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Control of the IBM 3800 Printing Subsystem

Abstract: The IBM 3800 Printing Subsystem is controlled by a high speed multilevel, interrupt-driven microprocessor. The design of this system has included several innovative concepts to take advantage of the flexibility of electrophotographic laser printing. New functions that are introduced include intermixed pitches, fonts, and line spacings; user-alterable character sets; on-line forms generation; and superior retry, fail-soft and diagnostic capabilities. Compatibility with the operational characteristics of IBM 1403 and 3211 printers is maintained. This paper discusses many of the objectives, development tradeoffs, and resultant control implementations for an on-line computer output printing subsystem.

Introduction

The technology of IBM chain and train impact printers set a standard for computer output printing for many years [1, 2]. These printers offer quality printing, relatively high speed (up to 2650 lines per minute), and good reliability. Current demands, however, impose restrictions and limitations on the user and on the expansion of the technology. At the high speed end of the spectrum, hammer flight times become critical. Present requirements to extend speed go far beyond the state of the mechanical printing art. The quality of carbon copies cannot be improved greatly, and the number of characters that can be printed at maximum speeds is limited. These drawbacks, plus the objectives of compatibility with the present product line, lower total cost of printing, and better performance for the user in terms of speed and function, defined the objectives for a new technology.

A study of printer utilization identified several major design considerations: paper handling, paper quality, copy quality and quantity, system peak loads, form sizes and generation, and compatibility of new printers with existing products. These are covered in the subsequent section, followed by sections on the printer control system, and printing by translating codes to dots.

Design considerations

Of all the design considerations, paper was the most important. Our studies indicated that forms cost and handling were the largest expense items associated with computer printing. A portion of the paper handling problem involves services and procedures prior to printing. They are the costs, time delays and annoyances associated with forms design, ordering, vendor turnaround, warehousing, controlling inventories, and moving forms to and from the printer. A second portion of the problem involves paper handling from printer to user. This portion deals with time delays and costs associated with forms placement and adjustment in the printer, deleaving and bursting operations, binding, and distributions to users. The printer was designed to use plain paper, sometimes preprinted, in continuous forms. Plain paper rather than treated paper was chosen to minimize costs.

- *Technology choice*

Transfer electrophotography [3] was an available technology currently being used in IBM copiers. Electrophotography uses plain paper, produces print of excellent quality, and can operate with an unlimited number of characters at very high speed to solve peak load problems. The process is also compatible with preprinted forms, permitting a user to change from impact to nonimpact printing without significant effect on forms inventory.

A transfer electrophotographic process for paper of continuously variable width and length was beyond the state of the art, and was abandoned in favor of discrete form sizes based on those most commonly used. The quantity of forms types could be reduced if a simple method could be found to generate forms on line and permit stocking of essentially plain paper. The solution to this problem was to use a fixed film negative of the format desired and to flash-expose the film image in the electrophotographic process. Variable print data were then added by laser exposure, creating the completed page.

As a technology, impact printing has always imposed an arbitrary limit upon quality and quantity. In general, as the quantity of copies increases, their quality and legibility decreases, because of the carbon paper. Since the electrophotographic process can print only on single-part forms, multiple-ply forms and carbon paper are eliminated, and forms cost is reduced. Copies are printed as desired, each with high legibility. The desirability of having output either in continuous forms or burst and trimmed into sheets led to the development of a positive action continuous-forms stacker and a burster-trimmer-stacker.

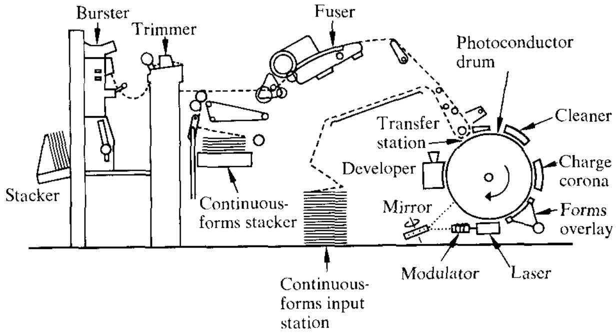


Figure 1 Key elements in the printing process, including the paper path.

Table 1 Print speeds, showing page sizes and line spacings.

Forms length (in.)	*Pages per min*	*Lines per minute*		
		6 LPI	*8 LPI*	*12 LPI*
3½	526	7890	10 520	15 780
5½	334	9118	12 024	18 236
7	263	9486	12 624	18 972
8½	215	9675	12 900	19 350
11	167	10 020	13 360	20 040

- *The printing process*

A brief overview of the printing process would be helpful for an understanding of the control aspects.

Figure 1 shows the key elements in this process and the path that the paper takes, from the continuous-forms input station through to the continuous-forms stacker or the optional burster-trimmer-stacker.

