

THE NONCONVENTIONAL MECHATRONIC SYSTEM

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ABSTRACT: Mechatronics is a nonconventional technology which is developed and continues to grow. The mechatronic system is considered the result of the integration of electrical, mechanical and electronic parts, using the informational technology. Per total, this is a nonconventional system. As the technology evolves over time, more and more engineering fields need to adapt and develop. Mechatronics produces a design solution that unifies each of these sub-domains. The development of mechatronic systems involves the use of several disciplines, from mechanical engineering to electronic and computer engineering. Each discipline was developed independently and then integrated to generate a final system. But high-quality projects cannot be done without simultaneously considering all engineering disciplines. Mechatronics brings an intrinsic complexity in the system design process and a lot of research is developed to find out the optimal methods. This article will discuss about the mechatronic nonconventional system components and how the technology is used.

KEYWORDS: mechatronics, electric, mechanic, electronic components, interfaces and computing hardware

1. INTRODUCTION

Mechatronics, which is also called mechatronic engineering, is a multidisciplinary branch of engineering that focuses on the engineering of electrical and mechanical systems. It is a combination of robotics, electronics, computer, telecommunications, systems, control and product engineering. The term "mechatronics" is defined to provide a framework for technical and practical considerations. [4] [36] [37]

The concept of mechatronics has evolved from the original definition given by the Yakasawa Electric Company. The term "mechatronics" was introduced by an engineer (Tetsuro Mori) from the Japanese company in 1969. [11]

As a word, it was registered as a trademark by the Japanese company, with registration number "46-32714" in 1971 and used since 1972. The company subsequently issued the right to use the word in public, after which this term began to be used throughout the world. [67]

In dictionaries, the term officially appeared in 2005, in Larousse (France). Nowadays, the word is translated into many languages and is considered an essential term for the industry.

The French standard NF E 01-010 (2008) defines mechatronics as an "approach to the synergistic integration of mechanics, electronics, automation and informatics in the design and manufacture of a product to increase and / or optimize its functionality". Many people treat mechatronics as a

modern word, synonymous with robotics or electromechanical engineering. [49] [52]

The term mechatronics is used to denote a rapidly developing and interdisciplinary field of engineering that deals with the design of products whose function is based on the integration of mechanical and electronic components coordinated by the control architecture. [14] [53]

As concept, mechatronics is a nonconventional system, which can be defined as a synergistic and systematic combination of mechanics, electricity / electronics and real-time computing, with "mecha" from the word mechanism and "tronic" from the word electronic. [32]

Mechatronics is an integration of sensors, actuators, signal conditioning, power electronics, decision and control algorithms, as well as computer hardware and software to manage complexity, uncertainty and communication in designed systems. [54] [61]

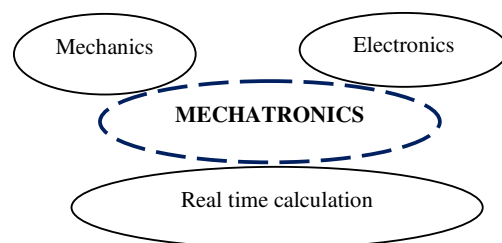


Figure 1. The mechatronic concept

As technology advances, the fields of engineering have managed to diversify. The intention of mechatronics is to produce a design solution that unifies each of them. [12] [13]

Initially, the concept of mechatronics was just to be a combination of mechanics and electronics, hence its name. [15]

As the complexity of technical systems continued to evolve, the definition was extended to include more technical areas. [22]

The interest of this area of interdisciplinary engineering is to design powerful automated systems and to allow the control of complex systems. [38]

Important primary disciplines in the design of mechatronic systems include mechanics, electronics, controls and computing. A mechatronic system engineer must be able to design and select analog and digital circuits, microprocessor-based components, mechanical devices, sensors and actuators, and controls so that the final product achieves a desired goal. [39]

The development of mechatronic systems involves the use of several disciplines, from mechanical engineering to electronic and computer engineering. Each discipline was developed independently and then integrated to generate a final system. But high-quality projects cannot be done without simultaneously considering all engineering disciplines. Mechatronics brings an intrinsic complexity in the system design process and a lot of research is developed to find out the optimal methods. [57]

The engineering of such mechatronic systems requires the simultaneous and multidisciplinary design of several subsystems:

- an operative part (the skeleton and the predominantly mechanical, electromechanical system);
- part of the control (integrated system information, mainly electronic and real-time computers);
- part of the machine / machine interface (data exchange between two separate systems, in particular IT and networks);
- part of the human / machine interface (geometric shape and dialogue of the predominantly ergonomic and aesthetic system).

