GLOBAL INKJET SYSTEMS

CONTROL | PERFORMANCE | INNOVATION

Analysing, Understanding & Improving Image Quality

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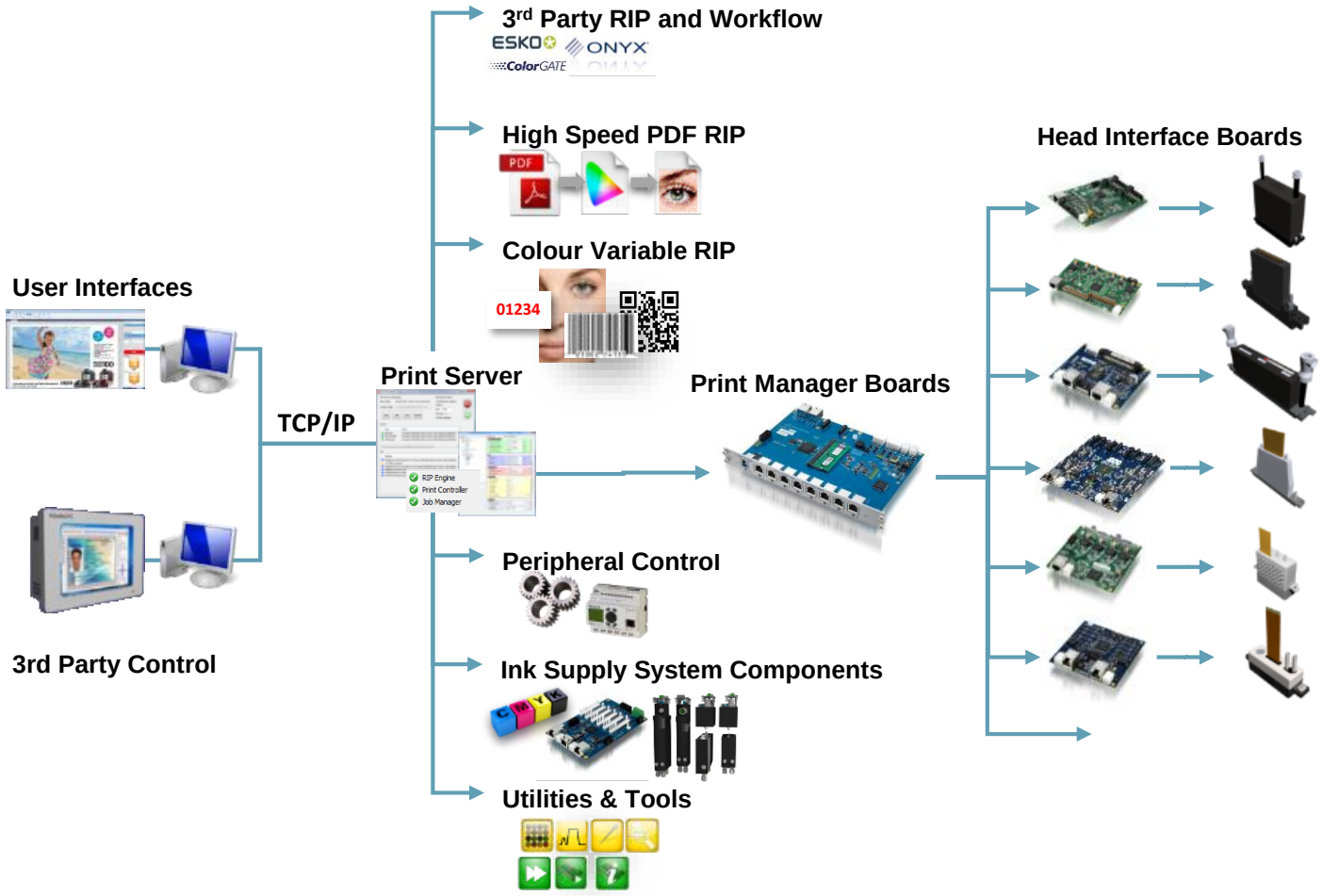
IMI – Inkjet Printing Conference

THE QUEEN'S AWARDS FOR ENTERPRISE INTERNATIONAL TRADE 2013

Global Inkjet Systems

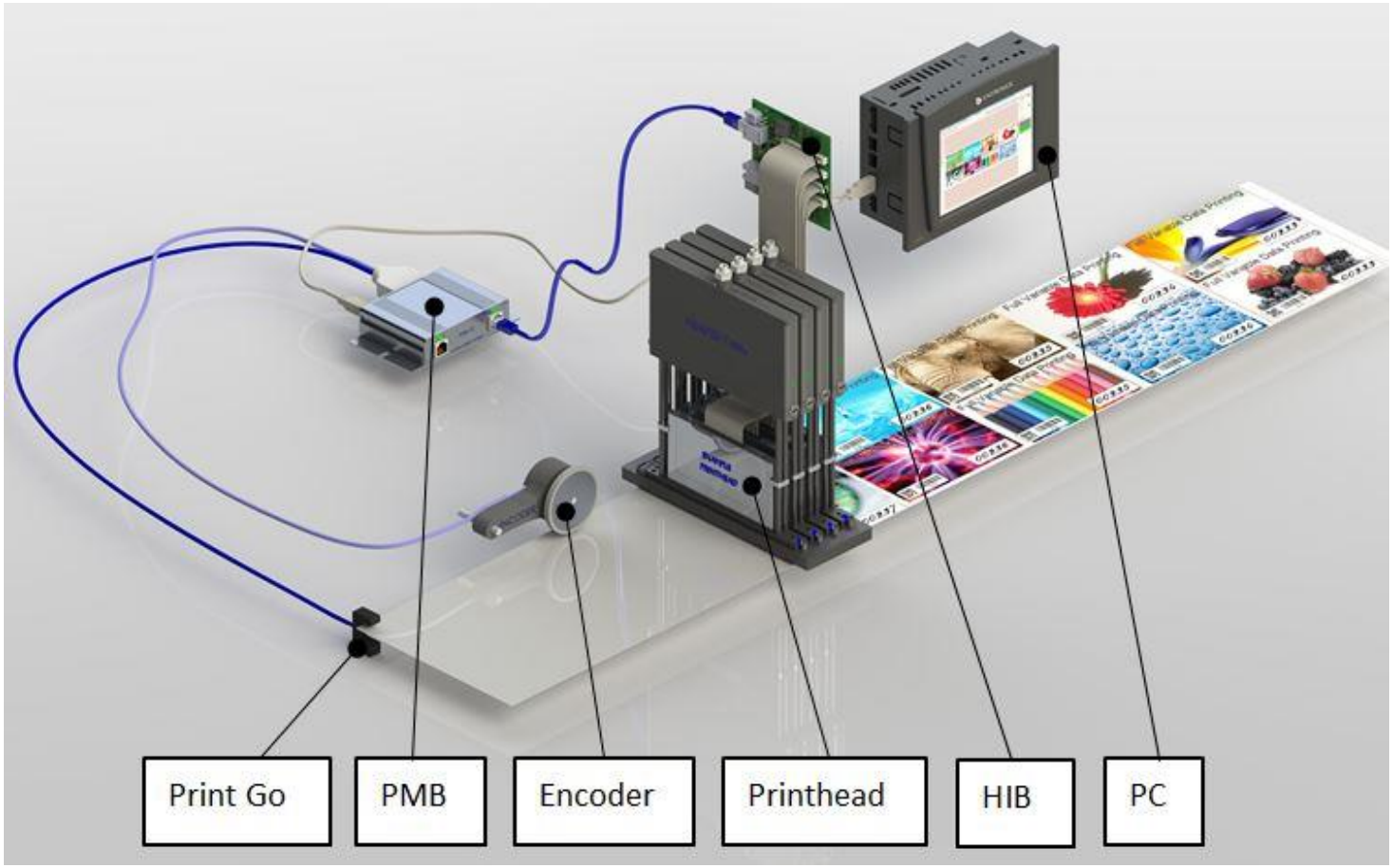
- **Electronics, firmware, drivers, RIPs, software utilities, user interfaces and ink system components**



Defining Image Quality

- **Qualitative definition**
  - Acceptable to the customer
    - Does it look right?
    - Pleasing colours
    - Colour matching
    - Readable barcodes
    - Legible and sharp text
- **Quantitative definition**
  - Physical parameters
    - Drop placement accuracy
    - Drop quality
    - Edge acuity/line quality
    - Optical density
    - Functional attributes (e.g. tracks) – do they work

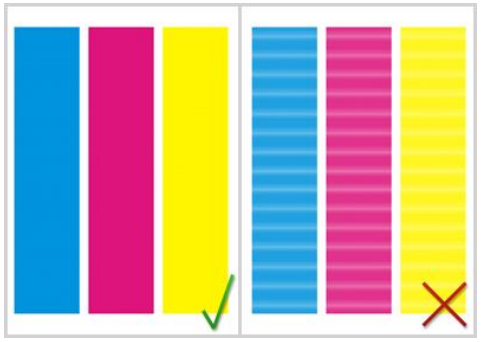
Inkjet System Integration

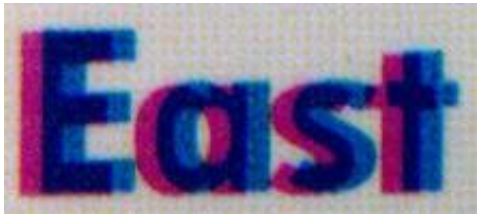


How hard can it be?

