

# **TWISTER**

ASSEMBLY MANUAL v1.0

## ENGLISH

### IMPORTANT!

Follow these instructions at your own risk. Misuse of a soldering iron and other tools required for assembly can lead to injury. Seek assistance if you have no prior soldering experience. This document assumes basic knowledge of electronics; improper installation of key components can cause the unit to malfunction. Please follow all instructions exactly, unless you have a very good reason to do otherwise. Once the unit is assembled, there is no guarantee that it will work as intended, nor that its function will be suitable for your specific purpose. However, it works pretty great for the author, so there's a good chance it will do the same for you.

## DEUTSCH

### WICHTIG!

Befolgen Sie diese Anweisungen auf eigene Gefahr. Missbrauch von einem Lötkolben und andere Werkzeuge für die Montage erforderlich kann zu Verletzungen führen. Suchen Sie Unterstützung, wenn Sie keine vorherige Löten Erfahrung haben. Dieses Dokument setzt Grundkenntnisse in der Elektronik; unsachgemäße Installation der wichtigsten Komponenten können zu Fehlfunktionen des Geräts verursachen. Bitte befolgen Sie alle Anweisungen genau, wenn Sie einen sehr guten Grund, es anders zu machen. Sobald das Gerät montiert wird, gibt es keine Garantie, dass es wie vorgesehen funktioniert, noch, dass seine Funktion als geeignet für einen speziellen Zweck. Allerdings funktioniert es ziemlich ausgezeichnet für den Autor, so gibt es eine gute Chance, es wird das gleiche für Sie tun.

## FRANÇAIS

### ATTENTION!

Suivez ces instructions à vos propres risques. Une mauvaise utilisation d'un fer à souder et autres outils nécessaires à l'assemblage peut entraîner des blessures. Solliciter l'assistance si vous n'avez aucune expérience préalable de soudure. Ce document suppose une connaissance de base de l'électronique; une mauvaise installation des composants clés peuvent provoquer des dysfonctionnements. S'il vous plaît suivez les instructions à la lettre, sauf si vous avez une très bonne raison de faire autrement. Une fois l'appareil assemblé, il n'y a aucune garantie que cela fonctionnera comme prévu, ni que sa fonction sera adaptée à votre objectif spécifique. Toutefois, cela fonctionne plutôt bien pour l'auteur, il ya donc de bonnes chances qu'il en sera de même pour vous.

## NEDERLANDS

### BELANGRIJK!

Volg deze instructies op eigen risico. Misbruik van een soldeerbout en andere gereedschappen die nodig zijn voor de montage kan leiden tot letsel. Zoek hulp als je nog geen soldeer ervaring. Dit document gaat basiskennis van de elektronica, onjuiste installatie van de belangrijkste componenten kan het toestel leiden tot storingen. Gelieve precies alle aanwijzingen te volgen, tenzij je een zeer goede reden om anders te handelen. Als het apparaat eenmaal is gemonteerd, is er geen garantie dat het zal werken zoals bedoeld, of dat zijn functie zal geschikt zijn voor uw specifieke doel. Echter, het werkt vrij goed voor de auteur, dus er is een goede kans dat het hetzelfde zal doen voor je.

## ITALIANO

### IMPORTANTE!

Segui le istruzioni a vostro rischio e pericolo. L'uso improprio di un saldatore e altri strumenti necessari per il montaggio possono causare lesioni. Chiedere l'aiuto se non si hanno precedenti esperienze di saldatura. Questo documento presuppone la conoscenza di base di elettronica; errata installazione di componenti chiave possono causare un malfunzionamento. Si prega di seguire tutte le istruzioni esattamente, se non avete una buona ragione per fare altrimenti. Una volta che l'apparecchio è montato, non vi è alcuna garanzia che funzionerà come previsto, né che la sua funzione sarà adatto per il vostro scopo specifico. Tuttavia, funziona abbastanza grande per l'autore, quindi c'è una buona probabilità che farà lo stesso per voi.

## ESPAÑOL

### ¡IMPORTANTE!

Siga estas instrucciones a su propio riesgo. El mal uso de un soldador y otras herramientas necesarias para el montaje se puede llevar a una lesión. Buscar ayuda si usted no tiene experiencia en soldadura antes. Este documento supone un conocimiento básico de la electrónica, la instalación incorrecta de los componentes clave puede causar malfuncionamiento de la unidad. Por favor, siga todas las instrucciones exactamente, a menos que tenga una muy buena razón para no hacerlo. Una vez que la unidad está montada, no hay garantía de que funcionará como está previsto, ni que su funcionamiento sea adecuado para su propósito específico. Sin embargo, funciona bastante grande para el autor, así que hay una buena probabilidad de que hará lo mismo para usted.

## PORTEGUEΣ

### IMPORTANTE!

Siga estas instruções a seu próprio risco. Uso indevido de um ferro de solda e outras ferramentas necessárias para a montagem pode levar a lesões. Procurar ajuda se você não tem experiência anterior de solda. Este documento pressupõe conhecimentos básicos de eletrônica, instalação indevida de componentes-chave podem causar o mau funcionamento do aparelho. Por favor, siga todas as instruções à risca, a menos que você tenha uma razão muito boa para fazer o contrário. Uma vez que a unidade é montada, não há garantia de que vai funcionar como pretendido, nem que sua função será adequado para o seu propósito específico. No entanto, ele funciona muito grande para o autor, então há uma boa chance de ele fará o mesmo por você.

## SVENSKA

### OBS!

Följ dessa instruktioner på egen risk. Missbruk av en lödkolv och andra verktyg behövs för montering kan leda till skador. Sök hjälp om du har någon tidigare lödning erfarenhet. Detta dokument förutsätter grundläggande kunskaper i elektronik, felaktig installation av nyckelkomponenter kan orsaka fel i enheten. Följ alla instruktioner exakt, om du inte har en mycket bra anledning att göra annorlunda. När enheten är monterad, det finns ingen garanti att det kommer att fungera som avsett eller att dess funktion kommer att vara lämpliga för din specifika ändamål. Dock fungerar det ganska bra för författare, så det finns en god chans att det kommer att göra detsamma för dig.

## SUOMI

### HUOM.!.

Seuraa näitä ohjeita omalla vastuullasi. Väärinkäytö juotin ja muut tarvittavat välineet kokoonpano voi aiheuttaa vammoja. Hakea apua, jos sinulla ei ole aiempaa juottamalla kokemusta. Tässä ohjeessa oletetaan perustiedot elektronikan, väärä asennus avainkomponentit voi aiheuttaa toimintahäiriötä. Noudata kaikkia ohjeita tarkasti, ellei sinulla ole erittäin hyvä syytä tehdä toisin. Kun laite on koottu, ei ole takeita, että se toimi tarkoitettulla tavalla tai että sen toiminta on sopivia tiettyyn tarkoitukseen. Kuitenkin se toimii ihan hyvin tekijälle, joten siellä on hyvä mahdollisuus se tehdä saman sinulle.

## ROMÂN

### IMPORTANT!

Urmati aceste instructiuni pe propriul risc. Abuzul de un fier de lipit si alte instrumente necesare pentru asamblare poate duce la un prejudiciu. Solicita asistenta în cazul în care nu aveti experienta anterioara de lipit. Acest document presupune cunoștințe de baza de electronica, instalarea incorreata a componentelor cheie poate provoca functionarea defectuoasa a unitatii. Va rugam sa urmati toate instructiunile exact, daca nu aveti un motiv foarte bun pentru a face altfel. Odata ce unitatea este asamblat, nu exista nici o garantie ca ea va lucra ca fiind destinate, si nici faptul ca functia sa va fi potrivita pentru scopul dvs. specific. Cu toate acestea, functioneaza destul de mare pentru autor, astfel incat exista o sansa buna va face acelasi lucru pentru tine.

## 中國

### 重要！

按照這些指示在自己的風險。誤用烙鐵等工具所需的程序集可以導致受傷。尋求幫助，如果你沒有事先接觸經驗。本文假定基本知識電子，關鍵零部件安裝不當會導致本機故障。請遵守所有的指示準確，除非你有一個很好的理由不這樣做。一旦單元組裝，也不能保證它會按照預期的工作，也不意味著它的功能將適合的特定目的。然而，它的工作原理非常偉大的作者，所以這是一個很好的機會，它將為你做同樣的。

## 日本

### 重要！

各自の責任で、次の手順に従ってください。はんだごてや組み立てに必要な他のツールは使い方を誤ると、けがにつながることができます。あなたが事前半田付け経験がない場合の支援を求める。この文書は、電子機器の基本的な知識を前提とし、キーボードコンポーネントの不適切なインストールが誤作動を引き起こす可能性があります。もしそうでなければ行うには非常に良い理由がない限り、正確にすべての指示に従ってください。ユニットが組み立てられる、そこにそれが意図したとおりに動作を保障するものではありません、またその機能は、特定の目的に適したものとなること。しかし、それは、著者にとってかなり素晴らしい作品は、まずまずの確率であなたのための同じをすることがあります。

# TWISTER

## ASSEMBLY MANUAL v1.0

Copyright © 2011 Josh Siegle

### General Instructions

Congratulations on choosing to build your own Tetrode Twister for Arduino!

Building one or more Twisters is a great way to expand your lab's tetrode-making capabilities without breaking the bank. The Twister was designed to equal or surpass all commercially available products in terms of quality, while being an order of magnitude less expensive. Furthermore, all of the source files are freely available, allowing you to modify the design as you see fit.

Assembling your own Twister is also a great way to learn the basics of electronics. The Twister contains a microcontroller, an LCD display, a servo motor, a voltage regulator, photocells, potentiometers, buttons, and more. If you know how all of the pieces work together, you'll have a solid foundation in electronic circuits, which you can use to start building your own devices. Knowing your way around a circuit board is incredibly empowering, especially for those of us working in electrophysiology.

This document contains a complete parts list, assembly instructions, and troubleshooting hints for constructing your own Twister. Once you've collected all the supplies, it should take about 2 hours to put together. After that, you'll be able to twist tetrodes to your heart's content.

Although the following pages list all of the information and tools necessary for building the Twister itself, you'll need some more supplies to actually start twisting tetrodes. These include a pair of sharp scissors (BRI model 25-1000 are expensive, but work amazingly well), forceps for handling tetrodes (Fine Science Tools's ceramic-tip model is extremely reliable), and a tetrode stand (McMaster-Carr item #1958A31 is recommended). You may want to tape a small metal cannula to the stand (17 gauge is about right) to support the tetrode itself. And, of course, you'll also need tetrode wire, which can be purchased on Amazon (Sandvik Kanthal HP Reid Precision Fine Tetrode Wire, Nickel-Chrome 0.012 mm diameter, various lengths). If you need more background information on the tetrode-making process, check out the following article in the Journal of Visualized Experiments: [www.jove.com/details.php?id=1098](http://www.jove.com/details.php?id=1098)

If you've never done any soldering before, and don't have anyone who can teach you the basics, check out the online tutorial at SparkFun ([www.sparkfun.com/tutorials/106](http://www.sparkfun.com/tutorials/106)). It's really easy once you get the hang of it. This site has a lot of other useful electronics tutorials that offer a great starting point for someone new to electronics.

### Using the Twister

The Twister was designed to be as intuitive as possible, but here are the basics of operation:

1. There is no ON/OFF switch. Plug it in to turn it on, unplug it to turn it off. The design is much simpler this way.
2. If you can't see anything on the display, try adjusting the Contrast knob. If that doesn't help, check out the Troubleshooting section of this manual for more tips.

3. Use the large black knobs to adjust the number of forward and reverse turns. It's fine to have more reverse than forward turns or zero of either turn direction. If you're not sure what parameters to use, 80 forward turns / 40 reverse turns is a good place to start. If you move the knobs while the motor is running, the total number of turns will not be updated until the twister has stopped.

