This document describes the method for calibrating the x, y, and z offsets of an "automatic z probe" in Klipper. This is useful for users that have a `[probe]` or `[bltouch]` section in their config file.

Calibrating probe X and Y offsets

To calibrate the X and Y offset, navigate to the OctoPrint "Control" tab, home the printer, and then use the OctoPrint jogging buttons to move the head to a position near the center of the bed.

Place a piece of blue painters tape (or similar) on the bed underneath the probe. Navigate to the OctoPrint "Terminal" tab and issue a PROBE command:

```
PROBE
```

Place a mark on the tape directly under where the probe is (or use a similar method to note the location on the bed).

Issue a `GET_POSITION` command and record the toolhead XY location reported by that command. For example if one sees:

```
Recv: // toolhead: X:46.500000 Y:27.000000 Z:15.000000 E:0.000000
```

then one would record a probe X position of 46.5 and probe Y position of 27.

After recording the probe position, issue a series of G1 commands until the nozzle is directly above the mark on the bed. For example, one might issue:

```
G1 F300 X57 Y30 Z15
```

to move the nozzle to an X position of 57 and Y of 30. Once one finds the position directly above the mark, use the `GET_POSITION` command to report that position. This is the nozzle position.

The x_offset is then the `nozzle_x_position - probe_x_position` and y_offset is similarly the `nozzle_y_position - probe_y_position`. Update the printer.cfg file with the given values, remove the tape/marks from the bed, and then issue a `RESTART` command so that the new values take effect.

Calibrating probe Z offset

Providing an accurate probe z_offset is critical to obtaining high quality prints. The z_offset is the distance between the nozzle and bed when the probe triggers. The Klipper `PROBE_CALIBRATE` tool can be used to obtain this value - it will run an automatic probe to measure the probe's Z trigger position and then start a manual probe to obtain the nozzle Z height. The probe z_offset will then be calculated from these measurements.

Start by homing the printer and then move the head to a position near the center of the bed. Navigate to the OctoPrint terminal tab and run the `PROBE_CALIBRATE` command to start the tool.

This tool will perform an automatic probe, then lift the head, move the nozzle over the location of the probe point, and start the manual probe tool. If the nozzle does not move to a position above the automatic probe point, then `ABORT` the manual probe tool and perform the XY probe offset calibration described above.

Once the manual probe tool starts, follow the steps described at "the paper test") to determine the actual distance between the nozzle and bed at the given location. Once those steps are complete one can `ACCEPT` the position and save the results to the config file with:

```
SAVE_CONFIG
```

Note that if a change is made to the printer's motion system, hotend position, or probe location then it will invalidate the results of PROBE_CALIBRATE.

If the probe has an X or Y offset and the bed tilt is changed (eg, by adjusting bed screws, running DELTA_CALIBRATE, running Z_TILT_ADJUST, running QUAD_GANTRY_LEVEL, or similar) then it will invalidate the results of PROBE_CALIBRATE. After making any of the above adjustments it will be necessary to run PROBE_CALIBRATE again.

If the results of PROBE_CALIBRATE are invalidated, then any previous bed mesh results that were obtained using the probe are also invalidated - it will be necessary to rerun BED_MESH_CALIBRATE after recalibrating the probe.

Repeatability check

After calibrating the probe X, Y, and Z offsets it is a good idea to verify that the probe provides repeatable results. Start by homing the printer and then move the head to a position near the center of the bed. Navigate to the OctoPrint terminal tab and run the `PROBE_ACCURACY` command.

