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# Introduction to the IBM 3800 Printing Subsystem Models 3 and 8

*The IBM 3800 Printing Subsystem Models 3 and 8 are high-speed, non-impact, electrophotographic printers which are designed for system printing, text, and graphics applications requiring flexibility and high print quality. Features such as their print density of 240 × 240 pels/in.$^2$ and all-point addressability extend substantially their printing capabilities beyond those of the Models 1 and 2.*

## Background

Automatic computer-system printing used in IBM word- or data-processing systems falls into two main categories, namely impact printing, as in serial-by-character printers [1] and line printers [2], and non-impact printing, as in ink jet printers [3] and electrophotographic [4] printers.

The need for high-speed system printing prompted the development in the mid-1970s of the IBM 3800 Printing Subsystem Models 1 and 2 [5–9], using an electrophotographic process [10]. Referring to **Figure 1**, the process is initiated by charging a photoconductor which is wrapped around a rotating drum to a negative potential by use of a grid-controlled charge corona. The charged photoconductor is then exposed to light by a laser subassembly that scans a data image onto the photoconductor, and/or a xenon flash subassembly (the latter is used for the exposure of forms). The latent image thus created is developed; i.e., toner (thermoplastic) particles are transported to the image by means of a rotating magnetic brush. The toned image is transferred electrostatically from the photoconductor to the paper and subsequently fused onto it with heat and pressure. Upon further rotation of the drum, the exposed portion of the photoconductor reaches a restoration unit, where its surface charges are neutralized and the untransferred toner is removed by a cleaner brush. The photoconductor can then be used for another printing cycle.

The physical configuration of the Models 1 and 2 (hereafter cited as the Model 1 except where noted) is shown in **Figure 2**. Data to be printed are transmitted a line at a time from the computer to the internal printer page buffer. After each page is completed inside the buffer, the information is transmitted to an acoustic modulator, which permits the optical transmission of the light beam to a rotating mirror [10]. The sequential images are then projected or raster-scanned onto the photoconductor surface by means of a variety of optical lenses in order to obtain image fidelity and spatial alignments. The helium-neon laser used in the Model 1 provides stability in power level and long life, and this distinguishes it from typical, commonly available lasers [5]. The superior characteristics of the laser, along with the high-speed rotating mirror and the optical path, provided the basis for all-points-addressable printing with multiple fonts and graphics. The high-speed throughput of the Model 1 in terms of lines/min and pages/min is dependent on the line spacing, the number of lines per page, and the number of pages that can be accommodated around the circumference of the process drum. **Table 1** shows the relationship of page size and printing speed of the Models 1 and 3. For each, the rate of paper transport is 0.81 m/s (32 in./s).

## Key features of the Models 3 and 8

The Model 3 [11] is designed for system printing, text, and graphic applications. The Model 8 [12], which is the successor to the previous Model 2 and was introduced by IBM's Americas/Far East Corporation, has all the functions of the Model 3 plus the capability to print ideographic character sets, such as kanji and Chinese. Both print with a density of 240 × 240 pels (picture elements) per square inch. Except when noted, the Models 3 and 8 are hereafter referred to as the Model 3.

The key features of the Model 3 are an all-points-addressable printing format, a print density of 240 × 240 pels/in.$^2$

compared to 180 × 144 pels/in.$^2$ for the Model 1 (thus resulting in a substantial improvement in character appearance), large font and character set selections (up to 64 character sets), and improved reliability, availability, and serviceability [13]. These features have opened new application areas, such as in-house publishing, image printing, and electronic forms.

The Model 3 uses essentially the same paper path as the Model 1 (Fig. 2). Components such as the developer, transfer, fuser, cleaner, charging, drum, and paper path assemblies are substantially unchanged. To achieve improved performance, the following key modifications have been incorporated into the Model 3: a new processor and control assembly to monitor and control many of the process variables such as print contrast and font management [14], a print head modification to include two laser beams in order to accommodate higher pel density [15], and a multi-layer photoconductor to improve optical sensitivity [15]. These modifications resulted in print quality improvements which were measurable using specially designed instrumentation [16].

