White Paper

April 2015

Advances in Imaging to Improve Output Quality

The Xerox Versant and EFI Fiery Digital Front End

Service Area

On Demand Printing & Publishing
Consulting Service

Comments or Questions?

InfoTrends
A Questex Company

Table of Contents

List of Tables

List of Figures

Executive Summary

Print service providers have long been frustrated with the limitations of some digital print processes, particularly in regard to the reproduction of fine shade gradations in computer illustrations and photography. Digital print processes often have the ability to reproduce these gradations more accurately, but the limiting factor for many of these systems is the image processing in their digital front ends. The Xerox Versant product family with its EFI Fiery front ends holds a solution to this problem because of the system's ability to support 10-bit processing (rather than 8-bit). Other image processing capabilities of the system contribute to additional quality improvements.

Key Findings

- Definitions of key terms, such as vector and raster graphics, spatial and tonal resolution, as well as halftones, clarify how important the 10-bit processing is for a range of image types.
- The combination of 2,400 by 2,400 spatial resolution of the Xerox Versant family, a 10-bit capable printer interface, and 10-bit processing capability in the EFI Fiery front end contribute to improved quality rendering that Xerox refers to as "Ultra HD Resolution."
- The image processing using Ultra HD Resolution increases the possible number of pick points from 256 (with 8-bit) to 1,024 with 10-bit for each color separation.
- Building on Ultra HD Resolution, the system is capable of reproducing blends in a significantly smoother fashion. EFI calls this capability "Fiery Ultra Smooth Gradients."
- Using the high resolution of Versant VCSEL ROS imaging system, EFI leverages a Xerox technology called "GrayFont" to improve the edge definition on output of solid graphics or text.
- 10-bit processing is not currently available on any other Fiery-driven front end on the market. This capability is brand new and represents a significant advance in image processing and quality for production digital print.

Recommendations

- End users with demanding quality requirements and subject matter that require extremely smooth blends should examine output from Xerox Versant products, such as the Versant 2100 and Versant 80 systems.
- Sites with demanding customers that may refuse output from (or never even consider) production color digital printing technologies should re-assess their prior expectations in regard to digital print.

Introduction

Quality advances in digital printing have a foundation in a dizzying array of technologies working together to produce the desired end result. How the data is handled from start to finish is critical to the end quality. Image processing plays a huge role in this. In this white paper, InfoTrends will explore the role of resolution and image processing techniques in quality improvements associated with the Xerox Versant product family. The definitions and descriptions in this white paper apply across a broad category of products, but the image processing improvements are specific to the Xerox Versant family and its EFI Fiery front end. This sponsored white paper has been written with the benefit of technological insight from Xerox and EFI experts.

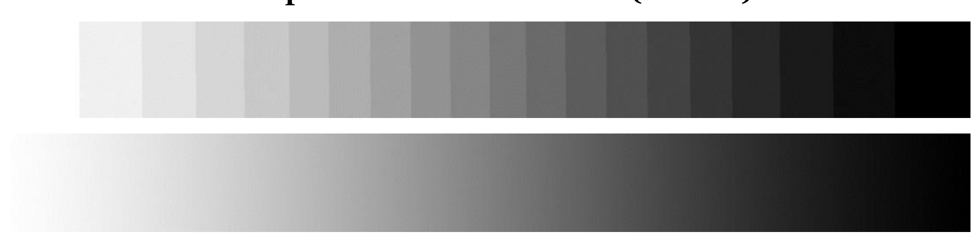
Defining Resolution

Any discussion of print quality requires an understanding of the factors that contribute to it. For the purpose of this white paper, it is important to see that some key technological advances in image processing and output can have a big impact on the reproduction of text, illustrations, and photographs. We will start with some important definitions in regard to image types and their resolution.

