Precision Piezo – Piezo20 Hotend Z-Probe For V6 Hotend

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Thank you for purchasing the Piezo20 sensor. 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.

If you have the ready to run version please proceed, if you have the self assembly kit then please follow the assembly video here http://bit.ly/2g01AjN and please read appendix 3.

Contents of package

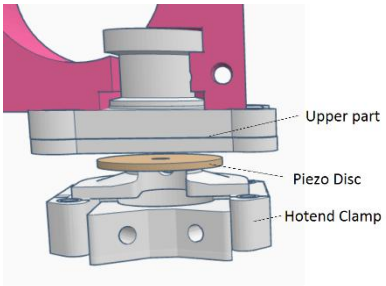
- Assembled Piezo20 sensor module
- With hotend clamp attached By 2x M3x20mm bolts
- Cable (attached) with 3 and 4 pin connector housings.
- Short length of Bowden tube/filament guide
- (For screw mount version also a drilling guide/keyfob)

Specifications

- Operating Voltage 3.3-5vdc, approx. 180mA (**NOT** tolerant of higher than 5v input)
- Indicator: LED Red power on, Blue Triggered
- Output: Active high 5v/3.3v when triggered
- Accuracy 0.01mm depending on printer's mechanical precision
- Repeatability std deviation: 0.007mm
- Probing Speed: 4-7mm/s
- Probing Force: 10-15g
- Operating temperature 10-35 deg C unless retuned (see below).

Open Source Hardware and replacement parts

Please note this is an Open Source Hardware device. As such all stl files to print replacement parts are available at https://www.precisionpiezo.co.uk/resources-osh for download. We suggest you print replacement parts before using the unit so that in the event of any problems you can replace any parts that you might need to.



Please use 0.2mm layer height, a 0.4mm nozzle (or smaller) and ABS filament, support is built in but in order for the parts to snap apart after printing, your extrusion needs to be well calibrated. Having as little first layer squash as possible will make printing and detaching the parts from one another more straightforward. The small upside down cone in the centre of the lower part is a custom support and should be discarded after printing, as are the two small angled towers with circular bases at the sides of the hotend clamp. File off any burs/blobs and ensure the hotend fits into the clamp, filing slightly where necessary.

The system of using piezo electric sensors for nozzle contact detection on 3D printers has been developed by Njål Brekke, Mike Simpson , Idris Nowell and Simon Khoury all active members of the reprap 3D printing community, and is an open source hardware project. If you want to adapt and develop this technology please get in touch and work with us, if you prefer to work alone all we ask is that our contribution is given attribution going forwards.

