Applications of Real-Time Systems:

1. Industrial Applications

Industrial applications constitute a major usage area of real-time systems. A few examples of industrial applications of real-time systems are: process control systems, industrial automation systems, SCADA applications, test and measurement equipments, and robotic equipments.

Example 1: Chemical Plant Control

Chemical plant control systems are essentially a type of process control application. In an automated chemical plant, a real-time computer periodically monitors plant conditions. The plant conditions are determined based on current readings of pressure, temperature, and chemical concentration of the reaction chamber. These parameters are sampled periodically. Based on the values sampled at any time, the automation system decides on the corrective actions necessary at that instant to maintain the chemical reaction at a certain rate.

Each time the plant conditions are sampled, the automation system should decide on the exact instantaneous corrective actions required such as changing the pressure, temperature, or chemical concentration and carry out these actions within certain predefined time bounds. Typically, the time bounds in such a chemical plant control application range from a few micro seconds to several milliseconds.

Example 2: Automated Car Assembly Plant

An automated car assembly plant is an example of a plant automation system. In an automated car assembly plant, the work product (partially assembled car) moves on a conveyor belt. By the side of the conveyor belt, several workstations are placed. Each workstation performs some specific work on the work product such as fitting engine, fitting door, fitting wheel, and spray painting the car, etc. as it moves on the conveyor belt. An empty chassis is introduced near the first workstation on the conveyor belt. A fully assembled car comes out after the work product goes past all the workstations. At each workstation, a sensor senses the arrival of the next partially assembled product. As soon as the partially assembled product is sensed, the workstation begins to perform its work on the work product. The time constraint imposed on the workstation computer is that the workstation must complete its work before the work product moves away to the next workstation. The time bounds involved here are typically of the order of a few hundreds of milliseconds.

Example 3: Supervisory Control and Data Acquisition (SCADA)

SCADA are a category of distributed control systems being used in many industries. A SCADA system helps monitor and control a large number of distributed events of interest. In SCADA systems, sensors are scattered at various geographic locations to collect raw data (called events of interest). These data are then processed and stored in a real-time database. The database reflects the current state of the environment. The database is updated frequently to make it a realistic model of the up-to-date state of the environment. An example of a SCADA application is an Energy Management System (EMS). An EMS helps to carry out load balancing in an electrical energy distribution network. The EMS senses the energy consumption at the distribution points and computes the load across different phases of power supply. It also helps dynamically balance the load. Another example of a SCADA system is a system that monitors and controls traffic in a computer network. Depending on the sensed load in different segments of the network, the SCADA system makes the router change its traffic routing policy dynamically.

2. Medical

A few examples of medical applications of real-time systems are: robots, MRI scanners, radiation therapy equipments, bedside monitors, and computerized axial tomography (CAT).

Example 4: Robot Used in Recovery of Displaced Radioactive Material

Robots have become very popular nowadays and are being used in a wide variety of medical applications. An application that we discuss here is a robot used in retrieving displaced radioactive materials. Radioactive materials such as Cobalt and Radium are used for treatment of cancer. At times during treatment, the radioactive Cobalt (or Radium) gets dislocated and falls down. Since human beings can not come near a radioactive material, a robot is used to restore the radioactive material to its proper position. The robot walks into the room containing the radioactive material, picks it up, and restores it to its proper position. The robot has to sense its environment frequently and based on this information, plan its path. The real-time constraint on the path planning task of the robot is that unless it plans the path fast enough after an obstacle is detected, it may collide with it. The time constraints involved here are of the order of a few milliseconds.

3. Peripheral Equipments

A few examples of peripheral equipments that contain embedded real-time systems are: laser printers, digital copiers, fax machines, digital cameras, and scanners.

