XAAR

A Guide to **Industrial Inkjet**

CONTENTS

INTRODUCTION

This book is designed to introduce you to the basics of industrial inkjet printing. Whether you are an Original Equipment Manufacturer (OEM) who is interested in exploring inkjet technology, a product manufacturer who needs to improve the flexibility of an existing printing process by going digital, or you are simply curious, we hope you find this pocket guide useful.

We have all become familiar with inkjet printing thanks to the wide availability of low-cost desktop printers using inkjet technology. Desktop inkjet printers work by using replaceable print cartridges to scan to and fro across the paper, building up an image. This book is not about desktop printing, although it shares similar technology, but rather industrial inkjet printing – the use of inkjet technology for commercial or industrial use.

Industrial inkjet is already having a significant impact in higher volume or industrial-scale printing that has been traditionally done by conventional 'analogue' printing techniques such as offset lithography, flexography, gravure, screen and pad-printing.

This is in so-called 'print-for-pay' applications, where the end-product has value because it is printed, like a brochure or an advertisement, or where the printing is incidental to the function of the product, like the label on a bottle, or the pattern on a bathroom tile. This use of inkjet is a much more recent phenomenon. This is 'industrial strength' printing – done in high volume, with high reliability and very cost-effectively.

One sector that has adopted industrial inkjet widely is that of outdoor signage or graphics. This book uses this application to illustrate how inkjet can be employed in production printing systems.

Picture shows items printed using digital inkjet

Industrial scale printing is often defined as being either analogue or digital – quite simply, analogue refers to the traditional system of making plates, or screens, and digital refers to either using inkjet or (less often, as time progresses) electrophotography (what we generally call 'laser') printers.

The artwork files that are to be printed are typically created by designers in the same way for both analogue or digital processes, but there are considerable differences once they leave the creative agency's hands. The diagram below outlines the main steps in both processes.

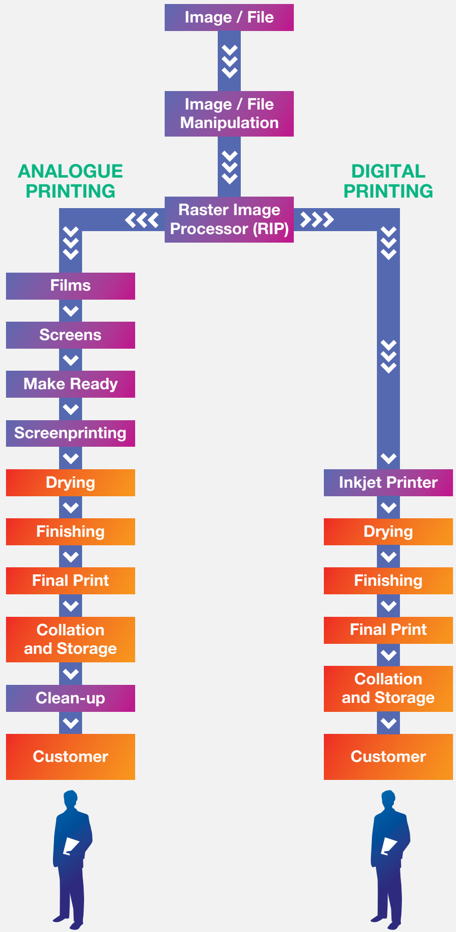


Figure 1: Comparing analogue and digital printing

NO PLATES, NO WASTE

In analogue printing the first step is always to make plates, screens or printing cylinders (we will just say plates from now on for brevity) that are used to print the image on the substrate over and over again. This traditionally involved making films in order to make screens or plates. As shown in **Figure 1**, with digital printing this is eliminated. This saves cost and time as well as waste, as once used the plates are typically scrapped. Another limitation of the analogue process is that the size of the repeatedly-printed image is constrained to the maximum size of the plate; with digital printing onto a continuous roll of paper or plastic there is no such limit, meaning that images like decorative patterns can be longer and less repetitive.

THE PROOF IS THE REAL THING

Buyers generally like to see at least one proof to judge what their job will look like after printing. In fact they may ask to see more than one, if the first trial doesn't live up to their expectations. With digital printing, the same equipment can be used to print the proof, or proofs, giving the buyer confidence without incurring any additional costs. With conventional printing, by contrast, the buyer has to accept a digital proof, a digitally printed equivalent, or a 'press proof', which means that the printer has to actually make plates and print. A digital proof is only an approximation of the final job, but the lead time and cost of making a press proof is significantly higher.

Picture shows an example of sign graphics which can be printed with inkjet technology

‘MAKE-READY’ MEANS MAKE MORE

In all printing, once the image is prepared for print, the production line must be set up. This is often referred to as ‘make-ready’. In both analogue and digital printing, the substrate has to be aligned, and the ink system prepared and tested. In analogue printing in colour, the plates (one for each of the printing process colours: cyan, yellow, magenta, and black) also have to be mounted and positioned – this takes some skill and is usually verified by running the machine for a short period of time so that you can be sure everything lines up properly – what printers call being ‘in register’. The amount of ink transferred to the substrate must also be carefully adjusted to ensure good reproduction. All of this takes time and wastes materials. With digital printing, make-ready is a much shorter process which can be reduced to virtually nothing and consequently benefits from much less waste.

DIGITAL’S SHORTCUT

Most printing is still analogue, and traditional methods still offer the lowest cost per print for long print runs, but as shown in **Figure 2**, there is a breakeven point where digital jobs are less expensive per copy. Although this breakeven point varies depending on the type of print job, the setup costs involved in analogue printing mean that, for short print runs, the costs per copy are typically higher than for digital printing. Until the breakeven point is reached, digital printing can be much less expensive per copy.

This ability to print short runs economically has a lot of advantages:

- It opens up new markets for industrial printing, such as personalising a direct mail piece (a run-length of one!), customising a product with the local retailer’s name, printing promotional items, or in local languages on low-volume product labels
- It makes ‘just in time’ delivery of printed items possible, because there is no set-up time
- It avoids waste, because you only need to print what you want, instead of printing X,000 copies because any lower quantity is not economical – which saves money and helps the environment
- It potentially allows businesses to improve the efficiency of their supply chains, both because of the reasons above and also because they might be able to bring printing in-house.

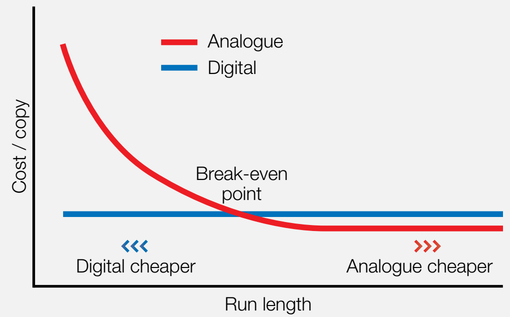


Figure 2: Cost effectiveness of analogue versus digital printing

DIFFERENT TYPES OF DIGITAL PRINTING

Colour printing with electrophotography (i.e. industrial-scale colour laser printing) has been around for a couple of decades, improving in quality and reducing in cost all the time. The technology is now relatively mature, and is widely accepted for short-run printing onto paper. Products like the Xerox DocuColor, HP Indigo, and Kodak NexPress are examples of electrophotographic printers that use toners instead of printing ink for high volume printing.

Industrial inkjet – outside of wide-format imaging and bar-coding – is still relatively in its infancy; but it is maturing extremely fast. Its key advantage over toner-based laser printers is that inkjet is non-contact: the printhead does not touch the substrate at all. This means that inkjet printers can be engineered to deal with a wide variety of substrates not open to laser printers – rigid board, thin films, wide sheets of vinyl, 3-dimensional objects and so on. It also means that no mechanical pressure is put on the substrate – important if you are printing onto fragile objects!

Also, inkjet printers can deal with a wide range of different inks (discussed later in Chapter 3). These can be formulated to be optimised for different substrates e.g. glass or plastic, paper or ceramic tiles. This flexibility is the driving force behind the rapid acceptance of industrial inkjet printing.

In summary, neither the fastest inkjet nor electrophotographic printers can match the production speed of the fastest conventional presses, but both techniques have the ‘digital advantage’ of offering fully variable data printing and having almost no set-up time, and both offer a print quality that, at its best, can equal analogue printing. Where the technologies compete head to head, in commercial or label printing, for example, the argument tends to be about economics – which usually favours inkjet. In other applications, the flexibility of inkjet wins out.

Inkjet printing is seeing increased adoption in several industrial markets because of the advantages we outlined in the previous section. Furthermore, a wide variety of new applications for inkjet have now become possible due to the advances in inkjet printhead technology. Before going into details about the different market segments, we need to explain some basic terms.

CONTINUOUS INKJET

Continuous inkjet (CIJ) is a system where there is a continuous flow of ink from a pressurised reservoir. Pressure waves (acoustic or ultrasonic) break the stream of ink into individual droplets which are then variably charged. The strength of this charge will determine the extent of the deflection of the droplet when it passes through electrostatically-charged plates and will determine where the drop will land on the substrate. A series of these deflected droplets build up the image whereas the non-electrostatically-charged droplets are collected in a gutter and recirculated.

The main advantage of continuous inkjet is its speed. Continuous inkjet systems are capable of running at speeds of over 300 metres per minute. Another advantage of this type of printhead is that the volatile inks used don't dry up in the printhead because they're being constantly dropped and recirculated. They do however require the ink to be topped up with the solvent lost through evaporation. This technology is widely used in high-speed coding and marking production lines where its low resolution, ability to fire the drops further, and its high speed are advantageous. CIJ has also found a niche in utility billing where high-speed, low-quality printing of variable data is required. More recently, CIJ has improved in quality and is being used to print transpromotional documents.

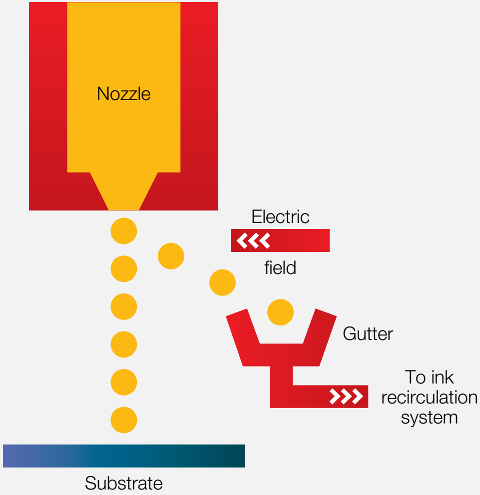


Figure 3: Illustration of continuous inkjet printing

DROP-ON-DEMAND

Drop-on-demand (DoD) printing means essentially that a drop of ink is only generated when it is needed. This can be done in three main ways: thermal inkjet (also known as bubble-jet), valvejet, and piezoelectric inkjet. Valvejet printers use needle valves and solenoids to control the flow of ink, so they are relatively slow and their use – mainly in the coding and marking industry – is declining. We will explain thermal and piezoelectric DoD technologies below.

