Instructions for building the Zen Harp

These instructions that capture what I've learned in building three Zen Harps. There are probably better or alternative ways to do this so feel free to experiment.

The tools and materials that I've used (not included) are:
sandpaper
1/32" drillbit and drill
a hobby saw (coping saw or Xacto saw)
hot glue gun or silicone rubber caulk
masking tape
wood glue
wood stain
varnish
solder and soldering iron
wire strippers/cutters
clamps (wood clamps and clothespins)

Starting tip: don't remove the protective paper on the plastic panels until you need to install the metal plugs (just so that they are protected)

I. Building the housing

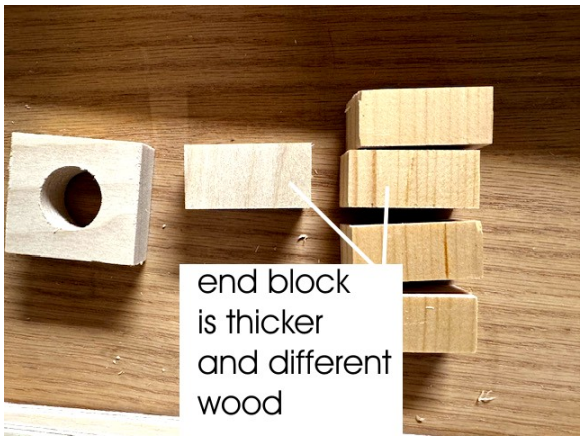
(a) Lightly sand the plywood to remove splinters and smooth the edges. You can do additional sanding later, but this is an easy time to get some of the edges.

(b) Stain the outside surfaces of the plywood and end blocks but not where glue will go. The reason I do this is because the glue tends to leak out of the joints and make it hard to stain the wood evenly later. I am using diluted tube acrylics which come in a wide variety of interesting colors but you can also use conventional wood stain. The stain will be covered with varnish which will make it durable. Leave the gluing surfaces bare for best bonding.

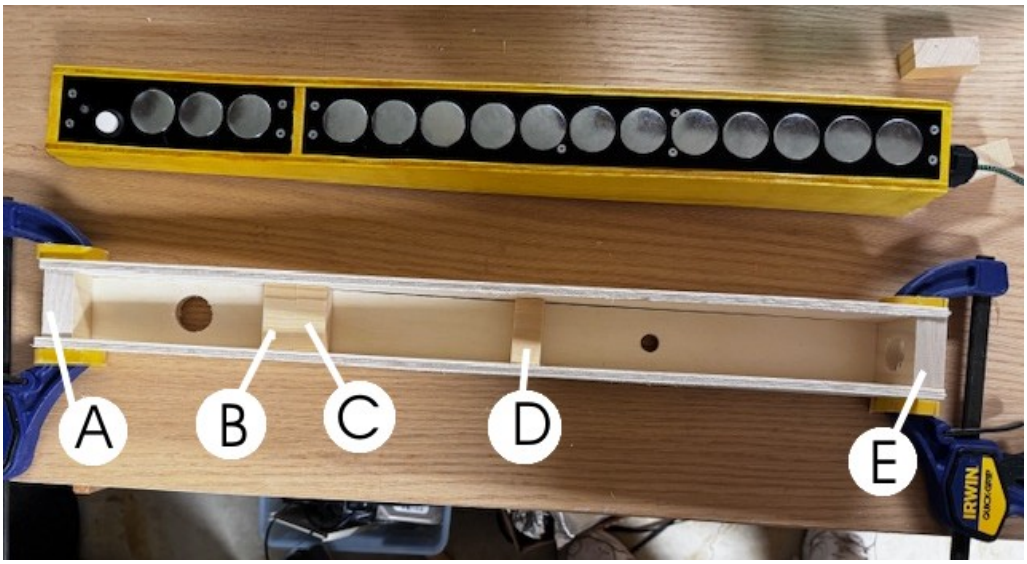
(c) Line up the pieces as shown making sure that the right angle ends of the plywood side panels are oriented as shown and that the holes in the bottom panel are oriented as shown with respect to the slope of the side panels.

