Financial Services Program

Semiconductor Industry Overview

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This Overview represents a sampling of the research and analysis available to clients of Dataquest's Semiconductor Industry Service.

The contents of this Overview have been taken directly from material previously published by the Service, and are included in order to provide the reader with evidence of the quality and scope of research provided.

This Overview is not intended to provide a comprehensive analysis of all aspects of the Semiconductor Industry Group. Interested parties should contact their Dataquest representative for the most current information on the Semiconductor Industry Group, its research, and delivery format.

Semiconductor Industry Service
Executive Issues

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- "1986 Preliminary Market Share Currency Revaluations Change Market Standings" (January 1987-1)

  The "Who's Who" of global semiconductor market share--Dataquest's ranking of worldwide semiconductor companies by dollar revenue in each major product segment.

- "The Dataquest Semiconductor Megatrends" (October 1986-44)

  The Dataquest Semiconductor Industry Service has summarized ten trends that we believe are currently transforming the semiconductor industry. These megatrends have been defined by key Dataquest analysts from not only the semiconductor service, but from many other services as well.

- DQ MONDAY REPORT

  The DQ Monday Report is a weekly update of news affecting the semiconductor industry in each of the regions tracked. Included is comprehensive worldwide pricing and lead time information for semiconductor products. The DQ Monday Report is accessible 24 hours a day via a computer terminal with standard modem interfaces or can be received every other Monday by first-class mail immediately following the pricing updates.

Industry and Technology Overview

SCOPE

Electronic goods are an increasingly pervasive part of our daily lives. In the last few decades alone, the electronics industry has revolutionized a wide and varied range of human activity by means of computers and data processing equipment, electronic games, telecommunications, industrial automation, television and radio, and defense electronics.

From 1979 to 1984, total worldwide revenue for electronic equipment grew from just under $100 billion to over $172 billion--a compound annual growth rate (CAGR) of 11.5 percent. It comes as no surprise that the American Electronics Association (AEA) recently announced that the U.S. electronics industry now employs more people than any other manufacturing segment of the American economy.

The semiconductor industry has been called the "crude oil" of our modern industrial society. The industry supplies billions of products consisting of thousands of types of individual components--including diodes, transistors, integrated circuits (ICs), and optoelectronic devices. In 1986, nearly $31 billion worth of semiconductor products was consumed worldwide.

More than 200 companies throughout the world compete in the semiconductor industry. These companies range in size, products, and marketing strategy from giant, multinational corporations engaged in volume production of "commodity" ICs, to much smaller companies addressing specialized niches. And still more companies are being founded--between 1977 and 1984 Dataquest recorded approximately 115 semiconductor manufacturing start-ups. In 1984 alone, new semiconductor enterprises accounted for $3 billion in venture capital funding. Despite such entrepreneurial energy, the top 10 merchant suppliers produced over 55 percent of world semiconductor output for 1985. The major world semiconductor manufacturers are listed in Table 1.

Despite their diversity, semiconductor companies share a commonality that provides a clear definition for the industry: Their businesses are based on the miniaturization of electronic devices through the use of semiconductor materials. The technology behind this industry involves elements of physics, chemistry, and electronic theory that are at the cutting edge of their respective disciplines.

The following overview provides a basic description of the semiconductor industry--including its structure, special characteristics, and the unique challenges it faces.

Table 1

MAJOR WORLD SEMICONDUCTOR MANUFACTURERS
RANKING BY 1985 REVENUES
(Millions of Dollars)

	1985 Revenue	1985 Rank	Nationality
NEC	1,984	1	Japan
Motorola	1,850	2	U.S.
Texas Instruments	1,766	3	U.S.
Hitachi	1,671	4	Japan
Toshiba	1,459	5	Japan
Philips-Signetics	1,068	6	Europe
Fujitsu	1,020	7	Japan
Intel	1,020	8	U.S.
National Semiconductor	940	9	U.S.
Matsushita	906	10	Japan
Mitsubishi	706	11	Japan
Advanced Micro Devices	603	12	U.S.
Fairchild	492	13	U.S.
Sanyo	457	14	Japan
Siemens	420	15	Europe
Sharp	329	16	Japan
RCA	325	17	U.S.
Thomson	324	18	Europe
Oki	307	19	Japan
SGS	300	20	Europe
General Instrument	280	21	U.S.
ITT	270	22	U.S.
Harris	265	23	U.S.
Rohm	250	24	Japan
Analog Devices	206	25	U.S.
Monolithic Memories	200	26	U.S.
Fuji Electric	173	27	Japan
Telefunken Electronic	170	28	Europe
Sony	168	29	Japan
Hewlett-Packard	155	30	U.S.
Total Worldwide Revenue	24,823		

Note: Top 10 make up more than 55 percent of world total

Source: Dataquest
December 1986

Industry and Technology Overview

HISTORY

The semiconductor industry is less than 30 years old. Although some simple diodes were manufactured earlier, the first transistor was produced by Bell Laboratories on December 23, 1947. Technical breakthroughs in the manufacturing of transistors followed rapidly, and by 1952 a number of companies were producing devices commercially. These devices, however, used germanium as the semiconductor material.

In 1954, Texas Instruments (TI) began to manufacture silicon transistors on a commercial scale. (Prior to that time, TI was not a factor in the semiconductor industry.) In the late 1950s, the industry was still in its infancy with sales just beginning to pass the $100 million mark. The major market for semiconductor devices was provided by the military, which recognized the potential of semiconductors and actively supported the industry's development. Another large semiconductor market, of course, was for transistor radios.

In 1959, Fairchild Camera and Instrument developed the planar technology for making transistors, which later became the basic technology for the manufacture of integrated circuits (ICs). Integrated circuits, however, were not commercially produced until 1961, when they were first marketed by Texas Instruments. About the same time, semiconductor devices began to proliferate, including MOS devices, junction field effect transistors, and Schottky diodes. At this time, several improvements in manufacturing technology also occurred, providing rapid increases in productivity and device reliability.

In the late 1960s, the use of integrated circuits grew rapidly; by 1965 worldwide industry sales had passed the $1 billion mark. Uses for semiconductor devices escalated in this period, including many markets for industrial products, data processing devices, and communications equipment. During this time, MOS devices also began to be sold on a commercial scale. U.S. companies began to assemble their products overseas and both the European and Japanese markets became important. In 1968, the first light-emitting diodes were sold commercially by Hewlett Packard. Bell Labs developed the light-emitting diodes in 1964.

The late 1960s and early 1970s brought some major changes to the semiconductor industry. During that time more than 36 new merchant companies entered the market. At the same time, many captive semiconductor facilities emerged. These new participants added technical and competitive impetus to an already fast-moving industry. This period also saw the rapid rise of the MOS integrated circuit as a major product area in the semiconductor industry. Major emerging products in this area included semiconductor memory, custom devices, complex linear circuits including operational amplifiers, voltage regulators, and A to D and D to A convertors. The early 1970s marked the advent of large scale integration (LSI) devices, and uses for consumer devices such as calculators and watches. An era of low-cost electronics was emerging.

The late 1970s saw the emergence of a large worldwide semiconductor industry, with competition on an international scale. The emergence of very large scale integration (VLSI) devices brought important new products, including microprocessors. Other major new devices included various types of customizable semiconductors such as ROMs and EPROMs.

The 1980s have seen continuing growth in VLSI circuit complexity leading to 64K, 256K, and 1 megabit (Mb) RAMs, and the 32-bit microprocessor. Chip complexities have increased to the point that standard products cannot fill all market needs, which has led to the rapid growth of application specific integrated circuits (ASICs). Major innovations in wafer fabrication equipment that allow for the shrinking of device geometries, and in powerful computer-aided design (CAD) tools that automate the chip design process, have combined to make possible today's advances in component density and customization.

A history of technical milestones in the semiconductor industry appears in the section entitled the Impact of Technological Change, beginning on page 57 of this overview.

SEMICONDUCTOR INDUSTRY STRUCTURE

Products

The semiconductor industry has a wide diversity of products. The most basic breakdown consists of integrated circuits (ICs), discrete devices, and optoelectronics. An integrated circuit is a single chip that has more than one active device on it. For example, it may have a number of transistors, diodes, resistors, or capacitors as part of the electronic circuit. Integrated circuits vary widely according to the functions that they perform and the technologies used in their manufacture. Circuits can perform digital or linear electronic functions and may be based on a number of basic technologies, such as bipolar or MOS (metal oxide silicon). ICs can be configured to an almost limitless number of different types of circuits.

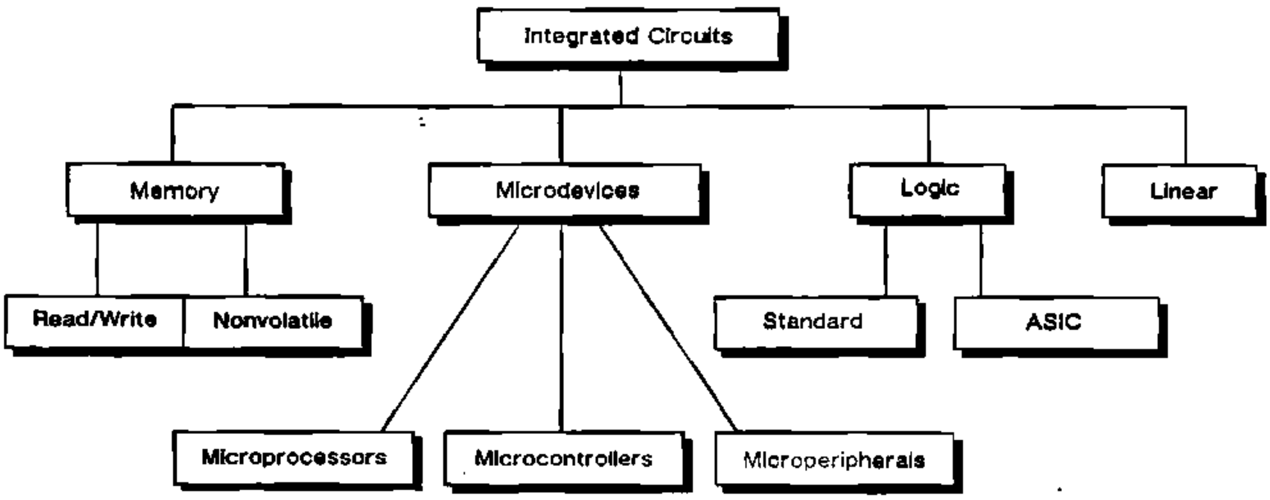
Discrete devices have an even wider diversity. They consist of many types of transistors, diodes, and switching devices such as SCRs and triacs. Again, the wide diversity of product applications requires tens of thousands of types of discrete devices. This product diversity requires many variations in manufacturing.

A description of many of these products is provided in the section entitled the Impact of Technological Change, beginning on page 57 of this overview.

As semiconductor products proliferate and change in terms of technology, function, and end-use, it will be necessary to reevaluate current schemes of IC classification. For now, Dataquest uses the following classification chart (Figure 1) to further distinguish between IC products:

Figure 1

IC CLASSIFICATION



Source: Dataquest
December 1986

The above product categories are described as follows, with some examples of commercially available device types:

- Memory ICs are designed for the storage and retrieval of information in binary form.

- Read/write memory, generally referred to as RAM (random-access memory), allows storage and retrieval of information created by the user. Such information remains in memory only as long as power is supplied (volatile).

  - Dynamic RAMs (DRAMs)
  - Static RAMs (SRAMs)
  - Hierarchical RAMs (HRAMs)

- Nonvolatile memory devices do not lose information when power is turned off.

  - Read-only memory (ROM)
  - Programmable read-only memory (PROM)
  - Erasable programmable read-only memory (EPROM)
  - Electrically erasable programmable read-only memory (EEPROM/E^2 PROM)

- A microprocessor can be a single chip component or a collection of architecturally independent components that function as the central processing unit (CPU) in a system. Microprocessors may contain some input/output (I/O) circuits but they do not usually operate in a standalone fashion.

- A microcontroller is an IC containing a CPU, memory, and I/O capability, that can perform the basic functions of a computer.

- Microperipherals are support devices for microprocessors or microcontrollers that either interface external equipment or provide system support.

  - Disk drive controllers
  - CRT controllers
  - Graphics chips

- Bus controllers
- Serial and parallel I/O Chips

- Logic, in the semiconductor sense of the word, may be thought of as the "glue" that surrounds the IC devices listed above. Logic devices handle digital signals in a variety of ways: routing, multiplexing/demultiplexing, encoding/decoding, counting, comparing, and also serve as input/output (I/O) interfaces.

- Standard Logic ICs are readily available "off-the-shelf" from a number of suppliers.

  - TTL (transistor-transistor logic)
  - ECL (emitter-coupled logic)
  - MOS (metal-oxide silicon) logic

- Application specific ICs (ASICs) are integrated circuits designed or adapted for a specific application.

  - PLD (programmable logic device)
  - Gate arrays
  - Cell based design
  - Full custom design

Only within the past few years have a significant number of integrated circuits become commodity products: products that have been universally accepted and are produced in high volume by more than one manufacturer. Commodity devices are usually characterized by high volume, low cost, and relatively low margins. Their emergence marks a major advance in the maturity of semiconductor markets. In general, these products are manufactured by the larger companies, which have a competitive edge in volume efficiency.

Competition in the worldwide market for commodity ICs has forced companies to not only advance the technologies behind their products, but to become equally effective in the manufacturing and marketing of them as well. The expertise of Japanese semiconductor companies in high volume manufacturing, and their ability to survive on much lower profit margins, has dramatically shifted market share dominance in commodity products toward the Pacific. Nowhere has this been more evident than in the loss of U.S. market share in memory ICs.

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In more recent years, the demand for customized IC applications has stimulated promising growth in application-specific (ASIC) devices, while equipment and design tool advances have made it profitable for semiconductor manufacturers to offer ASIC products to lower volume niche markets. For ASIC suppliers, the emphasis no longer resides most heavily in manufacturing, but in close customer support and the lowest possible turn around time from customer order to first silicon.

Markets

Dataquest has standardized semiconductor end-users into the following six major application market segments:

- Data processing
- Communications
- Industrial
- Consumer
- Military
- Transportation

Data processing comprises all equipment whose main function is flexible information processing, including all personal computers, regardless of price or environment in which they are used.

The communications segment is made up of telecommunications, which Dataquest classifies as customer-premises and public-telecommunications equipment, and all other communications equipment such as radio, studio, and broadcast equipment.

Industrial consists of all manufacturing-related equipment, including scientific, medical, and dedicated systems.

The consumer segment comprises equipment that is designed primarily for home or personal use, such as audio and video equipment, and household appliances.

Military equipment is primarily defense-oriented electronic equipment as classified by major budget area. This does not include all electronic equipment procured by the government, in order to avoid double-counting equipment that belongs in an already included applications market segment.

Transportation consists mainly of automotive and light truck electronics.

World Market Shares

U.S. companies have always supplied a majority of the semiconductor devices produced in the world. Over the last several years, however, U.S. companies have experienced a rapid loss of market share to Japanese and European manufacturers. This loss has taken place in a number of key areas once dominated by American chip makers.

In 1974, U.S. companies controlled an estimated 62 percent of the total world semiconductor market and about 75 percent of the total world integrated circuit market (more than 80 percent including captive manufacturers). By 1985, the U.S. market share edge had eroded to 45.9 percent of the total world semiconductor market, and 49 percent of the total world IC market. Table 2 shows a history of world semiconductor market share held by U.S., Japanese, and European companies.

Table 2

ESTIMATED SEMICONDUCTOR MARKET SUPPLIED BY U.S., JAPANESE, AND EUROPEAN COMPANIES

Year	U.S.	Japanese	European
1970	56.5%	27.1%	16.1%
1974	62.3%	20.7%	16.3%
1975	63.9%	19.3%	16.8%
1976	60.4%	24.5%	15.1%
1977	59.6%	25.4%	15.0%
1978	55.3%	28.4%	16.3%
1979	57.9%	25.8%	16.3%
1980	57.2%	27.4%	15.4%
1981	51.4%	35.5%	13.1%
1982	51.4%	35.3%	13.3%
1983	49.1%	38.7%	11.3%
1984	48.7%	39.5%	11.0%
1985	45.9%	41.2%	11.6%

Source: Dataquest
December 1986

U.S. companies are positioned in the fastest growing semiconductor market segments. They have a much larger share of the integrated circuit market than they do of the discrete market, and have enjoyed their largest integrated circuit sales in metal oxide silicon (MOS) devices and bipolar digital devices. While the U.S. has maintained its presence in the bipolar market over the last five years, it has suffered a startling market share decline of over 20 percent in the larger arena of MOS. Looking at several broad semiconductor areas, Table 3 compares U.S. market share in 1980 with that of 1985.

Table 3

COMPARISON OF U.S. MARKET SHARE: 1980 AND 1985

	1980	1985	Change
Integrated Circuits	62.7%	49.0%	(13.7%)
Bipolar Memory	64.2%	53.8%	(10.4%)
Bipolar Logic	71.1%	65.4%	(5.7%)
MOS Memory	73.7%	36.3%	(37.4%)
MOS Logic	55.8%	46.1%	(9.7%)
MOS Micro Device	74.6%	55.5%	(19.1%)
Total CMOS	62.3%	39.7%	(22.6%)
Total Linear	46.5%	46.6%	.1%
Total Discrete	43.5%	36.2%	(7.3%)
Total Semiconductor	57.2%	45.9%	(11.3%)

Source: Dataquest
December 1986

There are a number of basic reasons for the decline in market share that the U.S. semiconductor industry has suffered. To begin with, as U.S. companies have transferred manufacturing to foreign plants, the accompanying transfer of technology has been more rapid, and the technical superiority held by U.S. companies has decreased. With the emergence of high volume commodity markets for semiconductors, the U.S. has also found it extremely difficult to match the manufacturing resources and expertise of foreign companies whose relationships with large and diversified parent firms allow them to operate with more favorable economies of scale, and at lower profit margins. Particularly in the area of MOS memories, U.S. semiconductor manufacturers have been unable to successfully compete with Japanese suppliers on price, and up to now, on reliability. While the signing of the U.S.-Japan

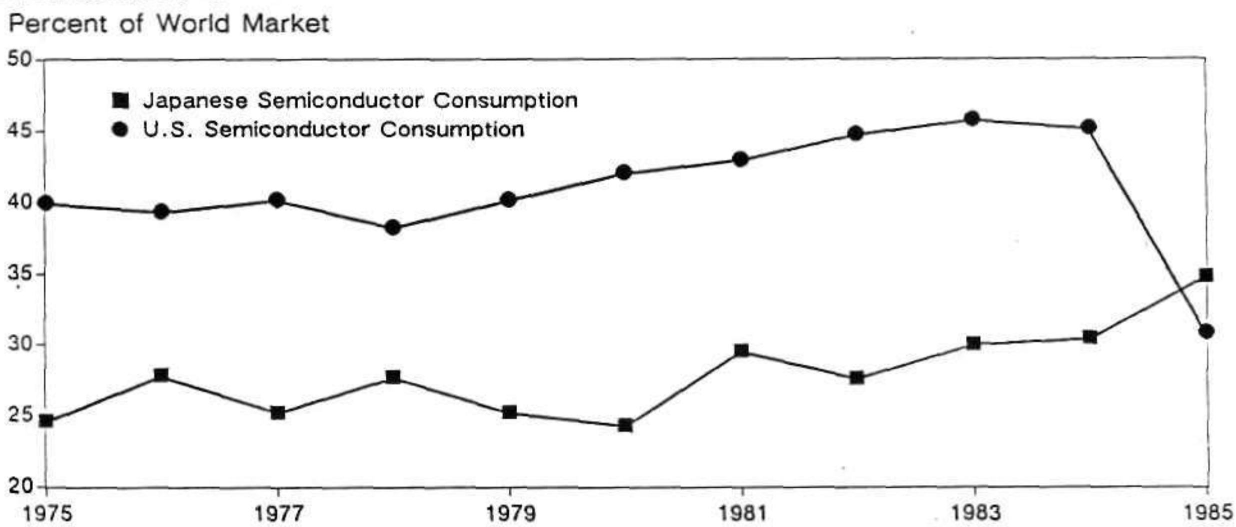
Semiconductor Trade Agreement in July 1986 may restore some degree of price equity, the agreement comes too late for the many U.S. firms who were previously forced to withdraw from the memory market.

A more basic problem for U.S. chip makers has been the decline of the domestic electronics industry. This decline shows up most clearly in the drop in domestic demand for semiconductor devices. In 1980, the U.S. market accounted for 42.1 percent of the world market for semiconductors, compared with 24.3 percent for Japan. In the last five years this relationship has shifted significantly. In 1985, the U.S. market declined to 38.8 percent of the worldwide total, with Japan accounting for 34.8 percent. Figure 2 illustrates the shift in market demand over the last ten years. This shift forces the U.S. semiconductor industry to depend less on domestic consumption of its products, and turn toward more effective competition on a global scale. Historically, this has not been U.S. industry's strong suit--a fact borne out by the current U.S. trade deficit.

To the extent that trade barriers have mitigated against successful U.S. competition in foreign markets, industry and government will need to cooperate more closely in balancing the need to level the international playing field for U.S. semiconductor manufacturers against the negative aspects of protectionist legislation.

Figure 2

SHIFTS IN MARKET DEMAND



Source: Dataquest
December 1986

It should be noted that the above references to market share refer only to merchant semiconductor manufacturers. IBM and AT&T, which are considered captive manufacturers, together produce an estimated $900 million in semiconductors. If the production of captive companies were included, worldwide market share for U.S. companies would appear larger.

The major markets supplied by the semiconductor manufacturers have a large number of different applications that result in an extremely large number of smaller market segments. The smaller markets often require special types of devices with unique technologies or specialized applications. This situation creates opportunities for small companies to be both competitive and profitable.

With a few exceptions, semiconductor devices are sold to manufacturers that design, assemble, and market the end products. Thus, the vast majority of semiconductors are sold to other industrial manufacturing corporations rather than used internally.

Manufacturing

The central manufacturing focus in the semiconductor industry is the fabrication of semiconductor devices from extremely thin, raw silicon wafers, typically 3 to 6 inches in diameter. This process entails hundreds of individual manufacturing steps, each requiring complex technology and high precision. The manufacture of the semiconductor device can be divided into three major operations: wafer fabrication, testing, and assembly.

The manufacturing structure of the semiconductor industry is experiencing change. In the past, semiconductor companies typically performed all or most of the steps required to produce the devices they supplied. A number of newer semiconductor companies are now disassociating design and manufacturing, choosing a strategy based on adding value through design innovation and service, rather than solely through improved manufacturing. While changes in technology that effect the design process and chip densities have contributed greatly to this emerging strategy, another key element is the sheer cost of building a wafer fabrication facility. Dataquest estimates that a company wishing to build a state-of-the-art CMOS wafer fab will need to invest over $30 million for the facility alone. Given today's venture capital climate, the price of admission to the exclusive domain of IC manufacturers will be beyond the means of most future start-ups.

Among those companies who possess a manufacturing capability, marked differences exist in the number of support functions that they integrate. These support functions include fabrication of the package in which the devices are assembled, manufacture of the semiconductor wafers on which the devices are made, manufacture of the masks involved in the photolithographic process, and other related functions. Larger (or older) companies, such as IBM and Texas Instruments, operate on a greater level of backward integration. Smaller (or newer) companies, in general, do not perform these manufacturing functions. Intel, for example, purchases masks, wafers, and packages.

In recent years, there has been a proliferation of companies offering various semiconductor manufacturing services. These services include semiconductor device design, mask making, semiconductor wafer fabrication (wafer foundries), assembly and packaging services, and testing services. This vertical segregation has made it possible to design, manufacture, and market semiconductors without a significant investment in manufacturing or engineering manpower. These companies design and make various custom devices that serve the needs of manufacturers and users alike.

Dataquest has observed an increasing number of alliances between companies involving the exchange of technology for manufacturing capacity. This trend is becoming more pronounced between U.S. and Asian firms, as Japanese commodity device manufacturers seek to absorb some of their over-capacity with innovative products from cash hungry U.S. start-ups.

Distribution and Marketing

Semiconductor devices are sold and distributed in the following three basic ways:

- Through a direct sales force with shipment from the manufacturing company
- Through a sales representative organization with shipment from the manufacturing company
- Through a distributor typically with shipment from its own stocks

Historically, semiconductor companies have preferred to market directly whenever possible, especially to larger users. However, a direct sales force cannot market economically to smaller users or in areas where sales volumes are low, such that direct selling represents a proportionately larger fixed cost. As a result, many companies have turned increasingly to manufacturers' representatives (reps). These organizations may handle several companies with nonconflicting product lines. Generally, a representative organization receives a higher commission than does the direct sales force. However, for small companies that cannot economically maintain a direct sales force, this approach is a viable alternative.

Distributors generally buy semiconductor devices from the manufacturers in large quantities and resell them in smaller quantities and at higher prices. Distributors also often market actively to many companies. They relieve the semiconductor companies of the problems associated with handling many small orders and perform a valuable inventory function for the industry, as well as some marketing functions. For more information on this facet of the industry see the Distribution section of the Companies notebook.

Forward Integration

In the past, forward integration has rarely played a role in the structure of the U.S. semiconductor industry. Well-known domestic manufacturers that entered the consumer products business include Texas Instruments (calculators, educational toys, and home computers), Intel (watches), Fairchild (video games), and National (calculators and watches). While TI continues to produce educational toys and calculators, it assembles these products offshore. Most U.S. chip makers who attempted to crack the consumer market abandoned it in the wake of Asian competition.

Notable exceptions to this rule have been Delco, a General Motors supplier, IBM, and AT&T Technology (formerly Western Electric). While some U.S. semiconductor manufacturers have increased their forward integration with ventures into higher level products (particularly board-level products), the separation of semiconductor manufacturing and end-product manufacturing still prevails in the majority of cases.

One major problem that U.S. firms have experienced in simultaneously addressing the semiconductor components business and the consumer products business stems from the marked differences in operational structure that these markets necessitate. The separation of semiconductor component and end-product manufacturing certainly does not apply to Japanese electronics firms. The vertical structure of Japanese electronics companies has proved effective in linking the design, manufacture, and end-product application of semiconductors in a highly synergistic way. Japan's success in doing so has given captive Japanese semiconductor companies significant advantages over their U.S. rivals in manufacturing economies of scale and capital resources.

Industry and Technology Overview

Ownership

The ownership of semiconductor manufacturing can be divided into three broad categories: independent manufacturers, divisions of major corporations, and captive manufacturers. These distinctions are not always entirely clear, but they serve generally to identify the various types of companies. The first two groups actively compete in the merchant market, but the latter does not.

Independent Manufacturers

Most semiconductor manufacturing (about 70 percent in the United States) is performed by independent manufacturers. By definition, the semiconductor operations of these manufacturers constitute a major portion of their businesses. Companies in this category include Advanced Micro Devices (AMD), Intel, Motorola, National Semiconductor, and Texas Instruments. A very large number of smaller companies, both publicly and privately owned, are in this category.

A basic characteristic of these companies is that their survival depends on their performance in the semiconductor industry. As independent companies, they have neither guaranteed markets or financing. In general, they are competitive, aggressive, and leaders in bringing new technologies to the marketplace. Moreover, they have been leaders in expanding the international scope of the industry, both in manufacturing and marketing.

Divisions of Major Corporations

Many major corporations in the United States, Japan, and Europe have divisions that manufacture semiconductor devices. These divisions are distinct from totally captive manufacturing in that they actively market their semiconductor products. In some cases, the divisions do not supply products directly to their parent corporations, although many of them do. Most such organizations, however, derive only a minority of their sales from captive markets. Companies with large semiconductor divisions include General Electric/RCA, Hitachi, ITT, Nippon Electric Corporation, Philips, Raytheon, Siemens, Westinghouse, Hughes, Rockwell, Gould, and Schlumberger.

Structurally, these organizations may be treated as divisions of the parent corporation or they may be organized as semiautonomous companies. Such an example would be Fairchild, which is set up as an independent company from its parent, Schlumberger.

These companies vary greatly in (1) their outlook toward the semiconductor industry, (2) their treatment by the parent company, and (3) their competitiveness in the industry. They may be slightly less competitive and aggressive than the independent companies, but it is difficult to generalize. All of these companies, however, can benefit from the financial resources of the parent. Considering the increasingly high capitalization requirements in the industry, having parental resources available is a distinct advantage. Furthermore, large parent corporations often have a sheltered market that the semiconductor division can supply. On the other hand, such companies can have problems attracting talented individuals from the industry because the fast pace of the semiconductor industry frequently is at odds with the slower decision-making processes of a large corporation. Moreover, the senior officers of the parent corporations often have little or no experience with the semiconductor industry.

Captive Manufacturers

Several companies have totally captive semiconductor facilities and make semiconductor devices for their own use, but do not market devices to industry. Major manufacturers with captive lines include General Motors, Hewlett-Packard, Honeywell, and IBM. The existence of such captive facilities tends to decrease the market available to the companies competing in the semiconductor industry. Many captive facilities provide services and special devices not available in the marketplace, i.e., these companies make what they cannot buy.

