Three Dimensional Tic Tack Toe

This is the classic game of Tic Tac Toe, but played on three levels. You can win by connecting three of your positions in a row on any single level. But you can also score by having three connected across levels. The game is more fun because it is easier to win, so there is often a winner and every game played doesn't end in a draw. Also, the game is open source. The onboard computer has the Arduino UNO bootloader and there is an FTDI port to allow easy uploading of sketches. You can make the game your own or re-purpose the hardware for another project.

The hardware consists of an Atmel(Microchip) 328p microcontroller, support electronics for the processor, a reset switch (which resets the computer), four momentary pushbuttons, and 27 multicolored WS2812 LEDs. The LEDs are distributed over 3 levels and the levels are connected with brass rods to carry power and signals between the levels and to give separation to the levels.

How to Play

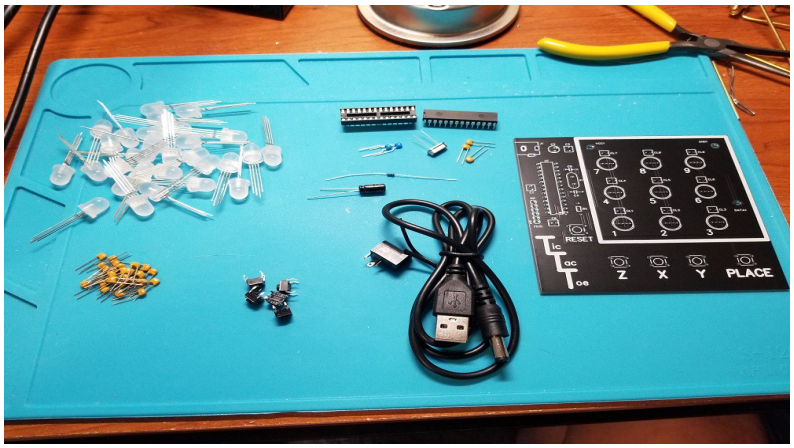
The microcontroller comes shipped with the Arduino UNO bootloader and the current version of the firmware. To play the game, press the reset switch to start a new game. Player 1 is Red and Player 2 is Green. The matrix of LEDs will show the current cursor by using the base color of the player and adding Blue. The Red cursor will show up Purple, and the Green cursor will look Teal. When it is your turn, determine which space you want to occupy. Then use the switches to place your cursor there. The Z switch will select the level, the X will select across the level, and the Y will select down the level. There is only one switch so once you get to the end of a row, pressing the button again will cycle you back around to the beginning of that row or level. When you are happy with the position, press the PLACE button. This will mark your position and return the cursor to the home position, change the color to the next player, and wait for the next move. If you try to place your move over a previous move, the system will do nothing. If you won, you will see a small animation play. The rows will display random colors and then the top row will flash the winning color.

Assembly

Assembly is both easy and challenging. It is easy because the entire soldering is through-hole. It is challenging for three main reasons:

1) I chose to create a very large “copper pour” To make the boards look a cool flat black. This served its function, but it makes for a very large ground plane. You will find that the ground connections take a significantly more amount of time or heat to get good connections. I soldered a lot of my components by connecting everything but the ground connections, and then I increased my iron temperature and went back for the ground connections.
2) The leads of the LEDs are very close together. Bridging them is easy and sometimes difficult to detect. When I put my kit together, I missed a very small bridge on the center LED on the top level. When I powered the game on, every LED past that one would not light. As I troubleshooted the game, I found that the last two connections of the middle LED were shorted. I cleared the short, and the game still wouldn't work. I looked at every possible case and the only thing that made sense is that shorting the LED (the last two are power and output to the next LED) caused the LED to fail internally. I cut off the LED and tested and sure enough, there was a permanent short between those two pins. I replaced with a good LED and the device worked fine. Be careful with these. You may want to test the connections with a meter before powering on.

3) My decision to connect the levels with brass rod turned out pretty cool. However, I did not do a good job of designing for this. Consequently, it was pretty tough to align and solder the rods. I give some instruction below, but you may have better of worse holding devices than me, so this may be challenging or easy. Creativity here is the key. If you ask me, that actually adds fun to the construction. (Like how I tried to cover poor design with optimism?)