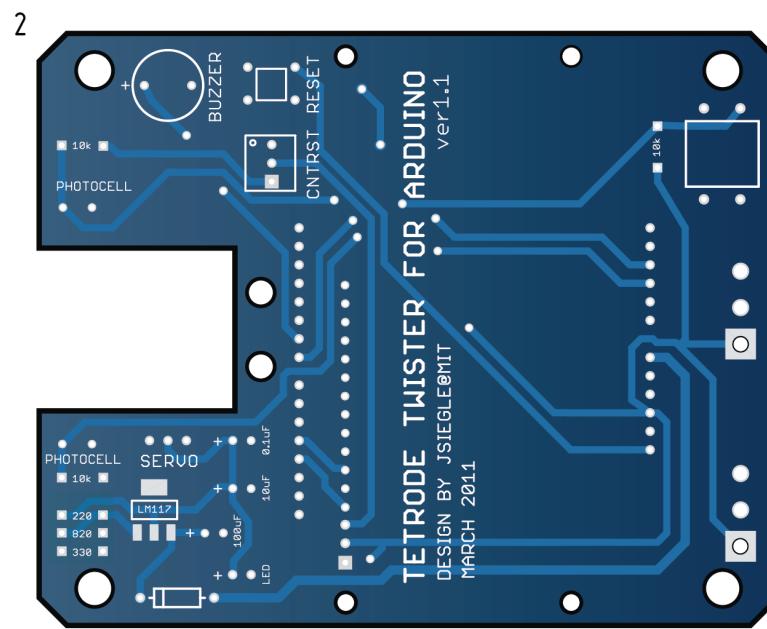
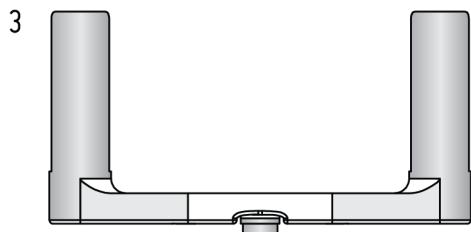
4. Use the Play/Pause button to start and stop the twister. Once you start the Twister, it will run by itself until it has completed the specified turn sequence.

5. Make sure the photocells are not blocked while the Twister is operating, otherwise it won't be able to track its turns. If there is a dramatic change in light levels while the Twister is running, it will automatically re-calibrate its photocells. However, the Twister will not operate in complete darkness (and neither will you).

6. If the Twister loses power or is reset during operation, it will reset its turn count to zero. If you want the Twister to save its state, you'll have to modify the source code that's uploaded to the Arduino.

### License Information

This document and the custom hardware used in the Twister are protected by the TAPR Open Hardware License. The software written for the Arduino is covered by the GNU General Public License. This means you are free to use the hardware and software in any way you see fit and are free to distribute it to anyone you want. However, if you build upon this work to create your own product, that product must be covered by the same licenses. This is done to ensure that the design of the Twister remains open. So, feel free to hack away at the hardware and software, and even release your own products based on the Twister. Just keep it open.

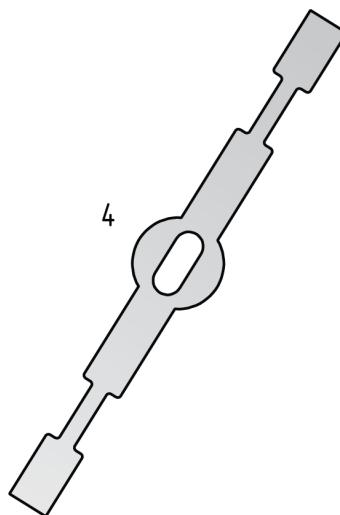


#### CUSTOM PARTS (source files)

##### Ponoko

<http://www.ponoko.com/>

- 1 Twister Cover- 3 mm yellow acrylic, \$5.83 ea.  
[Case/twister\\_cover.eps](#)  
Twister Base- 3 mm black acrylic, \$7.93 ea.  
[Case/twister\\_base.eps](#)



##### Silver Circuits

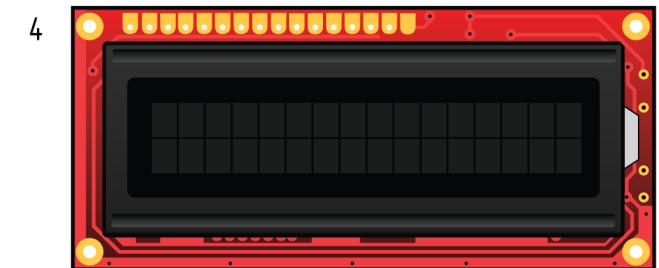
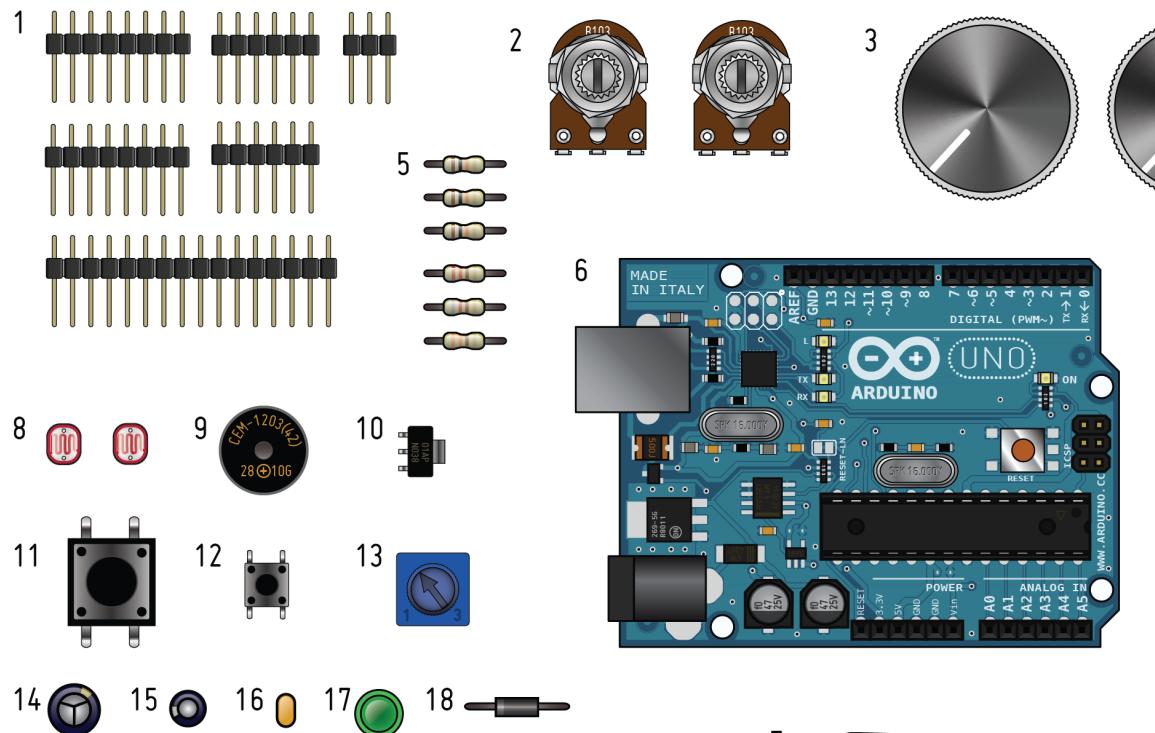
<http://www.custompcb.com/>

- 2 Printed Circuit Board, 0.062" FR4, 1oz HASL Blue Solder Mask, White Silkscreen, \$214.80 / 30 boards  
[Circuit Board/twister\\_board.zip](#)

##### American Precision Prototyping

<http://www.approto.com/>

- 3 Guide Posts – SLA Accura 55 Plastic, \$101.80 / 10 units  
[Stereolithography/guide\\_posts.stl](#)
- 4 Tetrode Clip Holder – SLA Accura 55 Plastic, \$77.00 / 10 units  
[Stereolithography/clip\\_holder.stl](#)



## STANDARD PARTS

### SparkFun Electronics

<http://www.sparkfun.com/>

- 1 47x Break Away Headers - Straight, \$2.50 / pack of 40 [PRT-00116]
- 2 2x Rotary Potentiometer - 10k Ohm, Linear, \$0.95 ea. [COM-09939]
- 3 2x Black Metal Knob - 14x24mm, \$1.50 ea. [COM-10002]
- 4 1x Basic 16x2 Character LCD - White on Black 5V, \$15.95 ea. [LCD-00709]
- 5 Assorted resistors (220, 330, 820, 10K), \$10.95 / kit [COM-09258]
- 6 1x Arduino Uno, \$29.95 ea. [DEV-09950]
- 7 1x Wall Adapter Power Supply - 9VDC 650mA, \$5.95 ea. [TOL-00298]
- 8 2x Mini Photocell, \$1.50 ea. [SEN-09088]
- 9 1x Buzzer - PC Mount, \$1.95 ea. [COM-07950]
- 10 1x Voltage Regulator - Adjustable LM1117 SMD, \$1.50 ea. [COM-00595]
- 11 1x Momentary Push Button Switch - 12 mm Square, \$0.50 ea. [COM-09190]
- 12 1x Mini Push Button Switch - Tall, \$0.50 ea. [COM-08605]
- 13 1x Trimpot 10K with Knob, \$0.95 ea. [COM-09806]
- 14 1x Electrolytic Decoupling Capacitor - 100 µF/25V, \$0.35 ea. [COM-00096]
- 15 1x Electrolytic Decoupling Capacitor - 10 µF/25V, \$0.45 ea. [COM-00523]
- 16 1x Ceramic Capacitor 0.1 µF, \$0.25 ea. [COM-08375]
- 17 1x Basic LED - 5mm Green, \$0.35 ea. [COM-09592]
- 18 1x Diode Rectifier - 1A 50 V, \$0.15 ea. [COM-08589]
- 19 1x Servo - Large Full Rotation, \$13.95 ea. [ROB-09347]

### McMaster-Carr

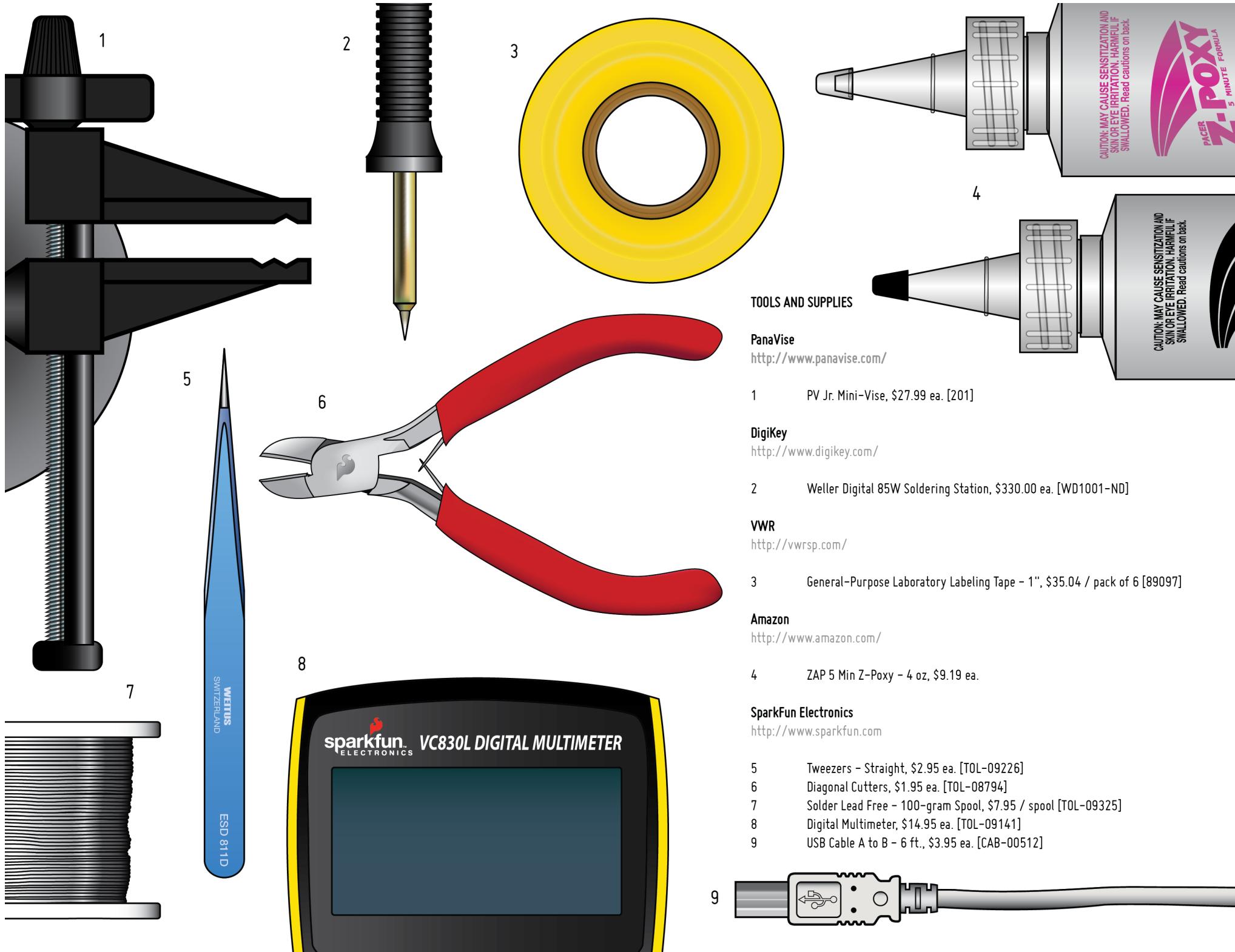
<http://www.mcmaster.com/>

- 20 4x M5 Stainless Steel Screw - 35 mm, \$6.27 / pack of 25 [91292A193]
- 21 4x M5 Stainless Steel Hex Nut, \$3.94 / pack of 50 [94150A340]
- 22 4x M3 Stainless Steel Screw - 16 mm, \$3.24 / pack of 100 [91292A115]
- 23 4x M3 Stainless Steel Hex Nut, \$4.90 / pack of 100 [91828A211]
- 24 4x M5 Aluminum Unthreaded Spacer - 20 mm, \$1.48 ea. [92871A063]

