Computer Production Automation in Embroidery Factories[1]

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Abstract: In embroidery factories the designs (artist concept) are coded on punch paper tapes. The punched paper tapes are mounted on needlework machines to produce the final products in multiplicity (lace, in-wrought textile etc). In this paper it is described a method to replace the paper tapes usage, by a data acquisition system controlled by a personal computer. This has multiple benefits in the various production stages that lower the production cost, improves the required production time, the production scheduling, the quality, and the monitoring process. Furthermore this computer automation can facilitate the reinforcement of composites structures[2] and tailored fiber placement to minimize stress concentrations[3].

Marios Hatziprokopiou was born in Greece in 1945. He graduated from New York Institute of Technology, New York USA in 1974. He pursued a Master's degree in Electrical and Computer Engineering, graduating from S.U.N.Y. at Buffalo in 1976. In 1981 Mr. Hatziprokopiou took his Ph.D. in Electrical and Computer Engineering at S.U.N.Y. at Buffalo, USA. Since 1989 he has been a Professor at the Technological and Educational Institute of Patras, Greece. During his career he has taught the following courses in English or Greek: Digital Control; Advanced Vacuum Techniques; Power Electronics; Digital Electronics; Design of Computer aided Electronic circuit and Simulation. He published the following books: Computer aided Electronic circuit design and simulation 1996 (Papasotiriou, Amazon publishing); Introduction to Computers and Telematics 1997; Excel and its Advance capabilities 1998; Office Automation 1999.

1. Indroduction

In embroidery factories the needlework production of designs is realized through mostly old, mechanically operated machines, capable of producing multiple pieces (400 copies simultaneously). The means of driving those machines is a punch coded paper tape. Each paper role represents a design (average length for a medium size design is 400 meters). The use of the paper tape significantly deteriorates the production cost since it has many disadvantages:

- Transportation cost. Significant storage space, before and after hole encoding.
- Extensive time required for punching the hole coding (6 hours on average).
- Inefficient classification and retrieval of designs.
- Deterioration due to transportation conditions, insect penetration into paper holes, dust accumulation, moisture sensitivity, and a lifetime of approximately six to ten uses.

The proposed method automates embroidery factories, with the aid of a computer and appropriate building of hardware and software, which eliminates the use of paper punch coded tape as a mean of driving embroidery machines and its substitution with a standard electronic file, stored in a diskette readable by an IBM compatible PC. Consequentially, not only is the cost significantly reduced and data reading process of a design accelerated, but also the possibility of error is virtually eliminated. Furthermore, possible errors can be corrected very fast, the classification and finding of a design is dramatically improved, and the production scheduling of many embroidery machines could be done through the PC RS-232 port or the standard Windows network, if the appropriate card is added.

It should be noted that this system was installed in the largest embroidery factory in Greece, located in a rural area where the presence of qualified operators is practically at a minimum and the budget is limited. The above restriction dictated that the data presentation had to be very similar to those used by the paper tape, so that it can be used from untrained operators. Furthermore the system guaranties compatibility with the old paper tape, so that the old designs can be used, and in the case of failure, it can be switched immediately to use paper tape. Dedicated software was developed to convert old designs. Lastly, it should be noted that there was no technical information either on the hardware used, or of the hole coding on the paper tape. Information was extracted only from visual inspection and oscilloscope measurement.

2. Historical Overview

Embroidery production was one of the dominant sectors of the Greek industry. Their products are characterized by their authenticity and variety of ideas, and could be categorized as textiles and needlework. The last decade this important sector lost its leading position due to machine wear, lack of modernization, increase of labor cost and lack of qualified operators. Additional reasons were the intense competition from Asian and Latin American countries, which hold a significant market share in spite of their products' mediocre quality. However, they exhibited a low production cost since they modernized their equipment and automated the line production methods (know-how transferred from USA), not to mention the low cost of raw material and inexpensive labor cost. Those reasons put this industry sector in a difficult position with respect to the International market[4]. The production process could be characterized in two phases:

a. Design creation and paper tape production in which the design is coded as a group of holes.

b. Reading of the paper tape (coded with holes) by the embroidery machine and design production on the cloth. The produced design corresponds to the embedded coding of the group of holes produced in the previous stage and are shown in the next illustration.

