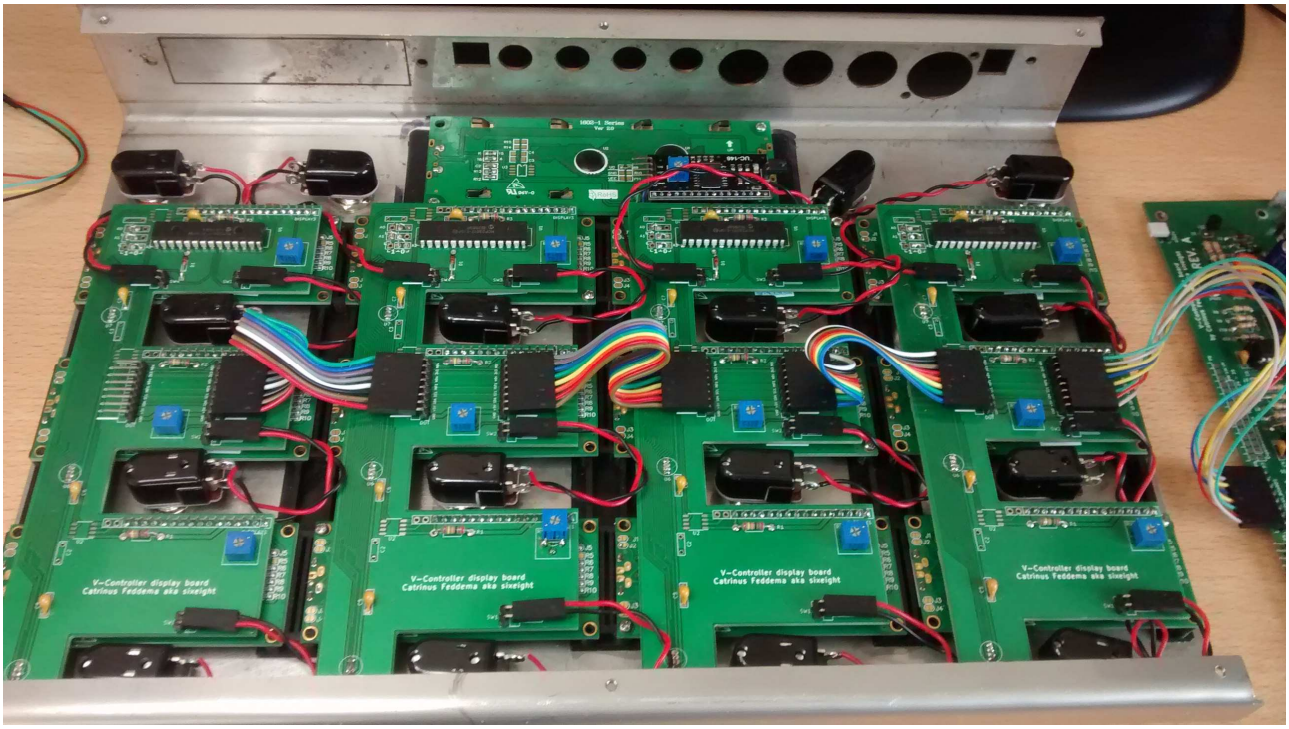
**V-Controller production model building guide**
**- First beta version -**
**By sixeight at vguitarforums.com**




## Introduction

Here is a quick guide for building the V-Controller, a dedicated MIDI controller for Boss GP-10 / Roland GR-55 / Roland VG-99 / Zoom G3 and Zoom MS70-CDR. Building this device should cost around 20 - 40 hours and $200 - 400 for parts, depending on the cost for the enclosure.

## Features of the V-Controller:

Check out the VController User Guide for features.

## Main parts of the VController:

The VController has the following main parts:

- Enclosure of sheet metal with 3D printed supports for the displays
- Main PCB board with Teensy and all the connectors.
- 4 display PCB boards with 12 displays and Neopixel LEDs connected. Also 16 footswitches connect to the these boards
- 1 main display connected to a i2c module
- Option board: Raspberry Pi model B+ adding 4 USB host ports.

## Additional documents – see https://github.com/sixeight7/VController_v3:

- PDF, DWG and step files for the enclosure:
- STL files for the 3D printed files:
- PDF and gerber files of the PCBs

## Options for parts:

The following options are available for the VController:

- Type of display: LCD monochrome or LCD RGB color. The RGB color option has not been build, tested or implemented yet.
- Position of on/off switch – at the back or using one of the top switches.
- Enclosure: spray paint, spray coating or wrapped.