Vector and Raster

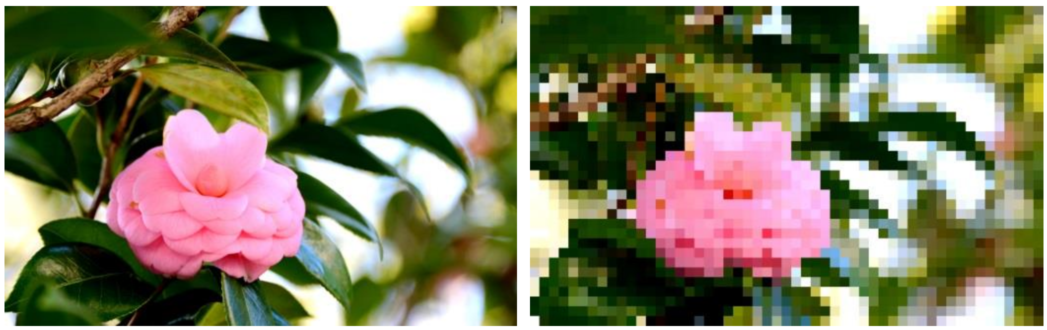
There are two major types of images. These can be classified broadly as vector and raster. **Vector images** are mathematical in nature. They are created from curves and lines and tints that are rendered mathematically. For example, text is produced using vectors. So are illustrations of the type that a vector drawing program can produce (Adobe's Illustrator is a well-known example of a vector drawing tool). Vector images can be scaled up or down in size and still reproduce well, retaining their original shapes and sharp edges. There is a limit, though, in terms of how tints and blends can be reproduced effectively as vector drawings. An artifact commonly known as shade-stepping can occur when a blend between two colors or shades is stretched out too far. This artifact may not even be noticeable on a computer monitor, but may appear on output, depending on factors like the output resolution in dots per inch of the printer it is produced on (more on this later).

Figure 1: Shade-stepping on a Gray Blend (top) compared to a Smooth Blend (bottom)



Scanned images and digital photographs are part of a different category called raster images. **Raster images** are built upon a grid. If you were to look at a magnified square inch of an image that had been captured at a 300 pixel[1] per inch resolution, what you would see is 90,000 pixels (300 x 300) crammed into that space in perfectly symmetrical rows and columns. Raster images can be reduced in size without any issue, but as you enlarge a raster image, you may begin to see an edge-acuity artifact that is described as pixelation. Raster images are, by definition, resolution dependent. Vector images, in contrast, are resolution independent. They can be enlarged on screen without distorting their mathematically-calculated lines and curves[2].

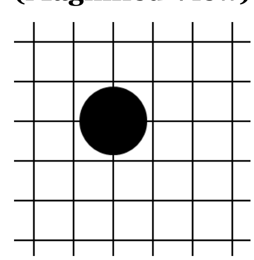
Figure 2: Non-pixelated and Pixelated Raster Images



Spatial and Tonal Resolution for Images and Printers

The two most important types of resolution are spatial and tonal. **Spatial resolution** refers to the amount dots, spots, or pixels that can be captured or reproduced by an imaging device. Typically, spatial resolution is measured in dots, spots, or pixels in a linear inch. For digital cameras, you will hear the term "megapixels," which refers to the number of pixels the device can capture. Whether measured in dots, spots, pixels, or megapixels, spatial resolution applies to digital cameras and scanners as well as to computer monitors, television screens, and digital printers. Spatial resolution may not be the same on the horizontal and vertical axes. For example, a printer may have a spatial resolution of 600 by 1,200 dots per inch, which means that one axis is twice as densely populated as the other. In Figure 3, we see an artist's conception of the gird (or raster) of a printer. In this case, the printer can place a mark everywhere that the grid lines cross. If the grid lines are separated by 1/600 of an inch, then this printer would have spatial resolution equivalent to 600 dots per inch.

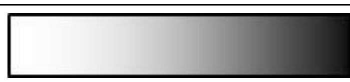
Figure 3: One Mark on a Raster Grid Representing a Printer's Spatial Resolution (Magnified View)



[1] The term "pixel" is a contraction of "picture element."
[2] Keep in mind that anything that gets printed digitally ultimately has to be translated to the raster grid of the digital printer.