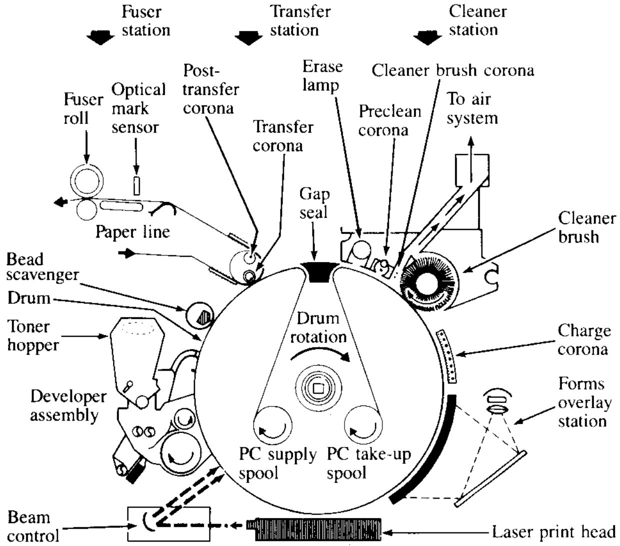


**Figure 1** Electrophotographic section.

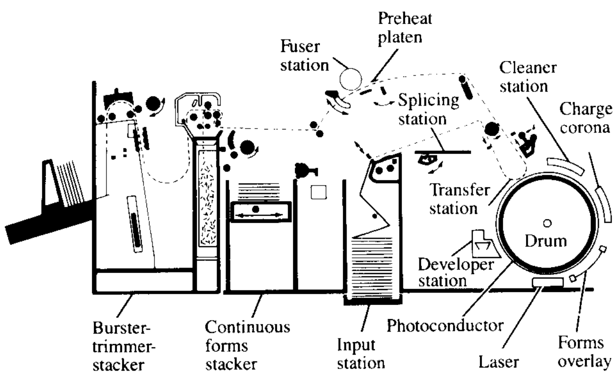


**Figure 2** Physical configuration.

## All-point addressability

The cornerstone of the new functions of the Model 3 is its all-point addressability, which includes such functions as "electronic overlay," image capability, libraries of fonts and characters, and line generation. The Model 3 also emulates the functions of the Model 1 in the "compatibility mode."

• *Compatibility mode*

The compatibility mode allows easy migration of Model 1 applications to the Model 3 by emulating its commands. In this mode, the Model 3 processes Model 1 channel command words so that application programs need not be changed. The immediate benefit is the improved print quality of the characters resulting from the 240 × 240 pels/in.$^2$ print density. In addition to a capability to print at the 6-, 8-, and 12-line-per-inch line spacing of the Model 1, the Model 3 can print at a spacing of 10 lines per inch in the compatibility mode.

• *All-points-addressable mode*

The all-points-addressable mode, also known as "page mode," allows characters to be located at any defined position on the

**Table 1** Print speeds, showing page sizes and line spacings for common-use forms.

| *Forms length* (in.) | *Pages/min.* | *Lines/min.* | | | |
|---|---|---|---|---|---|
| | | *at 6 lines/in.* | *at 8 lines/in.* | *at 10 lines/in.** | *at 12 lines/in.* |
| 3½ | 526 | 7,890 | 10,520 | 13,150 | 15,780 |
| 5½ | 334 | 9,118 | 12,024 | 15,030 | 18,236 |
| 7 | 263 | 9,486 | 12,624 | 15,780 | 18,972 |
| 8½ | 215 | 9,675 | 12,900 | 16,125 | 19,350 |
| 11 | 167 | 10,020 | 13,360 | 16,700 | 20,040 |

* Added feature of the Model 3.

