

Drops and Spots: Latest Trends in Inkjet Printheads and Printer Design



There is an old, well-known business adage reflecting the trade-offs inherent in any enterprise: “Cheap, fast, good — pick any two.” While it applies to both services and products, this article focuses on products and will recast the three descriptors in terms of price, productivity and quality. While I will refer primarily to “print quality” (PQ), sometimes I will refer to the quality of the machine itself, in terms of build standard, reliability and fitness for purpose.

Product strategists often find it helpful to think in terms of a positioning diagram like Figure 1, page 16, with productivity and quality forming the two axes and price shown as a series of contours — simplified to rough arcs centered at the origin. The lines indicate that all products on that particular line cost the same amount of money. In general, each line represents a trade-off between quality and productivity. Products A, B, C and D reflect different value propositions at extremes of the market.

At the risk of over-simplification (ignoring, for example, print width, type of substrate, mechanical handling, as well as a hundred other features), the wide-format digital printing market has been divided historically into groups of products clustered at points B and C. Until recently, “photo-quality” printing meant limited

format sizes and limited productivity and grand-format printing meant high-productivity, but with an image quality that was suitable only for viewing at a distance. As showcased at recent trade shows, this is no longer the case. We have seen advances in printheads and inks, as well as in software, electronics, motor control and the reduced cost of precision mechanical engineering, UV lamps and computing power. All of these led to the availability of printers that bridge the gap between small “point-of-purchase (POP) quality” machines and high-productivity behemoths. The cost contours on the diagram are moving outward, implying that you get more quality and productivity for each dollar invested. Let’s look a little more closely at productivity and quality.

Productivity

Productivity in the wide-format digital world is usually measured in square feet/hour and is a notoriously elusive concept. It is hard to compare different specifications from different manufacturers. Manufacturers talk about “draft mode,” “production mode” and “high-quality mode” — all of which reflect a PQ/productivity trade-off within the machine, usually based on the number of passes the printhead makes to lay down the image. For a single pass, the area covered in a fixed time depends on the

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width of the print swath and the speed of the carriage. Sometimes, the speed of the carriage can be limited by the maximum frequency of the printhead (i.e., how many drops of ink it can deliver per second). A quick sum, however, shows that this is not usually an issue. Take the case of a Xaar **Proton** head jetting at 9kHz. If it has to deliver 180 drops in the print direction to match the 180 dpi resolution across the head (to create square pixels), it can travel at up to $9000/180 = 50$ inches/second. This is much faster than most carriages can move. Of course, the area covered per hour is not simply the print swath multiplied by carriage speed, which is multiplied by number of passes. The carriage instead has to be accelerated and decelerated (turn-around time) with pauses for automatic maintenance.

Printhead improvements and a better understanding of ink rheology have made a substantial contribution to productivity gains. The **Proton** head, for example, is three times the width of the industry-standard Xaar 128 head, and significantly faster. The extra width means that it replaces — for equivalent swath — three 128 heads that would have to be mechanically aligned on the carriage. This saves both building costs and maintenance time. In general, there is an industry trend toward bigger printheads with more nozzles, or from some companies, arrays of lower-resolution heads.

Print Quality

If productivity is an ambiguous concept, PQ is even more so. In a recently published table of UV flatbed printers, quoted resolutions ranged from 500–1,440 dpi. Is a bigger number better, and are we talking about the same thing in each case? Let’s start by observing that there

is a great deal of confusion between resolution, meaning the finest detail in an image that can be distinguished, and addressability, meaning how many spots per inch can be printed. In other words, addressability refers to the size of the grid of pixels the printer can aim at without referring to whether it puts a single size of dot or a variable-sized dot that reflects a grey-level value.

