

White Paper

Additive Manufacturing with Six Sigma Repeatability Combined with the Industry's Fastest Throughput and Time-To-Part



New digital molding technology from 3D Systems is revolutionizing the direct production of 3D printed plastic parts, and it is doing so at scale.

3D Systems not only invented the tool-less plastic parts manufacturing process, but laboratory testing has confirmed 3D Systems' Figure 4 technology offers the fastest 3D printing production throughput for time-to-part.

Figure 4 is a modular and scalable manufacturing solution using non-contact membrane DLP (Digital Light Printing), state-of-the-art plastic resins, and a light-based UV curing

process that takes minutes versus hours with heat-based curing processes.

The system architecture of Figure 4 enables superior final part and material quality, including improvements to toughness, durability, high temperature deflection and elastomeric properties. This is possible due to the speed of the non-contact membrane process combined with the low static volume print tray, which allows for more highly reactive material chemistries that might not be achievable with other photopolymer 3D printing methods.

Fastest throughput via technology

3D Systems' testing shows the Figure 4 system offers print speeds up to 100mm/hr (Table 1).

These print rates remain constant regardless of how many parts are being built due to the non-contact membrane DLP technology that powers the 3D Systems' Figure 4 platforms.

Taking the fast curing process into consideration, Figure 4 enables a time to first part-in-hand (printed, cured, washed, dried) of 160 minutes (2.67 hours) in draft print mode, or less in standard print mode (Table 2). This is a newly achieved benchmark in the 3D printing industry.

Here it is important to note the critical distinction between throughput and raw print speed. True industrial 3D printing throughput must account for the print process, any required curing time, as well as other post-printing requirements (such as washing or drying).

Only when the part is ready for manufacturing or shipping can it be considered complete. Print technologies that offer fast raw print speeds but require extended cure times can be highly deceptive. A 3D printing process must be looked at holistically to determine the true productivity that is possible.

TABLE 1. PART PRINT SPEEDS ON 3 MATERIALS

SPEED (MM/HR)	DRAFT	STANDARD
Figure 4 TOUGH-GRY 10	103	77
Figure 4 TOUGH-GRY 15	71	41

Figure 4 technology provides breakthrough printer speed at up to 100 mm/hr (Preliminary data. Both Draft and Standard print quality used).

TABLE 2. TIME TO PART-IN-HAND

MATERIAL	TIME TO PART
Figure 4 TOUGH-GRY 10	160 min (2.67 hr)
Figure 4 TOUGH-GRY 15	280 min (4.67 hr)

Time to first part-in-hand, including printing, curing, washing and drying based on test geometry on run on a Figure 4 Standalone using Draft mode (Preliminary data).



Fastest throughput via scalability

Early benchmark testing by 3D Systems shows that within 11 days, eight Figure 4 printers can turn out 10,000 units of a textured automotive vent. In those same 11 days the injection molding process would still be in the mold design stage.

The CAD-to-production speed of digital molding makes it ideal for Low Rate Initial Production (LRIP) or bridge manufacturing.

Companies can go to market faster, with the option to convert to injection molding to ramp up volume as demand grows.

Figure 4 Standalone is an affordable and versatile solution for low volume production, and fast prototyping in the tens and hundreds of parts per month.

With a compact and easy-to-use design, Figure 4 Standalone delivers ultra-fast speed at an affordable price and low total cost of operation.