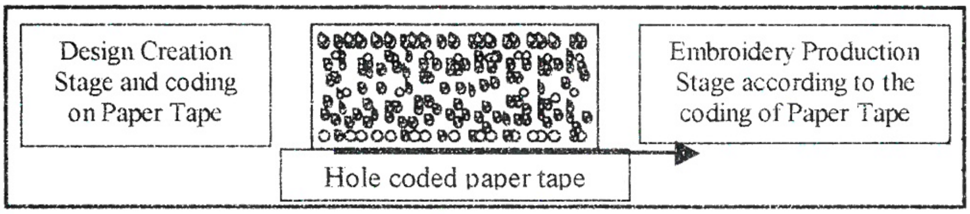


Figure 1. Production stages (Graphical representation)

3. Design, Creation and Paper Coded Production Stage

The design is produced by an artist and then graphically improved by an HP Vectra running a customized version of AutoCAD. This is transferred on a **digitization board** (linked to a computer running OS-9, Unix) where it is manually digitized with the aid of a special keypad. A typical system overview appears in the next illustration.

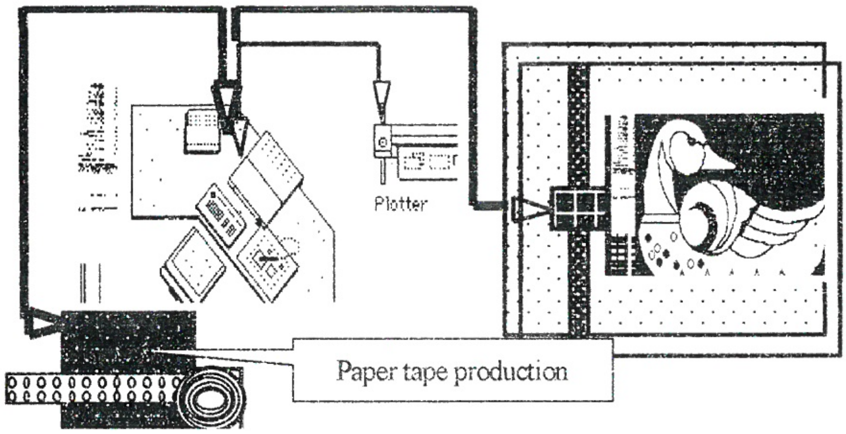


Figure 2. Typical Design Creation Stage

This manual digitization requires an experienced operator with broad knowledge and understanding on how the system and the embroidery machines work. Thus the operator marks every point of the design, in this way coding all the details using click combinations. This process is very long and tedious and a sample is shown in the next illustration.

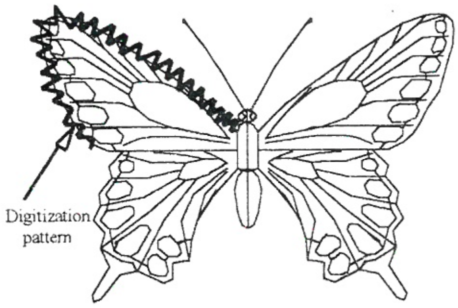


Figure 3. Manual digitization and coding

We could describe this process in the following steps:

- Artist's concept (design),
- Design scan and correction of imperfections, oversize plotting (x12),
- Manual digitization and data collection by a Unix computer and
- Paper tape production, 14 cm wide, coded with holes (design information).

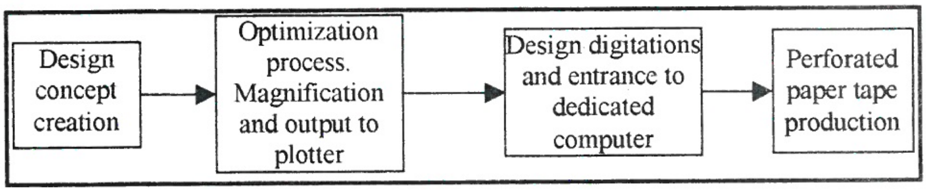


Figure 4. (Block) design creation stages

4. Decoding Interpretation of the Paper Code holes

Observing the holes on the paper tape, and running various tests and trials, the code could be explained and analyzed. In short and with respect to the next illustration we observe that paper tape is divided into five zones **A, B, C, D, A.** Zones **A** (left and right) comprises the paper role moving guides. Zones C contains control command for various operations (signals for the needles, knives and cloth template (in, out, advance etc).

Zones **B** και **D** defines the Horizontal and Vertical movement and in turn they are divided into three rows, every one having a weight factor of one, two and three. Line 3 has the greater weight, line 2 has smaller weight, and line 1 has the least weight Data is acquired line after line. The position of a hole represents horizontal or vertical motion times the weighting factor. All the holes of a line represent the total motion the needle has to travel.

