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Integrated Circuits

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Abstract

The technology of integrated circuits is_ almost new in Peru, writer's country-. It is being used mainly in black and white television sets and in some audio amplifier equipment. As any new technology, first, it is necessary to be very familiar with it in order to exploit it adequately and get all the benefits from it. The writer feels this lack of knowledge, and wants to take advantage of being here to learn the technology and techniques for using integrated circuits.

INTEGRATED CIRCUITS

A Research Paper
Presented to
the Department of Industrial Arts
and Technology

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

by
Julio Garcia
March 24, 1975

Approved by:

Graduate Committee, Chairman

April 11, 1975
Date

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My special thanks to:

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THE PROBLEM

Integrated circuits are looked upon as a revolutionary technology that has literally exploded on the scientific horizon. Since their discovery in 1958, integrated circuits have improved in reliability, size and cost. The manufacture and the use of these devices has been phenomenal.

The writer has studied electronics for ten years in Peru. After leaving the university in 1968, he taught electronics for four years at the high school, post high school and university level. At the same time, the writer has worked in the private electronics industry as a laboratory assistant making tests on new equipment and electronics components, and sometimes in the final inspection.

Statement of the Problem

The technology of integrated circuits is almost new in Peru, writer's country. It is being used mainly in black and white television sets and in some audio amplifier equipment. As any new technology, first, it is necessary to be very familiar with it in order to exploit it adequately and get all the benefits from it. The writer feels this lack of knowledge, and wants to take advantage of being here to learn the technology and techniques for using integrated circuits.

Purposes of the Study

The purposes of this study are:

1. to become familiar with the process of making integrated circuits.

2. to learn the techniques of choosing the best type of integrated circuit according to the needs for a specified electronic circuit.

3. to be able to test integrated circuits in an electronics laboratory without specialized equipment.

4. to develop the necessary skills to handle integrated circuits correctly.

5. to make a project using an integrated circuit.

Limitations and Delimitations

This study will be made from library research related to integrated circuits and from written material supplied by the manufacturers of these devices.

Because the technology of integrated circuits is vast and there are many methods of manufacturing ICs, this study will be limited to the process of making bipolar ICs, and an introductory information regarding the other integrated circuit types.

Assumptions of the Study

The writer assumes that the reader of this study:

1. is familiar with the concepts of basic transis-

torized circuits.

2. is familiar with the techniques of measuring and testing electronic circuits.

3. has a high school mathematics background.

Definition of Terms

Active Elements: Electronic components, such as transistors, diodes, thyristors, etc., which can operate on an applied electrical signal so as to change its basic character; i.e., rectification, amplification and switching.

Chip (sometimes called die): A tiny piece of semiconductor material, broken from a semiconductor wafer, on which one or more electronic components are found.

Discrete Element: An electronic element, such as a resistor or transistor, manufactured in such a manner that it can be individually measured and transported.

Hybrid Circuit: Sometimes used to define multi-chip circuits. More often used to denote circuits made by two different processes (i.e., semiconductor and thin-film) or by a combination of integrated structures and discrete components.

Monobrid Circuits: An integrated circuit in which two or more chips, at least one of which consisting of a monolithic circuit, are interconnected in a single package.

Monolithic Integrated Circuits: An electronic circuit in which all circuit elements are fabricated and interconnected on or within a single piece of silicon.

Multichip Circuit: A form of integrated circuit in which separately manufactured, unpackaged, diffused or film components are placed on a suitable substrate and interconnected either by means of a metallization pattern or by conventional wire bonding. This type of circuit is sometimes called a hybrid circuit because separate parts of various types may be employed.

Passive Elements: Electronic components, such as resistors and capacitors, which simply introduce resistance or reactance into an electrical circuit but cannot change the waveform of an applied sinewave.

Substrate: The basic material on or within which the components of an integrated circuit are fabricated.

Wafer: A thin slice of semiconductor material (silicon, in integrated circuits), most often round and about 1 to 2 inches in diameter, on which integrated circuits and other semiconductor devices are fabricated.

Chapter 2

RELATED INFORMATION

Historical Information

Integrated Circuits (ICs) are improved transistors belonging to the family of semiconductors. Therefore, it would be worthwhile to begin this chapter with transistors, since the invention of the transistor marked the beginning of the semiconductor industry.

The transistor was invented in 1948 by Shockley, Bardeen and Bratten at the Bell Laboratories. It was a remarkable invention. It was a solid state device that could do almost anything a vacuum tube could. The transistor was also strong in many areas where the tube was weak; it was very small and potentially reliable and inexpensive.

A semiconductor device is one in which the basic material used to make the transistor has electrical properties somewhere between glass, a non-conductor, and a metal, a pure conductor. Silicon is one material which has the necessary half non-conductor/conductor characteristics. Since the transistor is a semiconductor, it moves electrical elements or electrons from one area to another without requiring much power and thus generating significant amounts of heat.

The transistor replaced the unreliable, heat-generating electronic tubes. Replacement of tube-type radios, TV receivers, and hi-fi sets with semiconductor equipment has saved up to 80% of the energy consumed by these entertainment devices. In this way electronics has helped the conservation of energy since then (Frye, April 1974, p. 9).

Small size had for some time been desired in the electronics industry because complex systems needed to be light and portable. The transistor was the solution with its great reduction in size. The first computer, for example, contained 19,000 electronic tubes and occupied a large room. The transistor initiated the age of microelectronics wich evolved to today's hand-held computer (The Inside Story on Integrated Circuits, 1972, p. 1).

One is all familiar with the results of the transistor's appearance on the electronics scene. The inexpensive pocket radio, so popular today, is the result of the transistor, as is the success (in spite of television) of the radio broadcasting business (Hamer and Biggers, 1972, p. 8).

By 1960, the industry had come to still another impasse. Some of the new systems had so many components that, no matter how carefully they were connected, a loose wire, a crossed connection, or some other similar mistake was bound to occur, thus preventing the system from functioning. This problem was overcome by the invention of the Integrated Circuit by Jack S. Kilby of Texas Instruments in 1958. The IC eliminated the need for masses of separate transistors and a multitude of mechanical connections in an electrical system. Kilby was awarded the National Medal of Science in 1969 as a result of this invention (Turner, 1971, p. 7). Very shortly after Kilby's invention, a major improvement in technique was introduced by Noyce and his co-workers at Fairchild Semiconductor Components Group. With the Fairchild development, the basic form of the monolithic IC was established. There is controversy about which of the two -Noyce or Kilby- was the actual inventor of the integrated circuit. The matter is in the courts, where decisions have been made and reserved, with appeals continuing (Hamer and Biggers, 1972, p. 14).

About the middle of 1961, silicon monolithic microcircuits were introduced to the electronics industry by the Fairchild Semiconductor Corp. Since that time, there have been considerable advances in the technology of integrated circuits and these devices have gain wide acceptance by the industry (Kile, 1967, p. 3).

In the integrated circuit, all the components of an electronic circuit are "integrated" or manufactured, at the same time within a piece of semiconductor material, ordinarily silicon, that is between 1/20 to 1/10 of an inch square. It is evident that this new innovation greatly reduced the number of components needed to build equipment. The IC also has all of the advantages of the transistor since it is also a semiconductor.

Integrated circuit technology has expanded rapidly over the past few years to include more and more of the electronic discrete components onto the "chip" of silicon. A discrete component is an electronic element, such as a resistor or transistor, manufactured in such a manner that it can be individually measured and transported.

The reliability of ICs was dramatically illustrated in the Apollo moon landings. Integrated circuits were used in the guidance systems, computing equipment, life support backpack and other support equipment (The Inside Story on Integrated Circuits, 1972, p. 2)

The integrated circuit has brought the following changes in the electronics industry:

1. The same technology in making ICs is used by all manufacturers. ICs are made by technologies very different from those that are familiar to the older component makers.

2. The "assembly" (put components together) is being done differently—via diffusion, vacuum evaporations, and screen printing rather than with soldering iron and nimble-fingered girls.

3. Overlapping of technologies has increased. Before the invention of the IC, the technologies of making components, assembling them, and designing the equipment had little to do with one another. People who made components did not need to know how the components worked or what they were used for. The assembler was not concerned with the technology of making components, but worried only about having them when he needed them. To the designer, the

components were abstract symbols. This is completely different when ICs are being made. The user or the maker of ICs must have technological capabilities across the board. The circuit designer now becomes the focal point of a team that must become almost as integrated as the circuits themselves. Not only must he acquaint himself with the various fabrication procedures for integrated circuit parts, since parts made by different methods exhibit different electrical characteristics, but he must also be thoroughly familiar with the end product (Stern, 1968, p. 14).

The separation of technologies of the "old days" and the overlap of today's IC era are illustrated in Figure 1 (Hamer and Biggers, 1972, p. 12).

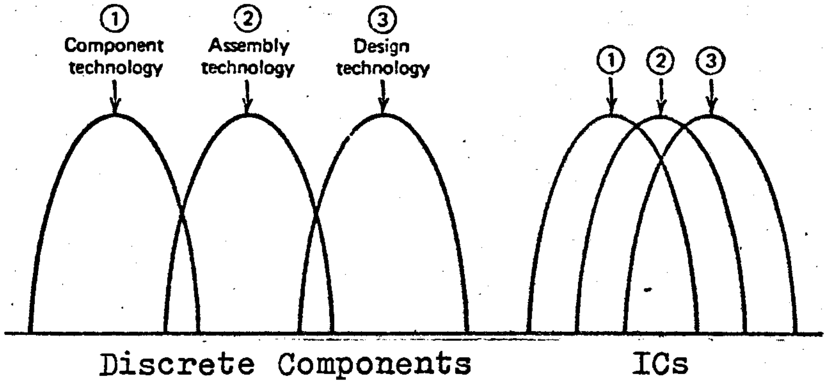


Figure 1

Changes in Technological Overlap

(Hamer and Biggers, 1972, p. 12)

In the late forties and early fifties the makers of ceramic capacitors were pursuing another approach to the integration of electronic circuits that would eventually evolve into what it is referred to as the thick film IC (circuits fabricated utilizing the deposition of material having an approximate 0.5-mil thickness. Examples: stainless steel-screened circuits or etched cermet circuits). This approach is based on screen printing and uses "fired-on" materials for making components. With these thick film circuits it is possible to get a fair degree of integration of passive devices. In silicon monolithic ICs there are limitations in these components.

Centralab Division of Globe Union pioneered these thick film devices and deserves a large share of the credit for starting technologies that eventually developed into today's thick film hybrid IC technology. Other companies which developed the thick film IC were CTS, Sprague, DuPont, and IBM.

A third approach to integration has been that of thin-film ICs. Thin-film IC is a circuit fabricated by the deposition of material of several thousand Angstroms in thickness. Example: a circuit fabricated by vapor-deposition. These ICs have about the same capabilities as do thick film ICs. Also, the same disadvantage exists -no active device capability is in the process.

Another type of Ic is the hybrid (an IC utilizing a combination of techniques such as diffused monolithic, thin-film elements and discrete devices) or, more generally, a multi-chip circuit. This hybrid IC is not a monolithic device. Rather, it is composed of individual parts, made either by film or diffusion processes. The hybrid IC is particulary useful for applications where only a small number of identical circuits are required -principally for economic reasons.

The latest development on ICs has been the MOS/LSI (Metal-oxide semiconductor/Large scale integration) by the scientists at North American Rockwell Company (NRMEC) around 1965.

LSI circuits are electronically dense, solid-state devices. Compared with conventional semiconductors, LSI circuits increase the repair-free service life, enlarge the work capacity, and reduce the cost of electronic systems. Large Scale Integration identifies the highest level of density of electronic elements in an integrated circuit. NRMEC defines an LSI circuit as one containig 500 or more transistors in a "chip" typically one-tenth of an inch square, or an electronic element density of greater than 50,000 transistors per square inch (The Economics of Change, 1973, p. 11).

Industrial-Geographical Information

Cedar Falls manufacturers and users of ICs. There are neither manufacturers nor known Cedar Falls users of ICs. Most people who work in electronics are only distributors or have workshops and these people only replace ICs, mostly in color TVs.

Iowa users. According to Thomas Register of American Manufacturing, 1972-73, there are no manufacturers of ICs in Iowa. There is only one user which is Collins Radio Co. in Cedar Rapids. Figure 2 shows its location. The rest fall into the same category as the Cedar Falls users.

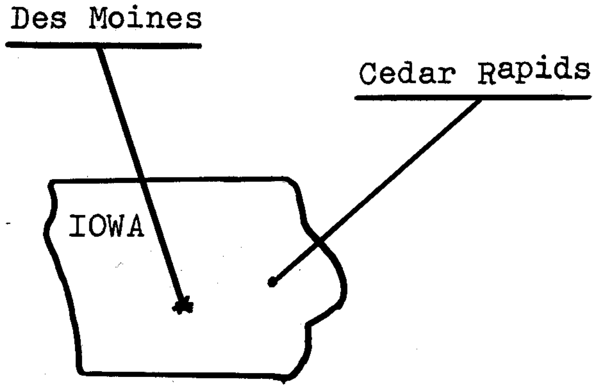


Figure 2

Location of Cedar Rapids

National manufacturers and users of ICs. Electronics manufacturing plants of ICs are located in nearly every state, but the majority of these plants are in eight states: California, New York, New Jersey, Illinois, Massachusetts, Ohio, Pennsylvania, and Indiana. Figure 3 shows the locations of some industries using and manufacturing ICs. Appendix A (p. 99) shows the complete list of these industries which have a minimum total tangible asset of $1,000,000 (Thomas Register of American Manufacturing, 1972-73, p. 1).

