

Precision Piezo – Piezo Z-Probe Universal Kit V2 PCBs (with mounting holes)

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Thank you for purchasing the Piezo Z-Probe Kit. This device can detect the contact of your 3D printer’s nozzle with the print bed to a precision better than 10 microns, using as little as 15g of force.

Contents of package

- Piezo Sensor PCB V2, with removable mounting holes (can be snapped off if not needed)
- Piezo disc/s (drilled or undrilled)
- 3 Wire "Endstop" Cable
- 3 and 4 pin connector housings for the endstop cable to suit your printer controller.
- 2 pin dupont-style plug/s for piezos and crimp connectors.

Specifications

- Operating Voltage 3.3-5vdc, approx. 180mA (**NOT** tolerant of higher than 5v input)
- Indicator: Red TRG LED off when triggered, Blue SIG LED on when triggered
- Output: Active LOW via TRG 0v when triggered
- Repeatability std deviation: 0.007mm
- Optimal Probing Speed: 4-7mm/s
- Probing Force: 10-15g
- Operating temperature 10-35 deg C unless retuned (see below).

Safety

Piezo discs ceramic (PZT) contains lead. It is sealed-in if they are undrilled and presents no hazard. If drilled trace amounts might be shed from the drilled edge so wash your hands after handling them.

If you are drilling your own please do so in a workshop area, with adequate ventilation, wipe the dust away afterwards. Do not inhale or ingest the dust. Use gloves or wash hands thoroughly.

Attach the electrical connections carefully and as directed getting the polarity of the power (red), ground (black) and signal wires correct. We are not responsible for damage to 3D printer controllers caused by incorrect wiring. The controller comes with its endstop wire pre-connected correctly.

V2 Piezo PCB fail-safe when used normally with TRG connected to signal pin on your controller. So if the power has failed, or a wire between the piezo PCB and controller has broken, the 3D printer reads triggered and the nozzle will not descend during a probing move. However a piezo can become



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<http://www.precisionpiezo.co.uk>

disconnected and the system cannot detect this, so make sure the unit works before each use. See Operation below.

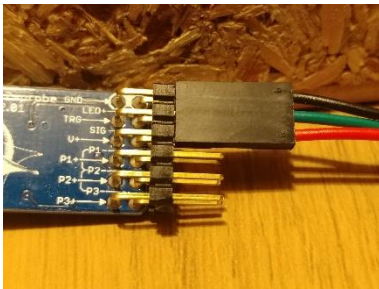
Instructions Mechanical

You may wish to download one of our designs for a piezo module or one of the other designs on Thingiverse <https://goo.gl/dGTBM3> and build it using our kit. Or design your own piezo probe as below:

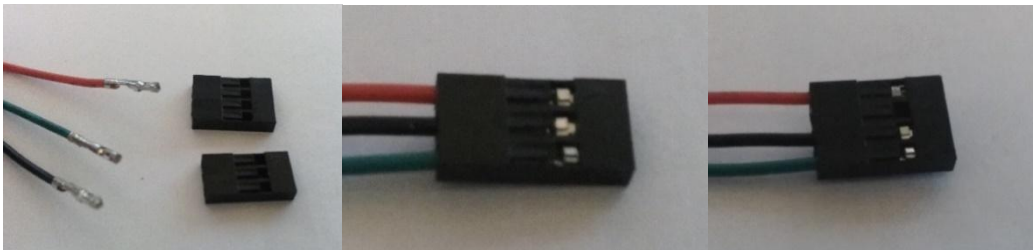
- 1) The aim is to position the piezo disc or discs in such a way that they either flex across the disc or are compressed through the thickness of the disc. Doing so generates a voltage rise, which the PCB detects, if it exceeds an adjustable threshold, a trigger is generated, TRG drops to 0v for your controller board to detect.
- 2) Ideally keep the leads to the piezo's from the piezo PCB as short as possible, for hotend systems place the PCB on the carriage or effector, for underbed systems place the PCB somewhere under the bed centrally to ensure short wires. Avoid running wires from piezo discs to the controller in bundles of cables containing motor wiring, and heater/fan wiring as electrical interference can reduce the effectiveness of your sensor system.
- 3) Your design for a sensor system is yours to consider, however the following guidance will enable you to optimise your design to get the most out of the system. A huge amount of additional information is available on the support pages of our website, <https://www.precisionpiezo.co.uk/resources-osh> please see the rewrap thread, and the other designs on thingiverse for inspiration and ideas.
 - a) Using drilled Piezo discs.
 - i. Place the disc in the filament path above the hotend, they are drilled to enable the filament to pass through the disc either within a PTFE guide tube (1.75mm) or without one (3mm). Upwards force generated by nozzle contact needs to squeeze, or bend the disc in order to generate a signal.
 - ii. The bending method generates a larger signal. To create the bending effect try to support the disc on one face around its perimeter, then on the other face design a much narrower flange to press up into the disc to create the bending. Only around 0.1-0.2mm of flex is required to give a strong signal.
 - iii. Try to avoid direct contact with the metal of the hotend, this is to prevent a potential short circuit being created between the hotend, in the event of failure of the heater cartridge (or thermistor) and the piezo disc, which would potentially damage your controller board. If the hotend is to contact the disc consider putting a fibre washer or printed spacer between the hotend and the piezo disc.
 - iv. Heat will affect the piezo disc's ability to generate a signal, generally with hotend mounted piezo sensors the disc is above the hotend (above the cold-end in reality) which is actively cooled so its temperature should be only a little above room temperature in use. If using it in a chamber please tune the disc with the chamber at the typical temperature set during probing (typically before a print begins), higher than 60 deg C might be unreliable).

