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**«ТОМСКИЙ ПОЛИТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ»**

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# MECHATRONICS: FOR PRACTICAL WORKS IN PROFESSIONAL ENGLISH

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Учебное пособие предназначено для углубленного изучения вопросов использования профессионального английского языка в области обучения элитных специалистов по мехатронике. Рассмотрены базовые понятия мехатроники, этапы развития и современные подходы к построению мехатронных систем, сенсоры и актуаторы мехатронных систем, роль компьютеров в мехатронике, вопросы обработки информации в мехатронных системах. Предназначено для изучения профессионального английского языка при подготовке магистров, бакалавров и дипломированных специалистов направления 220200 Автоматизация и управление, в том числе для учебной дисциплины «Professional English» включаемой в учебные планы подготовки магистров по магистерской программе «Управление в технических (мехатронных) системах».

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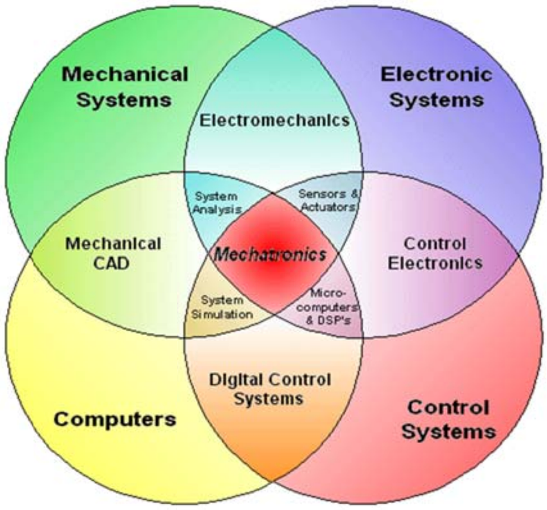
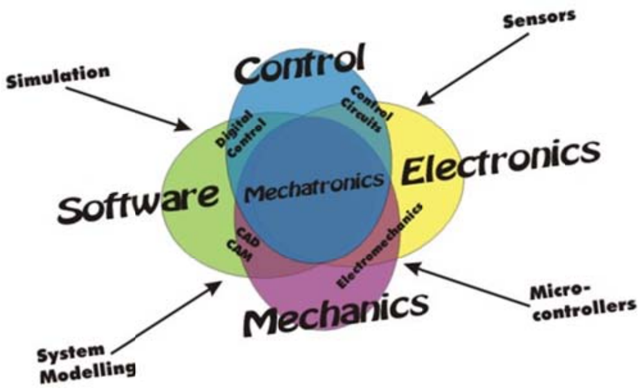
# UNIT 1
# BASICS OF MECHATRONICS: SECTION 1

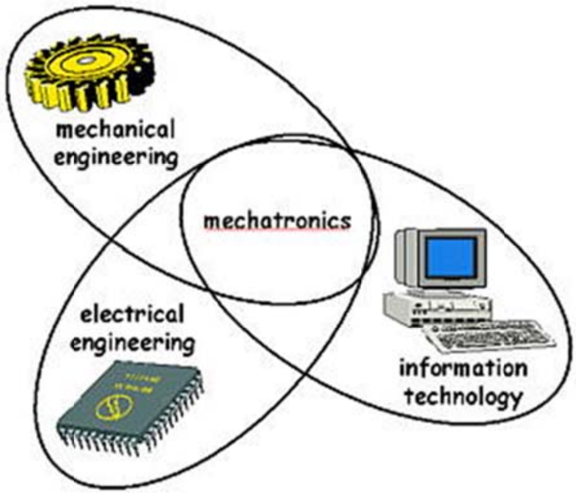



## *LEAD- IN*

**1 Look at the pictures which give a visual representation of "mechatronics", then sum up all the definitions of mechatronics given below and suggest your own variant of its description.**








- Mechatronics is defined as the synergistic integration of mechanical engineering, with electronics and intelligent computer control in the design and manufacturing of industrial products and processes.
- Mechatronics is the application of complex decision making to the operation of physical systems.

- Mechatronics is a methodology used for the optimal design of electromechanical products.
- A mechatronic system is not just a marriage of electrical and mechanical systems and is more than just a control system; it is a complete integration of all of them.

**2 Read the introduction to the subject of Mechatronics and fill the gaps in it with the words from the box.**

| mechatronics | technologies | |
|---|---|---|
| natural | engineering | twentieth |

Mechatronics is a (1) __________ stage in the evolutionary process of modern (2) __________ design. The development of the computer, and then the microcomputer, embedded computers, and associated information (3) __________ and software advances, made mechatronics an imperative in the latter part of the (4) __________ century.

Standing at the threshold of the twenty-first century, with expected advances in integrated bioelectro-mechanical systems, quantum computers, nano- and pico-systems, and other unforeseen developments, the future of (5) __________ is full of potential and bright possibilities.

***LISTENING***

**3 Read the following summary of the text about basic definitions of mechatronics, then listen to the recording and for Questions 1–10, fill in the gaps. Use not more than 3 words in each gap.**

The definition of mechatronics **1** __________ since the

original definition by the Yasakawa Electric Company. The word,

mechatronics, is composed of "mecha" from **2** __________
and the "tronics" from **3** __________ The definition

continued to develop but being **4** __________ and informative, all definitions and statements can not capture the totality of mechatronics. For many practicing engineers on the front line of

| **5** | |
|---|---|

mechatronics is nothing new. Many engineering products of the last 25 years

| **6** | |
|---|---|

mechanical, electrical, and computer systems, yet were designed by engineers that were never formally trained in mechatronics *per se.* Being not only a convenient structure for

| **7** | |
|---|---|

by academicians; mechatronics is a way of life in modern engineering practice. The ongoing revolution of information technology, advances in

| **8** | |
|---|---|

communication, smart sensors design, and

| **9** | |
|---|---|

engineering ensures that the engineering

| **10** | |
|---|---|

will continue to evolve in the early twenty-first century.

***READING***

**4 You are going to read a text about the basic definitions of mechatronics. For Statements 1 – 8, choose the correct mark T (true) or F (false) according to the information given. Correct the false statements.**

**Basic Definitions**

The definition of mechatronics has evolved since the original definition by the Yasakawa Electric Company. In trademark application documents, Yasakawa defined mechatronics in this way: The word, mechatronics, is composed of "mecha" from mechanism and the "tronics" from electronics. In other words, technologies and developed products will be incorporating electronics more and more into mechanisms, intimately and organically, and making it impossible to tell where one ends and the other begins.

The definition of mechatronics continued to evolve after Yasakawa suggested the original definition. Oneoft quoted definition of mechatronics was presented by Harashima, Tomizuka, and Fukada in 1996. In their words, mechatronics is defined as the synergistic integration of mechanical engineering, with electronics and intelligent computer control in the design and manufacturing of industrial products and processes.

That same year, another definition was suggested by Auslander and Kempf: Mechatronics is the application of complex decision making to the operation of physical systems.

Yet another definition due to Shetty and Kolk appeared in 1997: Mechatronics is a methodology used for the optimal design of electromechanical products.

More recently, we find the suggestion by W. Bolton: A mechatronic system is not just a marriage of electrical and mechanical systems and is more than just a control system; it is a complete integration of all of them.

All of these definitions and statements about mechatronics are accurate and informative, yet each one in and of itself fails to capture the totality of mechatronics. Despite continuing efforts to define mechatronics, to classify mechatronic products, and to develop a standard mechatronics curriculum, a consensus opinion on an all-encompassing description of "what is mechatronics" eludes us. This lack of consensus is a healthy sign. It says that the field is alive, that it is a youthful subject. Even without an unarguably definitive description of mechatronics, engineers understand from the definitions given above and from their own personal experiences the essence of the *philosophy* of mechatronics.

For many practicing engineers on the front line of engineering design, mechatronics is nothing new. Many engineering products of the last 25 years integrated mechanical, electrical, and computer systems, yet were designed by engineers that were never formally trained in mechatronics *per se.* It appears that modern concurrent engineering design practices, now formally viewed as part of the mechatronics specialty, are natural design processes. What is evident is that the study of mechatronics provides a mechanism for scholars interested in understanding and explaining the engineering design process to define, classify, organize, and integrate many aspects of product design into a coherent package. As the historical divisions between mechanical, electrical, aerospace, chemical, civil, and computer engineering become less clearly defined, we should take comfort in the existence of mechatronics as a field of study in academia. The mechatronics specialty provides an educational path, that is, a roadmap, for engineering students studying within the traditional structure of most engineering colleges. Mechatronics is generally recognized worldwide as a vibrant area of study. Undergraduate and graduate programs in mechatronic engineering are now offered in many universities. Refereed journals are being published and dedicated conferences are being organized and are generally highly attended.

It should be understood that mechatronics is not just a convenient structure for investigative studies by academicians; it is a way of life in modern engineering practice. The introduction of the microprocessor in the early 1980s and the ever increasing desired performance to cost ratio revolutionized the paradigm of engineering design. The number of new products being developed at the intersection of traditional disciplines of engineering, computer science, and the natural sciences is ever increasing. New developments in these traditional disciplines are being absorbed into mechatronics design at an ever increasing pace. The ongoing information technology revolution, advances in wireless communication, smart sensors design (enabled by MEMS technology), and embedded systems engineering ensures that the engineering design paradigm will continue to evolve in the early twenty-first century.

1 There is no common understanding of what mechatronics is.
2 Nowadays engineers are used to understanding mechatronics not taking into account their personal experience but only existing theory of mechatronics.
3 Engineers have been designing mechanical, electrical and computer systems during 25 years without being trained in the mechatronics field.
4 When studying mechatronics, scientists are provided with the mechanism for creating a coherent package of product design.
5 An educational path of mechatronics specialty is treated as a set of sophisticated applications for engineering students.
6 Being a new field of studying, mechatronic engineering is not widespread in educational institutions.
7 The microprocessors were introduced in the early 1918s.
8 All state-of-art technologies are being successfully used in the $21^{st}$ century.

*VOCABULARY AND GRAMMAR*

**5 Here are the basic terms of Unit 1 on the left. Match them with their definitions on the right.**

| | | | |
|---|---|---|---|
| 1 | mechatronics | A | an engineering practice for design of products based on the mechatronics principles |
| 2 | mechatronics system | B | the synergistic integration of mechanical engineering, with electronics and intelligent computer control |
| 3 | mechatronics products | C | a complete integration of control, electrical, and mechanical systems |
| 4 | mechatronics design | D | a mechanism for understanding and explaining the engineering design process to define, classify, organize, and integrate many aspects of product design |
| 5 | mechatronics study process | E | the results of the mechatronics principles implementation in the design and manufacturing |
| 6 | synergistic integration | F | the effect of the coordinated interaction of parts of mechatronics system |
| 7 | DSP | G | a device that consists of a microprocessor, memory and other attached devices |
| 8 | actuator | H | a device which is used in digital control systems of mechatronics systems alongside with microcomputers |
| 9 | microcontroller | I | a device which detects or measures some condition, indicates, or responds to the information received |
| 10 | sensor | J | a device which causes realization of mechatronics system functional motion |

## Passive and Active Voices

**There're 2 Voices in English: *Passive* and *Active.***

1. We use an ***active*** verb to say what the subject does.
   *e.g. Charles Babbage **invented** the computer.*
2. We use a ***passive*** verb to say what happens to the subject.
   *e.g. The computer **was invented** by Charles Babbage.*

- When we use the passive, who or what causes the action is often unknown or unimportant.
  *e.g. This information **has** already **been processed**.*
- The passive is formed with the verb *to be* in the correct tense and the past participle of the main verb. Only transitive verbs (verbs which take an object) can be put into the passive.

**to be + past participle (-ed/V3)**

*e.g. Instructions **are processed** by the CPU.*
*The computer **was invented** by Charles Babbage.*
- Present Perfect Continuous, Future Continuous and Past Perfect Continuous are not normally used in the Passive.
- After the modal verbs (e.g. *must, should, can,* etc) and *will, would* the verb ***to be*** isn't changed. The past participle of the main verb is also added in this case.
- Use ***by*** if you want to mention who does or what causes the action.
  *e.g. This function **can be performed** by a PC.*
  *These functions **will be performed** by a PC.*
- In passive questions with *who, whom* or *which* we do not omit "by".
- *e.g. **Who** was the database made **by**?*
- If a verb is followed by a preposition or is a phrasal verb (make off, take down, etc.), in the passive the preposition is placed immediately after the verb.
  e.g. *What **is** this spreadsheet **made off**?*
  *I think this array should **be taken down**.*

| Tense Form | Active voice | Passive voice |
|---|---|---|
| Present Simple | The mechatronics specialty **provides** an educational path. | An educational path **is provided** by the mechatronics specialty. |
| Present Continuous | In the 21st century people successfully **use** all state-of-art technologies. | All state-of-art technologies **are being** successfully **used** in the 21st century. |
| Present Perfect | People widely **use** electrohydraulics in aerospace, industrial, and mobile fluid power systems. | Electrohydraulics **has been** widely **used** in aerospace, industrial, and mobile fluid power systems. |
| Past Simple | They **introduced** microprocessors in the early 1918s | The microprocessors **were introduced** in the early 1918s |

| Tense Form | Active voice | Passive voice |
|---|---|---|
| Past Continuous | Specialists **were making** the definition if mechatronics during several years. | The definition of mechatronics **was being made** during several years. |
| Past Perfect | Engineers **had designed** integrated mechanical, electrical, and computer systems before they were formally trained in mechatronics. | Integrated mechanical, electrical, and computer systems **had been designed** by engineers before they were formally trained in mechatronics. |
| Future Simple | We **will describe** Inductors in the same notation. | Inductors **will be described** in the same notation. |
| Future Perfect | They **will master** most engineering students at least one tool before obtaining a bachelor's degree. | Most engineering students **will have mastered** at least one tool before obtaining a bachelor's degree. |

**6 Open the brackets in the following sentences and put the verb in the correct passive form.**

1 In Europe and Russia, between seventeenth and nineteenth centuries, many important devices ___________ (invent) that would eventually contribute to mechatronics.
2 The first historical feedback system claimed by Russia ___________ (develop) by Polzunov in 1765.
3 This is an example of a feedback control system where the feedback signal and the control actuation ___________ (completely/couple) in the mechanical hardware.
4 During the same time period, control theory ___________ (also/develop) in Russia and Eastern Europe.
5 The term mechatronics ___________ (introduce) by Yasakawa Electric in 1969 to represent such systems and the inventor ___________ (grant) a trademark in 1972.

**7 Read the text below. Some lines contain a mistake. If there is a mistake in the line, write it out in your paper and correct. If the line is correct, write 'OK'. There is an example at the beginning.**

Example:
0 ok
00 are

| | | |
|---|---|---|
| 0 Mechatronics as a science is a comparatively new | 0 | ok |

00 branch. In the name itself two separate notions
1. include. They are “mecha” from mechanism and
2. “tronics” from electronics. Now Mechatronics
3. studied as a subject in Higher Schools of some
4. countries. In spite of the fact that there is no
5. common definition of the term Mechatronics, it is
6. accept to treat it as integration of electrical,
7. mechanical and control systems. Today from
8. different recourses it knows that Mechatronics
9. are rooted in Greece from 300 to 1 B.C.
10. Nowadays it is not climax of Mechatronics
11. evolution, even the nearest future will filled with
12. new advances and advent of smarter information
13. technology products.

| | |
|---|---|
| 00 | are |
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| 7 | |
| 8 | |
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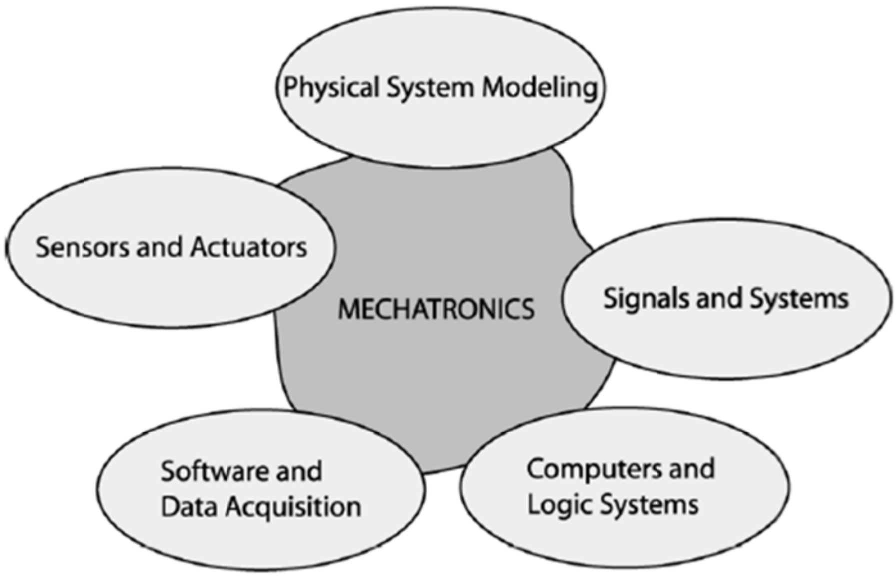
| 11 | |
| 12 | |
| 13 | |

## *SPEAKING*

**8 The figure below represents key elements of mechatronics. Study it and comment on these aspects.**




**9 You are given 5 situations. Choose one of them and make a plan for its oral presentation, then make a report. Let it be of not less than 160 – 200 words.**

1 You are a lecturer, who is teaching Mechatronics subject at University. Tell your students about Yasawaka Electronics Company and its place in Mechatronics studying.

2 What should be observed speaking about Basics of Mechatronics? Tell about it in details.

3 You are a student of Computer Science Faculty. Your home task was to find information about main points in Mechatronics History. Present your task now.

4 You are to prepare report devoted to Mechatronics sphere. Your particular area is History of Mechatronics. Take one of its stages (in you case it is classification of mechatronic products into 4 categories by the Japan Society for the Promotion of Machine Industry.) and tell about it, observing thoroughly every category.

5 Introductory Mechatronic Course is being studied in educational institutions in different countries today. Tell about its role in process of education, taking into consideration material given earlier and express your attitude to it from the point of view of its utility.

## Basics of Mechatronics: Section 2

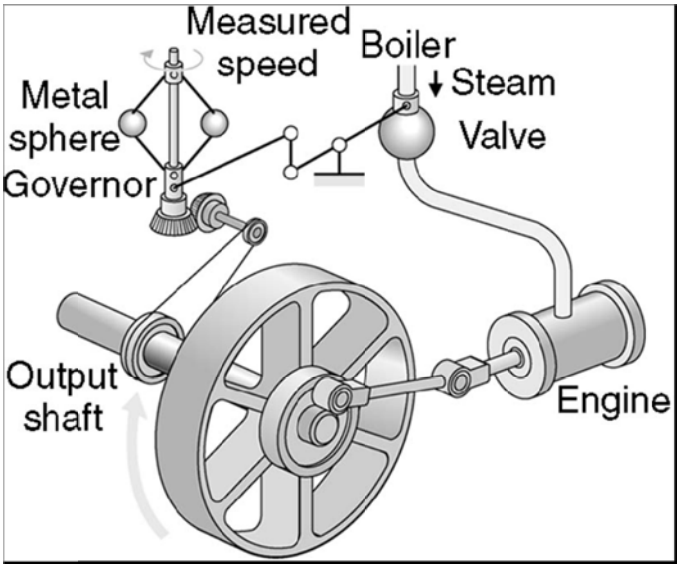
***READING***

**10 You are going to read a text about the historical perspectives of mechatronics. Say what you know about its history.**

**11 Now read the text and answer the questions below.**

1 What does synergistic integration mean?
2 What were the roles of cam, linkages, and chain drives for the invention of new products in 1950s?
3 When was the first Russian feedback system developed?
4 What is the role of flyball governor in Watt's steam-engine?
5 What were the reasons of using feedback control system development in the USA during 1940s?
6 What is the difference between classes of the JSPMI mechatronics products classification?
7 Why achievements of electronic industry exerted big influence on mechatronics products implementation?
8 In your opinion, what factors promoted intensive development of control systems at 1950s?
9 What is the importance of mathematical theory of regulators formulated by Vyshnegradskii?
10 What was the role of Nikola Tesla invention in the late 1880s?

## Historical Perspectives




Early applications of automatic control systems appeared in Greece from 300 to 1 B.C. with the development of float regulator mechanisms.

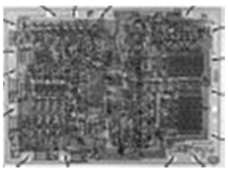
In Europe and Russia, between seventeenth and nineteenth centuries, many important devices were invented that would eventually contribute to mechatronics.

Cornelis Drebbel (1572–1633) of Holland devised the temperature regulator representing one of the first feedback systems of that era. The first mechanical calculating machine was invented by Pascal in 1642. The first historical **feedback system** claimed by Russia was developed by Polzunov in 1765.

Further evolution in automation was enabled by advancements in control theory traced back to the Watt flyball governor of 1769. The flyball governor was used to control the speed of a steam engine. This is an example of a **feedback control system** where the feedback signal and the control actuation are completely coupled in the mechanical hardware. These early successful automation developments were achieved through intuition, application of practical skills, and persistence. The next step in the evolution of automation required a *theory* of automatic control. The precursor to the numerically controlled (NC) machines for automated manufacturing (to be developed in the 1950s and 60s at MIT) appeared in the early 1800s with the invention of **feed-forward control** of weaving looms by Joseph Jacquard of France. In the late 1800s, the subject now known as control theory was initiated by J.C. Maxwell through analysis of the set of differential equations describing the **flyball governor**. At about the same time, Vyshnegradskii formulated a **mathematical theory of regulators**. In the 1830s, Michael Faraday described the **law of induction** that would form the basis of the electric motor and the electric dynamo. Subsequently, in the late 1880s, Nikola Tesla invented the alternating-current induction motor. The basic idea of controlling a mechanical system automatically was firmly established by the end of 1800s. The development of pneumatic control elements in the 1930s matured to a point of finding applications in the process industries. However, prior to 1940, the design of **control systems** remained an art generally characterized by trial-and-error methods. During the 1940s, continued advances in mathematical and analytical methods solidified the notion of control engineering as an independent engineering discipline. In the United States, the development of the telephone system and **electronic feedback amplifiers** spurred the use of feedback by Bode, Nyquist, and Black at Bell Telephone Laboratories. During the same time period, control theory was also being developed in Russia and Eastern Europe. Further developments of **time domain** formulations using state variable system representations occurred in the 1960s and led to design and analysis practices now generally classified as “modern control.”

The World War II war effort led to further advances in the theory and practice of automatic control in an effort to design and construct automatic airplane pilots, gun-positioning systems, radar antenna control systems, and other military systems. The complexity and expected performance of these military systems necessitated an extension of the available **control techniques** and fostered interest in control systems and the development of new insights and methods.

On the commercial side, driven by cost savings achieved through mass production, automation of the production process was a high priority beginning in the 1940s. During the 1950s, the invention of the **cam, linkages**, and **chain drives** became the major enabling technologies for the invention of new products and high-speed precision manufacturing and assembly. Examples include textile and printing machines, paper converting machinery, and sewing machines. High-volume precision manufacturing became a reality during this period.



The development of the microprocessor in the late 1960s led to early forms of computer control in process and product design. Examples include numerically controlled machines and aircraft control systems.

The launch of Sputnik and the advent of the space age provided yet another impetus to the continued development of controlled mechanical systems. The need to minimize satellite mass while providing accurate control encouraged advancements in the important field of optimal control. **Time domain methods** developed by Liapunov, Minorsky, and others, as well as the theories of optimal control developed by L.S. Pontryagin in the former Soviet Union and R. Bellman in the United States, were well matched with the increasing availability of high-speed computers and new programming languages for scientific use.

Advancements in semiconductor and integrated circuits manufacturing led to the development of a new class of products that incorporated mechanical and electronics in the system and required the two together for their functionality. The term mechatronics was introduced by Yasakawa Electric in 1969to represent such systems. Yasakawa was granted a trademark in 1972, but after widespread usage of the term, released its trademark rights in 1982. Initially, mechatronics referred to systems with only mechanical systems and electrical components–no computation was involved. Examples of such systems include the automatic sliding door, vending machines, and garage door openers.

In the late 1970s, the Japan Society for the Promotion of Machine Industry (JSPMI) classified mechatronics products into four categories:

1. *Class I:* Primarily mechanical products with electronics incorporated to enhance functionality. Examples include numerically controlled machine tools and variable speed drives in manufacturing machines.
2. *Class II:* Traditional mechanical systems with significantly updated internal devices incorporating electronics. The external user interfaces are unaltered. Examples include the modern sewing machine and automated manufacturing systems.
3. *Class III:* Systems that retain the functionality of the traditional mechanical system, but the internal mechanisms are replaced by electronics. An example is the digital watch.
4. *Class IV:* Products designed with mechanical and electronic technologies through **synergistic integration**. Examples include photocopiers, intelligent washers and dryers, rice cookers, and automatic ovens.

The enabling technologies for each mechatronic product class illustrate the progression of electromechanical products in stride with developments in control theory, computation technologies, and microprocessors.

Whatever definition of mechatronics one chooses to adopt, it is evident that modern mechatronics involves computation as the central element. In fact, the incorporation of the microprocessor to precisely modulate mechanical power and to adapt to changes in environment is the essence of modern mechatronics and smart products.

**12 Choose 3 words or word combinations on the topic “Mechatronics” from the text, activity 11 and give definitions.**

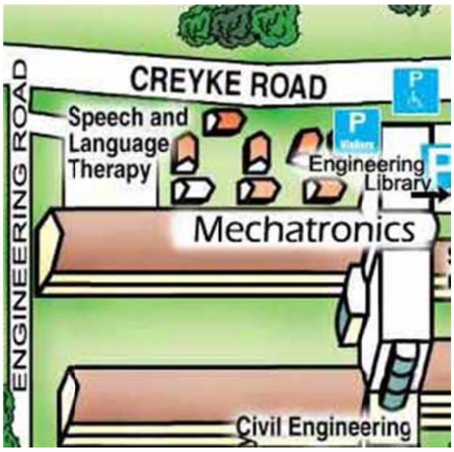
### Basics of Mechatronics: Self Study Section

**13 For Questions 1 – 15, read the text below. Use the word given in capitals at the end of each line to form a word that fits in the space in the same line. Use the example at the beginning.**

Example:
(0) engineers

### What is Mechatronics?

For some **(0)** ___________, mechatronics is — **ENGINEERING**
nothing new, and, for others, it is a **(1)** — **PHILOSOPHY**
___________ approach to design that serves as a
guide for their **(2)** ___________. Certainly, mech- — **ACTIVE**
atronics is an **(3)** ___________ process, not a **(4)** — **EVOLUTION**
___________ one. It is clear that an all- — **REVOLUTION**
encompassing definition of mechatronics does




not exist, but in reality, one is not needed. It is understood that mechatronics is about the synergistic **(5)**
___________ of **(6)**
___________, elec- — **INTEGRATE**
trical, and computer — **MECHANICS**
systems.

One can understand the **(7)** ___________
that mechatronics reaches into **(8)** ___________ — **EXTENDED**
disciplines by **(9)** ___________ the constituent — **VARIETY**
components comprising mechatronics, which in- — **CHARACTER**
clude **(10)** ___________ systems modeling, sen-
sors and **(11)** ___________, signals and systems, — **PHYSICS**
computers and logic systems, and software and — **ACTUATE**
data acquisition. Engineers and scientists from
all walks of life and fields of study can **(12)**
___________ to mechatronics. As engineering
and science boundaries become less well **(13)** — **CONTRIBUTION**

| | |
|---|---|
| __________, more students will seek a multi-disciplinary **(14)** __________ with a strong design component. Academia should be moving towards a curriculum, which includes **(15)** __________ of mechatronic systems. | **DEFINITION**<br>**EDUCATE**<br><br>**COVER** |

**13 For Questions 1 – 10, complete the following text by writing down each missing word. Use only one word in each gap. The exercise begins with the example (0).**

**What's Next?**

In the **(0)** _*future*____, growth in mechatronic systems will **(1)** ___________ fueled by the growth in the constituent areas. Advancements in traditional disciplines fuel the growth of mechatronics systems **(2)** ___________ providing "enabling technologies." We should expect continued advancements in cost-effective microprocessors **(3)** ___________ microcontrollers, sensor and actuator development enabled by advancements in applications of MEMS, adaptive control methodologies and real-time programming methods, networking and wireless technologies, mature CAE technologies **(4)** ___________ advanced system modeling, virtual prototyping, and testing. The continued rapid development in these areas **(5)** ___________ only accelerate the pace of smart product development. The Internet is a technology that, **(6)** ___________utilized in combination with wireless technology, may also lead to new mechatronic products. While developments in automotives provide vivid examples **(7)** ___________ mechatronics development, there are numerous examples of intelligent systems in all walks of life, including smart home appliances **(8)** ___________ as dishwashers, vacuum cleaners, microwaves, and wireless network enabled devices. In the area of "human-friendly machines", we can expect advances in robot-assisted surgery, and implantable sensors and actuators.

**(9)** ___________ areas that will benefit from mechatronic advances **(10)** ___________ include robotics, manufacturing, space technology, and transportation. The future of mechatronics is wide open.

***WRITING***

**14 Read information about the procedure of writing annotations in the section "Additional Material" at the end of the book. Then**

**read a text about the development of an automobile as a mechatronic system and write an annotation to it.**

### The Development of the Automobile as a Mechatronic System

The evolution of modern mechatronics can be illustrated with the example of the automobile. Until the 1960s, the radio was the only significant electronics in an automobile. All other functions were entirely mechanical or electrical, such as the starter motor and the battery charging systems. There were no “intelligent safety systems,” except augmenting the bumper and structural members to protect occupants in case of accidents. Seat belts, introduced in the early 1960s, were aimed at improving occupant safety and were completely mechanically actuated. All engine systems were controlled by the driver and/or other mechanical control systems. For instance, before the introduction of sensors and microcontrollers, a mechanical distributor was used to select the specific spark plug to fire when the fuel–air mixture was compressed. The timing of the ignition was the control variable. The mechanically controlled combustion process was not optimal in terms of fuel efficiency. Modeling of the combustion process showed that, for increased fuel efficiency there existed an optimal time when the fuel should be ignited. The timing depends on load, speed, and other measurable quantities. The electronic ignition system was one of the first mechatronic systems to be introduced in the automobile in the late 1970s. The electronic ignition system consists of a crankshaft position sensor, camshaft position sensor, airflow rate, throttle position, rate of throttle position change sensors, and a dedicated microcontroller determining the timing of the spark plug firings. Early implementations involved only a Hall effect sensor to sense the position of the rotor in the distributor accurately. Subsequent implementations eliminated the distributor completely and directly controlled the firings utilizing a microprocessor.

The Antilock Brake System (ABS) was also introduced in the late 1970s in automobiles. The ABS works by sensing lockup of any of the wheels and then modulating the hydraulic pressure as needed to minimize or eliminate sliding. The Traction Control System (TCS) was introduced in automobiles in the mid-1990s. The TCS works by sensing slippage during acceleration and then modulating the power to the slipping wheel. This process ensures that the vehicle is accelerating at the maximum possible rate under given road and vehicle conditions. The Vehicle Dynamics Control (VDC) system was introduced in automobiles in the late 1990s. The VDC works similar to the TCS with the addition of a yaw rate sensor and a lateral accelerometer. The driver intention is determined by the steering wheel position and then compared with the actual direction of motion. The TCS system is then activated to control the power to the wheels and to control the vehicle velocity and minimize the difference between the steering wheel direction and the direction of the vehicle motion. In some cases, the ABS is used to slow down the vehicle to achieve desired control. In automobiles today, typically, 8, 16, or 32-bit CPUs are used for implementation of the various control systems. The microcontroller has onboard memory (EEPROM/EPROM), digital and analog inputs, A/D converters, pulse width modulation (PWM), timer functions, such as event counting and pulse width measurement, prioritized inputs, and in some cases digital signal processing. The 32-bit processor is used for engine management, transmission control, and airbags; the 16-bit processor is used for the ABS, TCS, VDC, instrument cluster, and air conditioning systems; the 8-bit processor is used for seat, mirror control, and window lift systems. Today, there are about 30–60 microcontrollers in a car. This is expected to increase with the drive towards developing modular systems for plug-n-ply mechatronics subsystems.

Mechatronics has become a necessity for product differentiation in automobiles. Since the basics of internal combustion engine were worked out almost a century ago, differences in the engine design among the various automobiles are no longer useful as a product differentiator. In the 1970s, the Japanese automakers succeeded in establishing a foothold in the U.S. automobile market by offering unsurpassed quality and fuel-efficient small automobiles. The quality of the vehicle was the product differentiator through the 1980s. In the 1990s, consumers came to expect quality and reliability in automobiles from all manufacturers. Today, *mechatronic features* have become the product differentiator in these traditionally mechanical systems. This is further accelerated by higher performance price ratio in electronics, market demand for innovative products with smart features, and the drive to reduce cost of manufacturing of existing products through redesign incorporating mechatronics elements. With the prospects of low single digit (2…3 %) growth, automotive makers will be searching for high-tech features that will differentiate their vehicles from others. The automotive electronics market in North America, now at about $20 billion, is expected to reach $28 billion by 2004. New applications of mechatronic systems in the automotive world include semi-autonomous to fully autonomous automobiles, safety enhancements, emission reduction, and other features including intelligent cruise control, and brake by wire systems eliminating the hydraulics. Another significant growth area that would benefit from a mechatronics design approach is wireless networking of automobiles to ground stations and vehicle-to-vehicle communication. Telematics, which combines audio, hands-free cell phone, navigation, Internet connectivity, e-mail, and voice recognition, is perhaps the largest potential automotive growth area.

In fact, the use of electronics in automobiles is expected to increase at an annual rate of 6 % per year over the next five years, and the electronics functionality will double over the next five years. Micro Electromechanical Systems (MEMS) is an enabling technology for the cost-effective development of sensors and actuators for mechatronics applications. Already, several MEMS devices are in use in automobiles, including sensors and actuators for airbag deployment and pressure sensors for manifold pressure measurement. Integrating MEMS devices with CMOS signal conditioning circuits on the same silicon chip is another example of development of enabling technologies that will improve mechatronic products, such as the automobile.

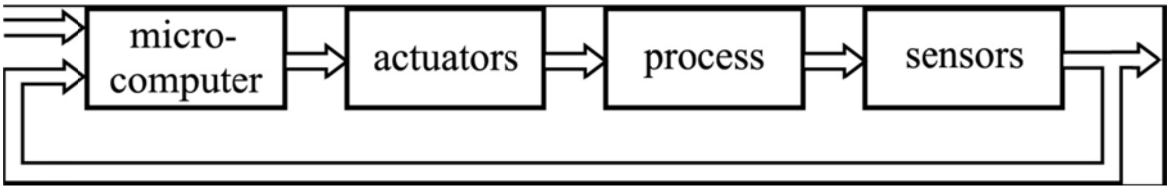
Millimeter wave radar technology has recently found applications in automobiles. The millimeter wave radar detects the location of objects (other vehicles) in the scenery and the distance to the obstacle and the velocity in real-time. This technology provides the capability to control the distance between the vehicle and an obstacle (or another vehicle) by integrating the sensor with the cruise control and ABS systems. The driver is able to set the speed and the desired distance between the cars ahead of him. The ABS system and the cruise control system are coupled together to safely achieve this remarkable capability. One logical extension of the obstacle avoidance capability is slow speed semi-autonomous driving where the vehicle maintains a constant distance from the vehicle ahead in traffic jam conditions. Fully autonomous vehicles are well within the scope of mechatronics development within the next 20 years. Supporting investigations are underway in many research centers on development of semi-autonomous cars with reactive path planning using GPSbased continuous traffic model updates and stop-and-go automation. A proposed sensing and control system for such a vehicle involves differential global positioning systems (DGPS), realtime image processing, and dynamic path planning.

