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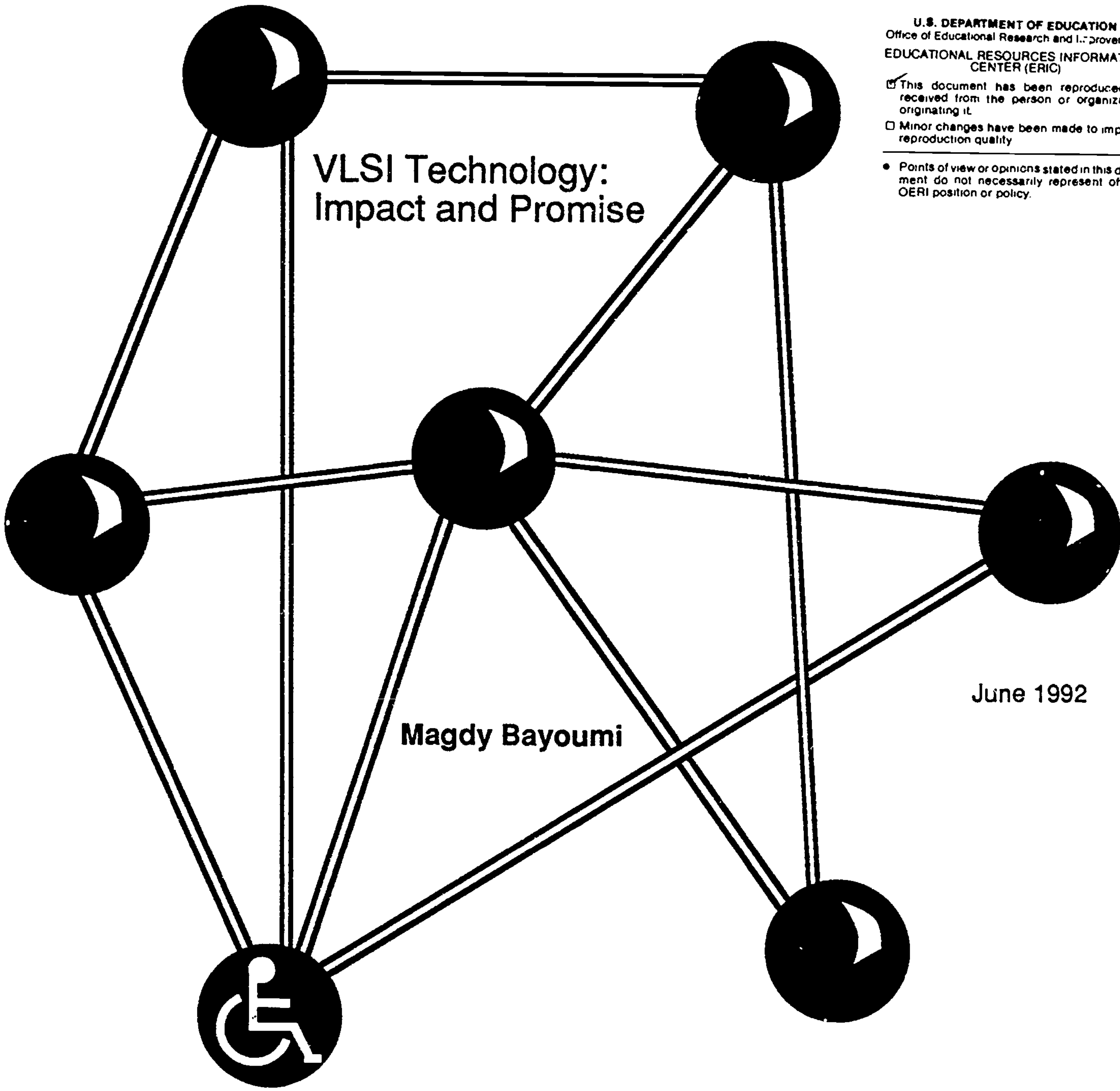
ABSTRACT

As part of a 3-year study to identify emerging issues and trends in technology for special education, this paper addresses the implications of very large scale integrated (VLSI) technology. The first section reviews the development of educational technology, particularly microelectronics technology, from the 1950s to the present. The implications of very high computational power available at low cost are then examined for the fields of education, medicine, assistive devices for individuals with disabilities, home electronics, business, management information systems, music, defense applications, space programs, industrial applications, and super computing. The second section then briefly considers future applications of new technologies including gallium arsenide technology, fuzzy logic, and neural networks. A high level of technological integration is predicted for the 21st century based on the immense power of VLSI-based automation. An appendix outlines, through text and figures, the fundamentals of VLSI. (Contains 25 references and 5 figures.) (DB)

Identifying Emerging Issues and Trends in Technology for Special Education



VLSI Technology: Impact and Promise

June 1992

Magdy Bayoumi

Prepared by COSMOS Corporation for:
U.S. Department of Education
Office of Special Education Programs
under Contract No. HS90008001

PREFACE

COSMOS Corporation is conducting a study of the issues and trends affecting the role technology will have in the 21st century for individuals with disabilities. This three-year study is funded by the U.S. Department of Education, Office of Special Education Programs (OSEP), under Contract No. HS90008001.

COSMOS Corporation was founded in 1980, and is located in Washington, D.C. Since its inception, the firm has conducted a wide range of applied social science projects for public and private organizations and foundations. COSMOS's specialties include: conduct of case studies; identification and validation of exemplary practices; evaluation of education, job training, and human services programs; provision of technical assistance to state and community agencies; and strategic planning for public agencies and public firms.

Project participants include expert panels, project fellows, an advisory board, a consortia of practitioners, and project staff. These experts in the fields of technology and special education have come together to examine the issues and trends in these two fields, and how they impact the use of technology for special education in the 21st century. Three expert panels have started examining these issues: one with a focus on technology outside the field of education, one on special education instruction, and one on evolving service delivery systems in special education. Over the three year period their research will be synthesized and become the basis for predictions about the future.

This document is one of the papers commissioned in the first year. The purpose of the paper is to present information on one or more issues as part of the expert panel discussions. It is being shared with people inside and outside of the project to stimulate discussion on the impact of technology in the early 21st century. Readers are welcome to comment on these findings and contact COSMOS Corporation for further information.

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I. VLSI TECHNOLOGY: IMPACT AND PROMISE

Technology in Special Education

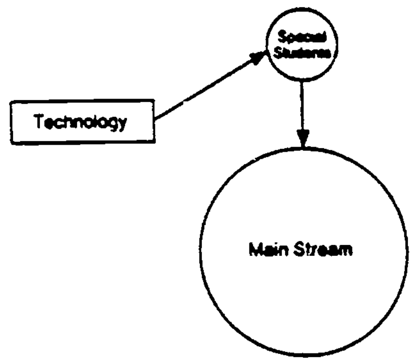
The role of technology in special education changes based on the definitions, concepts, strategies, and policies of the society towards special students. In the year 2010, the technology model will be based on the integration strategy which is gaining increasing support and recognition among educators, social workers, governments, and schools, Figure 1. This model has a stronger impact at the cognitive level. Effective technology should enable special education students to attain higher levels of intellectual performance to prepare them for high-skill job positions.

The main essence of the integration model is to deal with the special person as a normal person by augmenting his or her disability by technology. He or she should enjoy a high degree of independence and productivity. Existing and evolving technology are adapted to make mainstream society a natural environment to live, work, communicate, and socialize. Adapting technology to special education needs depends on several factors, depicted in Figure 2. In the next two decades, a revolution in adaptive technology is expected to take place where several evolving and expected technologies will be adapted for special education.