## Parts list: Enclosure

| Reference | Number | Part | Where to get |
|---|---|---|---|
| | 1 | Metal enclosure | DIY |
| | 1 | Large LCD support | DIY |
| | 3 | Small LCD support | DIY |
| | 2 | Half small LCD support | DIY |
| | 52 | 2,2mm x 6,5mm screws for LCDs | Conrad: 839536 - 8J<br>Microschroeven.nl |
| | 10 | M3 screws | reichelt.de: **SKL M3X10-50** |
| | 1 | Coloured plastic wrapping | |
| | 1 | large 16x2 LCD character display ERM1602DNS-1-5V | Buydisplay.com: ERM1602DNS-1-5V |
| | 1 | I2c module | ebay |
| | 1 | 4 pin 20cm 2.54mm Female to Female jumper wire Dupont cable | Ebay – can also be 2x 2pin jumper wire. |

**Parts list: four PCB displays**

| Reference | Number | Part | Where to get |
|---|---|---|---|
| U1 | 4 | MCP23017 | Conrad.nl: 651440 - 89<br>reichelt.de: **MCP 23017-E/SP (large)** |
| Display1-3 | 12 | 16x2 LCD character displays ERM1602DNS-4-5V | Buydisplay.com: ERM1602DNS-4-5V |
| Display1-3 | 12 | RGB backlight Positive or negative LCD 16x2** | Adafruit: 398 or 399 |
| Display1-3 | 12 | 16 pin* or 18 pin** header | reichelt.de*: **SL 1X50G 2,54 (x4)**<br>reichelt.de**: **SL 1X36G 2,54 (x6)** |
| Display1-3 | 12 | 16 pin female header<br>18 pin female header** - cut to size<br>The BL 1x20G is less high!!! | reichelt.de: **MPE 094-1-016**<br>reichelt.de: **BL 1X20G 2,54** (pins)<br>or 40 pin female headers from ebay |
| U2-U4 | 12 | WS2811** | Adafruit: 1378 |
| U5-U7 | 12 | Neopixel LED 5mm (Neopixel or PL9823 F5) | Adafruit: 1938<br>Ebay (search for PL9823 F5) |
| U5-U7 | 12 | Female header 2.54 mm, 1x4 straight<br>Or 4 pin male header | reichelt.de: **MPE 115-1-004** or<br>reichelt.de*: **SL 1X50G 2,54 (x1)** |
| U5-U7 | 12 | 5mm Chrome Plastic LED Bezel Holder | ebay |
| C1 – C7 | 16* or 28** | Capacitor 100n | reichelt.de: **KERKO 100N** |
| SW1-4 | 16 | Footswitch | http://www.ebay.com/itm/271930278587 |
| SW1-4 | 16 | 2 pin angled header (for switch) | reichelt.de: **SL 1X40W 2,54** |
| SW1-4 | 8 | 2 pin 20cm 2.54mm Female to Female jumper wire Dupont cable | ebay |
| RV2 | 4 | 10k trimmer 10 mm horizontal | reichelt.de: **76-10 10K** |
| R1-3 | 12 | Resistor 100 Ohm* | reichelt.de: **1/4W 100** |
| P1, P2 | 8 | 8 pin angled header | reichelt.de: **SL 1X40W 2,54** |
| P1 | 1 | 8 pin 20+cm 2.54mm Female to Female jumper wire Dupont cable | Could also be 2 4 pin cables |
| P1, P2 | 3 | 8 pin 10cm 2.54mm Female to Female jumper wire Dupont cable | ebay |

