Technical white paper

HP High Definition Nozzle Architecture

HP HDNA Technology in HP PageWide Web Presses

HP High Definition Nozzle Architecture ("HDNA") — with a native resolution of 2400 nozzles per inch and dual drop weight printing — powers a new generation of HP PageWide Web Presses. HDNA offers higher levels of quality and productivity, and the installed base of presses using HP A51 Printheads can be upgraded to HDNA performance.

Introduction

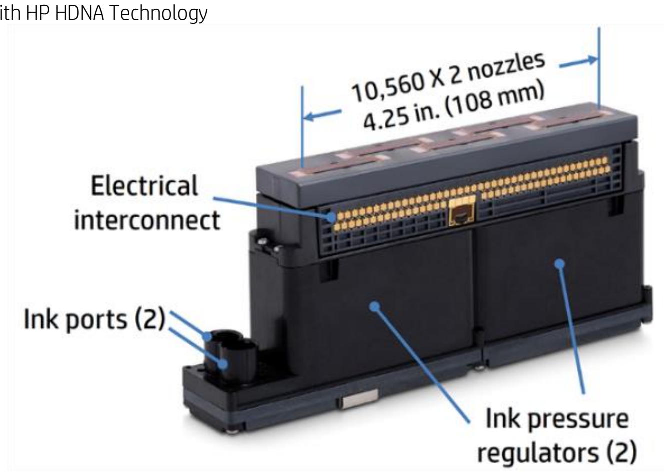
In 2016, HP will introduce a new generation of HP PageWide Web Presses[1] based on HP High Definition Nozzle Architecture (HDNA) Technology. By printing with dual drop weights, new HP A53 Printheads using HP A50 Pigment Inks will offer enhanced image quality and higher productivity. Low weight drops deliver more precise color reproduction, finer image grain, and better rendering of subtle shading in images; high weight drops deliver high ink flux for saturated colors and high productivity.

To implement HP HDNA Technology with consideration to upgrading existing HP PageWide Web Presses,[2] the HP A53 Printhead leverages the HP A51 Printhead design by placing low drop weight nozzles between high drop weight nozzles. This gives an HP A53 Printhead twice as many nozzles as the HP A51 Printhead: 21,120 vs. 10,560. Both electronic and fluidic redesign of the printhead was made possible by the design and manufacturing processes of HP Scalable Printing Technology.

HP A53 Printheads

Figure 1 shows an HP A53 Printhead. It is built on the same backend assembly as the HP A51 Printhead, which provides mechanical, electrical, ink interconnects, and ink pressure regulators. This reuses printhead subsystems that have been proven by printing over 110 billion pages on HP PageWide Web Presses (as of June 2015) and facilitates the upgrade of existing presses to HP HDNA Technology.[2]

Figure 1. HP A53 Printhead with HP HDNA Technology



[1] HP PageWide Web Presses were formerly designated HP Inkjet Web Presses. For example, the HP T400 Color Inkjet Web Press is now the HP PageWide Web Press T400 Color.

[2] Excluding HP PageWide Web Press T260, T400S, and T1100S until further notice.

The key characteristics of the HP A53 Printhead are high nozzle density and dual drop weight printing with low drop weights (LDW) and high drop weights (HDW). All color inks—C, M, and Y— use the same values of LDW and HDW, where LDW is 50% of HDW. Black ink uses a higher value for HDW, and LDW for black is 33% of HDW. For all inks, their HDW values are the same as those used in corresponding HP A51 Printheads.

In another innovation, the HP A53 Printhead for HP Bonding Agent uses a single drop weight but with twice the number of nozzles as the HP A51 Printhead. HP PageWide Web Presses with HP HDNA Technology can use a single Bonding Agent printbar—rather than tandem printbars. This frees a printbar position for future developments.