- b) For underbed piezo sensors
 - i. In this case at least 3 piezo discs are required to cover a delta printbed or square printbed supported on 3 mounts though you can use 4. The aim is to place the piezo discs under the bed in such a way that downwards pressure on the bed squeezes or bends the disc.
 - ii. Various methods have been tried including flexible bed supports to which discs can be bonded, so that they bend as the pressure is applied, and more complex levers which press onto the disc when the bed is pushed by the nozzle. There are 3 connectors on the PCB these are connected in parallel. If your PCB has only one piezo connector connect the discs in parallel. Ensure all three discs have the same polarity – see electrical below.
 - iii. Heat is problematic for piezo disc and this is especially worthy of consideration when a heated print bed is being used. Try to design your mount to keep the disc away from the heat of the bed. Tune and probe with the bed heated to normal printing temperatures.

Instructions Electrical



1. The kit comes with a PCB, it has an endstop cable attached. The cable comes ready connected to the PCB by the three way plug at one end. If you detach it please ensure you replace it correctly, reverse polarity might damage the PCB and/or your 3D printer controller. The pins are not the same way around as a standard endstop cable, they go V+, TRG, GND – red, green, black.
2. The default connections on the piezo v2 PCB are GND, TRG, and V+. The GND, TRG and V+ are usually connected to your endstop connector on your printer controller, but some controllers do not have a V+ (they have 2 pin connectors GND, SIG/TRG) so V+ should be connected to a source of 5v or 3.3v depending on your setup. The TRG is a modulated signal, when the board triggers it goes from having a voltage to zero volts (equivalent to NC also called active low). There is a 0.25sec delay on this trigger so you can see it triggering easily. If your printer cannot use an active LOW signal for a probe/endstop and you cannot change the firmware/config then see appendix 1.
3. The other end has crimped connections. A 3 way and 4 way plug are provided. Please insert the crimped connectors into the plug housing in the correct order for your controller board. You should check your controller's documentation to ensure they are the right way around. This is your responsibility, make sure it is correct.



The 3 pin plug shown above (middle) is suitable for ramps, the four pin (right) is setup for Duet wifi/ethernet. Make sure the crimp locks into place in the plug housing, if not rotate it and re-insert it. Check your controller board's documentation carefully!

4. The piezo disc should be attached to a two pin dupont-style 2.54mm/0.1inch connector. It has a red lead and a black lead. We do not pre-crimp these for you as you may need to extend the leads from the piezo to suit your design. You cannot always presume the piezo leads are positive-red and negative-black as it depends on the ceramic contained within. However there is a method by which you can test it.
 - a. If you have an oscilloscope attach it to the disc with Red to your probe connector, and black to ground. Press or bend the disc in the same way you intend to use it in your implementation, and ensure the trace shows voltage rising as it is pressed. If voltage rises as you release it the polarity may need to be reversed when connecting it to the PCB. There another method which can be used after assembly see "tuning" below.
5. If you have multiple discs then they should be connected to the PCB either individually (up to 3 discs if you want to connect more ensure all their positives and negatives are joined in parallel. As in 3 (above) polarity might need to be checked and reversed, see tuning below.

Instructions Firmware

In your firmware you need to configure a `z_min_endstop` or `z_probe`. Follow your manufacturer's instructions and those for your firmware. More details can be found on thingiverse <http://www.thingiverse.com/thing:2069480> however firmware changes so use forums/facebook/github relevant to your controller to keep up to date. The PCB by default provides a voltage when open (untriggered/at rest) and this drops to 0v when triggered.