* Only for monochrome display
** Only for colored display

## Parts list: PCB main

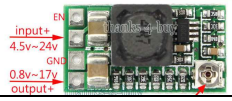
| Reference | Number | Part | Where to get |
|---|---|---|---|
| U1 | 1 | Teensy 3.2 | https://www.pjrc.com/store/teensy32.html<br>reichelt.de: **TEENSY 3.2** |
| U1 | 2 | 14-pin strips (male and female) for holding the Teensy in place – cut to size | reichelt.de: **BL 1X20G 2,54** (pins) |
| U2, U3 | 1 | 6n137 optocoupler | reichelt.de: 6N 137 |
| U4 | 1 | uA7805 Voltage regulator or<br>5V buck converter (when Rpi is in the option slot)<br>  | reichelt.de: **L 7805 CV**<br>ebay: 5V buck convertor – check if pinout corresponds to the image on the left. |
| U5 | 1 | 24LC512 I/P serial EEPROM | reichelt.de: **24LC512-I/P** |
| U2, U3, U5 | 3 | 4x 8 pin IC socket | reichelt.de: **GS 8** |
| JK1, JK3 | 2 | 7 pin din socket (MIDI)<br>Cliff FM6727<br>Pro Signal PSG03465 | Farnell: 1791759 or 2679728<br>reichelt.de does not stock these. Could use 5 pin instead if power is not needed |
| JK2 | 1 | 5 pin din socket (MIDI)<br>Pro Signal PSG03463 | Farnell: 1791756<br>reichelt.de: **MABP 5S** |
| J1 | 1 | RRC2: Neutrik NE8FAH<br>(screws not included) | Farnell: 3886256 |
| J1 | 2 | 2 screws: self tapping 2.9 x 1.05 tri-rondular configuration, 8 mm long, panhead (Neutrik A-SCREW-1-8) | Thought the official Neutrik screws were way overpriced. Found similar screw on ebay. |
| JK4, JK5, JK6, JK7 | 4 | jack socket 6.35 mm stereo<br>Neutrik NR-J6HF | reichelt.de: **NEUTRIK NR-J6HF** |
| JK4, JK5, JK6, JK7 | 4 | jack mounting nut<br>Neutrik NR-JNUTB | reichelt.de: **NEUTRIK NR-JNUTB** |
| JK8 | 1 | Power barrel – centre pin 2 mm | reichelt.de: **LUM NEB 21R**<br>Farnell: 1737246 |
| JK9 | 1 | 1x USB male socket type B | reichelt.de: **USB BW** |
| Q1 | 1 | IRF9530 P-channel MOSFET | reichelt.de: **IRF 9530** |
| Q2 | 1 | BC547 transistor or similar | reichelt.de: **BC 547C** |
| Q3, Q4 | 2 | 2N7000 MOSFET TO92 | reichelt.de: **2N 7000** |
| D1, D2, D4, D8 | 4 | 1N5817 shottky diode | reichelt.de: **1N 5817** |
| D3,D5, D6, D7 | 4 | 1N4148 diode | reichelt.de: **1N 4148** |
| SW1 | 1 | Power switch | Anything you like – drill your own hole or use a regular footswitch… |
| C1 | 1 | 220 uF capacitor, >=16V | reichelt.de: **RAD FR 220/35** |
| C2 | 1 | 100 uF capacitor, >=16V | reichelt.de: **RAD FR 100/35** |
| C9 | 1 | 10 uF capacitor, >=16V | Reichelt: **SM 10/16RAD** |
| C7 | 1 | 4,7 uF >= 16V | Reichelt: **SM 4,7/50RAD** |
| C3, C4 C5,C6 | 4 | 100 nF capacitor | reichelt.de: **KERKO 100N** |
| R1, R6, R7, R8 | 4 | 47 resistor | reichelt.de: **1/4W 47** |
| R2, R3, R38, R39 | 4 | 10k resistor | reichelt.de: **1/4W 10K** |
| R13, R14 | 2 | 2k2 resistor | reichelt.de: **1/4W 2,2K** |
| R15, R16 | 2 | 3k3 resistor | reichelt.de: **1/4W 3,3K** |
| R4, R5 | 2 | 220 resistor | reichelt.de: **1/4W 220** |
| R9, R10, R17, R34, R36, R37 | 6 | 4k7 resistor | reichelt.de: **1/4W 4,7K** |
| R35 | 1 | 100k resistor | reichelt.de: **1/4W 100K** |

| | | | |
|---|---|---|---|
| R18-R24, R26, R28,R30, R32 | 3 | Resistor network 4 res./8 pin 4k7 | reichelt.de: **SIL 8-4 4,7K** |
| R27, R29, R31, R33 | 1 | Resistor network 470k | reichelt.de: **SIL 8-4 470K** |
| P1, P2, P3, P4, P5, P6, P8 | 2 | 5 + 5 + 4 + 4 + 8 + 12 + 3 = 41 pins in angled pin strips | reichelt.de: **SL 1X40W 2,54** |
| P12, P13 | 1 | M3 PCB Holder | http://nl.rs-online.com/web/p/screw-terminals/6142425/ (small numbers) https://www.ettinger.de/en/product/13.42.320 (large quantities) |

## Parts list: Option board Rpi (internal)

| Reference | Number | Part | Where to get |
|---|---|---|---|
| U1 | 1 | Raspberry Pi model B+ | reichelt.de: **RASPBERRY PI B+** |
| U1 | 4 | Distance sleeve (3-5mm) | reichelt.de: **DK 5mm** |
| U1 | 1 | Micro SD card 16 Gb class 10 | reichelt.de: **INTENSO 3433470** |
| | 1 | Bracket | |
| | 1 | Connecting wire – could be 4 pin Dupont | |