A global approach also reduces costs, increases reliability and modularity. [40] [62]

The advantages of mechatronic systems

- cost-effective and good quality products;
- high degree of flexibility for modification or redesign;
- very good performance characteristics;
- wide fields of application;
- higher productivity in the case of the manufacturing organization;
- greater expansion of the use of machinery.

Disadvantages of mechatronic systems

- high initial cost;
- multidisciplinary engineering history required for design and implementation;
- the need for well-qualified workers;
- complexity in identifying and correcting problems in the system.

A typical mechatronic system takes signals from the environment, processes them to generate output signals, transforming them, for example, into forces, movements and actions. This combination results in simple, efficient, economical and reliable systems. [16] [17]

Many technical processes and products in the field of mechanical and electrical engineering show a growing integration of mechanics with digital electronics and information processing. [5]

This integration takes place between components (hardware) and information-based functions (software), resulting in integrated systems called mechatronic systems. Their development involves finding an optimal balance between the basic mechanical structure, the implementation of the sensor and the actuator and the automatic processing of information and general control. [9] [55] [56]

Mechanical functions are frequently replaced by electronically controlled functions, leading to simpler mechanical structures and increased functionality. [8] [41]

The development of mechatronic systems opens the possibility to other innovative solutions and synergistic effects that are not possible only with mechanics or electronics. This technical progress has a very strong influence on a multitude of products in the fields of mechanical, electrical and electronic engineering and is increasingly changing the design of conventional electromechanical components, such as machines, vehicles and precision mechanical devices. [20] [21] [42] [43] [58]

2. THE EVOLUTION OF MECHATRONICS

This technology is constantly expanding. [61] [66]

It refers to the design, manufacture and operation of the products or devices or processes designed, which can be followed by:

- the industrial revolution;
- the semiconductor revolution;
- the information revolution.

At the industrial level, semiconductor and information revolutions have led to major technological advances in the design and operation of engineering products. [44] [59]

Mechanical engineering, as a widespread professional practice, experienced a development

during the early nineteenth century, because it provided a necessary basis for the rapid and successful development of the industrial revolution. At that time, the mines needed large pumps to keep the wells dry, the iron and steel mills needed pressures and temperatures above the levels used in the trade until then. In addition, transportation systems needed more power to move goods. The structures began to expand more and more, and manufacturing moved from the storefront to large factories. To support these technical parts, people began to specialize and build bodies of knowledge that formed the beginnings of engineering disciplines. [48] [60]

The primary engineering disciplines of the twentieth century - mechanical, electrical, civil and chemical have retained their individual body of knowledge, textbooks and professional journals, because the disciplines were considered to have an intellectual and professional territory exclusively reciprocal. Those who study the area of mechatronics can evaluate their individual intellectual talents and can choose one of these fields as a profession. We are now witnessing a new scientific and social revolution, known as the information revolution, in which engineering specialization seems to concentrate and diversify simultaneously. This contemporary revolution was initiated by the engineering development of semiconductor electronics, which led to an explosion of life-enhancing information and communications.

2.1 The industrial revolution

It began in the late eighteenth century and continued into the first decades of the nineteenth century. The industrial revolution was a complex technical process by which manual labor was increasingly replaced by the work done by machines. In this mechanized process, the worker has the role of supervision, regulation and feeding of the machine and quality control. The industrial revolution had the effect of increasing production, developing cities and science. [61]

The social impact of the industrial revolution marked the development of the social division of labor. New branches of production appeared, new industrial centers, capitalist economic relations prevailed over feudal ones. There is also the middle class, a category that benefited from reasonable financial gains and had a careful attitude towards bourgeois or aristocratic elites. There is a big change in clothing and investments for good-looking and comfortable homes. Of all social classes, the bourgeoisie asserts itself, a basic class of capitalist society.