As semiconductors have become more important to major manufacturing companies, captive facilities allow semiconductor design to be integrated with final product design. Moreover, there are often planning and control advantages. The ability of a captive facility to know the future quantity while controlling its output, and the lack of marketing costs are strong advantages.

Captive facilities have many of the same problems facing divisions of major corporations: difficulty in attracting top-grade technical personnel, slow decision-making processes, and changes in the technology that may outmode facilities. In the past, only a few manufacturers (e.g., AT&T and IBM) have had sufficient in-house requirements for semiconductors to support the necessary efficiencies of scale for cost-effective semiconductor manufacturing. However, this situation is rapidly changing with both the increasing scale of equipment manufacturers and the increasing solid-state content of their products. Companies with semiconductor purchases in excess of $100 million numbered only 2 in 1975, increased to 7 in 1979, and approached 50 in 1985.

Industry and Technology Overview

INTERNATIONAL ASPECTS

The semiconductor industry is highly international. Devices are manufactured and marketed throughout the industrialized world. Historically, the U.S. has been the largest market for semiconductor devices. In the last five years, however, the global semiconductor market has shifted significantly. In 1980, both the Japanese and European markets were roughly half the size of the U.S. market--which consumed 42 percent of semiconductor devices sold worldwide. Since that time, the Japanese semiconductor market has nearly tripled in size. In 1985, Japan accounted for nearly 35 percent of all semiconductor consumption, compared to 39 percent for the U.S.

Japan

The use and manufacture of semiconductor devices developed very rapidly in Japan beginning in the late 1960s, and for the next decade the Japanese market grew at roughly an equal pace with the world market. Since 1980, both production and consumption of semiconductors in Japan has accelerated. Japanese consumption of semiconductor devices in 1985 was valued at $8.6 billion--more than eight times the amount purchased in 1975. In Japan, semiconductor devices are used primarily for consumer applications, with nearly 46 percent of all devices applied to that market. In recent years, however, industrial applications for semiconductors have been growing in Japan.

In the past, the Japanese market for semiconductor devices has been well protected by the Japanese government through a variety of means, including high tariffs, import restrictions, and subsidies. This situation has allowed the Japanese semiconductor industry to develop successfully to maturity and viability. As a result, Japanese companies can manufacture a high percentage (estimated at about 88 percent) of the semiconductor devices consumed in the country. Japanese semiconductor technology, at all levels, is now at par with or sometimes more advanced than the best in the United States. Nine major companies dominate Japanese semiconductor manufacture, although there are also many smaller companies.

In the past, foreign companies have been restricted to a minority interest in semiconductor manufacturing in Japan. Several U.S. companies established manufacturing facilities on a minority ownership basis with little success. Until recently, Texas Instruments was the only U.S. company allowed to have a wholly-owned facility in Japan. Now, however, many import and capital investment restrictions have been lifted, and foreign companies are allowed to have wholly-owned manufacturing plants in Japan. Both Motorola and Fairchild now operate plants in Japan. Among European companies, Philips holds a 30 percent interest in

Matsushita Electronics, and Siemens has a smaller interest in Fujitsu and Fuji Electric. National Semiconductor, Intel, and AMD are likely to establish Japanese facilities in the near future.

The most pernicious barriers to U.S. trade with Japan have been non-tariff barriers (NTBs). These arise from an "old boy" network of key industry players who prefer to do business among themselves rather than with an outsider. From a cultural standpoint, the U.S. finds such barriers difficult to surmount. U.S. outrage over the NTBs has intensified during the last few years, culminating in a lawsuit by the Semiconductor Industry Association (SIA) charging Japan with unfair trade practices, and the recent passage of an omnibus trade bill by the House of Representatives seeking greater access to the Japanese semiconductor market.

In late July of 1986, the U.S. Department of Commerce (DOC), and Japan's Ministry of International Trade and Industry (MITI), signed an historic trade agreement concerning export price monitoring and U.S. access to the Japanese market. The intent of the agreement is to prevent Japanese semiconductor firms from selling products offshore at prices below their cost of manufacture--a practice generally referred to as "dumping." The agreement also specifies that Japan will increase its purchase of foreign semiconductor products, thus reducing its balance of payments surplus with major trading partners.

The success of this agreement will have far-reaching implications on the future of semiconductor trade between the U.S. and Japan. The failure of Japanese companies to abide by the semiconductor trade agreement could, in the short term, result in the imposition of dumping penalties in the form of import tariffs, on those companies found guilty of selling products to the U.S. market at below their cost of manufacture.

Europe

The European market for semiconductors amounted to an estimated $4.6 billion in 1985, roughly 17 percent of total worldwide consumption. By way of contrast, European consumption in 1976 represented 27 percent of the worldwide market. Throughout the late 1970s and early 1980s, European consumption of electronic goods lagged significantly behind that of the U.S. and Far East--attributable in part to the weakness of European currencies against the U.S. dollar. The corresponding effect on European chip sales reflected a problem of consumption rather than innovation.

Industry and Technology Overview

The European market for semiconductors is now growing stronger. Europe is benefiting from negligible inflation, cheaper energy prices, lower interest rates, and stronger currencies. Dataquest predicts that the European market growth rate over the next ten years will exceed that of the world, ending up at $25 billion by 1996.

Until recent years, discrete devices made up the major portion of European semiconductor consumption. In 1976, over 50 percent of Europe's semiconductor market was in discretes. In 1985, this figure dropped to slightly under 21 percent. While Europe continues to consume a higher percentage of discrete devices than the world market as a whole, this trend is rapidly changing. The European integrated circuit market is currently growing at a rate averaging twice that of the current world rate.

Semiconductor end-use in Europe is divided somewhat evenly into industrial, telecommunications, computer, and consumer applications. The telecommunications market is a major one for Europe, representing 25 percent of the total European semiconductor marketplace, and 35 percent of worldwide telecommunications semiconductor consumption. Both telecommunications and automotive applications are growing in their significance to total European semiconductor consumption. Dataquest predicts the automotive market, currently at slightly less than 6 percent of European semiconductor consumption to increase at a compound annual growth rate of nearly 22 percent between 1986 and 1991.

For several years the total worldwide market share held by European semiconductor manufacturers has been diminishing--from 16 percent in 1978 to 12 percent in 1985. The total output of European manufacturers for 1985 represented 38 percent of the semiconductors consumed in Europe, with American and Japanese suppliers playing a major role in the European market.

A new breed of more entrepreneurially inclined management may increase the marketing prowess of European semiconductor companies, and spread R&D and capital investment costs through strategic alliances. A notable example of this is the Philips/Siemens "Mega Project," a joint undertaking aimed at next generation SRAM and DRAM devices, including 1Mb DRAMs and SRAMs. European companies such as Wacker Chemitronic, SGS, Siemens, and Philips have contributed significantly to the areas of materials, processing, systems architecture, and packaging. In recent years, several major European suppliers have been investing heavily in plant and equipment with the intent of boosting their international presence. Thomson's acquisition of Mostek, and the Siemen's recent purchase of Hyundai Electronics America's wafer fab in Silicon Valley testify to this growing vitality.

Industry and Technology Overview

SPECIAL INDUSTRY CHARACTERISTICS

The semiconductor industry has many characteristics that set it apart from other industries. For the most part, these characteristics arise from the industry's high technological dependence, intense competitiveness, and broad variety of products. These special characteristics include:

- Intense competition
- Product diversity
- High technology
- Rapid rate of change
- Cost and price reductions
- Short product life cycles
- Maturity with change

Competition

The semiconductor industry has always been intensely competitive and should remain so in the foreseeable future. The effects of this competition are to make the industry aggressive, to make it readily adaptive to any change or competitive advantage, and to limit profit margins.

The reasons for this intense competitive situation are as follows:

- A lack of any major barriers to competition
- Low barriers to entry
- Market share advantages
- A wide range of products
- A very large number of companies
- A continual influx of new products and new markets

More than 160 companies worldwide make semiconductor products of one kind or another, although many of these companies produce only specialized products or manufacture limited lines for their parent companies. More than 90 U.S. companies actively compete in the mainstream of the industry. In addition to these companies, more than 30 European and more than 30 Japanese companies make and sell semiconductor devices.

In any given semiconductor market segment, there are usually many competitors from which a buyer may choose. The large number of semiconductor companies may be reduced in the future, but they can exist at present because of the wide range of products in the industry. A company can specialize in a given area and have a particular advantage in manufacturing a few products. Although any competitive advantage in a product line is temporary, the diversity of products allows all the companies in the industry to be competitive in at least some areas.

New products are continually being developed by the industry. Since ~~a new~~ product, by definition, does not have established suppliers, the company producing it can gain a short-term advantage. Thus, many small companies compete effectively in the semiconductor industry by continually advancing the state-of-the-art technology. The same advantage inherent in new products also applies to new markets created by these products. Nevertheless, since market share and the resulting volume production is important in the industry, particularly as markets become mature, competition is intense. This situation leads to recurrent price competition, which can be extremely severe.

Another reason for the large number of competitors in the industry and the severity of the competition is that barriers to entry into the semiconductor industry have, in the past, been relatively low. Although such barriers as start-up costs, technology, and market entry are rising, they nevertheless remain low in comparison with many other industries. Between 1968 and 1971, more than 36 new companies were formed in the United States to compete in the semiconductor industry. Despite declining semiconductor demand in 1970 and 1971, at least 80 percent of these companies survived in one form or another and some, such as AMD, Intel, and National Semiconductor, have been quite successful. More recently, there has been an upsurge in semiconductor start-ups. Nearly 130 companies were formed between 1977 and 1985. More than 30 percent of which were formed in the last two years. Wafer foundries and other special service areas continue to see the creation of new companies. Furthermore, increased international competition by Japanese and European companies is providing more market competitors. In the future the global market will have to adjust to new players from Taiwan, Korea, and eventually mainland China.

A corollary to the low entry barriers to the semiconductor industry is the historical lack of any artificial market or manufacturing barriers that might serve to lessen competition, such as government regulation, price controls or supports, or labor union policies. With the July 1986 signing of the U.S.-Japan trade agreement, however, price monitoring and regulation has now been initiated as a means of easing frictions between two major trading partners. The ultimate enforceability of the agreement, and its effects on competitiveness, are as yet unclear. As the semiconductor industry grows in its importance to national security, and the U.S. gross national product, we can expect the federal government to pay closer attention to the structure and health of the domestic chip industry. As the semi industry grows to become a bigger percentage of GNP, the government will pay more attention.

Product Diversity

The semiconductor industry is characterized by an extremely wide range of products. Several different types of transistors or other semiconductor devices are based on different physical laws. Each type of product has a large number of operating characteristics, including power-handling capability, speed, amplification level, and rated voltage. The possible design value chosen for each of these characteristics for a given product can vary over an extremely wide range, and the possible combination of product characteristics is nearly infinite. Integrated circuits have even wider diversity than discrete devices because of variations in circuit designs.

Product diversity occurs because semiconductor products have been specialized to perform distinct functions, and their design and manufacture have been optimized for those functions. Thus, there are literally tens of thousands of different products in the industry.

The extremely wide diversity of semiconductor products has many important consequences for the industry. Because diversity allows a large number of competitors to exist by forming a large number of specialized markets, it paradoxically increases the competition in the industry. Product diversity also decreases volume manufacture of any single product, thus inhibiting increased industry automation.

Technology

It is important to emphasize the role that technology plays in the industry. The primary products--discrete devices and integrated circuits--are, of course, technological in nature. Their concept, design, and function are the very basis of sophisticated electronics. It is also important, however, to note that the manufacture of the devices is also highly technical in all its aspects--the processes employed, the sophisticated equipment used to manufacture and test the devices, and the skill levels of all personnel concerned with the operation. Furthermore, the products in which most semiconductors are used are also highly technological.

Industry and Technology Overview

A large scale integration (LSI) semiconductor memory exemplifies this technological complexity. To be competitive in this field, a company must have a thorough understanding of the device's complex end use. Moreover, the manufacturer must have the design capability and the processing technology to make the device. The company must also be able to choose successfully among the trade-offs available in the various technologies to produce a successful cost-competitive product. This understanding is fundamental to being a competitive supplier with state-of-the-art design, state-of-the-art manufacturing, and products that are useful and cost effective for the user.

Furthermore, the technological nature of the business makes timing critical. Every facet of a product--its design, its process, and its market--is viable and competitive for only a short period of time. Before that time, manufacture is too difficult, too costly, or simply not viable; after that time, the product may be obsolete.

Because of the technological intensity of the industry, research and development expenses are unusually high compared with those in many other industries and constitute from 10 to 20 percent of revenues. Extensive research and development is a necessary investment for any company that wishes to remain competitive.

Nearly everyone who works in the industry must be highly trained in one phase or another of semiconductor technology. This requirement includes a large cadre of engineering specialists; managers who are trained not only in management but who also have a thorough understanding of the general aspects of the technology; and the technicians, supervisors, and workers who must have a thorough understanding of the equipment they operate.

A recurring problem for all companies is the threat of technological obsolescence of their products. This threat occurs not only over time, as new and improved products displace old ones, but also because at any time a completely different semiconductor technology could obsolete the products they manufacture. For example, silicon transistors replaced germanium transistors, TTL logic replaced DTL logic for integrated circuits, NMOS replaced PMOS for low-cost memory, and CMOS is now replacing NMOS in devices requiring low power and high density.

Rate of Change

The semiconductor industry is very dynamic; it truly suffers from "future shock." It has very rapidly changing technology, processes, products, manufacturing methods, and markets. This characteristic of rapid change is perhaps the least understood and the most underrated by observers of the industry.

Industry and Technology Overview

Improvements in the capability of semiconductors come at breathtaking speed. For example, in the 14 years between 1962 and 1976, the products of the industry progressed from a simple transistor, to an IC performing a simple logic function (such as a gate), to an IC performing an entire functional block of a system (such as an adder), to a one-chip calculator circuit, to a one-chip computer processor. Similarly, RAM densities have increased from 1,000 bits in the early 1970s to more than 1,000,000 (1Mb) in today's DRAMs--with devices of more than 4 million bits on the drawing in development. Processing technology has changed from alloy junctions to bipolar planar technology to MOS technology--all with many alternative variations. Markets have changed from primarily military applications to a wide range of industrial equipment, EDP (Electronic Data Processing) applications, and consumer products.

The dynamic nature of the semiconductor industry is both exciting and profoundly unsettling. Products, technologies, and even companies are based on the shifting sands of technological progress. Past benchmarks are not applicable to the future. It is important to understand that this rapid rate of change is not a transitory phenomenon. Rather, it is a built-in characteristic of the industry. That is, the industry is geared to change. Indeed, its dynamic nature is a more fundamental element of the industry than are the semiconductors that the industry manufactures.

The following three main factors account for the dynamic nature of the industry:

- Technological progress
- A large number of talented people
- Heavy competitive pressure

None of these factors are independent, but they work together in constant reinforcement. Because the industry is highly competitive, companies strive for improvements in technology to gain a competitive advantage, even if it is only temporary. The industry seeks large numbers of individuals with technological expertise, creative ability, and drive. These people must have the special ability to manage under the constant change that is occurring in the industry--circumstances that bewilder competent managers in other industries. However, it is the excitement and change that attract these people to the industry. In turn, their abilities add to the competitive crush and the high rate of technological progress.

Not all of the effects of this environment are positive. The change takes its toll both in people and companies, through technological obsolescence. Although the industry has made laudable progress, adaptation to the rapid change keeps industry profits low and tends to undermine any basic strength that a single company may have, so that any competitive advantage may be short-lived. Moreover, both the change and the growth in the industry create a continual financial strain for most companies.

Cost and Price Deflation

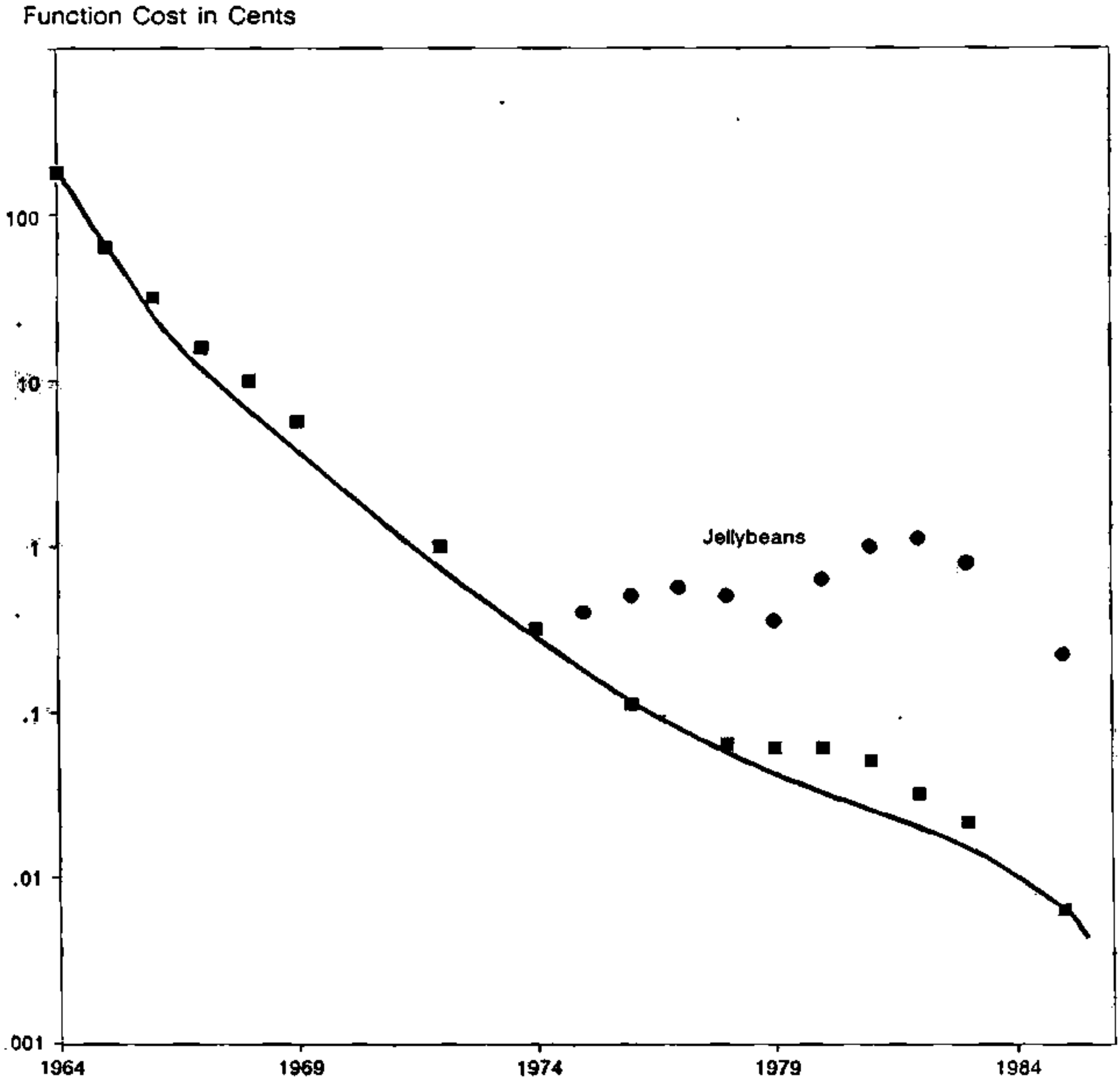
One of the most remarkable characteristics of the semiconductor industry is the rapid and continual price decreases that occur. The price of an average function in an integrated circuit has declined an average of more than 40 percent per year since 1962, as shown in Figure 3. If these price changes over the past 20 years had been matched by the automobile industry, one could buy a car today for $1.00. In 1960 the average price of one transistor was more than $5.00. In 1985, one could purchase an integrated circuit with 500,000 transistors for $5.00 or less. In the semiconductor industry, the high-volume markets for commodity devices traditionally have been called "jelly bean" markets, but today the nomenclature is no longer germane since transistors are considerably less expensive than jellybeans. The price of a semiconductor is effectively decreased in four ways:

- Decreased unit price
- Increased functions per device
- Improved device parameters
- Greater sophistication or complexity per device

Average unit price deflation has been the most visible indication of price decreases in the industry, although it is possibly the least significant. Unit price decreases for a discrete device, the silicon transistor, are shown in Table 4 for the years 1962 to 1985. Unit price decreases for integrated circuits from 1963 to 1985 are shown in Table 5. The average price for discrete devices has fallen even though many lower cost devices are no longer sold, having been replaced by integrated circuits. Integrated circuit prices have fallen slowly although the complexity of the circuits themselves has increased. It should be noted that for both discrete devices and integrated circuits, the recent price per unit is not decreasing as fast on a percentage basis as it has in the past.

Figure 3

AVERAGE PRICE PER FUNCTION (ICs)



Source: Dataquest
December 1986

Table 4

PRICE HISTORY OF SILICON TRANSISTORS
1962-1985
(Noncaptive U.S. Factory Sales)

Year	Unit Volume (In Millions)	Average Unit Price
1962	26.6	$4.39
1963	50.6	$2.54
1964	118.1	$1.46
1965	274.5	$0.86
1966	487.2	$0.64
1967	489.5	$0.58
1968	684.1	$0.44
1969	934.5	$0.37
1970	786.9	$0.38
1971	803.0	$0.33
1972	1,208.4	$0.27
1973	1,466.7	$0.30
1974	1,733.3	$0.27
1975	1,472.0	$0.25
1976	1,900.0	$0.22
1977	2,081.0	$0.21
1978	2,375.0	$0.20
1979	2,786.0	$0.21
1980	3,295.0	$0.20
1981	4,111.1	$0.18
1982	4,137.5	$0.16
1983	4,471.4	$0.14
1984	6,516.6	$0.12
1985	5,371.5	$0.13

Source: SIA, EIA
Dataquest
December 1986

Table 5

PRICE HISTORY OF INTEGRATED CIRCUITS
1963-1985
(Noncaptive U.S. Factory Sales)

Year	Unit Volume (In Millions)	Average Unit Price
1963	0.5	$31.60
1964	2.2	$18.50
1965	9.5	$ 8.33
1966	29.4	$ 5.05
1967	68.1	$ 3.24
1968	133.2	$ 2.28
1969	252.9	$ 1.63
1970	298.8	$ 1.45
1971	361.5	$ 1.23
1972	603.5	$ 1.01
1973	1,093.6	$ 1.09
1974	1,441.4	$ 1.04
1975	1,228.3	$ 0.99
1976	1,612.0	$ 1.00
1977	1,989.2	$ 1.02
1978	2,922.0	$ 0.91
1979	3,884.0	$ 0.98
1980	4,437.0	$ 1.08
1981	4,669.5	$ 1.05
1982	5,216.3	$ 1.04
1983	6,705.6	$ 1.06
1984	9,316.0	$ 1.13
1985	7,803.0	$ 1.09

Source: SIA, EIA
Dataquest
December 1986

Industry and Technology Overview

The greatest change in semiconductor prices comes from the increasing number of functions performed by a single device. In 1962, each unit sold performed essentially a single function because nearly all devices were discrete units such as transistors or diodes. With the advent of integrated circuits, the average number of functions of a single unit began to increase. In 1969, the estimated average was 3 functions per unit; by 1972, the average was about 16 functions per unit. The increasing market penetration of very-large-scale integrated circuits (VLSI) ensures that the average number of functions per unit will continue to increase. Since a 1Mb DRAM contains up to 1.2 million transistors, relatively small unit sales of these devices can have a dramatic effect on the average number of functions per unit for the overall industry. Dataquest estimates that by late 1986 the average number of functions per device will be more than 15,000 (see Figure 4).

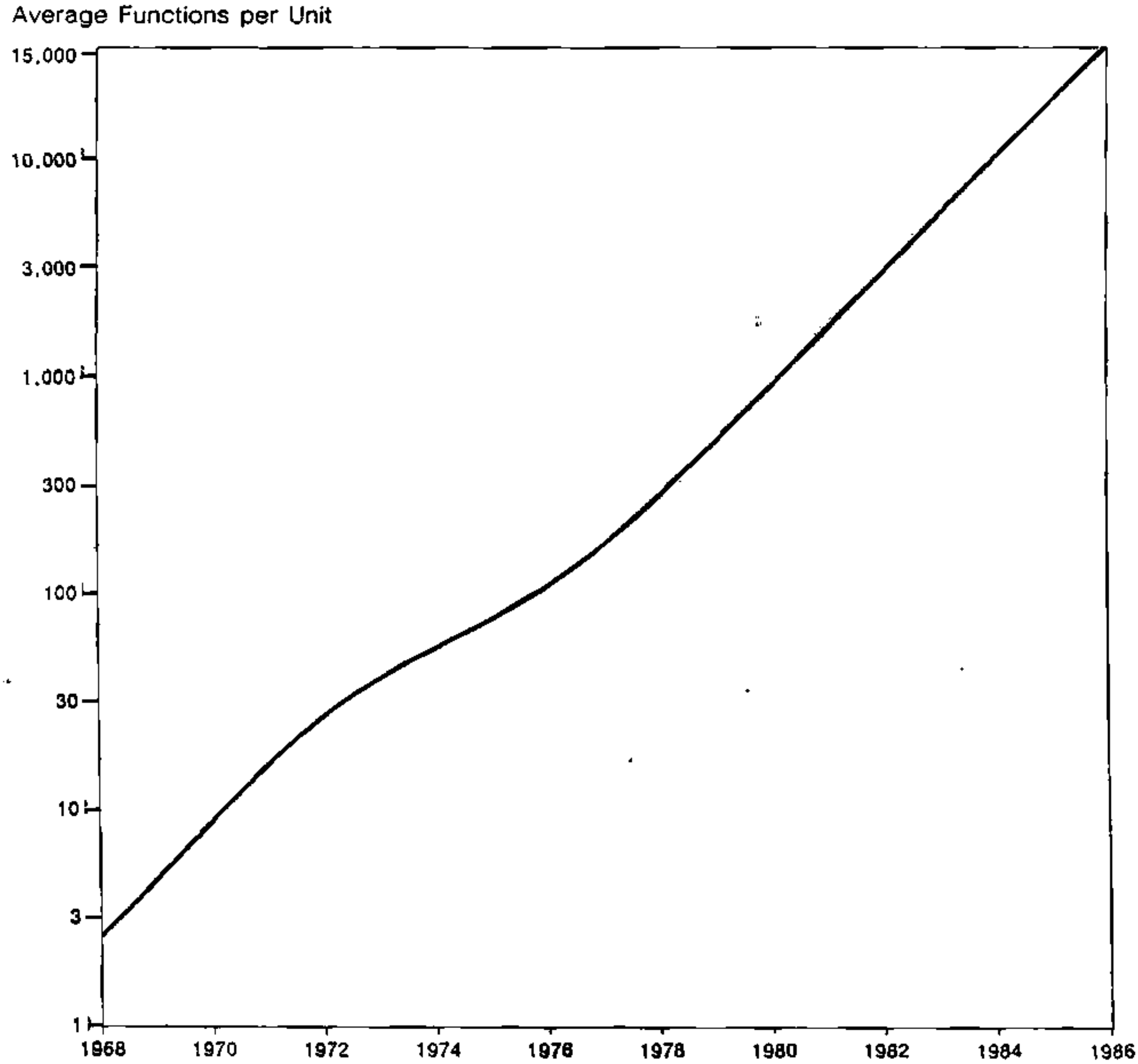
Unit pricing has also been affected by the vast improvement that has occurred in device performance, such as greater power-handling capability, increased speed, greater reliability, lower power consumption, and longer life. For example, one of the greatest factors in the growth of the power semiconductor transistor market in the last few years was not lower prices per se, but the ability of these devices to handle either higher power or higher voltages and to do so with greater reliability. Integrated circuits capable of higher speeds have allowed computers to have much greater computational power using the same amount of electronics.

Although the list of device improvements is long, the net effect is that the user of semiconductors has had an effective price decrease either because he can obtain greater performance using the same devices, or because he can improve device performance to decrease the number of devices needed. It is not possible to quantify effectively the price deflation of improved device performance.

Besides being larger (more functions) and better (improved parameters), ICs can also be more complex, i.e., more sophisticated. For instance, a microcontroller is no larger nor more difficult to manufacture than many memory devices that were introduced earlier by semiconductor manufacturers. However, a microcontroller employs sophisticated systems design concepts. It comprises a complicated interplay between logic design, random access memories, read-only memories, and input-output circuits. Many different logic and memory designs are on the same chip and complicated computer organization concepts are used. In other words, it is more sophisticated. This type of improvement takes time to evolve; it is important as a means of greater performance at a given price. Even if semiconductor process technology remained at its current limits, this type of design innovation and optimization would continue for many years. In the semiconductor industry, technological advances always remain ahead of the diverse commercial implementations that they drive.

Figure 4

NUMBER OF FUNCTIONS PER UNIT FOR THE AVERAGE SEMICONDUCTOR DEVICE



Source: Dataquest
December 1986

There are several underlying reasons for the four types of price reduction discussed above. The highly competitive nature of the industry has spurred technological improvement as a means of gaining competitive advantages or opening new markets. Price decreases have come from the continuing improvement of old technologies and the development of new technologies, manufacturing improvements, the use of new materials (especially in packaging), the move to overseas assembly to take advantage of lower labor costs, and a large increase in unit volume.

