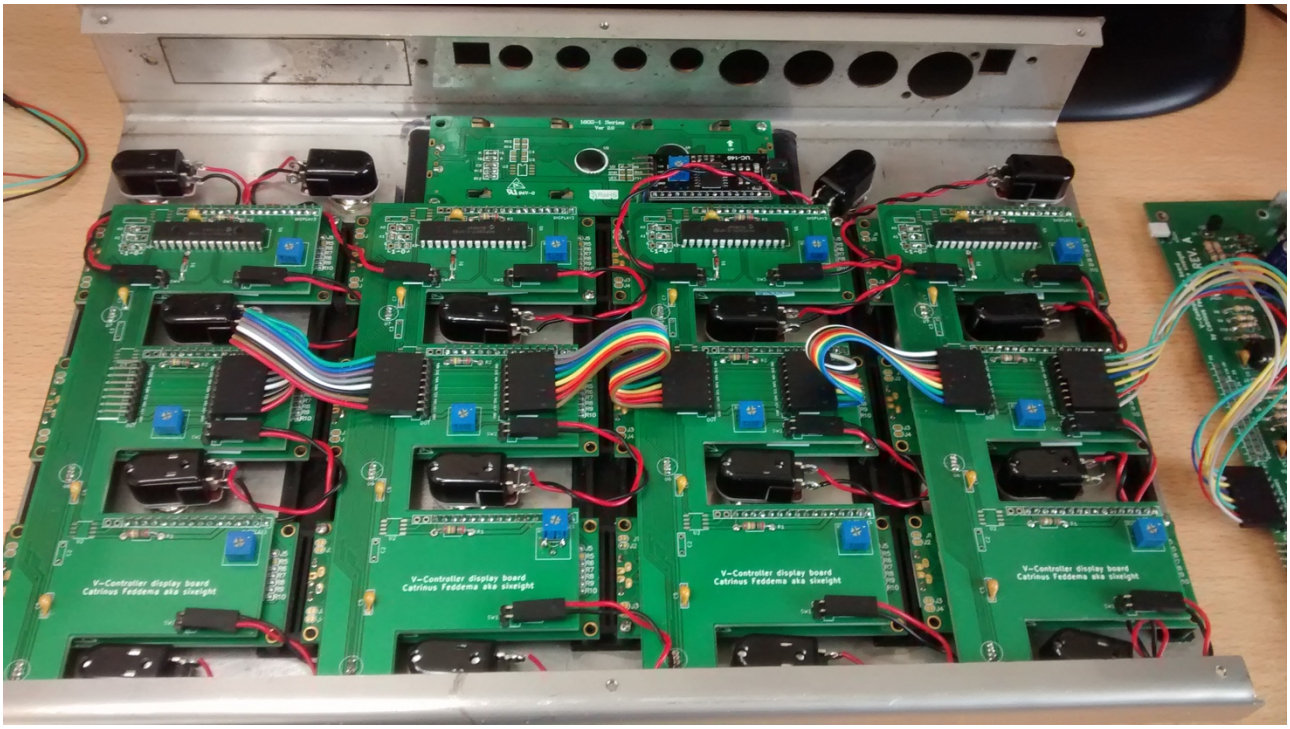
V-Controller production model building guide
Version 1.2
By sixeight at vguitarforums.com



