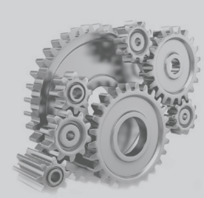
MECHANICAL ENGINEERING

Mechatronics and Robotics



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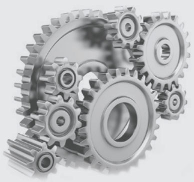

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Mechatronics and Robotics

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CHAPTER 1

Microprocessor, Microcontroller & PLC

1.1 INTRODUCTION

The most important technological invention of modern times is the "microprocessor". A microprocessor, usually abbreviated as μP, is a large scale integration (LSI) chip that is capable of performing arithmetic and logic functions as defined by a given programme. A microprocessor is a multiple purpose programmable clock driven, register based electronic device that reads binary instructions from memory, accepts binary data as input and processing this data according to the instructions written in the memory.

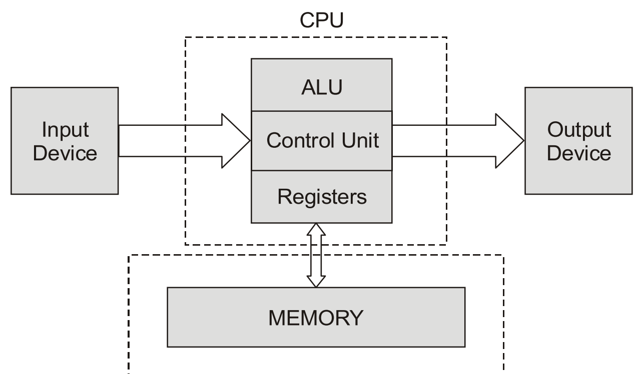

Figure: Block diagram of microcomputer

The microprocessor is capable of performing computing functions and making decisions to change the sequence of program execution.

The microprocessor can be embedded in a larger system, and can function as the CPU of a computer called a microcomputer. A state machine on a single IC chip with very large scale integration, capable at a desired instant of working as per programme or an instruction of a programe, and which is driven by a clock of frequency of 1 MHz or more, is called as microprocessor. Such a machine is also called a central processing unit (CPU). A CPU forms the main part of a computer.

The figure shows the basic block diagram of a microcomputer which processes binary data and traditionally represented by four blocks i.e. CPU, memory, input device and output device. Here, input device is a device that transfers information from outside world to the computer for example: Key board, mouse, webcam, microphone, scanner, electronic white boards, etc. The output device transfers information from computer to the outside world like monitor, printers (all types), speakers, headphones, projector, plotter, Braille embosser, LCD projection panel, computer output microfilm (COM) etc. Memory is an electronic medium that stores binary information. Central Processing Unit (CPU) is the heart of computer systems. The microprocessors in any microcomputer act as a CPU. The CPU can be made up of the following:

1. **Arithmetic logic unit (ALU):** In this area of the microprocessor, computing functions are performed on data. The ALU performs arithmetic operations such as addition and subtraction, and logic operations such as AND, OR and exclusive OR. Results are stored either in registers or in memory or sent to output devices.
2. **Register unit:** This area of the microprocessor consists of various registers. The registers are used primarily to store data temporarily during the execution of a program. Some of the registers are accessible to the user through instructions.
3. **Control unit:** The control unit provides the necessary timing and control signals to all the operations in the microcomputer. It controls the flow of data between the microprocessor and peripherals including memory.

Microcontroller is a programmable device that includes microprocessor, memory and I/O signal lines on a single chip, fabricated using VLSI technology. Microcontrollers are also known as single chip microcomputers. They are mostly used to perform dedicated functions such as automatic control of equipment, machines and process in industries and consumer appliances.

Characteristics of Microprocessor

1. It handles shorter words than other computers, usually 4 to as many as 16 bits.
2. It consists of integrated circuits from 1 to 30 in number.
3. It contains arithmetic logic unit (ALU), registers, control, random access memory (RAM), data buses and read only memory (ROM) with programs.

Important features of microprocessors:

- Low cost
- Small size
- Low power consumption
- Versatile
- Extremely reliable

1.1.1 System Bus

Buses are the baths along which digital signals move from one section to another. A bus is a group of wires/lines used to transfer data (bits) between components inside a computer or between computers. In most simple form, they are communication path used to carry the signals between microprocessor and peripherals. A bus is just a number of conductors along which electrical signals can be carried. It might be tracks on a printed circuit board or wires in a ribbon cable.