Tonal resolution provides another dimension. If spatial resolution occupies the X and Y axes, then tonal resolution is the Z axis. Tonal resolution may be referred to as "bit depth" and one of the simplest examples of bit depth is to compare three basic types of scans: Black & white line art, grayscale (i.e., monochrome) images, and color images. A black & white scan is sometimes referred to as a one-bit scan because one bit is capable of reproducing two shades; in this case those shades are black and white. This is also referred to as a "one-bit per pixel" scan because every pixel can reproduce either of those two shades. A grayscale scan requires more bits per pixel to accurately reproduce the required shades of gray. Typically, grayscale digital images contain anywhere from 8 to 16 bits per pixel, depending on how they are scanned or captured. Theoretically, an 8-bit scan can reproduce 256 shades of gray[3]. For each bit added, the tonal resolutions doubles, so from two possible shades for 1 bit of tonal resolutions, the number of shades becomes 256 bits for 8 bit tonal resolution, 1,024 for 10-bit, 4,096 for 12-bit, and so on.

Table 1: Bits and Levels

	Number of Bits	Levels Reproducible	Distance Between*
	1	2	0.5"
	2	4	0.25"
	3	8	0.125"
	4	16	0.0625"
	8	256	0.0039"
(Beyond 256 levels, the improvement is not easily illustrated on screen.)	10	1,024	0.0010"
	12	4,096	0.0002"

**Distance between each level for a 0% to 100% grayscale over a linear inch.*

You can see from the Table above how the number of gray shades expands as the number of bits increases. As more shades are added, this is helps provide a smoother blend, but it also helps better represent the lightest tones. As bit depth increases, it offers the imaging system more choices for each shade. For example, with 8-bit processing, there are 256 choices (or pick points) for the digital front end system's raster image processor (RIP) to choose from. With 10-bit processing, the number of choices increases four-fold to 1,024. You can imagine how this could translate into a very positive quality improvement, assuming that the system could handle and reproduce that amount of data effectively.

[3] 256 equals 2 to the 8^{th} power (i.e., 2 x 2 x 2 x 2 x 2 x 2 x 2 x 2).

This is particularly important for longer blends and transitions between two similar shades.

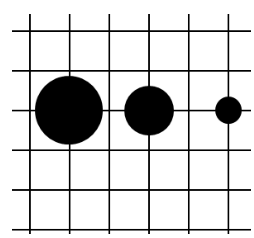
As we move to color, we see that color scans capture more data than grayscale ones. Typically, color scanners capture three channels of tonal information: Red, green, and blue (RGB). Each channel of information has a bit-depth associated with it for its tonal resolution. This is why you will hear some scanners referred to as 24-, 36-, or 48-bit—even though they are only capturing 8, 12, or 16 bits per channel (i.e., red, green, and blue).

Table 2: Summary of Common Raster Image Types

Name	Computer Name	Tonal Resolution	Minimum Acceptable Spatial Resolution
Monochrome line art	Bitmap	1 bit	600 dpi
Grayscale photographs and artwork	Grayscale	8-bit to 16-bit	150 dpi
Color photographs and artwork	Color (RGB)	24-bit to 48 bit	150 dpi

Tonal resolution for a digital printer can be pictured as a variation in the size of the mark (i.e., the laser spot or inkjet droplet) that the device can lay down on paper. Some digital printers, whether laser or inkjet, have the ability to vary the size of the mark they can print. Imagine, for example, a printer capable of making dots of three different sizes. In essence, this represents 2-bit tonal resolution because four different shades are possible (i.e., no dot plus the shades produced by the small, medium, and large dots).

