Chapter 14. Laser Printers

14.1 INTRODUCTION

Non-impact printing is making a big impact in the electronic printing and computing industries. In the North American market, the ratio of non-impact to impact printers shipped is now about 1:1. World-wide the trend is the same as rapid advances are made in thermal, electrophotographic (laser), ink-jet, and ionographic printing. *Electrophotographic,* or more popularly, laser printing technology will be dealt with in this section.

Laser printers currently represent the main bulk of non-impact printers in use today. Laser printers have excellent print quality, low noise levels, high speed and the ability to print both graphics and text. With the continued reduction in prices, laser printers have become a rapidly growing market and consequently an area of intense technological focus. Laser printers range from large machines used in a centralised data processing facility capable of printing 100 pages/minute and to unit with 4-6 pages/minute intended for the small single-user PC.

Electrophotography was invented by Chester Carlson in 1938 and developed by Xerox Corp. Initially the technology was used for plain-paper photocopiers. About 1976, Laser printer development begun, and electrophotography was initially used in high performance machines. Intense development efforts and hence market growth because of excellent print quality has brought about the gaining popularity for this printer. Its popularity and market volume has thus brought about declining in prices

Laser printers have become commonplace in recent office automation. Laser printers, given its wide range of product, support printing speeds up to tens of thousands of lines per minute.

Figure 1: Laser printer printing mechanism shows an internal construction of a typical laser printer. The semiconductor laser directs a beam of infrared light onto the hexagonal scanner. This mirror reflects the beam onto a light sensitive drum, forming a raster scan as the drum rotates. The charging corona produces a positively charged dot on the drum, which is neutralised wherever the laser beam strikes the drum surface. The pattern of dots produced by the laser beam forms the complete image on the page. Toner adheres to the charged portions of the page as it passes by the toner cartridge, and is fused onto the paper under heat.

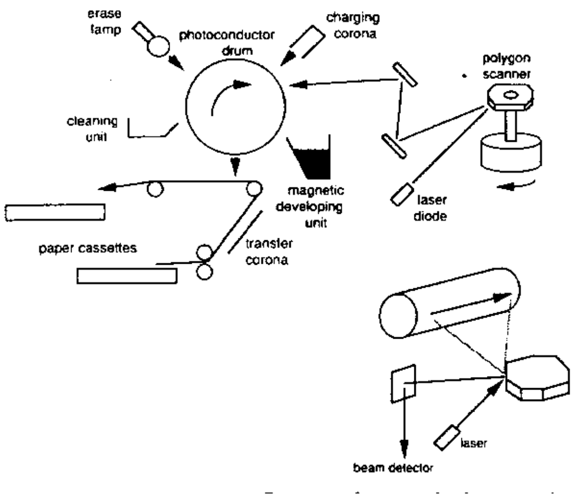

Figure 1: Laser printer printing mechanism

Traditionally, High initial cost and reliability problem shunt low end user away from EP technology. Canon got around the problems associated with multi-step printing process by packaging all of the troublesome parts into a cartridge which the customer could discard after 3,000 copies. This concept is know as the virtual reliability (if it breaks down, throw it away).

A typical laser printer is the Apple Laserwriter, which uses a Canon laser engine, and is controlled by a MC68000-based microcomputer with 1.5MBytes of RAM and 500kBytes of ROM. It is shown in diagrammatic form in Figure 2: Schematic diagram of Apple laserwriter. Interfacing to the Laserwriter is via either 25-pin RS232c or 9pin RS422 D-type connectors, at baud rates of either 1200 or 9600.

