GLOBAL INKJET SYSTEMS

CONTROL | PERFORMANCE | INNOVATION

Introduction to Image Quality Issues

Debbie Thorp, Business Development Director

Barcelona, November 2014

IMI - Improving Image Quality Seminar

THE QUEEN'S AWARDS FOR ENTERPRISE INTERNATIONAL TRADE 2013

Digital Printing Week 2014

Improving Image Quality Seminar

- **The "chain of pain" – Mike Willis (recent blog)**
- **Process – inks, printheads, system configuration**
  - Ink system supply technology – Atomjet
  - Optimising jetting of inks - Xennia
  - Printheads & drive waveform – TTP
  - Putting drops down – Inca Digital
  - DPI & resolution – JR Bane Consulting
- **Process - curing & drying**
  - Implementation of pinning – Phoseon
  - Controlled drying - Adphos
- **Software**
  - Getting the most out of your RIP – Global Graphics
- **Development tools**
  - Measurement & evaluation – ImageXpert

And special thanks to:-

John Corrall, Industrial Inkjet Ltd

GIS - Introduction

- **Electronics & software for industrial inkjet printheads**
  - Electronics, firmware, drivers, RIPs, software utilities, user interfaces and ink system components
    - Particular expertise in large single pass systems
    - Experienced in handling high data rates (high speed, high resolution, large numbers of printheads)
    - Significant presence in ceramic tile printing, security printing, labels, packaging, textiles, product decoration, demanding variable data applications, 3D printing, coatings and materials deposition

3rd Party RIP and Workflow

ESKO ONYX ColorGATE

High Speed PDF RIP

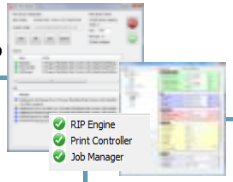
Colour Variable RIP

User Interfaces

3rd Party Control

TCP/IP

Print Server



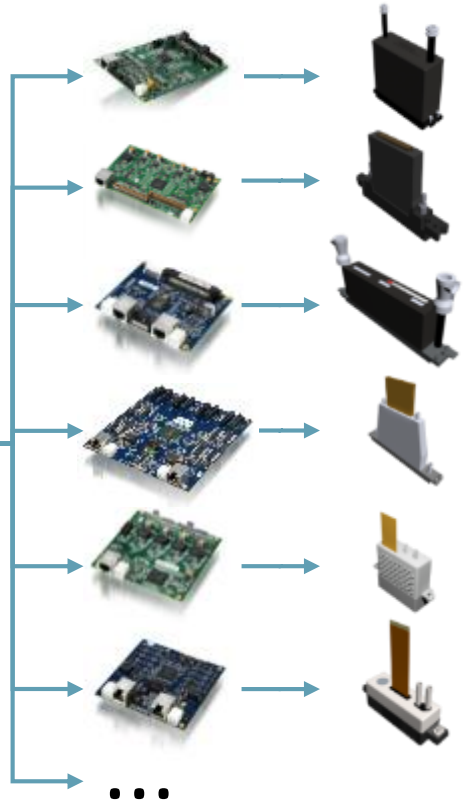
Print Manager Boards

Peripheral Control

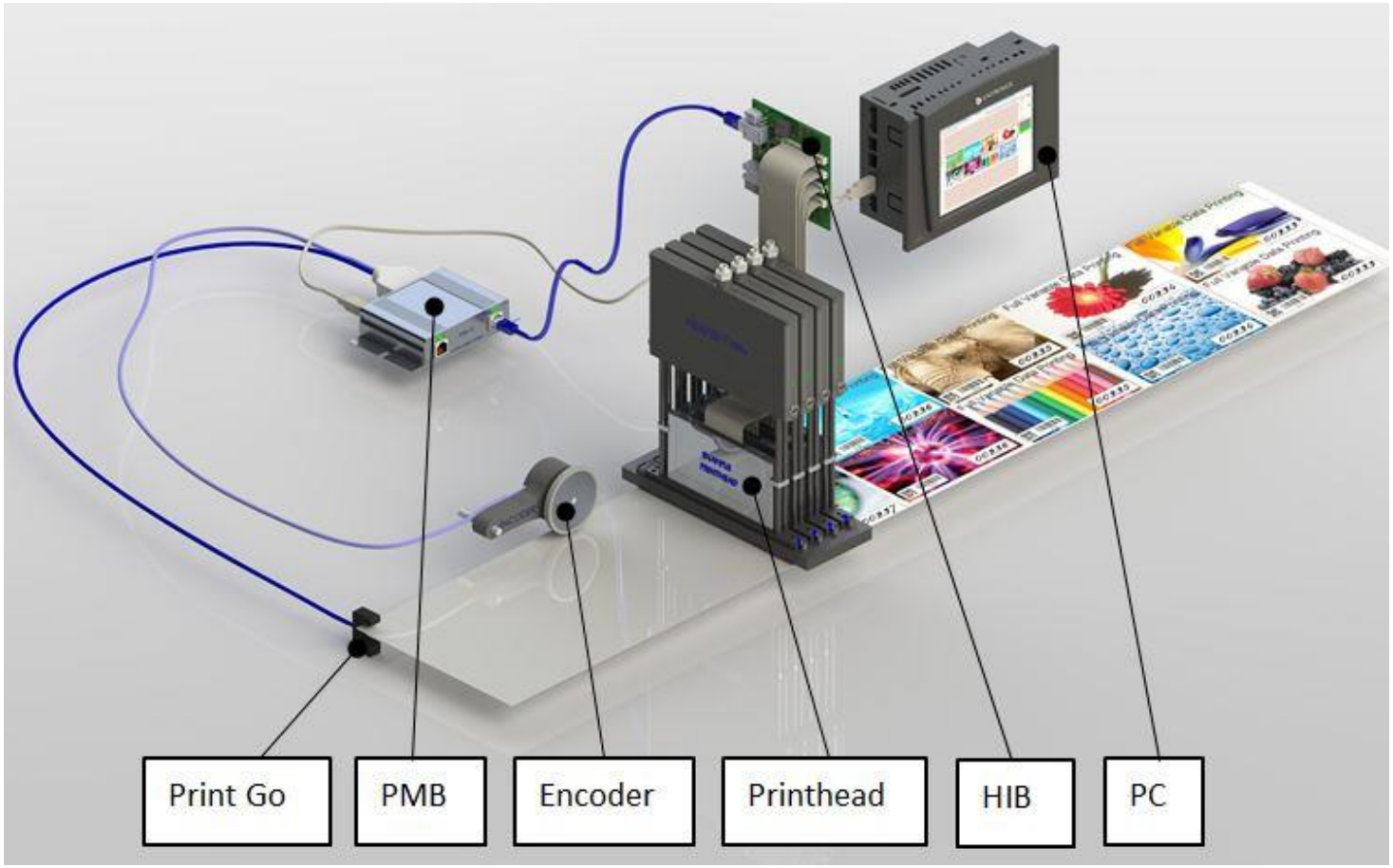
Ink Supply System Components

Utilities & Tools

Head Interface Boards



How Hard Can it Be?



We will find out…

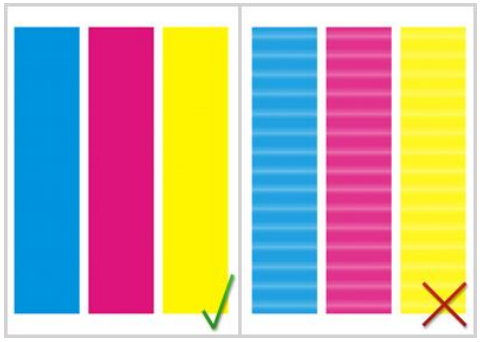
Factors Effecting Print Quality

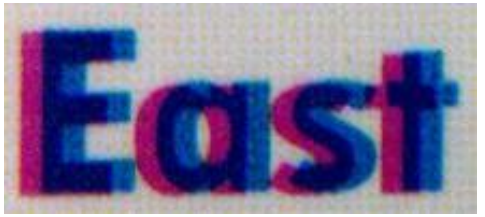
Introduction to the Seminar's Main Themes

- **System configuration**
  - Mechanical
    - Encoder
    - Media control
    - Colour registration
  - Printhead alignment & rotation
    - Jet straightness
  - Ink systems
- **Process**
  - Inks and substrates
    - Surface energy
    - Pre-post treatment
  - Stitching strategies
- **Software**
  - Grey levels
  - Colour calibration
  - Colour & gamut
  - Screening & linearization

Quality Issues Seen in the Field

- Wrong colours
- Grainy images
- Jetting errors
- Image artefacts
- Missing colours
- Texture in flat colour
- Resolution too low
- Spot colour mismatch
- Edge definition
- Ink bleed
- Density shift
- Nozzle drop outs
- Colour stability
- Ink supply issues
- Reticulation