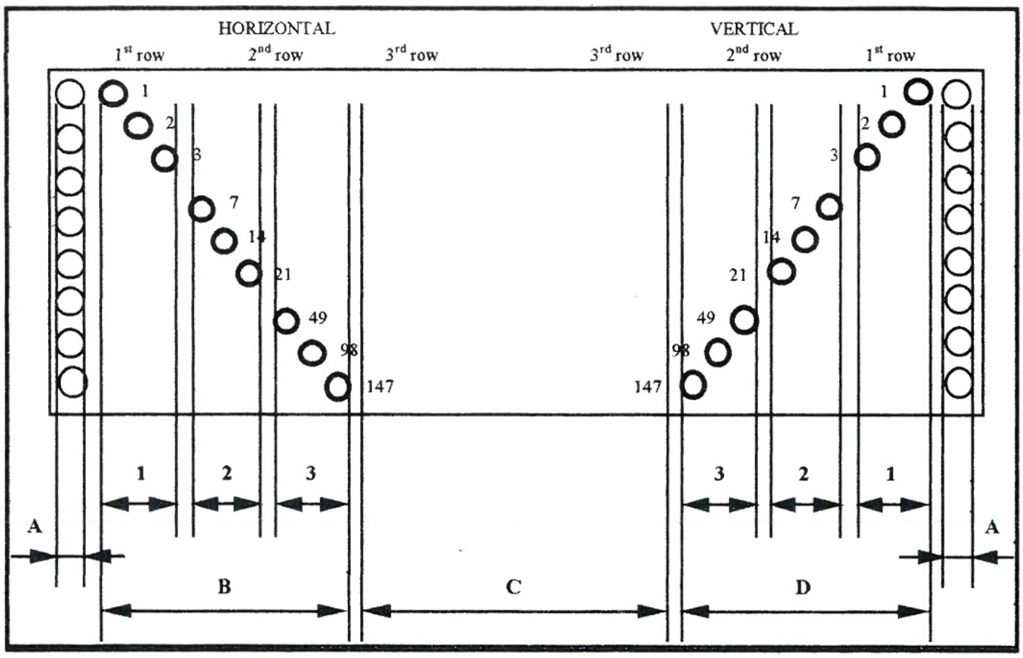


Figure 4. Hole code postion identification

An analytical and complete description of the coding algorithm is given elsewhere[5]. A typical design has a length of 400 meters and every meter has 50 lines.

The maximum number of holes per line is twenty-four.

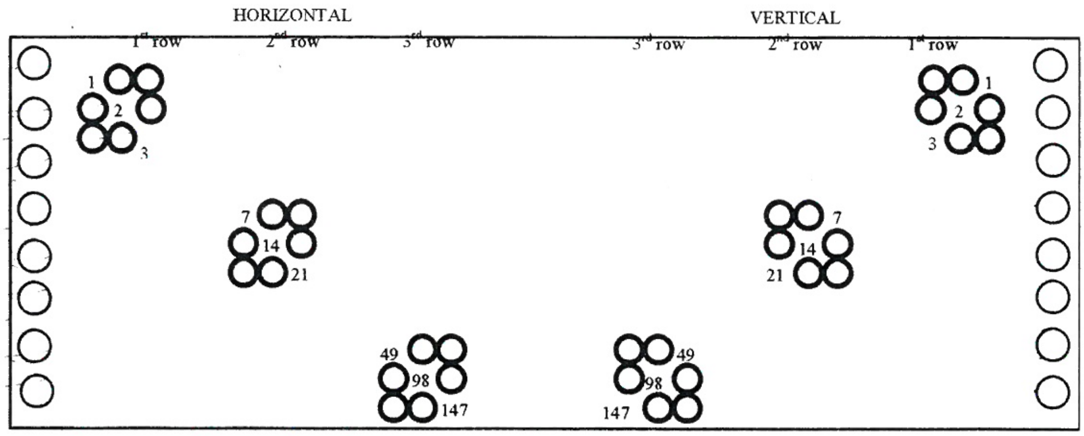


Figure 5. Hole decoding

5. Use of the Paper coded tape to produce embroidery

Now the paper tape is mounted on a mechanical reader that exhibits 24 small metal pistons. A gear mechanism pulls and pushes the paper tape so that contact with the tape occurs. Each piston corresponds to one of the specific locations of the 24 holes. If there is a hole, the pistons pass through, signalling a hole (an arithmetical 1). If there is no hole the piston is pushed back, signalling the non-existence of a whole (an arithmetical 0). In this way the coded information carried by the paper is transferred to the machine in order for the needlework to be produced.