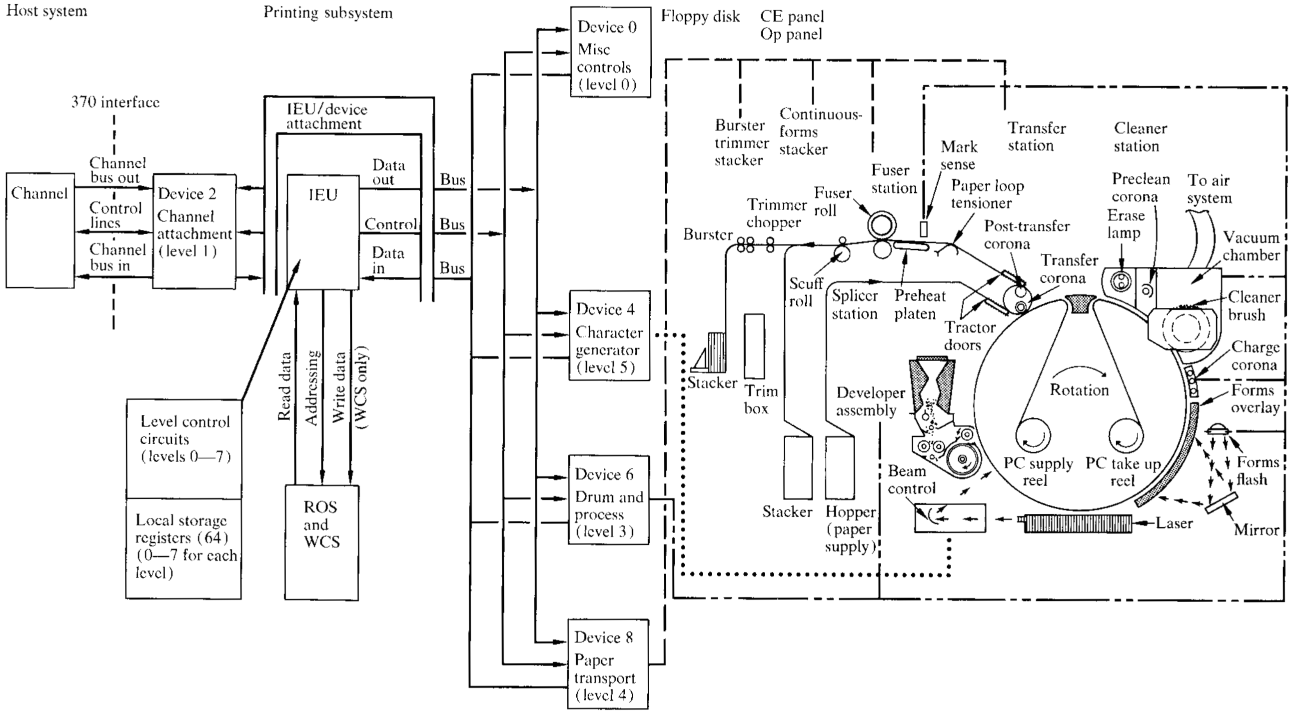
Data to be printed are transmitted one line at a time from the CPU to the printer, where they are stored in an internal page buffer. After each page is completed within the buffer, it is exposed by the modulated beam of a low-powered laser onto the photoconductive surface of a rotating drum, to create an electrostatic image of the page to be printed. This latent image is coated with toner, a thermoplastic material impregnated with lampblack, by the developer. At the transfer station the toned image is transferred from the drum to the paper. The paper then passes through a fuser, which fuses the toned image into the paper, as discussed in depth by Brooms [4]. Meanwhile, the surface of the drum is cleaned and reconditioned for subsequent exposures. If there are sufficient data in the page buffer to print another page, printing continues without stopping the paper motion. Forms can be printed with the data by flashing the image of a forms overlay negative onto the drum.

- *Throughput*

With a constant-velocity printing process, the line-per-minute rate is dependent upon the line spacing, 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 relationships of page size and printing speed. These velocities are achievable independently of the number of different characters being printed or their frequency distribution across the printed line, a characteristic not found in impact printers.

