



FORMLABS WHITE PAPER:

3D Printing with Desktop Stereolithography

An Introduction for Professional Users



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Executive Summary

The business landscape is constantly evolving. Why shouldn't your company change with it?

As technology continues to advance, companies and customers expect high quality products faster than ever before. Whether you're representing a small business or a large corporation, the tools you need should match these new demands to ensure continued success.

Throughout this paper, you'll learn about:

- Changes in 3D printing technology over time
- The parts and processes involved in stereolithography
- The speed of desktop SLA compared to industrial 3D printing and service bureaus
- The quality of desktop SLA compared to FDM
- Where Formlabs fits into the 3D printing equation

Reaching New Frontiers in 3D Printing

Advancements in 3D printing continue to change the way we approach prototyping and production as the technology becomes more accessible and affordable than ever. These changes in technology create major opportunities for designers and engineers to rapidly iterate and improve upon their designs.

3D PRINTING: THE FIRST WAVE

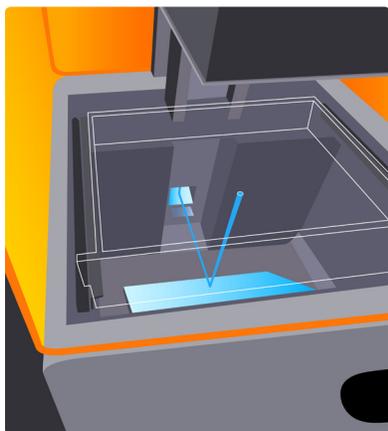
In the past, industrial rapid prototyping demanded a significant investment. Beyond purchase costs, it required skilled technicians and costly service contracts to maintain. Today, industrial 3D printers are often housed in model shops, printing laboratories, or jobs are outsourced to industrial service bureaus. For these reasons, industrial 3D printing is often limited to priority projects and final presentation models, rather than being fully integrated into the workflow of individual designers.

THE EMERGENCE OF DESKTOP 3D PRINTING

Recently, the introduction of desktop 3D printing has widened access to this technology. Fused Deposition Modeling was the first to gain adoption in desktop platforms, although SLA was the first invented 3D printing technology. While this affordable extrusion-based technology aided the widespread use of 3D printing, the quality of parts and printer reliability has limited the use of these machines, as repeatable, high-quality results are crucial to success.

A NEW SOLUTION: DESKTOP STEREOLITHOGRAPHY

The introduction of desktop stereolithography (SLA) 3D Printing in the Form 2 offers the quality of industrial 3D Printing in an affordable, accessible desktop package. With SLA, professional designers and engineers can print high-quality objects on their desktop, reducing iteration cycles from days or weeks to hours.



How Does SLA Work?

Stereolithography is a light-based process that builds individual layers of a model with liquid polymer, hardened by a laser beam. The laser is directed and controlled by two galvanometers. After each layer, the resin tank peels away to release the hardened material. The build platform then moves up from 25 to 100 microns, depending on the chosen layer height, to prepare for the process of solidifying the next layer. The part appears to be built upside down, which is called *inverse stereolithography*.

KEY PARTS OF THE PRINTER

1. The Laser

The Form 2 contains a blue 405 nm laser. Custom circuitry activates the laser in timed bursts, generating the energy to turn the photopolymer from liquid to solid.