### Fine Science Tools

<http://www.finescience.com/>

- 25 1x Bulldog Serrefine Straight - 50 mm, \$44.00 ea. [18050-50]



#### TOOLS AND SUPPLIES

PanaVise

<http://www.panavise.com/>

1 PV Jr. Mini-Vise, \$27.99 ea. [201]

DigiKey

<http://www.digikey.com/>

2 Weller Digital 85W Soldering Station, \$330.00 ea. [WD1001-ND]

VWR

<http://vwrsp.com/>

3 General-Purpose Laboratory Labeling Tape - 1", \$35.04 / pack of 6 [89097]

Amazon

<http://www.amazon.com/>

4 ZAP 5 Min Z-Poxy - 4 oz, \$9.19 ea.

SparkFun Electronics

<http://www.sparkfun.com>

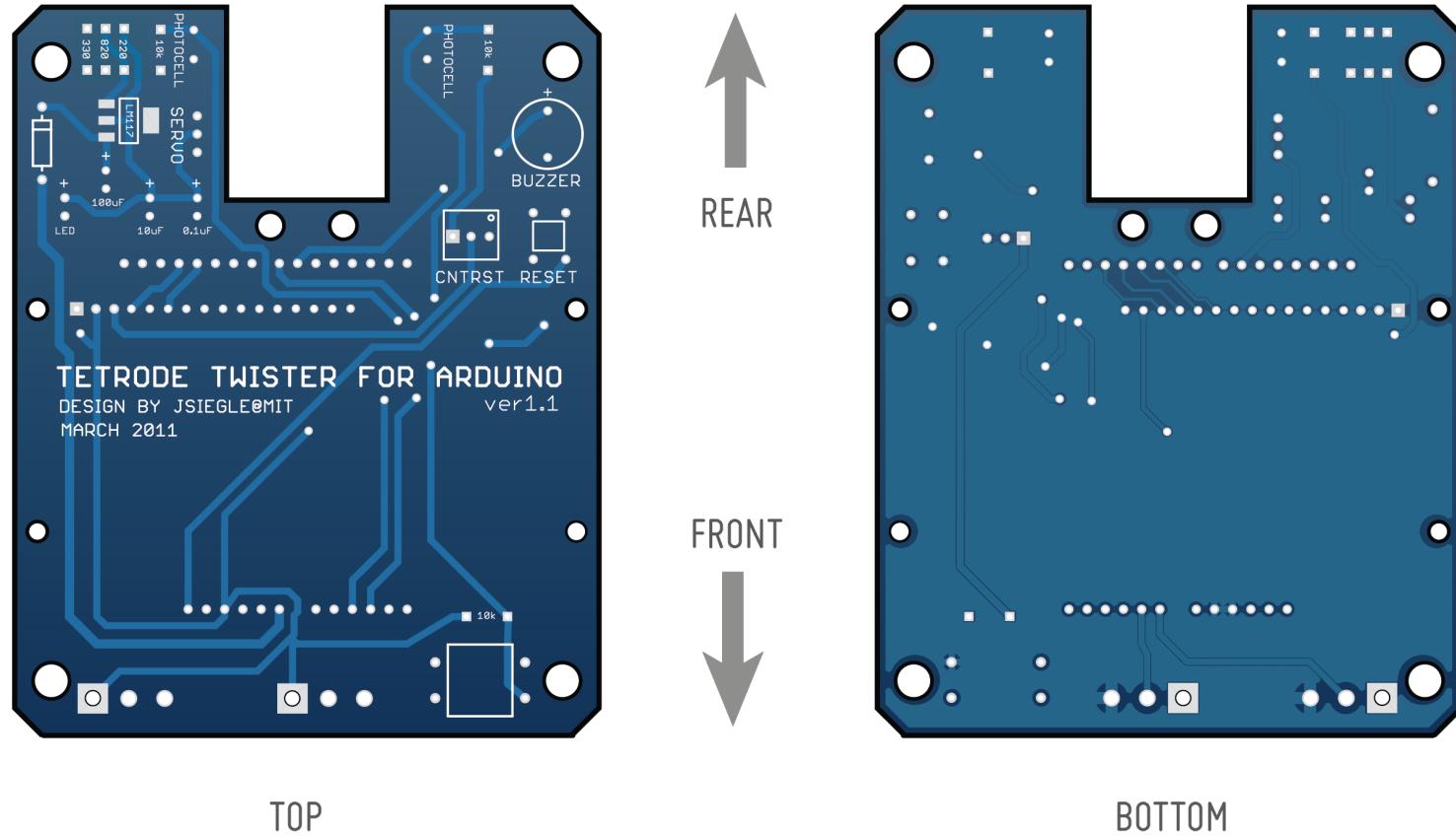
5 Tweezers - Straight, \$2.95 ea. [TOL-09226]

6 Diagonal Cutters, \$1.95 ea. [TOL-08794]

7 Solder Lead Free - 100-gram Spool, \$7.95 / spool [TOL-09325]

8 Digital Multimeter, \$14.95 ea. [TOL-09141]

9 USB Cable A to B - 6 ft., \$3.95 ea. [CAB-00512]



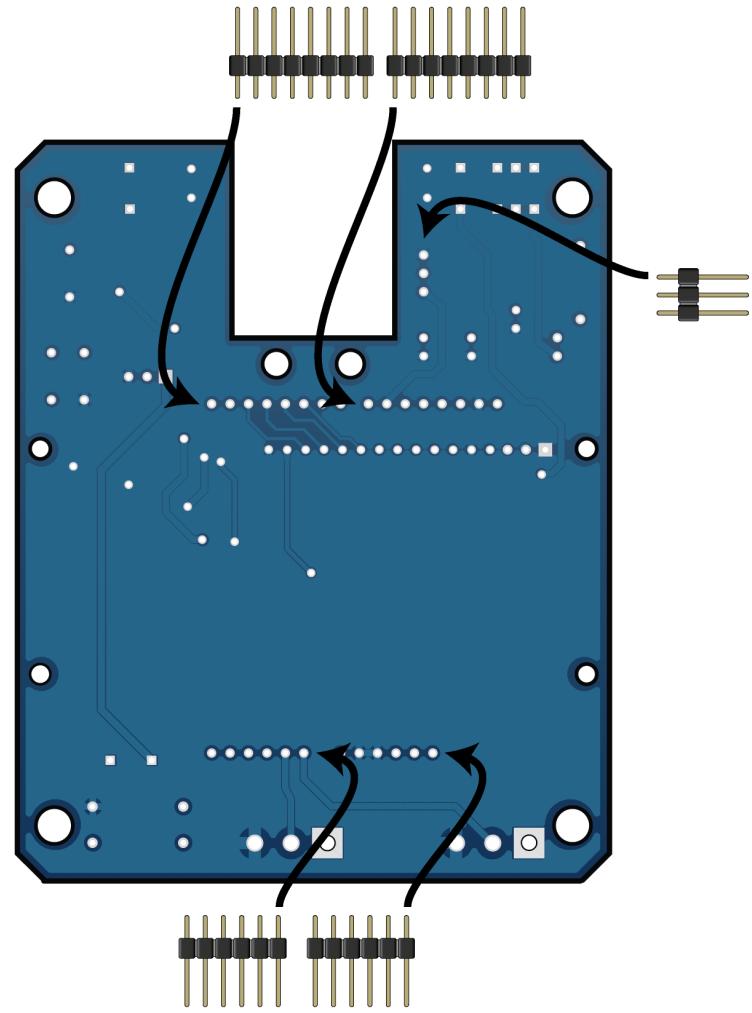
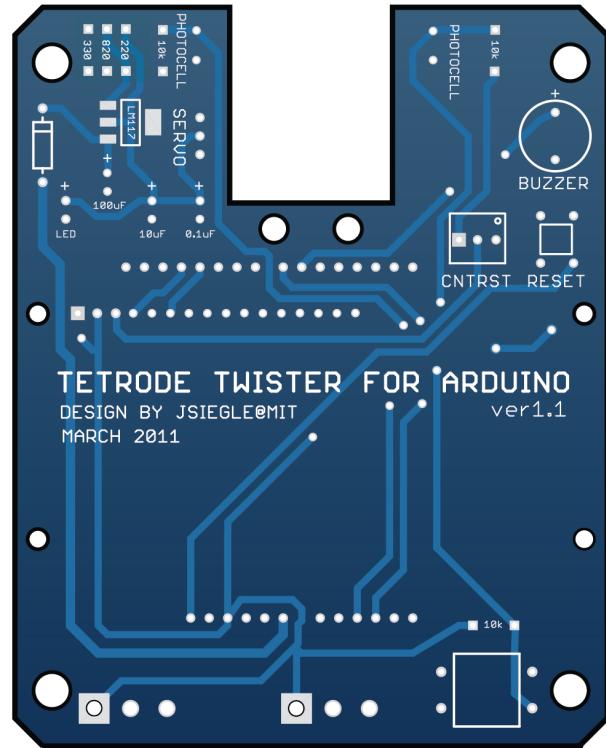
---

#### Step 1    **Prepare circuit board**

Secure the circuit board in a vise. The side without lettering (bottom) should be facing up.