Image Quality Issues Seen in the Field

- **Jetting errors**
- **Image artefacts**
- **Resolution too low**
- **Edge definition**
- **Grainy images**
- **Density shift**
- **Nozzle drop outs**
- **Wrong colours/gamut**
- **Missing colours**
- **Texture/unevenness in areas of solid colour**
- **Colour stability**
- **Colour bleed**
- **Ink supply issues**
- **Reticulation**

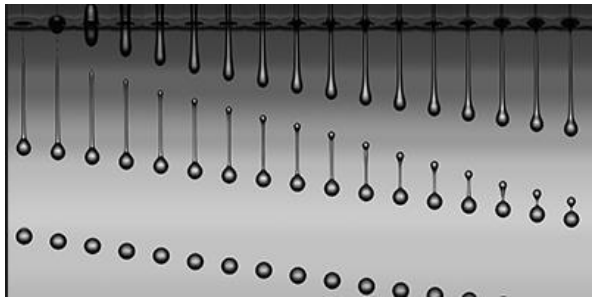




Factors Effecting Image Quality

Analysing, Understanding & Improving Quality

- **The "chain of pain"** – ***Mike Willis, The Ink Jet Blog***
- **Factors affecting print quality**
  - Understanding the (many) variables
- **Inks & substrates**
- **System configuration issues**
- **Process issues**
- **Software & colour management**



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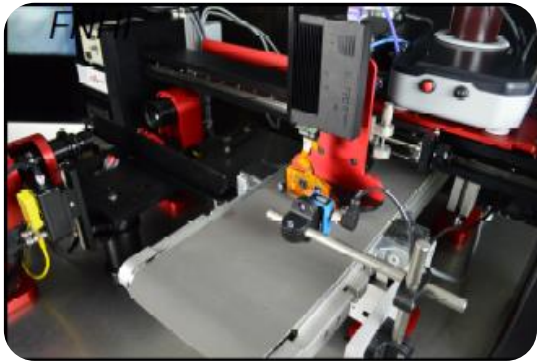
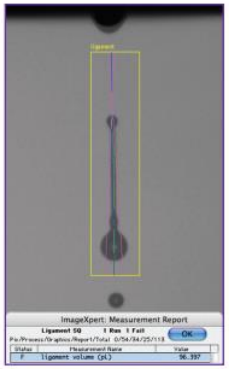
Process – Inks & Substrates

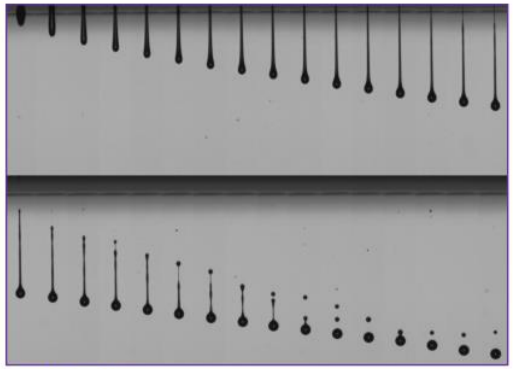
Inks & Substrates

- **It all starts with the ink/fluid**
  - Compatibility
    - Printhead, substrate, print process etc.
  - Characterisation
    - Core formulation (viscosity, surface tension, particle size etc.) through to printability (drop formation, reliability, open time, stability etc.)
- **Established inks/fluids**
  - Waveform, temperature settings are known
- **New ink/fluid development**





Ligament volume measurement



View droplet formation

Ink & Substrates

- **Ink wetting & adhesion**
  - Substrate surface energy vs. ink surface tension

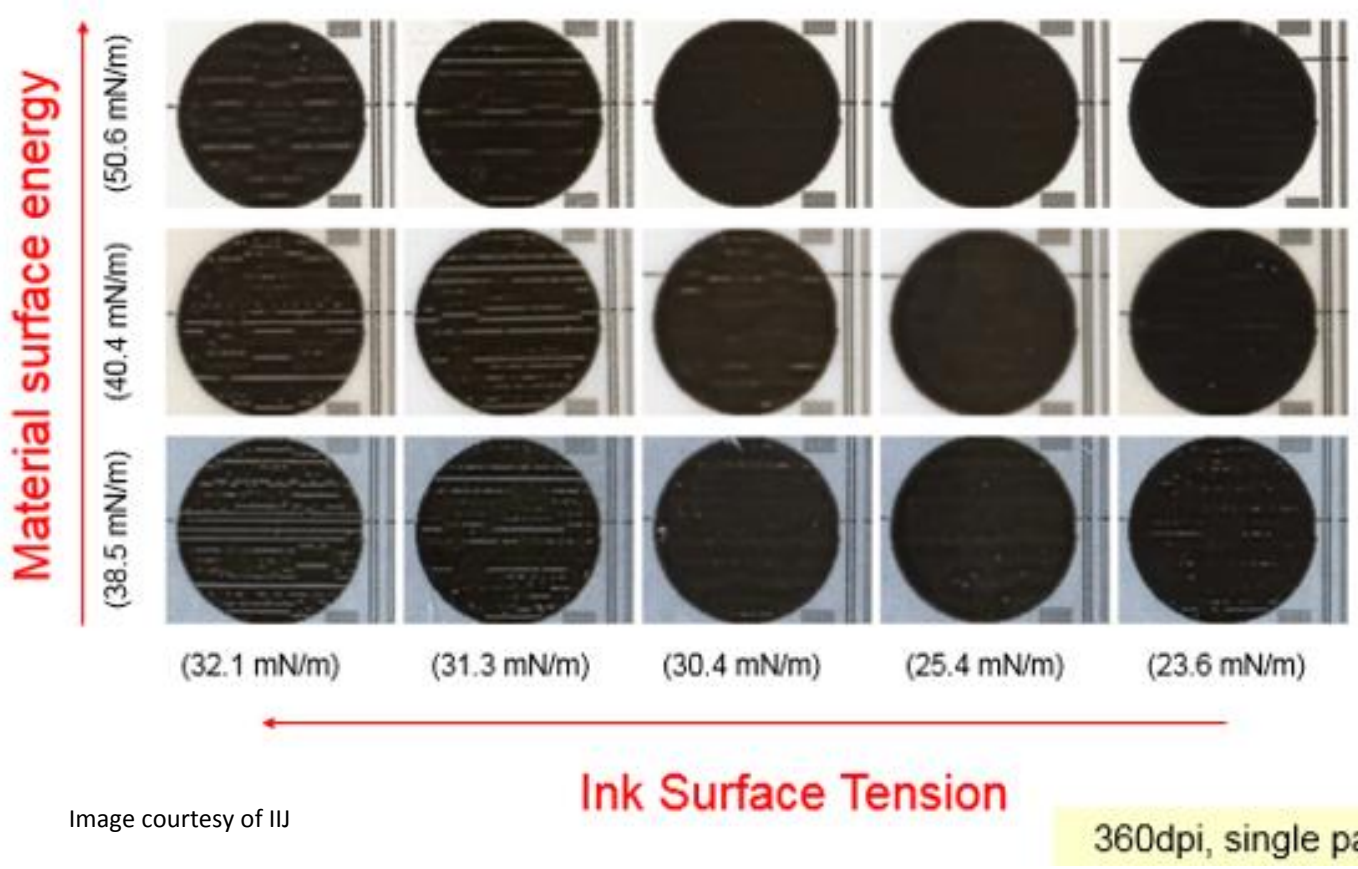


Image courtesy of IIJ

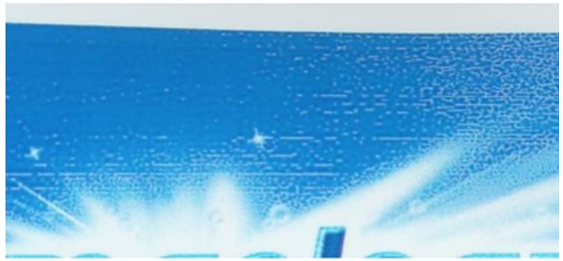
Inks & Substrates

- **Ink wetting & adhesion**
  - Varies from substrate to substrate – and ink to ink

Ink 1 Ink 2 Ink 3

  - Importance of pre-treatment for some substrates
    - Alcohol
    - Flame
    - Corona
    - Plasma
    - Primer

