Top Ten Prints to Calibrate your 3D Printer

Get the most out of your 3D printer with these calibration tests which are designed to reveal small adjustments you can make to get your 3D prints to really shine.
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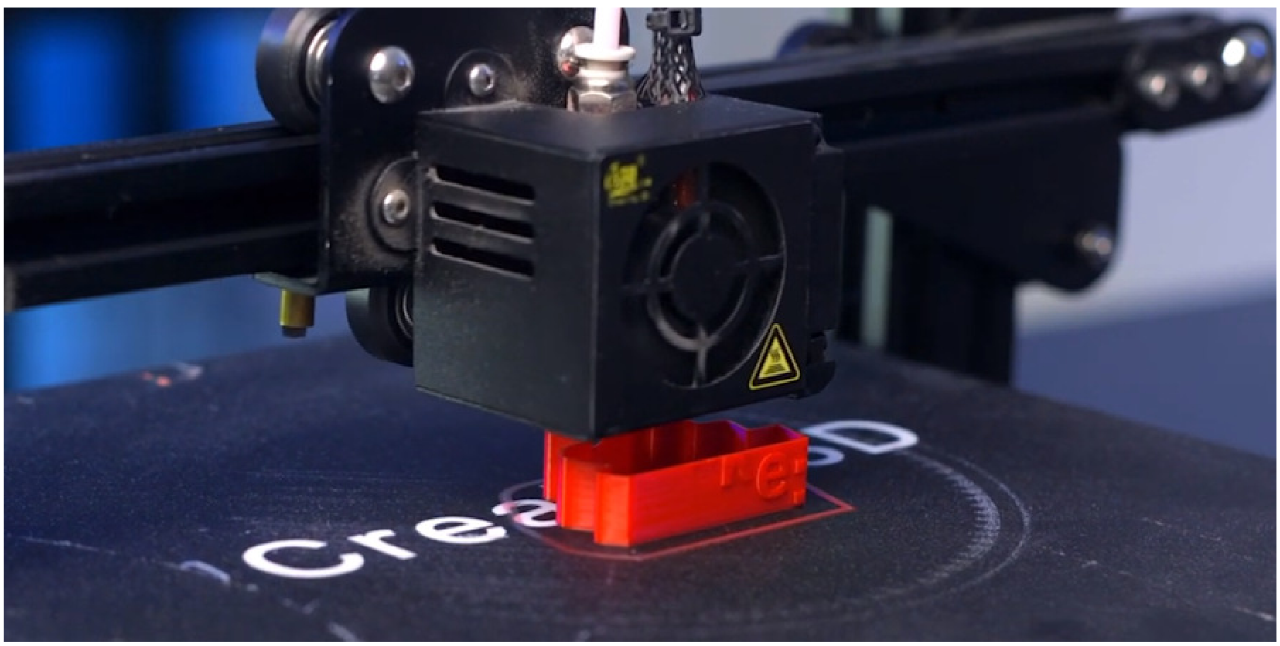
When we test a new printer or material, we will usually run them through these set of different calibration prints. In previous years, MAKE magazine put together a list of FFF and SLA 3D printers and tested them using a set of 3D models specifically tailored for different geometry conditions. Each model is designed to test one specific facet of the 3D printing experience, from overhang quality to Z-banding to support removal. MAKE would score each test from 1 to 5 with 1 being a total failure and 5 being a perfect print with no defects related to that test (and one test was pass or fail). With this set of 3D models, you can fine tune your 3D printer to optimize your 3D printer's capabilities and finished 3D print quality.

Vertical Surface Test

This test is designed to look for "ghosting" or “ringing,” where features echo and ring out along vertical surfaces.

As the print head makes a quick movement, it can oscillate, which creates a ring effect.The oscillations diminish on longer lines and the vertical surfaces clear up until a sharp turn is made again. Ghosting can come from a lack of rigidity like a loosely mounted hotend or a wobbly frame, springy belts, printing at high speeds with a heavy direct-drive print head, a bed that isn't rigidly mounted, or firmware settings for acceleration or jerk that are too high for what the printer can achieve.

Some printers can handle high jerk and acceleration, where others will falter and show significant error because of it.