Example 5: Laser Printer

Most laser printers have powerful microprocessors embedded in them to control different activities associated with printing. The important activities that a microprocessor embedded in a laser printer performs include the following: getting data from the communication port(s), typesetting fonts, sensing paper jams, noticing when the printer runs out of paper, sensing when the user presses a button on the control panel, and displaying various messages to the user. The most complex activity that the microprocessor performs is driving the laser engine. The basic command that a laser engine supports is to put a black dot on the paper. However, the laser engine has no idea about the exact shapes of different fonts, font sizes, italic, underlining, boldface, etc. that it may be asked to print. The embedded microprocessor receives print commands on its input port and determines how the dots can be composed to achieve the desired document and manages printing the exact shapes through a series of dot commands issued to the laser engine. The time constraints involved here are of the order of a few milli seconds.

4. Telecommunication Applications

A few example uses of real-time systems in telecommunication applications are: cellular systems and cable modems.

Example 6: A Cellular System

Cellular systems have become a very popular means of mobile communication. A cellular system usually maps a city into cells. In each cell, a base station monitors the mobile handsets present in the cell. Besides, the base station performs several tasks such as locating a user, sending and receiving control messages to a handset, keeping track of call details for billing purposes, and hand-off of calls as the mobile moves. Call hand-off is required when a mobile moves away from a base station. As a mobile moves away, its received signal strength (RSS) falls at the base station. The base station monitors this and as soon as the RSS falls below a certain threshold value, it hands-off the details of the on-going call of the mobile to the base station of the cell to which the mobile has moved. The hand-off must be completed within a sufficiently small predefined time interval so that the user does not feel any temporary disruption of service during the hand-off. Typically call hand-off is required to be achieved within a few milliseconds.

Example 7: Cell Phones

Cell phones are possibly the fastest growing segment of consumer electronics. A cell phone at any point of time carries out a number of tasks simultaneously. These include: converting input voice to digital signals by deploying digital signal processing (DSP) techniques, converting electrical signals generated by the microphone to output voice signals, and sampling incoming base station signals in the control channel. A cell phone responds to the communications received from the base station within certain specified time bounds.

5. Internet and Multimedia Applications

Important use of real-time systems in multimedia and Internet applications include: video conferencing and multimedia multicast, Internet routers and switches.

Example 8: Video Conferencing

In a video conferencing application, video and audio signals are generated by cameras and microphones respectively. The data are sampled at a certain pre-specified frame rate. These are then compressed and sent as packets to the receiver over a network. At the receiver-end, packets are ordered, decompressed, and then played. The time constraint at the receiver-end is that the receiver must process and play the received frames at a predetermined constant rate. Thus if thirty frames are to be shown every minute, once a frame play-out is complete, the next frame must be played within two seconds.

6. Defense Applications

Typical defense applications of real-time systems include: missile guidance systems, anti- missile systems, satellite-based surveillance systems.

Example 9: Missile Guidance System

A guided missile is one that is capable of sensing the target and homes onto it. Homing becomes easy when the target emits either electrical or thermal radiation. In a missile guidance system, missile guidance is achieved by a computer mounted on the missile. The mounted computer computes the deviation from the required trajectory and effects track changes of the missile to guide it onto the target. The time constraint on the computer-based guidance system is that the sensing and the track correction tasks must be activated frequently enough to keep the missile from diverging from the target. The target sensing and track correction tasks are typically required to be completed within a few hundreds of microseconds or even lesser time depending on the speed of the missile and the type of the target.

7. Miscellaneous Applications

Besides the areas of applications already discussed, real-time systems have found numerous other applications in our every day life. An example of such an application is a railway reservation system.

Example 10: Railway Reservation System

In a railway reservation system, a central repository maintains the up-to-date data on booking status of various trains. Ticket booking counters are distributed across different geographic locations. Customers queue up at different booking counters and submit their reservation requests. After a reservation request is made at a counter, it normally takes only a few seconds for the system to confirm the reservation and print the ticket. A real-time constraint in this application is that once a request is made to the computer, it must print the ticket or display the seat unavailability message before the average human response time (about 20 seconds) expires, so that the customers do not notice any delay and get a feeling of having obtained instant results.