As with HP A51 Printheads, HP A53 Printheads are available in single- and bi-color configurations. Two independent ink supplies and regulators support two columns of 10,560 nozzles producing a 4.25-inch (108mm) print swath. There are 5,280 LDW and 5,280 HDW nozzles in each column. Single-color configurations provide built-in redundancy of LDW and HDW nozzles for dependable print quality. The bi-color configuration is used for cyan and magenta inks in the HP PageWide Web Press T200 HD.

HP A53 Printheads deliver similar quality to HP A51 Printheads—but at higher speed—using only HDW drops in *Performance mode*. HP PageWide Web Press T400 and T410 series print up to 600 feet (183 m) per minute in color with HP A51 Printheads, and with HDNA and HP A53 Printheads color print speeds are increased up to 800 feet (244 m) per minute. Enhanced quality is produced using LDW and HDW drops together in *Quality mode* at up to 400 feet (122 m) per minute.

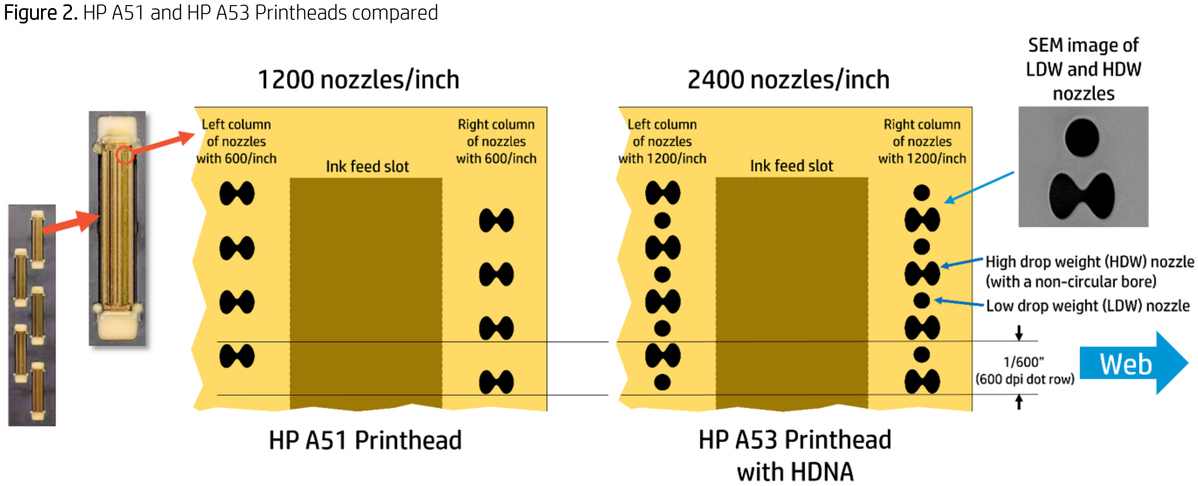
Implementing HP HDNA Technology

Nozzle layout, nozzles per inch (npi), and native resolution (dpi)

From left-to-right, Figure 2 shows a printhead with five (5) die, a single die, and magnified schematic views of nozzles on HP A51 and HP A53 Printheads. This figure will clarify two concepts: nozzles per column inch (npci) and native (printing) resolution in dots per inch (dpi). For simplicity, only the upper (right) corner of half of each die is illustrated. The figure shows two columns of nozzles, one on each side of an ink feed slot that supplies ink to both columns. The web moves left to right in this view.

A scanning electron microscope (SEM) image in the upper right of Figure 2 shows actual LDW and HDW nozzles. The "bowtie" shape of the HDW nozzles is a "non-circular bore", designed to drive faster drop break-off during drop ejection to improve dot shape at high web speeds.