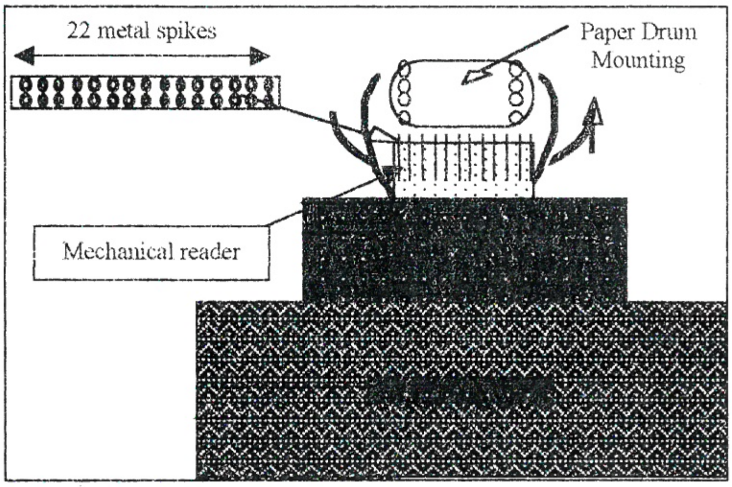


Figure 7. Embroidery machine equipped with the Mechanical reader

Old Method Disadvantages

In order to produce the coded paper tape of the design many qualified persons are required (artist, improvements operator, manual digitations). The next table shows the benefits of the new and old method. The financial benefits of not using paper tape anymore is described elsewhere.

Table1: Required time for the production of a medium size design (400 meters)

Methods	Digitations	Paper tape production	Persons used
Old method	8-10 hours	3 hours	3
New method	1 hour	Not required	1

6. New Improved Used System Implementation

Industry modernization through line production automation with computer aid, is common today, and transition from old to new is a routine process. From the above, it is obvious that one of the factors to improve the system performance is the substitution of the paper-coded tape by an electronic file. Since the code logic was decoded from the preliminary measurements, a collection of hardware-software data was designed to acquire the data from the paper-punching machine.

7. Data Acquisition

The **Data collection system**[6] includes a P.C. equipped with an 8255 microprocessor that offers twenty-four digital (data acquisition)[7] and a Control Box and Electronics Interface (custom made), having twenty-four digital inputs connected with a DB37 connector to the ports on 8255. Every port is optically isolated and connected to a punching relay so that the safety of the computer and the embroidery machine is ensured. When a relay is activated (to produce a hole) a high signal is routed to the corresponding optically isolated channel. The developed software in the PC is dedicated to scan all the 8255-microprocessor's twenty-four digital ports for a low or high condition. When it senses a condition charge it performs a D/D conversion and it stores it in memory. After the entire signals are acquired, it creates a file and stores it on a disk. The correspondence between 400-meter designs is a file of approximately 400 K. The synchronization between the relay punching machine and the computer is guaranteed by proximity switches located at critical points so that the computer collects the exact numbers of the forward lines. The logical process is shown in the next illustration.

