E. R. Wyma

A Three-Dimensional Printed Back Panel

Abstract: A new design for interconnections of printed circuit packages in the IBM 608 Transistorized Computer is described. The three-dimensional arrangement for connections among circuit cards is shown to be flexible in design and adaptable to a highly mechanized manufacturing method. An arrangement for automatic cabling is discussed briefly. The various relationships among the design problems for circuit packaging, back panel connections and cabling are shown.

Introduction

The successful application of printed circuit techniques to complex computing machines involves two important problems: the design of individually printed circuit cards for economical mass production and the interconnection of these printed circuit packages. In a recent transistorized computer the printed cards terminate on a back panel for a large number of circuit connections. The purpose of this paper is to show how the three-dimensional printed circuit concept was developed to satisfy requirements for flexible design of the panel and to permit highly mechanized production of the connecting device.

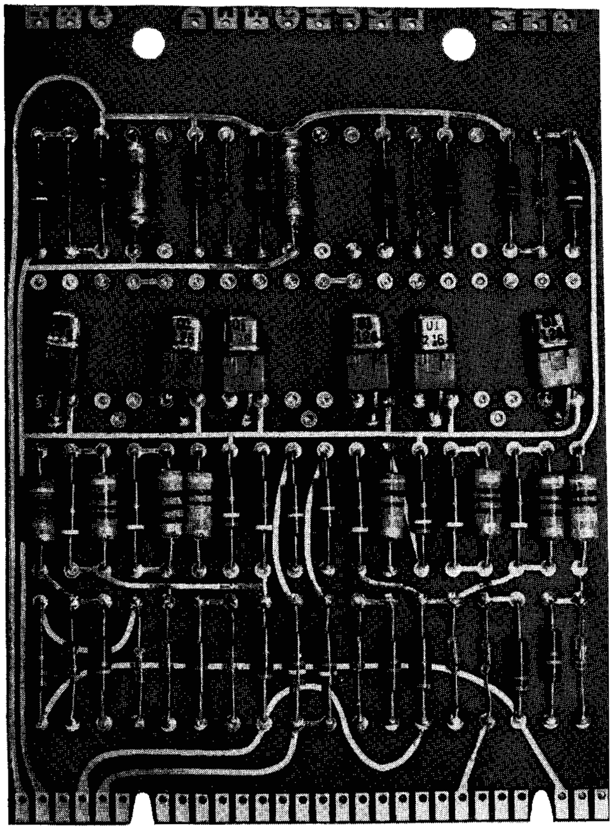

Figure 1
Etched component card for IBM 608.

Back-panel design requirements

For the development of the computer the circuit package shown in Fig. 1 was selected. This package, consisting of a printed card, with components lying in a plane parallel to the card, contains a number of functional circuits interconnected to form a logical circuit module. This package has a rather high mechanization potential. All the component interconnections are accomplished in one manufacturing process. The insertion of the components can be mechanized and the resulting assembly dip-soldered to effect multiple circuit connections. Through optimum layout of circuits on the cards, this technique keeps the number of different assemblies to a minimum, thereby creating a rather high usage of individual parts and enabling the production of a volume part.

All input and output signals, as well as service voltages, connect to the contact pads shown at the bottom of the card in Fig. 1. The cards are inserted into sockets containing mechanical spring contacts that mate with the tabs of the card. The spring contacts are attached to three barrels that protrude through the back of the socket. Electrical connections can be made by a taper-plug terminated wire coming from the barrel of one contact to the barrel of another contact with a similar taper plug. The problem encountered in interconnecting the circuit cards is illustrated in Fig. 2. This view is from the back of the sockets containing the circuit cards. Such a maze of wiring has disadvantages when manual assembly methods are used. Hand methods often lead to wiring errors which are difficult to detect. Repeatability of wiring paths is necessary because of noise problems, stray-capacitance, inductance, and stray-coupling considerations, thereby making hand methods unacceptable. From an economic standpoint, a manual operation of this type is clearly out of step with mechanization