Make sure that you have the correct end blocks. The one on the thin end of the housing looks a lot like the spacer blocks so see the drawing below for distinguishing them (the size and wood type are

different). Note that the end block with a hole in it needs to be rotated properly to match the width of the bottom panel.



(d) Do a dry run with the other pieces assembled as follows (see label the diagram below):



(E) <u>right end block</u> should be flush with the rightmost edges of the side panels with the bottom pressed against the upper surface of the bottom panel and the top about 1/8 of an inch below the upper edge of the side panels (this will provide a recess for the plastic button panels).

(D) <u>spacer block</u> has its bottom pressed against the upper surface of the bottom plywood panel and it's center about 10.5 inches from the rightmost edge of (E). This position is not critical but will prevent interference with wiring etc. later.

(B) and (C) these <u>spacer blocks</u> support the upper plastic panels and are positioned with their upper edges 1/8 inch below the upper edge of the side panels and their lower edges spaced away from the bottom panel providing a gap through which wires can run. These blocks are centered about 16.75 inches from the rightmost edge of (E). You can confirm this positioning in the next step.

(A) left end block should be flush with the shortest of the sidewalls and bottom walls. Some trimming of the plywood that extends beyond this point will bring everything flush.

(e) Lay the plastic panels lightly over the spacer and end blocks as positioned to make sure that the plastic panels are properly supported at the desired height approximately flush with the upper edge of the side panels and that the holes for mounting the plastic panels are over solid wood surfaces that will accept mounting screws.

(f) Glue everything together and clamp. *Make sure that the bottom panel is flush with the bottom edges of the side panel*. I used wood clamps but it may be possible to do this with weights and rubber bands.

(g) Glue thin supports strips to the inner surfaces of the side panels at approximately 11 ½ inches between the rightmost edge of the supports strips and the rightmost edge of the right end block (E). The upper edges of these panel support strips should be approximately 1/8 inch beneath the upper edge of the side panels so that the plastic panel can rest on these ledges approximately flush with the upper edge of the side panels. This positioning prevents interference with the printed circuit board that will be attached to the larger plastic panel.

(h) After the glue has dried, place one thin wood strip over the seam between spacer blocks (B) and (C) and position the plastic panels on either side abutting this thin strip. Slide additional wood strips to abut the left and right ends of the left and right plastic panels as so positioned. Glue these down and clean up any glue leakage that would interfere with the seating of the plastic panels (remove the plastic panels and wipe off any glue). These latter left and right most wood strips will protrude slightly and will be trimmed after the glue has hardened.

(i) Trim the edges of the plywood and the wooden strips that extend past the left and right end blocks and sand all surfaces to a desired smoothness. Re stain or color as necessary and then apply a varnish sanding lightly according to instructions between coats.

(j) Remove the nut and washer from the black strain relief and apply a thick bead of hot glue within the hole of the right end block and lightly screw the strain relief into position and hold until the glue hardens. Silicone rubber might work for this as well.

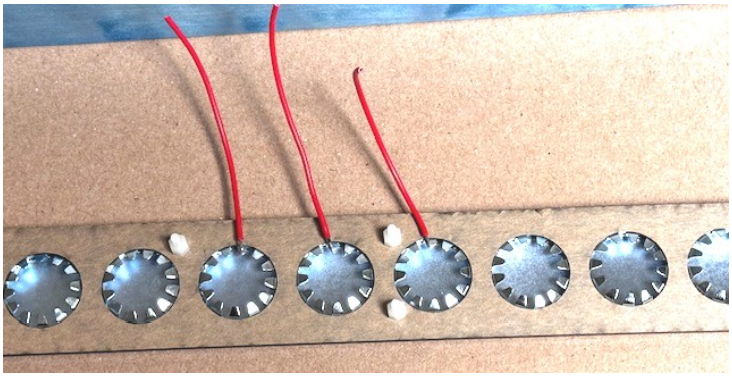
II. Building the electronics

Starting note: you will need to solder wires to the prongs of the metal plugs. I have a hot soldering iron (about 400°) and a light touch and so I can do this with the plugs in the panels. If you are finding your way on this process, consider soldering the plugs removed from the panels and then inserting them afterwards. Or at least tinning the plugs (as described below) before you insert them. This will keep you from melting the plastic panel.