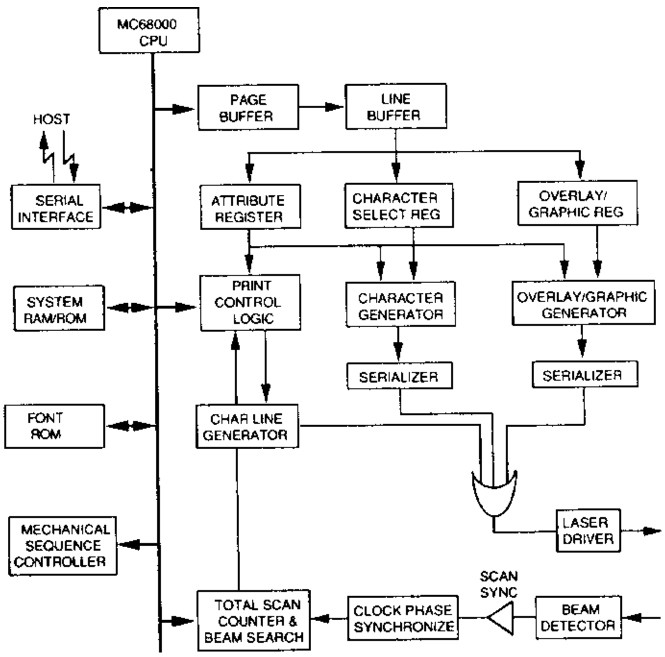

Figure 2: Schematic diagram of Apple laserwriter

In 1986, Laser printers are categorized into four groups:

GROUP	SPEED	BASE PRICE	APPLICATION
Centralised Xerox 9700	> 100 ppm	S$ 500,000	Data Processing with Mainframes
Satelitte Xerox 5700	30 ppm	S$ 100,000	Mainframes and Minis
Office cluster Canon LBX-10	15 ppm	S$ 10,000	Departmental Servers
Workstation Canon LBP-CX	4 - 8 ppm	S$ 2,000	Individual work-stations and PCs

Shipments in the US	1984	1986	1989
Units	50,000	350,000	650,000

Given the fast pace of development, the updated grouping in 1995 is:

GROUP	SPEED	Resolution	APPLICATION
Centralised Xerox 4135	135 ppm	300 dpi	Data Processing with Mainframes
Satelitte Xerox 4050	50 ppm	300 dpi	Mainframes and Minis
Large Network HP LaserJet 5 Si MX	24 ppm	600 dpi	Large Network
Office cluster HP LaserJet 4V	16 ppm	600 dpi	Departmental Servers $3,190
Workstation HP LaserJet 5P	4 ppm	600 dpi	Individual work-stations and PCs; $1,390

14.2 ELECTROPHOTOGRAPHIC PROCESS

14.2.1 SUMMARY OF EP PROCESS

The general process of making a print utilising EP involves six steps:

1. Charge- a photoconductive (PC) surface is exposed to a corona discharge to impart a uniform electrostatic charge on its surface.
2. Expose- the charged photoconductor (PC) is exposed to a light pattern of the appropriate wavelength to discharge it selectively. If discharge occurs in those areas that will eventually be white in the final print, the process is called charged area (CAD) or direct development. If the discharge occurs in areas to be printed black, it is called discharge area (DAD) or reversal development.
3. Develop- black toner particles are transported by electrostatic or magnetic forces into the vicinity of the PC. The toner particles are electrostatically attracted to the appropriate areas on the PC and the latent image is developed.

4. Transfer-the developed image is transferred from the PC to a sheet of paper by contacting the PC with the paper.
5. Fuse- the transferred image is permanently fixed to the paper by pressure, heat or solvent vapours.
6. Clean- the PC drum is cleaned of all excess toner by a scraper blade, brush or other means and the EP system is ready to begin another cycle.

14.2.2 CHARGE--CORONAS

The initiation of the EP process requires the deposition of a uniform charge layer onto the PC. Corona charging is the only method used in modern electrophotography.