Future mechatronic systems on automobiles may include a fog-free windshield based on humidity and temperature sensing and climate control, self-parallel parking, rear parking aid, lane change assistance, fluidless electronic brake-by-wire, and replacement of hydraulic systems with electromechanical servo systems. As the number of automobiles in the world increases, stricter emission standards are inevitable.

# UNIT 2
# PHYSICAL SYSTEM MODELING: SECTION 1

***LEAD- IN***

**1 Study the following scheme of a classical mechanical-electronic system. Then explain the connection between all the components in it.**




**2 Read the text "Ways of Integration" and put the abstracts in the right order.**

**Ways of Integration**

A. The limits of this approach were given by the lack of suitable sensors and actuators, the unsatisfactory life time under rough operating conditions (acceleration, temperature, contamination), the large space requirements, the required cables, and relatively slow data processing. ______

B. Such systems resulted from adding available sensors, actuators, and analog or digital controllers to mechanical components. ______

C. The integration within a mechatronic system can be performed through the integration of components and through the integration of information processing. ______

D. With increasing improvements in miniaturization, robustness, and computing power of microelectronic components, one can now put more emphasis on electronics in the design of a mechatronic system. ______

E. Figure above shows a general scheme of a classical mechanical-electronic system. ___*1*___

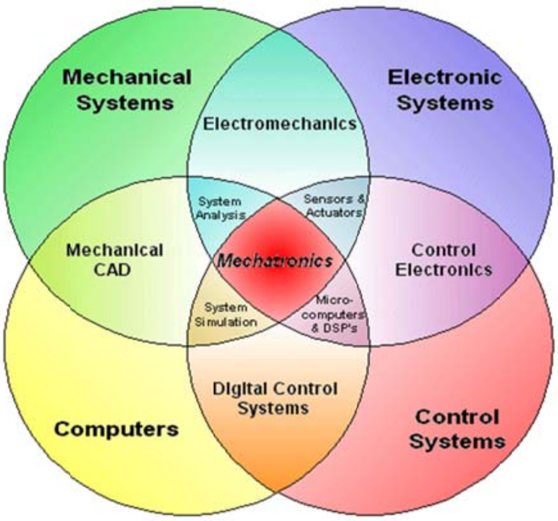
F. More autonomous systems can be envisioned, such as capsuled units with touchless signal transfer or bus connections, and robust microelectronics. ______

*READING*

**3 You are going to read a magazine article about the functions of Mechatronic systems. For each part (1 – 7) of the article, choose the most suitable heading from the list (A – F). There is one extra heading which you do not need to use. There is an example at the beginning (0).**

| | |
|---|---|
| **A** | Designer's task |
| **B** | Adjustable damping advantage |
| **C** | Way of linearization |
| **D** | Way for mechatronics systems creation |
| **E** | Nonlinear mechanical systems adaptation |
| **F** | Mechanical component simplification |
| **G** | Ways of mechatronic system implementation |

**Functions of Mechatronic Systems**




| **0** | ***D*** |
|---|---|

Mechatronic systems permit many improved and new functions. For designing mechatronic systems, the interplay for the realization of functions in the mechanical and electronic part is crucial.

| **1** | |
|---|---|

Compared to pure mechanical realizations, the use of amplifiers and actuators with electrical auxiliary energy led to considerable simplifications in devices, as can be seen from watches, electrical typewriters, and cameras. A further considerable *simplification in the mechanics* resulted from introducing microcomputers in connection with decentralized electrical drives, as can be seen from electronic typewriters, sewing machines, multi-axis handling systems, and automatic gears.

| **2** | |
|---|---|

The design of lightweight constructions leads to elastic systems which are weakly damped through the material. An *electronic damping* through position, speed, or vibration sensors and electronic feedback can be realized with the additional advantage of an adjustable damping through the algorithms. Examples are elastic drive chains of vehicles with damping algorithms in the engine electronics, elastic robots, hydraulic systems, far reaching cranes, and space constructions (with, for example, flywheels).

| | |
|---|---|
| **3** | |

The addition of closed loop control for position, speed, or force not only results in a precise tracking of reference variables, but also an approximate linear behavior, even though the mechanical systems show nonlinear behavior. By *omitting the constraint of linearization* on the mechanical side, the effort for construction and manufacturing may be reduced. Examples are simple mechanical pneumatic and electromechanical actuators and flow valves with electronic control.

| | |
|---|---|
| **4** | |

With the aid of freely *programmable reference variable generation* the adaptation of nonlinear mechanical systems to the operator can be improved. This is already used for the driving pedal characteristics within the engine electronics for automobiles, telemanipulation of vehicles and aircraft, in development of hydraulic actuated excavators, and electric power steering.

| | |
|---|---|
| **5** | |

With an increasing number of sensors, actuators, switches, and control units, the cable and electrical connections increase such that reliability, cost, weight, and the required space are major concerns. Therefore, the development of suitable bus systems, plug systems, and redundant and reconfigurable electronic systems are challenges for the designer.

***LISTENING***

**4 Listen to the text and for Questions 1 – 8, fill in the gaps. Use not more than 3 words in each gap.**

**Improvement of Operating Properties**

By applying active feedback control, precision is obtained not only

through the high mechanical precision of a passively

| 1 | | controlled mechanical element, but by

comparison of a programmed reference variable and a

| 2 | | control variable. Therefore, the mechanical precision in design and manufacturing may be reduced somewhat and more simple | 3 | | for bearings or slideways can be used. An important aspect is the compensation of a larger and time variant friction by *adaptive friction compensation*. Also, a larger | 4 | | on cost of backlash may be intended (such as gears with pretension), because it is usually easier to compensate for friction than for backlash. *Model-based* and | 5 | | *control* allow for a wide range of operation, compared to fixed control with unsatisfactory performance (danger of instability or sluggish behavior). A | 6 | | of robust and adaptive control allows a wide range of operation for flow-, force-, or speed-control, and for processes like engines, vehicles, or aircraft. A better control performance | 7 | | the reference variables to move closer to the constraints with an improvement in efficiencies and yields (e.g., higher temperatures, pressures for combustion engines and turbines, compressors at stalling limits, higher | 8 | | and higher speed for paper machines and steel mills).

## VOCABULARY AND GRAMMAR

### Compound nouns

Compound nouns are a group of two or more nouns which act a single noun. In order to understand what these nouns mean it is necessary to be able to recognize how such nouns are formed. The *last word* in the chain says what the thing is, while the other *word\words that preface* it describe the thing. So, to translate the compound nouns we should start with the last word and work backwards.

e.g. a digital input converter
an aircraft stability control
an optic device switch
an analog signal commutator
a flow intensity sensor
a direct current actuator

By means of compound nouns a large number of possible meanings can be expressed.

1 Function (the first noun tells what the second one is for)

e.g. a pressure sensor (a sensor for pressure measurement)

2 Material (the first noun tells what the second one consists of)

e.g. a mercury switch (a switch element made of mercury)

3 Activity or person (the second noun refers to an activity or person related to the first noun)

e.g. a mechatronics engineer (a person who implements mechatronic solutions)

4 Part (the second noun refers to a part of the first one)

e.g. robustness control (the control of robustness)

5 Multiple nouns (some expression are joint by hyphens)

e.g. a digital-to-analog converter (a converter that converts a digital signal into an analog one)

**5 Give names to the following things, units etc using information about compound nouns.**

Example:
A calculating machine is a device that calculates data.

1. vehicle-to-vehicle communication
2. a modern engineering design
3. a synergistic integration
4. software integration
5. data processing
6. an bioelectro-mechanical system
7. embedded systems engineering
8. a smart actuator
9. engineering design process
10. a quantum computer

**6 Give short explanations to the items below. Use information about compound nouns.**

1. precision mechanics
2. a smart sensor
3. an analog input
4. an enabling technology
5. a millimeter wave radar technology
6. modern concurrent engineering design practice
7. physical systems modeling
8. a feedback control system
9. a speed driver
10. high-speed precision manufacturing

 ***SPEAKING***

**7 Make up dialogues using one of the situations given.**

1 **Student A:** You are a journalist, whose task is to write the article "Role of Modeling in Creating Mechatronics Systems." Ask a specialist to help you in this task.
**Student B:** You are a mechatronics engineer whose specialty is modeling.

2 **Student A:** You are a student of Computer Science faculty. Your home task was to find information on the topic “The importance of physical systems modeling.” Make a report and answer your teacher’s questions.
**Student B:** You are a teacher of Mechatronics. Ask the student some questions to check his understanding of the subject.

3 **Student A** and **Student B:** You are students of Computer Science faculty. Your individual task for the next lesson is to make a presentation of the functions of mechatronics systems. Discuss what aspects of the area are necessary to cover.

4 **Student A:** You are a student of Computer Science faculty. You want to know what a sensor is used for. You enter a forum on computer science. Ask all necessary questions.
**Student B:** You are a specialist on Mechatronics. In a forum you come across the question about sensors. Help a young guy to understand the subject.

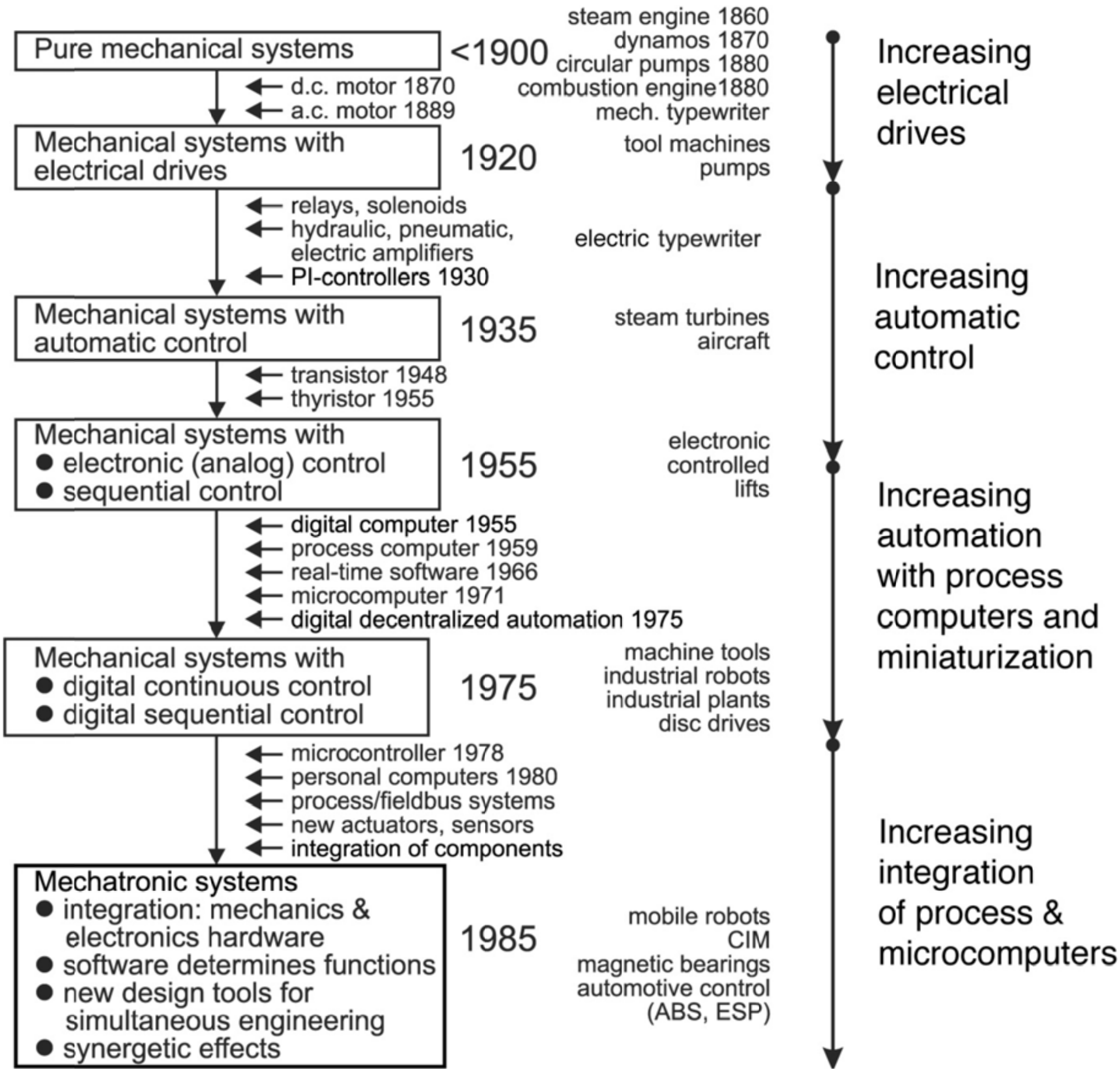
5 **Student A:** You are a specialist on Mechatronics. You are going to take part in a conference on Information Technology. Ask a colleague to be a co-author of your article about actuators.
**Student B:** You are a specialist on Mechatronics too. You’ve been invited by your colleague to take part in the conference. Accept an offer and share your knowledge on the subject.

6 **Student A:** You are a manager of a company called “Robotech.” You want to develop a mechatronics system for improving of precision properties of a welding robot. Address the firm which specializes on developing mechatronics systems.
**Student B:** You are a specialist who works in the company Student A needs. Tell your client about the ways of integration in mechatronics systems.

## Physical System Modeling: Section 2

***READING***

**8 Look at the diagram that schematically shows historical development of mechanical, electrical, and electronic systems. Use it to tell about this historical development.**




**9 Read the first part of the text "Historical Development and Definition of Mechatronic Systems" then answer the questions below.**

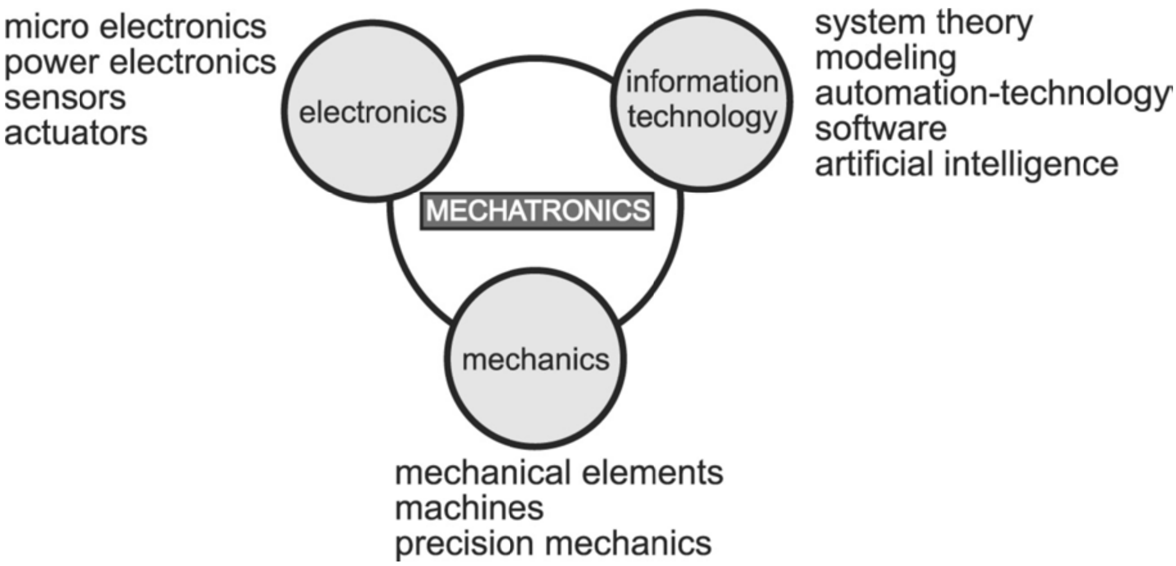
1 What are the components of electronics part of Mechatronics system?
2 What are the components of mechanics part of Mechatronics system?
3 What are the components of information technology part of a mechatronics system?
4 What's the role of sensor in Mechatronics system?
5 What's the Mechatronics system in terms of historical development?
6 What's the energy flow in a machine?

7 What types of energy can be used in Mechatronics systems?
8 What's the distinctive feature of mechanical systems which developed since about 1980?

## Historical Development and Definition of Mechatronic Systems

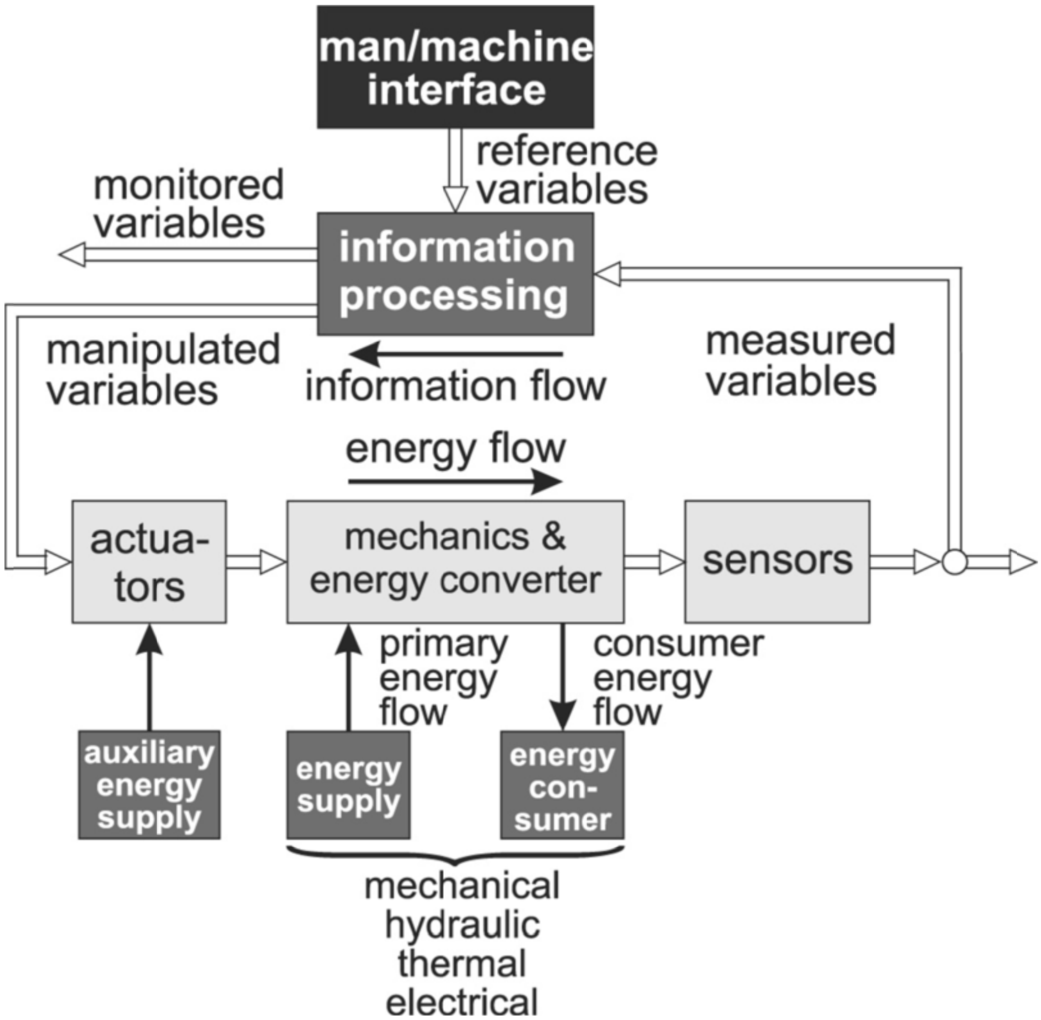
In several technical areas the integration of products or processes and electronics can be observed. This is especially true for mechanical systems which developed since about 1980. These systems changed from electro-mechanical systems with discrete electrical and mechanical parts to integrated electronic-mechanical systems with sensors, actuators, and digital microelectronics. These integrated systems are called *mechatronic systems*, with the connection of MECHAnics and elecTRONICS. The word "mechatronics" was probably first created by a Japanese engineer in 1969. Mechatronics is an *interdisciplinary field,* in which the following disciplines act together:

- *mechanical systems* (mechanical elements, machines, precision mechanics);
- *electronic systems* (microelectronics, power electronics, sensor and actuator technology); and
- *information technology* (systems theory, automation, software engineering, artificial intelligence).




The figure above shows a general scheme of a modern mechanical process like a power producing or a power generating machine. A primary *energy flows* into the machine and is then either directly used for the energy consumer in the case of an energy transformer, or converted into another energy form in the case of an energy converter. The form of energy can be electrical, mechanical (potential or kinetic, hydraulic, pneumatic), chemical, or thermal. Machines are mostly characterized by a continuous or periodic (repetitive) energy flow. For other mechanical processes, such as mechanical elements or precision mechanical devices, piecewise or intermittent energy flows are typical.

**10 Now study the figure below and for Questions 1–10, fill the gaps in the second part of the text "Historical Development and Definition of Mechatronic Systems". Use not more than two words for each gap.**




The energy flow is generally a product of a generalized flow and a potential (effort). Information on the state of the mechanical process can be obtained by measured generalized flows (speed, volume, or mass flow) or electrical current or potentials (force, pressure, temperature, or voltage). Together with **(1)** ____________, the **(2)** ___________are the inputs for an **(3)** ___________through the digital electronics resulting in **(4)** ___________for the **(5)** ___________or in **(6)** ___________on a display.

The addition and integration of feedback information flow to a feedforward energy flow in a basically mechanical system is one characteristic of many mechatronic systems. This development presently influences the design of mechanical systems. Mechatronic systems can be subdivided into:

- mechatronic systems
- mechatronic machines
- mechatronic vehicles
- precision mechatronics
- micro mechatronics

This shows that the integration with electronics comprises many classes of technical systems. In several cases, the **(7)** ___________part of the process is coupled with an **(8)** ___________, **(9)** ___________, thermodynamic, chemical, or information processing part. This holds especially true for **(10)** ___________ as machines where, in addition to the mechanical energy, other kinds of energy appear. Therefore, *mechatronic systems in a wider sense* comprise mechanical and also non-mechanical processes. However, the mechanical part normally dominates the system. Because an auxiliary energy is required to change the fixed properties of formerly passive mechanical systems by feedforward or feedback control, these systems are sometimes also called *active mechanical systems.*

### Physical System Modeling: Self Study Section

**11 Find all compound nouns from the text, activities 9, 10, and then give explanations to them.**

**12 For Questions 1 – 10, read the text below. Use the word given in capitals at the end of each line to form a word that fits in the space in the same line. Use the example at the beginning.**

Example:
(0) integration

### Integration of Components (Hardware)

| | |
|---|---|
| The **(0)** __________ of components (hardware | **INTEGRATE** |
| integration) results from **(1)** __________ the | **DESIGN** |

mechatronic system as an overall system and
**(2)** __________the **(3)** __________, actuators, **IMBED**
and microcomputers into the mechanical pro- **SENSE**
cess. This spatial integration may be **(4)**
__________ to the process and sensor, or to **LIMIT**
the process and actuator. Microcomputers can
be integrated with the actuator, the process or
sensor, or can be **(5)** __________at several **ARRANGEMENT**
places. Integrated sensors and microcomput-
ers lead to *smart sensors*, and integrated ac-
tuators and microcomputers **(6)** __________ **LEADING**
to *smart actuators*. For **(7)** __________ sys- **ENLARG**
tems, bus **(8)** __________will replace cables. **CONNECT**
Hence, there are several **(9)** __________ to
build up an integrated overall system by **(10)** **POSSIBLE**
__________integration of the hardware. **PROPERTY**

***Smart Sensor***

***Smart Actuator***

**13 Read the text about integration of information processing and for Questions 1–12, fill the gaps in it with the words from the box given below.**

### Integration of Information Processing (Software)

| | | |
|---|---|---|
| **available signals** | **problem solutions** | **equations** |
| **control** | **performance criteria** | **influence** |
| **methods** | **online information** | **properties** |
| **software integration** | **models** | **algorithms** |

The integration of information processing, i.e. **(1)** ____________ is mostly based on advanced **(2)** ____________ functions. Besides a basic feedforward and feedback control, an additional **(3)** ____________ may take place through the process knowledge and corresponding **(4)** ____________ processing.

This means a processing of **(5)** ____________ at higher levels, including the solution of tasks like supervision with fault diagnosis, optimization, and general process management. The respective **(6)** ____________ result in real-time **(7)** ____________ which must be adapted to the mechanical process properties, expressed by mathematical models in the form of static characteristics, or differential **(8)** ____________ Therefore, a *knowledge base* is required; comprising **(9)** ____________ for design and information gaining, process **(10)** ____________, and **(11)** ____________. In this way, the mechanical parts are governed in various ways through higher level information processing with intelligent **(12)** ____________, possibly including learning, thus forming integration by process-adapted software.

## *WRITING*

**14 Choose one of the topics below and do the written task according to the instructions given. Let your assignment be of 160–200 words.**

- You are a scientist who is researching a new area of modern Control Theory. You are interested in Mechatronics as an initial part of this subject. You are going to take part in International Conference, which is devoted to this scientific sphere. Write an article about main aspects and components of Mechatronics.
- You are a student of Computer Science Faculty and your task is to write a report on the Mechatronics field. Your theme is 'Main Aspects of Mechatronics'.
- You are a student who is given material on Mechatronics subject. Make written task, following the topic: "Mechatronics and its main aspects in my vision".

**15 Read the text below and write an annotation to it.**

### A Brief History of Feedback Control

There have been many developments in automatic control theory during recent years. It is difficult to provide an impartial analysis of an area while it is still developing; however, looking back on the progress of feedback control theory it is by now possible to distinguish some main trends and point out some key advances.

Feedback control is an engineering discipline. As such, its progress is closely tied to the practical problems that needed to be solved during any phase of human history. The key developments in the history of mankind that affected the progress of feedback control were:

1. The preoccupation of the Greeks and Arabs with keeping accurate track of time. This represents a period from about 300 BC to about 1200 AD.
2. The Industrial Revolution in Europe. The Industrial Revolution is generally agreed to have started in the third quarter of the eighteenth century; however, its roots can be traced back into the 1600's.
3. The beginning of mass communication and the First and Second World Wars. This represents a period from about 1910 to 1945.
4. The beginning of the space/computer age in 1957.

One may consider these as phases in the development of man, where he first became concerned with understanding his place in space and time, then with taming his environment and making his existence more comfortable, then with establishing his place in a global community, and finally with his place in the cosmos.

At a point between the Industrial Revolution and the World Wars, there was an extremely important development. Namely, control theory began to acquire its written language- the language of mathematics. J.C. Maxwell provided the first rigorous mathematical analysis of a feedback control system in 1868. Thus, relative to this written language, we could call the period before about 1868 the prehistory of automatic control.

Following Friedland, we may call the period from 1868 to the early 1900's the primitive period of automatic control. It is standard to call the period from then until 1960 the classical period, and the period from 1960 through present times the modern period.

Having some understanding of the history of automatic control theory, we may now briefly discuss the philosophies of classical and modern control theory.

Developing as it did for feedback amplifier design, classical control theory was naturally couched in the frequency domain and the s-plane. Relying on transform methods, it is primarily applicable for linear time-invariant systems, though some extensions to nonlinear systems were made using, for instance, the describing function.

The system description needed for controls design using the methods of Nyquist and Bode is the magnitude and phase of the frequency response. This is advantageous since the frequency response can be experimentally measured. The transfer function can then be computed. For root locus design, the transfer function is needed. The block diagram is heavily used to determine transfer functions of composite systems. An exact description of the internal system dynamics is not needed for classical design; that is, only the input/output behavior of the system is of importance.

The design may be carried out by hand using graphical techniques. These methods impart a great deal of intuition and afford the controls designer with a range of design possibilities, so that the resulting control systems are not unique. The design process is an engineering art.

A real system has disturbances and measurement noise, and may not be described exactly by the mathematical model the engineer is using for design. Classical theory is natural for designing control systems that are robust to such disorders, yielding good closed-loop performance in spite of them. Robust design is carried out using notions like the gain and phase margin.

Simple compensators like proportional-integral-derivative (PID), lead-lag, or washout circuits are generally used in the control structure. The effects of such circuits on the Nyquist, Bode, and root locus plots are easy to understand, so that a suitable compensator structure can be selected. Once designed, the compensator can be easily tuned on line.

A fundamental concept in classical control is the ability to describe closed-loop properties in terms of open-loop properties, which are known or easy to measure. For instance, the Nyquist, Bode, and root locus plots are in terms of the open-loop transfer function. Again, the closed-loop disturbance rejection properties and steady-state error can be described in terms of the return difference and sensitivity.

Classical control theory is difficult to apply in multi-input/multi-output (MIMO), or multi-loop systems. Due to the interaction of the control loops in a multivariable system, each single-input/single-output (SISO) transfer function can have acceptable properties in terms of step response and robustness, but the coordinated control motion of the system can fail to be acceptable.

Thus, classical MIMO or multiloop design requires painstaking effort using the approach of closing one loop at a time by graphical techniques. A root locus, for instance, should be plotted for each gain element, taking into account the gains previously selected. This is a trial-and-error procedure that may require multiple iterations, and it does not guarantee good results, or even closed-loop stability.

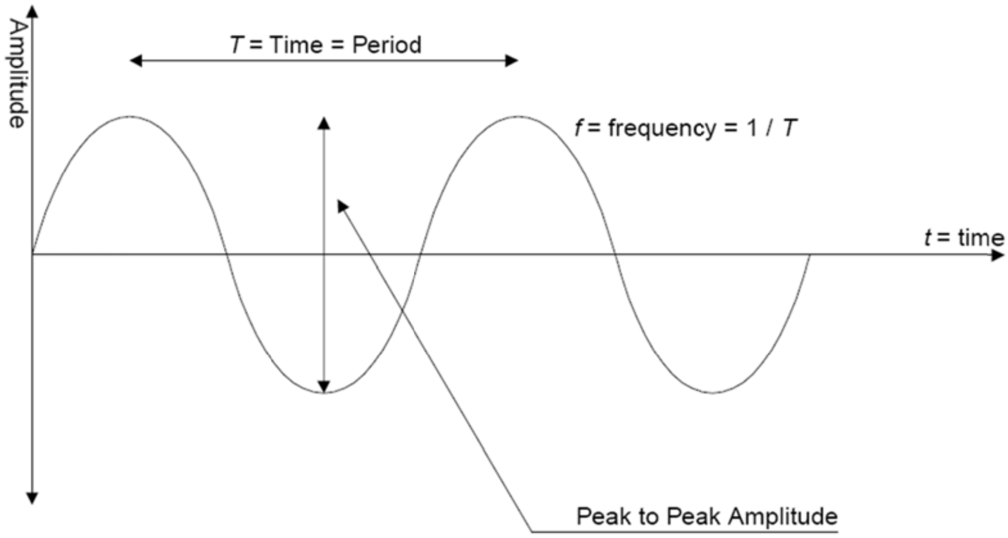
The multivariable frequency-domain approaches developed by the British school during the 1970's, as well as quantitative feedback theory, overcome many of these limitations, providing an effective approach for the design of many MIMO systems.

# UNIT 3
# SENSORS AND ACTUATORS: SECTION 1

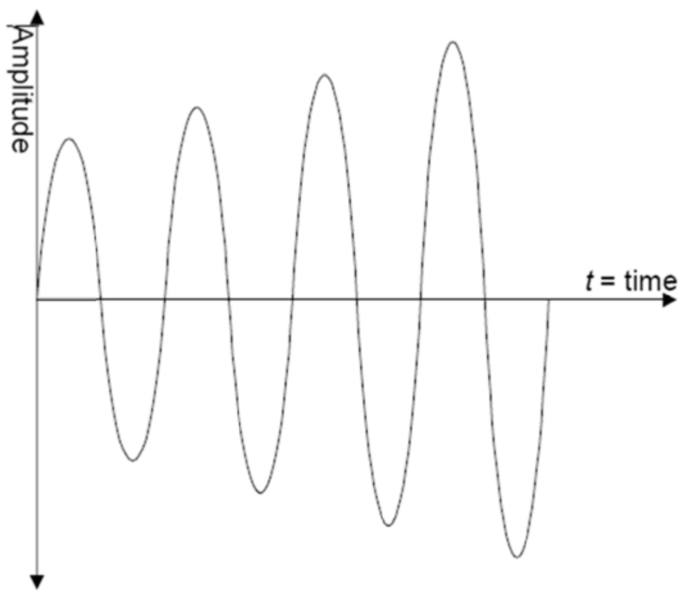
### *LEAD- IN*

**1 Look at the diagrams below and answer the following questions.**

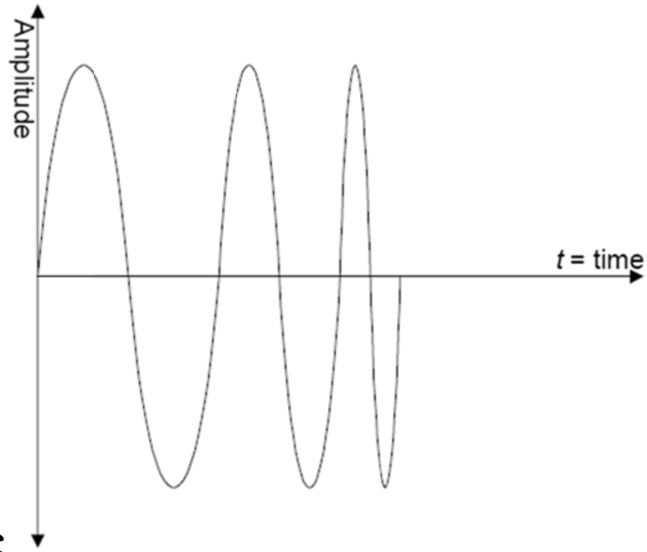
- What do these pictures show?
- What are the distinguishing characteristics of these signals?
- What is the difference between them?