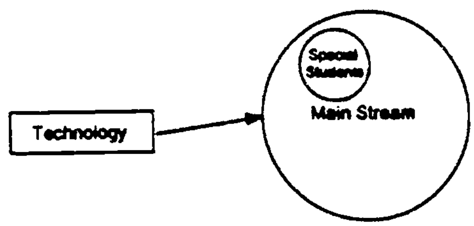
Technologies are adapted for special education to support the learning environment through preparing and training teachers, educators, and specialists for the special demands of the students. The classroom will be equipped with new technologies such as the Virtual Reality environment where audio and visual sensors provide an interesting simulation of reality. A human and natural interface for various machines will be available. Both the classrooms and the instruction process will utilize the multi-media technology which supports the communication of knowledge in understandable, simple, and innovative ways. This technology is based on several innovations such

Figure 1

SPECIAL EDUCATION TECHNOLOGY MODEL



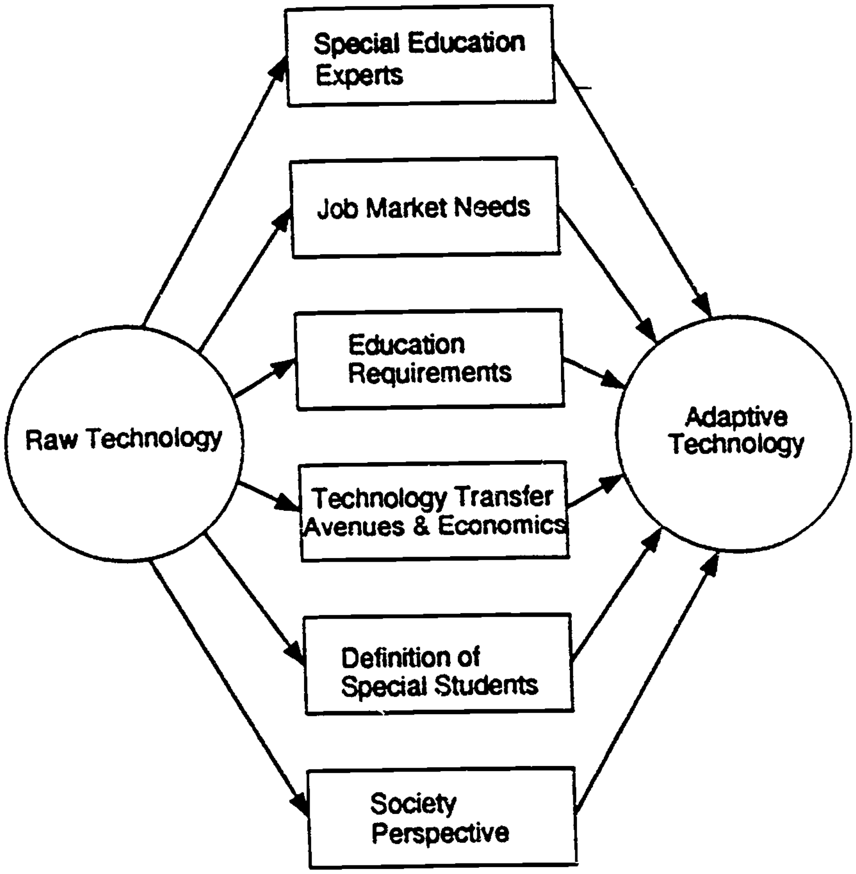
Traditional Model



Integrating Model

Figure 2

ADAPTIVE TECHNOLOGY FOR SPECIAL EDUCATION



as High Bandwidth Computer Communication Networks which support transfer of image, video, and speech information at a high rate. Three-Dimensional graphics will stimulate imagination and bring modeling aspects close to real life. Instruction will utilize as High Bandwidth Cognitive Technologies which provide intelligent tutoring and interactive thinking tools. Technology also is employed to enhance and integrate special persons on a higher level, which will impact special education in general. The main fields on that level are preventive technologies and rehabilitative technologies. The main example of the first field is genetic engineering to be used to control the spread of some genetic disorder. The latter makes use of advanced electronics, miniaturization, and robotics.

Microelectronics Technology

Microelectronics is considered the heart of current economic and social infrastructure, and the nucleons in the development of other technologies. It is expected that this hypothesis will be valid for the next three decades. In special education, microelectronics will play a major role at different levels and aspects as illustrated in Figure 3. The importance of this technology stems from the fact that it transfers two other root technologies; the advanced material technology and the semiconductor technology, into many real application technologies, Figure 4. The main innovation of microelectronics technology is the chip which has been extensively employed in the past to develop other inventions. Figure 4 shows the interrelation among several technologies. Most of the future developments in these technologies depend on the advances in microelectronics technology. Moreover, it is the core of many future technologies. In the rest of this report, we will analyze and discuss in general terms, the attributes, features, and impact of chip technology.

Technology Evolution

Twenty years ago, one would not have thought of a television receiver that fits in the pocket or a laptop computer which costs a few

Figure 3

ROLE OF MICROELETRONICS IN SPECIAL EDUCATION

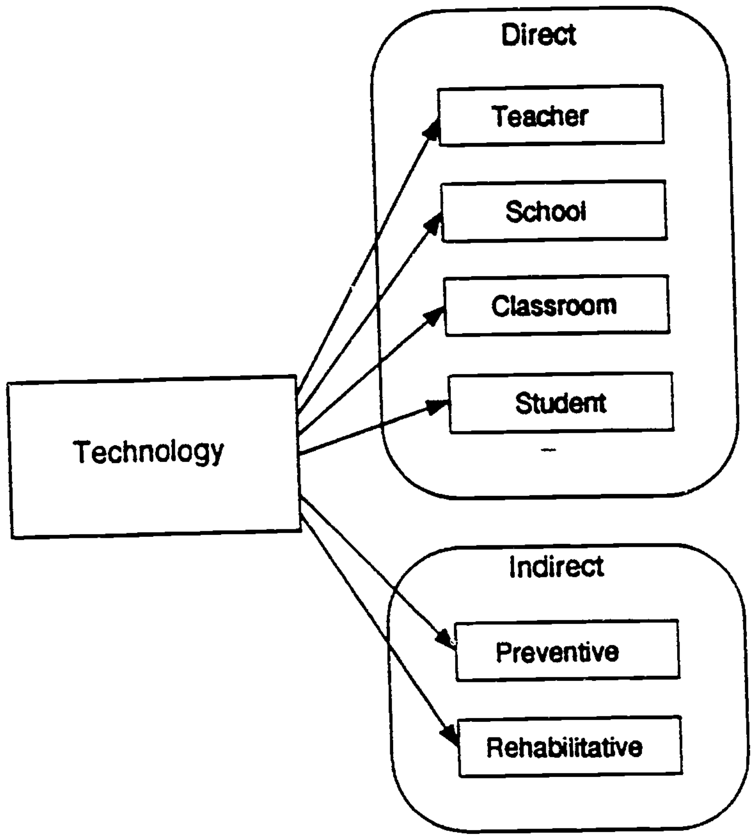
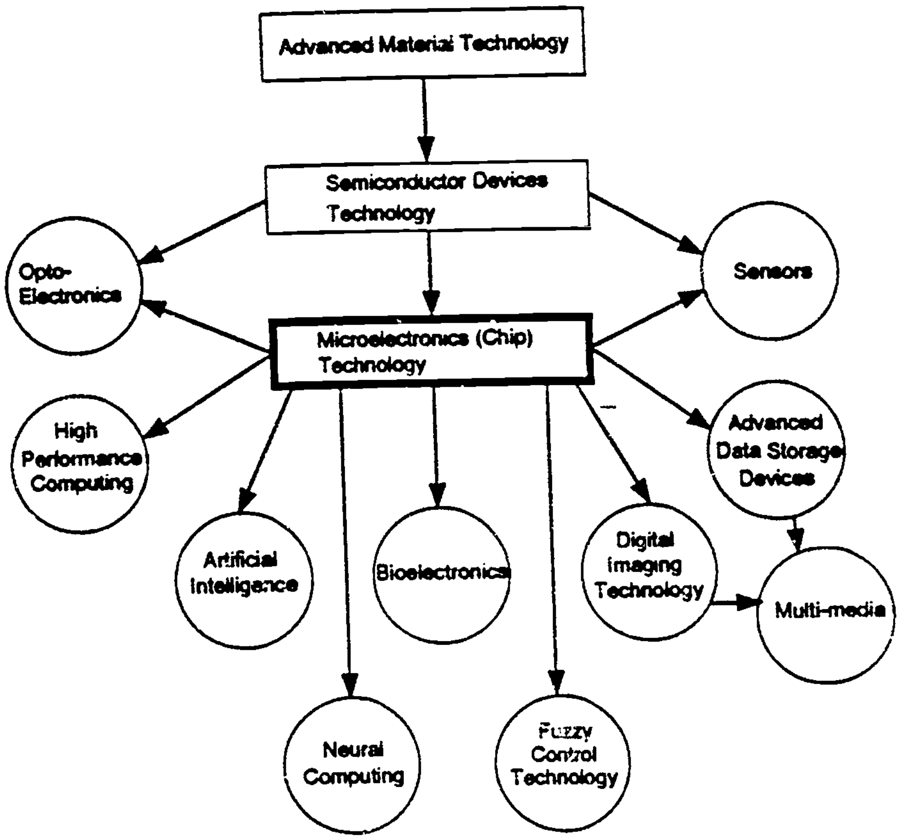