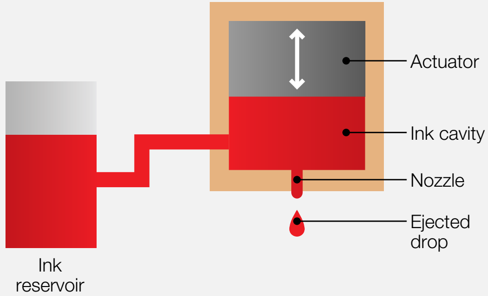


Figure 4: Schematic illustration of the DoD inkjet printing

Thermal inkjet

Thermal inkjet (TIJ) is the most common technology in SOHO (small office, home office) desktop printers, some wide-format printers, and some transactional printers. TIJ printers utilise a tiny heating element within the printhead to eject drops of ink. A current is applied to this element causing it to heat up rapidly. This element is in contact with the ink and causes a small amount of ink to vaporise. This creates a bubble within the printhead chamber forcing ink out of the nozzle. This is shown in the image below. Due to the heat the inks are subjected to there is only a limited range of inks available for this method of inkjet, mainly water-based, and using dyes instead of pigments. Thermal inkjet inks are low-cost to make, but difficult to control on the substrate, so creating high quality photo-realistic images requires specially-coated papers.

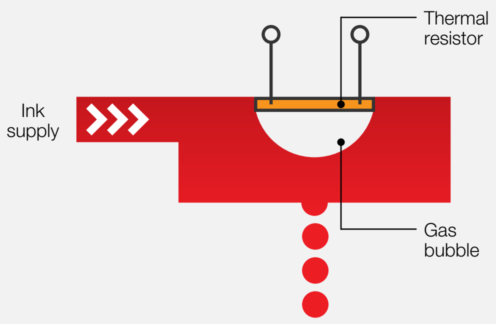


Figure 5: Schematic illustration of thermal inkjet printing

Piezoelectric inkjet

These printheads are made from a ceramic material that exhibits the reverse piezoelectric effect – that is it deforms when a voltage is applied to it. This effect is used in two ways: bend mode or shear mode.

Bend mode

In 'bend mode' printheads, the ink drop is ejected by an array of bilaminar electromechanical transducers. This array is formed by piezoceramic plates, which are attached to the diaphragm. As an electrical field is applied to the plates, the material expands and contracts. This movement of the plates forces the diaphragm to move in and out, which in turn generates pressure on the ink in the chamber, forcing out a drop from the nozzle.

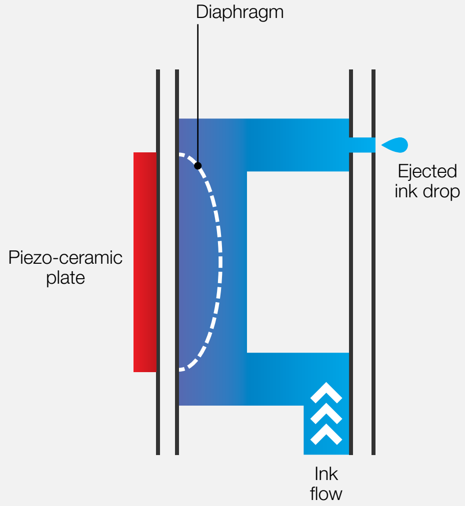


Figure 6: Schematic illustration of bend mode piezoelectric printhead

Shear mode

In shear mode printheads, the electrical field is designed to be perpendicular to the polarisation of the piezoceramics. This causes the piezo crystal to shear, not lengthen or shrink. Using two pieces of the ceramic material for the wall of the ink chambers and then applying the voltage causes the material to flex in the middle.

This flexing is done at very high frequency, which creates a pressure wave which in turn forces out the ink – it's not a physical push action as with bend mode.

This structure is very energy-efficient which reduces the required driving voltage and hence reduces power consumption (benefiting the environment as well as the bill-payer!)

One of the areas of innovation in DoD printhead technology is the way that some companies have invented ways to stop the ink from drying in the nozzles, such as in the Xaar 1003 and Xaar 2001+ with Xaar's recirculating ink system (TF Technology).

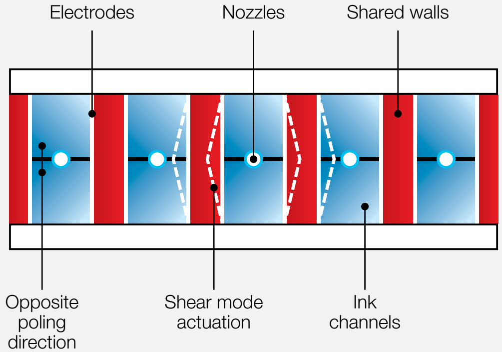


Figure 7: Schematic illustration of Xaar shear mode actuator structure

INTERESTING FACTS: INKJET PRINTHEADS

The basic operation of different inkjet technologies has been described above. What's amazing about these printheads is that this is all done on a micro scale.

Inside a typical printhead the ink channels are only a few tens of microns across and the nozzles out of which the ink is fired are typically 20-50 µm. A 1 pl (picolitre) ink droplet is typically 13 µm across; the width of a human hair is approximately 80 µm.

With printheads operating at high frequencies (over 100 kHz) and several hundred nozzles per printhead it is possible to print millions of drops per second out of the latest printheads.

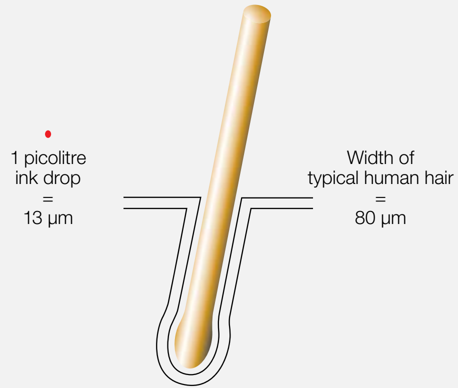


Figure 8: Illustration comparing a 1 pl ink drop to a typical human hair

BINARY OR GREYSCALE

The first inkjet printheads developed were 'binary', i.e. they either printed a drop of a fixed size or they didn't. More recently printheads with variable drop sizes have become commercially available; these are called greyscale printheads.

Binary

As shown in **Figure 9** (a), in binary printheads either a drop is printed or it isn't, on or off. Typically binary printheads offer drop sizes from 30 pl to 100+ pl. Bigger drops generally mean bigger nozzles so these printheads are less sensitive to mechanical artefacts (any objectionable appearance in the print that is not in the original) and more forgiving of the print environment. It also means that they offer lower resolution.

Smaller drop sizes are available, but with smaller ink drops multiple passes are necessary to achieve full coverage because it is not practical or economical to get the nozzle density required to get full coverage in a single pass.

Greyscale

Greyscale printheads fire drops made up of smaller sub drops (typically between 6–20 pl). By varying the drop size the human eye is tricked into seeing a smooth image. Small drops provide the fine details in an image and larger drops give coverage and colour density. Greyscale printing is depicted in **Figure 9** (b) to (d).

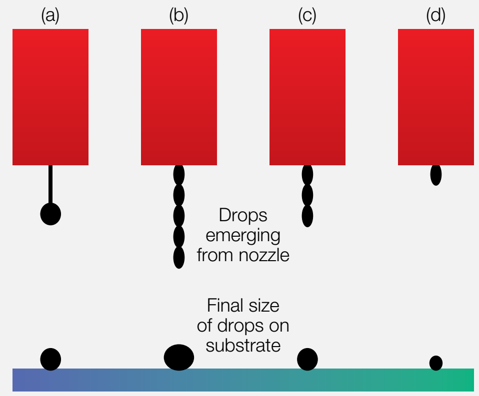


Figure 9: The principles of operation of binary and greyscale printheads (Qualicer 2010, Professor Ian Hutchings)

Whilst the same result can be achieved printing with all small drops (small-drop binary) the ability to print multiple drop sizes means that you can get higher productivity combined with high quality out of a smaller number of nozzles. This is typically more cost-effective and more productive than small-drop binary printing.

Greyscale printing gives results that most people perceive as much higher quality as shown in the set of images in **Figure 10**. The higher apparent resolution is directly related to the small 6 pl sub-drop size and not the native pitch of the nozzles (often referred to as dpi or dots per inch).

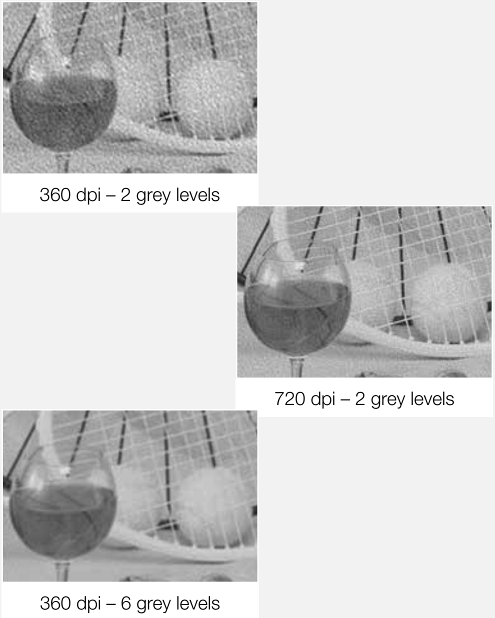


Figure 10: Binary vs greyscale printing

This brings us to a topic that causes a lot of confusion – how do we compare different printheads and printers? Most manufacturers describe their products in terms of dots per inch (dpi) but as we can see from the pictures in **Figure 11**, this isn't the whole story when it comes to quality of the final image.

Picture shows laminate boards printed using Xaar printheads

RELATING PRINTHEAD SPECIFICATIONS TO IMAGE QUALITY

As we noted earlier, printhead manufacturers state the dpi that their product is, but how does that relate to the perceived image quality we can expect from that printhead?

What it is actually telling us is the native resolution of the printhead. A 360 dpi printhead has nozzles that are 1/360" apart, or alternatively we can think of them being able to print a dot on a grid spaced at approximately 70 microns (or µm).

1/360" = 0.0028" = 70 microns

It is better to think of this specification as the 'addressability' of the printhead, its ability to place drops in a grid as in **Figure 11**(a).

If we have an 80 pl drop, this will typically make a spot bigger than 70 microns across. **Figure 11**(b) shows a series of such drops placed in a 360 dpi grid. They overlap slightly and the area is completely covered with ink where they land (full coverage).