***A***

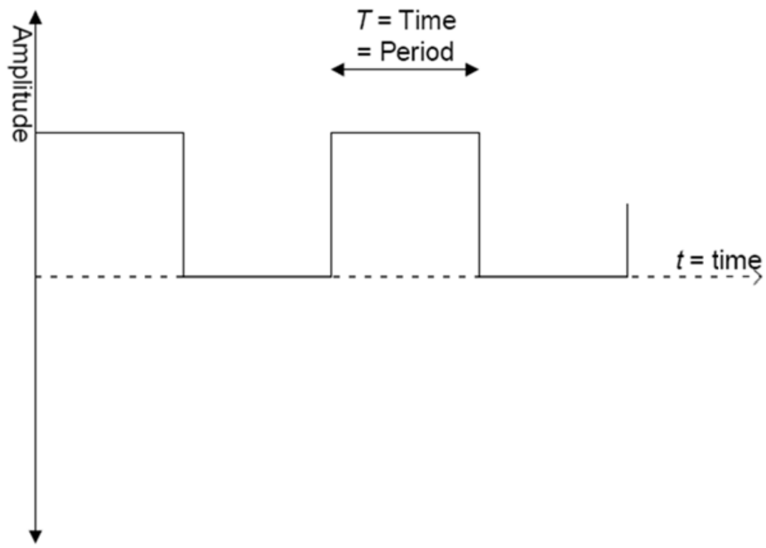



***B***



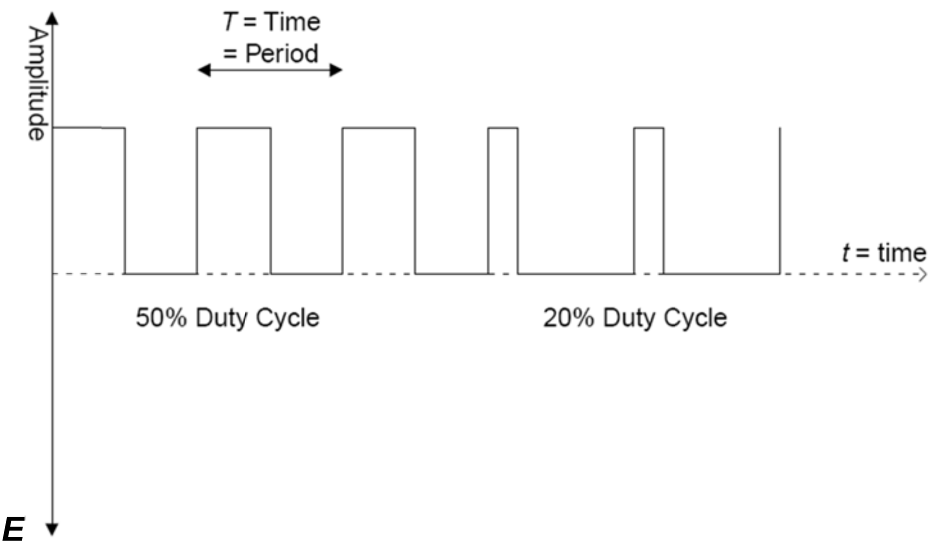
Amplitude
t = time


**C**



T = Time
= Period
Amplitude
t = time


**D**



T = Time
= Period
Amplitude
t = time
50% Duty Cycle
20% Duty Cycle


**E**

**2 Read the names of the signals and say what picture from activity 1 shows each of them.**

1. amplitude modulation
2. frequency modulation
3. sine wave
4. pulse width modulation
5. square wave

***READING***

**3 Now read the text about signals of a mechatronic system and check your answers.**

## Signals of a Mechatronic System

All inputs to mechatronic systems come from either some form of sensory apparatus or communications from other systems. Transducers, devices that convert energy from one form to another, are often used synonymously with sensors.

Sensors can be divided into two general classifications, active or passive. Active sensors emit a signal in order to estimate an attribute of the environment or device being measured. Passive sensors do not. A military example of this difference would be a strike aircraft "painting" a target using either active laser radar (LADAR) or a passive forward looking infrared (FLIR) sensor.

The output of a sensor is usually an analog signal. The simplest type of analog signal is a voltage level with a direct (though not necessarily linear) correlation to the input condition. A second type is a pulse width modulated (PWM) signal, which will be explained further in a later section of this chapter when discussing microcontroller outputs. A third type is a wave form (diagram A). This type of signal is modulated either in its amplitude (diagram B) or its frequency (diagram C) or, in some cases, both. These changes reflect the changes in the condition being monitored.

There are sensors that do not produce an analog signal. Some of these sensors produce a square wave as in diagram D that is input to the microcontroller using the EIA 232 communications standard. The square wave represents the binary values of 0 and 1. In this case the ADC is probably on-board the sensor itself, adding to the cost of the sensor. Some sensors/recorders can even create mail or TCP/IP packets as output.

An example of this type of unit is the MV100 MobileCorder from Yokogawa Corporation of America.

The three common actuators are switches, solenoids, and motors. Switches are simple state devices that control some activity, like turning on and off the furnace in a house. Types of switches include relays and solid-state devices. Solid-state devices include diodes, thyristors, bipolar transistors, field-effect transistors (FETs), and metal-oxide field-effect transistors (MOSFETs). A switch can also be used with a sensor, thus turning on or off the entire sensor, or a particular feature of a sensor.

Solenoids are devices containing a movable iron core that is activated by a current flow. The movement of this core can then control some form of hydraulic or pneumatic flow. Applications are many, including braking systems and industrial production of fluids. Motors are the last type of actuator that will be summarized here. There are three main types: direct current (DC), alternating current (AC), and stepper motors. DC motors may be controlled by a fixed DC voltage or by pulse width modulation (PWM). In a PWM signal, such as shown in diagram E, a voltage is alternately turned on and off while changing (modulating) the width of the on-time signal, or duty cycle. AC motors are generally cheaper than DC motors, but require variable frequency drive to control the rotational speed. Stepper motors move by rotating a certain number of degrees in response to an input pulse.

**4 Read the text (activity 3) again. For Question 1 – 8, choose the correct answer *A, B* or *C*.**

1 What's the transducer?
- A a converter of energy from one form to another
- B a converter from one form of sensor to another
- C a converter of information

2 Sensors can be divided into
- A active or passive
- B active or non-active
- C active or inductive

3 Input signals come into mechatronics systems from
- A sensors or other systems
- B outputs of other systems
- C other systems

4 The output of a sensor is only
- A analog signal and TCP/IP packets
- B digital signal and TCP/IP packets
- C analog, TCP/IP packets and square signals

5 Difference between active and passive sensor is that
- A active sensors emit signals, passive sensors do not emit signals
- B active sensors receive signals, passive sensors do not emit signals
- C both active and passive sensors emit signals

6 Solenoids are
- A devices which have an immobile iron core that is activated by a current flow
- B devices which have a movable iron core that is activated by a current flow
- C devices having a mobile iron core that is not activated by a current flow

7 Switches
- A control some activity
- B control relays and solid-state devices
- C switch some devices

8 Ways of DC motor control is
- A fixed DC voltage
- B fixed DC voltage and pulse width modulation
- C pulse width modulation

**5 Study these abbreviations and say what they stand for.**

1 LADAR
2 FLIR
3 PWM
4 EIA
5 ADC
6 TCP\IP
7 FET
8 MOSFET
9 DC
10 AC

## *LISTENING*

**6 You will hear definitions of terms given below. For Definitions 1 – 15, choose from the list of terms A – O in the order they appear in the recording. Use letters once only. There is one extra term which is not defined.**

| | | | |
|---|---|---|---|
| **A** | Actuator | Definition 1 | **1** |
| **B** | Digital-to-analog converter | Definition 2 | **2** |
| **C** | Synergy | Definition 3 | **3** |
| **D** | Modulation | Definition 4 | **4** |
| **E** | Sensor | Definition 5 | **5** |
| **F** | Systems engineering | Definition 6 | **6** |
| **G** | Antilock Braking System | Definition 7 | **7** |
| **H** | Mechatronics | Definition 8 | **8** |
| **I** | Microprocessor | Definition 9 | **9** |
| **J** | Measurement | Definition 10 | **10** |
| **K** | Microcontroller | Definition 11 | **11** |
| **L** | Switch | Definition 12 | **12** |
| **M** | Data Acquisition | Definition 13 | **13** |
| **N** | Frequency response | Definition 14 | **14** |
| **O** | Filtering | | |

## *VOCABULARY AND GRAMMAR*

**7 Now complete the following sentences with the words from activity 6.**

1 Integrated sensors and microcomputers lead to *smart* ____________.

2 Integrated actuators and microcomputers lead to *smart*___________.
3 The process of ___________ begins with the measurement of a physical value by a sensor.
4 A(n) ___________ is then often used to convert the digital value into an analog signal.
5 ___________ are simple state devices that control some activity.
6 A(n) ___________ is a simpler, more rugged microcontroller designed for industrial environments.
7 ___________ is a natural stage in the evolutionary process of modern engineering design.
8 Measured variables are the inputs for a(n) ___________ through the digital electronics resulting in manipulated variables for the actuators.
9 A primary ________ into the machine and is then either directly used for the energy consumer in the case of an energy transformer, or converted into another energy form in the case of an energy converter.
10 ___________ is the modification of a signal to make it more useful to a system.

## Explanations and Definitions

Texts containing technical terminology often contain definitions and explanations, especially in case when the text is aimed at non-experts or students of technical subjects, or if the purpose of the text is to inform specialists about new developments.

1 The following common words and expressions are used in definitions or explanations

| | |
|---|---|
| is\are | by … we mean |
| means | by … is meant |
| is taken to be | in other words |
| denotes | that is (to say) |
| is\can be defined as | |

e.g. Mechatronics is a modern trend of science.
It can be defined as synergetic association of mechanics, electronics and control.
In other words, it is not a simple fusion of these components.
By mechatronics approach is meant a qualitatively new stage of engineering practice.
Electronics development denotes an opportunity of practical implementation of complex control algorithms, which is a unique platform for industrial achievements.

2 Some explanations and definitions may give further distinguishing characteristics with the help of a defining relative clause.

***Relative clause*** is a sentence which gives information about the subject of a sentence and is introduced with **relative pronouns** and **relative adverbs.** The relative pronouns used in this type of definitions or explanations will be **who** or **that** for people, **that** or **which** for things, and relative adverbs **when** and **where** to refer to a period of time and a place or location, correspondingly.

e.g. A sensor is a device that receives a signal or stimulus and responds to it.
An actuator is a device that puts something into an action or a mechanical motion.
An engineer is a person who is trained in any branch of engineering.
A transducer is any device that converts one form of energy into another.

3 To define a term it is possible to use a noun, a noun phrase, or a clause which is separated from the rest of the sentence by commas or dashes.

e.g. Mechatronics – the combination of mechanical engineering, computing, and electronics – is used in the design and development of new manufacturing techniques.
A system – assembly of electronic, electrical, or mechanical components with interdependent functions – usually forms a self-contained unit.
A measuring system, complex of devices which are processing signals, is applied in mechatronics systems.

4 Structure of a definition. Generally, a definition consists of three parts: the term to be defined, the group it belongs to, the characteristics which are special about it and distinguish the term from other members of the group.

| Term | Group | Characteristics |
|---|---|---|
| e.g. A core | is a ferrite ring | which is capable of being either magnetized or demagnetized. |

| | | |
|---|---|---|
| An electric motor | is an actuator | which is used for realization of functional motion of mechatronics system. |

**8 Read the following definitions and complete the crossword below with the terms they identify.**

**Across:**

2 ________ converter – a device converting an analogue electrical signal into a digital representation so that it can be processed by a digital system

3 The science and technology concerned with the development, behaviour, and applications of electronic devices and circuits.

4 ________ current – a continuous electric current that periodically reverses direction, usually sinusoidal

6 Process ________ – the branch of engineering concerned with industrial processes.

8 The science of designing, constructing, and operating machines.

9 Velocity ________ is a device, converting measured magnitude of velocity in a signal for the subsequent transfer, registration, etc.

10 A device for measuring, recording, or indicating time; also a switch or regulator that causes a mechanism to operate at a specific time or at predetermined intervals.

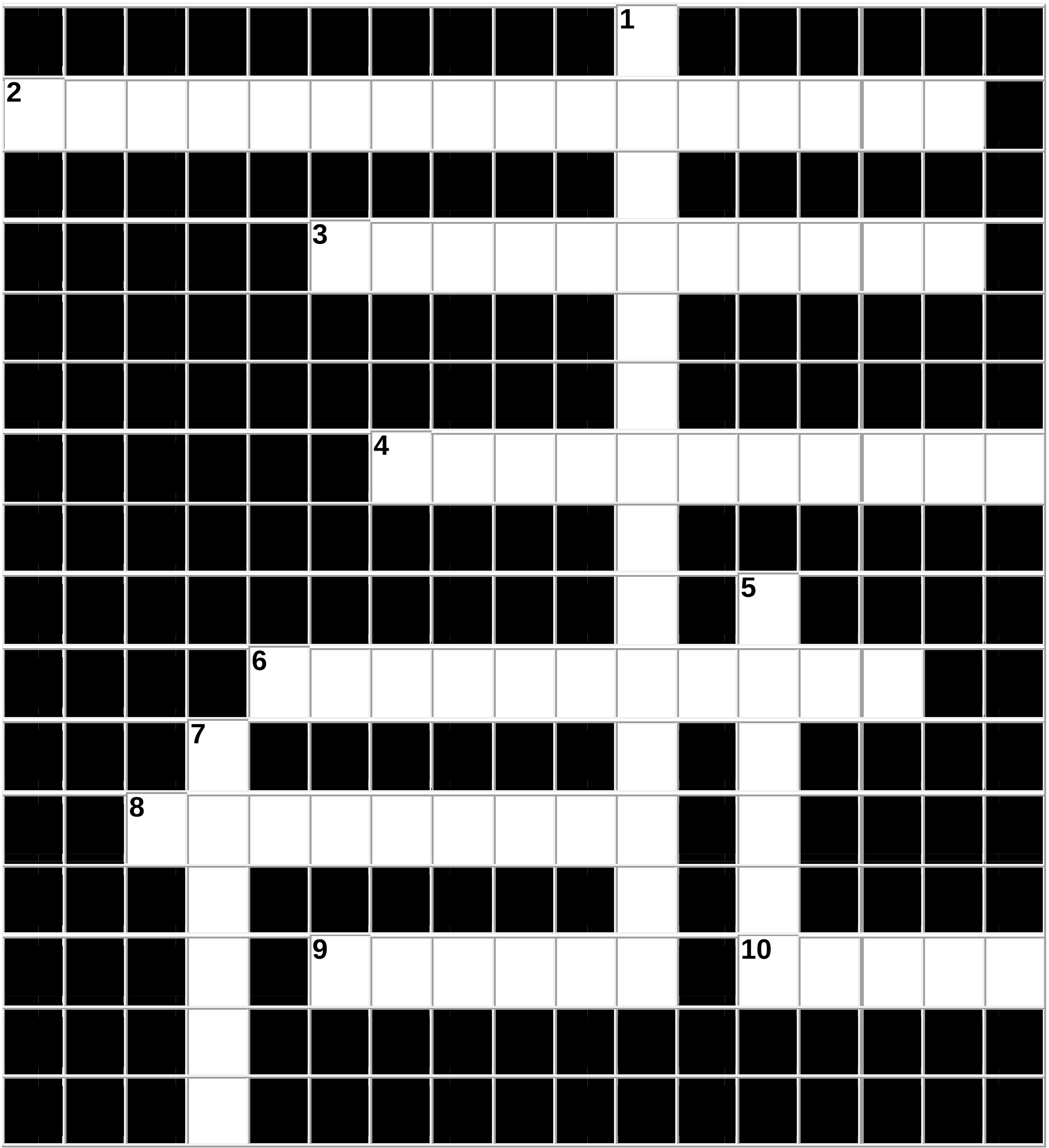
**Down:**

1 A single integrated circuit performing the basic functions of the central processing unit.

5 ________ current – a continuous electric current that flows in one direction only, without substantial variation in magnitude

6 Industrial ________ – the practice of designing any object for manufacturing.

## Crossword




 ***SPEAKING***

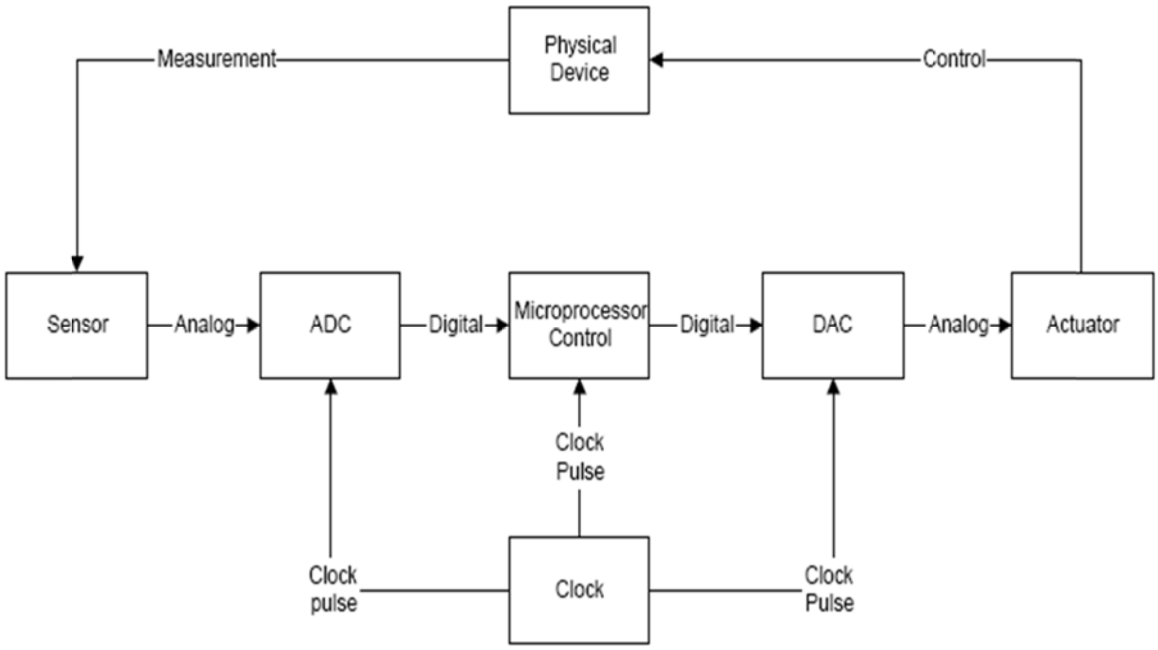
**9 Choose any type of Mechatronics systems signals given below and make a report on it.**

- harmonic signal
- step signal
- amplitude modulation
- frequency modulation
- pulse width modulation

## Sensors and Actuators: Section 2

***READING***

**10 Study the figure which shows a typical mechatronic system with mechanical, electrical, and computer components, given below. Explain the connection between all its components.**




**11 Read the text about the mechatronic system, and answer the questions below.**

1 Do system data acquisition processes begin with the sensor measurement by an operator only?
2 Is analog-to-digital converter output signal sent to analog signal?
3 Do Actuators use analog signal for control physical equipment?
4 Is DAC-converter used in heating/cooling system for homes and offices?
5 Does the microcontroller use the digitized temperature data after conversion by the DAC and the user requested temperatures to produce a digital control signal?
6 Can microprocessor outputs be represented in digital form by a set of bits?
7 Is the rotational speed of the wheels determined by velocity sensor of each wheel in the ABS?
8 Can system calibration adjust the response to the driver during stopping the vehicle?

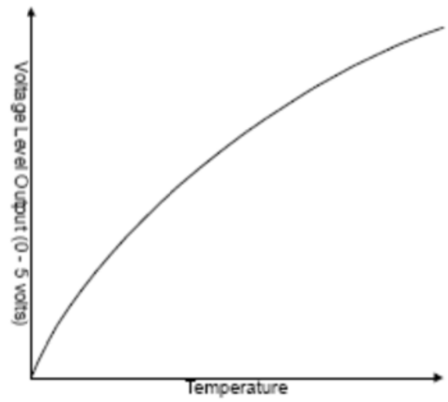
## The Mechatronic System

Figure in activity 6 shows a typical mechatronic system with mechanical, electrical, and computer components. The process of system data acquisition begins with the measurement of a physical value by a sensor. The sensor is able to generate some form of signal, generally an analog signal in the form of a voltage level or waveform. This analog signal is sent to an analog-to-digital converter (ADC). Commonly using a process of successive approximation, the ADC maps the analog input signal to a digital output. This digital value is composed of a set of binary values called bits (often represented by 0s and 1s). The set of bits represents a decimal or hexadecimal number that can be used by the microcontroller. The microcontroller consists of a microprocessor plus memory and other attached devices. The program in the microprocessor uses this digital value along with other inputs and preloaded values called calibrations to determine output commands. Like the input to the microprocessor, these outputs are in digital form and can be represented by a set of bits. A digital-to-analog converter (DAC) is then often used to convert the digital value into an analog signal. The analog signal is used by an actuator to control a physical device or affect the physical environment. The sensor then takes new measurements and the process repeated, thus completing a feedback control loop. Timing for this entire operation is synchronized by the use of a clock.

## A Home/Office Example

An example of a mechatronic system is the common heating/cooling system for homes and offices. Simple systems use a bimetal thermostat with contact points controlling a mercury switch that turns on and off the furnace or air conditioner. A modern environmental control system uses these same basic components along with other components and computer program control. A temperature sensor monitors the physical environment and produces a voltage level (though generally not nearly such a smooth function).

After conversion by the ADC, the microcontroller uses the digitized temperature data along with a 24-hour clock and the user requested temperatures to produce a digital control signal. This signal directs the actuator, usually a simple electrical switch in this example. The switch, in turn, controls a motor to turn the heating or cooling unit on or off. New measurements are then taken and the cycle is repeated. While not a mechatronic product on the order of a camcorder, it is a mechatronic system because of its combination of mechanical, electrical, and computer components. This system may also incorporate some additional features. If the temperature being sensed is quite high, say 80°C, it is possible that a fire exists. It is then not a good idea to turn on the blower fan and feed the fire more oxygen. Instead the system should set off an alarm or use a data communication device to alert the fire department. Because of this type of computer control, the system is "smart," at least relative to the older mercury-switch controlled systems.




**An Automotive Example**

A second example is the Antilock Braking System (ABS) found in many vehicles. The entire purpose of this type of system is to prevent a wheel from locking up and thus having the driver loose directional control of the vehicle due to skidding. In this case, sensors attached to each wheel determine the rotational speed of the wheels. These data, probably in a waveform or time-varied electrical voltage, is sent to the microcontroller along with the data from sensors reporting inputs such as brake pedal position, vehicle speed, and yaw. After conversion by the ADC or input capture routine into a digital value, the program in the microprocessor then determines the necessary action. This is where the aspect of human computer interface (HCI) or human machine interface (HMI) comes into play by taking account of the "feel" of the system to the user. System calibration can adjust the response to the driver while, of course, stopping the vehicle by controlling the brakes with the actuators. There are two important things to note in this example. The first is that, in the end, the vehicle is being stopped because of hydraulic forces pressing the brake pad against a drum or rotor–a purely mechanical function. The other is that the ABS, while an "intelligent product," is not a stand-alone device. It is part of a larger system, the vehicle, with multiple microcontrollers working together through the data network of the vehicle.

## Sensors and Actuators: Self-Study Section

**12 For Questions 1 – 15, read the text below. Use the word given in capitals at the end of each line to form a word that fits in the space in the same line. Use the example at the beginning.**

Example:
(0) implementation

| | |
|---|---|
| The critical focus themes in MEMS development and (0) _________ are rapid synthesis, design, and prototyping through synergetic multi-disciplinary system-level research in electromechanics. In particular, MEMS devising, (1) _________, simulation, analysis, design and optimization, which is relevant to cognitive study, classification, and synthesis must be performed. | **IMPLEMENT**<br>**MODEL** |
| As microtransducers and MEMS are devised, the fabrication techniques and processes are developed and (2) _________ out. Devising microtransducers is the closed (3) _________ process to study (4) _________ system-level evolutions based upon synergetic integration of microscale structures and devices in the (5) _________ functional core. | **CARRIER**<br>**EVOLUTIONARY**<br>**POSSIBILITY**<br>**UNIT** |
| The ability to devise and optimize microtransducers to a large extent depends on the (6) _________ and integrity of mathematical models. Therefore, mathematical models for different microtransducers were derived and analyzed. It is documented that microtransducer modeling, analysis, simulation, and design must be based on (7) _________ reliable mathematical models which nonlinear electromagnetic features. | **VALID**<br>**INTEGRITY** |
| It is important to (8) _________ that the secondary (9) _________ and effects, usually neglected in conventional miniscale electromechanical motion devices (modeled using lamped-parameter models and analyzed using finite element analysis techniques) cannot be ignored. The (10) _________ processes were described to make high-performance microtransducers. | **EMPHATIC**<br>**PHENOMENAL**<br>**FABRIC** |

**13 For Questions 1 – 10, read the text below and decide which answer A, B, C or D best fits each gap.**

### Microprocessor Input–Output Control Polling and Interrupts

There are two basic methods for the microprocessor to control input and output. These are polling and interrupts. Polling is (1) ___________ that, the microprocessor periodically checking various peripheral devices to determine if input or output is waiting. If a peripheral device has some input or output that (2) ___________ be processed, a flag will be set. The (3) ___________ is that a lot of processing time is (4) ___________ checking for inputs when they are not changing.

Servicing an interrupt is an alternative method to control inputs and outputs. In this method, a register in the microprocessor must have set an interrupt enable (IE) bit for a particular peripheral (5) ___________. When an interrupt is initiated by the peripheral, a flag is set for the microprocessor. The interrupt request (IRQ) line will go active, and the microprocessor will service the interrupt. Servicing an interrupt (6) ___________ that the normal processing of the microprocessor is (7) ___________ (i.e., interrupted) while the input/output is completed. (8) ___________resume normal processing, the microprocessor needs to store the contents of its registers before the interrupt is serviced. This process includes saving all active register contents to a stack, a part of RAM designated for this purpose, in a process (9) ___________ as a push. (10) ___________ a push, the microprocessor can then load the address of the Interrupt Service Routine and complete the input/output. When that portion of code is complete, the contents of the stack are reloaded to the registers in an operation known as a Pop (or Pull) and normal processing resumes.

| | | | | |
|---|---|---|---|---|
| **1** | **A** just | **B** yet | **C** only | **D** quite |
| **2** | **A** ought | **B** have | **C** should | **D** need |
| **3** | **A** problem | **B** idea | **C** way | **D** point |
| **4** | **A** had | **B** prolonged | **C** spent | **D** wasted |
| **5** | **A** hardware | **B** set | **C** device | **D** equipment |
| **6** | **A** means | **B** is | **C** intends | **D** is aimed |
| **7** | **A** removed | **B** prevented | **C** halted | **D** cancelled |
| **8** | **A** Because | **B** Although | **C** However | **D** In order to |
| **9** | **A** known | **B** made | **C** called | **D** identified |
| **10** | **A** Because of | **B** After | **C** When | **D** As well as |

## WRITING

**14 Read the text, activity 3 again and write an annotation to it.**

**15 Study the information in the texts given below and show the importance of one of these three programs, devices or tasks for mechatronics. Let your assignment be 160 – 200 words.**

### Verification and Validation

Verification and validation are related tasks that should be completed throughout the life cycle of the mechatronic product or system. Boehm in his book *Software Engineering Economics* (Prentice-Hall 1988) describes verification as "building the product right" while validation is "building the right product." In other words, verification is the testing of the software and product to make sure that it is built to the design. Validation, on the other hand, is to make sure the software or product is built to the requirements from the customer. As mentioned, verification and validation are life cycle tasks, not tasks completed just before the system is set for production. One of the simplest and most useful techniques is to hold hardware and software validation and verification reviews. Validation design reviews of hardware and software should include the systems engineers who have the best understanding of the customer requirements. Verification hardware design and software code reviews, or peer reviews, are an excellent means of finding errors upstream in the development process. Managers may have to decide whether to allocate resources upstream, when the errors are easier to fix, or downstream, when the ramifications can be much more drastic. Consider the difference between a code review finding a problem in code, and having the author change it and recompile, versus finding a problem after the product has been sold and in the field, where an expensive product recall may be required.

### Debuggers

Edsgar Dijkstra, a pioneer in the development of programming as a discipline, discouraged the terms "bug" and "debug," and considered such terms harmful to the status of software engineering. They are, however, used commonly in the field. A debugger is a software program that allows a view of what is happening with the program code and data while the program is executing. Generally it runs on a PC that is connected to a special type of development microcontroller called an emulator. While debuggers can be quite useful in finding and correcting errors in code, they are not real-time, and so can actually create computer operating properly (COP) errors. However, if background debug mode (BDM) is available on the microprocessor, the debugger can be used to step through the algorithm of the program, making sure that the code is operating as expected. Intermediate and final variable values, especially those related to some analog input or output value, can be checked. Most debuggers allow multiple open windows, the setting of program execution break points in the code, and sometimes even the reflashing of the program into the microcontroller emulator. An example is the Noral debugger available for the Motorola HC12.

The software in the microcontroller can also check itself and its hardware. By programming in a checksum, or total, of designated portions of ROM and/or EEPROM, the software can check to make sure that program and data are correct. By alternately writing and reading 0×55 and 0×AA to RAM (the “checkerboard test”), the program can verify that RAM and the bus are operating properly. These startup tasks should be done with every product operation cycle.

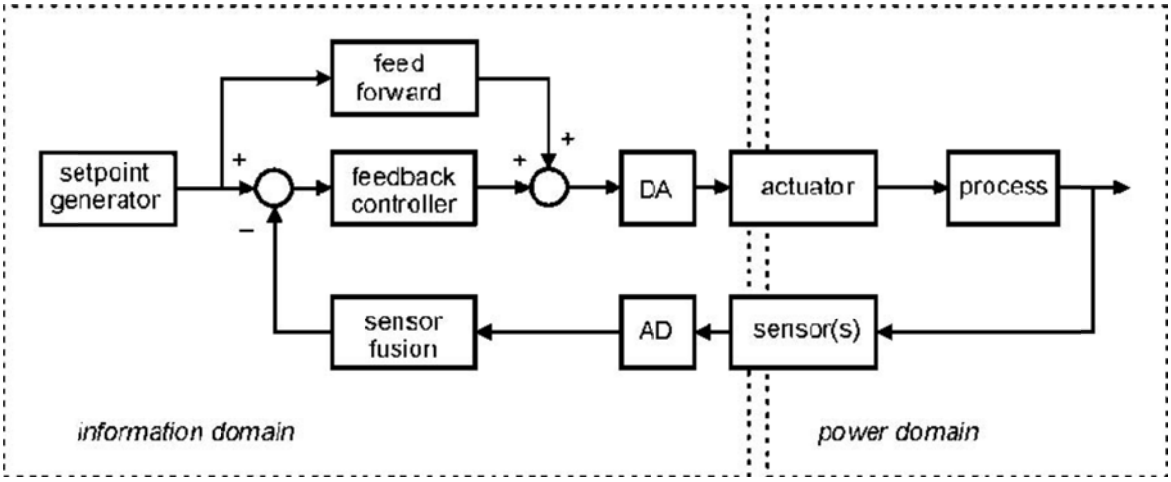
### Logic Analyzer

A logic analyzer is a device for nonintrusive monitoring and testing of the microcontroller. It is usually connected to both the microcontroller and a simulator. While the microcontroller is running its program and processing data, the simulator is simulating inputs and displaying outputs of the system. A “trigger word” can be entered into the logic analyzer. This is a bit pattern that will be on one of the buses monitored by the logic analyzer. With this trigger, the bus traffic around that point of interest can be captured and stored in the memory of the analyzer. An inverse assembler in the analyzer allows the machine code on the bus to be seen and analyzed in the form of the assembly level commands of the program. The analyzer can also capture the analog outputs of the microcontroller. This could be used to verify that the correct PWM duty cycle is being commanded. The simulator can introduce shorts or opens into the system, and then the analyzer is used to see if the software correctly responds to the faults. The logic analyzer can also monitor the master loop of the system, making sure that the system completes all of its tasks within a designated time, e.g., 15 ms. An example of a logic analyzer is the Hewlett Packard HP54620.

# UNIT 4
# SYSTEMS AND CONTROLS: SECTION 1

***LEAD-IN***

**1 Look at the figure and say what it shows. Then explain the connection between all its components.**




**2 Now read information about a mechatronic system and put the sentences in the right order.**

G. Power amplifiers convert signals into modulated power. __________

H. In most cases the power supply is electrical, but other sources such as hydraulic and pneumatic power supplies are possible as well.

I. This in contrast to the electronic part of the system where information processing is the main issue. __________

J. A controlled mechanical motion system thus typically consists of a mechanical construction, one or more actuators to generate the desired motions, and a controller that steers the actuators based on feed-forward and sensor-based feedback control. __________

K. Sensors convert the mechanical motions into electrical signals where only the information content is important or even into pure information in the form of numbers (if necessary, through an AD converter). __________

L. A mechatronic system consists by definition of a mechanical part that has to perform certain motions and an electronic part (in many cases an embedded computer system) that adds intelligence to the system. ***1***

M. In the mechanical part of the system power plays a major role. ________

## *LISTENING*

**3 You are going to listen to an overview of control computers. Before listening study these abbreviations and say what they stand for.**

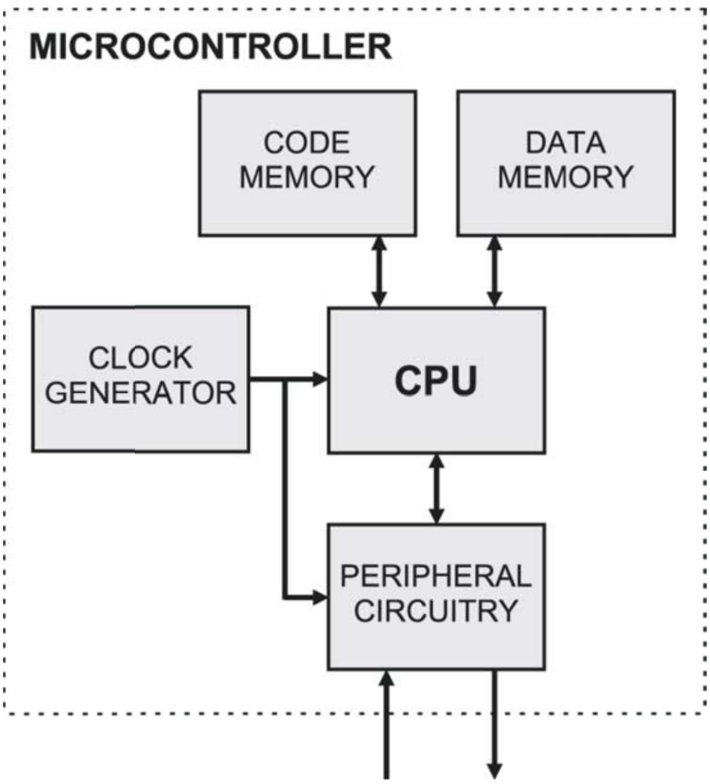
1 ADC
2 CPU
3 DAC
4 DSP
5 LAN
6 LCD
7 LED
8 MFLOPS
9 MIPS
10 PC
11 PCB
12 WWW

**4 Listen to the recording and For Questions 1 – 15, choose the correct mark T (true) or F (false) Correct the false statements.**

1 Single-room mainframe computers and single-case minicomputers were primarily used for scientific technical computing and financial planning techniques.
2 High-level computer programming language COBOL was used for operations with databases.
3 The invention of a universal central processing data unit in a single chip was very important for the computer technology.
4 Before 1981, multi-boxes (desktop or tower case, monitor, keyboard, mouse) or single-box (notebook) microcomputers became a daily-used personal tool.

5 Now not many embedded microcomputers are hidden in technical products.
6 Code and data memories are split embedded microcomputers architecture.
7 Nonvolatile memory stores firmware (program code).
8 Hard disks and vacuum tube monitors replace memory cards or LED segment displays or LCDs.
9 Flexibility of the devices brings programmability to embedded microcomputers.
10 Central processing unit is integrated with code memory, data memory, clock generator, and a diverse set of peripheral circuits.
11 DSPs are specialized embedded microprocessors.
12 DSPs computing architecture is not parallel.
13 DSPs have floating point instruction set optimized for discrete transformations.
14 Digital signal processor is used for sound processing/generation and is not used for vector control of AC motors.
15 PCs architecture and operating systems make PCs useful for computing-intensive measurement.