GLOBAL INKJET SYSTEMS

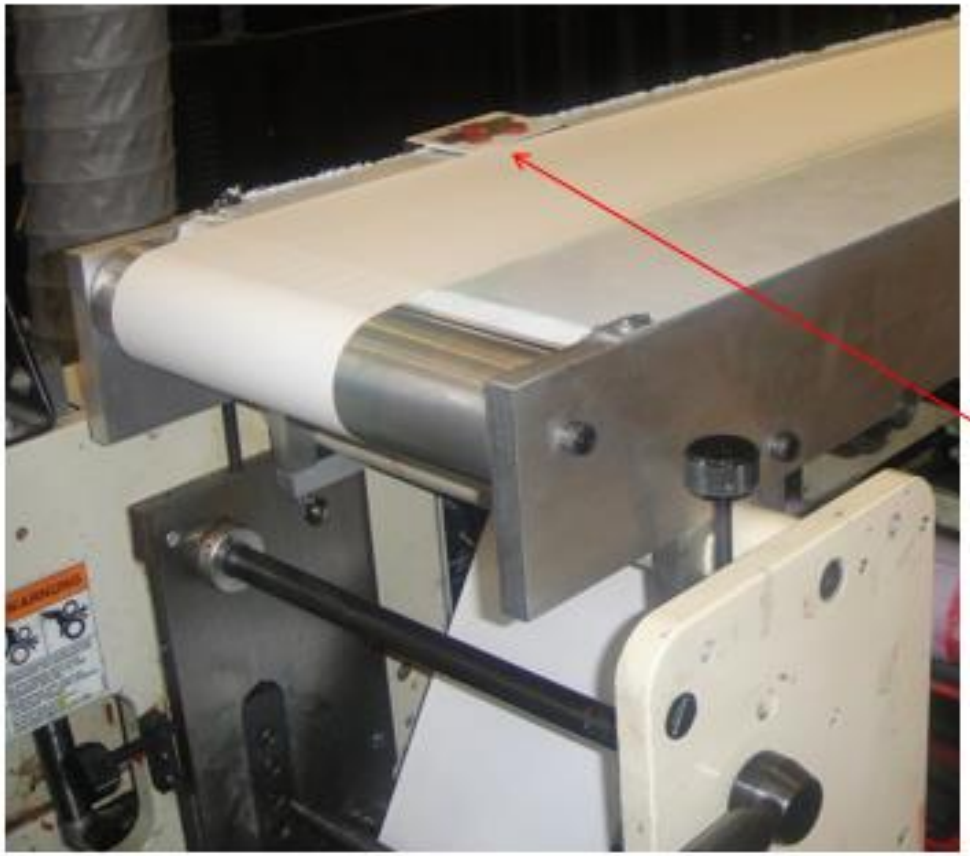
CONTROL | PERFORMANCE | INNOVATION

Mechanical – Encoder & Media Control

KONICA MINOLTA

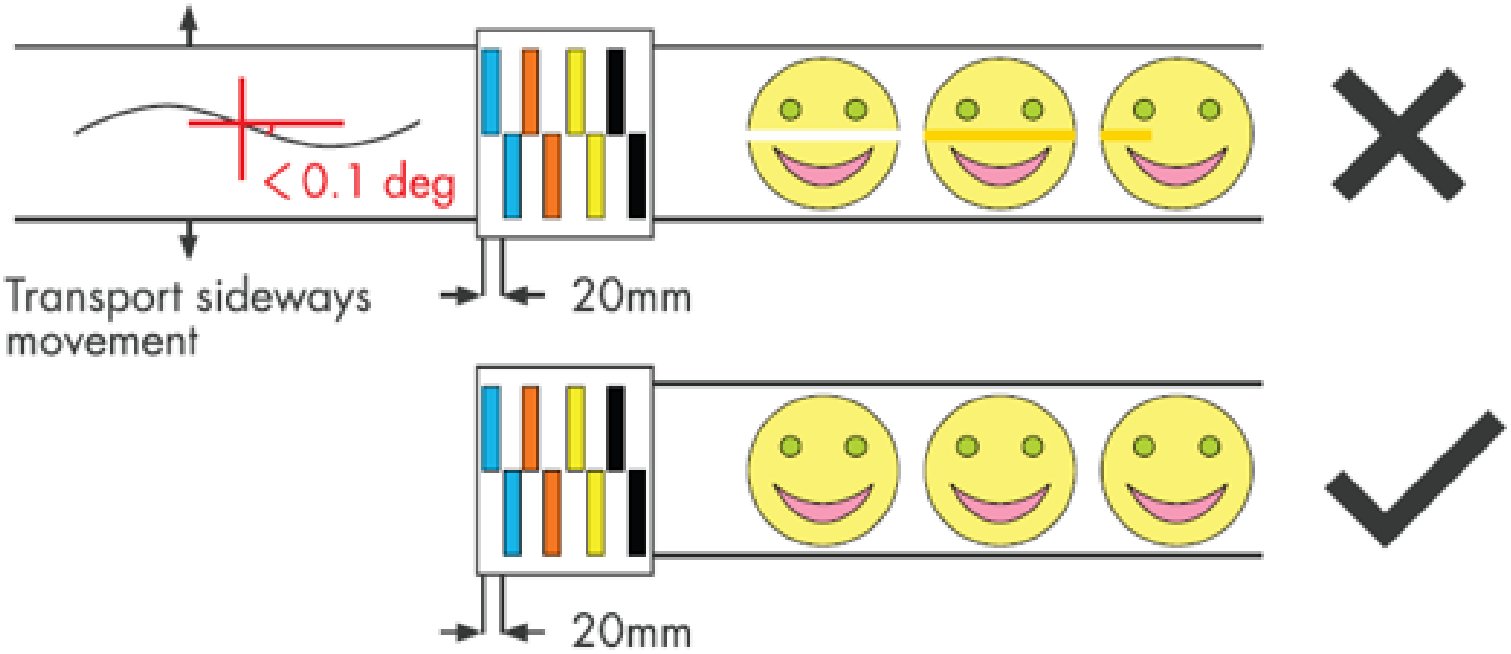
Effect of Accuracy of Movement

Accuracy of Movement



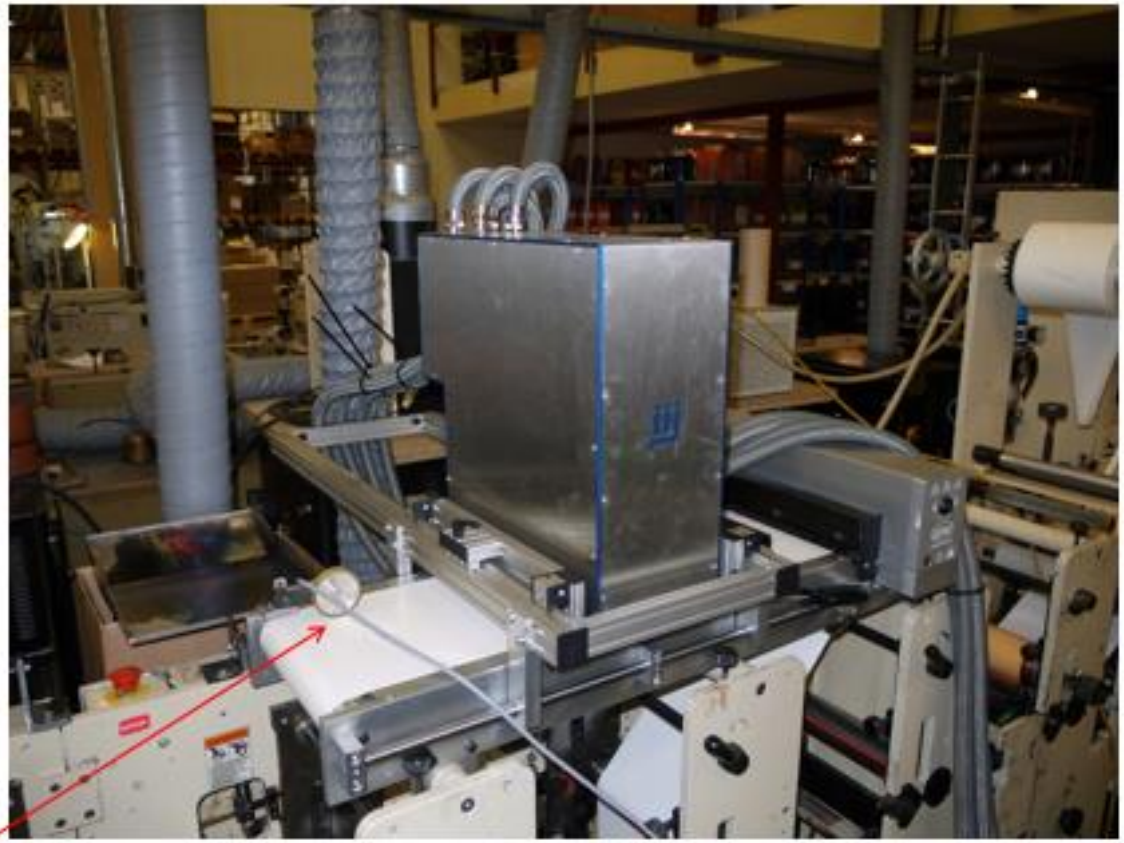
KONICA MINOLTA

Effect of Accuracy of Movement



KONICA MINOLTA

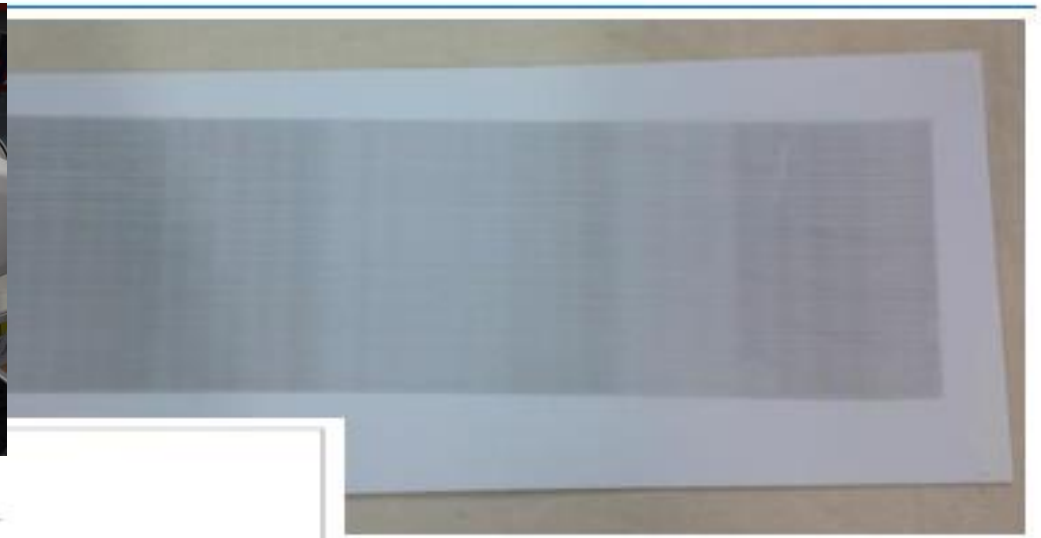
Effect of Accuracy of Movement



Shaft Encoder as close to inkjet as possible!

KONICA MINOLTA

Effect of Accuracy of Movement



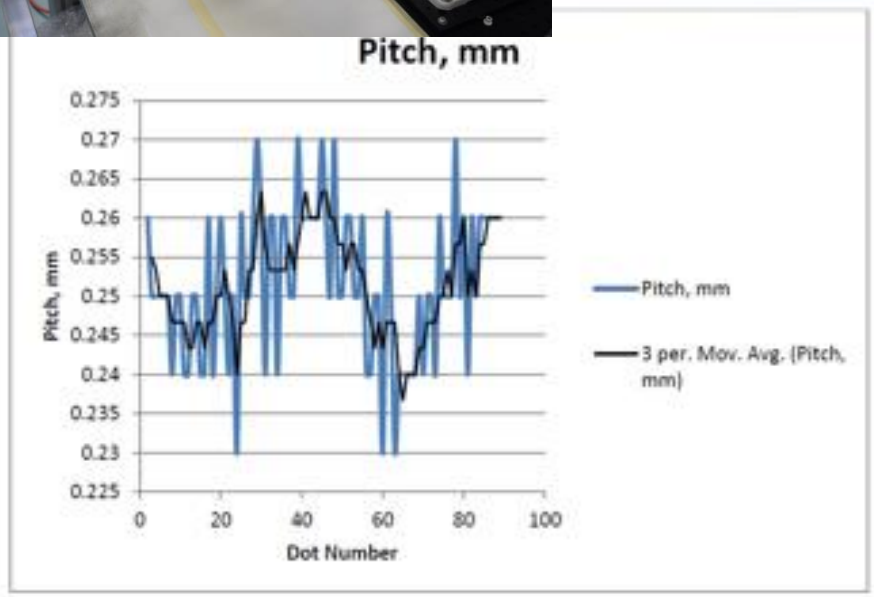
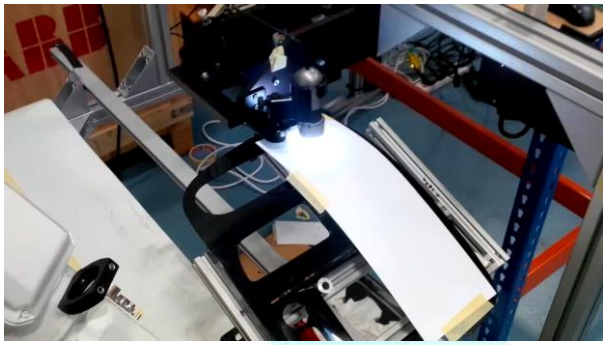


Figure 4 Moving Average of Pitch Variation, sample 8 28/01/14

Even small inconsistencies in drop placement show clearly – banding effect in solid area



Industrial Ink Jet

InPrint 2014

GLOBAL INKJET SYSTEMS

CONTROL | PERFORMANCE | INNOVATION

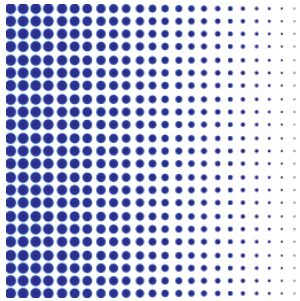
Mechanical - Colour Registration

Colour Registration

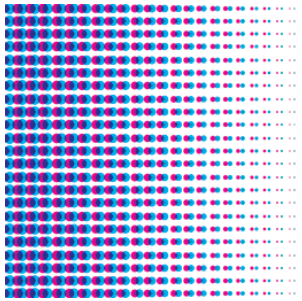
Colour registration is a measure of the accuracy with which two or more colours are aligned with each other.

The most common causes of poor colour registration are:

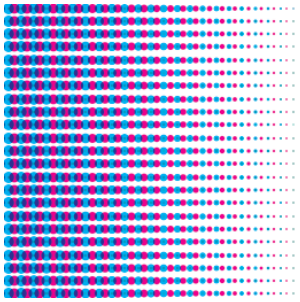
- **System Setup** : The printheads may simply not be aligned mechanically or offset correctly in the electronics / software relative to each other.
- **Encoder**: The encoder is not accurately reporting the movement of the media. (e.g. Slippage / Misalignment)
- **Media Control** : The media is stretching, slipping or accelerating.
- **Jetting Parameters** : The time of flight of the drops is not the same for all printheads. Typically visible at higher print speeds.



Full Dot Overlap



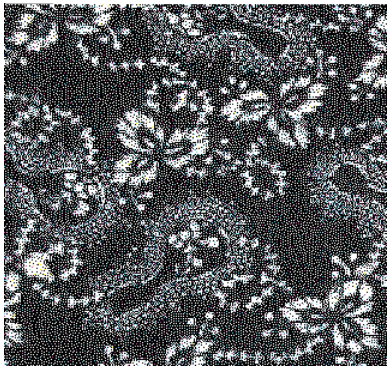
Partial Dot Overlap



No Dot Overlap

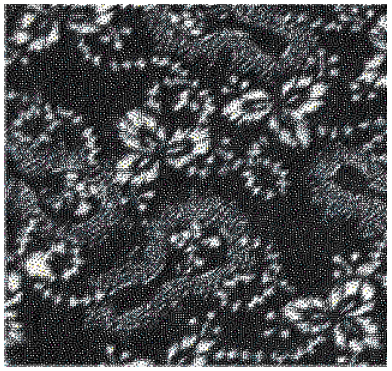
Colour Registration

- Colour registration can effect output colour and detail
- Typically there is a reduction in colour gamut and darkening of the image

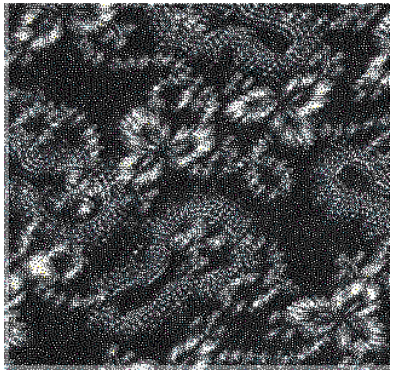


Perfect Alignment

+1,+1 Pixel Nudge

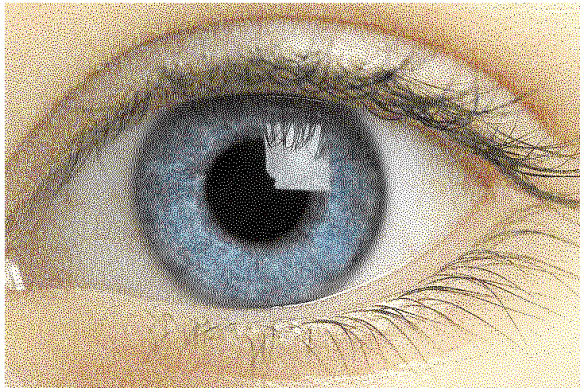


+2,+2 Pixel Nudge

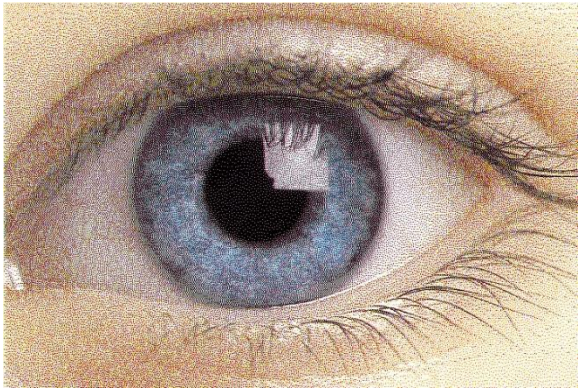


+4,+4 Pixel Nudge

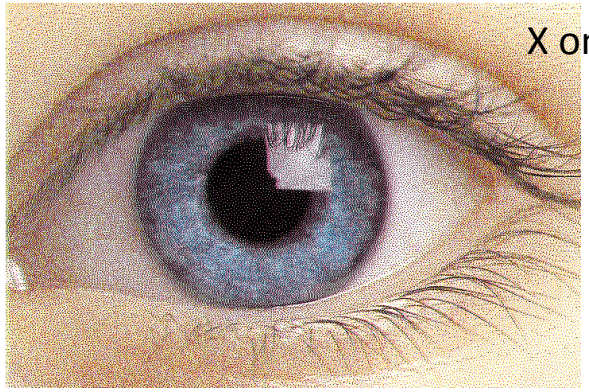
X & Y



Perfect Alignment



+2,0 Pixel Nudge

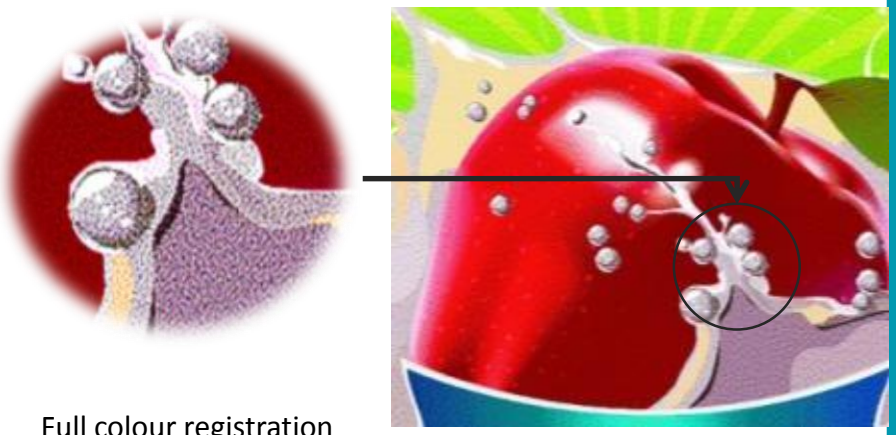


+4,0 Pixel Nudge

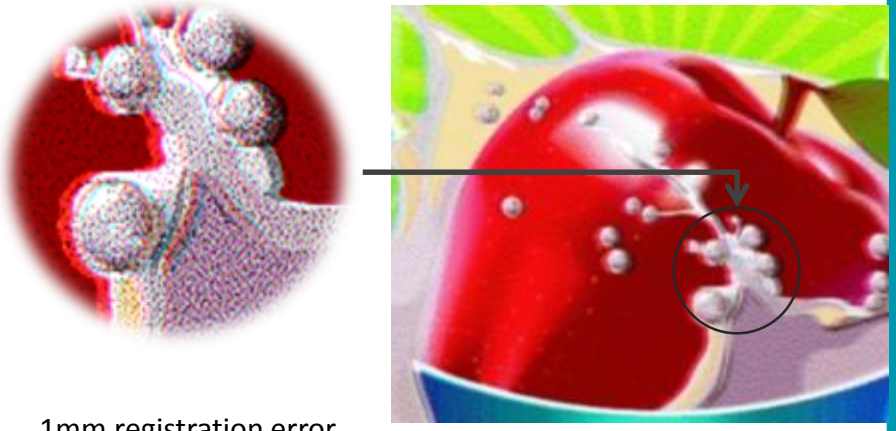
X only

Poor Colour Registration Image Effects

- **Images are less clear**
- **Text less readable**
- **Fine detail is lost**
- **Colours are not accurate**
  - Gamut reduced
- **Some images look worse than others**