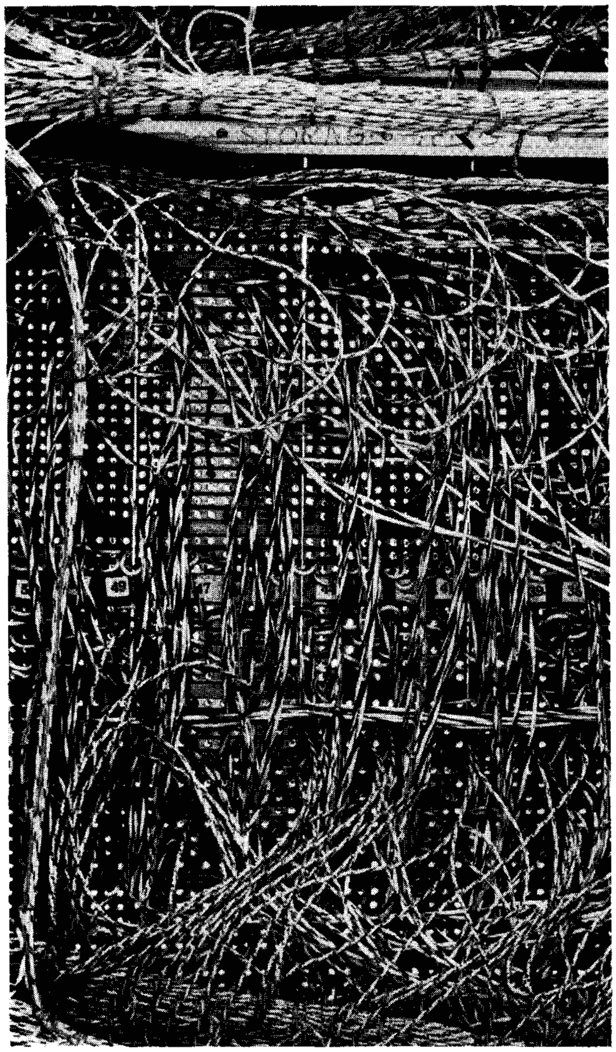

Figure 2
Storage register conventional wiring for IBM 608.

concepts.

Mechanization of this operation seems entirely possible. Plate models built in the laboratory proved that a machine could be built to prepare the correct length of wire, locate the proper barrels and insert the two taper plugs. Such a machine could be controlled from punched cards or other programming means and would be sufficiently flexible. It would be quite costly, however, and, because of the number of wires involved, would require considerable time to complete a panel. These economic factors indicated the desirability of a different solution to the problem.

The back panel method shown in Fig. 2 does, however, have some desirable features. Changes in wiring are easily executed, both during manufacture and in the field. Engineering changes and added features are taken care of by removal of unwanted wires and plug-in of the new circuits. Each contact tab is available at the back panel for trouble shooting while the machine is in operation. The sockets shown have the cards arranged on ½-inch vertical centers, which gives a very high circuit-to-volume ratio. The number of conductors that can be inserted is very high, permitting complicated logical hook-up. This system makes it easy to construct an engineering prototype that will be physically the same as the manufactured machines. Such a flexible arrangement is becoming increasingly important as our electronic performance requirements increase.

A solution utilizing etched wiring would be one answer to this problem. The interconnections could be etched conductors. Then, with the attachment of suitable connectors, the circuit cards would join at right angles to complete the electrical connections. This solution is limited by the number of conductors that can be physically spaced on the two sides of a conductor board. In the actual circuits involved, it was impossible to complete all the wiring necessary. An additional problem arises with such a panel when an engineering change has to be made.

Many circuits may have to be re-routed to allow the addition of one small conductor, which creates a serious artwork problem. Disposing of inventory of panels in stock or process could prove expensive because of lack of salvage value and difficulty of modification. It would be difficult to use this method for fabricating model machines because of the work and time involved.

Two other solutions are apparent at this point. The first would be to construct as much of the circuit as possible with etched wiring and to complete the remainder with conventional wires. This solution would still involve hand assembly methods with the disadvantages noted above. The second solution would be to laminate several etched panels together, sandwich fashion, and to effect electrical connections to the various levels in the stack. This scheme has many manufacturing problems and has the disadvantage of inaccessible wiring.

It should be pointed out that this problem can be approached from a different direction, that of the circuit package itself. If the size of the circuit package in Fig. 1 were increased with more basic circuits on a card and with the logical hook-up on the circuit card, the number of interconnections necessary on the back panel would tend to be reduced. There would then be a large number of rather unique circuit cards. Such an arrangement would greatly complicate the manufacture of the circuit cards, and make the inventory of cards in the field for service requirements impractical. However, this could simplify the back panel to the point where one of the approaches mentioned above might be practicable.

On the other hand, it might be desirable to reduce the size of the circuit package to that of a single function, which would aid manufacturing and inventory methods, but would also increase the number of interconnections required. The general problem is that of controlling several apparently incompatible parameters in order to stabilize the system.