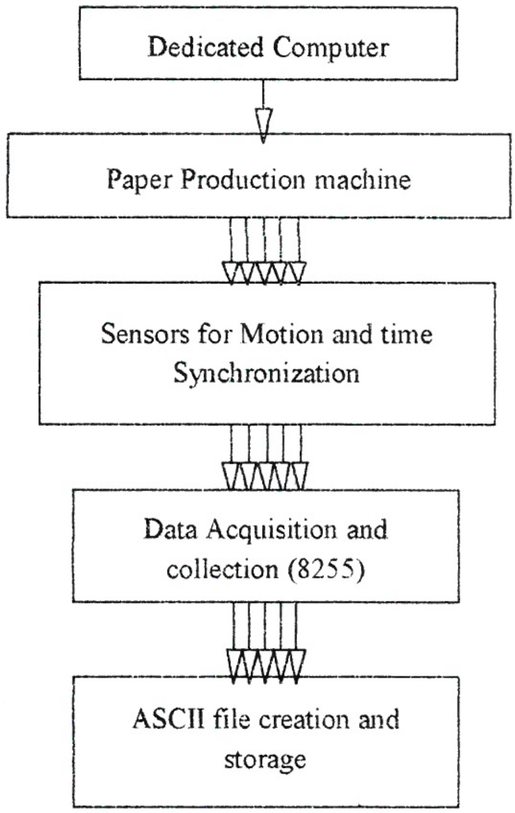


Figure 8. Block diagram of data collection

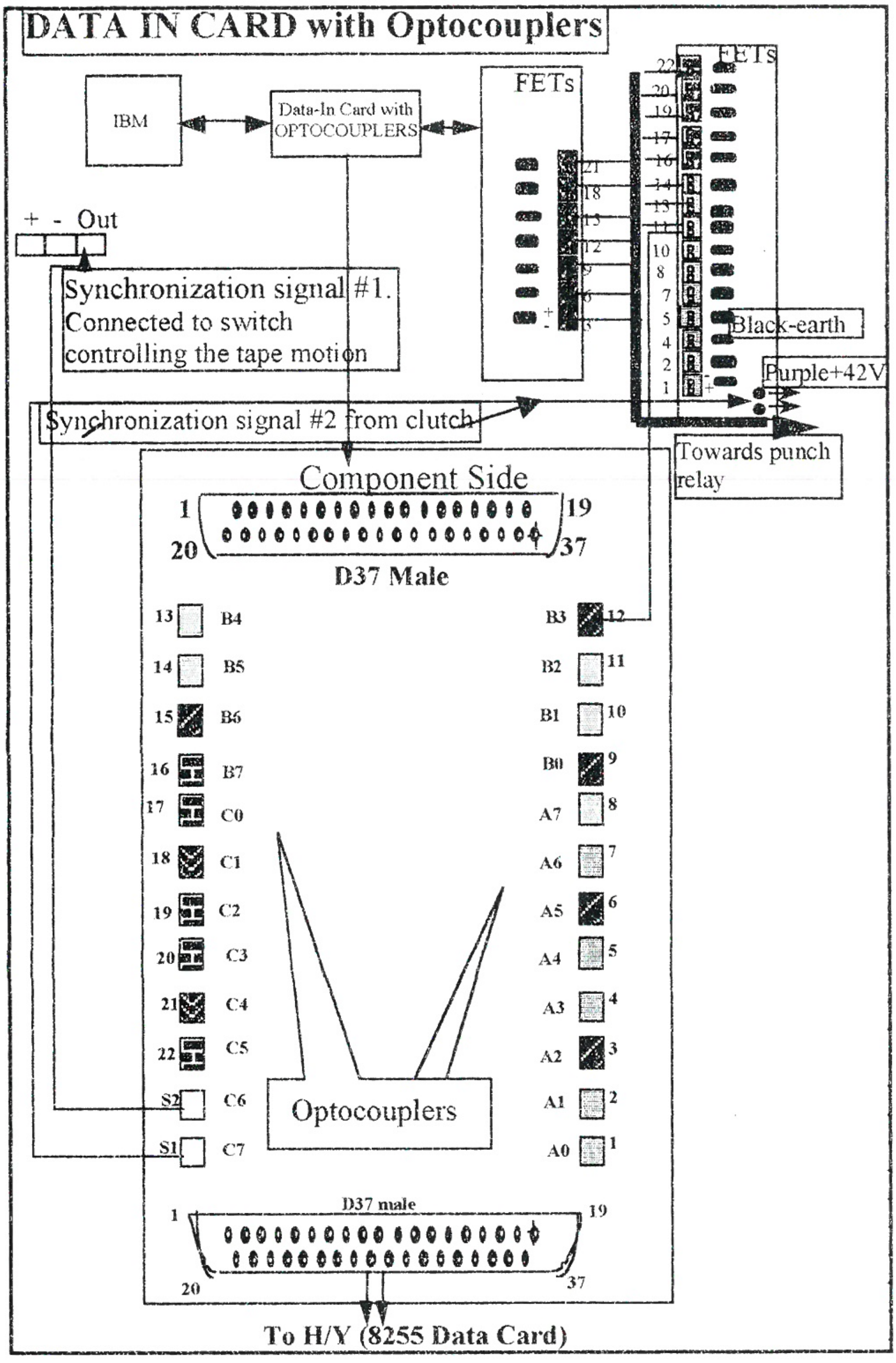


Figure 9. Component side of the Aqusition Electronics and Synchronization hardware

The next illustration exhibits the actual schematics and interconnection for synchronization with the relay-punching machine, the signals from the punching relay to the optocoupler, and the transfer to the 8255 card, which resides in the PC. At the input of each optocoupler a resistor is connected for the necessary voltage drop. Appropriate shielding and necessary noise reduction precaution were used.