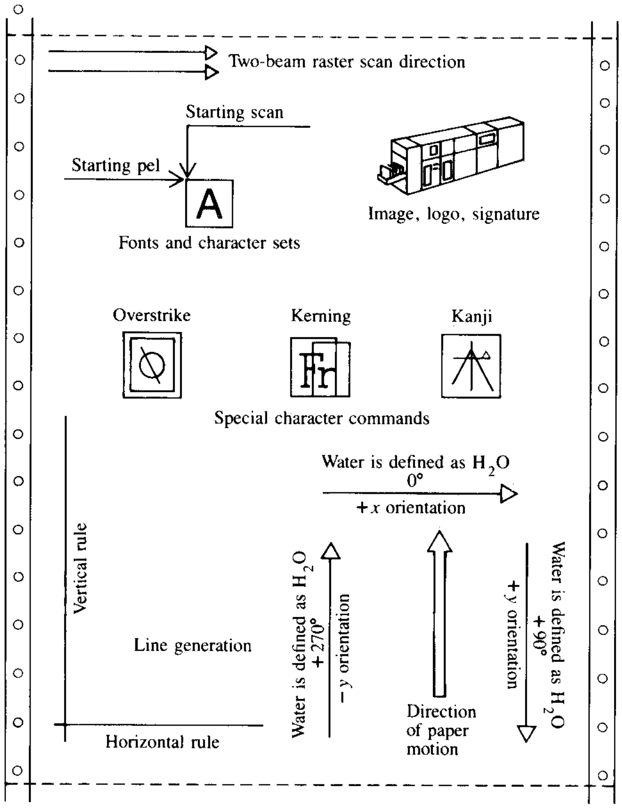


**Figure 3** Illustrative text orientation, formatting in the all-points-addressable mode.

printable area of the page. The information to be printed can be sent to the printer out of line sequence; that is, the data need not be sent in line-by-line order. Proportionally spaced and fixed-spaced fonts can be printed on the same page, as well as on the same line. Each character has a defined width that allows the printer to position the next in-line character. Multiple characters can be specified in the same position providing a new character, and overlapped with parts of each character having a common area. Lines, images, and overlays may be intermixed throughout a page in any sequence and located at any pel position. In addition, both proportionally spaced and fixed-spaced characters may be printed on the same page. Text can be printed on the same page in three orientations—one horizontal (0°) and two vertical (+90° and +270°). (See **Figure 3**.)

Line generation is possible with the Model 3 commands. Solid lines (rules) can be generated by printer command; dashed lines can also be generated. These lines can start from any defined point on the printable area of the page and be generated a defined length in a horizontal or vertical direction. Line width is selectable up to a width of approximately ⅛ inch.

Fonts and character sets can be printed on the same page and in multiple directions. The font size ranges between 4 and 36 points (a point is $^1/_{72}$ inch). The maximum character-cell size is 128 × 128 pels. Each font can have 255 characters. The fonts to be printed must be in the printer for the page on which they are to be printed. The printer can address up to 64 different fonts. The actual limit depends on the amount of raster pattern storage available, the number of characters in a font, and the character size. Double-byte character sets, used with the Model 8, can have up to 11 900 characters within a single character set (one identifier code). Fonts are loadable from the host system or they can be staged from the printer's internal diskette. Character sets introduced with the Model 3 fall into the following categories: 20 library characters sets (LCGs) initially supplied with the Model 1, converted to the 240 × 240 pels/in.$^2$ density; character sets provided with the Document Composition Facility (DCF) Release 2 program product; and character sets designed for printing in the 240 × 240 pels/in.$^2$ density. The latter include fixed-spaced single-pitch character sets, as well as tri-pitch character sets.

Images (raster data with 240 × 240 pels/in.$^2$) can be printed. The size of the image that can be handled depends on the amount of printer storage available to retain the image data. The base machine can print approximately 30 square inches of image on a page. Expansion features allow printing an image that covers the entire printable area of the maximum form size. Multiple small images, such as a signature or a company logo, can be printed on the same page. When reduced precision is acceptable, images created at 120 × 120 pels/in.$^2$ can be printed by using the "double-dot" function. For each dot indicated on a scan line, the printer generates two dots horizontally and prints each such scan line twice. Images printed in this manner appear equal in size to the original scanned or generated image. Image sources can include those already in computer data form, those created and entered manually, or those scanned and loaded into the host system by a document scanner. Any image-enhancement processing (for instance, rescaling, cropping, or conversion to half-tones) or library management of image data must be carried out independently of the printer. Images are printed in the orientation in which they are sent to the printer. Any change in image orientation, for example, rotation, must be carried out prior to transmission to the printer.