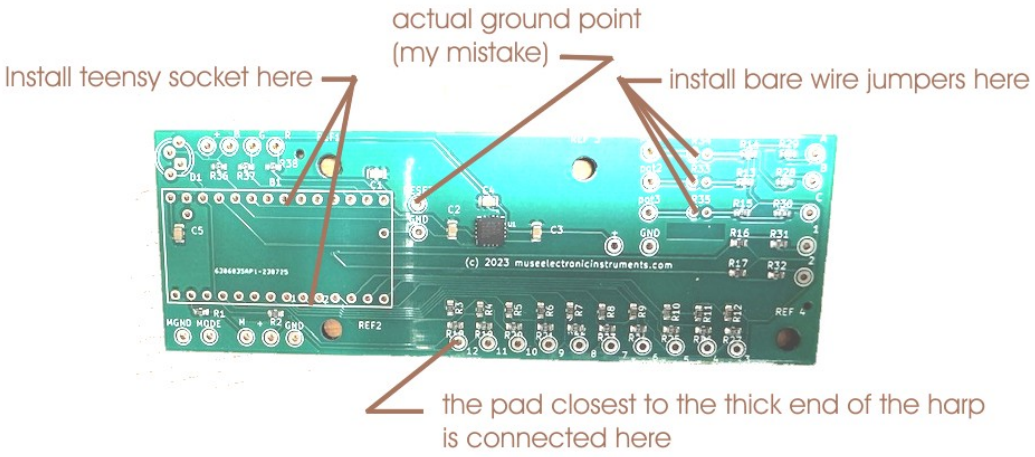
The plugs are nickel plated in order to accept solder but they big heatsinks and so it is hard to get them hot enough to solder to. You will want to do this in two steps. First "tin" the very narrowest tip of one prong, which mean heating up the prong tip with the soldering iron while applying solder until the solder sticks. You don't need much area of solder contact. Next "tin" the end of the wire you will attach to the plug. Then melt the tinned wire and tinned plug together by heating the wire and pressing downward. This has proven robust for me although I understand it violates some basic soldering principles like having an independent mechanical connection.

When you press the plugs into the panel be careful to keep your fingers only on the plastic close to the hole only to keep from breaking the plastic panel in the regions between holes.

(a) Install the nylon standoffs as shown with metal countersink head machine screws so that the nylon threads extend away from the panel (upward as shown (inward to the flute)). Arrange the larger plastic panel as shown below noting the position of the nylon standoffs You probably will want to remove the paper from the top side of the plastic panel at this point so it doesn't get captured under the plugs as you install them. The standoffs show where the printed circuit board will fit and thus an area where access to the back of the plugs will be blocked, so pre-solder the plugs that will be so blocked with short (approximately 3 inch) stranded wire.



(b) Prepare the printed circuit board for installation using the bare wire to create small jumpers (across R33-R35. Install the 14 pin sockets that will hold the Teensy (use the header pins that will be put on the Teensy to align the two sockets to be parallel to each other by plugging the header into the sockets crosswise across the sockets). Afterwards, solder the header pins to the Teensy using the socket for initial alignment. Remove the Teensy and place it back in the static resistant bag for safety



(c) Use the stranded wire to start connecting the plugs successively to pin locations 12-1. Pin 12 connects to the pad closest to the strain relief or thickest end of the harp. I've had luck installing the circuit board on to the large plastic panel with the nylon standoffs using the included nylon nuts and then soldering from the top side of the printed circuit board pressing the wire downward to expose a little bit of the metallic uninsulated portion above the pad. You can also try the more typical approach of inserting the wire up through the pad and soldering on the other side. Try to keep the wire length close to the minimum length necessary, but you don't want to bundle the wires together because that will cause capacitive coupling which is a bad thing in this application. So there will inevitably be somewhat of a loose tangle. Press the plugs into the panel after each wire is attached to a plug if you are soldering to the plugs removed from the plastic panel.

