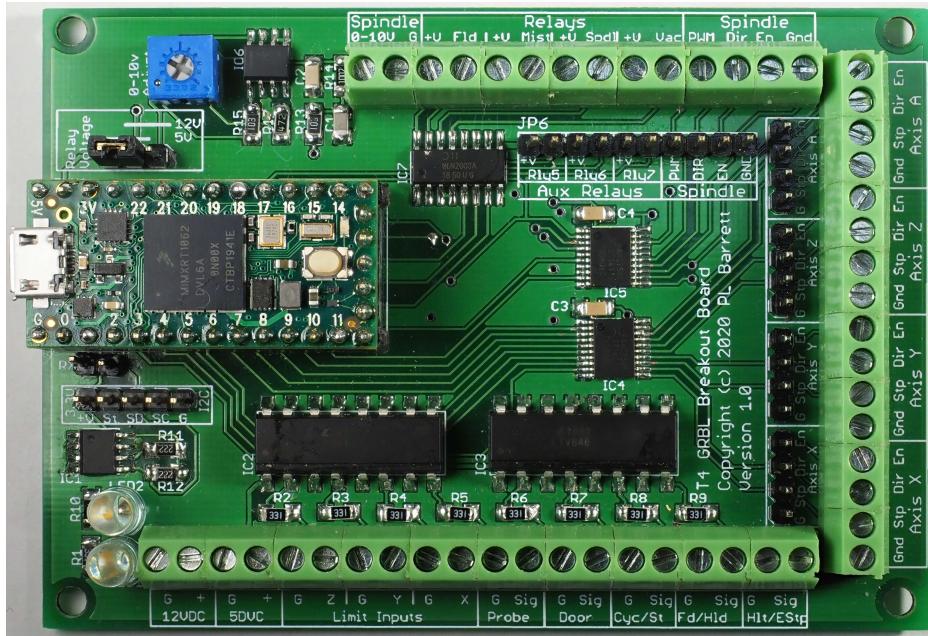


# grbl/HAL Teensy 4.0 Motion Controller

V1.00



This document describes V1.00 of the grbl/HAL Teensy 4.0 Motion Controller.

## Features:

- 4 Axis control outputs – 5V Compatible.
- 8 Opto-isolated inputs.
- 7 Relay Outputs.
- Relay voltage switchable between 5V and 12V.
- Screw Terminal I/O for reliable connections.
- I2C header.
- EEPROM footprint for SOIC8 devices.
- Full spindle control outputs – 5V CMOS compatible.
- 0-10V spindle control output.
- Dust Extraction relay output slaved to spindle.
- LED indicators for 5V and 12V.

## Stepper Driver outputs.

There are 4 sets of standard GRBL stepper driver outputs: X, Y, Z and A axes. Each has 3 pins: step, direction and enable. Each are 5V compatible and capable of driving opto-isolated stepper driver inputs. Each axis has a set of screw terminals as well as pin headers (0.1"/2.54mm spacing).

## Limit Pins.

There are X, Y and Z opto-isolated limit pins available via screw terminals.

## Input Pins.

Standard GRBL input pins are supported via screw terminals: Feed/Hold, Cycle/Start, Halt/Stop and Safety Door open. These are opto-isolated.

## Probe Input

Probe input is opto-isolated and is available via screw terminals.

## Spindle Control.

Screw terminal and pin header outputs for Spindle Enable, Spindle Direction and PWM signals. These are 5V CMOS logic compatible. There is a relay output for the spindle. See Relay section for more details. In addition, 0-10V output for spindle control is provided via a screw terminal.

## Relay outputs.

Standard GRBL Flood and Mist relay outputs are supported via screw terminals. Spindle relay output via a screw terminal is supported and controlled by Spindle Enable. In addition, a separate screw terminal relay output for Dust Collection is slaved off the Spindle Enable output.

3 additional relay outputs are supported via pin headers and used via M62-M65 grbl/HAL pin control.