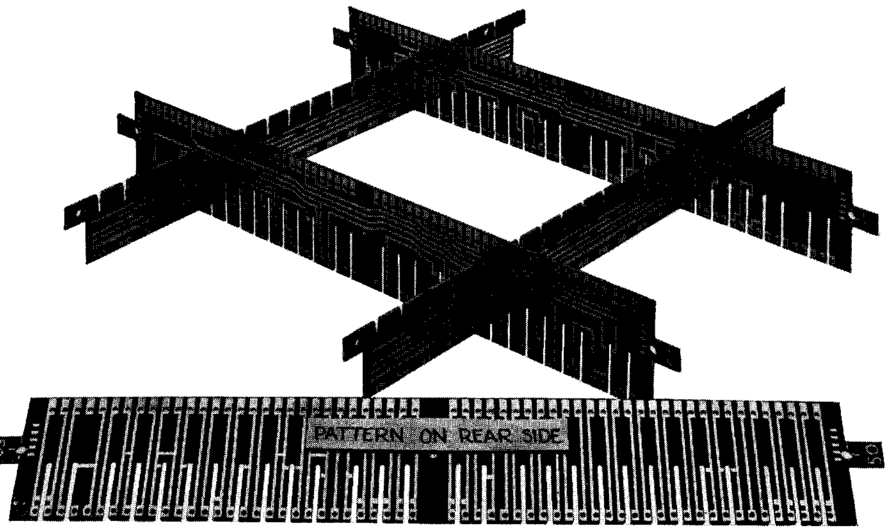

Figure 3
Modular back panel elements.