The simplest corona device that could be used to charge a PC is a thin (~0.1 mm) wire charged to 5-7 kV. Because of the extremely high electric field in the vicinity of the thin corona wire, electrons present naturally in the surrounding gas are accelerated to energies high enough to ionise molecules and atoms in the gas. Depending on the direction of the field, either positive or negative ions are swept out of the ionising region onto the insulating surface of the PC. One important factor that determines the charge on the PC is the sign of the mobile charge in the PC. Many inorganic PC's, Se for example, can most effectively transport negative charges when illuminated, requiring the use of a positive surface charge. Most organic PC's, however, are positive charge conductors and thus require a negative surface charge.

The requirement of coronas is in the charging step is very demanding. In this step, the corona must lay down a uniform, well-controlled layer of charge on the PC. Nonuniformities in charge may result in nonuniformities in the printed copy. A simple way of controlling the uniformity of both positive and negative coronas (and also preventing arcing from wire to PC) is to place a grounded metal plate in the vicinity of the wire. This corona configuration is called a corotron, which is shown in Figure 3 Corona configuration-Corotron.

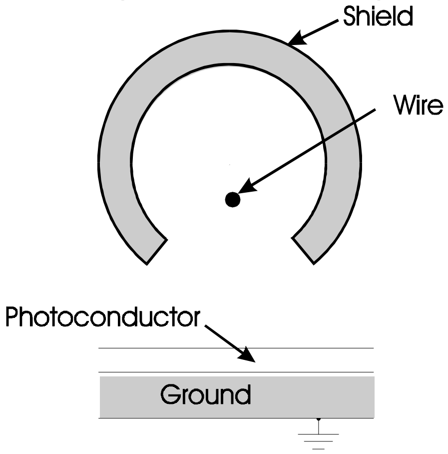

Figure 3 Corona configuration-Corotron

The problems associated with the coronas are: Coronas are easily contaminated with toner or paper dust, and is difficult to clean. Thus it represents a major reliability problem; They are sources of corrosive ions, and reactive neutral species that can damage the PC as well as the corona itself; They create ozone (negative coronas produce an order of magnitude more ozone than positive coronas).

14.2.3 PHOTOCONDUCTOR

PC is the heart of the EP process. This is the photoconductive element that bears the latent image produced by light. The latent image is then developed by toner.

The PC is expected to satisfy a variety of concurrent requirements: The PC must be capable of charging to a uniform, high voltage level; On exposure to light, it must discharge to a voltage level low enough to provide the necessary contrast in the developed image. The light induced discharge must be rapid in relation to the process time of a print but there must be no significant discharge in the dark; Residual potential should not build up even after repeated cycling; The PC must be sensitive to the wavelength of the light source (visible / IR light) used to expose it; Toner particles must be attracted to the charged area and remain in place until transferred to the paper; The surface must release the toner to the paper at the appropriate time; The surface should not easily wear with prolonged use; Its properties should be constant over a range of humidities and temperature; It must be nonhazardous and inexpensive to manufacture. Figure 4 PC voltage behaviour as a function of the process steps in the EP shows the charging and discharging behaviour of a typical PC.

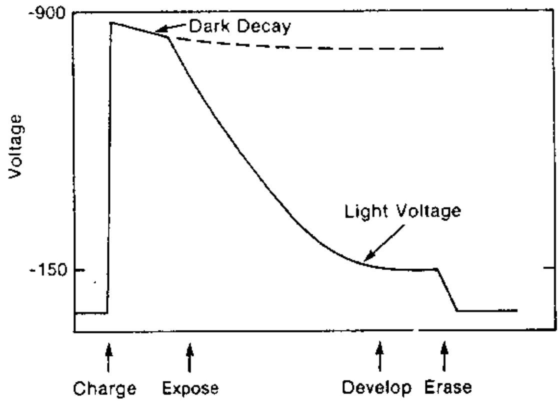

Figure 4 PC voltage behaviour as a function of the process steps in the EP

14.2.4 IMAGING

Figure 5 The operation and requirements of a photoconductor illustrates how most the latent image is formed. Initially charged by a corona, the PC develops a high voltage. When exposed to light, light absorbed within the PC causes the generation of electron/hole pairs. In the negatively charge PC, electrons move to the ground plane and positive holes to the PC surface. At the surface the positive charges neutralise negative surface charges to form the latent image. It is easy to see how the choice of a PC can determine the sign of the surface charge and thus the type of corona. In many PC's either holes or electrons but not both have a mobility high enough to be useful in the EP process.