No corona

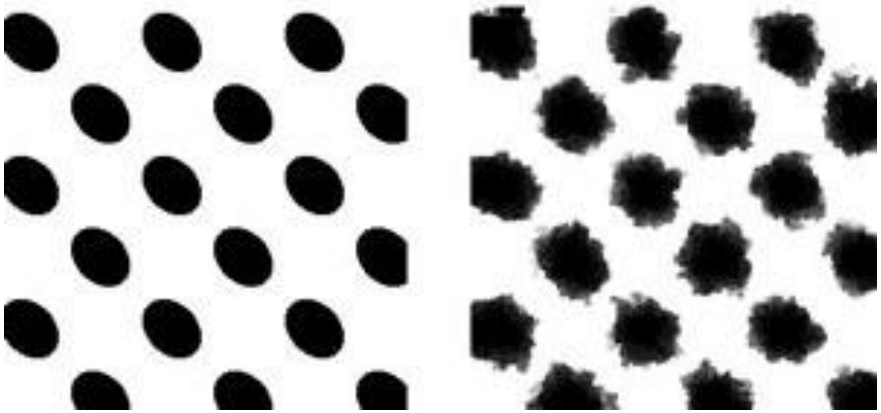


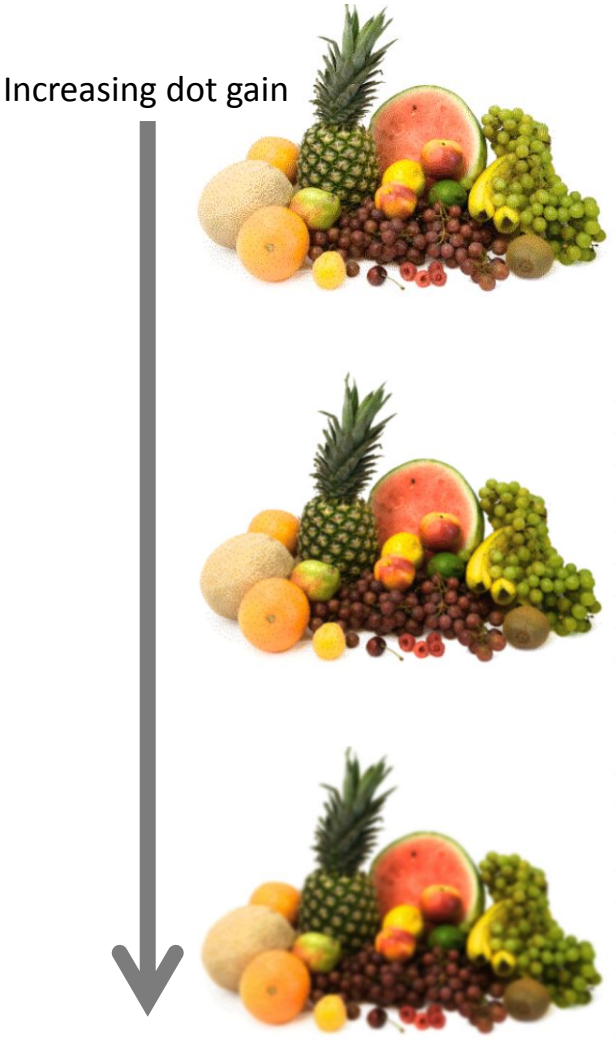
Corona

Images courtesy of IIJ

Inks & Substrates

- **Dot gain**
  - A measure of how far the ink drop spreads out when it hits the substrate
  - Any substrate 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





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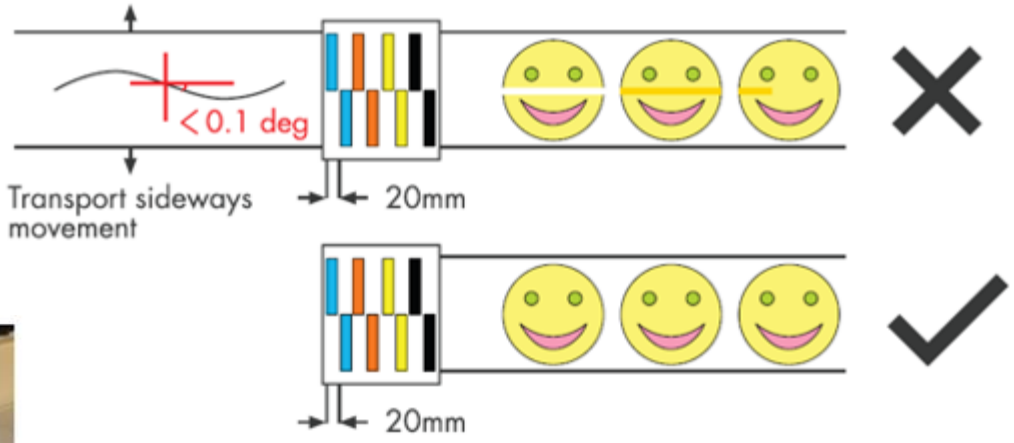
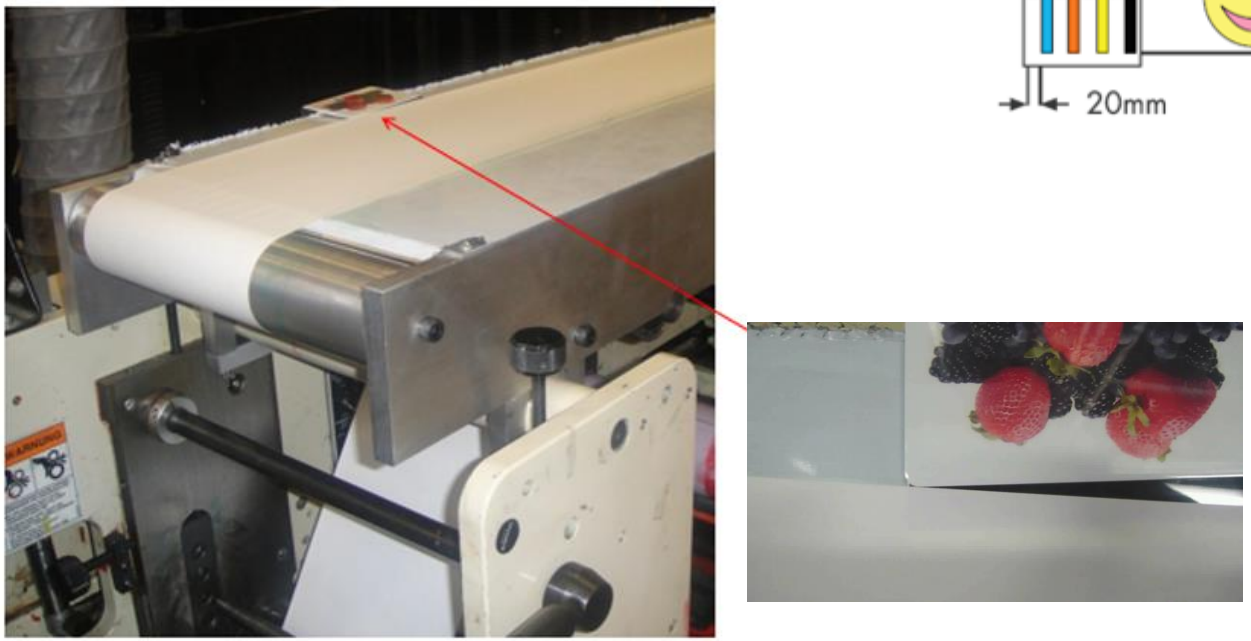
System Configuration

- Encoder & Media Control
- Ink Systems

Accuracy of Substrate Movement

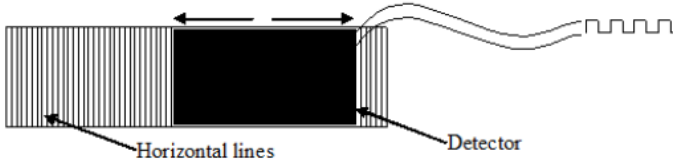




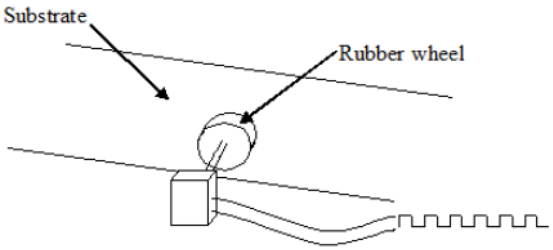
Images and video courtesy of IIJ

Encoders

- **Responsible for regulating all of the printing, by determining how much substrate has moved relative to the printhead**
  - One of the most common factors contributing to poor print quality
- **Linear encoders (optical & magnetic)**
  - Signal generated based on number of lines read
    - Detector lifting off the strip
    - Ink/dirt on the optical strip or lens



- **Rotary encoders (rotary & shaft)**
  - Speed of rotation generates the encoder signal
    - Positioning (distance from printheads)
    - Wheel slippage/misalignment
    - Substrate stretching or bunching
    - Resolution



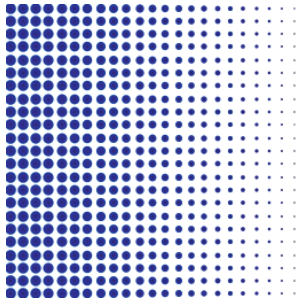
- **Signal noise**
- **Wiring**

Colour Registration

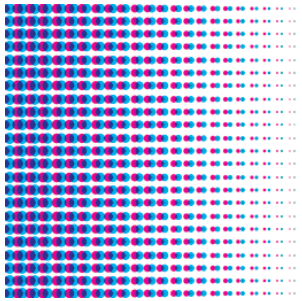
- Colour registration is a measure of the accuracy with which two or more colours are aligned with each other

- The most common causes of poor colour registration are:-

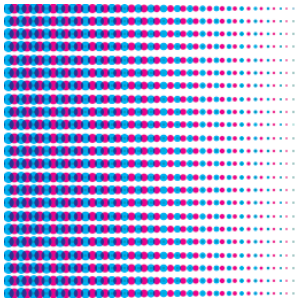
- **System Setup** : The printheads may simply not be aligned mechanically or offset correctly in the electronics / software relative to each other.
- **Encoder**: The encoder is not accurately reporting the movement of the media. (e.g. slippage / misalignment)
- **Media Control** : The media is stretching, 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