For new products, improvements in device yields per wafer, combined with larger batch fabrication, have significantly reduced the costs of semiconductor chips and, therefore, prices. As the technology becomes more refined, the yields should improve for more complex or more sophisticated devices.

While the effects of improved manufacturing techniques and market forces may decrease unit prices for specific IC products, such as 64K DRAMs, the learning curve theory does not hold true for ICs as a whole. Between 1976 and 1985 the number of ICs shipped on a worldwide basis increased by a CAGR of 21 percent. Rather than decreasing, however, the ASP for IC devices in total rose by 0.7 percent. The effects of the learning curve are best appreciated not in an overall decline in IC package prices, but rather in the decline in the cost of functions per unit, as seen in Figures 1 and 2.

As the cost per bit or per transistor in an IC diminishes, manufacturers must increase the functional density of their devices in order to keep their profits per unit from seriously eroding. This trend has been highly evident in memory ICs. Companies employing the latest technological advances to produce higher capacity DRAMs may initially enjoy a higher margin of profit as a reward for early market entry. As economics of scale and increased competition take their toll on the price per function, however, technology becomes a relentless taskmaster. To remain a force in the memory IC market, a company must continue to push chip densities higher in an effort to shore up unit profit. Dataquest has observed that the area of read/write memory, the ASP per bit has decreased 35 percent each year.

Because of reduced dimensional tolerances made possible by VLSI, semiconductor prices per function will continue to decrease. Dataquest predicts that while the ASP per unit for read/write memory devices will show a CAGR of 11 percent between 1985 and 1990, the actual ASP per bit will decline by nearly 29 percent.

Major new technological changes in the industry, such as the development of planar technology or MOS transistors in the past, are not expected in the next few years. However, the current state-of-the-art in semiconductor fabrication allows for considerable evolutionary improvement. It takes several years for many small technological improvements to have an effect on the industry as a whole. We believe that the current rate of technological progress and the eventual possibilities indicate that there will be no foreseeable change in the rate of price decreases over the next few years.

Product Life Cycles

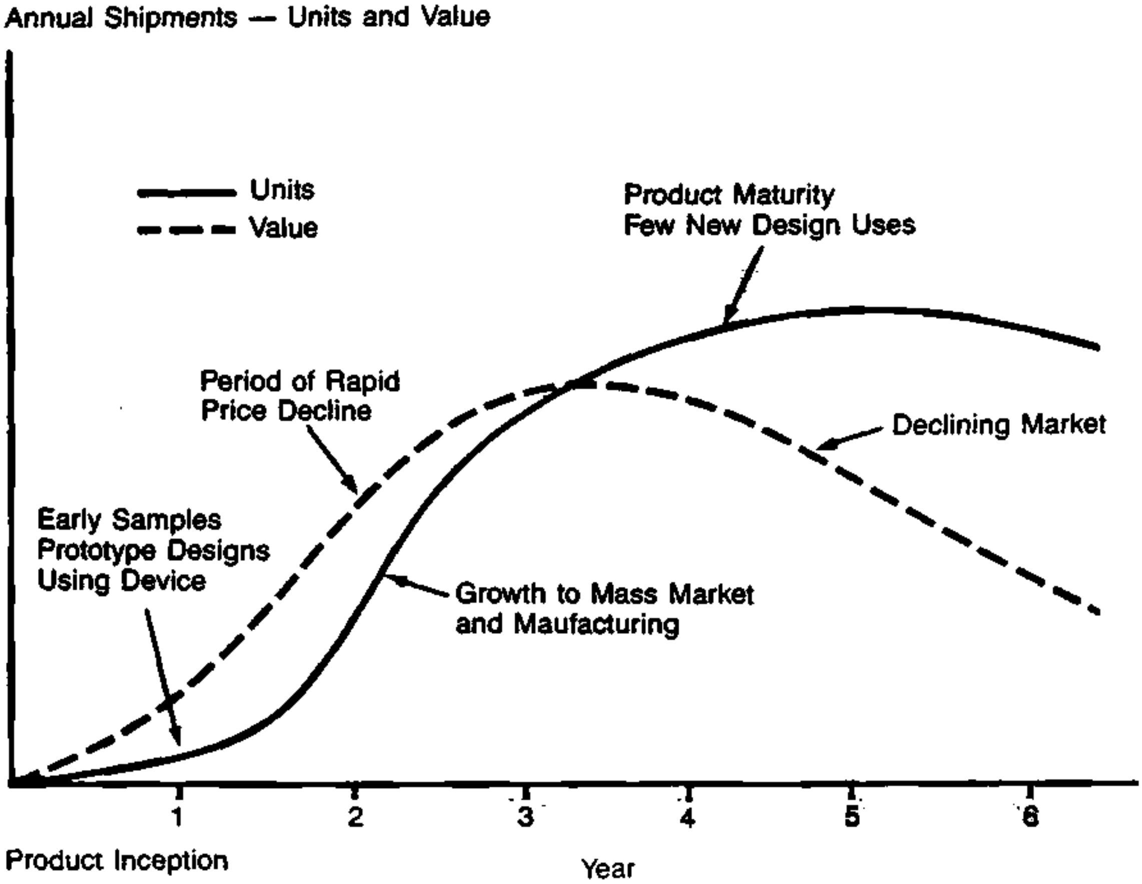
Short product life cycles are a basic consequence of the rapid change in the semiconductor industry. Any product is useful in the marketplace for only a certain period of time after its inception, but in the semiconductor industry that time can be extremely short. It is important to differentiate between the single product and the product family (in which the actual products themselves change). A product family has a somewhat longer life time, usually three to five years. A technology's life cycle may be even longer since it may be used for a number of successive product families.

Figure 5 shows a typical product life cycle for the semiconductor industry. After its introduction, a product rapidly increases its market--both in units and in dollars. Because initial prices are high and decline thereafter, unit volume always increases somewhat faster than dollar volume. Initial growth may be slow, until the product is accepted and understood, and new equipment is designed to include it. After that, unit volume grows very fast. Then several things happen--the market for the equipment using the product becomes saturated, new equipment is designed using new improved products, and the price declines. Subsequently, the dollar volume of the market for the product reaches its highest point. If equipment using that product has a relatively long life cycle, unit volume of a particular product may remain fairly stable (or even grow somewhat) for a longer period of time, but it will eventually begin a gradual decline.

DTL integrated circuits are an excellent example of product life cycles in the semiconductor industry. The market for these circuits grew very rapidly between 1966 and 1969. After that time, new logic designs generally employed TTL circuits. However, because of the use of older equipment designs, the DTL market kept growing in unit volume through 1973. The dollar value, however, peaked in 1969 and has declined since then as the average unit selling price continued to decline. DTL was replaced by TTL, which is being eclipsed by CMOS.

Figure 5

TYPICAL SEMICONDUCTOR PRODUCT LIFE CYCLE



Source: Dataquest
December 1986

Industry Maturity

The semiconductor industry is both young and rapidly changing. It is both a growth industry and a mature industry. The semiconductor industry aggressively seeks new and growing markets. This, in turn, leads to rapid change and growth. The dynamic nature of the industry is reflected in its management of technology and technological change. The industry's characteristics are more an indication of industries of the future rather than a reflection of industry immaturity. There is currently no reason to believe that the industry will change its basic characteristics and start to resemble the older, more stable industries of the United States.

The industry can be characterized as being highly sophisticated, especially in its use of technology, research, and development, and in its international marketing and manufacturing approaches. Management in the industry is exceptionally competent, even though rapid change and competitive pressures present very challenging problems. Nevertheless, some of the best managed corporations in the United States have failed in the semiconductor industry.

INDUSTRY TRENDS

The semiconductor industry has always been characterized by change. The most basic industry trends may be described as:

- Low-cost electronics
- Market pervasiveness and new markets
- Device complexity
- Market crowding
  - Fewer suppliers
  - Increase in very large users
- Mergers and acquisitions
- Internationality
- Vertical integration
- Continuing rapid technical change
- Captive semiconductor manufacturing
- Increasing automation

Industry and Technology Overview

Low-Cost Electronics

A principal feature of the semiconductor industry is the continual reduction in costs and prices, resulting in the emergence of even lower-cost electronics. Previous concepts of electronics as being expensive must be discarded. Cost, of course, must refer to the function that a semiconductor performs and not simply unit price. Costs can be expected to decrease in the future for the following reasons:

- An increasing number of functions on integrated circuit chips
- Improvements in yields through larger wafers, better equipment, and improved processing
- Greater unit volume and, therefore, greater efficiencies of scale

The results of lower-cost electronics are expected to become even more visible in the future. Some of these capabilities--such as in low-cost, hand-held, personal calculators and inexpensive home computers--are already visible. In discrete devices, much of the effect is yet to be seen, but capability has increased and cost has decreased to the point where discrete devices such as triacs and SCRs are cost-competitive with a wide range of electromechanical and electromagnetic components. Because these components have a definite requirement for raw materials, their costs have set lower limits. Moreover, many of them cannot be batch fabricated, allowing semiconductor devices to be more cost-competitive. In the future, semiconductors are expected to be substantially less expensive than electromechanical and electromagnetic devices.

Market Elasticity

In general, decreasing semiconductor prices have opened up enough new areas of market growth to allow increases in the dollar value of the total market. In other words, the semiconductor market has a basic elasticity greater than one. Precise determination of this elasticity, however, is extremely difficult because the effective change in semiconductor prices is difficult to measure. Furthermore, there is a question of timing. It is apparent that changes in semiconductor prices or capability--essentially the same thing--lead to new markets. However, it may take several years for these markets to develop because many electronic systems are so complex that they require a long learning curve in employing new devices, designing them into systems, and developing the market for those systems. Thus, even if semiconductor prices do not change in the future, the market can be expected to expand at current prices for several years. Items such as telecommunication applications, large computers, and military systems have life cycles lasting many years. With the very high rate of price decline for electronic functions, ignoring timing differences might indicate that the average 15 percent rate of growth in the semiconductor industry indicates elasticity a little greater than one. But in many cases, current markets reflect the devices developed several years ago. Today's products ensure market growth for several more years at current long-term growth rates.

Market Pervasiveness and New Markets

Market growth, particularly from the penetration of new markets, should be a continuing characteristic of the industry. Growth in the semiconductor market comes from either expansion of established markets or creation of new markets. Even in an established market, the redesign of a product resulting in the use of more semiconductors occasionally makes the difference between "new" and "established" markets less defined.

Established markets, such as those for radios or minicomputers, grow in two different ways:

- The end market grows: For example, the basic market for minicomputers has grown rapidly, spurring a demand for the semiconductor devices used in them. However, because of the declining prices of semiconductors, market growth must be rapid enough to overcome the effect of declining prices if the dollar market is to grow.

- New or changed products that employ more semiconductor devices are introduced: For example, a new computer may use more electronics to make it faster or more powerful. In some semiconductor markets, it is common for product designers to take advantage of falling semiconductor prices to increase instrument or product capability. As a result, these markets grow through higher semiconductor content.

The largest market growth in semiconductors still comes from the creation of new markets. These markets develop because of the increasing capabilities of semiconductor devices and their decreasing costs. There are three basic types of new markets:

- Component replacement

- Creation of completely new products

- Replacement of labor with capital

Industry and Technology Overview

Component replacement has recently opened up vast new markets for semiconductor devices. This market is of two basic types--individual component replacement and replacement of small systems. Individual components are replaced by semiconductors in three areas:

- Electronic components
- Electromechanical devices
- Electromagnetic devices

Basic electronic component replacement includes such items as the replacement of lights with LEDs, or the substitution of semiconductors for tubes in products such as television or high-fidelity equipment. In the past, the switch from electronic tubes to solid state in color television created a strong area of growth for the semiconductor industry.

Large areas of growth have come from the replacement of electromechanical and electromagnetic devices, including: solid-state engine controls; solid-state relays and SCRs replacing electromagnetic relays; disk memories; and semiconductor timing circuits replacing electromechanical devices in appliances. These new markets open up vast areas of growth for semiconductors.

At the systems level, semiconductors are replacing basic electromechanical or mechanical systems. For example, semiconductor controllers are replacing electromechanical devices in industrial control applications. Occasionally, as in watches, semiconductors have replaced a fully mechanical system.

In some instances, the greater capability of integrated circuits and their rapidly falling prices have created totally new markets. The best known of these is the personal computer market. In this case, semiconductors have resulted in the creation of a market that never existed before. The future proliferation of "smart cards" will open a major end market for ICs in the near future. Numerous small markets of this type are also being created in industrial applications.

A basic factor in the growth of the semiconductor market has been the use of semiconductors in equipment that replaces labor with capital. In some instances, this approach also encompasses mature markets. Integrated circuits have opened up many new market possibilities in such areas as computers, industrial automation, office equipment, and industrial control. These new products are primarily aimed at replacing labor, increasing productivity, or both.

Device Complexity

The complexity and performance of integrated circuit devices are increasing rapidly. Device complexity, already great, is expected to increase a hundredfold over the next 10 years. A current LSI device has interconnections that approach the complexity of a road map of the entire North American continent. Devices in the late 1980s will have an interconnection complexity equivalent to a road map of the entire world. In 1983, a MOS memory bit cost approximately 8 millicents. That cost is expected to decline by a factor of 50 over the next ten years. Memory costs will be paralleled by similar changes in the thrust of logic and other semiconductor functions. At the same time, the performance of semiconductor devices as measured by their speed, power, or other parameters will increase steadily and significantly. These estimates are based on current semiconductor research.

The Effect of Dimension

One of the overriding engineering concerns of semiconductor manufacturers is to reduce the minimum dimensions of the devices they make. Minimum line widths for semiconductor devices decreased from about ten microns to about five microns between 1965 and 1978. Most of the increase in complexity of LSI devices (and the reduction in cost per function) came from other factors. These factors are best described by Dr. Gordon Moore of Intel as "cleverness," such as the ability to reduce memory cells from six devices to one device. Table 6 gives estimates of the contribution of various factors to the annual growth of component cost per LSI device. The first two columns are estimates by Dr. Moore. In the last column are estimates by Dataquest. Once a cell reaches one transistor, further improvements become difficult. As a result, reduced dimension tolerance is now the critical factor in increasing component count.

The yield of semiconductor devices is directly related to the size of the semiconductor chip. If component dimensions are reduced, chip size declines and yield increases significantly. A decrease from five microns to three microns (HMOS dimensions) can result in a yield increase of a factor of 10 for a device of equivalent complexity. This can result in a decrease in die cost and ultimately price, by the same amount. Conversely, if die size remains constant, the complexity can increase by a factor of 2 1/2. It is easy to see why the semiconductor industry is striving to reduce dimension. Those manufacturers who first achieve this reduction will have a significant competitive advantage. This direction ensures that device complexity will increase and device cost per function will decline significantly in the future. Essentially, electronics are inexpensive and will continue to get cheaper.

Table 6

ESTIMATED CONTRIBUTION OF VARIOUS FACTORS TO ANNUAL GROWTH
OF COMPONENT COUNT PER LSI DEVICE

	1968-1972	1973-1977	1978-1983	1984-1989
Dimension	26%	26%	67%	70%
Die Area	7	13	15	14
Cleverness	67	61	18	16
Compound Growth	100%	100%	100%	100%

Source: Dataquest
December 1986

System Considerations

The increasing complexity and lower cost of semiconductor devices have resulted, and will continue to result, in semiconductors performing more and more systems tasks. Semiconductor design is now concerned not only with circuit design and logic blocks, but very often with system architecture. New devices, such as some microprocessor peripherals, need to take system application and system software into account during the design of the device. For the electronic system manufacturer, some important consequences are:

- In the future, system design and semiconductor design can no longer be organizationally separated.
- System design and semiconductor design must be performed concurrently.
- If the semiconductor manufacturer does the semiconductor design, the manufacturer will gain de facto system knowledge and expertise.
- System manufacturers that effectively use semiconductors to speed system design will gain an advantage.
- System manufacturers that effectively use semiconductors to enhance performance or reduce system costs will gain an advantage.

The latter point is not entirely obvious, but there are many functions that now can be more cheaply performed by employing silicon "real estate," i.e., the trade-off between software costs and memory costs will continue to favor memory more and more. It may save costs to reduce wire harnesses by employing more sophisticated digital electronic methods. Only those companies with semiconductor design knowledge can effectively choose the most appropriate trade-offs for any given point in time.

Design Considerations

In the future, a major emphasis will likely be on system design and system integration. The reason for the emphasis is that the complexity of semiconductor devices is increasing so rapidly that the ability to put logic on silicon will outpace the conceptualization of what that logic should be. In the past, the transition from device-to-logic gates to logic blocks to small processors has been fairly steady and reasonably obvious.

Cost of Design - The rapidly increasing complexity of VLSI devices shows up most dramatically in the cost and time it takes to do the device engineering and design. Prior to 1970, the cost to design a state-of-the-art semiconductor device was in the tens of thousands of dollars. Currently, the cost for a state-of-the-art device can be in the millions of dollars. For example, state-of-the-art memory devices, such as 1Mb dynamic RAMs, cost semiconductor manufacturers an estimated $4 million to $6 million to design, including special processing work. The recent cost of design and development for 32-bit microprocessors is estimated to be a minimum of approximately $100 million. Those costs include the design of peripheral chips, software aids, and other considerations associated with chips of this complexity.

It is important to note that these costs are a function of system complexity, whether one or more chips is involved. It is estimated that within five years the entire circuitry of today's 16-bit (or 32-bit) microprocessor chips, peripheral chips, and some memory will be included on a single device. While these costs are not growing quite as fast as complexity, they are escalating rapidly. Design aids, including computer-aided design (CAD), redundancy on the chip, modularization of functions, and some other methods of cutting and pasting, help to reduce costs.

Time of Design - Today the capability of putting a million transistors on a chip is a reality. The time required to design will be an extremely critical factor in the near future. Those companies that learn to reduce those times will have a definite advantage.

IC Complexity--The Consequences

The implications of the preceding discussion are important to captive manufacturers and systems houses. The complexity potential of integrated circuits has increased from single-chip, four-function calculators to 32-bit microprocessors in slightly less than eight years. There are some important consequences:

- Potential chip performance will outpace system design capability.
- The major constraints on implementing or designing VLSI devices will not come from wafer fabrication or yield considerations.
- Chip capability will be increasingly important in defining the system and, conversely, the system will be important in defining the semiconductor device.

Thus, the sensitive technical areas that define state-of-the-art limitations will shift. Dataquest believes that the following factors will be future constraints on either advancing the state-of-the-art or implementing a new (VLSI) semiconductor device:

- Semiconductor design, including conceptualization, cost, and time
- Cost, time, and engineering of testing procedures
- Software costs
- System definition, design, and architecture

Chip yield will be a major constraint only for a limited number of high-volume products. The problems mentioned above apply particularly to custom devices. They indicate the areas where a systems company should be concerned about future allocation of resources--dollars, equipment, and labor. Dataquest believes that these factors are especially important because the future supply will be limited. Systems houses must effectively shift their software and design capability to the semiconductor level.

Rise in Major Users

The number of major users of semiconductors is increasing rapidly as shown in Table 7. This increase is spurred by the growing pervasiveness of semiconductors and their importance in end-user electronics markets. As recently as 1977, only one company purchased more than $100 million in semiconductors. This number rose to 46 companies in 1985, accounting for more than 31 percent of all semiconductor consumption. The larger users, each individually representing hundreds of millions of dollars of purchases, will be powerful market forces and the extent of their needs is likely to alter the structure of semiconductor purchasing. However, the large number of major users probably indicates that any single company will not command undue attention from the suppliers.

Table 7

ESTIMATED SEMICONDUCTOR USERS PURCHASING MORE THAN $100 MILLION

Year	Number of Companies	Total Semiconductor Consumption (Billions of Dollars)	Percent of Total Semiconductor Consumption
1976	1	$0.11	2%
1977	1	$0.13	3%
1978	5	$0.69	8%
1979	7	$0.93	10%
1980	12	$1.80	17%
1981	17	$2.80	22%
1982	23	$3.90	26%
1983	30	$4.80	27%
1984	36	$5.80	28%
1985	46	$7.10	31%

Source: Dataquest
December 1986

Internationality

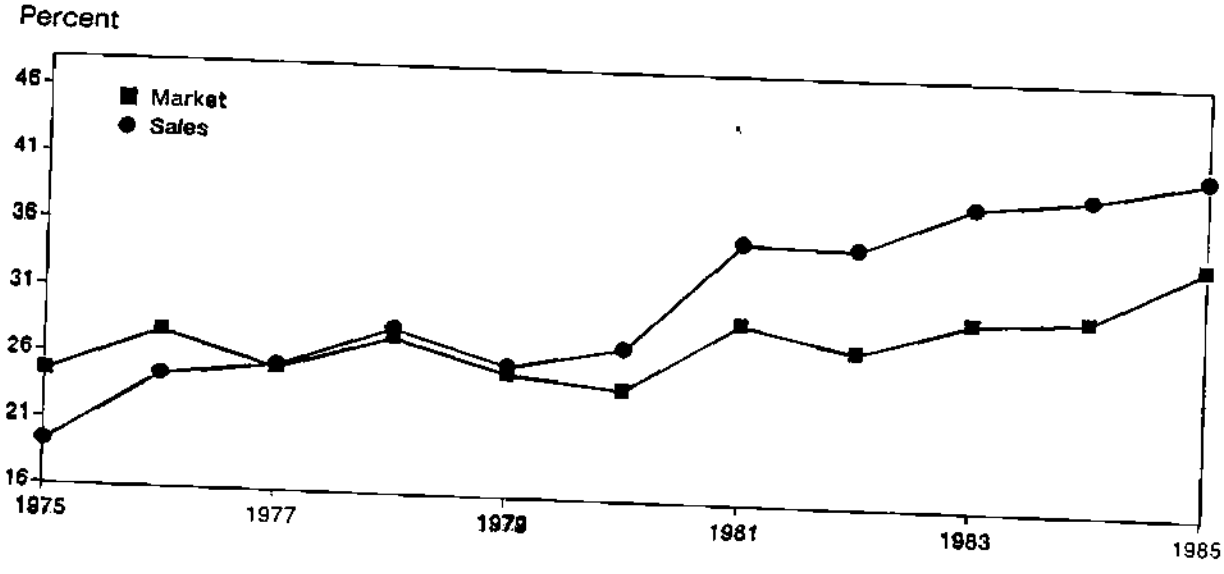
The international character of the semiconductor industry is evident both in marketing and manufacturing. Most U.S. companies derive 20 to 35 percent of their revenues from foreign sales, with the average about 23 percent. In the arena of commodity devices, international marketing is a necessary means to supporting efficiencies in manufacturing. In the growing market for semi-custom solutions, however, the emphasis is on niche market identification and customer service, rather than on simply filling manufacturing capacity.

Industry and Technology Overview

While Japanese semiconductor manufacturers have been very effective in the expansion of their international marketing, the growing consumption of semiconductor devices in Japan makes its domestic market an attractive one. Current negotiations between the U.S. Commerce Department and the Japanese Ministry of International Trade and Industry (MITI) concerning the "dumping" of semiconductor devices by several prominent Japanese manufacturers could result in a significant increase in the purchase of U.S.-made chips by Japan. Whatever the outcome of this trade settlement, the fact remains that Japan has been widening the distance between manufacture and consumption of semiconductor devices, and must therefore aggressively export (see Figure 6). In 1979, the U.S. supplied approximately 13 percent of Japan's semiconductor needs, while the Japanese share of the U.S. market amounted to roughly 5 percent. In 1985, U.S. market share in Japan declined by nearly 4 percent, while Japanese penetration of the U.S. market increased over 8 percent (see Figure 7).

Figure 6

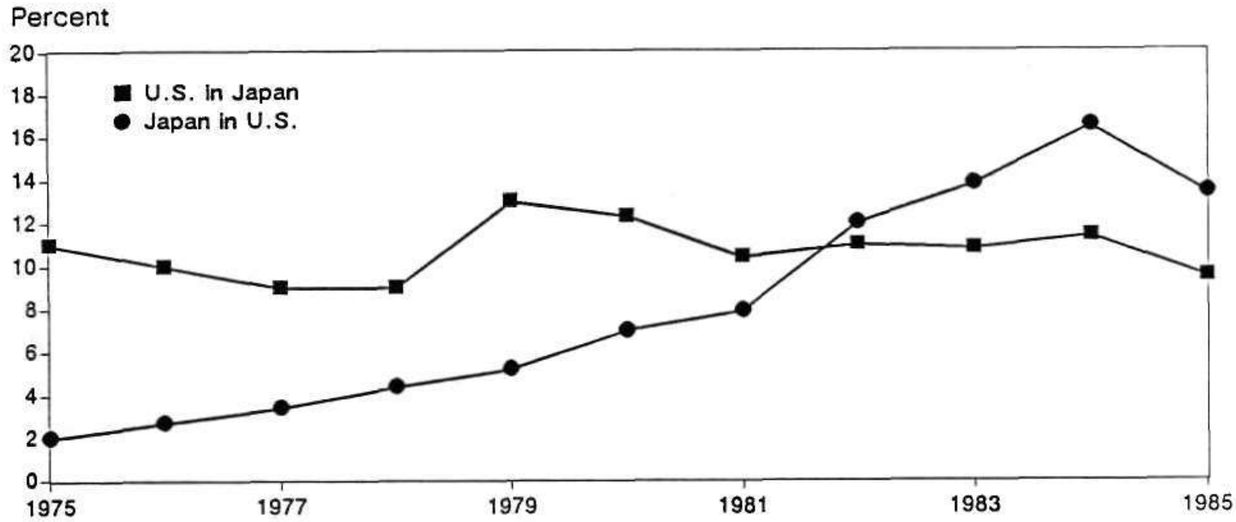
JAPANESE MARKET AS A PERCENT OF WORLDWIDE MARKET VERSUS JAPANESE SALES AS A PERCENT OF WORLDWIDE SALES



Source: Dataquest
December 1986

Figure 7

U.S. SHARE OF JAPANESE MARKET VERSUS
JAPANESE SHARE OF U.S. MARKET



Source: Dataquest
December 1986

International manufacturing is increasing for three reasons. First, semiconductor device manufacturing has areas that are capital and technology intensive and areas that are labor intensive. As a result, it is generally cost-effective to do the capital- and technology-intensive manufacturing in areas such as the United States, where technical personnel and equipment are more available, and to do the highly labor-intensive manufacturing (e.g., assembly) in areas where labor costs are low, as in Asia. It is not unusual for wafers to be fabricated in one country, devices assembled in a second country, and final testing and shipping performed in a third country. This highly mobile means of manufacturing is made possible, of course, by the small size and low weight per dollar value of semiconductor devices. The search for the most cost-efficient allocation of manufacturing has led more and more companies to invest in overseas assembly plants. This trend is expected to continue even though it may be slowed eventually by increased automation in assembly processes.

Another reason for international manufacturing is for market access--the consuming country desires to have the manufacturing process performed locally. This approach is encouraged in a number of ways, especially through import quotas and high tariffs and duties. These nationalistic attitudes place a strong pressure on U.S. companies to achieve even greater internationality. In 1985, there were 26 foreign wafer fabrication facilities owned by U.S. companies, the majority of which were in Europe.

The third reason for international manufacturing is access to technology. Excellent semiconductor technology now exists in Europe and Japan as well as in the United States. Limited access to that technology is a competitive handicap. An excellent way to ensure access to foreign technology is through design, fabrication, and other manufacturing functions in overseas locations.

Captive Semiconductor Manufacturing

Systems companies that integrate backward with the purpose of producing their own semiconductor components, and that produce solely for their own needs, are considered captive manufacturers. Our research into silicon wafer usage and semiconductor manufacturing equipment indicates that captive manufacturers constitute an estimated 24 percent of the markets for these products.

Successful captive suppliers tend to be those that supply to their parent organizations the services that the merchant semiconductor industry is unwilling, or unable, to cost-effectively supply. These services include the following:

- Special processes--Some captive semiconductor suppliers have developed special processes that are not available elsewhere. These processes make possible products that could not be made in any other way.

- Special designs--This service includes custom VLSI designs that are made in such small volume that they are not of interest to semiconductor firms. Usually, these designs are justified through cost savings and by the fact that they tend to protect proprietary systems concepts.

- Education--It is desirable to educate design engineers in VLSI technology to allow them to develop more competitive systems concepts--concepts that optimize the application of semiconductor technology.

- Second source--A captive facility may be justified as a second or backup source, e.g., as an insurance premium.

- Purchasing support--The captive manufacturing facility can aid in vendor evaluation, cost analysis, and may even help vendors with problems.

- Public relations--Customers of major equipment companies may feel that the supplier is more capable if it has its own semiconductor facility.

- Design integration--A captive facility allows integration of semiconductor and systems design. Among the benefits that may emerge from such integration are faster design turnaround, more efficient handling of engineering change orders, and the optimization of cost/performance through design control of this entire vertical chain.