TWISTER ASSEMBLY MANUAL

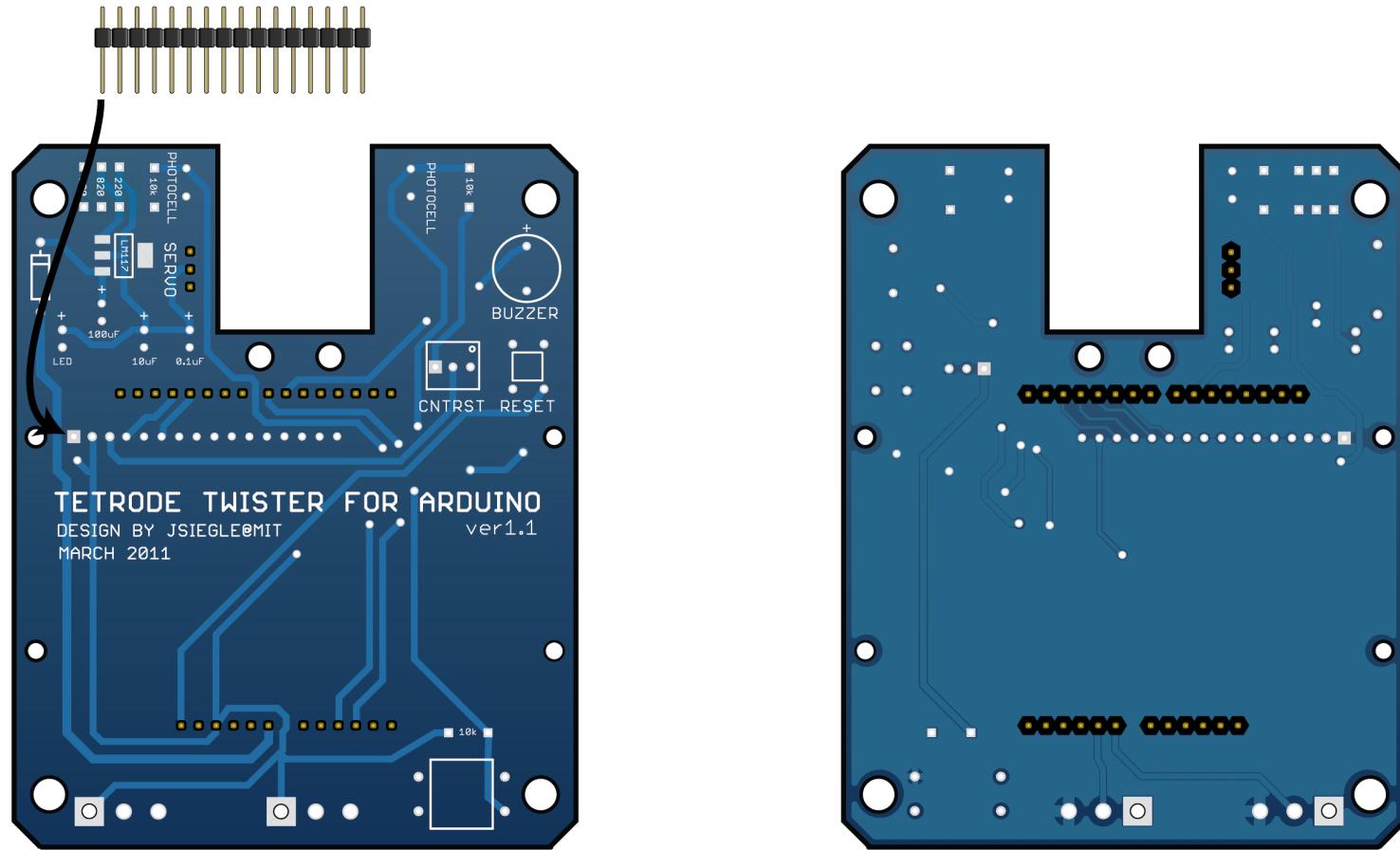
page 007 of 027



---

#### Step 2    Add bottom headers

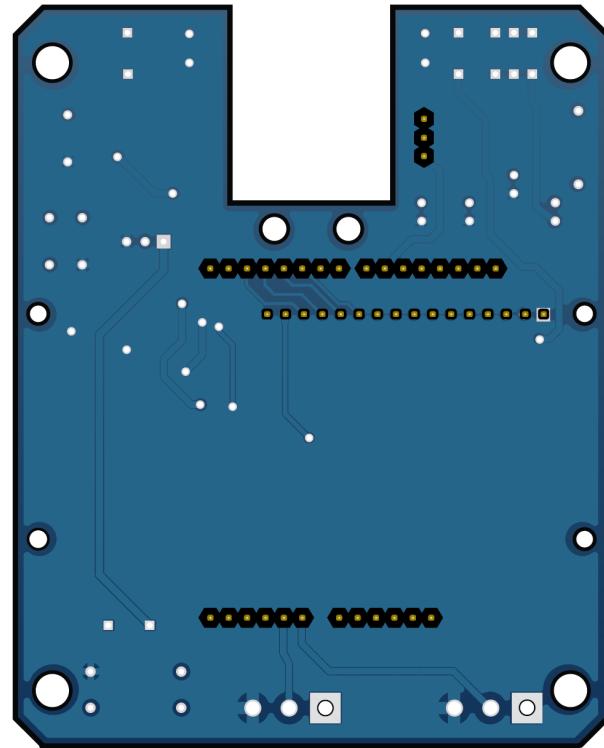
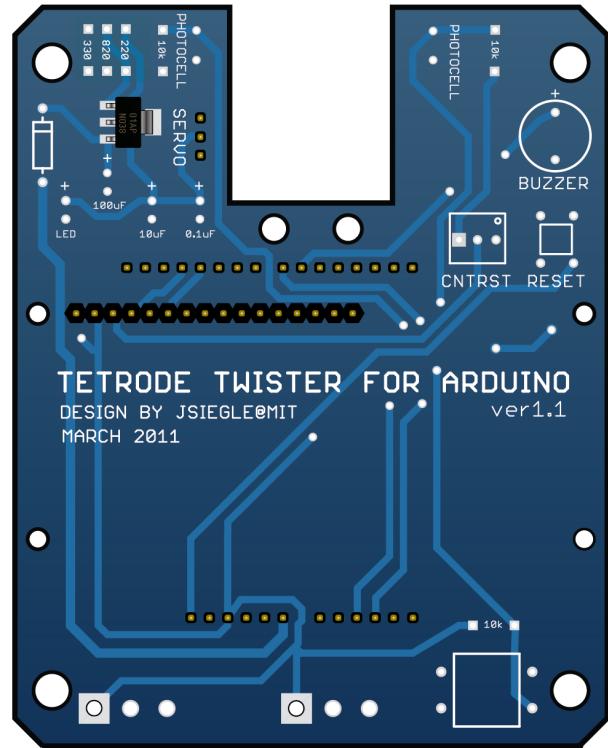
Place the **short** ends of the 3, 6, and 8-segment headers through the bottom of the board. Use a piece of tape to secure the headers. Flip the board over and solder the headers in place.



---

### Step 3    Add top-side headers

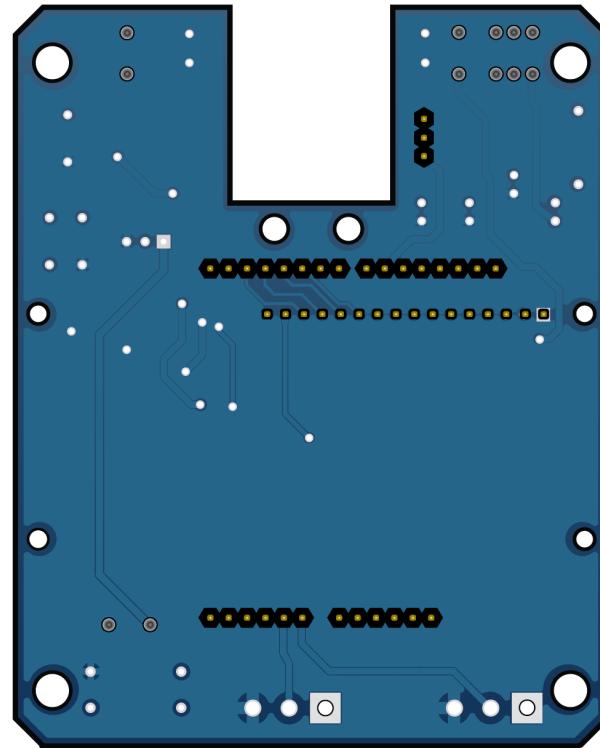
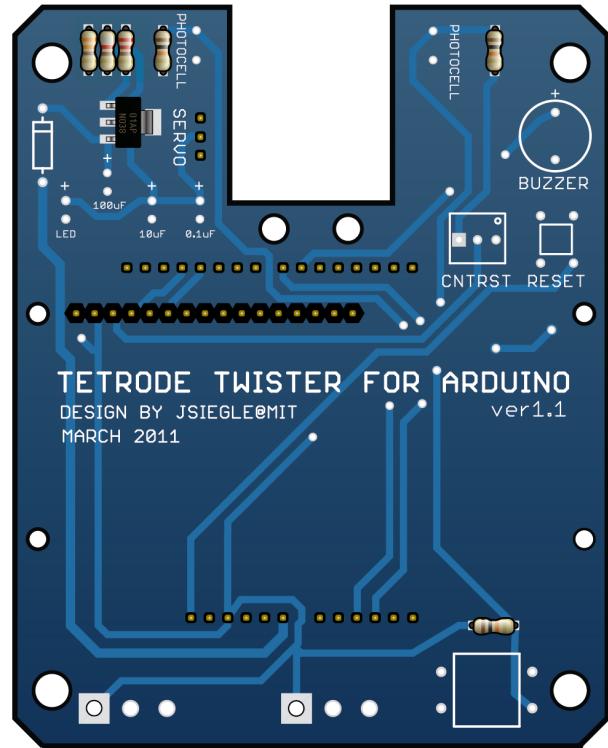
With top side still facing up, place the **long** ends of the 16-segment header through the top of the board and secure with a piece of tape.  
Flip the board over and solder these headers from the bottom.



---

#### Step 4    Add LM1117

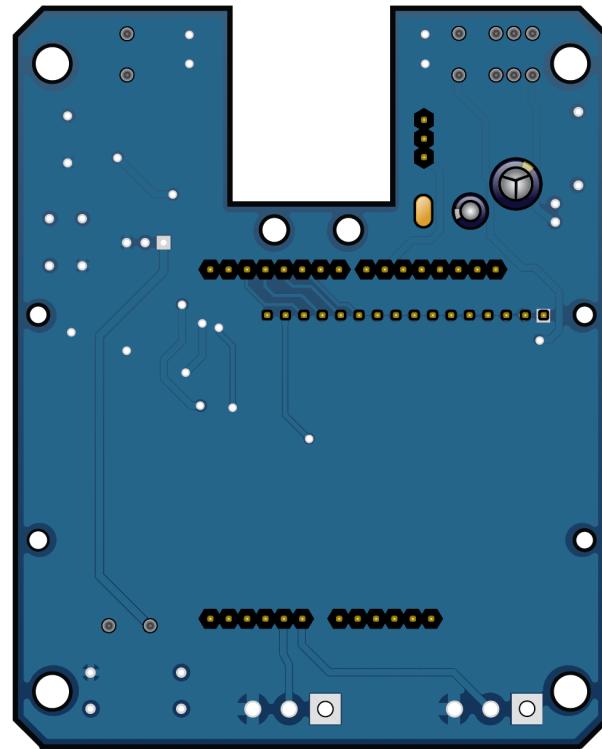
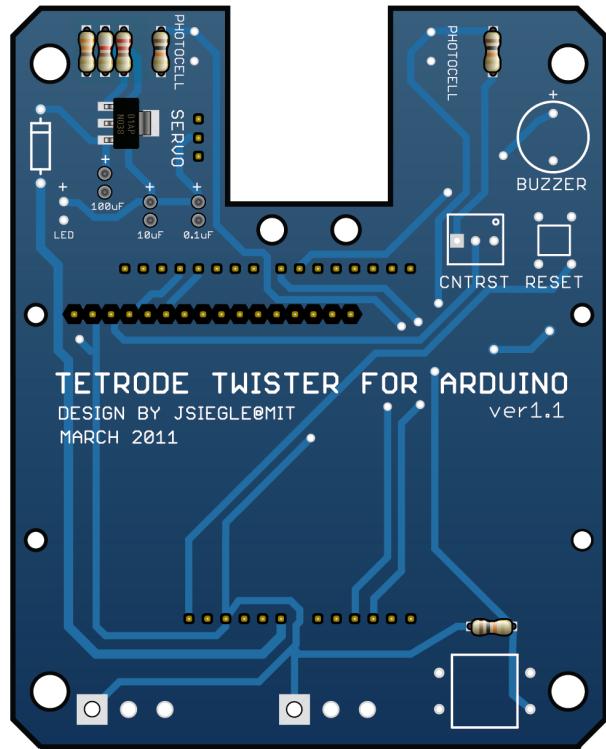
Place the LM1117 voltage regulator on the circuit board and solder it into place. Make sure there is solder connecting all four leads to all four pads.