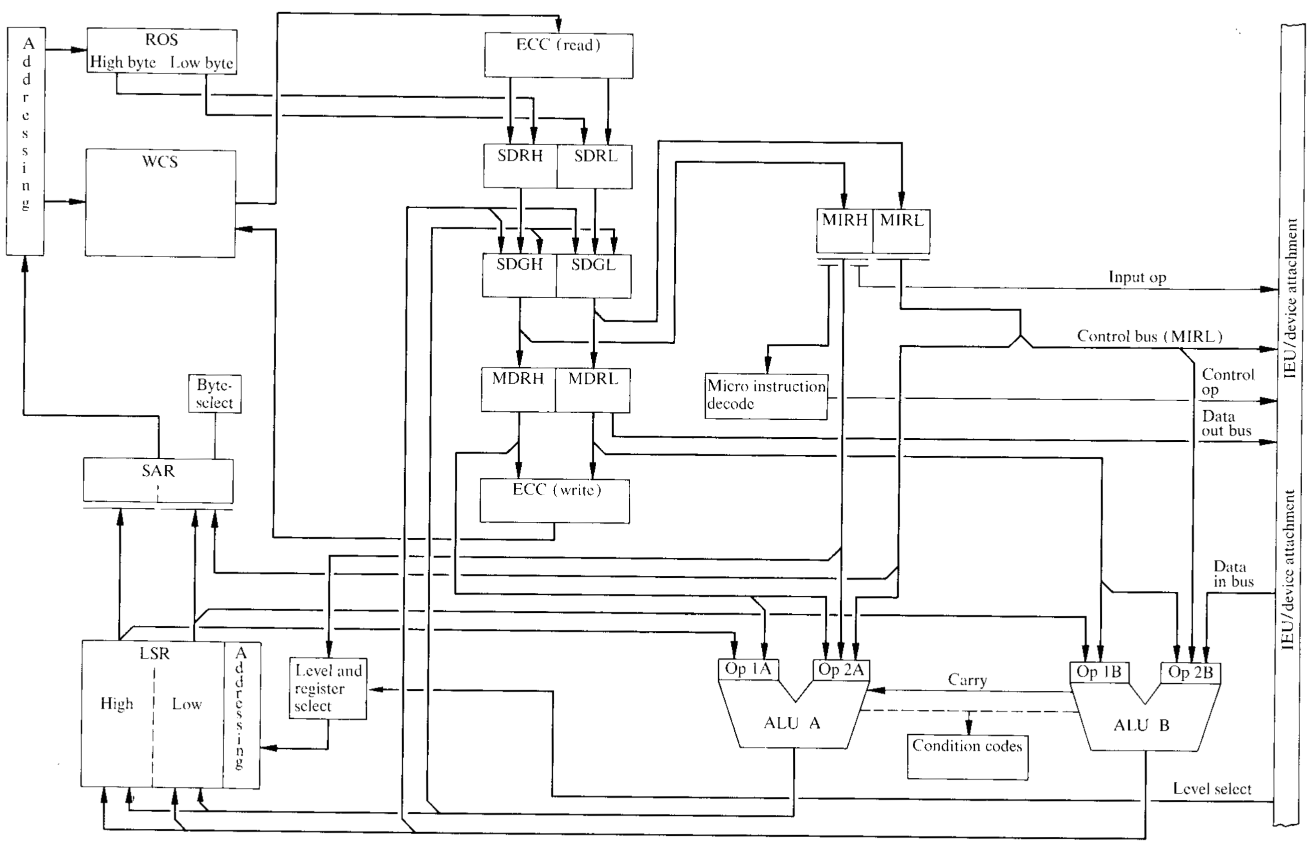
Printer control systems

As the operating characteristics of the printer were being determined and the hardware and technology problems were being solved, four kinds of control requirements were identified: 1) system interface, 2) machine component control, 3) operator and customer engineer interfaces, and 4) print control data buffering and processing. The interactive complexity of these requirements and the evolutionary nature of the development process led to the use of microprogrammed control logic so that hardware could be added or changed with less difficulty and at relatively little expense [5]. The microprocessor used multilevel, priority-interrupt-driven logic to handle the fairly complex control algorithms, the requirements for synchronizing events with the essentially asynchronous printer hardware, and a set of data and event rates that ranged from once-per-week operator activity through a 250-kilobyte-per-second channel data rate to a 13.3-MHz laser bit rate.



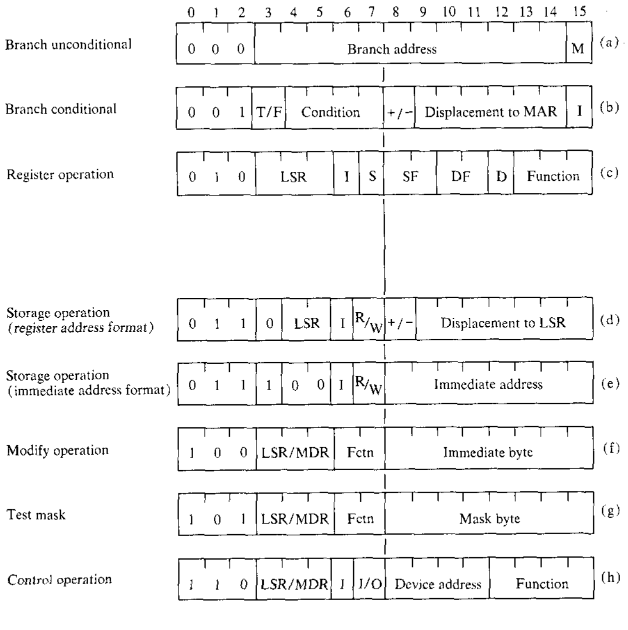
Host system
Printing subsystem
370 interface
Channel
Channel bus out
Control lines
Channel bus in
Device 2 Channel attachment (level 1)
IEU/device attachment
IEU
Data out
Control
Data in
Bus
Bus
Bus
Level control circuits (levels 0—7)
Local storage registers (64) (0—7 for each level)
Read data
Addressing
Write data (WCS only)
ROS and WCS
Device 0 Misc controls (level 0)
Device 4 Character generator (level 5)
Device 6 Drum and process (level 3)
Device 8 Paper transport (level 4)
Floppy disk
CE panel
Op panel
Burster trimmer stacker
Continuous-forms stacker
Transfer station
Cleaner station
Mark sense
Fuser station
Fuser roll
Paper loop tensioner
Trimmer chopper
Burster
Post-transfer corona
Preclean corona
Erase lamp
To air system
Vacuum chamber
Transfer corona
Scuff roll
Splicer station
Preheat platen
Tractor doors
Cleaner brush
Charge corona
Stacker
Trim box
Developer assembly
Rotation
Forms overlay
Forms flash
Beam control
PC supply reel
PC take up reel
Stacker
Hopper (paper supply)
Laser
Mirror

(a)

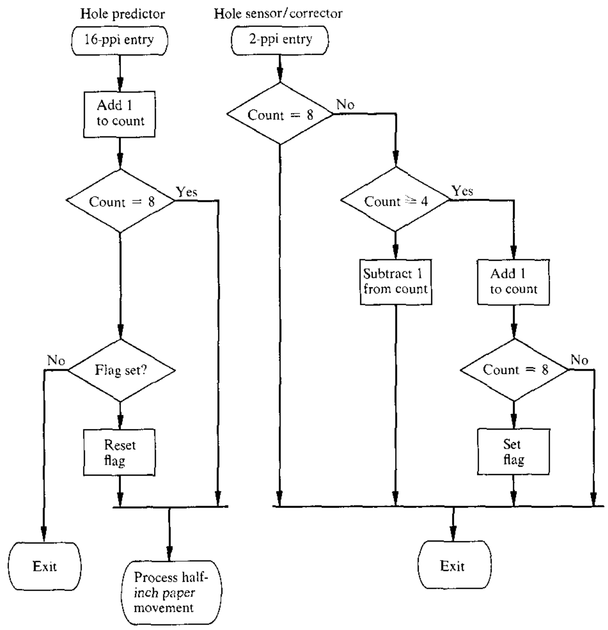


Addressing
ROS
High byte
Low byte
WCS
ECC (read)
SDRH
SDRL
SDGH
SDGL
MDRH
MDRL
ECC (write)
MIRH
MIRL
Micro instruction decode
Input op
Control bus (MIRL)
Control op
Data out bus
Data in bus
IEU/device attachment
IEU/device attachment
Byte-select
SAR
LSR
High
Low
Addressing
Level and register select
Op 1A
Op 2A
ALU A
Carry
Condition codes
Op 1B
Op 2B
ALU B
Level select

(b)



(c)



(d)

Figure 2 Printer control systems. (a) Internal attachments in the subsystem, showing the native channel used by the Instruction Execution Unit to communicate with functional attachments. (b) Data flow in the Instruction Execution Unit. (Symbols used: ECC, error correction circuits; SAR, storage address register; LSR, local storage register; WCS, writable control storage; SDR, storage data register; SDG, storage data gate; MDR, memory data register; MIR, microinstruction register; ALU, arithmetic logic unit; H, high byte; and L, low byte.) (c) Microinstruction format. (d) Half-inch paper motion predictor/corrector.