**5 Listen to the recording again and describe the following diagram of a microcontroller.**



### *READING*

**6 For Questions 1 – 8 read the text below and decide which answer A, B or C best fits each gap.**

**Introduction to Microelectronics**

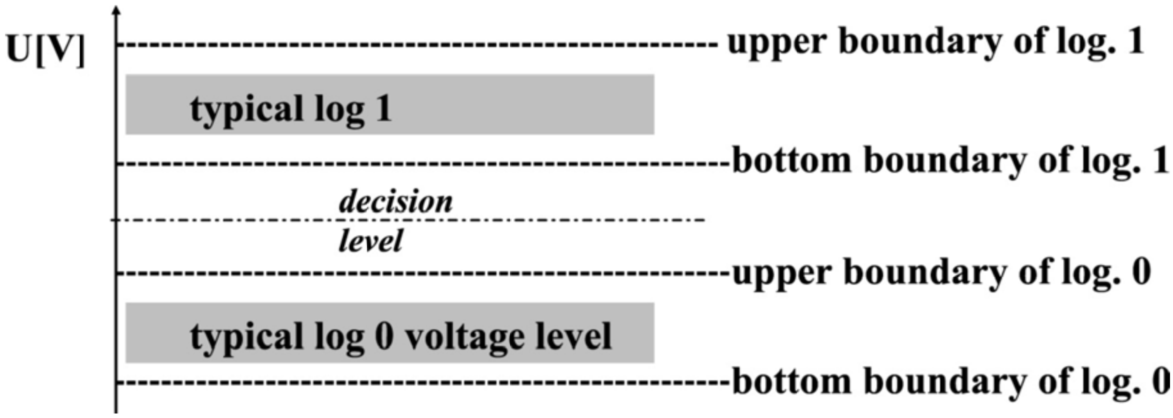
The field of microelectronics has changed dramatically during the last two decades and digital technology has governed most of the application fields in electronics. The design of digital systems is supported by thousands of different integrated circuits supplied by many manufacturers across the world. This makes both the design and the production of electronic products much easier and cost effective. The permanent growth of integrated circuit speed, scale of integration, and reduction of costs have resulted in digital circuits being used instead of classical analog solutions of controllers, filters, and (de)modulators.

The growth in computational power can be demonstrated with the following example. One single chip microcontroller has the computational power equal to that of one 1992 vintage computer notebook.

This single-chip microcontroller has the computational power equal to four 1981 vintage IBM personal computers, or to two 1972 vintage IBM 370 mainframe computers.

Digital integrated circuits are designed to be universal and are produced in large numbers. Modern integrated circuits have many upgraded features from earlier designs, which allow for "user-friendlier" access and control. As the parameters of Integrated circuits (ICs) influence not only the individually designed IC, but all the circuits that must cooperate with it, a roadmap of the future development of IC technology is updated every year. From this roadmap we can estimate future parameters of the ICs, and adapt our designs to future demands. The relative growth of the number of integrated transistors on a chip is relatively stable. In the case of memory elements, it is equal to approximately 1.5 times the current amount. In the case of other digital ICs, it is equal to approximately 1.35 times the current amount.

In digital electronics, we use quantities called logical values instead of the analog quantities of voltage and current. Logical variables usually correspond to the voltage of the signal, but they have only two values: log.1 and log.0. If a digital circuit processes a logical variable, a correct value is recognized because between the logical value voltages there is a gap. We can arbitrarily improve the resolution of signals by simply using more bits.




1 Which of the following is right?
A electronics technology has controlled most of digital applications
B electronics technology has controlled most of the fields in digital applications
C most electronics applications are controlled by digital technology

2 Different integrated circuits
A make both the design and the production of electronic products much easier and cost effective
B which support the design of digital systems, do not affect the production of electronic products cost effectiveness
C which are supplied by many manufacturers across the world is irrelevant to the design of digital systems

3 Which of the following is right?
A reduction of costs, scale of integration, and growth of integrated circuit speed led to the replacement of digital circuits by classical analog solutions
B reduction of costs, scale of integration, and growth of integrated circuit speed led to the replacement of classical analog solutions by digital circuits
C classical analog solutions of controllers, filters, and (de)modulators have resulted in permanent growth of integrated circuit speed

4 A computer notebook
A is equal to computational power of one single chip microcontroller.
B is equal to one single chip microcontroller of 1992.
C of 1992 had the computational power equal to one modern single chip microcontroller.

5 Which of the following is right?
A Modern single-chip microcontroller has the computational power equal to four 1972 vintage IBM 370 mainframe computers.
B Two 1972 vintage IBM 370 mainframe computers had the computational power equal to one single-chip microcontroller.
C Modern single-chip microcontroller has the computational power equal to one 1972 vintage IBM 370 mainframe computers.

6 Many
A upgraded features from earlier designs are used in up-to-date integrated circuits, which allow "user-friendlier" access and control.
B earlier features from contemporary designs are used in up-to-date integrated circuits, which allow "user-friendlier" access and control.
C up-to-date features from earlier designs are used in modern integrated circuits, which allow "user-friendlier" access and control.

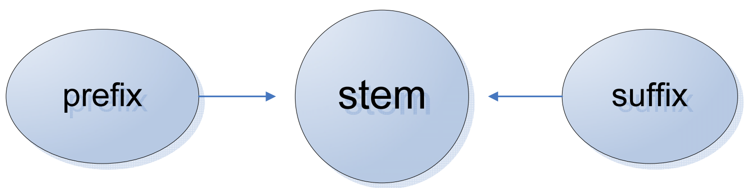
7 In digital electronics
A logical values are used instead of voltage and current.
B voltage and current of logical values are used.
C logical values use analog quantities of voltage and current.

8 In a digital circuit
A a correct value is recognized because there is a gap in digital circuit.
B a gap is recognized between logical variable.
C a correct value is recognized because a gap is between the logical value voltages.

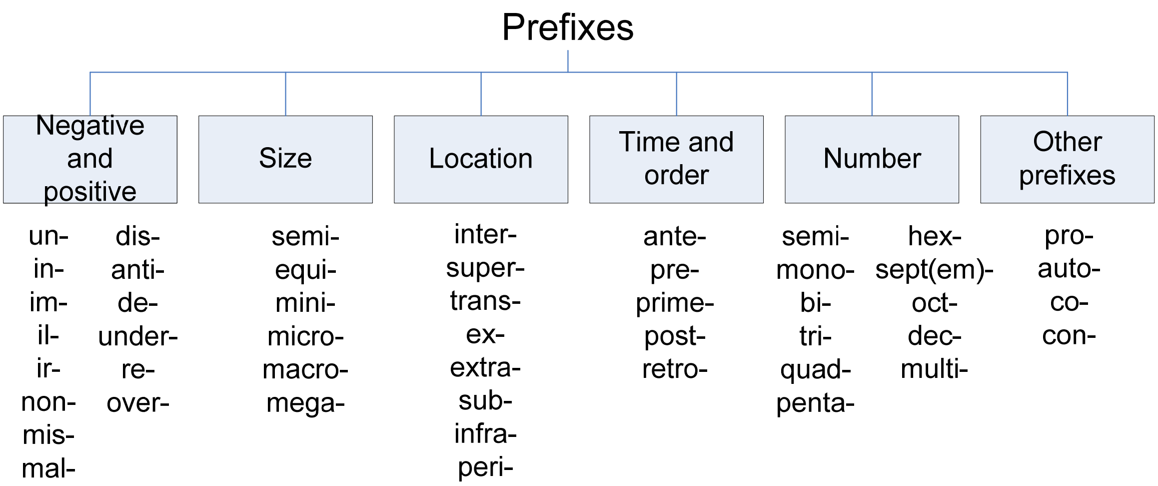
## VOCABULARY AND GRAMMAR

### Word formation: prefixes

While reading you may come across unfamiliar words and it is often possible to guess their meanings if you understand the way words are generally formed in English. An English word can be divided into three parts:



Prefixes change the meaning of the word. Suffixes change the word from one part of speech to another.




**7 Study these tables and complete them with the examples on the topic "mechatronics."**

| **Group 1** | Prefix | Meaning | Example |
|---|---|---|---|
| Negative | un- | | |
| | in- | | |
| | im- | not | |
| | il- | | |
| | ir- | | |
| | non- | not connected with | |
| | mis- | | |
| | mal- | bad, wrong | misalignment |
| | dis- | | |
| | anti- | opposite feeling\action | |
| | de- | against | |
| | under- | reduce, reverse | antiblooming |
| | | too little | |
| Positive | re- | do again | |
| | over- | too much | |

| **Group 2** | Prefix | Meaning | Example |
|---|---|---|---|
| | semi- | half, partly | |
| | equi- | equal | |
| | mini- | small | |
| | micro- | very small | microprocessor |

| | | | |
|---|---|---|---|
| | macro-<br>mega- | large, great | |

| Group 3 | Prefix | Meaning | Example |
|---|---|---|---|
| | inter- | between, among | |
| | super- | over | |
| | trans- | across | |
| | ex- | out | |
| | extra- | beyond | extrapolation |
| | sub- | under | |
| | infra- | below | |
| | peri- | around | |

| Group 4 | Prefix | Meaning | Example |
|---|---|---|---|
| | ante- | before | |
| | pre- | first | |
| | prime- | after | primary |
| | post- | backward | |
| | retro- | | |

| Group 5 | Prefix | Meaning | Example |
|---|---|---|---|
| | semi- | half | semicircle |
| | mono- | one | |
| | bi- | two | |
| | tri- | three | |
| | quad- | four | quadrature |
| | penta- | five | |
| | hex- | six | |
| | sept(em)- | seven | |
| | oct- | eight | |
| | dec- | ten | |
| | multi- | many | |

| Group 6 | Prefix | Meaning | Example |
|---|---|---|---|
| | pro- | before, in advance, for- | |
| | auto- | ward | automatic |
| | co- | self | |
| | con- | together, with | |

**8 For questions 1–13 fill in the gaps in the sentences with the correct prefix from the box.**

| | | | |
|---|---|---|---|
| **semi** | **anti** | **nano** | **under** |
| **inter (2)** | **self** | **over** | |
| **im** | **multi** | **micro (2)** | |

1. _____ processors can be used as a kernel of a control system.
2. _____ possibility of an effective control algorithms realization was the main obstacle of Mechatronics approach development.
3. _____water robot is an example of a mechatronics system.
4. _____technology allows to achieve great results in the field of actuators miniaturization.
5. _____lock braking system is one of examples of mechatronics implementation.
6. _____action between mechanical, electronic and algorithmic components determines success of creating a mechatronics system.
7. _____ -adjustment is an effective way of the regulators organization.
8. _____shoot is one of the important characteristics of a closed loop system.
9. _____conductors had revolutionized electronics.
10. In practice the majority of industrial control systems can be described as _____loop systems.
11. _____sensors are a perspective direction of development of mechatronics element base.
12. _____ connection of the mechatronics system parts is based on the synergetic approach.

## *SPEAKING*

**9 Choose any area of systems and controls given below and make a report on it.**

1 Typical Control Loop
2 Robust Control Definition
3 Modeling of Control systems
4 Available tools and techniques developed for robust control systems
5 Hard Real-Time Systems versus Soft Real-Time Systems
6 A Brief History of Automatic Control
7 The Philosophy of Classical Control
8 The Philosophy of Modern Control

**10 Make up dialogues using one of the situations given.**

1 **Student A:** You are a scientist, whose task is to write the article "Role of Microprocessors and Microcontrollers in Creating Mechatronics systems" and take part in a conference devoted to this topic. Ask your colleague to assist you in this task.
**Student B:** You are a scientist, too. You were asked to take part in a conference as a co-author. Together with your colleague discuss the plan of your report.

2 **Student A:** You are a student of Computer Science faculty. Your home task was to make a research on the topic "Studies of Classical Control in Russia and abroad."
**Student B:** You are a teacher of Mechatronics. Check your student's research results.

3 **Student A** and **Student B:** You are teachers of Mechatronics. Soon you'll act as examiners. Formulate some questions on the subject "Mechanics Control Systems" and give students short answers to the questions.

4 **Student A:** You are an extra-mural student. As a topic of a coursework, you've chosen the sphere of Robotechnics. Ask your friend to help you.
**Student B:** You are a graduate student of Computer science. Help Student A with his task.

## Systems and Controls: Section 2

### *READING*

**11 Before reading the text study the abbreviations below and say what they stand for.**

1 FPU
2 ISP
3 UART
4 RTC
5 ENOB
6 FPGA
7 PLC
8 LD
9 SFC
10 FBD

**12 Read the texts, activity 13 and check your answers.**

**13 Read these texts and briefly describe importance of the subjects for design and implementation of Mechatronics systems.**

### Microprocessors and Microcontrollers

There is no strict border between microprocessors and microcontrollers because certain chips can access external code and/or data memory (microprocessor mode) and are equipped with particular peripheral components.

Some microcontrollers have an internal RC oscillator and do not need an external component. However, an external quartz or ceramic resonator or RC network is frequently connected to the built-in, active element of the clock generator. Clock frequency varies from 32 kHz (extra low power) up to 75 MHz.

Another auxiliary circuit generates the reset signal for an appropriate period after a supply is turned on.

Watchdog circuits generate chip reset when a periodic retriggering signal does not come in time due to a program problem. There are several modes of consumption reduction activated by program instructions.

Complexity and structure of the interrupt system (total number of sources and their priority level selection), settings of level/edge sensitivity of external sources and events in internal (i.e., peripheral) sources, and handling of simultaneous interrupt events appear as some of the most important criteria of microcontroller taxonomy.

Although 16- and 32-bit microcontrollers are engaged in special, demanding applications (servo-unit control), most applications employ 8-bit chips. Some microcontrollers can internally operate with a 16-bit or even 32-bit data only in fixed-point range–microcontrollers are not provided with floating point unit (FPU). New microcontroller families are built on RISC (Reduced Instruction Set) core executing due to pipelining one instruction per few clock cycles or even per each cycle.

One can find further differences in addressing modes, number of direct accessible registers, and type of code memory (ranging from 1 to 128 KB) that are important from the view of firmware development.

Flash memory enables quick and even in-system programming (ISP) using 3–5 wires, whereas classical EPROM makes chips more expensive due to windowed ceramic packaging. Some microcontrollers have built-in boot and debug capability to load code from a PC into the flash memory using UART (Universal Asynchronous Receiver/Transmitter) and RS-232C serial line. OTP (One Time

Programmable) EPROM or ROM appear effective for large production series. Data EEPROM (from 64 B to 4 KB) for calibration constants, parameter tables, status storage, and passwords that can be written by firmware stand beside the standard SRAM (from 32 B to 4 KB).

The range of peripheral components is very wide. Every chip has bidirectional I/O (input/output) pins associated in 8-bit ports, but they often have an alternate function. Certain chips can set an input decision level (TTL, MOS, or Schmitt trigger) and pull-up or pull-down current sources. Output drivers vary in open collector or tri-state circuitry and maximal currents.

At least one 8-bit timer/counter (usually provided with a prescaler) counts either external events (optional pulses from an incremental position sensor) or internal clocks, to measure time intervals, and periodically generates an interrupt or variable baud rate for serial communication. General purpose 16-bit counters and appropriate registers form either capture units to store the time of input transients or compare units that generate output transients as a stepper motor drive status or PWM (pulse width modulation) signal. A real-time counter (RTC) represents a special kind of counter that runs even in sleep mode. One or two asynchronous and optionally synchronous serial interfaces (UART/USART) communicate with a master computer while other serial interfaces like SPI, CAN, and I 2 C control other specific chips employed in the device or system.

Almost every microcontroller family has members that are provided with an A/D converter and a multiplexer of single-ended inputs. Input range is usually unipolar and equal to supply voltage or rarely to the on-chip voltage reference. The conversion time is given by the successive approximation principle of ADC, and the effective number of bits (ENOB) usually does not reach the nominal resolution 8, 10, or 12 bits.

There are other special interface circuits, such as field programmable gate array (FPGA), which can be configured as an arbitrary digital circuit.

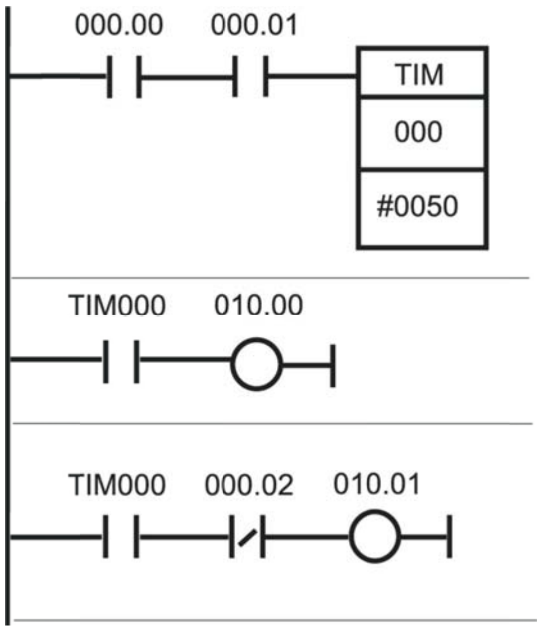
Microcontroller firmware is usually programmed in an assembly language or in C language. Many software tools, including chip simulators, are available on websites of chip manufacturers or third-party companies free of charge. A professional integrated development environment and debugging hardware (in-circuit emulator) is more expensive (thousands of dollars). However, smart use of an inexpensive ROM simulator in a microprocessor system or a step-by-step development cycle using an ISP programmer of flash microcontroller can develop fairly complex applications.

## Programmable Logic Controllers

A programmable logic controller (PLC) is a microprocessor-based control unit designed for an industrial installation (housing, terminals, ambient resistance, fault tolerance) in a power switchboard to control machinery or an industrial process. It consists of a CPU with memories and an I/O interface housed either in a compact box or in modules plugged in a frame and connected with proprietary buses. The compact box starts with about 16 I/O interfaces, while the module design can have thousands of I/O interfaces. Isolated inputs usually recognize industrial logic, 24 V DC or main AC voltage, while outputs are provided either with isolated solid state switches (24 V for solenoid valves and contactors) or with relays. Screw terminal boards represent connection facilities, which are preferred in PLCs to wire them to the controlled systems. I/O logical levels can be indicated with LEDs near to terminals.

Since PLCs are typically utilized to replace relays, they execute Boolean (bit, logical) operations and timer/counter functions (a finite state automaton). Analog I/O, integer or even floating point arithmetic, PWM outputs, and RTC are implemented in up-to-date PLCs. A PLC works by continually scanning a program, such as machine code, that is interpreted by an embedded microprocessor (CPU). The scan time is the time it takes to check the input status, to execute all branches (all individual rungs of a ladder diagram) of the program using internal (state) bit variables if any, and to update the output status.

The scan time is dependent on the complexity of the program (milliseconds or tens of msec). The next scan operation either follows the previous one immediately (free running) or starts periodically.




Example of PLC ladder diagram: 000.xx/ 010.xx–address group of inputs/outputs, TIM000–timer delays 5 s. 000.00–normally open input contact, 000.02– normally closed input contact.

Programming languages for PLCs are described in IEC-1131-3 nomenclature:
LD–ladder diagram
IL–instruction list (an assembler)
SFC–sequential function chart (usually called by the proprietary name GRAFCET)
ST–structured text (similar to a high level language)
FBD–function block diagram
PLCs are programmed using cross-compiling and debugging tools running on a PC or with programming terminals (usually using IL), both connected with a serial link. Remote operator panels can serve as a human-to-machine interface. A new alternate concept (called SoftPLC) consists of PLC-like I/O modules controlled by an industrial PC, built in a touch screen operator panel.

## Systems and Controls: Self Study Section

**14 For questions 1 – 15, read the text below. Use the word given in capitals at the end of each line to form a word that fits in the space in the same line. Use the example at the beginning.**

Example:
(0) composed

### Digital Logic

| | |
|---|---|
| Digital circuits are (0) _________ of logic | **COMPOSITION** |
| gates, such as elementary electronic circuits (1) _________ in only two states. These gates oper- | **OPERATE** |
| ate in such a way that the resulting (2) _________ value corresponds to the resulting value of the | **LOGIC** |
| Boolean algebra (3) _________. This means that | **STATE** |
| with the help of gates we can (4) _________ every logical and arithmetical operation. These opera- | **REALIZATION** |
| tions are performed in (5) _________ circuits for | **COMBINE** |
| which the resulting value is (6) _________ only on the actual state of the inputs variables. Of course, | **DEPEND** |
| logic gates are not enough for automata (7) _________. For creating an automaton, we also | **CONSTRUCT** |
| need some (8) _________ elements in which we capture the responses of the arithmetical and logical blocks. | **MEMORISE** |

A (9) _________ scheme of a digital finite state automaton is given in figure below. The automata can be constructed from standard ICs containing logic gates, more (10) _________ combinational logic blocks and registers, counters, memories, and other standard (11) _________ ICs (12) _________ on a printed circuit board. Another possibility is to use application specific integrated circuits (ASIC), either (13) _________ or full custom, for a more advanced design. This approach is (14) _________ for designs where fast hardware solutions are preferred. Another possibility is to use microcontrollers that are designed to serve as universal automata, which function can be (15) _________ by memory programming.

**TYPE**

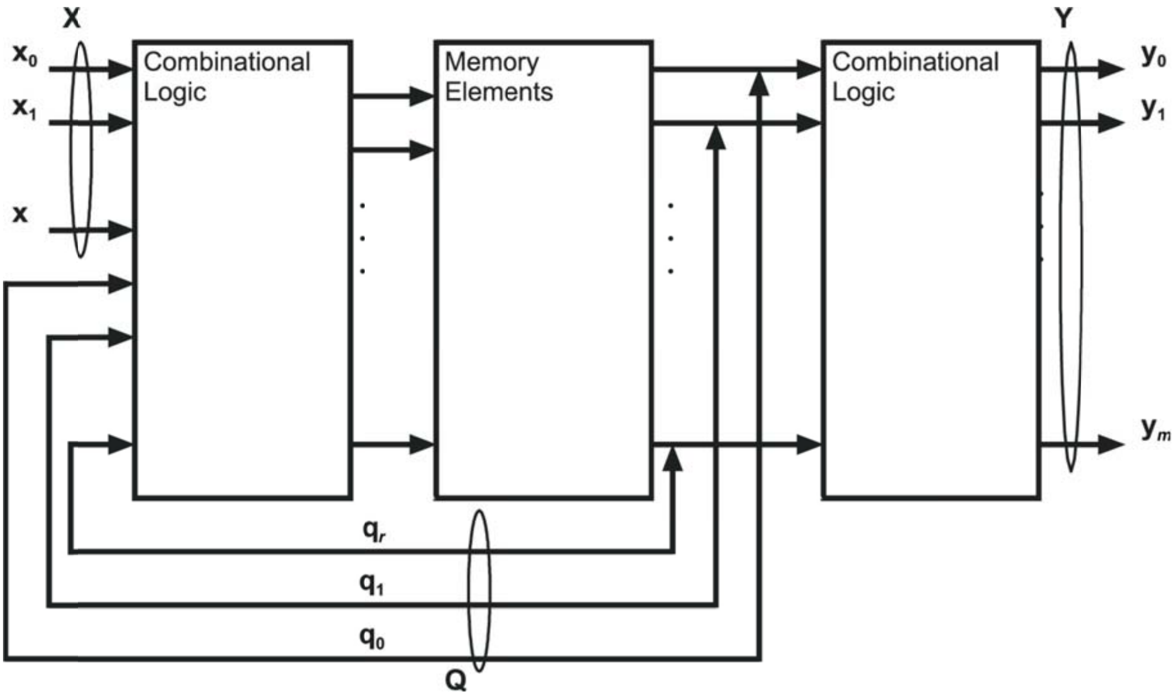
**COMPLEXITY**

**SEQUENCE**
**ASSEMBLY**

**PROGRAM**
**SUIT**

**SPECIFY**

*X*–input binary vector
*Y*–output binary vector
*Q*–internal state vector




**15 Read the terms from the texts, activity 13 and give definitions to them.**

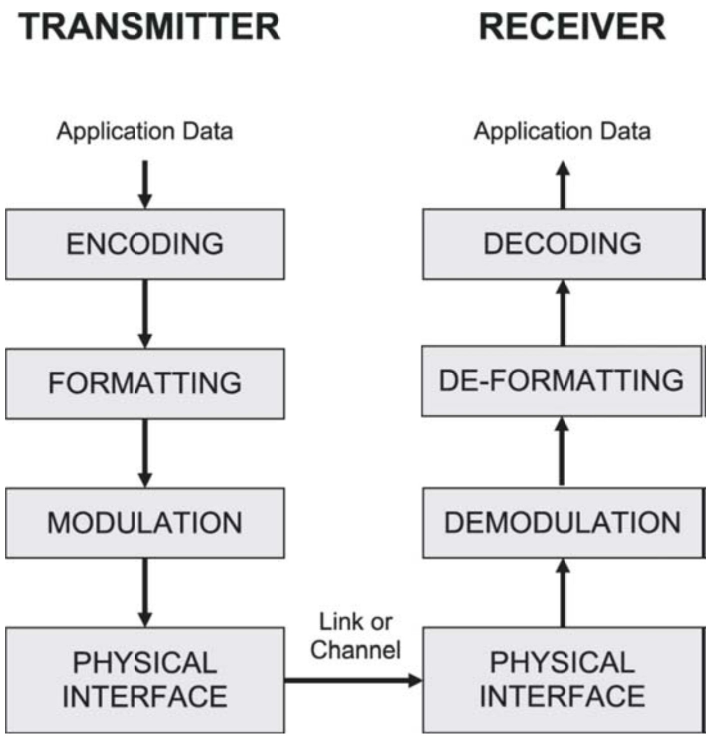
1 16-bit counter

2 A/D converter
3 addressing mode
4 asynchronous receiver
5 clock frequency
6 complexity
7 data memory
8 debugging hardware
9 flash memory
10 interrupt event
11 isolated input
12 ladder diagram
13 logic controller
14 peripheral component
15 ROM simulator
16 screen operator panel

## *WRITING*

**16 Read the text from activity 9 again and write an annotation to it.**

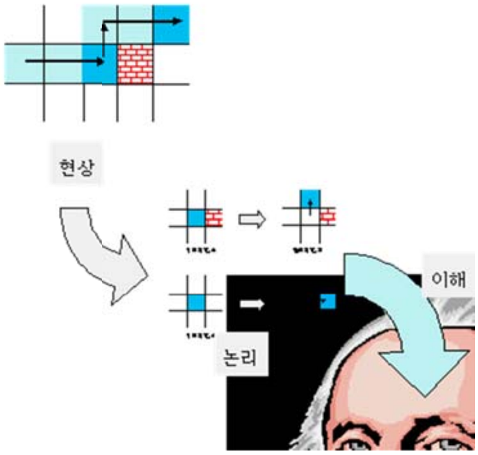
**17 Study the diagram which shows the example of multilayer communication and describe the process of data transmission.**



# UNIT 5
# COMPUTERS AND LOGIC SYSTEMS: SECTION 1

***LEAD-IN***

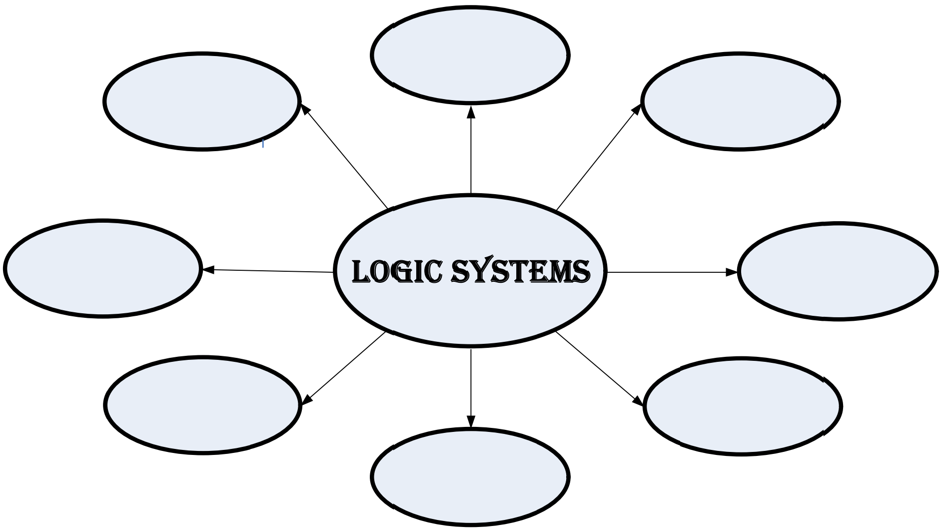
**1 In pairs or groups of three give explanation to the term '*logic system.*'**




**2 Look at the picture which shows a human computer. And answer the questions below.**

1 What is a human computer?
2 What is special about it?
3 What is special about any logic system?
4 What is the role of logic systems in modern science?
5 What are the future predictions about logic in computers?

**3 In pairs or groups of three complete the mind map below with your associations, then compare your maps open-class. Explain your choice.**



***LISTENING***

**4 Read the text below and put the sentences in the right order. Then listen to the recording and check your answers. The first sentence is already marked for you. There is one extra sentence which should not be used.**

A These actuators can also be regarded as a variable capacitance type, since they operate in an analogous mode to variable reluctance type electromagnetic actuators (e.g., variable reluctance stepper motors).

B The rotor of the wobble motor operates by rolling along the stator, which provides an inherent harmonicdrive-type transmission and thus a significant transmission ratio (on the order of several hundred times).

C The maximum achievable stroke in a comb drive is limited primarily by the mechanics of the flexure suspension.

D Electrostatic actuators have been developed in both linear and rotary forms.

E The two most common configurations of the linear type of electrostatic actuators are the normal-drive and tangential or comb-drive types.

F The typical stroke of a surface micromachined comb actuator is on the order of a few microns, though sometimes less.

G The most common configurations of rotary electrostatic actuators are the variable capacitance motor and the wobble or harmonic drive motor.

H Useful levels of torque for most applications therefore require some form of significant micromechanical transmission, which do not presently exist.

I The suspension should be compliant along the direction of actuation to enable increased displacement, but must be stiff orthogonal to this direction to avoid parallel plate contact due to misalignment.

| | |
|---|---|
| ***1*** | ***J*** |
| ***2*** | |
| ***3*** | |
| ***4*** | |
| ***5*** | |
| ***6*** | |
| ***7*** | |
| ***8*** | |
| ***9*** | |

J The most widely utilized multicomponent microactuators are those based upon electrostatic transduction. **10**

K The drawback to this approach is that the rotor motion is not concentric with respect to the stator, which makes the already difficult problem of coupling a load to a micro-shaft even more difficult. **11**

L The net effect is that increased displacement requires increased plate separation, which results in decreased overall force. **12**

M Note that the rotor must be well insulated to roll along the stator without electrical contact. **13**

N Both motors operate in a similar manner to the comb-drive linear actuator. **14**

O These modes of behavior are unfortunately coupled, so that increased compliance along the direction of motion entails a corresponding increase in the orthogonal direction. **15**

P The variable capacitance motor is characterized by high-speed low-torque operation. **16**

## VOCABULARY AND GRAMMAR

### Word formation: suffixes

As it was said in the previous unit, suffixes change the word from one part of speech to another.

Suffixes

| Nouns | | Verbs | Adjectives | | Adverbs |
|---|---|---|---|---|---|
| -ance | -ion | -ize | -al | -ous | -ly |
| -ence | -ing | -ate | -ar | -ful | |
| -or,-er | -ment | -fy | -ic | -less | |
| -ist, -yst | -ity | -en | -ical | -ish | |
| -ian | -ism | -ify | -able | -ed | |
| -tion, -ation | -dom | | -ible | -ive | |
| -ness | -ship | | | | |

**5 Study these tables and complete them with the examples on the topic “mechatronics.”**

| Group 1 | Suffix | Meaning | Example |
|---|---|---|---|
| | -ance | state | |
| | -ence | quality of | |
| | -or,-er | a person who\a thing | |
| | -ist, -yst | which | |
| | -ian | a person who | |
| | -tion, -ation | pertaining to | |
| | -ness | the act of | |
| | -ion | condition of | |
| | -ing | action\state | |
| | -ment | activity | measurement |
| | -ity | state action | |
| | -ism | state, quality | |
| | -dom | condition\state | freedom |
| | -ship | domain\condition | |
| | | condition\state | |

| Group 2 | Suffix | Meaning | Example |
|---|---|---|---|
| | -ize | | |
| | -ate | | indicate |
| | -fy | to make | |
| | -en | | |
| | -ify | | |

| Group 3 | Suffix | Meaning | Example |
|---|---|---|---|
| | -al | | |
| | -ar | | |
| | -ic | having the quality of | |
| | -ical | | technical |
| | -ed | | |
| | -ive | | |
| | -able | capable of being | |
| | -ible | | |
| | -ous | like, full of | |
| | -ful | characterized by | |
| | -less | without | useful |
| | -ish | like | |

| Group 4 | Suffix | Meaning | Example |
|---|---|---|---|
| | -ly | In the manner of | |

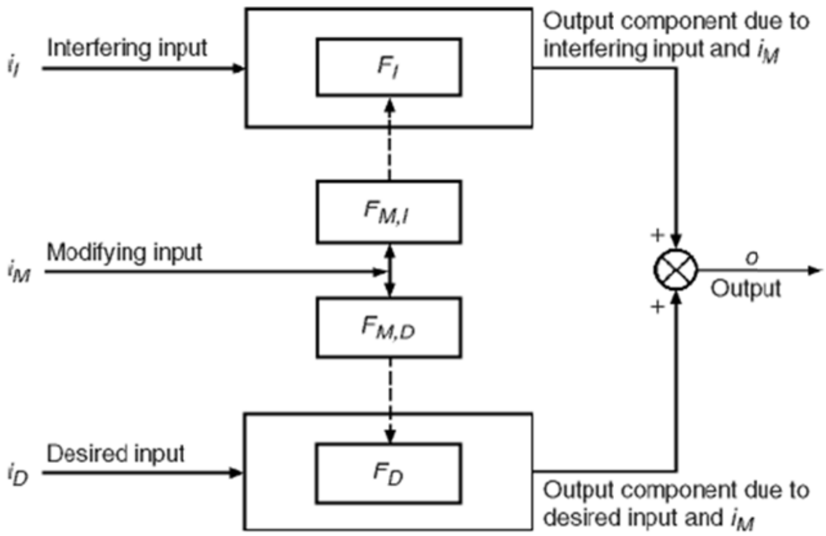
**6 For Questions 1–10, fill in the gaps in the sentences with the correct suffix from the box.**

| | | | | |
|---|---|---|---|---|
| **ment** | **ity (2)** | | **ance** | **ist** |
| **ation** | **ship** | **ing** | **ion** | **ic** |

1 Measure________ of signals is very important for control tasks.
2 Sensitiv________ of sensors of mechatronics system should be high.
3 Perform________ of monitoring allows carrying out the operative control of mechatronics system.
4 Mechatronics special________ should use the newest technical achievements.
5 Miniaturiz________ of computers gives big advantages.
6 Stabil________ of system work is highly determined by the quality of control.
7 Hard________ of mechatronic solutions realization has been overcome.
8 Information process________ is of particular importance in mechatronics system.
9 Nanotechnology is a branch of technology dealing with the manufacture of objects with dimensions of less than 100 nanometres and the manipulat________ of individual molecules and atoms.
10 Semiconductor is used in optoelectronics for mechatron________ system design.