The technical impact caused a strong impetus in the field of inventions. Factories appear, and manual labor is replaced by mechanized one. An important invention was made in 1760, when James Watt invented the steam engine. The steam engine began to be used in various branches of industry, initially in the textile industry. In 1829, the English inventor and engineer George Stephenson inaugurated the "Rocket" locomotive, and this was considered the first profitable locomotive.

The industrial revolution allowed the design of products and processes to convert and transmit increasing amounts of energy to industrial activities. The engineering designs of this era performed operations of motion transmission, detection, actuation and calculation using mechanical components, for example: cams, gears, levers, connections, etc. Unfortunately, purely mechanical systems suffer from the inability to amplify power and energy loss due to tolerances, inertia and friction (Tse and Morse, 1989). [67]

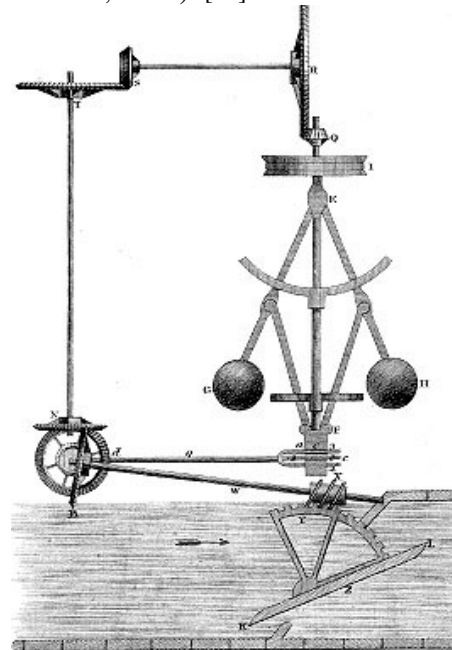


Figure 2. The industrial revolution

J. J. Thomson, the man who discovered the electron in 1898, had a saying: "The electron: it may never be useful to anyone!" Today, the electron is useful to everyone, thanks to electronic tubes and semiconductor devices, which have unique properties for controlling the flow of electrons. [57]

2.2 The semiconductor revolution

This has led to the development of integrated circuit technology and created a key impact on the design of engineering products. This contemporary revolution was born through the engineering development of semiconductor electronics, which

led to an explosion of information and communications that transformed human life. These days, new ways of processing information can be devised and we may be able to use semiconductor electronics in our products, regardless of the label we put on ourselves as practitioners. Mechatronics is one of the new and interesting fields in the engineering landscape, subsuming parts of traditional engineering fields and which requires a broader approach to the design of systems that we can formally call mechatronic systems.

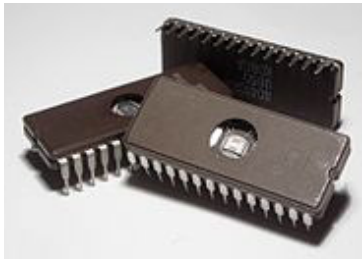


Figure 3. The semiconductor revolution: an integrated circuit

On the drive side, via miniaturized cost power electronics, for efficient power amplification, semiconductor technology has provided a practical means of providing the power levels needed for mechanical devices by electrical means. Similarly, on the sensor side, semiconductor technology provided the ability to condition and encode physical measurements as analog / digital signals. In addition, the on-board analog / digital electronic systems of an electronic device provided computing skills to rudimentary mechanical devices. Rapid advances in mechanical detection and drive hardware that began in an earlier era have further fueled the adoption of semiconductor technology in the design and operation of mechanical devices.

2.3 The information revolution

The information revolution (the second industrial revolution) marked the leap from the industrialized society to the information society, generating a wave of innovations in technology and education. The development of VLSI technology led to the introduction of the microprocessor, microcomputer and microcontroller. As a result, the structure of computing hardware is ubiquitous, inexpensive, and small in size. The large-scale integration of electronic circuits is one of the cutting-edge technologies of modern industry. Known in English as VLSI (Very Large-Scale Integration), this technology provides the basic components and functional structures needed to achieve an extremely wide range of products and systems, for the most diverse applications, starting with household and ending with those for aerospace industry.