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Figure 5 The operation and requirements of a photoconductor

14.2.5 MATERIALS

The earlier type of PC's involves the use of amorphous chalcogenide (S, Se, Te) alloys. Most commonly used are a-Se, a-As2Se3 and Te doped Se. These materials have low dark decay and high charge acceptance and can be manufactured inexpensively. The spectral sensitivity of these materials is high in the visible range but low in the IR region.

Organic materials are relatively inexpensive to make and because of the wide variety of organic molecules available, the spectral response can be tuned almost at will. Despite their softness and consequent shorter lifetime they are widely used. The first organic was a mixture of trinitrofluorenone (TNF) in polyvinylcarbazole (PVK).

To improve the efficiency of the PC and permit tailoring of wavelength response, layered organic photoconductors are used. In these layered systems, the steps of charge generation and charge transport are separated and optimised. The charge generation layer is a thin (~ 0.5 μm) layer chosen to have high charge generation efficiency and to have a spectral response matched to the wavelength of the light source. The charge transport layer is a thicker (20-30 μm) layer. Since most charge transport layers can only transport holes, a negative surface charge is commonly produced by the corona.

14.2.6 PRINTHEADS

Figure 1: Laser printer printing mechanism shows the internal construction of a typical low cost printer using a semiconductor laser. First, the drum passes under the charging corona where a uniform electrostatic charge is placed on the surface of the photoconductor drum.

The PC must be discharged by light in a pattern of dots of 240, 300 or 600 dots per inch (dpi). Light from gas lasers, diode lasers, lamps, light emitting diodes (LED) and cathode ray tubes (CRT) can be used to discharge the PC. All of these exposure methods require that the wavelength of the light source overlap with the wavelength sensitivity of the PC and that the light source itself can be switched on and off rapidly to scanned across a page and has sufficient power to write at the desired speed.

Most of the EP printers available today utilise a laser printhead. The laser is either a gas laser or a diode laser.

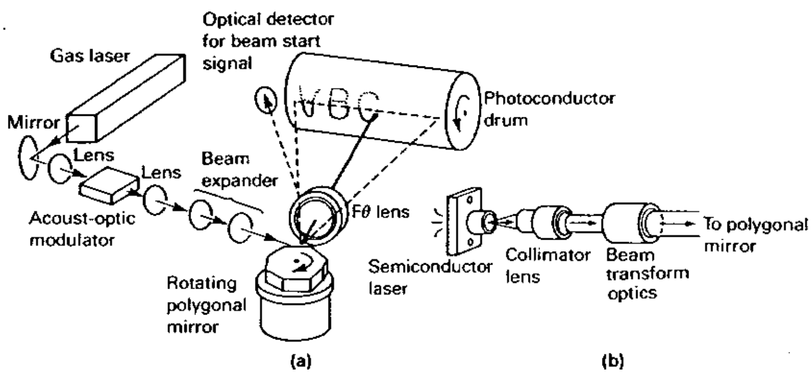

Figure 6 Laser print head

In a laser system, the beam must be scanned across the PC. The most widely used system is the rotating polygon mirror. In such a system, a laser beam strikes a facet of a multifaceted polygon mirror (8-36 facets) rotating at a speed of 2000-50,000 rpm. The beam is reflected off a facet and swept across the PC surface. As the drum rotates, a raster-scan pattern is produced on the surface of the drum in which at every point where the laser beam strikes the drum, the electrostatic charge is neutralised. The pattern of neutralised dots forms the complete image on the page. The charged image is later developed by passing the drum near the toner cartridge. Another scanning technology is the holographic scanner. The hologram can be designed to focus the beam onto the PC so that an additional lens would not be necessary.