- Reliability

- Production control and assured delivery

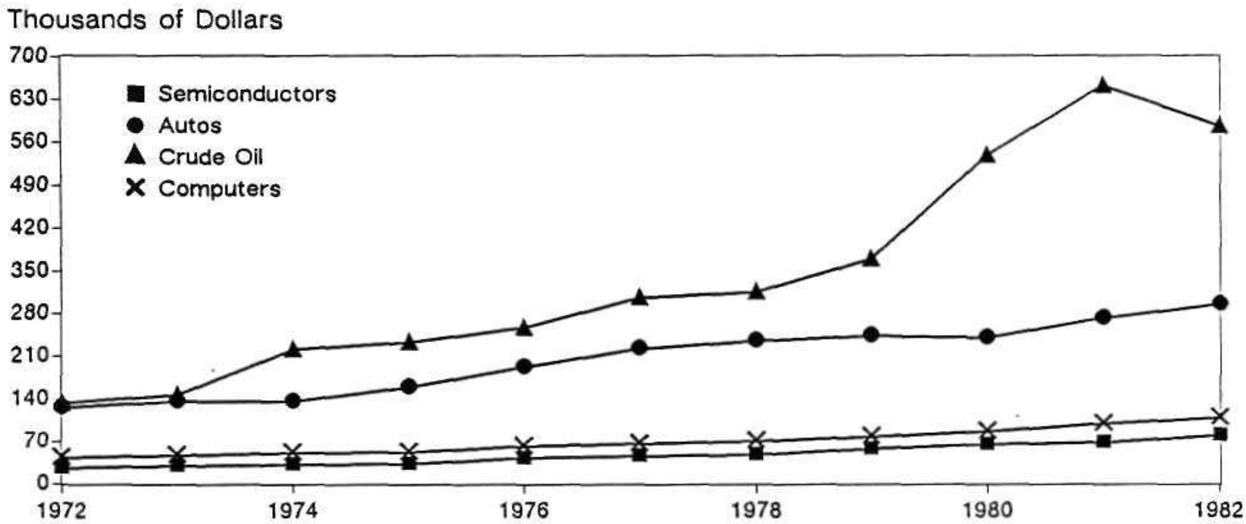
Automation

The need to automate manufacturing is being recognized more than ever by the semiconductor industry. As the device geometries demanded by state-of-the-art semiconductor products become more rigorous, maintaining wafer yield becomes increasingly difficult. A decline in yield translates into lower productivity, and lower return on each dollar invested in capital equipment. For the semiconductor industry as a whole, both these trend lines have been moving downward. Pressure on the U.S. industry to automate is also felt through competition with Japan, where the automation of wafer fabrication plants has been much more successful.

In spite of the large amounts of sophisticated capital equipment required to manufacture semiconductors, the industry is still highly labor intensive. The semiconductor industry as a whole has one of the lowest ratios of revenues per employee, or assets per employee, of any U.S. industry. Figure 8 compares revenue per employee for the semiconductor industry with those of the automotive industry (passenger vehicles only), the oil industry (certainly a "commodity" supplier), and another high-technology business, the computer industry. The disparities in revenue per employee are striking.

Figure 8

**REVENUE PER EMPLOYEE
AN INDUSTRY COMPARISON**



Source: Dataquest
December 1986

Some areas of semiconductor manufacturing, especially assembly, are performed overseas where low labor costs can substitute for the capital costs that would be incurred using more automated assembly operations in the U.S. However, this area is becoming more expensive because of rapid wage inflation in many parts of Asia. For example, in 1980 wages increased by as much as four times in only 18 months. Today, wage increases continue. There has also been increasing concern over tariffs and duties, particularly Sections 806/807 of the Customs Code, (which deal with the rates applied to foreign assembly as interpreted by the U.S. Commerce Department). Regulated freight rates are also an important cost factor for Asian assembly. In 1980 an FCC decision allowed a 60 percent increase in freight rates charged to some semiconductor companies. These high rates may be circumvented in the future by companies that purchase and operate their own airplanes.

Between 1967 and 1983, the unit volume of integrated circuits increased over 100 times and should increase further in the future. In addition to this volume increase, more devices are becoming industry standards and are manufactured in extremely high quantities. Greater volume makes automation more economically feasible. These factors argue for increased automation. On the other hand, some factors slow automation, including:

- Lack of capital in the industry
- Continuing technical changes
- Implementation of communication protocol standards that will link manufacturing equipment in a wafer fab facility

Since the industry generally is underfinanced, it cannot afford a great deal of capital equipment without a large infusion of equity. The continuing evolution of the technology and the consequent rapid obsolescence of products and equipment tend to lower the expected return on investment for equipment. In the past, many companies have been severely affected by the rapid obsolescence of capital equipment.

While semiconductor equipment manufacturers have been able to keep pace with ever tightening design rules and increased device density, the U.S. industry has been slow in integrating equipment for computer controlled wafer processing. Equipment manufacturers are now adding microprocessors to their products in order to facilitate integration through communications software based on SECS (semiconductor equipment communications standard), but implementation of a protocol standard has been slow.

Two areas that are highly labor intensive are likely to become more automated: mask alignment and lead bonding. Operation repeatability and improved process tolerances are the principal motivators to automate these areas. Mask alignment is done primarily in the United States because it is an integral part of wafer fabrication. Automatic aligners are beginning to appear and should see greater acceptance in the future. Lead bonding is performed mainly in the Asian assembly facilities. Whether this step should be automated has become a very controversial subject. We believe that increased automation will occur eventually. Although adequate automated bonding machines have not yet been designed, they are certainly technically feasible. Both Motorola and Texas Instruments have major in-house programs to develop improved bonding equipment.

In general, newer, more automated equipment will have four major features:

- Contamination-free environments
- Repeatable process capability

- Faster throughput or higher productivity
- Integration through a standard communications protocol

There are important consequences of the shift toward increased automation. First, more production will be performed in the consuming nation--that is, manufacturing will be performed where the market exists. Increased automation should make the higher labor costs of these market areas less important. Second, the industry will become less labor intensive, but with higher fixed costs. Third, underfinanced companies that cannot afford automated equipment will be at a competitive disadvantage.

INDUSTRY PROBLEM AREAS

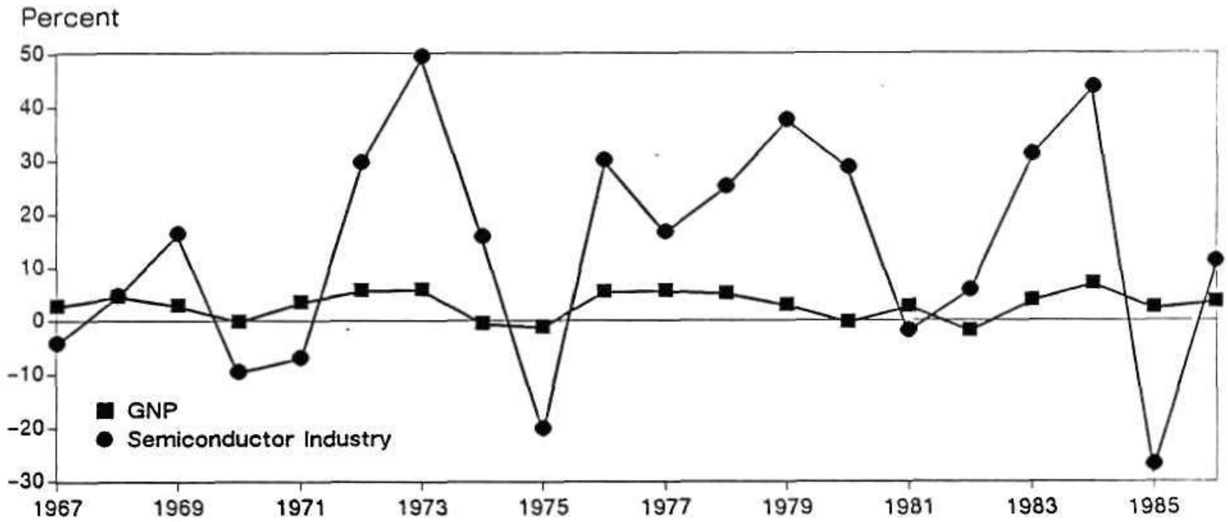
Economic Cycles

A major problem in the semiconductor industry is the effect that cycles in the general economy have on semiconductor markets. Small changes up or down in the general economy are magnified several times in the semiconductor industry. This problem arises because the basic market for semiconductors--about two-thirds of the U.S. semiconductor market--is accounted for by capital equipment. In general, these items are purchased for expansion of industrial capacity or productivity. When the economy is expanding, industry expands its capacity and there is a good market for equipment using semiconductors; conversely, when the economy is not doing well, the market for such items as computers is diminished considerably. Figure 9 shows this effect quantitatively.

In good years such as 1966 and 1973 when the economy was doing well, the semiconductor industry had high market growth. However, in years when the economy was in a slowdown, such as 1967, 1970, 1975, 1981, and 1985 the semiconductor market was very poor. The large swing in market growth, over a range from minus 26 percent to plus 45 percent, shows the industry's extreme sensitivity to the economy.

Figure 9

SEMICONDUCTOR INDUSTRY GROWTH
(U.S. Consumption)



Source: Dataquest
December 1986

Such rapid changes in the semiconductor market, of course, pose difficult problems for the industry. In very good times, it is difficult for companies in the industry to adjust to the rapid growth--such as in 1973 and 1979. In difficult times, these companies face the task of cutting production and must make hard decisions on prices. They must choose, in essence, between profit margins and retaining market share. A company often faces the dilemma that if it tries to retain its profits, its market share will shrink so drastically that its efficiencies of scale will disappear and its profits with them. Because the industry is highly competitive, this decision generally means that profits suffer. In 1970 and 1971, when semiconductor demand decreased, the semiconductor industry was grossly unprofitable, with only 6 companies out of about 70 remaining profitable. In 1975--a much more severe downturn--only a limited number of companies were unprofitable.

Because the semiconductor industry is basically labor intensive, the industry has only one prime method of cutting costs--by reducing employment. Laying off employees is painful, of course, because employees represent such a considerable training investment. Severe reductions in employment can reduce the ability and speed with which a company can return to normal production levels. Product development can also be slowed if engineers are laid off. It is clear that down cycles in the economy have been a major factor in the high mobility of employees in the industry. However, since the more experienced and more productive workers are usually retained, initial reductions in employment in a semiconductor company have little effect on production. Some semiconductor manufacturers have found that personnel reductions of up to 25 percent have caused a decrease in unit output of only 10 percent. Beyond this point, however, the effect of employment reduction on output becomes more directly proportional. A more sinister aspect of staff reduction is the time it takes to regain productivity during a market recovery. The hiring and training of personnel introduces learning curve periods which affect a manufacturer's ability to quickly regain market share. The resulting productivity lags have benefited Japanese firms since the last semiconductor downturn in 1981. Historically, the Japanese have been able to ride out soft market periods with fewer layoffs than their U.S. competitors, leaving them better able to respond in recent years to industry upturns.

Availability of Engineers and Other Personnel

The rapid growth of the semiconductor industry and other related electronics and EDP industries from 1976 through 1979 placed severe demands on the available pool of engineering talent in the United States. Since the early 1950s, the number of engineering graduates in the United States has grown very slowly, while the number of companies in electronic and other technical disciplines have grown very rapidly. This condition was further aggravated by a temporary decline of engineering graduates in the early 1970s.

Table 8 shows the declining proportion of U.S. engineering graduates to total graduates between 1950 and 1978. This proportion has been increasing since the mid-70s, but available technical talent in all areas is still limited, especially in semiconductor design and processing and computer software programming. Fortunately, the boom in high technology career opportunities has lured talented foreign engineers to U.S. firms. The inability of many Third World countries to absorb their own engineering graduates has provided the U.S. semiconductor and electronics industries with a valuable supply of technical expertise. Many foreign students have enrolled in engineering schools in the U.S., only to remain after graduation. As the newly industrialized countries (NICs) of the Pacific rim bolster their high technology industries, the U.S. import of brain power may well decrease. Possible compensations for a shortage of engineering talent include increased automation, the use of computer-aided design, and overseas expansion.

Table 8

U.S. ENGINEERING GRADUATES

Year	Engineering Graduates	Percent of Total Graduates
1950	57,159	11.5%
1960	45,624	9.5%
1970	63,753	5.9%
1975	65,308	5.0%
1978	74,792	5.6%
1980	87,643	6.6%
1983	111,451	8.2%

Source: U.S. National Center for Education Statistics (Department of Education Statistics, 1980)

The manpower shortage is intensified by the limited locations preferred by technical professionals--areas such as the Santa Clara Valley (Silicon Valley), California. Increasingly, site locations for the new semiconductor facilities are predicated on the available work force, the pool of technical talent, and a location's appeal to engineering professionals.

Unionization

The semiconductor industry has proved a difficult target for organized labor. The Silicon Valley exemplifies the lack of impact that unions have had on high technology businesses in general: while four of every five manufacturing jobs and 31 percent of private sector employment in Santa Clara County are accounted for by high tech, not even one major computer manufacturer is organized.

There are several factors that explain the inability of unions to penetrate the semiconductor industry:

- The semiconductor work force has been more mobile than that of unionized industries. Typically, if employees do not like the working environment, they job hop.

- The semiconductor industry employs a high number of workers who do not fit the pro-union stereotype. These include women, foreign-born workers, and technical professionals with a deep mistrust of any outside body dictating their work habits.

- Instilling a sense of worker solidarity is difficult in an industry typified by small work shifts, staggered hours and scattered plant sites.

- Finally, up until recently the semiconductor industry has had the reputation of being a "growth" industry. Companies fostered a belief among their workers that they enjoyed greater job security than their brethren in traditional smoke stack industries, and could look forward to an ever brighter future.

Over the last two years, some of the bloom has left the high tech rose. Wall Street now views the semiconductor industry as a "growth cyclical" industry, and semiconductor employees are beginning to see themselves as the ballast that must be jettisoned when their companies ride out the cyclical troughs. No-notice layoffs, minimum severance pay and little or no retraining are becoming issues that favor organized labor's encroachment into the high technology work force.

If organized labor can champion itself as a hedge against the growing insecurities of being a semiconductor worker, the industry will probably face a greater challenge from union organizers than it has experienced in the past. To counter this challenge, if it comes, semiconductor firms will have to impress upon their employees the need to remain globally competitive in order to survive, while at the same time increasing their investments in automation.

Health and Safety

Because the semiconductor industry is a light industry, a worker in a semiconductor plant is generally safe from both injury and illness assuming adequate precautions have been taken by the company. Nevertheless, the semiconductor industry is essentially a chemical factory with a number of various potential problems if precautions are relaxed. Potential problems could come from toxic gases, dangerous acids, toxic cleansing chemicals, employee sensitivity to various chemicals, high temperatures, high voltages, and microscope work. These potential problems are currently undergoing close scrutiny by unions, government bureaus, newspapers, and other organizations. Overreaction by them could blow minor problems out of proportion. The issue could be an explosive problem for the industry if not handled properly.

Industry and Technology Overview

Shortages

The semiconductor industry uses a wide range of materials. As a result, it often finds that one or more of these materials is in short supply, especially in times of general world economic expansion. In the past, there have been shortages in copper and chemicals such as hydrofluoric acid. Rapid semiconductor industry expansion creates shortages of its own. In 1973, for example, there were shortages of silicon, glass quartz diffusion tubes, and packaging. The suppliers of these items had difficulty expanding fast enough to meet industry demands.

Similarly, in 1979, many materials were in short, if not critical, supply. In particular, various acids and silicon wafers were difficult to obtain at times. Other materials, especially gold, had rapid price increases.

A particular problem that concerns the semiconductor industry is the possibility of a shortage of electric power. Electricity is necessary for the production of diffusion tubes and the powering of deposition and epitaxial reactors, as well as all other types of testing and assembly equipment. Other power sources cannot be substituted; a shortage of electric power could shut down the industry. Although that is highly unlikely, the imposition of quotas during a general power shortage could halt industry expansion and penalize fast-growing companies. Shortages may not be avoided, but they can be alleviated if they are detected early and the problem is communicated both to industry and to suppliers.

Capitalization

Undercapitalization will probably be a severe problem for the industry. Historically, the industry has been somewhat underfinanced, partially because of the industry's rapid growth. For the future, the semiconductor industry will continue to require financing for two major reasons--to fund research and development, and to purchase capital equipment.

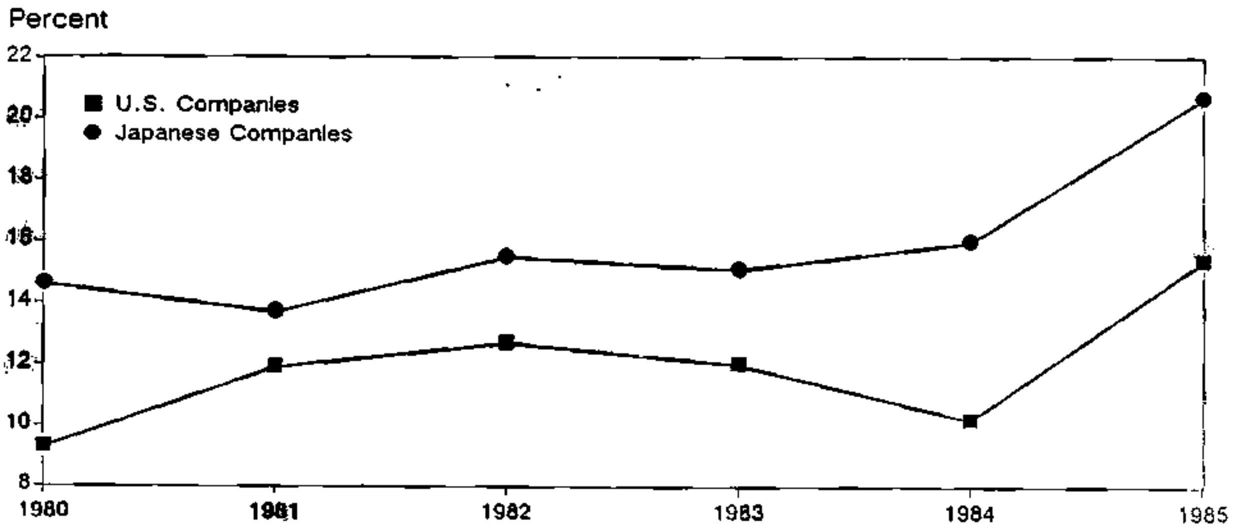
Given the current over-capacity plaguing many U.S. merchant semiconductor firms, and the extreme business cycle fluctuations that the domestic industry has witnessed, it is highly unlikely that U.S. semiconductor companies will be spending heavily on brick and mortar. Assuming normal growth in the U.S. economy, however, the semiconductor industry should grow at an average annual rate of about 18 percent. This growth will require companies to continue their R&D efforts in order to grow market share. As was earlier discussed, the technological nature of the semiconductor industry demands that companies either innovate or wither away. This is as true for companies targeting niche markets through semi-custom devices as it is for large commodity IC manufacturers developing a 4Mb DRAM.

In addition to R&D funding, a large financial need will come from the requirement for capital equipment capable of manufacturing chips to more stringent design rules. To remain competitive, commodities manufacturers must also address increased automation. Looked at by several measures of worker productivity--such as assets per employee, sales per employee, sales revenues per employee, and the cost of buildings and equipment as a percentage of revenues--the semiconductor industry is at one of the lowest levels of any industry in the U.S. Through greater automation, the industry can raise current yield levels, and lower variable costs of manufacturing.

The U.S. merchant semiconductor industry faces a unique challenge. Because the majority of domestic chip manufacturers are independent companies whose revenues depend entirely on sales of semiconductor products, periods of lowered sales and/or profits have a direct effect on their ability to invest in R&D and capital equipment. For several years now, the U.S. semiconductor industry has fallen behind Japan in both these critical areas of capitalization, while Japanese firms, whose associations with powerful manufacturing and financial entities provide a dependable source of capital, have taken market share from U.S. manufacturers (see Figure 10 and 11).

Figure 10

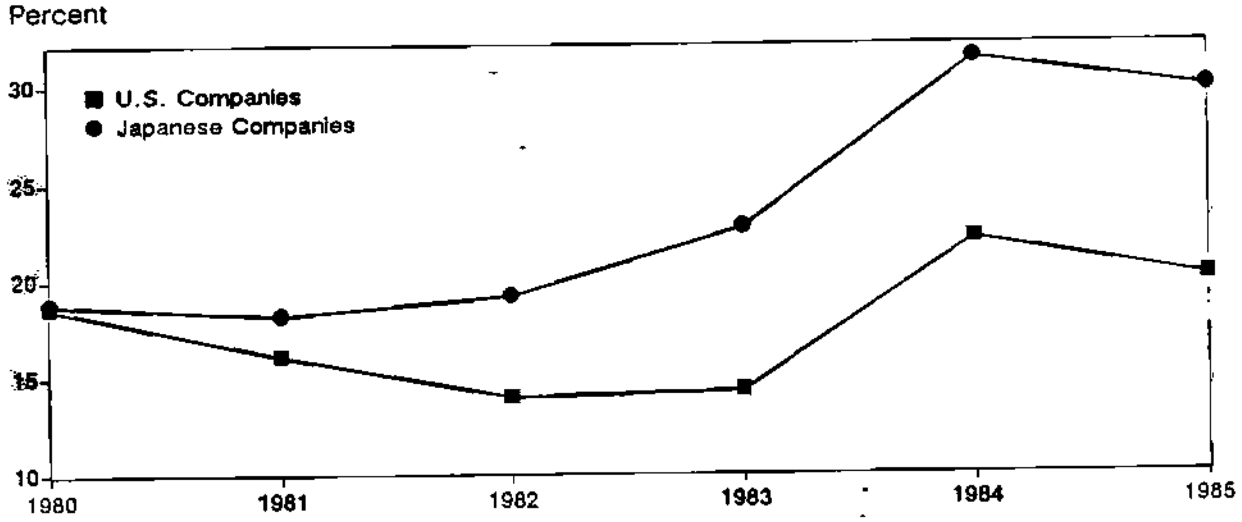
**SEMICONDUCTOR R&D SPENDING
AS A PERCENT OF SEMICONDUCTOR SALES**



Source: Dataquest
December 1986

Figure 11

**SEMICONDUCTOR CAPITAL SPENDING
AS A PERCENT OF SEMICONDUCTOR SALES**



Source: Dataquest
December 1986

The basic need for capital within the industry could have three major effects. First, companies with cash will have an advantage. The importance of financing may also be a benefit to semiconductor manufacturers that operate as divisions of large corporations that can supply the necessary financing. Second, if the stock market improves, many companies will go to the equity market to obtain financing. Third, the lack of cash in the industry is apt to slow automation. To overcome these disadvantages, many U.S. chip makers will have to look at strategic alliances with other manufacturers and with foundry services to spread the costs of R&D, and to secure dependable second-source manufacturing without adding more capacity.

Other Problems

Many lesser problems arise in the semiconductor industry. These problems are caused primarily by the rapid changes in the industry, the high technological content of the products, and the relative immaturity of the market that the industry serves. For example, the industry serves markets that can grow, or disappear, overnight. This rapid change has been true in the small computer market, which has had several major shifts in only a few years. Managers in the industry have to anticipate changes both in prices and technology to be effective. Short product lifetimes, which are characteristic of the industry, mean that a high proportion of funds must be committed to the research and development of new products. Rapid changes in markets and in products mean rapid changes in market shares. This condition lends a high degree of instability to the industry and the companies in it.

IMPACT OF TECHNOLOGICAL CHANGE

Time Lag Between Technology and Production

Although new technologies and products have evolved rapidly in the semiconductor industry, a significant time lag may exist between the inception of an idea and its successful implementation into manufacturing. The duration of this lag varies and is difficult to predict. Moreover, many highly heralded products and ideas never become commercial successes.

As an example of this time lag, the principle of field effect modulation used in MOS devices was patented in 1935, more than 25 years before the first commercial MOS transistor was available in 1963, and the complete theory of operation was described by William Shockley in 1954. In this case, the idea was far in advance of the technology available. Significant discoveries and advancements had to occur before the device could be manufactured. Similarly, CMOS circuits, ion implantation, and automated film bonding have all had long gestation periods.

A widely acclaimed technological achievement was the development of the tunnel diode in 1958. The advantages of this device included very high frequency response, negative resistance (current decreases with increasing voltage over part of the voltage range) at low power dissipation, and insensitivity of its electrical characteristics to temperature. More than 25 years later, however, commercial application of tunnel diodes is minimal; they are used primarily as research tools to study semiconductor properties. Other examples include beam lead devices, unijunction transistors, and junction field effect transistors. All of these were expected to have much larger markets than they currently have.

Processes now exist that will drastically alter the fabric of semiconductor processing. Some of these processes are also successful in other support areas such as maskmaking, and will eventually find increased use as line geometries shrink below 1 micron in production (steppers and E-beam equipment are examples).

Other technologies that now exist in prototype form will be improved to compete with current technologies. An example is X-ray lithography equipment. Dataquest believes that other incipient technologies will replace equipment markets worth more than $100 million in yearly shipments. These new technologies include: direct writing by lasers; the use of eximer lasers for etching, diffusion, and deposition; and focused ion-beam systems. Because of the established base of capital equipment, the learning curve with respect to new processes, and the technical difficulties inherent in these processes, we expect these technologies to be very slow in maturing. However, once any of these new technologies is successfully implemented, it will profoundly effect the types of semiconductor products that will be generally available.

Many semiconductor firms have announced product concepts long before they become production realities. In many instances, the time lag results from problems of transferring a technology from the R&D stage to production, while incorporating it into a suitable product. A process developed during the R&D phase is usually executed with great care by highly trained engineers, scientists, and technicians. Wafers are processed in small batches with great care and very little time pressure. Moreover, the process equipment is usually substantially different from that used in the manufacturing area--smaller (since fewer are processed), older (many are relics disposed of by the production area), and "hand-tweaked" to perform a process.

The process developed under these constraints is usually not production-oriented, and its weaknesses become evident as volume increases and less sophisticated personnel attempt to work with it. Consequently, the yields realized in the R&D phase always fall dramatically when a process and product are transferred to production. The loss in time may be only a few months, but typically has been a year or more in the semiconductor industry. This lag may be several years if other technical improvements need to be made to fully implement the process or product and make it economically feasible. By that time, other approaches may be more attractive. Many processes and products never make the transition from research and development to production.

Once a technology is established, several years may be required before it becomes a major market force. This is due to the time required for devices to be designed and implemented into electronic equipment and for that electronic equipment to be accepted in the market.

Displacement Effect

The remarkable growth and evolution of the semiconductor industry has resulted largely from both the development of new markets and the displacement of other technologies. For example, the use of transistors instead of vacuum tubes has had a major impact on the manufacturing of radios. The transistor displaced vacuum tubes in virtually every new radio design. Low-power transistors allowed the manufacture of small, portable, battery-powered radios for the first time. The following discussion considers some examples of the displacement effect with respect to both nonsemiconductor and semiconductor technologies.

Nonsemiconductor Technologies

Electromechanical - There are a number of notable examples of the displacement effect of semiconductors on electromechanical equipment. One of the most evident today is the electronic calculator. In the early 1960s, all adding and calculating machines were electromechanical. The more the capability of the machine, the more cumbersome it was likely to be.

The electronic calculator, first introduced in 1966, brought compactness, portability, lower power dissipation, and more complex calculating power to a world dominated by the four-function electromechanical machines. Continued advancements allowed all four functions to be integrated onto one MOS chip, costing less than $5.00 by 1970. Electromechanical machines were quickly displaced and a new breed of calculators, the hand-held calculator, was born.

Magnetic Memories - In the past, magnetic cores were the dominant memory technology for information storage. The replacement of magnetic core memories was delayed because of the size and cost reductions achieved by core manufacturers. Today, semiconductor memories predominate and account for 100 times the number of annual bit shipments.

Semiconductor Technologies

Although the semiconductor industry has been able to generate new markets by displacing nonsemiconductor technologies, displacement also occurs among semiconductor products. Newer bipolar and MOS processes rapidly obsolete existing devices by providing cheaper or higher performance circuit functions or both.

Product Displacement - One displacement that is now occurring resulted from the development of microprocessors and microcomputers. A number of MOS and bipolar microprocessors and microcomputers are now available from semiconductor manufacturers. Depending on the application, from 100 to 300 or more standard TTL packages may be displaced by each microprocessor set.

Industry and Technology Overview

MOS versus Bipolar Technology - In the early days, MOS and bipolar technologies had relatively little impact on each other. Bipolar technology has concentrated on high-speed, relatively high-power dissipation (compared with MOS), and medium component density. MOS, on the other hand, found its niche in medium-speed, medium (P and NMOS) and low (CMOS) power dissipation, and high component density. Today, as line widths fall below 2 microns, MOS speeds are beginning to challenge those of bipolar circuits. As a result, MOS technology shows a higher growth rate in dollar sales. CMOS is the fastest growing MOS technology because of its low power and increasing encroachment on the speed domain of NMOS technology.

Displacement within Technology - As indicated previously, a considerable amount of displacement takes place even within the bipolar and MOS technologies. RTL was displaced by DTL in less than two years and, within the next two years, TTL became the dominant family. MOS has progressed through similar iterations, beginning with metal gate, high-threshold P-channel in 1973.

