Hi-Volume Digital Photo Finishing System Using Elcography® Technology

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Abstract

A novel digital printing technology, called Elcography® based on the electrocoagulation phenomenon, has been recently developed for commercial printing markets.

The process consists of sending electric current into an electrolytic water-based polymeric pigmented ink. When subjected to such electric pulsations by a cathodic array, the polymer binder coagulates onto the anodic positive electrode forming three-dimensional dots, which are then revealed by a squeegee before being transferred on a non-photosensitive paper. Each printed dot can assume 256 different thickness layers as well as varying spot size, thus reproducing a wide tone gamut with four sequential color printing stations.

Due to its continuous-tone image quality and low cost of processing, Elcography® is also likely to play an important role in the future development of centralized digital photo finishing centers.

This high-speed technology can print 210,000 continuous-tone pictures per hour directly from computer networks. Mega pixel digital pictures are printed with a resolution of 400 dpi with 256 gray levels per dot. Combined with increasing pixel density and the wide dynamic range of digital CCD cameras, Elcography® photo printers will push digital photo quality to levels equivalent to the modular transfer function exhibited by conventional photo-sensitive reproduction methods.

Furthermore, this system completely eliminates photochemical processing and silver recycling concerns for photo finishing firms with digital expansion plans.

Introduction

A new digital printing technology called Elcography®is now finding applications in the printing industry. Recent developments in digital photography makes also Elcography®a strong contender for hi-volume digital photo finishing. The advent of higher resolution digital cameras with lower price points at every product generation looks very promising for the long-term future of picture taking. Digital photography will bring a new psychology of picture taking. Even though, a digital camera is still pricier than conventional analog cameras, the marginal cost of taking digital pictures is very low. Future digital camera exposure statistics will most likely show higher averages than film based cameras.

Hard copy prints still seem to be the preferred way of viewing and sharing images. Even if Internet web sites with stored pictures of photographers are an additional way of sharing memories, end-users often desire a portable print version.

Thermal printing and ink-jet systems are most adequate for the print-at-home paradigm, but they have not yet shown the productivity levels required of a mass market digital photo finishing operation.

Although a case can be made for customer involvement in the printing of his digital pictures, there are market segments that will most likely adopt the more conventional centralized photo finishing buying patterns. The time usually needed to print high-resolution images on desktop printers could also be a deterrent for hurried picture takers.

Silver-halide hybrid digital systems have very high quality imaging but relatively high cost per print. This high variable cost structure doesn't meet the film less world of infinite picture taking. It will merely displace film-based photo finishing with no significant growth in total exposures.

In view of these drawbacks, Elcorsy Technology has developed a powerful digital printing technology called *Elcography®* with the following fundamental features:

- Continuous-tone
- Hi-volume
- Low-cost per print

Technology

Elcography® is based on an electrolytic system that turns a liquid ink into a gelled dot with electric fields generated by 20 µ metallic wires opposite of a rotating imaging cylinder. The Elcography® ink is made of special smart polymers and standard process colour pigments mixed in water with electrolytic salts.

With each electric pulse, a latent dot is formed and is strongly grafted onto the imaging cylinder. A doctor blade then reveals the image. A pressure roller applied on the back of the web transfers the revealed image on paper. A cleaning station using water and soap is then renewing the imaging cylinder surface for the next printing cycle.

