Course Materials

Chapter-1. INTRODUCTION TO MECHATRONIC SYSTEMS

DEFINITION OF MECHATRONICS

“Mechatronics is the Synergistic Integration of Mechanical Engineering with Electronics and Electrical with intelligent Computer control in the design and Manufacture of Industrial products, processes and operations”

EVOLUTION OF MECHATRONICS

i) Primary Level Mechatronics
ii) Secondary Level Mechatronics
iii) Tertiary Level Mechatronics
iv) Quaternary Level Mechatronics

INTEGRATION OF VARIOUS ENGINEERING BRANCHES (MULTI DISCIPLINARY SCENARIO) IN MECHTRONICS

Mechanical Design and Modelling
Actuators and sensors
Vibration and noise control
Manufacturing
Motion control
Micro devices and optoelectronic system
Intelligent control
System Integration
Automation systems

OBJECTIVE OF MECHATRONICS

i) Design Objective
ii) Data extraction Objective
iii) Output generation
iv) Processing objective
v) Control Objective
vi) Communication Objective
vii) Automation Objective
viii) Display Objective
ix) Performance Objective

NEED OF MECHATRONICS IN INDUSTRY

i) Changing market condition
ii) Variety in product range
iii) Short production run
iv) Good product quality and consistency
v) Ease of Reconfiguration of the process
vi) Enhancement in process capability
vii) Demand for increased flexibility

MECHATRONICS TECHNOLOGY

i) Engineering design
ii) Drives and actuators
iii) Sensors and instrumentations
iv) Embeded microprocessor system
v) Automation and computerization

MECHATRONICS ENGINEERING SKILLS

i) Modelling (Mathematical)
ii) Mechanical design
iii) Design of mechanical circuits
iv) Design of electrical circuits
v) Design of electronic circuits
vi) Development of control algorithm
vii) Design of control system

SYSTEMS& MECHATRONICS: System: Any mechanical, electrical or electronic element or set of elements that can give out certain useful outputs under the understandable inputs can be named system

Types of system

i) Measurement system
ii) Actuation system
iii) Control system
iv) Microprocessor system

MEASUREMENT SYSTEM

CONTROL SYSTEM-DEFINITION a group of devices or units or elements which maintain the required output based on the preset or predefined level or quantity by controlling or manipulating the parameters responsible for the output constitutes a control system

Types of Control system

i) Open loop control system
ii) Closed loop control system

Elements of Closed loop control system

i) Comparison element
ii) Control unit
iii) Correction unit
iv) Process unit
v) Feedback unit

MICROPROCESSOR BASED CONTROL SYSTEM

i) AUTOMATIC WASHING MACHINE
ii) AUTOMATIC CAMERA
iii) ENGINE MANAGEMENT SYSTEM

Chapter-2. REVIEW OF TRANSDUCERS AND SENSORS

Sensors: It is used for an element which produces signal relating to the quantity being measured

Performance Terminology:

Range and span:

The range of a transducer defines the limits between which the input can vary
The span is the maximum value of the input minus the minimum value.
Span = Max. value of input – Min. value
Ex: A load cell for the measurement of forces might have a range of 0 to 50 KN.
Span = 50 – 0 = 50 KN.

Error:

It is the difference between the result of the measurement and the true value of the quantity being measured.

Error = Measured value – True value

Error = 25 – 24 = 1ºc

Error = 25 – 26 = -1ºc

Accuracy:

It is the extent to which the value indicated by a measurement system might be wrong.

Ex: A measuring system having an accuracy of ±2ºc implies that the reading given by the instrument can be expected to lie within + or - 2ºc of the true (actual) value

Sensitivity:

It is the relationship indicating how much output you get per unit input i.e., output / input

Ex: A resistance thermometer may have a sensitivity of 0.5 Ώ/ºc

Hysterisis Error:

Transducers can give different outputs from the same value of quantity being measured according to whether that value has been reached by a continuously increasing change or a continuously decreasing change. This effect is called Hysterisis.

