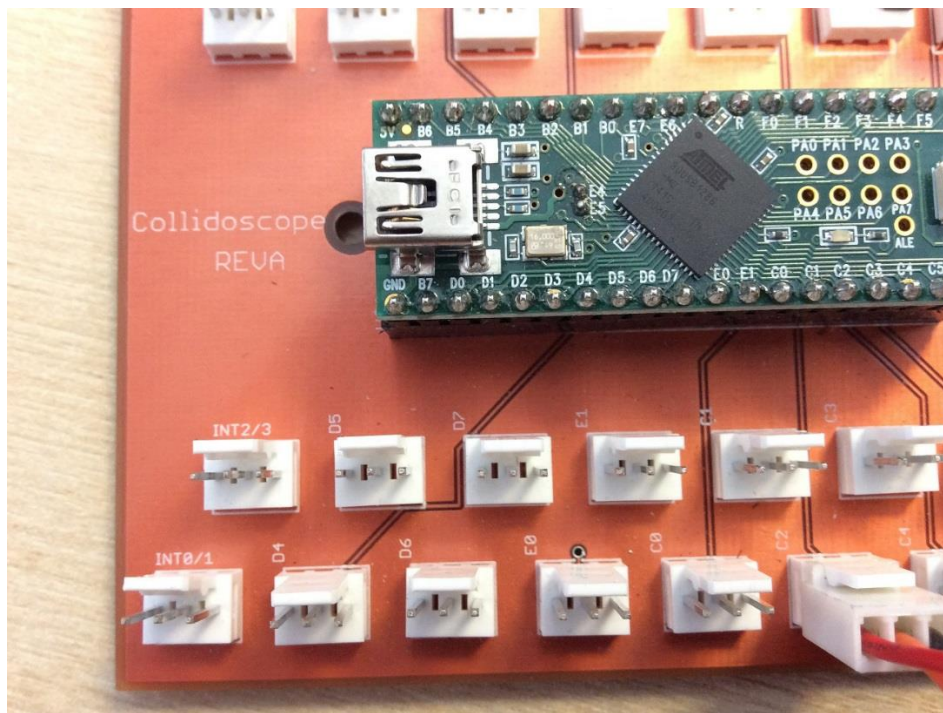


Figure 13: close-up of pin codes on pcb boards

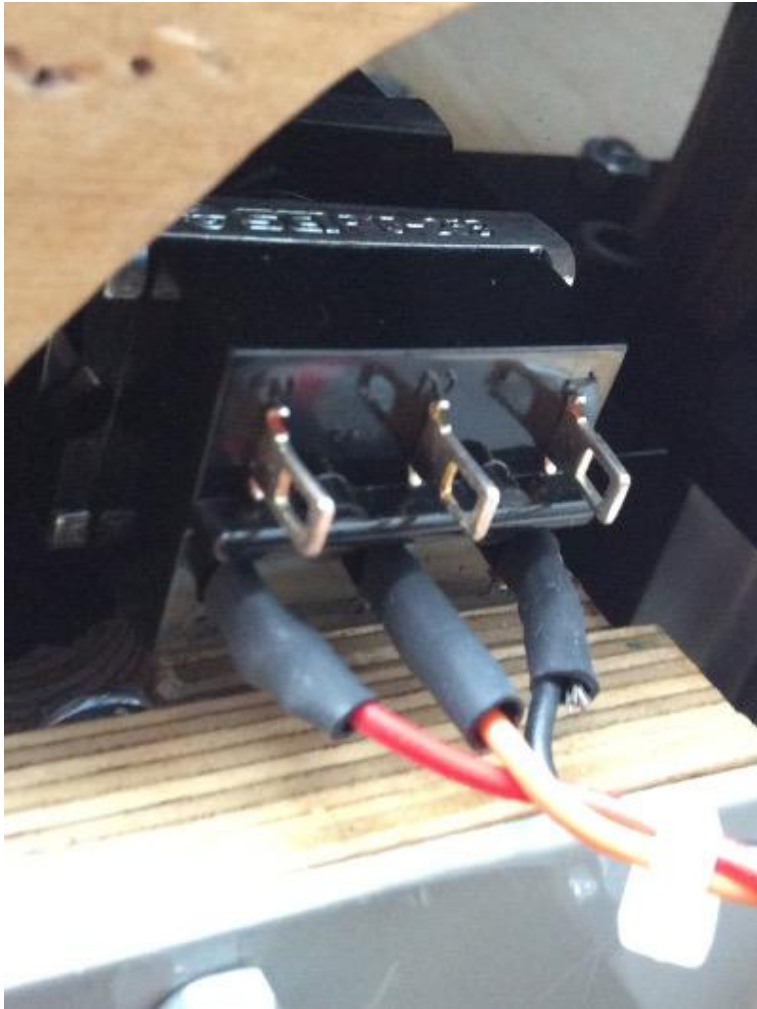


Figure 14: close-up of TinkerKit cable attached to a toggle switch