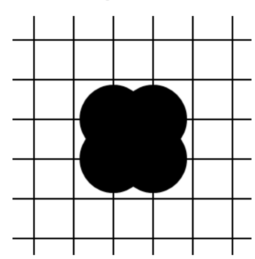
Figure 4: Three Marks on a Raster Grid Representing Tonal Resolution on a Printer with Three Dot Sizes (Magnified View)



Reproducing Grayscale and Color Images in Print with Halftones

There is another layer of complexity in regard to image reproduction in print. Photographic images are typically reproduced using halftones. A halftone is comprised of a series of small dots on a regular grid. Each halftone dot is made up of multiple laser marks or inkjet droplets.

Figure 5: Halftone Dot Consisting of Four Printer Dots (Magnified View)

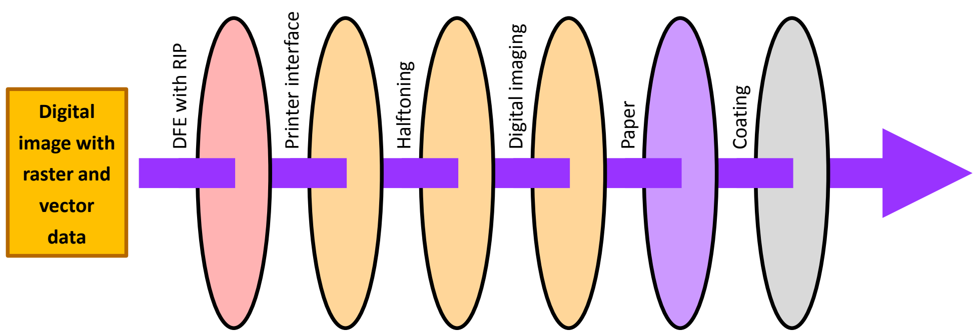


Xerox's Versant family supports a number of different types of halftone screens, including 150, 175, 200, 300, and 600 line per inch[4] varieties. Versant's imaging can also reproduce a frequency modulated (FM)[5] halftone that does not adhere to the regular rows and columns of halftone dots. Instead, it scatters the individual printer dots in a "random"[6] pattern using more or less of them as necessary to replicate various shades.

A Multi-layered Approach to Quality

How do these definitions apply to the full process? Each step presents an opportunity to enhance the original image.

Figure 6: A Multi-layered Approach



It is a multi-layered approach that starts with the digital images (vector and raster), which are submitted to the digital front end for image manipulation and raster image processing. The digital printer has three important components: An interface, halftoning capability, and its laser or inkjet imaging. The printer interface takes the data from the front end and applies halftoning to the parts of the image that require it. The digital printer takes this digital data (one for each of the four planes: Cyan, magenta, yellow, and black) and then uses toner or ink to apply the image to the selected substrate. After printing, an aqueous or UV coating may be applied for gloss or scuff-resistance. Along with the paper, these factors have a significant impact on how the gloss and texture of the printed piece is perceived by the viewer. Throughout, process calibration and color management techniques are employed to provide consistent output and color results that align with the designer's intent. Spatial and tonal resolution have an impact on each of the steps in this multi-layered process. Achieving high image quality requires that the images and their processing maintain detail, gradations, and color throughout.

In regard to halftoning, vendors with printers that offer more than 1-bit tonal resolution will position that as an advantage, and (to some extent) this does improve output quality. You may ask: "Which is better—high spatial resolution and 1-bit tonal resolution or lower

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4 The higher the number in lines per inch, the finer the screen ruling, and therefore the less visible the dot patterns to the human eye.
5 Frequency modulated halftones are sometimes called 'stochastic' halftones.
6 Given that the printer dots must be placed on the page according to the regular rows and columns of the printer's raster grid, they are not truly randomly placed.

spatial resolution and multi-bit tonal resolution?" Xerox engineers determined that they preferred the benefits of high spatial resolution, which gives excellent flexibility in the creation of halftones and allows the rendering of very fine detail. Many devices with high spatial resolution have 1 bit of tonal resolution. This is perfectly suitable for halftoning. It should also be noted that the high spatial resolution of the VCSEL ROS lasers is a true 2,400 by 2,400 dpi. No interpolation is used to achieve this.