The system bus of a microprocessor is of three types:

1. **Address Bus**
   - It is a group of lines that are used to send a memory address or a device address from the Microprocessor Unit (MPU) to the memory or the peripheral.
   - The address bus is always uni-directional i.e address always goes out of the microprocessor.
   - If the address line are 'n' for a MPU then its addressing capacity is 2^n.
   - It carries signals which indicate where data is to be found and so the selection of certain memory locations or input or output ports.
   - Each storage location within a memory device has a unique identification, termed its address, so that system is able to select a particular instruction or data item in the memory.
   - Each input/output interface also has an address.
2. **Data Bus**
   - It is a group of lines used to transfer data between the microprocessor and peripherals and/or memory
   - Data bus is always bi-directional.
   - The data bus carries the data associated with the processing function of the CPU.

- Each wire in the bus carries a binary signal i.e., a0 or a1.
- The more the wires, the data bus has the longer the word length that can be used.

3. Control Bus

- Control bus provides signals to control the flow of data.
- This bus carries the signals relating to control actions.
- It is also used to carry the system clock signals; these are to synchronize all the actions of the microprocessor system.

NOTE: The internal architecture of the microprocessor unit depends on the data bus width, which is equal to the bit-capacity of the microprocessor.

1.2 EVOLUTION OF MICROPROCESSORS

- In 1971, the first microprocessor was introduced by "Intel corporation". This was 'Intel 4004", a processor on a single chip. It had the capability of performing simple arithmetic and logical operations, e.g., addition, subtraction, comparisons, AND, and OR. It also had control unit which could perform various control functions like fetching an instruction from the memory, decoding it and generating control pulses to execute it.

Table: Differences among different processors

Name	Date	Transistors	Data with (Bits)	Microns	Clock speed (MHz)	MIPS
4004	1971	2250	4	10	0.1	0.06
8008	1972	3500	8	10	0.2	0.06
8080	1974	6000	8	6	2	0.64
8085	1974	6500	8	3	5	0.37
8086	1978	29000	16	3	5 8 10	0.33 0.66 0.75
8088	1979	29000	16	3	5	0.33
80286	1982	134000	16	1.5	16	1
80386	1985	275000	32	1.5	16	5
80486	1989	1200000	32	1	25	20
Pentium	1993	3100000	32	0.8	60	100
Pentium II	1997	7500000	32	0.035	233	~300
Pentium III	1999	9500000	32	0.25	450	~510
Pentium 4	2000	42000000	64	0.18	1500	~1700
Pentium 4 "Prescott"	2004	125000000	64	0.09	3.6 Hz	~7000

NOTE: Most of the general purpose microprocessors used in the modern world computers are the family of 8086.

CHAPTER

5

Robotics

5.1 INTRODUCTION

Robotics, in different forms, has been on human's mind since the time we could build things. Mankind has always strived to give life-like qualities to its artifacts in an attempt to find substitutes for himself to carry out his orders and also to work in a hostile environment. The popular concept of a robot is of a machine that looks and works like a human being. This humanoid concepts has been inspired by science fiction stories and films in the Twentieth century. The industrial robots of today may not look the least bit like a human being although all the research is directed to provide more and more anthropomorphic and human-like features and super-human capabilities in these. Although in principle humanoids are robots and are designed and governed by the same basics. In this chapter, we will primarily study industrial manipulator type robots.