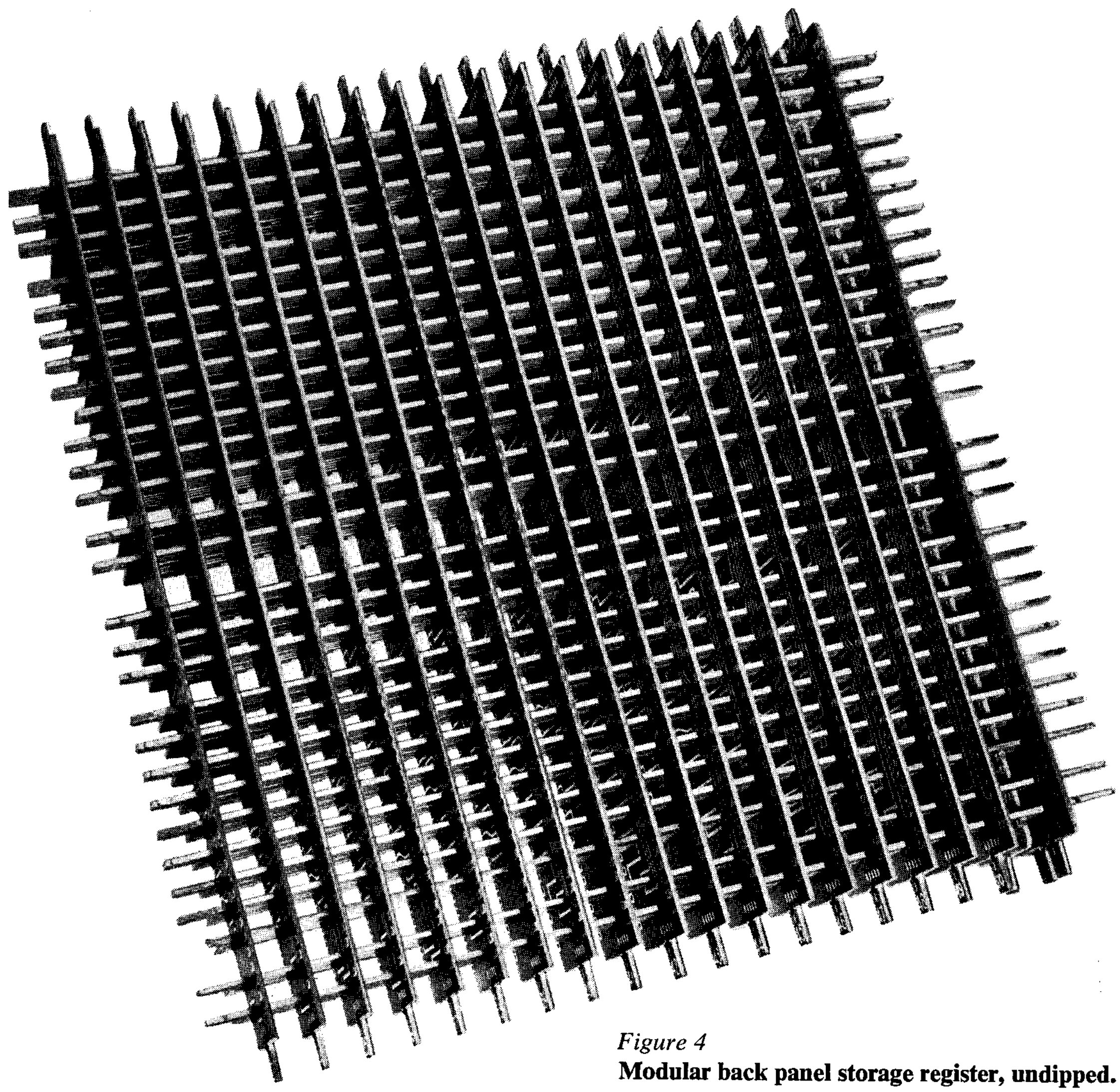

Figure 4
Modular back panel storage register, undipped.

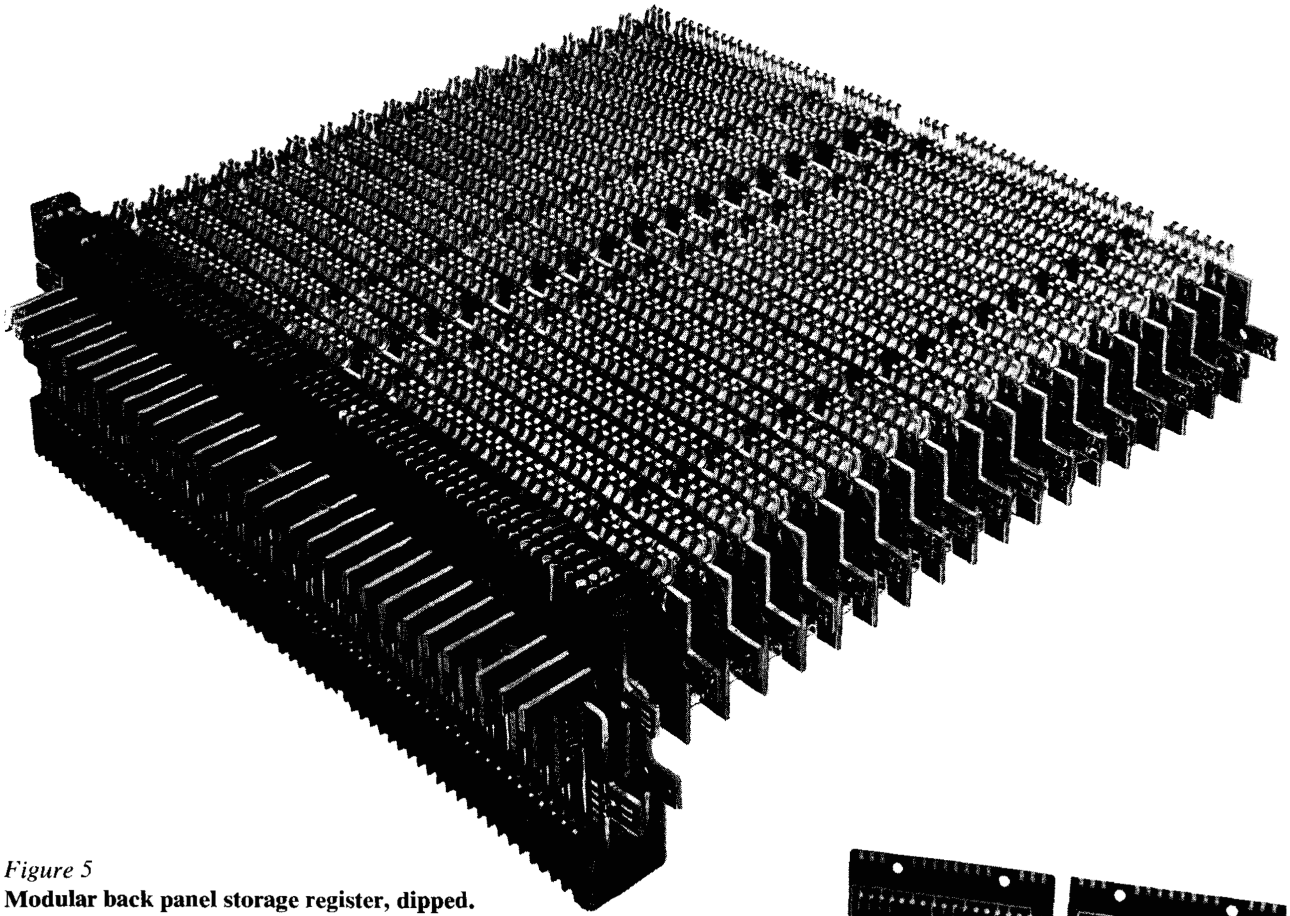

Figure 5
Modular back panel storage register, dipped.