The controlling microprogram is executed by an Instruction Execution Unit (IEU) in the microprocessor. The IEU contains a native channel to communicate with functional attachments as shown in Fig. 2(a). This channel consists of a data bus-in, data bus-out, and a control bus. Information can be transmitted out to the attachments and data and status can be read into the IEU from the attachments. These attachments contain data registers, control lines, status bits, counters, hardwired control logic, magnet/solenoid/relay drivers, and sensor logic. The digital logic in some attachments communicates directly with analog circuits to perform special control functions.

To save processing time required for executing polling loops and to obtain fast interrupt switching, the IEU data flow contains eight interrupt levels, each with eight local store registers (LSRs). These registers contain the instruction counter and seven general-purpose work registers to be used in that level.

The next requirement for the microprocessor was to develop an instruction repertoire, address space, and data flow width. Control algorithm kernels were generated to represent functional (instruction set) and speed requirements. Mixing these requirements with available and projected logic and storage hardware and costs resulted in a half-word data flow with a basic seven-instruction microorder set [see Fig. 2(c)], including byte and half-word data arithmetic and manipulation instructions with addressing space for a writable control storage (WCS) and a read-only storage (ROS) of 64 kilobytes each [see Fig. 2(b)]. Byte Select capability was added to provide automatic byte field processing using the half-word data flow. WCS holds the functional microprogram, space for many pages of printable data, and space for control buffers. ROS, being faster and more expensive, is used only for tightly coded high-performance algorithms (e.g., character processing) and for some functions that must be performed before the WCS has been loaded (e.g., initial power on resident diagnostics, WCS loading from a floppy disk, and communication with the customer engineer panel).

Cost performance curves for the logic and storage technologies then available broke sharply upward at two million microinstructions per second for ROS and one million microinstructions per second for WCS. These two rates were then used with an internal native channel attachment to resolve the problems of logic/microprogram design tradeoff. That is, some of the faster, highly repetitive requirements, such as table lookup and serialization of the character images to the laser modulator, were cast in hardware (Character Generator Attachment), and complex but relatively slow functions like channel command decode and execution were accomplished in the microprogram with minimal hardware.

- *Timing control concepts*

The basic requirements of a systems printer, converting a serial stream of channel data bytes (control data followed later by printable data) to formatted lines of characters on paper, had to be merged with the basic serial nature of electrophotographic printing. Furthermore, that process has two serial procedures—imaging and paper handling. Since the machine was to handle many page lengths in start/stop mode, its fixed geometry forced nearly all of the major printer stations to be separately timed and controlled. Synchronism requirements called for the merging of images on the paper forms within close registration tolerances. This required tight servo controls [6, 7] on the drum rotation and transfer station in both the velocity and space domains, and tight controls on the initiation of these and other machine actions in the time domain. The time domain was synchronized through the control electronics and microprogram with a series of shaft encoders and position sensors.

A problem representative of this asynchronism and serialization is that of placing the forms flash and the laser character generation images on the usable part of the photoconductor (PC) on the drum surface and in alignment with each other, and starting the paper transfer station such that the paper registers with the combined images. The basic targets are provided through a drum encoder pulse occurring every 95 μm of drum motion (109.2 μs) and a drum index occurring once per drum revolution for synchronism with the PC gap. After the data for a printed page are contained in the control electronics and all the printer elements are at their proper operating parameters, the imaging process starts.

A drum management routine inserts the page print request into a set of program timers that keep track of the physical position of the drum and the images. The timers are used for the photoconductor gap position, the forms flash station, the laser page and line starts, the laser print contrast mark and mark form starts, page locations, page scheduler, and for transfer servo. The program timers are essentially loaded with binary values for the number of drum encoder counts representing physical distances between the stations and some attributes such as flash or no flash. The timers are decremented by the drum encoder. When an entry reaches zero, the appropriate action is initiated (e.g., forms flash routine).

Since timer service is frequently required and uses computation power, hardware assistance is provided, giving the microprogram a loadable logic counter (drum counter) which is decremented by the drum encoder and gives a microprogram interrupt when reaching zero. The management routines need only scan the timers for the next action event, subtract the minimum value from all active timer entries, load that value into the drum counter, and wait for the interrupt to initiate the next action. This assist reduces the overhead significantly and allows the remaining computation power to be applied elsewhere.

Tracking of the printed images through other portions of the machine is coordinated with a combination of motion sensor queue entries until the page is safely stacked in the continuous-forms stacker or the burster-trimmer-stacker. The page control information is passed from control queue to control queue and purged from each queue as the image leaves that physical station.

Longitudinal position sensing of the paper web at the fusing station posed a major problem in that an optical hole sensor is susceptible to missing holes because of occasional chads left in the holes, or perhaps to small defects such as a few inches of missing carrier strip. The paper position had to be known accurately to keep the tracking, perforation location and queue control operational. The paper passes through the fuser hot roll element asynchronously. Though mechanical tolerances are small, a shaft encoder on the end of the roll does not accurately represent paper motion over long distances. The solution was to use both types of sensors and a microprogrammed predictor/corrector algorithm. A 16-ppi roll shaft encoder predicts where a 2-ppi tractor hole should be sensed and injects a count if the hole should fail to show up. The tractor hole sensor, upon the detection of a hole, biases the predictor plus or minus to provide a slow correction that will skip over defects in the paper. Figure 2(d) shows the basic predictor/corrector algorithm. Added to that algorithm are controls for error detection of excessive predicted holes and filters for increased immunity to noise.