Table 3: Spatial and Tonal Resolution Summary

	Common Value Range	Comment
Digital image (raster)[7] • Spatial resolution (dpi) • Tonal resolution (bits per pixel)	• 8 to 30 megapixels • 8 bits to 16 bits per RGB channel	A megapixel is equal to 1 milion pixels
Raster image processor (RIP) • Spatial resolution (dpi) • Tonal resolution (bits per pixel)	• 600 to 1,200 • 8- to 10 bit	Some processing may occur inside the RIP at 12 bits, but no device passes 12-bit data to the printer
Output device interface • Spatial resolution (dpi) • Tonal resolution (bits per pixel)	• 600 to 1,200 • 8- to 10-bit	This step occurs inside the printer and is essentially the hand-off of data between the RIP and the printer
Halftoning	• 85 to 300 lpi[8]	For grayscale images and blends
Output device resolution • Spatial resolution (dpi) • Tonal resolution (bits per pixel)	• 600 to 4,800 • 1- to 8-bit	High spatial resolution allows grayscale to be effectively reproduced via halftoning

The Versant Product Family

The newest Xerox color electrophotographic products are called Versant (pronounced "verse-ent"). Like other Xerox color electrophotographic products, they use a laser technology that is known as VCSEL ROS[9]. These imaging systems are capable of 2,400 by 2,400 dpi spatial resolution and 1 bit (i.e., on or off) of tonal resolution. The high spatial resolution of VCSEL ROS systems lend themselves to accurate reproduction of fine vector

[7] As noted previously, vector images are resolution independent and do not have a spatial resolution value associated with them.
[8] Screen rulings such as these refer to conventional halftones. FM/Stochastic halftones are less commonly used and are not defined by their screen ruling in dots per inch.
[9] VCSEL stands for vertical-cavity surface emitting laser diode. ROS stands for raster output scanner.

line work and small text. Raster graphics also benefit from high spatial resolution because it helps in the reproduction of conventional and stochastic halftones[10].

Another important contributor to Ultra HD Resolution is the printer interface's ability to accept 10-bit data from the EFI Fiery digital front end. For most products today that exchange is an 8-bit one, because that is what most printer interfaces are capable of accepting.

Table 4: Components of Ultra HD Resolution

Component	Spatial Resolution	Tonal Resolution
Fiery Processing	1,200 by 1,200 dpi	10-bit[11]
Versant Printer Interface	Capable of accepting 10-bit data from the Fiery	
Versant VCSEL ROS	2,400 by 2,400 dpi	1 bit

The processing in the Fiery digital front end takes place at 1,200 by 1,200 dpi spatial resolution and 10-bit tonal resolution. Why not at 2,400 by 2,400 dpi? Keep in mind that every time you double the spatial resolution, you are actually quadrupling the total amount of data[12]. That would add a significant level of additional processing requirements (in addition to the move from 8- to 10-bit, which also increases the amount of data). From an output quality perspective, it is more important to have the 10-bit capability, which then translates into smoother blends when the data is converted to the final output raster grid of the printed piece. In addition, the 1,200 by 1,200 will be halftoned and converted to 2,400 by 2,400 on the output device.

Of course other factors also come into play in print quality. For example, the extremely small particle size[13] of the toners used in the Versant product family facilitates the accurate reproduction of blends, small type, fine-line graphics, and photos. Factors such as the gloss of the paper and any coatings that have been applied also contribute to the visual experience and can improve the viewer's appreciation of a printed piece.

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[10] In short, the higher the spatial resolution, the easier it is to reproduce a fine halftone screen ruling with a large available number of shades, thus avoiding shade-stepping.

[11] 12-bit processing is used by the Fiery for a limited amount of internal processing, but no Fiery-based system passes 12-bit data to a printer interface.

