Drop on Demand
Inkjet Tutorial

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Inkjet Technology
History
Inkjet Printer Product Lines

• Solutions evolved from desktop into business and industrial applications

HP Thinkjet <1 page per minute

First Inkjet Product, 1984

Industrial Print Engines
>1 page per second

• Modular, expandable systems
• Precision dispense
• Drop on demand
• Multiple fluids
• High flux capacities

Increasing Performance
Inkjet Generations
Continuous Innovation Increases Performance

1985 ThinkJet
1987 PaintJet
1987 DeskJet
1999 DJ970Cxi
1993 DJ1200C
2001 Photosmart
1995 DJ850C
1998 HP 2000C
2000 DesignJet

0.125 inch

12 orifi
1.2 KHz
96 dpi
180 pi

30 orifi
3.5 KHz
180 dpi
100 pi

60 orifi
3.6 KHz
300 dpi
85 pi

3 X 136 orifi
18 KHz
600 dpi
5 pi

104 orifi
8 KHz
300 dpi
77 pi

3 X 100 orifi
18 KHz
300 dpi
5 pi

300 orifi
12 KHz
600 dpi
35 pi

304 orifi
12 KHz
600 dpi
8 pi

612 orifi
15 KHz
600 dpi
12 pi

Performance has doubled every 18 months for the last 17 years!
Drop weights decrease

<table>
<thead>
<tr>
<th>picoliters</th>
<th>86</th>
<th>50</th>
<th>32</th>
<th>10</th>
<th>4</th>
<th>0.01</th>
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<tbody>
<tr>
<td>relative drop size</td>
<td>70µm</td>
<td>45µm</td>
<td>40µm</td>
<td>26µm</td>
<td>19µm</td>
<td>3µm</td>
</tr>
</tbody>
</table>

Relative drop sizes in picoliters (trillionths of liters)

(3 micron, 10 fl)
Photo Printing
precise color placement is the key

• Photo quality images are formed through precise placement of colored dots
  • ~5um radial placement error
Modularity Enables Rapid Development of High Performance

• Multiple die mounted on a single carrier enable high performance, scaleable systems
Drop on Demand Printheads: Thermal and Piezo Inkjet Technology
Thermal Inkjet technology

- **barrier** defines the walls of the chamber where the vapor bubble forms
- **refill channel** lets fresh ink flow into chamber
- **heater** generates the vapor bubble in the ink
- **nozzle** is positioned over resistor to form a drop of ink

Microscopic view under stroboscopic illumination
- Up to 36,000 vapor bubble cycles per second
Nucleation and Bubble Growth

Images of bubble nucleation and expansion, numbers are microseconds
Piezo Inkjet Printheads optimized for aqueous, solvent, and UV-curable inks

- proven industrial inkjet technology
- OEM printheads from different manufacturers

- How it works:
  - voltage pulse* deforms walls of ink channel
  - ink drop is squeezed out

* This is a complex waveform, animation shows the squeeze phase for simplicity
Inkjet Ink
Ink Technologies

- Aqueous Inks
- Latex Inks
- Solvent Inks
- UV-curable Inks
Aqueous Inks for absorbent and coated media

With water, many additives are needed to obtain the required vehicle properties.
Latex Printing Technologies

overview

• “Latex” is a descriptive term for aqueous-dispersed polymers
  – polymer particles are dispersed (suspended) in the ink
  – the polymer in Latex Inks is synthetic and chemically different from natural rubber latex
  – Latex Inks are non-allergenic

• Latex Inks are water-based
  – compatible with most low-cost media for low-solvent inks
  – compatible with a variety of uncoated media

• Performance is comparable to low-solvent inks*
  – indoor, in-window/outdoor display permanence
  – scratch-, smudge-, and water-resistance
  – color gamut

* Low-solvent inks include HP 780 and HP 790 Supplies for HP Designjet 8000sr, 9000s, and 10000s printers. HP image permanence and scratch, smudge, and water resistance estimates by HP Image Permanence Lab. Display permanence tested according to SAE J2527 using HP Latex and low-solvent inks on a range of media, including HP media; in a vertical display orientation in simulated nominal outdoor display conditions for select high and low climates, including exposure to direct sunlight and water; performance may vary as environmental conditions change. Scratch, smudge, and water resistance tested using HP Latex and low-solvent inks on a wide range of HP media; water resistance is comparable when printed on water-resistant substrates. Laminated display permanence using Neschen Solvoprint Performance Clear 80 laminate. Results may vary based on specific media performance. For more information, see www.hp.com/go/supplies/printpermanence.
Latex Inks (water based) 
liquid and solid components

Latex Inks deliver performance comparable to low-solvent inks using a water-based ink vehicle, co-solvent concentration similar to aqueous inks, and Latex (dispersed) polymer.