---

#### Step 5    Add resistors

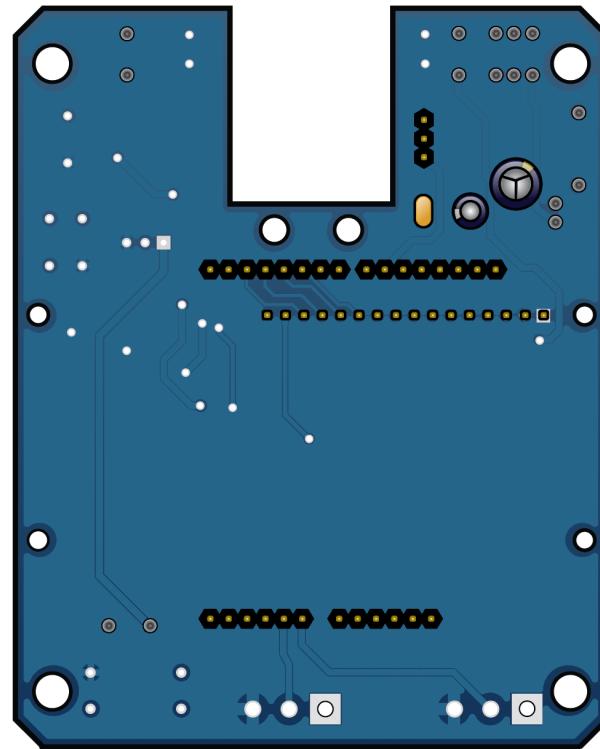
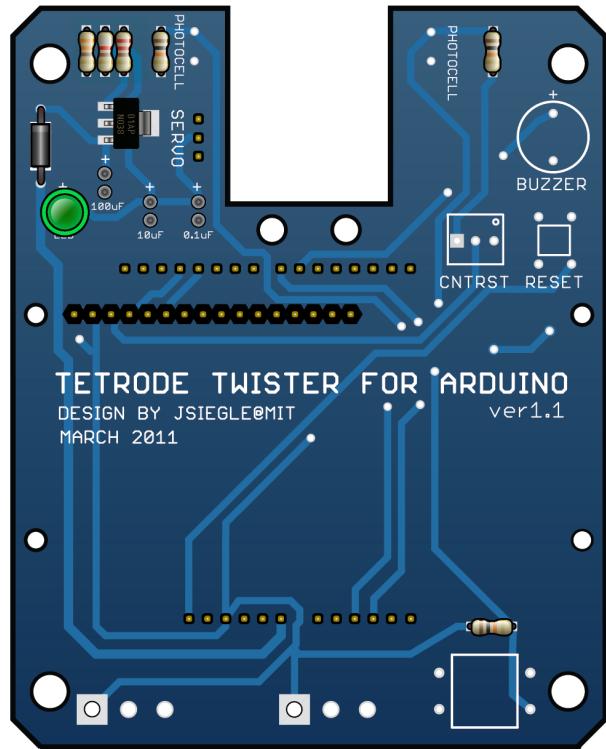
Place the resistors on the top of the board and solder from the bottom. Suggested resistor values are approximate, they can be changed if necessary. If using different values for the resistors labeled "220" and "820," use an LM317 Calculator (<http://www.electronics-lab.com/articles/LM317>) to find a pair of resistors that will output ~6V.



---

#### Step 6    Add capacitors

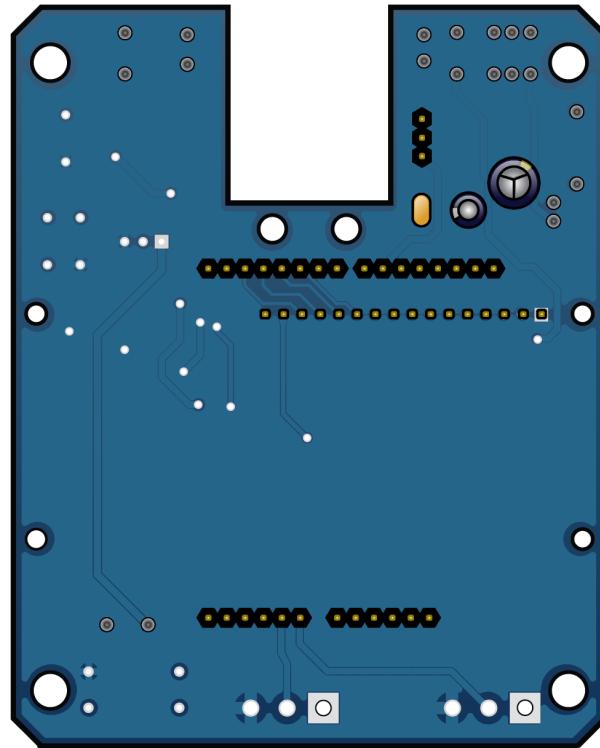
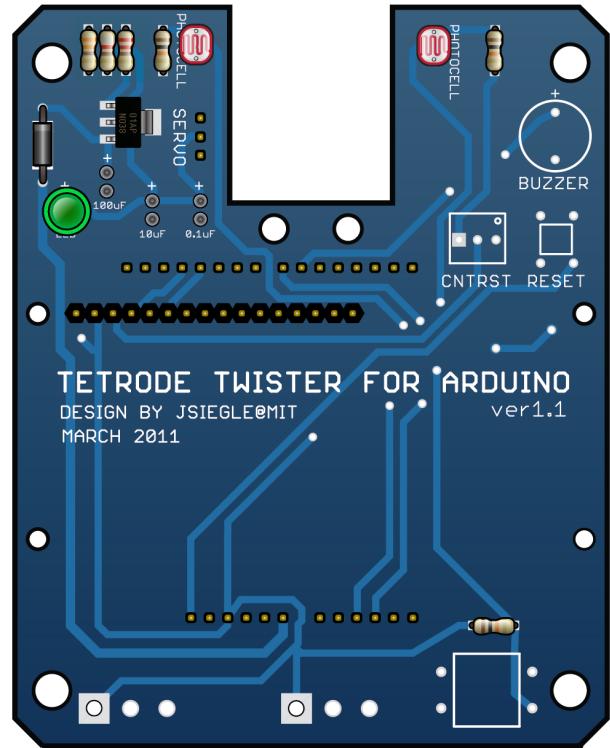
Place the capacitors in the bottom of the board and solder from the top. If the capacitors are not placed on the bottom of the board, they will interfere with the case. Make sure the 10 µF and 100 µF caps have the longer lead in the "plus" hole. The 0.1 µF capacitor can be oriented in either direction.



---

#### Step 7    Add diodes

Place the diode rectifier and green LED on the top of the board and solder from the bottom. The longer lead of the LED goes into the "plus" hole. The stripe on the diode should be oriented as indicated on the circuit board.

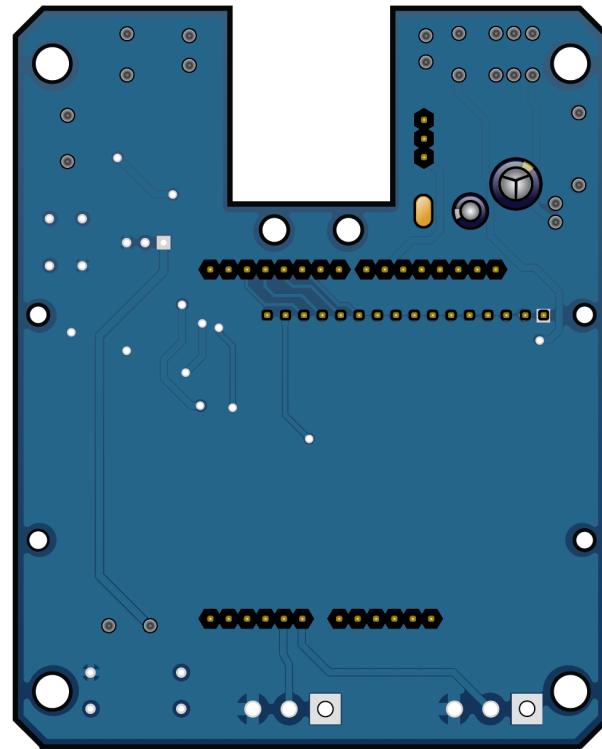
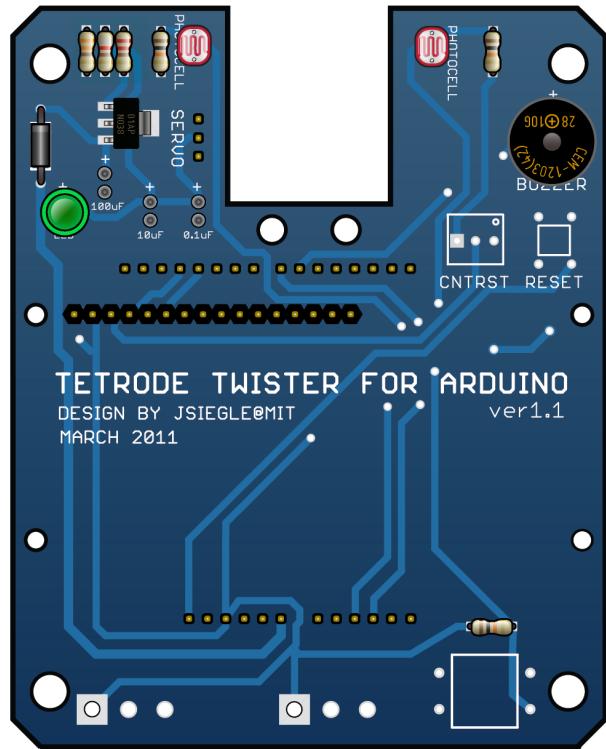


## Step 8 Add photocells

Place the photocells in the top of the board and solder from the bottom. The directions of the leads does not matter.

TWISTER ASSEMBLY MANUAL

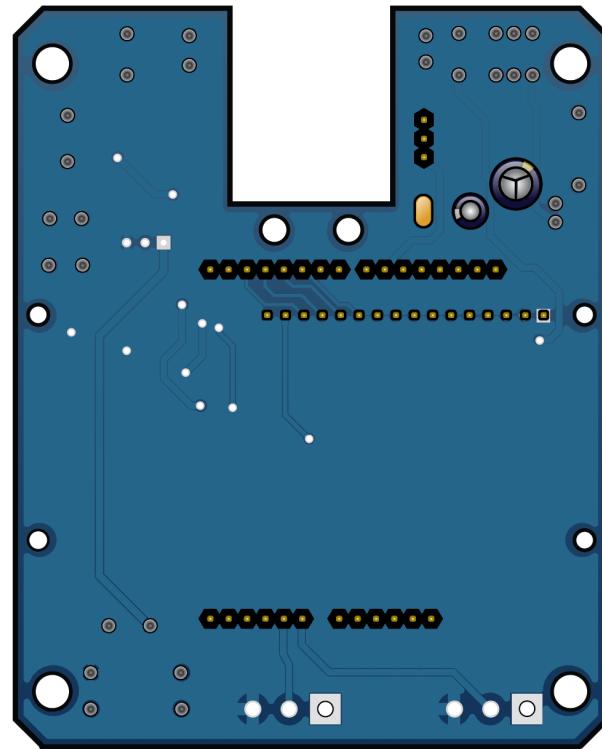
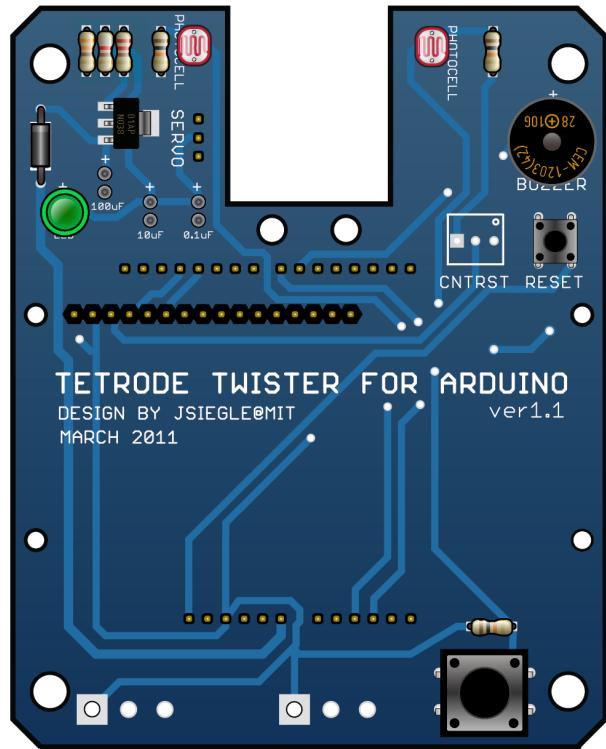
page 014 of 027