Repeatability / Reproducibility:

The transducer that are used to describe its ability to give the same output for repeated applications of the same input value.

Repeatability = ((Max. – Min. values given)/Full range)* 100

Stability:

Its ability to give the same output when used to measure a constant input over a period of time.

Resolution:

It is the smallest change in the input value that will produce an observable change in the output.

Types of Sensor

Displacement sensors:

These are concerned with the measurement of the amount by which some object has been moved.

Position sensors:

These are concerned with the determination of the position of some object with reference to some reference point.

Proximity sensors:

These are a form of position sensors and are used to determine when an object has moved to within some particular critical distance of the sensor.

Consideration for selecting a displacement, position and proximity sensor

1. The size of the displacement: for a proximity sensor, how close should the object be before it is detected.
2. Whether the displacement is linear or angular. Linear displacement sensors might be used to monitor the thickness or other dimensions of sheet materials.

Angular displacement methods might be used to monitor the angular displacement of shafts.

3. The resolution and accuracy required.
4. What material the measured object is made i.e., some sensors will only work with ferromagnetic materials some with only metals, some with only insulators.
5. The cost.

Hall Effect sensors

Beam of charged particles passes through a magnetic field, forces act on the particles and the beam is deflected from its straight line path.

A current flowing in a conductor is like a beam of moving charges and thus can be deflected by a magnetic field. This effect is called Hall effect.

Electrons moving in a conductive plate with a magnetic field applied at right angles to the plane of the plate.

As a consequence of the magnetic field, the moving electron is deflected to one side of the plate and thus that side become negatively charged while opposite side becomes positively charged since the electrons are directed away from it.

Light Sensors

Sensors which sense the presence of light are called light sensors or photo sensors. These sensors are also called photo electric transducers because when light falls on these sensors, there exist a change in their electrical property. i.e., light signals induce change in electrical properties of conductance, resistance, inductance etc., of the material.

This change in electrical properties of the material is used to measure a wide range of radiations including intensity of light.

The phenomenon is observed in terms of three effects known as photoemmissive, photoconductive.

Eddy current proximity Sensors

If a coil is supplied with an alternating current, an alternating magnetic field is produced.

If a metal object is in close proximity to this alternating magnetic field, then eddy currents are induced in it.

The eddy current themselves produce a magnetic field. This distorts the magnetic field responsible for their production.

As a result, the amplitude of the alternating current changes. At some preset level this change can be used to trigger a switch.

Chapter-3. ELECTRICAL ACTUATION SYSTEMS:

Solid – state switches

The solid – state switches does not have any moving components, as a result, there will be no inertia, no frictional forces, no delay in operation and no bouncing of the switch. Further, these solid-state switches are quite compact in size.

There are a number of solid-state devices which can be used to electronically switch circuits. These include:

i) Diodes
ii) Thyristors and triacs

Diodes

The diode is an simplest electronic device. It is the simplest of semiconductor devices but play a very vital role in electronic systems with its characteristics that closely match those of a 'simple switch'. It will appear in a range of applications, extending from the simple to the very complex.

The ideal diode is a two – terminal device having the symbol and characteristics shown in fig.

The characteristics of an ideal diode are those of a switch that can conduct current in only one direction.

Thyristors

It is one of the most important type of semi-conductor device. These are used extensively in a power electronic circuits.

A thyristor also called Silicon controlled rectifier (SCR) is a 4 layer semiconductor device of pnpn structure with 3 pn junctions. It has 3 terminals: Anode, Cathode and gate.

When the Anode is connected +ve with respect to cathode the Junction J_1 and J_3 are forward biased and junction J_2 is reverse biased and a small leakage current flows from Anode to cathode.

Triac

It is a combination of 2 SCR's connected back to back as a single units as shown in fig. with a single gate.