## Parts list: Option board Rpi (external)

| Reference | Number | Part | Where to get |
|---|---|---|---|
| | 1 | Raspberry Pi model B+ | reichelt.de: **RASPBERRY PI B+** |
| | 1 | Micro SD card 16 Gb class 10 | reichelt.de: **INTENSO 3433470** |
| | 1 | Enclosure (3d printed) | |
| U1 | 1 | 6n137 optocoupler | reichelt.de: **6N 137** |
| U2 | 1 | 74HC14 6xinv. Smitt trigger | reichelt.de: **74HC 14** |
| U3 | 1 | 5V buck converter   | ebay: 5V buck convertor – check if pinout corresponds to the image on the left. |
| CON1 | 1 | Power barrel – center pin 2 mm | reichelt.de: **LUM NEB 21R** Farnell: 1737246 |
| | 2 | 7 pin din socket (MIDI) Cliff FM6727 Pro Signal PSG03465 | Farnell: 1791759 or 2679728 reichelt.de does not stock these. Could use 5 pin instead if power is not needed |
| P2 | 1 | Female header 2x20 pin | reichelt.de: **MPE 094-2-040** |
| D1, D3, D4 | 4 | 1N5817 shottky diode | reichelt.de: **1N 5817** |
| D2 | 1 | 1N4148 diode | reichelt.de: **1N 4148** |
| C2 | 1 | 100 uF capacitor, >=16V | reichelt.de: **RAD FR 100/35** |
| C3 | 1 | 10 uF capacitor, >=16V | Reichelt: **SM 10/16 RAD** |
| C1, C4 | 2 | 100 nF capacitor | reichelt.de: **KERKO 100N** |
| R1, R4, R5 | 3 | 220 resistor | reichelt.de: **1/4W 220** |
| R2 | 1 | 4k7 resistor | reichelt.de: **1/4W 1,8K** |
| | 4 | 12mm spacer | reichelt.de: **DI 12mm** |
| | 4 | M3 x 12mm (black) | ebay |
| | 4 | M3 x 16mm (black) | ebay |

### Cable for external RPi

| | | | |
|---|---|---|---|
| | 2 | Neutrik NYS323G 7 pin plug | Farnell: 8020442 |
| | | Tasker C281 7x0,25 $mm^2$ audio cable | Or something similar |

### Power supply (optional)

| | | | |
|---|---|---|---|
| | 1 | Compact switching power supply, 18W, out 9V | Reichelt.de: **PSAA 18U-090** |

**Enclosure**
See https://github.com/sixeight7/VController_v3/tree/master/Enclosure/Metal.
There are three parts to the enclosure:

- Top plate
- Bottom plate
- RPi expansion board bracket

There are two versions of the Top plate of the VController:

- top plate VController_mk4_05122016
- top plate VController Adafruit displays

The difference is in the size of the holes for the displays. I found Adafruit displays (both monochrome and RGB) to have a slightly larger bezel than the Buydisplay ones. Make sure you use the Adafruit version of the top plate when you have those displays.

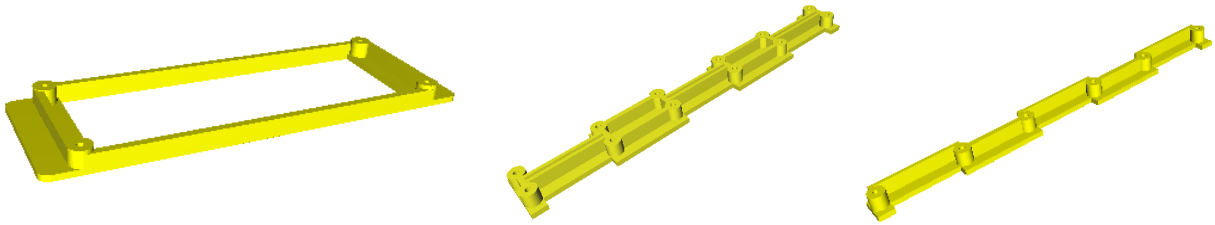
The dwg files show flat versions of each of these boards. Extra space for bending has been taken into account, but different type of metal may give different results.

You may want to give the VController_mk4.step file to a metal company and let make their own design for the flat version of the enclosure. That way they can be sure the extra space for making the bends is compatible with the materials and tools used.

I found a metal company that does laser cutting to build the enclosure for me. Bending the enclosure was done at a different place, but it would be wise to have both done at the same place. See additional documents for building plans for the enclosure.

**3D printing:**
See https://github.com/sixeight7/VController_v3/tree/master/Enclosure/3D%20printing:

The holes in the 3D design are 2 mm, but turned out to be slightly smaller when printed. The preferred color for the filament is black. I use Innofil PLA black 2.85 mm on a Ultimaker 3 printer. The print quality setting is “draft”. This will have fewer layers, give a stronger result and reduce printing time. The display supports will be out of view, so there is no reason to go for high quality fine layer settings.