The main advantages of the products made in VLSI technology refer to the implementation of systems with a high functional complexity in small capsules, in conditions of low power consumption and extremely high reliability. For example, without the use of VLSI technology, the equipment encountered in consumer goods would not be conceivable. Because computing hardware can be effortlessly interfaced with real-world electromechanical systems, it is now commonly incorporated into products / processes designed for decision making. Since the end of the twentieth century, as the semiconductor and information technology industry has experienced explosive growth, computing hardware has become ubiquitous and reasonably priced. An important transformation in the design and operation of mechanical devices and systems has begun to take place, with information technology becoming a stimulus of technology that brings information to many products, processes and machines.

Microprocessors have begun to replace precision mechanical components (for example, the precision camshaft, which in many applications functions as a distribution device). The camshaft, or distribution shaft, has the role of controlling the closing and opening of the valves; it is mounted in the engine block or in the cylinder head in parallel with the crankshaft and other units mounted on the engine also operate the oil and petrol pumps.

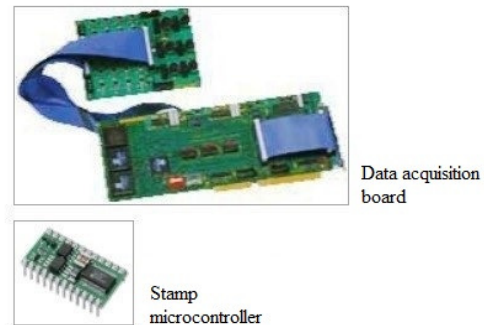


Figure 4. The information revolution: the data acquisition board and the stamp microcontroller

In addition, microprocessor programmability has provided a versatile and flexible alternative to analog / digital computing hardware. Integrated computerized electrical and mechanical devices have now become able to convert, transmit and process both physical and virtual energy (information). As a result, highly efficient products and processes are now being developed through the careful selection and integration of sensors, actuators, signal conditioning, power electronics, decision and control algorithms, and computer hardware and software. These past years, engineers have begun to develop highly efficient products and processes, carefully

selecting and integrating sensors, actuators, signal conditioning, power electronics, decision and control algorithms, and computer hardware and software.

The stages of mechatronics

- primary level mechatronics: integrates electrical signaling with mechanical action at the basic control level for example fluid valves and relay switches;
- secondary level mechatronics: integrates microelectronics in electrically controlled devices, such as cassette recorder;
- tertiary level mechatronics: incorporates the advanced control strategy using microelectronics, microprocessors and other application-specific integrated circuits, for example the microprocessor-based electric motor used for robot operation;
- quaternary level mechatronics: this level tries to improve intelligence one step further by introducing intelligence (artificial neural network and fuzzy logic) and the ability to detect and isolate errors in the system. [63]

The main concept of mechatronics is to work smartly and efficiently to achieve remarkable results in a short time. Mechatronics can be described in several ways: it is the combination of mechanics and work with precision engineering, sensor technology, actuator technology, computer science, control theory and sensor technology. [6] [7] [62]

3. CONSTITUENT ELEMENTS OF MECHATRONIC SYSTEMS

The mechanical elements that make up the mechanical structure, the mechanism, the thermo-fluid, as well as the hydraulic aspects, form a mechatronic system. These may include static / dynamic mechanical characteristics and interact correctly in the environment. The mechanics of mechatronic systems require physical power to produce movement, force, heat, etc. [35]

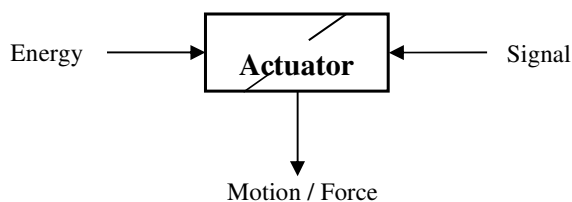


Figure 5. The actuator

Electromechanical elements refer to sensors and actuators. A servomotor is something that turns energy into motion. It can also be used to apply a force. A servomotor is usually a mechanical device that takes energy - usually energy that is created by air, electricity, or liquid - and turns it into a kind of motion. This movement can be in any form, such as

locking, gripping or removing. Actuators are commonly used in manufacturing or industrial applications and can be used in devices such as motors, pumps, switches and valves. [34]

Most mechatronic systems involve the same movement or action. This motion or action can be applied to anything from a single atom to a large articulated structure.