Figure 4

CHIP TECHNOLOGY IS THE HEART OF CURRENT AND FUTURE TECHNOLOGIES



thousand dollars but performs computations many times faster than the 30-ton ENIAC computer which filled one huge room. These and many countless, once impossible, things are made possible due to the rapid and remarkable progress made in the microelectronics industry during the past quarter century.

The invention of the vacuum tube heralded the electronics era. If one had an opportunity to peep inside the radio receiver of the 1940's and early 1950's, one would have noticed the odd shaped glass bulbs which are nothing but vacuum tubes. For many of us it is a thing of the past and has only historical importance. The vacuum tubes were big, consumed more power, and were not very reliable.

The invention of the transistor at the Bell labs in 1947, was a milestone in the electronics era. Systems were built by mounting and connecting the transistors and the devices on printed circuit boards. The transistor circuits were far more reliable, less power consuming, and more compact than their predecessors. However, these circuits had a problem of their own. There were too many vulnerable soldered connection points which broke-up due to vibration or heat.

In 1959, the most remarkable feat in the electronic age was achieved. The method for forming the entire circuit, consisting of many transistors, on a single silicon base was devised at Texas Instruments and at Fairchild Semiconductor, independently. Thus the (electronic) chip or the Integrated Circuit (IC) was born. Since then, the integrated circuit has undergone enormous improvements in its ability to integrate several thousand more transistors on a chip. Chips which contain 50,000 or more transistors are referred to as Very Large Scale Integrated (VLSI) Circuits. At present, using VLSI technology, about ten milllion transistors can be packed on a chip. Because of its low cost, compactness, speed, and the ability to store and process data in various ways, the chip has been used in various applications ranging from an electronic toy to the Columbia Shuttle.

Since the components of the chip are very minute in nature, their switching speed is many times greater than that of the discrete devices. Moreover, the propagation delay between the devices on a chip is very small because the interconnect wires are very short. This makes the IC many times faster than its discrete counterpart. The component density has steadily increased from less than 100 transistors per chip to ten million transistors per chip. The reliability of the chip also has improved dramatically since its invention. These tremendous improvements can be attributed to the development in high resolution lithographic techniques and processing techniques, and improvements in VLSI circuit and layout design techniques. A high level of automation of the various phases of the design and fabrication processes has greatly reduced the cost of the chips.

The IC technology paved the way for the kind of chips which incorporated the arithmetic, logic, memory, and control capabilities. These chips are referred to as microprocessors or simply processors. The speciality of the microprocessors is that the function to be performed by them is not fixed at the time its manufactured. It is rather determined by the way they are programmed. This makes the microprocessors extremely flexible and versatile. Because of their infinite application domain, the microprocessors could be manufactured in large quantities. This again contributed to the reduction in their cost.

In essence, very high computational power has been made available at a very low cost, the result of which is that many electronic products and applications are being developed everyday to transform this world once for all.

Education

In the educational front, computers have been put to use effectively for the past 25 years. There are hundreds of computer tools available for teaching, learning, managing information, and solving problems in all subject areas. Because of their highly interactive and stimulating nature, Computer Aided Instruction (CAI) tools are being used as instruction medium from the elementary school level to the college level. In an elementary school, a student would use the computer to learn the alphabet, names of different animals and their sounds, and so on. In a high school physics class, a student may study the variation of the trajectory of an object with its initial velocity and mass as inputs. In medical school, students diagnose the illness of simulated patients. In a chemical engineering class, students learn process dynamics using a computer-simulated chemical plant. In an electrical engineering lab, students build and test various circuits using computer-models.

CAI has many advantages compared to the conventional mode of instruction. First, CAI is individualized because the computer serves as a dedicated tutor for every student and provides its fullest attention. However in a conventional set up, one instructor teaches a group of students and the instructor's attention may be divided. CAI also is flexible enough to tutor a small group of students. Secondly, CAI is more interactive in nature. There is a constant communication between the system and the student throughout the session. In some lessons the computer poses questions, the student responds, and the computer presents feedback. In other lessons, the student prompts to initiate the interaction and the computer responds. Thirdly, CAI can be very stimulating. In teaching, the system challenges the student to come up with the answer. This motivates the student to learn more. Finally, CAI is very flexible. One can work with the system as long as one desires. One can go through the lessons many times. One can interrupt the system whenever one likes and can revisit the parts of the lesson not clearly understood the first time.

The Computer Aided Instruction system, PLATO, developed at the University of Illinois was used in the early stages of teaching computer topics as well as math and language drills. Besides the general purpose computers, some special purpose computers such as the IBM 1500 also were built for CAI. The full fledged PLATO system assists students in several subjects such as mathematics, medicine, music, political science, accounting, library science, engineering, speech and many foreign languages. In the industries, computer-aided tools are used to train personnel to perform various tasks such as piloting aircraft, operating an equipment or a plant, etc.

Often people are required to solve complex problems and maintain sophisticated equipment. To help accomplish these tasks, several Intelligent Tutoring Systems (ITS) were developed that instruct in qualitative reasoning and decision-making skills. One of the early systems, SCHOLAR, was developed to tutor students about the geography of South America. The SOPHIE system was developed to train people to become experts in electronics troubleshooting. The WEST system was developed to coach students in mathematics through games. The GUIDON system is an intelligent tutoring system to teach medical diagnosis.

Apart from learning tools, students use various text processing tools to process and manage information. Students also use various problem solving tools such as MATHCAD to solve problems in a variety of subject areas. Communication capabilities of computer networks make it possible for students in different locations, even in different countries, to engage in co-operative science experiments. Networks allow students to engage in lively dialogues, express views, listen to others, and develop thinking skills.

Medicine

In the medical field, scores of life-saving computerized equipment have been developed. Since the problems that arise in the biomedical applications involve a large number of data and many complicated interrelating factors, computer-based tools are well suited to these applications. The advantage in using such computers is derived not only from the fact that the computer can perform complex mathematical and logical operations rapidly but also from the fact that the computer makes possible the solutions to the problems that could not be approached in the past.

The automatic anesthetic administrator utilizes the electro-encephalographic response (response of the brain) of the patient to directly control the amount of anesthetic that is being administered. The automatic respirator is used to assist a premature infant with respiratory irregularities. This device senses the infant's attempt to inhale and lends an assist at precisely the proper moment it is needed. If the infant fails to initiate an inspiration within a 15-second interval, the automatic respirator senses this and gives the infant artificial respiration until the infant resumes normal respiration. Special types of equipment are available to monitor the condition of the fetus. Since the stethoscope is not powerful enough to pick up the heart sound of the fetus, a special device called the Ultrasonic Doppler Instrument is used for this purpose.

Various powerful, non-invasive, imaging techniques have been developed to examine the internal organs and tissues. The computed tomograph (CT) and nuclear magnetic resonance (NMR) imaging are widely used in developed countries to detect cancers, tumors, damaged tissues of the brain and other internal organs. These techniques involve so much computation that without the help of the modern day chips it is practically impossible to realize them. There are a number of highly sophisticated analysis tools, such as chromatographs and optical spectrographs, available for the analysis of the body fluids. These analysis tools use only a small fraction of the sample when compared to the conventional techniques to arrive at very accurate results.

