CNC MACHINES AND AUTOMATION

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Lesson Plan

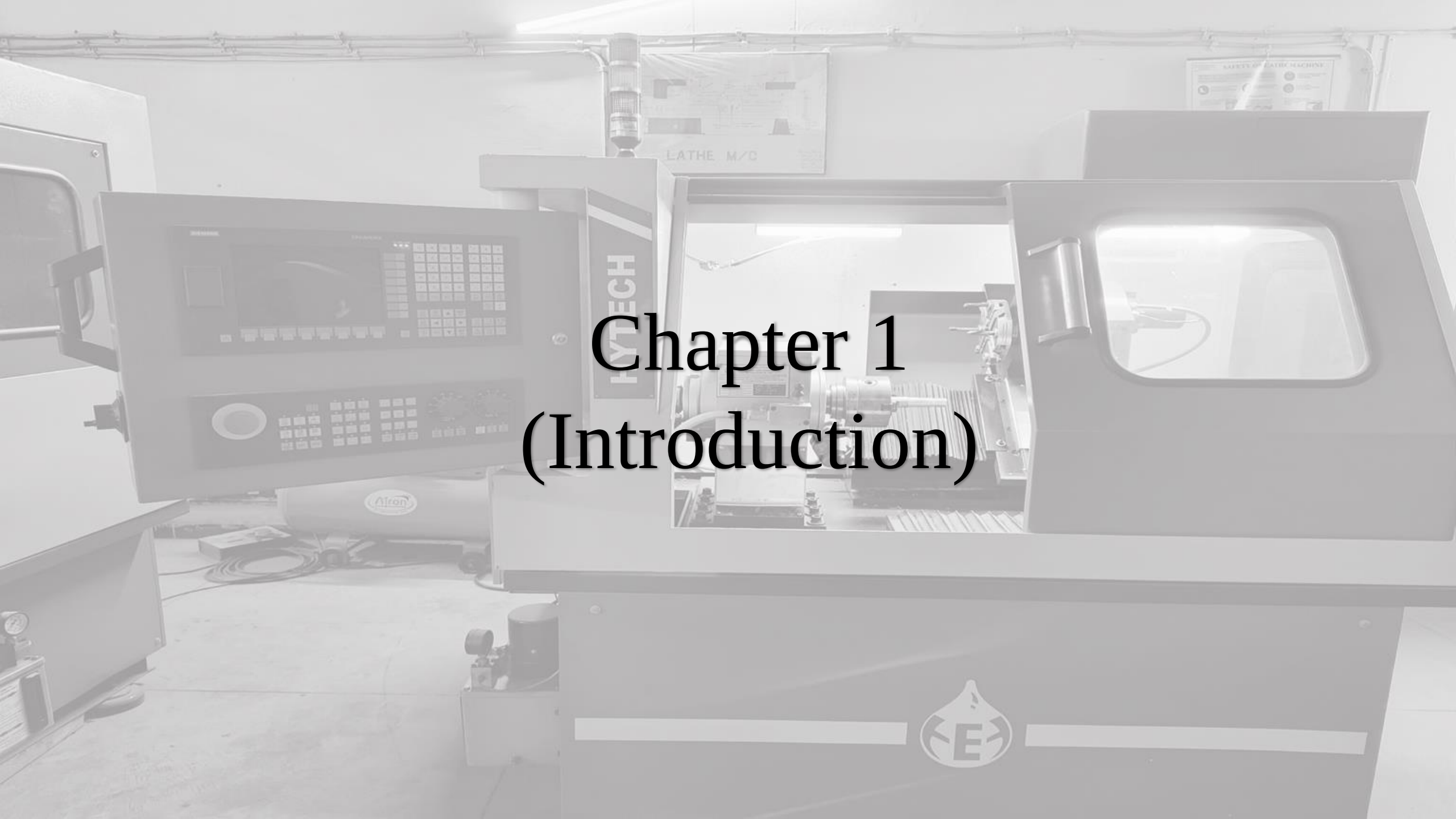
Name of the faculty	**:**	**AMIT JANGRA**
Discipline	**:**	**Mechanical Engineering**
Semester	**:**	**5th**
Subject	**:**	**CNC Machines and Automation**
Lesson Plan Duration	**:**	**15weeks**
Work Load	**:**	**(Lecture/Practical)** **(3 Periods/ 2 periods) /Week**

For full syllabus please visit here

Attendance
Minimum 70%.

Grading policy
3 Sessional each carry 30 marks (Best of 2 will be considered)
3 Assignments must be submitted

Internal Assessment			External Assessment		
Th	Pr	Total	Th	Pr	Total
40	40	80	60	60	120



Chapter 1
(Introduction)

Why NC?