All relay outputs are capable of directly driving relay coils. Each relay driver is capable of up to 100 mA. All 7 are limited to 500 mA in total though above 250 mA, forced air cooling is recommended.

All relays drivers have open collector outputs.

Relay voltage is selectable between 5 and 12V via pinheader labeled Relay Voltage in the upper left corner of the PCB.

## I2C Header

An I2C header is provided. 3.3V only, there is no translation to/from 5V. In addition a strobe line from Teensy 4.0 pin 33 is provided on the header. Currently, only a limited number of devices are supported. Check the grbl/HAL github site for more details.

## PCB Assembly

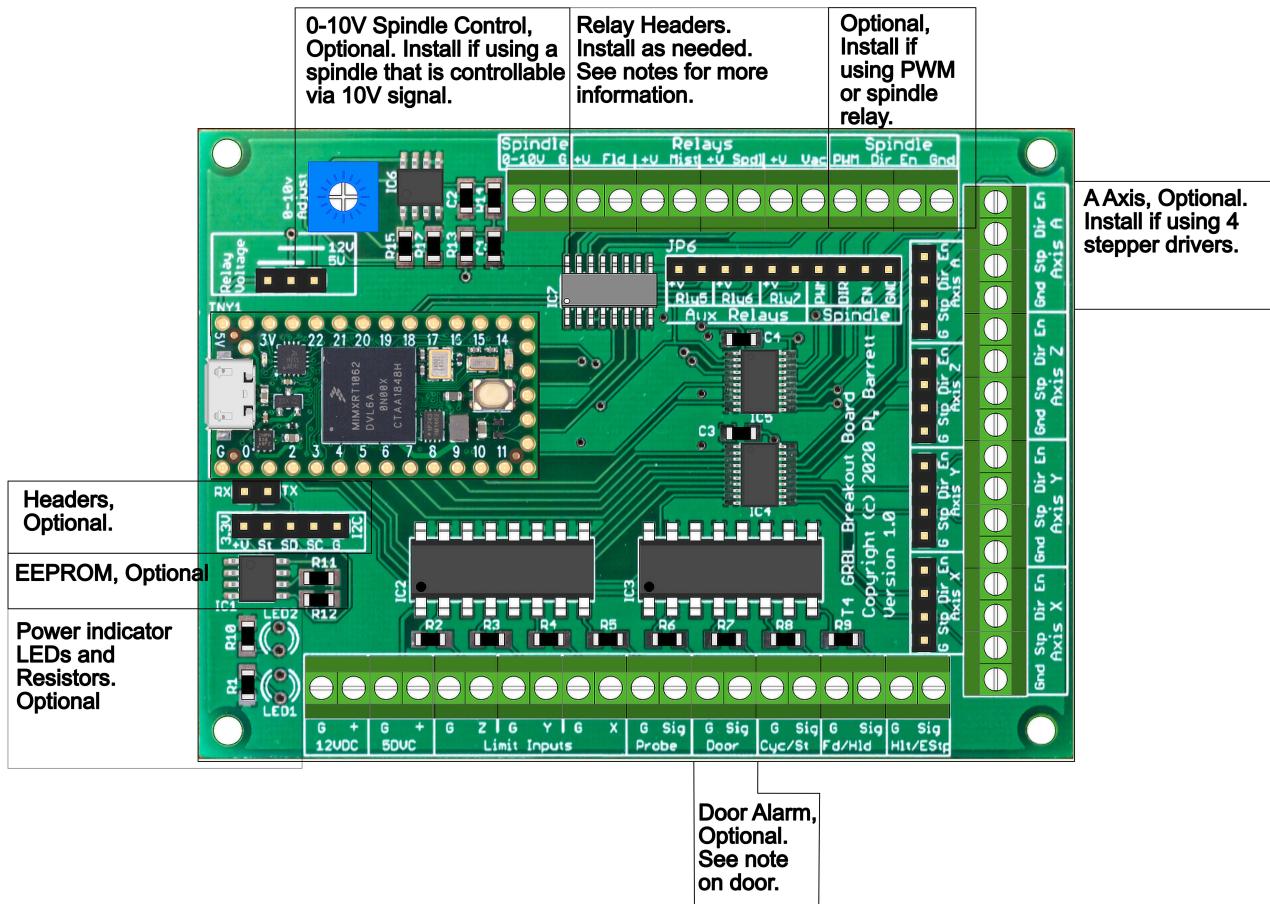
Not all components are required. See Optional Components section for more information.