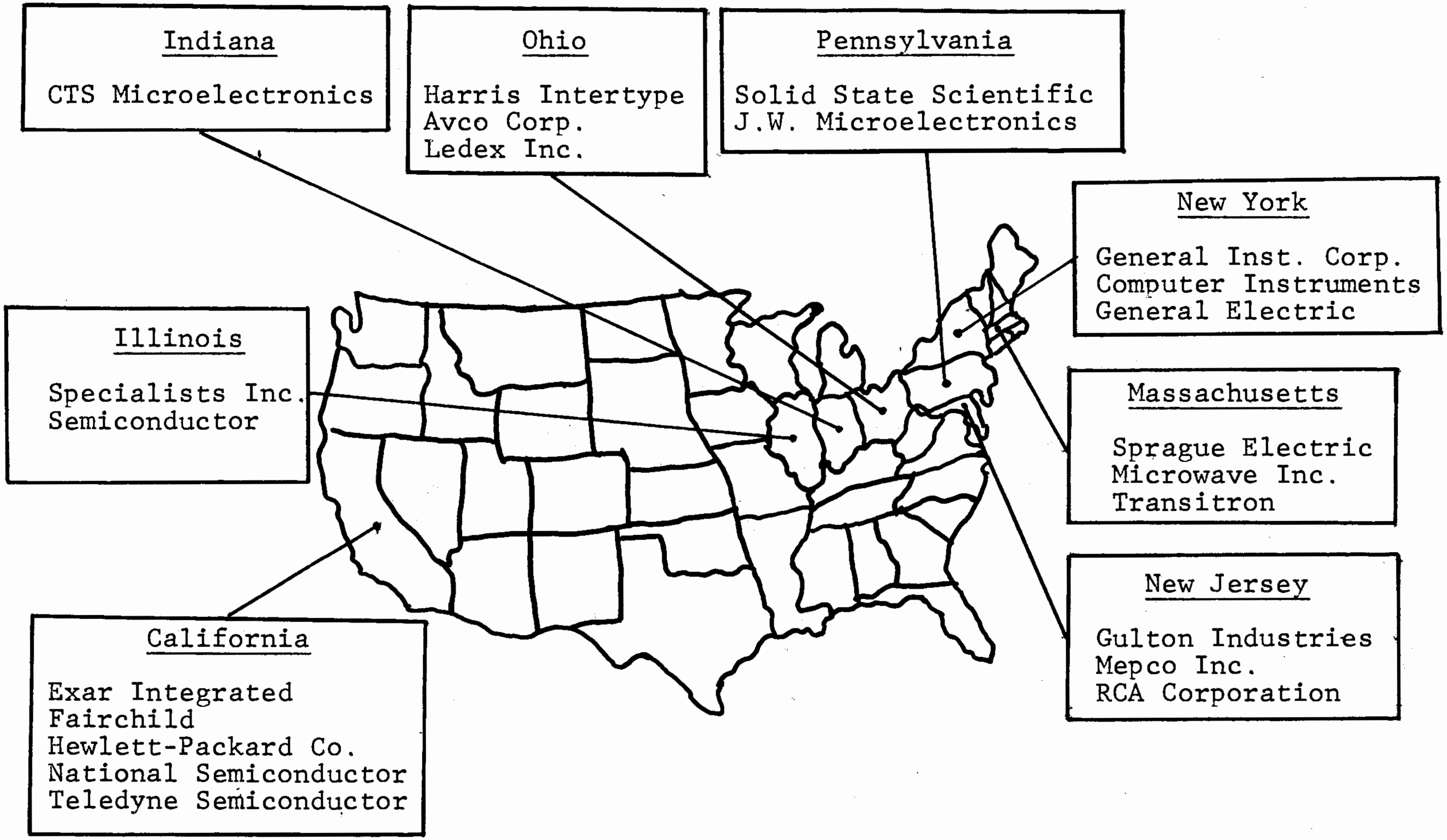


Figure 3

Location of some Industries Manufacturing and Using ICs in the United States

Worldwide manufacturers. Almost all worldwide manufacturers of ICs are subsidiaries of North American Companies. Four of the biggest companies are: Fairchild Camera & Instruments Corp., Motorola Inc., RCA Corporation, and Texas Instruments Inc. Table 1 shows which company and/or companies have factories manufacturing ICs in the listed countries. Figure 4 is a map siting locations of the above mentioned companies in accordance with Table 1.

Career Information

Electronics products may be grouped into four major categories:

1. Government products: electronic guidance and telemetering systems for missiles and space-craft; radar and other detection devices.
2. Industrial products: computers; commercial radio and television broadcasting equipment.
3. Consumer products: television sets, radios, phonograps, tape recorders, and hearing aids.
4. Components: tubes; semiconductors, transistors and integrated circuits; and "other components" as capacitors, antennas, resistors, and electronic switches.

In 1970, an estimated 1.1 million workers were employed in electronics manufacturing in a wide range of occupations. Of these workers, about three-fifths -670,000 worked in plants producing end products. About 355,000 produced military and space equipment; 200,000 produced industrial and commercial products; and 115,000 produced

Table 1

Worldwide Manufacturers of ICs

Continents	Countries	Fairchild	Mot.	RCA	Texas Inst.
Asia	Hong Kong	x			
	Japan		x		
	Korea	x	x		
	Singapore	x			x
	Taiwan		x	x	x
	Tokyo				x
Australia	Australia	x	x	x	x
Europe	Austria	x			
	Belgium		x	x	
	England		x	x	x
	France	x	x	x	x
	Germany	x	x	x	x
	Holland				x
	Italy	x		x	x
	Spain			x	
	Switz		x		
Middle East	Israel		x		
North America	Canada		x		x
	Mexico	x	x	x	x
	Puerto Rico		x	x	
South America	Argentina			x	x
	Brazil		x	x	

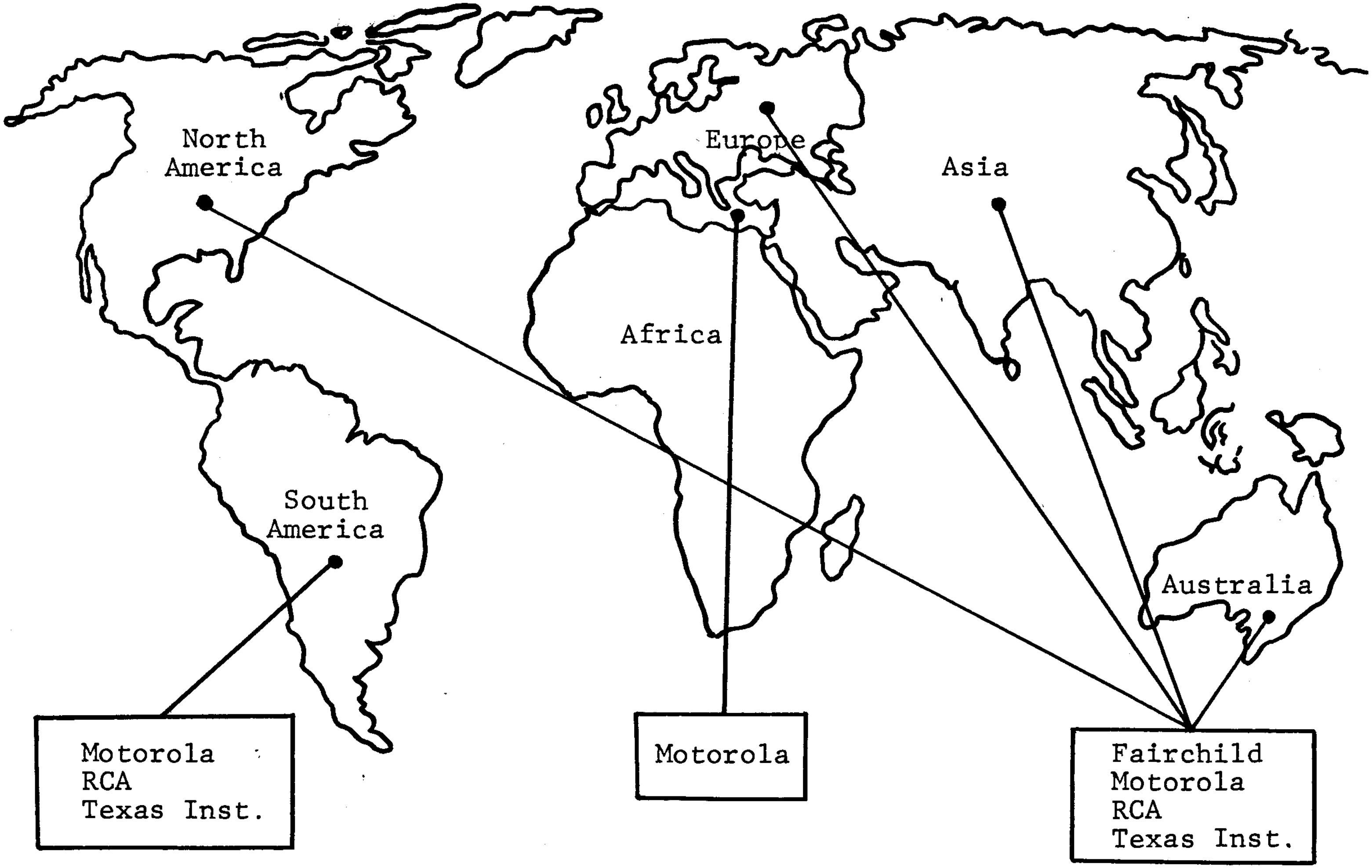


Figure 4

Location of the IC Manufacturing Companies over the World consumer items. The remaining 405,000 workers were in plants making electronic components. In addition to the employees in electronics manufacturing plants, about 80,000 electronics workers were employed by the Federal Government in activities such as research, development, and the negotiation and administration of contracts.

A very rapid increase in employment is anticipated through the 1970's. Job opportunities are expected to be particularly favorable for engineers, scientists, technicians, and skilled maintence workers (Occupational Outlook Handbook, 1972-73, p. 651).

Electronics manufacturing occupations. Although integrated circuits have made obsolete a number of job classifications currently in demand, they have created an unprecedented need for physicists, mathematicians, metallurgists, chemists, and semiconductor engineers (Stern, 1968, p. 14).

Professional and technical occupations. A large proportion of electronics manufacturing workers are in engineering, scientific, and other technical jobs. Engineers and scientists alone represent about 1 out of every 9 electronics workers. Electronics technicians represent 1 out of every 20 electronics manufacturing workers (Occupational Outlook Handbook, 1972-73, p. 653).

Electrical or electronics engineers are the largest group of engineers. They work in research and development, although many work in production operations as design engineers or as test methods and quality control engineers. Electronics engineers also work as field engineers, sales engineers, or engineering liaison men.

Mechanical engineers work as design engineers in product development and in tool and equipment design. Industrial engineers are employed to work as production engineers, methods, or time-study engineers. Other engineers employed in Electronics manufacturing include chemical, metallurgical, and ceramic engineers.

Physicists make up a large group of scientists in electronics manufacturing. They work mainly in the development of microminiaturization to produce the complete circuit (integrated circuit). Many scientists are chemists and metallurgists who are employed in research work and in materials preparation and testing. Mathematicians and statisticians work with engineers and scientists on complex mathematical problems, especially in the design of military and space equipment and computers.

Technicians are classified as electronics technicians, draftsmen, engineering aids, laboratory technicians, mathematical assistants, technical writers, and technical illustrators.

Electronics technicians are engaged in research and development work, helping engineers in the design and construction of experimental models. They are also employed by manufacturers to work on electronic equipment in customers' establishments. Other electronics technicians work in highly technical inspecting, testing, and assembly jobs in the engineering laboratories of firms manufacturing electronic products.

Draftsmen work in preparing drawings from sketches or specifications furnished by engineers.

Engineering aids are employed to assist engineers by making calculations, sketches, drawings, and by conducting performance tests on components and systems.

Laboratory technicians help physicists, chemists, and engineers by performing duties; such as, setting up apparatus and assisting in laboratory analyses and experiments.

Mathematical assistants help to solve mathematical problems, following procedures outlined by mathematicians.

Technical writers prepare training and technical manuals describing the operation and maintenance of electronic equipment. They also prepare catalogs, product literature, project reports and proposals.

Technical illustrators draw pictures of electronic equipment for technical publications and sales literature.

Plant occupations. About half of electronics manufacturing employees work in assembly, inspecting, testing and maintenance occupations.

a. Assembly occupations. Assemblers make up the largest group of electronics plant workers. Most of them are semi-skilled workers.

Most end products are assembled mainly by hand, using small hand-tools, soldering irons, and light welding devices. Machines are used in some assembly work on end products. For example, in putting together subassemblies such as circuit boards, automatic machines often are used to position components on the boards and to solder components. Here the assemblers work as machine operators or loaders.

The assembly of semiconductors is made by highly complex machines and some of them are automatically controlled.

Most assemblers are women. They are employed mainly as machine operators or tenders, and as hand assemblers of items made in large quantities. Men are employed in assembly jobs requiring relatively heavy work and as "trouble-shooters."

b. Testing and inspection. Testing and inspection in electronics manufacturing begins when **raw materials** enter the plants and continue throughout fabricating operations.

In end-product manufacturing plants, testers use voltmeters, oscilloscopes, and other test meters to make certain that components, subassemblies, and end products conform to specifications. Some testing jobs require technically trained workers who have had several years of experience in electronic testing. These jobs are commonly found in research and development work, where electronics technicians test, adjust, and align circuits and systems as part of their overall responsability.

In integrated circuits manufacturing plants, automatic equipment is used to check their characteristics, provide a punched tape of test results, throw away those which fail the test and sort the good ones into batches for shipping.

The work of inspectors in end product plants varies from checking incoming materials to inspecting subassemblies and final products for flaws in circuit assembly. Tools used by inspectors include micrometers, magnifying lenses and microscopes—as is the case of integrated circuits.

c. Maintenance occupations. Many workers are employed in electronics manufacturing plants to maintain machinery and equipment. They are mainly electricians, hydraulic mechanics, air-conditioning and refrigeration mechanics. Painters, plumbers, carpenters, sheet-metal workers, and other building maintenance craftsmen are also employed in electronics plants.

Vocational training. Electronic manufacturing plants employ many engineers, scientists and technicians because of the technical nature of plant production operations and the great emphasis on research and development work. Beginning engineering jobs usually are filled by recent graduates of engineering colleges (some with advanced degree). To keep up with new developments in their fields and to help them qualify for promotion, they must obtain additional training, read technical publications and attend lectures and technical demostrations.

Almost all mathematicians, physicists and other scientists working in electronics have college degrees, and many have advanced degrees. Job prospects are usually better for scientists who have at least a master's degree than those with only a bachelor's degree.

Technicians generally need some specialized training to qualify for their jobs. Most electronics technicians have attended either a public, private, or Armed Forces technical school. Some have obtained their training through apprenticeships, usually of 3 or 4 years' duration. Applicants with a high school education, including courses mathematics and science, are preferred for these apprenticeships.

Electronics technicians need color vision, manual dexterity, and good eye-hand coordination. They also must be able to understand technical publications.

Draftsmen usually enter their trade by taking a course in drafting at a trade or technical school. They should know basic electronic theory and circuits and the reading of electronic schematic diagrams in order to do their work efficiently.

Laboratory technicians, engineering aids, and mathematical assistants frequently have had 1 year of college training or more in a scientific or engineering field, but have not completed course requirements for a degree.

Technical writers must have a flair for writing and are usually required to have some technical training. Electronics firms prefer to hire those who have had some technical institute or college training in science or engineering. Some have a college engineering degree. Many have college degrees in English and journalism and have received their technical training on the job and by attending company-operated evening classes.

Technical illustrators usually have attended special schools of art or design.

Formal training in electronics usually is not necessary for workers entering plant jobs, but completion of high school frequently is required. Job applicants may have to pass aptitude tests and demonstrate skill for particular types of work. On-the-job training, usually for a short period, generally is provided for workers who have had no previous experience. Assemblers, testers, and inspectors need good vision, good color perception, manual dexterity, and patience.