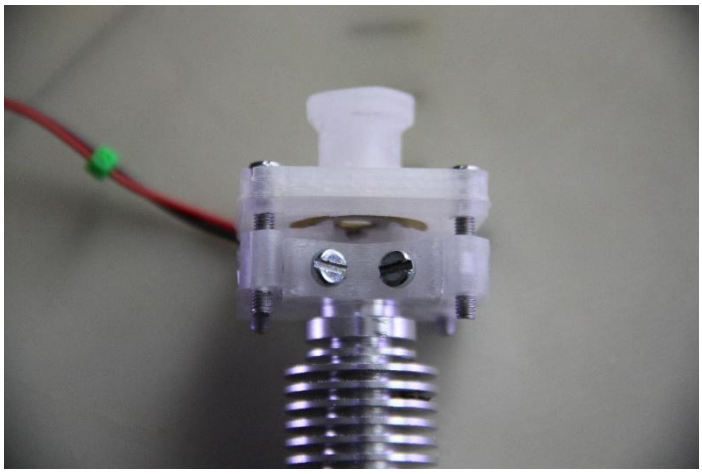
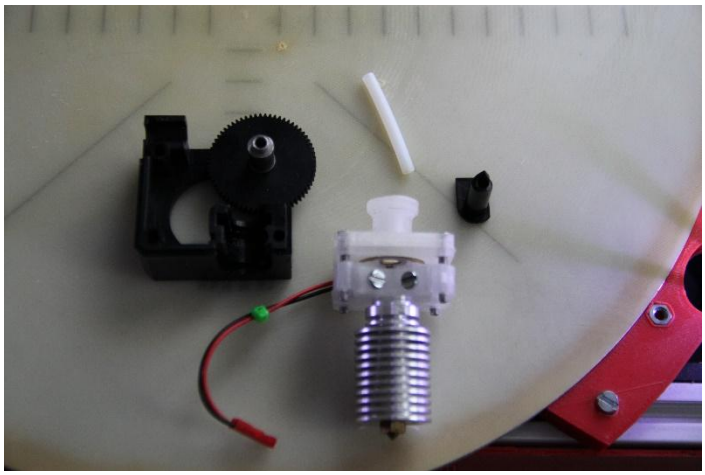
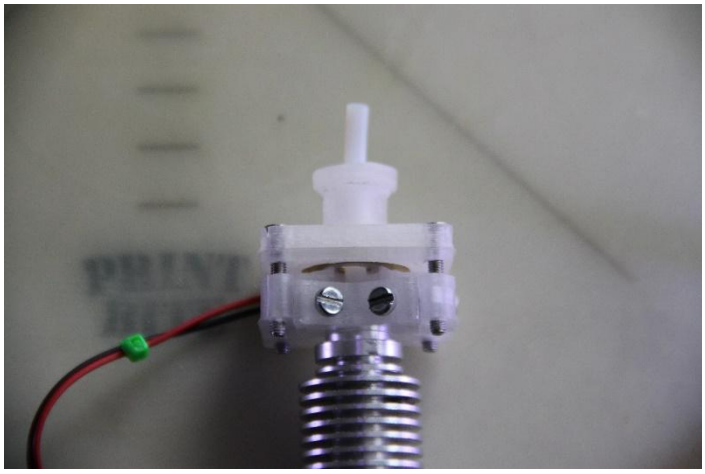
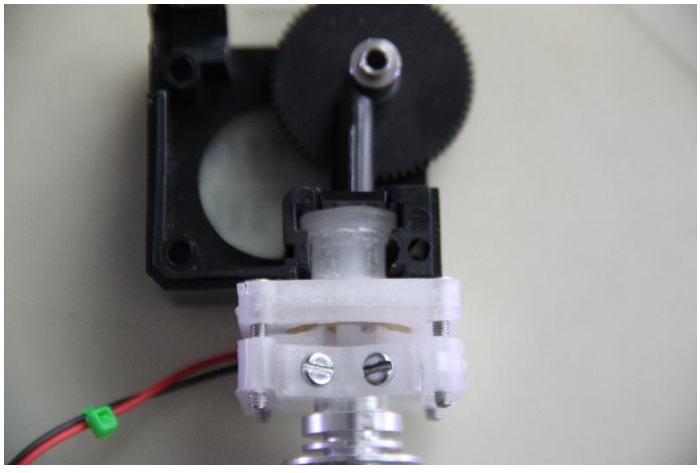
Safety

Piezo discs contain PZT which contains Lead (Pb) do not ingest or inhale the ceramic material within. However there are a couple of things to consider for safe operation. 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.

Like many endstop devices the module will not fail-safe although in a later version we hope to address this. What this means is that like any sensor without inherent failsafe i.e. inductive, IR, it is sensible to test the sensor before each printing session by just pushing up gently on your **cold** nozzle and observing to see the triggered LED light up to ensure it is working normally. Failure to do so in rare cases may occasionally result in a head crash.

Instructions Mechanical – For Screw-mount version see Appendix 1

1. Remove your groovemount hot end from your 3D printer. Insert it into the clamp firmly and

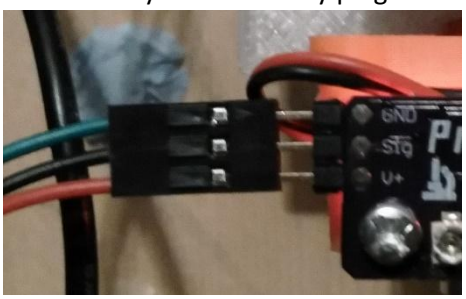





screw in the two m3x20mm screws. **Screw one in most of the way, then the other, then tighten them both.**

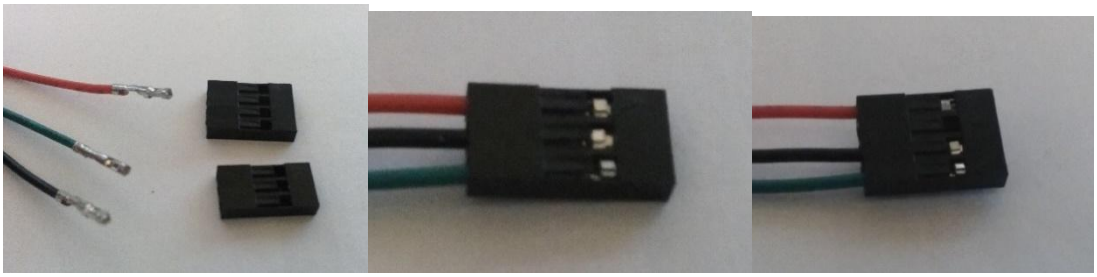
2. For 1.75mm direct drive, use the supplied Bowden guide tube (cut it to length with a very sharp knife) it needs to go from as close to the drive gear/hob as possible and down into your hotend. Depending on your extruder you might need to insert the bowden tube before installing the unit, see images above. Insert the Piezo20 module using its groovemount which matches the dimensions of the groovemount on your v6/clone hotend. It should be quite tight and the top surface of the upper part should sit flush with the base of your carriage/extruder for stability. The design has been optimised to fit into a titan extruder, although not all grooves are the same size. If it is too tight a little filing may be needed. Should it be too loose, which is unusual as the groovemount is deliberately slightly oversized, you can shim it with a small piece of paper, or aluminium foil etc..