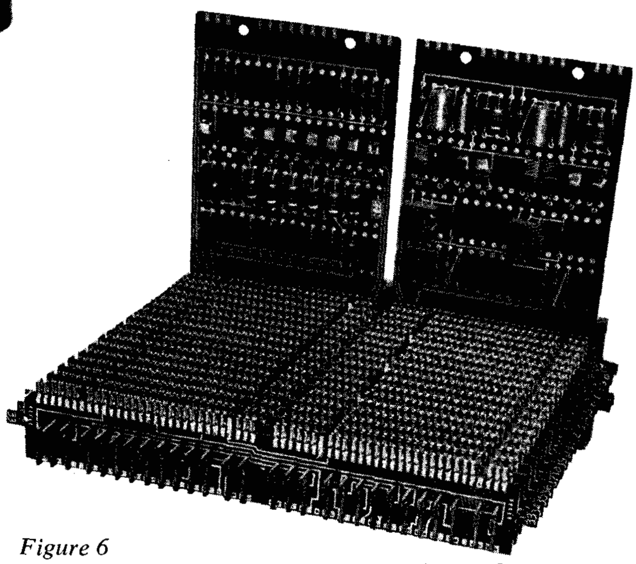

Figure 6
Modular back panel storage register with cards.

The three-dimensional array

Initial work on the computer was confined to use of the circuit card shown in Fig. 1 and the same physical spacing. This work led to the development of the three-dimensional array shown in Figs. 3 and 4. Then, very rapidly, it became apparent that this approach also offered worthwhile gains in other directions.

With this system, conductors are arranged on narrow strips as shown in Fig. 3. The strips are slotted to allow nesting of the pieces at right angles. When conductors must connect at strip junctions, conductor paths are brought together on the same level at the corner, as shown in Fig. 3. The entire circuit is prepared in this manner and all the circuit strips assembled. The assembly is then immersed in a solder bath. The solder wets the conductors and fillets in the corner where two conductors meet, completing the electrical circuit.

An assembly of the elemental strips nested together prior to the soldering operation is shown in Fig. 4, and the same assembly after immersion into the solder and affixing of hardware is illustrated in Fig. 5. The spring contacts shown on the top of the assembly are the connecting device between the back panel section and the tabs of the circuit cards. Two of the 36 circuit cards are plugged into the assembly in Fig. 6. The molding at the left of Fig. 5 is a connector for cable information for service voltages and communication to and from the rest of the computer. This assembly physically and electrically replaces the sockets and wiring shown in Fig. 2. The array replaces approximately 650 wires and the sockets. It should be noted that the cable entry and exit hubs have been centralized and systematized in one location. This aspect will be elaborated upon in a later section.

In comparing this approach with the list of desirable features for the plugged wire array mentioned previously, we find that we have answered the requirements in the following ways. Engineering changes can be handled by several methods. In Fig. 3, in the rear view of the larger element, the contact pads on top all have conductors leading to pads on the bottom of the strip. In the array, the bottom pads are at the back of the panel and are easily accessible. Part of a conductor is easily removed by scratching or cutting with a sharp tool. After all of the undesired circuits have been removed, the customer engineer can either clip or solder conventional insulated wires to the small pads in the rear and thereby create a new wiring hook-up. Preliminary indications are that it might be possible to remove a vertical card from a soldered assembly and install a new vertical card. On an extensive change, the relatively low cost of a back panel module would indicate it might be economical to send a new, completely tested assembly to the field to replace an obsolete section. The old section would either be destroyed or returned to the factory for updating.

Changes can be accomplished quite easily at the manufacturing level. Because of the relatively large number of conducting paths available, it is comparatively easy to effect a change in artwork to add new circuits to the required vertical elements.

Each point in the circuitry is available for probing by virtue of the pads at the bottom of the strip. In Fig. 3 it can be seen that these pads also serve a mechanical purpose. After the circuit strips are soldered, a strong fillet is formed at the intersection of the horizontal and vertical elements, adding much to the inherent strength of the assembly.

The physical spacing is identical to that of the sockets used in the IBM 608, thus allowing the same circuit-to-volume ratio. This system provides a large number of conductor paths. By increasing the width of the strips and thereby allowing more conductors, the designer can allow for his circuit requirements.