Figure 2. HP A51 and HP A53 Printheads compared



Nozzles per column inch specifies the number of adjacent nozzles per inch in a column. As shown in Figure 2, there are two columns of nozzles—one on each side of a feed slot—and npci applies to one column. NPCI is useful as an engineering specification: a high value of npci relates to the ability of a fabrication technology to produce printheads with high nozzle density. Compared to piezo inkjet manufacturing technologies—typically offering only 30 to 180 npci—the latest generation of HP printheads made with HP Scalable Printing Technology have 1200 npci. This allows compact HP Thermal Inkjet printheads to offer capabilities such as dual drop weights, multiple colors, and built-in nozzle redundancy that can only be done with bulkier, more costly piezo printheads—requiring more offset columns of sparsely-spaced nozzles—or multiple separate printheads.[3]

[3] For example, the Kyocera KJ4 printhead uses 16 offset columns of piezo drop generators spaced at 37.5 npci to achieve a native printing resolution of 600 dpi. To achieve nozzle redundancy at 600 dpi, two KJ4 printheads printing in tandem would be required.

As seen in Figure 2, the HP A51 Printhead has 600 npci in each of two columns offset by 1/1200-inch across the feed slot giving 1200 nozzles per inch (npi). 1200 is also the printhead's native resolution in dpi.

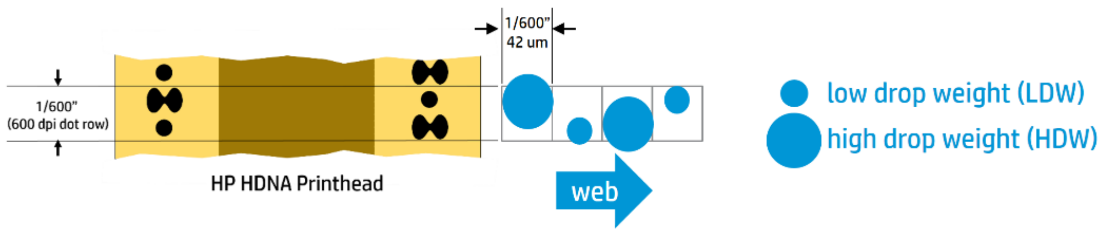
The HP A53 Printhead has 600 HDW npci and adds 600 LDW npci. This gives two columns each with 1200 npci for 2400 npi. Because a LDW nozzle and a HDW nozzle print together in the same 1200 dpi dot row to deliver more printable levels per color, the native resolution in dots per inch for printing with dual drop weight drops is still 1200 dpi.

Printing with dual drop weights

Figure 3 shows a portion of the HP A53 Printhead from Figure 2 to illustrate how two LDW and two HDW nozzles address each 600 dpi dot row down the web.[4] LDW and HDW dots can be printed in either the upper or lower half of a 600 X 600 dpi grid. Each LDW nozzle is aligned with an HDW nozzle across the feed slot and offset from the other LDW nozzle by 1/1200-inch.

Since both HDW nozzles in the same 600 dpi dot row, they are considered *redundant* for print quality purposes; likewise, the two LDW nozzles are redundant. LDW nozzles are not counted as redundant with HDW nozzles.

Figure 3. Dual drop weight printing

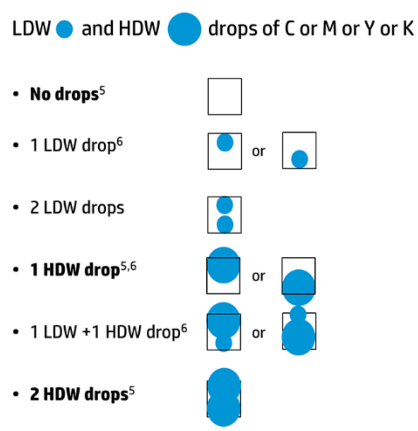


Combinations of dual drop weight drops

Figure 4 shows how HP HDNA Technology can combine LDW and HDW drops to produce tones intermediate to those produced by an HP A51 Printhead with a single drop weight (HDW). In this figure, the *three* printable gray-levels by an HP A51 Printhead using 0, 1, and 2 HDW drops are highlighted in **bold** text.