These displacements have occurred because the newer products and processes demonstrated improved performance capabilities, lower costs, or both. Thus, products and technologies in the semiconductor industry exhibit limited lifetimes. Companies must adapt to changes or lose their competitiveness. Unfortunately, many products are often displaced before an adequate return is realized on the investments made to develop them.

Historical Trends

Technological milestones that have occurred in the past are summarized in Table 9, which shows the year a technology was developed and the pioneering company, and gives pertinent comments on current status. This table shows the constant evolution of semiconductor technology.

The pioneering company is not necessarily the company that was successful with the technology despite introducing the first commercial devices. Four pioneering companies (Westinghouse, Sylvania, General Microelectronics, and Cogar) are no longer in the IC business. Texas Instruments has been the most successful company in retaining a position of leadership in the technology it pioneered, with much of its success derived from its development of silicon transistors and iterations of the TTL technology.

RCA began its efforts in CMOS in the early 1960s and announced its 4000 series in 1968. Having generated the market and having been virtually the sole source of CMOS logic circuits for many years, RCA has placed itself in a strong leadership position.

Table 9

SEMICONDUCTOR INDUSTRY MILESTONES

Year	Technological Advance	Pioneering Company	Comments
1947	Point contact transistor invented	Bell Laboratories	By Shockley, Bardeen, and Brattain
1948	Junction transistor proposed	Bell Laboratories	By Shockley
1950	High-purity germanium developed	Bell Laboratories	Early transistors were germanium
1950	Junction transistor	Bell Laboratories	
1951	Zone refining of semiconductors developed	Bell Laboratories	By William Pfann
1951	Junction device sold commercially	General Electric and others	
1951	Gallium arsenide material	Siemens	
1952	Alloy transistor	Bell Laboratories	
1953	Surface barrier transistor	Philco	No longer in competitive market
1953	Unijunction transistor	General Electric	Not commercially successful
1953	Silicon solar cell	Bell Laboratories	
1954	Junction field-effect transistor proposed	Bell Laboratories	By Shockley
1954	Diffusion process developed	Bell Laboratories	
1954	Oxide masking	Bell Laboratories	
1954	Photolithographic techniques	Bell Laboratories	
1954	Zener diode	National Semiconductor and others	
1954	Transistor radio	Texas Instruments, Regency	
1954	Silicon transistor	Texas Instruments	Development started TI as a major manufacturer
1954	Interdigitated transistor	Transistor Products	Idea survived, company did not
1955	Diffused base transistor	Bell Laboratories	
1956	Silicon controlled rectifier	General Electric	Commercially successful
1956	Commercial unijunction transistor	General Electric	Not commercially successful
1957	Mesa transistor	Motorola	
1958	First integrated circuit	Texas Instruments	
1958	Tunnel diode	Sony	Not commercially successful
1958	Step recovery diode	Hewlett-Packard	

(Continued)

Table 9 (Continued)

SEMICONDUCTOR INDUSTRY MILESTONES

Year	Technological Advance	Pioneering Company	Comments
1959	Planar process, planar transistor	Fairchild	Invention boosted FCI as a major manufacturer and led to modern commercial ICs
1960	Epitaxial transistor	Bell Laboratories	
1960	MOS FET	Bell Laboratories	
1960	Schottky barrier diode	Bell Laboratories	
1961	First commercial IC	Fairchild, Texas Instruments	
1961	First planar field effect transistor	Amelco	
1961	RTL logic IC	Fairchild, Texas Instruments	Obsoleted by DTL
1962	Solid state (GaAs) laser	General Electric, IBM	Parallel inventions, 10 days apart
1962	DCTL logic IC	Fairchild	Never became popular
1963	Gunn diode	IBM	
1963	TTL logic IC	Sylvania	Sylvania left semiconductors in 1970
1963	ECL logic IC	Motorola	Still leads market
1963	Commercial MOS discrete	Fairchild	
1963	Linear IC	Fairchild, TI, Westinghouse	
1964	Light emitting diode	Bell Laboratories	
1964	GaAsP LED	Bell Laboratories	
1964	MOS IC	General Microelectronics	GMe was purchased by Ford and later dissolved
1964	First static flip-flop IC	Fairchild	
1965	IMPATT diode	Bell Laboratories	
1965	LSA diode	Bell Laboratories	
1965	High speed TTL	Texas Instruments	
1966	NMOS	Fairchild	
1968	Ion implantation	Accelerators, Inc.	Acquired by Veeco
1968	Commercial light emitting diode	Hewlett-Packard, Monsanto	
1968	Low-power TTL IC	Texas Instruments	Obsoleted by Schottky TTL
1968	CMOS IC	RCA	Still leader
1969	GaAs junction FET	IBM	
1969	ROM	Electronic Arrays	Purchased by NEC
1969	Silicon gate MOS	Intel	

(Continued)

Table 9 (Continued)

SEMICONDUCTOR INDUSTRY MILESTONES

Year	Technological Advance	Pioneering Company	Comments
1970	Charged coupled device	Philips	Developed commercially by Intel and Fairchild
1970	Schottky TTL	Intel, Texas Instruments	
1970	Single chip for calculator	Texas Instruments	
1971	Isoplanar process	Fairchild	
1971	Barrit diode	Bell Laboratories	
1971	Commercial silicon on sapphire	Inselek	Went bankrupt
1971	Ion implantation	-	
1971	Bipolar PROM	Monolithic Memories	
1971	EPROM	Intel	
1972	Low-power Schottky TTL	Texas Instruments	
1972	Microprocessor	Intel	
1973	Electrically erasable nonvolatile memory	Hitachi, NCR	
1973	Emergence of optical projection aligners	Perkin-Elmer	
1974	I^2L logic circuits	Philips, IBM Texas Instruments	TI did not invent, but made first commercial devices
1975	Japan launches VLSI project	MITI/NTT	Key to establishing expertise in high density devices
1975	Bit-slice bipolar microprocessor	Bipolar	MMI, AMD
1976	Power MOS FET	Siliconix	
1977	E-beam mask making	Bell Labs	Bell Labs licensed the technology to a number of companies
1977	Memory with on-chip-redundancy	IBM	
1977	Microprocessor controlled automobile engine	GM	
1978	Japanese firms enter MOS memory and micro-processor market in U.S.		
1978	Wafer stepper technology	GCA	
1978	Emergence of programmable logic device (PLDs)	Signetics	Major PLD supplier
1978	Speech synthesis chip	Texas Instruments	
1979	Programmable array logic product introduced (PAL)	MMI	Major PLD supplier

(Continued)

Table 9 (Continued)

SEMICONDUCTOR INDUSTRY MILESTONES

Year	Technological Advance	Pioneering Company	Comments
1980	Single-chip color TV sensor	Sony	
1981	32-bit microprocessor	AT&T	WE3200 used in AT&T computer systems--was not shipped commercially
1981	Speech-recognition chip	Weitek	
1982	Emergence of standalone IC CAD workstations	Daisy, Mentor, Valid	
1982	Introduction of IBM Personal Computer		Major end market for ICs
1983	Use of 6-inch wafer		
1984	First automated fabs		
1984	President Reagan signs semiconductor chip protection act		Key intellectual property law
1985	1Mb DRAM developed	IBM/AT&T	Both companies had working die at this time
1985	Gate array achieve more than $1 billion worldwide sales		
1985	Tokyo University launches TRON project 32-bit microproessors		
1985	Commercial trial of "smart card" devices	Mastercard	Potential major IC end market
1986	Bi-CMOS SRAM	Hitachi	
1986	First "Fabless" semiconductor company speaks at Dataquest conference	Lattice	Marks industry trend toward adding value through design expertise
1986	Signing of U.S.-Japan semiconductor trade agreement		

Source: Dataquest
December 1986

Motorola followed much the same path as RCA in developing the ECL products and market. It also maintains the leadership in the technology it pioneered, although the expected ECL volume will be far less than that of CMOS.

The latest company that is still the leader in the technology it pioneered is Intel, with its N-channel silicon gate products.

Glossary

Accelerated life testing--Operating semiconductors beyond maximum ratings to induce premature failures as an aid to estimating semiconductor life expectancy.

Acceptance sampling--Inspection of a sample for the purpose of predicting the number of defects present in an entire lot of semiconductors.

Access time--The time required to retrieve data from a memory location.

Accumulator--A register or storage location for the result of an arithmetic calculation.

A/D (Analog to Digital)--A circuit that transforms a linear (analog) signal to a digital representation. The digital representation is usually in the binary format of 1s and 0s.

Aligner--A type of wafer fab equipment used for applying a mask to a wafer.

Alpha particles--A form of radiation emitted by certain radioactive elements or isotopes that has a low penetration ability. Semiconductor devices are susceptible to the presence of alpha particles in package materials.

ALS (Advanced Low-power Schottky)--A logic family of TTL integrated circuits.

ALU (Arithmetic Logic Unit)--(1) An integrated circuit capable of performing arithmetic operations. (2) That part of a microprocessor that carries out arithmetic and Boolean logic operations on data presented in binary form.

Amplifier--An integrated circuit that increases signal amplitude without a significant change in waveform.

Analog--A circuit or system in which the output signals bear a continuous relationship to the input signals, as opposed to a digital circuit.

AQL (Acceptable Quality Level)--A point on the quality coordinator of the attribute acceptance sampling plan that is in the region of good quality and reasonably low rejection probability. A 95 percent accept point on a sample plan. This is established by the percent-defective level acceptable to a standard.

Array--A regular matrix (gates, cells, devices).

ASIC (Application-Specific Integrated Circuit)--An integrated circuit designed or adapted for a specific application.

Glossary

ASLP--(Application Specific Logic Product)--A logic device that fits a very defined end-product logic design requirement.

ASM (Application Specific Memory)--A memory device designed for a unique application, such as a video RAM.

ASP--Average Selling Price.

Asynchronous--In a computer, a mode of operation in which the performance of any operation starts as the result of a signal that the previous operation has been completed, rather than on a signal from a master clock.

Assembly--The IC manufacturing steps of mounting a die in a package, bonding the pads to the package leads, and sealing the package.

ATE (Automatic Test Equipment)--Equipment that contains provisions for automatically performing a series of preprogrammed tests.

Automatic refresh circuitry--Circuitry that periodically restores the charge in a semiconductor memory cell to maintain data retention.

Base--The control electrode of a bipolar transistor.

Bathtub curve--A plot of the failure rate of an item versus time. The failure rate initially decreases, then stays reasonably constant, then begins to rise rapidly. It has the shape of a bathtub.

Baud rate--The rate at which bits of information are transferred in a communications link. One baud equals one bit per second.

BiFET (Bipolar Field-Effect Transistor)--Refers to a type of semiconductor comprising both bipolar and MOS structures.

BiMOS (Bipolar Metal Oxide Semiconductor)--An IC manufactured with both bipolar and a MOS process that yields a hybrid with the benefits of both technologies.

Binary--A two-value numbering system that usually uses the symbols 1 and 0. This numbering system is used with computers because computer logic and memory devices are two-valued: on/off or high/low.

Bipolar transistor--A device used to control current flow in solid matter. A small base current controls the large emitter-to-collector current flow, similar to a valve controlling the flow of a liquid.

Bit (Binary digit)--A single binary digit, 1 or 0. A bit is the smallest unit of information that a computer can recognize.

Glossary

Bit slice--A multichip microprocessor in which the control section is contained on one chip, and one or more identical ALU sections and register sections are contained on separate chips called slices.

Bonding pads--Metallized areas on a semiconductor chip to which lead connections may be made.

Bonding wire--Fine-drawn wire manufactured from gold or aluminum, used for connecting the chip to a package.

Breadboard--A prototype model of an electronic system or circuit that is usually made with off-the-shelf components to test the feasibility of the circuit. Also used as a verb.

Bubble--A polarized magnetic domain, usually representing a binary digit, that looks like a bubble when examined under polarized light at high magnification. Magnetic bubble memories are a nonsemiconductor technology.

Burn-in--Refers to the operation of semiconductor devices at an elevated temperature or temperatures over a time interval, usually with the intent of identifying early-life failures in ICs.

Bus--In an electronic system, a line or pathway for transferring information or control between the elements of the system.

Byte--Eight consecutive bits treated as an entity.

Byte mode--A mode of accessing a memory device in which eight bits (one byte) are read at one time.

Cache--A fast, small memory (typically SRAM) used to enhance CPU performance, separate from main processor memory.

CAD (Computer-Aided Design)--The use of a computer for automated industrial design.

CAE--Computer-Aided Engineering.

CAD/CAM--Computer-Aided Design and Computer-Aided Manufacturing.

CAGR--Compound Annual Growth Rate.

CAM--(1) Content-Addressable Memory. (2) Computer-Aided Manufacturing. Use of a computer to aid and improve the manufacturing process.

CASE--Computer Aided Software Engineering.

Glossary

Capacitor--A device that stores energy in the form of an electrostatic charge.

Captive line--A semiconductor production facility owned by the user of its products.

CAS (Column Address Strobe)--A signal necessary to make a dynamic RAM function. (See RAS.)

CCD (Charge-Coupled Device)--A MOS device used for information storage or imaging applications.

Cell-Based Design--ASIC design technique utilizing nonfixed width or height cells.

CERDIP--A ceramic DIP-type package utilizing a glass-frit seal.

Chip--A small piece of silicon containing one semiconductor component, circuit, or function ranging from a diode to a microcomputer. (See Die.)

Chip carrier--An IC package that has connections on all four sides. A chip carrier is usually square and can be leaded or leadless, plastic or ceramic.

Chip-on-board (COB)--A package where a chip is directly mounted on a printed circuit board or ceramic board, wire bonded, and encapsulated with a blob of epoxy resin.

Class--(1) Refers to the purity of the atmosphere in the clean room of a semiconductor fabrication facility. Class 100 means a maximum of 100 particles 0.5 microns or larger in each cubic foot of air. (2) Refers to the level of semiconductor screening and documentation for government use, e.g., class S (space and satellite programs), class B (manned flight), and class C (ground support).

Clean room--An environmentally controlled area, usually a wafer fabrication or inspection facility. Temperature, humidity, and purity of the environment are all carefully controlled.

Clock driver--A circuit or component that provides a clean, stabilized timing signal for clocking logic or a system of devices such as a microprocessor, and associated peripherals.

Clock rate--The repetition frequency of the basic timing signal applied to a logic function.

CML (Current-Mode Logic)--A bipolar, emitter-coupled logic form.

Glossary

CMOS (Complementary MOS)--A semiconductor technology that uses both P-channel and N-channel transistors on the same silicon substrate to gain the primary advantages of very low power and high noise immunity.

CODEC (Coder/Decoder Circuit)--An integrated circuit that codes a voice signal into a binary waveform or decodes a binary waveform into a voice signal. Such circuits are now used in digital communications applications.

Collector--The majority receptor in a transistor; the major source of electrons in a pnp transistor.

Comparator--A type of amplifier that produces a logic output (1 or 0) based on comparison of an input voltage with a fixed reference voltage. A widely used form of linear IC.

Contact--The regions of exposed silicon that are covered during the metallization process to provide electrical access to the device.

Controller--A circuit that controls some function of a machine, device, or piece of equipment.

Coprocessor--A logic device that operates in association with a microprocessor to enhance system performance. Coprocessors are not capable of independent operation.

Cost--The dollar amount realized by the manufacturer to produce a product--not price.

COT (Customer-Owned Tooling)--Usually refers to the masks or pattern-generation tape for a semiconductor device prepared and owned by the customer.

CPU (Central Processing Unit)--A microprocessor or microcontroller.

CP/M (Control Program for Microcomputers)--An operating system developed by Digital Research, Inc., for use on microcomputers.

CRT (Cathode-Ray Tube)--The display element in a computer terminal. Frequently used to mean the terminal itself.

Custom circuit--A semiconductor circuit designed to meet the specific needs of one customer.

CVD (Chemical Vapor Deposition)--In wafer fabrication, a process for the deposition of solid insulators and metals from a chemical reaction in the gas phase.

Glossary

Cycle time--The minimum interval required to complete a full operation, such as writing into a RAM or performing an instruction.

DAC (Digital to Analog Converter). (See D/A converter.)

D/A converter (Digital to Analog converter)--A circuit that transforms a digital representation to linear (analog) representation.

DESC (Defense Electronics Supply Center)--The U.S. government command responsible for supervising supplier certifications and qualifications.

Design rules--Rules constraining IC topology to assure fab process compatibility.

DI water--Deionized water. High purity water from which all the impurities such as particles, organics, bacteria, and ions have been removed. Used in the manufacture of semiconductors.

Dice--Two or more semiconductor chips (the plural of die).

Dice bank--An inventory of chips maintained as a hedge against delays due to problems in the manufacturing of semiconductors.

Die--One semiconductor chip. (See Chip.)

Dielectric isolation--An IC design and process technique used to improve breakdown characteristics and/or increase resistance to radiation.

Diffusion--The use of a fab furnace to drive an impurity into a wafer.

Digital circuit--A circuit whose values or levels are binary.

Digitizing--(1) Converting an analog signal into a form recognizable by a digital circuit. (2) The process of encoding information into a form recognizable by CAD/CAM equipment.

Diode--A semiconductor element that favors unidirectional current flow; a pn junction.

DIP--Dual In-line Package.

Discrete device--A single circuit element packaged separately (e.g., a transistor or a diode).

DMA (Direct Memory Access)--A computer feature, set up by the CPU, that provides for high-speed direct data transfer from a peripheral device to the computer memory or to magnetic disk or tape storage units.

Glossary

Dopant--Atoms of materials such as phosphorus, boron, or arsenic that are diffused into silicon to create resistors, diodes, and transistors.

DOS (Disk Operating System)--A program used to manage disk files, supervise all I/O operations with other peripherals, and allocate all the system's resources. MS-DOS is an operating system developed by Microsoft Corporation for microcomputers. PC-DOS is a version of this operating system developed for the IBM personal computer.

Double poly--The use of two layers of polysilicon for increased IC density.

Drain--The majority carrier collector in a MOS transistor.

DTL (Diode Transistor Logic)--An obsolescent digital IC family.

Dynamic RAM--A random-access memory device that must be electrically refreshed frequently (many times each second) to maintain information storage.

EAROM (Electrically Alterable Read-Only Memory)--Same as EEPROM.

E-beam--A sophisticated system that uses an electron beam for maskmaking or for projecting patterns onto wafers. E-beam equipment allows smaller geometries (typically less than 1 micron) than are possible under other production methods.

ECL (Emitter-Coupled Logic)--A form of integrated circuit used to implement very high speed logic functions.

Edge triggered--A circuit actuated by an input signal transition.

EEPROM (Electrically Erasable Programmable Read-Only Memory)--A non-volatile memory used to store data or programs. EEPROMs can be reprogrammed in circuit.

E^2PROM--See EEPROM.

EEROM (Electrically Erasable Read-Only Memory)--Same as E^2PROM. IC memory that can be erased electrically and reprogrammed by the user.

EMI--Electromagnetic Interference.

Emitter--The source of majority carriers in a transistor; the electron receptor in a pnp transistor.

Emulator--Hardware or a combination of hardware and software that exactly reproduces the operation and performance of other hardware.

Glossary

Epitaxial--Silicon grown in a crystalline silicon substrate.

EPROM (Erasable Programmable Read-Only Memory)--IC memory that can be erased with an ultraviolet light source and reprogrammed by the user.

Ethernet--A cable-based communication network originated by Xerox Corporation, designed to link office equipment.

Eutectic alloy--That combination of two or more metals that gives the lowest possible sharply definable melting point. Used in bonding chips.

Evaporator--Semiconductor production equipment used for depositing a thin film on a wafer.

Fab--Abbreviation of wafer fabrication.

FAE--Field Applications Engineer.

Failure rate--The number of system or device failures per unit of operating time.

FACT--A Fairchild Semiconductor trademark denoting Fairchild Advanced CMOS Technology.

FAST--A Fairchild Semiconductor trademark denoting Fairchild Advanced Schottky TTL.

FET--Field-Effect Transistor (MOS transistor).

FFT (Fast Fourier Transform)--An IC or other circuit used for time-to-frequency domain conversion.

Firmware--Instructions committed to some form of ROM hardware.

FITS (Failure In Time)--The number of failures per 10^7 hours.

Flash converter--A type of digital to analog converter that performs a parallel, as opposed to serial, conversion. Used primarily in applications requiring high speed, such as video.

Flat-pack--A type of IC package that has its leads in a plane parallel to the chip.

Flip-chip--A packaging technique in which the IC chip is mounted face-down on the substrate.

Flip-flop--A circuit capable of assuming one of two steady states, depending upon signals input to the circuit. Also a binary counter.

Glossary

Flop--Floating point operation. A measure of math processing performance.

Foundry--A semiconductor manufacturer that uses a customer's masks to produce custom ICs for the customer. (See COT.)

FPGA (Field-Programmable Gate Array)--Gate array in which programming is accomplished by blowing fuse links or shorting base-emitter junctions.

FPLA (Field-Programmable Logic Array)--Logic array in which programming is accomplished by blowing fuse links or shorting base-emitter junctions.

FPMH (Failures Per Million Hours)--A measure of system failure rate.

FPU (Floating Point Unit)--A high-speed mathematic coprocessor for a microprocessor.

Frit--Material used to attach a die to a package.

Furnace--Fab equipment that performs diffusion at approximately 1,200°C.

Fuse links--Structures used in PROMs, PLAs, or other ICs to allow the customer to store data or modify logic functions using programming hardware.

Gain-bandwidth product--A measure of transistor or amplifier performance.

Gang bonding--A replacement for wire bonding using planar copper tape for connecting the chip to the package.

GaAs (Gallium Arsenide)--A type of semiconductor material offering very high speed operation in excess of 10 gigahertz.

Gate--(1) The MOS transistor equivalent of the base electrode in a bipolar transistor; the control electrode of a MOS transistor. (2) Part of an IC that performs a simple logic function such as NAND or NOR.

Gate array--An IC consisting of a structured pattern of logic devices that is processed except for the final interconnect metallization. These devices are offered as a standard product and then customized to meet each customer's unique requirements.

Gate delay--The time required for a gate output to respond to stimulus applied to the input.

Geometry--Sometimes used to refer to the minimum feature size of a semiconductor structure, such as gate length or line width.

Gigahertz (GHz)--One billion cycles per second.

Glossary

GPIB (General-Purpose Interface Bus)--An interface for passing information and control between a computer and measuring instruments that conforms to I.E.E.E. standard 488.

Hardware--ICs and other electronics and their associated boards, connectors, and mechanical packaging.

Header--A form of package using glass-metal seals.

Hermetic--A package or seal designed to protect its contents from the effects of adverse environmental conditions such as moisture and chemical contaminants.

Hybrid--A package containing semiconductor chips and passive components, such as resistors and capacitors.

IC--Integrated Circuit.

ICE (In Circuit Emulation)--As of a microprocessor. (See Emulator.)

I.E.E.E--Institute of Electrical and Electronic Engineers.

I^2L (Integrated Injection Logic)--A low-power bipolar IC form.

Inductor--A passive component that stores energy in the form of a magnetic field (flux) around a core body.

Infant mortality--Premature failures occurring at a much greater rate than during the period of useful life prior to the onset of substantial wearout.

Integrated circuit--A semiconductor structure combining the functions of many electronic components (i.e., transistors, resistors, capacitors, and diodes) interconnected on a single chip.

Interrupt--A temporary disruption of the normal operation of a routine by a special signal from the computer.

I/O (Input/Output)--A bidirectional IC lead or port.

I/O port--A place of access to a system or circuit whereby the transmission of information from external hardware to the computer or from the computer to external hardware occurs.

Ion implantation--The use of an ion beam to bombard a silicon wafer, altering the concentrations of p-type or n-type material. This method of doping allows for very precise control of the device parameters.

Glossary

IRED--Infrared-Emitting Diode.

Isolation--The technique used to electrically separate different parts of a system on a semiconductor die.

JAN (Joint Army Navy)--A registered trademark of the U.S. government used to mark semiconductors that comply with MIL-M-38510.

JEDEC (Joint Electronic Devices Engineering Council)--A U.S. industrial organization working on IC standardization and other industry concerns.

Jellybean--A commodity-type product.

JFET--Junction Field-Effect Transistor.

JJ (Josephson junction)--A form of very high speed circuit that is based on superconductivity at very low temperatures.

Junction--The boundary between a p region and an n region in a semiconductor substrate.

K--(1) 1,000. (2) 1,024, when defining memory size.

Kilobit--1,024 bits.

Kilohertz (KHz)--1,000 cycles per second.

LAN (Local Area Network)--A communications network designed to link office automation equipment. Usually cable based.

Laser trimmer--Fab equipment used for opening metal connections on IC chips.

LCC (Leadless Chip Carrier)--A form of high-density packaging for IC chips.

LCCC--Leadless Ceramic Chip Carrier.

LCD--Liquid Crystal Display.

LDCC--Leaded Chip Carrier.

Lead frame--A stamped or etched metal component that connects a chip to larger electrical components through pins.

Lead time--The interval between the date of ordering semiconductor products and the expected time of delivery.

Glossary

LED--Light-Emitting Diode.

Linear--A semiconductor circuit whose output varies directly with the input. Also, a subset of the analog product category.

Logic--(1) The use of digital signals in structured ways to perform tasks such as addition, accumulation, comparison, and inference. (2) Devices that perform such functions.

Logic Analysis -A technique and instrumentation for evaluating the integrity of a circuit design in real time by sampling various test points and examining for ANOM.

LS (Low-power Schottky)--Usually refers to LSTTL.

LSI (Large-Scale Integration)--ICs comprising 100 to 10,000 gates or gate equivalents.

LSTTL (Low-power Schottky TTL)--A popular bipolar logic IC form.

LTPD (Lot Tolerance Percent Defective)--A point on an acceptance sampling plan which is in the region of bad quality and reasonably low acceptance probability.

Mask--A thin sheet of material with a design pattern on it, used to selectively expose areas on a wafer during the semiconductor fabrication process. The mask is used in the same way that a photographic negative is used to produce a positive print.

Masked ROM--A read-only memory programmed to the customer's specified pattern during the manufacturing process.

Mass storage--Devices for storing large quantities of data for use by a computer. Data cannot usually be accessed directly by the CPU. Common mass storage systems include floppy disks, hard disks, and magnetic tape drives.

Mb (Megabit)--1,048,576 bits.

MBD--Magnetic Bubble Device.

MBM--Magnetic Bubble Memory.

MCU--Microcontroller Unit.

Megabit (Mb)--1,048,576 bits.

Glossary

Memory--An IC designed for the storage and retrieval of information in binary form.

Memory management--A technique (and device) for efficiently allocating main processor memory storage upon the issuance of each address request from the CPU.

Memory module--A multiple memory device mounted onto a small PC card.

Metal gate--An older but still popular technique for controlling MOS transistor current flow by applying a control voltage to an aluminum gate.

MMU (Memory Management Unit)--A component (or set of components) that implements the memory management function in a processor-based system.

MHz--Megahertz. One million cycles per second.

Micro--(1) Very small. (2) One millionth.

Microcircuit--An IC.

Microcomputer--A small computer system or circuit board.

Microcontroller--An integrated circuit, containing a CPU, memory, and I/O capability, that can perform the basic functions of a computer.

Micron--One millionth of a meter.

Microperipheral--A support device for a microprocessor or microcontroller that either interfaces external equipment or provides system support.

Microprocessor--A single-chip component or a collection of architecturally interdependent components that function as the CPU in a system. A microprocessor may contain some input/output circuits but does not usually operate in a standalone fashion.

Mil--One thousandth of an inch. Approximately 25.4 microns.

MIL-M-38510--The detailed military specification for military IC qualification.

MNOS (Metal Nitride Oxide Semiconductor)--An IC technique used to make some types of EAROMs.

Model--Identifiable variable parameter set with formulas for predicting final costs/price when one or more variables are changed.

Glossary

Modem (Modulator/Demodulator)--A device that converts audio signals to digital for transmission on telephone lines and converts received digital signals back into audio.

Module--An item that is packaged for ease of maintenance of the next higher level of assembly.

Monolithic--A device constructed from a single piece of material.

MOS--Metal Oxide Silicon.

MOS transistor--A voltage-mode device used to control current flow in solid matter. The device uses a gate conductor, such as silicon or metal (usually aluminum), over a very thin insulator (usually oxide). A voltage applied to the gate controls the flow of current between source and drain.

MOSFET--MOS Field-Effect Transistor.

MPU--Microprocessor Unit.

MSI (Medium-Scale Integration)--ICs comprising 10 to 1,000 gates or gate equivalents.

MTBF (Mean Time Between Failures)--For a particular interval, the total functioning life of a set of items divided by the total numbers of failures within the set of items during the measurement interval.

MTL (Merged Transistor Logic)--A high-density bipolar logic form, also referred to as integrated injection logic (I^2L).

Multilayer ceramic--Two or more layers of thin ceramic material, with buried metallization on each layer.

Multiplexed bus--A hardware method, as on a microprocessor, where data and address information share the same set of pins at different times in the processor cycle.

Multiplexor--An IC used to connect more than one set of equivalent inputs to a single set of outputs on a switchable basis.