If all dots are the same size (“binary” printing — so called because you either get a dot or you don’t), high addressability is good — provided that each dot fits inside its grid square. Figure 2 shows a 360dpi grid, overlaid with a

series of 80pl drops. The size of the dot on a substrate made by an ink drop of a particular volume depends on several factors including the surface tension of the ink and the surface energy and absorption of the substrate. These will affect whether the drop beads up, hardly spreads at all or spreads out flat on the surface. Solvent ink spreads more than UV-curable ink, and in the latter case, another factor is the amount of time the ink has to spread before the ink is hit with UV light, freezing it in place. The diagram in Figure 2 assumes little spreading, so each dot is about 100 microns on the substrate, but 360dpi implies that each square is only 70.5 microns in size! Clearly there is no point in trying to print with an 80pl drop size at 720dpi, equivalent to a 35 micron-sized grid. No more detail will be visible, and the only result will be a greater weight of ink from the overlapping dots, providing a darker image.

For a sense of scale, one thousandth of an inch is equal to 25.4 microns, and a cube of side 10 microns has a volume of 1pl, or one millionth of a millionth of a liter.

Most of today’s aqueous printers producing high-quality images use very small binary (constant) drop volumes (3–6pl) and high addressability. These small drops make an appropriately-sized dot for 1,440dpi (a 17.6 micron grid) that is quite typical of these printers. Nobody has yet made a 1,440dpi printhead, so this “resolution” is achieved by using multiple passes, interlacing both in the print direction and the paper direction.

Figure 3, drawn to show four-pass printing with a 185dpi printhead that makes a 370dpi image, shows how the dots are filled in on each pass. The first pass puts a dot in every other grid square in the print and paper direction (i.e., rows one and three, in positions 1, 3, 5, etc.). The second pass fills in positions 2, 4, 6, etc., in the second and fourth rows. The third pass fills in the even pixels in the first and third rows and, finally, the fourth pass fills in the odd pixels in the even rows.

For distant viewing on a billboard, 370dpi is plenty and 1,440dpi is complete overkill. It is not too long ago that we were screen-printing billboards at 30dpi! Today’s market demands, however, that printers are flexible and versatile, so their investments in equipment should be too. Having the same printer capable of both grand-format printing and high-quality POP-type graphics has advantages.

Recently, two main approaches to improved PQ have been taken in terms of UV printers: Smaller drop sizes and variable-sized drops, or grayscale.

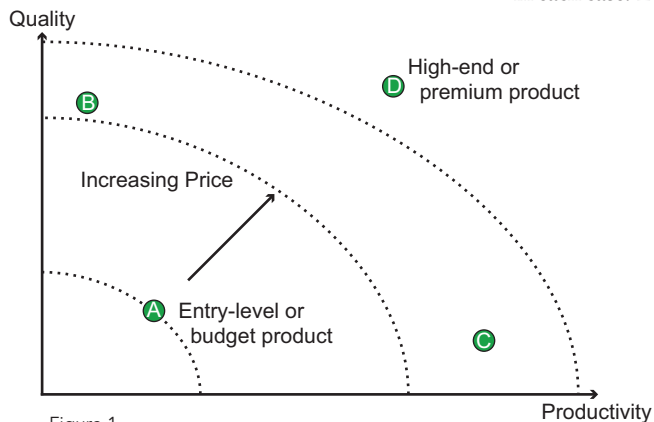


Figure 1

As addressed earlier, the minimum drop volume is a better metric for PQ than the number of dots per inch (DPI). But small drops need to be printed close together to get enough ink coverage in shadow areas, which means printing more slowly. A better solution is to take advantage of the fact that the eye perceives images with a high DPI and a fixed dot size as indistinguishable from images with a low DPI and several levels of gray.

In an influential 1997 paper, Joyce E. Farrell of HP Labs showed that observers found a 300dpi, eight-level photographic image to be more acceptable than a 1,200dpi single level image. She concluded that "...to optimize photographic image quality, it is much wiser to dedicate bits to represent grayscale rather than DPI. Increasing the number of gray levels gives us more quality for our bits than increasing DPI."