- Increasing efficiency is main goal of every business to make more profit.
- Stress has to be laid on maximizing the output with keeping input to lowest possible
- Also keep the quality and reliability
- Complexity of a product increases the time of production
- Today there is demand of faster production in harder and tougher material

The solution to this problem is, Numerical control as it supports 85% of market demand

- The solution to this problem is, Numerical control as it supports 85% of market demand.
- It is nothing, but relatively new process of organizing the information required for a process resulting in automation.
- Automation in production process may be achieved by one of the following strategies.

Automation

Industrial Process Control (IPC):

- Sensing physical quantity like temperature, pressure by transducers
- And controlling a process by actuators.
- E.g. Automatic control of boilers, air-condition of buildings

Computer Aided Data Processing (CADP):

- Lessen the burden of excessive data, to be processed in no time.
- Data processing may range from CAPP, MRP to making NC programs.

Special Purpose Manufacturing Machine (SPMM):

- To make the product in close tolerance and with least wastage.
- It is called fixed automation and is feasible only for mass production.

Numerical Control (NC):

- It is a form of digital control of a machining process.
- A flexible method of automation.
- E.g. assembly, inspection, spot-welding etc.

Difference between using **Special Purpose Manufacturing Machines (SPMM)** and **NC Machines**

(Conventional) S.P.M.	N.C. Machines
1. They have fixed sequence of operation with little or no variation to machine a part.	1. This is a flexible method in which the sequence of operations can be changed to machine a new part.
2. Suitable for mass production having identical parts	2. This can be applied to a short/batch production runs or even a single part.
3. The machine require more time for setting up.	3. Complex setting up procedures are almost by passed in these machines.
4. The programme or sequence of operation is built into hardware	4. In these machines the programme is stored as the software.
5. It has less scope of variation as it is too costly.	5. These machines have large scope for variations of different products without involvement of high costs
6. More floor area is required for tooling and work holding.	6. Lesser floor area is required.

Historical Background

It is unusual for more than hundred plane to be made of single design. They may be of different lengths, different speeds and different passenger capacity. As a result, the number of identical component is quite small. Copying profiles from master templates, was not a reliable method to produce accurate identical parts. This was felt by US Air force in 1940 design an equipment which could ensure quality in production of complex component of curved surface. Also to take care of variety, it has to be flexible.

Historical Background

- Mr. John T. Parsons used Punched card, containing X and Y co-ordinates recorded, to control a machine tool to manufacture helicopter rotor blades.
- In 1948 he demonstrated this to US Air Force at MIT
- In 1952, Alfred Herbert Ltd. Made their first controlled machine i.e. NC with three axis control.
- These days punched tapes or magnetic tapes are used as mean of storing information.

NC Machines

NC machines, is a method of automation, where automation of small and medium volume production is done by some control under instructions of a program.

- Numerical control is defined as a form of software controlled automation, in which the process is controlled by alphanumeric characters or symbols.
- The control of a machine tool by means of recorded information on punched tapes or cards is known as Numerical Control.

NC Machines

According to these definitions, a programme is prepared which consist of blocks; blocks consisting of combination of character and numbers in sequence describing the position of the tool and job, the cutting speed and feed etc. The data is converted into coded instructions which is called a **“Part Program.”** As the job changes, the instruction of part program is also changed. It easy to encode a new programme than to change the machinery for flexibility, thus arising the need of an NC machine tool.

Construction/Basic Components of NC Machines

a) Software

b) Machine Control Unit (MCU)

c) Machine Tools (MT)

Process Layout

a) Software

The program or set of instructions, languages, punched cards, magnetic tape, punched paper tape and other such information processing items are referred to as ‘Software.’ This software controls the sequence of movement of an NC. That is why these NCs are sometimes called software controlled machines.

- The programmer plans the operations and their sequence from seeing the drawing.
- Writes instructions in tabulated blocks of information, known as **Part Programme**.
- Then these instruction are punched on the control tape in binary format.
- Tape reader reads the code and send it to MCU.
- MCU conversely converts them into the machine movements of machine tool.

Binary coding for NC

The normal decimal number system has a radix of 10 because it has ten digits 0 to 9 for the information of any number. While binary number system uses only two digits ‘0’ and ‘1’ which may be represented by a simple ‘OFF/ON’ switch or simply by ‘hole’ or ‘No hole’ on punched tape. It has a radix base of ‘2’ because it has two digits.

Some standard Notations

- ‘BIT’ is a Binary digit which represents ‘0’ or ‘1’.
- ‘Character’ is a combination of holes punched to represent a symbol, letter or number.
- Byte is a combination of 8 characters. It is used to represent one ‘character’.
- ‘Row’ is a line of holes perpendicular to the length of tape.