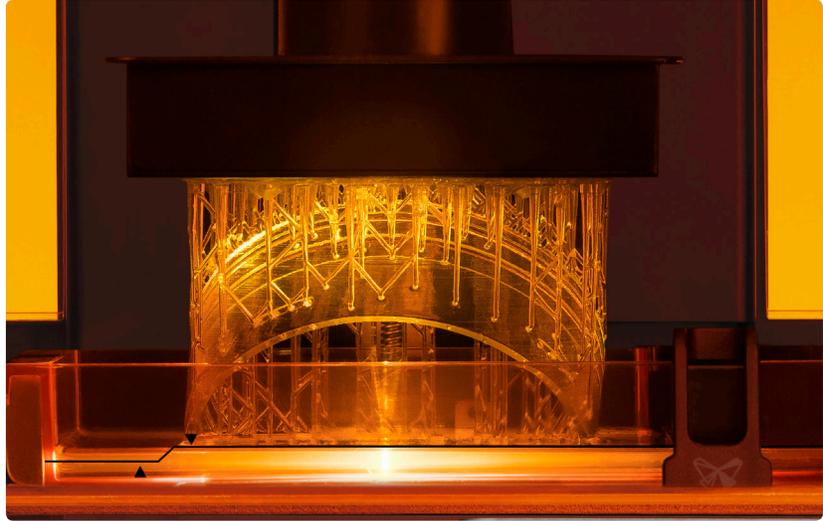
2. The Galvanometers

As the laser travels along the optical pathway, it is reflected by two rapidly oscillating, finely-tuned mirrors which accurately position the laser. This control hardware sweeps the laser repeatedly across the build platform hundreds to thousands of times per second with submillimeter accuracy.

3. The Resin Tank

The underside of the replaceable resin tank is an optically transparent window. Sitting at the bottom of the tank is a layer of clear, non-stick silicone, which allows the laser beam to pass into the tank of resin. The non-stick surface serves as a substrate for the liquid resin to cure against, allowing for the gentle detachment of newly-formed layers.

The Curing Process. As the laser contacts a thin layer of resin it chemically hardens, bonding with nearby layers, creating a fully dense, watertight part.



Desktop 3D Printing vs. Service Bureaus and Industrial 3D Printers

RAPID PROTOTYPING

Fast turnaround time is a huge advantage to owning a desktop 3D printer. When working with a printing bureau, lead times, communication and shipping all create delays. With a desktop 3D printer like the Form 2, parts are in-hand within hours, allowing you to print multiple parts a day. The Form 2 prints faster than other SLA desktop printers at identical layer height settings.

UK startup Suttrue (below), focused on developing suturing devices for hospitals, decreased their iteration cycle from months to days using a Form 1+.



QUICK DESIGN CHANGES

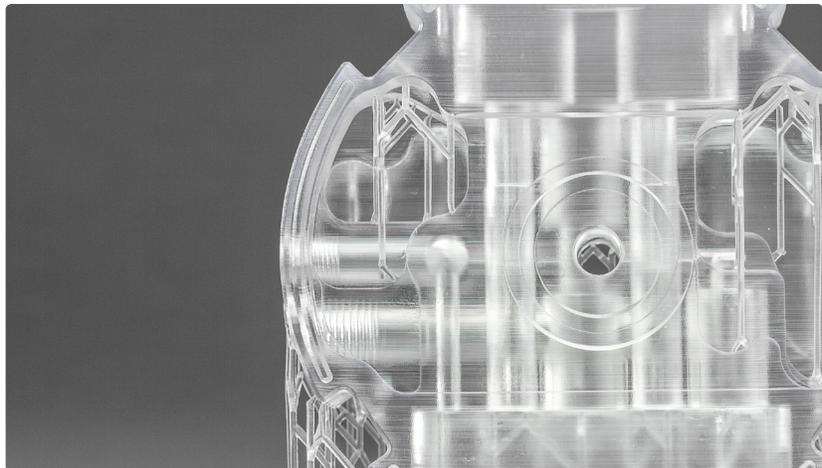
Desktop 3D printing allows you to quickly verify the fit and feel of a design. The high resolution of SLA creates functional components with the quality required to evaluate the design of parts without additional post-processing. Mechanisms and assemblies can be tested at your desk and easily modified over the course of a few days, helping to drastically reduce product development time and avoid costly tool changes.



COST SAVINGS

Industrial SLA printers can cost upwards of \$60,000 and require trained technicians and compulsory service contracts to operate. This value is equivalent to the purchase of a “farm” of desktop 3D printers. With greater potential throughput and reduced user wait time, machines may also be distributed on the desks of individual designers and engineers. Integrating this technology into day-to-day development can drastically change the prototyping workflow, making 3D printing much more accessible.