8. Signal Processing and Tracking

A few important use of real-time systems in signal processing and tracking are: Radar, ATC (Air Traffic Control) and satellite tracking systems.

Example 11: Radar

From hand written notes

Example 12: ATC (Air Traffic Control)

From hand written notes

✳ Real Time System :-

Real time system is required to complete its work and deliver services on a timely basis. RTS can be defined as those computing system that are designed to operate in a timely manner.

It is a quantitative notation of time & measured using a physical real clock.

✳ Application of RTS :-

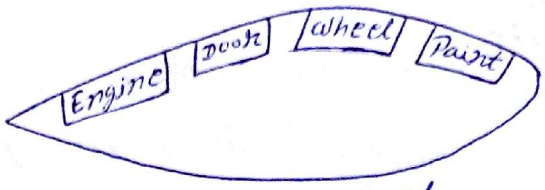
1) Chemical Plant
2) Automated Car Plant System
3) SCADA (Supervisitory control & Data Acquisition) } Industrial Application

4) Laser Printer } Peripheral Equipment
5) Missile Guidance } Deffence
6) Cellular System } Mobile handoff
7) Radar
8) ATC (Air Traffic control) } Signal Processing & Tracking
9) Video conferencing } Multimedia application
10) Railway Reservation } Miscellaneous application
11) AGV (Automated Guided Vehicle)

✳ Chemical Plant :-

In an automated chemical plant real time computer periodically monitors plant conditions - temperature, pressure etc. Based on the sample value at any time the automation system decides the corrective actions to maintain chemical reaction at a certain rate.

* Automated car Plant System :-



convayar Belt

* SCADA :- It controls large number of distributed system. It has sensor at different geographical location to access raw data, ~~and then~~ process and then store in real time database.