Binary coding for NC

Decimal to binary

Convert $(27)_{10}$ to $(?)_2$

2	27
2	13 - 1
2	6 - 1
2	3 - 0
2	1 - 1
	0 - 1

$(27)_{10} = (11011)_2$

Binary to Decimal

Convert $(11011)_2$ to $(?)_{10}$

1	1	0	1	1
2^4	2^3	2^2	2^1	2^0

i.e. $(1x2^4) + (1x2^3) + (0x2^2) + (1x2^1) + (1x2^0)$

$= 16 + 8 + 0 + 2 + 1$

$= 27$

$(11011)_2 = (27)_{10}$

For paper tape, the ‘Binary Coded Decimal’ (BCD) codes are used as adapted by EIA(Electronic Industries Association). It is having a small difference from Binary, in the sense, that in it each digit of the decimal number is represented by four holes in one row. For example,

27 will be represented as 0010 0111 for 2 and 7

and not as 11011 binary equivalent of 27

The NC machine uses two type of codes:

- EIA codes
- ISO/ASCII codes

Out of these EIA is the most popular, but ISO codes are slowly getting more importance than others.

EIA Codes

				2^3	2^2	2^1	2^0	**Binary Code**
8	7	6	5	4	3	2	1	Track or channel number
EB	X	O	CH	8	4	2	1	Code
●					•			EOB
		●			•			0
					•		●	1
					•	●		2
			●		•	●	●	3
					•	●		4
			●		•	●	●	5
			●		•	●		6
					•	●	●	7
				●	•			8
			●	●	•		●	9

EIA Codes

The numbers 1 to 8 on the top of the tape represent only the number of track and have no relationship with the holes punched. The following standard are followed:

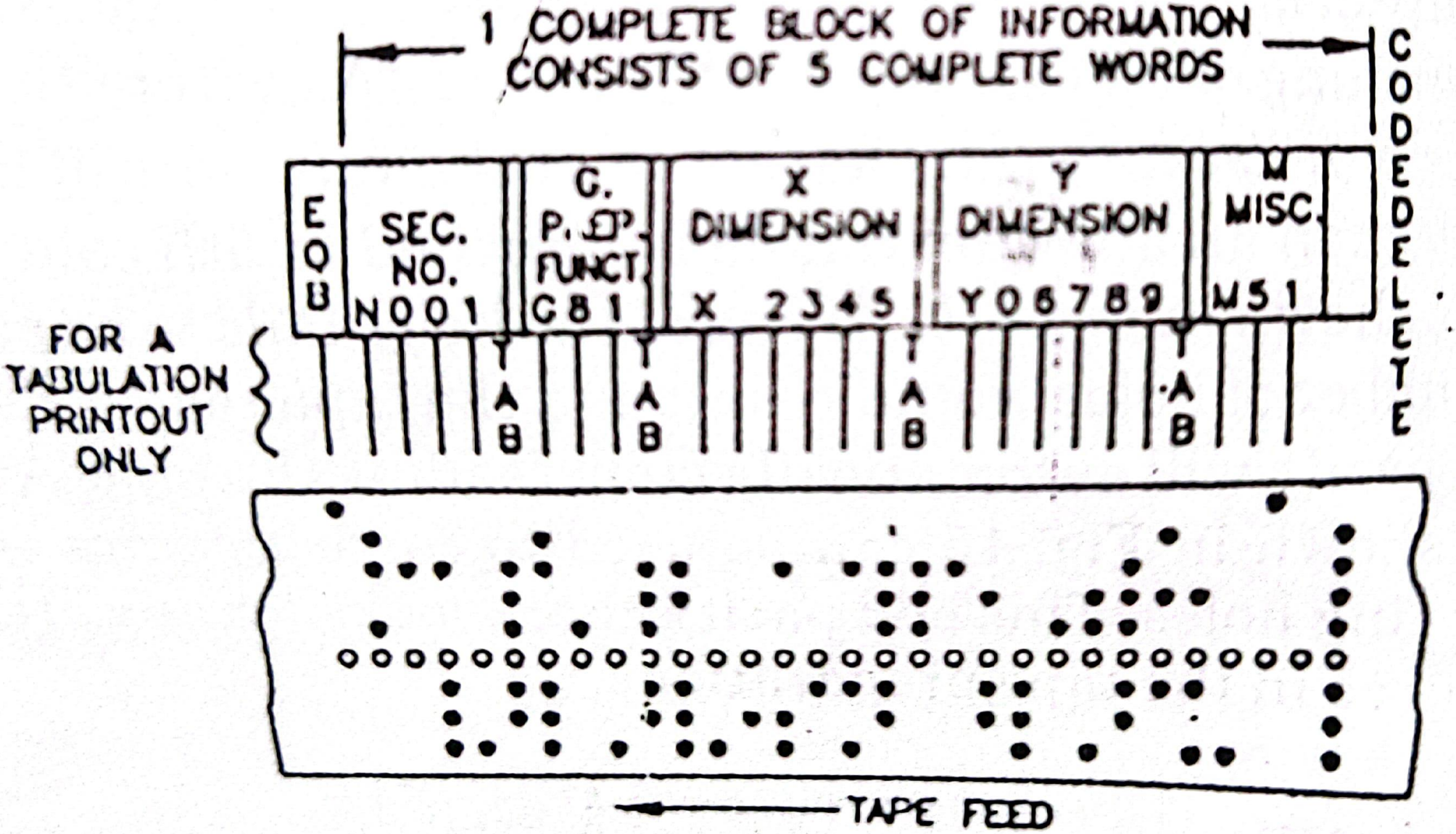
a) The ‘sprocket holes’ between 3 and 4 are offset and equilispaced holes used to advance or rewind the tape through reader.
b) Channels/Track 1,2,3 and 4 are used for numerical data such as dimension, speed and feeds etc.
c) Track 5 marked as CH is a parity check channel. (For EIA there must be odd number of holes for each character).
d) A single hole punched in track 6 represents a ‘zero’. Some alphabets also use track 6 for coding.
e) Track 7, marked X, is used to code alphabets to identify various machine operations. E.g. drilling, boring, etc.
f) Track 8, marked EB represents the end of block or a end of record and sometimes is used at the beginning of a punched tape.