Three *additional* combinations are available from HP A53 Printheads by printing 1 and 2 LDW drops and a combination of 1 LDW and 1 HDW drop. This gives *six* directly-printable gray-levels *per ink color*. LDW and HDW drops of different inks may be combined in within the 600 X 600 per inch grid to print more colors than with HDW drops alone.

Figure 4. Combinations of low drop weight (LDW) and high drop weight (HDW) drops in a 600 X 600 per inch grid



Using LDW and HDW drops

The digital front end (DFE) and the image processing electronics in HP PageWide Web Presses convert continuous-tone (contone) image data from the input file into halftone image planes for each color (and HP Bonding Agent, if used) and ultimately into commands for printing LDW and HDW drops at each addressable location on the web.

[4] A 600 X 600 grid is used to discuss how drops are combined to produce gray-levels for each color because the digital front end of the press renders contone data at 600 X 600 dpi. In addition, nozzle redundancy specifications are based on 600 dpi dot rows down the web.

[5] Pattern printable by HP A51 Printhead.

[6] Different dot arrangements for a specified combination of drops have equivalent optical density.

Image processing has a number of objectives including:

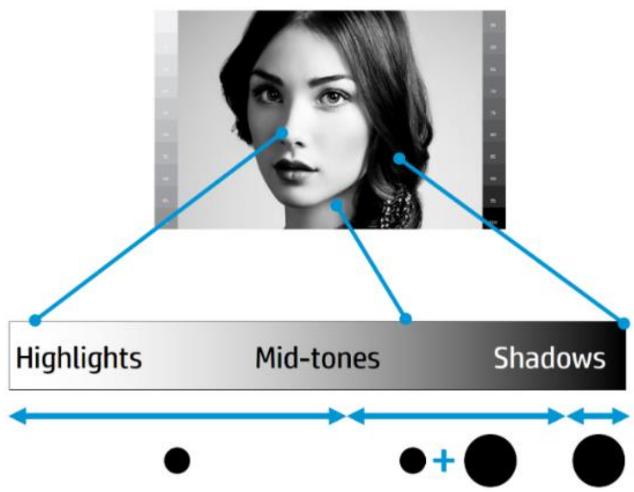
- Implement color or mono ICC profiles and setup options.
- Match printed colors to contone colors as closely as possible given the *Rendering Intent* chosen with the ICC profile.
- Minimize image grain and artifacts.
- Obtain smooth color and mono transitions between different colors and densities.
- Enforce ink limits for the paper loaded in the press.

Figure 5 shows how LDW and HDW drops are used in different portions of the density ramp for a monochrome image in *Quality mode*. The choice of which drop combinations are used in each element of the image grid is driven by the objectives of image processing outlined above. Note the following from Figure 5:

- In the image highlights, only LDW drops are used. This reproduces the required gray-levels with minimum grain because LDW dots are less-visible against the white background than HDW dots.
- Only LDW drops are used from highlights to the darker midtones.
- Combinations of LDW and HDW dots are used in the darker midtones and up to about 90% maximum density.
- Above 90% maximum density, in the image shadows, only HDW drops are used.

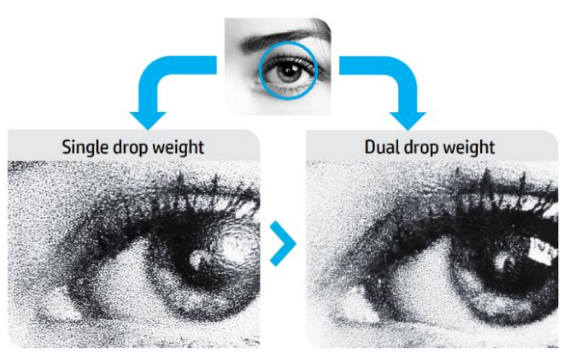
Fully-saturated primary (CMYK) colors are always printed with HDW drops. Secondary colors can use combinations of LDW and HDW drops of different inks to achieve finer color addressability within the gamut. *Productivity mode* uses only HDW drops to achieve similar quality to HP A51 Printheads, but at higher speeds.