- *Reliability, availability, and serviceability*

To establish a high level of availability for the printer, extensive error checking and automatic recovery capabilities were built in. These include single-bit error correction and double-bit error detection in WCS, byte parity checking and microinstruction retry in the microprocessor and its storage, floppy disk error detection track retry and alternate track data replication, and extensive error detection in the character generation logic. A malfunction in the electrophotographic process, such as excessive charge corona, can also be detected. Many of these error detections inhibit the transfer of the incorrect image to paper (skip transfer) and initiate a retry, regenerating the image. Multiple levels of transparent retry result in error recording and environmental records that warn a customer engineer of marginal machine components or adjustments. Such deficiencies may be corrected during the next preventive maintenance period, while allowing continued machine operation at nearly full performance.

To assist further in problem diagnosis and repair of the printing subsystem, the floppy disk, which contains the functional microprogram and 20 loadable character fonts, may be exchanged for a Reliability-Availability-Serviceability disk. This disk contains microdiagnostics and exercisers ranging from a simple check of a microswitch to a complex program called Test Page. The latter permits 100 percent off-line testing, using the functional microprogram without the IBM 370 channel routines. It permits the customer engineer to select options such as character sets, print spacing, BTS offset, many modes of start/stop operation, and precomposed print quality patterns. It also has full error checking, the results of which may be dumped to the printed page.

Some of the mechanical and process components of the printer are sensitive to usage. Therefore, the control electronics, in periods when no data come from the system, will turn off various machine components to extend life and machine availability.

Operation of the electrophotographic process high voltage coronas and the use of paper with its associated contaminants provide a hostile environment for control electronics. For example, the corona elements occasionally will arc with considerable energy, which causes spurious signals to be coupled into the various low-level sensors located in the printer. This problem was handled effectively by extensive use of microprogram and hardware filters. The arcs are detected in the high voltage power supplies and initiate a skip transfer retry to eliminate potential print defects.

Printing by converting codes to dots

In the printing subsystem, a line of data, represented by a string of character codes inside a CPU, is transformed into graphic characters consisting of many small printing dots. The process, illustrated in Fig. 3, is described in the subsequent sections.

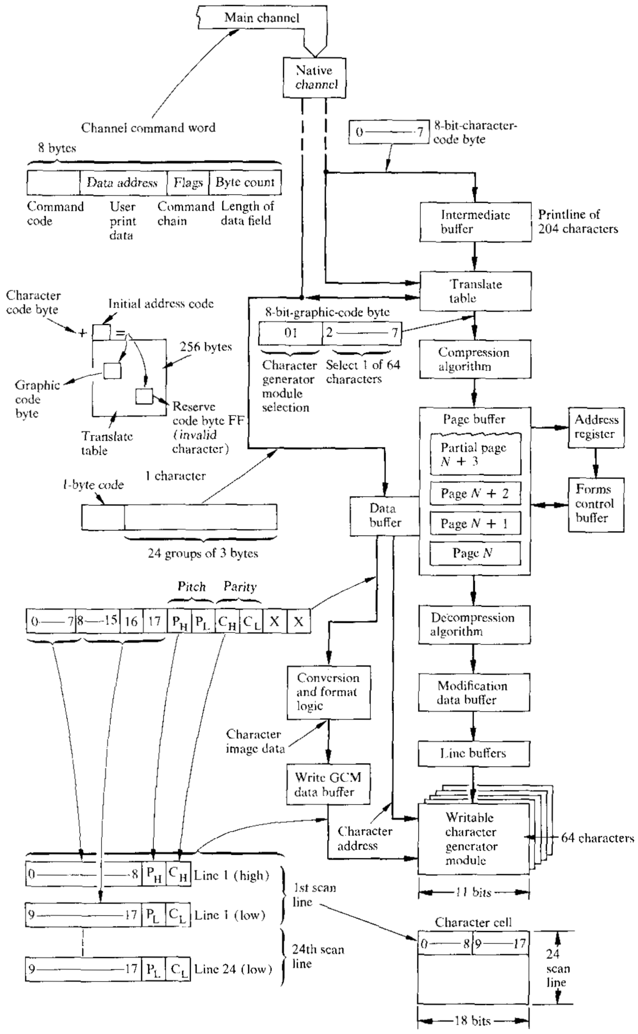


Figure 3 Print data flow. The chart shows the process by which a line of data, represented by a string of character codes in a CPU, is transformed into characters comprising small printing dots.

• *Compatibility*

Formatting in the printer permits 6, 8, or 12 lines per inch to be intermixed on a page. Character spacings may be 10, 12, and 15 to the inch, separate or intermixed.

To permit an orderly transition from impact printing, an interface similar to that used with impact printers was developed [1, 2]. This interface dictates that data to be printed are transmitted one line at a time from the CPU to the 3800. All the Space, Skip, and Write channel commands are used in a functionally equivalent mode of operation. Bit coding of the command codes is kept identical to that used in impact printers. Channel End status is presented at the end of the data transmission and the printer logically disconnects from the channel [8]. After the printer has manipulated the data and performed the associated form spacing operation, Device End status is presented. This allows any user programs that generate data a line at a time in either the ASA or Machine Code control character formats to print on the machine.

• *Code mapping*

As in impact printers, the functions provided include the universal character set, folding, and detection of unprintable characters [1, 2]. These functions are accomplished through a set of translate tables stored in the 3800. Each table contains 256 bytes, and there may be up to four tables. A table position exists for all possible character codes that can be transmitted from the CPU.

