AUTOMATIC PACKAGING OF MINIATURIZED CIRCUITS

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INTRODUCTION

This paper reviews the effort to utilize the advanced capabilities of semiconductor device fabrication and component interconnection techniques in the manufacture of digital computers. By taking advantage of the characteristics of these new devices and interconnections, substantial savings can be realized in manufacturing cost. If other potential advantages of this packaging capability are to be gained, it is important that all aspects of machine design, production, and maintenance be considered as an integrated whole.

Technical literature today is replete with references to "microminiaturization," "integrated circuits," "micromodules," "functional circuits," and numerous trade names. So that there shall be no misunderstandings, we state here what technology we are assuming is available. This is the manufacture of circuits which perform a single Boolean function (AND, OR, AND-INVERT, OR-INVERT) in a "module" (or "block") whose dimensions are referred to in terms of tenths of inches rather than multiples of inches. It is true there are special, more complex, circuits (triggers, flip-flops) available now in similar modules, but these may be treated in a similar manner. This paper will deal with computer considerations from the device or module "upward," as it were, into the computer system.

At present, for the manufacturer of general-purpose, commercial, digital data processing machines, the appeal of these new devices does not lie directly with their size or weight. These physical characteristics will appear rather far down on a list of machine characteristics the devices could affect. An order of decreasing importance might be:

1. Manufacturing cost
2. Reliability
3. Serviceability
4. Speed
5. Power consumption
6. Size
7. Weight

All these factors are inextricably related. The physical size of a semiconductor junction will affect the device speed. The machine speed will be affected by device speed, and to some extent now, by the interconnection length; i.e., the over-all machine size. On a system level, the serviceability requirement will affect the reliability possible, and both will affect manufacturing cost. Our comments in this paper will be mainly concerned with the first three items on the list presented.

An examination of the items involved in the manufacturing cost of the central processor of a digital computer would reveal the following major factors:

1. Circuit components
2. Power supplies
3. Interconnections
4. Mechanical hardware
5. Assembly

Miniaturized circuit module use will directly affect the amount of mechanical hardware required to house a given machine. In addition, the interconnections and assembly costs will be reduced. The cost of circuit components is also expected to be reduced due to standardized methods for the manufacture of circuit "modules."

The particular choice of circuit scheme for a miniaturized digital computer is, in general, compatible with the search for minimum-cost circuits. In general, however, more significance is now attached to the following:

1. Low power dissipation
2. Reduced number of interconnections
3. High logic power and flexibility
4. Efficient usage of any integrated units

Packing schemes developed in the past would not be directly applicable to miniaturized circuits because of the following limitations:

1. Pluggable levels of packaging would tend to be "pin limited." A "pin" is a pluggable connector.
2. Larger "pluggable levels" tend toward uniqueness and this presents a field servicing problem.
3. The interconnecting wiring itself requires space.

Factors 1 and 3 imply that (a) the interconnections (pluggable connectors, printed or deposited wiring) should be miniaturized as well, and (b) interconnections should be made "efficiently" as far as space occupied is involved. The latter would imply positioning of those devices to be interconnected and efficient wiring of nets.

Factor 2 poses a problem to the system designer. In general the larger a pluggable level (in terms of the number of modules in it) the less often it is used in a given machine. Can machines be designed so that they use relatively large pluggable levels repeatedly without too many redundant circuits? Thus far, the answer to this question is "Practically, no."

What then should be the size of the "pluggable level"—the smallest easily replaceable unit in the machine? The optimum size of replaceable level is that which maximizes the availability of a digital computer system to a user for the minimum cost.

The availability of the machine will depend on:
1. The number and reliability of the various types of modular interconnections
2. The maintenance strategy used

The over-all reliability of the machine will be affected by the replaceable level size because the smaller this level is, the greater will be the number of interlevel connections.

For larger replaceable levels, however, the time required for fault location will be lower and the maintenance costs beneficially affected. Large replaceable levels, however, will require a costly field inventory, both because of their intrinsic cost and their low frequency of usage in any given machine.

Thus, the determination of an optimum "replaceable unit" size is seen to involve many aspects of computer design, manufacture, and maintenance. No simple solution to the problem will be presented here, but the electronic packaging engineer must now be acutely aware of the compromises involved.