ISO/ASCII Code

This is also a seven bit code having 8 tracks. This code is getting more popularity and is being followed in internationally these days because it readily permits information exchange with the computers. It require even no of holes for parity check

Difference between using **EIA** and **ISO Codes**

EIA	ISO
1. It uses odd parity system. 2. It has codes for lower case alphabets. 3. Numerals for 0-9 are punched as Binary codes.	1. It follows even parity system. 2. It has for both lower and upper. 3. Two additional holes are punched for numerals i.e. in track 5 and 6.



A complete block of information punched on a tape

With the development of NC a variety of input media has been used to present the information from drawing of the product to MCU. Most N/C machines used following types of input media:

a) Punched cards
b) Punched Paper tape
c) Magnetic tape
d) Floppy disks.

https://5.imimg.com/data5/QS/WR/TT/SELLER-3066699/floppy-disk-drive.jpg

Source: https://upload.wikimedia.org/

Please refer to your book for details

Machine Control Unit (MCU)

Every NC machine tool has a main unit, which is known as MCU, consists of some electronic circuitry that reads from the NC program, interprets it and conversely translates it for mechanical actions of the machine tool. The MCU may be of three type:

Housed MCU : - This MCU, itself, may be mounted on the machine tool or may be built in the casing of the machine.

Swing around MCU : - This MCU is directly mounted on the machine which can ‘swing around’ it and can be adjusted as per requirement of the operator’s position.

Standalone MCU : - This MCU is enclosed in a separate cabinet which is installed at some remote or some place near to the machine.

Sub units of MCU

A typical MCU may consists of the following units:

A) **Input/Reader Unit** : - Used to read the data from input media using card readers, Punched tape reader etc.

B) **Data Buffer (Memory)** : - All the information read from tape is stored in temporary memory called buffer. The function of this memory is to keep on storing the next block of words, when the machine is doing processing of previous block.

C) **Processor** : - Now software base processor such as mini computer are used. The function of it is to co-ordinate and control the functions of other units, by giving ready signals to them at appropriate point of time.

D) **Output channels and actuators** : - The data stored in the buffer is converted into actuation signal and supplied though output channels in the form of pulses. These pulses are then amplified by electro-magnetic amplifiers. Then it drive the motors(servo/stepper) for positioning and contouring the machine tool, are known as actuators.

E) **Control Panel** : It permits the operator to interfere the machine operation manually.

F) **Feedback channels and transducers** : - To check the operations are done in the way we want to, the feedback is sent through feedback channels.

Machine Tools (MT)

It is the main components of an NC system, which executes the operations. It may consist of a simple drilling machine to the most flexible machining centres.

It includes different parts/sub-assemblies:

- Work table
- Cutting tools
- Jigs and fixtures
- Motors for driving the spindle and tool
- Coolant and lubricating system

Advantage of NC machines

i) Smaller batches
ii) Increased flexibility
iii) Production of complex parts
iv) Reduced set-up times
v) Machining accuracy
vi) Lesser scrap
vii) Longer tool life

Problems with Conventional NC

i) Part Programming mistakes
ii) Punched tape
iii) Tape reader
iv) Controller
v) Non-optimal speeds and feeds
vi) Management information