This result explains the advent in recent years of an increasing number of wide-format UV printers with variable-drop printheads. Heads based on Xaar technology from Toshiba-TEC, Seiko and Konica-Minolta (all licensees of Xaar patents), as well as from Xaar itself, are present in UV flatbed and roll-to-roll machines from manufacturers in the US, Europe and Asia. The technology is based on ejecting a number of "sub-drops" from each nozzle in quick succession so that they form a single larger drop with a volume that is a multiple of the sub-drop volume. A typical configuration uses a 6pl sub-drop and eight gray levels, so drops can be from 6pl up to 42pl in volume and are changing dynamically from pixel to pixel through the print. To do this, the sub-drops are fired at frequencies over 40kHz, and the shape of the firing pulses (or "waveform") is tailored carefully to the specific characteristics of a particular ink. This is done to ensure reliable printing, to maximize drop straightness and consistency and to avoid stray droplets or "satellites" that cause fuzziness in the print.

The use of grayscale is allowing printer manufacturers to achieve the productivity of a machine that prints with 42pl drops, while obtaining the "apparent resolution" of a 6pl printhead. Because smoother tonal transitions are possible, the need for light cyan and light magenta heads and inks is avoided, saving both cost and consumables. In fact, ink usage is generally much lower per square foot with a grayscale UV machine than on a printer with a fixed drop size. This is because wastefully printing one dot on top of another is

reduced on a grayscale machine with a well-designed RIP.

What's Next

Most recent developments have improved PQ and helped to reduce the cost of printers. Reliability of the machines, in terms of jet-outs, also has improved, although printheads still require the occasional purge and wipe to recover failed nozzles. This is less critical on a multi-pass scanning machine compared to single-pass applications like label-printing. It was for this type of application that Xaar developed the 1001 printhead with its unique "through-flow" ink recirculation system, which allows the head to "self-recover" from jet-outs. This printhead is now finding its way into some novel wide-format printers, thanks in part to its reliability, but also on another feature of the ink system: Its ability to keep solids in suspension in an ink that can be over twice as viscous as standard inkjet inks. This allows the use of high-opacity white inks and brings the prospect of metallic inks into view.

Productivity improvements will continue, including faster and self-recovering printheads, faster carriage speeds, automatic load/unload systems and remote diagnostics and control that will help bring about the "lights out" print shop. The next big jump in productivity will come when a six-foot array of heads becomes sufficiently cost-effective and reliable to allow extended single-pass operation. Such a machine, technically, but not yet commercially feasible with today's technology, would be capable of producing POP-quality output at 480 square feet — per minute. Stay tuned.

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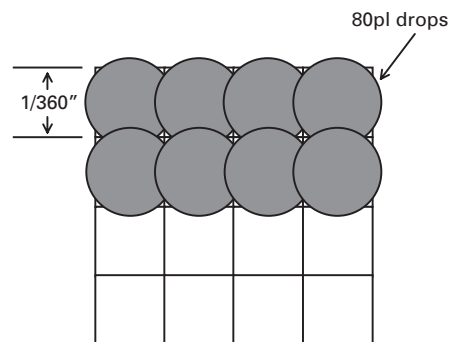


Figure 2

4 Pass Print Mode, Xaar 128 Printhead, 2x2 matrix

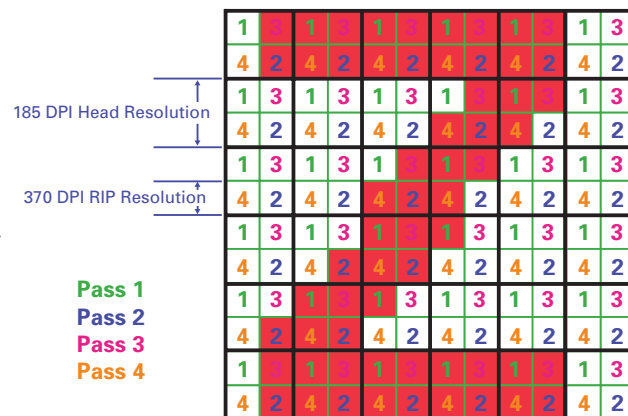


Figure 3