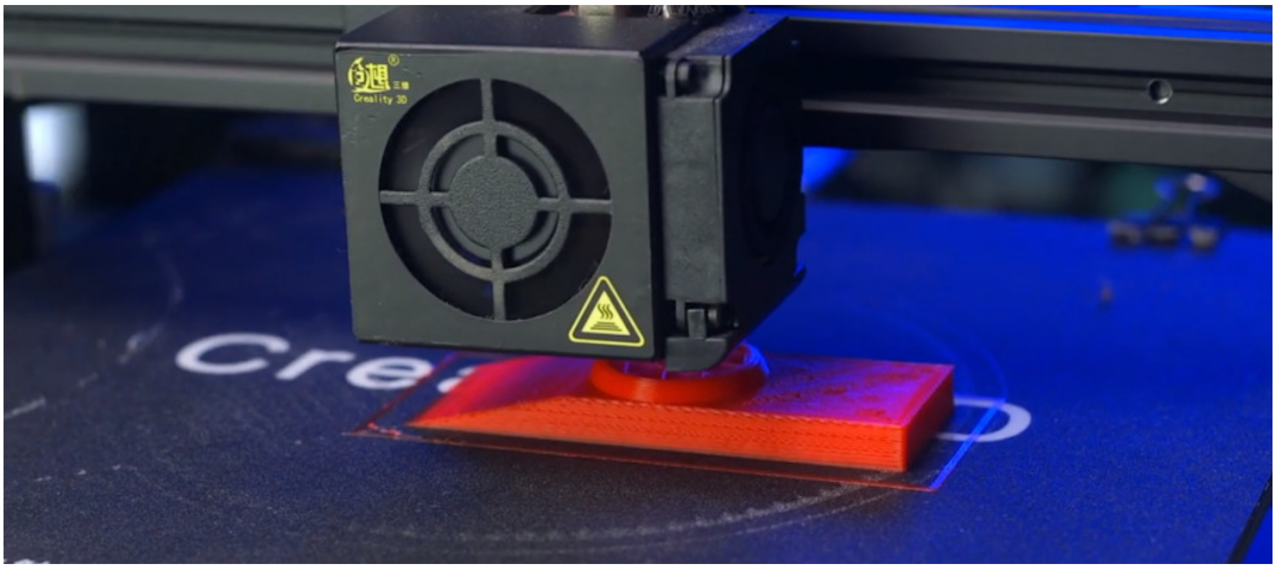


Vertical Surface Test

Horizontal Finish Test

With three different sections - flat, slope, and domed - you are able to see any sort of artifact or ridges from where the perimeters start and end. The more noticeable these points, the lower the score.

Cleaning this up depends on slice settings about perimeters, like start and end overlap, overlap percentage, and where the seam (start/end point of each outer perimeter) is located.