Employment outlook. Employment of engineers, scientists, and technicians is expected to increase faster than total employment because of continued high expenditures for research and development, and the continuing trend toward the production of complex equipment (Occupational Outlook Handbook, 1972-73, p. 658).

It is estimated that more than 32,000 of these workers will be needed annually through the 1970's, just to replace those who retire, die, or enter other occupations, but that the ratio of technicians to engineers and scientists will be 5 to 1 (Encyclopedia of Careers and Vocatioal Guidance, 1972, p. 93).

On the other hand, employment of semi-skilled workers probably will rise at a slower rate because of the growing mechanization and automation of assembly line operations (Occupational Outlook Handbook, 1972-73, p. 658).

Earnings. The average annual salary of electrical and electronics engineers is $10,400. Beginning engineers with a bachelor's degree start at $8,500; those with a Masters's degree start at $10,528; and those with a doctorate degree start at $16,000 (Occupational Outlook Hanbook, 1972-73, p. 66).

Salaries for technicians vary considerably depending upon their education, experience and specializing area. In general, however, average annual starting salaries for graduates of post-high school technical programs are $6,000 in industry and from $4,600 to $5,500 in the federal government in the early 1970's. Those with less formal training earn somewhat less (Encyclopedia of Careers and Vocational Guidance, vol. 2, 1972, p. 94).

The wages for assembliers vary from $2.80 per hour to $3.36 per hour depending on skill level and experience, length of service, geographic location, and amount of overtime (Occupational Outlook Handbook, 1972-73, p. 658).

Working conditions. Integrated circuits manufacturing plants are usually well lighted, clean, and quiet. Many plants are relatively new and are located in suburban and semirural areas. These plants have air conditioned where dust-free conditions or air temperature control is necessary for the manufacture of ICs. The work is not strenuous and some electronics manufacturing firms provide music during working hours, cafeterias, recreational facilities, and social programs for employees (Occupational Outlook Handbook, 1972-73, p. 659).

The frequency of injuries in electronics manufacturing is far below the average in manufacturing as a whole, and injuries are usually less severe.

Electronics workers are covered by the same health, life insurance, vacation, and sick leave programs as other employees.

The working schedule of electrical engineers and technicians is the regular 40-hour week on a five-day basis; however, it varies with the position and the type of project undertaken (Modern Vocational Trends Reference Book, 1970, p. 558).

As was stated previously, assembliers in manufacturing plants earn hourly and they receive premium pay for overtime work on Sundays and holidays. Virtually all plants provide extra pay for evening and night shift work (Occupational Outlook Handbook, 1972-73, p. 658).

Chapter 3

FINANCIAL TRENDS

The integrated circuits (ICs) sector is the most dynamic and sustainable growth in the entire electronic components market. Figure 4 shows the sales growth of integrated circuits in comparison with tubes and transistors. Note the fast growth of the discrete semiconductor (transistors and ICs). In only a decade the growth topped out, however, nipped, of course, by the integrated circuit.

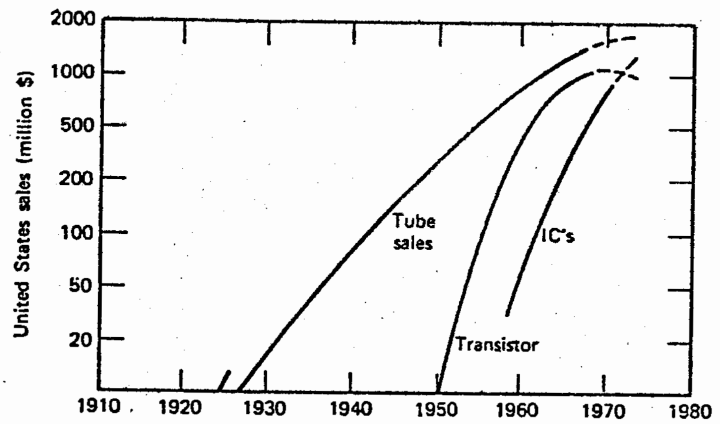


Figure 4

The Sales Growth of Integrated Circuits, Tubes, and Transistors

(Hamer and Biggers, 1972, p. 9)

Total dollar sales of monolithic integrated circuits rose from $534 million in 1971 to $718 million in 1972, which means an increase of 37%. The gain for 1973 is currently projected at 30% (Electronics-Electrical Basic Analysis, Sep. 1973, p. E37).

The 37% increase in unit sales in 1972 reflected a continuation of the recovery from the recessionary levels, and substantially higher demand by certain equipment manufacturers such as computer and calculator groups.

Linear integrated circuits; used widely in hi-fi, television, communication devices, and test instruments; should grow some 35% to 40% in 1973, following a 40% gain in 1972. These devices continue to increase their market base, finding applications in hundreds of new products each year.

Sales of MOS IC (Metal-Oxide Semiconductor)—used primarily in desktop and pocket calculators—were about $150 million in 1972, some 56% over the prior year. Another similar gain to about $235 million is projected for 1973, again based on the popularity of these calculators (Electronics-Electrical Basic Analysis, Sep. 1973, p. E38).

The IC Industry Today

The electronics industry has been in a ferment for twenty years because of the transistor and the IC. One now looks at the effects these technological innovations have had, both on the electronics industry itself and on the newly established "IC industry."

Figure 5 shows recent sales figures in the United States electronics industry and Figure 6 shows IC sales trends.

	1968	1969	1970	1971	1974
Government	10.7	10.7	10.6	10.0	12.5
Consumer	4.2	4.6	3.9	4.2	5.3
Industrial	8.3	9.5	10.1	10.2	13.7
Total	23.2	24.8	24.6	24.4	31.5

Figure 5

United States Electronics Sales (Billion $)

(Hamer and Biggers, 1972, p. 22)

	Monolithic ICs			Hybrid ICs			
Year	Factory Sales	In-house Production	Total	Factory Sales	In-house Production	Total	Grand Total
1965	70	10	80	30	280	310	390
1969	400	100	500	80	330	410	910
1973	730	320	1050	220	390	610	1660
1979	1050	490	1540	360	520	880	2420

Figure 6

IC Sales Trend (Million $)

(Hamer and Biggers, 1972, p. 22)

These figures show that the sales of ICs are not necessarily following the overall industry trends. The projected IC industry growth between 1969 and 1973 is 82%, whereas the estimate of growth for the entire electronics industry between 1969 and 1974 (one additional year) is only 27%. This growth differential exists because 1) conventional components are being replaced by ICs, 2) IC elements save assembly labor, and 3) ICs are allowing new kinds of electronic equipment to be produced that cannot be produced conventionally (Hamer and Biggers, 1972, pp. 22-23).

The writer has chosen the four companies prominent in the over-all semiconductor field in order to explain the possibilities for investment and the effect of the IC industry on employment and as a consumer. These companies are: Fairchild, Motorola, RCA Corporation, and Texas Instruments. Table 2 shows data from 1969 to 1973 regarding Net Sales, Net Income, and Earned Per Share; and from 1968 to 1972 regarding Number of Shares and Number of Employees (Moody's Industrials, 1973) backed by (Electronics-Electrical Basic Analysis, Sep. 1974, p. E5).

According to this Table the companies appear to have a stable if not rising trend. For the stock market investor, this seems to be a wise area in which to invest because the earnings per share are going up and the number of shares sold is greater. However, it would be better to seek the assistance of a stock brokerage in selecting the company. With the advent of integrated circuits the net income and sales are increasing and the employment rate is going up.

Table 2

Annual Report of Major IC Manufacturing Companies

	Year	Fairchild	Motorola	RCA Corp.	Texas Instruments
Net Sales	1973	$351,200,000	$1,437,100,000	$4,280,700,000	$1,287,300,000
	1972	223,896,000	1,163,315,000	3,838,180,000	943,694,000
	1971	193,088,000	926,592,871	3,529,771,000	764,258,000
	1970	219,138,000	796,418,521	3,317,271,000	827,641,000
	1969	314,793,859	873,224,220	3,405,583,000	831,822,000
Net Income	1973	$41,200,000	$82,000,000	$183,700,000	$83,200,000
	1972	11,026,000	52,038,000	158,104,000	48,030,000
	1971	7,841,000	31,749,944	155,850,000	33,723,000
	1970	2,696,000	24,240,440	91,349,000	29,861,000
	1969	13,138,407	33,792,573	159,832,000	33,511,000
Earned Per Share	1973	$5.12	$2.95	$2.39	$3.67
	1972	2.26	1.91	2.05	2.17
	1971	1.79	1.18	1.20	1.53
	1970	0.62	0.97	1.16	1.36
	1969	2.88	1.57	2.11	1.58
Number of Shares	1972	4,979,476	13,785,488	74,440,000	11,088,815
	1971	4,387,620	13,480,798	74,308,338	11,050,701
	1970	4,376,373	13,342,666	73,993,132	11,035,108
	1969	4,558,533	6,651,953	73,653,371	11,034,223
	1968	4,551,261	6,148,371	73,264,553	10,940,190
Number of Employees	1972	18,866	56,000	121,000	55,934
	1971	15,144	49,000	118,000	47,259
	1970	14,074	36,000	130,000	44,752
	1969	23,125	44,700	128,000	58,974
	1968	20,867	41,000	125,000	46,747

Chapter 4

TECHNICAL INFORMATION

The integrated circuit, or more commonly known in the electronics industry as simply the IC—it's been called the mighty midget, the electronics wonder, a miracle of modern American technology—perhaps is the most significant accomplishment of scientific and engineering ingenuity to date. "It's the very heart of the handheld electronic calculator—the modern day mathematical genius that's becoming extremely popular in all walks of life" (The IC: Heart of the Electronic Calculator and Key to Electronics Pervasiveness, 1974, p. 1).

The integrated circuit is an enormous bundle of task-performing circuitry packed in a ridiculously small chip of mirror—like material called silicon—something so minute and light that it can be blown away in a moderate breeze. For size reference, an IC is about as small as a baby's fingernail.

An IC in simplest terms is a tiny electronic device which incorporates an amazing amount of electronic functional capability. One IC can do the job of thousands of transistors, like the "calculator-on-a-chip" made by Texas Instruments. This IC, measuring less than a quarter of an inch square, contains the equivalent of over 6000 transistors and has all the electronics necessary for computing mathematical problems. See Figure 7.

Besides the calculator, other applications of the IC include: hearing aids, television, radio, automobiles, data processing equipment, wristwatches, small and large computers for industry, business, and space programs, and the list goes on.

The IC belongs to the family of semiconductors which includes transistors and diodes. All are similar in size and in the way they're fabricated. Only as the name implies, the integrated circuit has considerably more electronics functions integrated on practically the same small area as the transistor.

Basically, an IC measures and controls the flow of electrical current, and this enables IC of various types to control the performance of all kinds of electronics equipment.

The integrated circuit does not require many more manufacturing steps that an individual transistor. The difference is that individual transistors must be handled independently—tested, packaged, shipped, placed in circuit boards, soldered, and so forth. When all those assembly steps are multiplied by thousands, the tremendous economic leverage becomes extremely apparent. There are enormous reliability, size, weight, and functional advantages by integrating the electronic functions as the integrated circuit.

Figure 7

MOS/LSI containing more than 6000 Transistors

(Courtesy of Texas Instruments, Inc.)

Thus, the economic impetus behind more and better electronic products at ever decreasing costs is found in the integrated circuit technology itself (Electronics Pervasiveness, Opening New Horizons, 1974, pp. 1-2).

Classification of Integrated Circuits

There are many ways of classifying ICs. The most useful ones are:

1. according to construction
2. according to operating mode
3. according to packaging

According to construction. Depending upon construction, integrated circuits are divided into two major categories: monolithic and hybrid types as in Figure 8.

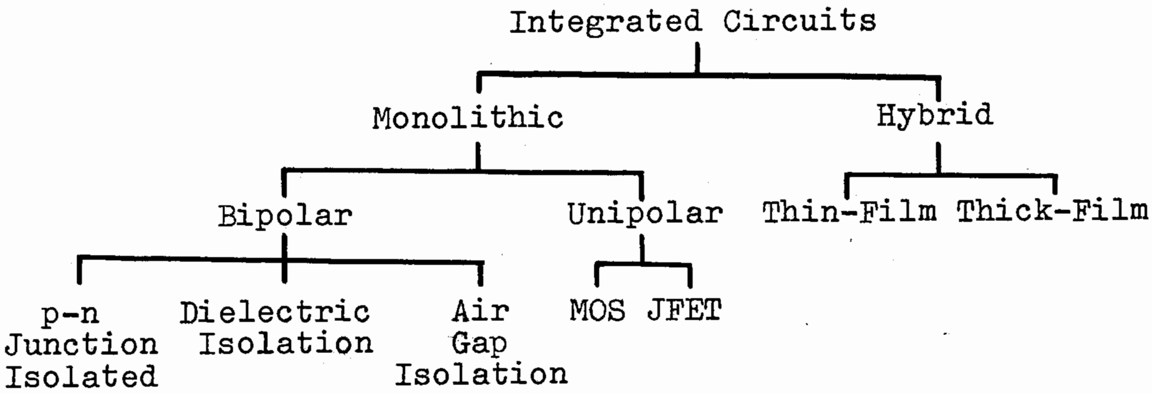


Figure 8

Classification of Integrated Circuits According to Construction

(Hnatek, 1973, p. 2)

The term "monolithic" describes an IC construction in which all the components and interconnections are formed in a single chip or wafer of silicon. Monolithic ICs can be subdivided into bipolar and unipolar types. Bipolar ICs require charge carriers of both positive and negative polarities for operation of the active elements. Unipolar ICs require only one of those polarities ("hole" or electron).

Bipolar ICs include diodes, npn or pnp transistors and related devices such as silicon-controlled rectifiers (SCRs). Unipolar ICs include various types of field-effect transistors (FETs). Bipolar ICs can be further divided into three categories according to isolation.

Unipolar monolithic ICs are divided into metal-oxide semiconductor (MOS) and junction field-effect transistor (JFET) categories, according to the type of FET made. The FET is a type of semiconductor in which the output current is controlled by an electrical field.

Moving to the right side of Figure 8, the reader can see that hybrid integrated circuits are divided into two categories—thin film and thick film ICs. (See pp. 54-55 for further information).

Sometimes the previously mentioned types can be combined to form mono-brid ICs to improve the passive components.

<u>According to operating mode</u>. Depending upon the mode of operation, ICs are divided as: a) linear and

b) digital.

Linear integrated circuits perform analog functions. They amplify, regulate or compare electrical signals. They can be used as: AF amplifier, differential amplifier, Darlington amplifier, i-f amplifier, operational amplifier, power amplifier, video amplifier, voltage comparator, and voltage regulator.