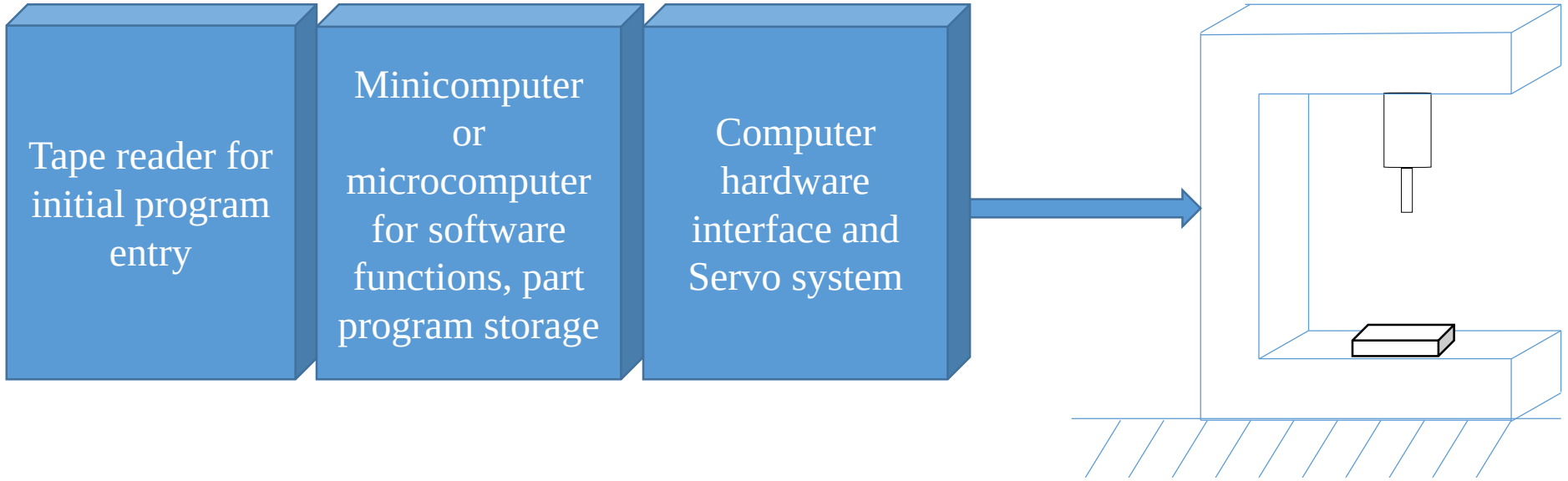
Advances in NC controller Technology

i) Vacuum Tubes
ii) Electromechanical relays
iii) Discrete semi-conductors
iv) Integrated circuits (IC)
v) Direct Numerical Control
vi) Computer numerical control
vii) Programmable Logic Controllers (PLC)

CNC (Computer Numerical Control)

A CNC is specifically defined as “It is a self-contained NC system for a single machine tool which uses a dedicated mini computer, controlled by the instructions stored in its memory, to perform all the basic numerical control functions.

CNC offers flexibility and computational capacity along with options. New system options can be incorporated into the CNC controller simply by reprogramming the unit and due to this characteristics of the CNC machine, it is also termed as “soft-wired”



Computer Numerical System (CNC)

Function of CNC

The principal functions of CNC are:

1) **Machine tool control**: It involves conversion of part program instructions into machine tool motion through the computer interface and servo system.
2) **In-process compensation**: This involves the dynamic correction of the machine tool motions for change or errors which occur during processing. For example Offset adjustment for tool radius and length.
3) **Improved programming and Operating features**: The soft wired control has permitted the introduction of many convenient programming and operating features. Such as:
   - Editing of part program at the machine
   - Graphic display of the tool path to verify the tape
   - Manual Data Input (MDI)
4) **Diagnostics**: Presently, CNC machines are equipped with a diagnostics capability to assist in maintaining and repairing the system. For example, to give warning about imminent failurity of a certain component.

Advantage of CNC machines over NC machines

1) **More flexibility**: Modification can be made to program rather than making a complete new tape
2) Reduce data reading error: The tape is read once and the program is stored in memory.
3) **Online editing of program**: It there is any mistake in dimension or cutting conditions then it can be easily modified by the part data stored in computer memory.
4) **Conversion of units**: Inches to S.I. units can be done within the computer memory.
5) **Integration with DNC systems**: It can be integrated with DNC systems in highly sophisticated manufacturing systems.

Disadvantages of CNC

1) High initial cost
2) High maintenance cost
3) Skilled CNC personnel
4) Not suitable for long run applications
5) Machines have to be installed in air-conditioned places.