Computer simulation is extensively used in the field of medicine to design and develop various devices and equipments that assist or replace the organs during surgery or incapacitation. For example, simulation was used to develop an extra corporeal profusion device—a heart lung machine. The circulatory system was modeled and the response of the overall system to the various parameter settings of the heart lung machine was studied. Based on the study, a set of parameters which resulted in a desirable system response was chosen for the realization of the heart lung machine.

Hearing aids employing special purpose chips already are available in the market. The pace maker is a device which measures the heart beat and provides electrical impulse to the heart if there is abnormality. Researchers are currently working on artificial limbs for the handicapped. These artificial limbs will be incorporated with special purpose chips for sensing and controlling the movements of various parts of the limb.

In many hospitals, automated interviewing systems are being used to find the patient's chief complaints, his family history, personal history, and other factors that may ultimately affect the future course of therapy or give a clue to the cause of patient's illness. These systems are preferred over doctor-patient interviews for the following reasons; they save a physician's time which can be devoted to specialized activities such as surgery. When the physician directly interviews a patient the choice of questions is often compromised by external factors, such as the physician's schedule, general physical condition, personal interest, and other influences extraneous to the development of the initial database. Also, in some situations the patient may be embarrassed to tell the truth to the physician.

Automated Intensive Care Units (AICU) are widely used in developed countries to monitor the conditions of the critically ill patient and to initiate necessary life saving procedures. A cardiac patient can go beyond resuscitation within a minute after the onset of certain types of heart malfunction. Such an attack can be determined by monitoring the heart's electrical activity with an Electro Cardio Gram (ECG). These attacks are often preceded by small anomaly in the ECG which serves as an early warning that preventive action should be taken. An electronic system can monitor and detect this anomaly with a success rate of nearly 100 percent, which is otherwise not possible through a human observer. Automation of clinical labs helps in reducing errors, reducing lab turnaround time, producing collated test reports, and managing the database for future research and quality control.

Computer-aids for the Handicapped

The chip intelligence has been effectively used to develop many products which help the handicapped in overcoming their impairments. The Kurzweil Reading Machine, developed by Kurzweil Computer Products, helps blind individuals by reading the typewritten matter in a synthesized voice. The electronic camera of the system scans the printed material and transmits the image to the specially programmed microcomputer. The microcomputer segregates the image into words, recognizes them, computes the pronunciation of these words, and produces the audible speech pattern. The Autocuer instrument converts the spoken words into visual display. It consists of a portable computer which senses the words spoken to the hearing impaired person and projects the corresponding symbol on to the lens area of a pair of eyeglasses worn by the hearing impaired person. The Sonar Cane is a kind of walking stick which can sense obstruction in the path of a blind person.

Voice synthesizers, which can speak the words manually fed through the computer key boards, are available. These instruments can be used by the speech impaired person in various situations. For example, it can be used in a classroom setting to interact with the teacher or in an office setting to interact with co-workers. Voice synthesizers are available with a head mountable optical scanner and a special keyboard. This device is useful for persons who have lost their upper limbs or cannot use them. The handicapped individual directs the optical beam from the head mounted scanner on to the character on the special key board. The computer translates this input into voice. This information also can be displayed on the screen or it can be printed on the attached printer. Mechanisms for converting Morse code into speech, display, and hard copy also are available. Braille to English and English to Braille translators also are available to aid blind persons to prepare documents in English and to understand English documents.

The Telecom Device for the Deaf (TDD) is a device commonly used by deaf persons to communicate with others through the use of a telephone line. There are a number of special tools available for the disabled to learn different subject matter. There are tools available for lipreading training, sign language training, and finger spelling training. Researchers are currently working on implanted devices to correct various sensory perceptions such as sight and hearing. Active research also is being carried out to develop special artificial limbs with control circuitry.

Home Electronics

The market is being flooded with numerous home electronic products every day. A Hi-definition television, a HI-Fi CD player, a shirt-packet cordless phone, an answering machine that uses memory chip instead of tape to record information, an electronic security system, a programmable microwave oven, and a programmable sewing machine, represent a few of the products.

Business

The business world has benefitted greatly from the progress in the electronics industry. An automatic teller machine, electronic counter for billing and updating inventory, credit card verification machine, fax machine, color copier, and office telephone exchange are some of the business machines which are encountered in every day life. The personal computer is the most remarkable product of this century. Almost all offices use them for information management requirements.

Today, all banks act as a clearinghouse when dealing with checks to be paid, and the amount to be acquired by any or all of its customers. Computers perform this burdensome task by calculating, in a fraction of a second, the various amounts. The result is that each account is instantaneously updated and kept in memory. At the same time interests are computed and properly assigned to each account. Totals and statistics also are immediately available. Several banks provide the bank headquarters and branch offices with separate independent terminals, each directly connected to the central computer. This equipment allows tellers to promptly verify the consistency of any account while the customer is waiting at the counter. When the transaction is completed, the computer is automatically informed of this, and all the accounting and financial ledgers are immediately revised and the current values made available.

In addition to the on-line teller terminals used to handle customer deposits, and withdrawals, there also are several other types of financial transaction terminals that are commonly used. Some of these devices are used in the electronic transfer of funds. One such electronic fund transfer station is the Automatic Teller Machine (ATM). Besides ATMs, there are other types of electronic funds transfer terminals that are directly connected to financial computer systems. These terminals are located at the check out counter of supermarkets, hotels, and hospitals, to name a few. These terminals are used to verify the validity of the customer's check or credit card. These terminals also can be used to electronically transfer funds from a shopper's account to the merchant's account. A touch tone telephone also can be used as an electronic funds transfer terminal. A bank customer can call a bank computer and carry out various bank transactions.

Management Information System (MIS)

The fast growth of many new organizations and the speed with which new technological findings are now being applied for competitive purposes combine to produce a complex and challenging management environment. The reaction time available to managers is very limited, because of the increased competition from domestic and foreign businesses. Consequently, the previously acceptable systems are no longer adequate to meet the needs of managers.

Management information systems have been developed to assist managers in decision making. These systems provide managers at different levels with accurate, complete, and concise information in a timely fashion. MIS can be defined, in general, as "a network of computer-based data processing procedures developed in an organization and integrated as necessary with manual and other procedures for the purpose providing timely and effective information to support decision making and other necessary management functions." [17]

In an organization, MIS aids the top-level managers in developing strategic plans, and making decisions such as the development of a new product or opening a new plant. It helps middle-level managers in tasks such as resource allocation and the establishment of controls needed to implement the top-level plans. MIS assists the low-level management in scheduling and controlling specific tasks.

The Decision Support System (DSS), which is part of MIS, allows managers to model and simulate the proposed projects or strategies, and determine the effects of various assumptions and conditions. For instance, simulation techniques help top-level executives decide whether to acquire a new plant or not. Besides the numerous complicated variables that would have to be incorporated into the model, the facts and assumptions about the present and potential size of the total market and the present and potential company share of the total market would also be included in the model. Simulation models also are helpful to the middle-level management. For example, simulation models are used to improve inventory control. The problem of inventory control is complicated by the fact that the goals of the different organizational units are conflicting in nature. For instance, the purchase department may prefer to buy large quantities of materials in order to get lower prices. The production department also would like to have large inventories to avoid shortage and make possible long and uninterrupted production runs. The sales department prefers to have a large inventory of finished goods to avoid an out-of-stock situation. But, the finance department opposes large inventory levels because storage expense is increased, and funds are tied up for longer periods of time. With simulation techniques, managers can experiment with various approaches to arrive at more profitable inventory levels.

Other types of commonly used DSS are the Database Query Applications, Expert Systems, and Group Decision Support Systems, (GDSS). In GDSS, members of the group employ the DSS together. They communicate with the DSS, or with other members of the group via computers. Upwards in the hierarchy, MIS abstracts further into Executive Support Systems, (ESS) where all DSS, MIS, and lower level models are incorporated to produce (predominantly graphic) executive summaries.