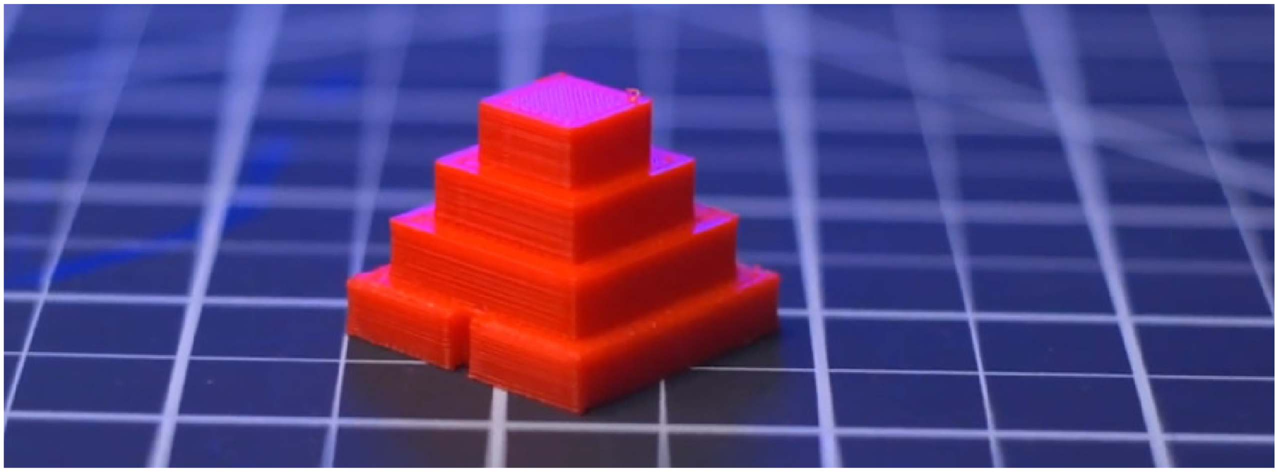
Horizontal Surface Test

Dimensional Accuracy Test

When you're printing coasters and keychains, it doesn't really matter if a part is 0.2mm too wide, but for multi-part prints that need to fit together, the accuracy of each part is very important to keep things fitting properly. Slots for connector pieces can be just fine off of Printer A but too tight to use from Printer B, or holes for nuts and bolts are supposed to allow for easy installation, but require unnecessary force to assemble.

The second level of this pyramid is supposed to be 20mm wide and deep, and loses points based on the average deviation from 20mm; if the average deviation is between 0 and 0.1mm, a full 5 points is earned. If the deviation is between 0.1mm and 0.2mm, 4 points are earned, and so on.

If you get a bad score, you should run through a calibration sequence for your extruder, making sure that your e-steps are accurate. You can find a helpful guide on how to do that here.



Dimensional Accuracy Test

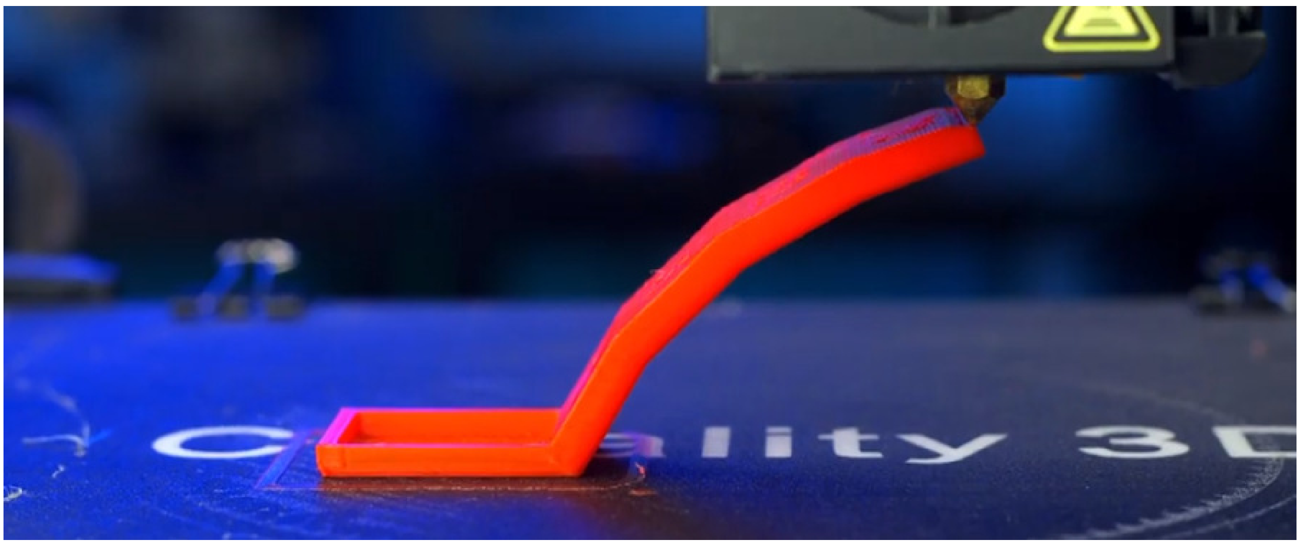
Overhang Test

This test is designed to see how well the printer can cool down the hot plastic as it is extruded; the better the cooling, the cleaner the bottom surface is. Printing speed does affect cooling, so the lower the print speed, the more time for freshly laid down filament to cool before the next layer is ready.

A small print with high print speeds is going to need much more cooling than a large print at slow speeds since material will have only a very brief amount of time to cool enough to solidify.

It is important to consider that the type of fan used for layer cooling (axial vs radial) and the direction your fan outlet is facing will impact how well an overhang is printed, so it would be wise to print this test rotated every 90 degrees to see if some faces fair better than others. You might even consider a new ducting for the cooling fan to try and direct the airflow toward the part.

Drooping, curling, and hanging filament all lower the score, especially when the lower angles have difficulty.