(d) Take the smaller plastic panel and install the LED which presses into a bezel. The bezel has a prong end and a flange end. The flange end fits against the upper or outer surface of the plastic panel. Press the LED upward into the bezel until you hear a click. Install the pushbutton switch with its nut.

(e) Connect stranded wire to the components on the smaller plastic panel but do not connect the other end of these wires to the printed circuit board on the larger plastic panel at this time because the wires need to feed underneath the spacer blocks of the housing. Instead, lay the two plastic panels approximately in their relative position as they would be installed in the housing and use wires of ample length to extend from the component on the smaller plastic panel all the way to the far edge of the printed circuit board on the larger plastic panel plus an inch. CAUTION: *The switch terminals melt the plastic of the switch body quickly so try tinning the wire and terminals in advance and keep a light touch (no more than three seconds)*

It is useful to label the loose ends of these wires connected to components on the small plastic panel using masking tape and a pen and then to gather them into bundles according to each component to make it easier to fish the wires under the spacer blocks. So for example, each of the wires going to the RGB LED should be labeled with respect to its particular color and then those wires bundled together to be inserted under the spacer blocks in the housing. Likewise, with the pads and the push button switch. Here's a diagram showing which leads of the LED are which colors

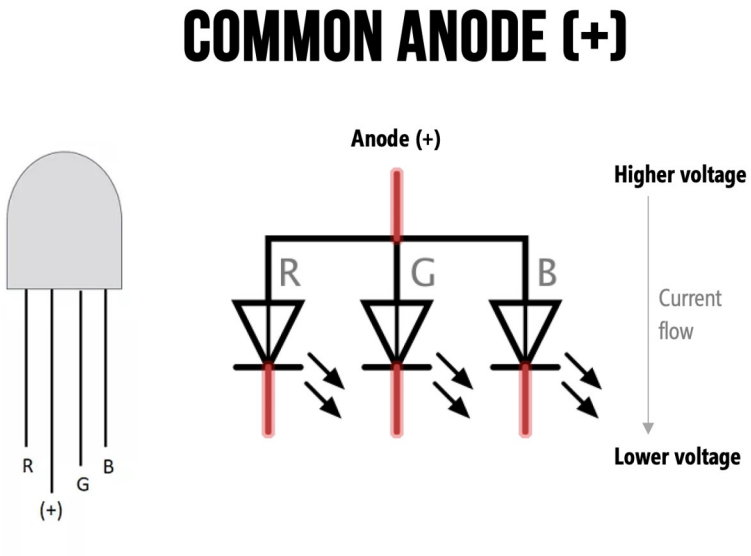
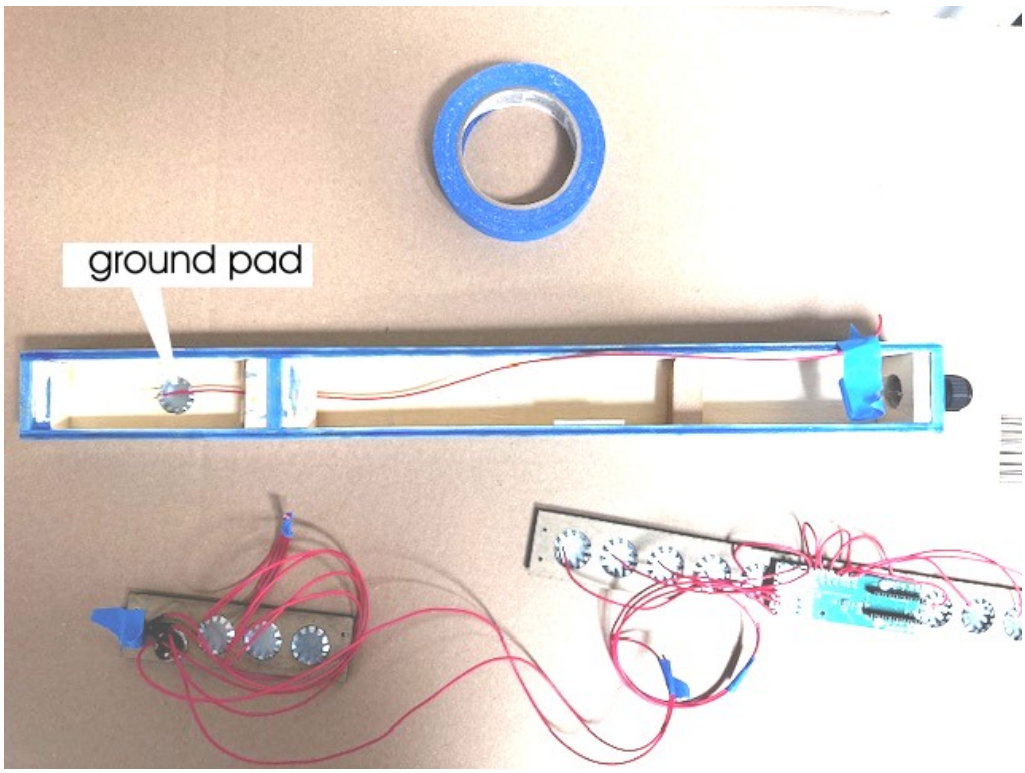