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 / Zoom MS70-CDR / Line6 M13 / Line6 Helix / Fractal AxeFX / Boss Katana and the Kemper Profiling Amp. 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 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 Make sure you add the I2c adapter board!
	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 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**	Buydisplay.com: ERM1602F7-6-5V or ERM1607DN7-6-5V Adafruit: 398 or 399
Display1-3	12	16 pin* or 18 pin** header	reichelt.de*: **SL 1X50G 2,54 (x4)** reichelt.de**: **SL 1X36G 2,54 (x6)**
Display1-3	12	16 pin female header 18 pin female header** - cut to size The BL 1x20G is less high!!!	reichelt.de: **MPE 094-1-016** reichelt.de: **BL 1X20G 2,54** (pins) 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 Ebay (search for PL9823 F5)
U5-U7	12	Female header 2.54 mm, 1x4 straight Or 4 pin male header	reichelt.de: **MPE 115-1-004** or 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
D1	4	1N4148 diode	reichelt.de: **1N 4148**
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 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	2	6n137 optocoupler	reichelt.de: 6N 137
U4	1	uA7805 Voltage regulator or 5V buck converter (when Rpi is in the option slot) 	reichelt.de: **L 7805 CV** 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) 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
JK2	1	5 pin din socket (MIDI) Pro Signal PSG03463	Farnell: 1791756 reichelt.de: **MABP 5S**
J1	1	RRC2: Neutrik NE8FAH (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 Neutrik NR-J6HF	reichelt.de: **NEUTRIK NR-J6HF**
JK4, JK5, JK6, JK7	4	jack mounting nut Neutrik NR-JNUTB	reichelt.de: **NEUTRIK NR-JNUTB**
JK8	1	Power barrel – centre pin 2 mm	reichelt.de: **LUM NEB 21R** 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, 4, 5, 6	4	2N7000 MOSFET TO92	reichelt.de: **2N 7000**
D1, 2, 4, 8	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,	3	Resistor network 4 res./8 pin 4k7	reichelt.de: **SIL 8-4 4,7K**

R26, R28,R30, R32			
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

Parts list: Option board Rpi (internal)

Reference	Number	Part	Where to get
U1	1	Raspberry Pi model B+ (or RPi model 3)	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+ (or RPi model 3)	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:

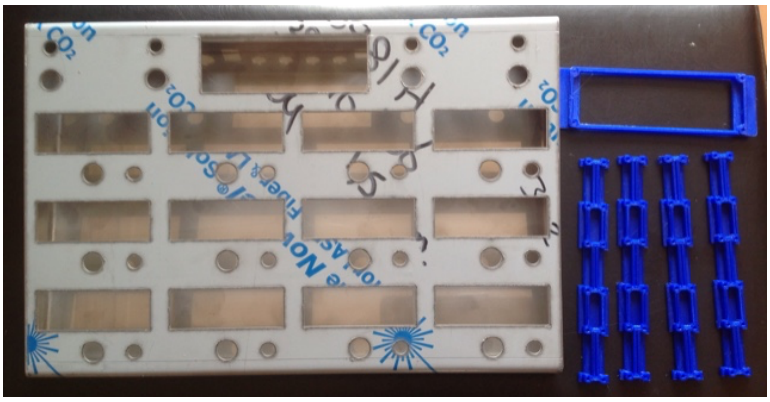
- top plate VController_mk4_05122016
- top plate VController Adafruit displays

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.



After the board is made, you may have to do some filing to get it smooth on all sides. Laser cutting often leaves some melted metal bits left on the enclosure.

You can take out the piece of metal for the option board slot if you need it. With a chisel and a hammer it is very easy to get it out.

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.

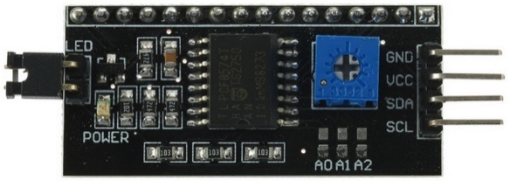
Check all the boards and displays fit before painting or wrapping the enclosure. I always have to do a little filing to get the displays to fit.