It can block the voltage of either polarity but allow current flow in either direction with a current pulse IN or OUT of its single gate.

Either T_1 or T_2 can be made anode, when T_2 is made anode, it resembles SCR and a current pulse into the gate will switch on the device.

When T_2 is made cathode current pulse out of the gate will switch on the device.

Stepper Motors

It is an electro mechanical device which converts discrete electrical pulse into discrete mechanical movements.

The shaft or spindle of a stepper motor rotate at equal angle of increment called steps when electrical command pulses are applied to it in the proper sequence.

Stepper motors with steps of 12, 24, 72, 144 180 and 200 per revolution are available resulting in angle of shaft increments of 30^0, 15^0, 5^0, 2.5^0, 2^0 and 1.8^0 per step.

There are 3 basic types of stepper motor. They are

i) Variable reluctance stepper motor

ii) Permanent magnet stepper motor

iii)Hybrid type stepper motor

Stepper motor specification Phase:

it refers to the number of independent windings on the stator Ex: two phase motor

The current, resistance and inductance of each phase will be specified so that the controller switching output is specified.

Step angle:

The angle through which the stepper motor rotates for one switching change for stator coils.

Holding torque:

it is the maximum torque that can be applied to a powered motor without moving it from its rest position and causing spindle rotation

Pull – in range:

it is the range of frictional load torque at which the motor can start and stop without losing steps.

Pull – in torque:

it is the max. torque against which a motor will start for a given pulse rate and reach synchronism without losing a step.

Pull – out torque:

it is the max. torque that can be applied to a motor running at a given stepping rate, without losing a step.

Pull – in rate:

it is the max. switching rate at which a loaded motor can start without losing a step.

Pull – out rate:

it is the switching rate at which a loaded motor remains in synchronism as switching rate is reduced.

Slew range:

this is range of switching rates between pull – in and pull – out with which the motor runs in synchronism but cannot start up or reverse.

Advantages of stepper motor

Its ability to be accurately controlled in an open loop system. This type of control eliminates the need for expensive and feedback devices. Position is simply known by keeping track of the input pulses.

The rotation angle of the motor is proportional to the input pulse.

The motor has full torque at stand still.

Precise positioning and repeatability of movement, since good stepper motors have an accuracy of 3% to 5% of a step and this error is not cumulative.

Excellent response to starting, stopping and reversing.

Highly reliable because of absence of contact brushes, resulting in increased life of the motor.

Very low synchronous speed can be achieved with a load directly coupled to the shaft of the rotor.

The response of the motor is to digital input pulse provides open-loop control. Motor is less expensive and simpler.

As the speed of the motor is proportional to the frequency of input pulses, a wise range of speed can be achieved

Disadvantages

Very difficult to operate at extremely high speed

Applications:

Because of controlled rotation angle, speed, position and synchronism, stepper motor have found their applications in

Printers, Plotters, Hard disk drives, Fax machines, Medical equipments and Automotive

Chapter-4. SIGNAL CONDITIONING:

Once a mechanical quantity has been sensed by the transducer, a measurement system delivers a signal. This signals needs further processing to make it suitable for the next stage of the operation.

The signal so delivered by the transducer may be too small and hence needed to be amplified, or may be the signal is non-linear and thus requires linearization or may contains interference, which has to be removed.

The process of bringing in the signal to the required status as demanded by the system is generally termed as "Signal conditioning".

SIGNAL CONDITIONING PROCESSES

1. **Protection:** to prevent damage to the next element.
   Ex: A microprocessor, as a result of high current or voltage, thus there can be series current-limiting resistors, fuses to break if the current is too high.
2. **Getting the signal into the right type of signal:**
   This can mean making the signal into a d.c.voltage or current.
   Ex: The resistance change of a strain gauge has to be converted into a voltage change. This can be done by the use of wheatstone bridge and using the out-of-balance voltage.