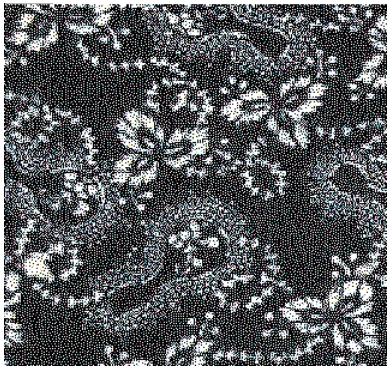
Partial Dot Overlap



No Dot Overlap

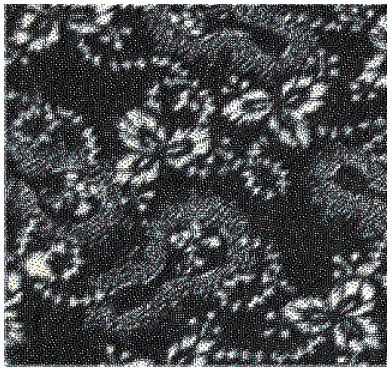
Colour Registration

- Colour registration can effect output colour and detail – images less clear, text less readable, fine detail is lost, colours not accurate
- Typically there is a reduction in colour gamut and darkening of the image

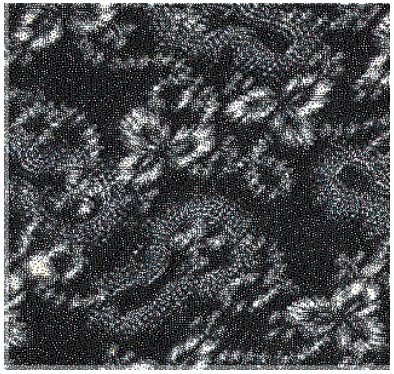


Perfect Alignment

+1,+1 Pixel Nudge

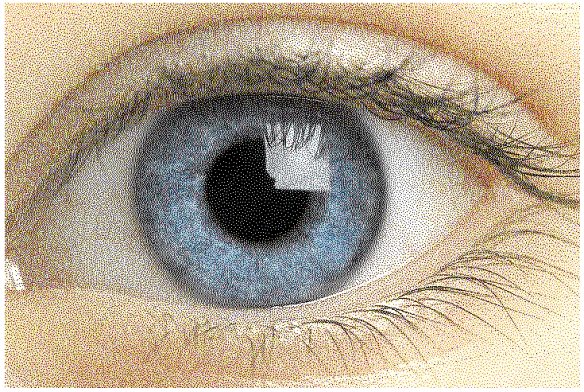


+2,+2 Pixel Nudge

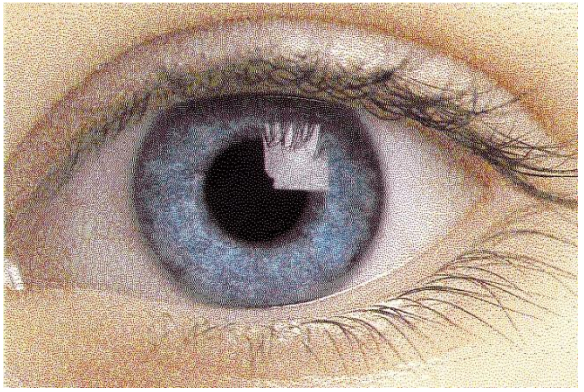


+4,+4 Pixel Nudge

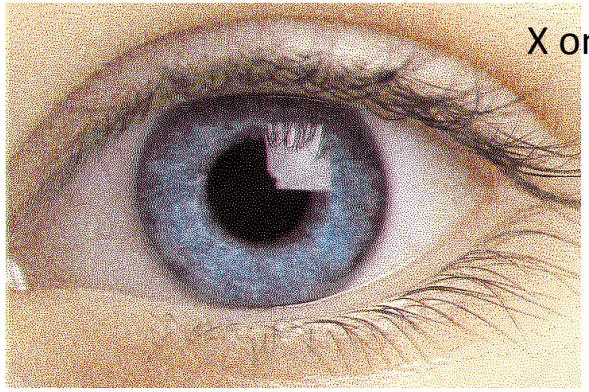
X & Y



Perfect Alignment

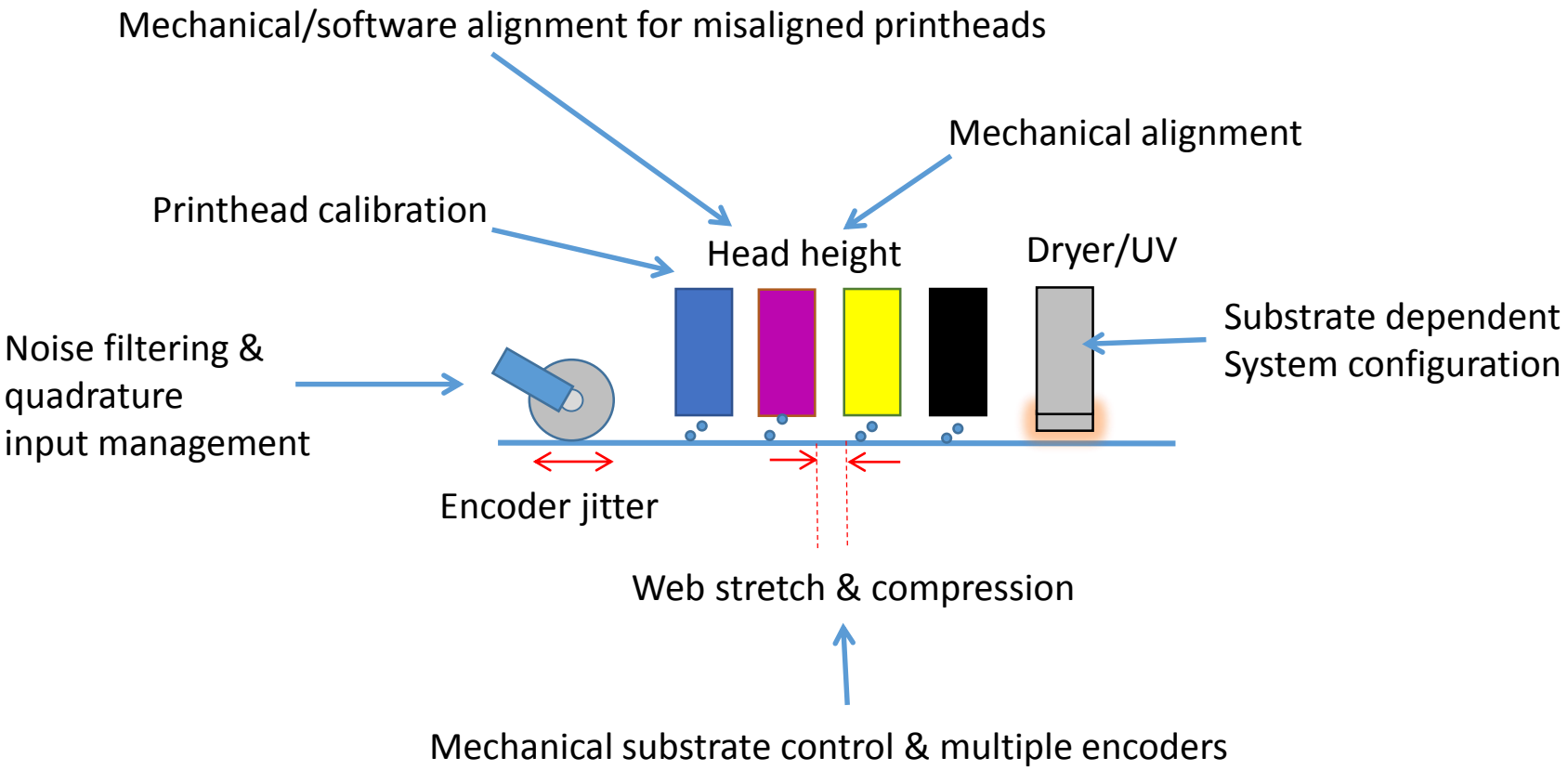


+2,0 Pixel Nudge



+4,0 Pixel Nudge

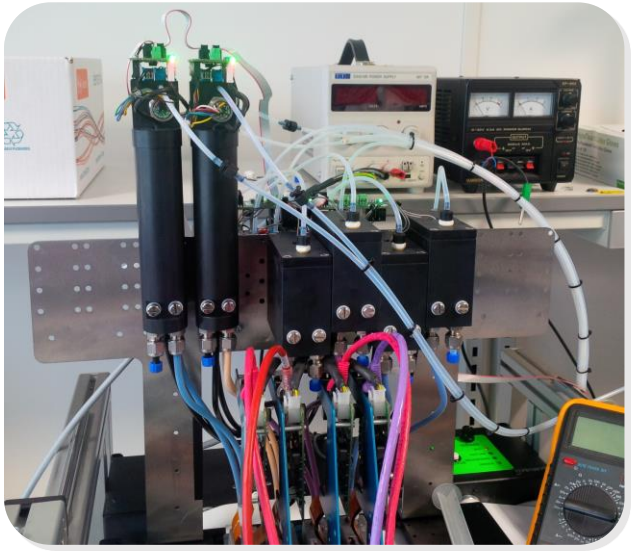
X only



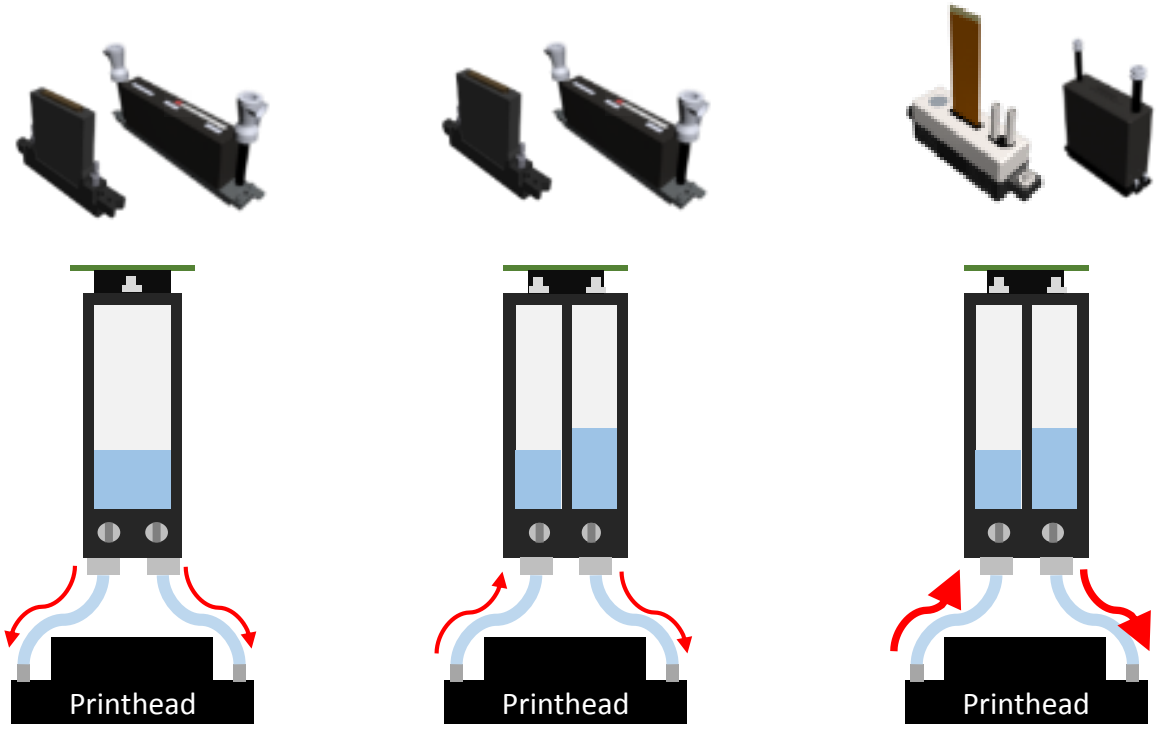
Typical Ink System Issues

- **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**



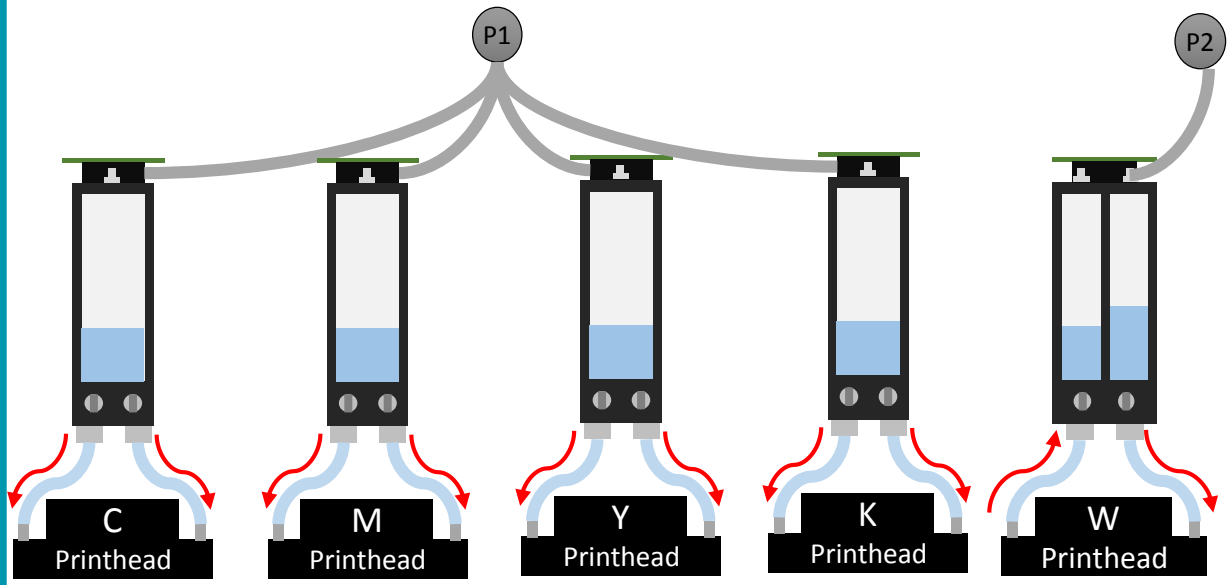
Ink Systems – Flow Modes



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