	Check out the video: **Gluing the enclosure** https://youtu.be/sExP2jf99Nc

Main display with i2C module

You can now order a display with the adapter board added and ready soldered from Buydisplay. Make sure you add the I2C adapter board when you order the part:

In case you want to buil dit yourself, you will need a i2c module, which can be bought from ebay easily. With most of these adapters you can set the i2c address (with A0, A1, A2 – see picture below)



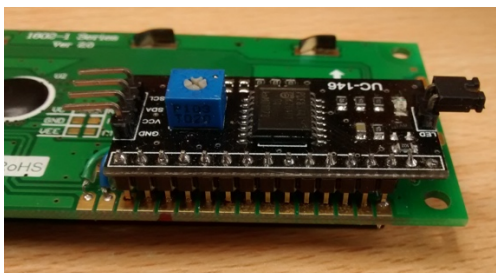
Some of these adapters have the PCF8574T chip. These are in the 0x20-0x27 i2c address range. Others have the PCF8574AT chip. These are in the 0x38-0x3F address range.

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.



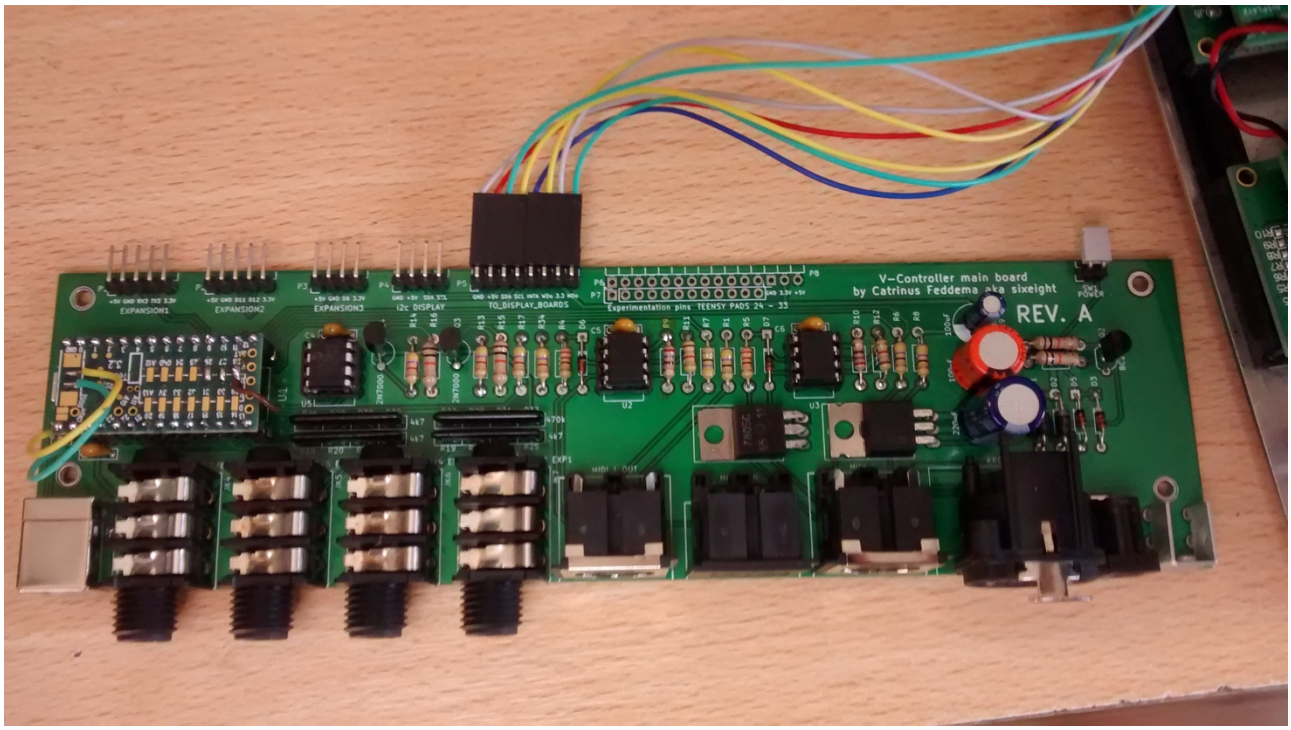
Building the Main PCB

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

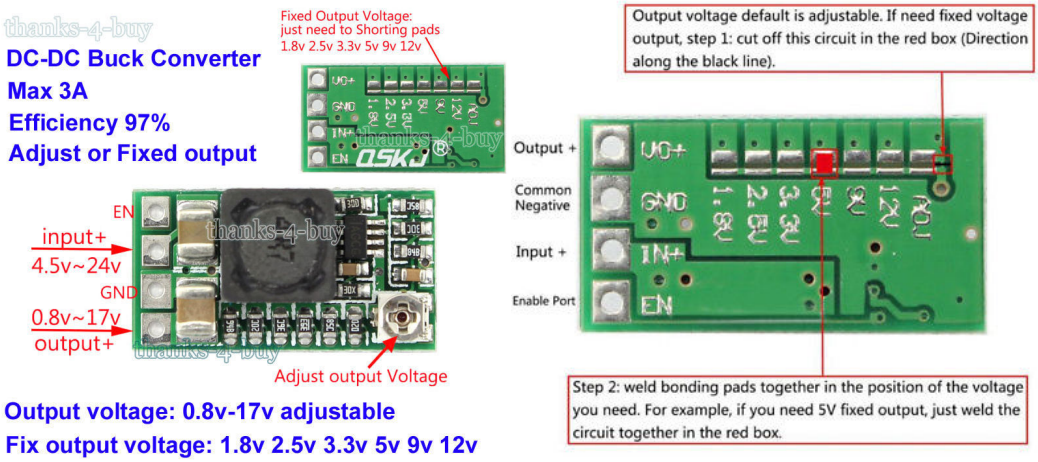
keep the VController on during updates and a capacitor of 4,7 uF to keep the power pin low when the VController has to be switched off.

- 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.

Check out the video: **Soldering the main board**

https://youtu.be/yJqYoJ4opok

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

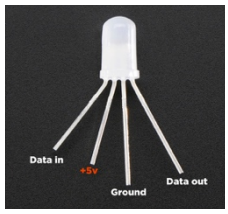
Soldering:
These board are a little tricky. Components are soldered to both sides of the board. The displays and neopixel LEDs go to the bottom side of the board.

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. You also have to watch that the legs of the LED do not short in the LED bezel. Therefore I put a small piece of insulation around the LEDs. I found the insulation of an old CAT5 cable to be a perfect fit. It is large enough to fit around the legs of the LED and small enough to fit in the bezel. You can also use electrical tape to make the isolation.

Be careful to check if everything fits and is at the right height as you fit the board in the enclosure. It is best to add the LEDs to the display boards after everything is in put together in the enclosure.

The neopixel LEDs are connected in a large chain. Every data out is connected to the next data in. The ground pin and “data out” pin are longer than the other pins. Also on some LEDs there is a small indent in the “ring” at the bottom of the LED above the “data out” pin. 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⌋