 ***SPEAKING***

**7 Study the following Input–output configuration of a measurement system. Then explain the connection between all the components in it.**



**8 Divide into pairs. Choose any five terms from activities 1 – 7 and give definitions of these terms for your partner to guess the words.**

## Computers and Logic Systems: Section 2

***READING***

**9 You are going to read the text "The Mechatronic Use of Computers". But before reading it, study the abbreviations below and say what they stand for.**

1 ALU
2 DSP
3 MAC
4 ASIC
5 A/D
6 D/A

**10 Read the first part of the text below and say what the mechatronic use of computers is. Then give your own examples of this way of using computers.**

### The Mechatronic Use of Computers

Mechatronics is the synergistic combination of mechanical engineering, electronics, control systems, and computers. The key element in mechatronics is the integration of these areas through the design process. Synergism and integration in design set a mechatronic system apart from a traditional, multidisciplinary system.

In a mechatronic system, computer, electronic, and control technology allow changes in design philosophy, which lead to better performance at lower cost: accuracy and speed from controls, efficiency and reliability from electronics, and functionality and flexibility from computers. Automotive engine control systems are a good example. Here a multitude of sensors measure various temperatures, pressures, flow rates, rotary speeds, and chemical composition and send this information to a microcomputer. The computer integrates all this data with preprogrammed engine models and control laws and sends commands to various valves, actuators, fuel injectors, and ignition systems so as to manage the engine's operation for an optimum combination of acceleration, fuel economy, and pollution emissions.

In Mechatronics, balance is paramount. The essential characteristic of a Mechatronics engineer and the key to success in Mechatronics design is a balance between two sets of skills:

- Modeling (physical and mathematical), analysis (closed-form and numerical simulation), and control design (analog and digital) of dynamic physical systems
- Experimental validation of models and analysis and understanding the key issues in hardware implementation of designs

In mechatronic systems, computers play a variety of roles. First, computers are used to model, analyze, and simulate mechatronic systems and mechatronic system components and, as such, are useful for control design. Second, computers, as part of measurement systems, are used to measure the performance of mechatronic systems, to determine the value of component parameters, and to experimentally validate models. Finally, computers or microcomputers form the central component in digital control systems for mechatronic designs. Thus, computers play an essential role in the two essential characteristics of the Mechatronics balance and comprise a key component to mechatronic system designs.

**11 Read the second part of the text about the Mechatronics and the Real-Time Use of Computers and for Questions 1 – 12, fill the gaps with one of the words from the box below.**

| | | |
|---|---|---|
| drift | analog/digital | disturbances |
| functionality | delays | estimate |
| algorithm | sampler | interlock |
| dedicated | rotate | discrete |

We turn to the field of closed-loop control using a digital computer as the controller. Several comments are in order. First, a mechatronic system typically involves continuous variables. Elements (1) _______________ or translate in space. Fluids or gasses flow. Heat or energy is transferred. Computers are, by their nature, digital elements. Variables are represented in a computer by discrete values or simply by collections of zeroes and ones. For a computer to be used as the controller for a mechatronic system, therefore, the continuous variables must be converted to (2) _______________ variables for processing and then back again to continuous variables. This might seem obvious. What is not so apparent is that the computer algorithm forms an inherent separation between the processing of the signals and the signals themselves, which is not true of other mechatronic system components. Even if digital logic elements are used the signals are converted to discrete form, but the flow of information is still continuous through the elements. When a computer is used for the control element, this information flow is broken and buried in the computer algorithm.

Other issues are involved when the mechatronic system controller is implemented in software. Software execution is often asynchronous to the other time constants in the system (i.e., the software execution and system response are often not synchronized). Software can be made synchronous by syncing it to the (3) _______________ period, but this typically limits performance and is difficult if the computer is to be used for other tasks than control. Once a computer is contained as an element in a mechatronic system, there is a tendency to use some of the processing power to provide additional (4) _______________ or ease of use for the product. This additional code can affect, sometimes adversely, the operation of the real time controller execution. Testing of the code and safety of the code are also issues. The engineer has to determine that his system operates deterministically and safely for all possible combinations of input signals and for all possible states in the execution of the (5) _______________. For real-time systems, execution order for the code is often not predictable since it can be dependent on the particular combination of input signals. Simplicity of the code, providing for testability of the code, using established software quality assurance practices, and developing extensive documentation are ways to achieve system determinism and safety. Often, a hardware (6) _______________, that is, a safety system utilizing electronic or mechanical hardware, is often included in software controlled systems.

In digital devices, it is simply the presence (logical 1) or absence (logical 0) of a voltage within some wide range that matters; the precise value of the signal is of no consequence. Digital devices are therefore very tolerant of noise voltages and need not be individually very accurate, even though the overall system can be extremely accurate. When combined (7) _______________ systems are used, the digital portions need not limit system accuracy; these limitations generally are associated with analog portions and/or the analog-to-digital (A/D) conversion devices. Since most mechatronic systems are analog in nature, it is necessary to have both A/D converters and digital-to-analog (D/A) converters, which serve as translators that enable the computer to communicate with the outside analog world.

The current trend toward using (8) _______________, computer-based, and often decentralized (distributed) digital control systems in mechatronic applications can be rationalized in terms of the major advantages of digital control:

- Digital control is less susceptible to noise or parameter variation in instrumentation because data can be represented, generated, transmitted, and processed as binary words, with bits possessing two identifiable states.
- Very high accuracy and speed are possible through digital processing. However, hardware implementation is usually faster than software implementation. Determining the time required to develop a system in software is notoriously difficult to (9) _______________.
- Digital control can handle repetitive tasks extremely well, through programming.
- Complex control laws and signal conditioning methods that might be impractical to implement using analog devices can be programmed. Very sophisticated algorithms can be implemented digitally.
- High product reliability can be achieved by minimizing analog hardware components and through decentralization using dedicated computers for various control tasks.
- Digital systems are more easily "programmed" and offer the ability to time-share a single processing unit among a number of different functions.
- Large amounts of data can be stored using compact high-density data storage methods.
- Data can be stored or maintained for very long periods of time without (10) ________________. and without being affected by adverse environmental conditions. Digital control has easy and fast data retrieval capabilities.
- Fast data transmission is possible over long distances without introducing dynamic (11) ________________, as in analog systems.
- Digital processing uses low operational voltages (e.g., 0–12 V DC).
- Digital control has low overall component cost.

Further, from the standpoint of the mechatronic product, the inclusion of a computer means that additional system functions can be provided. The user can select from a range of operations. Additional features can be included. A user interface providing indications of operation can be added with minimal cost.

In a feedback system, the analog signal coming from the sensor contains useful information related to controllable disturbances (relatively low frequency), but also may often include higher frequency “noise” due to uncontrollable (12) ______________ (too fast for control system correction), measurement noise, and stray electrical pickup. Such noise signals cause difficulties in analog systems and low-pass filtering is often needed to allow good control performance. The phase shift from this filter also adversely affects control system stability.

**12 Read the third part of the text. Seven sentences have been removed from it. Choose the most suitable sentence from the list A-H for each part (1–7) of the text. There is one extra sentence which you do not need to use.**

| | |
|---|---|
| **0** | ***C*** |

If a signal containing high frequencies is sampled too infrequently, the output signal of the sampler contains low-frequency (“aliased”) components not present in the signal before sampling. This is illustrated in fig. 5.1.

| | |
|---|---|
| **1** | |

From the standpoint of the controller, there is no way for the system to distinguish which signal is present. If we base our control actions on these false low-frequency components, they will, of course, result in poor control.

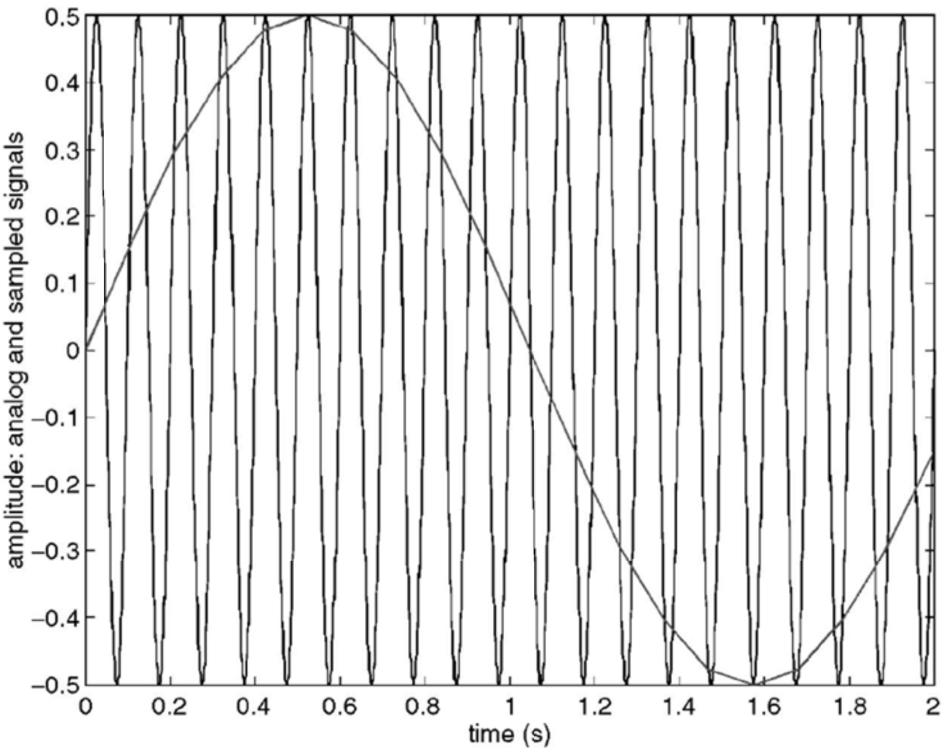



*Fig. 5.1. Simulation of continuous and sampled signal: aliasing*

The theoretical absolute minimum sampling rate to prevent aliasing is two samples per cycle; however, in practice, rates of about 10 are more commonly used.

| | |
|---|---|
| **2** | |

In all of the above, the word computer was used for the digital processing element. In electronics literature, a distinction is usually drawn between a microprocessor, microcomputer, DSP, and computer. There is no standard for what each of these terms can mean, but some insight can be gained by examining fig. 5.2, which is a general block diagram for a computer.

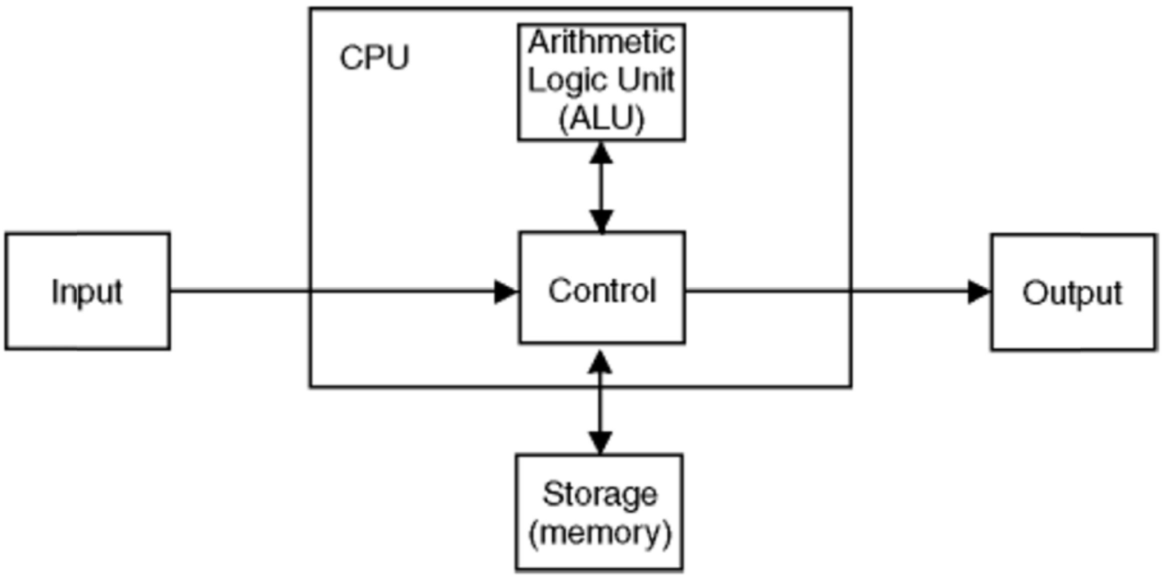



*Fig. 5.2. Elements of a computer*

All computers have a means of getting input, a means of generating output, a means of controlling the flow of signals and operations, memory for data storage, and an arithmetic logic unit (ALU) which executes the instructions. The ALU and control elements are often called the central processing unit (CPU).

| | |
|---|---|
| **3** | |

Memory for these computers is often attached to the microprocessor but in distinct electronic packages. Input and output to the microprocessor is often handled by electronics called peripherals. If the memory is included in the same package, the computer is called either a microcomputer or computer depending on its physical size.

| 4 | |
|---|---|

A single electronics package can contain many “chips,” which are connected by fine wires within the package. The overall package is still called a chip. Finally, if the A/D and D/A functions are provided in the same package, the computer is often called a DSP. However, these functions can also be contained in something which is called a microcomputer. DSPs are also computers which have a special instruction in the ALU called a multiply-accumulate (MAC) instruction even if the A/D and D/A are not present. Digital signal processing algorithms often involve MAC instructions and a computer, which can execute this instruction very effectively (in one instruction cycle of the computer), and are often called DSPs.

| 5 | |
|---|---|

These devices can be custom made to perform a specific operation (such as a PID algorithm). ASICs can contain a CPU or memory or peripheral functions or even a MAC cell as part of its makeup. Diagrams like the one shown in fig. 5.2 often accompany the electronic component so the internal capabilities can be determined.

| 6 | |
|---|---|

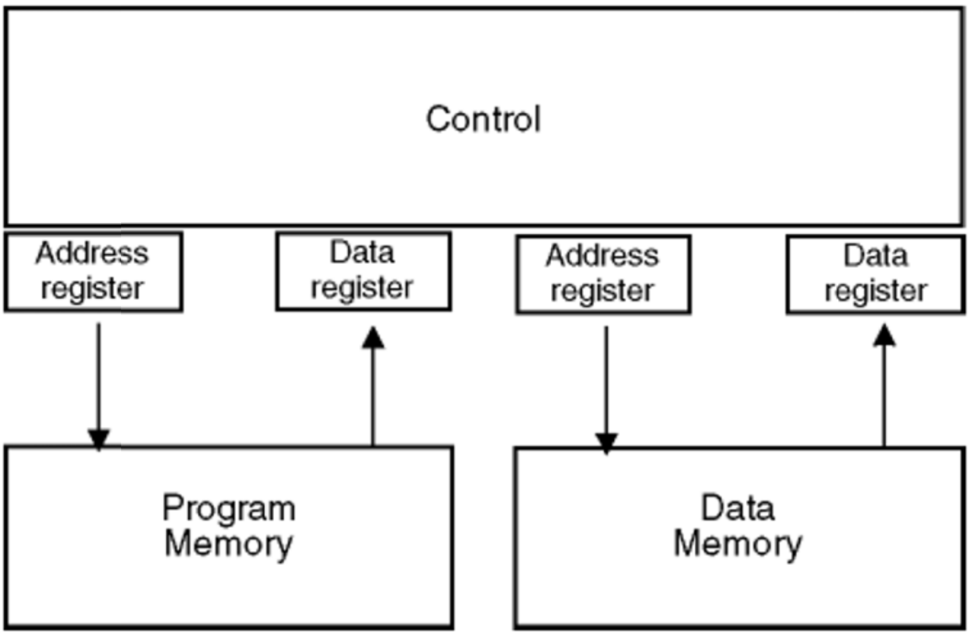



*Fig. 5.3. Computer memory organization*

It is shown in fig. 5.3. This representation is meant to be pictorial rather than to define a specific computer architecture. In a von Neumann architecture, for example, the program memory and data memory share the same space and information busses. Whereas in a Harvard architecture, program memory and data memory are distinct (looking more like the figure). In either case, for a mechatronic system, one can think of the program (in program memory) as the set of instructions which tells the CPU how to manipulate data (in data memory) to produce an output. This view should emphasize the earlier point that the flow of signals in a mechatronic system becomes confused if a computer is to be used for real-time control.

Because of the low cost of modern microcomputers, the use of logic elements as discrete components in a mechatronic system has diminished.

| | |
|---|---|
| **7** | |

In analyzing this logic, of course, any of the traditional methods can be employed.

**A** To further complicate the situation, electronic devices called application specific integrated circuits (ASICs) exist.
**B** Small computers, which just contain a CPU, are often called microprocessors.
**C** In digital systems, a phenomenon called aliasing introduces some new aspects to the area of noise problems.
**D** Memory in a computer can often be divided between program space and data space
**E** ASICs are also used to implement logic functions.
**F** If the higher frequency signal is sampled too infrequently, the result will be exactly the same values as the low frequency signal.
**G** CPU and memory on a single electronics chip is often called a microcomputer.
**H** A high-frequency signal, inadequately sampled, can produce a reconstructed function of a much lower frequency, which cannot be distinguished from that produced by adequate sampling of a low-frequency function.
**I** Microcomputers are often programmed to perform logic functions, which has the advantage that the operation can be altered in software rather than requiring electronic hardware changes.

**13 Now read the text, activities 10, 11 and 12 again and answer the questions below.**

1 What is the aliasing phenomenon?

2 Which type of digital control systems implementation (hardware or software) is faster in general case?
3 Why is it possible to use modern microcomputers instead of logic elements in mechatronic system?
4 What is the difference between a von Neumann architecture of computer memory organizations and a Harvard one?
5 Why are the Digital devices very tolerant to noise signal level?
6 Why is it necessary to have both analog-to-digital (A/D) and digital-to-analog (D/A) converters in mechatronic control systems?
7 What type of signal is more preferable to use for fast data transmission over long distances? Why?
8 Why is low-pass filtering necessary in analog systems to allow good control performance?
9 What are the main parts of computer unit in mechatronic systems?
10 What does an asynchronism in software execution of a mechatronic system controller mean?
11 Is it possible to improve the software asynchronism situation? Why is it not always suitable?
12 Why does the information flow break in a computer algorithm, when the computer is used for the control element?
13 What is the role of computers in mechatronic systems?

**Computers and Logic Systems: Self Study Section**

**14 For Questions 1 – 15, read the text below. Use the word given in capitals at the end of each line to form a word that fits in the space in the same line. Use the example at the beginning.**

Example:
(0) embedded

| | |
|---|---|
| PLCs and (0) _________.controllers are com- | **EMBED** |
| plementary technologies and, when (1) | **APPLICATION** |
| _________. strategically, they will both provide low | |
| cost and reliable (2) _________. to control prob- | **SOLVE** |
| lems. In general, an embedded controller (3) | |
| _________. more initial development time than a | **REQUIREMENT** |
| PLC for a simple system. As the system (4) | |
| _________. more complex, the embedded control- | **GROWTH** |
| ler benefits from the (5) _________. of software li- | **EXIST** |
| braries and design tools. When (6) _________. a | **USE** |

PLC the cost of the purchased hardware will al-
ways be (7) _________. per unit. The development **HIGHT**
costs for an embedded computer will usually be
higher, but these become (8) _________. when
amortized over a large number of units. As a result, **MINIMUM**
embedded controllers are (9) _________. selected
for applications that will be mass-produced and al- **TYPE**
low a greater development time, such as a toy ro-
bot. PLCs are often (10) _________. for applica-
tions that only require a few controllers and are to **SELECTION**
be completed in a relatively short time, such as the
production machines to make a toy.

**15 For Questions 1 – 15, complete the following text by writing down each missing word. Use only one word for each gap. The exercise begins with the example (0).**

Example
(0) Originally

(0) ________ arising (1) ________ the development of processes (2) ________ fabricating microelectronics, micro-scale devices are typically classified according not only (3) ________ their dimensional scale, but their composition and manufacture.

Nanotechnology is generally considered (4) ________ ranging from the smallest of these micro-scale devices down (5) ________ the assembly of individual molecules to form molecular devices. These two distinct yet overlapping fields (6) ________ microelectromechanical systems (MEMS) and nanosystems (7) ________ nanotechnology share a common set of engineering design considerations unique from other more typical engineering systems.

Two major factors distinguish (8) ________ existence, effectiveness, and development of micro-scale and nanoscale transducers from those of conventional scale. (9) ________ first is the physics of scaling and the second is the suitability of manufacturing techniques and processes. The former is governed (10) ________ the laws of physics and is (11) ________ a fundamental factor, (12) ________ the latter is related to the development of manufacturing technology, (13) ________ is a significant, though not fundamental, factor. (14) ________ to the combination of these factors, effective micro-scale transducers can often (15) ________ be constructed as geometrically scaled-down versions of conventional-scale transducers.

## WRITING

**16 Write an essay on the topic given. Let your assignment be of 160–200 words.**

"Computers in Mechatronic Systems"

**17 Read the text below and write an annotation to it.**

Real-Time systems span several domains of computer science. They are defense and space systems, networked multimedia systems, embedded automotive electronics etc. In a real-time system the correctness of the system behavior depends not only on the logical results of the computations, but also on the physical instant at which these results are produced. A real-time system changes its state as a function of physical time, e.g., a chemical reaction continues to change its state even after its controlling computer system has stopped. Based on this a real-time system can be decomposed into a set of subsystems i.e., the controlled object, the real-time computer system and the human operator. A real-time computer system must react to stimuli from the controlled object (or the operator) within time intervals dictated by its environment. The instant at which a result is produced is called a deadline. If the result has utility even after the deadline has passed, the deadline is classified as soft, otherwise it is firm. If a catastrophe could result if a firm deadline is missed, the deadline is hard. Commands and Control systems, Air traffic control systems are examples for hard real-time systems. On-line transaction systems, airline reservation systems are soft real-time systems.

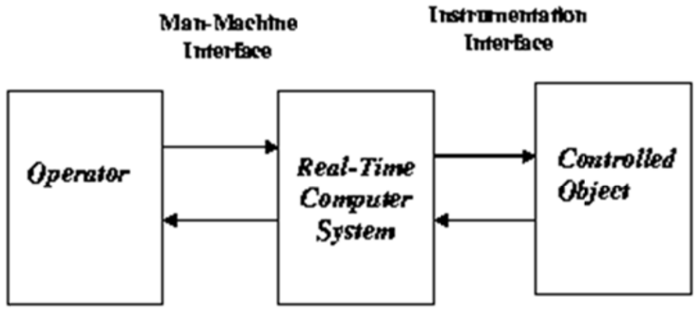



Figure 1: Real-Time System

Real-Time systems can be classified from different perspectives. The first two classifications, hard real-time versus soft real-time, and fail-safe versus fail-operational, depend on the characteristics of the application, i.e., on factors outside the computer system. The second three classifications, guaranteed-timeliness versus best-effort, resource-adequate versus resource-inadequate, and event-triggered versus time-triggered, depend on the design and implementation, i.e., on factors inside the computer system. However this paper focuses on the differences between hard and soft real-time classification.

The response time requirements of hard real-time systems are in the order of milliseconds or less and can result in a catastrophe if not met. In contrast, the response time requirements of soft real-time systems are higher and not very stringent. In a hard real-time system, the peak-load performance must be predictable and should not violate the predefined deadlines. In a soft real-time system, a degraded operation in a rarely occurring peak load can be tolerated. A hard real-time system must remain synchronous with the state of the environment in all cases. On the otherhand soft real-time systems will slow down their response time if the load is very high. Hard real-time systems are often safety critical. Hard real-time systems have small data files and real-time databases. Temporal accuracy is often the concern here. Soft real-time systems for example, on-line reservation systems have larger databases and require long-term integrity of real-time systems. If an error occurs in a soft real-time system, the computation is rolled back to a previously established checkpoint to initiate a recovery action. In hard real-time systems, roll-back/recovery is of limited use.

| Characteristic | Hard real-time | Soft real-time |
|---|---|---|
| Response Time | Hard-required | Soft-desired |
| Peak-load performance | Predictable | Degraded |
| Control of pace | Environment | Computer |
| safety | Often critical | Non-critical |
| Size of data files | Small/medium | Large |
| Redundancy type | Active | Checkpoint-recovery |
| Data integrity | Short-term | Long-term |
| Error detection | Autonomous | User assisted |

A hard real-time system must execute a set of concurrent real-time tasks in such a way that all time-critical tasks meet their specified deadlines. Every task needs computational and data resources to complete the job. The scheduling problem is concerned with the allocation of the resources to satisfy the timing constraints.

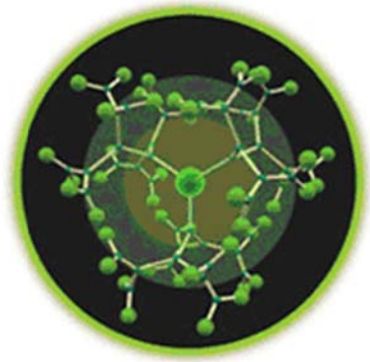
Real-Time scheduling can be categorized into hard vs soft. Hard real-time scheduling can be used for soft real-time scheduling. Some of the research on QoS Klara95 addresses this problem in detail and is not covered here. The present paper focuses on scheduling algorithms for hard real-time.

Hard real-time scheduling can be broadly classifies into two types: static and dynamic. In static scheduling, the scheduling decisions are made at compile time. A run-time schedule is generated offline based on the prior knowledge of task-set parameters, e.g., maximum execution times, precedence constraints, mutual exclusion constraints, and deadlines. So run-time overhead is small. More details on static scheduling can be found in Xu90. On the other hand, dynamic scheduling makes its scheduling decisions at run time, selecting one out of the current set of ready tasks. Dynamic schedulers are flexible and adaptive. But they can incur significant overheads because of run-time processing. Preemptive or nonpreemptive scheduling of tasks is possible with static and dynamic scheduling. In preemptive scheduling, the currently executing task will be preempted upon arrival of a higher priority task. In nonpreemptive scheduling, the currently executing task will not be preempted until completion.

Real-Time systems span a large part of computer industry. So far most of the real-time systems research has been mostly confined to single node systems and mainly for processor scheduling. This needs to be extended for multiple resources and distributed nodes. Real-time systems are expanding to several other domains such as automotive industry and embedded real-time systems. Especially the marriage of the Internet with multimedia applications has opened several new volume applications.

# UNIT 6
# SOFTWARE AND DATA ACQUISITION: SECTION 1

***LEAD-IN***



**1 Look at the picture and say what you can see in it. What do you know about it?**

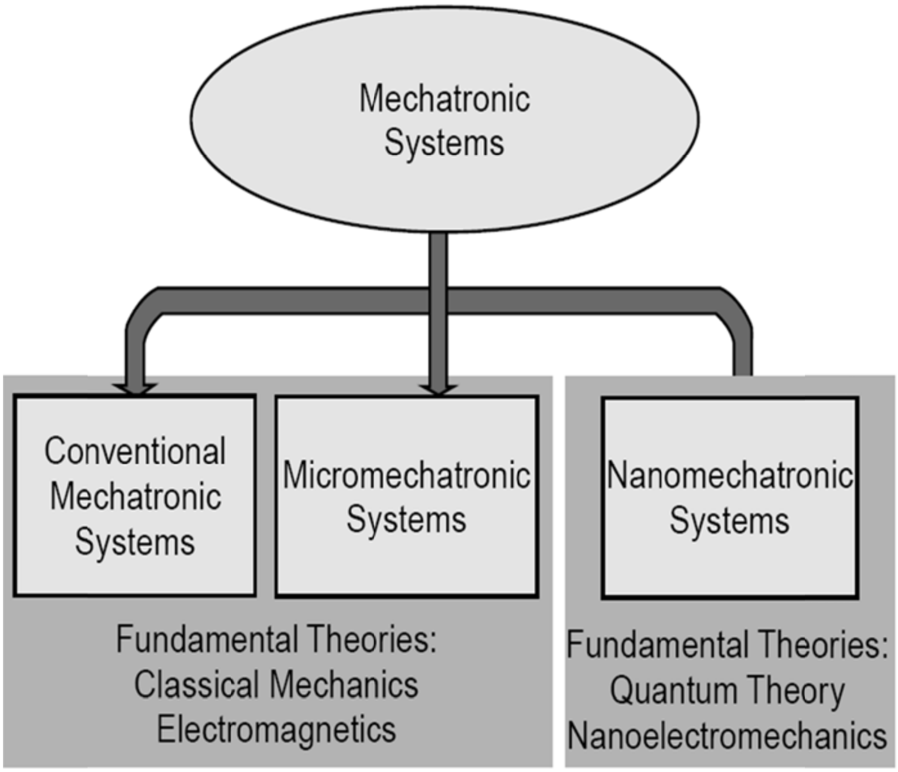
**2 Read the text given below and make up 3 questions to it. Then ask and answer them in pairs.**

## Mechatronics: New Directions in Nano-,Micro-, and Mini-Scale Electromechanical Systems Design

Modern engineering encompasses diverse multidisciplinary areas. Therefore, there is a critical need to identify new directions in research and engineering education addressing, pursuing, and implementing new meaningful and pioneering research initiatives and designing the engineering curriculum. By integrating various disciplines and tools, mechatronics provides multidisciplinary leadership and supports the current gradual changes in academia and industry. There is a strong need for an advanced research in mechatronics and a curriculum reform for undergraduate and graduate programs. Recent research developments and drastic technological advances in electromechanical motion devices, power electronics, solid-state devices, microelectronics, micro- and nanoelectromechanical systems (MEMS and NEMS), materials and packaging, computers, informatics, system intelligence, microprocessors and DSPs, signal and optical processing, computer-aided-design tools, and simulation environments have brought new challenges to the academia. As a result, many scientists are engaged in research in the area of mechatronics, and engineering schools have revised their curricula to offer the relevant courses in mechatronics.

Mechatronic systems are classified as:

1. conventional mechatronic systems,
2. microelectromechanical-micromechatronic systems (MEMS), and
3. nanoelectromechanical-nanomechatronic systems (NEMS).




The operational principles and basic foundations of conventional mechatronic systems and MEMS are the same, while NEMS can be studied using different concepts and theories. In particular, the designer applies the classical mechanics and electromagnetics to study conventional mechatronic systems and MEMS. Quantum theory and nanoelectromechanics are applied for NEMS.

***LISTENING***

**3 Listen to the second part of the text about new directions in Nano-, Micro- and Mini-Scale Electromechanical System design and for Questions 1 – 8, choose the correct variant A – C.**

1 What is right?

A difficulties to achieving sufficient knowledge in integrative electromechanical systems areas to solve complex engineering problems are weaknesses of the computer, electrical, and mechanical engineering curricula

B weakness of the computer, electrical, and mechanical engineering curricula is difficulties to describe complex multidisciplinary engineering problems

C integrative electromechanical systems areas can solve complex multidisciplinary engineering problems

2 Mechatronics introduces …

A disciplines from unified perspectives through the electromechanical theory research and designed sequence of mechatronic courses

B the subject matter from electromechanical theory fundamentals

C disciplines only from designed sequence of mechatronic courses

3 What is right?

A purpose of mechatronics education is the solving of wide spectrum of engineering problems

B purpose of mechatronics education is to prepare a new generation of students and engineers for wide spectrum of engineering problems solving

C new generation of students and engineers create mechatronics education for wide spectrum of engineering problems solving

4 What is right?

A integration, interaction, interpretation, relevance, and systematization features are not so important part of modern confluent engineering and Mechatronics

B Mechatronics is an important part of modern engineering because of integration, interaction, interpretation, relevance, and systematization features.

C Mechatronics is part of modern engineering as well as integration, interaction, interpretation, relevance, and systematization features of engineering.

5 What is right?

A the variety of active student learning processes and synergetic teaching styles combined with The multidisciplinary mechatronic research and educational activities will produce a level of overall student accomplishments

B The multidisciplinary mechatronic research combined with educational activities and synergetic teaching styles, will produce a level of overall student accomplishments

C The multidisciplinary mechatronic research and educational activities, combined with synergetic teaching styles, will produce a level of overall student accomplishments

6 The multidisciplinary mechatronic
   A only brings new depth to engineering areas, advances students' knowledge and background
   B brings new depth to engineering areas, advances students' knowledge and provides students with the basic problem-solving skills
   C brings new depth to engineering areas or advances students' knowledge and provides students with the basic problem-solving skills

7 It is …
   A unnecessary to examine the existing courses during creation of the mechatronic curriculum
   B necessary to improve the structure and content of engineering programs during creation of the mechatronic curriculum
   C not judicious to improve the structure and content of engineering programs during creation of the mechatronic curriculum

8 Enhancement and improvement in student knowledge …
   A can be achieved without the mechatronic curriculum development and implementation
   B lead to the mechatronic curriculum development and implementation.
   C can't be achieved without the mechatronic curriculum development and implementation.

## VOCABULARY AND GRAMMAR

### Organizing information

A paragraph is a group of related sentences that develop an idea. In nearly every paragraph, there is one idea that is more important than all the others. The main idea of the paragraph is usually found at the beginning.

Sample paragraph 1:

Conventional, mini- and micro-scale electromechanical systems are studied from a unified perspective because operating features, basic phenomena, and dominant effects are based upon classical electromagnetics and mechanics (electromechanics). Electromechanical systems integrate subsystems and components. No matter how well an individual subsystem or component (electric motor, sensor, power amplifier, or DSP) performs, the overall performance can be degraded if the designer fails to integrate and optimize the electromechanical system.

In sample paragraph 1, the first sentence *Conventional, mini- and micro-scale electromechanical systems are studied from a unified perspective because operating features, basic phenomena, and dominant effects are based upon classical electromagnetics and mechanics,* expresses the main idea of the paragraph.

All main idea sentences have a topic and say something about the topic.

Example:
*Conventional, mini- and micro-scale electromechanical systems* (a topic) *are studied from a unified perspective because operating features, basic phenomena, and dominant effects are based upon classical electromagnetics and mechanics* (about the topic).

In a lot of cases when you read you need to understand details. Sometimes it's more difficult to understand details than the main ideas. It will be helpful if you think of details as growing out of the main idea. In sample paragraph 1 there are two major details:

1 Conventional, mini- and micro-scale electromechanical systems (a topic) **are studied from a unified perspective.**
2 They are studied from a unified perspective because **operating features, basic phenomena, and dominant effects are based upon classical electromagnetics and mechanics.**

A major detail often has minor details growing out of it. These minor details tell more about a major detail, just as major details tell more about a main idea. Often there are paragraphs which have many small details that you must understand and remember. Breaking up a paragraph of this kind into its three components: the main idea, major details, and minor details will help you to understand and remember what it is about.

