THE 501 High-Speed Printer is an output device of the RCA 501 Electronic Data Processing System. This system is fully transistorized. It is expandable in both the area of the high-speed memory and the input-output devices. In the specific case of the High-Speed Printer, this expandability takes the form of optional use of the printer mechanism either as an on-line device or an off-line device.

Initially, the 501 product plan was to design and produce a minimum cost EDP system. Therefore, the first printer specifications called for on-line operation with the printer being driven directly by the computer. This accomplished two things. It held the cost of printer electronics to a minimum, but still allowed the system to have a high-speed output capability.

Subsequent product planning developed the need for system expandability, that is, a system which could be enlarged at the user's convenience if the work load increased. To meet this requirement, a program was also started to design buffer electronics to allow the printer to be run directly from magnetic tape—off-line.

Fig. 1 shows a scale model of a basic RCA 501 system. Information is entered through the paper tape reader at 1000 characters per second. Printed output is available from either the monitor printer or the on-line printer. Fig. 2 shows an expanded system with provision for punched card input and output and additional magnetic tape storage. The High-Speed Printer is now an off-line device with buffer electronics permitting it to operate from magnetic tape.

The specifications set up for this printer were that it should be capable of printing at least 600 lines per minute with 120 columns per line. It should be capable of producing at least an original and three carbon copies, offset masters and ditto masters, and contain the necessary logic to be applicable in all types of format printing. Not an integral part of the design specifications, but perhaps most important over-all, were the criteria that the printer should be low enough in manufacturing cost, but high enough in performance so that these factors alone could ward off early obsolescence. A corollary to this was the fact that the length of design cycle must be held to a minimum and the design cost should be reasonable.

The mechanism selected for the printer was of the "flying wheel" variety. Basic techniques employed in printers of this type are well known, therefore we shall only dwell on the functional aspects that illustrate the product development.

Fig. 3 shows a flow diagram for the on-line printer. Information to be printed is stored in the high-speed memory of the computer and the format is controlled by a program in the computer program control. The memory contents are scanned and a line is printed with each revolution of the print wheel cylinder. Synchronization of the memory and the character identity coming into position to be printed is accomplished by a photoelectric code disk assembly, mounted on the same shaft as the print cylinder. The coded bits emerging from this disk are mechanically phased with respect to the character they represent on the print cylinder. This allows sufficient time for a particular character to be compared for its occurrence in the computer's memory and if it exists, a bit is placed in the shift register corresponding to the proper print column. A clock pulse from the computer then causes printing of this character identity. The process is continued until the computer memory has been examined for all 51 possible printing characters. The computer next generates a sig-

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nal indicating the amount the paper should be moved, and upon receipt of a return signal indicating that the paper has been moved, the entire process is repeated.

Fig. 4 illustrates the off-line operation employing suitable buffering logic. The buffer unit is designed to accept one line of information at a time, from magnetic tape, store it temporarily, and then print it out. The line is stored in a core memory, the input to which consists of a coincidence between character identity and column location. The memory is clocked out by the photoelectric code disk assembly as each character identity comes into print position.

Printing is normally accomplished in an asynchronous manner. That is, provision is made to determine when all character identities to be printed on a line have been printed. Upon receipt of this signal, another line of information is immediately read in from magnetic tape as the paper is shifted. In this manner, basic printing speeds may exceed 600 lines per minute reaching as high as 900 for numeric printing. The logical circuitry in this area also serves as an accuracy check on the number of characters printed vs the number of characters which should have been printed.

In order to control the printed format, several features have been incorporated. First, by means of a plugboard, incoming information may be tabulated to any of 24 predetermined positions; this same feature may also be used to delete information which is not wanted. It is also possible to effect multiple printing of the same data on one line, again by use of the plugboard.

Fig. 5 shows the printer mechanism, which is used for either the on-line or off-line operation.

Now that the printer has been described, the following discussion will outline some of the factors which influenced the product design.

The need for economical high-speed printers for computer output has persisted. Both the electronic and electromechanical printers were considered at RCA. From an economic and state-of-the-art point of view, the electromechanical seemed more promising. Rotary wheel printers (Fig. 6) looked to us to be the best compromise as far as simplicity of mechanism and high printing speed are concerned. The earlier equipment was designed using mechanical printers of this type. Since we already had experience with this type of printing mechanism (certain problems were known to be problems) the new product development for the RCA 501 system consisted of refinements and improvements in the techniques. We already knew how to make good print wheels, and how to be consistent with the solenoid fabrication, and were familiar with the many other necessary techniques.