Check out the video: **Soldering the display boards**

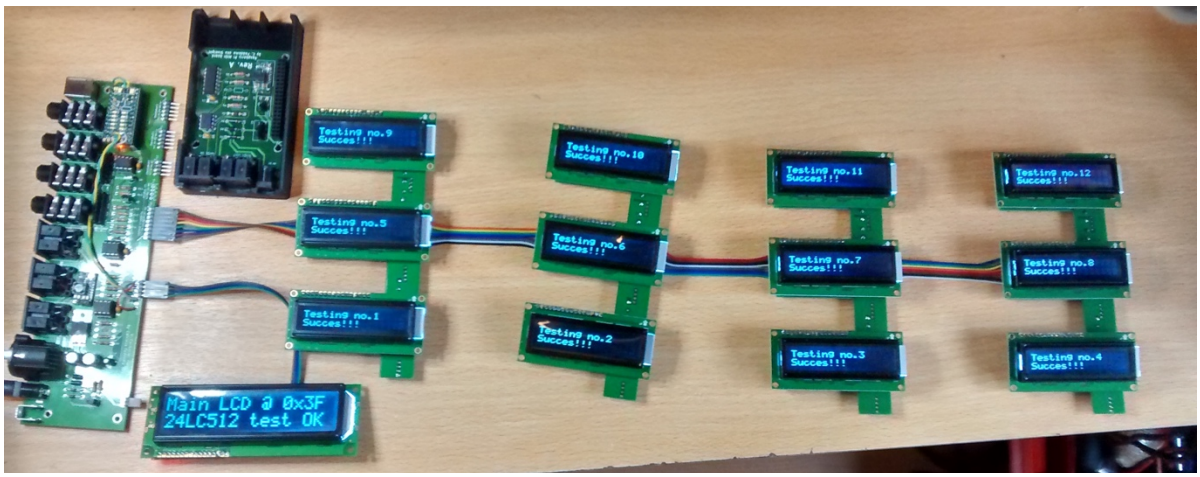
https://youtu.be/4Qu6WvendfU

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

The test sketch does a number of tests during boot. For every stage of the test the build in LED of the Teensy will flash. Here is a description of what happens during every flash:

1st flash: power on
2nd flash: Neopixel LEDs are initialized and on
3rd flash: Neopixel backlights are initialized and on (when present)
4th flash: i2c bus 1 initialized
5th flash: i2c bus 2 initialized
6th flash: main LCD initialized
7th flash: 12 display LCDs initialized
8th flash: main LCD data test
9th flash: other display data test
10th flash: EEPROM data test

I usually test the boards by interconnecting them and then I run the test sketch. When the test is ready, you should see the following:



Check that all the displays are on and that the 24LC512 tests out OK.

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.