Assemble the PCB in the following order:

1. Use a flux pen on all pads.
2. Solder the smallest SMD components first – resistors, capacitors.
3. SMD ICs next. Take care with IC4 and IC5 when soldering. Draw the soldering iron along the legs, not perpendicular to them as they easily bend.
4. Now is a good time to verify that all leads are properly soldered. Visual inspection with a magnifier is a good idea. Electrical continuity testing is very helpful – leads that look OK are sometimes not.
5. Mount and solder trimmer resistor R16 and the LEDs next. LED anode goes towards the top of the board (cathode connects to resistor). Trim excess leads.
6. Install the Teensy 4.0 – sockets or actual T4 with headers. See Teensy 4.0 Mounting Options for more information. Now is a good time to test the board before the headers and terminals are installed, making changes harder.
7. Mount and solder any pin headers that you will be using. See diagram xxx for options. Use tape to hold them in place while soldering. Solder an end pin and then adjust for proper alignment. Finish by soldering the rest of the pins.
8. Mount and solder screw terminals. Assemble a complete row, insert and solder an end pin. Then solder the pin at the other end, making sure the row is properly aligned. Then solder remaining terminals while ensuring that the row is straight.

## Optional Components.

Many components are optional. Refer to the following diagram.



### Notes:

- RX, TX and I2C headers are optional. Install if you need to use an alternate USB connection. Grbl/HAL will work correctly without either header installed.
- EEPROM is optional, Install if you need to use an external EEPROM. Grbl/HAL will work correctly without it.
- Power indicator LEDs are optional. Useful to see if you have power. Grbl/HAL will work correctly without it.
- 0-10V Spindle control is optional. Use if you are using a VFD controlled spindle. Grbl/HAL will work correctly without it if you are manually controller your spindle. We recommend installing the screw terminals as they are hard to add later.
- Relays are optional. The grbl/HAL Teensy 4 Motion Controller is capable of driving relay coils directly. It is recommended that you install the screw terminals even if you don't initially plan on using them. Installing later can be difficult. See note on Vacuum/Dust Collector relay below. But, Grbl/HAL will work correctly without any relays.
- A Axis is optional if you don't have one in your CNC machine.
- Safety Door alarm. Install if you have an enclosure for your CNC machine with a Safety Door sensor. See note about backside pins in the Teensy 4.0 mounting options section below. Grbl/HAL will work correctly without it but see Testing section for disabling the alarm.

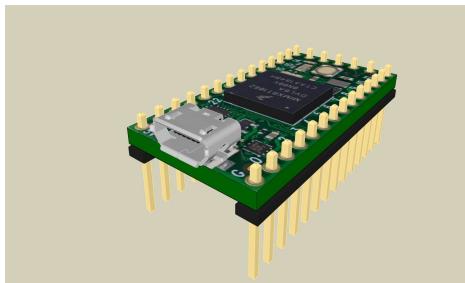
## Teensy 4.0 Mounting Options

The Teensy 4.0 comes with 3 sets of pins:

- The T4 has through holes around the perimeter. Typically header pins are soldered into them. The best way to ensure the pins are soldered in straight is to insert them into a solderless breadboard, place the Teensy 4.0 on top of them and solder in place. Take care when prying the assembly off the breadboard. The Teensy 4.0 should look like the picture below.
- There is a set of SMD pads for pins 24 through 33 on the bottom. PRJC calls them Backside Pins. We recommend you not bother with them unless you are using a Safety Door Open Sensor, Relays 5 through 7 or the I2C header. If you wish to use them, there are surface mount pin headers that will work. These are difficult to solder because there are a number of 402 SMD components close by and it is easy to knock them off. The author of this document has a dead Teensy 4.0 to prove that point. It is possible to use pogo pins though this has not been tested.
- The 3<sup>rd</sup> set of SMD pads, pins 34 through 39, are unused.

Mounting the Teensy 4.0 on the grbl/HAL Motion Controller PCB can be done in one of two ways:

- Solder directly. This is more reliable though commits the Teensy 4.0 to this application. Install pin headers as shown below and then insert the assembly in place on the PCB and solder. This is the recommended approach to ensure reliability.
- Use pin sockets. These are generally reliable but in a high vibration environment can shake loose. Ensure that the pin headers are installed on the Teensy 4.0 as shown in the picture below. Place the sockets on the Teensy 4.0 (with the headers pins installed) and then insert into the PCB for soldering. Using tape to hold the Teensy 4.0 assembly in place, solder 1 pin at the end of each row, check the alignment and adjust as necessary. Once you are satisfied with the alignment, solder all the pins in place.



## Relay Voltage

Relay Voltage source is selectable between 5V fed by the USB host and 12V (or higher) provided via an external power supply. Use a “suitcase jumper” as indicated on the PCB to select the desired voltage. Note, if using more than 2 relays at 5V, we recommend you use an external 5V supply. To do so, you must disconnect VUSB feed on the Teensy 4.0. On the bottom side of the Teensy 4 in the upper right hand corner, when looking at it from the bottom, there is a trace to be cut. That separates Vin from the USB cable and allows 5V input via the screw terminal. See the info card that comes with the Teensy 4.0 or PJRC.COM for more information.

Relay coil voltage up to 48V is permissible and is applied at the input terminal labeled 12V. If using higher than 12V, we recommend changing resistor R1 to limit LED current to below 10 mA. For 24V, use 2.2K Ohm and, for 48V, use 4.7K Ohm. The user is responsible for ensuring that all relays are rated for the voltage they provide.

## Dust Extractor/Vacuum Control

An additional relay driver is provided to drive a dust extractor relay. It is slaved to the Spindle Relay – both are energized when the spindle is turned on (M3). In addition, this relay can be separately and independently controlled by a switch that connects the terminal labeled Vac to ground. The switch must be rated for 200 mA or more. This makes it easy to do clean up with the same shop vac used for dust extraction.

## Loading grbl/HAL

A prebuilt binary is available on github at <https://github.com/phil-barrett/grbl-teensy-4>. One can also download the source code at <https://github.com/terjeio/grblHAL>, build and install it.

## Testing

Your grbl/HAL Teensy 4.0 based Motion Controller is ready to be tested. Attach it to a PC via a USB cable and run a compatible GRBL sender application. We recommend this one: <https://github.com/terjeio/Grbl-GCode-Sender> Check for the most recent release.

Note, if you don't attach any switches, the system will come up in the alarm state. This is normal. If you are not using the Safety Door Alarm, in the **Settings: Grbl** tab, **Invert control pins** section, check the **Safety Door** box. This makes the system see the (nonexistent) Safety Door as closed.

## 0-10V output setup

The 0-10V circuit works by using an opamp to filter a 3.3V PWM signal and amplify it to 10V. As such it needs 12V input which the user must provide. A second order filter with an aggressive low pass cut off frequency is used to provide a stable signal for the spindle controller.