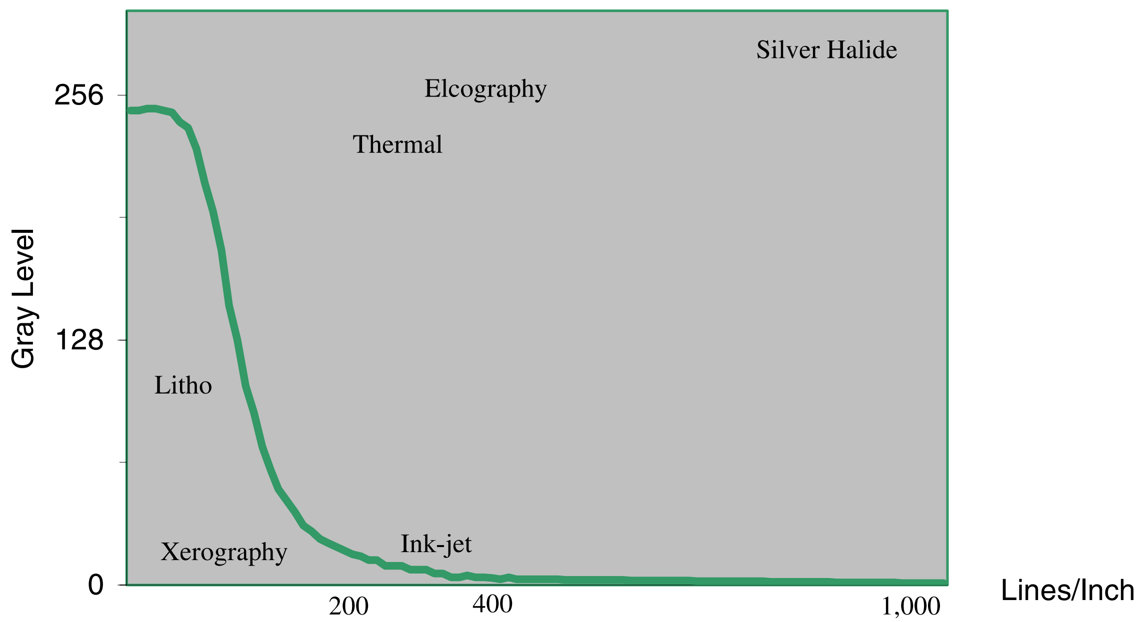
The ink is a mixture of pigments, polyacrilamide (PAAM), water and electrolytic salts. Pigments are grafted onto the PAAM macromolecules, which are in colloidal suspension before the electrocoagulation effect is triggered.[1] When the electric pulse is generated through the ink, the electrolysis generates chlorine ions at the anode surface. The chlorine breaks the passivation layer of the anodic imaging cylinder. The imaging cylinder is then entering in the transpassive region where ferric ions are cross-linking the polymeric strands.[2] The pigmented polymer is thus coagulated forming a latent dot, which can be separated later from the surrounding non-coagulated ink with an elastomeric squeegee.

Continuous-Tone

Furthermore, by controlling the activation time with electronic circuits the four print heads control the amount of ink that is deposited on each imaging cylinder. Elcography® is thus a high image quality continuous-tone process similar to gravure or photography. With a 400 x 400 dpi spatial resolution, Elcography® images are very close to photographic quality. Modulating the dot thickness and diameter reproduces each continuous-tone electronic pixel. This eliminates the need of special screening algorithms used by binary non-impact printing technologies. Emerging standard imaging formats of digital cameras with 2048 x 1536 pixels generate excellent print quality in continuous-tone in the traditional $3^{1/2}$"x 5" photo finishing format.

The advantage of continuous-tone is well documented in the engineering literature. Panel studies with focus groups have shown that the most efficient system design strategy to generate high quality photographic images is not to increase spatial resolution but rather to have the ability to control the number of gray levels for each pixel.[3] This conclusion is also confirmed by theoretical models of the human visual response system such as the Roetling curve shown below.[4]

Human Visual Response



The curve calculates the number of gray levels, which the human eye can detect as a function of spatial frequency. When we plot the different printing techniques with their line resolution and gray scale we can see that the Elcography® process is the closest one to Silver Halide photographic printing. Both processes clear the human visual limit by combining sharpness and wide dynamic range without using dithering technology.[5] It is particularly important distinction in photographic markets where prints are looked at close viewing distance and where binary dithering methods are reducing the apparent image sharpness.

Productivity

The Elcography® imaging speed is extremely fast; each cathode applies a 50 V electric pulse in a maximum period of 4 µs. Printing a single line of 7168 pixels is done in 32 µs.