Colorant
- pigments
Latex (dispersed polymer)

Additives
- surfactants
- humectants
Co-solvents for aqueous inks

Water

(figures does not represent exact proportions)
HP Latex Inks
image formation process

- Ink drop makes a colored dot on the media surface
- Ink vehicle softens vinyl for good film adhesion
- Print Zone Heater evaporates water from the ink vehicle
  - ink forms a thin liquid film on the media surface
  - pigment particles are dispersed throughout the film
  - dot is “fixed” to prevent color bleed and dot coalescence
- Curing Zone Heater causes latex particles to form a continuous film on the media
  - co-solvents evaporate
  - latex particles coalesce
  - pigments are encapsulated
  - print is now dry and durable

(schematic drawing is not to scale)
Solvent Inks
primarily for uncoated and nonabsorbent media

The formulation of solvent inks is somewhat simpler than aqueous inks.

The solvent is specifically selected for certain requirements, and its properties require less modification by additives.

Colorant (pigments)

Dispersing Agent
- ensures stable pigment suspension

Polymer/Binder
- forms surface film

Solvent
- drop-formation
- can soften and dissolve vinyl

ink “vehicle”

(figure does not represent exact proportions)
Solvent Ink Technology

Colorant is encapsulated into the dissolved region to form a permanent bond.

- Solvents in ink vehicle dissolve or soften nonabsorbent materials (such as vinyl)
- Pigments are encapsulated in surface layer
- Solvents evaporate to leave a durable colorant film
Solvent Inks
features and benefits

• Prints on low-cost, nonabsorbent materials, such as vinyl
• Flexible colorant film for substrates that will be folded, bent, or stretched in applications
• Long-term outdoor durability (up to 2 years unlaminated)
• High durability
  – excellent scratch and smear resistance
  – excellent water-resistance
• Good color gamut
• Low cost/m² suitable for
  – building wraps
  – billboards
UV-curable Inks
free radical cure, 100% solids

- **Colorant (pigments)**
  - ensures stable pigment suspension

- **Dispersing Agent**
  - provides low viscosity liquid carrier
  - crosslinks to form solid film on media

- **Oligomers**
  - provide film durability/flexibility

- **Surfactants**
  - improve wetting of print medium

- **Oxygen Inhibitors**
  - inhibits polymerization during storage

- **Photo Initiators**
  - initiate & sustain the UV curing process

- **Monomer**
  - provides low viscosity liquid carrier
  - crosslinks to form solid film on media
  - provides substrate adhesion

*figure does not represent exact proportions*
UV-curable Inks
media interaction

Colorant is contained in a layer that durably binds to the surface of the print medium

- **ink vehicle:**
  - does not “dry” by evaporation
  - all the ink remains on the substrate

- **ink hardens “instantly”**
  - ink is polymerized by intense UV light
  - photoinitiators produce “free-radicals” that convert liquid monomers to a solid

- **colorant is a thick film**
  - ink is formulated to prevent cracking on flexible substrates
  - well-suited to flat-bed printers and rigid substrate applications

- **UV-curable inks can be formulated to print on virtually any substrate**
UV-curable Inks
features and benefits

• Excellent durability
  – up to 2-year outdoor durability
  – high substrate adhesion
  – resists abrasion
  – resists cracking on flexible substrates
  – resists smearing from common cleaners

• Prints on virtually any substrate
  – inks form a durable mechanical bond to surface
  – rapid cure (typically 0.1 sec under UV exposure)
    • minimizes ink spread and feathering
    • minimizes penetration into absorbent media
    • can produce very sharp lines and edges
      and highly-saturated colors on a variety of media

• Delivers high production rates
  – “instant drying”

• Reduced environmental, health, and safety issues compared to organic solvent-based inks
  – extremely low VOCs
  – low risk of fire or explosion
  – high ink efficiency

1 based on HP Scitex testing according to ASTM D2565-99
Ink Technologies
how to choose?

- There many aspects to consider when choosing a printing solution

- Each type of ink and printing technology (i.e., thermal inkjet and piezo inkjet) satisfies different requirements

  - Product/Solution acquisition price
  - Prints on economical uncoated media
  - Cost per Copy
  - Image Quality
  - Durability and Fastness
  - Environmental Health and Safety requirements
  - Media Versatility

- Because there is no “universal” solutions.
Inkjet Media
Inks and Media

many different ways to make a colored dot

- Absorbent, Uncoated Media
  - papers, cloth
    - aqueous and solvent inks

- Coated Media
  - swellable and porous coatings
    - aqueous and solvent inks

- Nonabsorbent, Uncoated Media
  - typically adhesive-backed vinyl
    - hard-solvent inks
    - low-solvent inks
    - UV-Curable inks
Absorbent, Uncoated Media materials such as paper and cloth

Ink vehicle and colorant penetrate a porous surface. Bonding between colorant, binder, and cellulose provides durability.

- dyes carried by ink vehicle into the core material
  - this can reduce color saturation
- pigments coat the surface with a film ~1 micron thick
  - this can improve color saturation
- ink dries by evaporation
- dyes: low fade-resistance and poor waterfastness (aqueous inks)
- pigments: generally excellent fade resistance and good waterfastness

Electron microscope images (Source: HP R&D)
Coated Media

In an encapsulating (or “swellable”) coating, ink vehicle and dyes are absorbed by the coating and dyes are encapsulated. Encapsulation protects dyes from airborne chemicals but not from light and water.

