THIS PAPER ON THE HEWLETT PACKARD 2680A LASER PRINTING SYSTEM
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Abstract

This paper describes the HP 2680A Laser Printing System from the perspective of the HP 3000 programmer. The printer hardware is first described, then its features are explained. Concepts of downloadable character sets, electronic forms and logical pages are discussed. The implementation and use of these printer features via the system software is also covered. The impact of the laser printer in a distributed computing environment is briefly explored.

Overview

The HP 2680A is Hewlett Packards first page printer. It is based on an electrophotographic process which was licensed from Canon, a Japanese firm. The printer was designed and is manufactured by the Boise division in Boise Idaho.

Several key objectives were established at the start of the program. Reliability, flexibility, features matched to 3000 user needs, simple powerfail and paper jam recovery, very low CPU overhead, and the ability to access the printer and its features from existing programs without modification became the primary objectives of the development effort.

From the beginning the printer was designed as an extension of MPE, not an added on peripheral. This tight coupling yielded a fully integrated printing system that is fully supported by the MPE file system and spooler. In addition a powerful subsystem exists which allows complete character set and forms design. Flexible page formatting and a full complement of intrinsics provide access to all printer features.

By fully integrating the printer into the 3000 simple and reliable power fail and paper jam recovery is realized. All these benefits were achieved while the CPU overhead to drive the printer was reduced an order of magnitude from that required to drive conventional printers at comparable data rates.

Hardware

The 2680A is approximately 5.5 feet long, 2.5 feet deep and 4 feet high. It weights about 875 pounds. Power requirements are 4500 watts when printing. Throughput is 45 8.5 by 11 inch pages per minute. The equivalent lines per minute speed is 2900 lpm ranging up to 12000 lpm in reduction mode.

The paper path is short and readily accessible to the operator. It features a powered paper stacker. The fusing system is radiant, eliminating any pressure or high temperature rollers. Nothing contacts the upper side of the paper once the image is transferred from the drum to the paper, contributing to excellent reliability. The web is pulled by a programmable torque motor on the output tractors, and paper motion is gated by stepper motor driven input tractors. A solenoid powered retraction mechanism pulls the paper away from the drum when the seam

on the drum comes around. The input paper platform acts as a splice table; a vacuum is used to hold the paper onto the table when splicing a new box of paper onto the end of the previous box. The paper path can accomodate various widths up to 12.5 inches and lengths up to 17 inches. A width sensor on the input tractors allows the printer to energize only the correct width in the preheater section of the fuser. Paper which is heated produces odors, which are trapped and oxidized in replacable filter cartridges.

The image forming process is electrophotographic. The heart of the system is a photoconductive drum about 19 inches in circumference and 14 inches long. The drum is coated with cadmium sulfide and wrapped in mylar for protection. The drum is uniformly erased and then charged to several hundred volts at the first station. The laser is then scanned across the drum perpendicular to the direction of rotation. The beam is modulated to give 180 dots per inch resolution. There are 2048 dots in one scan line, giving a printable area 11.38 inches across. The drum rotation allows the sweeping laser beam to cover an area 17 inches long. The circular dot is about .008 inches in diameter on a grid .0055 inches square. When the laser beam hits the drum the voltage is depleted. Next the drum rotates past a cloud of fine flour-like black plastic. The plastic toner is attracted to areas of no voltage by electrostatic forces. The pattern traced by the scanning laser beam is now visable as a sharp black image on the drum. Finally the paper and the drum are brought together for about 1 inch of tangential contact. The paper is correctly charged to firmly attract the toner off the drum. The small amount of residual toner not deposited on the paper is then scraped off of the drum by a urethane wiper blade and collected by a vacuum system. As the drum turns these processes are executed simultaneously at different stations around the drum.