The web is 18", a perfect width for printing two twin pictures across the web or three single prints.

This translates in maximum speed of 210,000 pictures (4"x 6") per hour with three prints in landscape mode. When printing four pictures in portrait mode the speed would be slightly reduced to 190,000 pictures per hour. Such productivity levels make the ELCO 400 the fastest digital color printing technology with photographic quality.

The ELCO 400 electronic memory is based on a Dram read/write architecture. When one part of the large-scale memory is printing, the other part is being filled with the next images to be printed. Each color station has 2 Gigabytes memory card which are acting as intermediary buffers between the long-term memory composed of high capacity Raid system and the print head driver circuits.

The input side of such a system is a very critical component of the digital photo finishing workflow. To feed a digital printer of such speed would require input bandwidth close to 800 Megabytes per second if all pictures are different. Putting two twin across the web reduces throughput speed to 190,000 prints per hour but also reduces the required input bandwidth to 400 Megabytes/second. This is still higher than the maximum input bandwidth of 50 Megabytes/second allowed by the current electronic front-end architecture. The input bottleneck makes it necessary to print a minimum of sixteen twin prints in order to keep the press running non-stop. Loss less compression techniques can reduce further the transfer time from the long-term memory to the live memory. Still, with typical compression ratios of 2:1, each pair of print should be printed four times to keep the press busy with new images coming in.

Fortunately, the ELCO 400 architecture is scalable downward to 1 meter/second, which would make a more balanced input/output workflow and require a repeat cycle of only two twin prints or four prints per image.

While this might be a viable solution for digital photo finishing it limits the usefulness of the system for film based photo finishing. The necessary steps of scanning a negative film, memorizing it and retrieving it would make the whole process highly unbalanced.

To solve this basic problem Elcorsy has also developed new engineering designs for real-time film scanners coupled with pipelined image processing circuits.

Three TDI CCD cells with 2048 pixels were used to integrate negative film color information. The digitized signals are then sent to FIFO buffers where image processing functions such as sharpening, color correction, RGB to CMYK conversion and color masking are applied to each pixel. The images are not kept in hard disk memories but transferred directly in real-time to the electronic print heads.

Using two of these scanners in parallel will feed the electronic printer at speeds of up to 1 meter/second or 80,000 exposures per hour or more than 3,000 films per hour.

Cost

The final feature of the Elcography® system is its ability to print on non-sensitized papers. It greatly reduces the cost barrier to a more widespread use of digital picture printing. Preliminary estimates of the total cost of a 4X6 print indicate a total cost of 2 cents. This estimate includes depreciation, labor, supplies and paper.

Conclusion

As we have seen above, Elcography® has all the cost, productivity and quality attributes to meet the expected demand growth for hard copy digital photography. But an even more important aspect of Elcography® and film less photography, is the elimination of photochemical solutions disposal in the environment. This will ensure that picture taking will truly be priceless.

References

1. A. Castegnier & al: USPTO # 5,928,417, Electrocoagulation printing ink, (1999)
2. A. Castegnier: Proceedings of the NIP12 International Conference on Digital Printing Technologies, 276-280, (1996).
3. J. E. Farell: Proceedings of the IS&T NIP 14 International conference on Digital Printing Technologies, How to allocate Bits to optimize Photographic image Quality, 572-576, (1998).
4. J. Schneider: Print quality issues for digital electronic printing, IMI 7th Digital electronic printing presses conference, 1999.
5. H.Kotera: Proceedings of the IS&T 11th International congress on Advances in Non-Impact Printing Technologies, 12-15, (1995).

Biography

Pierre Castegnier, VP Marketing of Elcorsy Technology Inc, the developer of Elcography® digital printing systems, has been involved in system specification analysis, project management and market research for the project since 1984. He worked previously as a camera sales representative at Direct Film, a major Canadian photographic and photo finishing business. His interest in photography pre-dates his BA in Economics at McGill University, Montreal and his M.A. in Economics at Laval University, Quebec City.