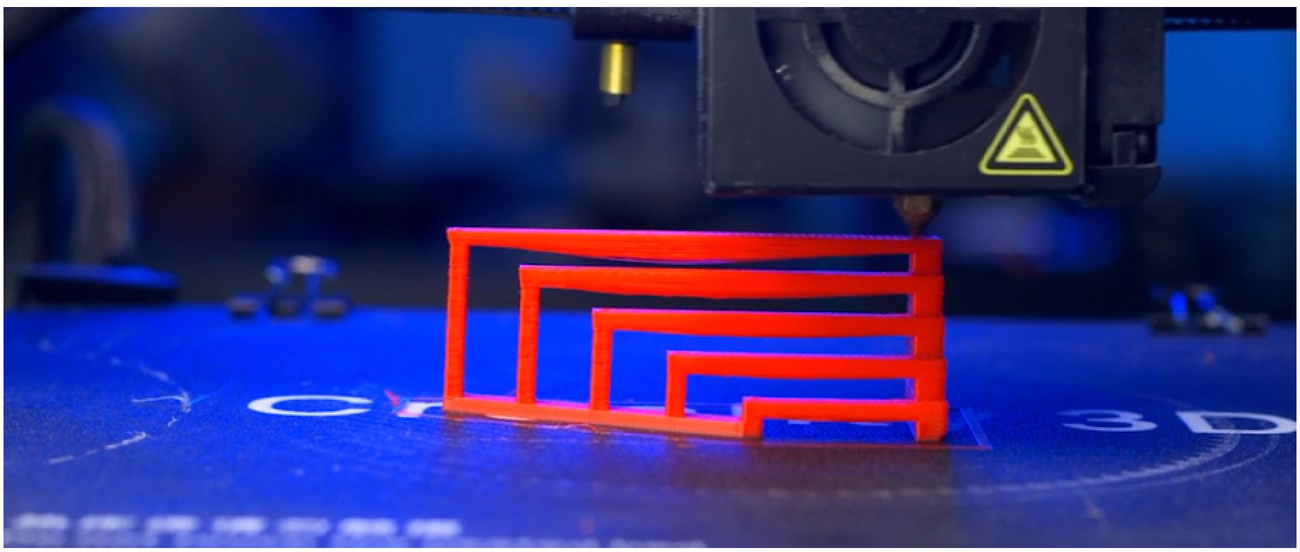
Overhang Test

Bridging Test

Most slicers have the ability to detect bridging, which is where filament needs to cross an unsupported span. Usually the slicer will turn up the layer cooling fan, slow down the print speed, and change how the this section is printed so the span is efficiently crossed with long strands rather than small zigzags.

This bridging test piece tests a bridging condition, but most models won't have bridges this obvious or long. You can expect to see some minor bridging over holes in the side of a model, over grooves, or over slots for inset nuts.

You get 1 point for each clean bridge.