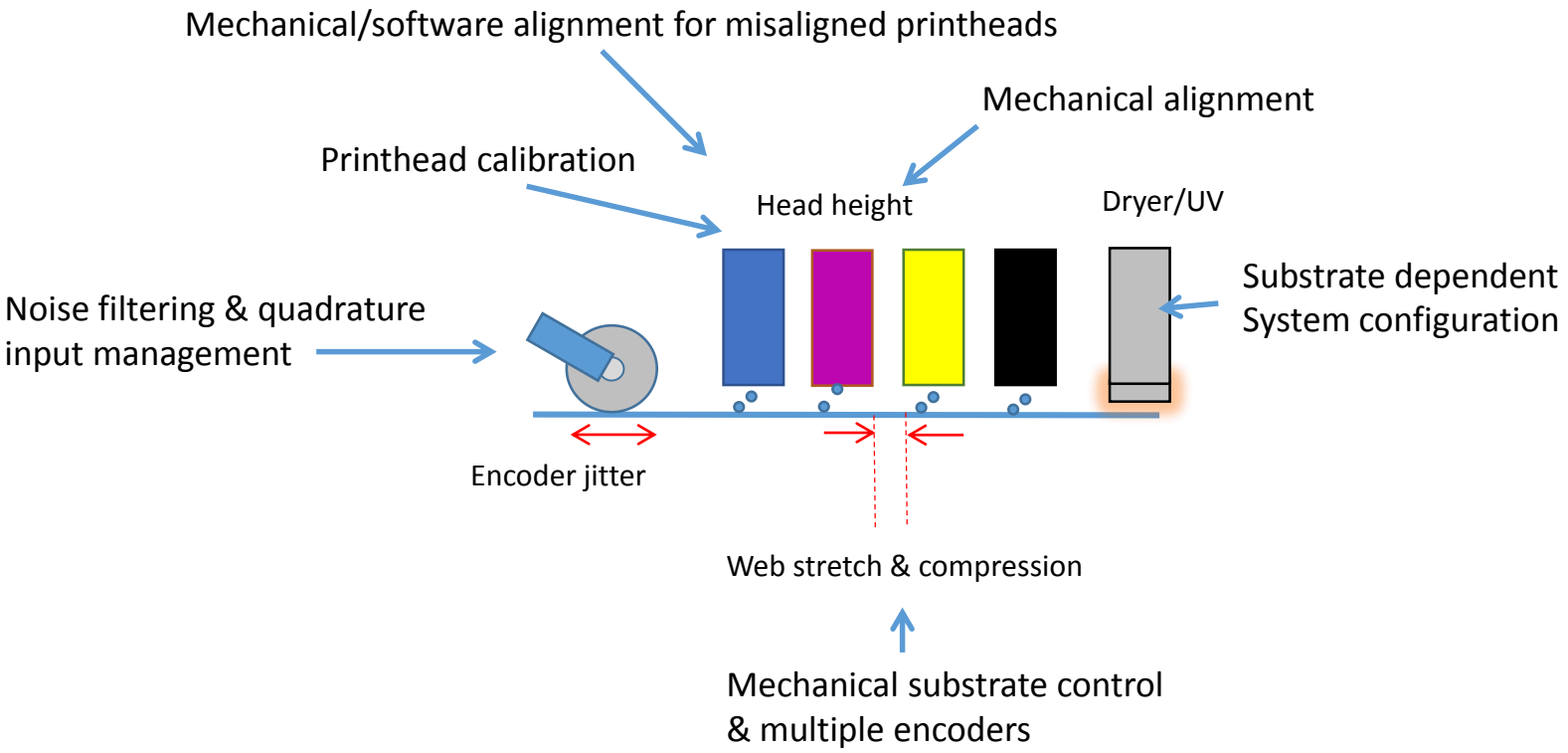


Full colour registration



1mm registration error
in black and cyan

Improving Colour Registration



GLOBAL INKJET SYSTEMS

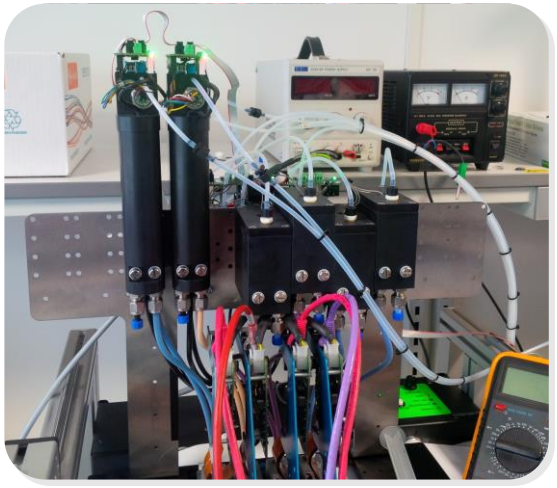
CONTROL | PERFORMANCE | INNOVATION

System Configurations - Ink Systems

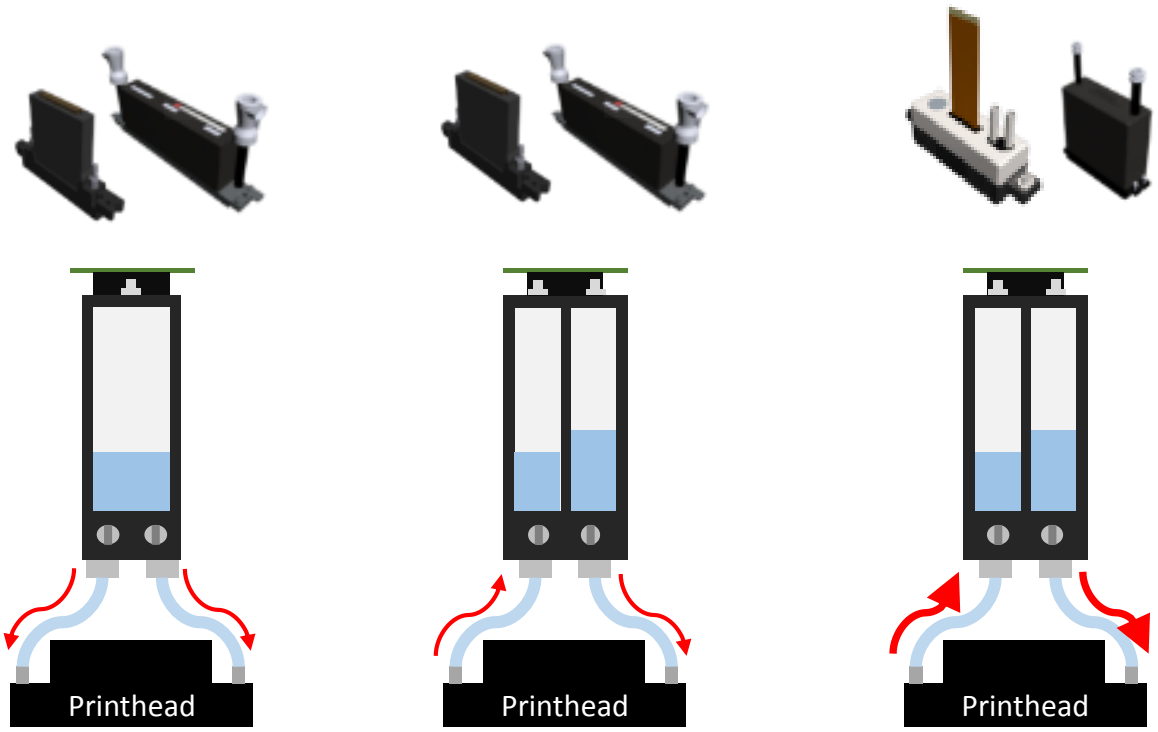
Typical Ink System Issues

- **Meniscus pressure control**
  - Shared or independent
- **Degassing**
  - Air bubbles
  - Dissolved air
- **Temperature control**
- **Flow rate**
  - Smooth flow control – not pulsing

- **Ink temperature**
- **Filtering**
- **Sedimentation**
- **Congealing**
- **Materials compatibility**
- **Fault detection**

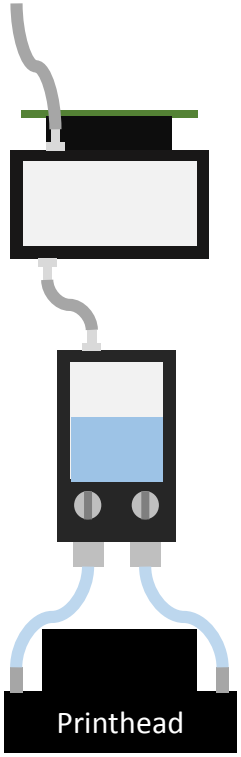


Ink Supply System – Flow Modes



No Flow | **Low Flow** | **Adjustable Flow**

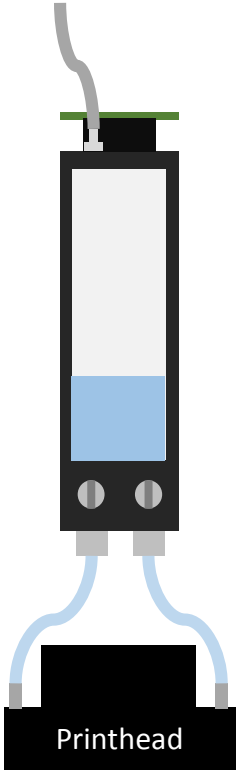
Header Tank Designs – End Shooter



Modular Header Tank

- Controllable height
- Cost effective design
- Large ink capacity
- Optional heater
- Ease of maintenance

Modular Header Tank

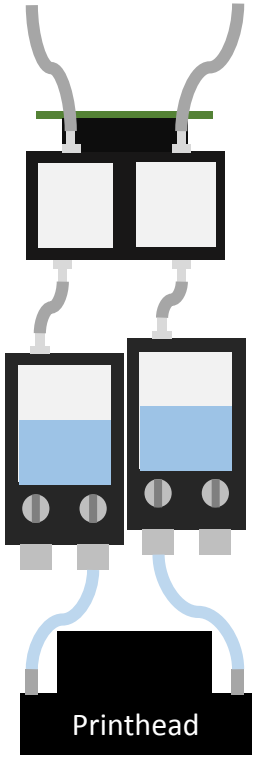


Integrated Header Tank

- Single unit
- Compact
- Fully sealed
- Smaller ink capacity

Integrated Header Tank

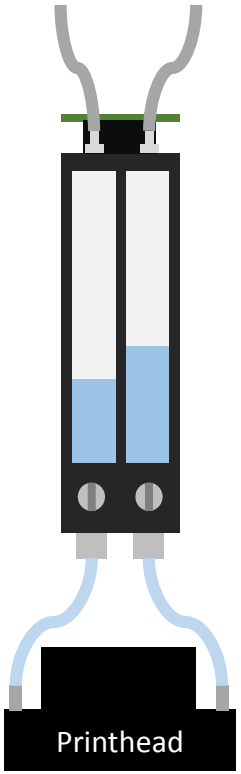
Header Tank Designs - Recirculating



Modular Header Tank

- Controllable height
- Cost effective design
- Large ink capacity
- Optional heater
- Ease of maintenance

Modular Header Tank

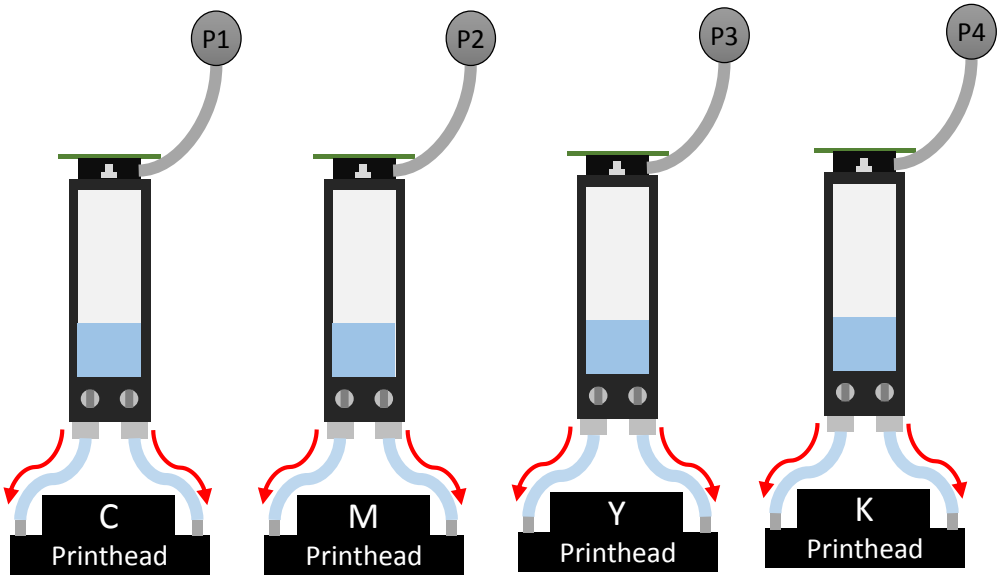


Integrated Header Tank

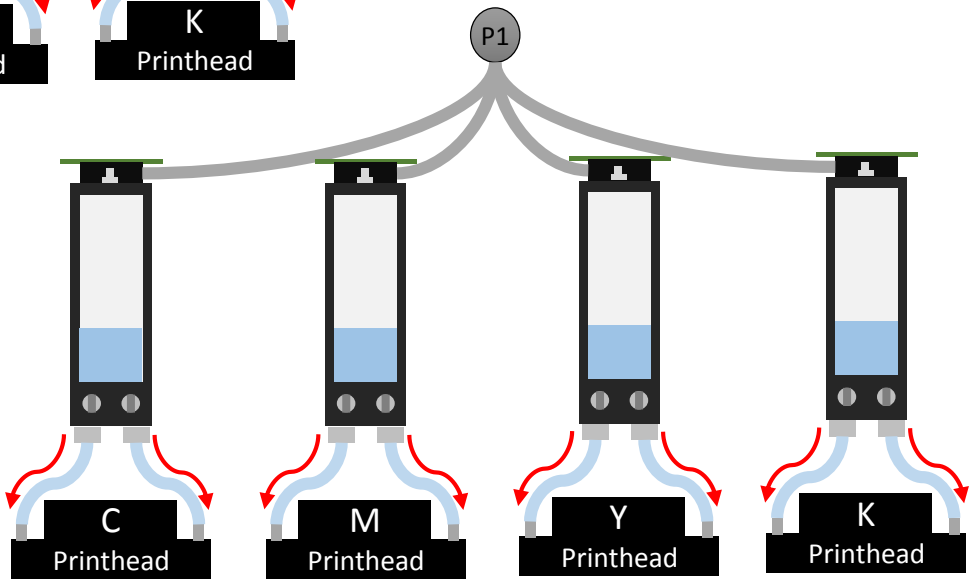
- Single unit
- Compact
- Fully sealed
- Smaller ink capacity