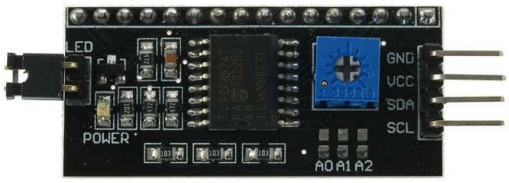
You will need 1x large LCD support, 3x small 3xLCD support and 2x half support 3xLCD. Or alternatively you could print four small supports and cut one in half. If you have Adafruit displays, make sure you print the Small 3xLCD support Adafruit stl. This one is easily breakable.

The 3D supports are attached to the enclosure with glue. I used Bison Kit. Tested beforehand if the glue would not make the 3D printed supports melt. So far the glue has been strong enough and the display supports have not loosened at all.


Check all the boards and displays fit before painting or wrapping the enclosure. I always have to do a little filing to get the displays to fit.

**Main display with i2C module**

You will need a i2c module, which can be bought from ebay easily On most of these adapters you can set the i2c address (with A0, A1, A2 – see picture below)



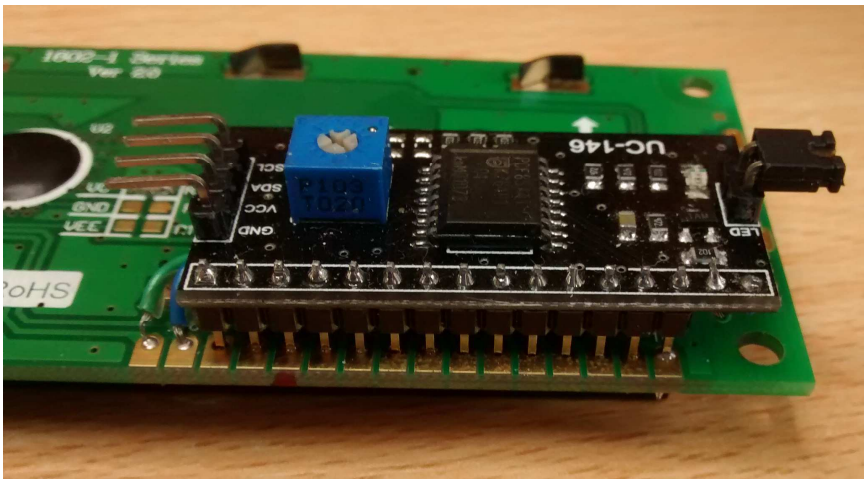

Some of these adapters have the PCF8574T chip. These are in the 0x20-0x27 i2c address range. Others have the PCF8574AT chip. These are in the 0x38-0x3F address range.

It does not matter which type you have. You can change the address in the VController firmware (hardware.h). Set it to address 0x27 if you have the PCF8574T and to 0X3F if you have the PCF8574AT. The hardware test sketch will check for both addresses and show the correct address on the display!

**Connecting the i2c adapter to the main display:**

The large display has a different pinout from the i2c module. To fix this:

- Pull out pin 15 and 16 from i2C module. First cut the plastic.
- Connect two wires running from pin 1 and 2 on the display to pin 15 and 16 on the i2c interface (pin 1 to pin 15 and pin 2 to pin 16)
- Place the i2c module shifted two pins to the right. Pin 1 - 14 of the i2c module should be connected to pin 3 – 16 of the display.