Your firmware or config files need to be setup to accept an active low signal, also called NC or inverted.

If you cannot set active low in firmware or config, then you need to see appendix 1 and instead use the SIG pin on the piezo PCB to connect to the signal pin on your controller.

With V1 board (or if using the SIG pin on V2) please ensure endstop pullup is disabled for the `z_min` endstop, or `z_probe` (if you use a separate z-probe connector on your controller).

When using TRG with V2 board (the default setup) the endstop pullup can be ON or OFF.

Tuning

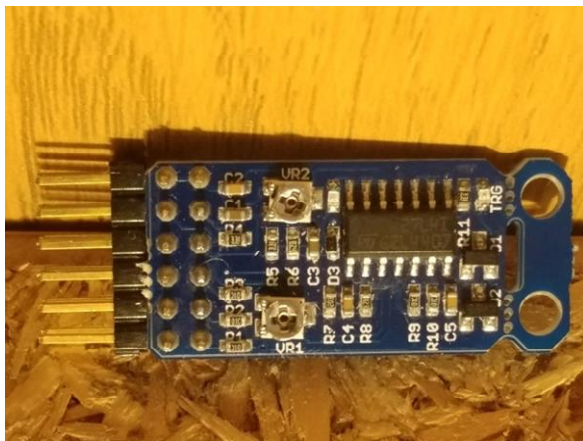
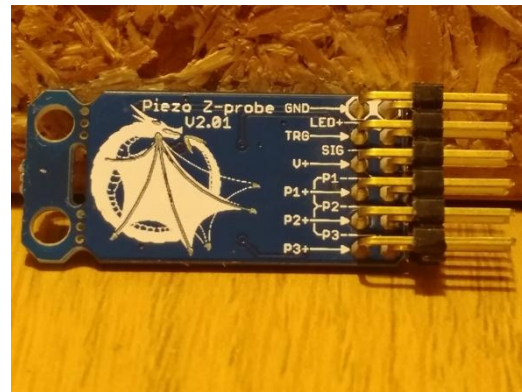
Please ensure your piezo disc/s are installed in your setup, that the PCB is powered up, and that the piezo disc/s are connected to the PCB.

- Set your hotend to around 130 Deg C (see “operation” below for why).
- It makes sense to set your print bed to normal first layer temperature.
- If using an enclosure set your chamber to the normal temperature you would use during probing i.e. at the start of a print typically, or allow your enclosure to warm up to the normal temperature it would be at the start of a print. Approaching 60 Deg C some piezos will lose the ability to produce a clear signal, so probing with a lower chamber temperature is advised, if it behaves oddly and no other cause can be found.

There are two adjustments possible. There is a VR2 adjuster and a VR1 adjuster.

It helps to measure the resistance of VR1 with a multimeter. Measure from the middle of the adjuster (or via your screwdriver) to any piezo positive (P1+,P2+,P3+) pin. If you read from a piezo negative (P1,P2,P3) pin you will always read approx. 10KOhm, so use a **positive** pin. A value of 0.4MOhm is the recommended starting point, higher resistance/value means more sensitive.

Don't turn these more than necessary they can wear out if turned fully more than 20 times.



1. Using a small screwdriver, carefully turn VR2 adjuster- at a certain point the blue LED goes out and the red (TRG) one turns on. Set it to the point *just* past the point where the red LED comes on, you might adjust this later, for fine sensitivity. See Appendix 2.
2. VR1 adjuster is a gross sensitivity adjustment. Tap lightly upwards on your nozzle (use a tool if hot), you should see the TRG red LED go off for 0.25 seconds. Move the head around and see if it triggers from normal head movement, if so turn the VR1 adjuster down (lower resistance value) to reduce sensitivity. The two adjustments affect one another so move to step 3.
3. After changing VR1 (higher resistance is more sensitive, lower resistance is less sensitive) you should repeat step 1. Slight flickering during moves is acceptable as you are not probing at that point. It is a balance between too sensitive resulting in too many false triggers, and

not sensitive enough which might not trigger on probing. Once set move on to section "operation" and test that it triggers normally. Optionally mark the adjusters. See "mechanical noise" below

