Articles

Semiconductors as a National Project of the National Technological Institute of Mexico

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Summary:

The electronics industry is the engine of technological innovation. Advances in the design of microprocessors, sensors and electronic devices drive the creation of new technologies and products, such as smartphones, computers, smart appliances and advanced medical devices that have revolutionized the way people communicate and connect, transforming everyday life. The Internet, mobile networks, the Internet of Things (IoT) and next-generation communication technologies such as 5G all rely on advanced electronic components and systems. As a result, the electronics industry is one of the largest and fastest-growing industries in the global economy.
Many automated processes using electronic circuits, both at industrial, commercial and domestic levels, enable a more rational and efficient use of material and energy resources. This makes electronics essential for key industries such as automotive, aerospace, healthcare, manufacturing and power generation. For example, modern cars rely heavily on electronic components for engine control, enabling greater fuel efficiency and improving safety systems. This is why the electronics industry is playing a crucial role in sustainability and energy efficiency. Innovations in green technology, such as solar panels, advanced batteries and energy-efficient devices, are essential to address environmental challenges and promote sustainable development.

Considering the importance of the electronics and semiconductor industry today, the National Institute of Technology of Mexico will begin the National Semiconductor Project in 2023, to incorporate relevant topics of this industry into its academic activity, seeking to significantly incorporate Mexican engineering into the global semiconductor industry.

Abstract:

ÿe electronics industry is the engine of technological innovation, advances in the microprocessors design, sensors and electronic devices drivethecreation of newtechnologiesand products,such assmartphones,computers,smart homeappliancesand advanced medical devices, haverevolutionized the way peoplecommunicateand connect, transforming lives.everyday. ÿeInternet, mobile networks, the Internet of ÿings (IoT), and next-generation communication technologies such as 5G depend on advanced electroniccomponentsand systems. ElectronicIndustry is one of thelargestand fastest growing industries in the globaleconomy.
Many automated processes using electronic circuits, at an industrial, commercial and domestic level, allow a more rational and efficient use of material and energy resources. ÿis makes electronics critical to key industries such as automotive, aerospace, healthcare, manufacturing and power generation. For example, modern automobiles rely heavily on electronic components for engine control, enabling greater fuel efficiency, improving safety systems. ÿat is why the electronics industry is playing a crucial role in sustainability and energy efficiency. Innovations in green technology, such as solar panels, advanced batteries and energy-efficient devices, are essential to address environmental challenges and promote sustainable development.
Considering the importance of today's electronic and semiconductor industry, the Tecnológico Nacional de México TecNM, begins the National Semiconductor Project in 2023, to incorporate the relevant topics of this industry into its academic activity, seeking to signiÿcantly incorporate Mexican engineering into the global semiconductor industry.

INTRODUCTION

Electronic technology is vital to national security and the defense of countries; communication systems, radars, satellites, drones and other military equipment rely on advanced electronic technologies. It is a cornerstone of digital transformation, enabling emerging technologies such as artificial intelligence, robotics, virtual and augmented reality, and cloud computing, are changing the way we live and work. On the economic side, the electronics industry is

Highly globalized, with supply chains spanning multiple countries, this fosters international trade and economic relations between nations. Countries such as China, the United States, Japan, South Korea and Germany are leaders in the production and export of electronic products that generate trillions of dollars in revenue and create millions of jobs worldwide, from research and development to manufacturing, marketing and distribution.

The modern electronics industry is based on semiconductor materials, these are the backbone of modern electronics as they are used in the manufacture of fundamental devices such as transistors, diodes and integrated circuits, which are essential components in virtually all electronic devices. The use of semiconductor materials has allowed the miniaturization of electronic components, leading to the development of smaller, faster and more efficient devices. Microprocessors and electronic circuits are made of semiconductor materials such as silicon, these devices are essential for the operation of computers and servers, making them vital to the computing industry.

Modern communications infrastructure also relies heavily on semiconductors.
Devices such as mobile phones, telecommunications networks, and data transmission systems use semiconductor components to operate, and they also play a crucial role in power management and conversion. Devices such as solar panels, LEDs, and energy efficiency controllers use semiconductor materials to improve energy conversion and use more efficiently. In the automotive industry and industrial automation systems, semiconductors are essential for the operation of sensors, actuators, and control systems. Electric vehicles and power management systems use semiconductors to improve performance and efficiency.

Advanced medical devices such as MRI scanners, ultrasound equipment, and wearable health monitoring devices rely on semiconductors for their operation.
These materials allow for greater precision and functionality in medical diagnosis and treatment.
They are fundamental to the development of emerging technologies such as artificial intelligence, augmented and virtual reality, and quantum computing. These technologies depend on the ability of semiconductors to handle large amounts of data and perform complex operations. Research into semiconductor materials has led to the development of superconductors such as gallium arsenide (GaAs) and gallium nitride (GaN), which have superior electrical conduction properties that are driving new areas of technological development, for example, for the development of new data storage technologies such as solid-state drives (SSDs), which offer higher processing speeds compared to traditional storage methods (Kaeslin, 2008).