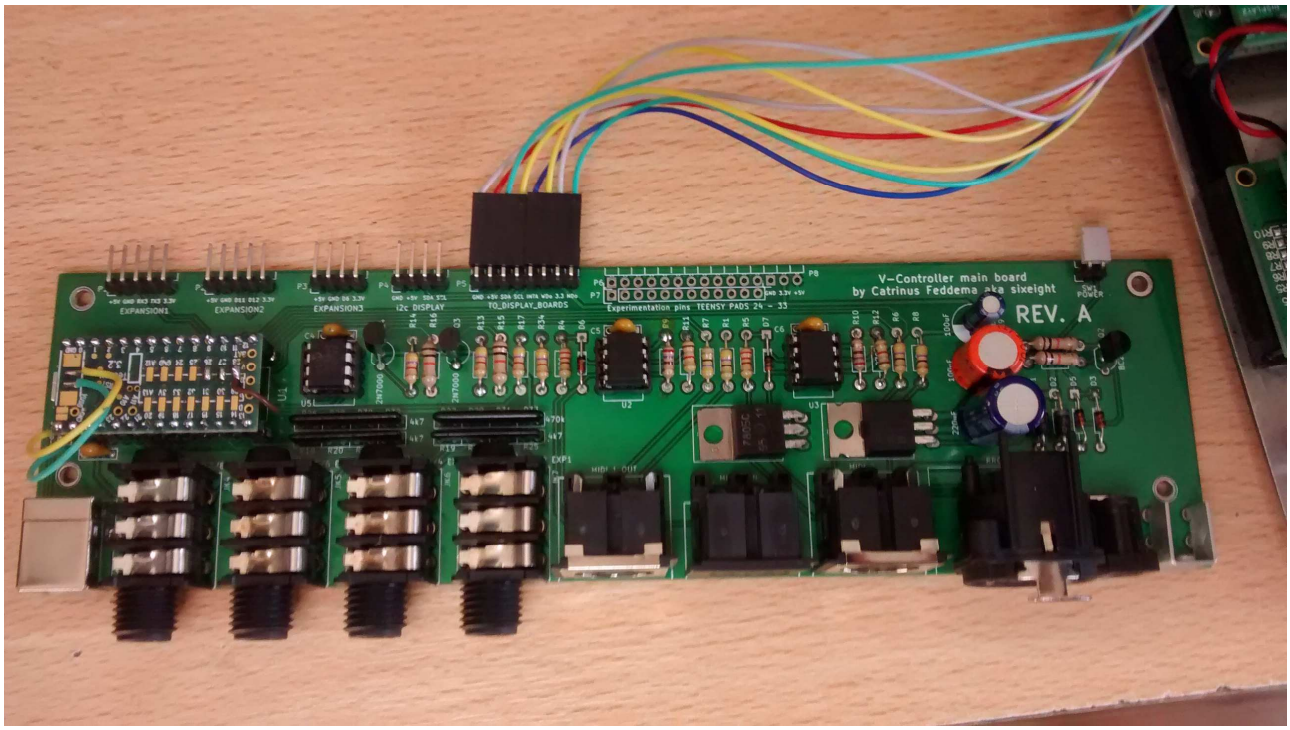
# Building the Main PCB

**PCB manufacturing:**
The schematic and design of the main PCB with Gerber files is here:
https://github.com/sixeight7/VController_v3/tree/master/Main%20board

The gerber files can be send zipped to a PCB manufacturer. I found easyeda.com to be very cheap as long as you stick to their defaults: 1.6 mm, green, HASL, 1oz. Copper weight, 1 design per panel.

Dimensions: 215 x 60 mm
Layers: 2
Thickness: 1.6 mm
Hole count: 320 plated pads + 13 non plated pads + 12 vias = 335 total

**Soldering:**
I always solder starting with the parts with the least height. Then I work my way up to the parts with more height. Before soldering all the pins of the connectors, check if they fit the enclosure. I found everything fitted fine without any filing.




See additional documents for schematic and large PCB design..

The first version (REV. A) of the main PCB board had some errors:

- Power barrel pins were connected backwards
- 2N7000 were connected backwards. This will fry the Teensy as it puts 5V power on the 3.3V power line!
- The external jacks use pin 13 of the Teensy. This pin is not suitable. It has been moved to pin 28 (pad on the Teensy)
- Capacitor C9 was too large and is changed to 10 uF.
- When installing new firmware, the Teensy drops the power pin and the VController is switched off! To solve this, there is a modification with a resistor of 100 kOhm to

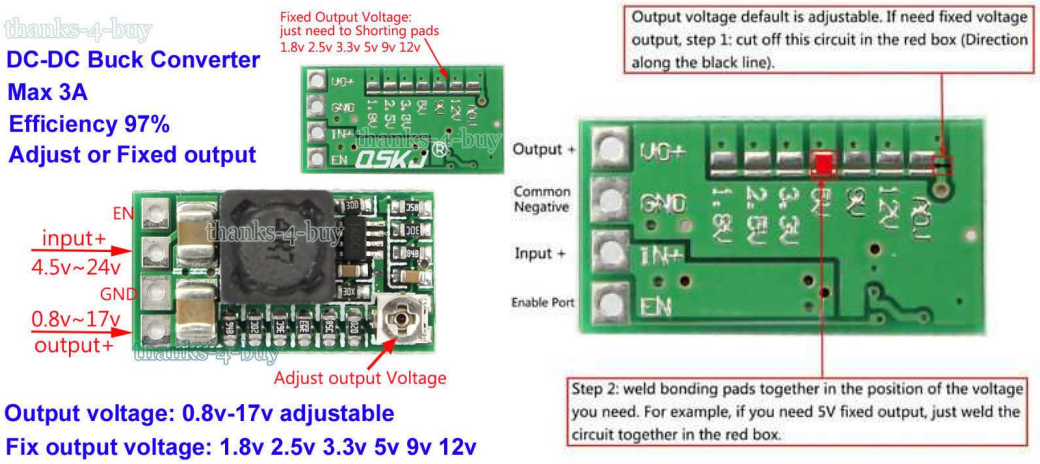
keep the VController on during updates and a capacitor of 4,7 uF to keep the power pin low when the VController has to be switched off.