Figure 5. Using LDW and HDW drops across a range of densities in Quality mode



The ability of HP HDNA Technology to reduce image grain and provide smoother tones is seen in the highly-magnified photomicrographs of print samples in Figure 6. On the left is an image printed with an HP A51 Printhead using HP A50 Black Pigment Ink. The dot structure is visible in the highlights and midtones. On the right is the same image printed with HP A53 Printheads and HP HDNA Technology in Quality Mode. The same gray-levels are reproduced with substantially less grain to give smoother tone transitions. At normal viewing distance, the image quality improvement is evident.

Figure 6. Example of print quality improvement with HP HDNA Technology



More printable colors

With more printable color combinations using LDW and HDW drops, HP HDNA Technology allows finer addressability within the gamut of HP A50 Pigment Inks. While HP HDNA Technology does not extend the gamut—which is determined by the inks, paper, and maximum saturation available in the selected color setup option—it allows more colors to be printed.

Figure 7. Example of color addressability

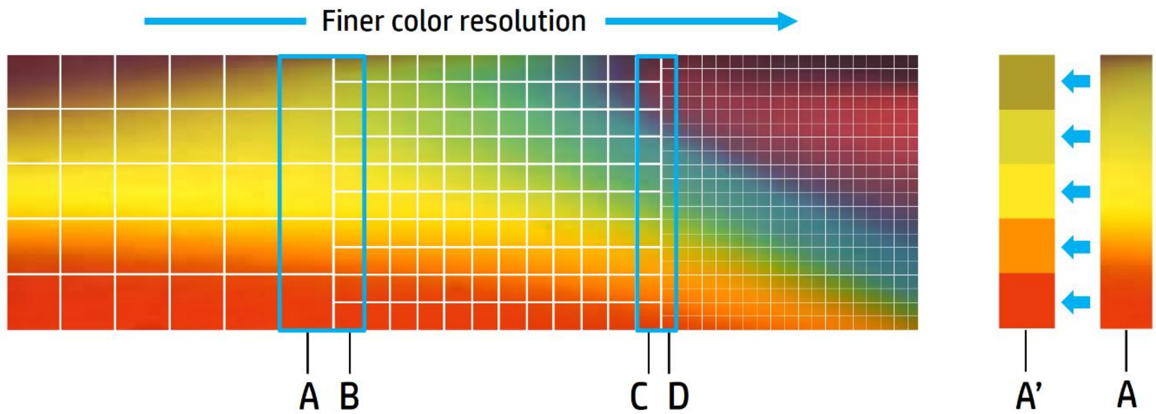


Figure 7 illustrates the effect of increasing the color resolution.[7] The white grid represents three different color printing resolutions which could be considered *coarse*, *medium*, and *fine*. While color changes continuously within a gamut, limitations on the available combinations of inks and drop weights allow a printer to address and print only a discrete number of colors. This is called "color resolution" (within the gamut). In practice, the finer the color resolution, the more colors a printer can reproduce, and this directly relates to reproducing smooth tones and density transitions.

Assume that the printable color is the average color within each square of Figure 7. The right-hand side of Figure 7 illustrates this effect for Column A. The grid overlays a range of continuous colors in Column A, but the (five) directly-printable colors are shown in Column A'. There is a visible *tone break*—a discontinuity in color—between the colors in Column A' that doesn't exist in the continuous tones. This is the effect of limited color resolution.

Returning to Column A in the left side of Figure 7, the range is addressed by five (5) directly-printable colors. By doubling the color resolution, Column B, there are now ten (10) directly-printable colors with smaller tone breaks between them. This is an improvement in color resolution.

Comparing Columns C and D, the finer color resolution in Column D gives twice as many directly-printable colors as in Column C (and B), and four times as many as in Column A. With an even smaller difference between directly-printable colors, the color transition is now much smoother and approaches continuous tones. These examples demonstrate what HP HDNA Technology provides with more directly-printable colors in Quality mode.