3. **Getting the level of the signal right:**
   The signal from a thermocouple might be just a few millivolts. If the signal is to be fed into an analogue – to – digital converter for inputting to a microprocessor then it need to be made much larger volts rather than millivolts. Operational amplifiers are widely used for amplification.
4. **Eliminating or reducing noise:**
   Filters might be used to eliminate main noise from a signal
5. **Signal manipulation:**
   The signals from some sensors.
   Ex: A flow meter, are non-linear and thus a signal conditioner might be used so that the signal fed on to the next element is linear

Operational Amplifier

The operational amplifier is a high gain d.c.amplifier.
It has two inputs, known as the inverting input (-) and Non-inverting input (+).
The output depends on the connections made of there inputs. There are other inputs to the operational amplifiers namely negative voltage supply, a positive voltage supply and two inputs termed offset null, these are being enable corrections to be made for the non-ideal behaviour of the amplifier.

Inverting amplifier or Negative scale amplifier

The input is given to the inverting input terminal through a resistor Ri with the non-inverting input being connected to the ground.
A feed back path is provided from the output through the feed back resistor Rf to the inverting input.
Input and feed back currents are algebraic added at point x, it is called summing point.

The concept of virtual ground arises from the fact that input voltage at the inverting terminal of the operational amplifier is forced to such a value, that for all practical purposes it may be assumed to be zero.

Differential Amplifier

It is one that amplifies the difference between two input voltages. There is virtually no current flow takes place through the high resistance in the operational amplifier between the two input terminals.

Comparator

It is used to determine whether one signal is greater than another. Due to the high gain.

A few hundred micro volts change in the input can be sufficient to change the output level of the operational amplifier from –ve saturation. (saturation implies that the output remains at its most +ve or most –ve output value).

The maximum range of input over which comparison can be made is limited by the allowable common mode voltage range.

Filters

It is used to describe the process of removing a certain ban of frequencies from a signal and permitting others to be transmitted.

The range of frequencies passed by a filter is known as pass band, the range not passed as the stop band and the boundary between stopping and passing as the cut-off frequency.

Filters are classified according to the frequency ranges they transmit or reject.

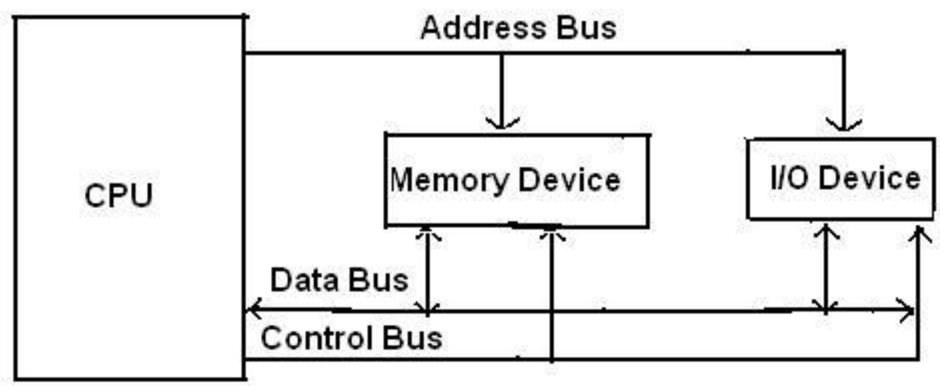
Types of filter

i) Low – pass filter
ii) High – pass filter
iii) Band – pass filter
iv) Band – stop filter

Chapter-5. INTRODUCTION TO MICROPROCESSORS

Introduction

A Microprocessor is a multipurpose programmable logic device which reads the binary instructions from a storage device called 'Memory' , accepts binary data as input and process data according to the instructions and gives the results as output. So, you can understand the Microprocessor as a programmable digital device, which can be used for both data processing and control applications. In view of a computer student, it is the CPU of a Computer or heart of the computer. A computer which is built around a microprocessor is called a microcomputer. A microcomputer system consists of a CPU (microprocessor), memories (primary and secondary) and I/O devices as shown in the block diagram. The memory and I/O devices are linked by data and address (control) buses. The CPU communicates with only one peripheral at a time by enabling the peripheral by the control signal. For example to send data to the output device, the CPU places the device address on the address bus, data on the data bus and enables the output device. The other peripherals that are not enabled remain in high impedance state called tri-state.