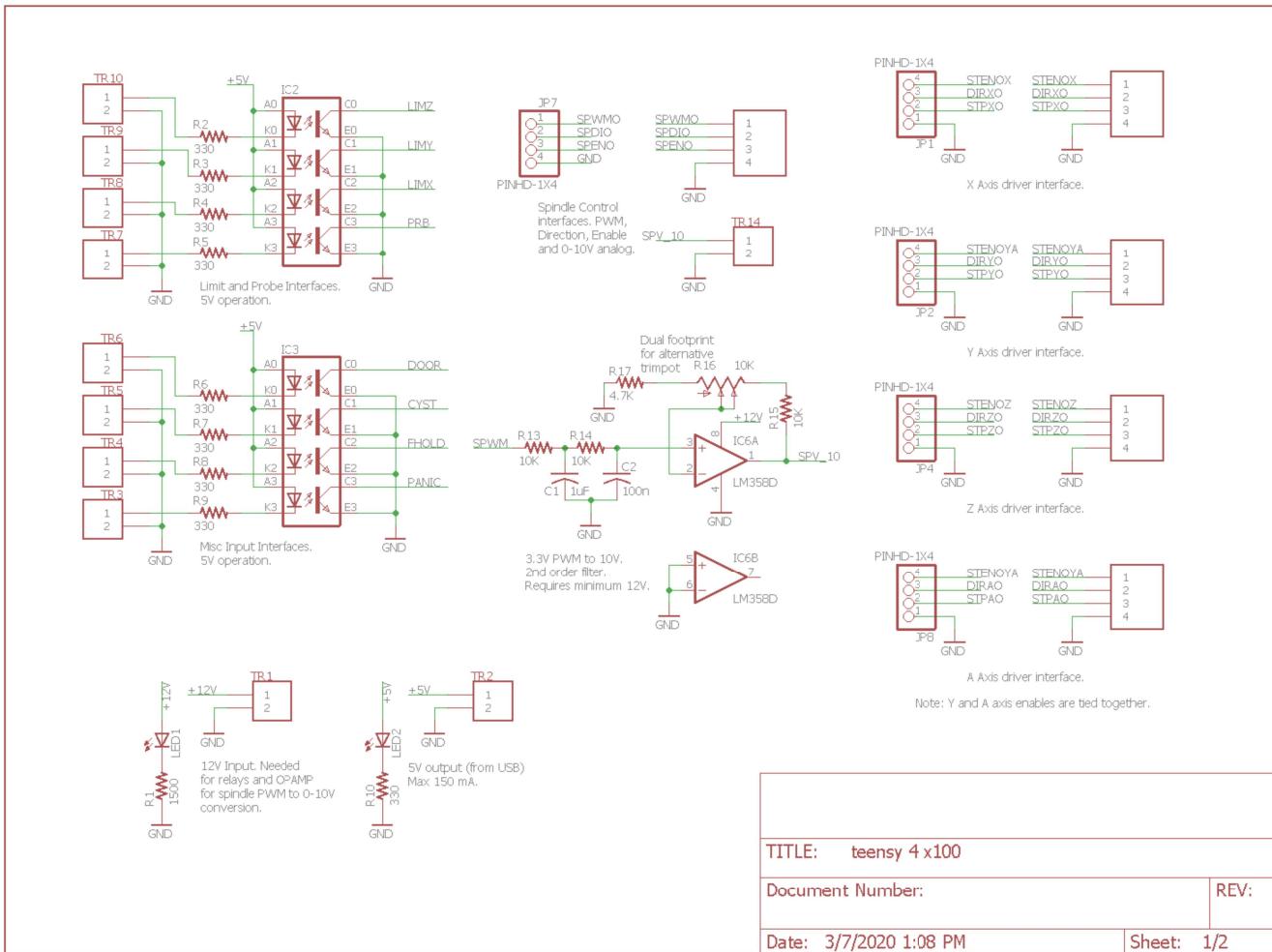
Because source voltage level can vary, the gain of the op amp must be adjusted. To adjust:

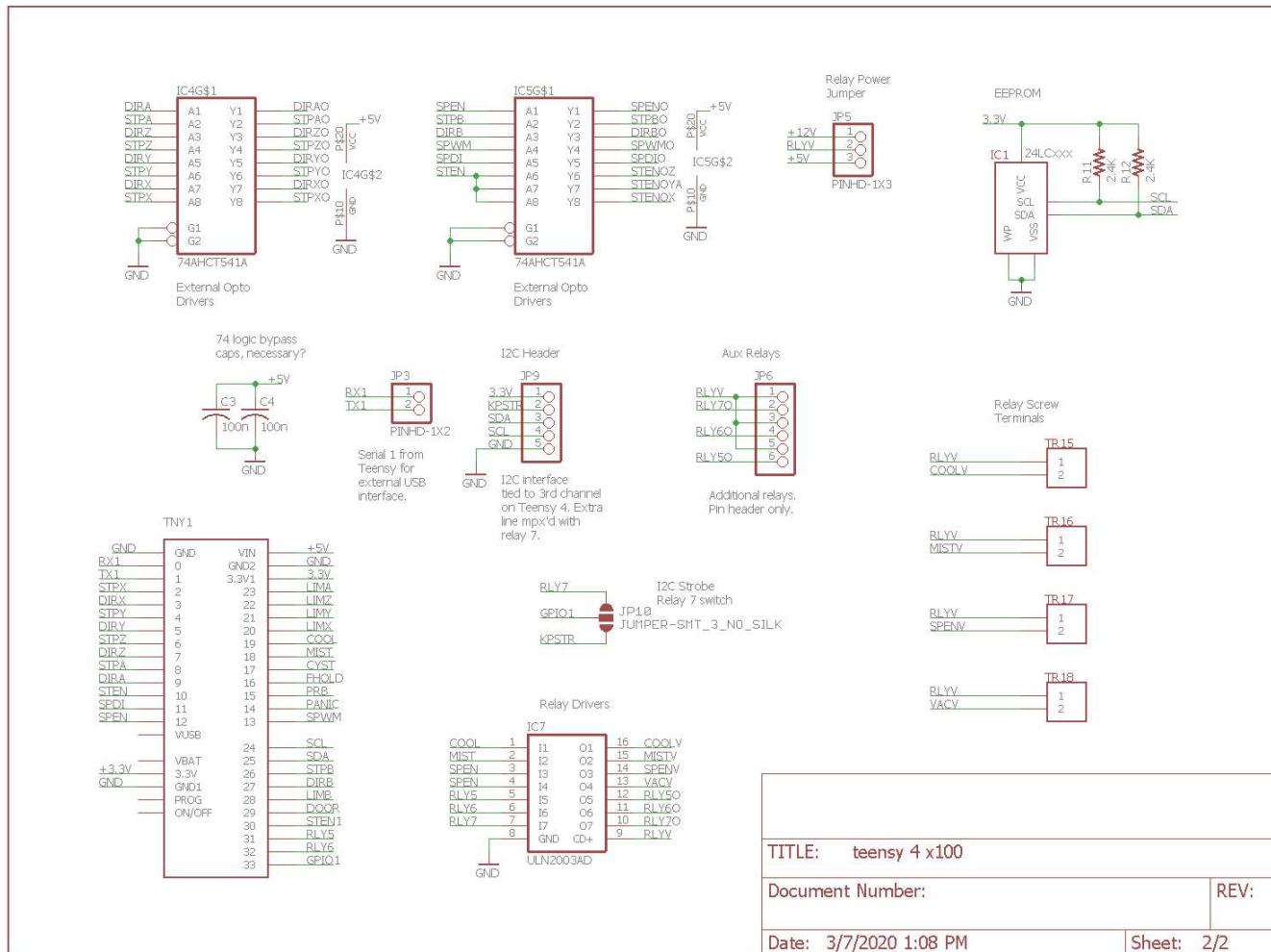
- In the **Settings: Grbl** tab, set \$30, **Maximum Spindle Speed**, to 1000.
- Send the following command to GRBL: **M3 S1000**. This turns on the spindle and causes the speed to be set to 100%. The LED on the Teensy 4 should light up.
- Connect a Volt Meter to the 0-10V output and G terminals.
- With a screwdriver, turn R16 until the voltage is as close to 10V as you can get. Anything in the range 9.990V to 10.010V is acceptable.