Illustration courtesy of Professor Jon E. Froehlich

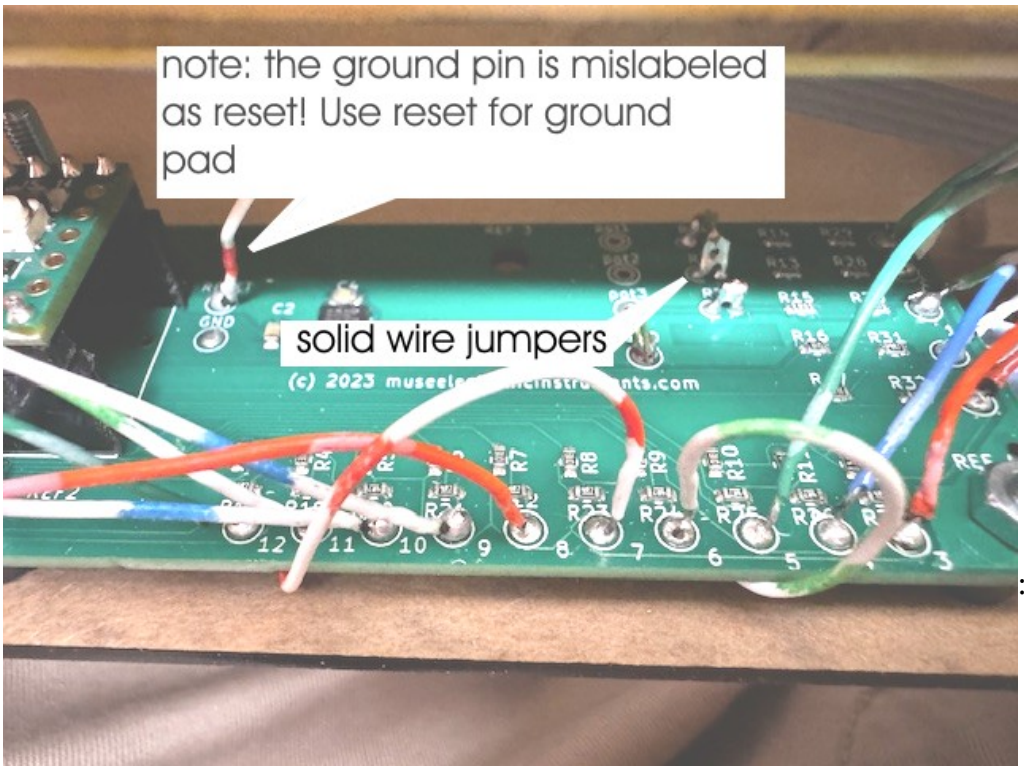
With respect to attaching wire to the LED, I've had some luck twisting a short portion of the stranded wire around the lead at its tip and then sliding the twisted portion downward toward the body of the LED and soldering it in place and then cutting the remaining LED lead off. After all leads are soldered to a wire, slip a short segment of the heat shrink tubing over each connection and heat it with a soldering iron or hot air gun to shrink it.