Engineering prototypes can be easily and quickly bench-built. Utilizing vertical elements that contain all the unvarying patterns of printed conductors, the technician can construct new circuit elements with conventional wires laid along the eventual path of the printed wires. The conventional wires are soldered to the printed

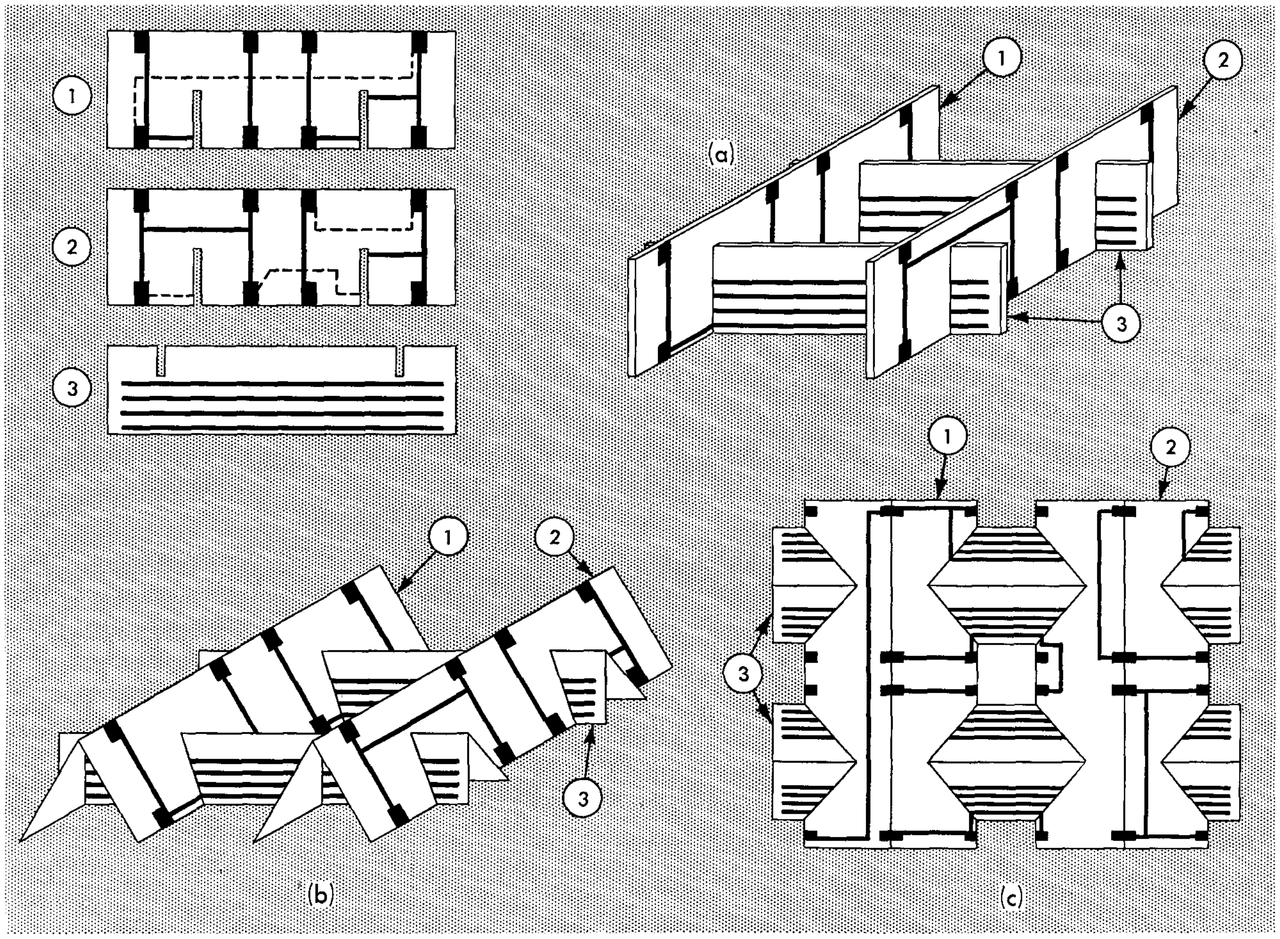

Figure 7

Three views of an assembly section, showing layout of circuits.

pads. When these elements are joined to the standard horizontal strips and the solder fillets made, the circuit is complete. Thus, circuits can be evaluated in a matter of a few hours after they have been designed, with electrical characteristics identical to those of the manufactured product.