In order to achieve high print quality over a wide range of ambient conditions the HP 2680A has two closed loop control systems. The electrostatic control system monitors the potentials on the drum just after the laser station. The voltage is measured both where the laser exposed the drum and where it did not. The microprocessor taking the measurements then controls several programmable power supplys to maintain the correct drum potentials. The readings and ajustments are made once per drum rotation. The electrostatic closed loop compensates for variations between replacement drums, drum degradation over time, humidity, temperature and altitude variations, and toner mixture fatigue.

A second closed loop system monitors the developed image on the drum to control print density on the page. By varying the amount of toner in the developer assembly which brushes the toner mixture across the drum the amount of toner on the drum and hence the final print darkness on the paper can be controlled.

The mechanical features of the printer were designed to be simple and reliable, and the operator functions are easy to learn and execute. A vacuum system in the printer contributes to cleanliness. It is used to recover toner wiped off the drum. It also is used for the splice table and to maintain good contact between the preheater pad in the fuser and

the paper. The operator loads a fresh kilogram of toner into the machine about once every eight hours of printing. Unused toner is collected with the vacuum system, trapped centrifigally and deposited in a disposable bottle which is replaced every couple of days. A new box of paper is loaded every hour. The new box can be conveniently spliced onto the end of the previous box or the new box can be easily loaded with the THREAD button.

There are two microprocessors in the HP 2680A. One is a 16 bit HP proprietary SOS device which controls all machine functions such as the operator keyboard and alphanumeric display, the paper path, the closed loop systems and internal diagnostics. The second processor is a high speed bi-polar bit slice processor which communicates with the 3000 and performs all processing on the data stream and ultimately modulating the laser beam to form the correct images at the proper place on the drum. This processor uses 256k bytes of RAM, with a second 256K available as an option. Approximately 40K bytes of this memory is used for tables and buffers, the remaining memory is partioned dynamically during each job for character sets, forms, and page buffering.

Extensive internal diagnostics constantly monitor the state of the machine, alerting the operator if a service engineer should be called. When arriving on site the service engineer can use additional internally contained diagnostics to troubleshoot any problems. A very complete self test program is available which prints many important parameters on the machine itself. Data such as serial number, drum rotations since last PM, firmware datecodes, and all operating values are labeled and printed. The printer contains a limited amount of nonvolatile memory.

Programming Features

Page printers, even with their inherent benefits of high thruput, low noise and exceptional print quality are rarely viable as simple print and space devices because of their higher cost. However the HP 2680A is a cost effective replacement for many line printers. This is because of the flexibility and features of the printer. Electronic forms allows the inventory of costly specialty forms to be eliminated. Long lead times and form modifiation costs are reduced to a few hours on a terminal. Definable character sets allows the printer to be used in a wide variety of industries and applications where conventional printers are useless. In addition the print quality and crispness in conjunction with the 8.5 by 11 inch paper size means HP2680A output never needs to be copied or reduced before general distribution.

The HP2680A implements a concept called logical pages. A physical page is a sheet of paper bounded by perforations. A physical page can be divided into up to 32 rectangular areas called logical pages. Logical pages can overlap. A programmatic command to page eject moves the print to the next logical page. If all logical pages have been used, the printer goes to the first logical page on the next sheet of paper. Each logical page has several attributes such as an associated vertical format control (VFC) table, a default line spacing, and one of four orientations. In addition each logical page can have up to two forms

associated with it. When the logical page is printed the forms are automatically overlaid by the printer. Several logical pages can share the same form and VFC, the printer will automatically relocate it to the correct origin for each logical page. Logical pages are a powerful concept which particularly supports existing programs. By defining the logical page format an existing job can have its output reduced two to 1 or four to 1 or rotated without even recompiling the job. Additionally a job which currently uses preprinted forms can be switched to run on the laser printer without modification. The existing form is converted to electronic format and then the corrsponding logical page is defined to use the form. The job is then printed on the laser printer and the data is merged with the form and printed.