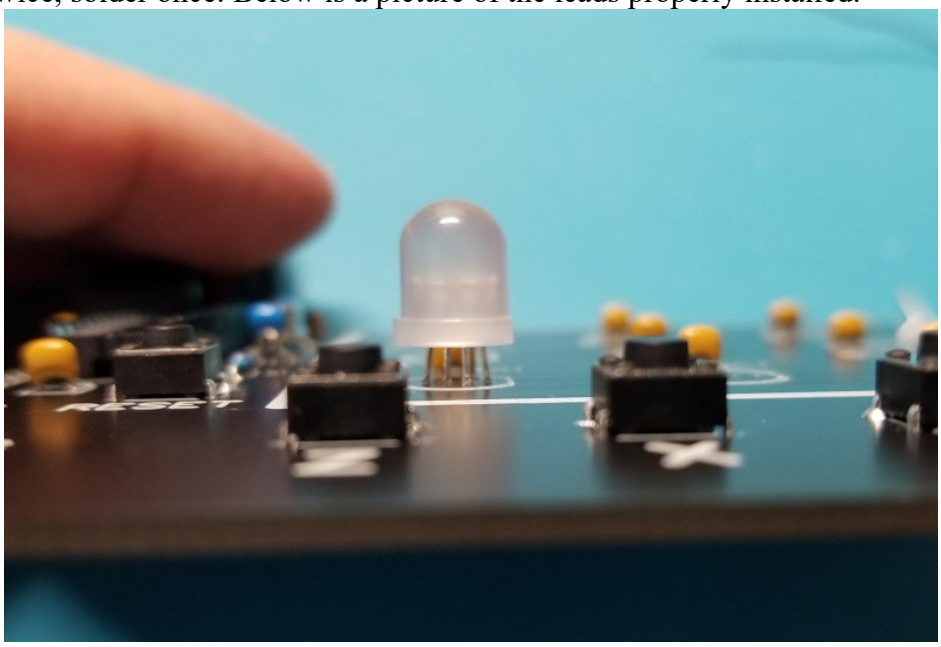


NOTE: MANY PARTS ARE POLARIZED AND WILL BE DAMAGED IF PLACED INCORRECTLY

You should have a load of parts to assemble on three PCBs. I recommend assembly in the following order:

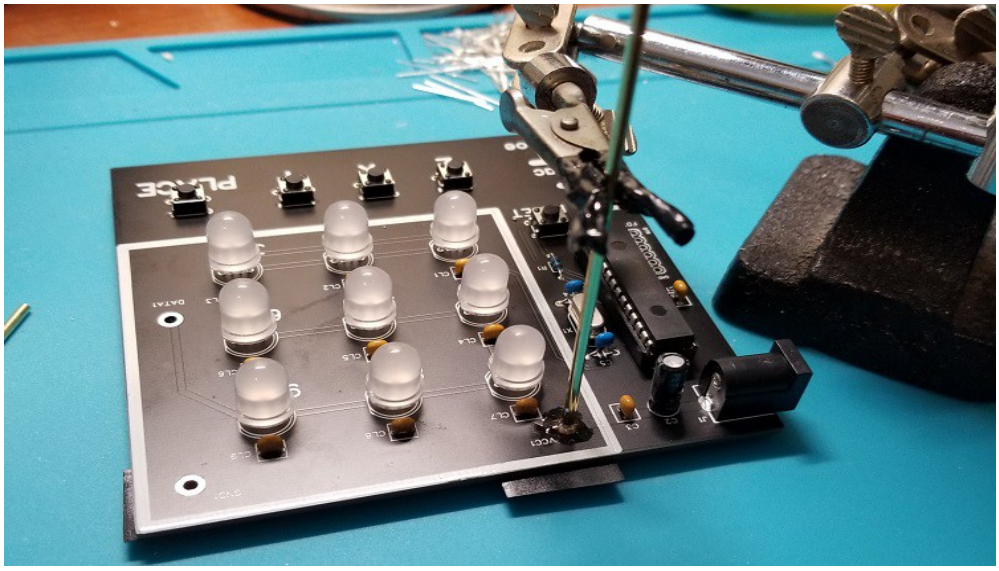
1) Start with the computer section on the base board.
   a) Solder the IC Socket first. This is a non-functional part so you really can't hurt it too bad. This will get you started and give you a chance to see what I mean about the ground plane soldering. Ensure you place this in the correct orientation. There is a small notch on one end of the socket that should match the indent on the PCB silk screen. This will not affect the operation if you put it in backwards like most of the other components. But, the socket covers the silkscreen when installed and it becomes the polarity indicator for the chip when you insert it.
   b) Then, I would move on to the resistor and capacitors (C1-C6) in the computer section. These are hardy components and also good to start with. C2 is a polarized capacitor so ensure you place it with the positive lead in the positive hole. The negative lead is marked with a white stripe on the body.
   c) Solder the crystal and the reset button.
   d) Lastly, solder the Power Connector. This completes the computer section. At this point, you could insert the microcontroller in the socket and, if you have the knowledge and an FTDI connector, you could power the computer and communicate with it. If you download a test program, be sure you have a copy of the TTT program so you can reload it.
2) The next step would be to solder the four selector switches.
3) At this point, hopefully you have had enough experience soldering with the large ground plane that the rest of the soldering will be easy. The only components left are the LEDs and their filter capacitors. I recommend soldering all of the capacitors in place (there are 27 of them on the three boards) and then tackle the LEDs.
4) The LEDs have small standoffs on the leads which will fit snugly into the PCBs plated through holes. WATCH THE POLARITY!!! These would be a bear to de-solder and solder again so