Each print line of data is transferred from the CPU/channel into an intermediate buffer inside the 3800 WCS, as indicated in Fig. 3. No manipulation is performed dur-

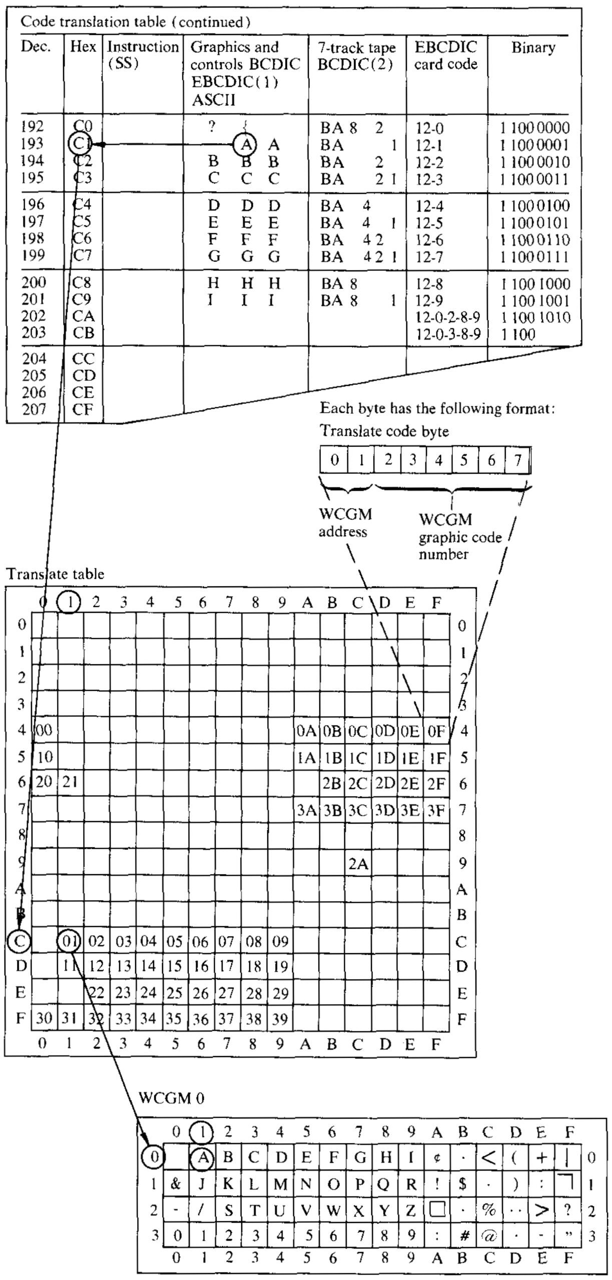


Figure 4 Method by which an eight-bit data code sent to the printer is transformed into an address in the Writable Character Generation Module (WCGM) by the translate table portion of the character arrangement table.

ing the transmission so that a high data transfer rate can be maintained. After the transfer, the data line in the intermediate buffer is translated by a previously selected translate table. This process involves replacing each character code in the buffer with the translate table value located (indexed) by the character code. The resultant value is stored in the page buffer.

Figure 4 shows how the eight-bit data code sent to the printer is transformed into an address in the Writable Character Generation Module (WCGM) by the translate table portion of the character arrangement table. The eight-bit EBCDIC assignment "C1," equivalent to the graphic character "A," is used to address the location in the translate table that contains the value "01." That value is the address of the WCGM location that contains the scan patterns for printing the "A."

As each code is translated, the resultant code is analyzed. If a hexadecimal FF (all bits) is detected, then an unprintable character has been received from the system. Unprintable codes are replaced by a blank and the data check status condition is presented to the system unless data checks have been blocked. The translate tables are more flexible than the universal character set (UCS). They permit one or more character codes to select a graphic character. UCS only allows one character code to print a graphic. If the four quadrants contain the equivalent values, the folding function is automatically provided.

Translate table entries select the graphic patterns in character generation storage as shown in Fig. 4. A WCGM is a 64-position portion of the character generation storage that holds the scan elements for one character set (see Fig. 5). Storage is provided for 128 characters with an optional feature capability for an additional 127 characters. Further flexibility is achieved by intermixing characters of different styles and pitches within one output data set or within one print line. There are several ways to accomplish the intermixing:

1. One translate table can point to more than one WCGM as long as each character being printed has a unique EBCDIC code.
2. One translate table can point to only one WCGM that contains characters with different styles or pitches.
3. More than one translate table can be used, each pointing to a different WCGM. The appropriate table to be used is selected by a Select Translate Table channel command. Any line of data can be printed by using any selected translate table. Characters of different styles or sizes can be printed on the same line by using any selected translate table and the Write with No Space channel command to merge partial lines of characters into one print line.

Because printing is accomplished by transferring images to the paper from a constantly revolving drum, overprinting cannot be done. Overprinting on an impact printer requires inhibiting the advance of the paper while two or more lines of data are printed in the same position. Lines of data can be merged into a single line only in the page