Figure 11(c) shows the same drops landing on a 720 dpi grid. The squares on this grid are only 35 microns across and the drops overlap heavily – there is way too much ink here. The printer could compensate by reducing the number of drops, but we can see that the drop size is the limitation of the accuracy with which fine features can be reproduced, and that the 'resolution' (addressability) of 720 dpi is meaningless in this case.

Resolution is actually related to the visual acuity (or sharpness) of the eye – our ability to 'resolve' two objects as separate from each other. For a person with average vision this means the ability to distinguish a pair of objects that subtend an angle at the eye of 1 arc-minute (1/60 of a degree).

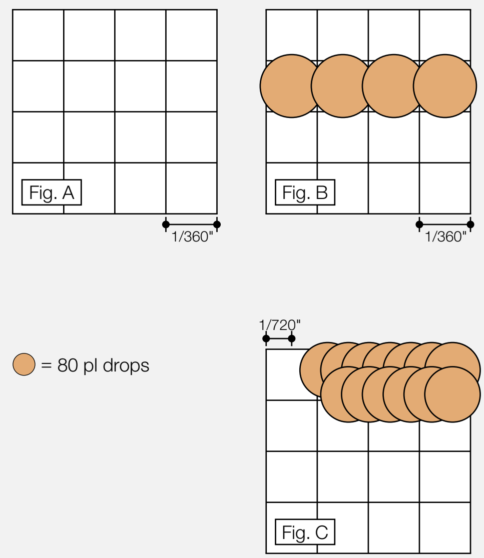


Figure 11: Inkjet drop placement

In terms of a printed image we can relate this to the eye's ability to perceive that the image is made up of separate dots/pixels. This has been measured and **Figure 12** shows the limits of human visual perception.

With binary printing, we need about 1,000 dots per inch for the eye to be fooled into thinking that the image is perfectly smooth. The great news is that for greyscale, as the number of bits per pixel increases, fewer and fewer dpi are needed to maintain the illusion of a smooth image.

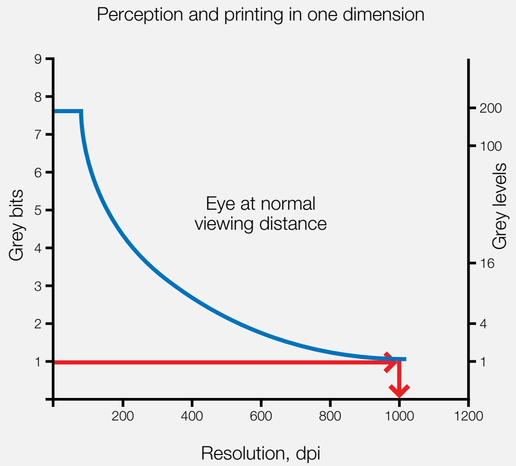


Figure 12: The limits of human visual perception

So, in summary, the dpi number – referring to addressability – is not the most important factor when it comes to perceived resolution in the new world of greyscale printing: the smallest drop size is really the measure that counts. Of course the expected viewing distance is also an important consideration: a billboard does not need to be printed at 1,000 dpi when normally viewed at a distance of several meters; whereas a photo on a glossy brochure probably does.

So let's move on now to the different market segments and how digital inkjet is addressing these with rapidly increasing penetration.

SCANNING OR SINGLE PASS

Inkjet printers print by applying ink in either single or multiple passes. This could mean the printheads are moving over the substrate or object, or that the object is moving past a fixed printhead or printhead array. The following sections go over the differences between these two approaches and why they matter. Inkjet printing of graphics typically consists of scanning, but advances in technology mean that single-pass printing is now becoming the more prevalent. Inkjet printing information such as bar codes or date stamps directly onto products has always been done by passing the product in front of a printhead.

Scanning, or multi-pass printing means that the printer performs many passes over the substrate (paper, cardboard or whatever) to cover it fully and to provide the detail required. This is how our home inkjet printers work.

A major benefit of scanning is that it makes any errors in the printing less visible. Errors are a result of either missing or misplaced dots. These could be caused by nozzles, wholly or partially blocked, or by a mechanical inaccuracy in the printhead.

Scanning also ensures 'full coverage' of the image – necessary so that there is no white space between the dots, ensuring the image looks smooth and colourful without graininess. It also allows us to print dots with finer granularity (called greater addressability – see previous section) than the natural resolution of the printhead, which might be as low as 50 nozzles/inch.

This is because it is less mechanically challenging to interleave dots over multiple passes than it is to try to align multiple printheads. Interleaving dots while using the minimum number of nozzles keeps the costs of a system down.

The downside to scanning is that it is relatively slow, as multiple passes over the same area are needed to provide complete ink coverage, and in addition time is lost at each end of the scan as the carriage containing the printheads needs to be decelerated and then accelerated in the opposite direction. In addition, scanning can degrade small features like text and fine lines, even on printing machines with tight mechanical tolerances.

In contrast, in single pass printing the printheads print directly onto a moving substrate, either a 'web' (the substrate mounted on rollers) or 'sheet' (individual pieces of substrate on a moving transport system).

The primary benefit of single pass printing is higher speed and therefore increased productivity. Simply put, printing directly onto a moving web or sheet minimises any time lost between items or pages so you can print as fast as the inkjet technology allows.

The printheads are aligned and assembled into a print bar (as shown in **Figure 13**), ready for mounting into the machine. The print bar makes it much easier to use multiple printheads because you are assured of proper alignment and registration between the print bars used for each of the colours you are printing.

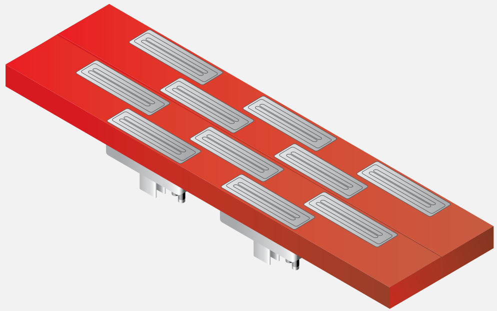


Figure 13: Example of two printbars with five Xaar 1003 printheads mounted in each

The choice of ink is probably the most critical decision in any new industrial inkjet application. It is essential to choose an ink that is well-suited to the application and that has the right appearance on the full range of substrates to be printed.

The main components of an ink are its colourant and its carrier fluid. The colourant can be a pigment or a dye; the carrier fluid may be aqueous, solvent, oil-based or something else. Other things are added to inks to improve their usability, for example: surfactants to control the surface tension of the ink drop to improve its behaviour in flight and when it impacts on the substrate; binders to improve the elasticity of the ink; dispersants to aid the dispersion of the colourant in the carrier fluid.

DYE v PIGMENT

Pigment inks consist of large particles (50–200 nm) which are tightly packed together and are held in a suspension (pigments are by definition insoluble). They have a narrower colour range (or gamut) than dyes, but they are more resistant to fading from light and ozone which makes them very attractive.

Dye inks consist of smaller particles (1.5–4 nm), which have a larger colour gamut and more vibrant colours than can be achieved by pigments, but on the downside, dyes are very prone to attack from light and ozone. This is why you often see posters (or curtains) in windows where the colours have faded.

INK TYPES

In most cases inks are described in terms of their carrier fluids, but in others the naming is based on their properties. Below are described some commonly found ink types in the digital inkjet market:

Aqueous inks

In aqueous inks the carrier fluid is water. These inks are used in printing onto coated substrates where the water is absorbed quickly into the coating and the dye or pigment is fixed to the surface of the coating to give a sharp defined image. They are mainly used in graphic and textiles applications.

Solvent inks

These inks use a solvent as their carrier fluid. Generally the solvent is a type of volatile organic compound which means they dry very quickly through evaporation. Solvent inks are cheap, durable and give good coverage on non-porous vinyl and other graphic arts substrates. They are however considered as being environmentally unfriendly and give off strong, often toxic, odours as they dry, meaning that special ventilation systems must be used. The durability of the final product though means that these are still widely used for printing posters and signage for outdoor use.

Latex inks

Latex ink is relatively new and composed of approximately 70% water and 30% additives to achieve the desired performance. Latex refers to microscopic polymer particles that are suspended in the ink. These are not the same as those in latex rubber and are non-allergenic. These inks give good durability, and although solvents are still better, some companies see the environmental and health advantages as outweighing that and are starting to use latex inks for their indoor and outdoor signage.

Unlike solvents though, they do require a drying mechanism. As the liquid evaporates the latex polymers coalesce and fuse together, encapsulating the colourant. What's left on the surface of the print is a continuous layer of latex polymer, encapsulating and protecting the pigment. The inks cure almost instantaneously, meaning that the drops do not have a chance to spread and bleed together, producing crisper detailing.

Oil-based inks

Oil-based inks consist of a binder, varnish and a colourant. The varnish is a vegetable oil used as it increases the glossiness of the dried substrate. Oil-based inks dry quickly by absorption and are suitable for printing on porous substrates such as plain paper, coated paper and cardboard. These inks are most commonly used in coding and marking and some paper-based wide-format graphic applications.

UV inks

UV inks represent the fastest-growing segment of the industrial printing ink market. These inks are cured into a solid when 'photo-initiators' in the ink interact with a high intensity source of ultraviolet light. With no solvent, UV inks are considered more environmentally friendly. Also, unlike aqueous and solvent inks, where the carrier fluid has to be dried off to leave the colour behind, the whole of the liquid UV ink is turned into a solid that remains on the substrate. UV inks are used for printing onto non-porous substrates and are used mainly in graphics and industrial printing, e.g. product decoration.

Hot melt inks

Hot melt, or phase change inks are heated in the printhead to keep them liquid and once jetted solidify on impact on the substrate. This phase change occurs during droplet spreading, allowing the final spread diameter and height of the droplet to be tightly controlled.

This ink has an advantage over aqueous inks in that it does not suffer from bleed and ink penetration through to the other side of the paper. These inks are used in the coding and marking and packaging segments. One disadvantage of these inks is that sometimes it is possible to scratch them off.

Other types of 'ink'

Many people have experimented with inkjet printing in applications that are not to do with decorating or marking a product. In these applications we call the 'ink' a Functional Fluid as it has a function to perform when laid down on the substrate, which is typically glass or silicon.

One example is where metallic or conductive functional fluids are printed to form electronic components and circuits. In this case the functional fluid consists of nanometer size particles of conductive metals such as silver and copper held in suspension in a carrier fluid. Once printed these inks are then sintered (heated until the tiny particles adhere to each other) enabling the printing of conductive tracks for electronic components and circuits.