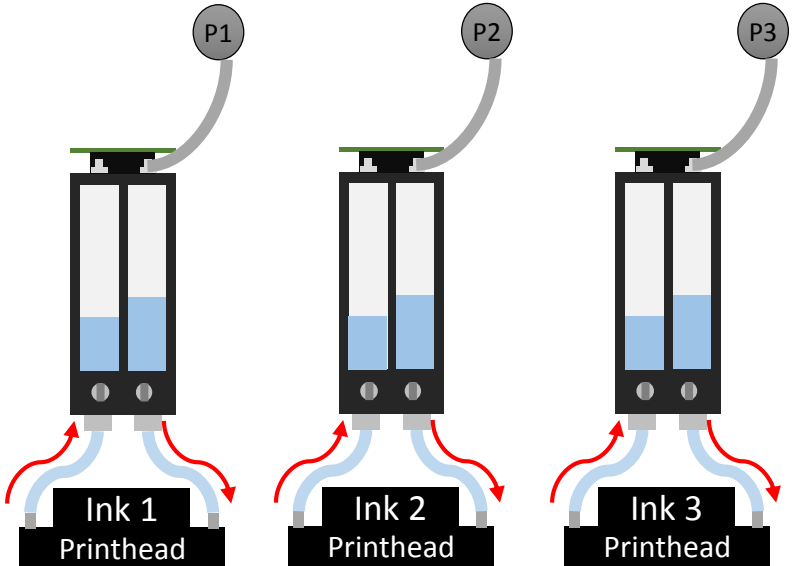
Trend to use low flow for increased reliability e.g. white, functional fluids

Ink Systems –Shared or Independent Pressure Control



Shared Pressure Control on CYMK – plus W

Independent Pressure Control and low flow for e.g. functional fluids



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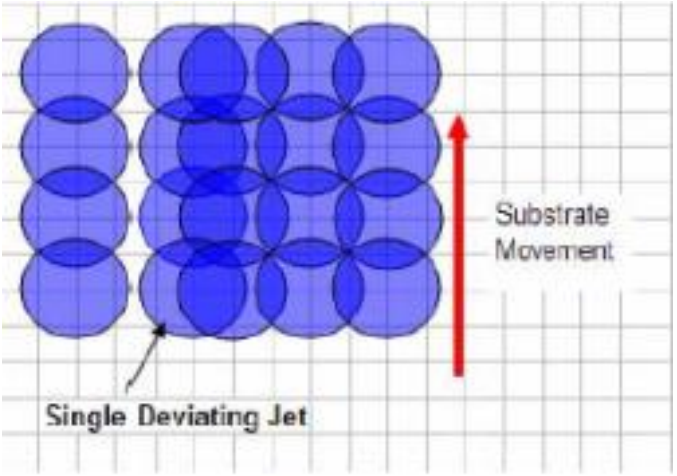
Process - Stitching and Multipass

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
    - Printhead density shifts
  - High productivity
  - Reliability critical



Nozzle Out Correction – Single Pass Systems

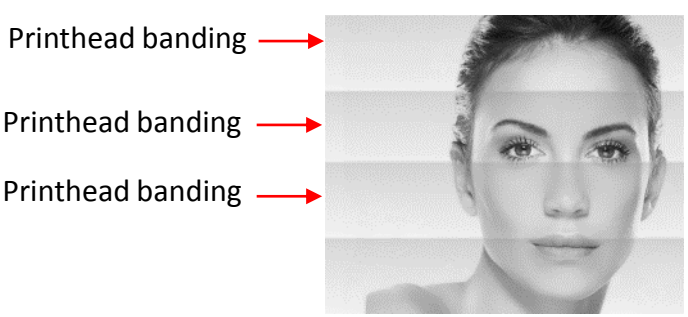
- As systems get larger (more printheads) and drop sizes get smaller the probability of blocked nozzles increases
- To maintain an acceptable level of print quality, GIS has developed integrated tools to support the correction of blocked nozzles
- Using image processing techniques, users are able to almost completely hide blocked nozzles in single pass systems in real time