Cost Savings. This baseblock (part of a larger gripping robotic assembly), was printed on a Form 2, saving the cost of machining the prototype instead. The part features threaded connectors that were required to hold a vacuum.



COST TO CREATE 1 BASEBLOCK*

Form 2 Material Cost	\$36.28
Service Bureau Form 2 SLA	\$684.60
Machine Shop CNC Milled Aluminum	\$1085.00
Number of Prints to Recover Printer Cost	5

*Service bureau costs were estimated for advertised Form 2 3D Hubs users with 5 stars. Machining quotes were received from Protolabs.com. Both quotes were received 03/2015.

Owning a Form 2 3D printer results in significant savings over 3D printing service bureaus and traditional machining, illustrated in the chart to the left. Costs per print can be calculated by multiplying part volume in the Form 2 PreForm software by the cost of resin (\$0.149/mL). PreForm is free to download and can be used for cost estimates before ordering a Form 2.

DESIGN FREEDOM

The low cost and high speed of desktop 3D printing changes the design workflow. Working with a personal 3D printer allows for rapid iterations of designs and the freedom to attempt unconventional ideas. Teams that work in multiple locations with multiple printers can print and verify designs independently, sharing physical objects over digital channels.

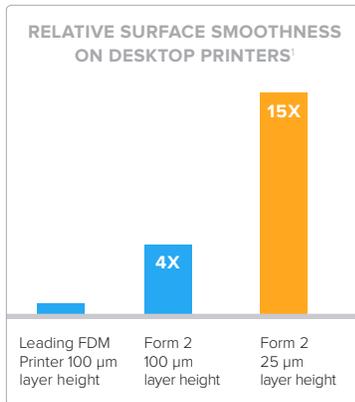


Desktop SLA vs. other Desktop 3D Printing Technologies

High quality 3D prints help propel projects forward in a professional work environment. Desktop SLA printers provide superior part quality when compared to FDM machines.

PART FINISH

SLA creates parts with a smooth surface finish directly off the machine. Parts are ready to paint or sand and polish into a glossy or optically transparent surface. This surface quality is ideal for applications requiring



a flawless finish, such as investment casting for jewelry or electroplating. At the other end of the spectrum, the combination of smooth surface finish and fine resolution allows for the creation of high fidelity textures, allowing designers and artists to capture more detail with desktop 3D printing than ever before.

Applications:

Presentation Models, Burnout, Advanced Finishing, Mold-making

FINE DETAILS

Depending on part geometry, positive and negative surface features can be produced at 300 micron or less (0.3 mm). The ability of a 3D printer to show fine details is important for reducing finishing time on larger prints and achieving accurate details on small prints that are hard to sand or polish.

Applications:

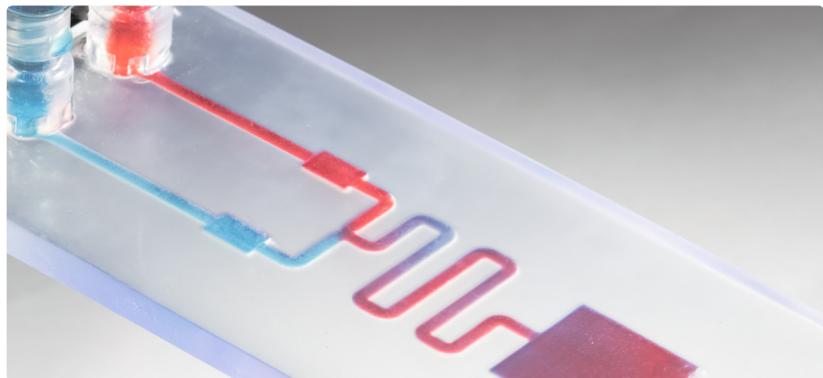
Precision Assemblies, Jewelry Design, Character Design, Model-making

WATERTIGHT PARTS

While FDM produces a mechanical bond between layers, SLA creates a chemical bond by cross-linking photopolymers across layers, resulting in fully dense parts. The bond is water- and air-tight, and strength does not change with orientation. Dense parts have several functional advantages. Microchannels can be designed to allow liquid transfer and mixing. Parts can be threaded or tapped, creating airtight connections using teflon tape for low pressure pneumatic prototyping. Fully dense parts transmit and refract light. Standard Clear resin can be used to create lenses or allow clarity for visibility into complex assemblies.