Other functional fluids include solders, epoxies, optical polymers, conductive and semi-conductive polymers, transparent conductors, dielectric and resistor materials.

The advantages of inkjet in these applications include the reduction in waste and toxic materials – the standard procedure for printed circuit boards (PCBs) requires the whole board to be coated, then masked and etched, which is wasteful and therefore more expensive.

Picture shows a label printed using Xaar's High Laydown Technology

CHOOSING AN INK

With such a wide variety of inks around, how do we choose?

Generally the first item to consider is the purpose of the final product. If we are talking about an outdoor poster that has to withstand sun, wind, rain, hail or other natural phenomena, we need a final result that can withstand these conditions: probably a pigment-based solvent ink. Conversely if we are talking about low-cost transactional printing, then we are more interested in getting fine printing on a paper substrate where the ink doesn't bleed.

Because industrial inkjet printheads are precisely manufactured products with ultra fine nozzles, the composition of the ink must be matched carefully to the printhead to ensure that the ink can be jetted reliably and consistently. Most printhead manufacturers fine-tune the way the printhead fires the drop for each of their approved inks to ensure optimal jetting performance for each specific application, or they provide tools to enable their customers to do this. This is sometimes called 'waveform optimisation'.

In industrial inkjet machines, the ink is usually supplied in 1 or 5 litre bottles, but how long would this last on a generic wide format graphics printer, and do we need to worry about the ink drying up? If we take the Xaar 1003 GS6 printhead with 1000 channels, this has a maximum drop size of 42 pl and a maximum firing frequency of 7kHz (each channel can jet 7000 times per second). If we set the machine up to jet continuously then it would use:

1000 nozzles x 42 x 10^{-12} litres x 7000 x 60 x 60 = 1.06 litres per hour.

In practise though, we would rarely have an image that is 100% covered in a single ink, it's usually made up of different colours and shades plus on a scanning machine there will be flyback time and more often than not there will be a white space around the image. In any case this gives some idea of the amount of ink an industrial machine can use.

INK DELIVERY SYSTEM

As we saw earlier, the printhead works by using a small amount of energy in each nozzle to eject a drop of ink. This breaks the meniscus at each nozzle. (The meniscus is the curved surface of the ink formed at the nozzle orifice by surface tension. Imagine a glass of water filled to the very brim. Look at it carefully and you will see that the surface of the water forms a convex curve slightly above the top of the glass. This is a meniscus.) The drop is held back in the nozzle by a slight negative pressure until the energy pulse is applied. If it were not, it would dribble out!

The main function of the ink supply system is to ensure that the correct negative pressure in the system is maintained, while ensuring that the printhead does not get starved of ink when printing. Too little ink, and you will see gaps in the printing; too much ink, and the nozzle plate might get flooded, causing irregular jetting, again compromising print quality.

The ink supply needs to do several other things: it will filter the ink to minimise the chance of particles clogging the nozzles; it might 'de-gas' the ink to remove air bubbles; it might heat the ink to ensure that it is at the right operating temperature; and in the case of an 'ink recirculation' printhead like the Xaar 1003 (which has unique TF Technology), it will continuously circulate the ink through the printhead past the back of the nozzle as in the schematic below.

In the case of scanning printers, the ink supply must also be able to withstand the acceleration and deceleration of the print carriage as it moves across the substrate without causing pressure variations in the ink.

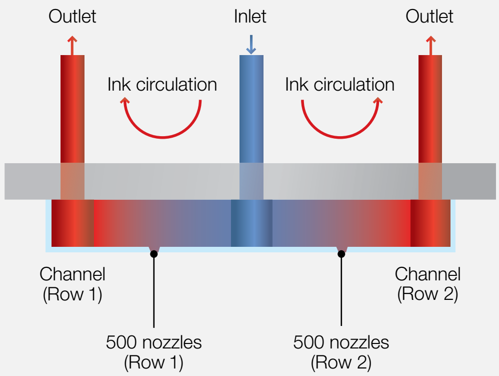
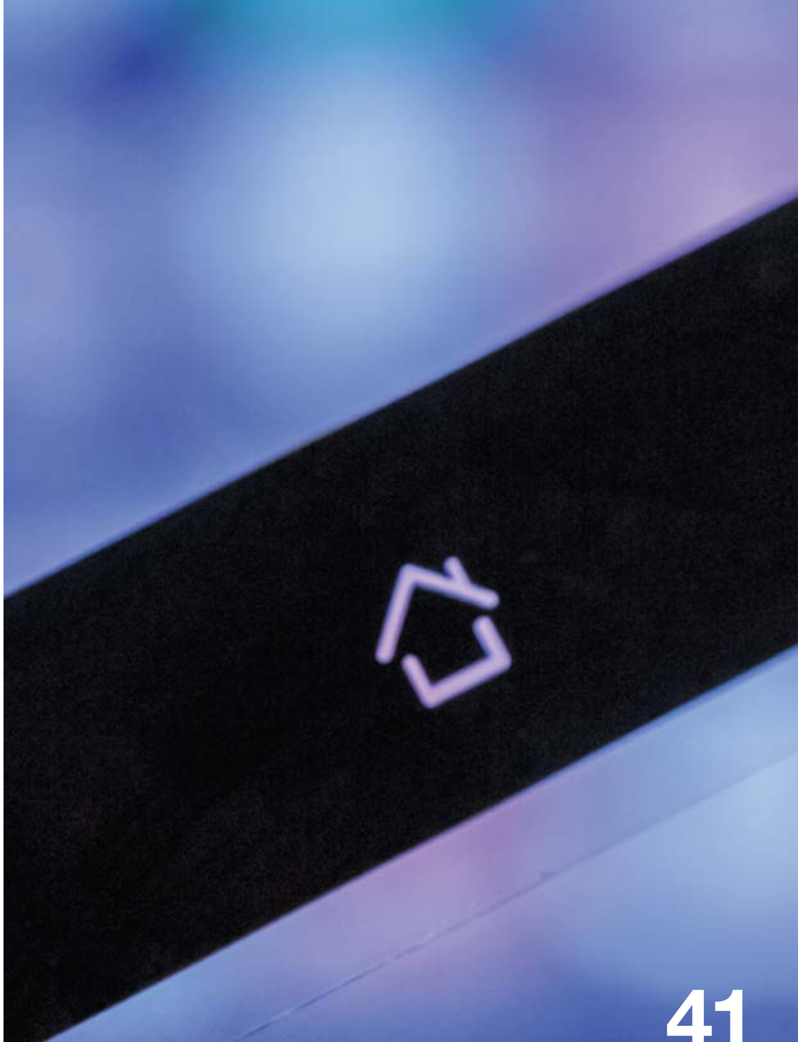


Figure 14: Illustration of TF Technology (ink recirculating past the back of the nozzle) in a Xaar 1003 printhead



Picture shows black mask printing for which inkjet technology is well-suited

An industrial inkjet printer is much more than a set of printheads and a well-chosen ink. There are many different components to a well-designed system, and they all have to work well together. So we'll now take a look at what is needed to build an industrial inkjet printer.

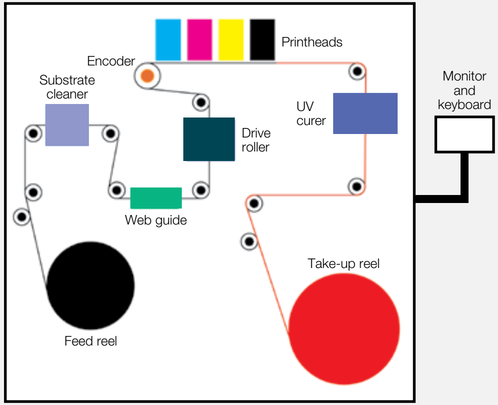


Figure 15: Illustration of a typical inkjet label press

PRINTHEADS

Firstly you will need to choose how you wish to print (greyscale, single-pass or scanning etc.) and how many colours you want to use. That will determine what type of printhead and how many printheads you will need in your print bar. Extra printheads might be added for a greater print swathe or for increased resolution. Cost of course is a consideration, but, in general, the more printheads you use the more productivity you get.

On the following page is an illustration of a printhead.

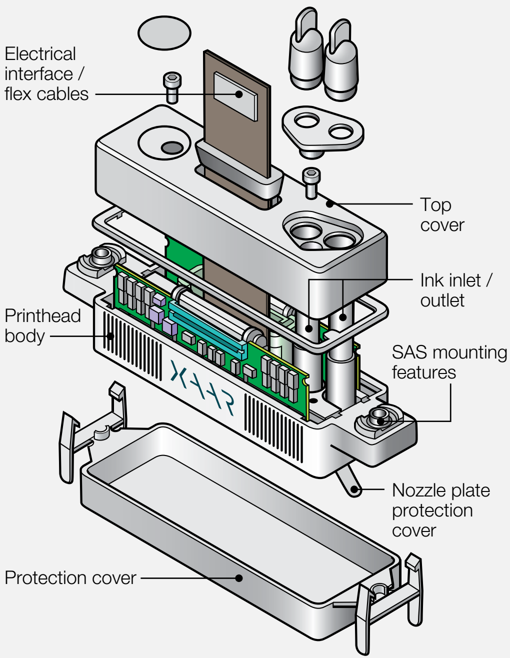


Figure 16: Illustration of a Xaar printhead

BULK PIEZO PRINTHEADS VERSUS THIN FILM SILICON MEMS PRINTHEADS

One key consideration when determining your printhead of choice is which core technology would suit your application best.

In Inkjet, the two main approaches are 'bulk piezo' and Thin Film printheads. Thin Film uses much less pzt than bulk (pzt is expensive). A variation of Thin Film printheads uses Silicon mems which allows nozzle arrays to be packed closer together. Xaar has a range of printheads of both bulk and Thin Film types.

Applications which lend themselves better to bulk piezo printhead are those requiring:
- Higher viscosity
- Larger drops
- Higher laydown
- Larger particle sizes
- Higher throw distance
- Higher temperature operation
- Long lifetime printheads.

Applications which lend themselves better to Thin Film Silicon mems printheads are those requiring:
- Very high productivity
- Image quality
- Smaller drops
- Higher density
- Higher drop placement accuracy
- Ultra high speed
- Lower cost
- Fluid versatility.

DRIVE ELECTRONICS

The drive electronics form a key element to the success of the digital inkjet process, providing the conduit between the processed image data and the printhead.

The printhead needs electronic signals to control where the ink will be applied. This delivery of signals is dealt with by the drive electronics, which take the digital image file and translate it into electronic signals that the printhead can understand.