---

#### Step 9    Add buzzer

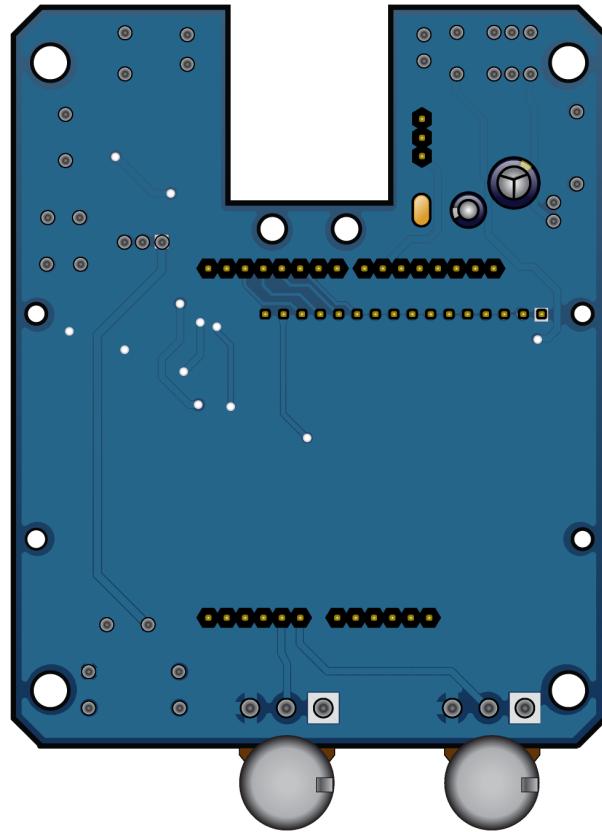
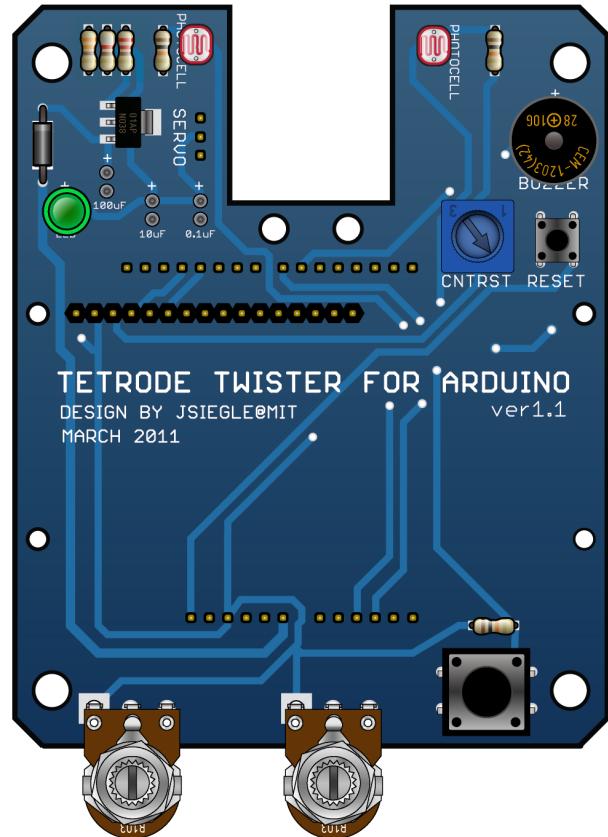
Place the buzzer in the top of the board and solder from the bottom. Make sure the plus signs on the board and buzzer are aligned.



---

#### Step 10    Add buttons

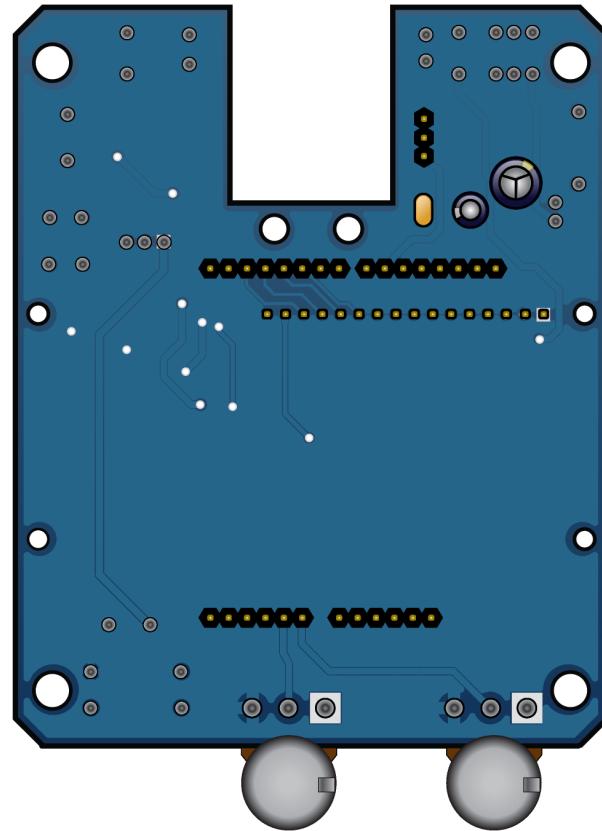
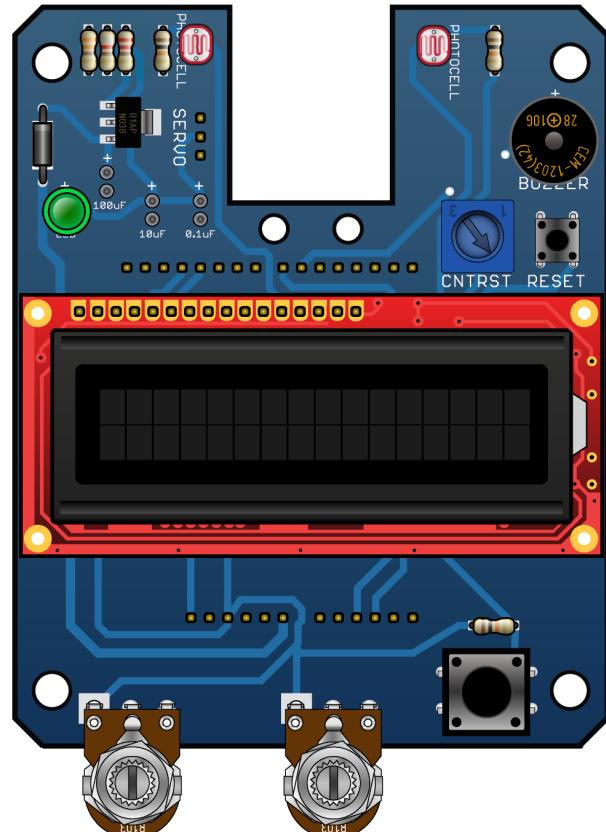
Place the large and small buttons in the top of the board and solder from the bottom.



---

### Step 11 Add potentiometers

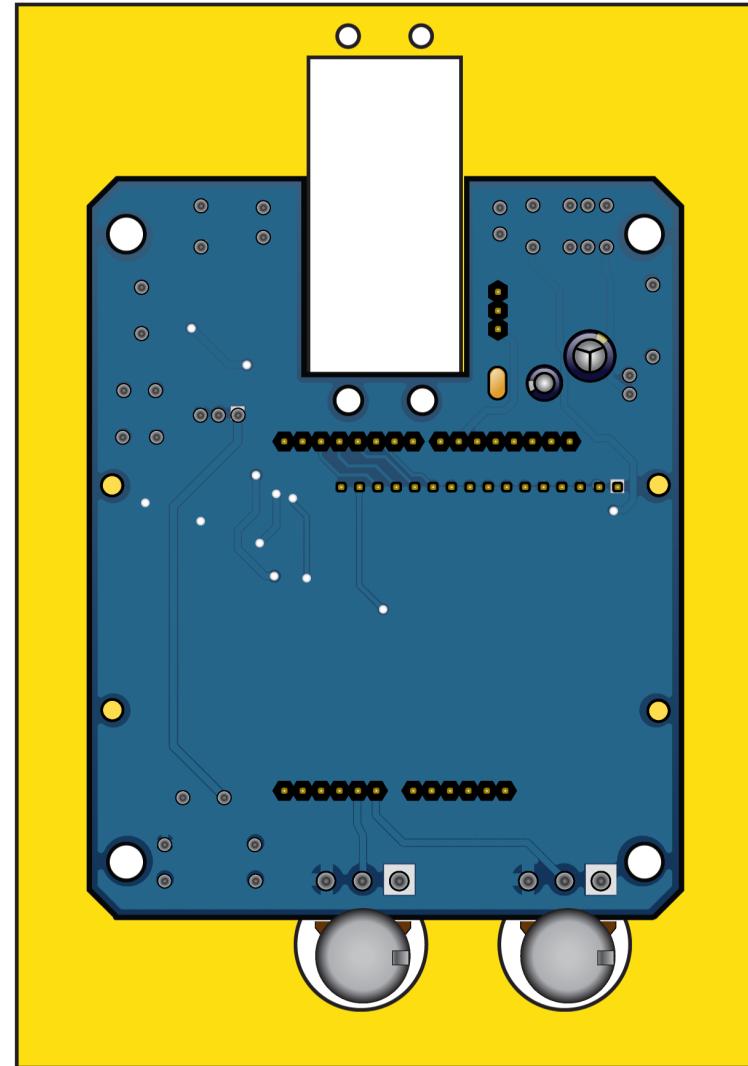
Place one small potentiometer and two large potentiometers in the top of the board and solder from the bottom. The numbers on the small potentiometer should be on the opposite side of the holes from the "CNTRST" label.



---

#### Step 12 Add display

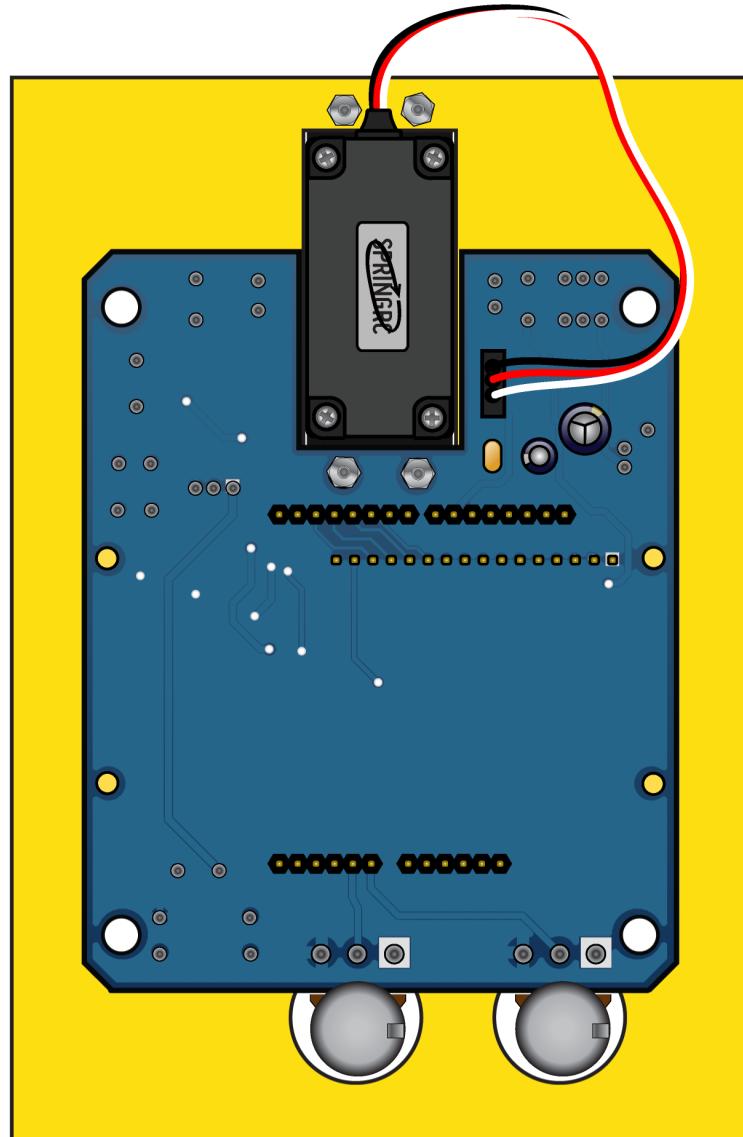
Place the display over the 16-segment header and solder into place.



---

Step 13    **Add the cover**

Place the Twister cover over the assembly.