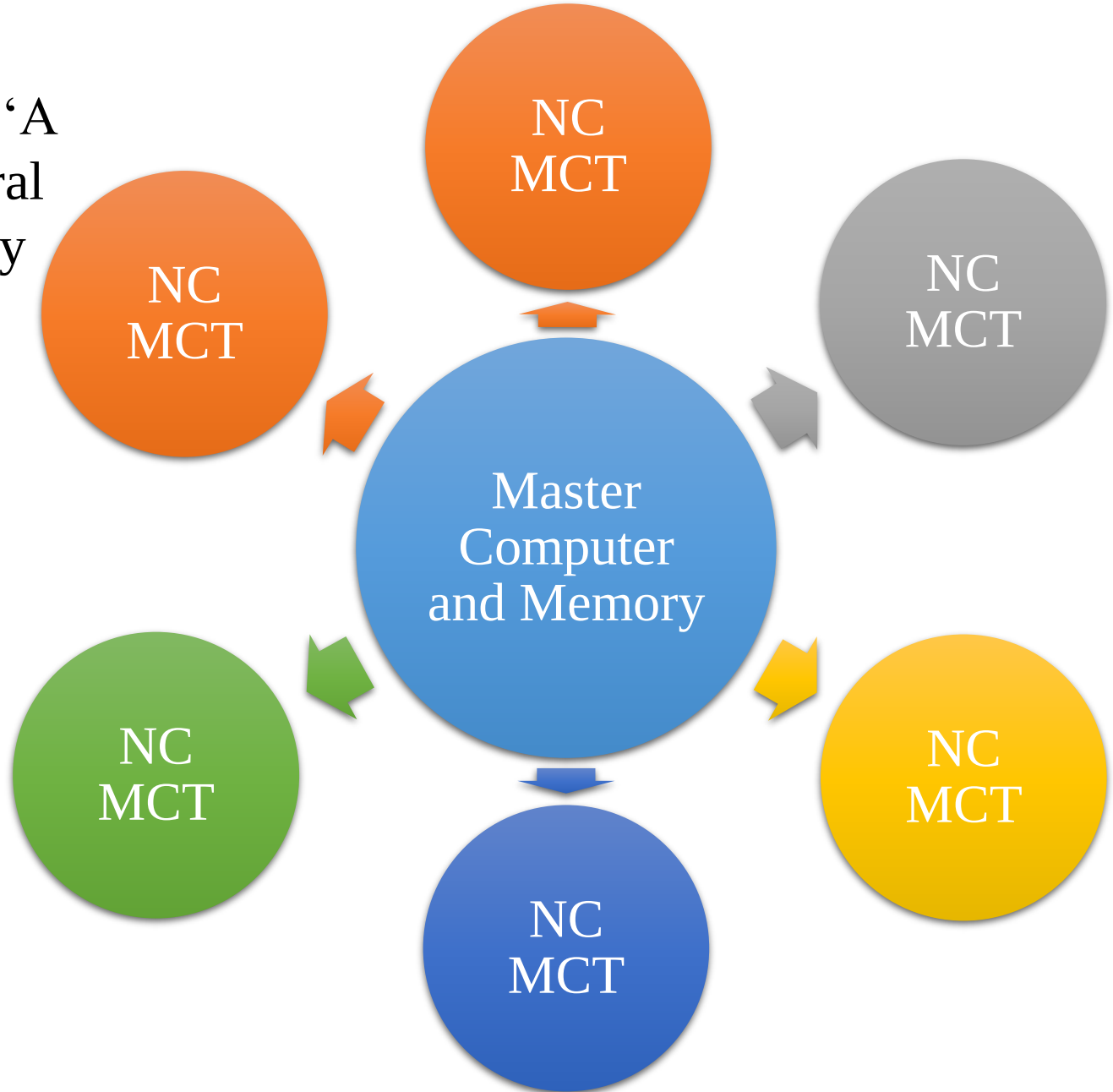
Please refer to your book for details

DNC (Direct Numerical Control)

Direct Numerical Control can be defined as, ‘A type of manufacturing system in which several NC or CNC machines are controlled remotely from a main frame computer.’

DNC require following basic components

- Main frame computer
- Memory
- Communication Network
- NC machine tool.



Types of DNC

There are two types of DNC, depending upon the communication link between the computer and machine tool.

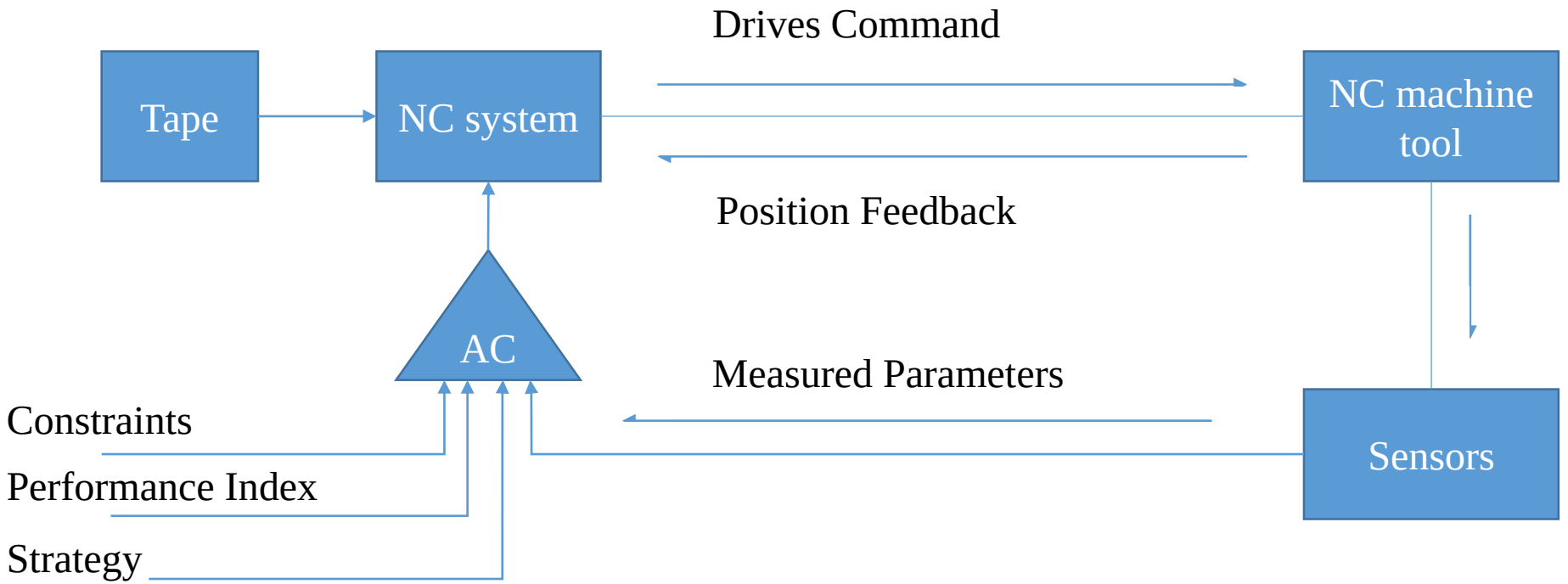
1) **Dedicated Machine Control Unit**: - In this configuration, regular NC controller is replaced by a special MCU, which is hard-wired to make it almost equivalent to CNC.
2) **Behind-Tape-Reader (BTR)**: - The second approach is also known as Behind Tape Reader interface. In this design, the data of all parts is stored in the central computer and the satellite computers are required only to receive and store the part program of the parts to be manufactured on individual NC machine tool or a group of machine tools.