check twice, solder once. Below is a picture of the leads properly installed.



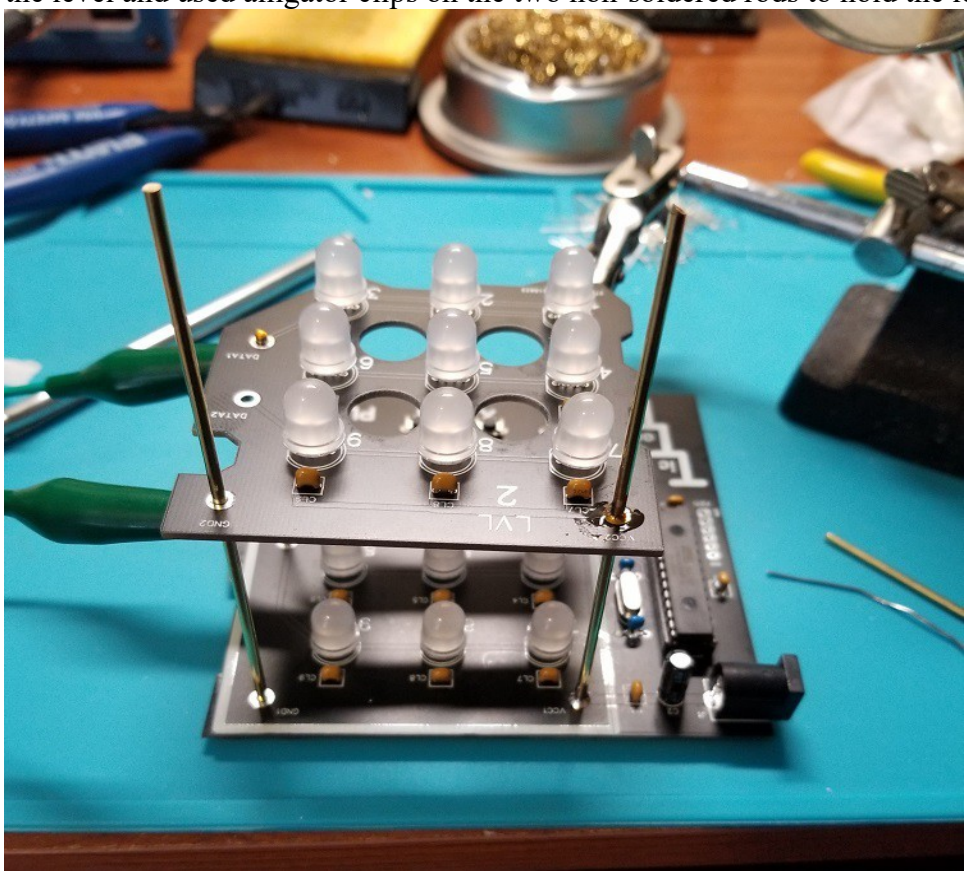
The LEDs have leads that are spaced very close. The PCB spacing is slightly larger. As you align the LED leads in the holes and start to insert them, you will see the leads start to bow outward on the opposite side of the board and you will feel resistance to the insertion. Gently rock the LED back and forth as you push it closer to the board. You will eventually feel the small standoffs on the leads (the little sections of the lead that have a slightly larger diameter) enter into the PCB holes. This is a good height for the LED. You will see from the picture that it is slightly elevated off the board. Don't force the LED any lower than this.