Evolution of Microprocessors

The first Microprocessor (4004) was designed by Intel Corporation which was founded by Moore and Noyce in 1968. In the early years, Intel focused on developing semiconductor memories (DRAMs and EPROMs) for digital computers. In 1969, a Japanese Calculator manufacturer, Busicom approached Intel with a design for a small calculator which need 12 custom chips. Ted Hoff, an Intel Engineer thought that a general purpose logic device could replace the multiple components. This idea led to the development of the first so called microprocessor. So, Microprocessors started with a modest beginning of drivers for calculators. Fedrico Faggin and Stanely Mazor implemented the ideas of Ted Hoff's and designed the Intel 4000 family of processors comprising 4001 (2K-ROM), the 4002 (320 bit RAM), the 4003 (10 bit I/O shift-register) and the 4004, a 4 bit CPU. Intel introduced the 4004 microprocessor to the world wide market on November 15, 1971. It was a 4-bit PMOS chip with 2300 transistors. Around the same time Texas Instruments developed a 4-bit microprocessor TMS 1000 and became the owner of microprocessor patent. Later Intel introduced world's first 8 bit general purpose microprocessor 8008 in 1972. This processor was used in the popular computer 'Mark-8' in those days. In 1974, Intel introduced the improved version of 8008, the 8080 microprocessor. This 8080 is the much more highly integrated chip than its predecessors which is built around N-channel MOS technology

The Intel 8085 Microprocessor: Intel 8085A is a single chip 8-bit N-channel microprocessor which works at +5V DC power supply. It is a 40 pin IC available as a DIP (Dual Inline Package) chip. 8085A can operate with a 3MHZ single phase clock and 8085A-2 version can operate at a maximum frequency of 5MHZ. This 8085 is an enhanced version of its predecessor the 8080A. Its instruction set is upward compatible with that of the 8080A. 8085A has an on-chip clock generator with external crystal, LC or RC network. This 8085 microprocessor is built with nearly 6200 transistors. The enhanced version of 8080 is the Intel 8085AH. It is an N channel depletion load, silicon gate (HMOS) 8-bit processor. Here 3MHZ, 5MHZ and 6MHZ selections are available. It has 20% lower power consumption than 8085A for 3MHZ and 5MHZ. Its instruction set is 100% software compatible with the 8085A. It is also 100% compatible with 8085A.

Organization of Microprocessor

Central Processing Unit (CPU)

(i). Arithmetic and logic unit (ALU)
(ii).Registers
(iii).Timing and Control unit.

Arithmetic and logic unit (ALU)

(a).Accumulator (A).
(b).Temporary register.
(c).Flag register

Register Organization

(i).Temporary registers.
(ii).General purpose registers
(iii).Special purpose registers.

Timing and control Unit

Address, Data and Control Buses

Number Systems

here's the decimal number system as an example:

digits (or symbols) allowed: 0-9
base (or radix): 10
the order of the digits is significant

345 is really

3 x 100 + 4 x 10 + 5 x 1
3 x 10**2 + 4 x 10**1 + 5 x 10**0

3 is the most significant symbol (it carries the most weight)
5 is the least significant symbol (it carries the least weight)

here's a binary number system:

digits (symbols) allowed: 0, 1
base (radix): 2

each binary digit is called a BIT

the order of the digits is significant

numbering of the digits

msb lsb
n-1 0
where n is the number of digits in the number

1001 (base 2) is really
1 x 2**3 + 0 x 2**2 + 0 x 2**1 + 1 x 2**0
9 (base 10)