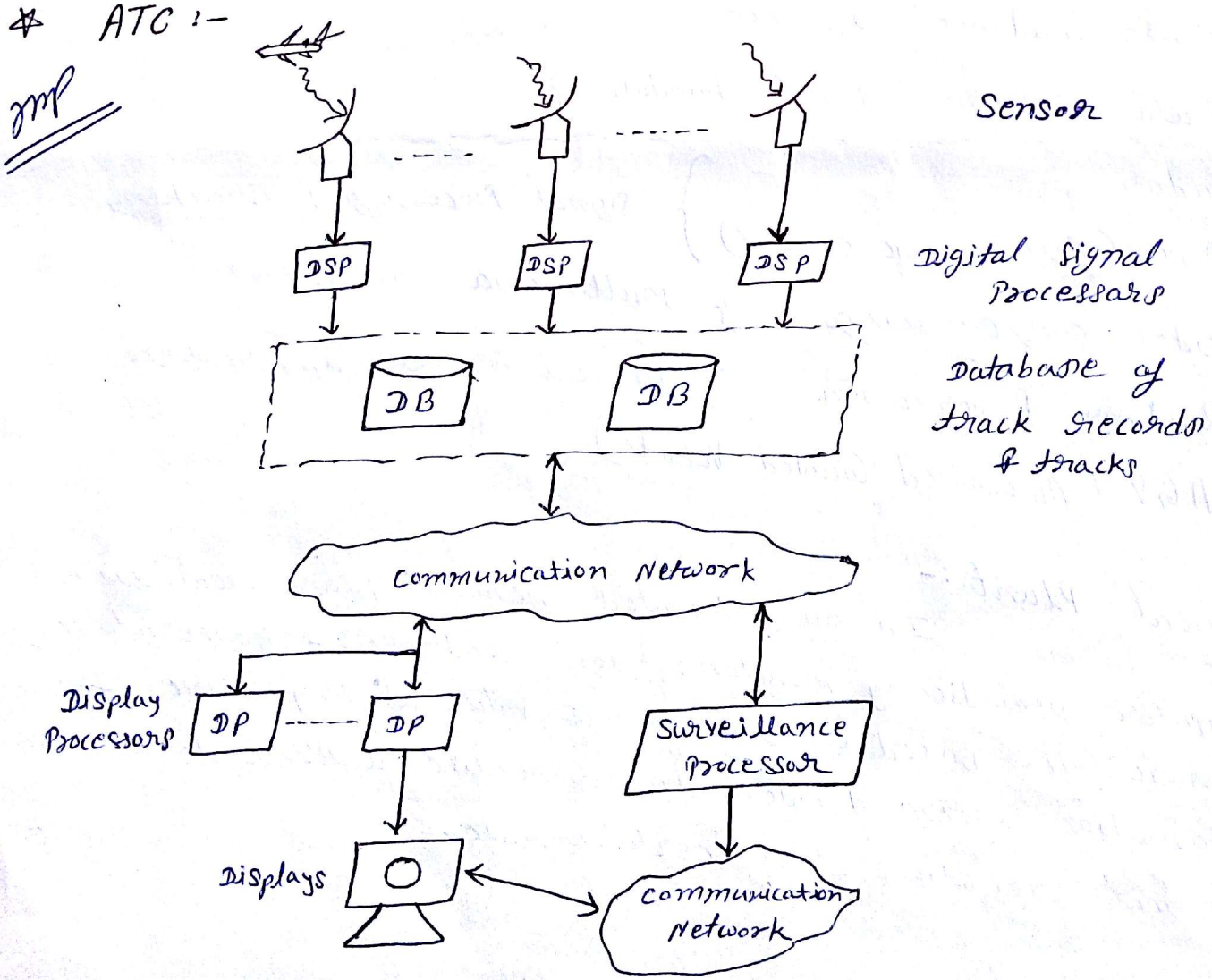
* Laser Printer :-

Paper sense → Ink → I/p → Font setting → Buffering

* Missile Guidance :-

It fix the missile target coordinate and speed of missile.