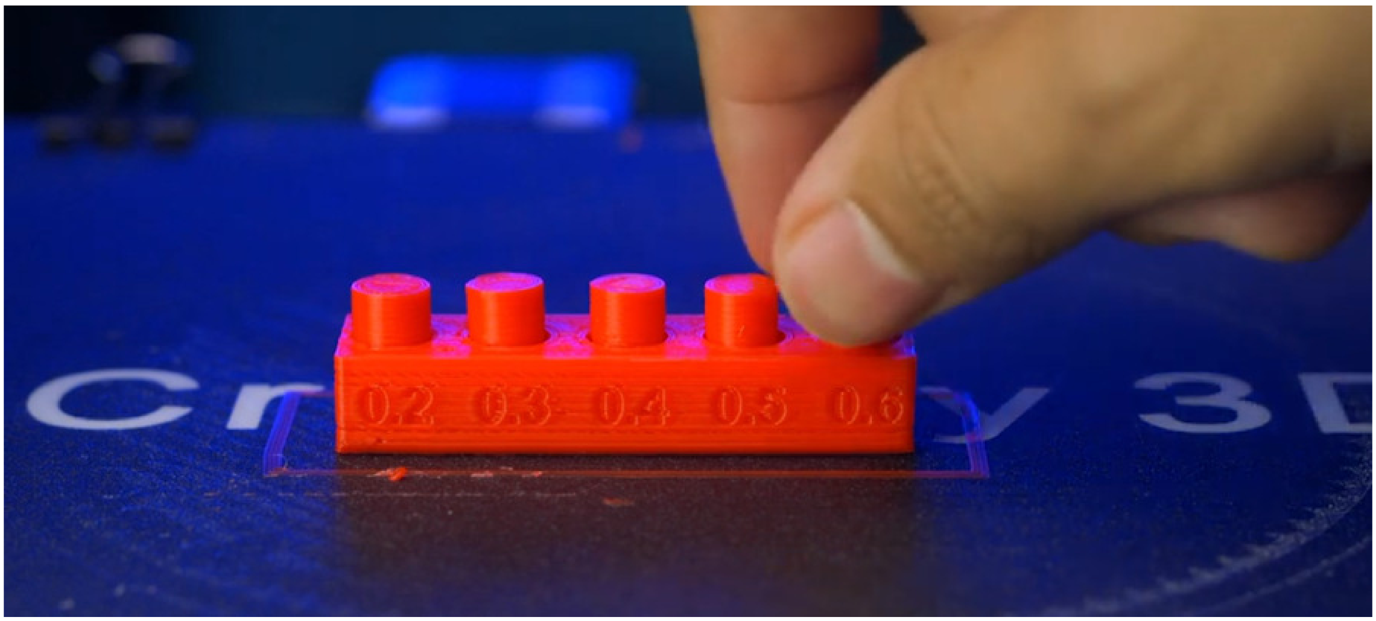


Bridging Test

Negative Space Test

Much like the dimensional accuracy test, it's important that negative space is accurately replicated. When you're trying to insert screws cleanly without drilling it out or threading the plastic, it's important to know how much extra space you need to model into your part to accommodate. In general, when I need to insert an M3 bolt, I'll model a 3.2mm hole to make sure it slides in easily.

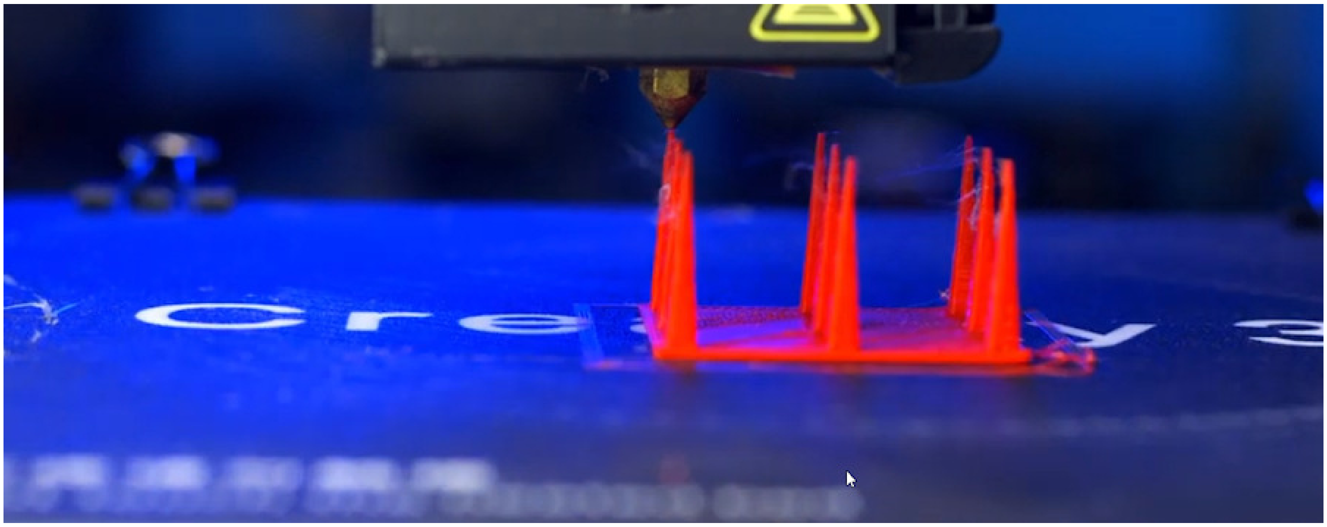
In general, if you precisely calibrate the steps/mm for the extruder, start and end overlap, and seam alignment, you can push out all 5 pins without much force. If there's difficulty removing any of the pins, there’s still something that needs to be calibrated out to achieve tighter tolerances. One point is earned for every pin that can be pushed out.



