How to measure a broken part for 3D printing without a scanner

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Abstract. A digital-caliper procedure for outside, inside, depth and step measurements, with Mitutoyo's ±0.02 mm accuracy set against Prusa's 0.3 mm printer tolerance.

Keywords: replacement-parts, reverse-engineering, home-repair

1 How do you measure a broken part without a 3D scanner?

With digital calipers. A 150 mm caliper reads to 0.01 mm and is accurate to ±0.02 mm, tighter than the 0.3 mm Prusa quotes for its printers in X and Y. Measure outside, inside, depth and step. Take broken features from the mating part, round to the designer's likely number, and print a test coupon first.

1.1 The number

Table 1. The number

Instrument or process	Figure	Source
Digital caliper, 0 to 150 mm (Mitutoyo 500-151-30)	Resolution 0.01 mm, accuracy ±0.02 mm	Mitutoyo catalog, section D
Same series, repeatability and modes	Repeatability 0.01 mm; outside, inside, depth and step	Mitutoyo Bulletin 2129 and catalog
Well-assembled Original Prusa printer	0.1 mm on Z, 0.3 mm on X and Y	Prusa Knowledge Base FAQ
After extrusion multiplier and linearity calibration	As little as 0.05 mm on all axes	Prusa Knowledge Base FAQ

Caliper figures from Mitutoyo's catalog for the ABSOLUTE Digimatic Series 500; printer figures from Prusa Research's FAQ, which adds that material shrinks as it cools and uneven filament causes uneven extrusion. Neither source states a clearance figure.

1.2 The procedure

This is reverse engineering: working out a part's dimensions and design intent from the object itself, so you can draw and print a replacement.

1. Clean the part, close the jaws and zero the display. Check the jaws show no light gap.
2. Outside: close the main jaws square on the feature. A tilted jaw reads long, so take three readings and keep the smallest.
3. Inside: open the knife-edge jaws in the bore or slot and rock them until the reading peaks. The peak is the diameter.
4. Depth: stand the caliper on the rim and lower the depth rod to the floor of the pocket or hole.
5. Step: rest the end of the slider on the higher face and the beam on the lower one. The display gives the height difference.

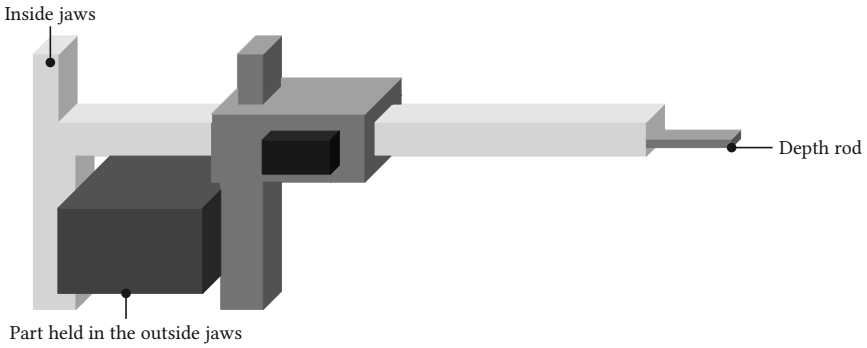


Figure 1. The main jaws close on outside dimensions, the knife-edge jaws open inside a bore or slot, and the depth rod slides out of the end of the beam.

6. Broken features: measure the mating part instead. A snapped peg is defined by the hole it sat in, a cracked tab by its slot.
7. Radii and fillets: hold a radius gauge against the corner, or print a strip of candidate radii and match by eye.
8. Flat profiles: lay the part on a flatbed scanner for a one-to-one image. Import the scan into computer-aided design (CAD) software, scale it to one caliper measurement and trace the outline. Without a flatbed scanner, photograph the part beside a ruler from far away and zoomed in to flatten the perspective.
9. Round each measurement to the value the designer most likely used. Hackaday's rule: lengths, diameters and radii are usually round numbers in the design phase.

Tolerance note: the printer's 0.3 mm in X and Y limits the part, and the caliper's ±0.02 mm disappears inside that band. Add fit clearance rather than replicating the part dead on, so measuring and printing errors leave the fit loose rather than jammed.

1.3 Why

The printer is the limit. Prusa Research puts a well-assembled Original Prusa at 0.1 mm on Z and 0.3 mm on X and Y, improvable to 0.05 mm on all axes with extrusion multiplier and extruder linearity calibration.

A caliper's resolution is the smallest step it displays, 0.01 mm. Accuracy is how far a reading can sit from the true size, ±0.02 mm across the 150 mm range. Repeatability is how close two readings of the same feature come, 0.01 mm. All three are far finer than an FDM (fused deposition modeling) printer holds.

Measuring the mating part works because the two were made to fit each other. The intact hole gives the peg's diameter, length and position more reliably than the broken stub. Design intent does the rest: a designer drew 6 mm, not 5.93 mm, so a 5.93 mm reading on the hole means a 6 mm nominal. Model the peg at 6 mm minus a clearance.

Get it wrong and the part fits the caliper but not the machine: a bore modeled at exactly the measured size can print anywhere in the printer's 0.3 mm band, and on the tight side it will not fit.

1.4 How to check it on your own part

1. Print a coupon that carries only the critical features (a peg, a bore and a step) in the final material and orientation.
2. Measure the coupon with the same caliper and note the difference from the model on each feature. That difference is your printer's offset for that material.
3. Trial-fit the coupon on the mating part. It should slide on without force and without slop.
4. Apply the measured offset to the full model, print it, and check the fit before trusting the part.

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