Advantage of DNC

1) The computer can program simultaneously many NC Machines.
2) The tape preparation, the tape reader and the control unit are not needed.
3) The computer can be remotely located, even a thousand miles away.

Adaptive control (AC): - It is the technique of automatically adjusting of cutting parameters such as speeds, feeds and depth of cuts etc. to an optimum satisfaction level during machining operation, and the maximum metal removal which will result in minimum machining cost. It involves in-process measurement of cutting parameters, together with an on line computer fed with information about the cost of running the machine tool.

In NC system these are prescribed by the part programmer which depends on experience and knowledge. Actually adaptive control is a feed back system in which the cutting speed and feed automatically adopt themselves to the actual conditions of the machining process.



Block diagram of AC system

Types of Adaptive Control Systems

- Adaptive control with optimization (ACO) : - This attempts to maximize ratio of work material removal rate (MRR) to tool wear rate (TWR), known as index of performance (IP).

$$IP = \frac{MRR}{TWR}$$

- Adaptive control with constraints (ACC) : - In this system, the machining condition such as feed rate or/ and speeds are maximized within given limits of machine and tool constraints.

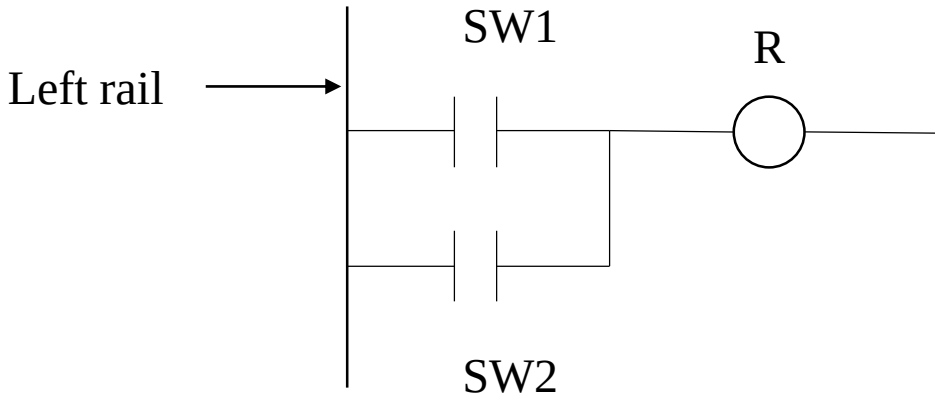
Advantage of Adaptive controls

1) Increased production rates.
2) Increased tool life.
3) Greater part protection.
4) Lesser operator intervention.
5) Easier part programming.
6) Less time is required to generate part program.

Programmable Logic Controllers (PLC)

A PLC is a microprocessor based special computer which can be programmed to carry out many types of control functions at any level of complexity. Its purpose is to monitor crucial process parameters and adjust the process accordingly.
The PLCs are programmed in a very simple language called “ladder logic”. This ladder logic drives the PLC output to switching for motors, valves or motor starters.

A ladder diagram consists of two rails of ladder and various control circuits called “rungs”. Each rung starts from left rail and finishes at right rail. Power flows from left rail to right rail. Each rung has one output and components on rung are relay, timers/counter or switches.