* ATC :-



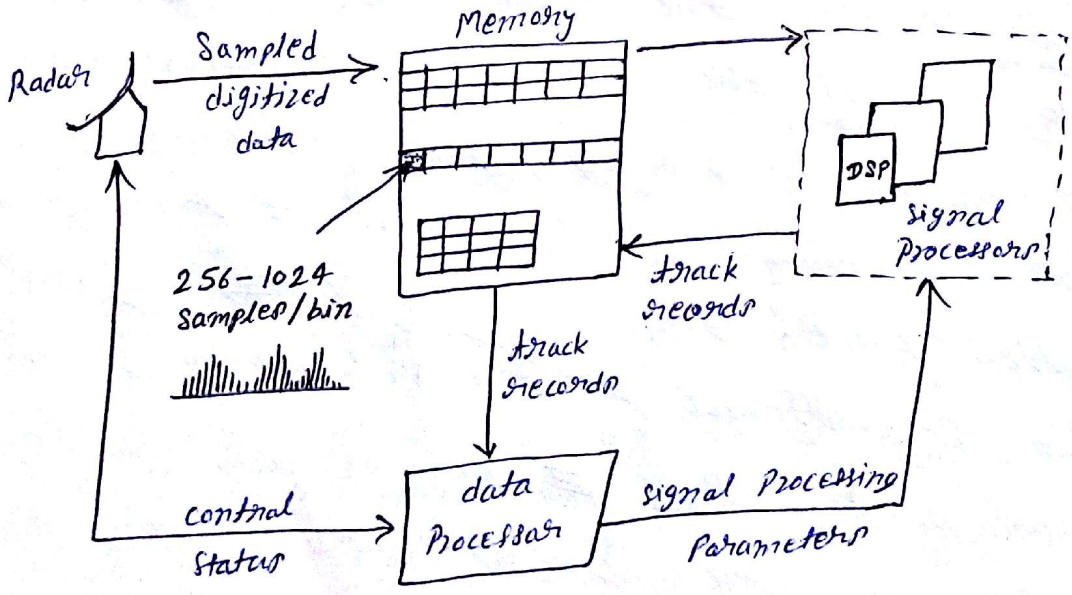
✱ Air Traffic Control :-

The ATC System monitors the aircraft in its coverage area and the environmental condition, and generates the information needed by the operator, i.e. air traffic controller. It supports the communication among the operators at both levels Pilots & air traffic controller.

The ATC system gathers information on the "state" of each aircraft via one or more active radars. Such a radar interrogates each aircraft periodically. when interrogated, any aircraft responds by sending to the ATC system, like: identifier, position etc. This variables are collectively refered as track record of air craft.

The ATC System processes messages from aircraft and stores the state information in the database. This information is picked up and processed by display processors. At the same time, a surveillance system continuously analyzes the ~~scenario~~ System and alerts the operators ~~whether~~ whenever it detects any potential hazard.

✱ Radar :-



[Radar Signal Processing & Tracking System]

→ The system consists of an I/O subsystem that samples and digitizes the echo signal from the radar and places the sampled values in a shared memory.

→ An array of DSP processes this sampled values.

→ Thus the data are analyzed by one or more data processors, which interface with the display system and generate commands to control the radar; and select the parameters to be used by signal processors in the next cycle of data collection and analysis.

→ To search for an objects of interest in its coverage area, the radar scans the area by pointing its antenna in one direction at a time.

→ It first sends a short radio frequency pulse, that collect the eco signal returning to the antenna.

→ The eco signal consists of background noise if the transmitted pulse does not hit any object.

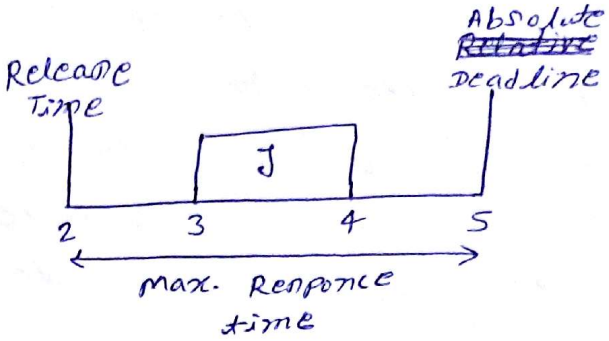
→ If there is any object at a distance x meters from the antenna, the eco signal reflected by the object returns to the antenna at approximately $2x/c$ seconds after the transmitted pulse, where $c = 3 \times 10^8$ m/s is the speed of light.

→ If the object is moving, the frequency of the reflected signal is no longer equal to that of the transmitted pulse; the amount of frequency shift is proportional to the velocity of the object.

→ So, by examining the eco signal, the system can determine whether there are object in the direction pointed by antenna and if there are objects, what are there positions and velocities.

✯ Task Parameters :-

1) Release Time
2) Responce Time
3) Deadline ⟶ Absolute
   ⟶ Relative
4) Tardiness of Job
5) Execution time



✯ Jobs, Task & Processors :-

Each unit of work that is scheduled and executed by the system, is called Job; and set of related Jobs which jointly Provide some system function, is called task.

Every Job executes on some resource, all these resources are called Processors.

→ Release Time :-

The release time of a Job is the instant of time at which the Job becomes available for execution. The Job can be scheduled and executed at ~~eg~~ any time at or after its release time, whenever its conditions are met.

→ Responce Time :-

The responce time is the length of time from the release time of the Job to the instant when it completes. The maximum allowable responce time of a Job is its relative deadline.

→ Deadline :-

It is the instant of time by which execution required of Job is to be completed. The maximum allowable responce time of a Job is its relative deadline; and absolute deadline is equal to its release time + relative deadline.