[12] For example, a square inch of a 100 by 100 dpi image contains 10,000 pixels (100 times 100), but the same square inch at 200 by 200 dpi would contain 40,000 pixels)

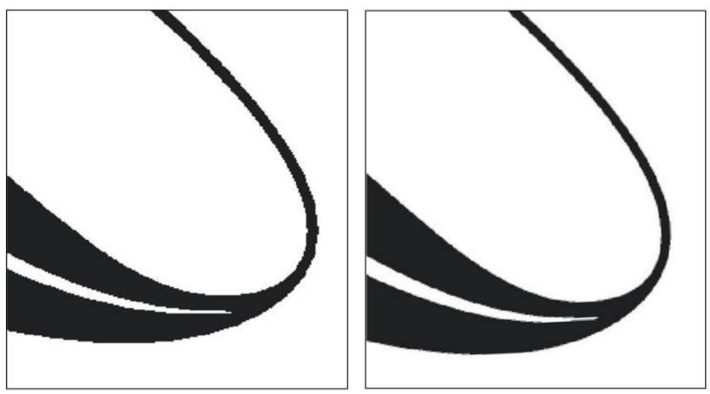
[13] Toner particles used in electrophotography need to be very small to benefit from the high spatial resolution of VCSEL ROS lasers. With 2,400 by 2,400 resolution, each laser spot is separated from the next by 1/2,400 of an inch, or about a 100 microns (each micron is one millionth of an inch). In the case of the EA toners used with the Versant product family, each toner particle is around 5.5 microns; in other words, much smaller than the distance between each laser spot.

The EFI Fiery Digital Front Ends for the Versant Product Family

Electronics For Imaging (EFI) developed the Fiery digital front ends for the Versant product family. For the Versant 2100, these are the Xerox EX-P 2100 Print Server and the Xerox EX 2100 Print Server. For the Versant 80, these are the Xerox EX 80 Print Server and the Xerox EX-i 80 Print Server. These digital front ends are capable of providing the Versant's printer interface with the 10-bit data that is an essential part of Xerox's Ultra HD Resolution. They also leverage other technologies that have an impact on quality, including Fiery Ultra Smooth Gradients and a Xerox technology called GrayFont.

- **Fiery Ultra Smooth Gradients** is a proprietary EFI image-smoothing technology that extends the number of addressable shades in a gradient created as a vector image.
- **GrayFont** is a Xerox edge-enhancement technology that leverages the high spatial resolution of the VCSEL-ROS lasers to improve the reproduction of solid fine lines and text. In addition, the Fiery digital front end provides a text/graphics "Best" option that uses high-resolution information from the RIP to image these pixels accurately using the VCSEL-ROS lasers to achieve sharp edges.

Figure 7: GrayFont Edge Enhancement (Enlarged Illustration)



Source: Xerox Corporation

InfoTrends' Opinion

Though it takes a lot of definitions to fully describe the significance of Xerox's Ultra HD Resolution, the important take-away is that a new level of image processing has been reached. Until the introduction of the Versant product family, no Xerox print engine was capable of accepting 10-bit data from the digital front end. In tandem with an EFI Fiery front end that provides 10-bit data, this means that blends in computer imagery and subtle shade differences in photographs can be reproduced more accurately. In the class of cut-sheet color electrophotographic products with Fiery front ends, no other system provider has a print engine capable of receiving 10-bit data. This sets the bar for all other systems whose print engines currently can only accept 8-bit data. This is a significant technological advance, and is an important differentiator for the Versant product family.

Figure 8: Xerox Versant Print Sample Demonstrating Fiery Ultra Smooth Gradients

The thumbnails shown here cannot adequately represent the 8-bit and 10-bit comparative sample, for that you need to see the actual printed piece.

In the end, though, what is important to print service providers is the actual printed result using the Xerox Versant systems. There is no way to show you that in the PDF version of this white paper. Therefore, InfoTrends highly recommends that you view Versant print samples to see the full impact of this important quality enhancement for yourself. Ask your Xerox representative for a print sample called the "Fiery Ultra Smooth Gradient Comparison," which provides a side-by-side illustration showing the visible improvement and smoother transitions possible with the Xerox Versant product family.

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Comments or Questions?