In general, some electronics are built into the printhead itself providing the correct voltage and current to actually drive the printhead. The drive electronics are contained within the black box that communicates between the PC that provides the image to be printed and the electronics on the printhead itself.

In some cases vendors refer to Head Personality Cards (HPCs). These allow connection of different printheads to a set of common drive electronics. The HPC converts the generic information from the drive electronics into the specific signals that particular printhead type requires.

The signals drive the piezo actuation (for printheads like the Xaar 1003 or Xaar 2001+) or the thermal activation (in HP and Canon printheads for example). The required pattern of coloured dots making up the image determines which printheads receive what signals, at what timing, while the substrate is passing underneath them.

Various printhead manufacturers offer their own designs of drive electronics. There are also a small number of independent suppliers, or the drive electronics can be provided by a systems integrator or the printer manufacturer itself.

Picture shows digitally printed packaging

FRAME AND SUBSTRATE TRANSPORT

Another issue with inkjet printing is getting the ink near to what you need to print on. You must decide how to handle your substrate to get it and your printbar and ink close enough to print in a regular pattern. This depends on the type of printer you use as illustrated here in graphics printing:

- On a scanning inkjet printer, the frame needs to be strong and sturdy enough not to vibrate or move during printing. The material transport mechanism is fixed onto this frame
- A roll to roll printer will need a roll spindle on the back to feed the material into the print section and a roll spindle to collect the printed material, with a mechanism on both rollers to maintain steady tension so the material remains stable. Some machines simply have a feed roller and the printed material collects on the floor. Others include a horizontal cutter at the delivery end so that the graphics can be cut to size as they are finished
- A flat-bed printer needs a flat surface on which the sheet material is placed ready for printing. To ensure the material doesn't move during printing, you can also add a vacuum system under the bed that draws a vacuum through small holes in the bed. This table will either be fixed with the printing gantry moving across it, or moving table with a fixed gantry and moving printheads
- A hybrid roll/flat bed printer needs to incorporate all these mechanisms.

CURING AND DRYING SYSTEM

A critical factor determining the speed of a printer is the drying time. There are essentially four drying options:

- Latex ink: needs a pre hot air drier to soften ink before use and a post dryer to fix it
- Solvent ink: needs a hot air post drier or radiated heat (such as LED or infrared lamps)
- Aqueous ink: needs a hot air post drier at great temperatures to encourage a rapid evaporation of the water within the ink
- UV ink: where the ink is fixed using UV curing lamps, either mercury arc or LED. Some designs of printer use an LED lamp for 'pinning' after each colour is printed, followed by an arc lamp for the final cure.

In the case of aqueous and solvent inks, heat is applied to the substrate after printing to drive off the carrier fluid, leaving only the pigment. As noted above, UV-curable inks need to be exposed to a short burst of intense UV light to cause them to 'polymerise'. The light source has usually been a mercury arc lamp designed to emit light at a specific range of wavelengths corresponding to the sensitivity of the photo-initiators in the ink. UV LED (light emitting diode) light sources are gaining increasing acceptance, despite some disadvantages. They typically operate at a narrower band of wavelengths, so the ink needs to be 'tuned' for use with LED-curing, and they put out less power than mercury lamps. However LEDs have longer life, consume less energy, throw off less heat, and avoid the environmental hazards of mercury. Expect their use to grow.

One use for UV LEDs in single-pass printing applications is to ‘pin’ or ‘freeze’ ink drops on the substrate after each colour is jetted. That is, to prevent the ink drops from spreading while all four colours are printed, before the main UV lamp fully cures the ink. A ‘pinning lamp’ after each colour freezes each drop in place before the next colour is jetted. This can improve the print quality.

SOFTWARE – RIP AND GUI

In the digital age, the starting point for print is inevitably a digital file: a BMP, PDF, JPEG, TIFF or EPS (encapsulated Postscript™) file containing the text, graphics and photographic images to be printed. The job of the software and datapath electronics in an industrial inkjet printer is to take this file and translate it into instructions to place drops of ink of the right size in the right place on the substrate to give the best possible reproduction of the image to be printed. This might involve:

- Scaling the image to the right size, and possibly ‘tiling’ it, if it must be printed in multiple sections
- Adjusting the resolution
- Optimising the dynamic range of the image (from shadows to highlights)
- Neutralising any colour casts
- Colour management, or adjusting the image to compensate for the colour profiles of the input and output devices
- Adjusting sharpness

- Colour-separating the image into the printing main colours – typically cyan, yellow, magenta and black, but possibly including white, and light versions of cyan, magenta and black, or ‘extended gamut’ colours like orange and violet. When separating colours, the software might make small adjustments where colours overlap, to overcome mechanical registration errors in the printer. This is called ‘trapping’
- In the case of variable data printing (e.g. a variable barcode, or personalised mailing), this must be integrated in some programmatic way with the template for the rest of the image.

These functions, and often many more, are carried out in Raster Image Processing, or ‘RIP’ software, and we often speak of ‘RIPing’ a file to create an output ‘bitmap’ – that is the raw data that specifies for every pixel location on the image whether or not a drop of ink of each available colour is to be placed there. Before the advent of ‘greyscale’ or variable drop printing, this file was binary – one bit per pixel, ‘1’ or ‘0’, a drop or no drop. With 8-level greyscale however, 3 bits/pixel have to be specified; and with 16-level, 4 bits/pixel.

Whether binary or greyscale, the datapath electronics have to take the value for each pixel and interpret that in terms of the layout of the printheads, the speed of the printheads over the substrate, and timing of the start of printing. The pixel data is typically ‘buffered’ in memory and ‘print swathes’ are streamed to the printheads. The printhead drive electronics therefore needs a ‘product detect’ signal to start printing, and an encoder signal, giving the speed of the substrate relative to the printheads.

All these functions and adjustments are controlled via a Graphical User Interface or GUI, typically on a PC.

MAINTENANCE

As anyone who has owned a desktop inkjet printer knows, occasionally it is necessary for a printhead to clear its nozzles by jetting a little ink, and in extreme cases, to manually wipe the nozzles to recover a blocked jet. Similar strategies are used in industrial inkjet printers for the same reasons – nozzles can become blocked by air bubbles, particles, or dried ink. Regular maintenance, either automatic or by the operator, can reduce the incidence of these blockages.

In the case of scanning printers, especially those using solvent ink which can dry out in the printhead, it is common for the printer software to instruct the printheads to 'spit' at regular intervals to ensure the nozzles remain clear. This is less important in the case of UV-curable inks, because the ink can remain in the nozzles for hours or even days without ill effects, as long as they are not exposed to UV light or too much heat. Also, because a scanning printer might use eight or more passes to build up the image, a single nozzle outage can be easily disguised.

In a single-pass printer like a narrow-web label press, a single nozzle out, or 'line down' is immediately visible in the print. This is why 'self-recovering' printheads like the Xaar 1003 and Xaar 2001+ are the main type of printheads used in these applications. Although these printheads are less susceptible to 'lines down' than conventional non-recirculating printheads, manual or automatic maintenance by jetting, wiping, or vacuum purging is still required at least once per shift. Different machine manufacturers take different approaches to this.

One key difference from desktop printers is that industrial inkjet printheads are designed to last many months and years. Unlike thermal inkjet components, the piezoelectric material lasts for billions of operations, corresponding to many years of life. The usual causes of printhead failure are (a) clogged nozzles, and (b) damage to the nozzle plate. Both of these typically result from poor maintenance or incorrect ink use, so it is important that the manufacturer's instructions are followed to get the most life from your inkjet system.

Another frequent cause of problems with industrial inkjet systems – especially ones that are used to decorate products or packaging – is nothing to do with the printheads or system design: it is the interaction of the ink with the substrate. If the surface tension of the ink is not compatible with the surface energy of the substrate, the ink may not adhere properly, or it may cause a variety of unpleasant print artefacts because of the way the ink drops behave when they strike the moving substrate. These effects can be mitigated by optimising the ink formulation, and by techniques such as corona-treatment or flame-treatment of the substrate.

Digital inkjet continues to expand beyond the traditional graphics markets into new applications and sectors.

Today, digital inkjet technology is used widely, from printing ceramic tiles to printing glass, laminates, product identification codes and packaging.

As we look to the future, more and increasingly diverse applications will turn to industrial inkjet, as they come to recognise the benefits this technology can deliver.

WIDE AND GRAND-FORMAT GRAPHICS

The wide and grand-format graphics (WFG) sector is a very broad sector which can cover items such as printing exhibition graphics, posters, bill boards and building wraps. Generally printers in this sector print things that are large or very large.

This market segment was the earliest to be revolutionised by the first generation of inkjet printheads to come onto the market – which were large drop, binary inkjet machines. The reason inkjet was successful in this segment was due to the forgiving nature of the long viewing distance, so that the initial lower quality of inkjet was more than compensated for by the lower cost of making very short print runs, or putting it in the customer's terms, the ability to have more customised posters, billboards etc. The ability to print images in a short time and at a lower cost has driven the on-demand business model to revolutionise the world of display graphics and has resulted in a large number of wide and super-wide (or grand) format printers being available on the market today. It is expected that inkjet printers will continue to take over the WFG sector in the coming years as the quality improves and more marketing departments understand the possibilities of a technology that can offer cost effective customised graphics.

WFG printers typically operate in scanning mode to ensure a good image, using a carriage containing many printheads making multiple side-to-side passes over the substrate. The carriage will typically contain one to eight printheads for each colour and the printer might use four, six, or eight colours, plus white and a varnish coat. So we can see in a WFG printer there is often a very large number of printheads. The substrate can be vinyl, textile, paper (in the case of roll-to-roll machines), foamboard or rigid laminates (in the case of flatbed units). Typically, outdoor applications will use eco-solvent inks that are durable and fade-resistant, usually printed onto vinyl, whereas indoor signage might be printed with aqueous inks or UV-curable inks.

LABELS

The label sector includes security, promotional and primary product labels, most of which are printed conventionally on flexographic printers. Digital printing has gained an increasing share of the industrial label market over the past 10 years, mainly using electrophotographic printers. (Thermal transfer printers are also used for small-scale applications, but are not cost-effective in high volumes).

As with the rest of the printing industry, run-lengths demanded for label production are getting shorter: two thirds of all label orders are now for under 10,000 labels – well within the breakeven point for digital. Inkjet printers are now expanding the use of digital production by label printers and converters. Coupled with a laser die-cutter, an inkjet printer can deliver custom-printed labels of any size and shape!

These single-pass label printers can print on a wide range of substrates: paper, plastic films, and metal foils for example. UV-curable ink is typically used on pressure-sensitive labels and aqueous ink is typically used on porous label stocks (or non-porous substrate if a coating is used).