Integrated Header Tank

Ink System – Independent or Shared Pressure Control

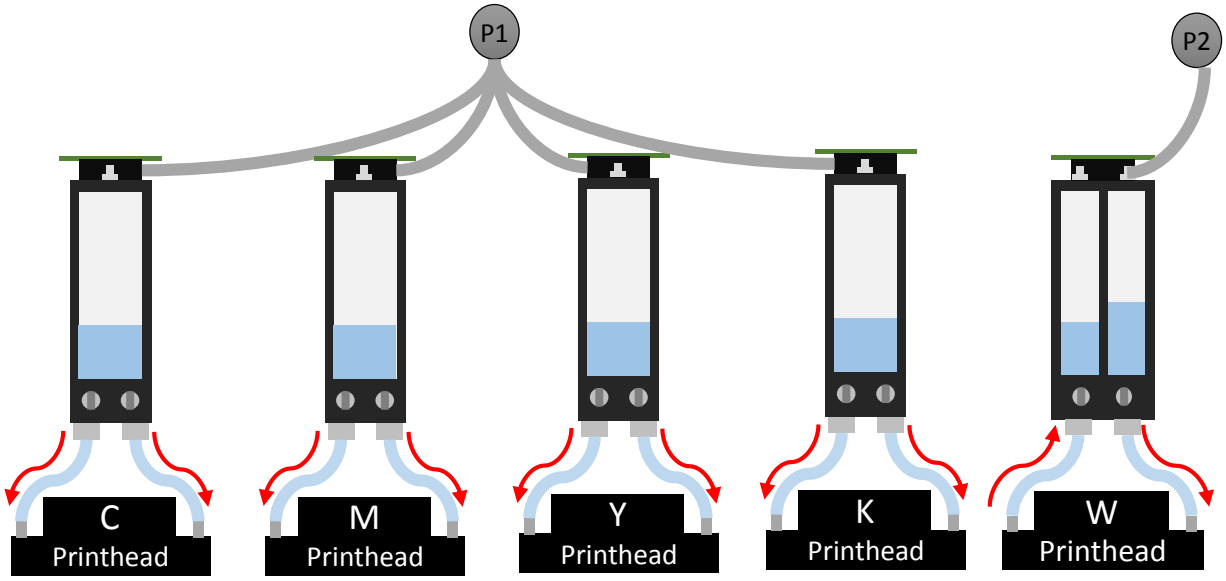


Independent Pressure Control



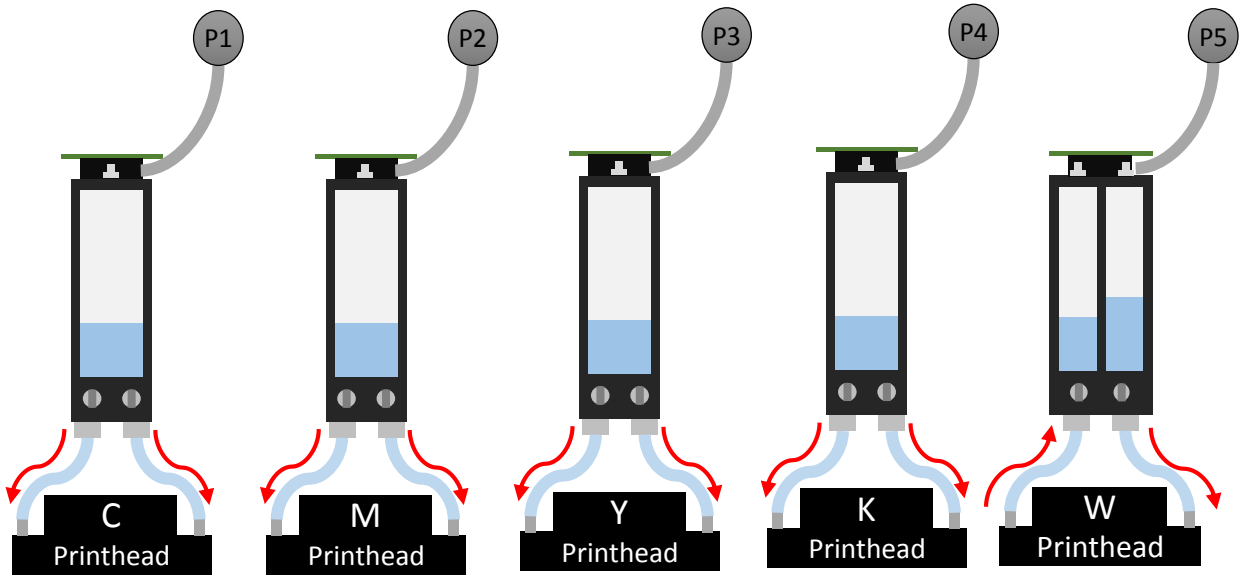
Shared Pressure Control

Ink Supply Systems – Options



e.g. Shared pressure control on CMYK no flow: independent pressure control and low flow recirculation on W

Ink Supply System - Options



e.g. Independent pressure control for all inks – CMYK no flow and low flow recirculation on W

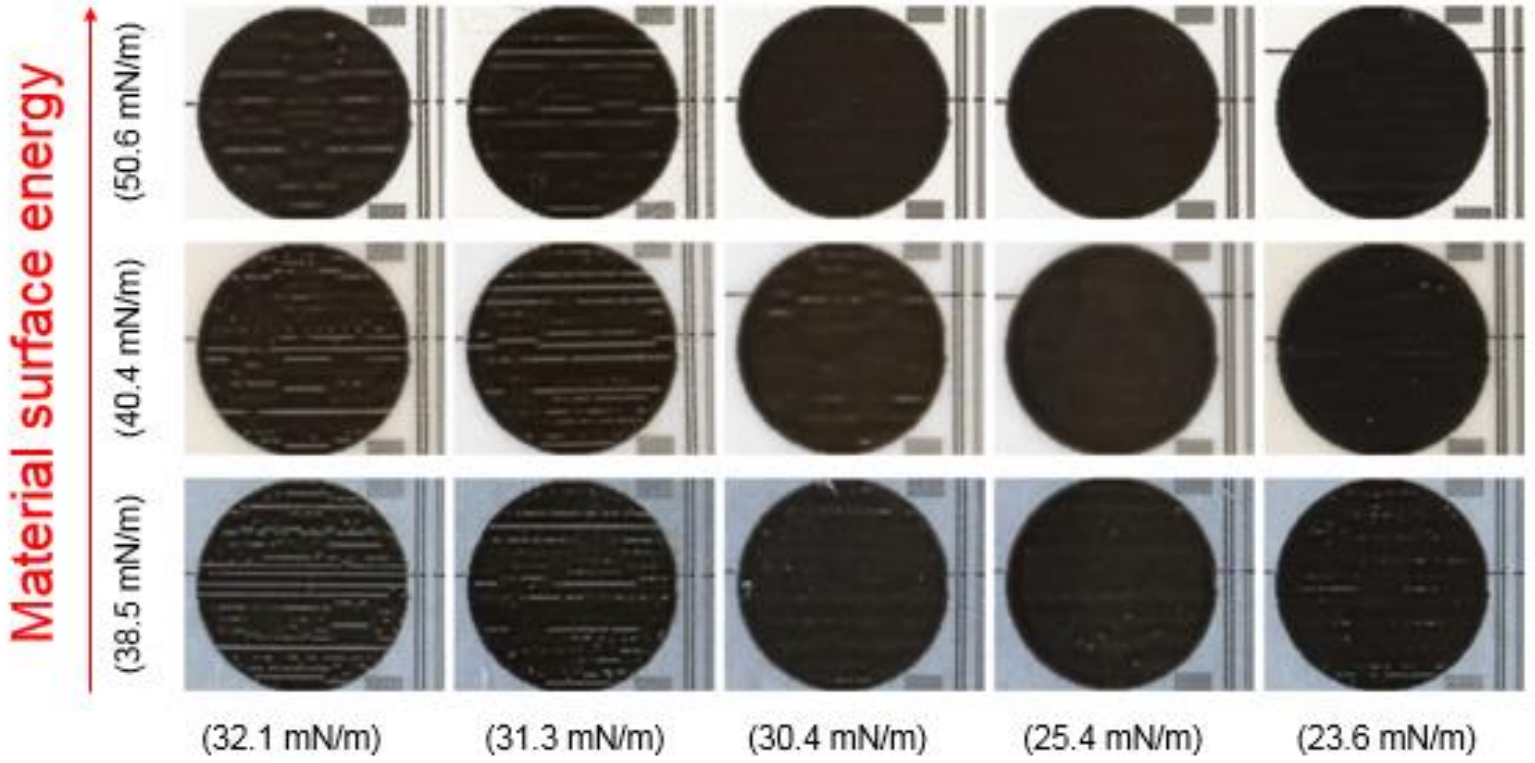
GLOBAL INKJET SYSTEMS

CONTROL | PERFORMANCE | INNOVATION

Process – Surface Tension

KONICA MINOLTA

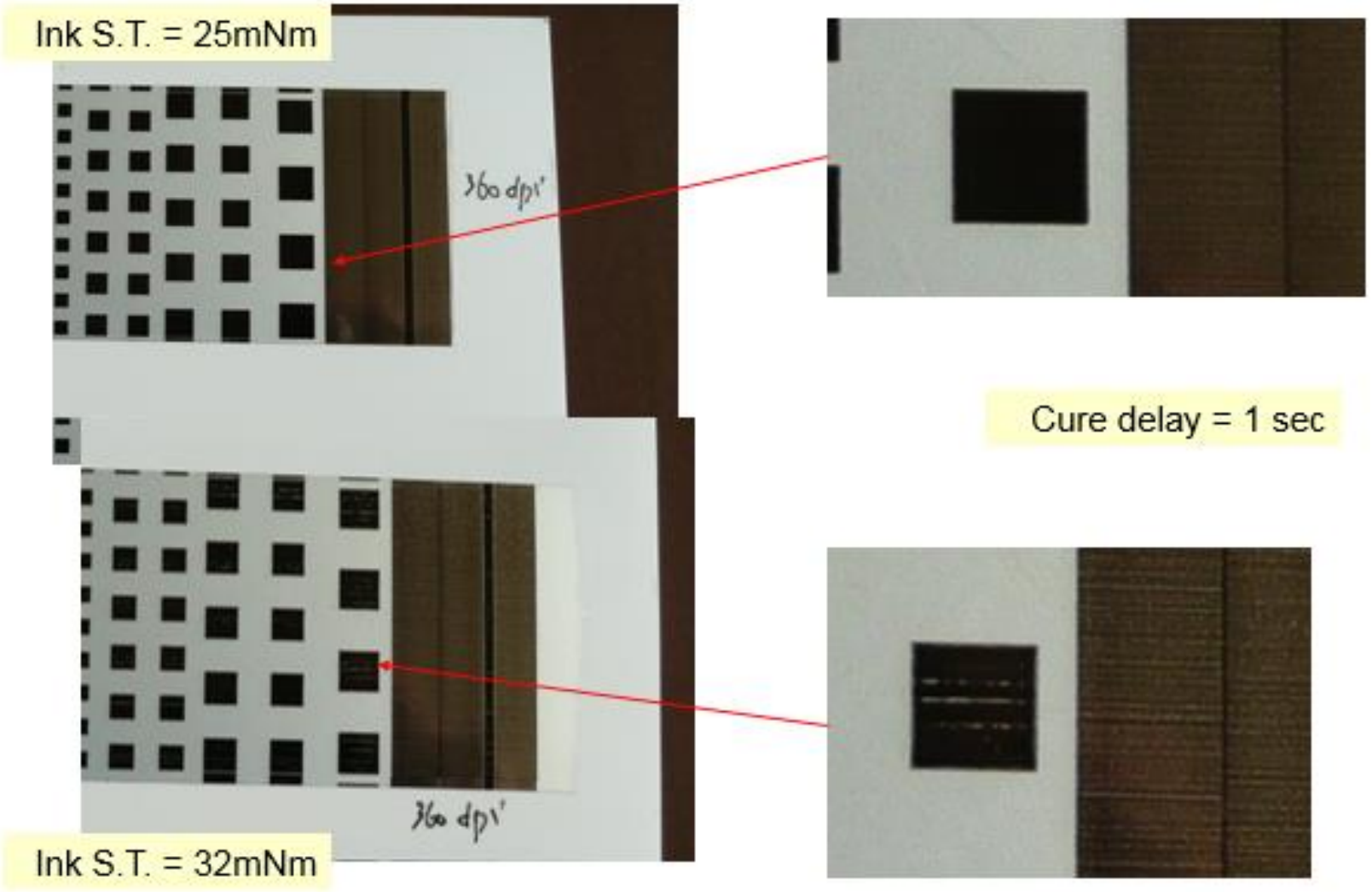
Effect of surface tension of ink



360dpi, single pass

KONICA MINOLTA

Effect of surface tension of ink



KONICA MINOLTA

Performance Limitations

Ink Wetting and Adhesion

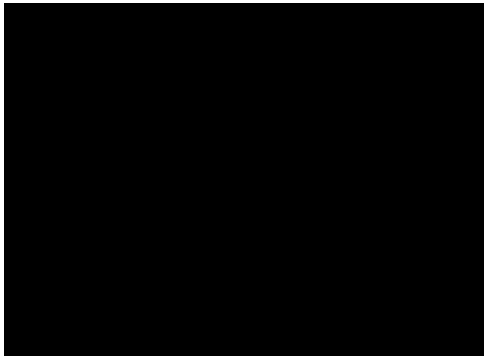
- Material Surface Energy versus Ink surface tension

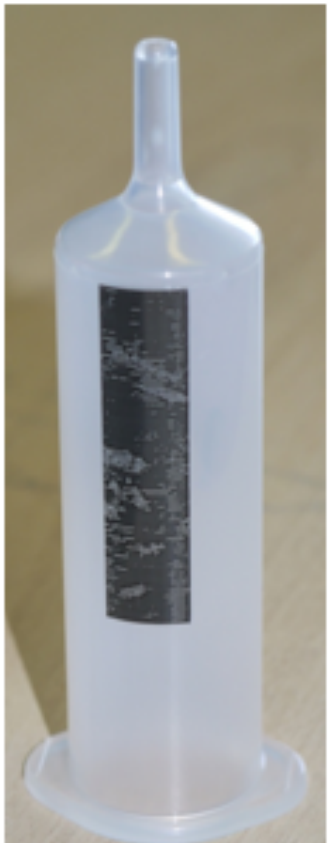
Most UV inks need a media surface energy >52mN/m

Best UV inkjet inks need >44mN/m

But most plastics are <40 mN/m

- ink wont wet = bad Print Quality
- ink wont stick !





