circuits. The fourth phase involved testing the manufactured wafers. The fifth phase involved packaging the integrated circuits. The last phase had to do with testing the packaged circuits. Thus, detailed investigation revealed that there was a whole array of different manufacturing processes and engineering technologies involved, and that the make-or-buy issue was not quite as simple as was originally thought.

1982 Environment Scan

A 1982 environment scan revealed some very interesting facts. The first and most important was that design engineers were in incredibly short supply. There were fewer semiconductor design engineers in the world than there were professional football players in the NFL.

A second finding was that there was adequate mask-making and manufacturing capacity for making ingots and imprinting integrated circuits. Manufacturing capacity (equipment and clean rooms) is incredibly expensive. To exacerbate the situation, technology moves very quickly and the obsolescence rate of the required capital equipment is quite high. For these reasons, senior executives properly were concerned about manufacturing capacity. But the research indicated that there was adequate capacity available worldwide and that sufficient capacity was being added to meet future demand.

The research effort revealed that the packaging issue consisted of at least two subissues: industry capacity and packaging technology. Capacity did not appear to be a problem. But management had some concerns about packaging technology to which the semiconductor industry was not sensitive. The semiconductor industry's attitude toward packaging was that parts would be placed into standard packages that would be good for all of the industry to use. The semiconductor industry's attitude was in conflict with Universal's ideas on manufacturing efficiency and module packaging, broad layout, size, weight, and other design requirements. Universal's ideas would allow the production of customized packages for special opportunities on new models.

Packaging

The issue of testing of the packaged semiconductor devices was extremely critical to Universal. The issue had to do with the relative value of a semiconductor to the various suppliers and to Universal. A semiconductor sold for $1 to $3, while an automobile, dependent on the semiconductor's performance, sold for $10,000 to $30,000 (1980 dollars). A $1 to $3 component could easily (and all too frequently did) cause a $20,000 automobile to malfunction, requiring the owner of the automobile to call a tow truck, pay for the tow truck, and have the vehicle towed in for repairs costing several hundred dollars. This is not the basis of customer satisfaction or of increasing market share for the auto manufacturer. The importance of defect-free semiconductors was of far greater importance to Universal than to the semiconductor industry, whose liability was limited to replacing the defective part. Universal executives recognized that the semiconductor industry did not have the same motivation to quality as it had.

Technology Leadership

After the above analysis was completed, another issue influencing the make- or-buy issue came into focus: technology leadership. A chip might offer Universal technological leadership in the automobile industry and possibly some very important marketing advantages. Management became very nervous about its semiconductor supplier(s) being able to sell identical or similar chips to the firm's competitors. Universal wanted to own the technologies incorporated in these circuits. These technologies were viewed as strategic keys to Universal's future.

Management, with the assistance of legal council, determined that if Universal designed the chips in-house, for all practical purposes it would own the technology. The processing technology would be covered by contract license agreements.