Let Release time = 2
Relative deadline = 3
then absolute deadline = 2+3 = 5

→ Tardiness of Job :-

The tardiness of job measures how late it complete with respect to its deadline.

T = 0, if job complete on deadline.

T = -ve, if job complete before deadline.

T = +ve, if job complete after deadline.

→ Execution Time :-

The execution time ~~of a job~~ is the time required to complete the job. It depends on complexity of job and speed of Processor.

Concept

✱ ~~Types~~ of Tasks :-

1) Periodic Task :-

A task which repeat after fix interval of time, is called periodic task. A periodic task T_i represented by four tuples —

$T_i = (\phi_i, P_i, e_i, d_i)$

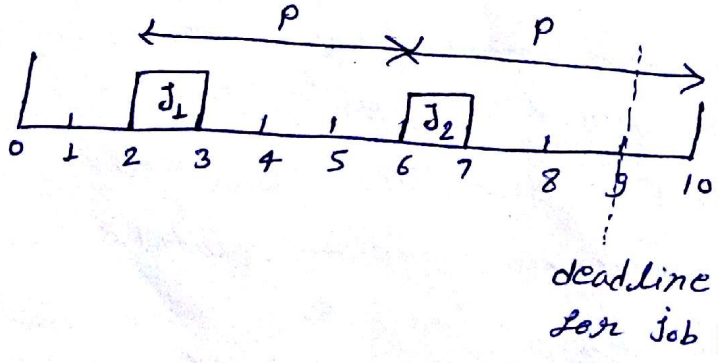
ϕ_i → Phase (Release time of first job J_{1i} in task T_i)

P_i → Period of each job in task T_i

e_i → execution time of each job in task T_i

d_i → ~~Abso~~ Relative deadline " " " " "

EX $T_1 = (\overset{2}{\cancel{1}}, 4, 1, 7)$



2) Sporadic Task :- A sporadic task in one that occures at random instant and have ~~minimum~~ separation time between two consecutive ~~int~~ instance of task implies that once an instance of sporadic task occare, the next instance cannot occure before g_i unit of time have elapsed. This type of task have hard deadlines.

It is denoted by three parameters :-

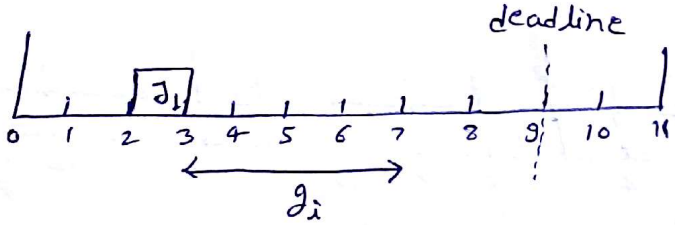
$T_i = (e_i, g_i, d_i)$

$e_i \rightarrow$ execution time

$g_i \rightarrow$ separation time

$d_i \rightarrow$ ~~Relative~~ Relative deadline

EX $T = (1, 4, 7)$



3) Aperiodic Task :- A task in called aperiodic task if the job in it have either soft deadlines or no deadlines, and there is no separation time between two instances of task.

* Numerical on Periodic Task ⇒

Hyper Period :- The hyper period (H) of a set of periodic task is the LCM of their periods.

$$H = LCM(P_i)$$

$$i = 1, 2, 3, \cdots n$$

Total no. of jobs in hyperperiod $= \sum_{j=1}^{n} H/P_j$

where $P_j \rightarrow$ period of task j

$n \rightarrow$ number of task

Utilization of task T_j is ratio of execution time & period of task P_j.

$$U_j = e_j/P_j$$

Total utilization of system is sum of the utilization of all the task in a given system.