Instructions Electrical

1. If your piezo disc needs to be connected to the unit (kit version) please note the PCB is marked on the back with + and – near the 2 pin piezo connector, these are actually the wrong way around, using Murata 7BB piezo discs, connect black to + and red to – please see appendix 4 for more details on piezo polarity.
2. The unit has the PCB on the front which has power (red) and triggered (blue) LEDs.
3. The cable comes ready connected to the Piezo20 unit 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.



4. 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 to ensure they are the right way around.



The 3 pin plug shown here (middle) is suitable for ramps, the four pin (right) is setup for Duetwifi. Make sure the crimp locks into place in the plug housing, if not rotate it and re-insert it.

5. To test the basic functionality of the device, which was pre-set at assembly, power up your machine. The red power LED should be visible on the Piezo20 PCB, or illuminating the module.
6. Press upwards on your (cold) nozzle with your finger. A light tap should cause a the blue LED to light up briefly which indicates triggered.

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 the forums to keep up to date.

Tuning

The unit has been setup at assembly so that it functions, and has been through tests simulating normal use, and a variety of probing speeds however some drift of this tuning may occur in transit or it might require retuning if you are using it in a heated chamber. Set your hotend to around 130 Deg C (see "operation" below for why). If using in a chamber heat your chamber to normal printing temperature.

There are two adjustments possible. There is a VR2 (left) adjuster and a VR1 (right) adjuster when viewed with Precision Piezo Logo facing towards you.

It helps sometimes to read the value of the VR1 adjuster with a multimeter set to measure resistance/ohms. Measure from the **LOWER** piezo connector (+) on the back, to the **centre** of the VR1 adjuster. The best starting value is 0.4Mohm. Set this value. If you are not sure if you can do this without risking shorting something with your multimeter probe remove the GND, Sig, V+ connector before measuring. If you are always measuring 10Kohm then you are measuring from the wrong piezo pin, try the other one.

1. Using a small insulated screwdriver, carefully turn VR2 adjuster- at a certain point the triggered LED goes out. Set it to the point *just* below the point where the LED goes out.
2. VR1 adjuster is a sensitivity adjustment. Tap lightly upwards on your nozzle (use a tool if hot), you should see the triggered LED light up positively. Move the head around and see if it triggers from normal head movement, if so turn the RIGHT adjuster down to reduce sensitivity. Measure the resistance, 0.4mOhm is standard, higher value is more sensitive.
3. After doing this you should repeat step 1. Slight flickering during moves is acceptable as this is below trigger level. It is a balance between too sensitive and too many false triggers, and not sensitive enough which might not trigger on normal probing. Once set move on to section "operation" and test that it triggers normally. Optionally mark the adjusters.
4. For a couple more tuning tips see appendix 2.

Operation

Probing is done by contact of the nozzle with the bed surface. Probing speed should be between 4-7mm/s (240-420mm/min) it is the equivalent of a gentle tap on the bed. Very slow probing might not trigger the device which works by detecting a sudden voltage rise as it is compressed quickly, think of it as somewhere between a microswitch and a microphone. You might need to increase your Z max federate if you use fine pitched leadscrews on your z axis.

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" 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) 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 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 module 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 module 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 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 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 assembly bends 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 (0.1mm) 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 i.e. enter it as -0.1. You can add this in your slic3r 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. To the best of our knowledge a momentary contact of a hot nozzle will not damage any common printing surface, but this slightly lower nozzle temperature, is recommended to avoid this occurring. 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 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.

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 triggered LED might flicker or light up, 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.

Maintenance, repair and retuning

The unit requires no maintenance under normal operation. The piezo sensors are extremely robust and will survive normal probing for many years and probably an occasional head crash. In testing one of these units probed 36800 times over 3 days, simulating several years use with no change in performance.

If you are using the unit in a higher-than-normal temperature environment, i.e. heated chamber or in a climate where air temperatures are likely to be 40 deg C or higher then the PCB might need to be re-tuned. Please see “tuning” above. 60 deg C or will result in unexpected behaviour, if your chamber can go higher than this please probe at or below 60 deg C.