The electronics and semiconductor industries are among the most important industries globally, with a significant economic impact. Semiconductor companies generate billions of dollars in revenue and create numerous jobs in research, development, manufacturing and marketing. In short, these industries are essential to technological progress, economic growth, improved quality of life and global sustainability. Their influence spans a wide range of sectors, making them strategic and fundamental industries in the modern world. Advances in semiconductor science and technology continue to drive innovation and economic development globally.

DEVELOPMENT

The value chain of the electronic industry is based on semiconductor materials, which in turn have their origin in mining and metallurgy for the extraction, purification and processing of the elements required for the manufacture of semiconductor materials, which are used for the construction of electronic components, mostly transistors, diodes, resistors and capacitors, which

In turn, they are the basic elements for the construction of electronic circuits (Wakerly, 2001). To reach this stage in the value chain of the electronics industry, the work of engineers from various areas of knowledge, programmers, physicists, chemists, mathematicians, among other areas, is required.

Broadly speaking, the value chain of the electronics industry is as shown in Figure 1.

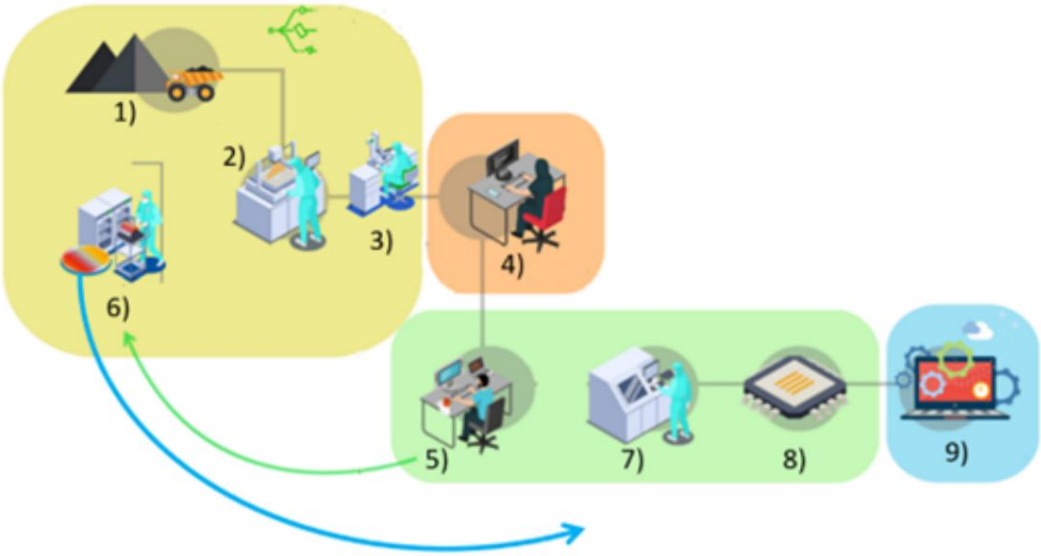

FIGURE 1.
Value chain of the electronics industry. 1) Mining for the extraction of materials 2) Design and characterization of semiconductor materials. 3) Design and characterization of electronic devices. 4) Functional design of discrete and integrated electronic circuits. 5) Physical design or layout of integrated circuits. 6) Manufacturing of integrated circuits. 7) Verification of circuits. 8) Packaging. 9) Design and manufacture of electronic products.

In the economic and social context of the electronics industry, the COVID-19 pandemic in 2020 had profound and multidimensional effects worldwide, causing a global recession with a significant drop in Gross Domestic Product (GDP) in many economies; sectors such as tourism, hospitality and aviation were particularly affected. Many people lost their jobs due to business closures and reduced economic activities; the resulting economic crisis increased poverty levels and widened the inequality gap in many regions. The pandemic tested the ability of governments to manage health, economic and social crises and the effectiveness of government responses varied widely between countries. Because of this, international collaboration in science and health was promoted, but it also exacerbated geopolitical and economic tensions. It highlighted the weakness of global supply chains and the dependence of the West on Asian factories, mainly in China. This critical situation significantly affected technology areas, mainly in the semiconductor industry, which has become a national security industry for some countries.

In response to this global crisis, the United States Congress enacted the CHIPS and Science for America Act in August 2022, which aims to strengthen domestic semiconductor production to foster technological innovation in this sector (Swanson, 2023). The act allocates more than $52 billion in incentives for semiconductor manufacturing, including 25% tax credits for investments in properties related to the manufacturing of these devices.