Digital ICs perform mathematical or logic type functions. The "inputs" of a digital circuit receive electrical signals, count, divide, add, store, decode or perform some other finite type function. Digital ICs are commonly identified by acronyms such as TTL (transistor-transistor logic), DTL (diode-transistor logic, or MOS (metal-oxide semiconductor), (The Inside Story on Integrated Circuits, 1972, p. 11).

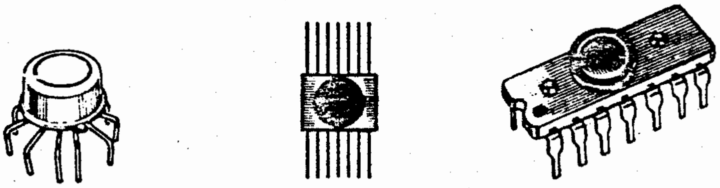
According to packaging. Depending on packaging, the covering which encloses the IC, ICs are divided into: a) TO-5 type, b) flat-pack, and c) dual in-line. See Figure 9 (Turner, 1971, p. 17).

The small TO-5 type cans (Figures 9A, B, C, and D) resemble small-signal transistors and are of the same size. The flat-pack type (Figure 9E) resembles somewhat the old plastic-molded resistor-capacitor networks. The dual in-line packages (ceramic: Figure 9F and plastic: Figure 9G) are "new looks" in electronic components and are tiny units.

(*A*) *TO-5 type, 8 lead.*

(*B*) *TO-5 type, 10 lead.*

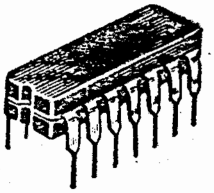
(*C*) *TO-5 type, 12 lead.*



(*D*) *TO-5 type, 10 formed leads.*

(*E*) 14-lead *flat-pack.*

(*F*) *TO-116 ceramic dual in-line.*



(*G*) *14-lead plastic dual in-line.*

Figure 9

Typical IC Packages

(Turner, 1971, p. 17)

Integrated Circuits Manufacturing

There are four steps of IC manufacturing:

1. Circuit design
2. Microphotography
3. Solid state physics - materials
4. Assembly—including testing

1. Circuit design. The task of the designer is to "integrate" any electronic circuit to one IC. Figure 10 shows the audio amplifier section of an AM/FM radio transistorized and Figure 11 shows the electrical diagram of this circuit ready to be integrated.

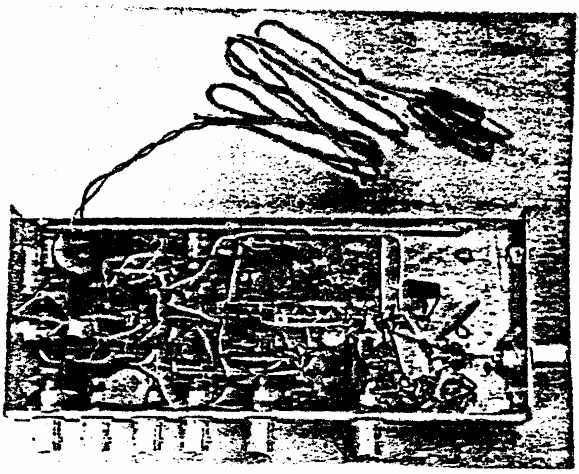


Figure 10

AM/FM Amplifier

(The Inside Story on Integrated Circuits, 1972, p. 2)

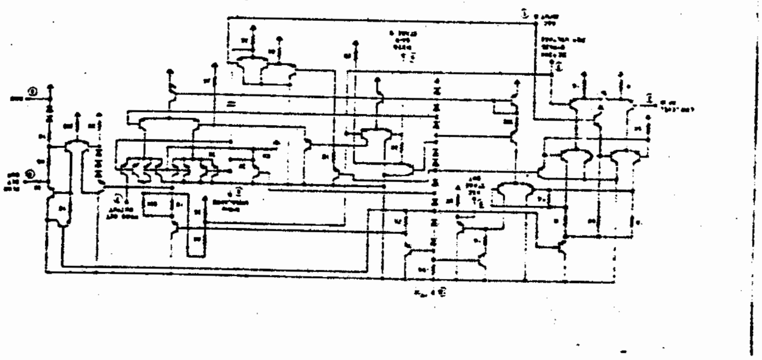


Figure 11

AM/FM Amplifier Diagram

(The Inside Story on Integrated Circuits, 1972, p. 2)

The designer, being more than that of a skillful draftsman, prepares a piece of art work called a "composite" which simulates the discrete components and interconnecting paths by representative patterns (See Figure 12). However, many IC manufacturers make the composite drawing with a computer-aided system which minimizes human error on complex IC desing.

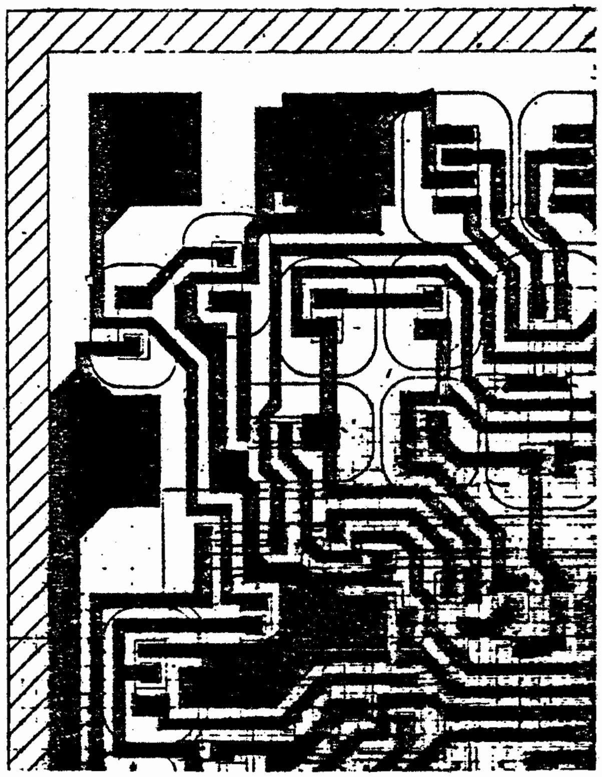


Figure 12

Audio Amplifier Section of AM/FM
Composite Drawing

(The Inside Story on Integrated Circuits, 1972, p. 3)

The electrical equivalent of all electronic components shown in Figure 11 is seen in Figure 13.

2. Microphotography. The second step in manufacturing ICs is known as "mask making." In this step the composite drawing is reconstructed in a series of drawings 30 x 30 inches square (See Figure 14) to as large as 60 x 80 inches square. Each piece of art represents discrete

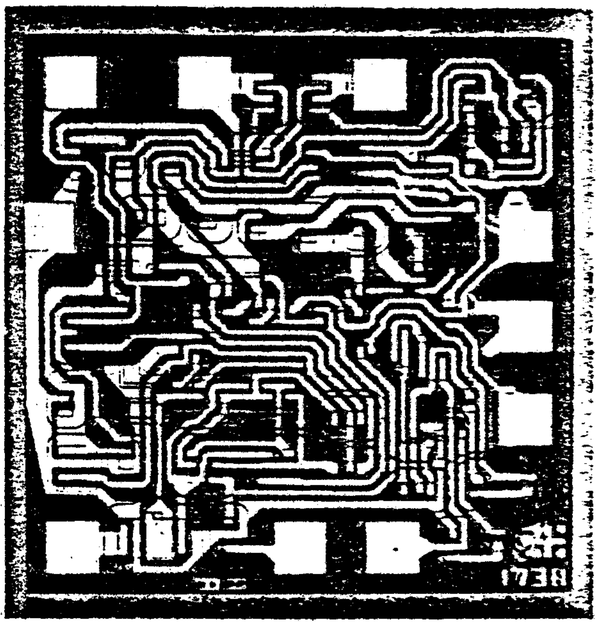


Figure 13

Audio Amplifier Section of AM/FM
Finished

(The Inside Story on Integrated Circuits, 1972, p. 3)

Figure 14

Mask of Up-Size Artwork

(The Inside Story on Integrated Circuits, 1972, p. 3) elements or parts that will be diffused into the IC. This artwork is reduced 40 times by a high precision camera onto a 2 x 2 glass plate (See Figure 15).

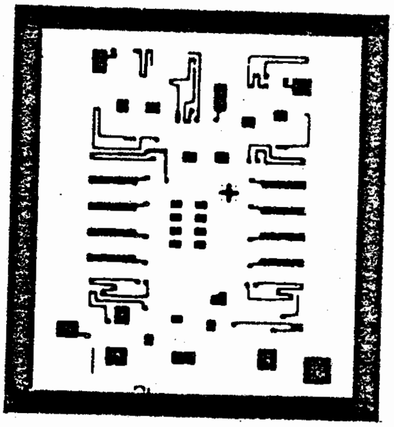


Figure 15

First Glass Plate
Reduction of
Artwork

(The Inside Story on Integrated Circuits, 1972, p. 3)

This 2 x 2 plate is again reduced as many as 1500 times, to the glass plate shown in Figure 16. Each IC will have a series of masks and thus, a series of plates—one for the diodes, one for transistors, etc. Most ICs have from 3 to 6 masks.

3. <u>Solid state physics and materials processing</u>. In this step, the writer will treat only the bipolar IC. The process of making ICs is different for each type previously described. There will be some general information on the other types of ICs later.

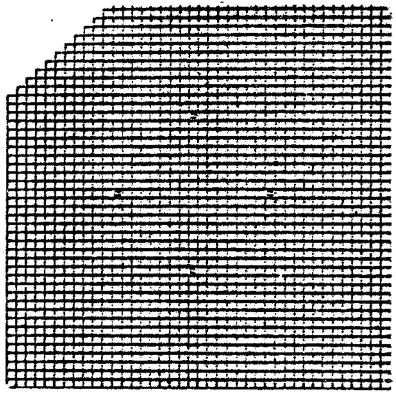


Figure 16

Step-and-Repeat of IC

(The Inside Story on Integrated Circuits, 1972, p. 3)

Silicon is the basic material used for ICs. It is "grown" into a cylinder 2 inches in diameter. This is then cut with a diamond saw into thin wafers 10 mils thick and 2 inches in diameter.

The silicon wafer processing requires four segments: a) surface preparation, b) epitaxial growth, c) diffusion, and d) metallization.

In the first segment, the wafers go through a process of polishing as seen in Figure 17. The over-all surface must be highly uniform in order to obtain good electrical perfomance.

The second segment, epitaxial growth, consists of "growing" additional semiconductor material on top of the surface of the polished wafer to assure a uniform molecular structure.

Before the third segment, diffusion, the manufac-

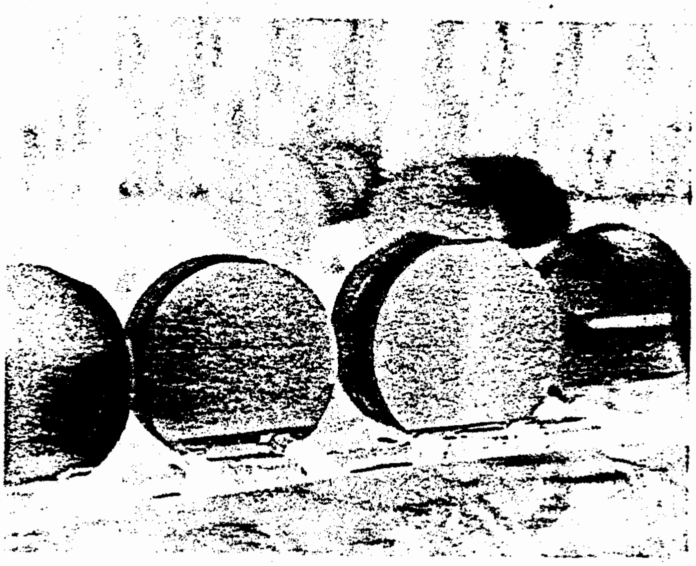


Figure 17

Silicon Wafer after Polishing

(Hnatek, 1973, p. 37)

turing process once again is coated with a photo resist or emulsion solution. The glass plate of Figure 16 is placed into the top of an "optical jig" and the wafer is placed into the bottom. All this is done in a photographic darkroom environment. The emulsion coated wafer is photographically exposed to the pattern on the glass plate by an ultra-violet light. The wafer is then "developed" and washed so that emulsion is dissolved in the exposed areas. The rest of the wafer's surface will be protected against diffusion. The wafers are then placed into a diffusion furnace (See Figure 18) to achieve the desired electrical characteristics.

These steps are repeated through each of the masking steps. The IC is constructed by a series of overlaying,

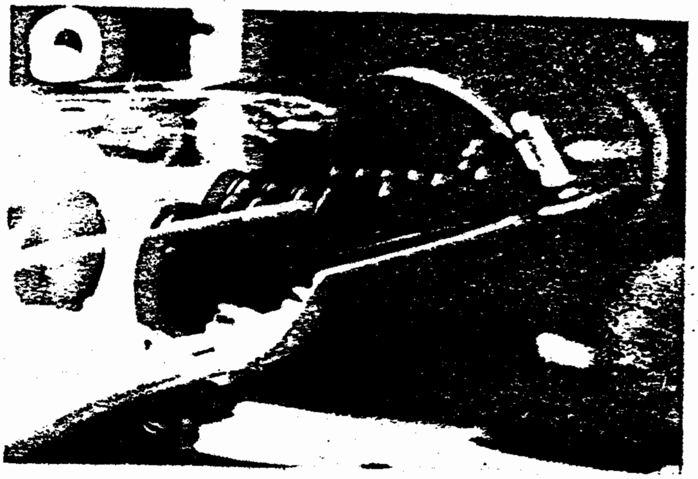


Figure 18

Wafer Diffusion
(Hnatek, 1973, p. 37)

patterns, exposure to light development, and diffusion.

In the fourth segment, communication links between the individual components on the chip are made. This is referred to as the "metal mask."

Since each wafer can contain 250 or more circuits, and many wafers are processed together, it is possible to process more than 50,000 ICs at one time. Figures 19a through 19r graphically illustrate the above process.

Figure 19a

The starting material is a slice of p-type silicon between 2 and 3 inches in diameter and a few mils thick.

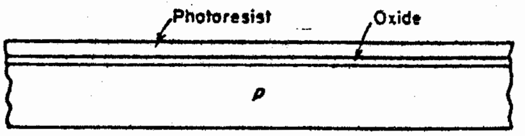


Figure 19b

First, an oxide layer is grown to protect the surface of the silicon during the ensuing operations. Next the entire surface is covered with a layer of photoresist.

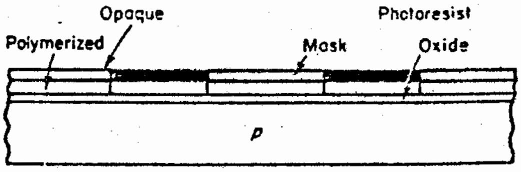


Figure 19c

Next, the mask containing the buried layer pattern is placed on top, and the photoresist is exposed to ultraviolet light. The portions of the photoresist exposed to the light polymerizes, the rest is dissolved.