Music

The use of digital systems for the synthesis of music dates back to 1957 when the piece Illiac Suite was published by Hiller and Isaacson. This pioneering work received wide publicity and acclaim.

Digital computers use a digital to analog convertor that can accept a string of numbers and convert them to a corresponding analog signal suitable for driving loud speakers to generate various tones. Such a system is very flexible. Absolutely, any sound within a restricted frequency range which is beyond the range of hearing can be synthesized and controlled. Natural sounds can be imitated with accuracy, limited only by the completeness of the corresponding mathematical model. To increase computation speed so that the computer can cater to the requirements of the generation of music, special devices such as hardware multipliers and fast Fourier transform processors are added to the standard configuration.

Personal Computers play an important role in music education. It is becoming common for children to first be exposed to the mechanics of music (pitch, rhythm, melodies, notation) by means of some kind of simple music program on a home computer. A big advantage of using such programs is that a child can produce a reasonably listenable final result as soon as the program is understood, long before any significant manual skills can be developed. Several drill programs are available to assist music learning at the intermediate levels which involve ear and music dictation training.

A growing number of composers have taken up an interest in what is called stochastic music, music composed from random numbers. In the last few years, composition through computers has broadened to include a wide base of techniques that attempt to embody modern analytical and compositional procedures.

Defense Applications

The defense industry has set standards for almost all technological fields. Electronics is no exception. If one followed the Persian Gulf War telecasts, one would not have missed the capability demonstration of the air-to-ground missiles that strike the target with an accuracy of a few inches or the patriot missiles that seek and destroy the enemy-launched missile in midair. The stealth bomber is a fighter aircraft filled with electronics that enable it to be invisible to the eyes of the enemy radar. The anti-radiation missile, once locked on to the enemy radar's microwave radiation, would streak towards the antenna and destroy it, thereby making the enemy war-blind.

A world-wide military command and control system has been developed for U.S. military commanders from the President on down. The system links approximately 35 large computers, 26 command posts around the world, and more than a dozen computers at the North American air defense command. It accepts, stores and constantly updates masses of data from world-wide radar installations. Every humanly produced object on earth orbits is tracked.

In weapon guidance, the target analysis and correlation requires that many inputs be obtained from the navigation systems, various types of radars, infra-red searching systems and the pilot. Often, the target of the greatest interest is equipped with facilities to engage in evasive measures or to conceal itself. When such counter measures are used, the detection and accurate identification of the target becomes an extremely difficult task, especially when the launch vehicle is moving at a very high velocity in relation to the target. The short decision-making time available makes the problem very complex. When the aircraft is pursuing a target over an unfriendly territory it may suddenly find that it has become a target itself. Not only does it have to seek the foe but also perform evasive measures to save itself. Masses of data must be gathered rapidly, analyzed instantly and complex decisions made.

The Airborne Warning and Command Control System, (AWACS) uses sophisticated digital systems for its efficient functioning. This system mainly consists of a large aircraft which can hover near or over a field of military operations. The aircraft is equipped with powerful radars so that it can directly monitor air and battlefield operations.

The radar information combined with inputs telemetered from various ground establishments may be analyzed and used to give more effective directions to the course of both air and ground operations.

Computers are being used increasingly by military planners. For example, they are used to simulate wars in order to sharpen analytical skills and to gain experience in decision making through the use of war games. They also are used by military leaders for planning and controlling logistics, such as managing the procurement, storaging and transporting needed supplies and equipment to the various battle-front locations.

The computer-simulated flight tests that teach military pilots to fly, refuel in mid air, drop air to ground missile, pursue enemy aircraft, evade enemy attacks from air and ground, take-off and land, are increasingly used in the military. The weather and lighting conditions also can be varied to simulate any real life situation. These computer simulation systems use large display screens capable of displaying moving targets, clouds and other visual situations that might confront a pilot on maneuvers. These systems also are capable of producing sound effects such as the whine of the turbo engine and the aerodynamic hisses. Because of the effectiveness of simulated flight tests, the Federal Aviation Administration has already approved the simulated test flights for pilot retraining.

Space Programs

Computers have exerted a profound influence in space applications such that one can safely state that there would be no space program without computers. Computers are used to design, develop, test, and launch flight systems and satellites. They also are used to simulate spacecraft system problems, and to train astronauts and ground operations personnel. During the flight, the system receives a huge volume of data on such life-and-death subjects as the astronaut's heartbeats, breathing, and oxygen supply at a very high rate. A worldwide network of computers is used to monitor the speed, altitude, azimuth, and position of the spacecraft for transmission to the mission control center.

During lift-off, the computer system continuously monitors the overall health of the flight systems and signals the engine when to start. If the lift-off is delayed even by a fraction of a second the computer calculates a new course instantly. During the entire mission the computer calculates the path of the spacecraft, taking into consideration the change in the pull of gravity from the earth, moon, sun, and the change in the wind speed.

The usefulness of the computer in space programs is best illustrated by its role played in the Appolo-13 mission. When Appolo-13 was about 200,000 miles away from Earth the main electrical system failed, making it necessary to abort the mission. The trajectory planners on the ground simulated the alternate plans to bring the three astronauts back home safely. The computer took 84 minutes to calculate the trajectory for the return path and the astronauts returned home safely. According to the NASA officials, if all of the 220 people of the Planning and Analysis Division used a desk calculator to calculate the trajectory for the return path, it would have taken 4,730 years to compute the return path.

Industrial Applications

Computers are used extensively in the industries for various purposes including production planning and scheduling. For example, on a farm tractor assembly line, thousands of components must come together at the right time at the right place and in the right sequence. Manually planning and scheduling such assembly processes can take weeks. The use of computers can reduce that time dramatically.

Computers are frequently used by managers for financial planning. The costs and revenues associated with alternative estimates of promotion plans and prices, and sales and production volumes must be analyzes to make provisions for adequate financial resources to carry out marketing and production plans. To evaluate these implications and to determine the expected profitability of various alternatives, computer programs are used to make cash flow analyses, time-series financial forecasts, and loan and interest rate projections. Decisions about the prudence of making investments in new plans, and equipment are often made with the help of computers.

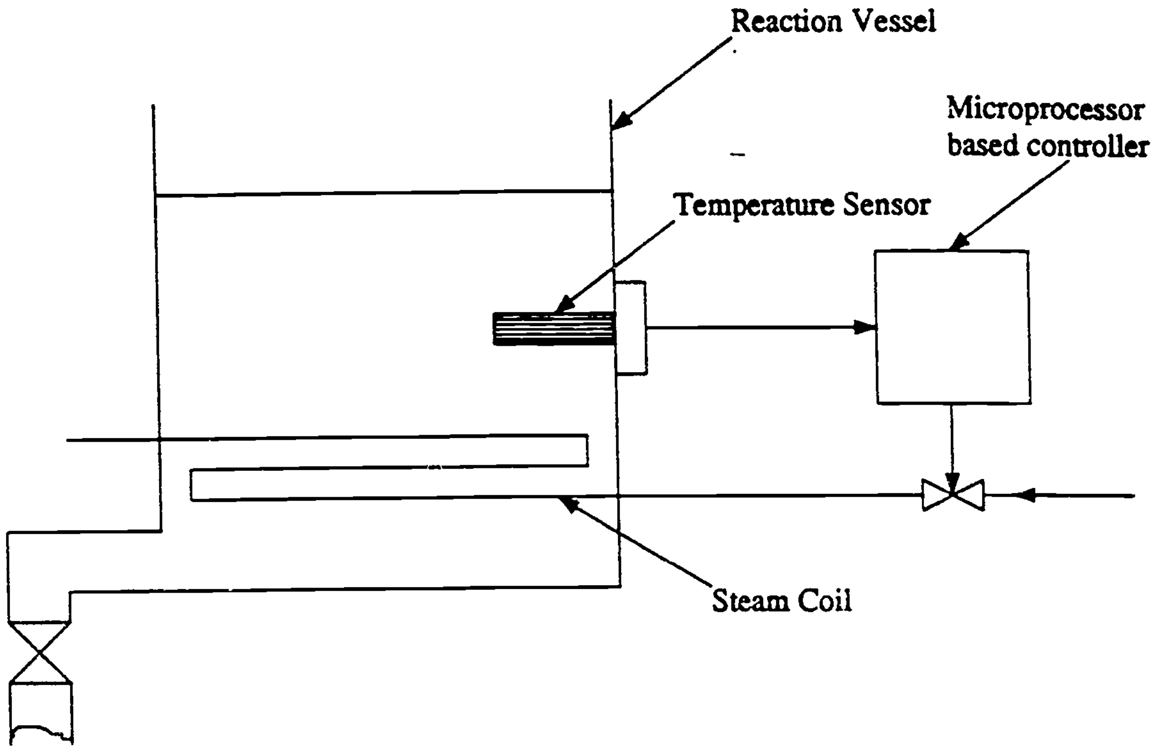
Computerized process control systems are being used to monitor continuously operating facilities such as oil refineries, chemical plants, steel and paper mills, and electric power generation stations. During the process, instruments measure variables such as pressure, temperature, and flow. If the process is deviating from an acceptable standard (set point), regulating devices are adjusted to bring the process back to the normal operating condition. In an open loop process control operation (Figure 5), the computer records the instruments' readings, compares the readings against the set points and notifies the process control operators of needed manual adjustments of regulating devices. In a more complex closed loop process control operations, the computer receives measurements, makes comparisons, computes and send signals to the regulatory devices to make the necessary changes. The use of computers in this way permits a faster response, and more accurate control than what would be possible otherwise.