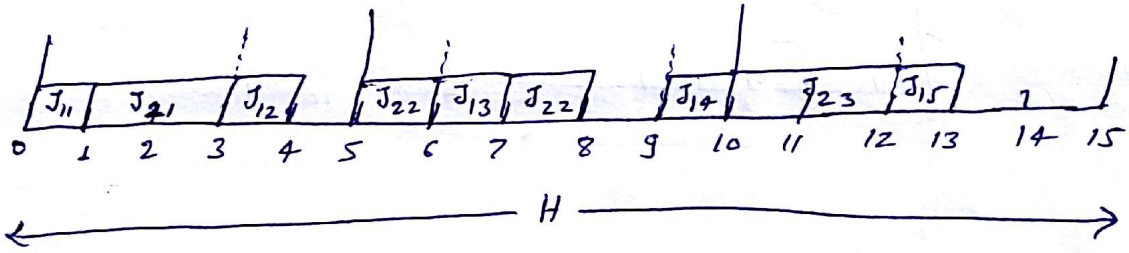
$$U = \sum_{j=1}^{n} U_j$$

EX $T_1 = (3, 1)$ $T_2 = (5, 2)$

$T_i = (P, e)$

$\phi = 0$ & $d = P$

Priority $T_1 > T_2$



$H = LCM(P_i)$

$H = LCM(3, 5) = 15$

Total no. of Jobs in $H = \sum_{j=1}^{n} H/P_j$

$= \frac{15}{3} + \frac{15}{5}$

$= 5 + 3 = 8$ Jobs

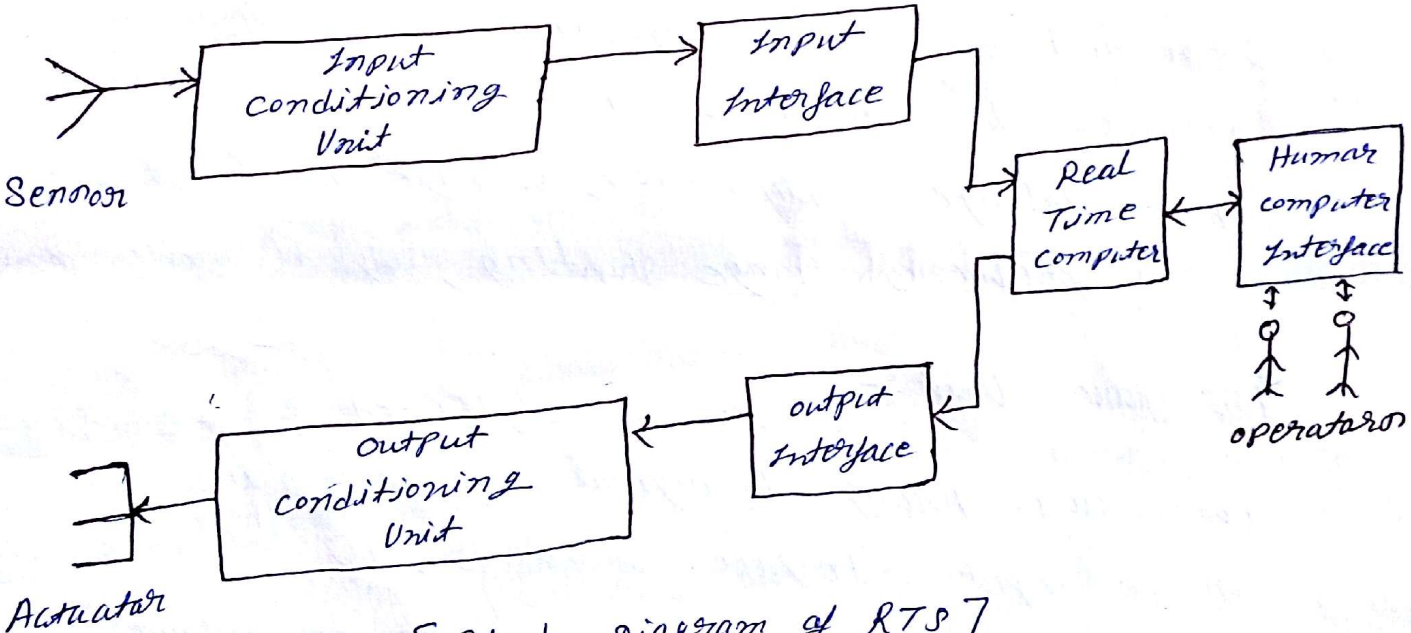
Utilization:- $U_1 = 1/3$

$U_2 = 2/5$

$$U = \frac{1}{3} + \frac{2}{5} = \frac{5+6}{15} = \frac{11}{15}$$

* RTS Block Diagram :-

A real time system is defined as a system in which the time where the outputs are produced is significant. The o/p must be produced within specified time bounds referred to as deadlines. The correctness of a RTS depends not only on the logical results produced, but also on the times at which such results were produced. The system may enter an incorrect state if a correct result is produced too early or too late with respect to the specified time bounds or deadlines.



[Block Diagram of RTS]

A block diagram is a simple model of a real time system in terms of its important functional blocks.

Sensor :- A sensor converts some physical characteristic of its environment into electrical signals. An example of sensor is a photo-voltaic cell which converts light energy into electrical energy.

Actuator :- An actuator is any device that takes its i/p from the output interface of a computer and converts these electrical signal into some physical actions on its environment. A popular example of actuator is motor.

Signal conditioning Unit :-

The electrical signals produced by a computer can rarely be used to directly drive an actuator. The computer signals usually need conditioning ~~unit~~ before they can be used by the actuator, this is termed as a output conditioning.

Similarly, input conditioning is required on sensor signals before they can be accepted by the computer.

EX :- Voltage Amplification, Voltage level shifting, frequency range shifting, signal mode conversion.