Multiplier--An IC used for generating the product of two binary numbers. It can be either analog or digital.

NAND gate--Part of an IC that performs the logic function Not-AND.

Nanosecond--One billionth of a second. In this time, electrical pulses travel approximately 12 inches.

Glossary

N-channel--A type of MOS transistor.

Nibble-mode--An operating mode of a dynamic RAM in which four bits are accessed in sequence at a higher than normal access rate.

Niche market--A small, specialty market, as opposed to the "mainstream" market.

NMOS (N-channel Metal Oxide Silicon)--A type of semiconductor in which the majority carriers are electrons.

Nonmultiplexed bus--A hardware convention, as on a microprocessor, where data and address information each have unique sets of pins for communication.

Nonvolatile--A semiconductor device that does not lose information when power is turned off.

NOR gate--Part of an IC that performs the Not-OR logic function.

npn--A type of bipolar transistor constructed using a p-type base. In such a device, a layer with p-type conductivity is sandwiched between two n-type layers.

ns (nanosecond)--One billionth of a second.

NVRAM (Nonvolatile Random-Access Memory)--A read/write semiconductor memory device that does not lose information when power is turned off.

Op amp (Operational amplifier)--A type of IC that generates an amplified output that is exactly proportional to its input.

Operating system--Computer software that enables a computer and its peripheral systems to work together as a unit.

Opto (Optoelectronic)--A type of IC used for converting electricity to light or vice versa.

Optocoupler--A device that transmits electrical signals, without electrical connection, between a light source and a receiver. Also called an optoisolator.

OTP ROM (One-Time Programmable Read-Only Memory)--An EPROM packaged in plastic without a quartz window for erasure. Such a device is therefore programmable only once.

Package--The container used to encapsulate a semiconductor chip.

Glossary

Pad--A metallized area on a chip, usually 10 to 35 square mils, used for bonding or test probing.

Paging--A memory management technique that divides logical memory into equal fixed-size quantities. This is different than segmentation and usually more efficient in memory usage.

PAL (Programmable Array Logic)--PAL is a trademark of Monolithic Memories, Inc., referring to a family of logic devices that are customer programmable.

Parallel--The simultaneous transmission or processing of the parts of a word, character, or other division of a word in a computer, using separate facilities for each part.

Parasitic effects--The results of the interaction of the stray components in an IC. Such stray components result from the high-speed operation of circuit elements in close proximity.

Parity bit--A binary digit that is added to an array of bits to make the sum always odd or always even, for checking accuracy.

Parts per million (PPM)--PPM is a statement of defect level arrived at by multiplying percent defective by 10,000. (Example: 0.1% = 1,000 PPM)

Passivation--The use of a protective layer on the surface of a chip.

Passive element--An element that is not active (e.g., resistor, capacitor, inductor).

Pattern generator--(1) Equipment used in IC maskmaking. (2) Equipment used to create test sequences.

p-channel--A type of MOS structure in which the majority carriers are holes.

PCM (Pulse-Code Modulation)--Digital transmission of analog signals by sending periodic binary-coded samples of the signal values.

Peripheral--Equipment that is connected to a computer but is not part of the computer. Examples include printers, terminals, and disk drives.

Photodiode--A junction diode that is responsive to radiant energy.

Photoresist--A light-sensitive coating used in photolithography.

Photolithography--The manufacturing process of coating and selectively exposing a wafer for selective etching.

Glossary

Phototransistor--A light-sensitive transistor that delivers an electrical output proportional to the light intensity at the input.

Picosecond--One trillionth of a second. Light or electrical pulses travel about 12 mils (0.012 inches) in one picosecond.

Piezoelectric crystal--A crystal that produces a mechanical force when a voltage is applied.

Pin-grid array (PGA)--A package where pins emerge from the bottom of a substrate.

PIO (Parallel Input Output)--A device that transfers data to and from an I/O port in a parallel fashion.

Pipelining--A processor feature where several computer instructions are fetched from memory and stored in an in-line manner (in a pipeline or queue) waiting to be executed.

PLA (Programmable Logic Array)--A form of LSI containing a structured, partially interconnected set of gates and inverters that are fuse programmed.

PLD--Programmable Logic Device. (See PLA.)

Planar--Refers to a semiconductor structure in which the circuit elements are located within a thin layer near the chip surface.

Plasma etch--Refers to the use of a highly ionized gas (plasma) in the manufacture of high-density semiconductors.

Plastic package--A molded IC package, usually a DIP. The majority of ICs and discretes are manufactured in plastic packages.

PLL (Phase-Locked Loop)--A type of linear IC used in frequency-modulated (FM) circuits.

PMOS--p-channel MOS.

pnp--A bipolar transistor that has an n-type base.

Polysilicon--A silicon layer grown on a wafer in a furnace.

Power transistor--A transistor designed for high-current, high-voltage applications.

Price--The dollar amount paid to the manufacturer for a product.

Glossary

Probe--A test lead designed to make contact with a bonding pad or other test point on a chip. Also used as a verb to describe such testing.

Product Quality Assurance (PQA)--Rejected units supplied by customer to quality assurance for evaluation, verification, and correlation.

Profit--Difference between price and cost.

Projection alignment--An optical alignment procedure in semiconductor fabrication in which the mask does not touch the wafer.

PROM (Programmable Read-Only Memory)--A ROM that may be programmed after manufacture by blowing fuse links or shorting base-emitter junctions.

Propagation delay--Time required for a signal to travel along a wire or to be processed through an IC.

Pseudostatic--A dynamic memory IC that looks like static memory but includes on-chip automatic refresh circuitry.

Quality control (QC)--The overall system of activities whose purpose is to provide a quality of product or service that meets the needs of users.

RAM (Random-Access Memory)--Read/write random-access memory that can be directly accessed by the CPU.

RAS (Row Address Strobe)--Input signal used by address-multiplexed RAMs.

Rating--The designated operating limits of a device or system in terms of electrical, mechanical, or environmental stress.

Rectifier--A device that converts alternating current into a current that has a large unidirectional component.

Redundancy--The addition of functions that may be substituted for other functions, in the event of a manufacturing defect or a hardware failure, to greatly improve yield, reliability, or both.

Refresh--The restoration of a logic level to its original voltage/current value.

Register--A small, fast, temporary storage location within an MPU or discrete logic.

Reliability--The probability that a device or system will perform satisfactorily according to its specifications for a definite period of time under specified operating conditions.

Glossary

Resistor--A device that measurably opposes the passage of an electric current (e.g., doped silicon).

Reticle--A master plate from which masks are made.

RF--Radio Frequency.

RFI--Radio Frequency Interference.

ROM (Read-Only Memory)--A memory device whose contents can be read but not altered.

RTL (Resistor Transistor Logic)--A form of low-power bipolar IC logic used extensively in the 1960s.

Sampling--(1) Acquiring statistics from a mass of data without taking a complete census of the data. (2) The early phase of a product life cycle in which the supplier provides the user with limited sample quantities for evaluation.

SAW (Surface Acoustic Wave)--An electronic device based on the generation and reception of high-frequency sound waves that travel along the surface of a piezoelectric crystal.

Schottky diode--A type of diode, invented at Bell Laboratories in 1960, that has a relatively fast response time because of its low capacitance.

Schottky TTL--A form of transistor-transistor logic using Schottky diodes as transistor clamps to speed up circuit operation.

SCR--Silicon Controlled Rectifier.

Second source--An alternative source of a semiconductor product. A licensed second source is one that has entered into an agreement with the original manufacturer.

Segmentation--A memory allocation technique for dividing logical memory into variable size chunks.

SEM (Scanning Electron Microscope)--A microscope used for semiconductor die examination at very high magnification.

Semiconductor--(1) A material that is neither a good conductor nor a good insulator and whose electrical properties can be altered by the selective introduction of impurities into its crystalline structure. (2) An electronic device made using semiconductor material.

Glossary

Semicustom--A semiconductor device manufactured using a standard process but alterable to a user's specific needs.

Shift register--An IC used for temporary synchronous storage of data.

Si--Chemical symbol for silicon, the basic ingredient of most semiconductors in use today.

Side-brazed package--A ceramic IC package that has the metal leads brazed to the sides of the package.

Silicide--A metal alloy used to improve semiconductor performance by reducing resistivity.

Silicon--A nonmetallic element that is the most widely used semiconductor material today. Silicon is used in its crystalline form as the substrate of semiconductor devices.

Silicon dioxide--A material often used as an insulating layer in semiconductor manufacture. It may be formed by heating the silicon wafer in a furnace in the presence of wet or dry oxygen.

Silicon foundry--An IC manufacturer specializing in processing using customer-owned tooling (COT).

Silicon gate MOS--MOS devices that have a controlling electrode (gate) consisting of silicon instead of metal over the oxide.

Silicon software--Computer programs stored in read-only memory (ROM). Also called firmware. (See Firmware.)

SIO (Serial Input Output)--A device or technique where data is transferred to or from an I/O port in a serial or in-line manner.

SIP (Single In-line Package)--An IC package that has a single row of leads.

SIP module--Multiples of SIP packaged memory devices mounted on a small PC card.

Slice--A wafer.

Smart power--A classification of ICs that contain both control logic circuits and power control elements.

SOS (Silicon On Sapphire)--An integrated circuit produced on a sapphire substrate. Such devices, which operate at high speed, are sometimes used for military applications. They are very expensive to manufacture.

Glossary

Source--(1) In a MOS transistor, the majority carrier emitter. (2) A semiconductor supplier or distributor.

Sputterer--IC manufacturing equipment used for depositing metal on wafers.

SSI (Small-Scale Integration)--IC devices containing fewer than 10 gates or gate equivalents.

Standard product--Semiconductor devices that are readily available from a number of suppliers.

Standard cell--Integrated circuits designed to a customer's specifications using precharacterized cells as building blocks.

S TTL (Schottky TTL)--A high-speed form of bipolar logic.

Static RAM--A RAM that maintains memory as long as power is applied and does not require refreshing.

Synchronous--In a computer, a mode of operation in which all operations are controlled by signals from a master clock.

TAB (Tape Automated Bonding)--Interconnection process where chips are bonded to leads etched in copper laminated tape.

Threshold--The point at which a semiconductor starts to conduct.

Thyristor--A four-layer semiconductor that can be switched from an ON state to an OFF state, usually by a voltage or current pulse to the gate terminal. The device will then continue to conduct so long as the principal current of the device flows through the thyristor's two main terminals.

Transistor--An active semiconductor that has three electrodes; used for amplification or switching.

TTL or T^2L (Transistor-Transistor Logic)--A popular form of bipolar logic IC.

UART (Universal Asynchronous Receiver/Transmitter)--A serial I/O device.

USART (Universal Synchronous Asynchronous Receiver/Transmitter)--A serial I/O device.

UNIX--A computer operating system developed by Bell Laboratories.

UV EPROM (Ultraviolet Electrically Programmable ROM)--An EPROM that is erasable with an ultraviolet light source.

Glossary

VHSIC (Very High Speed Integrated Circuit)--A program that is intended to develop advanced semiconductors for the U.S. government and for defense purposes.

Virtual memory--The presence of logical memory addressing that makes the physical memory space appear much larger than it really is.

VLSI (Very Large Scale Integration)--An IC chip containing more than 10,000 gates or gate equivalents.

Wafer--A thin (10 to 20 mils) disk of semiconductor material from which semiconductors are fabricated.

Wafer fab--The IC production process, from raw wafers through a series of diffusion, etching, photolithographic, and other steps, to finished wafers.

Wafer stepper--Fab equipment used for exposing multiple images of an IC pattern onto a wafer.

Word length--The word length of a microprocessor or microcontroller is defined by the bit width of its external data bus.

Working plates--Masks used in wafer fab.

Yield--The ratio of acceptable parts to total parts attempted; a measure of production efficiency.

Zener--A diode that has a controlled, reverse-voltage/current relationship.

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COPING WITH THE CRISES OF MODERATE GROWTH

SUMMARY

The semiconductor industry is accustomed to wide swings in its marketplace--frenzied growth followed by abrupt recessions. Now, for the second year in a row, it looks like there will be only moderate growth, lacking the luster of the usual industry upswings.

The challenge for the U.S. semiconductor industry is to learn to cope with this moderate growth in consumption. Industry participants are continuing to consolidate and restructure to deal with the reality of lower long-term growth rates. The continued shift of U.S. electronic equipment production to the Asia-Pacific basin will have a significant moderating effect on growth in U.S. semiconductor consumption.

U.S. semiconductor consumption grew 6.5 percent in 1986 as Dataquest projected at the October Semiconductor Industry Conference. We now project positive growth in the first quarter and an upswing in the second quarter of 1987. Though annual consumption in 1987 is expected to grow 12.7 percent or twice the 1986 rate, this growth rate pales in comparison to the historical rates in the boom years. We do not anticipate growth rates in excess of 20 percent until in 1988.

HOW DID WE DO WITH LAST YEAR'S FORECAST?

A comparison of the quarterly growth rates that we forecast in February 1986 with our current estimate of 1986 consumption is shown in Figure 1. Shipments grew faster than we predicted in the second quarter of 1986, and then flattened out rather than continuing to grow as we expected. Annual shipments in 1986 in U.S. dollars came within 4 percent of what we predicted in February 1986.

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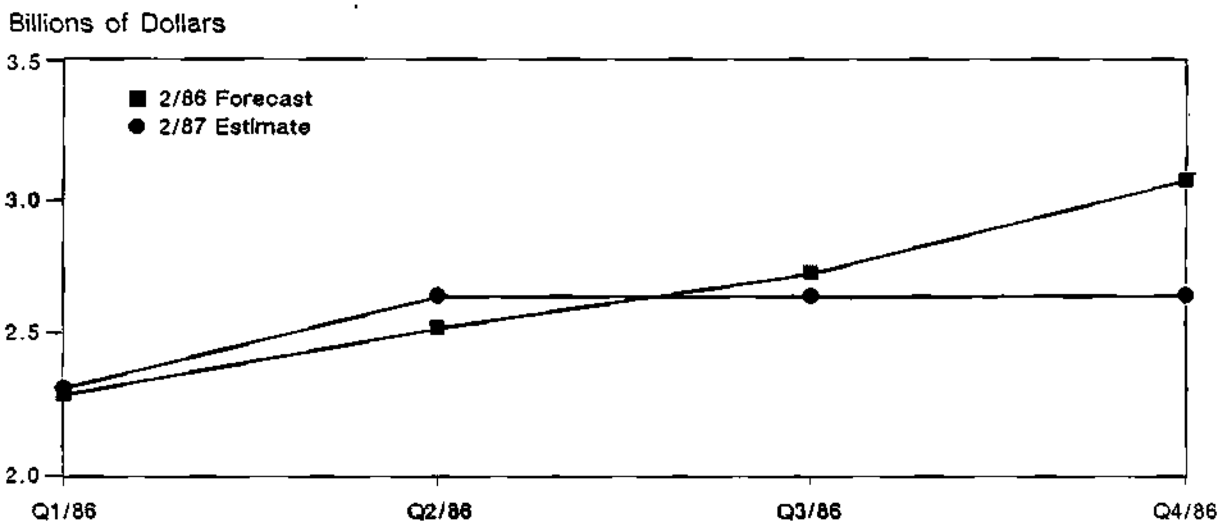
Figure 1

U.S. QUARTERLY SEMICONDUCTOR CONSUMPTION
1986



Source: Dataquest
February 1987

ASSUMPTIONS FOR THIS FORECAST

The Book-to-Bill is Up

The book-to-bill ratio has been rising since October, and we expect the current level of bookings to result in 1.1 percent growth in first-quarter shipments. We expect the book-to-bill to stay above 1.0 percent in the first quarter, contributing to a healthy 6.2 percent growth in the second quarter. Recent upward movement in semiconductor stocks also anticipates this growth.

Modest Growth in End Equipment

Our current semiconductor industry forecast assumes a modest 7 percent growth in end-equipment shipments in 1987. End-equipment trends tracked include computers, communications, industrial, transportation (including automotive), military, and consumer electronics.

Movement to ROW Dampens U.S. Growth

Preliminary results from a Dataquest Semiconductor Application Markets (SAM) procurement survey indicate a 9 percent shift in electronics production from the United States to the Asia-Pacific basin in 1987, compared with a 7 percent shift in 1986. Since the U.S. dollar exchange rate remains virtually unchanged relative to Korea and Taiwan, U.S. electronics companies are leveraging this movement to compete with the Japanese. The movement to ROW has a significant moderating effect on the growth in U.S. semiconductor consumption.

Other Economic Assumptions--1987

GNP is expected to grow about 3 percent in 1987, with about a 4 percent rise in the consumer price index. Further interest rate cuts are expected to spur investment.

For the semiconductor industry, we expect a stable environment with tight inventory levels and no large swings. We do not expect shortages or steep price erosions. Capacity remains largely underutilized, with about 70 percent utilization in 1987.

THE FORECAST: MODERATE GROWTH

Our quarterly forecast of North American semiconductor consumption for 1987 and 1988 is shown in Table 1.

Table 1

ESTIMATED NORTH AMERICAN SEMICONDUCTOR CONSUMPTION
(Millions of Dollars)

	1986	Q1/87	Q2/87	Q3/87	Q4/87	1987	% Chg. 1987
Total Semiconductor	10,233	2,678	2,845	2,922	3,087	11,532	12.7%
Total IC	8,162	2,159	2,300	2,362	2,502	9,323	14.2%
Bipolar Digital	2,061	513	545	563	605	2,226	8.0%
Memory	339	90	97	101	106	394	16.2%
Logic	1,722	423	448	462	499	1,832	6.4%
MOS Digital	4,449	1,229	1,297	1,325	1,383	5,234	17.6%
Memory	1,570	416	441	448	459	1,764	12.4%
Micro	1,241	330	348	354	375	1,407	13.4%
Logic	1,638	483	508	523	549	2,063	25.9%
Linear	1,652	417	458	474	514	1,863	12.8%
Discrete	1,652	413	431	444	466	1,754	6.2%
Optoelectronic	419	106	114	116	119	455	8.6%

	1987	Q1/88	Q2/88	Q3/88	Q4/88	1988	% Chg. 1988
Total Semiconductor	11,532	3,265	3,551	3,666	3,744	14,226	23.4%
Total IC	9,323	2,667	2,925	3,031	3,116	11,739	25.9%
Bipolar Digital	2,226	638	681	701	718	2,738	23.0%
Memory	394	109	113	118	123	463	17.5%
Logic	1,832	529	568	583	595	2,275	24.2%
MOS Digital	5,234	1,501	1,682	1,761	1,824	6,768	29.3%
Memory	1,764	499	585	615	598	2,297	30.2%
Micro	1,407	409	456	479	526	1,870	32.9%
Logic	2,063	593	641	667	700	2,601	26.1%
Linear	1,863	528	562	569	574	2,233	19.9%
Discrete	1,754	475	493	499	488	1,955	11.5%
Optoelectronic	455	123	133	136	140	532	16.9%

Source: Dataquest
February 1987

CONSUMPTION TRENDS

While 1986 was a slow year with only 6.5 percent growth in overall North American semiconductor consumption, some product categories fared better than others. MOS logic was a winner, growing 28.2 percent, particularly due to the strength in ASICs. MOS memory declined 11.5 percent and MOS micros grew only 3.8 percent, slower than total semiconductors. Linear and discrete product categories did better than total semiconductors.

Our projection for 1987 is for MOS logic to remain the fastest-growing segment, with ASICs showing stellar performance. MOS memories and micros are expected to rebound with growth rates more than 12 percent, hinging on an upswing in computers and data processing equipment.

DATAQUEST CONCLUSIONS

Dataquest projects 12.7 percent growth in U.S. semiconductor consumption in 1987. Though this is moderate growth, this rate is about twice the rate of growth in 1986. We are already seeing signs of an upswing. There is optimism in the industry. End-equipment demand seems to be bottoming out, inventory levels are low, prices are holding, and bookings are up.

Howard Z. Bogert
Joseph K. Borgia

Dataquest

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Research Newsletter

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1986 PRELIMINARY MARKET SHARE
CURRENCY REVALUATIONS CHANGE MARKET STANDINGS

Preliminary estimates of the world semiconductor market indicate a 26.0 percent increase in revenue when measured in dollars. By this measure, Japanese producers fared well, chalking up approximately a 43 percent growth in worldwide factory shipments. European producers had the next best growth with a 16 percent increase in factory shipments and the North American region fared worst of all with only a 10 percent growth.

These figures do not correlate with the emotional response heard from the major producing regions: cries of anguish from Japan, distress from Europe, and the loud sound of bullet biting in North America. The real market picture is perhaps different from that portrayed by the growth of revenue expressed in dollars.

A different picture appears when consumption in the three regions is expressed in local currencies: The North American region shows a 6.4 percent growth, Japan shows a negative growth of 2.0 percent, and European producers have a market decline of 6 percent. This helps explain the reaction of producers in the three regions, but it still may not be an accurate view.

If producers outside North America can increase their dollar market shares in the face of increasing dollar prices it must be that their products were undervalued. By this argument, the dollar market share is significant. Japanese sales in 1986 outside Japan (expressed in yen) fell only 8 percent from 1985. Currency revaluations against the dollar were an increase of 43 percent in Japanese yen and an increase of 20 percent in the European basket of currencies.

Dataquest believes that the true impact of currency revaluations on market standing lies somewhere between the local-currency point of view and the dollar-denominated point of view. We anticipate that suppliers in various geographic regions will continue to adjust their strategies to further compensate for these changes during 1987.

1986 MARKET SUMMARY

Tables 1 through 8 rank the top 50 major worldwide suppliers by total semiconductor, integrated circuits, bipolar, MOS, linear, discrete and optoelectronics (opto) product areas. These rankings are all stated in dollars. In each instance, these suppliers accounted for at least 90 percent of the total world market and thus give a good preliminary snapshot of 1986. The total world market increased 26.0 percent, and was made up of an increase of 26.3 percent in ICs and 25.1 percent in discrete and opto. Among the markets comprising ICs, MOS digital exhibited the fastest growth at 28.0 percent and bipolar digital noted the slowest growth at 19.3 percent. Generally, Japanese suppliers exhibit higher growth than European suppliers which in turn exhibit higher growth than North American suppliers. These variations in growth rates reflect the currency revaluations discussed above. In spite of this, a number of North American suppliers exhibited growth rates above the world averages in their segments, reflecting, Dataquest believes, a successful search for niches. These suppliers will be pointed out in the discussion of each table.

SEMICONDUCTOR MARKET SHARE

In total semiconductor, as indicated in Table 1, NEC maintained its first place ranking. Hitachi and Toshiba made it to second and third place, respectively, passing Motorola and Texas Instruments. Toshiba showed an above average growth rate even when currency effects are accounted for. Dataquest believes Toshiba is currently expanding its productive capacity in a bid for even greater market share. In the top 10, Mitsubishi is a new entrant, pushing National Semiconductor from the top 10.

A number of smaller North American companies showed growth rates above the industry average of 26.0 percent. These include TRW, LSI Logic, Honeywell, and VLSI Technology. Dataquest believes these firms have successfully exploited market niches in this difficult year.

IC MARKET SHARE

IC market share rankings are shown in Table 2. These company sales are included in the total semiconductor sales of Table 1. NEC ascended to first position in these rankings, followed by Hitachi, thus relegating Texas Instruments to third place. Toshiba advanced two positions, pushing Motorola from third place to fifth place. In the top 10, Mitsubishi is a new entry, replacing Advanced Micro Devices.

Smaller North American companies showing growth rates above the industry average for this segment of 26.3 percent include Honeywell, Integrated Device Technology, LSI Logic, Silicon Systems, TRW, and VLSI Technology.

Gold Star and United Microelectronics are new to the list this year. Gold Star is a Korean company and United Microelectronics is located in Taiwan. This is significant because it is the first time Asian suppliers outside Japan have achieved this ranking. Both companies had growth rates much higher than the world average, which is also significant because both of these countries have currencies that are tied to the dollar.

BIPOLAR DIGITAL MARKET SHARE

The bipolar digital market shares are shown in Table 3. These figures are included in the IC totals of Table 2. This market has fewer suppliers than other markets in the integrated circuit category.

In the top 10, Texas Instruments retained its first place ranking. Philips-Signetics edged out Motorola for second place and Fujitsu climbed into fourth place edging out Fairchild. No new players appear in the top 10.

Honeywell and Raytheon are two North American companies that showed growth rates significantly in excess of the 19.3 percent growth rate of this segment.

MOS DIGITAL MARKET SHARE

MOS digital market shares are shown in Table 4. These figures are included in the IC totals of Table 2.

In the top 10, NEC retains its first place ranking, followed by Hitachi and Toshiba who pushed Intel from second to fourth place. New entrants to the top 10 include Matsushita and Oki, which replace National Semiconductor and Advanced Micro Devices.

North American companies that show growth rates above the average for this segment of 28.0 percent include LSI Logic, Integrated Device Technology, Rockwell, VLSI Technology, Cypress Semiconductor, Micron Technology, and Honeywell.

Two East Asian companies outside Japan showing high growth rates are Samsung and United Microelectronics. Dataquest believes these firms benefitted by being exempt from the U.S. Department of Commerce FMV prices for memory devices, as did Micron Technology, Cypress, and Integrated Device Technology.

LINEAR MARKET SHARE

Linear market shares are shown in Table 5. These figures are included in the IC totals of Table 2.

In the top 10, Matsushita advanced to first place passing National Semiconductor, long the world's leading supplier of linear devices. Toshiba advanced to number three position and NEC maintained its number four slot. There were no new entrants to the top 10.

North American companies that show growth rates above the average for this segment of 26.9 percent include Silicon Systems, TRW, Mitel, Linear Technology, Cherry Semiconductor, Unitrode, and Solitron.

East Asian companies outside of Japan showing above average growth rates include Gold Star, Samsung, and KEC.

DISCRETE/OPTO MARKET SHARE

Discrete/opto market shares are shown in Table 6. These figures are added into the totals of Table 1.

In the top 10, Toshiba advanced to first place, edging out Motorola, long the leader in this segment. Hitachi and NEC retained their third and fourth positions respectively. There were no new entrants to the top 10.

North American companies showing growth above the world average for this segment include TRW and Supertex.

A new entrant to the list this year is Powerex. This company includes the former discrete operations of Westinghouse and a portion of the discrete business of General Electric. The new entity was backed in financing and technology by Mitsubishi.

DISCRETE MARKET SHARE

Discrete market shares are shown in Table 7. These figures are added into the totals of Table 6.

In the top 10, Motorola retained its number one position. Toshiba advanced to second place, pushing Hitachi down to third place. NEC maintained its position as number four. ROHM and Fuji Electric were new additions to the top 10, replacing ITT and International Rectifier. North American companies showing growth above the world average for this segment include TRW and Hewlett-Packard.

OPTO MARKET SHARE

Table 8 gives world market shares of optoelectronics. These figures are added into the totals of Table 6. Note that opto exceeds the MOS digital area in growth.

In the top 10, Sharp advanced to first place, edging out Hewlett-Packard. Matsushita and Sony advanced to third and fourth place respectively, relegating Toshiba to fifth place rather than third place. ROHM was a new entrant to the top 10, replacing Hitachi.

RCA was the only North American firm showing growth in excess of the segment average.

Definitions

Our data includes semiconductor revenue from products shipped to non-semiconductor segments of the same company where those products are initiated in the semiconductor group. These products are valued as if they were sold on the merchant market. By using this definition, Dataquest seeks to account for true manufacturing capability of semiconductor suppliers. Because of our definition, we differ from publicly reported semiconductor sector data for companies such as Motorola. Dataquest includes hybrid circuits, if they are manufactured in the semiconductor group. NRE costs are also included for those gate arrays, standard cells, and custom products included in a company's ASIC revenue.

Dataquest's preliminary Market Share Service Section is currently being completed and will be available to all binder holders this month.