The above solution seems well adapted to mechanization. All of the strips in one direction are identical, thereby making tooling and high production aspects attractive. The members in the other direction are physically identical but have a different conductor pattern. They possess the same mechanization potential, for the tooling would be universal, as the change in pattern is brought about by one simple manufacturing operation. The completed assembly lends itself to automatic checking before it is assembled on the product.

The mechanical design of the circuits for vertical cards turns out to be a fast and relatively simple task. The design of the printed wiring for the circuits shown in Fig. 2 has been done by an uninitiated technician in less than three hours. This includes the routing and assignment of the 170 cable conductors associated with this section. A section of an assembly is shown, in perspective, in Fig. 7 (a), and Fig. 7 (b) shows the same section with the elements split and opened at the bottom. A view looking directly down at the opened-element section is shown in Fig. 7 (c). A work sheet similar to Fig. 7 (c) is used to draw in the conductors connecting the desired contact points. From this work sheet the artwork for the vertical elements is drawn. The horizontal members are identical, a standardized conductor pattern on each element.

The above system appears to be adaptable to machines using components other than printed-wire circuit cards. Instead of using the spring contacts, it would be possible to mount right-angle tube sockets to the vertical members for pluggable units similar to the IBM 604 type. Similarly, receptacles for the IBM wire contact relay could be incorporated to provide the logical interconnecting of electronic and electro-mechanical machines.

Automatic cabling

All of the interconnecting required, however, is not confined to the same machine panel. Cabling between machine sections involves a considerable amount of additional communication. The system outlined above adapts itself to this problem. As shown in Fig. 8, the conductors on the horizontal set of strips can terminate as tabs along one edge of the strip. It is then possible to install a receptacle on the two strip ends as shown. If wires are attached to the terminals of the receptacles and correctly attached on their other ends to other terminals, automatic cabling is effected with the installation of the receptacle.

In a computer packaged as outlined above, the circuitry is contained in two gates, each consisting of ten

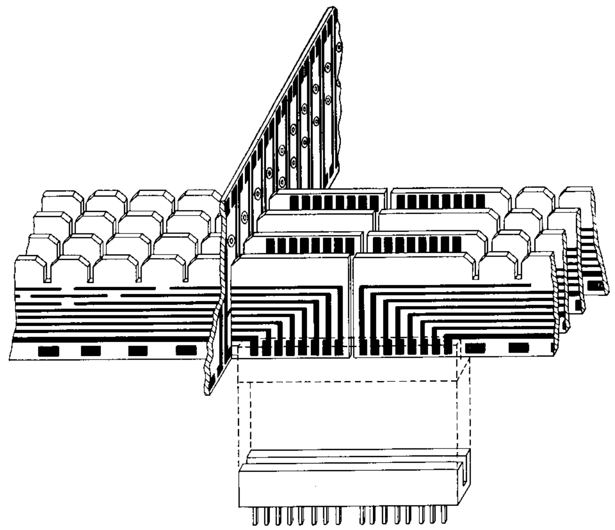

Figure 8
Drawing of cable receptacle and back panel.

back-panel wiring sections. Between the gates would be the fixed hardware of the system. Fig. 9 schematically shows a machine that might be used to effect such cabling. The fixed hardware would be rack mounted and inserted into the machine in the foreground. The rack would move to the working section of the machine at the center. Empty cable receptacles would be loaded along the right and left sides of the machine.

Under control of the program unit, shown at the left, the machine would attach one end of the wire to its correct terminal and lay the wire out along its prescribed path and attach the other end to its correct terminal. In this way, all the cable connections would be made. At the completion of the program, the wired receptacles and rack would be moved out to the third station. Here the cables could be laced, wrapped, etc. The rack would be moved to the frame of the computer being built, and fastened into place. After the insertion of the receptacles to their proper places in the back panel sections, the cabling would be complete.

Although the automatic cabling mentioned above is in the embyro stage, it is included with this paper to show the effect of design on the various problems related to building a product. This approach to cabling would certainly do much to remove the manual drudgery familiar to this operation, improve the reliability of the product, and reduce cost.