Sample paragraph 2:

Filtering is the lessening of certain frequencies from a signal. Filters can be divided into analog and digital types, the analog filters being further divided into passive and active types. Analog passive filters use resistors, capacitors, and inductors. Analog active filters typically use operational amplifiers with resistors and capacitors. Digital filters may be implemented with software. The software component gives digital filters the feature of being easier to change.

| | | | |
|---|---|---|---|
| Main idea | Filtering is the lessening of certain frequencies from a signal. | | |
| Major details | Filters can be divided into analog and digital types. | | Digital filters may be implemented with software. |
| Minor details | Analog passive filters use resistors, capacitors, and inductors. | Analog active filters typically use operational amplifiers with resistors and capacitors. | The software component gives digital filters the feature of being easier to change. |

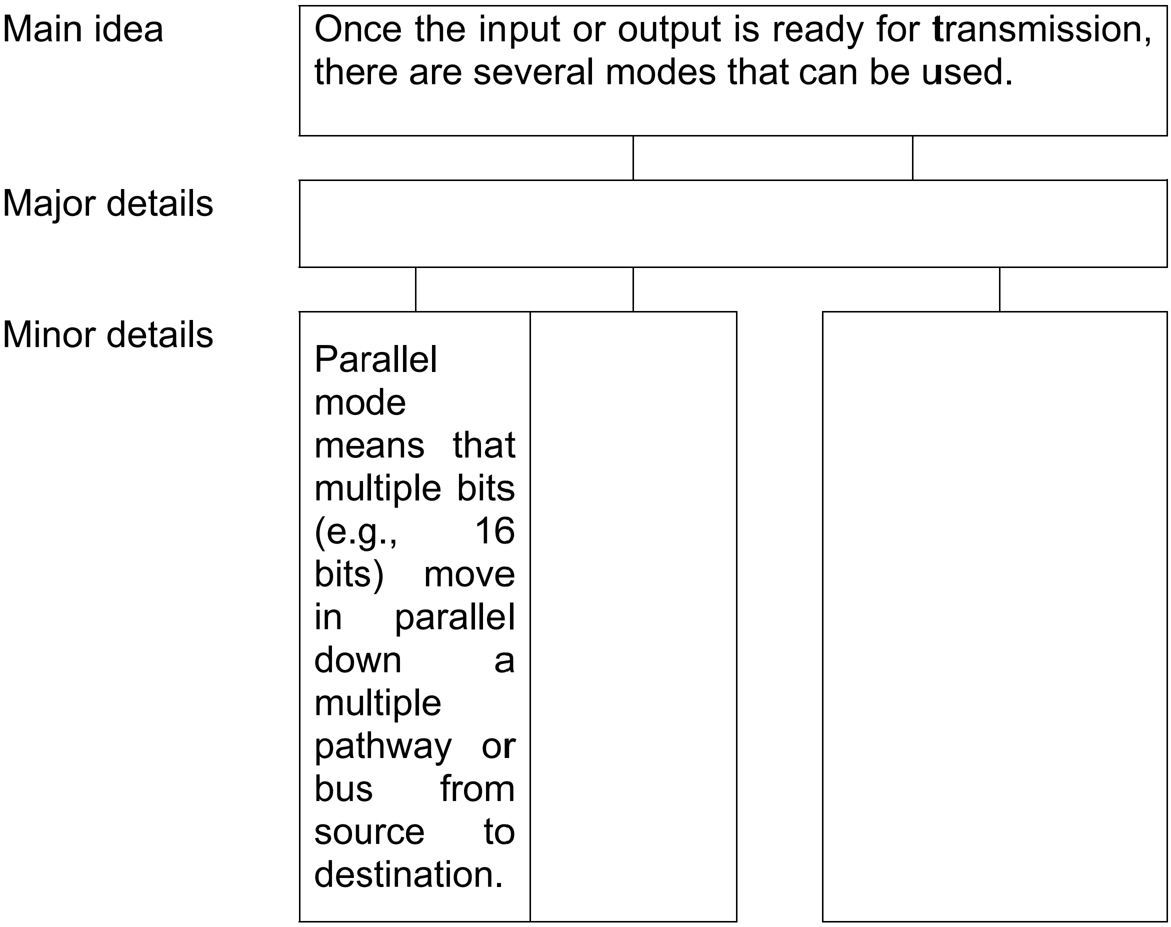
**4 Read the following paragraph and practice finding the major details and minor details by completing the block diagram given below.**

There are two basic methods for the microprocessor to control input and output. These are polling and interrupts. Polling is just that, the microprocessor periodically checking various peripheral devices to determine if input or output is waiting. Servicing an interrupt is an alternative method to control inputs and outputs.

| | | | |
|---|---|---|---|
| Main idea | There are two basic methods for the microprocessor to control input and output. | | |
| Major details | | | |
| Minor details | | | |

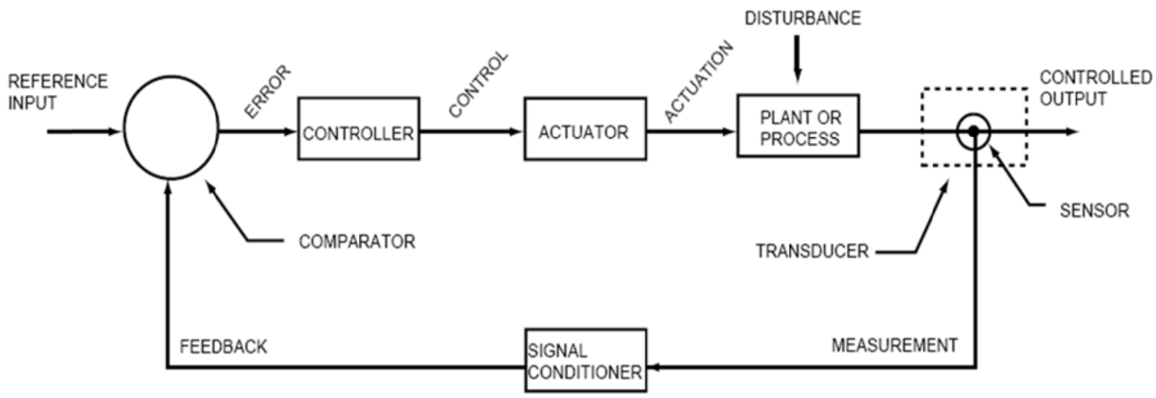
**5 Read the following paragraph and practice finding the major details and minor details by completing the block diagram given below.**

Once the input or output is ready for transmission, there are several modes that can be used. First, data can be moved in either parallel or serial mode. Parallel mode means that multiple bits (e.g., 16 bits) move in parallel down a multiple pathway or bus from source to destination. Serial mode means that the bits move one at a time, in a series, down a single pathway. Parallel mode traffic is faster in that multiple bits are moving together, but the number of pathways is a limiting factor.




***SPEAKING***

**6 Study the following Functional block diagram of a canonical (standard) automatic control system. Then explain the connection between all the components in it.**




**7 Make up dialogues using one of the situations given.**

1 **Student A:** You are a specialist on Mechatronics. You want to get a job at a research institute. Try yourself in a job interview.
**Student B:** You are a specialist on Mechatronics too. You work at a research institute, your specialization is NEMS. Conduct a job interview, ask as many questions as you can to check whether the candidate is good at the subject.

2 **Student A:** You are a specialist in the sphere of modeling. You work at a graduate center. Your task is to help your graduate student to write a chapter to his dissertation. Its topic is MEMS.
**Student B:** You are a graduate student. Ask your research advisor to help you with preparation of the chapter under the title MEMS.

3 **Student A:** You've just graduated from the university and your future job is lecturer. The first discipline is Data Acquisition in Mechatronics. Ask your senior colleague to help you to make a plan of your lecture course and discuss main terms of the subject.
**Student B:** You are a university teacher of Mechatronics. Help your colleague to develop the course of lectures.

4 **Student A:** You are a student of Computer science and you want to take part in a study placement abroad. The course is called "Nanoelectromechanical-Nanomechatronic Systems". But before entering the program you want to clear up main ideas of the topic. Ask your friend to help you.
**Student B:** You are a specialist in the sphere of Nanotechnologies. Help your friend to obtain a general understanding of the subject.

**Software and Data Acquisition: Section 2**

**8 Read the text below. For Abstracts 1 – 8, choose a suitable main idea from the list A – C.**

## Introduction to Data Acquisition

The purpose of a data acquisition system is to capture and analyze some sort of physical phenomenon from the real world. Light, temperature, pressure, and torque are a few of the many different types of signals that can interface to a data acquisition system. A data acquisition system may also produce electrical signals simultaneously. These signals can either intelligently control mechanical systems or provide a stimulus so that the data acquisition system can measure the response. A data acquisition system provides a way to empirically test designs, theories, and real world systems for validation or research.

| 0 | *A* |
|---|---|

At first, data acquisition devices stood alone and were manually controlled by an operator. When the PC emerged, data acquisition devices and instruments could be connected to the computer through a serial port, parallel port, or some custom interface. A computer program could control the device automatically and retrieve data from the device for storage, analysis, or presentation. Now, instruments and data acquisition devices can be integrated into a computer through high-speed communication links, for tighter integration between the power and flexibility of the computer and the instrument or device.

| 1 | |
|---|---|

Since data acquisition devices acquire an electric signal, a transducer or a sensor must convert some physical phenomenon into an electrical signal. A common example of a transducer is a thermocouple. A thermocouple uses the material properties of dissimilar metals to convert a temperature into a voltage. As the temperature increases, the voltage produced by the thermocouple increases. A software program can then convert the voltage reading back into a temperature for analysis, presentation, and data logging. Many sensors produce currents instead of voltages. A current is often advantageous because the signal will not be corrupted by small amounts of resistance in the wires connecting the transducer to the data acquisition device. A disadvantage of current-producing transducers, though, is that most data acquisition devices measure voltage, not current. Generally, the data acquisition devices that can measure current use a very small resistance of a known value to convert the known current into a readable voltage. Ultimately, the device is then still acquiring a voltage.

| 2 | |
|---|---|

Analog signals for data acquisition can be grouped into two basic classes: random and deterministic. Data acquisition devices can both acquire and generate these types of signals. Random signals never repeat and have a flat frequency spectrum. Microphone static is an example of a random signal. A deterministic signal, unlike random signals, can be represented by a sum of sinusoids. Deterministic signals can be subdivided into periodic and transient signals. Periodic signals constantly repeat the same shape at regular intervals over time, while transient signals start and end at a constant level and do not occur at regular intervals. Transient signals are nonperiodic events that represent a finite-length reaction to some stimulus.

| 3 | |
|---|---|

Digital input and output are commonly incorporated into data acquisition hardware for sensing contacts, controlling relays and lights, and testing digital devices. The most commonly used digital levels are TTL and TTL-compatible CMOS. These are both very common 5-V standards for digital hardware. Digital transfer rates to and from the data acquisition hardware vary from unstrobed to high speed. Unstrobed digital input and output involves setting digital lines and monitoring states by software command. This form of digital input and output is also known as static or immediate digital I/O. The maximum speed of an unstrobed I/O is highly dependent on the computer hardware, the operating system, and the application program. Pattern digital I/O refers to inputs and outputs of digital patterns under the control of a clock signal. The speed at which the data can be sent or received depends on the amount of data, the characteristics of the data acquisition hardware, and the computer speed.

| 4 | |
|---|---|

The final type of I/O on computer-based data acquisition hardware is counter/timer I/O. Counter/timers are capable of measuring or producing very time-critical digital pulses. These pulses, like the digital input and output, are generally TTL or TTL-compatible CMOS. These components are used for measuring or producing a number of time-critical signals including event counting, pulse train generation, frequency-shift keying, and monitoring quadrature encoders. The two main characteristics of a counter/timer are the counter size and maximum source frequency. The counter size is generally represented in bits and determines how high a counter can count. For instance, a 32-bit counter can count $2^{32} - 1$ = 4,294,967,295 events before it returns the count value back to zero. The maximum source frequency represents the speed of the fastest signal the counter can count. An 80-MHz counter can count events that are as fast as 12.5 ns apart. An "event" is actually the rising or falling edge of a digital signal.

| 5 | |
|---|---|

No real situation will ever have perfect signals or be completely free of noise. Signal conditioning is a method to remove, as much as possible, unwanted components of a digital or analog signal. A real analog signal usually comprises both deterministic and random signals, and a digital signal is not going to be perfectly square. Measurement hardware, particularly for high-frequency analog signals, is usually equipped with an antialiasing filter. This is a low-pass filter that blocks frequencies above the desired frequency range and increases the accuracy of the measurements. Digital and counter/timer lines are also commonly fitted with filters that remove spikes from the signal that could otherwise be mistakenly counted as a rising or falling edge. Isolation is another type of signal conditioning that separates the measurement hardware circuitry from the signal being measured. This is done to remove large differences in electric potential between the measurement hardware and the signal, and it protects the measurement hardware from damage, given a large surge in voltage or current.

| 6 | |
|---|---|

The heart of a data acquisition device is a digital-to-analog converter (DAC), an analog-to-digital converter (ADC), or some combination of the two. An ADC has a finite list of values which represents voltages. The purpose of the ADC is to select a value from this list, which is closest to an actual voltage at a specified time. The value is then transferred in binary format to a computer. Alternatively, a DAC can produce an analog voltage from a list of binary values. The voltage generated by a basic DAC stays the same until it receives another value from the computer. In order to acquire and produce analog waveforms, the DAC and ADC must activate at precise intervals. Consequently, measurement hardware has timing circuitry to produce a pulse train of a constant frequency to control the ADC and DAC.

| 7 | |
|---|---|

The data that is transferred from the ADC and to the DAC travels to the computer over a bus. A bus is a group of electrical conductors that transfer information inside a computer. Some common examples of a bus are PCI and USB. The bus can carry both control information and binary measurement data to and from measurement hardware. One of the most important considerations in selecting a bus is bus transfer rate, usually expressed in megabytes per second (Mbytes/s). A single analog value could require less than 1 byte or as much as 4 bytes, depending on the type of measurement hardware. The bus is shared among multiple devices, so data acquisition devices often have on-board memory to serve as a holding place for data when the bus is not available. In very fast data acquisition routines, the memory can hold all the data, and at the end of the acquisition, all the data can be transferred to the computer for processing.

| 8 | |
|---|---|

When data is acquired at high speeds on multiple channels, it is often important to understand the phase relationship from one signal to the next. If the signals are generated or acquired on multiple data acquisition devices, there are a number of ways to synchronize the systems and preserve relative phase relationships. One way is to share the ADC and DAC clock between the data acquisition devices. The real-time system integration bus (RTSI) is a bus that can connect multiple devices together to share timing circuitry among multiple devices. Phase-lock looping (PLL) is a more sophisticated synchronization method. A reference signal is supplied to all the data acquisition devices, and the internal clocks stay in phase with the reference signal. Consequently, the phase relationship can be reserved even if different measurement hardware is using different sampling or update speeds.

| 9 | |
|---|---|

Abstract 0

A Data acquisition system is necessary for reception of the information from the real world and its analysis

B Data acquisition system is necessary for transfer of the information to the real world

C Data acquisition system is necessary for analyze some sort of electrical signals phenomenon from the real world

Abstract 1

A In the beginning Data acquisition devices were manually controlled by computers

B In the beginning Data acquisition devices had controlled computers and operators.

C In the beginning an operator had controlled Data acquisition devices.

Abstract 2

A Signal will not be corrupted by small amounts of resistance in the wires connecting the transducer to the data acquisition device because a current is often advantageous.

B Signal will not be corrupted by small amounts of resistance in the wires connecting the transducer to the data acquisition device and a current is often advantageous from this standpoint.

C Signal will not be corrupted by small amounts of resistance in the wires connecting the transducer to the data acquisition device therefore a current is often disadvantageous.

Abstract 3

A The difference between periodic signals and transient signals is that periodic signals repeat the same values at irregular intervals.

B The difference between periodic signals and transient signals is that transient signals repeat the same values at regular intervals.

C The difference between periodic signals and transient signals is that periodic signals periodically repeat the values.

Abstract 4

A Computer hardware, the operating system, and the application program determine maximum speed of an unstrobed I/O

B Maximum speed of an unstrobed I/O dependents on computer hardware and used digital levels are TTL and TTL-compatible CMOS.

C Maximum speed of unstrobed I/O dependents the computer hardware and the operating system.

Abstract 5

A Counter/timer device has some nonprincipal features: the counter size and maximum source frequency.

B Counter/timer device has following features: the counter size and maximum source frequency.

C Counter size and maximum source frequency are pulses, like the digital input and output.

Abstract 6

A For increasing of the measurements accuracy the low-pass filter is needed

B Low-pass filter is needed for blocks the desired frequency and increases the accuracy of the measurements

C Low-pass filter is needed for high-frequency analog signals and increases the accuracy of the measurements

Abstract 7

A DAC can produce an analog voltage from a list of binary values and ADC can produce a value from a list, which is closest to an actual voltage.

B ADC can produce an analog voltage from a list of binary values and DAC can produce a value from a list, which is closest to an actual voltage.

C Combination of the DAC and ADC can produce a finite list of voltage

Abstract 8

A Memory can hold all the data, which are transferred to the computer during the acquisition processing.

B Memory can hold all the data, which are transferred to the computer at the end of the acquisition process.

C Memory can hold all the data, which are transferred to the computer at the end of the acquisition process in very fast data acquisition routines only.

Abstract 9

A Sharing the ADC and DAC clock between the data acquisition devices is very sophisticated method

B Phase-lock looping (PLL) method is one of the ways to synchronize the systems

C Phase-lock looping (PLL) method is one of the ways to share the ADC and DAC clock between the data acquisition devices

**Software and Data Acquisition: Self Study Section**

**9 For Questions 1 – 15, read the text below. Use the word given in capitals at the end of each line to form a word that fits in the space in the same line. Use the example at the beginning.**

Example:
(0) engineering

Mechatronics is an important part of modern confluent (0) _________ due to integration, interaction, interpretation, (1) _________, and systematization features. Efficient and (2) _________ means to assess the current trends in modern engineering with (3) _________ analysis and outcome (4) _________ can be approached through the mechatronic paradigm. The (5) _________ mechatronic research and (6) _________ activities, combined with the variety of (7) _________ student learning processes and synergetic teaching styles, will produce a level of overall student (8) _________ that is greater than the achievements which can be produced by (9) _________ the conventional electrical, computer, and (10) _________ engineering curricula.

The multidisciplinary mechatronic paradigm serves very important purposes because it brings new depth to engineering areas, advances students' (11) _________ and background, provides students with the basic problem-solving (12) _________ that are needed to cope with advanced (13) _________ systems controlled by microprocessors or DSPs, covers state-of-the-art hardware, and emphasizes and (14) _________ modern software environments. Through the mechatronic curriculum, important program (15) _________ and goals can be achieved.

**ENGINEER**
**RELEVANT**
**EFFECT**
**ASSESS**
**PREDICT**
**MULTYDISCIPLINE**
**EDUCATION**
**ACTIVITY**
**ACCOMPLISH**
**REFINE**
**MECHANICS**
**KNOW**
**SKILLFUL**
**ELECTROMECHANICS**
**APPLICATION**
**OBJECT**

**10 For Words 1 – 10, find synonyms under the letters A – J.**

| | | | |
|---|---|---|---|
| 1 | outcome | A | modify |
| 2 | exploration | B | investigation |

| | | | |
|---|---|---|---|
| 3 | optimize | C | best |
| 4 | optimal | D | sets of rules |
| 5 | algorithms | E | steadiness |
| 6 | embedded | F | evaluate |
| 7 | automate | G | mounted |
| 8 | stability | H | result |
| 9 | measure | I | perfect |
| 10 | faults | J | mistakes |

**11 Read the text below and fill the gaps with the words 1 – 10, activity 10.**

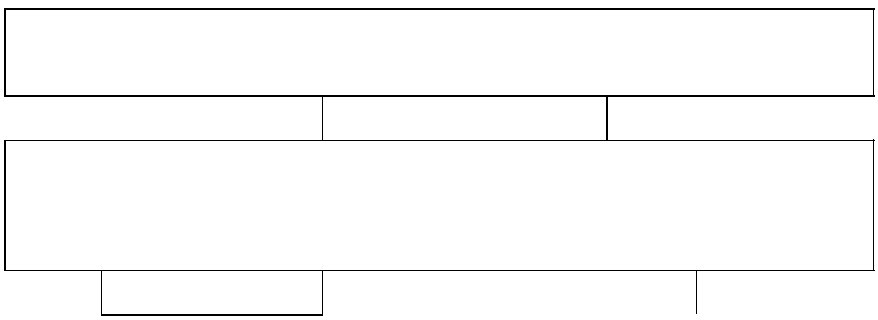
Conventional control theory has allowed man to control and (1) ______________ his environment for centuries. Modern control techniques have allowed engineers to (2) ______________ the control systems they build for cost and performance. However, (3) ______________ control (4) ______________ are not always tolerant to changes in the control system or the environment. Robust control theory is a method to (5) ______________ the performance changes of a control system with changing system parameters. Application of this technique is important to building dependable (6) ______________ systems. The goal is to allow (7) ______________ of the design space for alternatives that are insensitive to changes in the system and can maintain their (8) ______________ and performance. One desirable (9) ______________ is for systems that exhibit graceful degradation in the presence of changes or partial system (10) ______________.

***WRITING***

**12 Choose one of the paragraphs of text, activity 8 and practice finding the main idea, major details and minor details by completing the block diagram given below.**

Main idea

Major details



| | | | |
|---|---|---|---|
| Minor details | | | |

**13 Read the text below and write an annotation to it.**

In order to gain a perspective for robust control, it is useful to examine some basic concepts from control theory. Control theory can be broken down historically into two main areas: conventional control and modern control. Conventional control covers the concepts and techniques developed up to 1950. Modern control covers the techniques from 1950 to the present. Each of these is examined in this introduction.

Conventional control became interesting with the development of feedback theory. Feedback was used in order to stabilize the control system. One early use of feedback control was the development of the flyball governor for stabilizing steam engines in locomotives. Another example was the use of feedback for telephone signals in the 1920s. The problem was the transmission of signals over long lines. There was a limit to the number of repeaters that could be added in series to a telephone line due to distortion. Harold Stephen Black proposed a feedback system that would use feedback to limit the distortion. Even though the added feedback sacrificed some gain in the repeater, it enhanced the overall performanceConventional control relies upon developing a model of the control system using differential equations. Laplace transforms are then used to express the system equations in the frequency domain where they can be manipulated algebraically. Fig. 1 shows a typical control loop. The input to the system is some reference signal, which represents the desired control value. This reference is fed through a forward transfer function G(s) to determine the plant output, y. The output is fed back through a feedback transfer function, H(s). The feedback signal is subtracted from the reference to determine the error signal, e. Further control is based on the error signal. Therefore, the system serves to bring the output as close as possible to the desired reference input. Due to the complexity of the mathematics, conventional control methods were used mostly for Single-Input-Single-Output (SISO) systems.

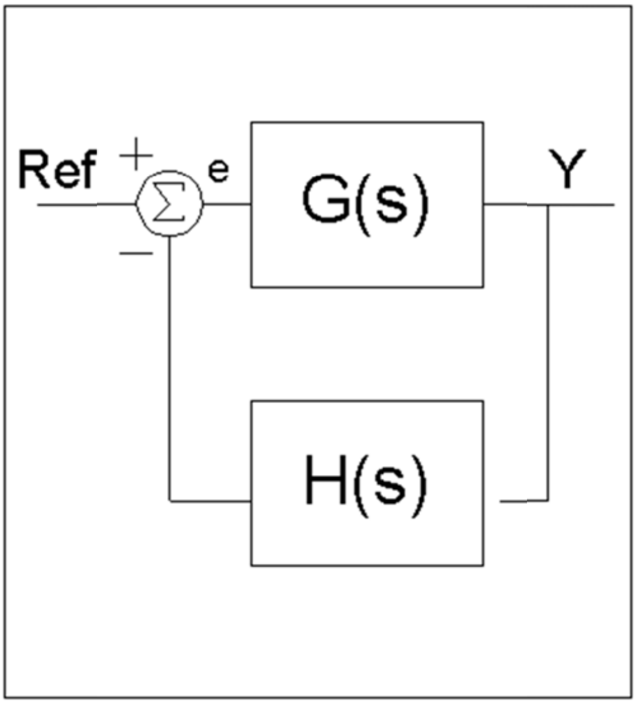



*Fig. 6.1. Typical Control Loop*

One development that was key to future developments in robust control was the root-locus method. In the frequency domain, G(s) and H(s) were expressed as ratios of polynomials in the complex frequency variable, s. Nyquist, Bode and others realized that the roots of the denominator polynomial determined the stability of the control system. These roots were referred to as "poles" of the transfer functions. The location of these poles had to be in the left half-plane of the complex frequency plot to guarantee stability. Root locus was developed as a method to graphically show the movements of poles in the frequency domain as the coefficients of the s-polynomial were changed. Movement into the right half plane meant an unstable system. Thus systems could be judged by their sensitivity to small changes in the denominator coefficients.

Modern control methods were developed with a realization that control system equations could be structured in such a way that computers could efficiently solve them. It was shown that any nth order differential equation describing a control system could be reduced to n 1st order equations. These equations could be arranged in the form of matrix equations. This method is often referred to as the state variable method. The canonical form of state equations is shown below, where x is a vector representing the system "state", $\dot{x}$ is a vector representing the change in "state", u is a vector of inputs, y is a vector of outputs, and A, B, C, D are constant matrices which are defined by the particular control system.

$$\dot{\vec{x}} = A\vec{x} + B\vec{u}$$
$$\vec{y} = C\vec{x} + D\vec{u}$$

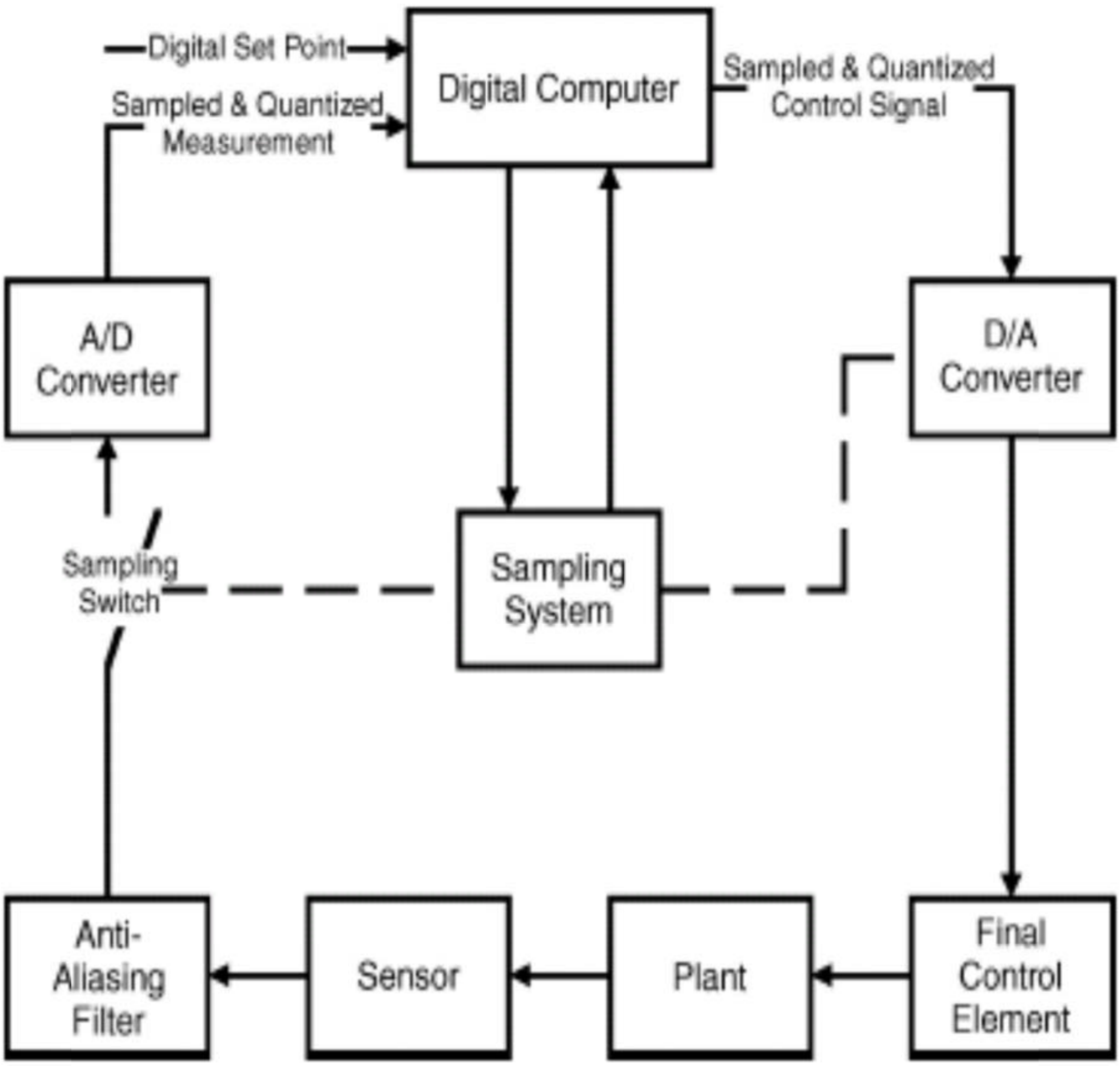
Modern control methods were extremely successful because they could be efficiently implemented on computers, they could handle Multiple-Input-Multiple-Output (MIMO) systems, and they could be optimized. Methods to optimize the constant state matrices were developed. For instance a spacecraft control system could be optimized to reach a destination in the minimum time or to use the minimum amount of fuel or some weighted combination of the two. The ability to design for performance and cost made these modern control systems highly desirable.

# UNIT 7
# MECHATRONICS ENGINEERING: SECTION 1

***LEAD-IN***

**1 Read the title of Unit 7 and say what it will be about. Give definition to the term "Mechatronics engineering".**

**2 Study the following General computer-control configuration. Then explain the connection between all the components in it.**



## *READING*

**3 For Words 1 – 12, find synonyms under the letters A – L.**

| | | | |
|---|---|---|---|
| 1 | acquisition | A | elastic |
| 2 | urgent | B | altering quantity |
| 3 | use | C | lighten |
| 4 | disturbance | D | application |
| 5 | specification | E | obtainment |
| 6 | flexible | F | range |
| 7 | facilitate | G | technical condition |
| 8 | array | H | hindrance |
| 9 | variable | I | emergent |
| 10 | analysis | J | pilot |
| 11 | reduction | K | review |
| 12 | experimental | L | decrease |

**4 Read the text and fill the gaps with the words, Activity 3. Sometimes you need to change the form of the word.**

### Systems Synthesis, Mechatronics Software, and Simulation

Modeling, simulation, and synthesis are complementary activities performed in the design of mechatronic systems. Simulation starts with the model developments, while synthesis starts with the (1) _______________ imposed on the behavior and analysis of the system performance through analysis using modeling, simulation, and (2) _______________ results. The designer mimics, studies, analyzes, and evaluates the mechatronic system's behavior using state, performance, control, events, (3) _______________, and other (4) _______________. Modeling, simulation, analysis, virtual prototyping, and visualization are critical and (5) _______________ important aspects for developing and prototyping of advanced electromechanical systems. As a (6) _______________ high-performance modeling and design environment, MATLAB has become a standard, cost-effective tool. Competition has prompted cost and product cycle (7) _______________.

To speed up analysis and design with assessment analysis, (8) _______________ enormous gains in productivity and creativity, integrate control and signal processing using advanced microprocessors and DSPs, accelerate prototyping features, generate real-time C code and visualize the results, perform data (9) _______________ and data intensive analysis, the MATLAB environment is used. In MATLAB, the following commonly used toolboxes can be applied: SIMULINK, Real-Time Workshop™, Control System, Nonlinear Control Design, Optimization, Robust Control, Signal Processing, Symbolic Math, System Identification, Partial Differential Equations, Neural Networks, as well as other application-specific toolboxes. MATLAB capabilities should be demonstrated by attacking important practical examples in order to increase students' productivity and creativity by demonstrating how to use the advanced software in electromechanical system (10) ______________. The MATLAB environment offers a rich set of capabilities to efficiently solve a variety of complex (11) ______________, modeling, simulation, control, and optimization problems encountered in undergraduate and graduate mechatronic courses.

A wide (12) ______________ of mechatronic systems can be modeled, simulated, analyzed, and optimized. The electromechanical systems examples, integrated within mechatronic courses, will provide the practice and educate students with the highest degree of comprehensiveness and coverage.

## *LISTENING*

**5 Listen to the recording and For Questions 1 – 8, choose the correct mark T (true) or F (false). Correct the false statements.**

1 New challenges to academia and industry were brought by Far-reaching fundamental and technological advances.

2 Electromechanical Systems and Mechatronics are offered by engineering schools as irrelevant interdisciplinary courses.

3 Fundamental theory and engineering practice are sources of mechatronics.

4 The attempts to introduce mechatronics were successful due to the absence of a long-term strategy.

5 It is possible to emphasize the cross disciplinary nature of mechatronics in one introductory course.

6 The engineering curriculum integrates a set of core mechatronic courses, and advanced hardware and software should be developed with the help of laboratory- oriented and project-oriented courses.

7 Versatility of mechatronics makes it worthwhile for all engineers to be acquainted with the basic theory and engineering practice.

8 Further contribution to mechatronics interdisciplinary concept is continued.

***VOCABULARY AND GRAMMAR***

**6 For Questions 1 – 8, complete the second sentence so that it has a similar meaning to the first sentence, using the word given. Do not change the word given. You must use between two and five words, including the word given.**

1 SWNTs are used as electromechanical actuators.
CAN
SWNTs ................................................ as electromechanical actuators.

2 We used nanoscale electromechanical devices to manipulate and interrogate nanostructures.
WERE
These nanoscale electromechanical devices …………………… to manipulate and interrogate nanostructures.

3 They might use this device to manipulate biological cells or even manipulate organelles and clusters within human cells.
COULD
This device ………………………………… to manipulate biological cells or even manipulate organelles and clusters within human cells.

4 They have proposed a wide variety of nanoscale manipulators including pneumatic manipulators that can be configured to make tentacle, snake, or multi-chambered devices.
BEEN
A wide variety of nanoscale manipulators ………………………… including pneumatic manipulators that can be configured to make tentacle, snake, or multi-chambered devices.

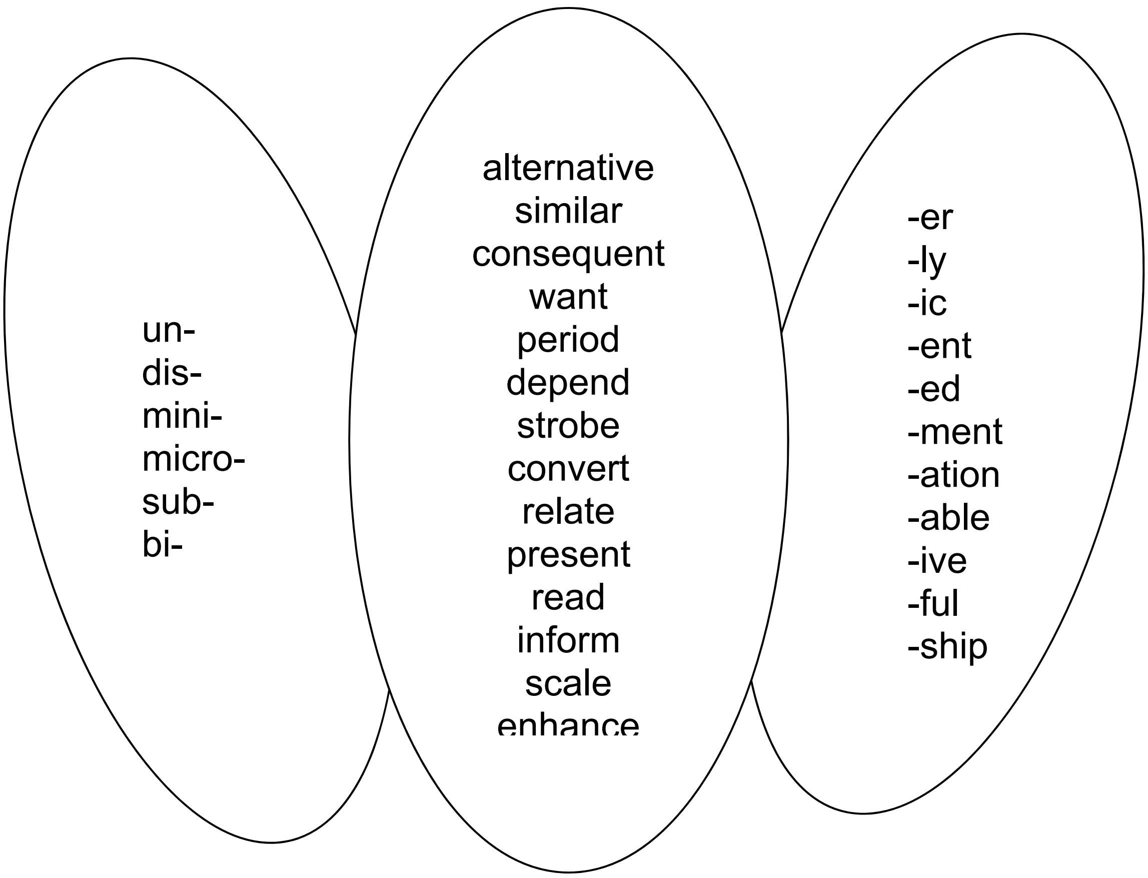
5 Currently, much thought should be devoted to molecular assembly and self-replicating devices (selfreplicating nanorobots).
BEING
Currently, much thought ………………………………… to molecular assembly and self-replicating devices (selfreplicating nanorobots).