The electronic forms capability is designed for maximum flexibility. Each form can contain horizontal and vertical lines of varying thicknesses, text written with any number of fonts in any of the four basic directions, plus areas or boxes of variable shading. Form elements can be positioned anywhere and are not restricted to certain character positions on the page as a "draw set" is. The printer can support 32 different forms simultaneously. Each logical page can use up to 2 forms as long as the total does not exceed 30. Additionally each physical page can be overlaid with up to 2 forms. Enough memory and processing power exists to create a form which is a dot per bit image of an 8.5 by 11 inch sheet of paper. Forms are easily created for the printer using an interactive program called IDSFORM.

The HP2680A printer accepts user defined character sets. Each character set contains from 1 to 128 characters. Each character has an associated cell of a specified size which contains any dot per bit representation desired. The spacing between characters and between lines can be set to any value. A character set can print in any of the four directions. Proportional character sets are supported. In this case each character has a parameter describing how far to move over after printing each character. The printer also allows the cells to be printed in any relationship to the current "pen" position. This allows centered symbols, or common base lines so different character sets can be mixed properly on a single line. When using more than one character set a primary and secondary set are defined and then selected with either shift in, shift out control codes or by setting the eigth bit of the ASCII code. HP supplies a large number of character sets of various fonts and sizes. In addition character sets and logos can be created interactively by terminal users via IDSCHAR.

Thirty two user definable VFC's are supported by the printer simultaneously. They are easily created with the IFS2680 program.

One additional feature was implemented to allow easy emulation of multi-part forms. When activated each physical page of data will be repeated up to eight times by the printer. As each copy of the page is printed, the printer will automatically overlay any two forms on the page. In this manner the same data can be repeated up to eight times, but each copy can be individual addressed to shipping, purchasing, order processing, etc.

These basic data structures provide a wide range of user features. When combined with the ability to place cells anywhere on the page and overlap at will plus the processing power to handle over 20,000 characters on an 8.5 by 11 inch sheet a truly unique printer results. The maximum number of cells on any raster scan is 255. As the cells get larger, fewer can be printed simultaneously. Character set switching, forms overlay and other features all occur at speed.

The printer's memory is allocated by a memory manager on a job by job basis. Approximately 40K bytes are used by the printer, the remaining memory is allocated to character sets, forms, VFC's and page buffering. As much memory as required is allocated to the user's character sets, forms and VFC's. All remaining memory is used to buffer pages in an intermediate linked list structure. More page buffering insures that pages are printed at speed. Insufficient page buffering causes a lower thruput rate. The programmer can add or delete character sets, forms and VFC's during the job.

Environment Files

All character sets, forms, VFC's and the logical page table and the multicopy forms table are placed in an environment file by a terminal user running IFS2680. This file is then sent to the printer at the start of a job automatically. This allows the output of a job to change appearance by changing the environment file or portions of the environment file. For example if the character set in an environment file is changed from elite to pica the next job to use the file will have output printed in pica. By simply changing the logical page description and substituting a smaller character set a job can be made to print in a 2 to 1 or 4 to 1 reduction mode. HP supplies several standard environment files to cover portrait mode pica and elite, landscape 132 column printer emulation, two to one and four to one reduction. The user can easily create additional environment files.

For new application programs the full power of the printer is available through HP supplied intrinsics. The intrinsics allow features such as writing a string to a named field on an electronic form. The form can be redesigned and rearranged without modification of any programs using the form. The data will automatically be placed in the correct field wherever it is on the page. Intrinsics also allow the pen to be moved, new primary and secondary character sets to be selected, any logical page to be turned on or off and other similar features.

System Software

Extensive system application software allows creation of character sets, forms, VFC's as well as the definition of logical pages and multicopy forms tables.