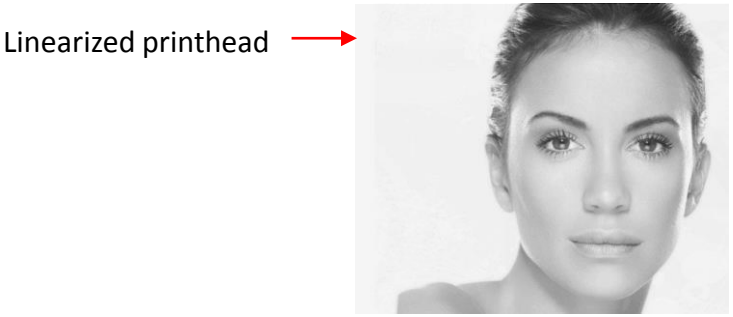
Nozzles Out →

Nozzles Out Compensated →

Printhead Density Control

- A print arrays get larger, the challenge of printing large flat colours becomes increasingly difficult
- Many printheads have a small amount of non-linearity in their drop volume across the length of head. This can make stitching printheads without visible joins very difficult
- GIS technology can compensate for printhead non-linearity in real-time making stitching easier and solid colours flatter and smoother



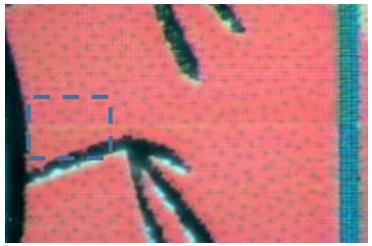


Printhead Stitching

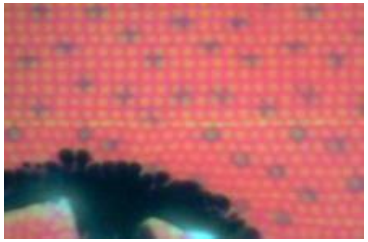
- **The human eye is very good at spotting discontinuities - particularly in areas of flat colour**
  - **Printhead alignment**: typically positioned <20% of the diameter of a drop
  - **Ink substrate interaction**: ink moves over time creating visible artefacts – ink migration control

"Flat" or "No" Stitch across flat colour

Stitch Line →



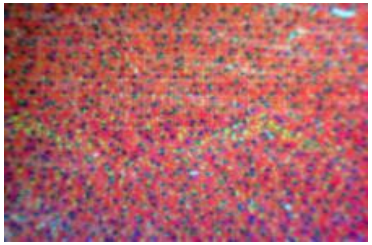
Stitch Line →



'Moving Stitch' across flat colour

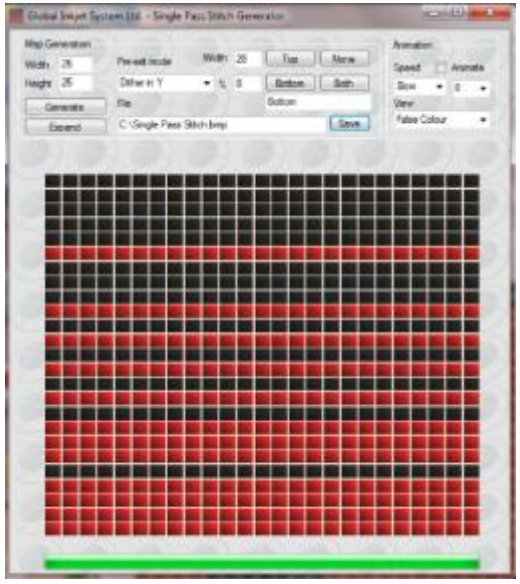
Stitch Line →

Stitch Line →

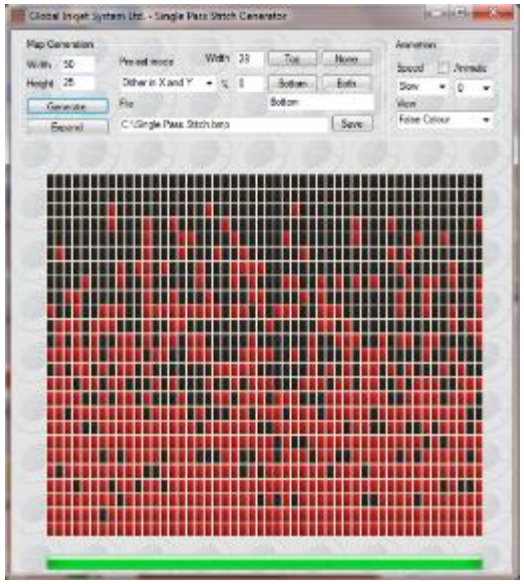


Stitching Strategies

- **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

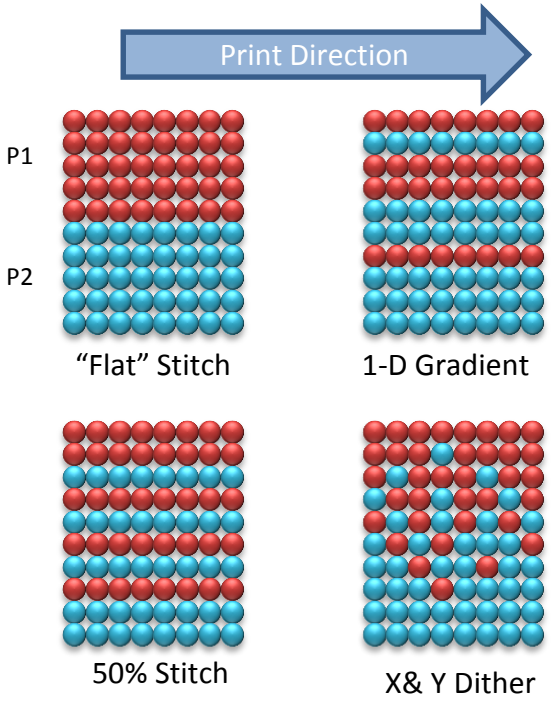


2-D Density



X & Y Dither

Digital Stitching Strategies - examples



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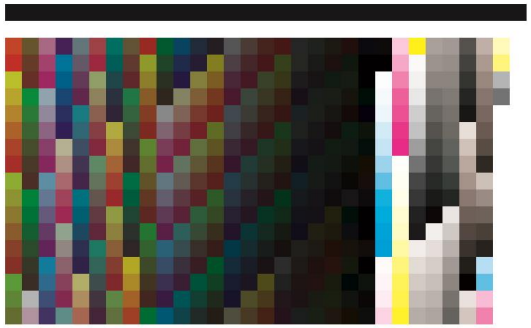
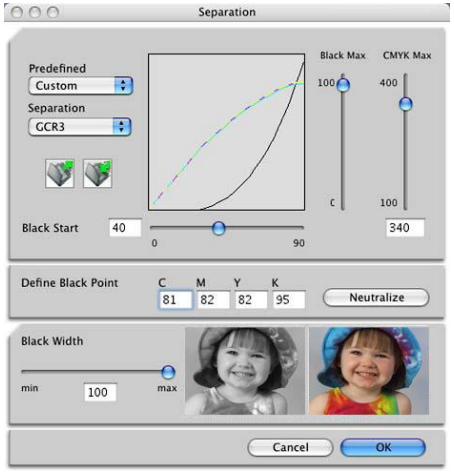
Software – Getting the best out of your RIP

Using the RIP to Improve Image Quality

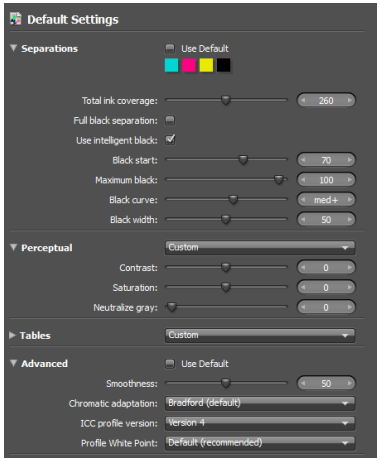
- **Two key parameters (of many):-**
  - Colour management tuned to the substrate and ink
  - Use of optimum halftone screen
- **Colour management**
  - Output colour profile using ICC specification
  - Specifies how colours should be transformed for rendering intent, when the gamut of the source exceeds that of the output device