Interface Unit :-

It is basically used for the signal conversion. Analog to digital conversion is deployed in an input interface. similarly, digital to analog conversion is frequently used in an output interface.

* Types of RTOS Tasks :-

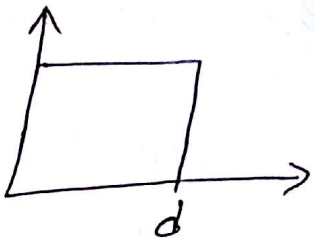
1) Hard Real Time System/task
2) Firm Real Time System/task
3) Soft Real Time System/task

1) Hard Real Time System :-

A hard real time system is one that is construct to produce its result within certain predefine time bounds.

The system is consider to have failed, whenever any of its hard real time task doesn't produce its require result before the specified time bound.

In this type system, it is necessary to complete task within deadline otherwise it will create big hazard.



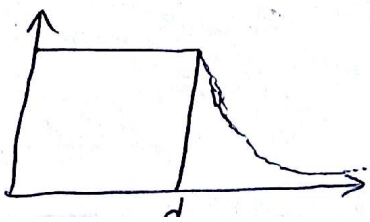
Ex Antimissile System
AGV (Automated Guided Vehicle)

In antimissile system, which sense the incoming missile and destroy before they hard or cause demage.

In AGV, sensor detector any obstacle present, tracking the object and finding path etc. If vehicle suddenly encounter an obstacle, sensor must detect it soonly and try to escape colliding with it.

2) Firm Real Time System :-

Every task is associated with some predefine deadline. Unlike hard real time system, when a firm real time system doesn't complete within its deadline the system doesn't fail. The late result are discarded.



EX satellite based tracking -

In tracking of animal movement using satelline, when the ground computer is overloaded, a new image may be received before an older image taken for processing. In this case the older image may be discarded and recently received image could be processed.

3) Soft Real Time System :—

Unlike hard and firm real time system, the timing constraint on Soft RTS are not express as absolute value. Instead the constraints are expressed in terms of average run time require.

EX :- Web browsing