During the actual production on an assembly line or a job floor, data entry stations are used to transmit the information such as the time spent on an operation, the status of a machine tool, the size of the queue requiring work, or the need for machine set up or repair. The computer then compares the actual conditions against the production plan and determines the appropriate control actions required.

Computers also are used to control individual production tools such as shapers, milling machines and drill presses. These numerically controlled machine tools directed by computer produced tapes can be used to automatically produce precision parts meeting the specifications. <u>Numerical Control</u>, (NC) machines are being used in various applications such as cutting air pane sections from solid metal, constructing prefabricated house walls, and producing hydraulic

Figure 5

CLOSED-LOOP PROCESS CONTROL SYSTEM USING MICROPROCESSOR BASED CONTROLLER



presses. Rapid operation and efficiency are important advantages of these automatic machines.

Computer Aided Design, (CAD), tools are used to assist the designer in the various stages of the design process, namely preliminary design, advanced design, model development, model testing, and final testing. In the manual design process the designer has to produce many drawings and analyze them thoroughly and produce additional drawings based on further modifications. In this way the preparation of drawings occupy a substantial portion of the designer's time. Devices such as special electronic pens and graphics displays make it possible to receive human sketching directly. The changes and modifications of the sketches can be made easily. Once the initial drawings are finished to the required specifications, the computer is instructed to analyze the design for certain characteristics. The designer interacts with the computer until a design with a set of desirable characteristic is produced.

CAD tools are widely used in the electronic industry for electronic circuit design. The engineer defines the circuit requirements then the computer develops, analyzes, and evaluates trial designs that may meet the requirements. The trail design may be modified by the engineer as required. The computer then analyzes and evaluates the modification. Computer aided design also is used to plan the layout of integrated circuits, the location of circuit boards in the computer and the ways in which these boards can be interconnected.

In the automobile industry, computers are used to evaluate the structural characteristics of alternative designs. Engineers can assemble models of the components in a car and then road test the proposed car design on a simulated road. For instance, a chassis cross member can be redesigned to reduce weight and the effect of the change can be determined by a computer program. This design approach significantly reduces the costly time-consuming process of making and testing a series of prototype parts until the desired results are obtained.

Robots are being used in various industry, and in dreary conditions to perform different kinds of tasks. Robots are used in the automobile industry for stamping, heat teating, welding and spray painting jobs. Since they are faster, reliable, consistent and immune to fatigue when compared to the human worker, they are becoming popular for performing repetitive and mechanical kind of jobs. In an engine factory in a suburb of north Tokyo, a small crew of human workers work in the day time. In the night time, the robots take over and work under the supervision of a lone human supervisor.

Robots also are used for hazardous and danger tasks such as mining and deep sea exploration. They also are used to perform various tasks in hostile environments such as high temperature and nuclear radiation. The U.S. military is planning to test a robot ammunition handler which will hoist and load 200-pound howitzer shells. In some hospitals, Robo-carts are used to deliver food and other necessities to patients.

The commercial robots of today are generally preprogrammed in nature. They perform a sequence of predetermined activities as dictated by the program that resides in the chip-brain. However, researchers are trying to develop robots with some intelligence incorporated in them. These robots will be capable of intelligently acquiring and interpreting sensory data, perceiving nature and changes in the working environment, planning the appropriate course of action, and executing them to accomplish the required task.

Super Computing

For applications such as structural analysis, weather forecasting, petroleum exploration, fusion energy research, medical diagnosis, aerodynamic simulation, artificial intelligence, expert system, industrial automation, remote sensing, defence and genetic engineering, high performance computer systems such as the super computer systems are required. Since in these applications a large amount of data need to be gathered and analyzed in a very short period of time, small computers are not adequate. For example, in weather forecasting, weather data supplied by a world wide network of space satellites, airplanes and ground station are fed to a super computer. These data are analyzed and correlated in a complicated manner to arrive at a forecast in a short period of time.

II. FUTURE DEVELOPMENTS

Gallium Arsenide Technology

Though the MOS technology has been the primary medium for computer implementation, it has some speed limitations, which is becoming apparent in the light of the current fast digital design. The Gallium Arsenide (GaAs) technology offers many advantages over the MOS technology. The electron mobility in GaAs is nearly seven times that in silicon. The GaAs devices have very high resistance to radiation and have a wide operating temperature range. Also, GaAs technology provides for efficient integration of electronics and optics. A few companies have already announced some products based on GaAs technology. Though GaAs may not totally replace MOS, it is likely to play a major role in high speed digital design.

Fuzzy Logic

Much of human knowledge is vague and imprecise. Human thinking and reasoning frequently involves inexact information. Fuzzy logic helps to handle fuzzy concepts such as very tall, very good or very hot and approximate reasoning in expert systems. Fuzzy logic is an extension of set theoretic multivalued logic, in which the truth values are linguistic variables such as true, very true or more or less true. Fuzzy logic based chips have been successfully used in various applications. Both the academic and industrial community are pursuing active research in this area.

Neutral Networks

Another area which has evoked considerable interest in the academic and industrial arena is Neural computing. It is believed that Neural network systems, with its learning by example capability, closely resembles the human brain. A handful of companies have already produced Neural network chips using VLSI technology. The University of California at Irvine, and Adaptive Solutions Inc. are currently working on a chip that would identify, discriminate and store odors. This project would help researches in understanding the function of brain.

Final Comments

By the turn of this century, a very high level of integration will become possible. Over ten million number of transistors could be packed on a single chip. Such a capability would lead to various products and services that will affect us in our private, social and organizational life.

Personal computers with very high computational power and very diverse functionality will become available at a reasonable cost to all people. Various kinds of databases around the globe will be accessible through computers. One can read newspapers, magazines, or weather reports, while sitting at home. Schools and offices will become concepts rather than concrete entities. Students will learn materials through home computers networked with the educational institutions. Offices will become fully decentralized. Staff members would do their work at home while communicating through their home computers. To a larger extent, teleconferencing would replace the present day conferences.

Opinion polls can be conducted to determine the view of the masses on various matters ranging from politics to ethics to deciding the winner of a talent contest. People would express their opinion through their computers while watching a television program. The results will be available instantaneously. Video phones will replace the present day phones. Smart automobiles with automatic navigational facilities will become available. Automated kitchens will start appearing in many homes. People with sensory and physical deficiencies will benefit to a larger extent. Electronic implants to correct vision and hearing problems will become practical. Sophisticated navigational aids for the blind will become available. Artificial limbs which resemble natural ones in appearance and functionality will be available. Very intelligent robots will become available. Most industries will be fully automated. The robots and other automatic machines will be used for this purpose. Voice-activated machines and robots will become feasible.