Movement is created by a force or torque that results in acceleration and displacement. Actuators are the devices used to produce this movement or action. [33] [64]

A sensor is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and to send information to other electronic components, often a computer processor. A sensor is always used with other electronic components. [28] [65]

Sensors are used in everyday objects, such as touch-sensitive elevator buttons (touch sensor) or lamps that darken or light up touching the base, in addition to countless applications that most people are not necessarily aware of. [29]

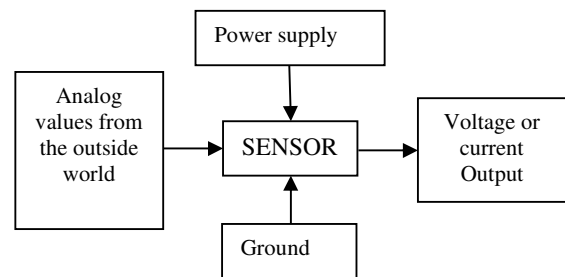


Figure 6. The sensor

With advances in micro-machines and easy-to-use microcontroller platforms, the use of sensors has expanded beyond traditional fields of measuring temperature, pressure or flow, for example in MARG sensors.

An Attitude and Position Reference System (AHRS) consists of three-axis sensors that provide attitude information for aircraft, including roll, pitch and tip. These are sometimes called MARG (magnetic, angular velocity and gravity) sensors and consist of either gyroscope systems, accelerometers and magnetometers with a solid or micro electromechanical system (MEMS). They are designed to replace traditional mechanical gyroscopic flight instruments.

Moreover, analog sensors such as potentiometers and force-sensitive resistors are still widely practiced.

Applications include production and machinery, aircraft and aerospace, machinery, medicine, robotics and many other aspects of our daily lives. [24] [25] [26]

Physical variables can be measured using sensors:

- light, using photo resistance;
- level and displacement, using the potentiometer;
- direction / tilt with magnetic sensor;
- sound, using the microphone;
- stress and pressure, using the nanometer;
- touching with a micro switch;
- temperature, using the thermistor;
- humidity, using the conductivity sensor.

Actuators such as light emitting diode (LED), DC servomotor, stepper motor, relay, solenoid, speaker, shape memory alloy, electromagnet and pump apply the controlled action on the physical process. In recent years, integrated circuit detection and actuation (IC) solutions have become ubiquitous (digital compass, potentiometer, etc.). The actuator is used in automatic systems for executing commands. [31] [70] [71]

Electrical elements refer to electrical components (resistor (R), capacitor (C), inductor (L), transformer, etc.), circuits and analog signals. [68]

Electronic elements refer to analog / digital electronics, transistors, thyristors, opto-isolators, operational amplifiers, power electronics and signal conditioning.

The electrical / electronic elements are used to interface electromagnetic sensors and actuators with the hardware elements of the control interface. [69]

The control / calculation interface hardware elements refer to analog-to-digital converter (A2D), digital-to-analog converter (D2A), digital input / output (I/O), meters, stopwatches, microprocessor, microcontroller, acquisition and control board. data (DAC) and digital signal processing board (DSP).

The hardware of the control interface allows the analog / digital interface, i.e. the communication of the sensor signal to the control computer and the communication of the signal from it to the actuator.

The control computing hardware implements a control algorithm, which uses sensor measurements, to calculate the control actions to be applied by the actuator. [30]

The computer elements used in mechatronic systems:

- the hardware and software used to perform the analysis, optimization, design and simulation of the dynamic computer-aided system;
- virtual instrumentation;
- prototyping with fast control;
- loop hardware simulation;
- computer-based data acquisition and control.

4. CONCLUSIONS

Applications of mechatronics

- smart consumer products: home security, camera, microwave, toaster, dishwasher, washer-dryer, air conditioning units, automatic digital camera, etc.
- computer disk VCR / DVD drivers, ATM, etc.
- medical: implant devices, assisted surgery, etc.
- defense: unmanned air, underground and underwater vehicles, smart weapons, jet engines, etc.
- manufacturing: NC and CNC machine tools, rapid prototyping, robotics, etc.
- vehicles: air conditioning, anti-lock brake, active suspension, cruise control, airbags, engine management, safety, etc.
- distributed systems centered in the network: distributed robotics, intelligent highways, etc.