11000 (base 2) is really
1 x 2**4 + 1 x 2**3 + 0 x 2**2 + 0 x 2**1 + 0 x 2**0
24 (base 10)

here's an octal number system:

digits (symbols) allowed: 0-7
base (radix): 8

the order of the digits is significant

345 (base 8) is really
3 x 8**2 + 4 x 8**1 + 5 x 8**0
192 + 32 + 5
229 (base 10)

1001 (base 8) is really
1 x 8**3 + 0 x 8**2 + 0 x 8**1 + 1 x 8**0
512 + 0 + 0 + 1
513 (base 10)

here's a hexadecimal number system:

digits (symbols) allowed: 0-9, a-f

base (radix): 16

the order of the digits is significant

hex decimal
0 0
1 1.
9 9
a 10
b 11
c 12
d 13
e 14
f 15

a3 (base 16) is really
a x 16**1 + 3 x 16**0
160 + 3
163 (base 10)

BINARY FRACTIONS

Example:
101.001 (binary)
1 x 2**2 + 1 x 2**0 + 1 x 2**-3
4 + 1 + 1/8
5 1/8 = 5.125 (decimal)

2**-1 = .5
2**-2 = .25
2**-3 = .125
2**-4 = .0625 etc.

Logic Gates

The basic logic gates are AND, OR, NAND, NOR, XOR, INV, and BUF. The last two are not
standard terms; they stand for \inverter" and \buffer", respectively.

Boolean Algebra and DeMorgan's Theorems

Boolean algebra can be used to formalize the combinations of binary logic states. The fundamental relations are given in Table 8.3 of the text. In these relations, A and B are binary quantities, that is, they can be either logical true (T or 1) or logical false (F or 0). Most of these relations are obvious. Here are a few of them:
$AA = A$; $A + A = A$; $A + A = 1$; $AA = 0$; $A = A$
Recall that the text sometimes uses an apostrophe for inversion ($A0$). We use the standard Over bar notation (A).
We can use algebraic expressions to complete our definitions of the basic logic gates

we began above. Note that the Boolean operations of \multiplication" and \addition" are defined by the truth tables for the AND and OR gates given above in Figs. 3 and 4. Using these definitions, we can define all of the logic gates algebraically. The truth tables can also
be constructed from these relations, if necessary. See Fig. 2 for the gate symbols.

AND: $Q = AB$
OR: $Q = A + B$
NAND: $Q = AB$
NOR: $Q = A + B$
XOR: $Q = A$ _ B

Chapter-6. LOGIC FUNCTION

The Intel 8085 Microprocessor

i)Central Processing Unit (CPU**)**
ii)Arithmetic and logic unit (ALU)
(a).Accumulator.
(b).Temporary register.
(c).Flag register.

Register Organization

(i).Temporary registers.
(ii).General purpose registers
(iii).Special purpose registers.

Address, Data and Control Buses

Timing Diagram

1. Opcode fetch
2. Memory read
3. Memory write
4. I/O read
5. I/O write
6. Interrupt acknowledge

Chapter-7. ORGANIZATION & PROGRAMMING OF MICROPROCESSORS

Pin configuration

The pin diagram of 8085 microprocessor is 40 pin DIP chip. The various pins of 8085 microprocessor can be grouped in the following categories

Power Supply and Clock pins
Data bus and Address bus
Control and Status signals
Interrupt signals
DMA signals
Serial I/O signals

Power supply and clock pins

Vcc: +5V power supply
Vss: Ground reference.

X_1 and X_2: A Crystal (or RC, LC Network) is connected at these two pins. The internal clock generator divides oscillator frequency by 2, therefore to operate a system at 3MHZ, the crystal of the tuned circuit should have a frequency of 6MHZ.