A recent trend has emerged for using digital inkjet technology to apply very high levels of varnish to create texture on the label as part of the print process. Another emerging practices is to add digital printing capabilities via a printbar to an existing analogue label press to create a 'hybrid' system. This means that label printers can extend the life of their existing analogue presses whilst delivering added value to their customers using digital technology.

CODING AND MARKING

The coding and marking segment – otherwise known as 'product identification' – refers to the practice of putting dates, barcodes, logos, and other images onto products such as food containers ('primary packaging') and the cardboard boxes and cartons that they are packed in ('secondary packaging').

Primary package marking (such as the date code on a milk bottle) is typically done with CIJ printers. Printing on cartons was done with mechanically-operated 'valvejet' DoD inkjet printers, but is now increasingly a piezoelectric inkjet application because of its superior speed and resolution. Low-cost thermal inkjet (TIJ) printers are also relatively common in the coding and marking market.

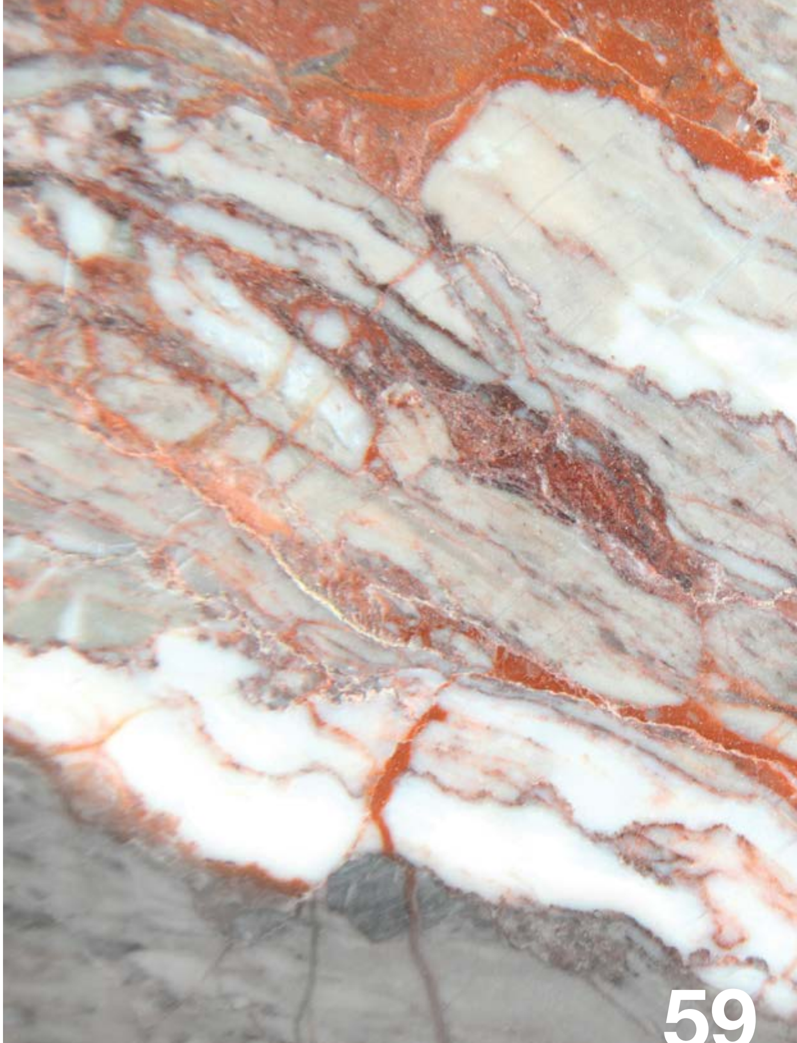
Printers are small and portable, and often networked to the factory's production system so that the barcodes and other data they print can be changed remotely.

Inkjet printers can also print on various substrates from porous to non-porous. Typically these printheads print oil-based ink onto cardboard or paper and solvent-based or UV-curable ink onto plastic packaging.

CERAMICS

The ceramic tile industry is highly dynamic, driven by consumer trends and retailer demands. Various print techniques have been used over the years to decorate tiles, mainly using traditional contact printing methods (such as screen, and rotogravure).

Inkjet printing onto ceramic tiles has many benefits. The non-contact technology of inkjet means that textured tiles and tile edges can easily be printed. The high graphic variability and greyscale quality of inkjet allows for each tile to be printed with a different design showing realistic replications of natural stone, for example. No printing consumables, such as rollers, are needed or required to be stored. Designs can be stored digitally at very low cost and changes to image sizes to match different tile sizes can be done quickly and efficiently. This results in reduced production times. Ceramic printers operate in single-pass mode with specialist ceramic inks.



Picture shows ceramic tile printed using Xaar 1003

DÉCOR

The Décor sector covers many different applications including glass and wallpaper printing, as well as decorative laminates where realistic natural finishes or creative design are the key features which sell the finished item. The digital quality that is now being demonstrated matches quality produced by the analogue process, thereby offering the opportunity for more economic short run work to be undertaken whilst reducing inventories and improving Time-to-Market.

PRODUCT PRINTING

Product decoration is a wide market segment that ranges through printing on nappies to printing on car dashboards. Printing text, barcodes, and logos onto products enables manufacturers to add information and branding to their products. Historically, this type of printing is mostly done by pad or screen printing.

Inkjet printing meets the needs of this industrial decorating market for variable data and short-run marking applications. Custom designs can be delivered quickly and the non-contact inkjet printer is able to print directly onto the products, which come in a variety of shapes and sizes including promotional gifts, automotive components, medical supplies, and other items for which the printing is incidental to the value of the product delivered.

A frequent challenge in the product decoration market is the need to match inks to a wide variety of substrates for optimal performance. Inkjet printing with UV-based inks enables single-pass machines that can be tuned to the ink and substrate combination.

PACKAGING

The essential role packaging plays in our consumer society is one of both branding and product protection. Packaging comes in many forms: folding cartons, labels, sleeves, flexible packaging, and containers such as drums, bottles, and cans. A wide range of flexible and rigid materials is used: plastics, wood, paper and board, metal plate and foils, glass, and textiles.

Nearly all packaging materials today are printed conventionally, but the use of digital inkjet is on the increase. Digital inkjet printing's ability to deliver short production runs cost-effectively supports the use of event-driven promotions, market testing, and niche mass customisation. It allows the same print technique to be used for the sample run and for short-run production, ensuring product consistency.

TEXTILES

The Textiles market covers Direct-to-Garment (DTG) flatbed printing, roll-to-roll scanning, printing speciality fabrics and single-pass printing for high productivity. Textile printing using digital inkjet technology is growing fast due to rapid shifts in consumer expectations such as fast changing fashion seasons, and the requirement to reduce waste and pollution. This drives the need for new, digital printing processes which are capable of delivering short print runs quickly, economically and in a more environmentally friendly way. Digital inkjet is particularly suitable for large format roll-to-roll apparel and also for printing soft signage textiles using dye sublimation.

TRANSACTIONAL AND PROMOTIONAL (TRANSPROMO)

Transactional and promotional (transpromotional) printing is related to document printing such as invoices, statements, or bills and is traditionally most likely to be printed using laser printers or CIJ-based machines.

The trend toward the addition of advertising or promotional messaging often tailored to the recipient is a relatively new marketing approach which combines CRM (customer relationship management) and data mining technology with variable data printing. Personalised invoices are an ideal media for advertising; so many consumer marketing departments are embracing this type of approach. Adding individualised, colour, promotional graphics to an invoice or statement requires multi-colour printing: a need that can be met by xerography (laser or similar) or by inkjet printing at a significantly lower cost per copy.

Most inkjet transpromotional printing machines are single-pass systems using aqueous inks.

INDUSTRIAL 3D PRINTING

3D Printing is a manufacturing methodology that encompasses a range of processes and applications, with a common theme of building parts up, usually layer-upon-layer. This additive approach ultimately enables manufacturers to eliminate the need for tooling. There are significant advantages, including superior geometric freedom, giving designers much more capability, and a substantial reduction in lead time for products.

Picture shows 3D printing using Xaar's High Laydown Technology

In addition 3D printing provides the facility to tailor unique products to consumers, enable de-centralised manufacturing and shrink spare part storage.

Industrial inkjet printing is an ideal technology for 3D printing because it perfectly suited to accurately jetting a specific volume of fluid, or droplet, onto a substrate repeatedly and consistently at high speed in a manufacturing environment.

ADVANCED MANUFACTURING (FUNCTIONAL FLUIDS)

Companies wishing to jet functional fluid are starting to turn to inkjet technology as it offers non-contact, fluid deposition with incredible precision and control. Typically applications are challenging, pushing current technology to and beyond known limits in markets such as Flat Panel Display, Semiconductors and Optics.

It is still early days, but as manufacturing processes develop inkjet will increasingly come to the fore as an efficient and environmentally friendly method of depositing functional fluids and coatings in the manufacture of many of the products we buy.

BIO-MEDICAL APPLICATIONS AND 3D MODELLING

Looking further into the future, inkjet is likely to find use in a wide range of bio-medical applications.

Already some companies are using inkjet to produce two dimensional microarrays for carrying out high throughput blood testing and analysis. In the dispensing of medicines, inkjet is also being considered as a means to micro-dispense dosages of individual medicines into a common carrier on demand to provide personalised medication for individuals.

If you apply the 3D capability referred to above with applications in the medical field then one day we may be looking at skin, bone and human organs ‘printed’ individually for a patient using advanced inkjet techniques.

Universities and companies around the world are already developing such micro-architecture applications and the benefits they bring will be of huge significance to medical care in the future.

The main reason why such novel applications have and will continue to become possible is that certain types of printhead technology can handle a variety of fluids with ease and can offer precise drop placement accuracy.

THE FUTURE OF INKJET

Like every other analogue industry touched by digital technology printing has been, and continues to be, profoundly affected. We have moved from ‘computer-to-film’, to ‘computer-to-plate’, to ‘computer-to-substrate’ – but not across all types of printing.

CHAPTER 5
LOOKING AT THE INDUSTRIAL MARKET

The overwhelming majority of pages printed globally are still printed by conventional analogue processes. Although in some applications like wide-format graphics, outer case coding, ceramics and book printing has inkjet become significant. But digital technology in the form of electrophotographic (laser) printing has made inroads into transactional printing and label printing, and inkjet is following closely behind.

Analysts like InfoTrends and I.T. Strategies believe that inkjet will overtake other technologies in the coming years for several reasons:

- Because it is non-contact, it can deal with many types of substrates, including those with uneven surfaces
- Engineering printers capable of handling a wide variety of substrate widths, flexibilities and thicknesses is easier with inkjet than with electrophotography
- Cost per copy, and total cost of ownership is likely to get lower
- Print speeds are likely to increase.