Barbara Van
Howard Bogert

Table 1

PRELIMINARY 1986 WORLD SEMICONDUCTOR MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	1	NEC	1984	2638	33.0%
2	4	HITACHI	1671	2305	37.9%
3	5	TOSHIBA	1468	2261	54.0%
4	2	MOTOROLA	1830	2025	10.7%
5	3	TEXAS INSTRUMENTS	1742	1820	4.5%
6	6	PHILIPS-SIGNETICS	1068	1356	27.0%
7	7	FUJITSU	1020	1310	28.4%
8	10	MATSUSHITA	906	1233	36.1%
9	11	MITSUBISHI	642	1177	83.3%
10	8	INTEL	1020	991	-2.8%
11	9	NATIONAL SEMICONDUCTOR	925	990	7.0%
12	12	ADVANCED MICRO DEVICES	615	629	2.3%
13	14	SANYO	457	585	28.0%
14	13	FAIRCHILD	492	510	3.7%
15	22	SONY	252	475	88.5%
16	16	SHARP	329	456	38.6%
17	17	THOMSON *	324	436	34.6%
18	15	SIEMENS	420	429	2.1%
19	19	OKI	307	427	39.1%
20	23	ROHM	249	379	52.2%
21	20	SGS	300	370	23.3%
22	18	RCA	310	370	19.4%
23	21	ITT	270	312	15.6%
24	24	HARRIS	247	264	6.9%
25	25	ANALOG DEVICES	226	232	2.7%
26	31	SANKEN	155	220	41.9%
27	29	TELEFUNKEN ELECTRONIC	170	219	28.8%
28	26	HEWLETT-PACKARD	206	217	5.3%
29	30	FUJI ELECTRIC	156	213	36.5%
30	36	TRW	125	213	70.4%
31	28	MONOLITHIC MEMORIES	172	210	22.1%
32	27	GENERAL INSTRUMENT	201	205	2.0%
33	32	LSI LOGIC	140	192	37.1%
34	41	SAMSUNG	95	183	92.6%
35	42	SEIKO EPSON	93	167	79.6%
36	44	HONEYWELL	88	157	78.4%
37	33	AMERICAN MICROSYSTEMS	140	155	10.7%
38	34	INTERNATIONAL RECTIFIER	128	145	13.3%
39	38	SILICONIX	110	126	14.5%
40	39	PLESSEY	99	112	13.1%
41	48	VLSI TECHNOLOGY	78	110	41.0%
42	49	BURR-BROWN	78	95	21.8%
43	N/A	POWEREX	0	95	N/A
44	40	FERRANTI	98	95	-3.1%
45	45	SPRAGUE	87	94	8.0%
46	43	UNITRODE	89	90	1.1%
47	37	GENERAL ELECTRIC	118	89	-24.6%
48	52	PRECISION MONOLITHICS	68	81	19.1%
49	46	INMOS	85	80	-5.9%
50	50	NCR	75	80	6.7%
		Top 50 total	21928	27623	26.0%

*NOTE: MOSTEK AND THOMSON REVENUES ARE AGGREGATED IN 1986 BUT NOT 1985.

Source: Dataquest
January 1987

Table 2

PRELIMINARY 1986 WORLD IC MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	2	NEC	1603	2154	34.4%
2	4	HITACHI	1236	1771	43.3%
3	1	TEXAS INSTRUMENTS	1653	1728	4.5%
4	6	TOSHIBA	1004	1605	59.9%
5	3	MOTOROLA	1281	1405	9.7%
6	7	FUJITSU	940	1198	27.4%
7	9	PHILIPS-SIGNETICS	808	1041	28.8%
8	5	INTEL	1020	991	-2.8%
9	8	NATIONAL SEMICONDUCTOR	882	956	8.4%
10	12	MITSUBISHI	465	923	98.5%
11	11	MATSUSHITA	595	807	35.6%
12	10	ADVANCED MICRO DEVICES	615	629	2.3%
13	13	FAIRCHILD	451	464	2.9%
14	14	SANYO	314	407	29.6%
15	15	OKI	289	402	39.1%
16	22	THOMSON *	197	293	48.7%
17	17	SGS	240	291	21.3%
18	24	SONY	155	290	87.1%
19	19	RCA	225	268	19.1%
20	16	HARRIS	247	264	6.9%
21	21	SHARP	201	259	28.9%
22	18	ANALOG DEVICES	226	232	2.7%
23	20	SIEMENS	205	216	5.4%
24	23	MONOLITHIC MEMORIES	172	210	22.1%
25	27	LSI LOGIC	140	192	37.1%
26	26	ITT	140	168	20.0%
27	30	SEIKO EPSON	93	167	79.6%
28	29	ROHM	105	163	55.2%
29	37	SAMSUNG	75	159	112.0%
30	25	AMERICAN MICROSYSTEMS	140	155	10.7%
31	45	HONEYWELL	57	122	114.0%
32	35	VLSI TECHNOLOGY	78	110	41.0%
33	31	PLESSEY	89	98	10.1%
34	33	BURR-BROWN	78	95	21.8%
35	53	TRW	43	88	104.7%
36	40	TELEFUNKEN ELECTRONIC	68	82	20.6%
37	39	PRECISION MONOLITHICS	68	81	19.1%
38	48	SANKEN	53	81	52.8%
39	32	INMOS	85	80	-5.9%
40	36	NCR	75	80	6.7%
41	34	FERRANTI	78	78	0.0%
42	44	ZILOG	59	74	25.4%
43	51	INTEGRATED DEVICE TECH.	50	72	44.0%
44	50	SILICON SYSTEMS	51	72	41.2%
45	46	WESTERN DIGITAL	56	70	25.0%
46	41	SILICONIX	63	69	9.5%
47	38	INTERSIL	70	68	-2.9%
48	60	GOLD STAR	32	65	103.1%
49	43	SPRAGUE	60	65	8.3%
50	58	UNITED MICROELECTRONICS	33	65	97.0%
		Top 50 total	16963	21423	26.3%

*NOTE: MOSTEK AND THOMSON REVENUES ARE AGGREGATED IN 1986 BUT NOT 1985.

Source: Dataquest
January 1987

Table 3

PRELIMINARY 1986 WORLD BIPOLAR DIGITAL MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	1	TEXAS INSTRUMENTS	796	875	9.9%
2	3	PHILIPS-SIGNETICS	372	427	14.8%
3	2	MOTOROLA	379	398	5.0%
4	6	FUJITSU	267	347	30.0%
5	4	FAIRCHILD	329	341	3.6%
6	7	HITACHI	195	339	73.8%
7	5	ADVANCED MICRO DEVICES	276	303	9.8%
8	9	MONOLITHIC MEMORIES	170	206	21.2%
9	8	NATIONAL SEMICONDUCTOR	194	206	6.2%
10	10	NEC	129	176	36.4%
11	11	MITSUBISHI	75	155	106.7%
12	16	TOSHIBA	33	129	290.9%
13	12	HONEYWELL	50	86	72.0%
14	13	FERRANTI	49	43	-12.2%
15	15	SIEMENS	41	36	-12.2%
16	22	RAYTHEON	22	33	50.0%
17	24	MATSUSHITA	21	30	42.9%
18	17	PLESSEY	30	30	0.0%
19	21	OKI	22	26	18.2%
20	26	ROHM	15	25	66.7%
21	23	AMCC	21	24	14.3%
22	25	SANYO	18	23	27.8%
23	14	HARRIS	43	21	-51.2%
24	20	INTEL	22	21	-4.5%
25	18	SGS	26	20	-23.1%
26	19	THOMSON	24	10	-58.3%
27	29	GOLD STAR	4	7	75.0%
28	28	INTERDESIGN	6	5	-16.7%
29	27	RIFA	9	5	-44.4%
30	33	CHERRY SEMICONDUCTOR	3	3	0.0%
31	34	TELEDYNE	3	3	0.0%
32	32	TRW	4	3	-25.0%
33	35	FUJI ELECTRIC	1	2	100.0%
34	30	MATRA-HARRIS	4	1	-75.0%
		Top 34 total	3653	4359	19.3%

Source: Dataquest
January 1987

Table 4

PRELIMINARY 1986 WORLD MOS DIGITAL MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	1	NEC	1174	1615	37.6%
2	3	HITACHI	852	1167	37.0%
3	4	TOSHIBA	736	1106	50.3%
4	2	INTEL	998	970	-2.8%
5	6	FUJITSU	631	791	25.4%
6	5	MOTOROLA	668	727	8.8%
7	10	MITSUBISHI	290	583	101.0%
8	7	TEXAS INSTRUMENTS	522	501	-4.0%
9	11	MATSUSHITA	269	384	42.8%
10	12	OKI	264	372	40.9%
11	8	NATIONAL SEMICONDUCTOR	318	366	15.1%
12	13	PHILIPS-SIGNETICS	228	314	37.7%
13	9	ADVANCED MICRO DEVICES	305	290	-4.9%
14	14	SHARP	173	214	23.7%
15	20	THOMSON *	107	210	96.3%
16	15	RCA	160	194	21.3%
17	17	LSI LOGIC	140	192	37.1%
18	21	SEIKO EPSON	93	167	79.6%
19	16	AMERICAN MICROSYSTEMS	140	155	10.7%
20	32	SAMSUNG	55	123	123.6%
21	19	HARRIS	111	117	5.4%
22	29	SONY	59	116	96.6%
23	26	VLSI TECHNOLOGY	78	110	41.0%
24	23	ITT	90	107	18.9%
25	24	SGS	88	106	20.5%
26	22	SIEMENS	92	89	-3.3%
27	28	SANYO	68	88	29.4%
28	25	INMOS	85	80	-5.9%
29	27	NCR	75	80	6.7%
30	30	ZILOG	59	74	25.4%
31	34	INTEGRATED DEVICE TECH.	50	72	44.0%
32	31	WESTERN DIGITAL	56	70	25.0%
33	42	UNITED MICROELECTRONICS	33	65	97.0%
34	35	ROCKWELL	44	64	45.5%
35	33	STANDARD MICROSYSTEMS	54	56	3.7%
36	51	CYPRESS SEMICONDUCTOR	18	50	177.8%
37	39	MICRON TECHNOLOGY	36	49	36.1%
38	38	MATRA-HARRIS	36	44	22.2%
39	36	GENERAL INSTRUMENT	42	40	-4.8%
40	43	XICOR	32	40	25.0%
41	37	HUGHES	36	39	8.3%
42	40	PLESSEY	35	39	11.4%
43	62	HONEYWELL	7	36	414.3%
44	41	SEEQ	33	31	-6.1%
45	48	EUROSIL	21	30	42.9%
46	46	IMP	25	30	20.0%
47	44	SOLID STATE SCIENTIFIC	28	30	7.1%
48	50	ASEA-HAFO	18	22	22.2%
49	47	FAIRCHILD	22	22	0.0%
50	49	MEDL	20	22	10.0%
		Top 50 total	9574	12259	28.0%

*NOTE: MOSTEK AND THOMSON REVENUES ARE AGGREGATED IN 1986 BUT NOT 1985.

Source: Dataquest
January 1987

Table 5

PRELIMINARY 1986 WORLD LINEAR MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	3	MATSUSHITA	305	393	28.9%
2	1	NATIONAL SEMICONDUCTOR	370	384	3.8%
3	5	TOSHIBA	235	370	57.4%
4	4	NEC	300	363	21.0%
5	2	TEXAS INSTRUMENTS	335	352	5.1%
6	9	PHILIPS-SIGNETICS	208	300	44.2%
7	7	SANYO	228	296	29.8%
8	6	MOTOROLA	234	280	19.7%
9	10	HITACHI	189	265	40.2%
10	8	ANALOG DEVICES	226	232	2.7%
11	13	MITSUBISHI	100	185	85.0%
12	14	SONY	96	174	81.3%
13	11	SGS	126	165	31.0%
14	16	ROHM	85	129	51.8%
15	15	HARRIS	93	126	35.5%
16	12	FAIRCHILD	100	101	1.0%
17	18	SIEMENS	72	91	26.4%
18	17	BURR-BROWN	78	95	21.8%
19	19	PRECISION MONOLITHICS	68	81	19.1%
20	26	SANKEN	53	81	52.8%
21	21	RCA	65	74	13.8%
22	20	THOMSON	66	73	10.6%
23	27	SILICON SYSTEMS	51	72	41.2%
24	30	TRW	39	70	79.5%
25	22	SILICONIX	60	65	8.3%
26	23	SPRAGUE	60	65	8.3%
27	24	TELEFUNKEN ELECTRONIC	55	63	14.5%
28	28	ITT	50	61	22.0%
29	29	FUJITSU	42	60	42.9%
30	25	INTERSIL	53	53	0.0%
31	38	GOLD STAR	22	48	118.2%
32	35	SHARP	28	45	60.7%
33	33	MITEL	29	38	31.0%
34	31	ADVANCED MICRO DEVICES	34	36	5.9%
35	32	EXAR	30	36	20.0%
36	40	SAMSUNG	20	36	80.0%
37	39	LINEAR TECHNOLOGY	22	29	31.8%
38	36	PLESSEY	24	29	20.8%
39	34	RAYTHEON	29	28	-3.4%
40	44	FUJI ELECTRIC	13	26	100.0%
41	37	FERRANTI	23	24	4.3%
42	45	CHERRY SEMICONDUCTOR	11	18	63.6%
43	43	INTERDESIGN	18	17	-5.6%
44	41	GENERAL INSTRUMENT	19	15	-21.1%
45	42	GTE MICROCIRCUITS	18	14	-22.2%
46	47	TELEDYNE	11	13	18.2%
47	50	UNITRODE	8	13	62.5%
48	49	SOLITRON	8	12	50.0%
49	48	KEC	8	11	37.5%
50	46	MICRO POWER SYSTEMS	11	10	-9.1%
		Top 50 total	4428	5617	26.9%

Source: Dataquest
January 1987

Table 6

PRELIMINARY 1986 WORLD DISCRETE/OPTO MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	2	TOSHIBA	464	656	41.4%
2	1	MOTOROLA	549	620	12.9%
3	3	HITACHI	435	534	22.8%
4	4	NEC	381	484	27.0%
5	5	MATSUSHITA	311	426	37.0%
6	6	PHILIPS-SIGNETICS	260	315	21.2%
7	9	MITSUBISHI	177	254	43.5%
8	8	HEWLETT-PACKARD	206	217	5.3%
9	10	ROHM	144	216	50.0%
10	7	SIEMENS	215	213	-0.9%
11	16	SHARP	128	197	53.9%
12	21	SONY	97	185	90.7%
13	13	FUJI ELECTRIC	136	178	30.9%
14	11	SANYO	143	178	24.5%
15	12	GENERAL INSTRUMENT	140	150	7.1%
16	15	INTERNATIONAL RECTIFIER	128	145	13.3%
17	14	ITT	130	144	10.8%
18	17	THOMSON	127	143	12.6%
19	19	SANKEN	102	139	36.3%
20	20	TELEFUNKEN ELECTRONIC	102	137	34.3%
21	24	TRW	82	125	52.4%
22	26	FUJITSU	80	112	40.0%
23	23	RCA	85	102	20.0%
24	N/A	POWEREX	0	95	N/A
25	22	TEXAS INSTRUMENTS	89	92	3.4%
26	18	GENERAL ELECTRIC	112	81	-27.7%
27	27	SGS	60	79	31.7%
28	25	UNITRODE	81	77	-4.9%
29	29	SEMIKRON	48	72	50.0%
30	30	SILICONIX	47	57	21.3%
31	32	FAIRCHILD	41	46	12.2%
32	33	KEC	34	39	14.7%
33	36	BROWN-BOVERI	29	35	20.7%
34	34	HONEYWELL	31	35	12.9%
35	31	NATIONAL SEMICONDUCTOR	43	34	-20.9%
36	35	SOLITRON	30	30	0.0%
37	37	SPRAGUE	27	29	7.4%
38	42	OKI	18	25	38.9%
39	41	SAMSUNG	20	24	20.0%
40	38	ACRIAN	23	18	-21.7%
41	44	TAG	18	18	0.0%
42	40	FERRANTI	20	17	-15.0%
43	45	MEDL	15	17	13.3%
44	43	RAYTHEON	18	16	-11.1%
45	39	VARO	22	15	-31.8%
46	49	PLESSEY	10	14	40.0%
47	46	ASEA-HAFO	10	13	30.0%
48	48	PIHER	10	11	10.0%
49	47	INTERSIL	10	7	-30.0%
50	50	SUPERTEX	5	7	40.0%
		Top 50 total	5493	6873	25.1%

Source: Dataquest
January 1987

Table 7

PRELIMINARY 1986 WORLD DISCRETE MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	1	MOTOROLA	532	602	13.2%
2	3	TOSHIBA	368	549	49.2%
3	2	HITACHI	393	484	23.2%
4	4	NEC	351	439	25.1%
5	6	MATSUSHITA	227	293	29.1%
6	5	PHILIPS-SIGNETICS	235	288	22.6%
7	7	MITSUBISHI	177	254	43.5%
8	11	FUJI ELECTRIC	126	170	34.9%
9	13	ROHM	110	160	45.5%
10	10	INTERNATIONAL RECTIFIER	128	145	13.3%
11	9	ITT	130	144	10.8%
12	12	THOMSON	123	138	12.2%
13	8	SIEMENS	140	133	-5.0%
14	16	SANKEN	97	132	36.1%
15	14	SANYO	103	129	25.2%
16	15	GENERAL INSTRUMENT	100	115	15.0%
17	N/A	POWEREX	0	95	N/A
18	20	TELEFUNKEN ELECTRONIC	61	84	37.7%
19	19	RCA	76	83	9.2%
20	21	SGS	60	79	31.7%
21	18	UNITRODE	81	77	-4.9%
22	24	SEMIKRON	48	72	50.0%
23	31	TRW	36	70	94.4%
24	26	SONY	42	65	54.8%
25	22	TEXAS INSTRUMENTS	56	58	3.6%
26	25	SILICONIX	47	57	21.3%
27	17	GENERAL ELECTRIC	92	56	-39.1%
28	27	HEWLETT-PACKARD	40	51	27.5%
29	29	FUJITSU	37	48	29.7%
30	28	FAIRCHILD	39	45	15.4%
31	34	BROWN-BOVERI	29	35	20.7%
32	32	KEC	32	35	9.4%
33	30	NATIONAL SEMICONDUCTOR	37	34	-8.1%
34	33	SOLITRON	30	30	0.0%
35	35	SPRAGUE	27	29	7.4%
36	39	SAMSUNG	20	24	20.0%
37	36	ACRIAN	23	18	-21.7%
38	41	TAG	18	18	0.0%
39	38	FERRANTI	20	17	-15.0%
40	42	MEDL	15	17	13.3%
		Top 40 total	4306	5372	24.8%

Source: Dataquest

Table 8

PRELIMINARY 1986 WORLD OPTO MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	2	SHARP	128	197	53.9%
2	1	HEWLETT-PACKARD	166	166	0.0%
3	4	MATSUSHITA	84	133	58.3%
4	6	SONY	55	120	118.2%
5	3	TOSHIBA	96	107	11.5%
6	5	SIEMENS	75	80	6.7%
7	8	FUJITSU	43	64	48.8%
8	13	ROHM	34	56	64.7%
9	7	TRW	46	55	19.6%
10	10	TELEFUNKEN ELECTRONIC	41	53	29.3%
11	9	HITACHI	42	50	19.0%
12	12	SANYO	40	49	22.5%
13	16	NEC	30	45	50.0%
14	11	GENERAL INSTRUMENT	40	35	-12.5%
15	15	HONEYWELL	31	35	12.9%
16	14	TEXAS INSTRUMENTS	33	34	3.0%
17	17	PHILIPS-SIGNETICS	25	27	8.0%
18	18	GENERAL ELECTRIC	20	25	25.0%
19	20	OKI	14	19	35.7%
20	23	RCA	9	19	111.1%
21	19	MOTOROLA	17	18	5.9%
22	22	PLESSEY	10	14	40.0%
23	21	FUJI ELECTRIC	10	8	-20.0%
24	26	SANKEN	5	7	40.0%
25	25	ASEA-HAFO	5	6	20.0%
		Top 25 total	1099	1422	29.4%

Source: Dataquest
January 1987

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THE DATAQUEST SEMICONDUCTOR MEGATRENDS

SUMMARY

In his influential best-seller, Megatrends, analyst John Naisbitt outlined ten societal transformations taking place in the United States. Mr. Naisbitt characterized these megatrends as:

- The shift from an industrial to an information society
- The combining of high-technology with "high touch"
- The shift from a national to a world economy
- The shift in perspective from short-term to long-term
- The shift from centralization to decentralization
- The shift from institutional help to self-help
- The shift from representative to participatory democracy
- The shift from hierarchical structures to networking
- The shift in regional importance from north to south
- The shift from either/or options to multiple options

The Dataquest Semiconductor Industry Service has summarized the ten trends that we believe are currently transforming the semiconductor industry. These megatrends have been defined by key Dataquest analysts from not only the semiconductor service, but from many other Dataquest high-technology groups as well. Dataquest's "Semiconductor Megatrends" are characterized as:

- The system is the chip
- The dawn of application-specific logic products

- Universal CAD/technology-specific CAD
- Service: The next high-technology battleground
- Hardware design versus software design
- The "commodization" of the computer industry
- The protection of intellectual property
- The new Japanese strategy
- The shifting of the electronic center of gravity to the Pacific Basin
- The growing importance of strategic alliances

This newsletter briefly describes each of these megatrends and weighs their impact on the semiconductor industry. A thorough understanding of these trends and their implications for the industry is certainly in order at this time.

THE SYSTEM IS THE CHIP

As standard cell libraries grow to include powerful microprocessors, the translation of systems-level architectures into silicon will become increasingly practical. More and more, therefore, the system is the chip. An intriguing question then arises: Who dictates the system, the IC designer or the systems engineer? Computer-aided design (CAD) tools are just now becoming sophisticated enough for engineers to translate systems designs directly to silicon. This is fortunate for the industry, since IC designers are not normally trained at a systems level. Until more sophisticated silicon compilation tools are joined to expanded cell libraries, however, a significant opportunity exists for IC start-ups, not unlike the opportunity seized by value-added resellers (VARs) in the computer industry.

Consider the following analogy. As desktop computers proliferated, software firms initially concentrated on developing products for high-volume applications. This created a need for companies dedicated to servicing application niches not addressed by the makers of "horizontal" products (general data processing, word processing, etc.). By tailoring systems and software to meet more highly specialized applications, value-added resellers became a force in the computer industry. What VARs lost in economies of scale could be made up through greater applications knowledge and correspondingly higher profit margins, given an effective means of distribution. The situation in the IC industry follows a similar script--engineers with their feet in both the systems and IC design worlds have the opportunity to become "VADs" (value-added designers). As with VARs in the computer business, the major commodity for sale-by-chip companies following the VAD route is applications know-how, with manufacturing handled through associations with wafer foundries or through joint ventures and licensing agreements with existing IC manufacturers.

APPLICATION-SPECIFIC LOGIC PRODUCTS

In 1985, the semiconductor industry witnessed the introduction of core microprocessors and specialized compilable cells in both gate arrays and cell-based ICs. Dataquest believes that in the 1990s the widespread use of high-performance CAD systems will blur the distinction between full-custom solutions and standard logic products. As a result, a growing number of IC products that address specific applications will emerge, but, unlike typical application-specific integrated circuits (ASICs), the new products will be sold to more than one customer as catalog logic products. Dataquest has recently observed the growth of products that apply ASIC design technology to end-market applications, giving rise to what we term ASLPs (application-specific logic products).

The economic force behind ASLPs is that they solve a current design dilemma for companies that seek larger markets for their chips even though the application windows are narrowing. As suppliers attempt to differentiate their products, they continually search for unique niches where they can have a dominant position. Meanwhile, design costs escalate because of complexity and the decreasing number of units over which the design costs can be amortized. The advent of ASICs has led to a design technology aimed directly at solving this problem. The application of this technology to end-market segments rather than single customers will both feed and drive product growth in areas such as telecommunications, digital signal processing, graphics, and voice and pattern recognition. Semiconductor suppliers can best prepare for success in these markets by anticipating end-use applications and exploiting state-of-the-art IC-CAD tools. ASLPs offer great opportunities to those companies that best combine the skills of the traditional catalog product and ASIC design.

UNIVERSAL CAD/TECHNOLOGY-SPECIFIC CAD

The successful penetration of ASIC and ASLP products is directly linked to a revolution in the computer-aided design of integrated circuits (IC-CAD). "CAD for the masses" will require systems that are both universal in design capture and technology-specific/manufacturer-specific in their implementations. These CAD tools will have the following characteristics:

- Highly automated design steps linking design, testing, and manufacturing

- Utilization of expert systems that understand what it is they are designing and perform layouts that optimize designed performance

- High-level architectures capable of design-in and layout of components from a conceptual systems level

- Emphasis not only on the management of design data, but also on design creativity from a systems level

- Incorporation of multivendor cell families into universal design processes

In achieving these characteristics, CAD tools will successfully encompass a design process spectrum that may be diagrammed as:

architectural concept→logic component specification→simulation of logic design→layout→test

At present, existing CAD products address single components of this process--most notably schematic capture and simulation. No systems as yet integrate the entire design gamut, nor are they process-independent.

The semiconductor industry will see a profound transformation when CAD technology arrives at design capture systems that are capable of handling any cell library and are translatable into any specified process technology. An important step in this direction will be taken when the semiconductor industry fully endorses silicon compilation and is willing to release physical libraries and layout programs to IC-CAD vendors.

SERVICE: THE NEXT HIGH-TECHNOLOGY BATTLEGROUND

In the past, seizing the competitive high ground in the semiconductor industry was achieved largely through dominance in technology, price, and quality. The application-specific IC (ASIC) market, however, demands that companies structure themselves as providers of service as well. A number of forces pushing the industry toward a higher degree of service orientation, such as:

- The erosion of profit margins in the commodities arena

- The growing market for ASIC solutions

- Lower inventory levels typical of "just-in-time" manufacturing

While many semiconductor companies will remain in the MOS memory market in order to maintain a technological edge in IC manufacture, profit margins and return on investment in this sector will continue to face the specter of overcapacity as newly industrialized countries enter the competitive crush. As technology advances, the confluence of systems and chips will require companies to preserve profit margins by addressing the more lucrative custom and semicustom needs of their clients.

The ASIC market, which Dataquest predicts will account for 26 percent of worldwide IC shipments in four years' time, is a service business with an estimated annual sales potential of more than $11.6 billion in 1990. As such, it requires an operating style that differs significantly from that of the standard products business. At the design level, ASIC suppliers will have to structure their customer interface to minimize engineering efforts on both sides of the customer/vendor relationship. Accomplishing this will require large investments in IC-CAD, allowing engineers to implement systems-level architectures directly into silicon.

At the marketing level, ASIC suppliers will need to work closely with customers to identify applications for high-integration ASIC devices. This will require personnel who are knowledgeable in applying systems solutions to specific end-use markets. The necessity for customers to entrust their suppliers with more highly proprietary information will forge significantly closer relationships than typically exist between customers and vendors in a price-driven marketplace.

Greater automation will be crucial to customer service regardless of whether a supplier's orientation is commodities or custom. ASIC manufacturers will demand higher yield predictability in order to reduce testing bottlenecks and improve cost effectiveness. Effective telecommunications links between design centers and foundries and computer control of wafer processes will be necessary as well. Commodities suppliers will rely on automation not only to service clients on the basis of pricing and quality, but in response to the changing manufacturing environment brought on by just-in-time delivery.

HARDWARE DESIGN VERSUS SOFTWARE DESIGN

In years past, the massive data processing tasks typical of computers in the corporate MIS environment justified the building of general-purpose, sequential-processing computing engines. Computer manufacturers or value-added resellers could then adapt these engines to specific applications through software development. This often resulted in software budgets that equaled the development costs of the hardware itself.

More recently, computer processing needs have changed dramatically. This change was brought about primarily by the explosive growth in technical computing systems, which in 1985 represented 38 percent of the total computer market. The fastest growing segment of the technical computing business has been technical workstations. Between 1981 and 1985, technical workstations proliferated at an astounding 226 percent compound annual growth rate (CAGR). Nor is this phenomenon short-lived: Dataquest forecasts continued growth in the technical workstation market at a 32 percent CAGR between 1986 and 1990. With its emphasis on graphics and simulations, the technical workstation is creating a greater demand for parallel processing. This growth in parallel processing applications will in turn result in more hardware-intensive computer design--for the simple reason that stored programs do not work as well in a parallel processing world as they do in a sequential one.

For technical computer designers, meeting the needs of specialized applications in parallel processing more often means finding solutions in hardware rather than software. Not only is the hardware approach more cost-effective in terms of development time, but it yields greater gains in performance as well. Certain technical applications that could take a Cray supercomputer up to two hours to perform (such as three-dimensional image processing) can be handled by a pair of specialized ICs in two minutes. In comparing the price of a Cray with that of a desktop workstation, the difference in price/performance can be measured in orders of magnitude. The significance of this trend to the semiconductor industry is quickly appreciated: the fastest-growing segment of the computer industry, which as a whole remains the largest end user of semiconductors, will be defining systems increasingly in transistors rather than lines of code.

Advances in "systems on a chip" will be both a driver and beneficiary of the trend toward application-oriented technical workstations. ASIC manufacturers will not be the only ones to benefit from the boom in technical computers. In 1986, memory devices made up 40 percent of the ICs consumed by technical computers, while microdevices accounted for 23 percent. Dataquest believes that the next wave in technical systems will be minisupercomputers, a market that will approach $2 billion in 1990. Following the current input/output ratios for semiconductor consumption by this market segment, growth in sales of minisupercomputers will result in the consumption of $180 million worth of ICs.

"COMMODIZATION" OF THE COMPUTER INDUSTRY

Much to its chagrin, IBM helped make the personal computer a commodity item through its open architecture design approach to the PC. Foreign and domestic clone manufacturers quickly discovered that duplicating IBM's PC success was no more mysterious than duplicating the machine itself. IBM's loss has, as a result of the clone wars, been the consumer's gain. Lower prices, the banner under which most clones do battle, have proliferated the spread of personal computers beyond even IBM's considerable marketing clout, while add-on memory products give each PC owner the potential for incredible desktop computing power. This proliferation comes at a time when the profile of the average computer user has metamorphosed from hobbyist, to early innovator, to everybody.