The sensors (sensitive elements) offer the possibility to take information about the state of the system or technological process, the environment in which it operates, or changes in some functional characteristics of the device.

At the same time, the sensors also allow decisions to be made about ordering or interrupting the operation of systems in the event of breakdowns or certain limit conditions. A wide variety of sensors can be placed on the mechanical structure or only on some of its components, depending on the parameters of interest of the mechatronic system. [16] [17]

The introduction of software modules (advanced computational algorithms for control, information flow, data acquisition, interface between human operator-mechatronic system virtual prototyping, modeling, simulation, visualization) transforms the mechatronic system into an advanced, complex, automatic, flexible and intelligent.

Flexibility is characterized by the ease of the system to be adaptable to changes in its operating environment. This is possible by modifying the control software. Intelligence, which increasingly defines mechatronic systems, is described by the adaptive capacity of the system, based on reasoning, self-learning, reproduction of work operations, the possibility of reconfiguring the system in case of malfunctions, error diagnosis, etc. [1] [2]

All these remarkable features provide an insight into the complexity and diversity of mechatronics as an interdisciplinary science, and its principles can be successfully applied in a wide variety of fields of technology. Practically, at present, there is no field in which mechatronic systems do not have a predominant role. Many companies have begun to

develop and produce mechatronic systems, with the role of improving the functional performance of technical systems, or to increase the quality and comfort of people's social life. [3]

Mechatronic systems are sometimes called smart devices. While the term intelligent is evasive in precise definition, in the sense of engineering we refer to the inclusion of elements such as logic, feedback and calculation that in a complex design may seem to simulate the processes of human thinking. It is not easy to compartmentalize the design of the mechatronic system in a traditional field of engineering, because such a design is based on knowledge from several fields. The designer of the mechatronic system must be a generalist, willing to seek and apply knowledge from a wide range of sources. This can intimidate the student at first, but offers great benefits for individuality and lifelong learning. [46] [47]

The following figure illustrates all the components of a typical mechatronic system, an office copier:

- the actuators produce motion or cause some actions;
- the sensors detect the status of the parameters, inputs and outputs of the system;
- digital devices control the system;
- the conditioning and interfacing circuits ensure connections between the control circuits and the input / output devices;
- graphic displays provide visual feedback to users. [23]

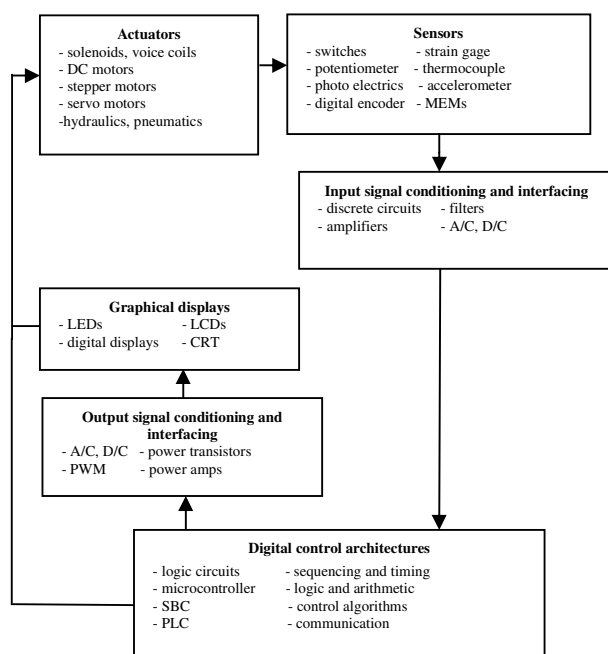


Figure 7. Components of the mechatronic system

All the components in Figure 7 can be found in this common office equipment. This includes analog and digital circuits, sensors, actuators and microprocessors.

The copying process works as follows: the user places an original in a cart and presses a button to start the process; the original is transported to the bottle with tray; and a high-intensity light source scans the original and transfers the corresponding image as a load distribution to a drum.