Electronic overlay, also known as "electronic form," is a major extension of the system printer's capability. It is a collection of constant data to be merged with variable data. In the Model 1, this is achieved with the forms flash, which is an opto-mechanical overlay requiring operator intervention. It allows a form to be generated from a sequence of printer commands that print lines (e.g., for creating boxes), constant alphanumeric text, shaded areas, or images. The latter information (the electronic overlay) is merged by the printer with the variable data for a given page and printed. This capability allows many custom forms of different sizes to be printed on blank paper—at a reduced forms cost. Multiple electronic overlays can be held in the basic printer and used within one application. The maximum addressable number is 127. The practical limit for an application depends on the complexity of the electronic overlay and the demands made by the application on the control storage or the raster pattern storage. Up to eight electronic overlays can be merged onto a single page.

## Printing technologies

• *Control assembly*

The control assembly used in the Model 1 to process channel commands and their associated data controls communicates among the host processor, the electrophotographic process components, and the paper motion mechanisms. For the Model 3, the control assembly has been redesigned for use with its compatibility and the all-points-addressable modes [14]. The flexibility of formatting a printed page with multiple fonts, character sets, different text orientations, electronic overlays, images, and page-segment allocations add to the complexity of the processor design. A raster pattern generator expands the coded data sent by the host processor into raster patterns and assembles them in the format for the page to be printed. The flexibility provided by the control function creates the storage requirements for the Model 3. For instance, 7200 bytes of raster pattern storage is required to retain the raster image of one square inch. The accumulator storage of 768K bytes is required to retain the image data for an 8½-in. × 11-in. page. The control storage, which is 512K bytes, contains the microcode, page buffers, coded data for electronic forms, font index tables, and other minor functions.

• *Laser print head*

The laser print head [15] had to be modified to maintain the Model 1 process speed of 0.81 m/s (32 in./s) at an increase in print density to 240 × 240 pels/in.$^2$ The Model 3 uses two printing beams to achieve the higher scan-line print density without increasing the speed of the rotating mirror. An anamorphic lens system is used to achieve a smaller and slightly elliptical spot.

• *Multi-layer photoconductor*

The use of a reduced spot size and higher print density necessitated the use of a photoconductor with improved exposure sensitivity [15]. For this purpose, use is made of a multi-layer photoconductor in which chlorodiane blue is used as the charge generation dye and p-Diethylaminobenzaldehydediphenylhydrazone (DEH) as the charge transport material. Its use provides the required improvement in sensitivity over the single-layer photoconductor which was initially used in the Model 1; it is presently being used in that model.

• *Reliability, availability, and serviceability*

A log-on analysis algorithm (LOA) has been developed for the purpose of identification of failures and determination of the significance of error due to corona arcing [13]. The algorithm transfers the error log from the functional diskette to the maintenance diskette. It is exercised to determine whether the error is caused by electrical noise, and serves as a reliability, availability, and serviceability (RAS) tool. Use of a digital voltmeter within the printer facilitates quick and accurate verification of critical voltage settings. Implementation of an automated preventive maintenance scheduling system optimizes preventive-maintenance task selection and reduces expensive part replacement by the tracking of selected parts.

## Print quality

Instrumentation was developed with which relevant subjective and objective measurements could be carried out, print quality assessed, and process variables modified. Objective measurements were performed with an optical scanner, designated as the Pictorial Information Dissector and Analyzer Systems (PIDAS) [16], which can be used to determine edge roughness, background reflectance, contrast, uniformity, stroke width, print registration, and gray-scale/halftone fidelity.

Improvements over the Model 1 in edge roughness, stroke-width flexibility, and character appearance are possible because of its higher pel density and smaller pel size. The resulting print characters of the Models 3 and 8 are comparable to commonly accepted letter-quality standards.

## Concluding remarks

A brief description has been presented of the printing functions of the IBM 3800 Printing Subsystem Models 3 and 8. Comparisons have been made with those of the Models 1 and 2. This paper serves as an introduction to the four following papers that address in more detail several important aspects of the Models 3 and 8. The subjects covered include technological aspects [15], design of the microcoded control unit [14], print quality measurements [16], and paper considerations [17].

## Acknowledgments

The author wishes to acknowledge the contributions made by the IBM 3800 Models 3 and 8 development team led by J. G. Belleson, C. H. Hammond, F. A. Litz, and P. T. Winn. In addition, the author expresses his sincere appreciation to P. Y. Hu for his help and suggestions.

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*Received October 12, 1983; revised December 12, 1983*

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