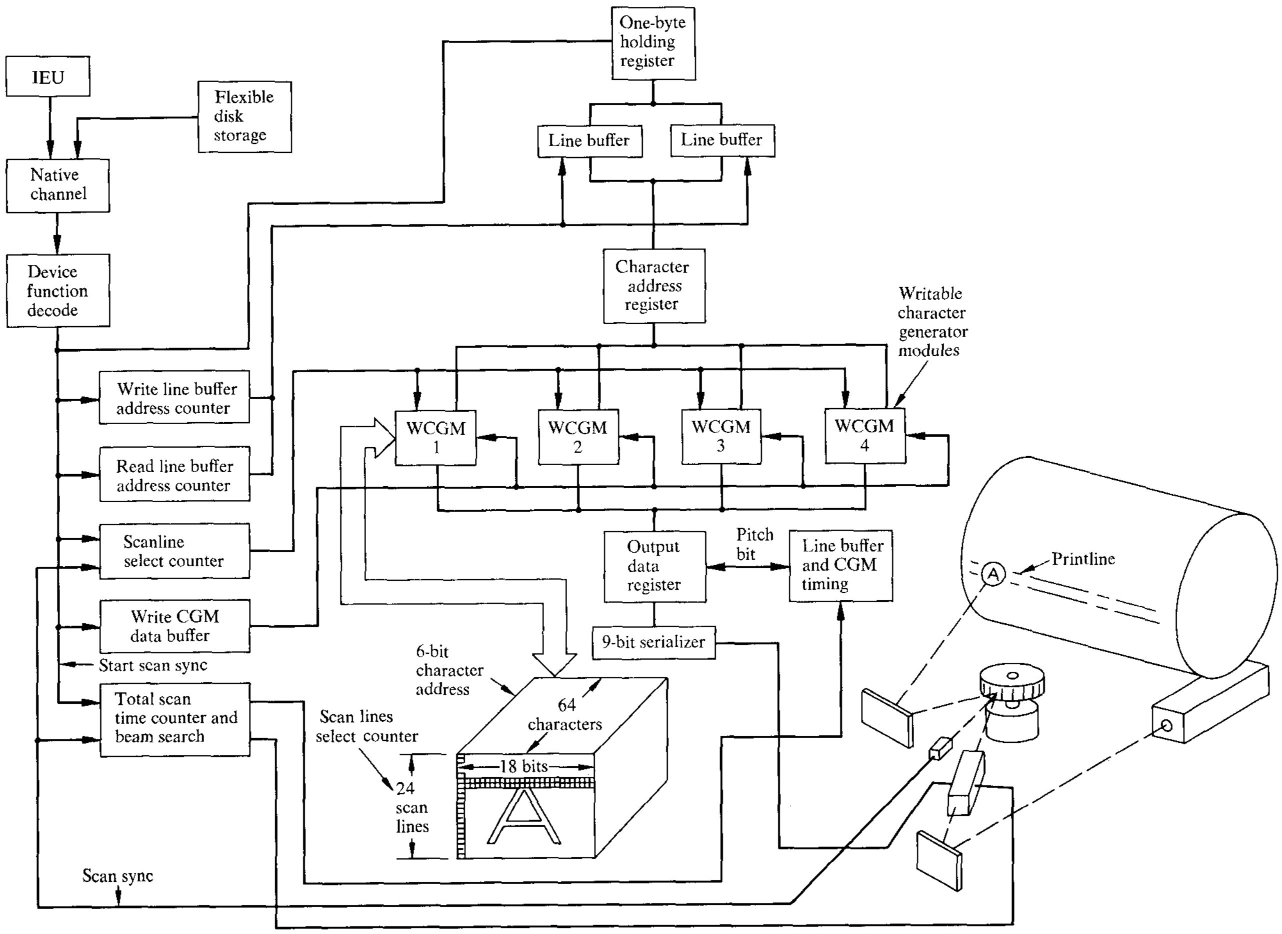


Figure 5 Character generator, showing how the Writable Character Generation Module (WCGM) provides the scan pattern for printing the character "A."

buffer. The Write with No Space channel command is used to initiate the merging. Data lines being merged will not be compressed until a forms operation is received by the printer. The merge algorithm will keep the first nonblank character in a print position. If multiple characters in a single position are merged, only the first character will be printed and a Data Check condition will be indicated unless Data Checks have been blocked or the two characters were identical. An exception in the merging process is an underscore. Underscoring is performed on an impact printer by overstriking a character with an underscore. The 3800 is unable to operate this way. Instead, if during the merge operation either of two coincident characters is an underscore (translate code B'XX10 1101), then two bytes are used for this print position in the page buffer. The first (the underscore flag) is a code which indicates that the second (the actual character) requires scan lines 21 and 22 (underscore, see Fig. 6) to be turned on by the character generator when the character is exposed. If a line contains an underscore flag, it will not be compressed.

• *Forms control*

Impact printers accomplish their forms control by mechanically advancing the paper [1, 2]. The 3800, however, places blank lines in the page buffer instead. Vertical compression, to conserve buffer space, requires only a single byte in the page buffer to indicate a spaced or skipped blank line. A forms control buffer (FCB) takes the place of the impact-printer carriage tapes. This buffer can contain any of the desired channel punch codes. It is examined for channel 9 or 12 codes during a space operation and will present the appropriate system status. As each line is placed in the page buffer, the relative position in the FCB is incremented. When the end of the FCB is reached, the page is considered full. Full pages in the page buffer are placed on a threaded list (chain) to preserve their location and printing sequence.

• *Buffer interlock*

Most CPUs and channels can generate and transmit data lines faster than the printer output rate. It would be pos-

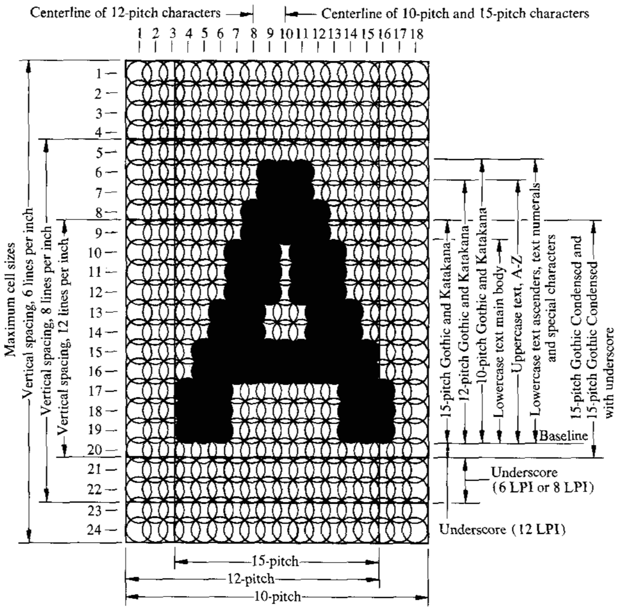


Figure 6 The 18-column by 24-row print cell, with a 10-pitch gothic "A."

sible to overflow the page buffer and continually fill back over the top with pages that had not yet been printed. To prevent this, a buffer interlock scheme was devised. A check is made to ensure that there is room in the page buffer for the next line. If sufficient room exists in the buffer, Device End is presented to the channel. If room is not available, as when the buffer is full of unprinted pages, the printer waits until room becomes available. When a page is printed out of the page buffer, buffer room is made available for new lines. Device End can then be presented. The channel can initiate the next channel command. The entire sequence then repeats, transferring data lines from the CPU into the page buffer in the printer.