(f) Solder a wire to the ground pad as shown below and feed that under the spacer blocks making sure the wire is amply long to reach anyplace on the printed circuit board. This metal pad may need hot glue or silicon and to help it remain in the opening. Here's basically what everything will look like before final assembly.



With the plastic panels roughly in position and aligned with the housing, fish the wires from the small plastic panel under the spacer blocks and solder them to the the larger printed circuit board. The switch wires connect to the pads labeled MODE and MGND (it doesn't matter which is which). The LED leads connect to the pads labeled +, R, G, and B as appropriate. The metal pads of the small plastic panel connect to the pads labeled A, B, C following generally the same trajectory of connection of the other pads so that the pad closest to the printed circuit board connects to C.

The ground pad should connect to the ground point on the printed circuit board which is ***mislabeled*** as "reset" see below.



(g) Fish the USB cable through the strain relief and connect it to the Teensy and connect the Teensy to the print circuit boards so that the USB connector on the Teensy is close to the thick end of the housing.

(h) Carefully maneuver the wires into the housing while placing the plastic panels in position. Drill pilot holes and install the plastic panels on the housing using the countersunk screws.

(i) Slip the black silicone split tube around the USB connector wire and slide it into the strain relief and tighten the strain relief to hold everything in place.

III. Loading the Program

You must now install the program for the Zen Harp into the Teensy microcomputer. These instructions are for Windows machines but a similar approach should work with Mac hardware and Linux hardware.

(a) Go to https://www.pjrc.com/teensy/td_download.html and follow the instructions for downloading the Arduino software and the Teensyduino add on. You can then then use the Arduino IDE to install the program that came on the disk (also available on the website www.museelectronicinstruments.com) into the teensy. A video that describes this process for the Zen Flute is here (https://www.youtube.com/watch?v=wfLB0oTqk0o)

(b) edit the program by finding this code:

```
void loop()
{
  debugmode = 0;
  //0= nothing
  //2= show pin capacitance sensing values
  //3= show accelerometer values as text
  //4= plot accelerometer values (use Arduino plotting function)
  //5= print overflows on timing
```

and editing the program to set debugmode to 2 (e.g. debugmode = 4;)

(c) Plug the USB cable of the Zen Harp into your computer. Load the program into the Arduino IDE then compile and download the program into the Teensy by selecting the "Sketch" menu and "Verify/Compile" or pressing the circular button in the upper left-hand corner with the right facing arrow. Assuming this compiles and downloads, open the Serial monitor using the "Tools" menu and "Serial Monitor". This should start a printout showing the sensor values for each of the metal buttons something like this

```
pin:0=0.00/0 pin:1=1.00/0 pin:2=0.00/0 pin:3=-2.00/0 pin:4=-1.00/0 pin:5=1.00/0 pin:6=1.00/0 pin:7=-1.00/0 pin:8=-2.00/0 pin:9=-1.00/0
pin:10=0.00/0 pin:11=1.00/0 pin:12=1.00/0 pin:13=0.00/0 pin:14=0.00/0
```

This is a listing of the sensed values of each metal pad providing a capacitive value and then the pin state (zero or one). Put one finger on the ground pad underneath the housing and successively touch each of the metal pads with the other hand to make sure that you can change the value from 0 to 1. The increase in measured capacitance should be similar across the metal pads as you touch them. Check the wiring on any pins that do not respond.

Assuming everything checks out you should be ready to play.

Contact me if you have any problems