Check out the video: **Soldering and testing displays**

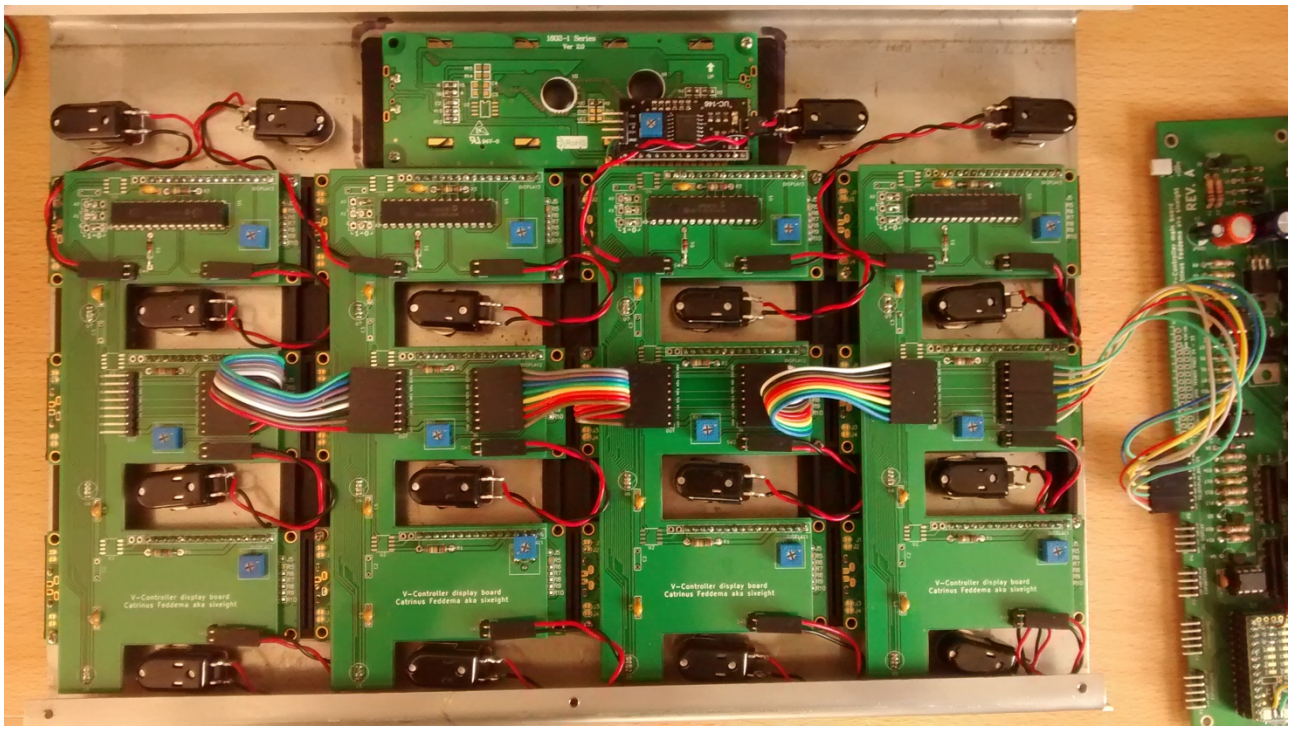
https://youtu.be/hMdTI5rJZvg

Putting it all together

Once the enclosure is ready and all the boards have passed the test, it is time to put everything together.

First solder the 2 pin dupont wires to the switches. The 2 pin dupont wires are cut in half and used for two switches.

Attach the LED holders to the enclosure. Next add all the displays. Now add the perspex plate and 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.

Now is a good time to run the test sketch again. The main display should show which switch is pressed or released. So you can test all switches here.

Lastly add the LEDs to the display boards.

Now it is time to run the final check. During the test sequence all LEDs should light up white. By pressing the switches the colour of the corresponding LED should change colour.

It is quite easy to short the data pins of the LEDs via the bezel. Make sure you isolated everything carefully.

After the test sketch runs succesfully, you can upload the VController firmware and test all the MIDI ports and switch/expression pedal connections.

Check out the video: **Putting it all together**

https://youtu.be/iXB7WEzQCkI

Firmware
There are two ways to install firmware. One is to use a pre-compiled hex file. The other way is to compile the data yourself, using the Arduino IDE.

Loading precompiled hex files to the Arduino:

In https://github.com/sixeight7/VController_v3/tree/master/Firmware/Compiled you can download the hex files for the test sketch and the VController firmware itself. Right click on the hex file and select Save as…

To install the firmware on the VController you need the following tool:
https://www.pjrc.com/teensy/loader.html

Follow the instructions on the PJRC website to install the tool for you operating system.

To install the firmware, take the following steps:

1. Connect the VController or just the Teensy to your computer using a USB cable
2. Press the small button on the Teensy. It is now ready to receive firmware.
3. Start the Teensy loader. You should see the following three buttons:

4. Press the first button to open the hex file.
5. Press the second button to upload it to the Teensy.
6. Press the third button to reboot the Teensy. This should reboot the VController with the hardware test sketch or the Vcontroller firmware.

Compile the Teensy sketches yourself:

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:
https://github.com/sixeight7/VController_v3/tree/master/Firmware/VController_v3

The first page of the VController gives instructions on how to compile the code for the full VController or for the VC-mini. Enable the correct hardware.h file and make the right settings in the Arduino IDE.

```
// **** Choose the correct hardware below and update the Arduino compiler settings ****
// Current version of Arduino: 1.8.9 and TeensyDuino: 1.46

// Hardware of production model
#include "hardware.h"
// Arduino IDE settings: Board: Teensy 3.1/3.2, USB Type: MIDI, CPU speed: 96 MHz, Optimize: Faster, Programmer: AVRISP mkII

// Hardware of VC-mini rev. B
//#include "hardware_VCmini_b.h"
// Arduino IDE settings: Board: Teensy 3.6, USB Type: MIDI, CPU speed: 180 MHz, Optimize: Fast(!), Programmer: AVRISP mkII
```