- ink-receptive coating: synthetic and natural polymers
- ink and dyes are absorbed into the coating
- coating swells then shrinks as ink vehicle evaporates
  - dries by evaporation: can be handled in ~5 minutes
  - generally poor water- and wet-smudge resistance
- offers excellent fade resistance when designed together with HP dye-based inks

Cross-section near the surface of photo paper with encapsulating coating

Coated Media encapsulating coatings
In a porous coating, ink vehicle and dyes penetrate into the open spaces (pores) between particles in the coating. Dyes are protected from water but airborne chemicals can diffuse into the pores to cause fade.

- ink-receptive coating: open-matrix of pores formed from microscopic particles bound together
- “instantly” dries by absorption
- ink capacity limited to void volume
- very high, uniform gloss with dyes
- pigments are too large to penetrate into pores
- gloss uniformity issues
- excellent water- and wet-smudge resistance
- lower permanence for dyes than with encapsulating coatings

Cross-section near the surface of photo paper with porous coating.
Nonabsorbent, Uncoated Media

solvent inks **dissolve or soften** the substrate

Colorant is encapsulated into the dissolved region to form a permanent bond.

Hard (or “aggressive”) solvent inks work this way on uncoated vinyl.

- drop of solvent ink softens and dissolves the surface
- colorants are absorbed into the dissolved region
- solvent evaporates leaving colorant integrated into the print medium
- image is highly-durable because it is incorporated in the substrate
  - resists scratches and abrasion
  - resists smearing from cleaning solvents

cross-section of uncoated vinyl (not to scale)
The ColorLok® Paper Program – An Industry Effort Benefiting the Industry and the End User

ColorLok® paper benefits

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Inkjet</th>
<th>Laser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolder text, darker black</td>
<td></td>
<td>○</td>
</tr>
<tr>
<td>More vibrant images and sharper colors</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>Fast dry time</td>
<td>○</td>
<td></td>
</tr>
<tr>
<td>High reliability</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Fewer electrical defects for better print quality</td>
<td></td>
<td>○</td>
</tr>
<tr>
<td>Better paper for better printing</td>
<td>○</td>
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Logos of participating companies:

- APRIL Fine Paper
- COPAMEX
- Domtar
- GP Georgia-Pacific
- INTERNATIONAL PAPER
- mondí
- m-real
- STORAENSO
- Suzano Pulp and Paper
- antalis
- Office DEPOT
- PAPYRUS
- STAPLES

that was easy:
Inkjet Web Press
Inkjet Web Press overview

- Prints a 30-inch web at speeds up to 400 ft (122m) per minute
- 1200 X 600 dpi, duplex 4-color printing
  - Bonding Agent for uncoated stock
- 4.25-inch SPT-based printheads
- Fault-tolerant design
- In-line process monitoring
- Raster image processing and process control at full press speed
Scalable Printing Technology
scalable in swath width

- Assembling printheads across the web
  - prints across web width without a gap
  - fully-modular printhead “pocket”
  - replace only printheads that require maintenance, not the entire printbar
    - in-line process monitoring identifies printheads to be replaced
    - printheads are user-replaceable
- Automatic printhead alignment across the web
  - using in-line process monitoring system

print swath width (inches)

7-printhead Printbar for 30-inch web
Pigment Inks
uncoated paper performance

• Water-based formulation
  – very low VOC emissions*
  – no ozone, no hazardous air pollutants**
  – non-flammable and non-combustible

• Inks work with PET (paper enhancing technology) or Bonding Agent on uncoated papers.

• Compared to Euroscale Uncoated gamut:
  – better black optical density
  – larger color gamut

• Durability
  – smudge-resistant
  – water-resistant
  – highlighter-resistant
  – suitable for direct mail and book production

* Dryer and print zone exhaust systems, along with non-hazardous, very low VOC inks provide a safe printshop work environment. Typically, no air discharge permitting is required for the HP Inkjet Web Press. Customers should consult state and local requirements and regulations.

** No ozone products expected based on ink composition and printing technology; HAPs per US Environmental Protection Agency Method 311.
Inkjet Web Press media solutions

- Coated media
  - HP has developed coated media works at 400fpm and delivers highest print quality available today on digital ink jet presses.

- Uncoated media options
  - Web press can supply bonding agent to increase media flexibility.
  - “For best performance”, use Paper Enhancement Technology (PET), which is optimized to provide offset comparable quality on uncoated papers.
    - Overall IQ similar to offset
    - Color gamut larger than SWOP
    - Black Optical Density similar to offset
    - Delivers 90gsm quality on 75gsm paper
    - Available though HP licensing program (announcing details at Print ‘09)
Take-away Messages

• Scalable Printing Technology extends core inkjet technologies into industrial printing solutions
  – industrial solutions benefit from HP’s manufacturing expertise and economies of scale
• With SPT, Inkjet Web Press offers performance scalable in features, speed, and web width
• Pigment inks and bonding agent give good print quality on a variety of uncoated stock
• Pigment inks and PET are optimized to provide offset comparable quality on uncoated papers.
• In-line performance monitoring and control assure consistent performance and fault-tolerant web printing.
Thank you!