Negative Space Test

Retraction Performance Test

This test is hard to quantify the difference between a 4 and a 5, but the main thing this is looking for is retraction optimization. This is one of the toughest slice settings to calibrate due to just how many factors affect retraction, like the number of retraction settings, and even things like layer cooling, print speed, extruder style, or even your extruder's ability to extrude and retract without chewing the filament.

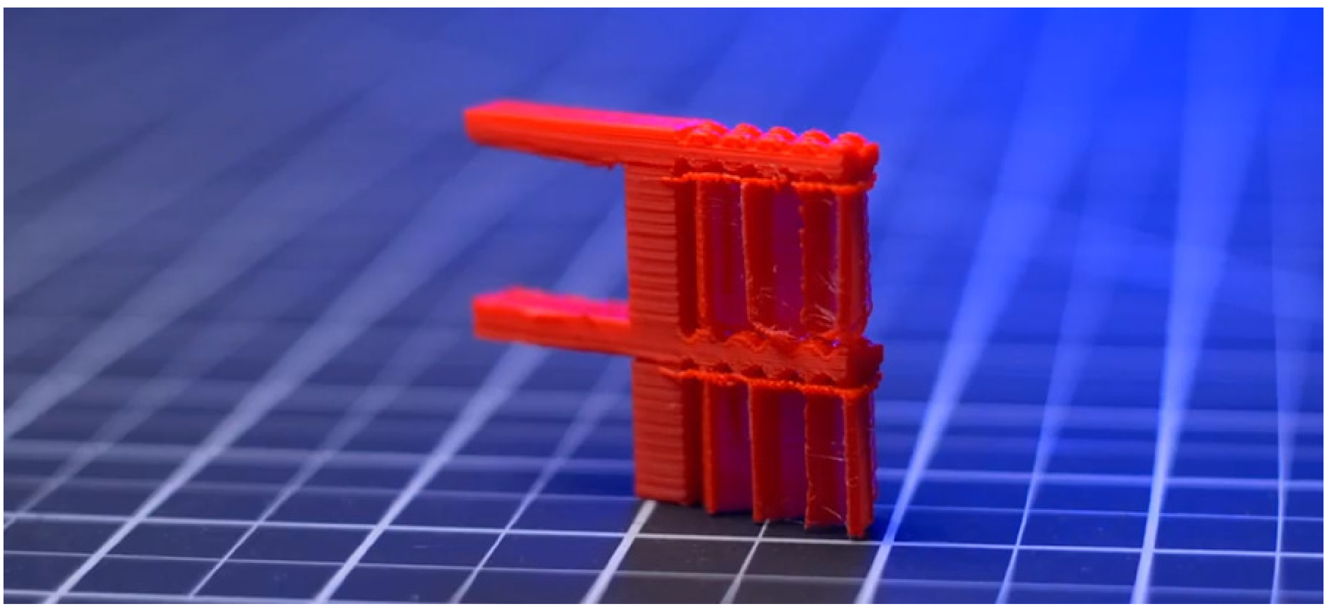


Retraction Test

Support Material Test

Whether you're using a dedicated support material like PVA or HIPS or you're using a single extruder printer and using the same material as your support material, it's important to have your support settings calibrated. Same material supports are printed with what's called an "air gap" where the print head rises above the print to create a slight gap between the roof of the support and the bottom of the printed part, giving the filament extra time to cool and droop onto the supports, preventing them from permanently adhering to each other. That air gap is something that needs to be optimized; too small and the supports adhere to the finished print, too large and the bottom surface will be really stringy and droopy until it can recover.