Test Chart with 1024 Patches

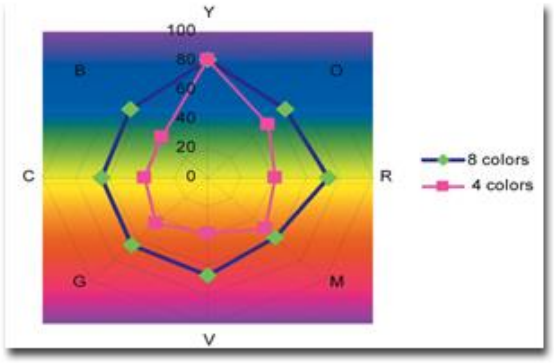


Profiles Maker 5's GUI

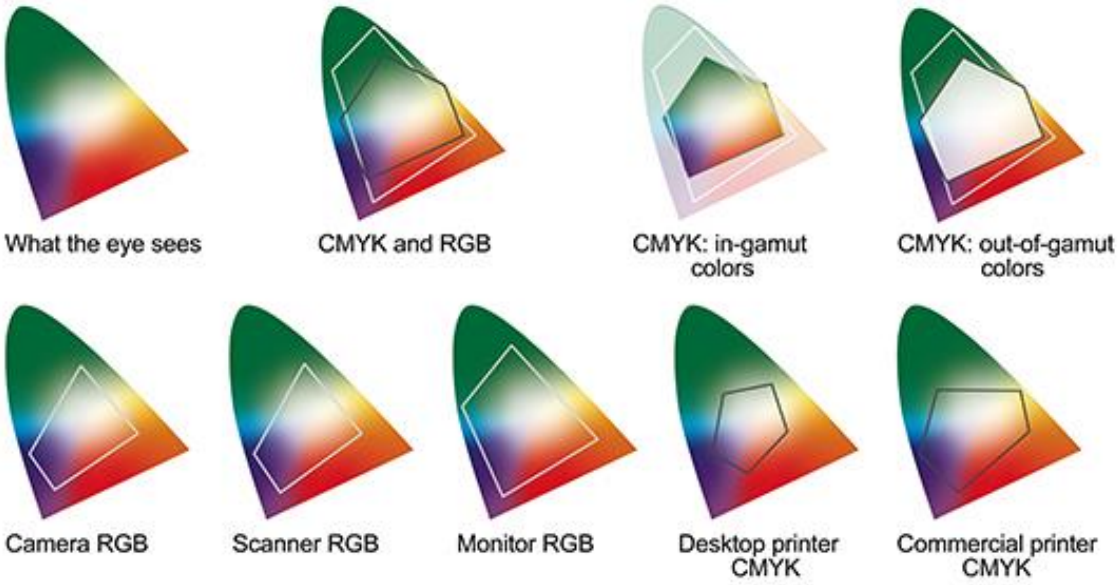


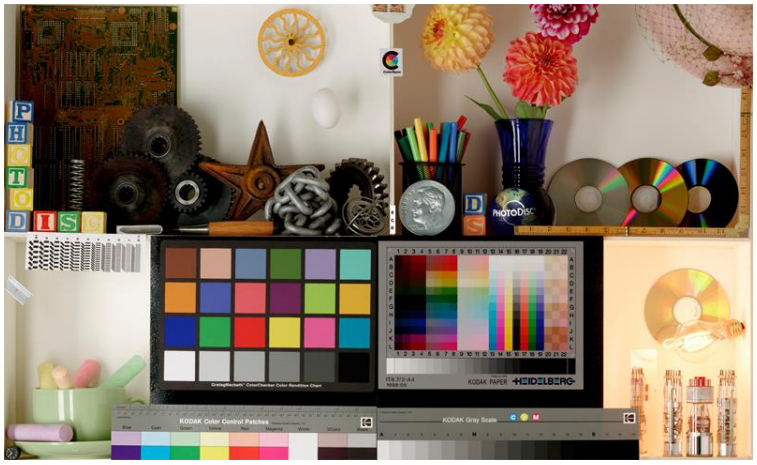
i1Profiler's GUI

Colour Gamut

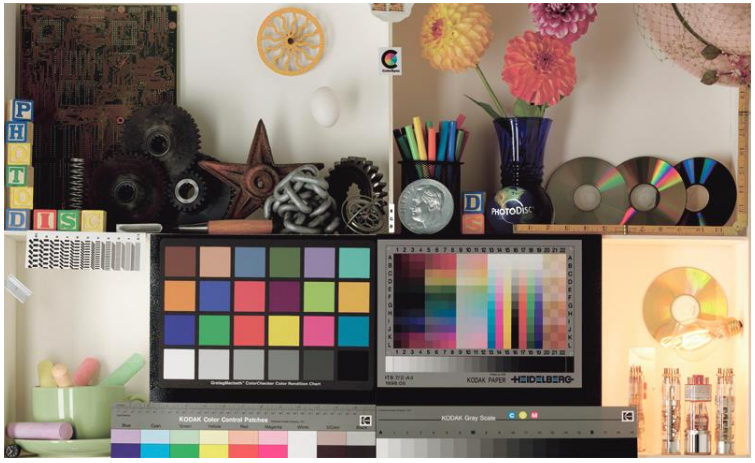


A selection of different colour gamuts





Original Image Section (sRGB IEC61966-21)



Simulated printer colour gamut

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

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)

Light Scatter

- We see colour by having light reflect off an image and back into our eyes
  - The more the light scatters, as opposed to being reflected directly back into our eyes, the less dense the colours will appear

Glossy

- 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

Matte

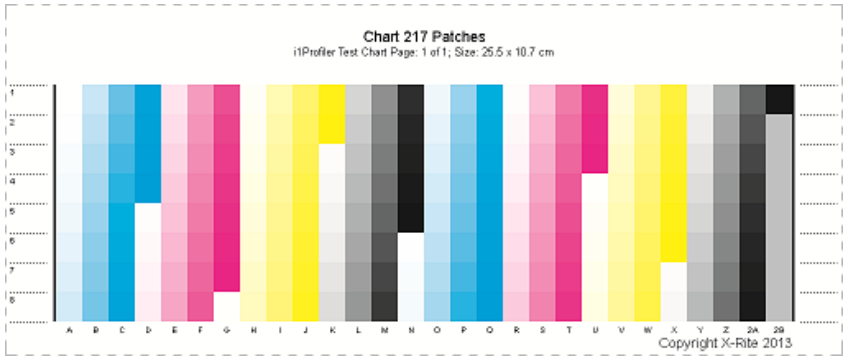
- The reason a paper is matte is because there is more texture on the surface of the paper
- The paper's comparatively irregular surface texture causes the light that hits the paper to bounce off in every direction, instead of bouncing straight back to your eye