Since gas lasers cannot be turned off and on quickly, an acoustic-optic modulator is used. This modulator consists of a piezoelectric transducer and modulation of the laser beam is accomplished by turning the acoustic wave off and on. In diode laser, which can be directly modulated by controlling the input current and therefore no separate modulation is necessary. In LED's, CRT's, or fluorescent lamps with a multi-element shutter, each addressable line across the PC surface corresponded to a light source array. Hence no scanner is required. These methods require a printhead with many elements (> 2000 for a 300 dpi resolution), that could be rapidly modulated and focused on the PC.

LED technology offers potential advantages over laser printheads. However, several problems are related to this technology: A major set of packaging and electronic problems arise related to integrating the over 2000 diodes into a single printhead (staggered or single row); The availability of inexpensive gradient index lens arrays for focusing the LED emission onto the PC.

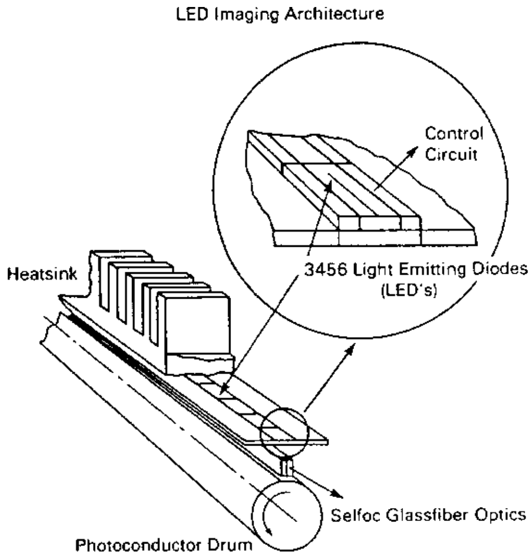

Figure 7 An LED printhead assembly

Another type of light source used in EP printers is the cathode ray tube which has full electronic control of scanning and modulation and maturity and consequently the reliability of CRT technology.

A final type of printhead utilizes a light shutter array. The most promising of the light shutter array technologies is the liquid crystal shutter.

14.2.7 DEVELOPMENT SYSTEMS

The development system provides a reproducible method for charging the toner particles, transporting them into the development region where they are transferred to the latent image on the PC. The most widely used development system today is the dual component magnetic brush system.

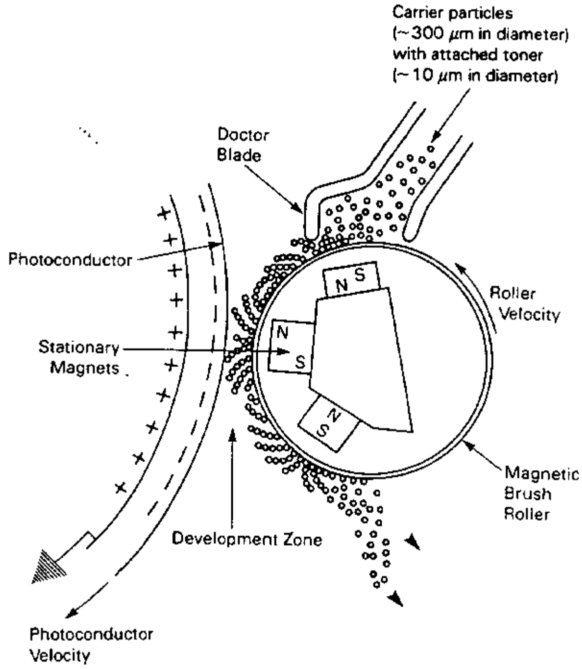

Figure 8 A dual component magnetic brush developer

In this system small (~ 10 μm) toner particles are charged by contacts with the surface of much larger (> 100 μm) carrier particles. The toner is a polymer binder with a carbon black pigment and other additives to influence the sign and magnitude of the charging. The carrier can be either a spherical or irregular shaped metallic core and may be bare or polymer coated. A rotating aluminium sleeve with internal stationary permanent magnets carries chains of carrier beads loaded with charged toner into the development region. The toner deposits onto oppositely charged regions on the PC, and the larger carrier beads and unused toner are recycled and used again. Sensors continuously monitor the toner concentration in the mix and replenish toner as it is used.