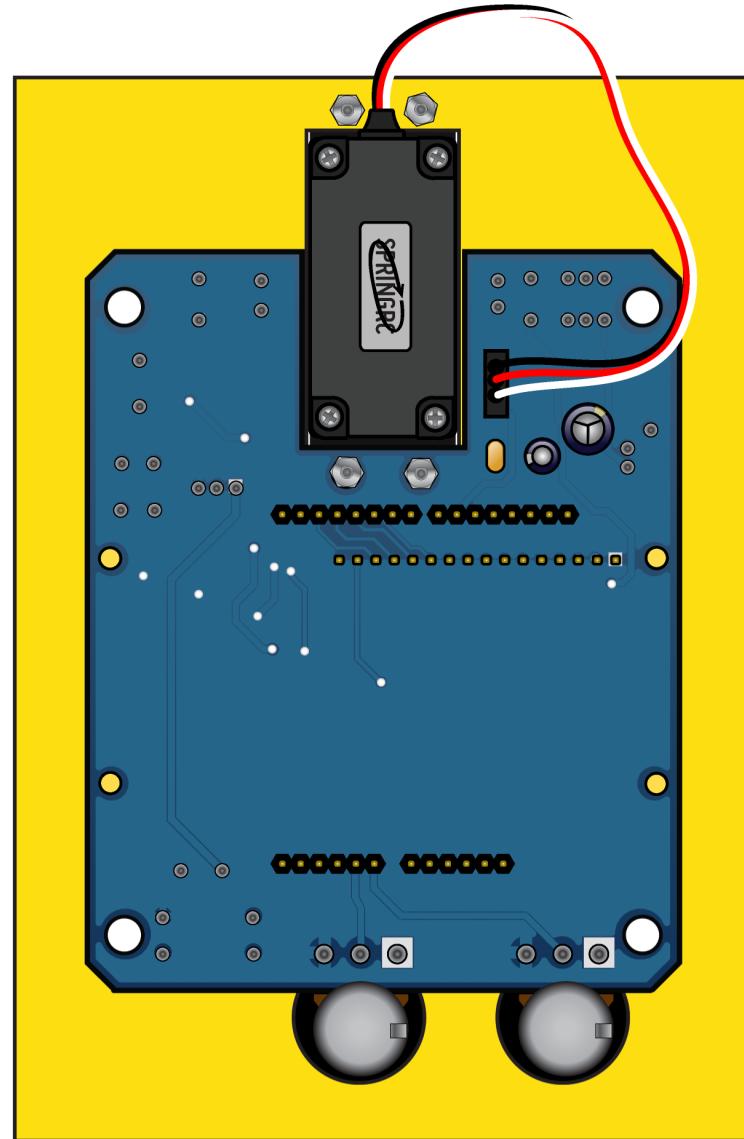


---

#### Step 14 Add the servo motor

Using four M3 screws and four M3 nuts, secure the servo to the cover and circuit board.

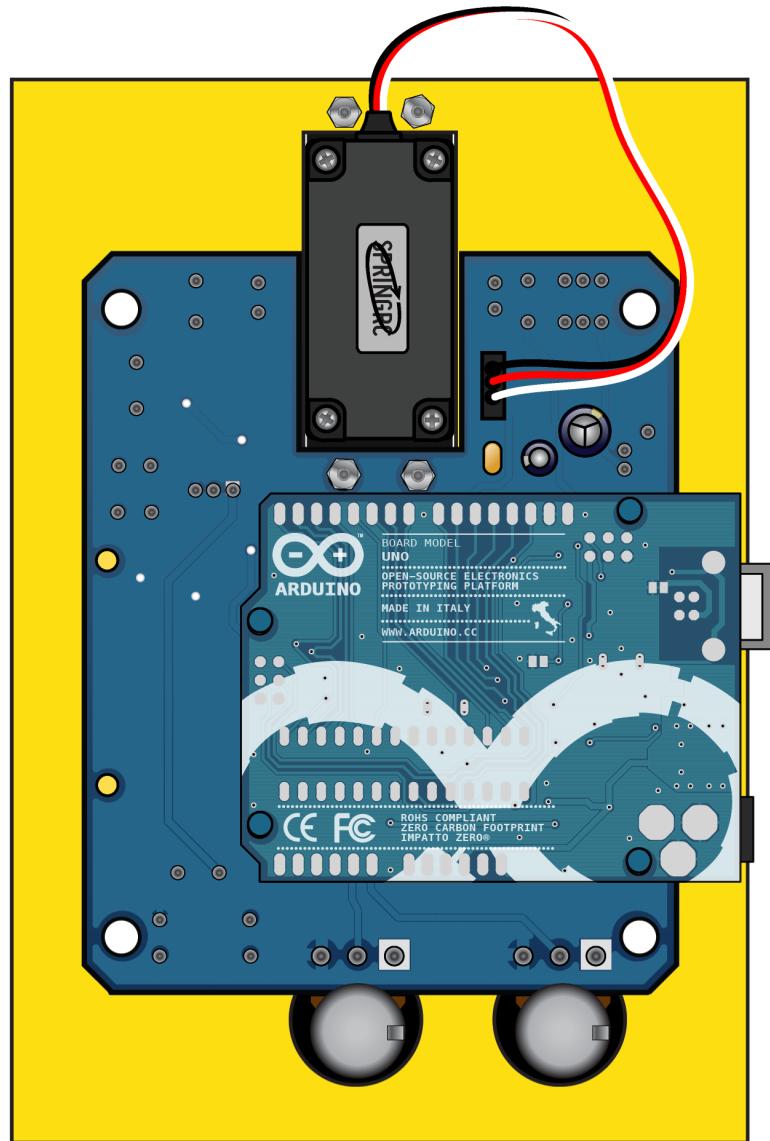
Plug the servo into the appropriate headers, with the black wire toward the rear of the assembly.



---

#### Step 15 Add knobs

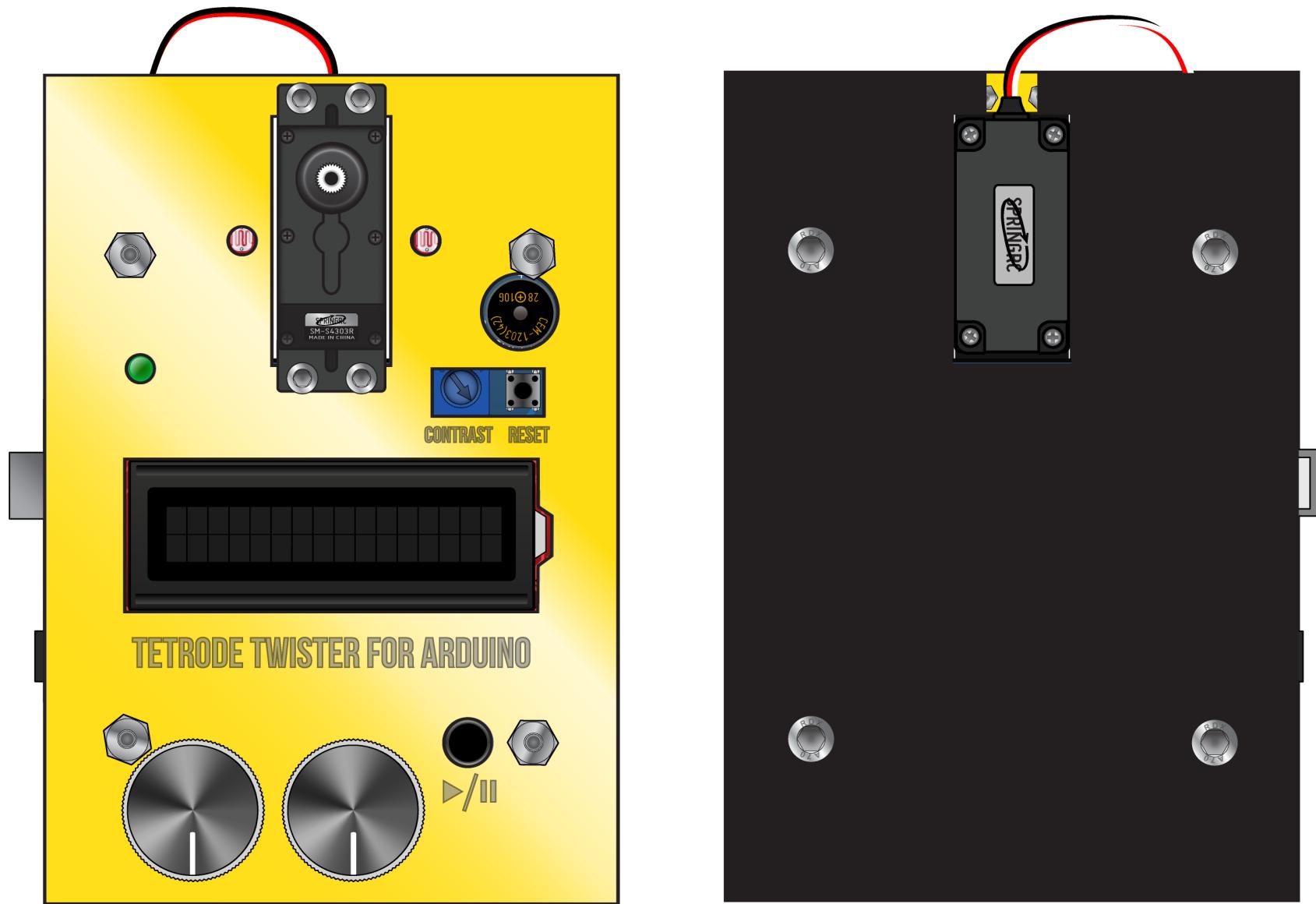
Twist the large potentiometers as far to the left (counterclockwise) as possible. Place the black knobs on top of the large potentiometers with the white indicators facing toward the front. Use a vise to press the knobs firmly into place.



---

#### Step 16 Add Arduino board

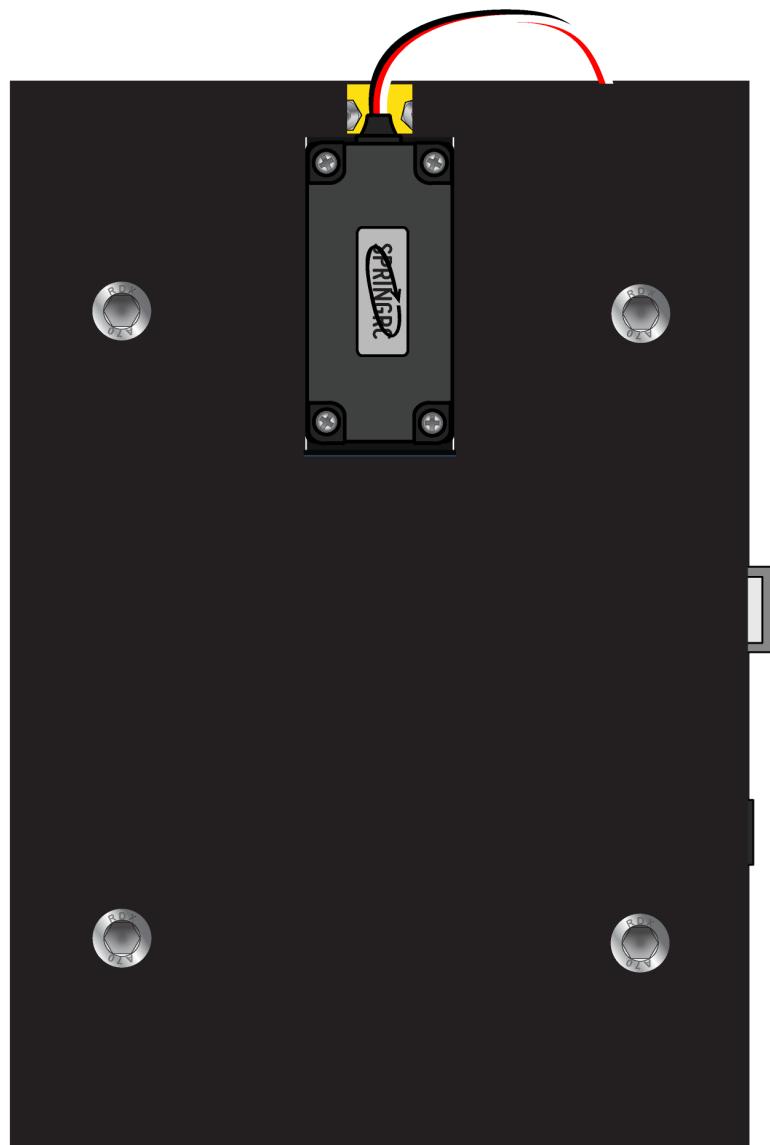
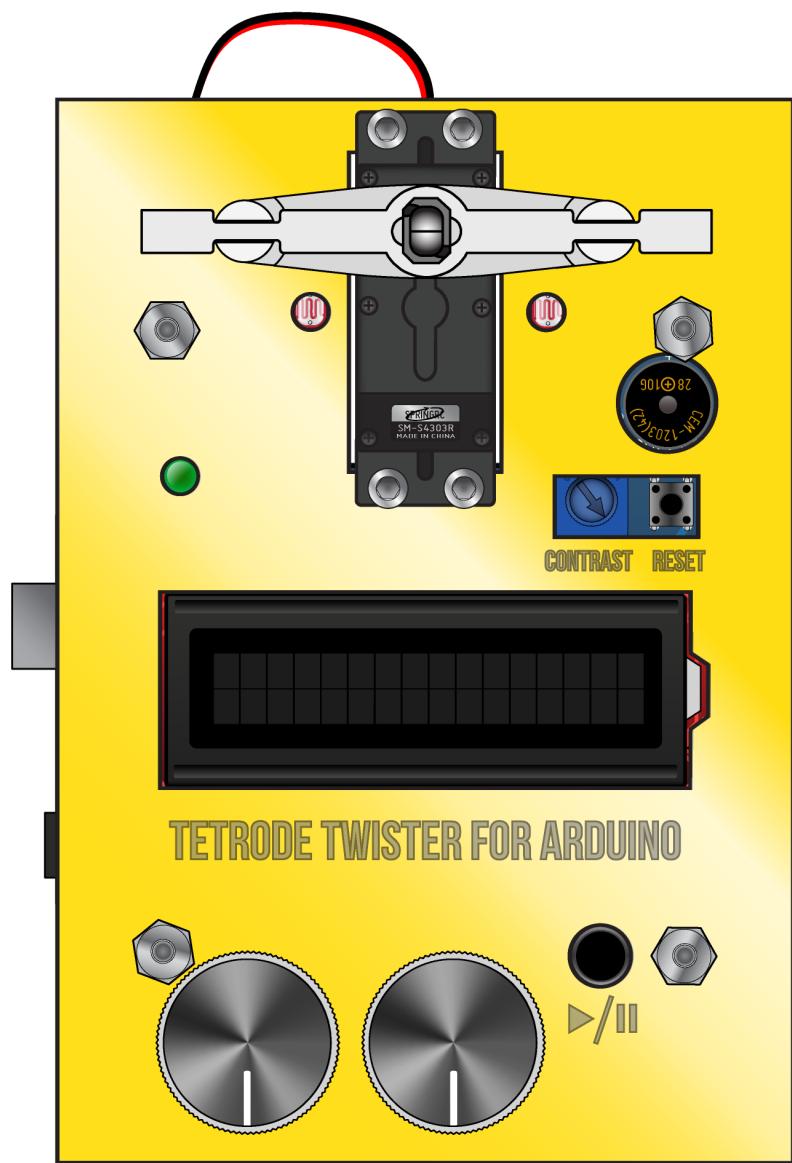
Align the Arduino with the headers on the bottom of the board and press it into place. Do not apply any solder.