6 A set of core mechatronic courses is integrated into the engineering curriculum.
SHOULD
A set of core mechatronic courses ……………………………… into the engineering curriculum.

7 The relevance of fundamental theory, applied results, and experiments is very important and it is necessary to emphasized them.
MUST
The relevance of fundamental theory, applied results, and experiments is very important and ………………………………

8 They widely discuss the role of mechatronics in modern engineering.
IS
The role of mechatronics in modern engineering …………………

**7 Read three groups of the parts of the words representing prefixes, suffixes and stems and make up as many words as possible.**



**8 Give short explanations to the items below. Use information about compound nouns.**

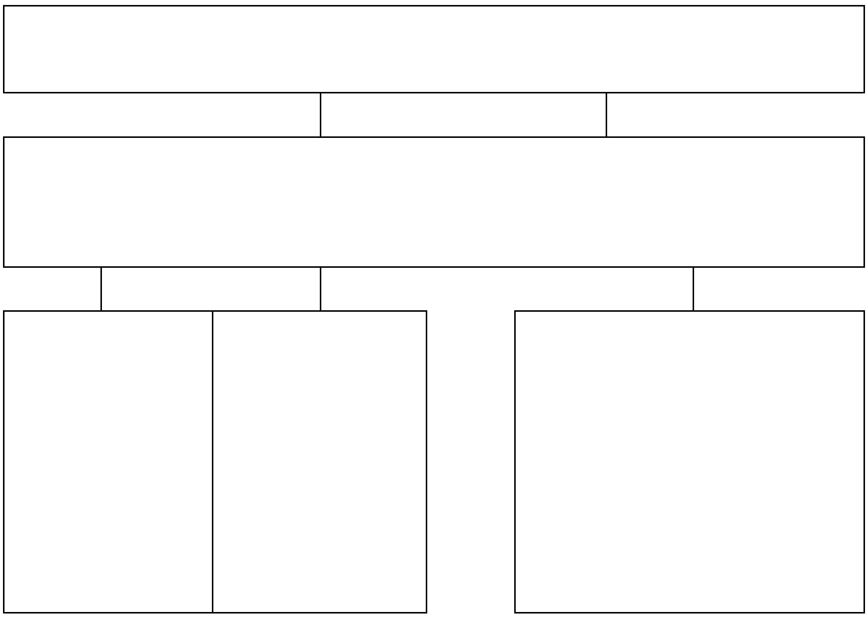
1 systems development
2 information flow
3 wire connection
4 current-producing transducer
5 performance criteria
6 component level
7 electric machines characterization
8 design process
9 transistor driver
10 computer-based data acquisition hardware

**9 Read the paragraph below and practice finding the main idea, major details and minor details by completing the block diagram given below.**

Main idea

Major details

Minor details



One of the most challenging problems in mechatronic systems design is the system architecture synthesis, system integration, optimization, as well as selection of hardware (actuators, sensors, power electronics, ICs, microcontrollers, and DSPs) and software (environments, tools, computation algorithms to perform control, sensing, execution, emulation, information flow, data acquisition, simulation, visualization, virtual prototyping, and evaluation). Attempts to design state-of-the-art high-performance mechatronic systems and to guarantee the integrated design can be pursued through analysis of complex patterns and paradigms of evolutionary developed biological systems. Recent trends in engineering have increased the emphasis on integrated analysis, design, and control of advanced electromechanical systems. The scope of mechatronic systems has continued to expand, and, in addition to actuators, sensors, power electronics, ICs, antennas, microprocessors, DSPs, as well as input/output devices, many other subsystems must be integrated. The design process is evolutionary in nature. It starts with a given set of requirements and specifications. High-level functional design is performed first in order to produce detailed design at the subsystem and component level. Using the advanced subsystems and components, the initial design is performed, and the closed-loop electromechanical system performance is tested against the requirements.

 ***SPEAKING***

**10 You are given 10 themes. Choose one of them, formulate a topic and make a plan for its oral presentation, then make a report in not less than 200 – 250 words.**

1 Mechatronics and Modern Engineering
2 What is Mechatronics?
3 Nano-, Micro-, and Mini-Scale Electromechanical Systems and Mechatronics
4 Mechatronic System Components
5 Mechatronics Perspectives
6 Functions of Mechatronic Systems
7 signal processing in Mechatronics
8 Fault Detection in Mechatronics
9 Mechatronic Intelligent Systems
10 Concurrent Design Procedure for Mechatronic Systems
11 Role of Microelectronics for mechatronic systems development
12 Sensors and Actuators of mechatronic systems

**Mechatronics engineering: Section 2**

***READING***

**11 Read the text and for Questions 1 – 8, choose the correct mark T (true) or F (false). Correct the false statements.**

## Mechatronic Systems

One of the most challenging problems in mechatronic systems design is the system architecture synthesis, system integration, optimization, as well as selection of hardware (actuators, sensors, power electronics, ICs, microcontrollers, and DSPs) and software (environments, tools, computation algorithms to perform control, sensing, execution, emulation, information flow, data acquisition, simulation, visualization, virtual prototyping, and evaluation). Attempts to design state-of-the-art high-performance mechatronic systems and to guarantee the integrated design can be pursued through analysis of complex patterns and paradigms of evolutionary developed biological systems. Recent trends in engineering have increased the emphasis on integrated analysis, design, and control of advanced electromechanical systems. The scope of mechatronic systems has continued to expand, and, in addition to actuators, sensors, power electronics, ICs, antennas, microprocessors, DSPs, as well as input/output devices, many other subsystems must be integrated. The design process is evolutionary in nature. It starts with a given set of requirements and specifications. High-level functional design is performed first in order to produce detailed design at the subsystem and component level. Using the advanced subsystems and components, the initial design is performed, and the closed-loop electromechanical system performance is tested against the requirements.

If requirements and specifications are not met, the designer revises or refines the system architecture, and other solutions are sought. At each level of the design hierarchy, the system performance in the behavioral domain is used to evaluate and refine the design process and solution devised. Each level of the design hierarchy corresponds to a particular abstraction level and has the specified set of activities and design tools that support the design at this level. For example, different criteria are used to design actuators and ICs due to different behavior, physical properties, operational principles, and performance criteria imposed for these components. It should be emphasized that the level of hierarchy must be defined, e.g., there is no need to study the behavior of millions of transistors on each IC chip because mechatronic systems integrate hundreds of ICs, and the end-to-end behavior of ICs is usually evaluated (ICs are assumed to be optimized, and these ICs are used as ready-to-use components).

Automated synthesis can be attained to implement this design flow. The design of mechatronic systems is a process that starts from the specification of requirements and progressively proceeds to perform a functional design and optimization that is gradually refined through a sequence of steps.

Specifications typically include the performance requirements derived from systems functionality, operating envelope, affordability, and other requirements. Both *top-down* and *bottom-up* approaches should be combined to design high-performance mechatronic systems augmenting hierarchy, integrity, regularity, modularity, compliance, and completeness in the synthesis process.

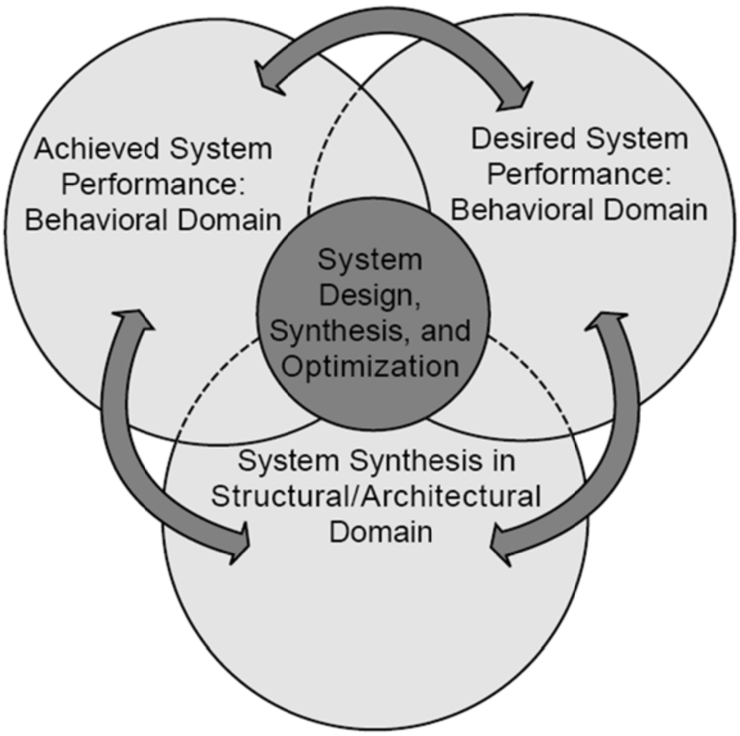



*Fig. 7.1. Design flow in synthesis of mechatronic systems*

Even though the basic foundations have been developed, some urgent areas have been downgraded, less emphasized, and researched. The mechatronic systems synthesis reported guarantees an eventual consensus between behavioral and structural domains, as well as ensures descriptive and integrative features in the design. These were achieved applying the mechatronic paradigm which allows one to extend and augment the results of classical mechanics, electromagnetics, electric machinery, power electronics, microelectronics, informatics, and control theories, as well as to apply advanced integrated hardware and software.

To acquire and expand the engineering core, there is the need to augment interdisciplinary areas as well as to link and place the multidisciplinary perspectives integrating actuators–sensors–power electronics– ICs–DSPs to attain actuation, sensing, control, decision making, intelligence, signal processing, and data acquisition. New developments are needed. The theory and engineering practice of high performance electromechanical systems should be considered as the unified cornerstone of the engineering curriculum through mechatronics. The unified analysis of actuators and sensors (e.g., electromechanical motion devices), power electronics and ICs, microprocessors and DSPs, and advanced hardware and software, have barely been introduced into the engineering curriculum. Mechatronics, as the breakthrough concept in the design and analysis of conventional-, mini-, micro- and nano-scale electromechanical systems, was introduced to attack, integrate, and solve a great variety of emerging problems.

Mechatronics integrates electromechanical systems design, modeling, simulation, analysis, softwarehardware developments and co-design, intelligence, decision making, advanced control (including selfadaptive, robust, and intelligent motion control), signal/image processing, and virtual prototyping.

The mechatronic paradigm utilizes the fundamentals of electrical, mechanical, and computer engineering with the ultimate objective to guarantee the synergistic combination of precision engineering, electronic control, and intelligence in the design, analysis, and optimization of electromechanical systems. Electromechanical systems (robots, electric drives, servomechanisms, pointing systems, assemblers) are highly nonlinear systems, and their accurate actuation, sensing, and control are very challenging problems. Actuators and sensors must be designed and integrated with the corresponding power electronic subsystems. The principles of matching and compliance are general design principles, which require that the electromechanical system architectures should be synthesized integrating all subsystems and components. The matching conditions have to be determined and guaranteed, and actuators– sensors–power electronics compliance must be satisfied.

Electromechanical systems must be controlled, and controllers should be designed. Robust, adaptive, and intelligent control laws must be designed, examined, verified, and implemented. The research in control of electromechanical systems aims to find methods for devising intelligent and motion controllers, system architecture synthesis, deriving feedback maps, and obtaining gains. To implement these controllers, microprocessors and DSPs with ICs (input-output devices, A/D and D/A converters, optocouplers, transistor drivers) must be used. Other problems are to design, optimize, and verify the analysis, control, execution, emulation, and evaluation software.

It was emphasized that the design of high-performance mechatronic systems implies the subsystems and components developments. One of the major components of mechatronic systems are electric machines used as actuators and sensors. The following problems are usually emphasized: characterization of electric machines, actuators, and sensors according to their applications and overall systems requirements by means of specific computer-aided-design software; design of high-performance electric machines, actuators, and sensors for specific applications; integration of electric motors and actuators with sensors, power electronics, and ICs; control and diagnostic of electric machines, actuators, and sensors using microprocessors and DSPs.

1 System architecture synthesis is a minor problem in mechatronic systems design.
2 Increasing of the emphasis on integrated analysis, design, and control of advanced electromechanical system are recent trends in engineering.
3 System performance in the behavioral domain is used to evaluate and refine the design process and solution devised at each level of the design hierarchy.
4 It is impossible to use automated synthesis for implementation of design flow in mechatronic systems.
5 Specification of requirements is a starting point of mechatronic systems design process
6 There is no need to augment interdisciplinary areas to acquire and expand the engineering core.
7 Electromechanical systems are highly nonlinear systems, and their accurate actuation, sensing, and control problems are already solved.
8 Adaptive and intelligent control laws are very important for mechatronic systems design in contrast with the robust control law.

**Mechatronics engineering: Self Study Section**

**12 You are going to read an extract from the text “Nanomachines”. For Questions 1–8, choose the correct answer A, B, C or D.**

Nanomachines are devices that range in size from the smallest of MEMS devices down to devices assembled from individual molecules. Built from molecular (0) **components** performing individual mechanical functions, the candidates for energy sources to actuate nanomachines are (1) _____________ to those that act on a molecular scale. Regarding manufacture, the assembly of nanomachines is by nature a one-molecule-at-a-time operation. Although microscopy (2) _____________ are currently used for the (3) _____________ of nanostructures, self-assembly is seen as a viable means of mass production.

In a molecular device a discrete number of molecular components are combined into a supramolecular (4) _____________ where each discrete molecular component performs a single function. The combined action of these individual molecules causes the device to (5) _____________ and perform its various functions. Molecular devices require an energy (6) _____________ to operate. This energy must ultimately be used to activate the component molecules in the device, and so the energy must be chemical in nature. The chemical energy can be obtained by adding hydrogen ions, oxidants, etc., by inducing chemical reactions by the impingement of light, or by the actions of electrical current. The (7) _____________ two means of energy activation, photochemical and electrochemical energy sources, are preferred since they not only (8) _____________ energy for the operation of the device, but they can also be used to locate and control the device. Additionally, such energy transduction can be used to transmit data to report on the performance and status of the device.

Another reason for the preference for photochemical- and electrochemical-based molecular devices is that, as these devices are required to operate in a cyclic manner, the chemical reactions that drive the system must be reversible. Since photochemical and electrochemical processes do not lead to the accumulation of products of reaction, they readily lend themselves to application in nanodevices.

| | | | | |
|---|---|---|---|---|
| 0 | A parts | B components | C elements | D integrants |
| 1 | A bounded | B limited | C restricted | D confined |
| 2 | A method | B technique | C system | D expertise |
| 3 | A gathering | B multitude | C congregation | D assembly |
| 4 | A structure | B pattern | C scheme | D order |
| 5 | A work | B operate | C go on | D switch on |
| 6 | A source | B store | C supply | D vein |
| 7 | A later | B late | C latter | D last |
| 8 | A give | B supply | C provide | D equip |

**13 In a jigsaw below find 20 words on the topic “Mecahtronics”.**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| m | r | h | r | e | c | u | d | s | n | a | r | t | f | m |
| s | e | n | s | o | r | y | h | e | y | o | g | e | l | c |
| i | a | c | t | u | a | t | o | r | a | d | e | s | o | e |
| n | m | f | h | j | o | s | e | f | o | d | x | b | w | n |
| e | p | g | s | a | l | f | r | c | b | b | y | a | c | o |
| w | l | d | x | z | t | e | i | a | o | t | u | c | o | i |
| a | i | m | e | a | g | r | c | l | g | l | d | s | n | t |
| v | f | l | i | t | c | k | o | q | t | g | o | a | t | a |
| e | i | e | c | u | r | r | e | n | t | e | l | n | r | c |
| l | e | a | i | t | a | g | s | l | i | i | r | u | o | i |
| a | r | t | g | m | y | a | i | e | a | c | b | n | l | f |
| n | b | j | h | a | i | o | x | s | s | m | s | o | u | i |
| g | p | u | l | s | e | w | i | d | t | h | o | c | f | r |
| i | s | e | s | j | m | n | n | o | t | p | x | a | r | e |
| s | y | n | e | r | g | i | s | t | i | c | f | b | o | v |

1 ____________________
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20 ____________________

**14 For Questions 1 – 15, read the text below. Use the word given in capitals at the end of each line to form a word that fits in the space in the same line. Use the example at the beginning.**

Example:
(0) combining

| | |
|---|---|
| MicroElectroMecahnical Systems (MEMS) | |
| are integrated micro devices or systems (0) | |
| _________ electrical and mechanical compo- | **COMBINATION** |
| nents that can sense, control, and actuate on | |
| the micro scale and function individually or in | |
| arrays to generate (1) _________ on the macro | **EFFECTIVE** |
| scale. MEMS is one of the most (2) _________ | |
| areas in future computer and (3) _________, | **PROMISE** |
| the next (4) _________ step in the silicon revo- | **MACHINE** |
| lution. Fabricated using Integrated Circuit (IC) | **LOGIC** |
| compatible batch-processing techniques, the | |
| small size of MEMS opens a new line of excit- | |
| ing applications, including aerospace, automo- | |
| tive, biological/medical, fluidics, military, optics, | |
| and many other areas. (5) _________ is of | |
| concern if MEMS machinery is used in critical | **RELIABLE** |
| applications. MEMS is usually a combination of | |
| circuits and micro-machinery. The reliability as- | |
| pect includes both the (6) _________ and the | |
| mechanical parts, (7) _________ by the inter- | **ELECTRONICS** |
| actions. Different from mechanical systems, in- | **COMPLICATION** |
| ertia is of little concern; the effects of (8) | |
| _________ forces and surface science domi- | |
| nate. Wafer Level Reliability (WLR) has re- | **ATOM** |
| ceived increasing interest in recent years. We | |
| still have limited knowledge on how MEMS de- | |
| vices (9) _________. Limited tools and models | |
| are available. How to model the (10) | **FAILURE** |
| _________ of MEMS is a challenge. | |
| | **RELIABLE** |

## *WRITING*

**15 Write an essay on the topic given. Let your assignment be of 160 – 200 words.**

"The Role of Mechatronic Approach in the Technological Progress"

**16 Read the text below and write an annotation to it.**

MicroElectroMechanical systems (MEMS) are integrated micro devices or systems combining electrical and mechanical components fabricated using Integrated Circuit (IC) compatible batch-processing techniques and range in size from micrometers to millimeters. These systems can sense, control, and actuate on the micro scale and function individually or in arrays to generate effects on the macro scale.

Technology has been pushed to the point that we can build machinery so small that it can not be seen by human eye. The typical size of MEMS devices is usually measured in micrometers or even microns. Using similar fabrication techniques as building microprocessors, we are now able to build sensors and actuators on the same microscopic level with the processor chip. Measured in microns, thermal sensors, pressure sensors, inertial sensors, flow and viscosity sensors, resonators, levers, gears, transmission systems, micro-mirrors, valves, pumps, motors, etc. can be batch produced together on the same chip with the processing unit. They indeed compose a "system on a chip".

A whole new line of applications are opened up by this fast developing technology, limited maybe only by imagination. We can now make medical and biomedical devices so small that they can be injected into humans' bloodstream. They may selectively kill sick cells or germs, leaving healthy body tissue intact. They may intelligently monitor blood substance and release drugs whenever necessary. "Microsurgery" is assigned a new meaning by intelligent MEMS devices. Controlled by outside central computers, MEMS microsurgery devices can do surgery inside human body without any cut on the skin. One day they may even be able to do DNA processing and sequencing right on site.

Controlled chemical reactions at microscopic level are also possible with MEMS technology. Miniature valves, pumps make it possible to build a chemical plant on a chip. New substances can be made when needed and a very fine grain control can be achieved.

Devices in many existing applications are facing the challenge of mass-fabricated, low-cost MEMS devices. At a relatively small fraction of the cost, size and weight of these systems, MEMS substitutes may even perform much better than their traditional counterparts. MEMS accelerometers that deploy airbags during a car-crash and the inkjet-printer cartridges that can inject fine drops of ink on paper to form letters or graphs have been widely used. MEMS displays are very power-efficient and have very high definitions. Storage devices can achieve density up to terabytes per square centimeter.

Traditional material and mechanical science is being revolutionized and rejuvenated. Polysilicon is still the prevailing material used in both mechanical parts and electronic parts in MEMS devices. VLSI fabrication technique has advanced to build mechanical components together with electronic components. Issues like strength, tear and wear, corrosion, are new challenging topics.

Just like IC technology 30 years ago, MEMS technology is still in its juvenile age. Most of the MEMS products are still prototypes. How MEMS devices would fail is not very well understood. At microscopic level, assumptions in macroscopic level will not always hold. Factors that can be ignored in macro scale become important in micro scale. Without sufficient attention on these factors, reliability and quality of MEMS devices can be so impaired that they are unusable or even destroyed the moment after fabrication. Reliability is the hindering factor to prevent commercialization and utilization of MEMS device in critical applications.

Today most of the present MEMS products are still prototypes, but MEMS is the next logical step in the silicon revolution. With a $10 Billion market today, and an estimated market of $34 Billion market in the year 2002, advances in reliability is a dominating factor to evolve from prototypes to real-world applications, from infancy to maturity.

The challenging issue in MEMS technology development and commercialization is justifying its reliability. The reliability issues of MEMS devices are more than a simple combination of electrical reliability, material reliability and mechanical reliability. Fabricating multiple devices on the same chip will have to deal with more failure modes. Complex interactions of cross-domain signals, interference and substances induce new failure modes. For sensor inputs, the chip will have to be exposed to some environmental stimuli, such as heat, humidity, vibration, etc. The input and output voltage may not be within the 5 volts range of standard IC. Some actuators need hundreds of volts to operate. And for microfluidic devices, there might be chemicals and fluids flowing around the chip, with higher potential for corrosion.

# REFERENCES


1 Boeckner K., P. Brown Ch. Computing. – Oxford: Oxford University Press, 1993
2 Cheremisina I.A., Basics of Writing Annotations for 3rd-year Computer Science Students, Tomsk, 2004
3 Hardisty D., Windeatt S., Eastment D. The Internet. – Oxford: Oxford University Press, 2000
4 Robert H. Bishop. The Mechatronics Handbook. – The University of Texas at Austin CRC Press – 2002
5 Stepanova A.V., Krupnikova A.V. English for Computer Science Students: Control Theory. Electronic Coursebook. – Tomsk: Tomsk Polytechnic University, 2006
6 Robert H. Bishop. The Mechatronics Handbook. – CRC Press – 2002
7 http://www.ece.cmu.edu/~koopman/des_s99/real_time/
8 http://www.ece.cmu.edu/~koopman/des_s99/mems/
9 http://en.wikipedia.org

# APPENDIX 1: TERMS

A

| | |
|---|---|
| actuator | силовой привод, исполнительный механизм |
| aliasing | наложение спектров, помеха дискретизации, искажение контуров |
| alternating current | переменный ток |
| amplitude modulation | амплитудная модуляция |
| analog input | аналоговый вход |
| analog-to-digital converter (ADC) | аналого-цифровой преобразователь, АЦП |
| antialiasing filter | фильтр для устранения эффектов наложения спектров (при дискретизации) |
| Antilock Brake System (ABS) | антиблокировочная тормозная система |
| arithmetic logic unit (ALU) | арифметико-логическое устройство |
| ASIC (Application-Specific Integrated Circuit) | проблемно-ориентированная (специализированная) интегральная микросхема |

B

| | |
|---|---|
| bandpass filter | полосовой фильтр, полосовой пропускающий фильтр |
| carbon nanotubes (CNTs) | углеродные нанотрубки |

C

| | |
|---|---|
| closed loop control | правление в замкнутой системе; управление с обратной связью |
| CMOS (Complementary Metal-Oxide Semiconductor, Complementary MOS) | комплементарная структура металл-оксид-полупроводник |
| combinational logic | комбинаторная логика, комбинационные логические схемы |
| counter timer | счётчик-таймер, цифровой частотомер |
| CPU (Central Processing Unit) | центральный процессор |

## D

| | |
|---|---|
| data acquisition | сбор данных |
| data acquisition system | система сбора данных |
| data acquisition unit | устройство сбора данных |
| debugger | отладчик, программа отладки, отладочная программа |
| digital computer | цифровой компьютер, цифровая вычислительная машина |
| digital control | цифровое управление; цифровое регулирование |
| digital I/O | цифровой вход/выход |
| digital input | цифровой вход |
| digital processing unit | блок цифровой обработки |
| digital-to-analog converter (DAC) | цифро-аналоговый преобразователь, ЦАП |
| direct current | постоянный ток |
| DSP | процессор цифровой обработки сигналов |

## E

| | |
|---|---|
| electronic damping | электронное демпфирование |
| electrostatic actuator | электростатический привод |
| embedded system | встроенная система |
| energy flow | поток энергии |

## F

| | |
|---|---|
| feedback control system | система управления с обратной связью, замкнутая система управления |
| feedback system | система с обратной связью, замкнутая система |
| feed-forward control | упреждающее регулирование или управление, управление с прогнозированием |
| filtering | фильтрация |
| FLIR | формирователь изображения на инфракрасных лучах с прямым предсказанием |
| frequency modulation | частотная модуляция |
| frequency response | частотная характеристика |

| | |
|---|---|
| | H |
| harmonic signal | гармонический сигнал |
| | I |
| information flow | поток информации, информационный поток |
| input binary vector | входной бинарный вектор |
| integrated circuit | интегральная микросхема, микросхема |
| internal state vector | вектор внутреннего состояния |
| | K |
| knowledge base | база знаний |
| | L |
| LADAR | лазерный локатор |
| LAN (local area network) | локальная вычислительная сеть |
| LCD (liquid-crystal display) | жидкокристаллический индикатор, жидкокристаллический экран |
| LED (light-emitting diode) | светодиод |
| logic analyzer | логический анализатор, анализатор логических состояний |
| low-pass filtering | низкочастотная фильтрация, фильтрация нижних частот |
| | M |
| mechatronics software | программное обеспечение мехатронной системы |
| mechatronics system | мехатронная система |
| mechatronics | мехатроника |
| MEMS | микроэлектромеханические системы |
| MFLOPS (Million Floating-Point Operations Per Second) | миллион операций с плавающей точкой в секунду единица быстродействия процессора или компьютера |
| microcomputer | микроЭВМ, микрокомпьютер |
| microelectromechanical systems (MEMS) | микроэлектромеханические системы |
| microprocessor | микропроцессор |

| | |
|---|---|
| MIPS (Million Instructions Per Second) | миллион команд в секунду единица быстродействия процессора |
| multiply-accumulate instruction | команда умножения с накоплением (промежуточных сумм) |
| multi-walled carbon nanotubes (MWNTs) | многослойные углеродные нанотрубки |
| | N |
| nanoelectromechanical systems (NEMS) | наноэлектромеханические системы |
| nanomachine | наномашина искусственная молекулярная машина, изготовленная с использованием нанотехнологии |
| nanomanipulator | наноманипулятор |
| | O |
| output binary vector | выходной бинарный вектор |
| | P |
| peripheral components interconnect (PCI) | PCI-шина |
| phase-lock looping (PLL) | схема фазовой синхронизации; система фазовой автоподстройки частоты |
| power amplifier | усилитель мощности |
| pressure sensor | датчик давления |
| programmable Logic Controller | контроллер с программируемой логикой |
| pulse width modulation | широтно-импульсной модуляции |
| | R |
| RC oscillator | RC-генератор |
| real-time system | система реального времени |
| robustness control | робастный контроль |
| | S |
| sampling system | дискретизатор |
| selfreplicating nanorobot | система дискретизации по времени |

| | |
|---|---|
| sensor | самовоспроизводящийся нanоробот датчик, чувствительный элемент |
| sine wave | синусоидальное колебание, гармоническая волна |
| single-walled carbon nanotubes (SWNTs) | однослойные углеродные нанотрубки |
| smart actuator | “интеллектуальный” актуатор, силовой привод с элементами искусственного интеллекта |
| smart sensor | “интеллектуальный” сенсор |
| software integration | компоновка системы программного обеспечения |
| square wave | прямоугольный импульс; прямоугольная волна |
| step signal | ступенчатый сигнал |
| synergistics | синергетика |
| | T |
| time domain | область времени |
| transducer | преобразователь; датчик; приёмник |
| TTL (transistor-transistor logic) | транзисторно-транзисторная логика, ТТЛ |
| | U |
| UART (Universal Asynchronous Receiver/Transmitter) | универсальный асинхронный приёмопередатчик |
| USB (Universal Serial Bus) | универсальная последовательная шина, шина USB |
| | V |
| validation | проверка достоверности; подтверждение правильности |
| verification | контроль; проверка |

# APPENDIX 2: WRITING ANNOTATION

1 Definition of the term “Annotation”

**Annotation** is a concise description of a particular work, including important aspects of content not evident in the title It enables the researcher to establish the relevance of a specific work and to decide whether to read the full text of the work.

*Basics of Writing Annotations for 3rd-year Computer Science Students*

**Annotation** is add on information asserted with a particular point in a document or other piece of information. Most commonly this is used, for example, in draft documents, where another reader has written notes about the quality of a document at a certain point, “in the margin”. Annotations about bibliographical sources, labeled annotated bibliographies, give descriptions about how each source is useful to an author in constructing a paper or argument. Creating these blurbs, usually a few sentences long, establishes a summary for and expresses the relevance of each source prior to writing.

*http://en.wikipedia.org/wiki/Annotation*

2 Elements of an Annotation

Information found in an annotation may include:

A qualifications *of author(s)*
B ‘Based on 20 years of study, William A. Smith, Professor of English at Leeds University…’;
C outline *of the major thesis, theories, and ideas* (i.e. main purpose and scope):
D ‘…sets out to place John Turner in eighteenth century England and show the development of his philosophy in relation to contemporary social mores’;
E audience *and level of reading difficulty*:
F ‘Smith addresses himself to the scholar, albeit the concluding chapters on capital punishment will be clear to any informed layman’;
G major *bias or standpoint of author in relation to his theme or topic*:

H ‘Turner gears his study more to the romantic aspects of the age than the scientific and rational developments’;
I relationship *of work to other works in the field*:
J ‘Here Turner departs drastically from A.F. Johnson (Two will not, New York, Riposte Press, 1964) who not only has developed the rational themes of the eighteenth century but is convinced the romantic elements at best are only a skein through the major prose and poetry’;
K findings, *results, and conclusions* (if available); and
L special *features* (e.g., bibliography, glossary, index, survey, instruments, testing devices, etc.).

3 Structure of an Annotation

Although there is no lower limit, annotations should not exceed 150 words. The third person should always be used.

4 Language and Vocabulary

Use the vocabulary of the author, as far as possible, to convey the ideas and conclusions of the author; paraphrasing can lead the reader into channels of thought unintended by the author. In these cases where you decide to include a quotation taken from the work, set it within quotation marks. Avoid introducing annotations with superfluous and/or redundant phrases like ‘The author states,’ ‘This article concerns,’ ‘This new contribution to,’ or ‘The purpose of this report is.’ Also avoid the monotonous repetition of sentences starting with ‘It was suggested that,’ ‘It was found that,’ and ‘It was reported that.’ Annotations in which most sentences end with ‘are discussed’ and ‘are given’ are similarly ineffective.

5 Format – Sentences

Whole sentences are preferable, but more telegraphic sentences, single descriptive words, and simple phrases or lists are acceptable. When sentences are used, sentence length should vary as much as possible to avoid the unpleasant effect of a series of short, choppy sentences. Every sentence should convey a maximum amount of information in a minimum number of words. Overlong, complex sentences should be avoided.

## 6 Format – Paragraphs

Annotations should be one paragraph long. The paragraph should contain a statement of the work's major thesis, from which the rest of the sentences can develop. You can avoid writing a paragraph that is nothing more than a series of unconnected sentences summarizing separate ideas, arguments, and conclusions, by following the same order of information as the author and by intelligently using transitional words and phrases.

# TEACHERS BOOK OF MECHATRONICS

## Unit 1
## Basics of Mechatronics

### Objectives

**Reading:** reading for detailed understanding of a text and text structure
**Listening:** listening for getting detailed information
**Vocabulary:** word formation, gaps filling, matching, open cloze
**Grammar:** active and passive voices
**Speaking:** describing a figure, making a presentation
**Writing:** writing an annotation

***LEAD-IN***

1 The activity introduces the problem involved in the unit. Students study the pictures and definitions and draw their own definition of mechatronics open-class.

2 Gaps filling. Students study the gaped text and fill in the words given in the box.

Answers:

1 natural
2 engineering
3 technologies
4 twentieth
5 mechatronics

***LISTENING***

3 Students read the summary of the text, then listen to the tape and fill in the gaps. Students do the task individually before checking it open-class.

Answers:

1 has evolved
2 mechanism
3 electronics
4 accurate
5 engineering design
6 integrated
7 investigative studies
8 wireless
9 embedded systems
10 design paradigm

Tapescript:

**Basic Definitions**

The definition of mechatronics has evolved since the original definition by the Yasakawa Electric Company. In trademark application documents, Yasakawa defined mechatronics in this way: The word, mechatronics, is composed of “mecha” from mechanism and the “tronics” from electronics. In other words, technologies and developed products will be incorporating electronics more and more into mechanisms, intimately and organically, and making it impossible to tell where one ends and the other begins.

The definition of mechatronics continued to evolve after Yasakawa suggested the original definition. Oneoft quoted definition of mechatronics was presented by Harashima, Tomizuka, and Fukada in 1996. In their words, mechatronics is defined as the synergistic integration of mechanical engineering, with electronics and intelligent computer control in the design and manufacturing of industrial products and processes.

That same year, another definition was suggested by Auslander and Kempf: Mechatronics is the application of complex decision making to the operation of physical systems.

Yet another definition due to Shetty and Kolk appeared in 1997: Mechatronics is a methodology used for the optimal design of electromechanical products.

More recently, we find the suggestion by W. Bolton: A mechatronic system is not just a marriage of electrical and mechanical systems and is more than just a control system; it is a complete integration of all of them.