- *Throughput*

To maintain a constant and maximum throughput rate, data must be available in the page buffer in time to print each successive page. A delay in filling the page buffer to complete the data for any following page can result in interruption of the printing process. To ensure an adequate supply of pages in the page buffer, each data line is compressed. This compression conserves space inside the page buffer and has the added advantage of increasing the internal processing rate for data. The compression algorithm uses a run length code of three bytes to replace four or more identical codes being placed in the page buffer. The first byte is a compression field identification. The second is the number of characters compressed. The third is the graphic code. No real time transmission demand is placed on the CPU or channels. The page buffer holds at least one full page. This ensures that the system will have sufficient data to expose a complete page once the character generation process is started.

- *Character generation*

Exposing of pages from the page buffer onto the drum is controlled by a character generator (CG), as indicated in Fig. 5. The internal processing speeds required of the character generator are so great that the microprogram is only able to supply the data from the page buffer. The CG contains two line buffers. The microprogram can be filling one buffer while the other buffer is used by the CG. Thus the microprogram can use the CG print time to fill the other line buffer and perform several other functions. The compressed data lines in the page buffer must be decompressed when loaded into the line buffer. If any underscored characters are encountered, they are stored in the line buffer with their underscore flag set. This flag will cause the CG to turn the laser beam on for scans 21 and 22 when the graphic pattern is generated for that character.

Impact printers can print only at a rate of either 6 or 8 lines per inch for the entire page and usually the entire data set. This is accomplished by mechanically advancing the paper. The 3800 does not operate this way. Instead, it uses a different number of horizontal raster scans to accomplish the line spacing, and is thus able to intermix rates of 6, 8, and 12 lines per inch within a page. Six lines per inch uses 24 scans, while 8 and 12 lines per inch use fewer scans by truncating the top and bottom scan lines in the character cell (see Fig. 6). Line spacing latches associated with each line buffer are set depending on bits in the forms control buffer. To conserve microprogram processing time, a blank line latch is also associated with each line buffer. If the blank line code is detected in the page buffer, the blank latch for the line buffer is set. This avoids having to blank out each position in the line buffer. Any remaining line buffer fill time can be spent in copy modification.

Impact printers can use multipart preprinted forms with spot carbon paper and data blockout to personalize copies and suppress printing of data on particular copies. The 3800 instead uses copy modification to allow printing of predefined data on a specified copy or copies of all pages of a data set. Copies can be personalized and/or blanks or printable characters can be used to suppress printing of normal data on particular copies of a page. The copy modification record, stored in the page buffer, is examined by the microprogram. If any segment of the record matches the current copy number and line number being placed in the line buffer, the associated data will be placed in the line buffer, replacing the normal data originally occupying those positions. The microprogram is then finished with its line buffer.

When it is time for the next line, the microprogram exchanges line buffers with the character generator. The character generator will access each data byte in its line buffer as many times as the number of scans for the line. When a character code is fetched from the buffer, the code is concatenated with the scan counter to address the selected WCGM. The WCGM is accessed and a set of bits representing a horizontal slice of the graphic character is obtained (see Fig. 6). Included with these bits are the pitch specification bits. The pitch bits control the number of horizontal bits to be used. Ten-pitch characters use 18 bits, 12-pitch use 15 bits, and 15-pitch use 12 bits. The set of bits is then serialized and used to modulate a scanning laser beam to produce a character pattern. It is important to understand that the print line data or copy modification data received from the CPU do not contain any pitch information. Pitch is specified by the data loaded in the WCGMs. The system programmer must keep in mind that merging, when used, occurs by logical character position rather than by physical position in the final print line.

- *Load commands*

The printing subsystem provides compatibility for user programs that have previously used impact printers. These functions are primarily controlled by load channel commands issued by the CPU. These commands are sent to the printer at the beginning of the data set, and condition it as to how the pages are to be printed. It can be instructed to load the WCGMs with the character sets stored on an internal disk. The translate tables are transmitted from the CPU. User-designed graphic characters, such as Greek, Arabic, or boldface fonts, can be stored in a WCGM. This Graphic Character Modification function provides for the substitution or extension of the graphic characters in an already defined character set. The FCB can be loaded and the number of copies of each page and an optional forms flash can be specified. Copy Modification information can be transmitted along with the copy number of the subsequent data set.

Summary

The new raster imaging and paper handling technologies in the 3800 Printing Subsystem have enhanced potential printer performance and flexibility. The internal controls provide the capability to meet the box design goals of compatibility with system printer functions and the introduction of new flexibility to the printer user.

A multilevel, interrupt-driven 0.5-μs microprocessor orchestrates the movement of data and control information to the printer, generates electrophotographic print images at up to 20 000 lines per minute, places those images on paper, and conducts the paper safely to the output stackers in sheet or continuous form. The required time-and-space synchronism of the intrinsically asynchronous mechanisms of the printer was accomplished with elaborate sensing, timing, and microprogram queuing stations. This permits the use of a variety of form sizes and print jobs.

The full page raster imaging, electronic character generation, and microprogrammed data manipulation and machine timing control were used to provide the following functions:

1. Up to 255 different characters printed at full throughput.
2. Twenty predefined 64-graphic character sets stored on internal disk, available through channel commands.
3. Graphic character modification to allow user-designed characters to be printed.
4. Vertical format control that allows intermixing of 6, 8, and 12 lines per inch within a page.
5. Horizontal intermixing of 10-, 12-, and 15-pitch characters within a print line.
6. Copy modification to permit changing or suppression of selected data from copy to copy.
7. On-line forms generation by means of an Emulsion Image and Forms Flash or with Format and Regular character sets.
8. On-line bursting, trimming, and stacking of printed pages.
9. Identical quality of duplicated pages.

The flexible microprogram-based control system has aided in the development of a new system printer standard for speed, quality, and function.

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