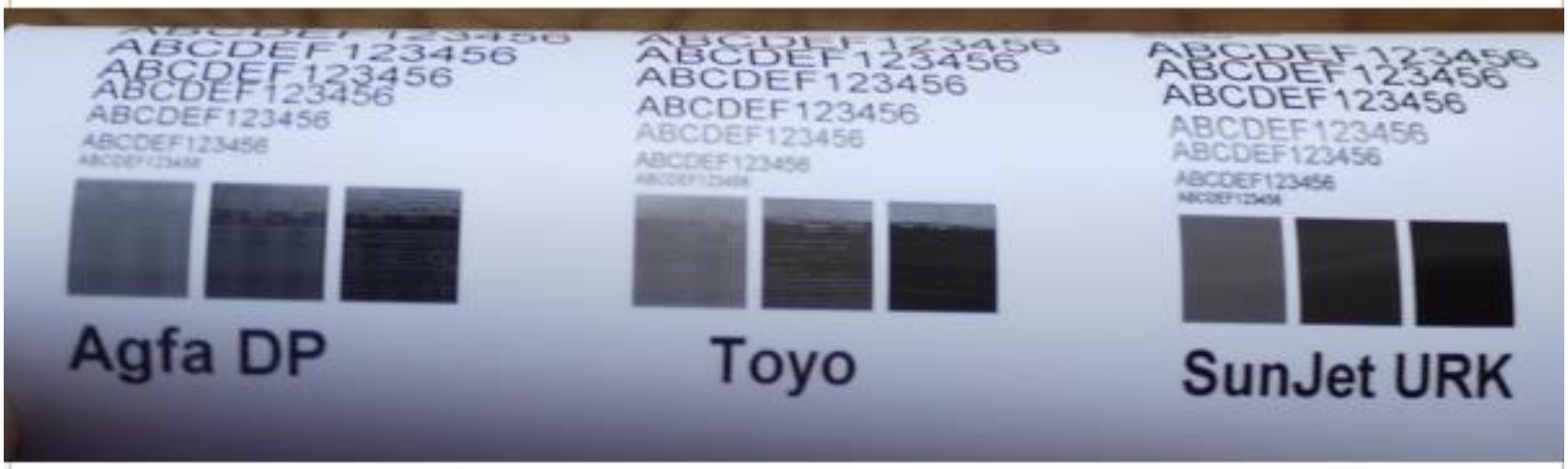
KONICA MINOLTA

Performance Limitations

Ink Wetting and Adhesion

Varies from material to material and ink to ink

Material surface texture is important!



KONICA MINOLTA

Performance Limitations

Ink Wetting and Adhesion

Most plastics need pre-treatment

- Pre-Treatment
  - Alcohol
  - Flame
  - Corona
  - Plasma
  - Primer

Sword Brush

WANDRES micro-cleaning

www.wandres.com

KONICA MINOLTA

Performance Limitations

No Corona

Corona

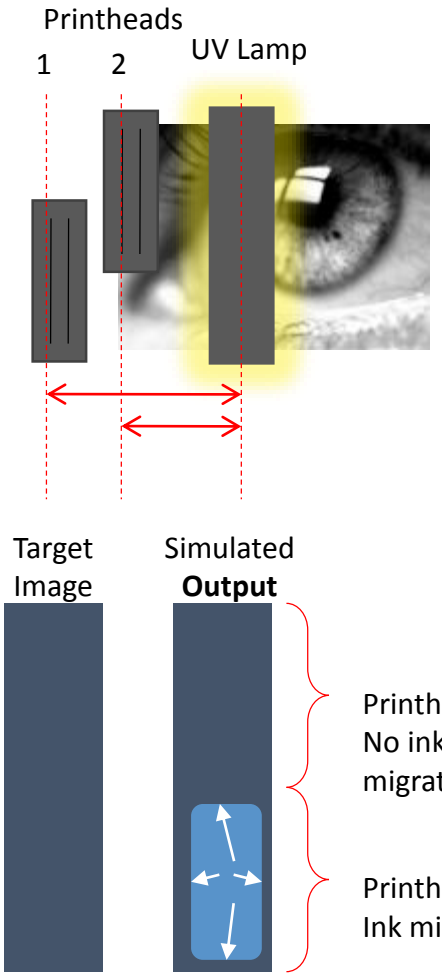
GLOBAL INKJET SYSTEMS

CONTROL | PERFORMANCE | INNOVATION

Process - Stitching and Multipass

Printhead Stitching

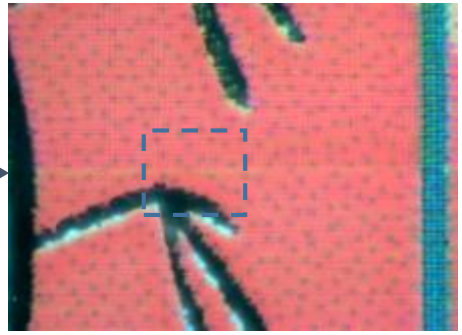
- **Why is a good stitch important?**
  - The human eye is very good at spotting discontinuities especially in areas of flat colour
- **What needs to be controlled?**
  - **Printhead alignment** : typically positioned to within <20% of the diameter of a drop
  - **Printhead calibration** : printheads ideally need to be tuned for jet straightness and drop size conformity
  - **Ink substrate interaction** : Ink moves over time creating visible artefacts – ink migration control
- **Stitched printheads do not all jet in the same place at the same time**
- **Some will be printing *wet on dry* while others will print *wet on / near wet***



Stitching Examples

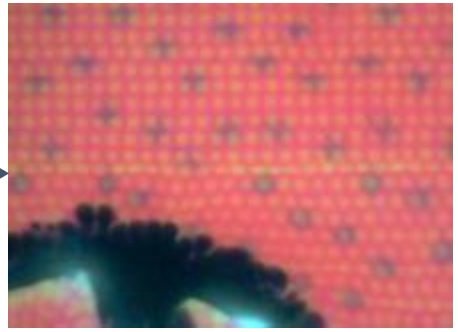
“Flat” or “No” Stitch across flat colour

Stitch Line →



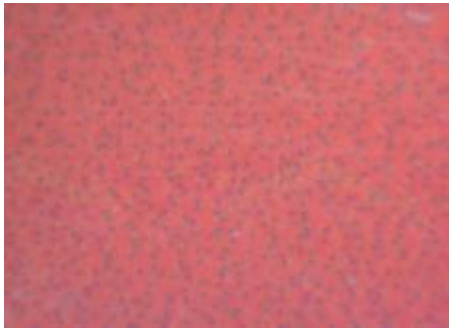
Higher Density Bands

Stitch Line →

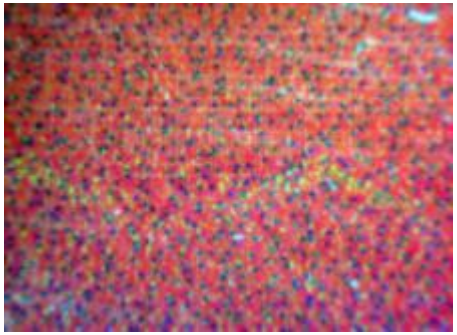


‘Moving Stitch’ across flat colour

Stitch Line →

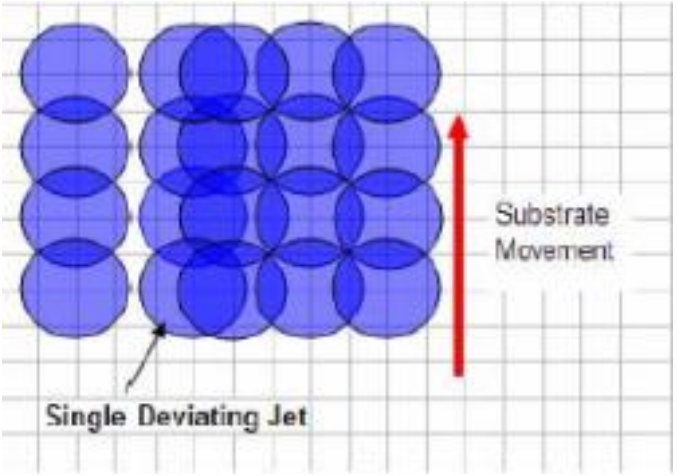


Stitch Line →



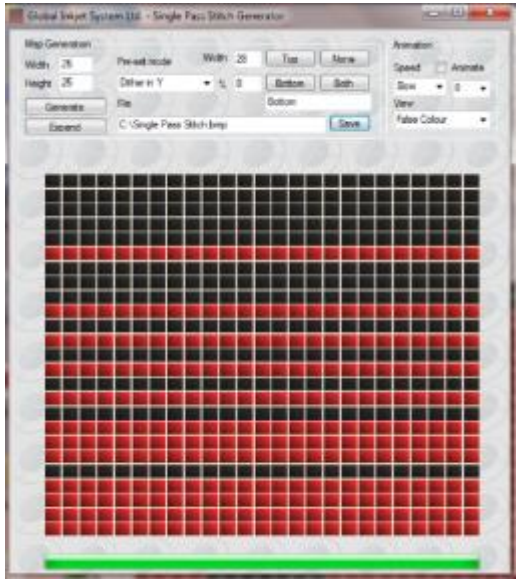
Scanning vs. Single Pass

- **Scanning**
  - Safe and reliable
  - Errors recoverable
  - Lower productivity
- **Single pass**
  - No room for error
  - Defects highly visible
    - Missing nozzles
    - Jet straightness
    - Consistent jet velocity
  - High productivity
  - Reliability critical

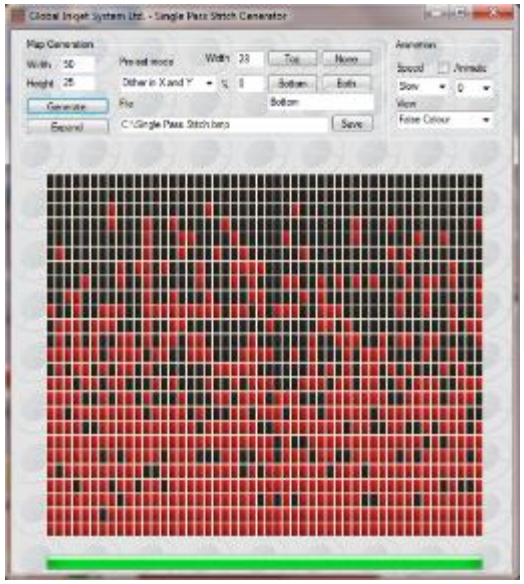


Stitching Strategies

- **Stitches can massively improve output quality**
- **Different applications benefit from different strategies**
- **Overlap of printheads**
  - 20-40 pixel (2-4mm)
  - Larger stitch area is better for quality

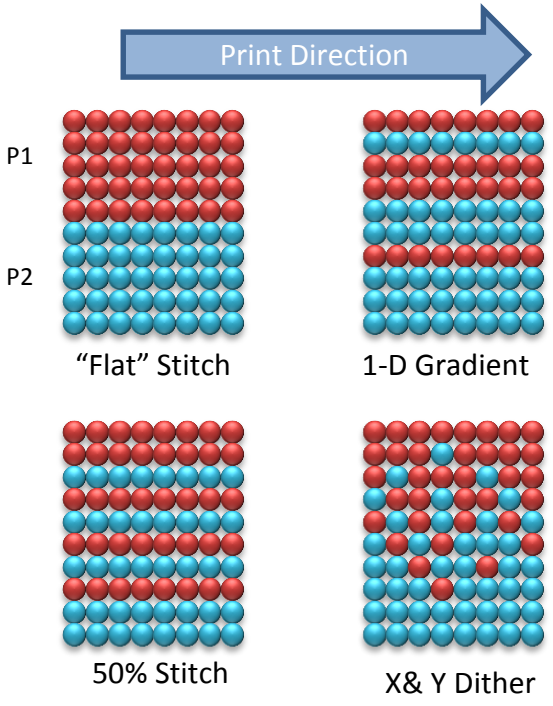


2-D Density

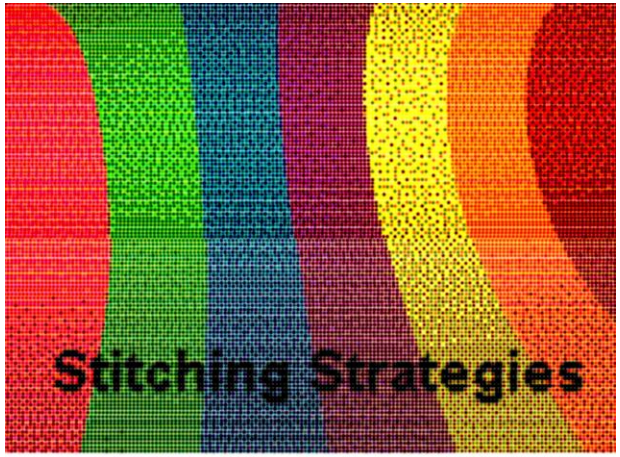


X & Y Dither

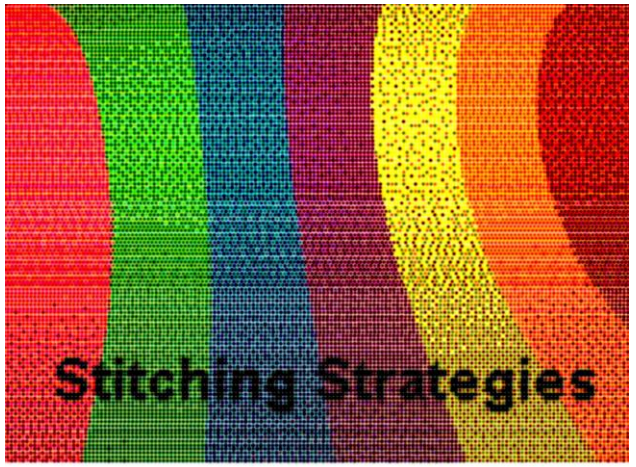
Digital Stitching Strategies - examples



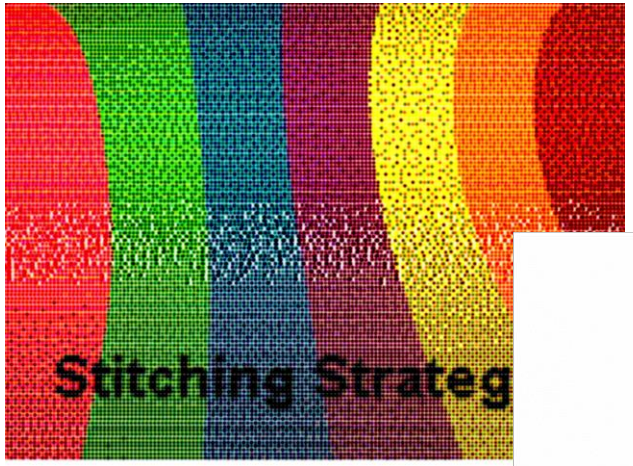
Exploring Stitching Strategies



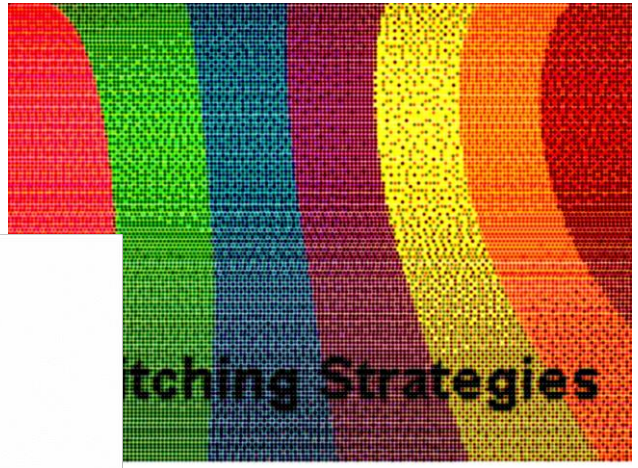
No Stitch



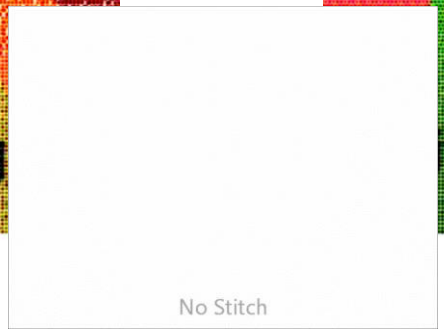
50% Stitch



2D XY Dither Stitch



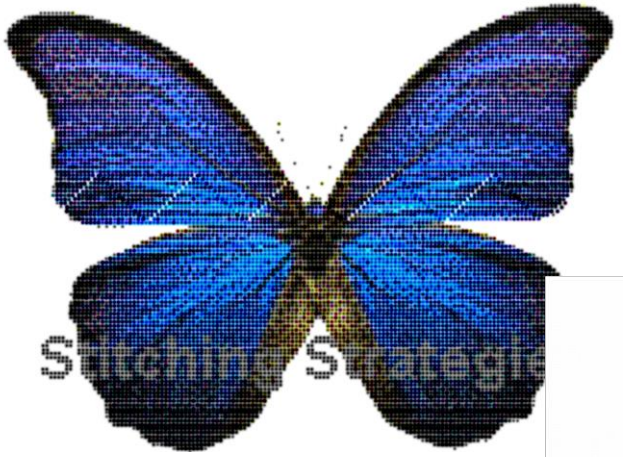
1D Gradient Stitch



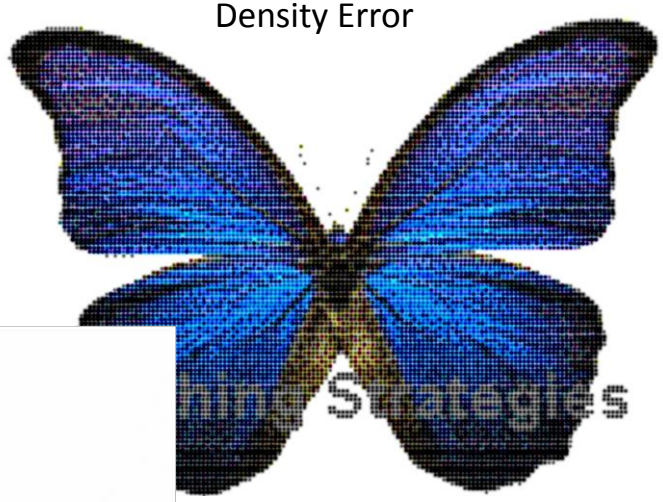
Stitching Strategies – Understanding Errors