14.2.8 FUSING

Toner particles, which are only weakly attached to the paper surface must become permanently fixed. Fusing involves three physical processes: coalescence or sintering together of toner particles into a single mass; spreading of the coalesced melt across the paper surface and penetration of the melt into the paper fibres interstices by capillary action. These steps are accomplished by elevating the temperature and/or pressure applied to the toner. Most EP printers today use hot roll contact fusing.

14.2.9 CLEANING

To prepare the EP system for another cycle, all residual toner must be removed from the PC before the charging process takes place again. This can be accomplished by three methods: a blade, a soft fibre brush, or a magnetic brush. The most straightforward method is to scrape the residual toner off the photoreceptor. A simple metal or polymeric blade will do an effective job for low end electrophotographic applications. Brushes made of fur and fibre have been used in high end products.

14.3 COLOUR LASER PRINTER

The print engine accomplishes this feat using dry toner and a special OPC (organic photoconductor) belt. The belt revolves at a continuous rate of eight times per minute. When a colour image is printed, four belt rotations - one for each toner colour - and numerous swipes of the laser beam assemble a complete colour image on the belt. A charged transfer drum and transfer roller extract this image off the belt and onto the medium, which can be plain paper, labels, or transparencies. Because the belt travels at a fixed speed, the ColorScript Laser 1000 is capable of printing 2 colour pages per minute or 8 black & white pages per minute.

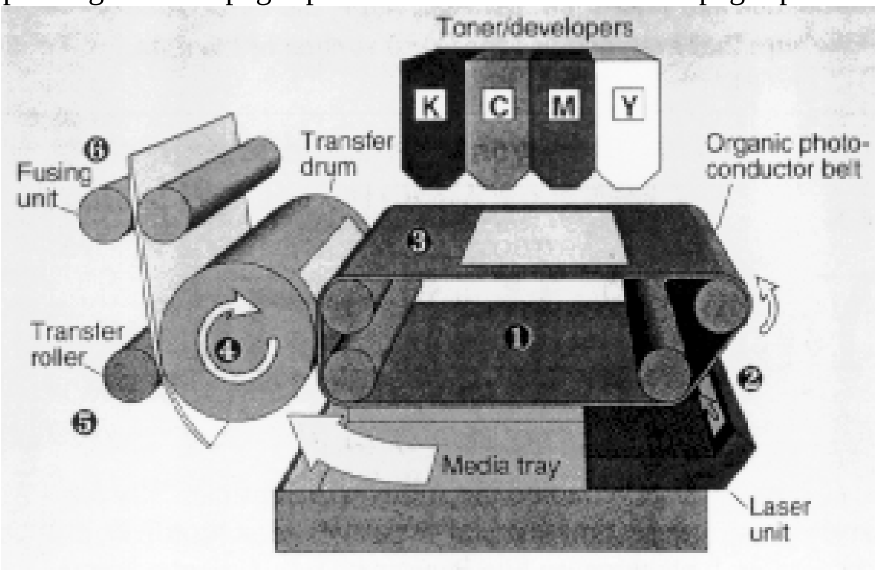

Figure 9 Colour laser printer

14.4 READING GUIDE

Wilkerson & Horrocks, Sections 4.4.7, 4.4.8.
Fulcher, Sections 7.4.
Durbeck & Sherr, Sections 10.1 - 10.4.