The CHIPS Act establishes several funds for different purposes, some of which are:

- CHIPS for America Fund to encourage semiconductor production in the US. • CHIPS for America Defense Fund that supports research and development in microelectronics.

- CHIPS for America International Technology Security and Innovation Fund that promotes security and innovation in the semiconductor supply chain and emerging technologies.

In addition to these economic incentives, the law also includes provisions for developing the microelectronics workforce, creating new manufacturing facilities, and strengthening international collaboration on technological security. The implementation of the CHIPS Act is seen as a crucial measure to reduce the United States' dependence on foreign manufacturers, especially in a context of trade tensions with China (Riquelme, 2022). Companies receiving subsidies are subject to restrictions, such as a ban on new high-tech investments in China and an obligation to share windfall profits to prevent cost overruns.

In this United States plan with the Chips Act, Canada and Mexico are included. In this context, in January 2023, at the initiative of the Federal Government, within the framework of the Sonora Plan, the National Technological Institute of Mexico is asked to train highly qualified human resources in the semiconductor area, this marks the beginning of the National Semiconductor Project of the National Technological Institute of Mexico.

The first step in this National Project was the launch of a Basic Diploma in Semiconductors, with the intention that the academic and professional community understand in detail the value chain of the electronics industry and within this context, the importance of semiconductor materials as the basis for the development of the electronics industry and the technologies that depend on it, as previously mentioned. This diploma was aimed at students, teachers, graduates and professionals, with an online modality and a duration of 120 hours divided into 5 modules entitled: Semiconductor Materials, Digital Circuit Design with CMOS technology, Analog Circuit Design with CMOS technology, Integrated Circuit Layout and Emerging Technologies, highlighting in each one the different stages of the value chain. This diploma was implemented in May 2023 and aimed to develop a combination of knowledge for students, teachers and the general public interested in the technical-scientific area of semiconductor studies, which contributes to the development of profiles in the realization of specific activities and applied research in the value chain of this strategic industry in our country for the development of competition at a global level.

The second stage of the project was the creation of specialties for educational programs related to semiconductors, such as Electronic Engineering, Electrical Engineering, Computer Systems Engineering and Industrial Engineering, among others, and for the recently created Semiconductor Engineering.
These specialties also attempt to cover different sectors of the semiconductor industry, from semiconductor materials to their applications in different areas of technological development. Four specialties were proposed, which will be described in detail.

Specialty 1. Design of Semiconductor Materials for Electronic Devices.

This specialty aims to provide the graduate profile of engineers with knowledge related to the techniques used for the design of semiconductor materials for electronic devices. 5 subjects are proposed. This specialty can be incorporated into different engineering degrees, such as Electronic Engineering, Mechatronic Engineering, Materials Engineering, Nanotechnology Engineering and degrees related to electronics.

The focus is on the design processes of semiconductor materials for electronic devices. Topics of solid state physics, design of experiments, analysis of properties and characterization of materials are addressed. The subjects of the Semiconductor Materials Design for Electronic Devices specialty are the following:

- Design of Experiments. •
  Physical Principles for the Design of Semiconductor Devices. • Analysis of Physical-Chemical Properties of Semiconductors. • Optoelectronic Devices.

• Control Semiconductor Components.

Specialty 2. Manufacturing of Electronic Devices and Integrated Circuits.

This specialty seeks to contribute to the graduate profile of engineers with knowledge related to the manufacturing industry of discrete electronic devices and integrated circuits, facilitating the insertion of graduates in the production chain in this sector. 6 subjects of 5 credits each are proposed, for a total of 30. This specialty can be incorporated into different engineering degrees, such as Semiconductor Engineering, Materials Engineering, Industrial Engineering, Electronic Engineering, Chemical Engineering, Mechatronics Engineering, Business Management Engineering, among others.

The focus is on the manufacturing processes of this type of products, the supply chain, the risks and the mitigation of the environmental impact of this type of industry, in turn, knowing in detail the characteristics of the expected products and the current regulations for ensuring the quality of products, also providing tools and skills for decision-making. The following list shows the subjects of the Semiconductor and Integrated Circuit Manufacturing specialty:

• Introduction to Semiconductors. • Characterization of Semiconductor Electronic Devices. • Quality in Manufacturing Processes. • Environmental Sustainability. • Semiconductor and Integrated Circuit Manufacturing Processes. • Communication Interface Engineering.

Specialty 3. Integrated Circuit Design.