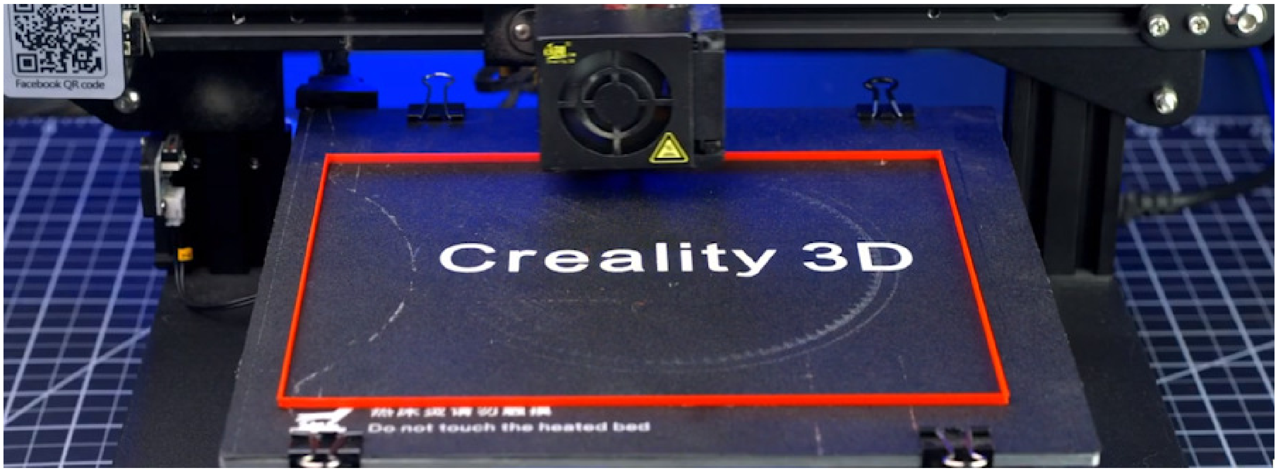
Dedicated support materials produce a bottom surface finish *almost* as clean as the top surface, because they are printed without an air gap since they can be dissolved away. The test model has separate sections for intricate supporting and a flat bottom surface, because an air gap optimized for one may not be enough for the other.



Support Test

Full Bed Dimensional Accuracy Test

While the dimensional accuracy test checks the accuracy of a fairly small part, this test checks accuracy across the entire bed. A small error in the dimensional accuracy test will compound into a larger discrepancy across the bed, which is 10 times longer than the first test. The smallest difference in expected vs actual measurement just means that any multi-part prints are going to skew depending on the orientation the part was printed in.