All of these definitions and statements about mechatronics are accurate and informative, yet each one in and of itself fails to capture the totality of mechatronics. Despite continuing efforts to define mechatronics, to classify mechatronic products, and to develop a standard mechatronics curriculum, a consensus opinion on an all-encompassing description of "what is mechatronics" eludes us. This lack of consensus is a healthy sign. It says that the field is alive, that it is a youthful subject. Even without an unarguably definitive description of mechatronics, engineers understand from the definitions given above and from their own personal experiences the essence of the *philosophy* of mechatronics.

For many practicing engineers on the front line of engineering design, mechatronics is nothing new. Many engineering products of the last 25 years integrated mechanical, electrical, and computer systems, yet were designed by engineers that were never formally trained in mechatronics *per se.* It appears that modern concurrent engineering design practices, now formally viewed as part of the mechatronics specialty, are natural design processes. What is evident is that the study of mechatronics provides a mechanism for scholars interested in understanding and explaining the engineering design process to define, classify, organize, and integrate many aspects of product design into a coherent package. As the historical divisions between mechanical, electrical, aerospace, chemical, civil, and computer engineering become less clearly defined, we should take comfort in the existence of mechatronics as a field of study in academia. The mechatronics specialty provides an educational path, that is, a roadmap, for engineering students studying within the traditional structure of most engineering colleges. Mechatronics is generally recognized worldwide as a vibrant area of study. Undergraduate and graduate programs in mechatronic engineering are now offered in many universities. Refereed journals are being published and dedicated conferences are being organized and are generally highly attended.

It should be understood that mechatronics is not just a convenient structure for investigative studies by academicians; it is a way of life in modern engineering practice. The introduction of the microprocessor in the early 1980s and the ever increasing desired performance to cost ratio revolutionized the paradigm of engineering design. The number of new products being developed at the intersection of traditional disciplines of engineering, computer science, and the natural sciences is ever increasing. New developments in these traditional disciplines are being absorbed into mechatronics design at an ever increasing pace. The ongoing information technology revolution, advances in wireless communication, smart sensors design (enabled by

MEMS technology), and embedded systems engineering ensures that the engineering design paradigm will continue to evolve in the early twenty-first century.

***READING***

4 Students read the text and mark the statements True or False. Ask students to correct the false statements.

Answers:

1 T
2 F
3 T
4 T
5 F
6 F
7 F
8 T

***VOCABULARY AND GRAMMAR***

5 The activity is aimed at introduction of the terminology of the unit. Student match terms with their definitions in pairs before checking it open-class.

Answers:

1 B
2 C
3 E
4 A
5 D
6 F
7 H
8 J
9 G
10 I

6 The activity is aimed at perfection of knowledge of the Passive voice. Students open the brackets in the sentences and fill the gaps with the proper form of Passive voice.

Answers:

1 were invented
2 was developed
3 are completely coupled
4 was also being developed
5 was introduced, was granted

7 Students find mistakes in the text and correct them. Students do the task individually or in pairs, then check it open-class.

Answers:

1 Included
2 ok
3 is studied
4 ok
5 ok
6 Is accepted
7 ok
8 is known
9 was rooted
10 ok
11 be filled
12 ok
13 ok

### *SPEAKING*

8 In pairs or groups of three students study the figure which represents key elements of mechatronics then comment on these aspects open-class.

9 Students are given 5 situations. They choose one from offered variants and present it after some minutes thinking.

### *READING*

10 Students tell what they know they know about the history of mechatronics.

11 Students read the text and answer the questions to it.

## *SELF-STUDY SECTION*

12 Students choose 3 words or word combinations on the topic "Mechatronics" from the text, activity 11 and give definitions.

13 This activity represents Word Formation. This consists of a short text with 15 gaps. For each gap, a base word (the prompt word) is given. Students have to form the correct word for the gap using this prompt word. Students read through the text to get an idea of what they are about, deciding what part of speech they need for each gap. The needed word could be a noun, verb, adjective or adverb. Tell students to look at the base word. They may need to add a prefix, suffix, to change the middle, or a combination of these. Students must be careful about negatives and plurals. When students have finished, they read the text again to check that their answers make sense. Students work individually before checking the answers open-class.

Answers:

1 philosophical
2 activities
3 evolutionary
4 revolutionary
5 integration
6 mechanical
7 extent
8 various
9 characterizing
10 physical
11 actuators,
12 contribute
13 defined
14 education
15 coverage

14 The activity represents Open Cloze. This is a text with 10 single-word gaps. This question tests students' knowledge of grammatical patterns. Students read the text once through for general understanding, identifying the type of word missing in each gap. They should only write one word in each gap. When students have finished, they read the text again to check that their answers make sense. Students work individually before checking the answers open-class.

Answers:

1 be
2 by
3 and
4 for
5 will
6 when
7 of
8 such
9 Other
10 may

***WRITING***

15 Students write an annotation according to the instructions given.

# Unit 2
# Physical System Modeling

**Objectives**

**Reading:** reading for detailed understanding of a text and text structure
**Listening:** listening for getting detailed information
**Vocabulary:** word formation, gaps filling, giving definitions
**Grammar:** compound nouns
**Speaking:** making up dialogues
**Writing:** an article, a report, a composition, an annotation

***LEAD-IN***

1 The activity introduces the problem involved in the unit. Students study the scheme of a classical mechanical-electronic system, then explain the connection between all the components in it.

2 Students read the text “Ways of Integration” and put the abstracts in the right order.

Answers

1 E
2 B
3 A
4 D
5 F
6 C

***READING***

3 Students read the magazine article about the functions of mechatronic systems, and then choose the most suitable heading from the list A – F. G is an extra heading which should not be used.

Answers:

**A** 5
**B** 2

**C** 3
**D** 0
**E** 4
**F** 1

## *LISTENING*

4 Students listen to the text and for questions 1 – 8 fill in the gaps. Pay attention of the students that they should write not more than 3 words in each gap.

Answers:

1 feedforward
2 measured
3 constructions
4 friction
5 adaptive
6 combination
7 allows
8 tensions

Tapescript:

### Improvement of Operating Properties

By applying active feedback control, precision is obtained not only through the high mechanical precision of a passively feedforward controlled mechanical element, but by comparison of a programmed reference variable and a measured control variable. Therefore, the mechanical precision in design and manufacturing may be reduced somewhat and more simple constructions for bearings or slideways can be used.

An important aspect is the compensation of a larger and time variant friction by *adaptive friction compensation*. Also, a larger friction on cost of backlash may be intended (such as gears with pretension), because it is usually easier to compensate for friction than for backlash.

*Model-based* and *adaptive control* allow for a wide range of operation, compared to fixed control with unsatisfactory performance (danger of instability or sluggish behavior). A combination of robust and adaptive control allows a wide range of operation for flow-, force-, or speed-control, and for processes like engines, vehicles, or aircraft. A better control performance allows the reference variables to move closer to the constraints with an improvement in efficiencies and yields (e.g., higher temperatures, pressures for combustion engines and turbines, compressors at stalling limits, higher tensions and higher speed for paper machines and steel mills).

### *VOCABULARY AND GRAMMAR*

5 Students give names to the things, units, etc. using information about compound nouns.

6 Students give short explanations to the items, using information about compound nouns.

### *SPEAKING*

7 Students make up dialogues covering one of the topics given.

### *READING*

8 Students study the diagram and use it to tell about the historical development of mechanical, electrical, and electronic systems.

9 Students read the text and answer the questions to it.

10 Students study the figure and for Questions 1–10 fill the gaps in the text with the words from it. Use not more than two words for each gap.

Answers:

1 reference variables
2 measured variables
3 *information flow*
4 manipulated variables
5 actuators
6 monitored variables
7 mechanical
8 electrical

9 thermal
10 energy converters

***SELF-STUDY SECTION***

11 Students look for compound nouns in the text, activities 9, 10, and then give explanations to them.

12 This activity represents Word Formation. This consists of a short text with 10 gaps. For each gap, a base word (the prompt word) is given. Students have to form the correct word for the gap using this prompt word. Students read through the text to get an idea of what they are about, deciding what part of speech they need for each gap. The needed word could be a noun, verb, adjective or adverb. Tell students to look at the base word. They may need to add a prefix, suffix, to change the middle, or a combination of these. Students must be careful about negatives and plurals. When students have finished, they read the text again to check that their answers make sense. Students work individually before checking the answers open-class.

Answers:

1 designing
2 imbedding
3 sensors
4 limited
5 arranged
6 lead
7 larger
8 connections
9 possibilities
10 proper

13 This activity represents Gaps Filling. Students read the text with 12 Gaps and for Questions 1–12 fill the gaps in it with the words from the box.

Answers:

1 software integration
2 control

3 influence
4 online information
5 available signals
6 problem solutions
7 algorithms
8 equations
9 methods
10 models
11 performance criteria
12 Properties

***WRITING***

14 Students choose one of the topics given and do a written task: they write an article, a report or a composition.

15 Students read the text and write an annotation to it.

# Unit 3
# Sensors and Actuators

## Objectives

**Reading:** reading for detailed understanding of a text and text structure
**Listening:** listening for getting detailed information
**Vocabulary:** gaps filling, completing a crossword, multiple choice cloze, word formation
**Grammar:** explanations and definitions
**Speaking:** making a report
**Writing:** writing an annotation, an essay

***LEAD- IN***

1 In pairs or groups of three students look at the diagrams and answer the questions given. Then check the answers open-class.

2 Students read the names of the signals and say what picture from activity 1 shows each of them.

Answers:

1 B
2 C
3 A
4 E
5 D

***READING***

3 Students read the text to check whether they were right or not when answering the questions, activity 1.

4 The activity represents Multiple Choice Cloze. For each gap, students choose an answer from three options: A, B or C.

Answers:

1 C
2 A

3 A
4 C
5 A
6 B
7 A
8 B

5 Students study the abbreviations and say what they stand for.

Answers:

1 LADAR – LAser Detection and Ranging
2 FLIR – forward looking infrared
3 PWM – pulse width modulated
4 EIA – Electronics Industries Alliance
5 ADC – analog-to-digital converter
6 TCP\IP – Transmission Control Protocol/Internet Protocol
7 FET – field-effect transistors
8 MOSFET – metal-oxide field-effect transistors
9 DC – direct current
10 AC – alternating current

6 Students listen to the recording and identify the terms being described. J (Measurement) – the definition is not given

Answers:

1 E (Sensor)
2 A (Actuator)
3 K (Microcontroller)
4 B (Digital-to-analog converter)
5 G (Antilock Braking System)
6 H (Mechatronics)
7 I (Microprocessor)
8 L (Switch)
9 D (Modulation)
10 N (Frequency response)
11 C (Synergy)
12 O (Filtering)
13 M (Data Acquisition)
14 F (Systems engineering)

Tapescript:

1 a device which detects or measures some condition or property and records, indicates, or otherwise responds to the information received.
2 a device which causes the operation.
3 a device which consists of a microprocessor plus memory and other attached devices
4 an apparatus for converting digital signals into analog ones.
5 a system which is intended to prevent a wheel from locking up and thus having the driver loose directional control of the vehicle due to skidding.
6 the branch of technology which combines mechanical engineering with electronics and control theory applications
7 a device that can function as the central processing unit of a computer and consist of one or more integrated circuits or chips.
8 a device for making and breaking a connection in a circuit.
9 the process of modulating a wave, especially in order to impress a signal on it.
10 the way in which the output-input ratio of a device depends on the signal frequency
11 a combined or correlated action of a group of parts which lead to combined effect grater than sum of their separate effects
12 the attenuation (lessening) of certain frequencies from a signal, it can remove noise from a signal and condition the line for better data transmission.
13 the action of data collection
14 the investigation of complex system in relation to the apparatus that is or might be involved in them.

## *VOCABULARY AND GRAMMAR*

7 Students read 10 sentences with gaps and fill them with the words, activity 6.

Answers:
1 Integrated sensors and microcomputers lead to *smart* ***sensors****.*
2 Integrated actuators and microcomputers lead to *smart* ***actuators***.
3 The process of **data acquisition** begins with the measurement of a physical value by a sensor.
4 A **digital-to-analog converter (DAC)** is then often used to convert the digital value into an analog signal.

5 **Switches** are simple state devices that control some activity.
6 A **PLC** is a simpler, more rugged microcontroller designed for industrial environments.
7 **Mechatronics** is a natural stage in the evolutionary process of modern engineering design.
8 Measured variables are the inputs for an ***information flow*** through the digital electronics resulting in manipulated variables for the actuators.
9 A primary ***energy flows*** into the machine and is then either directly used for the energy consumer in the case of an energy transformer, or converted into another energy form in the case of an energy converter.
10 **Signal conditioning** is the modification of a signal to make it more useful to a system.

8 In pairs students complete the crossword. Then check the answers open-class.

Answers:

Across:

2 analogue-digital
3 electronics
4 alternating
6 engineering
8 mechanics
9 sensor
10 timerDown:

1 microprocessor
5 direct
7 design

***SPEAKING***

9 Students make up a report covering any of the suggested aspects.

***READING***

10 Students study the diagram and explain the connection of all its components.

11 Students read the text and answer the questions to it.

## *SELF-STUDY SECTION*

12 This activity represents Word Formation. This consists of a short text with 10 gaps. For each gap, a base word (the prompt word) is given. Students have to form the correct word for the gap using this prompt word. Students read through the text to get an idea of what they are about, deciding what part of speech they need for each gap. The needed word could be a noun, verb, adjective or adverb. Tell students to look at the base word. They may need to add a prefix, suffix, to change the middle, or a combination of these. Students must be careful about negatives and plurals. When students have finished, they read the text again to check that their answers make sense. Students work individually before checking the answers open-class.

Answers:

1 modeling
2 carried
3 evolutionary
4 possible
5 unified
6 validity
7 integrate
8 emphasize
9 phenomena
10 fabrication

13 This activity represents Multiple Choice Cloze. This is a text with 10 single-word gaps. For each gap, students choose an answer from four options: A, B, C or D. Students read through the text for meaning before reading the four options. When students have finished, they read the text again to check that their answers make sense. Students work individually before checking the answers open-class.

Answers:

1 A
2 C
3 A

4 D
5 C
6 A
7 C
8 D
9 A
10 B

## *WRITING*

13 Students read the text, activity 3, again and write an annotation to it.

14 Students write an essay on the topic given.

# Unit 4
# Systems and Controls

**Objectives**

**Reading:** reading for detailed understanding of a text and text structure
**Listening:** listening for getting detailed information
**Vocabulary:** word formation, abbreviations, definitions
**Grammar:** word formation (prefixes)
**Speaking:** making a report
**Writing:** describing a diagram, writing an annotation

***LEAD- IN***

1 In pairs or groups of three students look at the diagram and describe the connection of all components in it.

2 Students read the text and put the abstracts in the right order.

Answers

1 F
2 G
3 C
4 E
5 A
6 B
7 D

***LISTENING***

3 Students study the abbreviations and say what they stand for.

Answers:

1 ADC – analog-to-digital converter
2 CPU – central processing unit
3 DAC – digital-to-analog converter
4 DSP – digital signal processor
5 LAN – local area network
6 LCD – liquid crystal display

7 LED – light emitting diode
8 MFLOPS – million floating-point operations per second
9 MIPS – million instructions per second
10 PC – personal computer
11 PCB – power control block
12 WWW – World Wide Web

4 Students listen to the recording and mark the statements true or false. Ask students to correct the false statements.

Answers:

1 F
2 T
3 T
4 F
5 F
6 T
7 T
8 F
9 F
10 T
11 T
12 F
13 T
14 F
15 F

Tapescript:

**Overview of Control Computers**

Huge, complex, and power-consuming single-room mainframe computers and, later, single-case minicomputers were primarily used for scientific and technical computing (e.g., in FORTRAN, ALGOL) and for database applications (e.g., in COBOL). The invention in 1971 of a universal central processing unit (CPU) in a single chip microprocessor caused a revolution in the computer technology. Beginning in 1981, multi-boxes (desktop or tower case, monitor, keyboard, mouse) or single-box (notebook) microcomputers became a daily-used personal tool for word processing, spreadsheet calculation, game playing, drawing, multimedia processing, and presentations. When connected in a local area network (LAN) or over the Internet, these “personal computers (PCs)” are able to exchange data and to browse the World Wide Web (WWW).

Besides these “visible” computers, many embedded microcomputers are hidden in products such as machines, vehicles, measuring instruments, telecommunication devices, home appliances, consumer electronic products (cameras, hi-fi systems, televisions, video recorders, mobile phones, music instruments, toys, air-conditioning). They are connected with sensors, user interfaces (buttons and displays), and actuators. Programmability of such controllers brings flexibility to the devices (function program choice), some kind of intelligence (fuzzy logic), and user-friendly action. It ensures higher reliability and easier maintenance, repairs, (auto)calibration, (auto)diagnostics, and introduces the possibility of their interconnection–mutual communication or hierarchical control in a whole plant or in a smart house.

Embedded microcomputers are based on the Harvard architecture where code and data memories are split. Firmware (program code) is cross-compiled on a development system and then resides in a nonvolatile memory. In this way, a single main program can run immediately after a supply is switched on.

Relatively expensive and shock sensitive mechanical memory devices (hard disks) and vacuum tube monitors have been replaced with memory cards or solid state disks (if an archive memory is essential) and LED segment displays or LCDs. A PC-like keyboard can be replaced by a device/function specifically labeled key set and/or common keys (arrows, Enter, Escape) completed with numeric keys, if necessary.

Such key sets, auxiliary switches, large buttons, the main switch, and display can be located in water and dust resistant operator panels.

Progress in circuit integration caused fast development of microcontrollers in the last two decades.

Code memory, data memory, clock generator, and a diverse set of peripheral circuits are integrated with the CPU to insert such complete single-chip microcomputers into an application specific PCB.

Digital signal processors (DSPs) are specialized embedded microprocessors with some on-chip peripherals but with external ADC/DAC, which represent the most important input/output channel. DSPs have a parallel computing architecture and a fixed point or floating point instruction set optimized for typical signal processing operations such as discrete transformations, filtering, convolution, and coding. We can find DSPs in applications like sound processing/generation, sensor (e.g., vibration) signal analysis, telecommunications (e.g., bandpass filter and digital modulation/demodulation in mobile phones, communication transceivers, modems), and vector control of AC motors.

Mass production (i.e., low cost), wide-spread knowledge of operation, comprehensive access to software development and debugging tools, and millions of ready-to-use code lines make PCs useful for computing-intensive measurement and control applications, although their architecture and operating systems are not well suited for this purpose.

5 Let students listen to the recording again if it's necessary and ask them to describe the diagram.

***READING***

6 This activity represents a Multiple Choice Cloze. Students read the text and for questions 1 – 8 choose from the options A, B or C.

Answers:

1 C
2 A
3 B
4 C
5 B
6 A
7 A
8 C

***VOCABULARY AND GRAMMAR***

7 Students study the information about prefixes, then complete the table with the examples related to the topic "Mechatronics."

8 For Questions 1 – 12 students fill the gaps in the sentences with the prefixes from the box.

Answers:

1 microprocessors
2 impossibility
3 underwater
4 nanotechnology
5 antilock

6 interaction
7 self-adjustment
8 overshoot
9 semiconductors
10 multiloop
11 microsensors
12 interconnection

***SPEAKING***

9 Students choose any area of systems and controls and make a report on it.

10 Students divide into pairs and make up dialogues, using one of the situations given.

***READING***

11 Students study the abbreviations and say what they stand for.

Answers:

1 FPU – floating point unit
2 ISP – in-system programming
3 UART – Universal Asynchronous Receiver/Transmitter
4 RTC – real-time counter
5 ENOB – effective number of bits
6 FPGA – field programmable gate array
7 PLC – programmable logic controller
8 LD–ladder diagram
9 SFC–sequential function chart
10 FBD–function block diagram

12 Students read the texts and check their answers.

13 Students read the texts given and describe the importance of the subjects for design and implementation of Mechatronics systems.

***SELF-STUDY SECTION***

14 This activity represents Word Formation. This consists of a short text with 15 gaps. For each gap, a base word (the prompt word) is

given. Students have to form the correct word for the gap using this prompt word. Students read through the text to get an idea of what they are about, deciding what part of speech they need for each gap. The needed word could be a noun, verb, adjective or adverb. Tell students to look at the base word. They may need to add a prefix, suffix, to change the middle, or a combination of these. Students must be careful about negatives and plurals. When students have finished, they read the text again to check that their answers make sense. Students work individually before checking the answers open-class.

Answers:

0 composed
1 operating
2 logical
3 statements
4 realize
5 combinational
6 dependent
7 construction
8 memory
9 typical
10 complex
11 sequential
12 assembled
13 programmable
14 suitable
15 specified

15 Students read the terms from the texts, activity 13 and give definitions to them.

***WRITING***

16 Students read the texts, activity 13 and write an annotation to it.

17 Students study the diagram and describe the process of data transmission.

# Unit 5
# Computers and Logic Systems

**Objectives**

**Reading:** reading for detailed understanding of a text and text structure
**Listening:** listening for getting the general idea
**Vocabulary:** gaps filling, open cloze
**Grammar:** Word formation: suffixes
**Speaking:** describing a scheme
**Writing:** writing an annotation, an essay

***LEAD-IN***

1 In pairs or groups of four students explain the term '*logic system*' before checking the task open-class.

2 Open-class students study the pictures and answer the questions given.

3 In pairs or groups of three students complete the mind map with their associations with the term *'logic system'.* Then check the answers open-class.

***LISTENING***

4 Listen to the recording and put the sentences in the right order. The first sentence is already marked for you. There is one extra sentence which is not on the recording. The sentence under the letter **M** is not used.

1 J
2 A
3 D
4 E
5 F
6 C
7 I
8 O
9 L
10 G

11 N
12 P
13 H
14 B
15 K

Tapescript:

A The most widely utilized multicomponent microactuators are those based upon electrostatic transduction.
B These actuators can also be regarded as a variable capacitance type, since they operate in an analogous mode to variable reluctance type electromagnetic actuators (e.g., variable reluctance stepper motors).
C Electrostatic actuators have been developed in both linear and rotary forms.
D The two most common configurations of the linear type of electrostatic actuators are the normal-drive and tangential or comb-drive types.
E The typical stroke of a surface micromachined comb actuator is on the order of a few microns, though sometimes less.
F The maximum achievable stroke in a comb drive is limited primarily by the mechanics of the flexure suspension.
G The suspension should be compliant along the direction of actuation to enable increased displacement, but must be stiff orthogonal to this direction to avoid parallel plate contact due to misalignment.
H These modes of behavior are unfortunately coupled, so that increased compliance along the direction of motion entails a corresponding increase in the orthogonal direction.
I The net effect is that increased displacement requires increased plate separation, which results in decreased overall force.
J The most common configurations of rotary electrostatic actuators are the variable capacitance motor and the wobble or harmonic drive motor.
K Both motors operate in a similar manner to the comb-drive linear actuator.
L The variable capacitance motor is characterized by high-speed low-torque operation.
M Useful levels of torque for most applications therefore require some form of significant micromechanical transmission, which do not presently exist.

N The rotor of the wobble motor operates by rolling along the stator, which provides an inherent harmonicdrive-type transmission and thus a significant transmission ratio (on the order of several hundred times).
O The drawback to this approach is that the rotor motion is not concentric with respect to the stator, which makes the already difficult problem of coupling a load to a micro-shaft even more difficult.

### *VOCABULARY AND GRAMMAR*

5 Students study the tables and complete them with the examples on the topic Mechatronics.

6 For Questions 1–10 students fill in the gaps in the sentences with the correct suffix from the box.

Answers:

1 Measure**ment**
2 sensitiv**ity**
3 perform**ance**
4 special**ist**
5 Miniaturiz**ation**
6 Stabil**ity**
7 Hard**ship**
8 process**ing**
9 manipulat**ion**
10 mechatron**ic**

### *SPEAKING*

7 Students study the Input–output configuration of a measurement system and explain the connection between all the components in it.

8 Students divide into pairs**,** choose any five terms, activities 1 – 7 and give each other definitions of these terms to guess the words.

### *READING*

9 Students study the abbreviations given and say what they stand for.

1 ALU – an arithmetic logic unit
2 DSP – digital signal processor

3 A/D – analog-to-digital
4 MAC – multiply-accumulate
5 ASIC – application specific integrated circuits
6 D/A digital-to-analog

10 Student read the first part of the text and say what the mechatronic use of computers is. Ask students to give their own examples of this way of using computers.

11 Students read the second part of the text about the Mechatronics and the Real-Time Use of Computers and for questions 1 – 12 fill the gaps with one of the words from the box.

Answers:

1 rotate
2 discrete
3 sampler
4 functionality
5 algorithm
6 interlock
7 analog/digital
8 dedicated
9 estimate
10 drift
11 delays
12 disturbances

12 Students read the third part of the text. Seven sentences have been removed from it. They choose the most suitable sentence from the list A-H for each part (1–7) of the text. *E* – is an extra sentence which should not be used.

Answers:

1 F
2 H
3 B
4 G
5 A
6 D
7 I

13 Ask students to read the whole text, activities 10, 11 and 12 again if it is necessary to answer the questions given.

***SELF-STUDY SECTION***

14 This activity represents Word Formation. This consists of a short text with 10 gaps. For each gap, a base word (the prompt word) is given. Students have to form the correct word for the gap using this prompt word. Students read through the text to get an idea of what they are about, deciding what part of speech they need for each gap. The needed word could be a noun, verb, adjective or adverb. Tell students to look at the base word. They may need to add a prefix, suffix, to change the middle, or a combination of these. Students must be careful about negatives and plurals. When students have finished, they read the text again to check that their answers make sense. Students work individually before checking the answers open-class.

Answers:

1 applied
2 solutions
3 requires
4 grows
5 existence
6 using
7 higher
8 minimal
9 typically
10 selected

15 For Questions 1 – 15, students complete the text by writing down each missing word. Ask students to use only one word for each gap.

Answers:

1. from
2. for
3. to
4. as
5. to

6. of
7. or
8. the
9. The
10. by
11. thus
12. while
13. which
14. Due
15. not

***WRITING***

16 Students read the topic and write an essay on the topic given. Ask students to write their assignments of 160–200 words.

17 Students read the text and write an annotation to it.

# Unit 6
# Software and Data Acquisition

**Objectives**

**Reading:** reading for detailed understanding of a text and text structure
**Listening:** listening for getting the general idea
**Vocabulary:** discourse cloze
**Grammar:** Organizing information
**Speaking:** describing a scheme, making up dialogues
**Writing:** organizing information, writing an annotation

### *LEAD-IN*

1 Students look at the picture which shows nano technologies. Ask student to say what it is. Let students tell everything they know about the topic.

2 Students read the first part of the text about new directions in Nano-, Micro- and Mini-Scale Electromechanical System and make up 3 questions to it. Then divide students into pairs or groups of three to ask and answer the questions.

### *LISTENING*

3 This activity represents Multiple Choice Cloze. Students listen to the second part of the text about new directions in Nano-, Micro- and Mini-Scale Electromechanical System and for questions 1 – 8 choose the correct variant A – C.

1 a
2 a
3 b
4 b
5 a
6 b
7 b
8 c

### *VOCABULARY AND GRAMMAR*

4 Students read the given paragraph and practice finding the major details and minor details by completing the block diagram given below.

5 Students read the given paragraph and practice finding the major details and minor details by completing the block diagram given below.

### *SPEAKING*

6 Students study the functional block diagram and explain the connection between all the components in it.

7 Students divide into pairs and make up dialogues, using one of the situations given.

### *READING*

8 This activity represents Multiple Choice Cloze. Students read the text about data acquisition and for abstracts 1 – 8 choose a suitable main idea from the list A – C.

1 C
2 B
3 A
4 A
5 B
6 A
7 C
8 B

### *SELF-STUDY SECTION*

9 This activity represents Word Formation. This consists of a short text with 15 gaps. For each gap, a base word (the prompt word) is given. Students have to form the correct word for the gap using this prompt word. Students read through the text to get an idea of what they are about, deciding what part of speech they need for each gap. The needed word could be a noun, verb, adjective or adverb. Tell students to look at the base word. They may need to add a prefix, suffix, to change the middle, or a combination of these. Students must be careful about negatives and plurals. When students have finished, they read the text again to check that their answers make sense. Students work individually before checking the answers open-class.

Answers:

1 relevance

2 effective
3 assessments
4 prediction
5 multidisciplinary
6 educational
7 active
8 accomplishments
9 refining
10 mechanical
11 knowledge
12 skills
13 electromechanical
14 applies
15 objectives

10 For Words 1 – 10 students find synonyms under the letters A – J.

Answers:
1 outcome – result
2 exploration – investigation
3 optimize – perfect
4 optimal – best
5 algorithms – sets of rules
6 embedded – mounted
7 automate – modify
8 stability – steadiness
9 measure – evaluate
10 faults – mistakes

11 Students read the text and fill the gaps with the words 1 – 10, activity 10.

Answers:
1 automate
2 optimize
3 optimal
4 algorithms
5 measure
6 embedded
7 exploration
8 stability

9 outcome
10 faults

### *WRITING*

12 Ask students to choose one of the paragraphs of text, activity 8 and to practice finding the main idea, major details and minor details by completing the block diagram given.

13 Students read the text and write an annotation to it.

# Unit 7
# Mechatronics engineering

**Objectives**

**Reading:** reading for detailed understanding of a text and text structure
**Listening:** listening for getting detailed information
**Vocabulary:** key word transformation, word formation, giving definitions, organizing information, jigsaw
**Grammar:** revision
**Speaking:** presentation
**Writing:** writing an essay, an annotation

## *LEAD-IN*

1 Students read the title of Unit 7 and say what it will be about. Ask students to give definition to the term “Mechatronics engineering”.

2 Students study the General computer-control configuration. Ask students to explain the connection between all the components in it.

## *READING*

3 Students match words with their synonyms in the second column.

Answers:

1 e
2 i
3 d
4 h
5 g
6 a
7 c
8 f
9 b
10 k
11 l
12 j

4 Students read the text and fill the gaps in it with the words, Activity 3. tell students that sometimes the form of the word should be changed.

Answers:

1 specifications
2 experimental
3 disturbance
4 variables
5 urgently
6 flexible
7 reductions
8 facilitate
9 acquisition
10 applications
11 analysis
12 array

***LISTENING***

5 Students listen to the recording and mark the statements true (T) or false (F). ask students to correct the false statements.

Answers:

1 T
2 F
3 T
4 F
5 F
6 F
7 T
8 T

**Tapescript:**

Far-reaching fundamental and technological advances in electromechanical motion devices (actuators and sensors), power electronics, solid-state devices, ICs, MEMS and NEMS, materials and packaging, computers and informatics, microprocessors and DSPs, digital signal and optical processing, as well as computer-aided-design tools and simulation software, have brought new challenges to academia, industry, and government. As a result, many engineering schools have revised their curricula in order to offer the relevant interdisciplinary courses such as Electromechanical Systems and Mechatronics. The basis of mechatronics is fundamental theory and engineering practice. The attempts to introduce mechatronics have been only partially successful due to the absence of a long-term strategy. Therefore, coordinated efforts are sought. Most engineering curricula provide a single elective course to introduce mechatronics to electrical, computer, mechanical, and aerospace engineering students. Due to the lack of time, it is impossible to comprehensively cover the material and thoroughly emphasize the cross disciplinary nature of mechatronics in one introductory course. As a result, this undergraduate or dual level course might not adequately serve the students' professional needs and goals, and does not satisfy growing academia, industrial, and government demands. A set of core mechatronic courses should be integrated into the engineering curriculum, and laboratory- and project-oriented courses should be developed to teach and demonstrate advanced hardware and software with application to complex electromechanical systems. The relevance of fundamental theory, applied results, and experiments is very important and must be emphasized. The great power and versatility of mechatronics, not to mention the prime importance of the results it approaches in all areas of engineering, make it worthwhile for all engineers to be acquainted with the basic theory and engineering practice. There is no end to the application of mechatronics and to the further contribution to this interdisciplinary concept.

We have just skimmed the surface of mechatronics application to advanced electromechanical systems. New trends will be researched and applied in the near future because mechatronics is an engineering–science–technology frontier. For example, novel phenomena and operating principles in NEMS and MEMS can be devised, studied, analyzed, and verified using nanomechatronics and nanoelectromechanics.

## *VOCABULARY AND GRAMMAR*

6 The activity represents 'Key' Word Transformation. For Questions 1 – 8, students complete the second sentence so that it has a similar meaning to the first sentence, using the word given.

1 SWNTs **can be used** as electromechanical actuators.
2 These nanoscale electromechanical devices **were used** to manipulate and interrogate nanostructures.
3 This device **could be used** to manipulate biological cells or even manipulate organelles and clusters within human cells.

4 A wide variety of nanoscale manipulators **have been proposed** including pneumatic manipulators that can be configured to make tentacle, snake, or multi-chambered devices.
5 Currently, much thought **is being devoted** to molecular assembly and self-replicating devices (selfreplicating nanorobots).
6 A set of core mechatronic courses **should be integrated** into the engineering curriculum.
7 The relevance of fundamental theory, applied results, and experiments is very important and **must be emphasized.**
8 The role of mechatronics in modern engineering **is discussed and documented**.

7 Ask students to divide into pairs or groups of three, read three groups of the parts of the words representing prefixes, suffixes and stems and make up as many words as possible. Ask student to define parts of speech of the words they've built.

Possible answers:

1 unwanted
2 converter
3 alternatively
4 consequently
5 periodic
6 unstrobed
7 dependent
8 presentation
9 readable
10 information
11 relation
12 enhancement
13 relative
14 etc

8 Students give short explanations to the items given. Remind students about the information about compound nouns.

9 Students read the paragraph and practice finding the main idea, major details and minor details by completing the block diagram given below.

***SPEAKING***

10 Students are given 10 themes. Ask students to choose one of them, formulate a topic and make a plan for its oral presentation, then make a report in not less than 200 – 250 words.

***READING***

11 Students read the text and for Questions 1 – 8, choose the correct mark T (true) or F (false). Ask students to correct the false statements.

Answers:

1 F
2 T
3 T
4 F
5 T
6 F
7 F
8 F

12 Students are going to read an extract from the text "Nanomachines". For Questions 1–8, they should choose the correct answer A, B, C or D.

Answers:

1 B
2 B
3 D
4 A
5 B
6 A
7 C
8 C

13 In the jigsaw students should find 20 words on the topic "Mecahtronics".

Answers:

1 actuator
2 aliasing

3 amplifier
4 bus
5 circuit
6 control
7 current
8 feedback
9 filter
10 flow
11 loop
12 mechatronics
13 pulsewidth
14 robust
15 sensor
16 signal
17 sinewave
18 synergistic
19 transducer
20 verification

14 This activity represents Word Formation. This consists of a short text with 15 gaps. For each gap, a base word (the prompt word) is given. Students have to form the correct word for the gap using this prompt word. Students read through the text to get an idea of what they are about, deciding what part of speech they need for each gap. The needed word could be a noun, verb, adjective or adverb. Tell students to look at the base word. They may need to add a prefix, suffix, to change the middle, or a combination of these. Students must be careful about negatives and plurals. When students have finished, they read the text again to check that their answers make sense. Students work individually before checking the answers open-class.

Answers:

1 effects
2 promising
3 machinery
4 logical
5 Reliability
6 electronic
7 complicated

8 atomic
9 fail
10 reliability

15 Students read the topic and write an essay on the topic given. Ask students to write their assignments of 160–200 words.

16 Students read the text and write an annotation to it.

Учебное издание

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