- I found I could raise the speed of the i2c bus. The MCP23017 chips and the 24LC512 EEPROM chip run at 1500 MHz, the PCF8574 chips on the expander run at 800 MHz. Raising the i2c speed drastically improves performance of the VController. To allow for maximum performance, I now use the second i2c bus of the Teensy for the main display at 800 MHz and run the primary i2C bus at 1500 MHz.
- Also the 6N138 optocouplers have been replaced by 6N137 optocouplers, as these perform much better according to internet sources.

These errors have been fixed in the REV. C version of the main board!

**Power conversion**

You may want to replace the 7805 with a buck convertor. I use these found on ebay:




I used a small knife to cut the trace next to the ADJ pad and added a blob of solder to connect the 5V. That way the voltage level is stable at around 4.95 Volts. I do not trust the small potmeter on the front. Touching it changes the voltage. The RPi and other attached USB devices may break when voltage exceeds 5.5 Volts.

The EN pin on the convertor is not connected. You probably could leave out Q1 (IRF9530 P-channel MOSFET) and connect its gate here, but I haven't tested that yet.

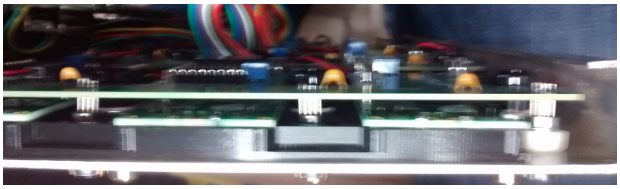
**Building the display board**

**PCB manufacturing:**
The schematic and design of the main PCB with Gerber files is here:
https://github.com/sixeight7/VController_v3/tree/master/Display%20board

Dimensions: 165 x 69 mm
Layers: 2
Thickness: 1.6 mm
Hole count: 152 plated pads + 53 vias = 205 holes

**Soldering:**
These board are a little tricky. Components are soldered to both sides of the board. The displays and neopixel LEDs go to the bottom side of the board.

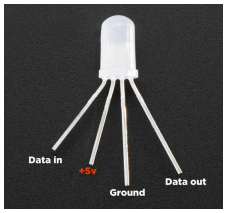
The biggest challenge is that the legs of the Neopixel LEDs are quite short. If you solder the display boards straight to the PCB the legs of the LEDS will just reach the board. But you can no longer reach the solderings below the displays.



Alternatively one could solder the LEDs to a 4 pin straight header. This will extend the legs and allow the display boards to be connected through 16 pin female headers.

Be careful to check if everything fits and is at the right height as you fit the board in the enclosure.

The neopixel LEDs are connected in a large chain. Every data out is connected to the next data in. On the board the data in pin should face to the bottom of the board:




**Addressing of boards:**

With the A0 – A2 jumpers next to the MCP23017 chip a unique address must be set for each board. I usually just hardwire the jumpers as wires to the board. The boards are addressed 0 to 3 from right to left, looking from behind the displays (VController opened up)

| **Address 3:** | **Address 2:** | **Address 1:** | **Address 0:** |
|---|---|---|---|
| A0 **O-O** O | A0 O **O-O** | A0 **O-O** O | A0 O **O-O** |
| A1 **O-O** O | A1 **O-O** O | A1 O **O-O** | A1 O **O-O** |
| A2 O **O-O** | A2 O **O-O** | A2 O **O-O** | A2 O **O-O** |
| ⌊1⌋⌊0⌋ | ⌊1⌋⌊0⌋ | ⌊1⌋⌊0⌋ | ⌊1⌋⌊0⌋ |