Inkjet technology has gained momentum and credibility over the last few years as a viable and cost-effective printing method for a range of industrial and commercial print applications.

Certain market segments have proven to be ideally suited for digital printing and the improved reliability and productivity of the latest generation of printheads is providing printers with opportunities to meet the demand for high-quality graphics on a variety of substrates, with short print runs at a low cost.

Digital printing and finishing is providing opportunities to disrupt current supply chains and economics in short-run, just-in-time packaging and label printing for example, and in customised ceramics and décor printing. These markets are all driven by the same motivators: print-on-demand, shorter runs, reduced costs, faster response times, all while maintaining analogue levels of quality and reliability. Product manufacturers who need to print as an ancillary process to the production of the product will adopt inkjet as a means of increasing flexibility and reducing cost. And printers can harness the innovations in inkjet technology to improve response times to existing customers while breaking into new markets.

Beyond the printing industry, inkjet technology is finding applications in bio-technology, printed electronics, display fabrication, solar, semiconductor manufacturing and 3D modelling and is likely to expand to many more areas. These advanced manufacturing applications take advantage of inkjet's capabilities to deliver precisely-metred volumes of a functional fluid to a precise location, with great repeatability. And these applications are driving further development of inkjet technology, improving speed, quality, and the robustness of the printheads. With applications from the nano-scale to the billboard, inkjet has a bright future.

So you want to use inkjet for a particular printing task? Perhaps it is to replace another, analogue, printing process – pad-printing, screen-printing or offset – or perhaps it is to apply a functional fluid that nobody has ever printed before. Whatever the application, here are 10 ideas to keep in mind as you approach the problem of how to print with inkjet:

WILL AN EXISTING PRINTER DO THE JOB?

It's almost certainly going to be quicker and possibly cheaper to use an off-the-shelf printer than to build one from scratch. If someone has already done the mechanical and electrical design, developed software for image-processing and a graphical user interface, and identified the best inks and drying methods, why not use their product?

CAN AN INKJET SYSTEMS INTEGRATOR HELP?

If you decide you need a customised printer, it still may be possible to shorten time-to-production or time-to-market by working with a company that has expertise in inkjet system development. Many companies think that, because they have engineering skills, they do not need help in developing industrial inkjet systems. But there is typically a two year development cycle involved in a new inkjet printer, and inkjet integrators can drastically reduce this time through their experience with inks and substrates, materials handling, printhead drive electronics, software, and curing or drying.

CHOOSE AN INK BEFORE YOU CHOOSE A PRINTHEAD!

If you decide to go it alone, keep in mind that the most important goal of your printer is to deliver a print onto the required substrate, whatever that substrate is – paper, glass, metal, plastic or whatever. So it is vital to choose an ink that is well-suited to printing on that substrate (or range of substrates): an ink that will adhere, will print well and look good, and will last. Decide what type of ink best fits your application, and then consider whether its physical properties (density, viscosity, surface tension etc) make it suitable for inkjetting.

DECIDE WHETHER YOUR PRINTER WILL BE A SINGLE PASS OR SCANNING TYPE

The decision will often be based on productivity required (how many square feet need to be printed per hour), and cost. A scanning system will use fewer printheads (cheaper than a single-pass array), but will be slower. A scanning system will be capable of higher resolution, because it might use up to 16 passes over the same area, and – for the same reason – will be more tolerant of missing nozzles than a single-pass printer.

CHOOSE A PRINTHEAD FOR THE PARTS OF ITS SPECIFICATION THAT MATTER MOST

The first consideration when choosing a type and manufacturer of printhead is: ‘Can it jet my chosen ink?’ The next, depending on whether you have decided on a single-pass or scanning design, should be whether its minimum drop size gives you the resolution (or minimum feature size, in the case of a functional fluid) that you want. After that, calculate: (the maximum drop size) times (the number of nozzles) times (the highest firing frequency of the printhead), and decide whether this rate of laying down ink meets your productivity needs – remember, you can always add more printheads! Decide on the core technology – do you need bulk piezo or Thin Film Silicon mems technology?

Finally, think about reliability and printhead maintenance – should you use a conventional ‘end-shooter’ design, or a more reliable ‘side-shooter’ like the Xaar 1003, with a slightly more complex ink supply system?

DESIGN THE SUBSTRATE TRANSPORT SYSTEM AND PRINTHEAD-MOUNTS

Remember that the best print quality is obtained when the substrate is about 1mm from the printhead – but that it is important to avoid 'printhead strikes' when the moving substrate hits the printhead. Remember also that single-pass printers are very sensitive to variations in the motion of the substrate relative to the printhead – the human eye can detect tiny variations in density or colour caused by vibration or changes in tension of a moving web. The 'stitch' between adjacent printheads is often visible unless the positions of the printheads are carefully adjusted. The encoder that controls the printheads' electronics needs to be physically close to the printheads, and of sufficiently high resolution to minimise errors. Thought must be given to the location of any UV curing lamps, to avoid direct or reflected UV light impinging on the printheads (curing ink in the nozzles is a good way to create an expensive paperweight!)

DESIGN A GOOD INK SYSTEM

The ink supply system must supply each printhead with enough ink to ensure it does not starve, while maintaining the right negative pressure to avoid too much ink flooding the nozzle-plate. Dissolved air is the enemy of inkjet printing, so the design must avoid causing foaming, and a 'degasser' might be necessary. The system must be robust and easily maintained, and the materials used must not be attacked by the ink.

CHOOSE A GOOD RIP

An inkjet printer is only as good as the bitmap it gets. Make sure the Raster Image Processor and printer driver software are well-matched to the printhead drive electronics and the number of grey levels used. If variable data is to be printed, consider the bandwidth required to print a variable image at maximum speed.

REMEMBER MAINTENANCE!

There are two types of maintenance on inkjet printers: routine wiping or vacuum purging to recover blocked or deviated jets, and removal and replacement of printheads and other components. The printer design should make both easy.

REMEMBER THE OPERATOR!

Becoming a 'pressman' on a conventional printing press used to take years of apprenticeship. Operating a modern digital press can and should be much less demanding. The user interface should be designed so that a production operator has very few controls to worry about – the more complex set-up features should be in a lower-level interface accessible to a maintenance technician. And needless to say, observe the usual safety standards in design of all machines with moving parts, with emergency stops, interlocks, and light curtains.

Acoustic wave: The pressure wave created in the ink within a printhead channel to eject drops. See waveform.

Actuator: The active element of the printhead that contains formed channels in which the pressure wave is generated to eject the ink.

Addressability: The ability to place individual droplets within a matrix a given distance apart (unit: dpi).

Adhesion: Ability of an ink to adhere to the substrate on which it is printed. In general, measured by cross-hatch, scrape, or peel tests.

Apparent resolution: The visually-equivalent resolution of an image printed with greyscale (variable drops), compared to the same image printed with binary drops.

Array: An arrangement of individual inkjet printheads mounted across and/or along the substrate path. Often a set of printbars populated with multiple printheads mounted across the substrate transport.

Bend mode: In a bend mode piezoelectric printhead a piece of piezoelectric material is glued to the roof of a chamber. The drop of ink is ejected when a voltage is applied to the piezoelectric material, causing it to deform (bend) and push the drop of ink out from the nozzle. See also shear mode.

Binary Inkjet: Binary printing means the drop is either there or it is not and only one drop size is possible so all drops are the same size, as opposed to variable sized drops used in greyscale printing.

Bitmap (.bmp): A raster graphics image file format used to store digital images. The image is made up of rows of dots or pixels rather than vector coordinates.

Calibration: The act of adjusting the colour output of a device to ensure consistency. Typically aligning one device relative to another, such as a monitor to a printer, or a scanner to a film recorder. Or, it may be the process of aligning the colour of an ink system to an established standard (e.g. using colour or ICC profiles).

Carrier: One of the main components of an ink. The carrier fluid may be water, solvent, oil-based or something else.

Chamber: In a printhead, this refers to the ink-filled cavity created in the actuator immediately behind the orifice or nozzle plate.

Channel: The pathway through which ink flows. Also, see chamber.

CMYK: The common colour system used in graphics and label printing. In CMYK, colours are expressed by the subtractive primaries – cyan, magenta, yellow and black. Black is called K or keyline.

Colour gamut: The complete range of colours reproducible from a printing system on a specific substrate.

Colour management: The controlled conversion between the colour representation on one device (e.g. computer) and another (e.g. printer) and media. The primary goal is to achieve a good colour match across colour devices.

Continuous inkjet (CIJ): A system where there is a continuous flow or stream of ink from a pressurised reservoir. This is broken up into droplets which are deflected by applying a varying electrostatic field to form an image.

Contrast: A measure of rate of change of brightness in an image. High contrast implies dark black and bright white content.

De-gas: The process of removing dissolved or entrained air from inks. Air or bubbles in inkjet systems may cause failures. Inks are de-gassed by using a vacuum or employing an in-line 'lung'.

Digital image: An image composed of pixels and stored electronically.

Direct mode: Direct mode jetting applies to printhead structures where the deformation of a piece of pizeoelectric material directly forces ink out of a chamber through a nozzle i.e. it is a physical push of a volume of ink.

DoD (Drop-on-Demand) Inkjet: These printheads produce ink drops only when required.

Dot: The term used to designate the mark or spot on the paper or substrate made by an individual ink drop.

Downshooter: Horizontal mode of the printhead relative to the substrate. Also known as skyscraper mode (vertical position).

DPD (Drops Per Dot): The number, or maximum number, of sub-drops in a printed drop. See grey levels.

DPI (Dots Per Inch): Measure of the regular spacing of dots printed on the substrate. Sometimes incorrectly used as a measure of resolution.

Drive electronics: Hardware & software products to enable the image to be sent as electrical signals to the printhead; usually split into several modules (printhead, Head Personality Card and Control Box) which interfaces with a PC. Xaar makes the XUSB/XPM drive electronics and HPC systems components.

Drop ejection: Drops fired from the nozzle.

Drop placement accuracy: The accuracy with which a printhead can place a drop. Typically measured in milliradians or microns at 1mm print distance and stated as a typical or statistically valid measurement (e.g. +/- 5um at 3 sigma).

Drop velocity: The speed at which a drop is ejected from the nozzle (m/s).

End-shooter: A printhead with a nozzle orifice through which the ink is ejected at the end of each channel.

ESD precautions: Electrostatic discharge, this includes a grounded wrist band or conductive work mat.

Finish: The term used to describe the surface appearance of a print (such as gloss, satin, matt).