This command will run the probe ten times and produce output similar to the following:

```
Recv: // probe accuracy: at X:0.000 Y:0.000 Z:10.000
Recv: // and read 10 times with speed of 5 mm/s
Recv: // probe at -0.003,0.005 is z=2.506948
Recv: // probe at -0.003,0.005 is z=2.519448
Recv: // probe at -0.003,0.005 is z=2.519448
Recv: // probe at -0.003,0.005 is z=2.506948
Recv: // probe at -0.003,0.005 is z=2.519448
Recv: // probe at -0.003,0.005 is z=2.519448
Recv: // probe at -0.003,0.005 is z=2.506948
Recv: // probe at -0.003,0.005 is z=2.506948
Recv: // probe at -0.003,0.005 is z=2.519448
Recv: // probe at -0.003,0.005 is z=2.506948
Recv: // probe accuracy results: maximum 2.519448, minimum 2.506948, range 0.012500, average 2.513198,
median 2.513198, standard deviation 0.006250
```

Ideally the tool will report an identical maximum and minimum value. (That is, ideally the probe obtains an identical result on all ten probes.) However, it's normal for the minimum and maximum values to differ by one Z "step distance" or up to 5 microns (.005mm). A "step distance" is `rotation_distance/(full_steps_per_rotation*microsteps)`. The distance between the minimum and the maximum value is called the range. So, in the above example, since the printer uses a Z step distance of .0125, a range of 0.012500 would be considered normal.

If the results of the test show a range value that is greater than 25 microns (.025mm) then the probe does not have sufficient accuracy for typical bed leveling procedures. It may be possible to tune the probe speed and/or probe start height to improve the repeatability of the probe. The `PROBE_ACCURACY` command allows one to run tests with different parameters to see their impact - see the G-Codes document for further details. If the probe generally obtains repeatable results but has an occasional outlier, then it may be possible to account for that by using multiple samples on each probe - read the description of the probe `samples` config parameters in the config reference for more details.

If new probe speed, samples count, or other settings are needed, then update the printer.cfg file and issue a `RESTART` command. If so, it is a good idea to calibrate the z_offset again. If repeatable results can not be obtained then don't use the probe for bed leveling. Klipper has several manual probing tools that can be used instead - see the Bed Level document for further details.

Location Bias Check

Some probes can have a systemic bias that corrupts the results of the probe at certain toolhead locations. For example, if the probe mount tilts slightly when moving along the Y axis then it could result in the probe reporting biased results at different Y positions.

This is a common issue with probes on delta printers, however it can occur on all printers.

One can check for a location bias by using the `PROBE_CALIBRATE` command to measuring the probe z_offset at various X and Y locations. Ideally, the probe z_offset would be a constant value at every printer location.

For delta printers, try measuring the z_offset at a position near the A tower, at a position near the B tower, and at a position near the C tower. For cartesian, corexy, and similar printers, try measuring the z_offset at positions near the four corners of the bed.

Before starting this test, first calibrate the probe X, Y, and Z offsets as described at the beginning of this document. Then home the printer and navigate to the first XY position. Follow the steps at calibrating probe Z offset to run the `PROBE_CALIBRATE` command, `TESTZ` commands, and `ACCEPT` command, but do not run `SAVE_CONFIG`. Note the reported z_offset found. Then navigate to the other XY positions, repeat these `PROBE_CALIBRATE` steps, and note the reported z_offset.

If the difference between the minimum reported z_offset and the maximum reported z_offset is greater than 25 microns (.025mm) then the probe is not suitable for typical bed leveling procedures. See the Bed Level document for manual probe alternatives.

Temperature Bias

Many probes have a systemic bias when probing at different temperatures. For example, the probe may consistently trigger at a lower height when the probe is at a higher temperature.

It is recommended to run the bed leveling tools at a consistent temperature to account for this bias. For example, either always run the tools when the printer is at room temperature, or always run the tools after the printer has obtained a consistent print temperature. In either case, it is a good idea to wait several minutes after the desired temperature is reached, so that the printer apparatus is consistently at the desired temperature.

To check for a temperature bias, start with the printer at room temperature and then home the printer, move the head to a position near the center of the bed, and run the `PROBE_ACCURACY` command. Note the results. Then, without homing or disabling the stepper motors, heat the printer nozzle and bed to printing temperature, and run the `PROBE_ACCURACY` command again. Ideally, the command will report identical results. As above, if the probe does have a temperature bias then be careful to always use the probe at a consistent temperature.