5) When you are done with the base board, you could test the system at that point. Make sure you do not have any bridging of solder and inspect all of your joints (particularly the ground connections) to ensure there is good electrical contact (no cold solder joints). Insert the computer chip into the socket observing the correct polarity. Plug the board into a USB source (I recommend a good phone charger and not a computer port) and press the reset button. You should see the LED at the home position (1,1,1) light purple signifying it is REDs turn. Use the X and Y buttons to move the cursor around the level. If you hit the Z button, the cursor should disappear and reappear on the level when you press it the third time.
6) If all looks good, finish the other two levels by installing the capacitors and LEDs and then we will get to hooking the levels together.
7) The levels are connected with brass rods that support the levels and pass the power and signals to those levels. Each level is about two inches above the other. You will have two 4-inch rods for the Power and Ground (these go to all the levels) and two 2-inch rods to pass the lighting signal to the next level. One is placed between level 1 and 2. The other, between 2 and 3.
8) At this point, you know what the final product should look like. You can assemble this in any way you like. I will demonstrate how I did this to give you a starting point. But if you have better ideas or more fancy holding equipment, feel free to complete these steps any way you like.
9) I connected the positive power rod first (a 4-inch rod).



You can see from this picture that I placed a piece of tape below the PCB to prevent the rod from extending beyond the board and I used a helping hand to hold the rod perfectly vertically. It is now pretty easy to solder this rod. This gives us a “corner-stone” to be able to align all of the levels.

10) Next, using the same technique with the tape, I slid the second level on to the positive power rod and placed the ground rod (4-inch) and signal rod (2-inch) in place. I used a helping hand to steady the level and used alligator clips on the two non-soldered rods to hold the level in place.



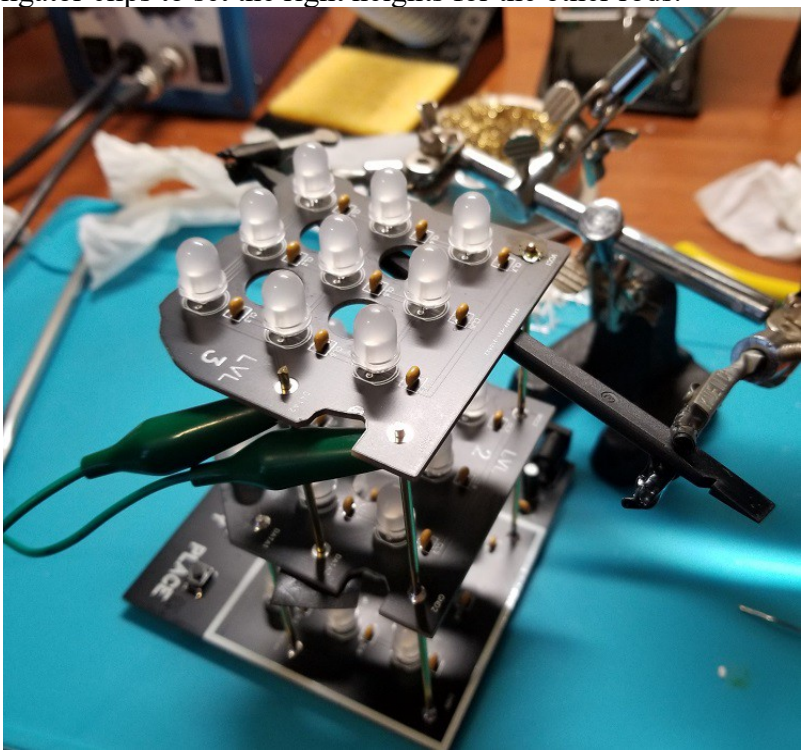
With the level looking level and the signal rod (2-inch) barely protruding, I soldered the power rod to the second level.

11) With the level pretty well supported, I soldered the ground rod to the second level and then

soldered the signal rod.

I would test the board at this stage as before. It will be much easier to troubleshoot problems on this level before connecting the next. With these joints completed, it is on to level 3.