4. POLARITY CHECK – after tuning is complete for hotend sensors, press up on your COLD nozzle sharply and observe the red TRG LED go off. If it goes off *as you press up* then the piezo polarity is correct. If it goes off *as you release the pressure* then it is reversed. Reverse the piezo plug and go back to step 1 above. For underbed piezo's press down sharply on the bed, observe the TRG LED go off as you press down. Press down on the bed over each of the the piezos and check the same behaviour occurs, also press in the middle of the bed and ensure the same behaviour. If any individual piezo generates the red LED going off (i.e. a trigger), when you release the pressure its polarity is wrong, reverse it at the PCB. Not all piezos have the red and black wires the right way around, though we do try to test them before we ship them.
 - Please note If your design is such that the piezo is bent in the other direction from most common designs the polarity might need to be the reversed. I.e. a design using levers which pull on the disc when the bed is pressed downwards.
 - When you first test the probing if it performs badly and seems to trigger late check the polarity.
 - Electrical interference – if when tuned you notice a lot of flickering on the triggered LED, especially when you aren't moving the hotend or bed, then it might be electrical interference, this is reduced by keeping piezo leads short and avoiding routing them with motor/fan/heater wires.
 - Mechanical noise is the vibrations caused by movement of the printer (bearings, motors etc..), piezos are very sensitive and will detect it. If the sensor is attached to an axis that must move when probing I.e. a corexy wth moving Z then low acceleration and zero jerk when probing will help a lot.

Operation

Probing is done by contact of the nozzle with the bed surface. Probing speed should be between 4-7mm/s (240-420mm/min) for hotend sensors, it is the equivalent of a gentle tap on the bed. Underbed sensors might trigger at even lower speeds such as 2mm/s (120mm/min). If too slow the probe might not trigger, as the device works by detecting a voltage rise from the piezo, as it is bent/squeezed quickly, it detects change, a faster tap gives a bigger signal. You might need to increase your Z max feedrate if you use fine pitched leadscrews on your z axis, use low acceleration for Z, such as 100mm/min but higher speed.

Piezo Sensors are very sensitive this makes them excellent z-probes however they are so sensitive false triggers can occur If your probe is on an axis that moves during the actual probing "dive" (I.e. underbed on a corexy) use zero jerk and low acceleration for probing (in your start gcode or macro). If the probe is on an axis that is stationary when the probing dive takes place you can use "pause before probing" (now available on all major firmwares after we requested it) of 0.5 seconds or so, coupled with Z-acceleration of 100-200 mm/s².

When first testing if possible (and easy to do from software) reduce your stepper motor currents to a minimum so that if it does not trigger no damage will occur, this is practical if your motor currents are set from software, i.e. digipot/duet etc.. Move your nozzle away from the bed around 100mm, command a single probe (G30 in most firmware) and then lightly tap the nozzle upwards as it descends with a finger/tool **before it hits the bed**. The firmware should respond, usually by moving the nozzle upwards (or bed downwards in the case of a bed moving in Z). This indicates that the kit is working and that the firmware is properly configured. If nothing happens, kill the power to avoid a head crash, check the firmware z_min or Z-probe logic is correct, if unsure reverse it and try this test again.

When you are confident it triggers on contact you can now use the kit for 3 functions:

- 1) Homing to Z-min.
- 2) Autolevelling/grid levelling/auto calibration
- 3) Setting the first layer height/enabling quick bed changes.

Homing to Z_min

This is self-explanatory, when firmware is set to home to Z-min the probe will trigger when the nozzle contacts the bed. This sets the z origin or z=0 level. This is best done with the probe at the bed centre but ensure the nozzle is somewhere over the bed when homing z.

Autolevelling/grid levelling/auto calibration

Probing across the bed can compensate for irregularities, tilt and in the case of deltas with appropriate firmware can calibrate the machine.

Setting the first layer height/Quick Bed Changes

This is most useful where a machine is perhaps not mechanically perfect and the level varies from time to time. After levelling or calibration, you can send G30 Z0 in Smoothieware or G30 in RepRapFirmware to reset the Z level which should mean the nozzle is the correct distance when you begin printing (provided you set the correct z offset - see below). This command can be added to

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your starting gcode, so if you remove one printing surface, and insert another a variation in thickness will not require you to perform lengthy calibration/adjustment, one quick probe or home and you can print immediately. This probe is not affected by reflectivity of the surface or coatings like hairspray/3dlac on the bed.