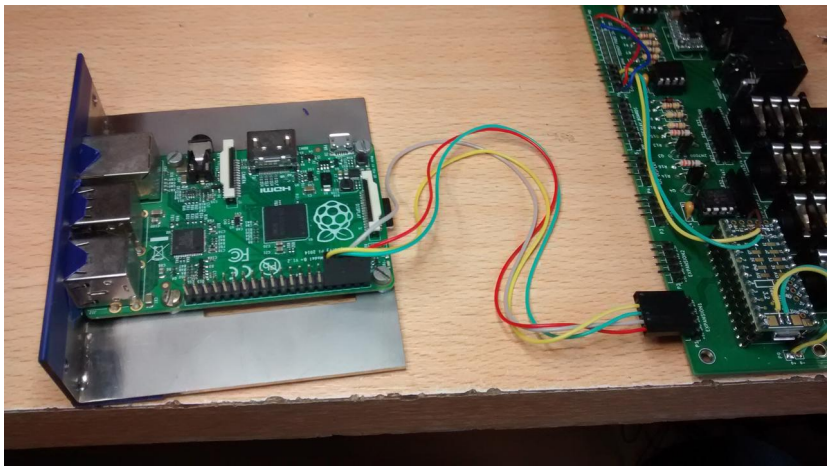
Raspberry Pi option board:
A Raspberry Pi can be added to the VController to have an additional four USB host ports, supporting all the devices the VController supports so far. This board can be build either internal or external.

Raspberry Pi firmware:
The Raspberry Pi runs with special firmware called VCbridge. You can find the source code and installation instructions here:
https://github.com/sixeight7/VCbridge

You can also download a ready-made image from here for the RPi model B+:
https://www.dropbox.com/s/cgy4ypnyhkf0ucw/2017-10-24%20VCbridge.rar?dl=0

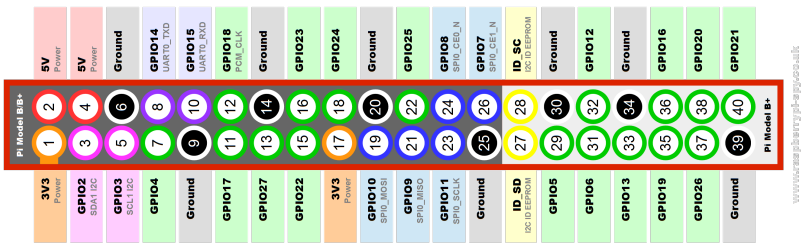
To install the ready made image:
1) Download and unrar the 2017-10-24 VCbridge.rar image.
2) Download Win32DiskImager from https://sourceforge.net/projects/win32diskimager/
3) Connect the microSD card to your PC.
4) Upload the image.

Internal Raspberry Pi board:
For the internal board we need a Raspberry Pi, a bracket and a four or five pin Dupont wire.



The design of the bracket is found here:
https://github.com/sixeight7/VController_v3/tree/master/Enclosure/Metal

A four pin Dupont wire can be connected to pin 4 (5V) ,6 (GND) ,8 (UART0_TXD) and 10 (UART0_RXD) of the GPIO to the +5V, GND, RX3 and TX3 pin of the main board. See pinout GPIO below:



I have built my own Dupont connector with 5 pin connectors, so I can connect it to GPIO pin 2, 4, 6, 8 and 10. This connects it to the edge of the GPIO.

External Raspberry Pi board:
For the external board we need a 3D printed enclosure and a PCB.