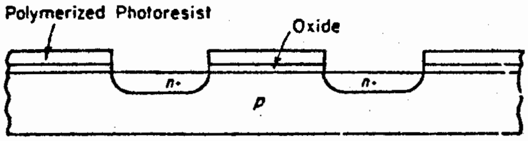


Figure 19d

The oxide that is not protected by the polymerized photoresist is etched away. N+ dopant is diffused through the windows forming the buried layer. Then the polymerized photoresist and oxide is washed away.

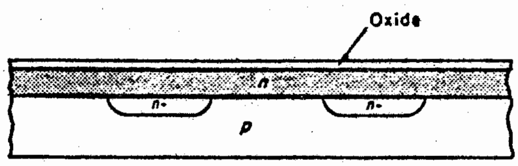


Figure 19e

A thin layer of n-type silicon is grown on the silicon in an epitaxial reactor, and a new oxide layer is grown.

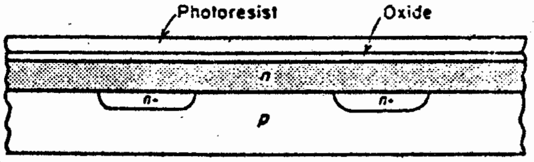


Figure 19f

The entire top surface is again covered with a layer of photoresist.

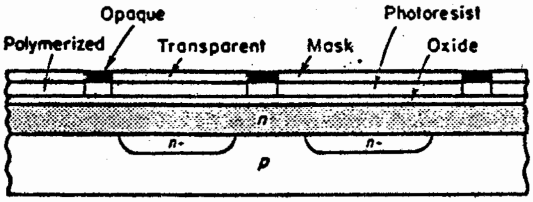


Figure 19g

The mask containing the isolation pattern is placed on top, and the photoresist is exposed to ultra-violet light. The portions of the photoresist exposed to the light polymerize; the rest can be dissolved.

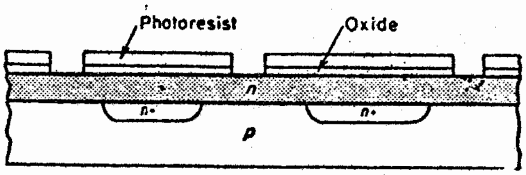


Figure 19h

The oxide that is not protected by the polymerized photoresist is etched away.

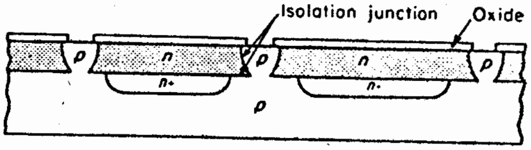


Figure 19i

P-type dopant is diffused through the windows. The diffused regions connect with the underlying p region (the substrate) and form isolation pockets in the epitaxial layer. The edge of the junction is under the oxide.

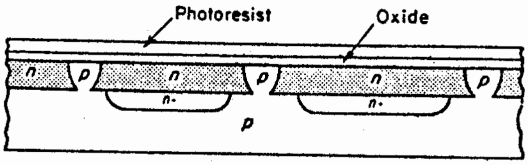


Figure 19j

The diffusion windows are closed with a new oxide layer, and the slice is again covered with photoresist.

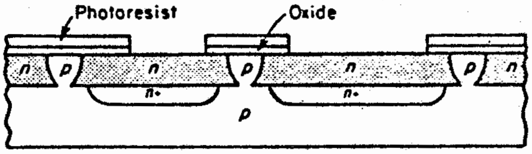


Figure 19k

The photoresist is exposed through the mask which outlines all shallow p regions, and the oxide is again etched away in the unexposed areas.

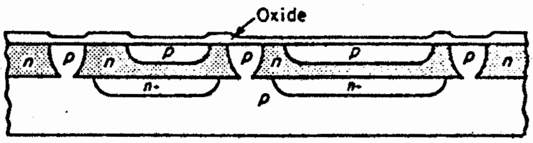


Figure 19l

P-type dopant is diffused into the unprotected regions, and the slice is covered with another oxide layer.

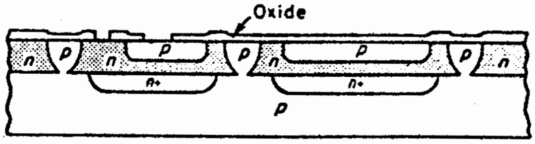


Figure 19m

Again the slice is covered with photoresist. The resist is exposed through the mask, which outlines all shallow n regions, and the oxide is etched away in the unpolymerized areas.

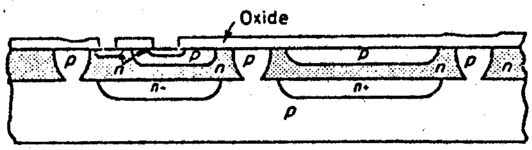


Figure 19n

A shallow layer of high n-type-dopant concentration is diffused into the unprotected areas.

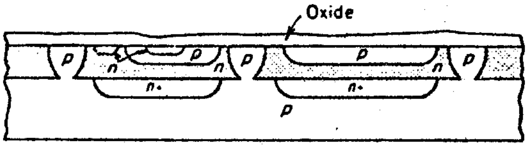


Figure 19o

Another oxide layer is grown.

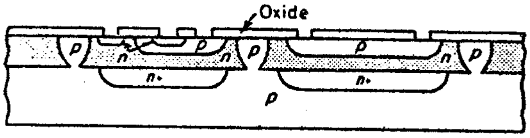


Figure 19p

The slice is covered with photoresist for the fourth time. The resist is exposed through a mask in the areas where contact to the devices must be made, and the unprotected oxide is removed.

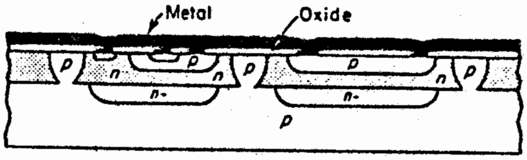


Figure 19q

The entire slice is covered with a thin metal film.

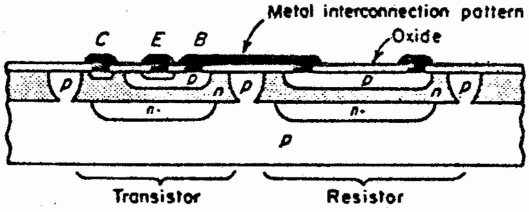


Figure 19r

With one more series of photolithographic steps, the portions of the metal layer not needed for interconnection are removed.

This process occurs <u>simultaneously</u> in each IC on the wafer. See Figures 20 and 21.

4. <u>Assembly—including testing</u>. Each circuit on the wafer is tested to see if they perform the desired function. This is made by a computer which drops a spot of ink on the IC if it fails the test. After this, the wafer is cut into the individual IC "die" or "chips". See Figure 22.

The assembly consist of covering the IC with a package to both communicate with and be protected from the outside world.

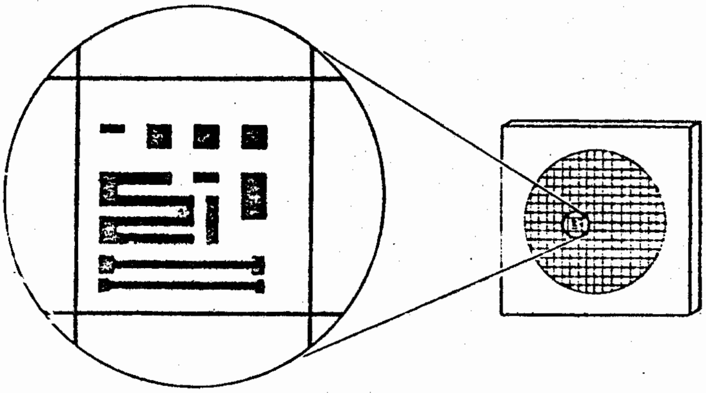


Figure 20

Photo Mask

(Hnatek, 1973, p. 29)

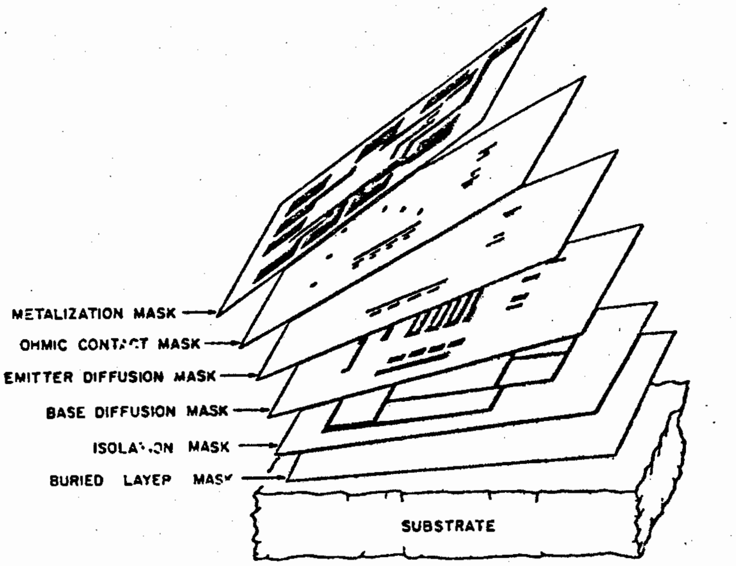


Figure 21

Application of Photolithography to Produce ICs

(Hnatek, 1973, p. 29)

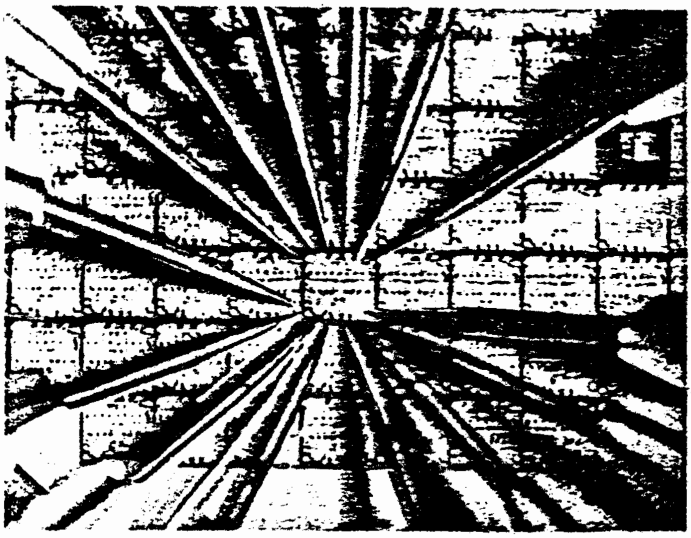


Figure 22

Computer Controlled Probes Testing
ICs on the Wafer

(The Inside Story on Integrated Circuits, 1972, p. 6)

In the following sections the advantages and disadvantages of bipolar, unipolar, thick-film, and thin-film ICs will be dicussed.

Bipolar ICs

The advantages of bipolar ICs are: 1) they are extremely inexpensive to build in large quantities 2) they are highly reliable 3) they are small and lightweight.

Bipolar ICs have as disadvantages: 1) limited range of passive components 2) limited high-frequency response 3) expensive when manufactured in small quantities.

Metal-Oxide Semiconductor (MOS)

The processing of MOS circuit wafers uses essentially the same technology required for the monolithic bipolar devices: mask making, photoetching, diffusion, oxidation, and metals processing. Although MOS technology requires fewer processing steps, tolerance requirements in each part of the process differ significantly. Most critical are surface cleanliness and accurately controlled oxide thickness because the MOS technology is surface sensitive.

MOS ICs are cheap and are used primarily in applications which require "memory" functions as: minicalculators, computers, business machines, numerical control equipment, timers, display signs and so on. Compared with monolithic bipolar ICs, MOS ICs have slower operation and lower output power. As with many different technologies, there are application areas in which the MOS structure clearly excels and there are others in which it does not compare favorably.

Thin-Film Hybrid Circuits

The thin-film technology is thus named because conductors, resistors, capacitors—and, theoretically, transistors—are prepared in the form of films only a few thousand angstroms thick. (An angstrom unit, Å, is 10^{-8} cm.) These thin films are generally put down on insulating substrates such as alumina or glass by a series of high-vacuum vapor-deposition processes.

The advantages of thin film ICs are a wider range of passive component values and improved component characteristics. However, the materials for any given circuit must be carefully selected for compatibility if low-cost mass-production is to be achieved. Another limitation is the inability of the technology to produce or fabricate active components simultaneously as bipolar ICs. In thin film ICs, the active components must be fabricated separately and attached to the thin-film network.

Thick Film Hybrid Circuits

The basic thick film processes are screen printing and ceramic firing. Passive components in thick film ICs consist of metal-oxide-glass systems. They are chemically bonded to a ceramic substrate by high temperature firing. A comparatively heavy amount of thick film material must be deposited on a substrate in order to make good conductors, resistors, and capacitors. Thick films are generally several microns thick and are less precisely controlled than thin films.

The thick film process is very straightforward and easy to grasp. This simplicity promises economic advantages ans easy technological control. However, the disadvantage is that thick film is usually restricted to resistors and conductors.

Differences Between Discrete and Integrated Circuits

Although the basic circuits used in ICs are similar to those of discrete transistors, there are certain differences. For example, inductances (coils) are never found as part of an IC. It is impossible to form a useful inductance on a material that contains transistors ans resistors. Likewise, large value capacitors (about 100 pF) are not found as part of an IC. When a large value capacitor, or an inductance of any type is a necessary part of a circuit, these components are part of the external circuit.

Integrated circuits often use direct-coupled circuits to eliminate capacitors. Transistors, such as the FET, are often used in place of resistors in IC packages.

Even though IC transistors are essentially the same as discrete transistors (except for some added capacitance produced across the substrate and transistor junctions), integrated resistors are significantly different from discrete versions. Discrete resistors are normally made in standard forms, and different values are obtained by variations in the resistivity of the material. In integrated circuits, the resistivity of the material cannot be varied. Thus, the value of the resistor depends primarily on its physical shape. An IC resistance value, R, is determined by the product of its diffusion-determined sheet or chip resistance Rs, and the ratio of its lenght L to its width W (that is, R = Rs x L/W). As a result, small-value resistors are short and squat, whereas large-value resistors are long and narrow.

The value of an integrated capacitor C is equal to the product of its area A, and the ratio of the dielectrical constant E to the thickness D of the oxide layer (that is, C = A x E/D). Because D is kept constant, capacitor values vary directly with area.

As a point of reference, a 1000-ohm IC resistor occupies about twice as much area as an IC transistor, whereas a 10-pF capacitor occupies three times the area of a transistor.