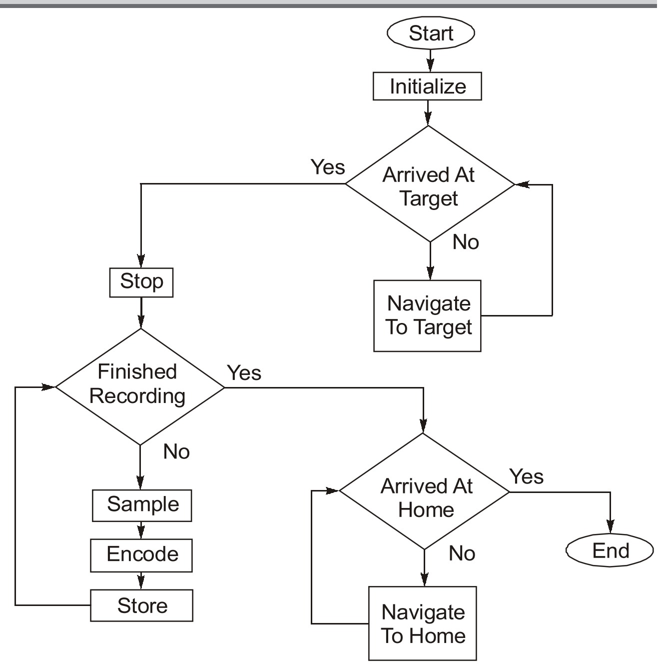

Figure: The simple robotic flow chart

This chapter some basic introductory material that familiarizes us with the subject, it presents an analysis of the mechanics of robots including kinematics, dynamics, and trajectory planning, and it discusses the elements used in robots and in robotics, such as actuators, Sensors, vision systems, and so on. Robot rovers are no different, although they usually have fewer degrees of freedom and generally move in a plane. Ecoskeletal and humanoid robots, walking machines, and robots that mimic animals and insects have many degrees of freedom (DOF) and many posses unique capabilities: However, the same principles we learn about manipulators apply to robot rovers too, whether kinematics, differential motions, dynamics or control.

Robots are very powerful elements of today's industry. They are capable of performing many different tasks and operations, are accurate, and do not require common safety and comfort elements that humans need. However, it takes much effort and many resources to make a robot function properly. Most companies of the mid-1980s that made robots are gone, and with few exceptions, only companies that make real industrial robots have remained in the market. Early industrialist predictions about the possible number of robots in industry never materialized because high expectations could not be satisfied with the present robots. As a result, although there are many thousands of robots in industry working tirelessly and satisfactorily for the intended jobs, robots have not overwhelmingly replaced workers.

They are used where they are useful. Like humans, robots can do certain things, but not others. As long as they are designed properly for the intended purposes, they are very useful and continue to be used.

Robotics is the art, knowledge base, and the know-how fo designing, applying and using robots in human endeavors. Robotic systems consist of not just robots, but also other devices and systems used together with the robots. Robots may be used in manufacturing environments, in underwater and space exploration, for aiding the disabled, or even for fun. In any capacity, robots can be useful, but they need to be programmed and controlled. Robotics is an interdisciplinary subject that benefits from mechanical, electrical enginering and electronic engineering, computer science, and many other disciplines.

5.2 WHAT IS A ROBOT?

If one compares a conventional robot manipulator with a crane attached to a utility or towing vehicle, then it is noticed that the robot manipulator is very similar to the crane. Both possess a number of links attached serially to each other with joints, where each joint can be moved by some type of actuator. In both systems, the 'hand' of the manipulator can be moved in space and placed in any desired location within the workspace of the system. Each one can carry a certain load and is controlled by a central controller that controls the actuators. However, one is called a robot and one is called a manipulator (or, in this case, a crane). Similarly, material handling manipulators that move heavy objects in manufacturing plants look just like robots, but they are not robots. The fundamental difference between the two is that the crane and the manipulator are controlled by a human who operates and controls the actuators, whereas the robot are designed and meant to be controlled by a computer or similar device. The motions of the robot are controlled through a controller under the supervision of the computer, which is running some types of a program. Therefore, if the program is changed, the actions of the robot will change accordingly.

5.3 COMPONENTS OF A ROBOT

A robot, as a system, consists of the following elements, which are integrated together to form a whole:

1. **Manipulator or the Rover:** This is the main body of the robot which consists of the links, the joints, and other structural elements of the robot. Without other elements, the manipulator alone is not a robot.
2. **End effector:** This part is connected to the last joint (hand) of a manipulator that generally handles objects, makes connections to other machines, or performs the required task. In most cases, the action of the end effector is either controlled by the robot's controller or the controller communicates with the end effector's controlling device.
3. **Actuators:** Actuators are the 'muscles' of the manipulators. The controller sends signals to the actuators, which in turn, move the robot joints and links. Common types are servomotors, stepper motors, pneumatic actuators, and hydraulic actuators.
4. **Sensors:** Sensors are used to collect information about the internal state of the robot or to communicate with the outside environment. Sensors integrated into robot send information about each joint or link to the controller that determines the configuration of the robot.