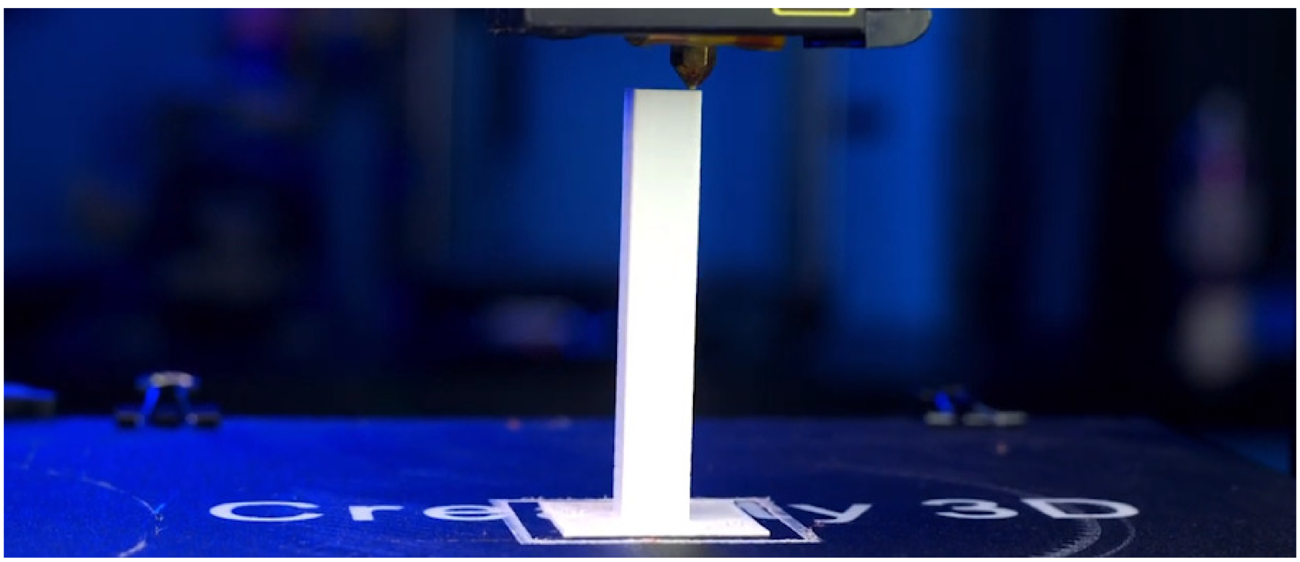


Full Bed Dimensional Accuracy Test

Z Wobble Test

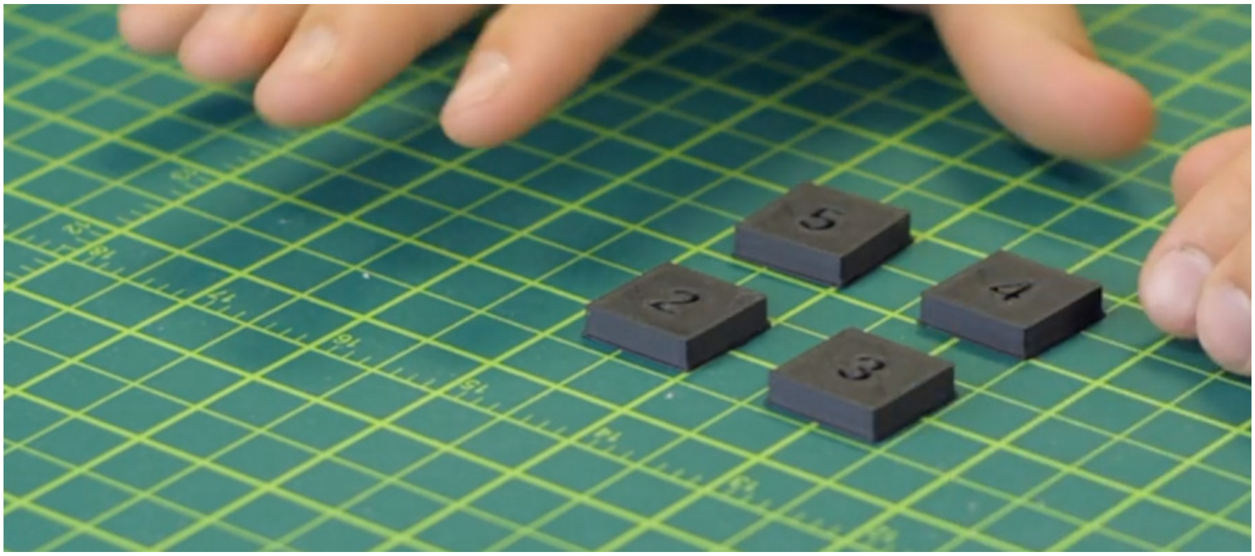
Unlike every other test, which uses a scale to grade the proficiency of the 3D printer, this test is simply a pass or fail. The tower has a wide brim to make sure it is well adhered to the bed, and to ensure that any sort of issue in the walls of the tower comes from the printer's structure, and not because it tipped off of the bed. If there is any wobble, it should be cyclical and repeat with a period identical to the pitch of the lead screw attached to the Z axis. If the lead screw had an 8mm pitch, then you should see the pattern repeat every 8mm.

A key thing to watch out for is to make sure that your Z axis is properly constrained *and* not over constrained. Properly constrained means you have smooth rods, linear rails, or extrusions with V-slot wheels making sure that the Z axis only moves on Z and doesn't shift around. Rods, rails, and wheels should be tensioned or secured so that they don't wiggle or move when the Z axis is raising or lowering. Over-constrained is something like installing bearings at the top of the leadscrews in a support bracket. This is actually counter intuitive, because no lead screw is perfectly straight and adding that bearing causes a deflection in the lead screw. There should in general only be two part interacting with the lead screw: a coupler that attaches it to a motor (or be part of the motor) and a lead screw nut, anything else is overconstraining it and can hurt print quality more than help.


Z Wobble Test

Squareness Test

This test was developed to make sure that the printer's X and Y axis are assembled square with each other; this test will determine if the printhead moves on X, does it move a marginal amount on Y as well, or vice versa. Using an angle gauge, you will measure each of the five squares and determine how far off each corner is from 90 degrees. The further off from 90, the lower the printer's score.



Squareness Test

These are the top ten ...really 11 prints because there's just no way to cut out any one of these, they all serve a very specific purpose that without them you're missing some element of troubleshooting and calibrating your 3d printer to perform at its absolute best. And these are the tests that we run to make sure that the printers that we work with are running at their best as well, so I hope that with these calibration prints you're better equipped to help calibrate your own 3D printer and getting it to perform at the best that it absolutely can.

All of these calibration prints, collected by Make:, can be found in one place on Thingiverse here:

https://www.thingiverse.com/thing:2755063

Happy calibrating!