---

#### Step 17    Add the base

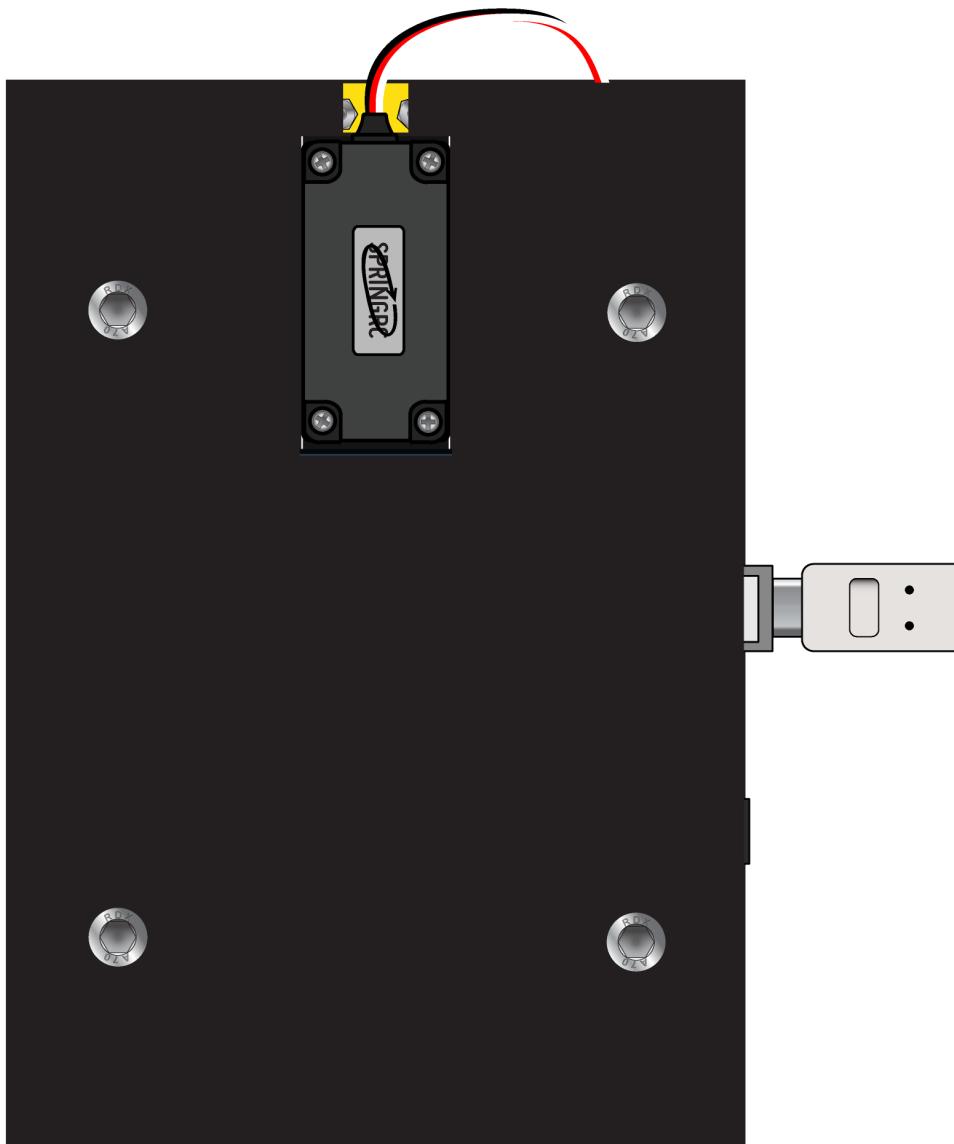
Place four M5 screws through the holes in the Twister base, four 25 mm M5 standoffs, and the holes in the cover. Secure the base with four M5 nuts.



---

#### Step 18 Add the tetrode clip holder

Attach the tetrode clip to the clip holder with dental acrylic or epoxy. Attach the servo adapter to the linear servo arm with tape or glue. Press the adapter firmly onto the top of the servo motor.



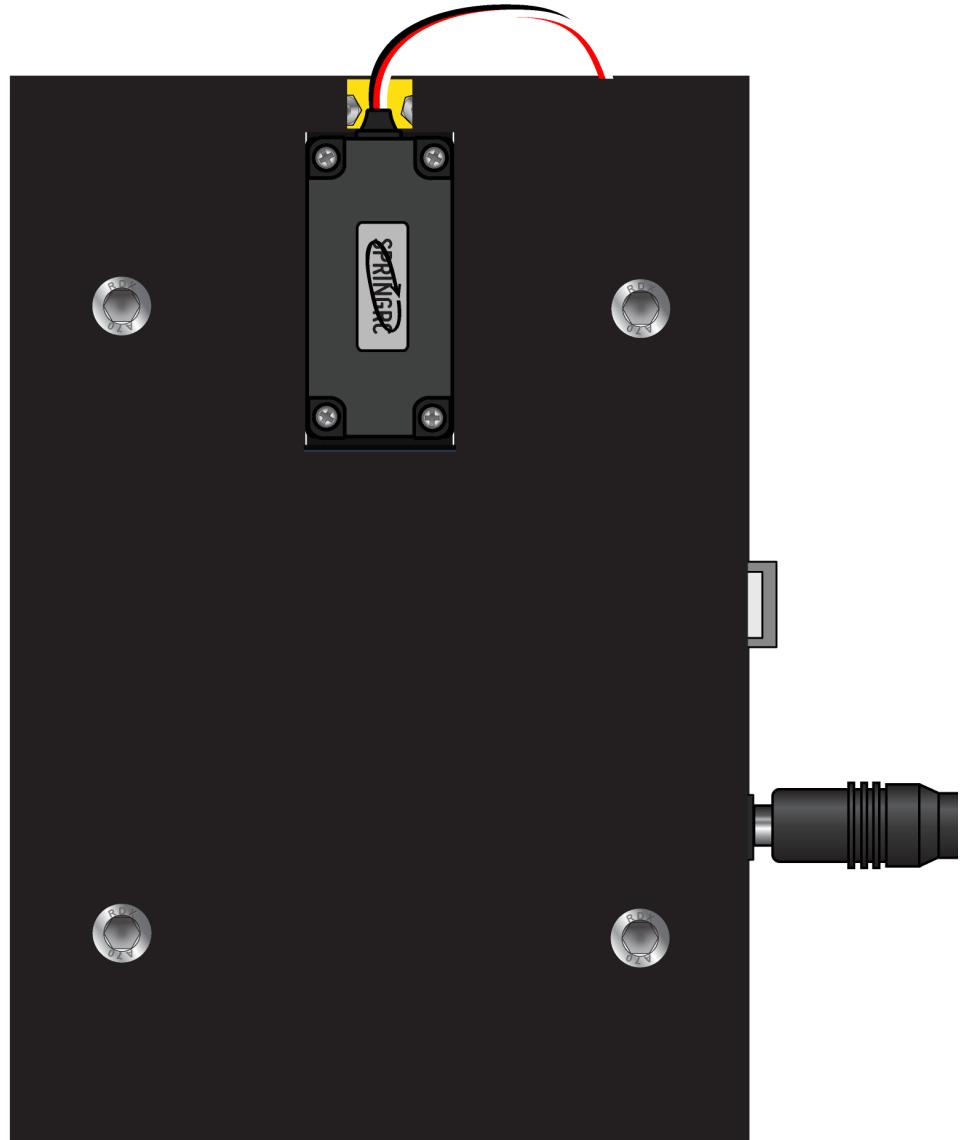
---

#### Step 19    **Upload firmware**

Connect the Arduino to your computer via USB port. Upload the tetrode twister firmware using the Arduino IDE (available at <http://www.arduino.cc>).

TWISTER ASSEMBLY MANUAL

page 025 of 027



---

#### Step 20 Attach power cable

Plug the Arduino board into a power outlet using the 9V power supply. You are now ready to twist!  
Use the knobs to adjust the number of the turns and the play/pause button to start and stop the twister.

---

# TROUBLESHOOTING

## BUYING PARTS

I can't find a particular part on SparkFun. Where can I buy it?

SparkFun always maintains the pages of discontinued parts. See if you can find a part number from the original manufacturer, which you can use to order the same part from DigiKey or Mouser. Otherwise, use the description of the part to find something as close as possible.

I have my own resistors / capacitors / potentiometers / buttons / etc. Can I use these instead of the recommended parts?

Sure, as long as the footprint and specs are the same.

I prefer to order circuit boards, laser-cut acrylic, or 3D-printed parts from a manufacturer other than the ones you recommend. Is this OK?

Yes. SilverCircuits, Ponoko, and APPproto were chosen for their price and reliability, but they are by no means the only choices. The design files are compatible with a variety of manufacturers.

Can I use a different material for the case?

Definitely. A wood or metal case would look particularly classy.

## BUILDING THE TWISTER

I'm not sure I did step X correctly. How do I make sure it's right before continuing?

After every step, it's recommended to test your solder connections with a multimeter. Make sure there is electrical contact between the metal leads and the board. You should also check for solder bridges between adjacent leads.

If you've gotten past step 2, you can already plug an Arduino into your circuit board. If you skip ahead to step 9, you can use the buzzer as a built-in sanity check to make sure everything is working OK. Upload the simple sketch located in `Code/BuzzerTest`. If you can hear a beeping sound after the Arduino is plugged into your board and has power, it means that nothing has gone catastrophically wrong. If you can't hear anything, it's possible that you have too much or too little solder somewhere. If something isn't obviously awry, try checking your connections with a multimeter, looking at the board under a microscope, or washing the board with ethanol. If that still doesn't fix it, perhaps it's time to scrap this board and start again.

The cover doesn't fit properly. Did I do something wrong?

Possibly, but it's not the end of the world. You can always shave away excess material with a Dremel or a file.

## AFTER IT'S FINISHED

My Twister is plugged in, but I don't see anything on the screen. How do I fix it?

First, try turning the contrast knob. It's possible that the screen is simply too dim.

If the contrast knob doesn't fix things, try uploading the Arduino sketch again.

If it's still not working, you may have a bad solder connection. Disassemble the case and check your connections by hand.

The motor is turning really slowly. How can I speed it up?

The servo speed is controlled by the voltage difference between the red and black leads, which should be approximately 6V. Measure this voltage with a multimeter to make sure it's in the right range. If it's significantly below 6V when using a 9V power supply (NOT a USB cable), double-check that you've used the correct resistor combination for the resistors labeled "220" and "820" on the board.