5.19 ROBOT PROGRAMMING

Online programming: in this type of programming, the robot arm itself is used during the direct programming operation. There are two methods:

(a) Tech by load through
(b) Teach by pendent

(a) Teach by lead through or lead through programming: In this type, the work cycle is taught to robot by moving the manipulator through the requires motion cycle and simultaneously entering the program into controller memory for later playback. This is used for programming continuous path operations such as are found in spray painting. In this type, no computer programming is needed and can be easily learned by the shop personnel.

(b) Teach by pendent: It is used for work that required point to point and point to point with coordinated path, movements this is the normal method of programming. It involves the programmer using a hand-held pendent which transmits commands through a cable to the robot controller, the robot then responds to these commands. The robot is programmed by moving the end-effectors to a desired position using and orientation a key in the keyboard is pressed to record the point.

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OBJECTIVE BRAIN TEASERS

Q.1 Single wheel robots are called as
(a) Legged robots (b) Arm robots
(c) Ball robots (d) 4-axis robots

Q.2. Maximum possible number of degrees of freedom for a rigid body in a plane motion is
(a) 6 (b) 3
(c) 2 (d) 5

Q.3 An android takes the form of:
(a) An insect
(b) A simple robot with human appearance
(c) Binocular vision
(d) A human body

Q.4 An automotive robot might best keep itself traveling down a specific lane of traffic by using:
(a) Binaural hearing
(b) Epi-polar navigation
(c) Edge detection
(d) A second-generation end effector

Q,5 A rule-based system is also known as:
(a) Artificial intelligence
(b) An expert system
(c) An analytical engine
(d) An automated guided vehicle

Q.6 According to motion of the arms which of following is a type of robot?
(a) Physical manipulator
(b) Continuous path robot
(c) Fixed sequence robot
(d) Intelligent robot

Q.7 In which year, one of the first humanoid robots was exhibited at the annual exhibition of the model engineers society in London?
(a) 1930 (b) 1920
(c) 1928 (d) 1924

Q.8 Who invented first humanoid robots?
(a) Czech (b) Josef capek
(c) W.H.Richards (d) None of the above

Q.9 Who created the first electronic autonomous robots with complex behaviour?
(a) Gakutensoku
(b) Archibald Low
(c) William Grey Walter
(d) Rodon Brooks

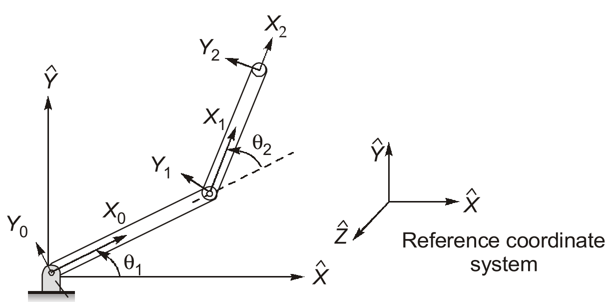
Q.10 The first palletizing robot was introduced in which year?
(a) 1947 (b) 1940
(c) 1936 (d) 1963

ANSWER KEY

1. (c)	2. (b)	3. (d)	4. (c)	5. (b)
6. (b)	7. (c)	8. (c)	9. (c)	10. (d)
11. (a)	12. (c)	13. (a)	14. (a)	15. (c)
16. (b)	17. (c)	18. (a)	19. (b)	20. (b)
21. (a)	22. (b)	23. (c)	24. (d)	25. (a)
26. (d)	27. (c)			

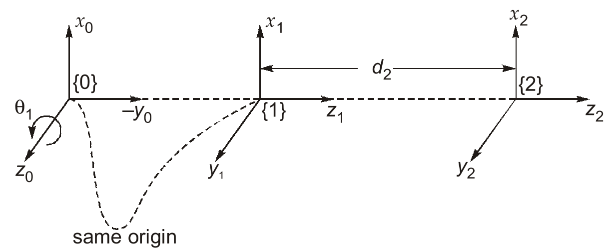
HINTS & EXPLANATIONS

21. (a)



For frame 1,
Z-axis is rotated about θ_1 that is angle between $\hat{X}$ and X_o is θ_1 and as $\hat{X}$ and X_o are intersecting, $d_1 = 0$.
As Z_o and Z_1 are parallel, $\alpha_1 = 0$ and distance between Z_0 and Z_1 is L_1, therefore $a_1 = L_1$.
For frame 2,
Angle between X_o and X_1 is θ_2 and as X_o and X_1 are intersecting, $d_2 = 0$.
As Z_1 and Z_2 are parallel, $\alpha_2 = 0$ and distance between Z_1 and Z_2 is L_2, therefore $a_2 = L_2$.