Applications: Microfluidics, Research, Lens Prototyping, Pneumatics

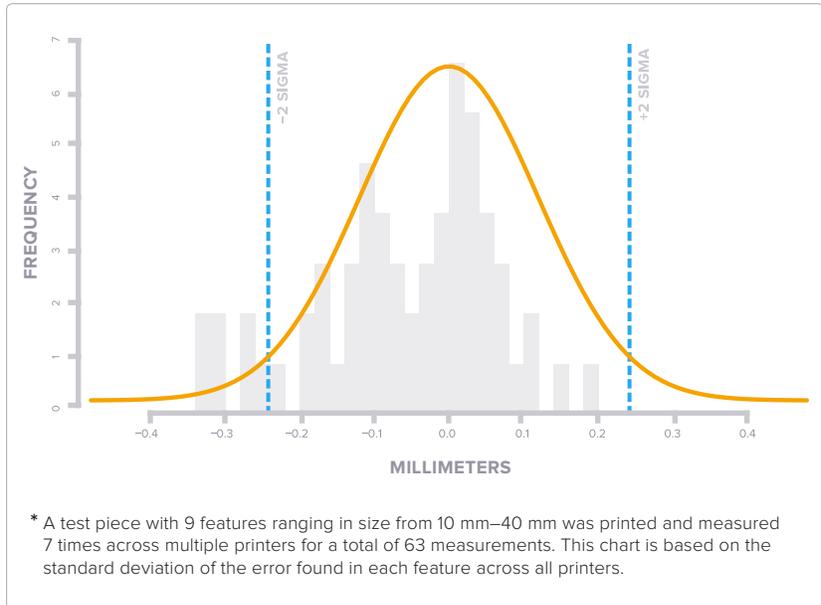
A Millifluidic Blender printed on a Form 2, this device blends fluids within internal channels. The surface was polished to provide a clear view of the interior.



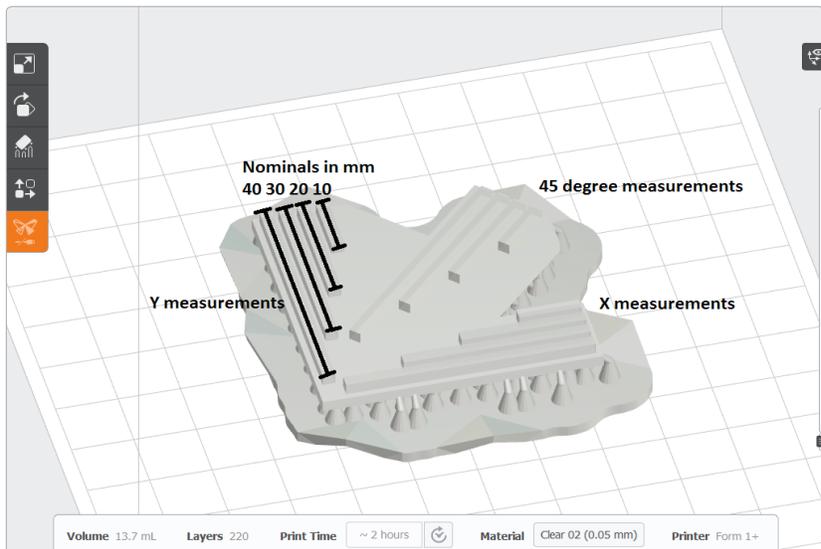
ACCURACY

Formlabs printers are capable of creating accurate parts with repeatable dimensions. This is important for designers or engineers creating assemblies or printing parts for investment casting. In recent testing, 95% of prints were measured to within 240 μm or less (0.24 mm) of the designed dimension.