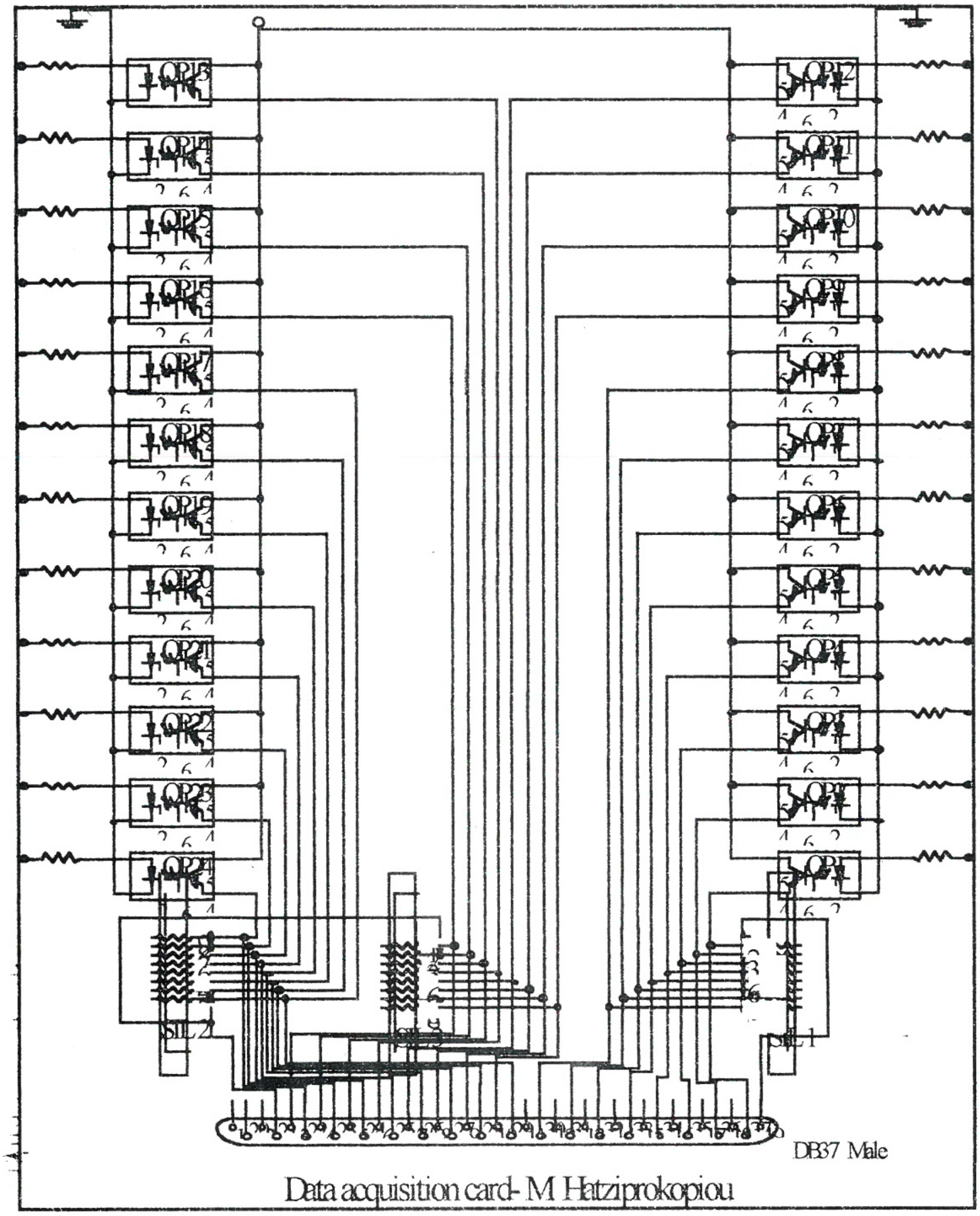


Figure 10. Data Acqusition Electronics Hardware8

8. System Output and Drive of the Embroidery Machine by the ASCII file

Now that an ASCII file has substituted the coded paper tape, the next task is how to drive the Embroidery Machine by this software file instead of being driven by paper tape. We should recall at this moment that the interface between the paper tape and the Embroidery Machine is a mechanical reader equipped with 24 small metal pistons. Those pistons sense the existing or not holes on the paper tape. To transmit the code information that is included in the ASCII file, we have designed and built a device called a **mechanical simulation head**, which is nothing more than a vertical plate on which we have mounted twenty-four electronic relays. The plate is mounted vertically where the paper tape was mounted before and moves in and out as the paper tape does. Inside the relay core an extended shaft passes. The plate is securely mounted vertically on top of the mechanical reader and the length of the shaft is adjusted so that it reaches the 24 small metal pistons. When a relay is activated its shaft is retracted (upwards) and doesn't interfere with the metal pistons. If the relay is not energized its shaft stays extended (downwards) and interferes with the metal pistons. By driving the relays with the ASCII file we can produce exactly the same results as the paper tape. Again we have an IBM or compatible computer equipped with the same 8255-microprocessor card (D/D conversion). Under the software control program the computer reads the ASCII file and classifies the data into memory. When the execution begins it scans one of the twenty-four ports, which is connected to **hall switch** sensors. This port senses the rotation of the motor driving the Embroidery Machine. When a signal is received then the first line of data is exported to the mechanical **simulation head** (logic 1s or 0s from the 8255 digital channels) that is connected to the input channels of the output card. Each channel is connected to one of the 24 optically isolated channels, and each optoisolator drives the gate of an F.E.T. transistor. Each F.E.T. supplies current to the winding relay of the **mechanical simulation head**. The system output block diagram is shown in the next illustration.