System Linearization or Calibration

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

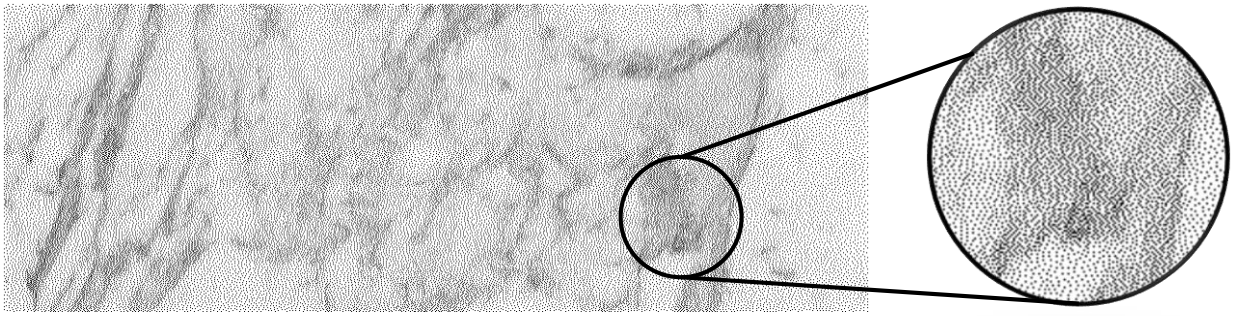
Not linearized

Linearized

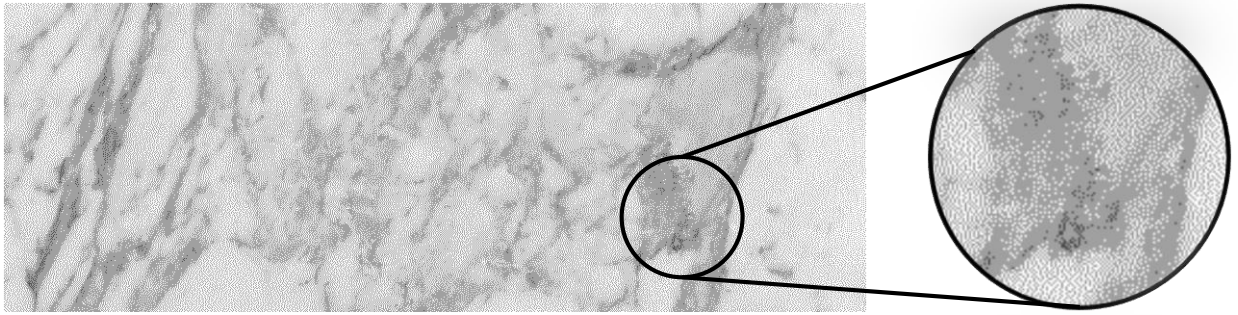


A Linearisation Test Chart

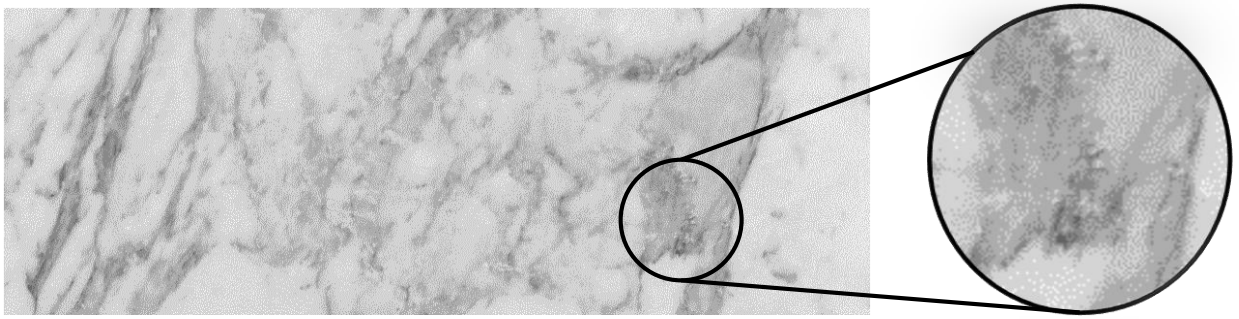
Effects of Grey Levels on Output



1 Level (Binary)

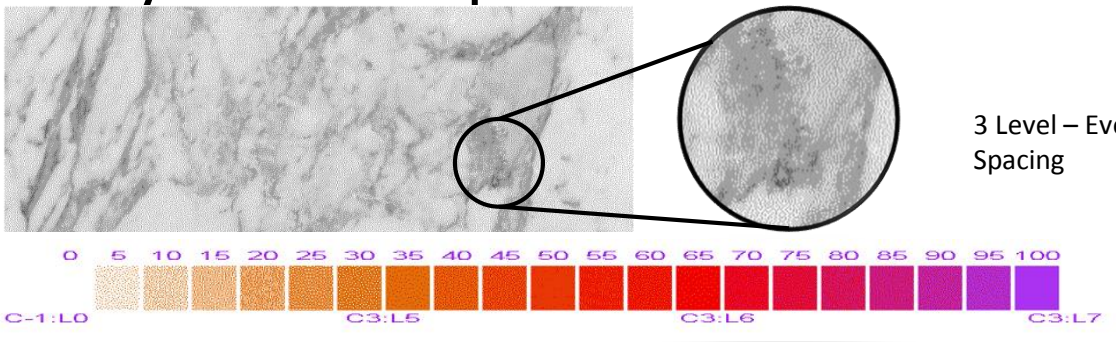


3 Level – Even Spacing

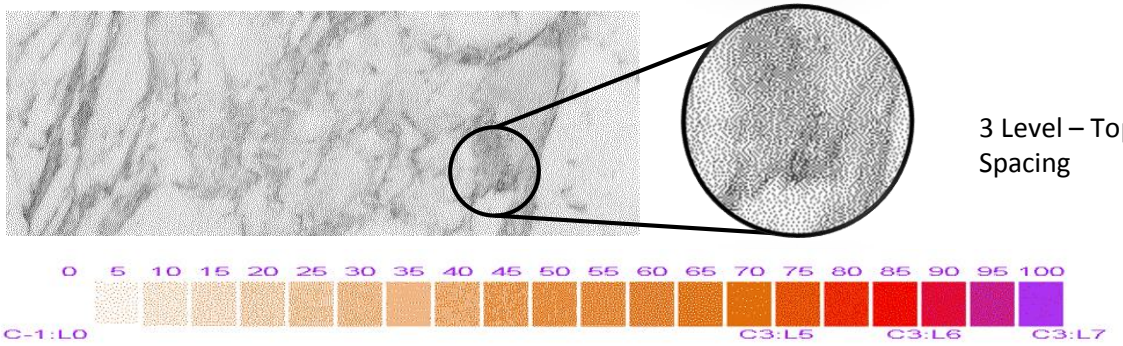


7 Level – Even Spacing

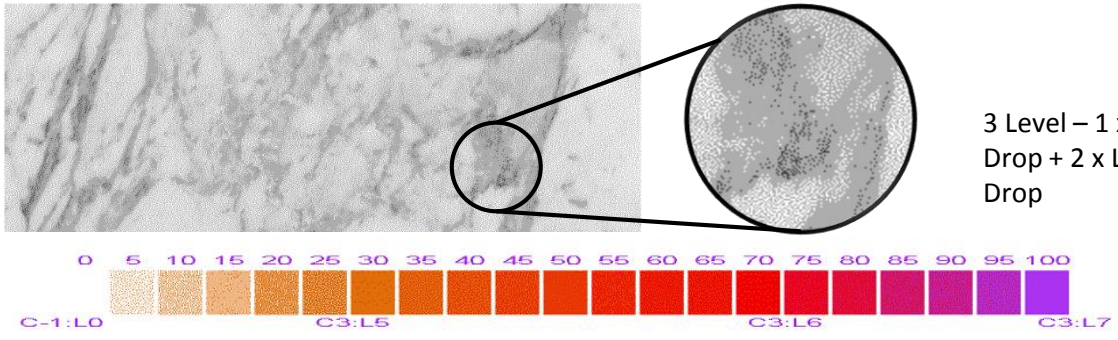
Grey Level Drop Size



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

Grey Level Drop Size and Resolution

Original Image

7 Level Greyscale Simulated Output

½ Inch at 400dpi
Effective resolution = 116dpi

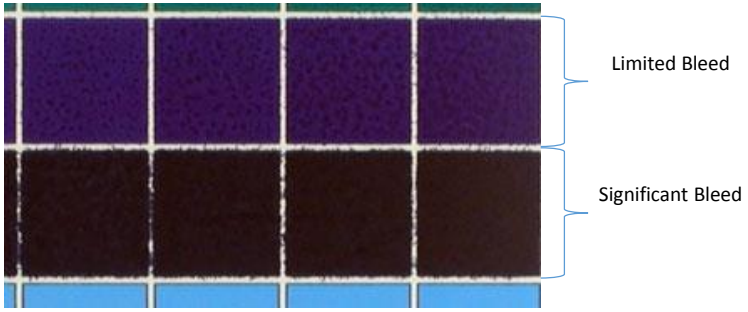
½ Inch at 400dpi
Effective resolution = 233dpi

½ Inch at 400dpi
Effective resolution = 350dpi

Close up of simulated output

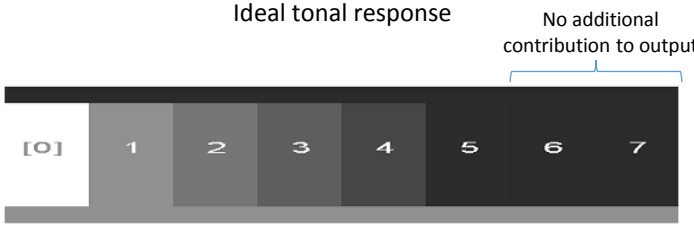
Ink Channel Limiting

- **For each ink in turn, reducing the maximum amount of ink that can be deposited**
  - It prevents bleeding and flooding of the substrate
  - Reduces total ink consumption
  - Improves print quality
  - Improve effectiveness of colour management
- **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

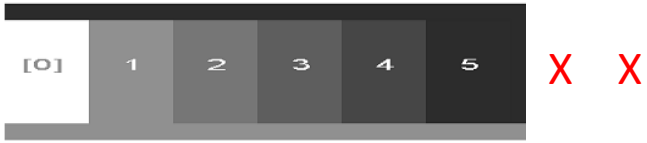


Example of ink bleed on a substrate

Ideal tonal response



Typical tonal response



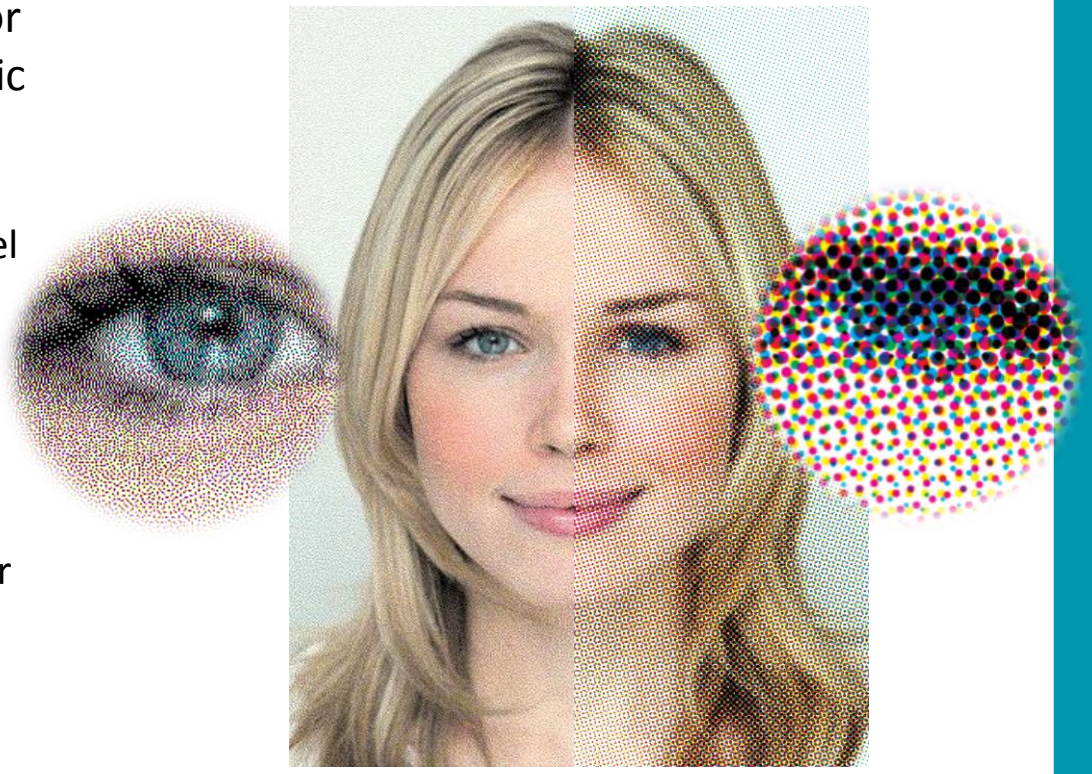
Final Grey Level Selection

Halftone Screening

- 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

- Most commonly used screens for inkjet are variations on stochastic halftones – typically called frequency modulated (FM)
  - Applies to binary and multilevel (greyscale) screens

- There are many types of FM screening
  - Error Diffusion – most popular
  - Floyd Steinberg – most popular method
  - Understanding the way screeners behave is crucial to solving some common print quality issues



FM Screening (Floyd Steinberg)

AM Halftone Screening

Summary

- **Achieving good print quality with inkjet is a complex challenge**
  - Many technical disciplines - expertise and understanding is needed across the many different parts of the inkjet system
  - Requires a step by step analysis of problems

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