## Errata:

1. Silk screen legends for Relays 5 and 7 are reversed.
2. The TX, RX header is lacking a ground. Use one of the other terminals or pins marked Gnd or G if you wish to use serial I/O. Grbl/HAL doesn't use it though.
3. Silk screen marks for LED's Anode are missing.

## Schematics:





## Bill of Materials

Part	Value	Number	Package	Mouser Part Number	Cost	Unit total	notes
C1	1uF 25VDC	1	1206	791-1206F105Z250CT	\$0.10	\$0.10	
C2 – C4	100n 25VDC	3	1206	710-885012208058	\$0.11	\$0.33	
IC1	24LC16	1	SOIC-8	579-24LC16BT-E/SN	\$0.34	\$0.34	
IC2 – IC3	LTV846S	2	DIL16-SMD	859-LTV-846S	\$0.68	\$1.36	
IC4 – IC5	74AHCT541A	2	TSSOP20	771-74AHCT541PW-T	\$0.40	\$0.80	
IC6	LM358D	1	SOIC-8	595-LM358ADRG4	\$0.36	\$0.36	
IC7	ULN2003AD	1	SO16	621-UJLN2003AS16-13	\$0.48	\$0.48	
LED1, LED2	Green	2	LED, TH, T-1 (3 mm)	859-LTL-4232	\$0.12	\$0.24	
R1	1500	1	1206	660-RK73B2BTTD152J	\$0.10	\$0.10	
R2 – R10	330	9	1206	660-RK73B2BTTD331J	\$0.10	\$0.90	
R11 – R12	2.4K	2	1206	660-RK73H2BTTD2401	\$0.10	\$0.20	
R13 – R15	10K 1%	3	1206	660-RK73H2BTTD1002F	\$0.10	\$0.30	
R16	10K trimmer	1	multiple	3362P-1-103LF	\$1.02	\$1.02 cheaper available	
R17	4.7K 1%	1	1206	660-RK73H2BTTD4701F	\$0.10	\$0.10	
TNY1		1	TEENSY4.0		\$19.95	\$19.95	pjrc.com
Pinheaders		36	2.54mm/0.1" pitch	varies		0 multiple sources	
TR1 – TR20	screw terminal	25	3.5mm Pitch 2 pin	varies		0 multiple sources	
					Total	\$26.58	
Sockets for Teensy		2	14 pin 2.54mm pitch	437-8018701410001101	\$1.20	\$2.40	
Sockets for Teensy		3	5 pin 2.54mm pitch	437-8018700510001101	\$0.49	\$1.47	
Backside Pin Header		1	5x2 pin 2.54mm pitch	571-5-146131-4	\$1.28	\$1.28	

If not using backside pins, you only need 2 14 pin and one 5 pin sockets.

### Notes:

- The PCB has a dual footprint for the 10K trimmer potentiometer and will accept 2 different footprints: 3 pins in a row with 0.1"/2.54 mm pitch or a triangular layout with the middle pin offset by 2.54 mm. The first footprint is used by more expensive multturn trimmers and the second is very common and low cost. The BOM has the lower cost version. Also, you could use a 2K trimmer in place of the 10K.
- 3.5mm pitch screw terminals are fairly common and can be purchased from ebay/amazon/banggood/ali express.
- Pin headers are readily available from the same sources.
- Single row sockets are also readily available from the same sources though good quality ones are not that expensive. We recommend you use good quality sockets.