No Error

Density Error



Alignment Error



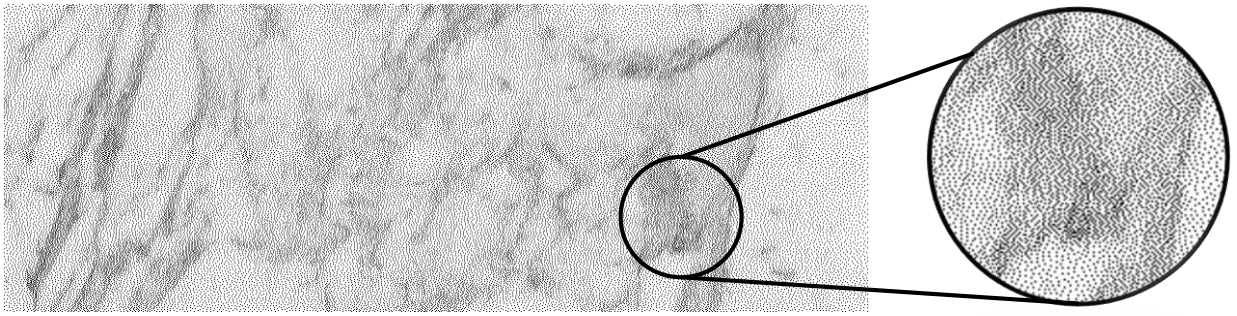
Jetting Error

GLOBAL INKJET SYSTEMS

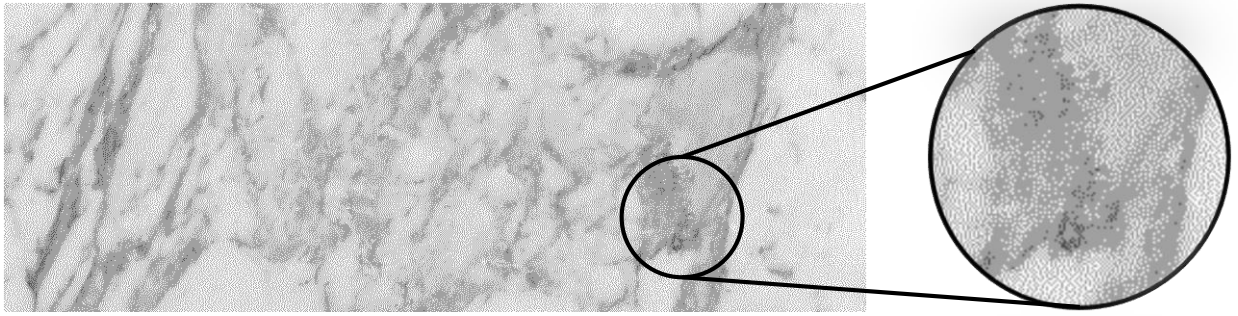
CONTROL | PERFORMANCE | INNOVATION

Software - Grey Levels

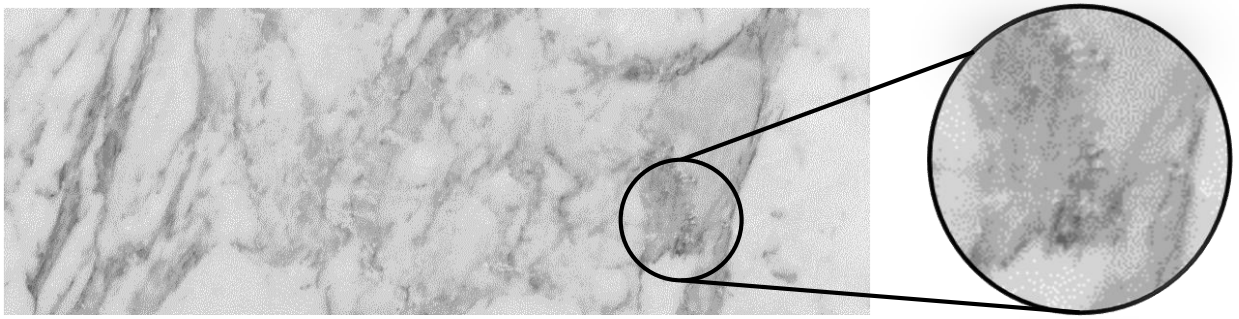
Effects of Grey Levels on Output



1 Level (Binary)



3 Level – Even Spacing



7 Level – Even Spacing

Grey Level Drop Size and Resolution

Figure 1 : Original Image

Figure 2 : 7 Level Greyscale Simulated Output

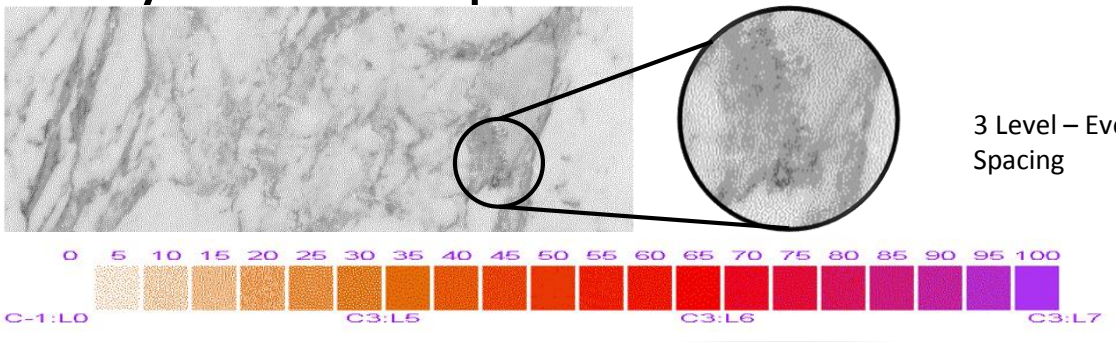
½ Inch at 400dpi
Effective resolution = 116dpi

½ Inch at 400dpi
Effective resolution = 233dpi

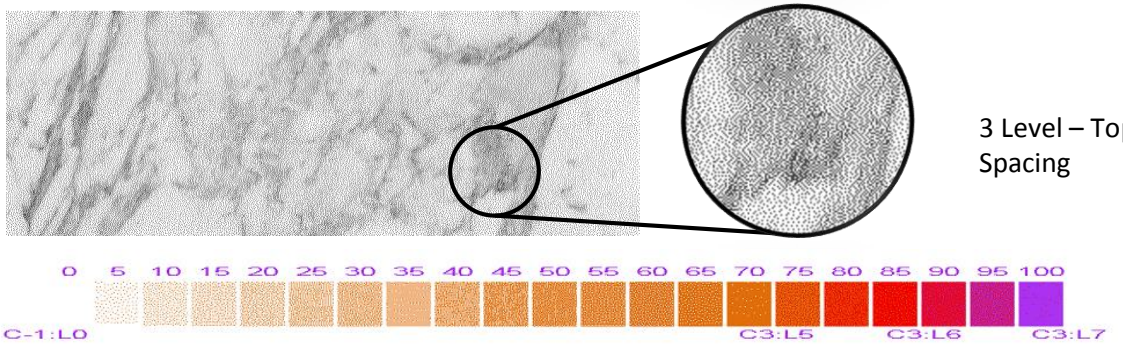
½ Inch at 400dpi
Effective resolution = 350dpi

Figure 3 : Close up of simulated output

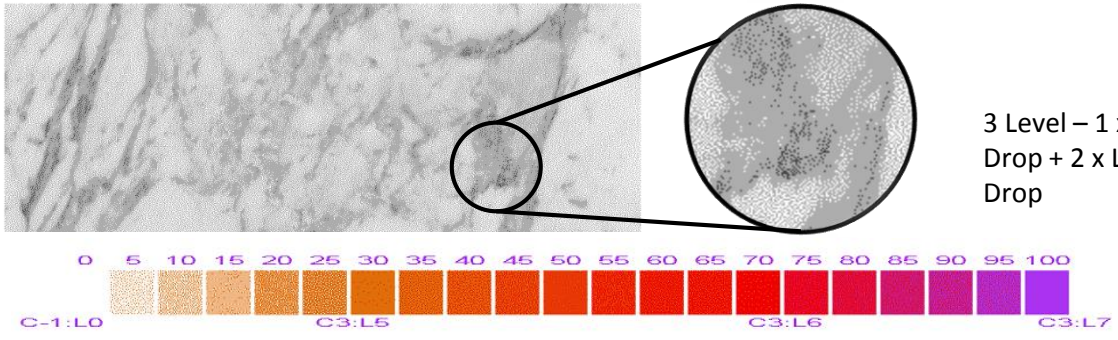
Grey Level Drop Size



3 Level – Even Spacing



3 Level – Top End Spacing



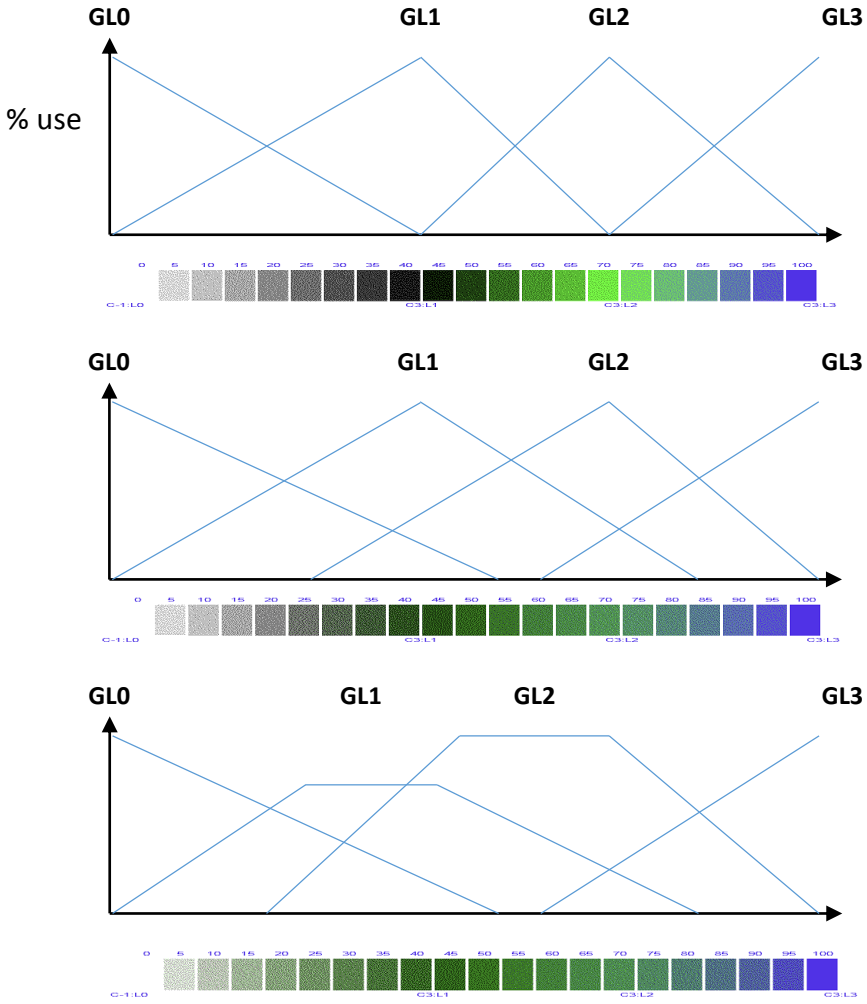
3 Level – 1 x Small Drop + 2 x Large Drop

A key starting point for maximising image quality is to chose your drop sizes carefully

The smallest drop will often dictate the perceived graininess of the image

Try to ‘spread out’ the grey levels over the contone range by selecting the appropriate printhead, ink and waveform

Blending Grey Levels



RIP technologies often allow the user to specify the locations where grey levels overlap and how they overlap

This can improve image quality especially on systems where the ink can have a gloss finish as it avoids areas of density where only a single drop size is used

This technique is only applicable to grey levels

GLOBAL INKJET SYSTEMS

CONTROL | PERFORMANCE | INNOVATION

Software - Colour Calibration

Ink Channel Limiting

- **What is it?**
  - For each ink in turn, reducing the maximum amount of ink that can be deposited
- **Why do it?**
  - It prevents bleeding and flooding of the substrate
  - Reduces total ink consumption
  - Improves print quality
  - Improve effectiveness of colour management
- **Method of control?**
  - Grey Level Selection
    - Only use grey levels that are required.
    - Can be done in the waveform or in RIP software
  - Software Ink Limiting
    - A mechanism to limit the maximum amount of ink deposited by each channel