Factors to Consider in Selecting a Linear IC

1. Do not overspecify. Consider only the critical specifications or parameters on the circuit to build. The cost of the electronic circuit can be increased needlessly by including unnecessary parameters.

2. Check the safety features. Check the safety features of the IC under fault conditions (Ex.: battery introduced backwards). Actually there are ICs with short-circuit protection. It's better to use these. Ungrounded soldering irons, excessive input signals, and static discharges are all apt to challenge the input of the IC.

3. Weigh cost against performance. Select an IC by considering the overall cost—not just the inmediate cost of the chip because reducing the cost of building or maintaining the system should justify adding features to the chip cost.

Cost is an important factor during the evaluation of an IC, but performance or reliability should not be sacrificed by buying a cheap IC. Determining the overall cost is complicated and it involves guesswork, but always keep in mind the cost against performance.

4. Consider frequency compensation. Consider the number of discrete components required for frequency compensation because they increase the space and the assembly cost. The IC should be evaluated to see whether oscillation will occur if the power supply is not bypassed properly or by varying capacitive loads and how probable it is that stray capacitance around the circuit will send it into oscillation.

5. Compare the specifications of various vendors. Evaluate the data sheets of various IC manufacturers and be sure that the test conditions are the same for the particular characteristic in which you are interested.

It is difficult to get the whole story on any IC from a data sheet because it's common practice for a manufacturer to give specifications for his product under favorable conditions. Therefore, the best way is to relate the data-sheet information to the characteristics of the circuit you plan to build.

6. Check the product's history. Remember that it's almost impossible to find all the information of any IC on its data sheet because these are prepared shortly before ICs are announced and there is insufficient time to run lifetest programs. Even after new ICs come out, the manufacturers are constantly modifying them to improve their performance, so you don't have enough time to run your own lifetests, and even if you do, the manufacturer may change

the device six times during the course of your test program.

Therefore, the reliability of ICs can be judged by checking the product's history. Find out if there are other applications similar to yours in which the same device has been used with success. For that matter, see how successful the manufacturer has been with products of this type.

7. Determine if the IC lends itself to mass production. See whether the IC you choose lends itself to mass production. This means that you won't have problems in getting the ICs on time and they don't have wide variety of tight-tolerance or difficult-to-make components.

8. Consider the probability of wide acceptance of the IC. Consider the probability that the selected IC will have wide acceptance. Keep in mind that if the IC is versatile the price can go down if a number of manufacturers jump in. Obviously the cost of your IC is not going to drop measurably in the future if the volume is small, but look out if the volume is large.

9. Check for applicable literature. Evaluate your own capability to work with ICs. In this area it is important to check the literature published by the IC manufacturer to see how much he knows about the use of his own product.

The applications literature on linear ICs progress rapidly so that one must be skeptical in using older literature as design criteria.

10. Evaluate the testing aspects. Consider if the test equipment you or your company have can be modified and used or new equipment must be obtained to evaluate the testing aspects of the IC circuit. The IC user will have to test the devices when they arrive and also to determine how they will be tested in completed systems by field maintenance personnel (Eimbinder, 1970, pp. 1-7).

Testing Integrated Circuits

In-a-circuit ICs can be tested by checking the voltages on each lead of the IC, and comparing them with the values indicated in the schematic. Normally, when an IC transistor does not function properly, it affects the rest of the circuit; therefore, the voltages change. However, first check to see if the discrete components associated with the IC is the cause, then replace it with another one. It is impossible to repair or change the transistor or any component inside the IC.

Chapter 5

PROJECT RESULTS INFORMATION

The project selected by the writer was a Stereo IC Amplifier with 2 Watts Per Channel. The integrated circuit used was the RS-2277 made by Radio Shack A Tandy Corporation Company, Fort Worth, Texas 76107.

Figure 23 shows the schematic design of the stereo IC amplifier. The IC is designed for use with a multi-impedance output, however 8 ohms is recommended for each channel.

The RS-2277 (Dual Audio Amplifier) is a linear monolithic integrated circuit for use in stereo phonographs, AM/FM and stereo receivers, auto radios, tape players/recorders, and motion picture projectors. It can deliver 2 watts per channel of continuous power and can be operated over a supply voltage of 9 to 30 volts.

Manufacturer's Specifications

The only specifications given by the manufacturer are stated on Table 3.

However, the manufacturer doesn't give the internal circuit of the IC and the writer was unable to find it on IC equivalents. He found that the IC equivalents were the uA 705 manufactured by Fairchild Camera & Instruments Corp., and the LM 377 manufactured by National Semiconductor Corporation.

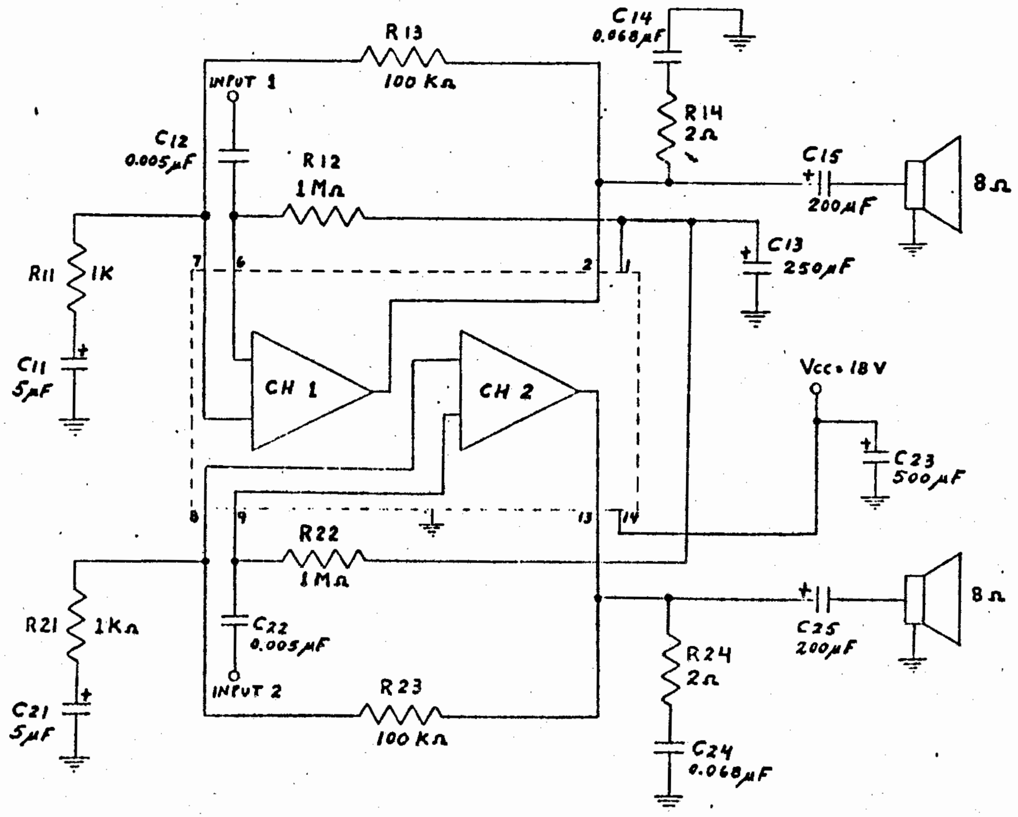


Figure 23

Stereo IC Amplifier - 2 Watts Per Channel

Table 3

Manufacturer's Specifications for the RS-2277 IC

Characteristics	Symbol	Test Condition	Limits			Units
			Min.	Typ.	Max.	
Supply Current	Icc	Without signal		15	50	mA
Input resistance	Rin	Each Device	3	20		M
Open loop Gain	Ae		55	72		dB
Total Harmonic Distortion	THD	Power Out= 2 W		0.75	2	%
		Power Out=.5 W		0.05	0.5	%
Audio Power Output	Po	THD= 2% Continuous	2			Watts
Channel Separation	Eout 1 Eout 2		35	55		dB

Description of the Components

Because of the symmetry of the two channels, the description of the components of only one channel will be given. In this case the writer will describe the components of channel 1.

CH 1.- It represents all the internal components of the IC needed for operation of channel 1.

R13.- Provides the feedback from the output to the terminal 7 of the IC, the input of the feedback. This resistor must alone be the path for DC, but AC is also coupled.

R11, C11.- Both components eliminate the AC signal coupling by R13, so that DC is only the feedback.

R12.- Provides the bias for the input of channel 1.

C12.- This small capacitor has two functions:

a) Provides a high impedance to the signal source in order to match the high impedance of the input of channel 1 to get the maximum power transfer.

b) Serves as the capacitor coupling of the input signal to channel 1.

C14, R14.- This network prevents any oscillations because of the high gain of the circuit.

C13.- Filters the bias voltage in order to get a pure DC.

C15.- It has two functions:

a) Prevents the DC voltage in terminal two of the IC from being short-circuited to the ground because of the low DC resistance of the speaker.

b) Couples the AC audio signal to the speaker.

C23.- Prevents the AC signal from reaching the power supply so as to cause oscillations.

Practical Considerations in Mounting Linear ICs

The writer had a hard time with the Stereo IC Amplifier because the circuit had oscillations and unwanted signals. He changed all the external or discrete components but the troubles didn't disappear. He also tried with another IC but the difficulties remained. Finally the writer changed the wires of the ground with others of greater area and the oscillations vanished. However, the unwanted signals still remained. By that time, he was looking for some information to solve these problems but he couldn't find any.

The writer feels he has lucky because the day after he solved the problem of the oscillations, the library acquired a new book about integrated circuits with a practical apprach in which the author gave very useful and practical rules to work with linear integrated circuits like the one used in this project. By applying these rules, the unwanted signals disappeared and now the circuit works properly. These rules are the following:

1. Keep in mind that the ICs are physically small, the input and output terminals are close, creating the ideal conditions for undesired feedback. Therefore, the main problem in mounting linear ICs is undesired oscillations due to feedback. Besides, most linear Ics are capable of passing frequencies higher than those specified on the data sheet. These higher frequencies can be harmonics of signals in the normal operating range and, with sufficient gain, can feed back to the input and produce undesired oscillations.

2. Always consider the integrated circuit as being radio frequency (RF), even though it is not supposed to be capable of RF operation, and the circuit is not normally

used with RF, particularly in the breadboard or experimental stage.

3. Bypass to ground all linear IC power-supply terminals. The capacitors should be as near to the IC terminals as possible. Do not mount the capacitors at the power-supply end of the line.

4. Consider that the inductance—the lead between the IC terminal and the capacitors—with the capacitor can form a resonant circuit. If the circuit resonates at some frequency (including fundamental, harmonic, or sub-harmonic), the signal could be passed by the IC to produce oscillation.

5. Keep IC input and output leads as short as practical. Use shielded leads wherever practical. Use one common tie point near the IC for all grounds. Resonant circuits can also be formed by poor grounding or by ground loops in general.

6. Be aware that as a general rule, ICs mounted on printed circuit boards (particularly with ground planes) tend to oscillate less than when conventional wiring is used. For that reason, an IC may oscillate in the breadboard stage, but not when mounted in the final form.

7. Monitor all IC terminals for oscillations with an oscilloscope before signals are applied after applying power to the circuit. Except in a few rare cases, there should be no evidence of AC or RF signals at any terminal under no-signal conditions. Of course, there can be power-

line hum, noise, etc., that is not the fault of the IC or the rest of the circuit (Lenk, 1973, pp. 51-52).

Measurements and Test

Because the internal circuit of the Ic is unknown, it will be treated as a double two-port network during measurements and test as seen in Figure 24.

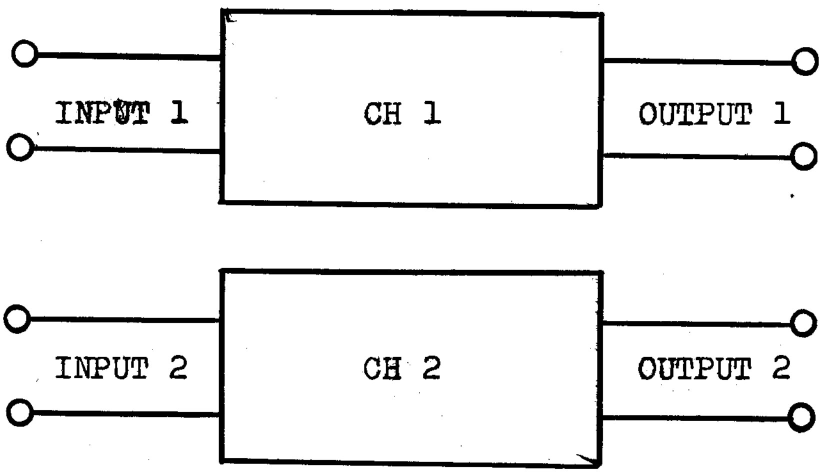


Figure 24

Double Two-Port Network Representing the
Stereo IC Amplifier

Again, because of the symetry of the circuit, the results of one channel will be given but the writer wants to remark that he made the measurements and tests on both channels and the results were the same. The measurements and test performed were:

Measuring voltages. The applied voltage Vcc was 14 volts and the voltages measured on each terminal of the IC were:

Terminal No.	Voltage (Volts)
1	6.4
2	6.3
6	5.5
7	6.3
8	6.3
9	5.5
13	6.3
14	13.5

Frequency response. In this test the hooked-up circuit is illustrated in Figure 25.

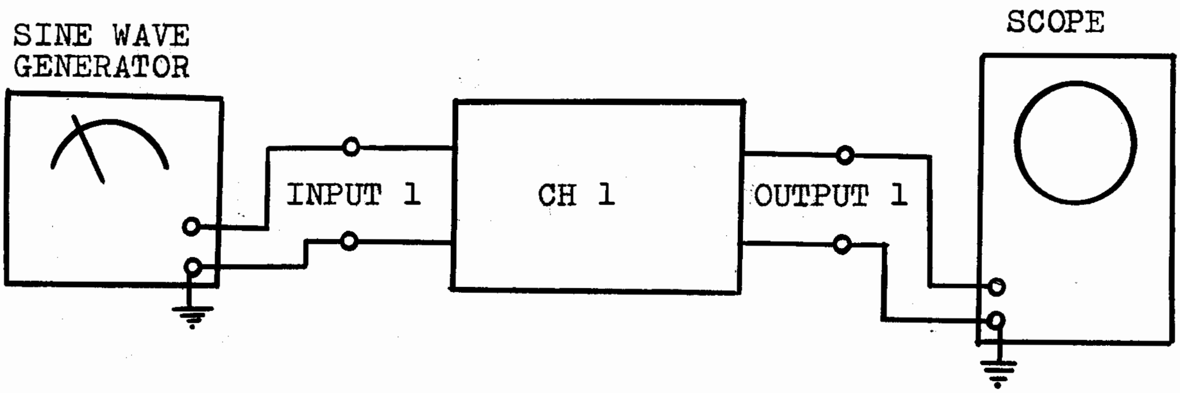


Figure 25

Hooked-Up Circuit for Measuring Frequency Response

The basic frequency response measurement procedure is to apply a constant amplitude signal while monitoring the IC input. The input signal is varied in frequency (but not amplitude) across the entire operating range of the IC.