In summary, the 21st century promises a much faster, but highly mechanized, society for mankind. It is undoubted that a winning horse has the better jockey atop him. Likewise, to harness and effectively utilize the immense power of VLSI based automation, we will need highly organized efforts with a keen foresight towards the society's future.

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Appendix A

VLSI FUNDAMENTALS

VLSI FUNDAMENTALS

The basic component of the digital integrated circuit is the transistor. Functionally, the transistor is a switch which turns on or off according to the voltage applied to its gate. The transistors are connected together appropriately to form the gates which perform the basic logic operations such as AND, OR. These gates are further interconnected together to build the modules and systems (memory, processor etc.).

Depending on the number of transistors contained, the chips are classified as Small Scale Integration (SSI), Medium Scale Integration (MSI), Large Scale Integration (LSI) and Very Lage Scale Integration (VLSI). Table 1 shows this classification along with some examples.

Table A-1

CLASSIFICATION OF TECHNOLOGY INTEGRATION

Scale of Integration	Components/Chip	Example
SSI	<64	4 two-input NAND gate package
MSI	64-2,000	4-bit ALU
LSI	2,000-64,000	16K-bit ROM
VLSI	<64,000	16-bit Microprocessor

There are two types of transistors, namely n-type and p-type, in CMOS (complementary metal oxide silicon) technology. The physical structure of nMOS and pMOS transistors have been depicted in Figures A-1(a) and A-1(b).

The nMOS transistor consists of a positively doped p-type silicon substrate into which two heavily doped n-regions, the source, and the drain are diffused. The narrow region of p-type substrate which lies between the source and drain regions is called the channel. The

Figure A-1(a)

n-MOS TRANSISTOR

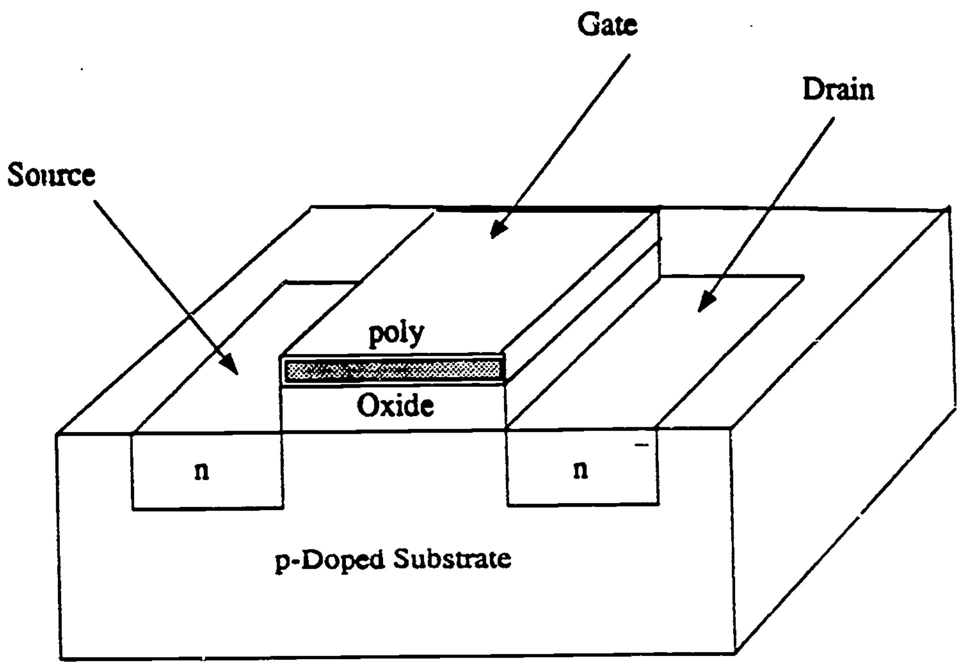
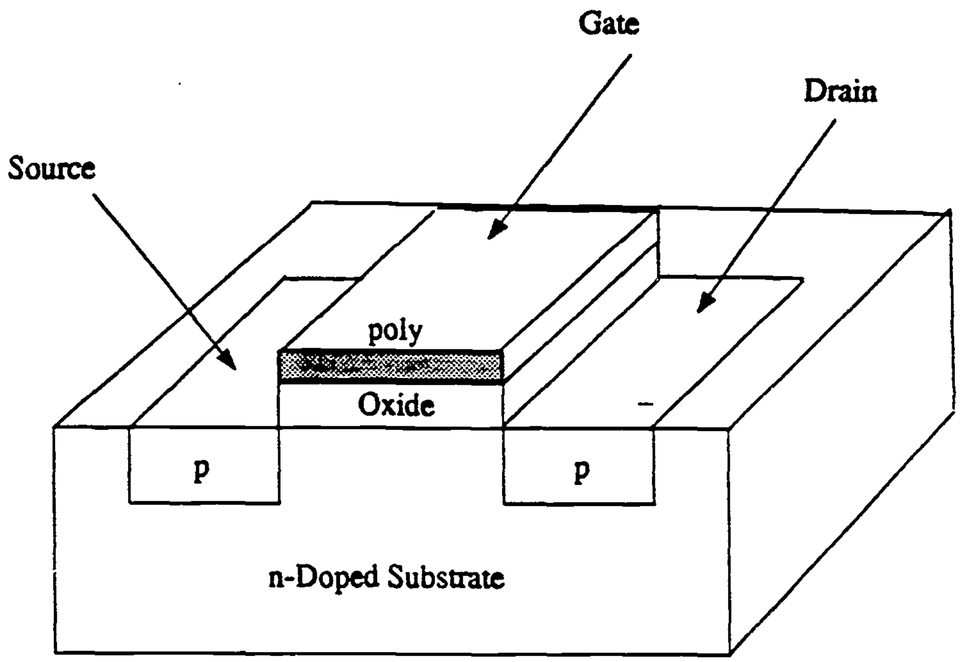


Figure A-1(b)

p-MOS TRANSISTOR



channel region is covered by a thin insulating layer of silicon dioxide (SiO_2) called gate oxide. Over this layer is a polycrystalline silicon (polysilicon) electrode called the gate. The physical structure of the pMOS transistor is similar to the nMOS transistor except that the n-type and p-type silicon are interchanged. The gate serves as the control input. It affects the flow of current between the drain and source. Functionally, the transistor can be considered as a voltage controlled switch with the source and drain as the switched terminals. Though the source and drain are physically equivalent their name assignment depends on the direction of current flow.

The Integrated circuits (IC) are manufactured by super imposing several layers of conducting, insulating and transistor forming materials. After several processing steps a chip might consist of levels called diffusion, polysilicon and metal which are separated by insulating (SiO_2) layers. To give a glimpse of the IC fabrication process we shall discuss briefly the production of a single nMOS transistor in the polysilicon gate self-aligning nMOS process. Figure A-2 illustrates the various steps involved.