IDSCHAR provides menu driven interactive creation of character sets on graphic terminals. The program can emulate various shaped dots and grid spacings. The laser printer has round dots about 8 mils in diameter on a 5.5 mil grid. IDSCHAR also supports a digitizer to allow

easy input of character or logo outlines. The outline can then be scaled and presented superimposed on the cells grid for easy filling in. IDSCHAR supports lines, arcs, rectangular area fills plus scaling and rotation. Special logo files are supported for use on forms. An experienced graphics designer can create a complex logo in 1 to 4 hours. Generating a high quality character set takes about 40 hours.

IDSFORM provides menu driven interactive forms creation of forms on graphics terminals. It supports horizontal and vertial lines of 3 different thicknesses. Boxes can be shaded from clear to black. IDSFORM supports subforms which can be defined and then easily moved around both on the page and between different forms. Windows describe boxes consisting of headers and data fields. Data fields can be labelled to allow symbolic access allowing the form to be changed around without modifying the program. The 1040 tax form was perfectly emulated in 14 hours by an experienced user of IDSFORM.

IFS2680 is the formatting program which bundles up different character sets, forms, VFC's and a logical page table into an environment file. IFS2680 also is the program which constructs VFC's and the logical page table for the user. Overall job parameters such as the number of copies of each page desired and the multicopy forms table are specified via IFS2680. HP supplied standard environments are available from IFS2680 either as they stand or as a base to begin creating a unique environment for a special job.

A contributed program called TR2680 which interprets commands imbedded in ASCII files is available. Text editors can be used to prepare memos and reports with the imbedded commands to utilize HP2680A features such as multiple character sets, forms overlay, pen moves etc.

Once an environment file is created it is specified with a new option in the file equation :FILE PRINT;DEV=PP;ENV=FOURTO1. The environment file is automatically placed in the spool file before the data. This allows existing programs to use all of the features accessible via environment files without modification.

Power fail and jam recovery are very simple and reliable. Non volatile memory exists in the printer. When power resumes the 3000 retransmits the job from the beginning at high speed. The printer processes the data and resumes printing at the correct point in the job. The only operator invention required is to insure top of form is correctly aligned and push run. Paper jams are similar. If no paper was damaged the job can be resumed without system intervention. If the operator wishes to backup several pages the spooler is suspended, the jam cleared, and the command :RESUMESPOOL LDEV#; BACK 5 PAGES is used. This allows backing up or skipping forward an arbitrary number of pages.

Another unique concept introduced with the laser printer is the error trailer. When a program executes an illegal function such as selecting a missing character set, moving the pen off of the logical page or trying to print a character off of the logical page the printer relays this information to the 3000. This information is then printed out at

the end of the job before the trailer is printed. The error trailer describes the error in english, along with the record number and actual page number where the error occured.

Distributed Printing

MRJE has been modified to support HP2680 environment files. If the device class is PP for page printer and the forms field is not empty then the forms identifier is used to locate an environment file.

RJE has an option which allows the translator procedure to process each record when received by the 3000. This allows complete access to the printers features from a mainframe.

One internal test site is running a Series 30 to front end the laser printer. They are printing over 130,000 pages per month. One half of the output is generated by an Amdahl 470 and sent at 9600 baud via MRJE.

At 2900 lpm the printer taxes the performance of most data communication systems. System configuration, CPU overhead and data format determine the printer utilization. The range can be from 10% to 100%. We are currently quantifying printer performance in these areas and welcome user inputs and insights.

Summary

The HP2680A laser printing system provides a cost effective solution to many computer output problems for HP3000 users. The reliability and servicability contribute to its low cost of less than 4 cents per page at 200K pages per month. The unmatched features provide capabilities unique in the industry. The complete software appliation package allows immediate turnkey solutions with no programming. The impact of the laser printer in the distributed network is significant and allows non HP systems to utilize the printer as well as enhancing distributed HP systems.

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** END OF FORMATTING, NO ERRORS
   IN=EDITOR WORKFILE, TEXT FROM PAPER
   OUT=*LP
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