Applications: Mechanical Assemblies, Prototyping, Design Error Checking



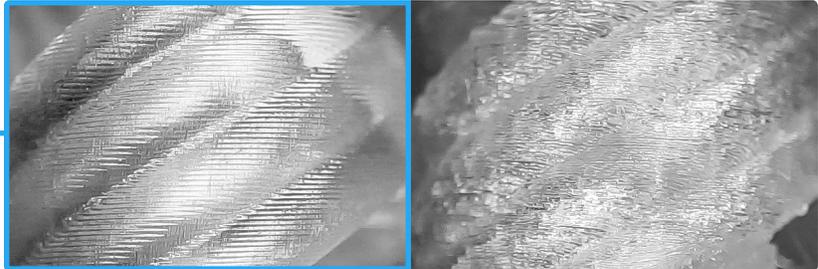
Using the PreForm file to the right, a series of prints were made to take measurements. All test prints were printed in Formlabs Clear resin at 50 μm settings with supports. All pieces were washed in IPA for 15 minutes and then post-cured for 15 minutes.



TIME VS. RESOLUTION

3D printers give control over layer height and build time. Larger layer heights, such as 100 μm , provide improved print speed while increasing the visibility of layers, particularly on shallow slopes relative to the build platform. Fine layers heights of 25 μm produce much smoother surfaces desirable for casting as well as fine details, but build times increase.

3D printers work by virtually “slicing” digital models and building them layer by layer into a physical form. 3D printers are often compared by the thickness of these layers, also referred to as layer resolution. However, a part printed at 100 micron layers on an FDM printer looks different from a part printed at 100 micron layers on an SLA printer, because of the way the layers are built. The process by which a layer is created has a dramatic impact on the quality and physical properties of the final part.



Surface Finish: Parts created on a Form 2 (left) display a significantly smoother surface finish than desktop FDM prints (right).



The Formlabs Ecosystem

We believe that 3D printing should be designed to fit in with day-to-day environments. Formlabs has created a complete, end-to-end system that allows users to 3D print from the convenience of their desktop.

FILE PROCESSING WITH PREFORM

3D Printing on the Form 2 starts with PreForm, a software package designed to prepare any .STL or .OBJ for printing. PreForm has several functions, two of which are essential to quality printing: orientation and support generation. Both of these functions have been automated in PreForm, allowing users to perform these complicated tasks quickly and reliably. PreForm also automatically repairs files if there are any issues, ensuring your model's geometry prints successfully. Once a file has been quickly uploaded to the printer via usb, you can disconnect your computer, allowing the system to run alone or even overnight. PreForm is free and available for download from our website.

MATERIAL PROPERTIES

Once a file has been prepared for 3D printing, a specific resin type must be selected for the print. Formlabs offers a growing library of acrylate photopolymer resins in two categories: Standard and Functional. Standard resins feature tensile strength comparable to monolithic ABS in a variety of shades and transparencies useful for prototyping. Functional resins allow designers to take advantage of material properties for specialized applications, such as flexibility or clean burnout properties for investment casting. With multiple light-blocking resin trays, materials can be swapped in seconds and stored near the printer.

FINISH KIT

After a part has been printed, it will still be coated with excess liquid resin. Each Formlabs printer includes a finish kit designed to make part cleaning simple and organized. Users remove models from the build platform and then wash parts in isopropyl alcohol for 20 minutes. Once the part is dried, users can easily remove the part using the flush cutters and the print is ready for final use.

WARRANTY

In a production environment, uptime of equipment is essential to maximizing productivity. Formlabs provides a one-year warranty with each printer as well as quick Customer Support with same-day email response. For professional users, an upgraded service plan is available, which includes dedicated training, phone support, and prioritized servicing.

¹Relative roughness was calculated based on roughness average values (Ra) of flat samples printed in 0°, 45° and 90° orientations, with and against layer grain . Readings were taken in triplicate using Daktek 150 profilometer using standard scan settings across a 4000 µm sample area .





See the Power of Desktop SLA

Request A Free Sample Part

Questions? [Contact us.](#)

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