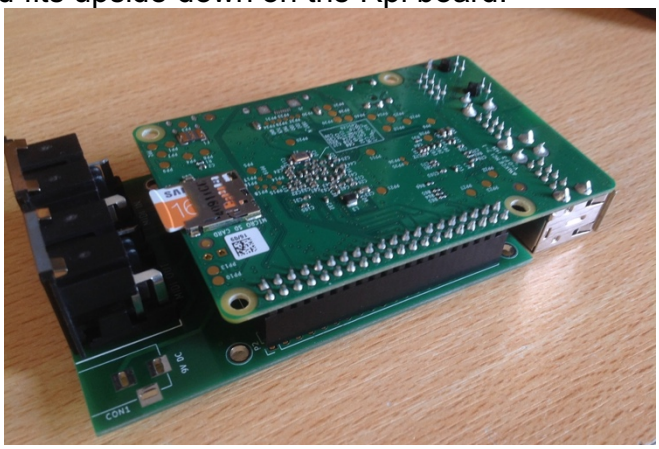
The design of the enclosure is found here:
https://github.com/sixeight7/VController_v3/tree/master/Enclosure/RPi%20case

It consists of two parts. In total the enclosure requires 87 gram of PLA.

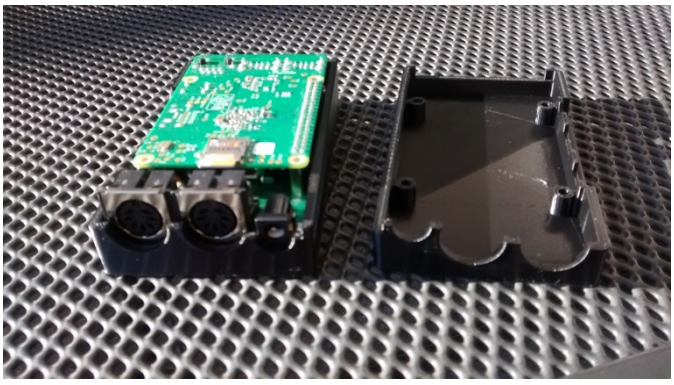
Building the PCB. You can find the gerbers here:
https://github.com/sixeight7/VController_v3/tree/master/RPi%20Expansion%20Board

Here is the data you need to get the board made:
Dimensions: 89 x 57 mm
Layers: 2
Thickness: 1.6 mm
Hole count: 118 plated pads + 1 via = 119 total

The raspberry Pi board fits upside down on the Rpi board:

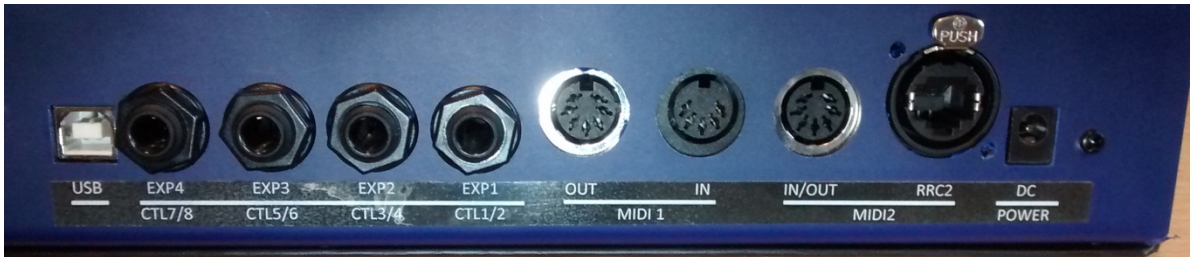


12 mm spacers go in between the boards. The two halves of the enclosure fit around the boards and are screwed tight in the spacers. Always start with the top side of the enclosure, add the PCB board and attach the spacers. Then add the Raspberry Pi and the bottom side of the enclosure.



	Check out the video: **Building the RPI expansion board** https://youtu.be/kFdNmJK0trg

Adding labels



For the back of the VController and for the top of the external Raspberry Pi there are some labels, which you can find here:
https://github.com/sixeight7/VController_v3/blob/master/Enclosure/VController%20labels.pdf

I have printed them and laminated them with an adhesive laminating pouche. After laminating, I cut them and then laminated them again to seal the edges.

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