This specialty seeks to contribute to the graduate profile of engineers with knowledge related to the techniques used for the design of integrated electronic circuits. Six subjects of 5 credits each are proposed, for a total of 30. This specialty can be incorporated into different engineering degrees, such as Semiconductor Engineering, Electronic Engineering, Mechatronic Engineering, Information Technology and degrees related to electronics. The focus is on the design processes of integrated circuits, both digital and analog. In the area of digital design, topics of analysis and synthesis of digital circuits are addressed, from the most basic to complex microprocessors and communication and testing interfaces. On the analog circuits side, the topics of basic analog circuits, amplifiers and analog-digital and digital-analog converters are analyzed. In addition, topics related to the physical design of integrated circuits and their manufacturing processes are addressed. The list of subjects for this Integrated Circuit Design specialty is:

• Characterization of Semiconductor Electronic Devices. • Communication Interface Engineering. • Analysis and Synthesis of Digital Circuits. • Memory Processing Architecture. • Design Analysis of Analog Integrated Circuits.

Specialty 4. Embedded Systems Design.

This specialty seeks to provide the graduate profile of engineers with knowledge related to the techniques used to design and use embedded systems with a focus on the needs of the semiconductor industry and related areas. This specialty can be incorporated into different engineering careers, such as Semiconductor Engineering, Electronic Engineering, Mechatronic Engineering, Information and Communications Technology Engineering, and careers related to electronics.

The focus is on understanding the capabilities of embedded systems, as well as being able to design and implement, in these systems, aspects related to Artificial Intelligence and the Internet of Things.

This specialty studies reprogrammable embedded devices, such as microprocessors and DSPs; it also provides training on the use of reconfigurable hardware embedded devices, such as FPGAs.

In addition, Artificial Intelligence techniques and basic concepts of the Internet of Things are described to be implemented in the aforementioned embedded devices. All these aspects are supported by concepts that promote the development of specific mathematical skills, which are essential for different disciplines of design, simulation and implementation of solutions for Electronic Engineering or related areas. For this specialty, five subjects are proposed, as shown below:

- Advanced Mathematics for Engineering.
- Artiÿcial Intelligence.
- Internet of Things.
- Embedded Systems Based on Digital Signal Processing.
- Embedded Systems Based on FPGAs.

In parallel with the design of the specialties, work was carried out on the Semiconductor Engineering educational program, whose objective is “To train competent engineers in the design and synthesis of semiconductor materials, electronic components and integrated circuits through technological research and development, which contribute to the strengthening of the strategic semiconductor industry of our nation, promoting the growth of the value chain, within a legal and sustainable framework with a social, ethical and humanistic sense”. This educational program consists of 260 credits (4860 hours), which correspond to the academic requirements established in the subjects and academic activities of the study plan. In 2023, as was the goal, seventeen technological institutes opened the Semiconductor Engineering degree.

During the process of designing the curricula, both for the diploma, the specialties, and the undergraduate and postgraduate educational programs, the TecNM academic team held work meetings with research centers such as INAOE and CINVESTAV, national leaders in semiconductor issues, as well as with leading companies in this sector. The team participated in the Semiconductor Conference of the Semiconductor Industries Association SIA of the United States, with the participation of governments, industry, and academia from the United States, Canada, and Mexico in Washington DC in May 2023.

CONCLUSIONS

The strategic projects that the National Institute of Technology of Mexico has implemented in the area of Semiconductors have been the design and creation of educational programs based on the analysis of the value chain of the electronic industry, starting with semiconductor materials and device characterization, up to the design and manufacture of embedded systems or consumer electronic products, passing through the stages of study, analysis and characterization of electronic materials and devices, integrated circuit design, layout or physical design, verification and packaging of integrated circuits. In addition, the requirements of the main actors in the industry, such as research centers and large technology companies, were taken into account. Not only the areas of development have been significantly considered, but also training schemes for the teachers of these educational programs. This gives great strength and very high possibilities of success to these new educational programs.

The semiconductor industry is not only vital to the global economy and technological innovation, but is also implicit in almost every aspect of our daily lives. This industry will continue to play a central role in the development of new technologies that will transform society and improve the quality of life around the world. Hence, the enormous importance of the actions of the Technological Institute.

National of Mexico in the Semiconductors project, with the development of new updated educational programs, with agile work methods that allow, not only to react to the demands of the industry immediately, but also allow, in the medium and long term, planning actions that contribute to the development of own technologies.

REFERENCES

Kaeslin, H.(2008). Digital Integrated Circuit Design: From VLSI Architectures to CMOS Fabrication. Estados Unidos: Cambridge University Press.

Riquelme, R. (2022, August 31). US Chip Law May Generate Collateral Investments in Mexico: Intel. The Economist.

Swanson, A. (2023, March 31). Five Keys to the U.S. Chip Law. ÿe New York Times.

Wakerly, J. (2001). Digital design, principles and practices. Mexico: Prentice Hall.

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