The most-visible effect of finer color resolution is eliminating tone (color) breaks in images. These are most-visible in smooth color transitions in portions of an image that are relatively featureless: for example blue sky and in the transition from light to shadow across a plain white surface. The eye and brain[8] seek detail and structure in the image, and sometimes they find only artifacts of color reproduction.

Exaggerated tone breaks are simulated in left-hand part of the image in Figure 8.[9] Without image detail to engage the eye and brain, these artifacts—representing the limits of color reproduction by a printing technology—can actually be highly visible and undesirable. In this simulation—where limited color resolution was applied across the entire left-hand image—tone breaks are particularly visible in the sky, but notice that the higher information content in the lower part of the image suppresses the visibility of tone breaks.

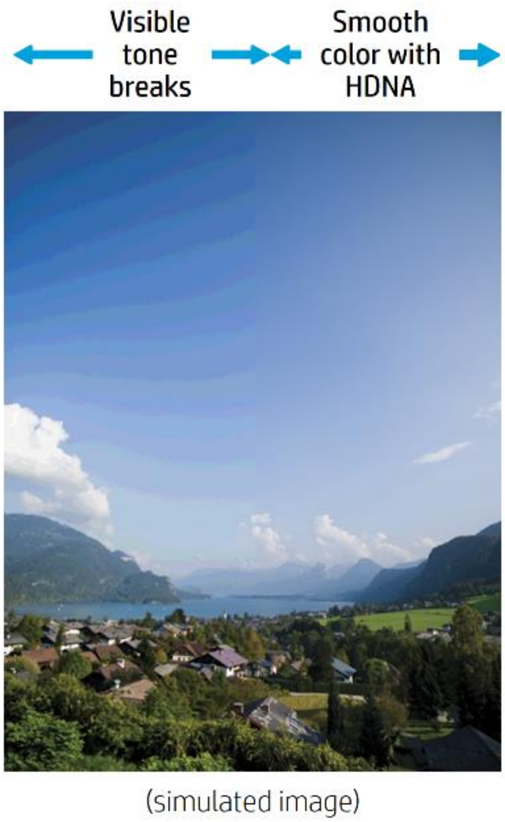
Smooth tone reproduction by HP HDNA Technology is illustrated in the simulation on the right in Figure 8.

[7] This graphic is intended only for illustrative purposes. It does not represent color addressability in any particular color printing system.

[8] The organ of sight is primarily the brain, which tries to impose order and structure on the sensory information coming from the eye.

[9] Tone breaks are simulated in the left-hand portion of the image by processing to restrict the number of printable colors compared to the right-hand side. The left-hand image is for illustrative purposes only and does not represent any particular printing technology.

Figure 8. Simulated example of tone breaks



HP PageWide Technology and HDNA

HP PageWide Printheads now power HP printing solutions from business printing to large-format and commercial (high-speed web) printing. HP PageWide Printheads are built using HP Scalable Printing Technology (SPT) that employs common design and manufacturing processes based on integrated circuit technologies.

HP manufactures printheads in its own factories around the world. Vertical-integration of research, product development, and manufacturing allows HP to monitor and control quality from silicon wafers through finished printheads. This gives HP an edge in innovating new solutions that support ever-expanding opportunities for HP's customers.