12) For level 3, I found that supporting the level flat was the best way to keep it level during soldering. I used my helping hands with a stick to act as a flat surface for the level to sit on. I again used alligator clips to set the right heights for the other rods.



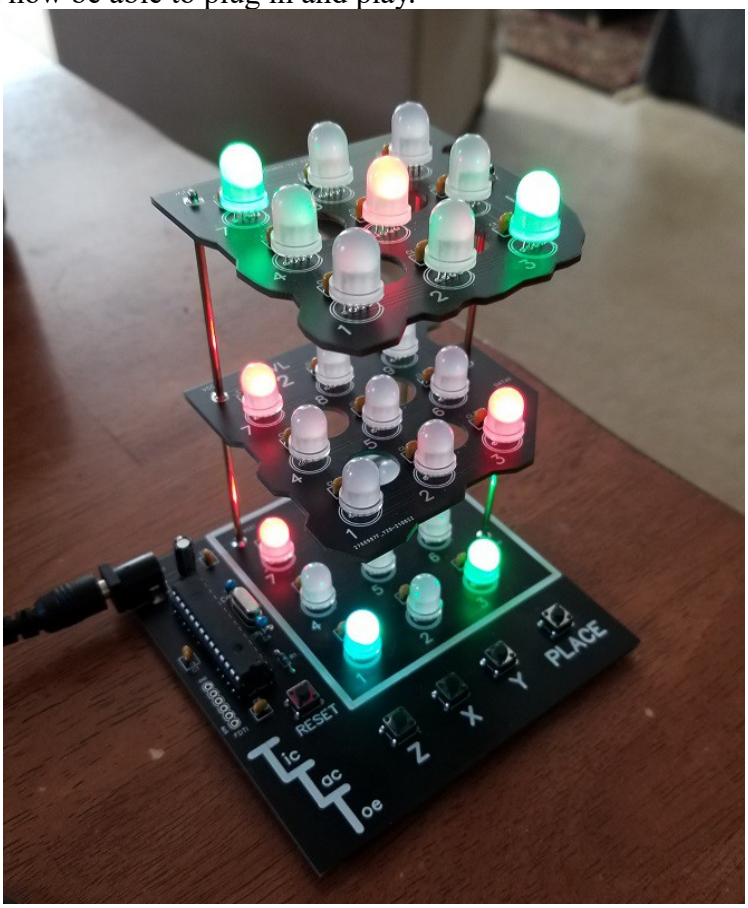
With the level well supported, I finished the solder joints.

13) Ensure you have cleaned all of the remaining flux and impurities off the boards and your kit

should be done with soldering.

14) After cleaning the bottom PCB, attach the rubber stick on feet to the bottom. This will help prevent scratching table surfaces from the solder joints. In general place them toward the corners but the goal is to have the game level, and not rock when you press the buttons. Here is where I put mine:

15) You should now be able to plug in and play.



Three dimensional TTT is both fun and frustrating. The extra levels open a lot of opportunity for winning. However, you can get into a rut of whoever goes first wins every time. You can help this out by stating to build some rules that make the game more challenging. Alternate who goes first every game. Make a rule that says you can not select the center LED on the middle row unless you are blocking a win. As you play, you may come up with more good rules to make the game more like chess and elevate this stale-mate-prone game to new heights.

And if you get sick of it, you can always re-purpose it due to its open-source nature. Crank up the Arduino IDE, look at my sample code for the game, and get modifying. In the IDE, select the Arduino UNO as the board and you are all set.

I hope you enjoy this build and game. If you come up with some excellent software, consider sharing it with us.

Parts List (Polarized Components are in RED)

Computer Section:

Part	Designator
10kOhm Resistor	R1
100nF capacitor (marked 104)	C1, C3, C6
22pF capacitor (marked 22)	C4, C5
16MHz Crystal	X1
Mega328P microcontroller (pre-programmed)	U1
28-pin Socket for mega328P	
5 Tactile Pushbutton Switches	RESET, X, Y, Z, PLACE
Power Jack	J1
USB Cable	
10uF electrolytic capacitor	C2

Lights:

WS2812 Multicolored LEDs	LED 1-9 on each level (27 total)
100nF capacitors (marked 104)	CL1-9 on each level (27 total)

Mechanical:

4 inch brass rods	Quantity 2
2 inch brass rods	Quantity 2
Rubber Feet	Quantity 4