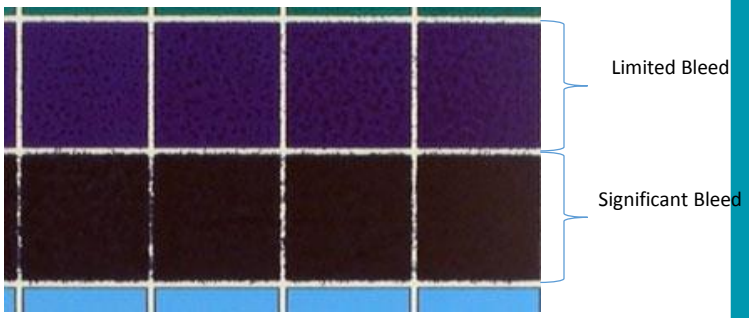


Figure 1: Example of ink bleed on a substrate

Figure 2: Ideal tonal response

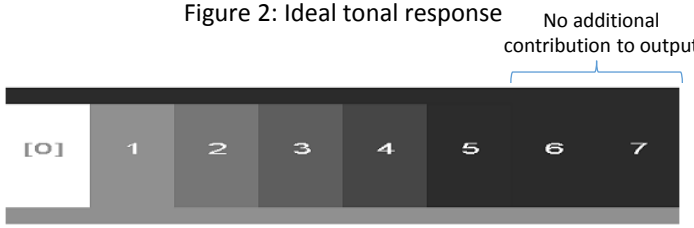


Figure 3: Typical tonal response

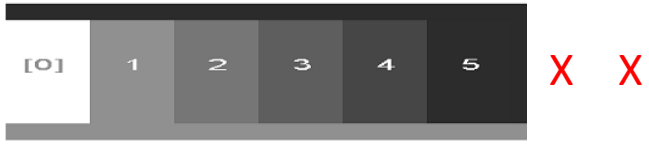


Figure 4: Final Grey Level Selection

Linearisation

- **What is it?**
  - Linearization ensures the printer prints contone values evenly throughout the scale, from 0-100%
- **Why do it?**
  - It makes multiple printers behave in a similar predictable way
  - It makes colour management easier
- **Method of control?**
  - Generate a linearisation test chart
  - Print it
  - Measure the output data
  - Import the measurement data into the RIP to apply

Figure 1: Not linearised

Figure 2: Linearised

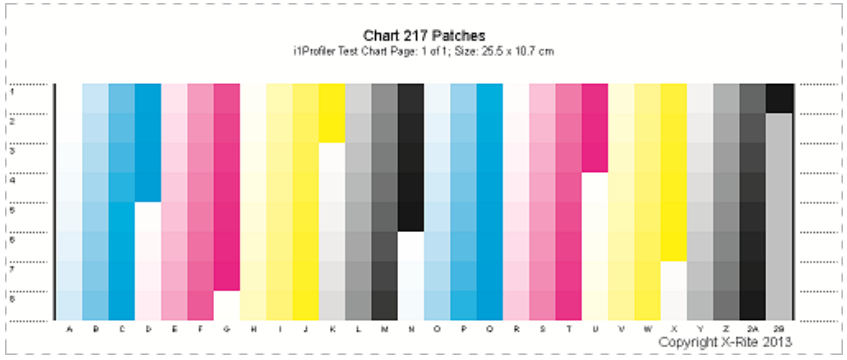


Figure 3: A Linearisation Test Chart

Colour Management

- **What is it?**
  - Colour Management is the method of control for converting colour from one colour space to another
- **Why do it?**
  - It significantly improves the quality of image output
  - It can save ink
  - Most colour systems are of little commercial use without it
- **Method of control?**
  - Typically through colour management software (standalone or part of the RIP)

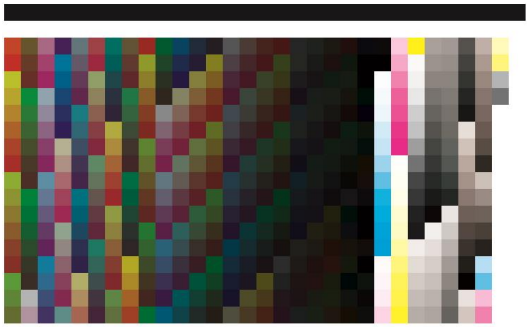


Figure 1: Test Chart with 1024 Patches (Page 1 of 2)

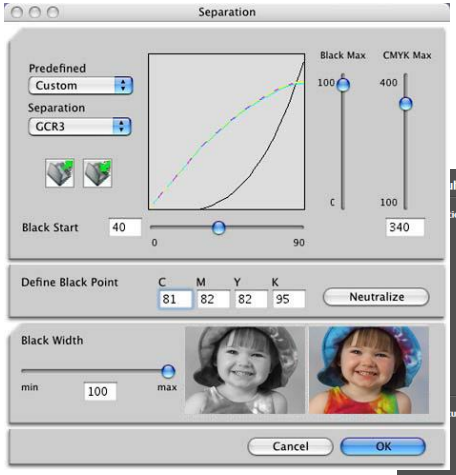


Figure 2: Profiles Maker 5's GUI

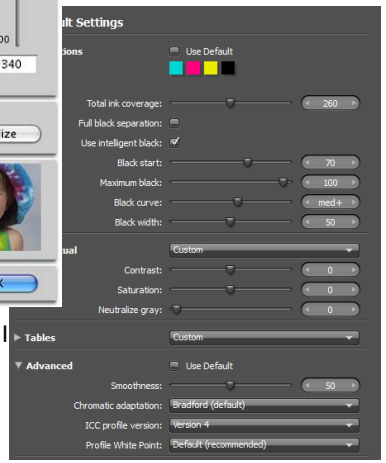


Figure 3: i1Profiler's GUI

Basic Colour Calibration Process

- **Assumptions**
  - The following have already been selected:-
    - Printhead, ink, waveform, substrate, process and cross process resolution
- **Possible approaches to calibration**

	Level 1	Level 2	Level 3
Steps	a. Colour Management	a. Linearisation b. Colour Management	a. Ink Channel Limiting b. Linearisation c. Colour Management
Comments	• Faster Calibration • May lose contone data when using 8bpp (recommend 16bpp) • Must be performed for each machine	• Slower Calibration • Less data lost in colour management • Colour management now usable on all machines	• Slower Calibration • Very little loss of information in contone data 8bpp ok • Optimised print speed

GLOBAL INKJET SYSTEMS

CONTROL | PERFORMANCE | INNOVATION

Software - Colour & Gamut - Drops on Substrate

Colour Gamut

- In colour reproduction, including computer graphics and photography, the gamut, or colour gamut, is a certain complete subset of colours
- The most common usage refers to the subset of colours which can be accurately represented in a given circumstance, such as within a given colour space or by a certain output device
- Another sense, less frequently used but not less correct, refers to the complete set of colours found within an image at a given time. In this context, digitizing a photograph, converting a digitized image to a different colour space, or outputting it to a given medium using a certain output device generally alters its gamut, in the sense that some of the colours in the original are lost in the process. – *Source Wikipedia*

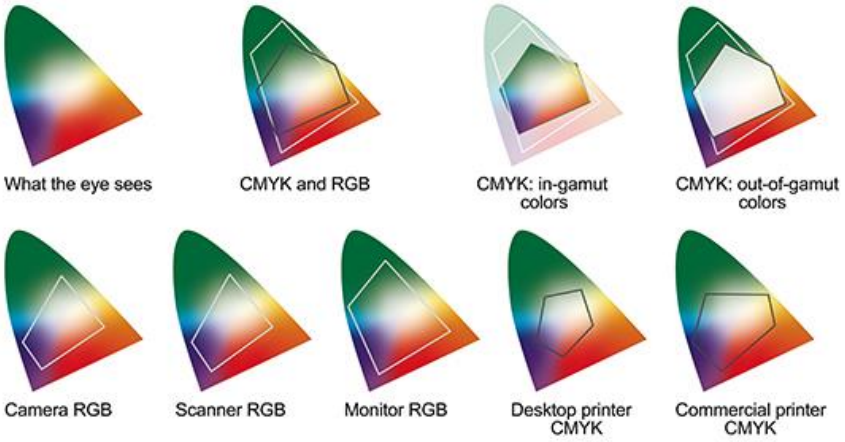


Figure 3: A selection of different colour gamuts

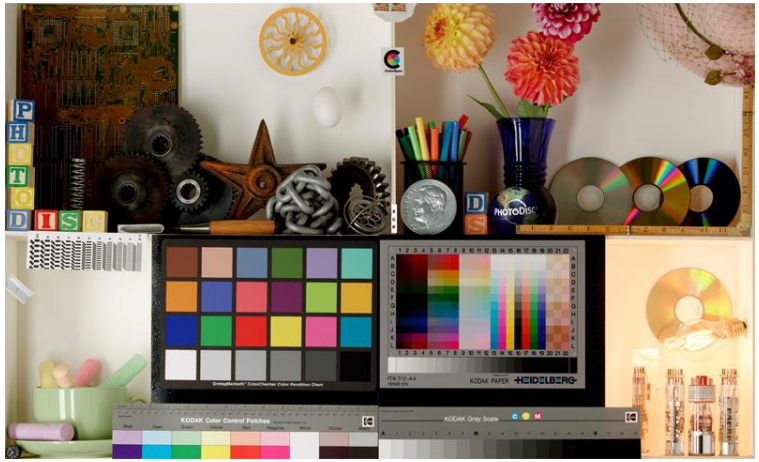


Figure 1: Original Image Section (sRGB IEC61966-21)

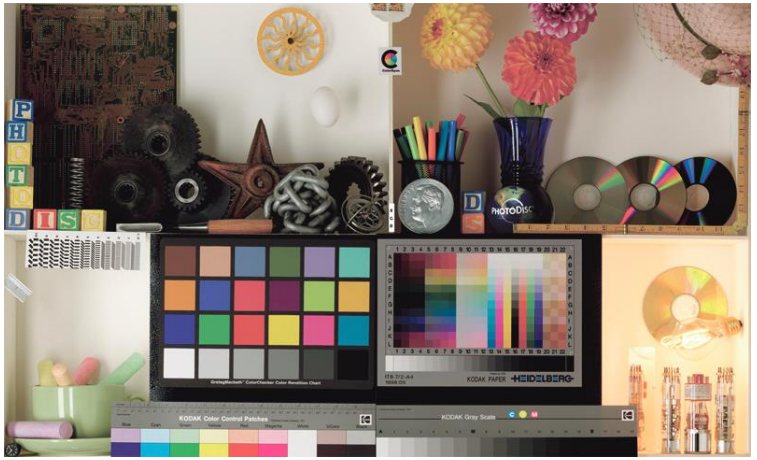


Figure 2: Simulated printer colour gamut

Inks

- Ink selection has a dramatic effect on output quality of the final print
- Increasing the number of inks will typically increase colour gamut (and cost of the machine)
- Lighter inks get consumed more quickly than error diffused dark inks

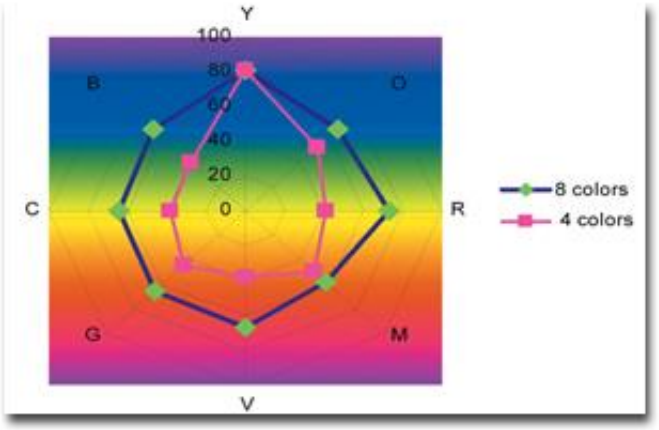
KONICA MINOLTA

Performance Limitations

Colour Gamut

- Applies equally to labels and direct product decoration
- CMYK is always a little restricted in colours – eg “Coca Cola red”

- Gamut of new inks is increasing all the time
- Add spot colours
  - But Minimum order quantity !
- 5, 6, 9 colour ink sets !



White Point

- White Point is the colour of the media you are printing on
- The closer the media is to pure white, the more colour range you are able to achieve

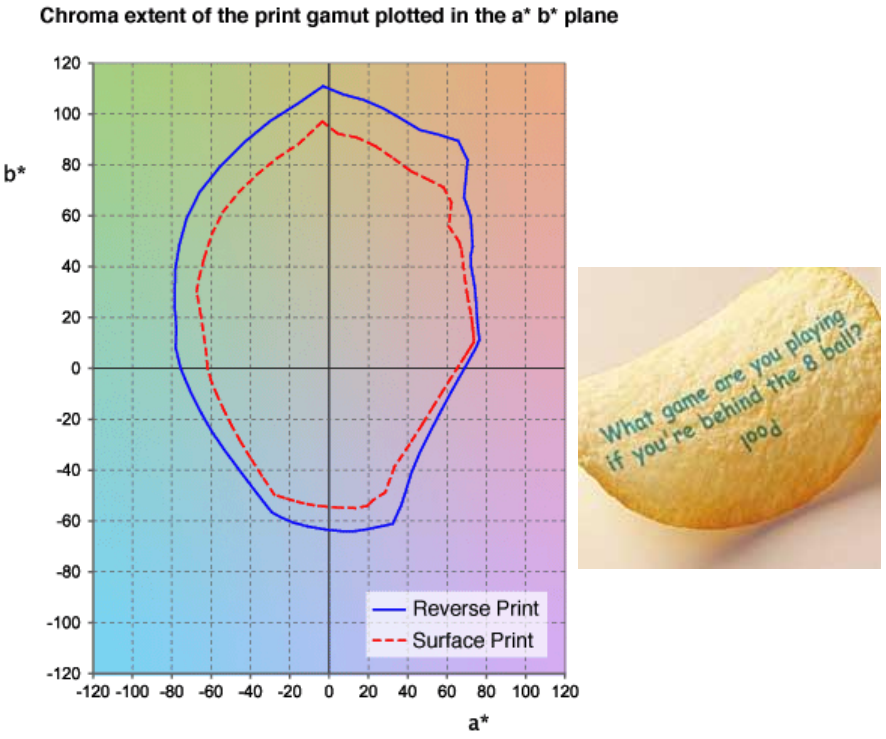


Figure 1: The image on the left was printed on a media with a white point (in L.a.b. values) of 98.0, -1.0, 0.5. The image on the right was printed on a media with a white point of 88.0, -3.0, -1.5. (all images are simulated)

Dot Gain

- Dot gain is the increase in the diameter of a halftone dot during the printing process or put another way it is a measure of how far the ink drop spreads out when it hits the surface you are printing to
- The reason dot gain is important for image quality is because any media with too much dot gain will lose sharpness and print darker than intended
- Dot gain can be managed by selecting media, coating media or modifying ink chemistry