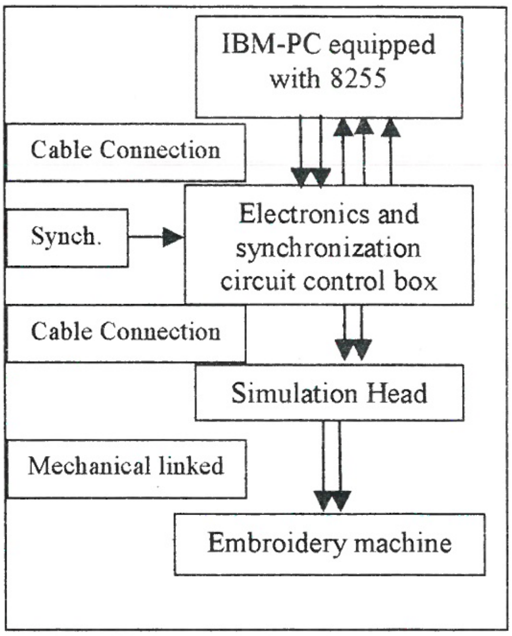


Figure 11. System Output Block Diagram

Next the system idles waiting for the next signal from the rotating wheel. The next illustration shows the computer at left driving the power output card, which in turn drives the **mechanical simulation head** mounted in a vertical position.

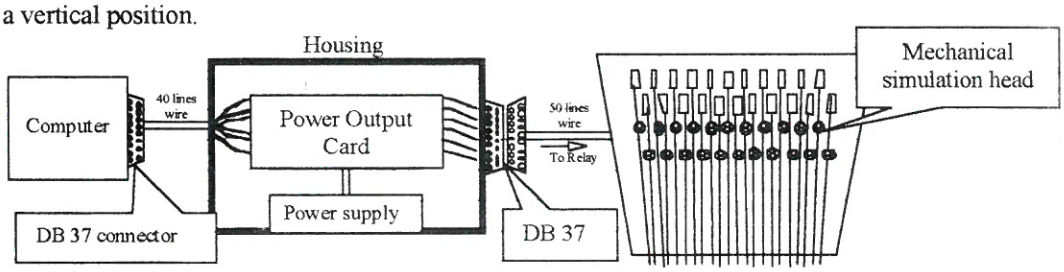
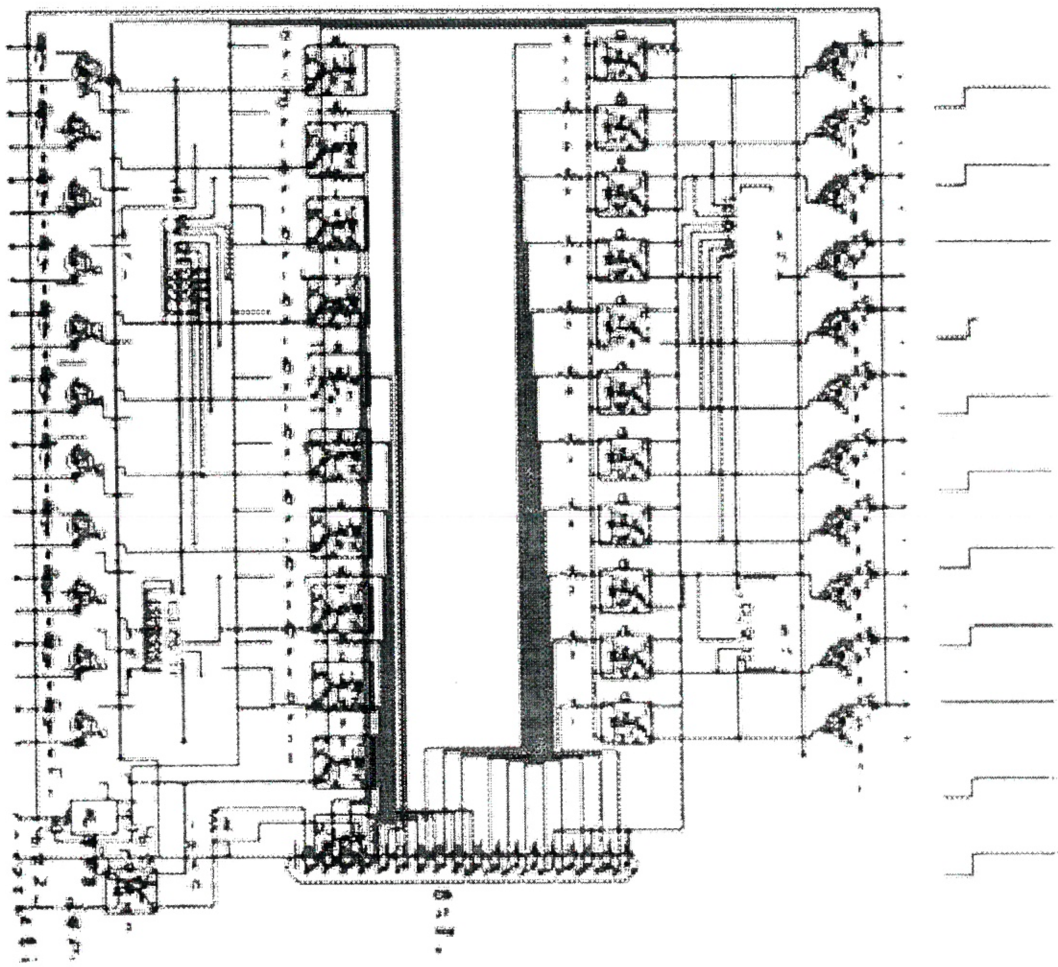