Z offset

Whilst there is no x or y probe offset as the probe is the nozzle, and this is one of the most advantageous features of this system, there does need to be a slight Z offset as the piezos bend/compress slightly on probing. To measure this home_z (if using probe as z_homing device) or send G30 to probe once. Then raise the nozzle and insert a piece of paper, lowering it manually in small increments (0.05-0.1mm) until it is gripped firmly. Measure the difference between the z=0 after the G30 and the Z level with the firmly gripped paper between nozzle and bed. This is likely to be 0.1-0.2mm now enter that in your firmware as z_probe offset, use a negative value e.g. enter it as -0.1. You can add this in your slicer instead using Z-offset +0.1 for example. Use something thinner than paper for an even more accurate result. Some firmware such as RRF allows G30 S-1 which reads out the distance travelled from which you subtract from the height before you sent the command, this means no paper is needed.

Temperature of Nozzle and Bed, Cleaning the nozzle

You should probe with a **clean nozzle**. Clip any residual filament from it with a wire cutter or similar instrument. It is possible to probe with slight residue on the nozzle if probing hot (see below) but large amounts of filament might affect the accuracy of your result (and leave blobs of filament on your printbed).

For best practice, we advise to set the nozzle to 130 deg C or thereabouts, which should be below the "ooze-temperature" of almost all filaments but allow deformation of any residue. To the best of our knowledge a momentary contact of a "warm" nozzle will not damage any common printing surface, after all filament when it is extruded is hot. Clip any residual filament from the nozzle. The bed should be set to the normal first layer temperature for the material you are using. This is especially important if your bed deforms when hot and you intend to use mesh/grid-levelling or equivalent to facilitate better printing.

It is possible to probe with nozzle and bed cold, if your nozzle is very clean. After probing heat up your printer's bed and nozzle then use the method above to calculate the z-offset when heated.

We calculate for an e3d v6 hotend the thermal expansion of the heater block and heatbreak from 130 to 250 deg C is only 0.02mm you might choose to factor that in to your z-probe offset, but it will make little difference to a typical 0.2-0.3mm thick first layer.

Additional Information

As your nozzle moves over a previous layer, the TRG LED might go out periodically, the sensor is so sensitive you are detecting nozzle contact with the previous layer. This will not affect your printer's operation as long as your firmware is set to "use endstops only for homing" or if you have connected the sensor to a dedicated z-probe connector. However, it is useful to see if your print is progressing well, a lot of contact with the previous layers may indicate over-extrusion or curling of overhangs or blobs on the print. More triggering on one side of the print than the other might indicate a bed level issue.

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Appendix 1 – TRG and SIG whats the difference?

There are two outputs from a v2 piezo PCB. TRG which has been discussed so far is a monostable active low output, i.e. it outputs a voltage when the system is open, and then drops to 0v when triggered and holds for 0.25 seconds. There is also SIG, which is marked on the PCB. SIG works the same as the V1 board and depending on how you have the board setup behaves differently.

If you cannot change your printers config/firmware to accept an active low signal on the z_min endstop or z_probe connector then you will have to connect V+, GND and SIG to your printer's controller instead of V+, GND and TRG. Make sure if you do to use 1 pin dupont plugs or insulate the SIG plug with heatshrink or electrical tape.

The two possible setups are:

Regular mode (as discussed above in this guide).

When open/untriggered the red TRG LED is ON, the blue LED is OFF. This is achieved by turning VR2 until the red LED is ON. When triggered the red LED goes OFF.

In this mode the SIG pin will output 0v unless triggered, then it rises to 3.3v/5v depending on what you power the piezo PCB with. Using SIG like this gives an active high (also called NO) signal. Use this if your printer cannot accept an active low signal.

Inverted mode (not required unless in some special circumstance)

In this mode the VR2 adjuster is turned so that the red LED is OFF and the blue LED is ON when in an open state/untriggered.

Now the SIG pin outputs a high voltage 3.3v/5v when open and drops to 0v when triggered. This is the equivalent of using TRG, but without the time delay, so we cannot see any advantage to using the board in this configuration, but it is an option if you find you cannot use it any other way. If you are coming from using the v1.x boards and you used to use this mode, retune the regular way and use TRG instead.

Appendix 2 – Fine adjustment of sensitivity.

Assuming you have set VR1 sensitivity to a reasonable level (0.4mOhm is the default setting) you can get a little fine tuning of sensitivity from VR2. Usually we suggest turning VR2 until the red LED come ON and leaving it there, just past that point. This is the **most** sensitive setting. If you turn it a little passed that point it reduces the sensitivity a small amount. This might be useful to eliminate false triggers. Don't turn it too far passed that point or it won't trigger at all. Experiment with it by tapping the hotend up, or bed down (depending on your setup) and see what effect this has on triggering behaviour.