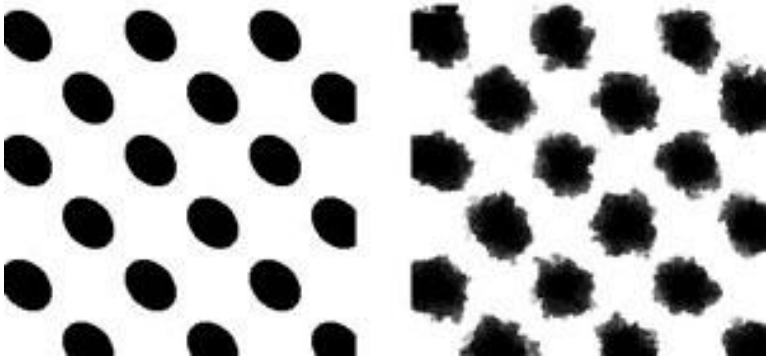
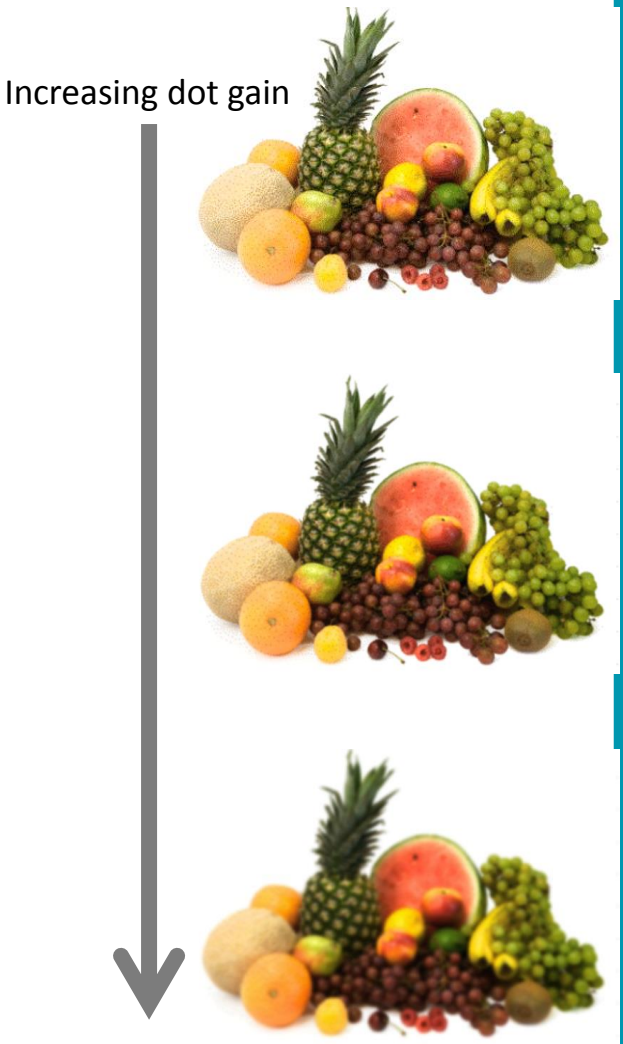
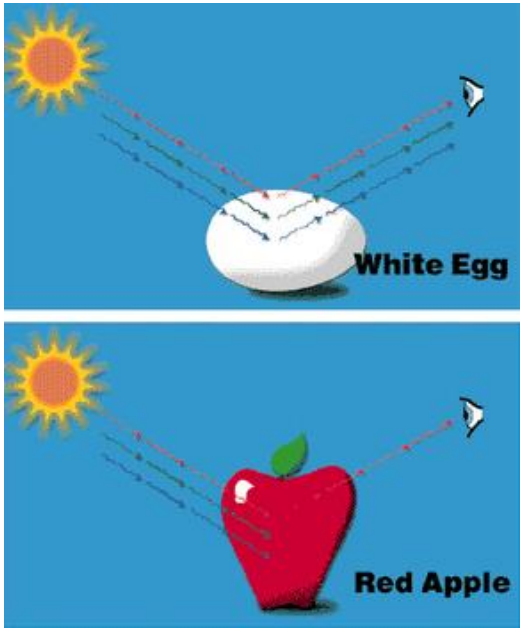


Figure 1: The dots on the left represent what the dots look like from a printer the second the ink hits the paper. The dots on the right represent what the dots look like after dot gain has occurred. You can see the dots lose their sharpness and the tonality is darkened.



Light Scatter

- Light scattering can be thought of as the deflection of a ray from a straight path
  - In other words, we see colour by having light reflect off an image and back into our eye
  - The more the light scatters, as opposed to being reflected directly back into your eye, the less dense the colours will appear



Light Scatter

Glossy

Matte

- Glossy surfaces have inherently less light scattering than matte surfaces
- A glossy paper will allow you to achieve darker richer colours, especially blacks
- This will increase the overall contrast of the image and improve image quality

- The reason a paper is matte is because there is more texture on the surface of the paper
- The paper's comparatively irregular surface texture causes the light that hits the paper to bounce off in every direction, instead of bouncing straight back to your eye

GLOBAL INKJET SYSTEMS

CONTROL | PERFORMANCE | INNOVATION

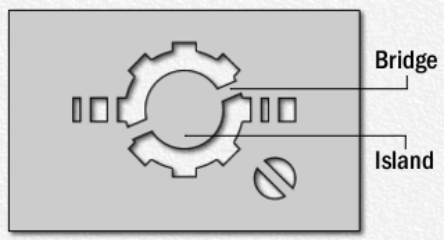
Software - Screening

Overview and History

- Screening is the most common term used to describe the process of turning a continuous tone (‘contone’) image into an image that a printer can use

- At its most basic, a stencil is a form of screen. It prevents ink from reaching the surface in some areas but allows it in others. Typically stencils can only allow ink (100%) or no ink (50%) to pass so there are only two levels of output achievable

- Printers quickly wanted to be able to print shades of colours and so a process called halftone screening was devised using ‘photographic screens or veils’ by William Fox Talbot in around 1850



Parts of a stencil

Stencil output

William Henry Fox Talbot, by John Moffat, 1864.

Adding Colours

Original Image (16,777,216 colours)

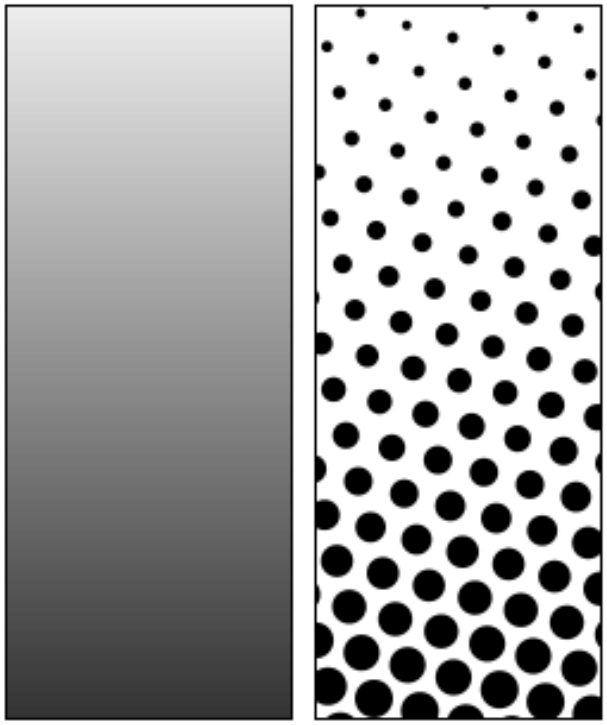
4 Colour Stencil

8 Colour Stencil

16 Colour Stencil

Halftone or AM Screening

- Halftone screening is technique that gives the viewer of a print the impression that they are seeing different shades or densities of ink
- It takes advantage of the eye's limited resolution and the brains ability to average colour across areas
- Up close, AM screening can look coarse and unappealing but from a distance the eye will have increasing difficult in distinguishing it from any other output method

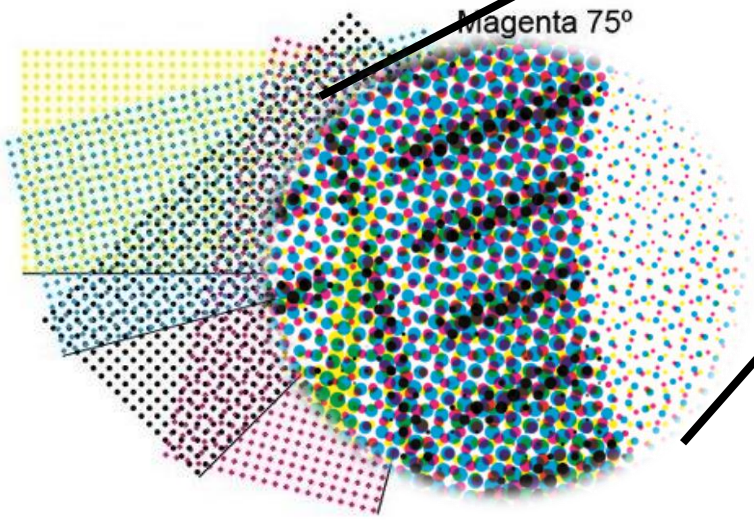


Halftone or AM Screening

AM Screening Example

Original Image (16,777,216 colours)

CMYK Halftone (4 Colours)



16 Colour Stencil

Screen Size Relative to Image Size

Original Image (16,777,216 colours)

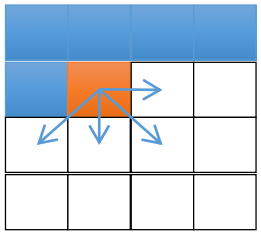
1 Pixel : 1 Pixel

16 Pixels : 1 Pixel

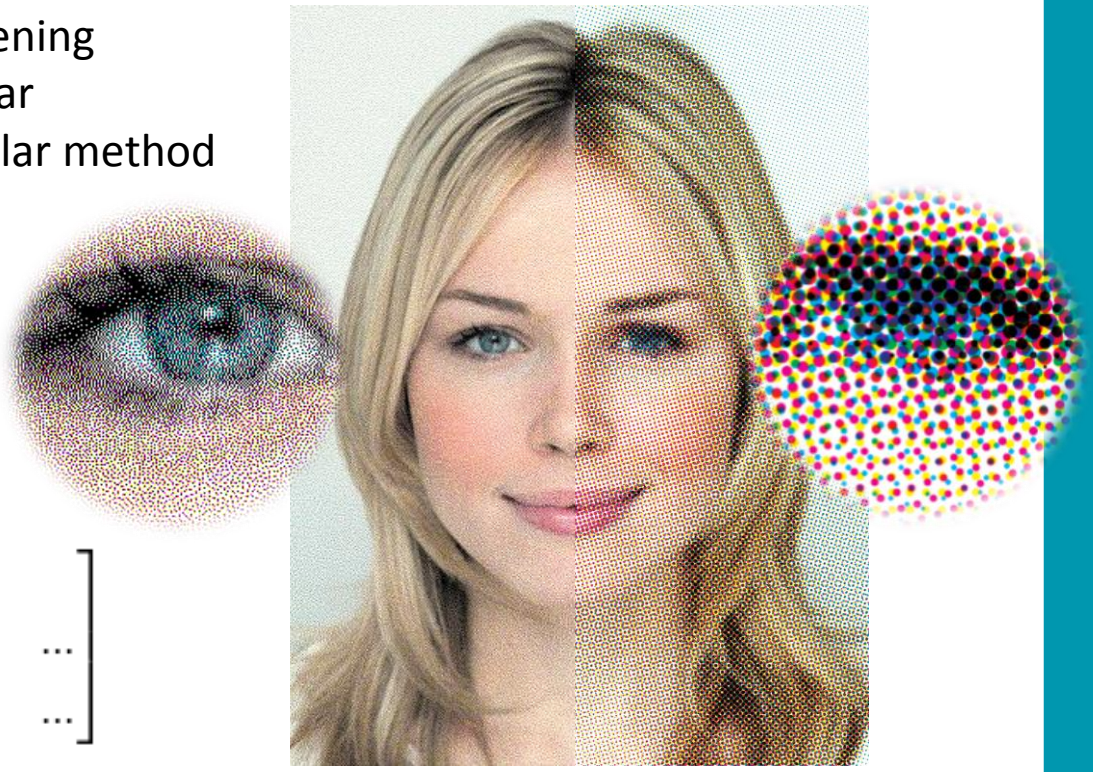
4 Pixels : 1 Pixel

FM Screening/Stochastic Screening

- FM Screening ('Frequency Modulated') was devised as an alternative to Halftone AM Screening
- There are many types of FM Screening
  - Error Diffusion – most popular
  - Floyd Steinberg – most popular method



$$\begin{bmatrix} \cdots & & & * & \frac{7}{16} & \cdots \\ \cdots & \frac{3}{16} & \frac{5}{16} & & \frac{1}{16} & \cdots \end{bmatrix}$$



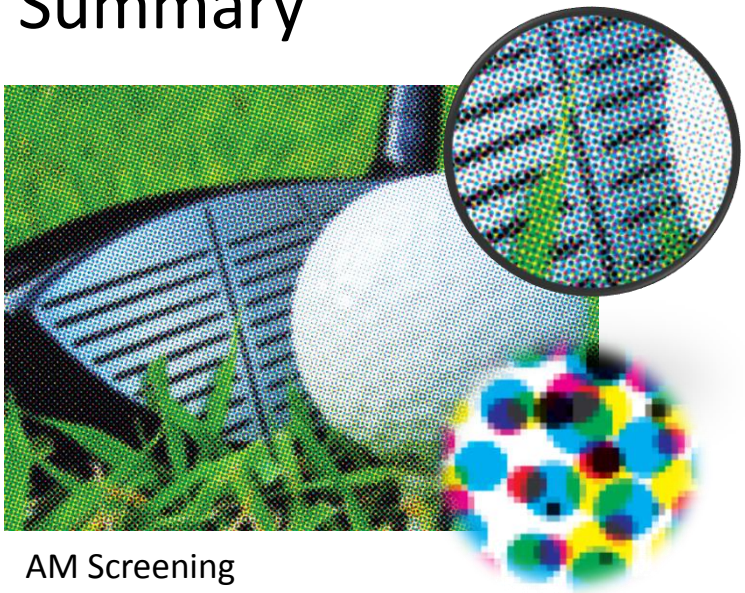
FM Screening (Floyd Steinberg)

AM Halftone Screening

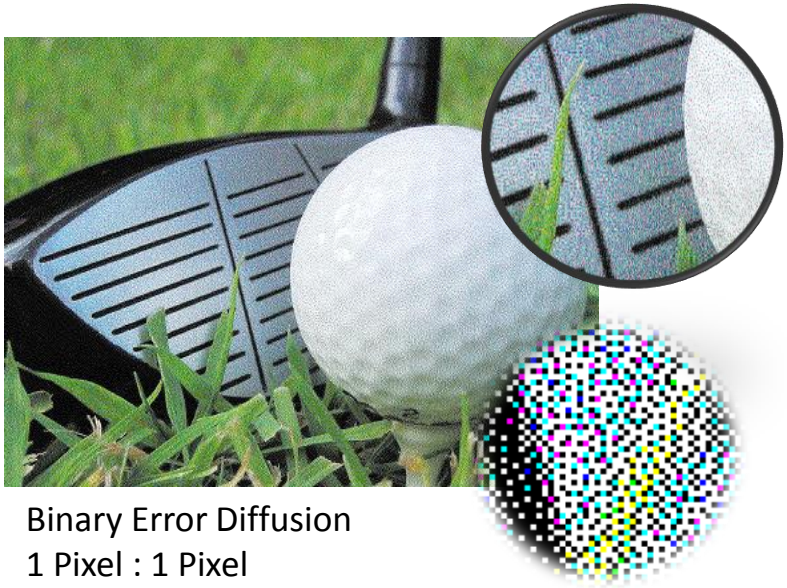
Understanding the way screeners behave is crucial to solving some common print quality issues

Error Diffusion vs AM Screening Summary

Original Image (16,777,216 colours)



AM Screening
1 Pixel : 1 Pixel



Binary Error Diffusion
1 Pixel : 1 Pixel

- AM Screening uses dot sizes of up to 8 pixels wide resulting in a 8 fold reduction in print resolution
- Binary Error Diffusion uses dots of only a single size maintaining resolution much more effectively

Factors Effecting Print Quality

Contacts

Nick Geddes, CEO
nick.geddes@globalinkjetsystems.com
Debbie Thorp, Business Development Director
debbie.thorp@globalinkjetsystems.com

Global Inkjet Systems Limited
The Jeffreys Building
Cowley Road
Cambridge CB4 0DS

Tel: +44 (0)1223 426 595 or (0) 1223 733 733

Web: www.globalinkjetsystems.com

THE QUEEN'S AWARDS
FOR ENTERPRISE
INTERNATIONAL TRADE
2013