Table 4 shows the results obtained during this measurement and Figure 26 illustrates the graph or <u>response curve</u> plotted according to the data on Table 4. In this case, the frequency response of the amplifier is from 80 Hz to 100 KHz.

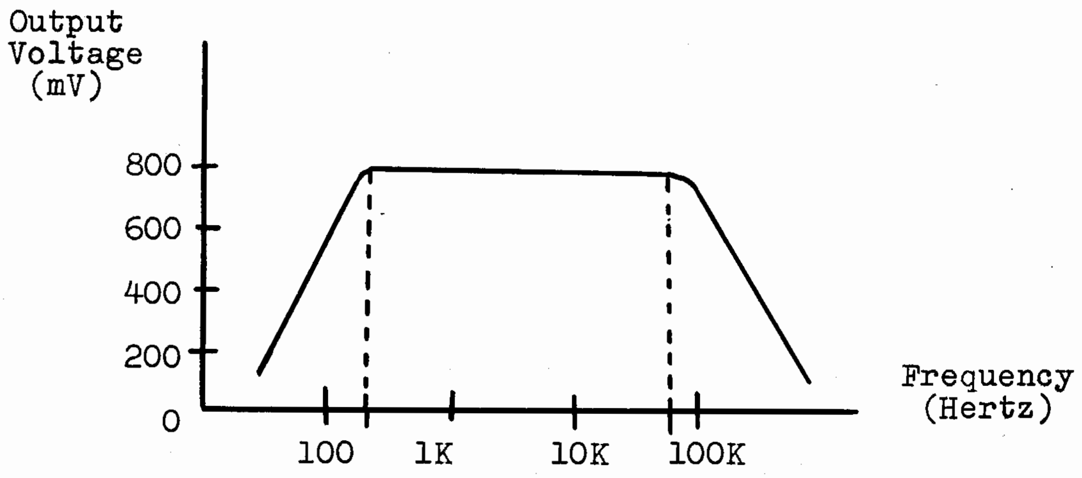


Figure 26

Frequency Response Curve of the Stereo IC Amplifier

<u>Voltage gain (Ae)</u>. Voltage gain (Ae) measurement of an IC is made in the same way as frequency response. The ratio of output voltage to input voltage Ae = Eout/Ein (at any given frequency, or across the entire frequency range) is the voltage gain. Since the input voltage (generator output) must be held constant for a frequency response test, a voltage gain curve should be identical to a frequency response curve. In this case, according to the data recorded on Table 4 the voltage gain is 80 from 140 Hz to

Table 4

Data Obtained for Frequency Response Measurement

Frequency (Hertz)	Input Voltage Vin (milivolts)	Output Voltage Vout (milivolts)	Gain Ae (No Units)
50	10	400	40
60	10	450	45
70	10	500	50
80	10	600	60
100	10	700	70
140	10	800	80
150	10	800	80
200	10	800	80
300	10	800	80
500	10	800	80
1,000	10	800	80
5,000	10	800	80
10,000	10	800	80
20,000	10	800	80
30,000	10	800	80
50,000	10	800	80
70,000	10	800	80
80,000	10	800	80
90,000	10	700	70
100,000	10	600	60
120,000	10	500	50
140,000	10	450	45

80 KHz. When the frequency is out of these limits the voltage gain rolls off.

Input sensitivity. Input sensitivity means the minimum power output obtained with a given voltage in the input. The formula for calculating power is:

$$Pout = (Vout)^2/R_L$$

According to table 4, if the output voltage is 800 mV = 0.8 V and the R_L or impedance of the speaker is 8 ohms, the Power output is:

$$Pout = (0.8)^2/8 = 0.64/8 = 0.08 \text{ Watts}$$

Then, the input sensitivity in this circuit is 80 mWatts output with 10 mV input.

Distortion. The procedure for checking distortion is by using a square wave generator and an oscilloscope. See Figure 27.

Although distortion can be checked by means of sine-waves, distortion analysis is more effective with square waves because of their high odd-harmonic content, and because it is easier to see a deviation from a straight line with sharp corners, than from a curved line.

During this test, square waves are introduced into the IC input, while the output is monitored on the oscilloscope. The primary concern is deviation of the IC output waveform from the input waveform (which is also monitored on the oscilloscope).

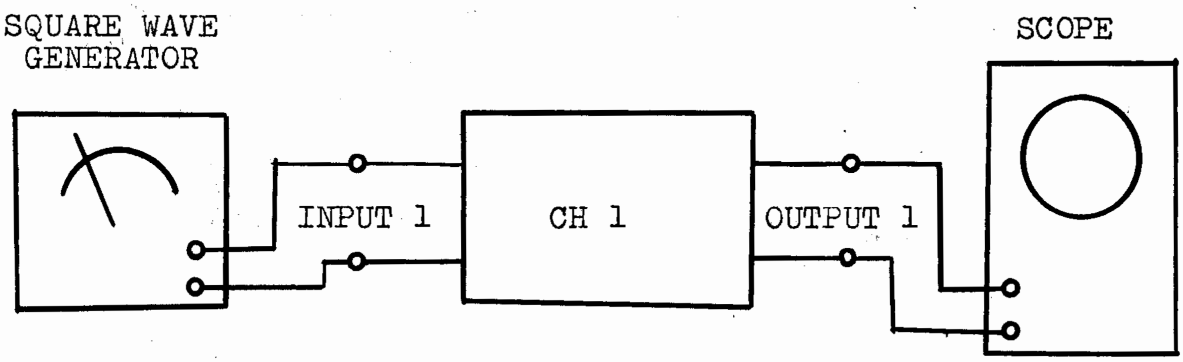


Figure 27

Circuit Arrangement for Checking Distortion

If there is a change in waveform, the nature of the change will often reveal the cause of distortion. This test revealed that this circuit presents a low frequency phase shift (leading). Output waveform is illustrated in Figure 28.

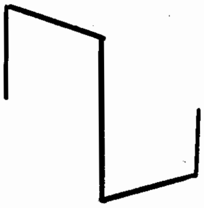


Figure 28

Output Waveform

Background noise. The noise on an IC is temperature-dependent, as well as dependent upon the method of compensation used.

The basic procedure for this measurement consist of measuring the IC output without an input signal. The oscilloscope is superior to a voltemeter for noise level measurement since the frequency and nature of the noise (or other signal) are displayed visually. The oscilloscope gain or sensitivity control is increased until there is a noise or "hash" indication.

In this case, the Stereo IC Amplifier has a background noise of 0.8 mV, which is within the normal value of integrated circuits of this type.

Chapter 6

PATENT INFORMATION

Any invention or discovery that is new and useful can be patentable. A patent is a government contract with the inventor for the exclusive right for a limited time -17 years except in Design Patents which may be 3 1/2 years, 7 years or 14 years. After this time, the idea is considered public domain—to make, use or sell Inventions, provided they promote the progress of the useful arts (Andrew, 1970, p. 11).

Patentable Discoveries

1. machines
2. compositions of matter
3. process, methods, or arts
4. articles of manufacture
5. ornamental designs
6. plants of certain types
7. improvements of the foregoing

Unpatentable Discoveries

1. an abstract principle or idea
2. a system of doing business
3. a bare scientific theory
4. a function of machine
5. a law of nature

6. a product of nature
7. an aggregation

Steps for a Patent

1. Make a clear drawing of the proposed invention (except if it a process or a composition of matter).

2. Write a concise description of the invention, the purpose of it, and how to accomplish that purpose by referring to the drawing.

3. Write the claims. This is the vital part of the patent and is usually done by an attorney. The claims tell what the invention is, how it functions and how it accomplishes the purpose of the invention.

4. Make two copies of the claims, sign and date them both, have them witnessed or notarized.

5. Take one of these copies, put it in an envelope and address it to oneself by registered mail. This copy must be put in any safe place. The other copy can be kept for personal reference in a private file.

Searching the Art

Before making an application for a patent, it is necessary to have a SEARCH made. A search is an intensive examination of the patents that have already been granted in the particular line of invention in order to find out if the idea is original and new. If one is skilled in this search, he can make it himself; otherwise he shouldn't attempt it. Searchers usually are made by patent attorneys or someone familiar in this matter.

If the search is made by an expert, the inventor will receive a report regarding this search. It will usually contain copies of different patents with words underlined in each one that point out the references or connections with the claims in one's patent. The final paragraph of the report will advise one if, in the expert's opinion, he should proceed with his application for the patent, or do nothing.

Application for a Patent

After deciding to apply for a patent, a filing fee of $65.00 is charged when the application is sent to the United States Patent Office for examination. This application must have the requierements laid down by the Patent Office as size of paper, wording of the claims and the like. The most common and advisable procedure is to procure the services of a patent attorney, who is registered with the government as competent to make out patent applications.

Finally, after receiving a notice from either the Patent Office or the attorney stating that the application has been filed and what the serial number is, one can talk about his invention and is free to show his drawings and look about a market (Andrew, 1970, p. 16).

Copyright

"Copyright is the right to prevent other from copying one's intellectual creations of certain kinds" (Federico, 1959, p. 479).

The owner of a copyright is granted by law certain exclusive rights in his work such as:

- The right to print, reprint and copy the work.
- The right to sell or distribute copies of the work.
- The right to transform or revise the work by means of dramatization, translation, musical arrangement, or the like.
- The right to perform and record the work.

The time of protection is 28 years. Renewal, once. 56 years in all.

What can be copyrighted?

1. Books, including composite and cyclopaedic works, directories, gazetteers, and other compilations. The term book includes pamphlets, leaflets, separate poems, or single pages.
2. Periodicals and newspapers.
3. Lectures, sermons, and addresses prepared for oral delivery.
4. Dramatic and dramatico-musical compositions.
5. Musical compositions.
6. Maps.
7. Works of art; models or designs for works of art.

8. Reproductions of works of art.

9. Drawings or scultural works of a scientific or technical character.

10. Photographs.

11. Prints, pictorial illustrations, and commercial prints or labels.

12. Motion picture photographs.

13. Motion pictures other than photoplays.

What can't be copyrighted?

1. Words and short phrases such as names, titles, and slogans.

2. Ideas, plans, methods, systems, or devices, as distinguished from the particular manner in which they are expressed or described in writing.

3. Works designed for recording information which do not in themselves, convey information, such as time cards, graph paper, bank checks, account books and the like.

4. Works consisting entirely of information that is common property containing no original authorship, such as standard-calendars, tape measures and rulers, schedules of reporting events or other common sources.

Procedure for a copyright.

1. Decide if the material is the type that can be copyrighted according to the previous information.

2. Write to the Library of Congress and ask them to

mail a form for type of material to be copyrighted.

3. Fill out form according to instructions and mail to Library of Congress with the government fee—and the material to be copyrighted.

Fee—Unpublished works—Published works	$6.00
Prints and labels	6.00
Renewals to copyrights	4.00

4. Write to the Copyright Office for information needed. They will mail a circular on the subject.

Who can claim copyright,.

Only the author or those deriving their rights through him can rightfully claim copyright. Mere ownership of a manuscript, painting, or other copy does not necessarily give the owner the right to copyright. In the case of works made for hire, it is the employer, and not the employee, who is regarded as the author (Andrew, 1970, p. 63).

Chapter 7

MASS PRODUCTION

The manufacture of integrated circuits themselves needs a great deal of capital. Therefore, the writer will consider the mass production by using the existing IC units in building a Stereo IC amplifier with 2 watts per channel. He assumes this will be done in a Peruvian electronics industry in which the main activity is assembly of circuits using integrated circuits.

Procedure. Six steps will be needed.

1. After deciding the type of integrated circuit and the discrete components the circuit needs, it is necessary to count the number of resistors and capacitors. In this case there are 8 resistors and 10 capacitors. The schematic is shown in Figure 23 (p. 62).

2. Three persons will be needed in putting in the printed circuit board the discrete components and one person for the IC. The writer would distribute these persons in the following form:

1 person would put the IC
1 person " " R11, R21. R12, R22, R13, R23
1 person " " C11, C21, C12, C22, C13, C23
1 person " " C14, C24, R14, R24, C15, C23

3. Next, another person would check to see if the values of the components are correct.

4. This step would consist in soldering all the components. This is done by another person.

5. Here, another person will check to see if there are short circuits caused by the soldering before applying power to the circuit.

6. The final step is to check the electrical characteristics by using instruments to see that it works correctly and use it. Otherwise, the person who works here, will send the circuit to the technician who will repair the defective component.

Then, the flow chart for mass production in this case is in Figure 29.

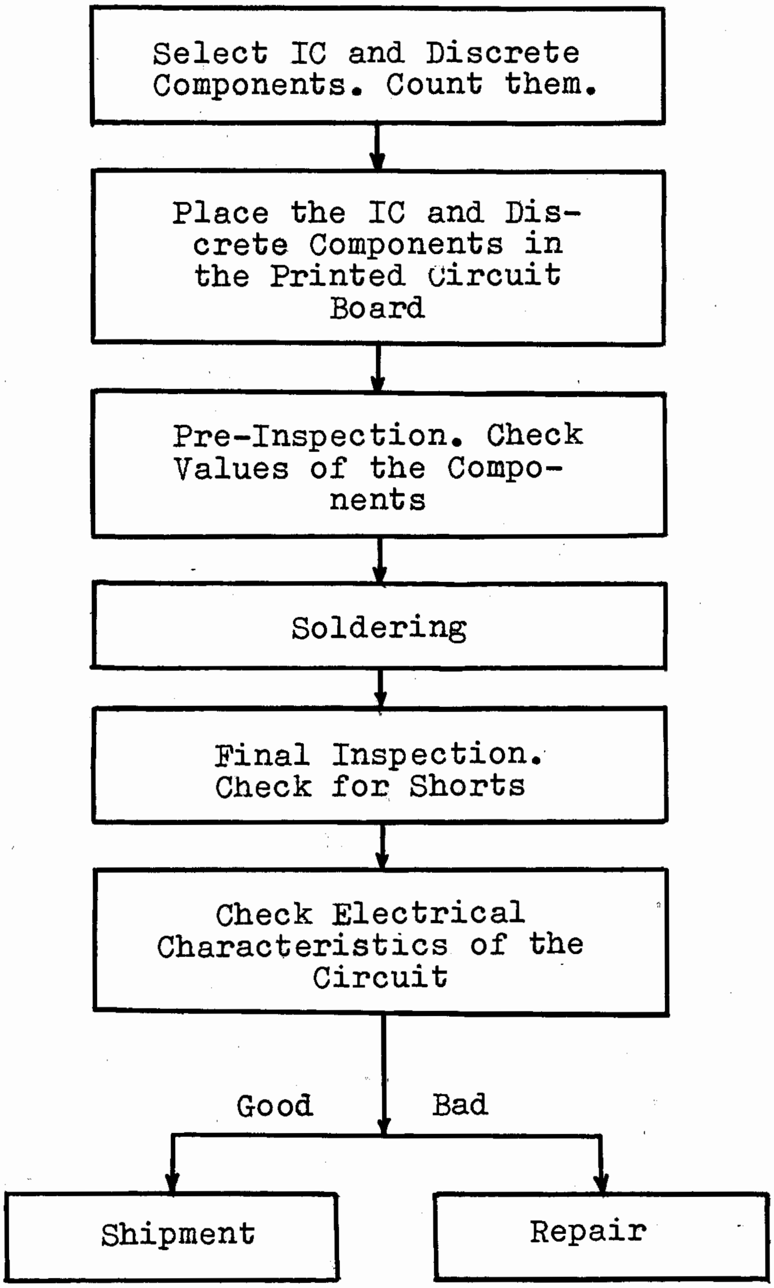


Figure 29

Steps in Mass Production for Building a Stereo IC Amplifier with 2 Watts Per Channel

Chapter 8

SAFETY PRECAUTIONS

The fabrication of any integrated circuit (IC) involves extreme care. Special handling of the IC from the acquisition of raw materials to the shipment of the finished product is the rule. If the IC is to operate satisfactorily in its final application this same special care must be followed in mounting and soldering. On the other hand, one must consider personnel safety of utmost importance because injuries and accidents have economic, familiar and personnel repercussions. The equipment also needs extreme care because in many cases there is only one in a laboratory or workshop and any fault in it could stop the work one is doing with it. By taking into account these considerations, the writer feels that the following regulations must be followed in an electronics laboratory or workshop.