Construction of PLC

A programmable controller consists of four major parts:

a) CPU (Central processing unit) & Memory : The brain or central part has three subparts

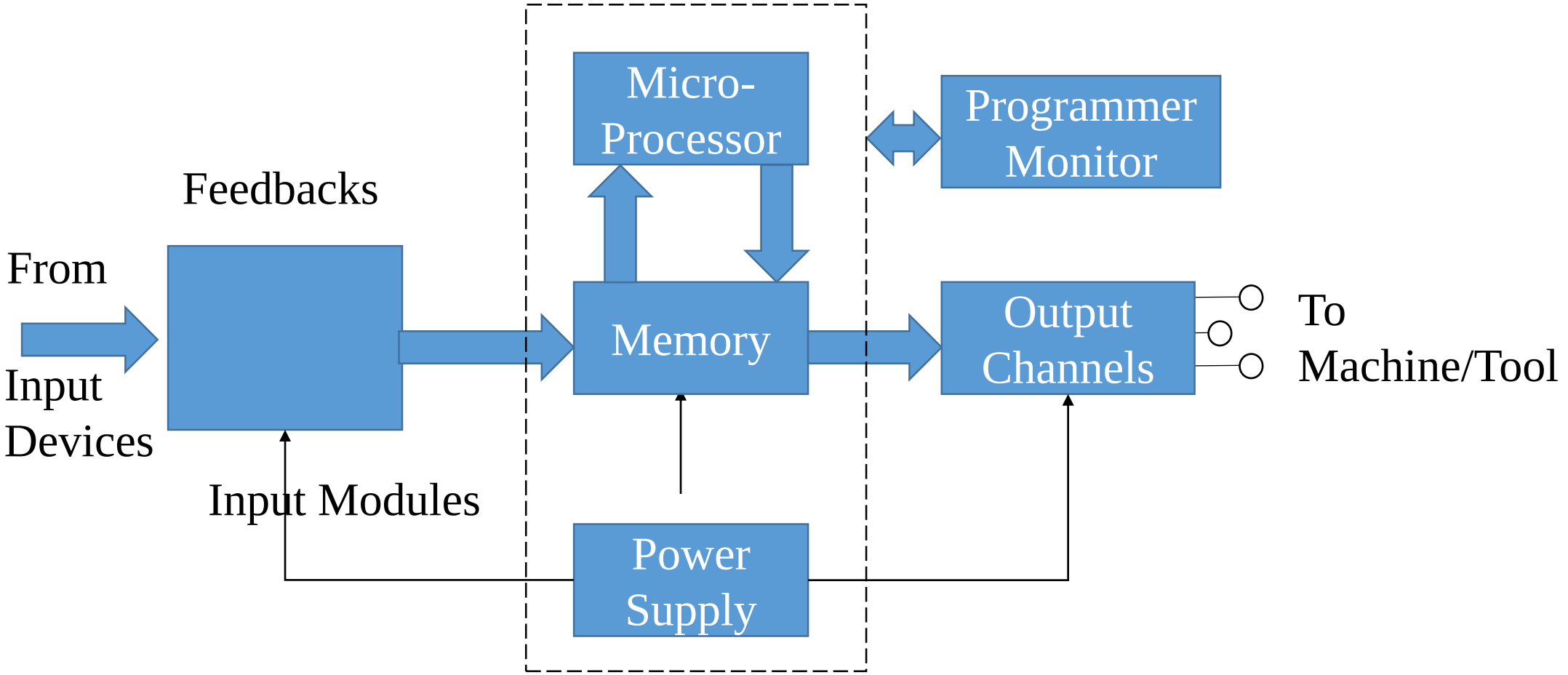
- Microprocessor, the IC used for carrying out arithmetic and logical operations
- Memory, both permanent EPROM and temporary RWM used to store/retrieve the data and program
- Power supply, an electrical supply that converts AC input to proper DC outputs for all the PLC subparts.

b) Programmer/Monitor: Generally a hand held terminal or keyboard + LCD monitor and sometimes VDU is provided to communicate with circuits of PLC.

c) Input-Output and Peripherals: Input Module receive signal from sensing devices and output signals are converted to relay activation signals or for solenoids, motor etc.

d) Power Supply

Construction of PLC



PLC Layout

PLC Advantages

1) **Maintenance/Diagnostic**: Built-in diagnostic routine
2) **Flexibility**: One PLC model can run 15 machine
3) **Implementing Changes and Correcting errors**: Program can be changed from keyboard within minutes
4) **Lower Cost**
5) **Visual Observation**
6) **Security**: A PLC program change cannot be changed unless PLC is properly unlocked.

PLC Disadvantages

1) Newer Technology
2) Fixed Program Applications
3) Environmental Considerations
4) Fail-Safe Operation
5) Fixed Circuit operation

Please refer to your book for details

New development in NC

a) Replacement of Punched tape and tape reader
b) Use of in-process inspection probes.

Parts Suitable for CNC machines

a) Where the operations or set-ups are very large or costly.
b) For small to medium batch quantity.
c) When the part geometry is so complex that the quantity production of it, involves possibility of human error.
d) The operations to be performed are very complex.
e) For parts subjected to regularly design changes.

Please refer to your book for details

Thank You