The confluence of systems and chips and the commodization of the personal computer are highly complementary trends. To maintain price competitiveness, computer manufacturers must reduce costs through the use of more highly integrated ICs. To increase performance and maintain product differentiation, manufacturers must also implement proprietary features through the use of custom chips. These trends bode well for the semiconductor industry as a whole, but there are some impediments to a rate of growth at anywhere near that of the past. One major obstacle is the absorption in the marketplace of the kind of memory and performance of which microcomputers are capable. Overcapacity in semiconductor MOS memories finds its equivalent at the systems level in a glut of memory bits that far exceed functional demand.

Some manufacturers believe that market growth for 32-bit MPUs will be spurred as these devices replace minicomputers and that future MPUs will have microcoded instruction sets that can emulate minicomputer instruction sets--systems on a chip. These devices will profoundly affect the industry by destroying the distinction between computer companies, thus raising the level of competition. While soaking up a glut of memory bits can be easily accomplished by more powerful machines, what the industry now requires is the software to justify purchasing the new products. Next-generation MPUs, such as Intel's 80386, will involve a major software development effort to take advantage of the new microprocessing technology.

PROTECTION OF INTELLECTUAL PROPERTY

On July 31, 1978, the National Commission on New Technological Uses of Copyrighted Works recommended that the Copyright Act be amended to "make it explicit that computer programs, to the extent that they embody an author's original creation, are proper subject matter of copyright." The Commission's report was relied upon by Congress in enacting the 1980 software amendment to the United States Copyright Act. Critics of the Commission's recommendation included the Commissioner himself, John Hersey, who argued that the inclusion of software "would mark the first time copyright had ever covered a means of communication, not with the human mind and senses, but with machines."

Mr. Hersey's misgivings underscore a problem that high-technology firms and our legal system must resolve. As we move from an industrial to an information society, the distinction between information and function becomes blurred, challenging the current dualisms of patent and copyright. While copyright law encourages abundant expression, patent law encourages substantial technological improvement.

As the recent copyright infringement lawsuit between NEC and Intel has demonstrated, this distinction begins to break down when an expression such as "microcode" can be argued to be functionally constrained. Here the industry faces a double-edged sword. On one hand, judges do not give functional works as broad a range of protection as expressive works. Thus, in weighing whether or not a copyright has been infringed upon, the courts tend to limit the criteria for infringement to literal or close to literal copies of the copyrighted work. This may leave the intellectual property investments of companies open to greater vulnerability. On the other hand, the danger of applying copyright to functional expressions is that in protecting against too wide a range of equivalents, copyright may monopolize all expression of the underlying function itself.

The application of copyright to intellectual property will face a challenge in areas where product differentiation is achieved through nonhardware customization. This would certainly include products such as gate arrays, PLDs, and ROMs. We expect to see infringement cases over device similarities begin to involve the users, suppliers, and licensors of cell libraries. As intellectual property increasingly accounts for the uniqueness of a device, litigation over such property will become more commonplace.

THE NEW JAPANESE STRATEGY

Surprising as it may seem, in 14 of the 20 years beginning in 1955, the value of Japan's imports exceeded that of its exports. Through the touchstone of high-quality, low-cost manufacturing, Japan has displayed a genius for leveraging borrowed innovation into successful consumer products. In 1985, this genius resulted in exports accounting for an impressive 3.5 percent of Japan's GNP. Japan's highly successful manufacturing strategy is epitomized by the rapidity with which it dominated the world market for MOS memories. Dataquest, however, sees a fundamental shift in Japan's strategy toward greater technological innovation and less reliance on the export-driven manufacture of lower-end commodities. A number of forces are compelling the Japanese to change direction, including:

- Competitive pressure from newly developed Pacific Basin countries in the commodity bastions of steel, automobiles, and low-end electronics
- The appreciation of the yen versus the dollar
- The Japanese government's move toward becoming less dependent on exports as an economic mainstay
- Technological parity with the West in a growing number of fields

Just as the semiconductor industry in Japan has always reflected the nation's export aggressiveness, it is now also reflecting the shift in strategy. Japanese semiconductor manufacturers now, in effect, own the markets in which they participate. Therefore, they no longer have to scramble to build market share through adding capacity. This is borne out by changes in the capital spending outlook for Japanese semiconductor firms. Measured in yen, 1986 Japanese capital spending is expected to decline approximately 30 percent from 1985. This steep decline represents the beginning of a fundamental restructuring of the Japanese semiconductor industry as it turns away from increasing manufacturing capacity and toward productivity-enhancing equipment and leading-edge technologies.

Between 1984 and 1988, Japanese electronics manufacturers will have opened at least 80 basic research laboratories. These R&D centers will oversee 25 IC-related projects in such leading-edge technologies as 4Mb and 16Mb DRAMs, 32-bit microprocessors, standard cells, three-dimensional CAD systems, VLSI design expert systems, automotive electronics, telecom ICs, optoelectronics, gallium arsenide, bioelectronics, voice recognition/synthesis, ceramic packaging, diamond substrates, and new materials. Assuming an average investment of $25 million to $33 million each, these laboratories collectively represent an estimated total investment of approximately $2.0 billion.

In addition to corporate R&D projects, Japan's Ministry of International Trade and Industry (MITI) has been working on its "Technopolis Project" since 1980. Combining urban and economic planning with Japan's desire for technological leadership, the technopolis strategy involves no less than the creation of Silicon Valley-like communities in more than 25 different locations in Japan--at a cost of between $1 billion and $2 billion each over the next two decades. These highly planned communities will combine academic centers, foreign and domestic corporations, public transportation systems, venture capital concerns--in short, all the necessary infrastructure for high-technology entrepreneurial activity.

Ironically, the short-term discomfiture that many of Japan's leading semiconductor exporters are now feeling as a result of the higher yen and the recent U.S./Japan trade agreement may well yield a long-term benefit. While the resulting price increases have a negative effect on the competitiveness of Japanese MOS memory devices, their positive effect on the corporate bottom line will likely help fund a transition to more value-added products. In part as a response to the MOS memory dumping suits and in part due to shifting strategies, the Japanese are already becoming more aggressive in the gate array market. Along with other Asian suppliers, some Japanese companies may be giving away nonrecurring engineering (NRE) costs to win designs. The impact is being felt: last year, CMOS gate arrays fabricated with 3-micron, double metal sold for approximately $0.01 per gate. Today's pricing is now down to $0.003 per gate.

ELECTRONIC CENTER OF GRAVITY SHIFTING TO THE PACIFIC

Winds of change from both the East and the West are propelling exports from the Pacific Basin's newly industrialized "Five Tigers": South Korea, Taiwan, Hong Kong, Malaysia, and Singapore. To begin with, a higher yen combined with the effects of the semiconductor trade agreement's Fair Market Values (FMVs) on MOS memory prices are forcing the Japanese to locate manufacturing in other Asian countries. Furthermore, since the currencies of the Pacific Basin countries are more or less pegged to the U.S. dollar, their goods and services become increasingly attractive as Japan's become more expensive. U.S. companies, which have already turned to Asia for low-cost manufacturing, have further incentive to invest brick and mortar in the region as a result of the new tax bill, which repeals investment tax credits for capital spending.

Dataquest estimates that because of increased off-shore manufacturing, $700 million in semiconductor devices that otherwise would have been consumed in Japan and the United States were instead consumed by the Five Tigers during the first half of 1986. This is further supported by the figures for rest-of-world (ROW) semiconductor consumption, which appear in the most recent Dataquest Quarterly Industry Forecast. While North American consumption of semiconductors for 1986 will increase less than 10 percent over 1985, ROW consumption will increase more than 50 percent, with a 60 percent increase in integrated circuits. The Pacific Basin markets have also grown stronger due to increased domestic demand for television sets, VCRs, and telecommunications products.

The U.S. trade deficit with Taiwan reached a record $13.1 billion in 1985, but this figure is somewhat misleading. The Five Tigers have become a manufacturing hinterland for both Japan and the United States. The economies of countries like Taiwan and Malaysia rest on the existence of large multinational corporations and thousands of cottage industries. Malaysia's leadership in chip assembly, for example, is due to the establishment of plants by Motorola, National Semiconductor, Texas Instruments, and Hewlett-Packard. As a result, exports from the Five Tigers are pulled from the United States and Japan more than they are pushed by the Pacific Basin countries themselves.

As Japan pursues its Technopolis strategy, it will increasingly relinquish low-end portions of its cherished commodity markets to the Five Tigers. Taiwan and South Korea have already emerged as leading personal computer producers, pulling off a feat that has as yet eluded their Japanese neighbors. Taiwan will export $730 million in kits and finished PC clones by year end, with 70 percent of these going to the United States. South Korea's Daewoo Telecom set the pace for Asian clone manufacturers with the successful Leading Edge Model D and expects sales of $400 million this year. While continuing in their roles as manufacturing hinterlands, we can expect to see the Pacific Basin countries follow the same value-added migration that the Japanese so successfully embarked on previously. The industrial and social changes that accompany this transformation may then draw new regions into the low end of high technology--countries such as India and China.

STRATEGIC ALLIANCES

High-technology firms have long found compelling reasons to form strategic alliances among themselves. As technologies advance, new commercial applications for technology abound. No one company, even in a well-defined area of expertise, can call all the new trends or exploit all the new product possibilities with equal proficiency. In a recent study of licensing agreements and joint ventures, Dataquest has observed the following trends:

- Alliances are increasing in number.
- Alliances are increasing in complexity.
- In alliances between U.S. and foreign firms that involve a transfer of technology, the technology is usually supplied by the U.S. company.
- An increasing number of alliances involve the sharing of fab capacity.

Dataquest has observed that from 1982 to the present, more than 60 licensing agreements and joint ventures have taken place in the United States in the MOS memory area alone--over 40 of which have occurred in the last 18 months. Many of these agreements have involved start-up companies unable to attract additional rounds of funding from venture capital sources.

Overall, the Japanese and Korean firms have weathered the current semiconductor slump better than their U.S. competitors. In Japan's case, this can be attributed to the association of semiconductor manufacturers with large, vertically integrated parent companies. In the case of Korea, government subsidies of exports have been a contributing factor. These advantages have given Asian electronics firms the cash to invest in new technologies. The prime targets of such investment have very often been cash-hungry U.S. start-up companies.

With technology as a bargaining chip, U.S. companies are trading innovation for capital, manufacturing capability, and market access. This trend has shown up most strongly in the area of MOS memories, where more than 80 percent of agreements have involved technology transfers by U.S. firms in return for cash or fab capacity. At the same time this trend in license agreements is occurring, U.S. companies are slowing their rate of R&D investment in response to the fiscal realities of the current industry slowdown. Unless the trend in R&D spending changes, U.S. firms may find themselves at the bargaining table with little to bid.

To avoid trading away tomorrow's competitive advantage for today's capital requirements, American firms must look to one another for the kinds of strategic alliances that provide the most effective sharing of resources. Given today's situation of overcapacity, there exists a logical opportunity for the pairing of companies possessing innovative design and technology with firms possessing the manufacturing capacity and marketing resources to carry them forward.

It is very likely that the industry will see increasing joint ventures and acquisitions among the larger merchant semiconductor firms in an attempt to consolidate market share in the face of low-cost suppliers from the Pacific Basin on the one hand, and to protect themselves from the deep-pocket clout of the NECs and AT&Ts of the world on the other. The imposition of price structures and the monitoring of Japanese manufacturers to prevent the precipitous erosion of IC prices may buy the critical time U.S. chip manufacturers need to make these kinds of accommodations.

DATAQUEST CONCLUSIONS

In reviewing the semiconductor megatrends under discussion, it becomes apparent that none are isolated phenomena. In actuality, each hints at the inevitability of another. Commodization of the computer is most certainly influenced by the ability to place a system on a chip. Advances in CAD technology are a critical factor in the advance of ASICs--the production of which will transform the industry into a more service-oriented business. The concentration on value-added products is further propelled by the shift in low-end manufacturing to the Pacific Basin, which in turn will drive the Japanese into competition with the United States in the value-added market and increase the concern of all players over the protection of valuable intellectual property.

The implications of all this are that the semiconductor industry is not only going through a recession, but through a restructuring as well. The nature of this restructuring very closely follows a megatrend pointed to by Mr. Naisbitt: the movement from centralization toward decentralization. To successfully compete in the ASIC world, the corporate structure of semiconductor firms increasingly will focus on the identification of application niches, particularly in transferring systems solutions to silicon. In so doing, these firms will stress customer support over internal fabrication capabilities. This will create a clear delineation between those firms that manufacture and those that supply. Future strategic alliance will recognize this distinction, bringing together the suppliers of applications know-how with the manufacturers and marketers of application-specific products. Such alliances will make possible the profitable servicing of market niches that the large, multinational semiconductor firms will not find economical to address.

Unquestionably, recognizing the directions and implications of change is important. Of greater ultimate importance, however, is how individuals and businesses structure themselves in response. In his book, Mr. Naisbitt challenges managers to continually ask the simple yet powerful question, "What business am I in?" Answering this question without assessing the forces that shape one's business does not augur well for a bright future. During the year to come, Dataquest will continue to focus on the semiconductor megatrends summarized in this newsletter. In so doing, we hope to both challenge our clients' assessments of their businesses, and to provide information and analysis in support of this process.

Michael Boss

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A Worldwide Semiconductor News and Pricing Service

April 3, 1987

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Major Industry Happenings

IBM ANNOUNCES NEW PCs

IBM yesterday made its long-anticipated announcement of new personal computer products. With the unveiling of its Personal System/2 family, IBM now offers eight new PC models, ranging from two 8086-microprocessor-based systems to floor-model 80386-based machines. Of particular importance to the semiconductor industry, is the fact that IBM components make up approximately 80 percent of the content of the Personal System/2 products--IBM 1Mb DRAMs, IBM ASICs, IBM 3.5-inch floppies and drive controllers, a new proprietary bus, and new a graphics-driven operating system (not yet available). Japanese memory suppliers will now lose a major buyer of 256K DRAMs, but they will eventually gain a high-volume customer for 1Mb memories once they have been qualified by IBM. The use of ASICs in the new IBM machines will make life much harder on the clone manufacturers but will certainly open up some interesting opportunities for a company such as Chips & Technologies. Having selectively sourced its 80286 and remaining the sole source for 80386 MPUs, Intel has much to gain from IBM's success with the Personal System/2 family. (For further details, see the on-line newsletter entitled, "IBM Raises the Bar--Dataquest Assesses the Impact.")

TI AND LINEAR TECHNOLOGY FORM ALLIANCE

Linear Technology Corp., a Milpitas, California-based semiconductor maker, recently announced a five-year alliance with Texas Instruments (TI) for production of linear ICs. Part of the agreement calls for TI to invest $1 million for warrants to purchase 735,000 shares of Linear stock--TI's first equity investment in another semiconductor maker. Dataquest views this alliance as a reflection of a restructuring that has been going on in the U.S. linear IC segment since 1985--a shift from low-cost commodity devices to ICs with higher performance and higher average selling price (ASP). Among the top three U.S. producers of linear ICs, National Semiconductor was the first to make this shift. TI has now responded with its Linear Technology alliance. It now remains to be seen how Motorola will respond. Motorola is positioned to enjoy greater market share in the commodities end of linear ICs, with Korea-based Samsung in the wings as a potential world-class competitor (see DQ Monday Report, 2/9/87).

CALIFORNIA DEVICES FORMS ASIC ALLIANCE WITH SGS SUBSIDIARY

California Devices, Inc. (CDI), a Milpitas, California supplier of CMOS technology application-specific integrated circuits (ASICs), has just announced a second-source and joint product development agreement with Innovative Silicon Technology (IST), a recently established ASIC subsidiary of the Italian semiconductor giant, SGS. The agreement gives IST the second-source license for two families of CDI's Channelless ASIC architecture products. Both product families are based on double-metal-layer CMOS technology, with gate complexities ranging from 24,000 gates (2-micron), to 100,000 gates (1.5-micron). For its part, CDI gains access to the silicon foundry facilities of SGS.

CMD ENTERS GaAs ASIC ALLIANCE WITH MILITARY SYSTEMS MANUFACTURER

California Micro Devices (CMD) of Milpitas, California and Tachonics Corp., a Grumman Corporation company, have entered into an agreement to produce gallium arsenide (GaAs) application-specific ICs (ASICs). CMD will provide cell design and tools for designing large ASIC gate arrays, while Tachonics will supply the GaAs processing and manufacturing expertise. The companies have announced gate array design starts in April 1987, with prototypes expected for sampling in the fall. The initial ASIC products will feature gate arrays with 500- to 2,500-gate complexities with radiation hardening capability.

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MMI'S SECOND QUARTER SALES UP 23 PERCENT

Monolithic Memories Inc. (MMI) reported sales of $52,608,000 for the second fiscal quarter of 1987, ending March 15. MMI's revenue improved 23 percent over the $42,653,000 in sales that the company garnered for the corresponding quarter of fiscal 1986. Second-quarter sales also exceeded the first-quarter level by 11 percent. MMI reported net income of $6,203,000 for the second quarter of 1987, compared to $1,030,000 in the second fiscal quarter of 1986. Current earnings, however, were bolstered by a nonrecurring gain of $6,789,000 from the sale of approximately 1 million shares of Cypress Semiconductor stock. According to MMI president Irwin Federman, the company's book-to-bill ratio has exceeded parity for the past two months.

TI TO EARN WINDFALL ROYALTIES FROM INFRINGEMENT SUITS

Having settled with all but three of the Asia-based companies named in its lawsuits regarding DRAM-patent infringement, Texas Instruments (TI) reports that it will earn $270 million in settlement royalties from six Japanese semiconductor makers. The licenses under which these royalties will be earned will expire in 1990, at which time new license agreements must be worked out. Of the original nine companies named in the lawsuits, NEC, Hitachi, and Samsung have yet to settle with TI.

NATIONAL INTRODUCES NEW MEMBER OF 32-BIT MPU FAMILY

National Semiconductor has unveiled the seventh CPU design in its Series 32000 family, the NS32532. Targeted at general-purpose, high-performance, and controller applications, the NS32532 is compatible with other devices in the Series 32000 product line. The new 32-bit microprocessor is based on 1.5-micron, double-metal-layer CMOS technology, scalable to 1.25 microns. The 1.5-micron process device operates at a 20-MHz clock rate, with the 1.25-micron version rated at 30 MHz. Samples of the 1.5-micron MPU will be available in the fourth quarter of 1987. Features include on-chip instruction and data cache, a memory management unit, and multiprocessor support in the form of hardware and software cache invalidation. The NS32532 contains 370,000 transistors in a 175-pin grid array (PGA) package. National supports the new family member with a variety of 32-bit peripheral devices.

CYPRESS SEMICONDUCTOR PLANS SECOND PUBLIC OFFERING

Following last year's highly successful initial public offering, Cypress Semiconductor Corp. has filed with the SEC for a public offering of 4,400,000 shares of common stock--3,080,000 by the company and 1,320,000 by certain selling shareholders. The net proceeds from the offering will be used for working capital and to increase the company's capital base.

VARIAN SELLS $1.75 MILLION ION IMPLANTER

A major European semiconductor manufacturer has ordered the first $1.75 million 500 XP high-energy ion implanter from the Extrion Division of Varian Associates, Inc. The 500 XP system can be used both in standard implantation and in advanced applications such as buried-layer and postprocessing implants needed in the manufacturing of newer VLSI devices.

MITI EXPORT CONTROLS CAUSE EUROPEAN SHORTAGES

In an effort to salvage the semiconductor trade agreement with the United States, Japan's Ministry of International Trade and Industry (MITI) has demanded that all Japanese chip makers obtain export licenses for non-U.S. exports over the value of $375. The resulting backlog of export license applications, according to Dataquest's London office, is causing component shortages for European electronic equipment manufacturers.

U.K.'S PLESSEY CONTEMPLATES JOINT VENTURES WITH SOVIET UNION

Plessey, a British manufacturer of electronic components, telecommunications, and electronic defense systems, has been holding talks in the Soviet Union aimed at joint ventures to manufacture telecom equipment. These talks have been made possible by new regulations introduced by Soviet Premier Mikhail Gorbachev, and they form part of a larger collaborative program worth more than $1.5 billion to the United Kingdom. Because of current export controls, it is probable that the only imminent order from the Soviets will be for pay telephones.

TAIWAN CONGLOMERATE TO INVEST IN BIPOLAR FAB

The Kuo Hwa conglomerate of Taiwan, best known for its life insurance business, has decided to invest more than US$29 million to establish a bipolar IC manufacturing plant and design center in the Hsin-Chu Science-Based Industrial Park. Monthly production of 10,000 5-inch wafers in expected in 1988.

IBM TO MAKE PUSH INTO CHINA

IBM is gearing up for a big drive into China. It has signed on four companies as authorized dealers for sales of System/36 machines on the mainland. In the meantime, a national information-processing system operating in the Chinese language has been established in China and has become the largest computer network in the country. The computer network, composed of 28 centers linking 12 provinces, was set up by the Ministry of Space Industry using a Burroughs computer system imported from the United States.

NBK INVESTS $8.3 MILLION IN U.S. WAFER FAB

NBK Corp., a subsidiary of Kawasaki Steel, has invested $8.3 million to expand production capabilities for its 6-inch wafer manufacturing operations in Santa Clara, California. Full production is expected by May. The investment allowed purchase of new equipment and installation of a Class 10 clean room. NBK plans to double the production achieved at its 1984 peak.

DQ MONDAY REPORT
VOLUME--MEAN 1K

Device Family	U.S.	Japan	Europe	Taiwan
74HC00	0.19	0.15	0.19	0.13
74HC244	0.53	0.68	0.37	0.41
74HC245	0.55	0.75	0.42	0.42
74HC368	0.41	0.34	0.33	0.34
74HC74	0.24	0.22	0.19	0.19
74HC86	0.24	0.20	0.20	0.19
339 COM	0.17	0.54	0.36	0.21
741 OP AMP	0.16	0.41	0.34	0.21
7805	0.16	0.34	0.34	0.23
74LS00	0.14	0.15	0.14	0.11
74LS244	0.32	0.44	0.31	0.37
74LS245	0.25	0.51	0.37	0.37
74LS368	0.24	0.25	0.31	0.31
74LS74	0.18	0.20	0.18	0.12
74LS86	0.22	0.19	0.18	0.12
DRAM 64K	1.00	0.92	1.13	0.69
DRAM 256K	2.50	2.04	2.44	2.12
EPROM 128K	5.00	2.52	2.70	2.86
EPROM 256K	8.50	3.45	3.80	-
SRAM 64K	2.40	2.24	3.22	-
68000 8MHz	11.00	12.24	9.56	8.48
80286 8MHz	85.00	53.06	100.00	38.47
8051	6.10	5.78	7.21	-
8086 8MHz	12.00	7.48	9.34	9.26
Z8400	1.10	1.09	1.30	1.24
Lead Time (Weeks):	4	2	4	6

Source: Dataquest
April 1987

DQ MONDAY REPORT
VOLUME--MEAN 10K

Device Family	U.S.	Japan	Europe	Taiwan
74HC00	0.17	0.12	0.16	0.13
74HC244	0.50	0.56	0.32	0.41
74HC245	0.51	0.61	0.38	0.41
74HC368	0.39	0.22	0.25	0.33
74HC74	0.20	0.18	0.16	0.18
74HC86	0.23	0.18	0.17	0.18
339 COM	0.15	0.31	0.26	0.20
741 OP AMP	0.15	0.25	0.27	0.20
7805	0.15	0.25	0.20	-
74LS00	0.12	0.12	0.10	0.11
74LS244	0.27	0.37	0.28	0.37
74LS245	0.30	0.41	0.32	0.37
74LS368	0.21	0.22	0.21	0.32
74LS74	0.16	0.14	0.14	0.12
74LS86	0.18	0.20	0.14	0.12
DRAM 64K	0.90	0.82	1.04	0.69
DRAM 256K	2.40	1.90	2.00	2.12
EPROM 128K	4.00	2.52	2.40	2.86
EPROM 256K	6.00	2.99	3.24	3.80
SRAM 64K	2.25	1.90	3.22	-
68000 8MHz	8.75	6.46	8.90	8.48
80286 8MHz	50.00	50.34	60.00	38.47
8051	4.60	3.27	4.80	-
8086 8MHz	9.00	4.90	8.75	9.26
Z8400	0.95	0.92	1.00	1.24
Lead Time (Weeks):	4	2	4	6

Source: Dataquest
April 1987

DQ MONDAY REPORT
VOLUME PRICE

Device Family	U.S.	Japan	Europe	Taiwan
74HC00	0.15	0.12	0.11	0.13
74HC244	0.35	0.54	0.29	0.35
74HC245	0.35	0.59	0.34	0.35
74HC368	0.34	0.27	0.21	0.28
74HC74	0.20	0.17	0.14	0.19
74HC86	0.21	0.17	0.14	0.19
339 COM	0.15	0.22	0.17	-
741 OP AMP	0.16	0.24	0.17	-
7805	0.16	0.24	0.17	-
74LS00	0.12	0.11	0.10	0.10
74LS244	0.27	0.38	0.27	0.32
74LS245	0.30	0.37	0.30	0.32
74LS368	0.21	0.21	0.19	0.25
74LS74	0.16	0.13	0.11	0.12
74LS86	0.17	0.18	0.11	0.12
DRAM 64K	0.85	0.75	0.90	0.90
DRAM 256K	2.15	1.87	1.90	2.30
EPROM 128K	2.90	2.52	2.55	2.50
EPROM 256K	3.90	3.75	3.50	-
SRAM 64K	2.00	1.84	2.80	-
68000 8MHz	4.80	6.46	7.80	6.70
80286 8MHz	40.00	47.62	45.00	35.00
8051	3.25	2.93	3.20	2.90
8086 8MHz	6.75	4.08	7.50	8.30
Z8400	0.89	0.92	0.90	0.85
Lead Time (Weeks):	4	2	4	6

Source: Dataquest
April 1987

UNITED STATES PRICING ANALYSIS

LOGIC: Prices continue to stabilize. Lead times for LS products range between 8 and 12 weeks, with SMT taking an additional 4 to 5 weeks. HC is stable with lead times unchanged--still 9 to 16 weeks. Little foreign competition is seen.

MPUs: Prices for MPUs have remained relatively stable. New IBM PC models may stretch lead times, depending on market acceptance. Products that could be affected are the 8086 and 80286.

MEMORY: DRAM prices are rising in response to cutbacks in Japan. Lead times are stretching out to 12 weeks for sub-100ns parts. Low-volume EPROM prices have risen as the result of a supply shortage, and volume prices are currently stable. Lead times are stretching out to 8 to 10 weeks. Statics remain unchanged.

EUROPE PRICING ANALYSIS

LOGIC: Unit demand has increased over the past two months. Manufacturers report backlogs starting to build up, not just in short-term orders but also in the 12 to 26 medium term.

Prices are stabilizing and have not shown any indication of moving upward.

Distribution inventories are declining. In contrast to 1986, the majority of the increase noted above is being generated by OEMs. Distributors are taking pains not to overcommit themselves.

The overall increase in demand is helping to stabilize the erosion in price per gate experienced by gate array manufacturers.

MPUs: Pricing is stabilized for MPUs, except for new introductions.

Intel has recently announced that lead times for its 8086/286/386 are extending due to an upturn in demand for these microprocessors.

MEMORY: In an effort to strengthen control over European memory prices, MITI is now monitoring European retail prices of commodity memory products that form part of the U.S.-Japan trade agreement. Managing directors of Japanese companies operating in Europe have been asked to relate information directly to MITI regarding any breaches of the price agreement.

Japanese semiconductor manufacturers in Europe are offering a 20 percent discount on orders placed now for delivery in the fourth quarter.

JAPAN PRICING ANALYSIS

LOGIC: Some devices are running short and have longer lead times to distributors--as much as two to three months because of decreased production.

MPUs: Low-price CPUs such as 8088, 6802, and Z80 need to set up a lead time gradually.

MEMORY: Memory prices are being forced to obey MITI's guidelines. Some surface-mount devices are in allocation.

The picture of DRAMs and EPROMs has changed. Major domestic makers requested an increase in prices to users, saying that they will cancel shipments if users do not accept their request.

TAIWAN PRICING ANALYSIS

LOGIC: The surplus stock in TTLs from Hong Kong has diminished, putting prices almost back at the normal level. This supply appears to have been used up faster than expected. The HC series demand remains low; therefore, prices are stable.

MPUs: Prices for these devices have increased slightly in response to the exchange rate increase; however, the demand is still low and prices other than exchange are stable. The 80286 8-MHz price is rising as a result of the 10-MHz shortage and increased use of the 8-MHz device for computer consumption.

MEMORY: The 64K DRAM is the only device not affected by the current U.S. pressure on Japanese manufacturers because prices and delivery are all allocated. In 256K devices, we have broken out the 120ns and 150ns categories separately to reflect the real price changes. The price rise in the 256K area is due to three factors--a quick growth in demand, a reduction in Japanese production of up to 32 percent, and the resulting shortages produced in the local market. The 128K EPROM prices are up along with the OTP EPROMs and SRAMs because of U.S. manufacturers raising their prices as an example for the Japanese to follow. The real winner from this will probably be Samsung (Korea) in the local market.