Figure 12. Mechanical Reader Head simulator

The following illustration exhibits the actual schematic of the output card. The computer signals are entered through the DB37 connector located at the lower part. Then they are directed to the optocouplers, which in turn bias the F.E.T. transistors. The winding of the relays is connected for transistor output. Appropriate shielding and necessary noise reduction precautions were used.



9. File Inspection and Handling

The developed software has a dual task: first to collect the data from the punch relay machine and then to drive the mechanical simulation head. Data after collection were presented on the monitor in the form of the image of a paper tape. One of the major issues was the capability of file post processing, particularly when an error occurred during the digitization phase. To confront this problem a software editor was developed, giving the operator the capability of altering the file, i.e. adding or removing lines or even changing the holes to no holes (1s to 0s or vice versa).

10. Networking

Since the factory has approximately fifteen embroidery machines, after the successful operation of the first machine, it was an easy task to interconnect the others with the computer located in the design office through RS232 (serial lines) and later with network cards added to each PC. This gave the possibility of advance scheduling of design production over long periods of time (a week or a month). Longer periods were considered practical due to frequent changes and modifications. The next illustration demonstrates the factory network connection and production scheduling.

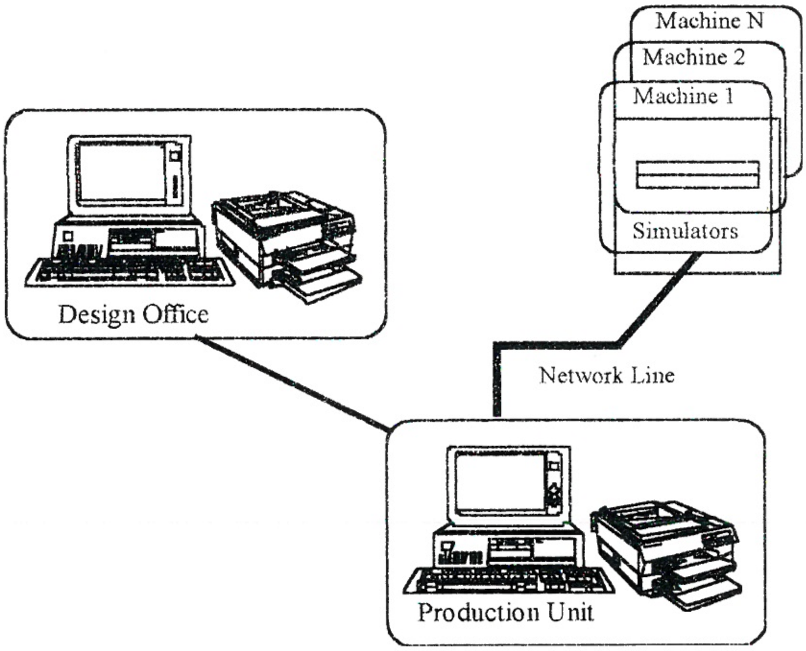


Figure 14. Network connection and production scheduling

Summary and closing remarks

The described method automates the embroidery production by replacing the coded paper tape with an electronic file. This has many benefits besides the economical cost of acquiring the paper tape. It also offers great speed improvement during the design data collection, error minimization, convenience in the classification and retrieval of designs, and post processing correction capabilities. Furthermore, taking into consideration that the factory has a total of fifteen embroidery machines, design production scheduling could be achieved through the computer serial port or the network Ethernet network.

REFERNCES

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