CLK (OUT): This signal is used as a system clock for other devices. Its frequency is half the oscillator frequency

Data bus and Address bus:

AD_0-AD_7: These lines are Address/Data lines, which are bidirectional with dual purpose. They are used as the low-order address bus as well as the data bus. During the first part of the machine cycle (T_1), lower 8 bits of memory address or I/O address appear on the bus. During the remaining part of the machine cycle (T_2,T_3) these lines are used as a bi-directional data bus

A_8-A_0: These are the upper half of the 16 bit address lines. These lines are exclusively used for the most significant 8 bits of the 16 bits of the16 bit address bus.

Control and Status Signals

ALE (Address Latch Enable): This is a positive going pulse generated every time the 8085 begins an operation. The ALE=High indicates that the bits on AD_7-AD_0 are address bits. This signal is mainly used to latch the low order address from the multiplexed bus and generate a separate set of eight address lines (A7-A_0)

$\overline{RD}$ (Read): This is an active low read control pin. This signal indicates that the selected I/O or memory device is to be read and data are available on data bus.

$\overline{WR}$ (Write): This is an active low write control pin. It indicates that the data on the data on the data bus are to be are to be written into a selected memory or I/O location

IO/$\overline{M}$: This is a status signal used to differentiate between IO and memory operations. When it is high, it indicates an I/O operation and when it is low, it indicates a memory operation. This signal is combined with $\overline{RD}$ and $\overline{WR}$ signals to generate I/O and memory control signals.

S_1 and S_0: These are status signals and they indicate the type of machine cycle in progress during execution of an instruction.

READY (Input): Through this pin, the microprocessor will know whether peripheral device is ready or not for data transfer. If the device is not ready the processor waits. So, this pin helps to synchronize slow devices to the microprocessor

Interrupt signals:TRAP, RST 7.5, RST 6.5, RST5.5 and INTR: These are the interrupt signals which are externally initiated.

INTR (Interrupt Request): This is used as a general purpose interrupt. It has a lowest priority and it is the only non-vectored interrupt.

RST 7.5: It is a restart interrupt pin. It has higher priority than RST 6.5, RST5.5 and INTR. It is a maskable vectored interrupt.

RST 6.5 and RST5.5: These two are maskable vectored interrupt with higher priority than INTR.

TRAP: It is a non-maskable vectored interrupt. It has higher priority.

$\overline{INTA}$ (Output): It is an active low interrupt acknowledge pin. This will acknowledge the receival of interrupt request to the peripheral device.

Hold: This pin is used during the Direct Memory Access. A high on this pin indicates that, a peripheral like DMA controller is requesting the use of address and data buses.

HLDA (Output): A high on this p in acknowledges the hold request from peripheral.

$\overline{RESET\ IN}$: It is an active low signal. When the signal on this pin goes low, the system is in reset i.e. the program counter is set to zero, the address & data buses are tristated.

RESETOUT: This signal is used to Reset other devices in microprocessor system.

Serial input/ Output signals:

SID: Serial input Data is a pin through which serial data are brought into the micro processor accumulator after the RIM instruction is executed.

SOD: Serial output Data pin is used by the microprocessor to output data serially to the external devices. Serial data is sent out of the microprocessor by executing SIM instruction. The most significant bit of accumulator should have the serial bit and D_6 bit of the accumulator must be made high to enable the serial data transfer.

Chapter-8. CENTRAL PROCESSING UNIT OF MICROPROCESSORS

Opcode fetch Machine cycle

Memory Read cycle

Memory Write cycle

I/O Read cycle

I/O write cycle

Instruction cycle, Machine cycle, fetch and execute cycles

i) **Instruction cycle**
ii) **Machine cycle**
iii) **Fetch operation**
iv) **Execute operation**

Instruction set of 8085

i) **One–byte instructions**
ii) **Two–byte instructions**
iii) **Three–byte instructions**

CLASSIFICATION OF INSTRUCTIONS

1. Data transfer (copy) group.
2. Arithmetic group
3. Logic group
4. Branch control group
5. Machine control and I/O group.