24. (d)
Frame assignment for 2-DOF planar manipulator is:



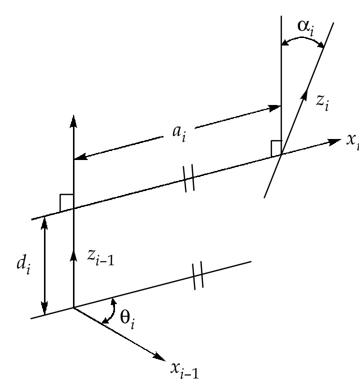
25. (a)

$$P_{xyz} = \text{Rot}(y, 90)\,\text{Rot}(z, 90)\,P_{noa}$$

$$= \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 7 \\ 3 \\ 1 \\ 1 \end{bmatrix} = \begin{bmatrix} 1 \\ 7 \\ 3 \\ 1 \end{bmatrix}$$

$$\therefore \quad P_{xyz} = (1, 7, 3)^T$$

26. (d)



a_i = link length, d_i = joint offset
α_i = link twist, θ_i = joint angle

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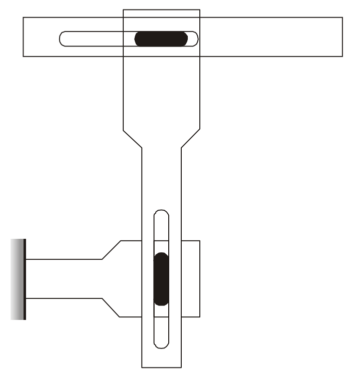
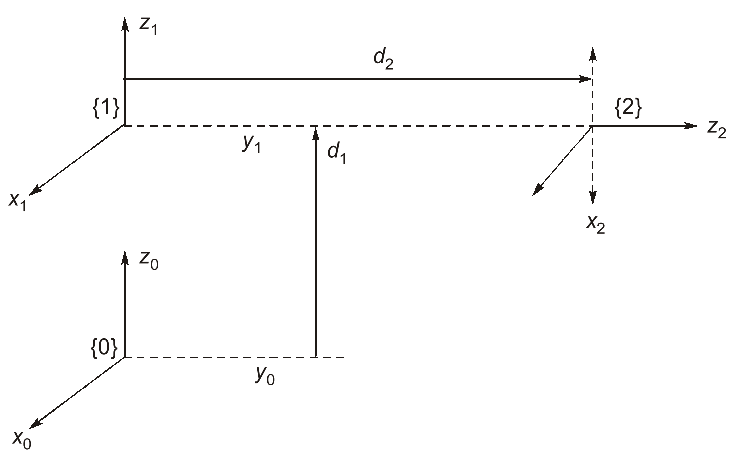
CONVENTIONAL BRAIN TEASERS

Q.1 Consider the two link Cartesian manipulator as shown in figure. Derive the forward kinematic equations using the D-H. convention. Make joint link parameter table and also find composite transformation matrices.



Solution:

In this manipulator, there are 2 prismatic joint.



Joint link parameter table:

Link(i)	a_i	α_i	d_i	θ_i	q_i	$C\theta_i$	$S\theta_i$	$C\alpha_i$	$S\alpha_i$
1	0	0	d_1	0	d_1	C_1	0	1	0
2	0	–90	d_2	0	d_2	1	0	0	–1

Transformation matrices:

We know that

$$^{i-1}T_i = \begin{bmatrix} C\theta_i & -S\theta_i C\alpha_i & S\theta_i S\alpha_i & a_i C\alpha_i \\ S\theta_i & C\theta_i C\alpha_i & -C\theta_i S\alpha_i & a_i S\theta_i \\ 0 & S\alpha_i & C\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$