If it is necessary to replace parts dismantle the unit carefully, being especially careful of the PCB and the wires from the piezo disc. Reassemble in reverse, ensure the piezo disc faces towards the nozzle and that the solder pad sits within the space in the flange on top of the clamp. Be extremely careful with the leads to the piezo disc, they can de-solder easily. See my Youtube channel for an assembly guide https://goo.gl/xWvVzD

Tighten the module 's 4 bolts evenly ensuring they are hand tight with the piezo disc lightly compressed but not grossly deformed.

Go to "Tuning" above and complete these steps.

If you have any issues we have a thread running in Reprap General Forum. Search it first as your issue may already be covered.

If you wish to dismantle the unit and rebuild it into your own version of the piezo hotend z-probe please do so, see our website for more resources. It is worth bearing in mind that the piezo disc is most sensitive to bending, so support it around its perimeter and ensure the upwards force of the nozzle probing the bed is transferred to as close to the centre of the disc as possible. Please note that warranty will not be offered if the unit is reassembled into something else, although support can still be obtained via our support thread on reprap forums (please see www.precisionpiezo.co.uk).

Appendix 1 – Screwmount Piezo 20

If you have purchased the screwmount version of the Piezo20, the instructions here are the same except for mounting your module to your printer.

If designing an effector or carriage then you will need 2x 3mm (3.5mm with tolerance) holes through which 2x m3 machine screws can be inserted which tighten onto 2x m3 nuts heat pressed into the upper part of the module. The hole spacing is 25mm, centre to centre.

Please ensure your screws go just far enough to hold the unit if they go a lot further they will prevent the unit from compressing on nozzle contact.

If you are attaching it to your existing setup, a drilling guide is provided, for your convenience, it looks like a keyfob.

Appendix 2 – Tuning Tips

So there are two cases generally where tuning might be needed:

Not Sensitive Enough

If the unit is not sensitive enough, it triggers but requires quite a heavy contact with the bed, or only triggers after a bit of deformation in the assembly. Check your probing speed is in the 5mm/s range (4-7 should work), if in doubt try slightly faster, the piezo works by generating a rising voltage on “impact” so too slow will result in poor/no trigger.

Quick fix: Adjust the Left adjuster (VR2) so that the blue LED just lights up, then turn the other way so that it goes out, If you are quite close to the point where it goes out the sensitivity will be boosted.

Longer Answer:

Now ideally measure the resistance of the right adjuster (also labelled VR1 on some boards) it is usually 0.4Mohm.

Adjust it to a higher resistance i.e. 0.6-0.8Mohm. Now turn VR2 the blue LED will light up at a certain point, turn the other way until it just goes out.

Hopefully this solves the problem.

Too Sensitive

You can probably guess reading the section above what the solution is:

Quick fix: turn Left/VR2 adjuster until the blue LED lights up, then back until it goes out, but carry on maybe 1/10 of a turn past that point.

Longer Answer: Lower the resistance of Left/VR1, then retune Right/VR2.

Appendix 3 – Self Assembly Piezo20 Module

If you have bought the self-assembly Piezo20 module you will be able to construct a fully functional Piezo20 by watching the all-in-one assembly video at http://bit.ly/2g01AjN there is also a longer sequence of videos here https://goo.gl/1pVG8g once your unit is assembled and has passed basic testing, please go back to the start of this manual.

There is one consideration which is not mentioned above and that is piezo polarity.

The piezo discs will output a polarised signal. If connected the right way around, then they generate a rising voltage when bent or compressed. The PCB detects this and if it is over threshold a trigger occurs.

If you press the (cold) hotend upwards and keep the pressure on you should get a trigger as you push up, then when you release nothing should happen. However if you get a trigger as you release then the piezo polarity is wrong, reverse the plug from the piezo disc to the piezo PCB.

Another sign that the polarity is wrong is seeing what appears to be a delayed trigger, or a heavy contact by the nozzle. If tuned correctly the force required to trigger the system will be the gentlest of gentle taps. Check polarity using these methods here, or reverse it and test the other way to rule it out. If polarity is correct go back to the tuning.

Appendix 4 Piezo Disc polarity

Because of the nature of piezo ceramic the polarity of a piezo disc cannot always be assumed from the colour of the leads. The Murata 7BB piezos we supply are mostly correct, but occasionally the manufacturing process means they will be reversed.

If you are assembling a kit Piezo20 unit then normally the black piezo wire will go the outermost pin of the 2-pin piezo connector.

To test polarity is correct follow the tuning steps on page 4, then power up your unit, PUSH up (not tap) and observe what happens. If it triggers as you push up its correct. If it triggers when you release then the piezo disc polarity is reversed. Reverse the piezo disc plug.