Personnel

1. Wear safety glasses at all times. Solder splashes are painful and can be dangerous.

2. Keep one hand away from the chassis, in an pocket if possible.

3. Remove rings, bracelets, wristwatches, and the like during trouble-shooting because they represent an electrical hazard.

4. Understand the proper procedure before performing a new operation.

5. Place all hot soldering irons in designated areas.

6. Do not talk to fellow workers while they are operating machines.

7. Report at once to the supervisor any injury or accident, no matter how small.

8. Wear clothing which is conducive to safety work.

9. Maintain proper ventilation at all times.

10. Clean up the working station at the end of the period.

Equipment

11. Hard-wired to ground all electrical equipment used for circuit assembly and wiring.

12. Be sure all instruments are fused.

13. Observe specific safety rules while using hand tools and instruments.

14. Turn off all the equipment at the end of the period.

15. Report defective and dull tools and equipment to the supervisor.

Integrated Circuits

16. Use a pair of long-nose pliers, an alligator clip, or other heat sink between the soldering iron and the

case when an IC lead is being soldered.

17. Use a 30 watts soldering iron. It should be very hot and in contact with a lead for the shortest period of time.

18. Observe correct polarity when a battery or any kind of power supply is installed in a circuit containing an integrated circuit.

19. Double-check all lead connections before applying power and always check the output setting of variable voltage bench power supplies before switching on when breadboarding circuits.

20. Do not insert integrated circuits into or remove them from circuits with power "on" because transient voltage spikes may cause permanent damage.

21. Use common sense—this is most important. Don't be frightened by imposing lists of "dos" and "don'ts" in working with ICs. In the final analysis, they are as easy to use as transistors if the foregoing rules are learned and observed.

Chapter 9

BOOKS, TOOLS AND SUPPLIES

Tools and Supply Information

Since the integrated circuits are an extension of the transistor in that both are constructed of the same types of materials, and both make use of the special properties of those materials, almost all the equipment used in the transistor can be used for the IC. Because the writer assumes a moderately well equipped electronics laboratory or workshop, only the following equipment and materials must be added:

Equipment.

1 0.5 - 50 VDC Regulated Power Supply. Brand: HEATHKIT, Model SP-27A.

Specifications: Input: 120/240 VAC, 50/60 Hz; 135 watts at full load (50 V, 1.5 A). Output: 0.5 - 50 VDC; 1.5 amps max. DC. Dimensions: 5 1/8" H x 13 1/4" W x 9" D. Net Weight: 12 lbs.

Source: Heath/Schlumberger Instruments
Dept. 583 - 122
Benton Harbor, Michigan 49022

Price: $125.00

Materials.

Stock Number	Quantity	Description	Total Price	Shipping Weight (ozs.)
TR-194J	1	ICs. Digital use. Pkg. of 10	$1.19	4
TR-417L	2	1-Watt IC Audio Amplifier	6.60	8
TR-418J	2	4-Watt IC Audio Amplifier	11.60	8
TR-416J	2	IC Operational Amplifier	3.36	8
TR-304J	2	IC HEP 590 Linear Hi Freq. Amp.	7.98	8
TR-305J	2	IC HEP 558 j-k Flip Flop	8.79	8
TR-245J	2	IC HEP 572 Dual J-K Flip Flop	7.80	8
TR-303J	2	IC HEP 581 Dual 4-Input Gate	1.90	8
		Total:	$55.74	

Source: OLSON Electronics
260 South Forge Street
Akron, Ohio 44327

718-044	2	Socket Transistor/IC 6 Contact	$6.48	4
718-045	2	" " " 8 "	8.36	4
718-045	2	" " " 10 "	9.94	4
718-045	2	" " " 12 "	11.96	4
750-104	2	Dual in line socket 14 "	1.64	4
750-104	2	" " 16 "	1.82	4
750-105	2	" " 24 "	2.72	4
		Total:	$42.92	

Source: Allied Electronics
A Division of Tandy Corporation
2400 W. Washington Blvd.
Chicago, Illinois 60612

Books and other Aids

It would be impossible to cover all IC technology in just one book. Instead, one looks at a few ideas of the kind most likely to be of interest. Then, if one is to obtain further value from the book, there must be expanding resources included.

There are three types of sources: books, magazines, and manufacturers' literature.

Books.

1. Ashe, Jim. Handbook of IC Circuit Projects. Blue Ridge Summit, Pennsylvania: Tab Books, 1973.

$7.95

This first edition book presents more than 40 practical and useful IC circuits which can be built by electronics hobbyists ranging from beginners to experts. The operation of each circuit is described in detail, and schematic diagrams are given.

The handbook includes brief descriptions of the theory, operation and application of the ICs used in the various circuits.

-It is fully illustrated and is designed for any electronics laboratory or workshop.

2. Hnatek, Eugene R. A User's Handbook of Integrated Circuits. New York: John Wiley & Sons, 1973.

$6.50

This book explains the internal IC design processes, advantages and disadvantages, and applications of all different kinds of IC such as: Bipolar IC, Metal-Oxide Semiconductor (MOS), Thin-Film and Thick-Film Hybrid Circuits.

Although the level of the book is for the practice engineer, or the engineering student, a high school student can follow it without difficulties. It is fully illustrated.

3. RCA Linear Integrated Circuits. RCA Corporation Distributor Products, Harrison, N.J. 07029. 1973

$2.50

Describes important factors of IC processing, design and operation. Its content ranges over basics, characteristics and applications, with visible boundaries. Reading this book will squelch any feelings that ICs are simply discrete-component circuits, greatly squeezed down. It's true that the same basics apply to ICs as to any other circuits, but factors discussed in the RCA book go far to demonstrate that when working with ICs one is well out of discrete-component technology.

The level of the book is for high school student. It is fully illustrated. This book is especially helpful for laboratory or workshop use.

Magazines.

1. Electronics (biweekly). McGraw-Hill Building, 330 W. 42nd St. New York City 10031.

$1 - each
$9 - 1 year
$18 - 3 years

This up-to-the-minute engineering oriented biweekly magazine combines new, general information, theory articles, and a lot of working-circuit detailed schematics. Its industrial-electronics and engineering-oriented views are not so much for the advanced electronics amateur, and the high school student or technician will find much good in its pages. This magazine would be an excellent addition to any electronics laboratory or workshop.

2. Popular Electronics (monthly). Post Office Box 2774. Boulder, Colorado 80302.

$0.50 - each
$3.97 - 1 year

This electronics-oriented monthly is a good source of news, design, and application information as well as construction articles. This magazine would be of more use for the home as it concentrates on the practical side of electronics.

3. Radio Electronics (monthly). 200 Park Avenue, New York City 10003.

$0.60 - each
$7.00 - 1 year

This service-oriented but not service-limited monthly excludes the fantasy that engineering principles are "abstract." Radio Electronics is good for news, design articles, and for construction projects. This is very similar to the above listed magazine.

Manufacturers' literature. Electronics manuals and catalogs are among the standard sources of reference data for technical personnel. Manuals are characterized by technical specifications, often supplemented by basic design and construction information, with application, installation, and operating notes. A manual serves a sales function indirectly, but it is primarily a working tool and not a sales tool.

There is no sharp dividing line between electronics manuals and catalogs, However, a catalog falls to a considerable extent under the jurisdiction of the sales department of an organization, whereas manual preparation is the sole responsability of the engineering department. Catalogs feature device or product photos and sales-oriented discussion in addition to basic technical data. Thus, a catalog is primarily a sales tool (Herrick, 1974, pp. 305-6).

The following manuals and catalogs will be useful in any electronics laboratory or workshop:

1. COS/MOS Digital Integrated Circuits. RCA/Solid State Division, Somerville, N.J. 08876

$3.00

2. *Electronic Components*. General Electric, Syracuse, New York 13201.

$20.00 1st. year

$6.00 after 1st.year

3. *Linear Integrated Circuits and MOS Devices*. Application Notes. RCA/Solid State Division, Somerville, N.J. 08876

$1.50

4. *The Integrated Circuits Catalog for Design Engineers*. Texas Instruments Inc. P.O., Box 5012, Dallas, Texas 75222

$4.95

5. *The Linear Integrated Circuits Data Catalog*. Fairchild Semiconductor Components Group. 464 Ellis Street, Mountain View, California 94040

Free

6. *The Semiconductor Data Book*. Motorola Semiconductor Products Inc. P.O. Box 955, Phoenix, Arizona 85001

Free

Chapter 10

SUMMARY

The main objectives of this research report were to be able to work with and handle integrated circuits. These objectives have been accomplished during the preparation of the report and during the process of building the project chosen for this course. The project was a stereo IC Amplifier.

Although the stereo IC amplifier presented many problems and the writer was getting frustrated with this project, he feels comfortable because by applying his own experiences and consulting the information available and related to integrated circuits, he was able to solve all the problems. Now, the writer feels he has been able to combine the theory and the practice onto his project in such a way that both go hand-in-hand. The practical rules to follow in working with ICs are stated on pp. 65-67.

The manufacture of integrated circuits is very complicated and it requires great quantity of money to purchase all the necessary equipment. Computers are now being used during this process to reduce human errors.

Integrated circuits can be divided according to construction into monolithic and hybrid types.

The monolithic circuit incorporates an entire electronic circuit in a single block of silicon, with the various circuit functions introduced through diffusion and photoetching techniques. This concept displaces a notion of discrete identifiable circuit elements, such as resistors or capacitors. The important principle is that the over-all circuit function is achieved by a single entity on a monolithic block.

A hybrid integrated circuit uses a monolithic circuit for a portion of the design, but also includes discrete components that are individually mounted and connected. Many hybrids are formed by using evaporative techniques on suitable substrates for the passive circuit elements and adding the active elements in the form of separate chips.

The MOS IC (Metal-Oxide Semiconductor), which belongs to monolithic IC, permits economical manufacturing of much larger circuits. Development of practical MOS mass production methods has led to volume sales of memory units, large shift registers, and complete functional units such as calculators and control circuits.

Integrated circuit techniques are growing rapidly in capability, but continue to exhibit limitations in power handling ability and in speed of response compared with discrete circuit elements. Their advantages lie in lower cost per complete circuit, compactness, and greatly increased reliability.

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APPENDIX A

National Manufacturers and Users of ICs

Alabama

Huntsville, Astro Space Laboratories

Arizona

Phoenix, Motorola Semiconductor Products, Inc.

Scottsdale, Dickson Electronics Corp.

California

Anaheim. North American Rockwell Corp.

Mountain View, Fairchild Camera & Instrument Corp.

Mountain View, Teledyne Semiconductor

Newport Beach, Hughes Aircraft Co.

Palo Alto, Hewlett-Packard Co.

Santa Ana, ITT Cannon Electric

Santa Clara, National Semiconductor Corp.

Santa Clara, Siliconix Inc.

Sunnyvale, Computer Microtechnology Inc.

Florida

Melbourne, Radiation Inc.

Illinois

Chicago, Semiconductor Specialists Inc.

Indiana

West Lafayette, CTS Microelectronics Inc.

Massachusetts

Burlington, Microwave Associates, Inc.

North Adams, Sprague Electric Co.

Wakefield, Transitron Electronic Corporation

Nebraska

- Columbus, Dale Electronics Inc.

New Jersey

- Harrison, RCA Corp. Electronic Components
- Metuchen, Gulton Industries, Inc.
- Morristown, Mepco Inc.

New York

- Hempstead, Computer Instruments Corp.
- Hicksville, General Instrument Corp.
- Schenectady, General Electric Company

Ohio

- Cleveland, Harris Intertype Corp.
- Dayton, Ledex Inc.

Pennsylvania

- Montgomeryville, Solid State Scientific, Inc.
- Philadelphia, J.W. Microelectronics Corp.

Texas

- Dallas, Texas Instruments Inc.
- Richardson, Collins Radio Co.

APPENDIX B

Sample Letter to Industry

date

xxxxxxxxxxxxxx
xxxxxxxxxxxxxx
xxxxxxxxxxxxxx

Dear Sirs:

I am a graduate student in the Dept. of Industrial Arts & Technology at the University of Northern Iowa where I am doing a research report in the field of Integrated Circuits.

In my research report, I plan to illustrate the process of making Integrated Circuits, their history and development, and how they are applied and used in industry.

I would appreciate any information, including schematics that would be helpful in developing this report.

Films illustrating their mass production would be of exceptional value.

I hope that you will be able to give an early response to my request.

Sincerely yours,

Julio Garcia
Graduate Student

Approved By: Dr. Rex Pershing
Associate Professor of
Industrial Arts & Technology

Sample Thank You Letter

date

xxxxxxxxxxx
xxxxxxxxxxx
xxxxxxxxxxx

Dear Mr. xxxxxx

Thank you very much for sending me the two documents THE STORY OF MICROELECTRONICS and THE ECONOMICS OF CHANGE from your company.

That information has definitely given me the opportunity to become familiar with the lasted development in Electronics.

I appreciate greatly your quick response in supplying information and offering further assistance for my research report.

Sincerely yours,

Julio Garcia
Graduate Student