Evolution of HP PageWide Printheads

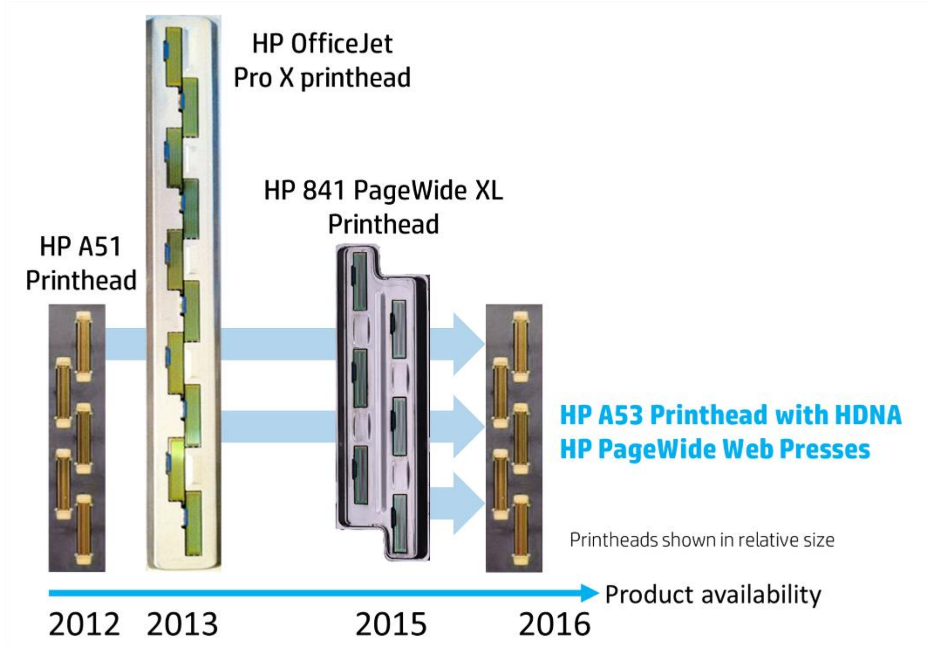
HP PageWide Technology is based on technology proven in HP PageWide Web Presses—printing more than 110 billion pages since 2008 and 4 billion pages per month[10] under demanding commercial printing conditions. Four generations of HP PageWide Printheads are shown in Figure 9.

Based on the original HP 4.25-inch printhead that powered the HP T300 Color Inkjet Web Press[11] introduced in 2008, the HP A51 Printhead was introduced in 2012 with HP A50 Pigment Inks. HP A51 Printheads offered improved image quality at high web speeds using nozzles with non-circular bores. This innovation improved drop break-off and produced a better dot shape on paper.[12] The ability to field-upgrade the installed base of HP PageWide Web Presses as new printhead technologies and inks become available was a key element of the design philosophy for HP PageWide Web Presses.

HP's next generation of HP PageWide Technology was introduced for business printing in 2013 with the HP OfficeJet Pro X-Series Printers and MFPs. These printers used an 8.6-inch (218 mm) wide printhead that incorporated significant technology advances: it delivers four colors of ink with 10,560 nozzles per color at 1,200 nozzles per inch for a total of 42,240 nozzles. Unlike other HP PageWide Printheads, this printhead is factory-installed and is not user-replaceable.[13]

[10] As of June 2015
[11] Now called the HP PageWide Web Press T300 Color series.
[12] See Figure 2 for an image of a nozzle with a non-circular bore.
[13] For more information, visit hp.com/go/officejetprox

Figure 9. Generations of PageWide Printheads based on HP Scalable Printing Technology



In 2015, HP introduced a new generation of high-productivity large-format printers—the HP PageWide XL family—using the 5.08-inch (129 mm) HP 841 PageWide XL Printhead. This printhead prints four colors of ink with 6,336 nozzles per color at 1,200 nozzles per inch for a total of 25,344 nozzles on each printhead. Eight (8) of these printheads are used to deliver a 40-inch (1016 mm) print swath in HP PageWide XL large format graphics printers.[14]

The HP A53 Printhead with HDNA Technology will be introduced on HP PageWide Web Presses in 2016. Compatibility in form-factor with the HP A51 Printhead allows existing presses to be field upgraded to HDNA by installing new printheads, printbars, and press electronics.[2]

HDNA development

Adding dual drop weight capability to the HP A53 Printhead required complete reengineering of the integrated circuits on the printhead's silicon die as well as the electronic hardware in the press. The silicon area required to support essential functions on the die had to be reduced to free space for the additional FETs (field-effect transistors) needed to drive the LDW nozzles and for circuits to handle the increased data bandwidth and on-chip processing for nozzle control.