Conclusion

The examples given in this paper are intended to show the importance of design in considering any program of mechanization. The entire design of the product is important for compatibility in packaging. In the examples cited, an attempt was made to show the relationships existing among circuit packaging, back-panel connections, and cabling. Similar relations exist among these items and power supplies, machine design, control de-

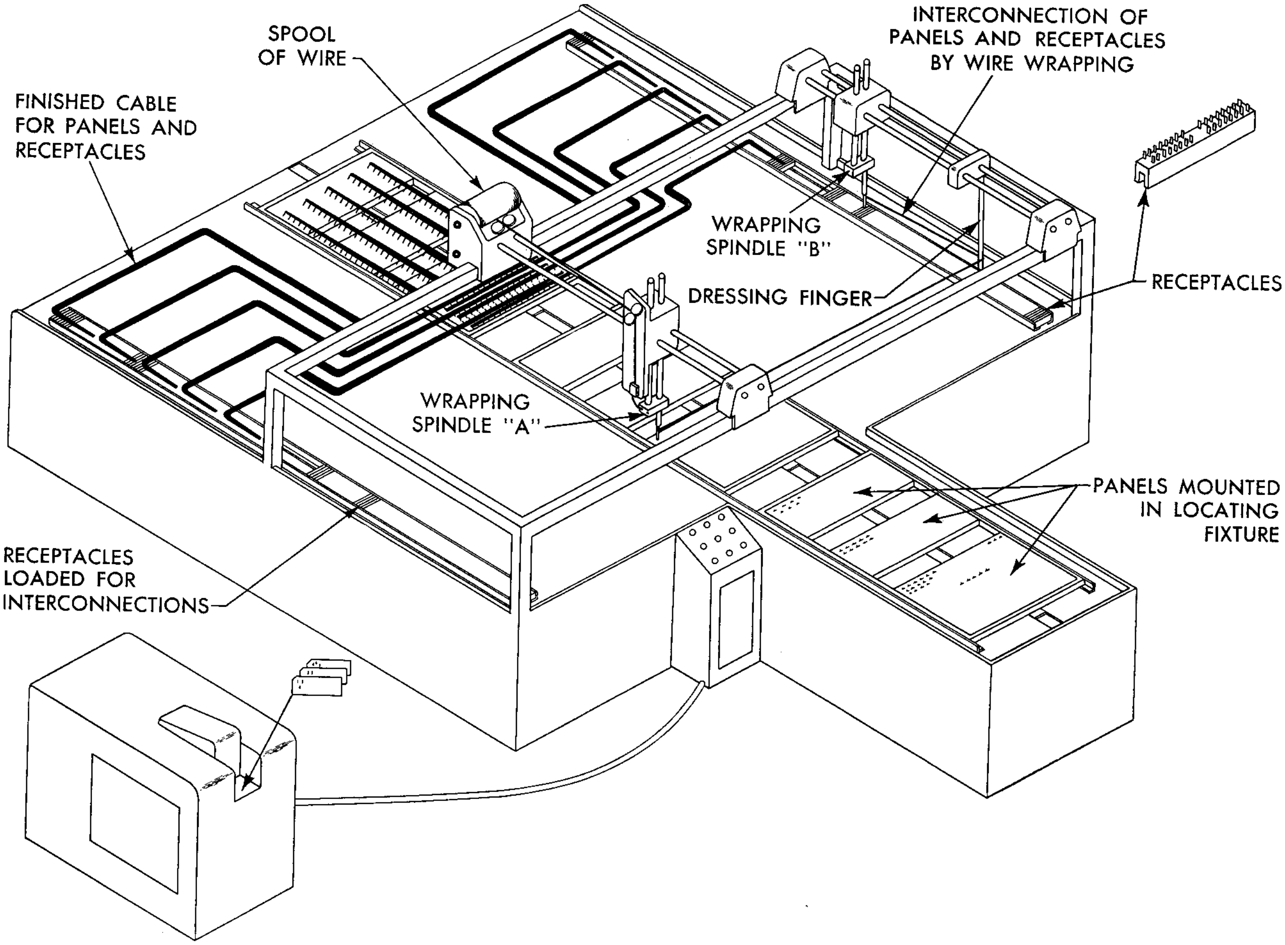

Figure 9
Proposed cable laying machine.

vices, and other operating hardware. The best solution to one phase of the problem is not necessarily the best solution for over-all product design. The interdependence of all aspects must be realized and evaluated so that the solution with the best over-all potential can be selected.

The section of back panel wiring shown in Figs. 5 and 6 has been in actual use on an IBM 608 Computer for several months. During this period it functioned without any trouble or disturbance. Compared to the conventionally wired circuits, the printed back panel shows approximately 15% more capacitance to ground. The same section shows approximately 33% less inter-lead capacitance than the conventional wires. This improvement is probably due to the greater uniformity of conductor spacing possible with printed wiring than with flexible wires. On the basis of limited experience thus far, it can be reported that the solder fillets performed satisfactorily on the low-power transistor circuits. Additional models are being constructed for accelerated environmental tests.

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