High purity Silicon ingots of diameter ranging from 75mm to 125mm diffused with specific amount of p-type impurities are produced from sand. These ingots are sliced into wafers of thickness less than 1mm. These wafers serve as the p-type substrate. Then, a uniform thin layer of about 1mm thick silicon dioxide is formed on the surface of the wafer. This layer serves as a protective coating for the wafer surface, as a barrier to dopants during further processing and acts as an insulating substrate for the deposition of other layers. A uniform layer of photoresist is applied over the SiO_2 layer. Then the photoresists layer is exposed to ultraviolet radiation through a mask which defines those areas in which the source and drain regions and channel has to be formed. The photoresist exposed to UV radiation is polymerized because of the photochemical reaction. The polymerized photoresist and the underlying SiO_2 layers are etched away using some chemical agent. This exposes the area of the wafer defined by the mask. The remaining portion of the photoresist is removed and a thin

Figure A-2

nMOS FABRICATION PROCESS

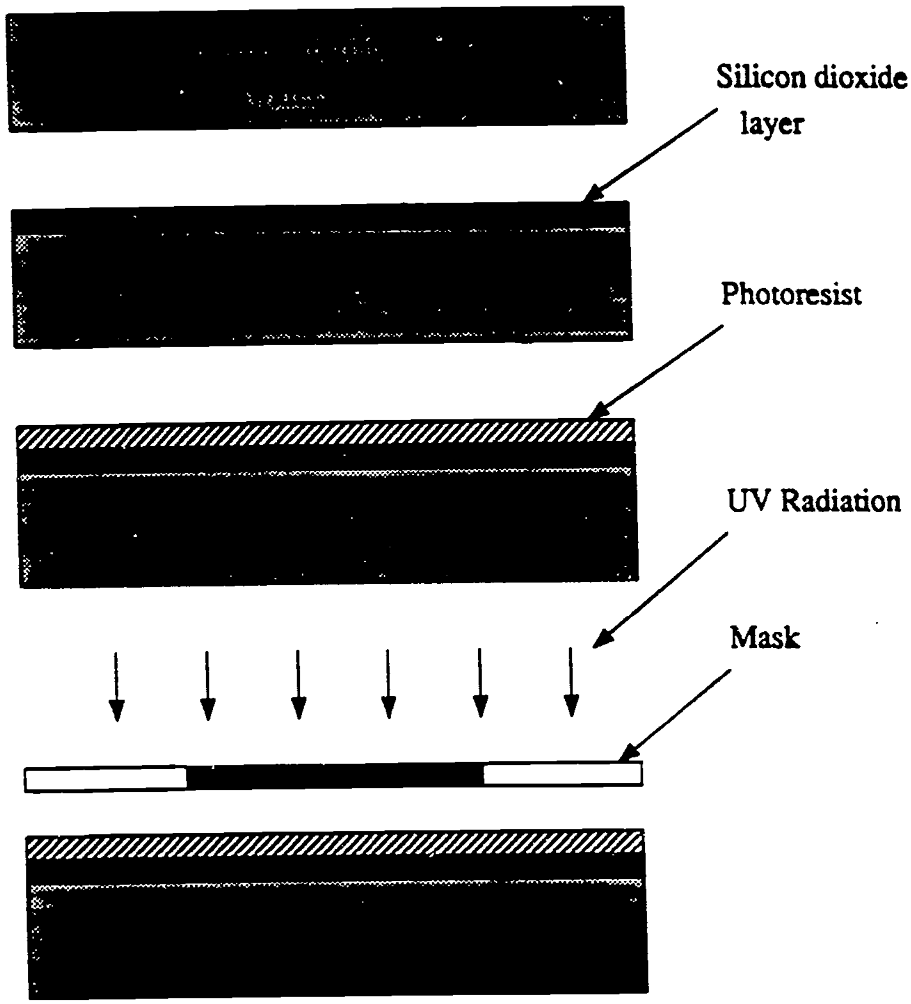
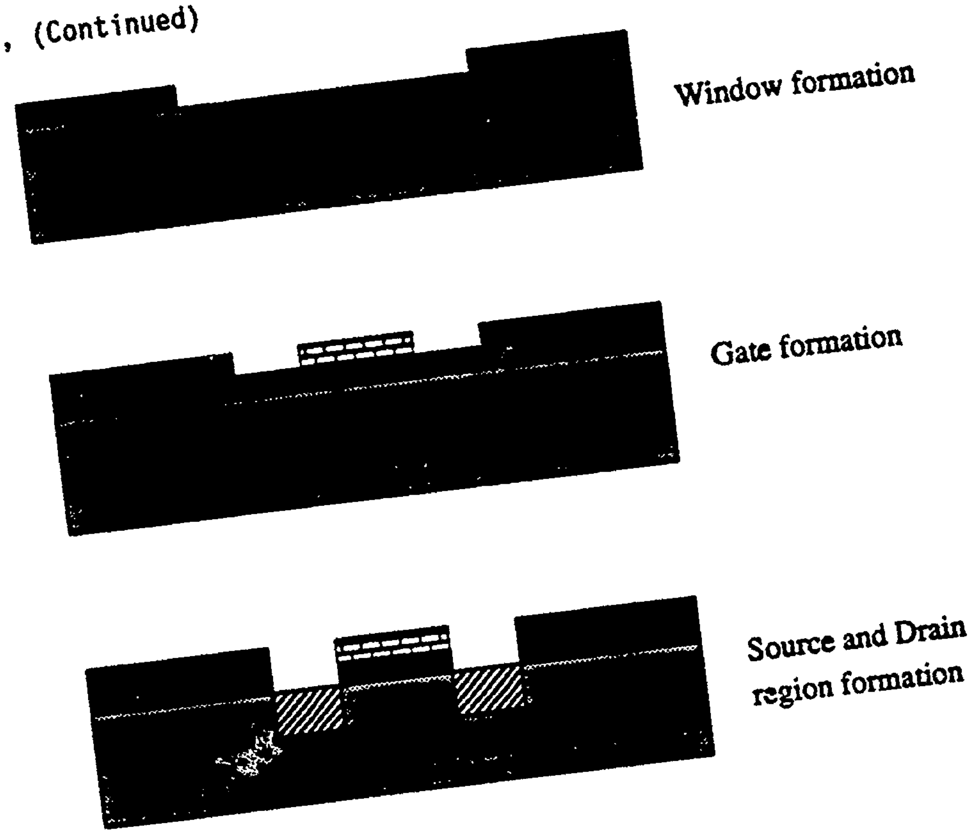


Figure A-2, (Continued)



layer of about .1mm thick SiO_2 layer is grown on the entire surface. Then a polysilicon layer of appropriate thickness is deposited overthis layer using vapor deposition process. Further photoresist coating and masking as before allows the polysilicon to be patterned to form the gate structure. Then photoresist coating, masking and etching steps similar to the ones discussed before are carried out to expose the wafer surface where the source and drain are to be formed. Then into this region n-type impurities are diffused and the source and drain are formed.

The fabrication phase is preceded by the VLSI Design phase. This phase of the design consists of logic design/schematic design, circuit design and layout design activities. Given the architecture of the system under consideration, in the logic design stage, each sub component of the system is implemented using the gates. At this stage only the symbol of the gates is used. Then the gate-level components are transformed into circuit components (transistors). This is called the circuit-level description. Then the circuit is transformed into layout description. In this level the circuit components (transistors) and their inter-connections are described in terms of diffusion, polysilicon, metal layers and contact cuts. At the layout design stage, one has to follow the geometric rules dictated by the fabrication process. The rules specify the width of different layers, the spacing to be provided between layers, the amount of overlap required to form a contact and so on. To assist a VLSI designer in his work, there are a number of Computer Aided Tools available today. These tools are in general called the VLSI CAD Tools. The industrial grade tools are very interactive in nature and come with many good features, including the provision to simulate the design at each level of description. This allows for ascertaining the validity of the design at various intermediate levels before proceeding to the next stage, thus avoiding the hardship of redoing the whole design from scratch in the presence of a design flaw. Once the layout design is complete the layout description is sent to the fabrication house, where the layout description is transformed into mask level description and patterning procedure. Then the fabrication of the chip is carried out.

PAPERS AVAILABLE FROM COSMOS

The papers commissioned by the project are available upon request include:

"Technology and Interactive Multimedia" by Ray Ashton;

"VLSI Technology: Impact and Promise" by Magdy Bayoumi;

"Conceptual Framework: Special Education Technology" by Richard Howell;

"Demographic Characteristics of the United States Population: Current Data and Future Trends" by Beth Mineo;

"School Reform and Its Implications for Technology Use in the Future" by John Woodward;

"Textbooks, Technology, and the Public School Curricula" by John Woodward;

"Workforce 2000 and the Mildly Handicapped" by John Woodward;

"Virtual Reality and Its Potential Use in Special Education" by John Woodward; and

"Annotated Bibliography: Training, Education Policy, Systems Change, and Instruction" by Lewis Polsgrove.

Copies of these reports are available upon request.