An area that we felt needed some investigation was that of high-speed paper shifting. At the time the project was initiated, we had a development design of an electromechanical detent spring clutch which gave promise of very high-speed paper shifting. We found, however, that a magnetic clutch, suitable for paper shifting, though not quite as fast, was already commercially available, and so it was adopted.
In order to appreciate the problems involved in fabrication of the print solenoids let us examine for a moment the general concept of print quality. Admittedly, this is a subjective type of thing and depends primarily on the ability and the resolving power of the human eye.

We have found, for example, that it is possible to detect a vertical misalignment of about 0.005 inch between adjacent characters in a line of print without much difficulty. In the conventional typewriting or typesetting, where similar misalignments occur more frequently in a horizontal direction, the effect is not generally displeasing. People are more familiar with this type of printed copy, and they usually accept it without notice. However, they detect any vertical misalignment quickly and question its reason for existing.

Fig. 7 shows the word “link” in which the $i$ is 0.005 inch above a line and $n$ is 0.005 inch below the line with $l$ and $k$ on a line. Here, also, you can see the irregular horizontal spacing in the top word, a design requirement of wheel printers. We readily accept this difference in spacing because of the differing widths of letters.

Obviously, vertical misalignment is a normal consequence of rotary wheel printers which must be minimized. The primary way in which this is done is to ensure that all 120 solenoids are as near alike as possible both electrically and mechanically.

From an ease of manufacturing and of maintenance standpoint, we would have liked to have placed the print solenoids in two banks, one on each side of the print wheel center line, that is, 60 per side, so that all the solenoids would be similar. However, the problem of getting enough energy into and out of a solenoid, which is only 2/10 of an inch thick, without crosstalk, resulted in a design compromise of two banks of solenoids on each side. We found that with the two-bank design, we could assemble and pot the solenoids in groups of five. Fig. 8 is a representation of the solenoid area of the printer.

The potted assembly of five solenoids is machined in a single operation so that the tolerances can be held. This technique is similar to that used in fabricating digital magnetic recording heads. By this means, we are able to make a good solenoid economically with the correct tolerances built in, thus eliminating later assembly adjustment. Fig. 9 shows the solenoid area with a view of an individual unit.

Another area of investigation centered in the code disk. This assembly has the function of establishing the angular position of character on the print drum and translating the character into coded notation. The code disk has perforations corresponding to the 7-bit code used in the RCA 501 system. Fig. 10 shows the code disk area.

Here we were able to affect manufacturing economies by photo etching through a plate to obtain the coding. The logic of the on-line and off-line printers is implemented with circuit boards of standard configuration. Most are the same board types used elsewhere in the system (Fig. 11).

The use of standard plug-in packages, plug-ins that are also used in the computer and the rest of the units of the system, also helps to keep manufacturing and service costs down.

Design for simplification and ease of field maintenance meant that the logic should be straightforward and easy to understand. All necessary adjustments should be in convenient locations and the mechanism should be designed in modules which are easily replaceable, such as the print drum, ribbon drive, and paper shift assembly. In the on-line case, a small maintenance panel simulates the computer so that the unit can be serviced independently without tying up the rest of the system.
A Digital Computer for Industrial Process Analysis and Control

EDWARD L. BRAUN†

INTRODUCTION

Among the more important reasons advanced for the relatively unexploited use of digital computers in industrial process control systems are 1) a lack of knowledge concerning process dynamics, 2) inadequate development of computers engineered for and suited to process control applications, and 3) inadequate reliability of current digital computers.

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Our purpose here is to describe a computer which has been designed specifically for industrial process control applications. It promises to satisfy reliability requirements, and can be of great utility even in the absence of complete information on the dynamics of a process. This type of machine can be used for either one or both of the following major functions: It can be used to advantage in the quantitative determination of the effects of different controllable parameters on process performance and also as a process optimization control computer.

CONCLUSION

In the computer field, the major problem encountered in product design is time. The technology is advancing at a rate which constantly makes new products obsolete in the design stage. The product design team must carefully weigh the technological advances which can be incorporated in a design against the need for production release so that the device can be made ready for sale. To insure that the product design remains saleable, the following three items are basic. First, the design should be functionally good. Second, it should be reliable, and third, it should be reasonably priced. When these characteristics are achieved in a product design, regardless of technological advance, the product will not become obsolete—it will remain marketable.