Finishing: Operations carried out after printing (such as folding, stitching or binding).

Firing: The event that causes the ejection of the droplet from the printhead. Also, the final baking stage of ceramic tiles in a kiln after printing.

Firing frequency: The rate at which drops are fired from the nozzle whether in binary or greyscale mode.

Flocculation: The adhesion or clustering of particles in a fluid, often caused by incompatible chemistries, and disastrous to a printhead.

Fluid optimisation: Optimising the fluid or ink jetting performance by modifying its physical properties. It is combined with optimising the firing waveform.

Fluid path: A series of pipes and channels that make up the active component called the 'actuator' that is found within the piezoelectric printhead.

Flush: The fluid used to clean a printhead. It is important that it should be matched to the ink with which it is used, to avoid flocculation.

Functional fluids: Fluids that play a role in the manufacturing process or functional performance of a product such as coatings, conductive tracks, lenses, chemical reactants, etc i.e. other than that of providing colour or text.

Gloss: The degree to which a printed surface possesses the property of reflecting light in a mirror-like manner.

Grey levels: The number of discrete density levels in an image, typically 256 levels, represented as an 8-bit binary number. In inkjet printing, 2, 4, 8 or 16 grey levels are typically used, together with error diffusion, to simulate a continuous tone image. The number of drops per dot (DPD) is one less than the number of grey levels, as zero is also a grey level.

Greyscale: A scale that shows the steps of increasing colour density (grey levels,) from light to dark, of the grey levels. A greyscale printhead can print variable-sized drops from the same nozzle.

Half-toning: The reprographic technique, performed in a RIP, that converts a continuous tone image to a number of dots that can be printed.

Hot melt ink: A class of inkjet inks that are solid at room temperature and liquid at an elevated temperature.

HPC: Head Personality Card, converts electrical signals from the XUSB so they can be used by the printhead.

HSS®: Xaar's Hybrid Side Shooter technology. Two acoustic waves moving through the channel in an actuator meet in the middle and cause pressure changes that fire a drop out of the side of the channel – downwards through the inkjet nozzle, the nozzle being on the side of the channel, not at the end.

Hydra: Xaar's recirculating ink system.

Image resolution: Resolution quantifies how close lines can be to each other and still be visibly resolved. However, it is often taken to mean the number of pixels per unit length of image: for example, pixels per inch, pixels per millimetre, or pixels wide.

Ink manifold: An element of inkjet printheads that receives ink from the supply system and distributes it to the individual chambers or channels within the actuator.

Ink port: A channel where the ink enters and exits the Xaar 1002 printhead.

Ink recirculation: Ink recirculation keeps the ink in constant motion, preventing sedimentation and nozzle blocking (in certain printheads). This is essential when printing heavily-pigmented, highly-viscous ceramic decoration inks to prevent sedimentation.
See Xaar TF Technology.

Inkjet: The firing or jetting of small drops of fluid (usually ink) from micro electromechanical systems. Xaar uses Drop-on-Demand inkjet technology.

Jetting orientation: An orientation of jetting ink: Downshooter, horizontal or skyscraper.

JFIF (JPEG file interchange format): A compact file format that enables JPEG bit streams to be exchanged.

Key: The colour black in CMYK.

Lightfastness: Ability of a colour or ink to resist fading on exposure to light, especially sunlight.

Matrix: A rectangular or orthogonal arrangement of elements into rows and columns. Characters and images are constructed of a matrix of dots from inkjet printing systems.

Meniscus: Also known as nozzle pressure PM. The meniscus pressure should always be negative.

Micro (μ): An adjective meaning small or one millionth of the base unit or 10^{-6}.

Monochrome: One colour printing or the separation of colours.

Monolithic cantilever: This describes one wall of the ink chambers in the actuator. It is a single piece of PZT, hence monolithic, that is attached only at the base, hence cantilever. It deforms (shears) when a voltage is applied.

Nano (n): One thousandth of a millionth of the base unit or 10^{-9}.

Natural or native resolution (natural DPI): The number of nozzles per inch on the printhead (NPI).

Non-contact: A process in which there is no contact between the substrate and whatever applies the ink. In digital inkjet ceramic decoration the distance between the substrate (the ceramic tile) and the printhead is generally 3-5mm. This means that no mechanical pressure is put on the ceramic tile, and breakages are rare. Non-contact also means that digital inkjet printers can print on 3D surfaces to create textured tiles.

Non-wetting coating (NW): A chemical coating sometimes used to change the wetting properties of printhead nozzle plates to assist drop formation.

Nozzle : In an inkjet printhead the nozzle is the carefully shaped hole from which the ink is ejected.

Nozzle stagger: In shared wall printheads not all channels can eject drops simultaneously. Every 3rd channel can be fired hence the ABCABC sequence. Nozzles are staggered to compensate for timing differences in an ABC firing sequence.

Npi (nozzles per inch): Number of nozzles per inch on a printhead.

OEM (original equipment manufacturer): Xaar's direct customers are typically OEMs, they use Xaar printheads and systems as components in the machines which they in turn sell to their customers.

PCB legend printing: PCB = Printed Circuit Board. The printing of the white component details and identifying text required to locate and identify items on a PCB.

Pico (p): One millionth of a millionth of the base unit or 10^{-12}

Piezoelectric effect: The effect of generating electricity when mechanical stress is applied to certain materials. The reverse piezoelectric effect is when these materials change shape under the influence of an electric field. Exhibited by certain ceramic materials, such as PZT or lead zirconate titanate.

Pigment: A class of colorants used in inks, paints, etc., where the colour is provided by the absorption or reflection of light by these small particles suspended in a carrier.

Pinning: The use of UV layers to partially cure inks between colours in a UV printing process.

Pixel: The smallest image-forming unit of a display screen.

Primary colours: The additive primaries for light are red, green and blue. Secondary colours, or subtractive primaries, are yellow, magenta and cyan (as used in printing).

Prime: The act of initially introducing ink to an inkjet printhead and forcing ink out of the nozzles to expel air from the chamber or the ink manifold. Done prior to printing to ensure printhead is ready to print.

Print distance (throw distance): The distance from the inkjet printhead's nozzles to the printing surface (substrate).

Print driver: A computer program that enables an application software to communicate with a printer.

Printbar / printbars: Precisely aligned number of printheads in a single mount. See array and stitching.

Printhead: The section of an inkjet printing system that generally contains multiple nozzles for the jetting of ink.

Printhead alignment: Factors such as mechanical printhead alignment, substrate movement and other tolerances have an impact on achieving highest print quality.

Printing artefact: Any objectionable visual effect in a print that was not in the original, such as banding, moire, streaking, clustering, jaggies and so on. Could also include satelliting.

Process colour: Colour reproduced in a printing process by mixing translucent Cyan, Magenta, Yellow, and Black (CMYK) inks.

Purge: To force ink through the printhead to clean out any accumulated debris or air.

PZT: (Lead) Plumbium Zirconium Titanate, the piezoelectric ceramic material used in making the active component (actuator) in a piezo printhead.

Quality: In inkjet terms this is a mix between resolution and tutorial range i.e. the number of shades or tones that go into making up a print.

Raster: Raster images are made up of individual dots; each of which has a defined value that precisely identifies its specific colour, size and place within the image. Also known as bitmapped images.

Recirculation ink system: A system designed to recirculate in and that pumps, filters, supply tank and return tank and Xaar 1003 printhead.

Resolution: Resolution is a function of the smallest dot in the printed image. The smaller the dot the higher the resolution as it is the ability of the eye to resolve separate dots that matters.

RIP (aka Raster Image Processor, Renderer): Hardware and software that converts graphics and text in a page layout file into the bitmaps required for output to a printer, using half-toning algorithms to render continuous tone images.

Screen printing: Traditional printing process. Screen printing is a contact printing process in which each colour is applied by a separate roller.

Shared wall technology: The technique patented by Xaar and licenced to other printhead manufacturers, of increasing native resolution by using the same piece of piezoelectric material to actuate adjacent channels.

Shear mode: In a shear mode piezoelectric inkjet printhead (such as the Xaar 1003 GS6 and Xaar 1003 GS12) the electric field is applied perpendicular to the polarisation of the material. This causes the piezoelectric crystal to shear, not to lengthen or shrink.

Side-shooter: In a side shooter printhead, the nozzle is at the side of each channel.

Single-pass: Printheads print directly onto a moving substrate.

Solvent: Typically, a volatile organic liquid used to dissolve pigments or dyes to form an ink solution known as solvent or eco-solvent ink. Also used to reduce the viscosity of inks.

Stitching: Matching and overlapping of printheads in a printbar to ensure no visible print gaps, differences or defects between adjacent printheads.

Sub-droplets / sub-drops: The small droplets that join together to make up a single, variable-sized drop in greyscale printing.

Substrate: The surface to be printed upon for example paper, textile and plastic. Use as standard term in place of ‘media’.

Surface tension: The intermolecular contracting force on the skin of a liquid. It acts like a rubber balloon and will exert a force to form a three dimensional shape of the smallest energy. For example, forming a liquid droplet into a sphere.

Swathe: The band of print produced by one pass of a printhead. Can be of either a single printhead or a printbar containing multiple printheads. Swathe width is generally less than the physical width of the printhead.

Thermal inkjet (bubble jet): An inkjet technology where the rapid expansion of a bubble in the ink is created by a localised electrical heating element.

Three cycle firing (aka ABC firing): In shared wall printheads not all channels can eject drops simultaneously as movement of a wall affects both adjacent channels. Every 3rd channel can therefore be fired independently hence the ABCABC sequence.

Tonal range: Range of highlights, shadows and intermediate tones in a halftone image – normally measured by EV (exposure values) in photography and by density values or grey levels in printing.

UV Curable Inks: A class of inks that are cured (polymerised) by the application of light energy with ultraviolet wavelengths. After printing the ink is cured by exposure to strong UV-light. The advantage of UV-curable inks is that they 'dry' as soon as they are cured. They can be applied to a wide-range of uncoated and plastic substrates.

Variable drop: See also greyscale. Creating variable drop sizes yields higher apparent resolution.

Viscosity: The physical property of fluids to resist flow. In general, ink viscosity increases with decreasing temperature. The normal unit of measurement in the metric system is poise, but with digital inks it is centipoise (cP).

VOC (volatile organic compounds): Organic compounds which have a high vapour pressure and emit gaseous compounds when employed. Frequently deemed a health hazard and a greenhouse gas. Many quick-dry solvents give off VOCs.

Waveform / waveforms: The electrical drive signal applied to the PZT wall actuator within a piezo printhead to produce an acoustic (pressure) wave in the channel.

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