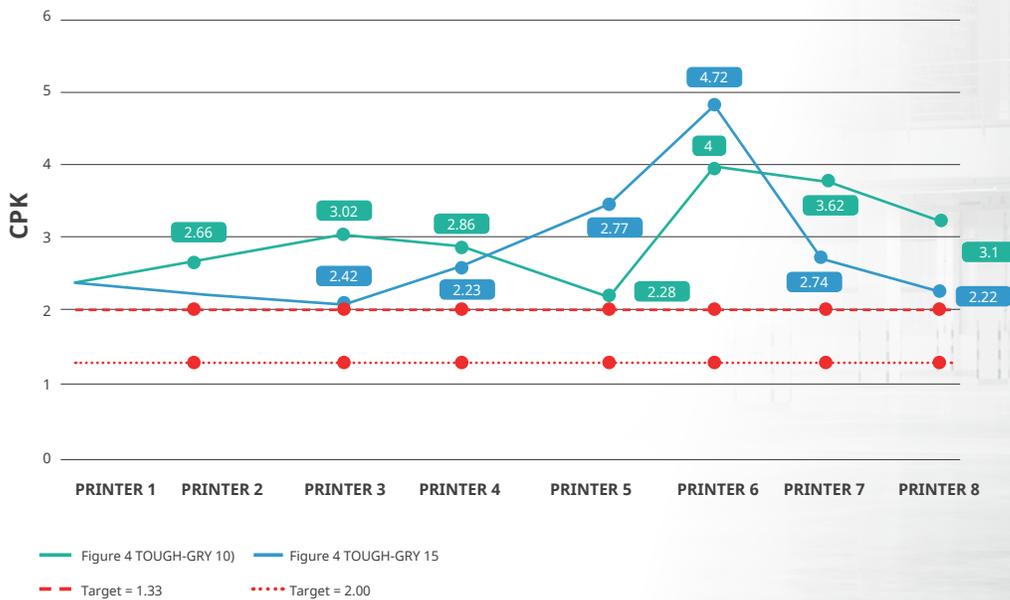
The baseline configuration of 3D Systems' Figure 4 Modular platform is comprised of a modular printer and a central control module. This can be easily scaled to up to 24 printer modules on a single control station, enabling production to rapidly multiply without disruption to the shop floor. Individual printer modules can also be dedicated to specific materials enabling simultaneous production of a diverse range of parts for production, prototyping and investment casting.

The Figure 4 Production platform is an integrated, automated digital molding solution with customized configurations to meet manufacturing needs.

Figure 4 Production combines cells containing print engines, post-processing units and robotics to enable the rapid production of parts across a variety of materials with virtually no human intervention.

Much like digital photography, digital printing, and digital video, digital molding with Figure 4 is the result of combining complementary technologies to achieve a result greater than the sum of its parts. Advances in CAD software, 3D printing technology, materials science, and robotics—along with new tools for digital texturing—come together in the Figure 4 digital molding platform.

IMAGE 3B. FIGURE 4 SIX SIGMA REPEATABILITY



Results from three Figure 4 printers with two different materials consistently deliver a Cpk > 2. This equals 0.002 parts per million are out of spec (Preliminary data).



Fastest throughput, highest accuracy

3D Systems' testing shows that Figure 4 offers print speeds up to 100 mm/hr—at six sigma repeatability.

The statistical result is stated as $Cpk > 2$, where Cpk is the process capacity index. A result of 2 or higher is considered a "six sigma" quality process (Image 3A).

IMAGE 3A. FIGURE 4 SIX SIGMA REPEATABILITY

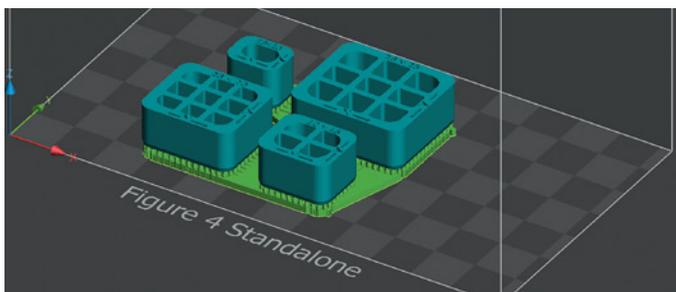
	FIGURE 4 TOUCH-GRY 10	FIGURE 4 TOUCH-GRY 15
C_{PK}	2.46	2.03

Repeatability results from 3 Figure 4 printers consistently deliver a Cpk above the target 2.0.

Cpk is a statistical measure of the ability to produce output within specification limits. Cpk takes into consideration how much natural variation a process experiences relative to the specified limits. Using a standard statistical measurement allows different processes to be compared without ambiguity.

To establish a Cpk value for the Figure 4 3D printing platform (Image 3B), tests were run on eight machines individually. Cpk testing requires running 30 samples. The test part was printed on each Figure 4 printer and measured using micrometers four times; the average was used for the statistical sample.