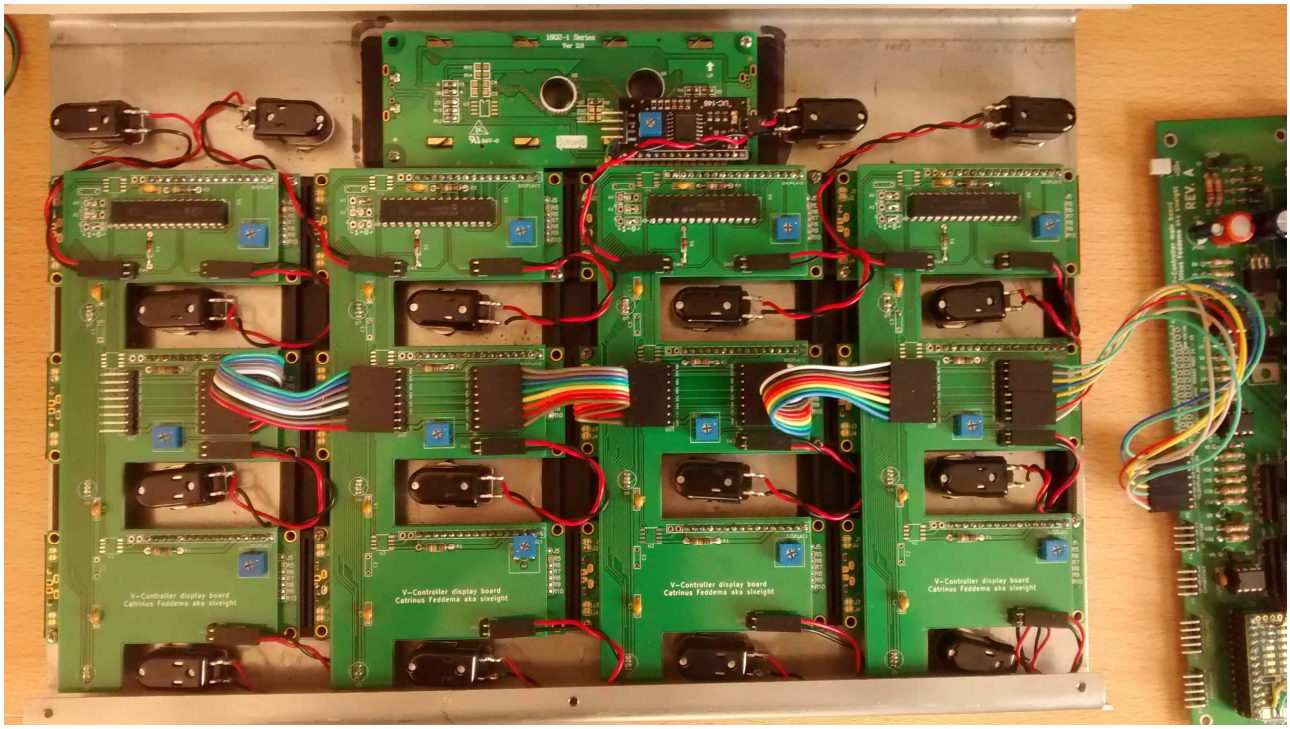
**Testing:**
You can find a link to a hardware test sketch in the firmware section below.

During the build I tested the boards first with just the lowest display connected. This way I still had access to the chip and the connection pins. Once that display worked I added the next one. Only at the end I added the neopixel LEDs.

**Putting it all together**

First attach the LED holders to the enclosure. Then solder the 2 pin dupont wires to the switches and attach them to the enclosure. The 2 pin dupont wires are cut in half and used for two switches.

Next add the display boards in the enclosure and connect the switches.




Three 8 pin dupont wires are used to interconnect the boards. One longer one is used to connect board 0 to the main board.

Also a four pin dupont wire is used to connect the main display i2C module to the main board.

**Firmware**
You will need to install Arduino IDE with the additional Teensyduino add-on:
https://www.arduino.cc/en/main/software
https://www.pjrc.com/teensy/teensyduino.html

You will need the correct LiquidCrystal library, which can be found here:
https://bitbucket.org/fmalpartida/new-liquidcrystal/downloads/LiquidCrystal_V1.2.1.zip

Test sketch for hardware: to test the displays, LEDs and switches:
https://github.com/sixeight7/VController_v3/tree/master/Firmware/Hardware_test_VC_PM

Firmware can be downloaded and installed from github:
- Will follow shortly…

**Raspberry Pi option board:**
A Raspberry Pi can be added to the VController to have an additional four USB host ports, supporting all the devices the VController supports so far.

Building the board:
Dimensions: 89 x 57 mm
Layers: 2
Thickness: 1.6 mm
Hole count: 118 plated pads + 1 via = 119 total

**External Raspberry Pi board:**
The RPi 3D-printed enclosure requires 87 gram of PLA.

**How much time does it cost to build a VController:**

| | |
|---|---|
| Ordering of parts | 2 hours |
| Having enclosure and 3D printing done | 1 hours |
| Building main board | 2 hours |
| Building display boards | 4 hours |
| Soldering i2c board to main display | 30 mins |
| Soldering wires to switches | 30 mins |
| Soldering pin headers to displays | 30 mins |
| Preparing LEDs | 30 mins |
| Gluing display holders to enclosure | 30 mins |
| Putting plastic on enclosure | 2 hours |
| Putting it all together | 3 hours |
| Building Rpi board | 1 hour |
| Testing and debugging | 2 hours |
| **Total time:** | **20 hours** |

**Additional information:**
Check out my blog at vguitarforums.com:
http://www.vguitarforums.com/smf/index.php?topic=15154.0

I have spent countless hours since May 2015 developing the VController. I would really appreciate a small donation:
https://www.paypal.me/sixeight