An important design objective of the HDNA platform was to optimize every element of the image processing pipeline from the press's digital front-end to the power-control circuits on the printhead itself. In HDNA presses—and existing presses upgraded to HDNA—redesign of press electronics with higher levels of integration reduced the number of printed circuit assemblies *by a factor of two.* Not only was this necessary to implement HDNA, the new press electronics incorporate features to support future upgrades when more functionality is developed and introduced.

In developing HDNA, HP engineers assessed the processing capabilities of advanced ASICs and FPGAs[15] and reevaluated which operations could and should be done on the printhead die. A key objective was to place computational functionality where it would be most cost-effective and to free space on the die for additional features—such as drive circuits for the LDW nozzles. HP's CMOS technology used in SPT printheads is optimized for HP Thermal Inkjet nozzle operation with efficient power delivery, low-cost manufacturing, and robustness in the presence of HP Pigment Inks. These constraints impose limitations to computational power, circuit interconnect density, data storage, and printer-printhead communications bandwidth. On the other hand, state-of-the-art CMOS used in ASICs and FPGAs achieve computational performance at least 10X greater than what can be done on a printhead die, and this is where computationally-intensive tasks were implemented in HDNA. For example, some functions that were once performed on printhead die—such as nozzle addressing logic and compensation for printhead location error—now reside entirely, or in part, in the printer ASICs and FPGAs. With HDNA's redesigned nozzle data processing and communication protocols, the nozzle data memory on the printhead die was reduced by 10X.

[14] For more information, visit hp.com/go/pagewidexl
[15] ASICS – application-specific integrated circuits. FPGAs – field-programmable gate arrays.

In HP A53 Printheads, the silicon area for integrated circuitry that was made available by reengineering the data path is now allocated to those functions directly related to printing (and drop ejection): doubling the number of nozzles with the ability to operate them 1.5-times faster (compared to the HP A51 Printhead), regulation of on-die energy differentials (between LDW and HDW drop generators), control of die temperature, and other capabilities reserved for future development. These features not only enhance productivity but enhance print quality as well. For example, circuits monitor and control temperature across each HDNA die to reduce temperature variations by up to 10X compared to older designs. Since drop volume increases with increasing ink temperature, this reduces drop volume variations that could produce "light-area banding" —where warmer regions of the die produce larger drops than cooler regions.

Summary

HP's High Definition Nozzle Architecture brings new levels of quality and productivity to HP PageWide Web Presses with dual drop weight printing and improved data-processing hardware. This enables HP PageWide Web Presses with HDNA to deliver higher quality and higher productivity compared to the previous generation.

Using low and high weight drops, HDNA can directly print more colors to reproduce smoother tones and reduce grain in images. HP A53 Printheads print mono and color with dual drop weights in Quality mode up to 400 feet/minute; in Productivity mode, they deliver similar quality to HP A51 Printheads with color speed increased up to 800 feet/minute.

For the HP A53 Printhead, electronics on the die were reengineered together with the image-processing electronics in the press. This new architecture moves some data processing off of the die where it can be processed more cost-effectively in ASICs and FPGAs. In addition, improved thermal monitoring and regulation on the printhead improves drop weight consistency across the printhead to suppress banding.

HDNA is a new platform for HP PageWide Web Presses designed for high performance now and upgradability in the future. HDNA carries on HP's commitment to preserving customers' investments as HP develops and introduces advancements in commercial inkjet printing technologies.

To bring the benefits of HP HDNA Technology to the installed base of HP PageWide Web Press customers, printbars and electronics of existing T200, T300, and T400-series presses can be field-upgraded to use HP A53 Printheads.[16]

Learn more at
hp.com/go/pagewidewebpress

[16] Excluding HP PageWide Web Press T260, T400S, and T1100S until further notice.

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