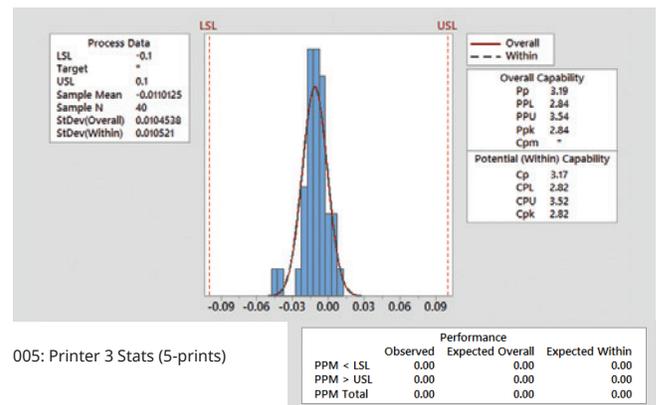
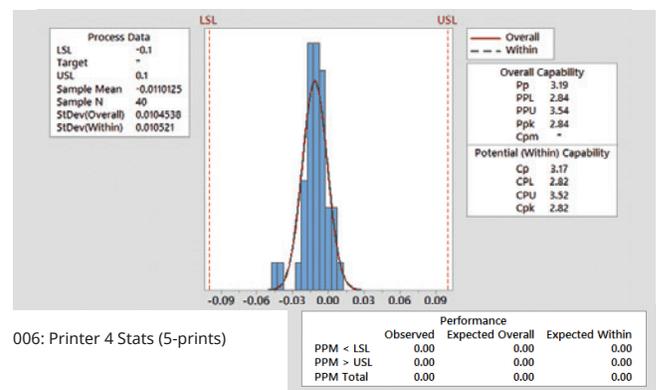
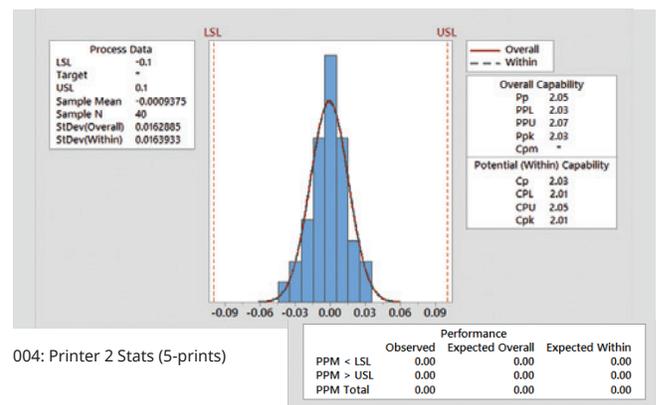
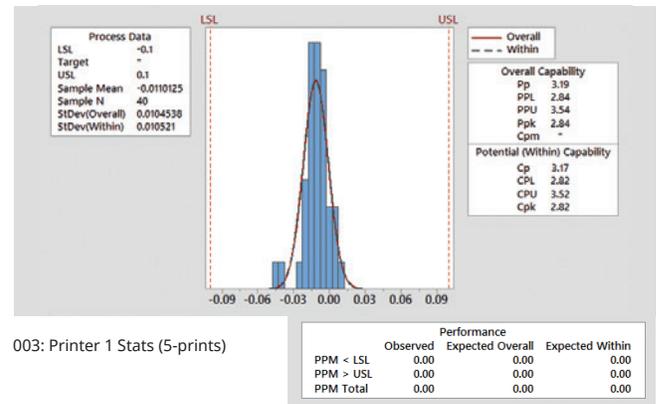
IMAGE 4. PRINT BUILD SETUP



Testing parts on the 3D Sprint build tray set up

Next the physical model was adjusted, and new objects were printed and measured again. The results for each printer from both runs were given their own results chart. The combined results scored 2 or higher, establishing six sigma quality in the repeatability of the process. Certain individual results scored $Cpk = 1.94$, which is not a six sigma result, but remains much higher than the other nearest standard of 1.67 for "safety or critical parameter for a new process" (Image 5).

IMAGE 5. PROCESS CAPABILITY RESULTS



Designed to fit your production needs

In combination with 3D Systems' software, Figure 4 printers can communicate in real time using industry standard protocols such as MTConnect and OPC Unified Architecture (OPC UA). 3D Systems' software is designed to provide operating and support intelligence both locally on the factory floor and remotely via web and cloud connectivity, promoting efficient data exchange for smart manufacturing.

Digital molding as implemented by 3D Systems is massively scalable and can operate within automated production lines. It can handle long- and short-run batches and allows fast switching of production to different parts. This gives manufacturers the ability to quickly iterate a design and immediately manufacture an end-use part.



FIGURE 4 STANDALONE:

An individual printer targeted at very fast prototyping, low volume production and jewelry casting patterns.



FIGURE 4 MODULAR:

A modular printer and a central control module expandable to up to 24 connected printers on a single control module.



FIGURE 4 PRODUCTION:

A configurable, in-line full production system that delivers automated, direct 3D production, customized to specific needs.

What's Next?

Interested in Learning More About Figure 4 and Digital Molding?

Talk to an expert about which materials
and printers would work for you

[Get in Touch](#)

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