Then, a blank piece of paper is taken from a loading cartridge, and the image is transferred to the paper with an electrostatic deposition of the ink toner powder which is heated to stick to the paper.

A sorting mechanism optionally delivers the copy to a suitable basket.

Pulse width modulation (PWM), or pulse duration modulation (PDM), is a method of reducing the average power provided by an electrical signal, by efficiently increasing it in discrete parts. The average value of the voltage (and current) supplied at load is controlled by turning the switch between power and fast charging and shutdown. The longer the switch is compared to the off periods, the higher the total power supplied to the load. Along with maximum power point tracking (MPPT), it is one of the main methods of reducing the power of solar panels to that which can be used by a battery. PWM is particularly suitable for running inertial loads, such as motors, which are not so easily affected by this discrete switching because they have inertia to react slowly. The PWM switching frequency must be high enough not to affect the load, i.e. the resulting waveform perceived by the load must be as smooth as possible. [10]

The analog circuits control the lamp, heater and other power circuits in the car. Digital circuits control the digital displays, indicators, buttons, and switches that form the user interface. Other digital circuits include logic circuits and microprocessors that coordinate all functions in the machine. Optical sensors and microswitches detect the presence or absence of paper, its correct positioning, and whether or not the doors and latches are in the correct positions. Other sensors include encoders used to track engine rotation. Actuators include servo and stepper motors that load and transport paper, rotate the drum, and index the sorter. [18]

These days, virtually all mechanical devices include electronic components and some type of computer monitoring or control. Increasingly, microcontrollers are being incorporated into electromechanical devices, creating much more flexibility and control possibilities in system design. [19]

Examples of mechatronic systems include an aircraft flight control and navigation system, car airbag safety system and anti-lock braking systems, automatic manufacturing equipment such as numerically controlled robots and machine tools (NC), smart kitchen and appliances, such as bread machines and washing machines or even toys.

Some large companies develop special programs with digital factories. Proven and tested components and technologies are used here.

Feasibility can be shown and tested directly in the learning factory environment. In addition, it is possible to qualify employees at the existing facility for practical and theoretical knowledge and prepare them for the future challenges of the digital factory.

In the area of digital manufacturing, Siemens has developed a digital manufacturing (DF) program.

Siemens has a complete portfolio of products, systems and solutions for manufacturing and process automation, as well as drive technology. This spectrum is complemented by innovative services tailored to the needs of our customers throughout the life cycle of a machine or factory. Siemens' automation technology makes a decisive contribution to the continuous optimization of processes throughout the company. [27]

Fully integrated automation, the unique end-to-end product spectrum and the automation system in the manufacturing and process industry are at the core of the company's offering. Siemens has such an optimal base for solutions perfectly adapted to individual requirements.

The digital factory offers a full range of hardware, software and embedded technology-based services. This range helps manufacturing companies around the world to maximize the flexibility and efficiency of their processes, thus reducing the marketing time of their products. The perfect integration of data on industrial value chains is becoming increasingly critical for the sustainable development of manufacturing companies.

Siemens' digital factory division strives to offer its customers a full range of hardware and software products to fully integrate development, production and supplier data. The ultimate goal is the complete digital representation of the physical value chain as a whole. To this end, the Enterprise Digital solution platform was created.

Today, the DF product line already connects the essential parts of the product and production life cycle. For example, powerful PLM (Product Lifecycle Management) software allows the development and optimization of new products on a completely virtual basis. In the real world of manufacturing, the TIA (Totally Integrated

Automation) concept, proven for about 20 years, ensures efficient interoperability of all automation components.

The TIA portal offers significant time savings and considerable engineering savings. The Digital Factory division works closely with its Siemens partners, including the Process Industries and Drives division, to offer a unique and wide range of PLM software tools and automation and drive technologies that adapt to the specific needs of each customer in different industrial areas. In addition, DF encourages the long-term development of its customers' business. Protecting our customers' investments today and in the future (an important aspect in the software industry) is one of the main pillars of Siemens' business strategy. In addition, in order to shape the future of the sector, DF combines its dynamic and innovative capabilities with those of its partners around the world. Thus, proven advanced technologies are used to optimize productivity and protect a competitive advantage. [45] [50] [51]

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