Introduction to Real time System

The earliest proposal to use a computer operating in " real time " as part of a control system was made at a 1950 by Brown and Campbell. They are assumed that analog-computing element.

The first digital computers developed specifically for real time control were for airborne operation and in 1954 digital computer was successfully used to provide an automatic flight and weapons control system.

Element of Computer Control System

As an example we shall consider a simple plant a "hot-air blower " as shown in figure bellow.

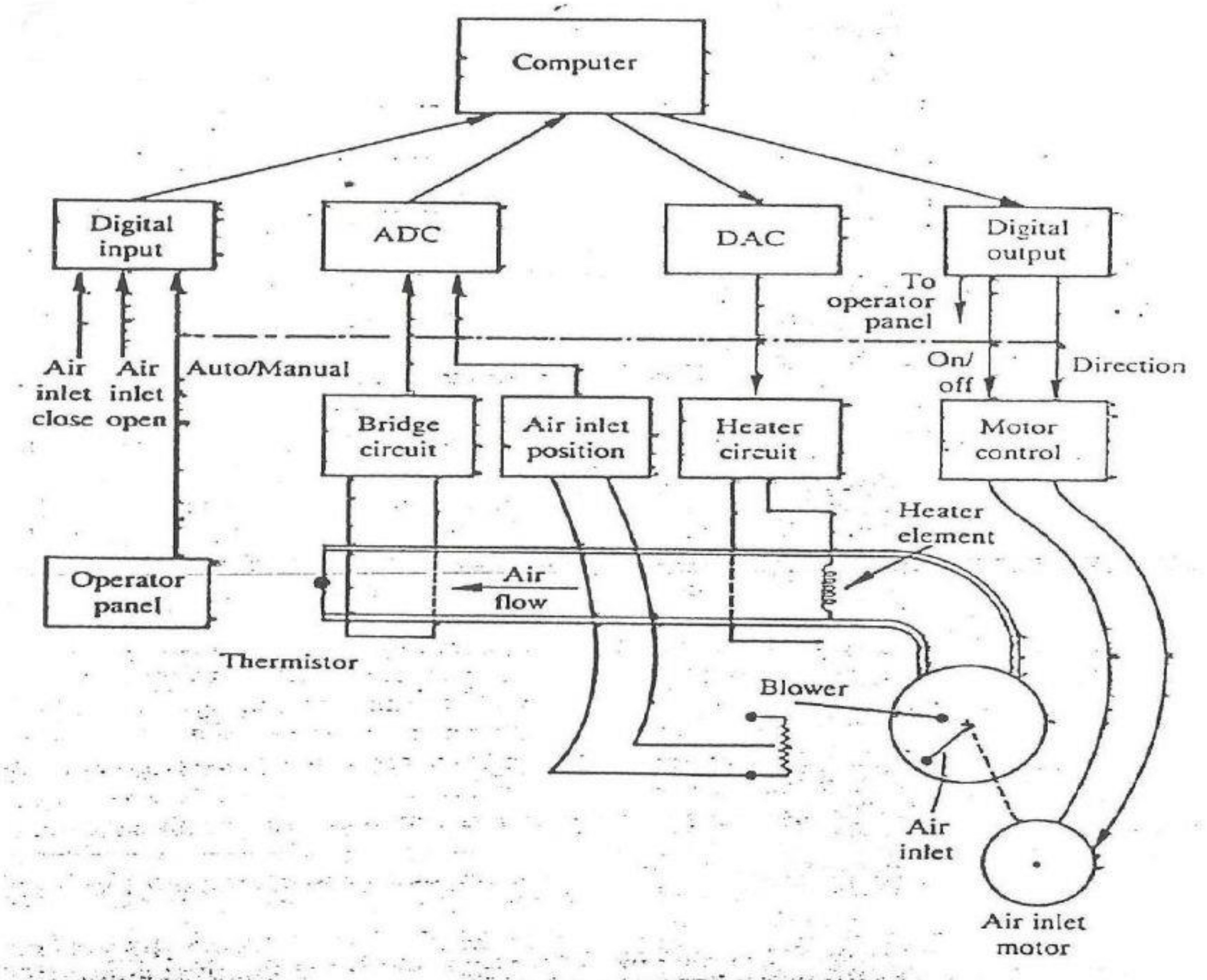

Fig. Computer control of a hot-air blower.

A Fan blows air over a heating element and into a tube. A thermistor bead (sensor) is placed at the outlet of the tube and forms one arm at a bridge circuit. The amplified output of the bridge circuit is provides a voltage in the range (0-10) volt , proportional to temperature. The current supplied to the heating element can be varied by supplying a dc voltage in the range (0-10) volt.

The position of the air-infect cover to the fan is adjusted by means of a reversible motor. The motor operates at constant speed and it turned On/Off by a logic signal applied to its controller, a second logic signal determines the direction of rotation. A potentiometer wiper is attached to the air-inlet cover and the voltage output is proportional to the position of cover. Micro switches are used to detected when the cover is fully open and fully closed.

The operation is provided with a panel from which the control system can be switched from auto to manual. Panel lights indicate "fan on" ,"heater on", "cover fully open", "cover fully closed" and "auto/manual" status. The operation of this simple plant by a computer requires **monitoring, control calculation, and actuation**.

Monitoring involves obtaining information about the current state of the plant. In the above example the information is available from the plant instruments in the form of analog signals for air temperature and fan-inlet cover position; in the form of digital (logic) signals for extremes of fan-inlet cover position (fully open, fully closed); and the various other status signal; auto/manual, fan motor on, heater on.

The control calculation involve the digital equivalent of continuous feedback control for the control of temperature (Direct Digital Control-DDC).There is feedback-position control for fan-inlet cover position and there is sequence and interlock control; the heater should not be on if the fan is not running ; automatic change from tracking to controlling when the operator changes from manual to auto.

The actuation requires the provision of a voltage proportional to the demand heat output for the heater control, logic signals indicating ON/OFF and direction of the fan-inlet cover and logic signals for the operation display .

The monitoring and actuation tasks thus involve a range of interface device including A/D, D/A, digital input and output lines and pulse generators. We will represent them simply as input and output devices. The generalized computer control as shown in figure bellow.

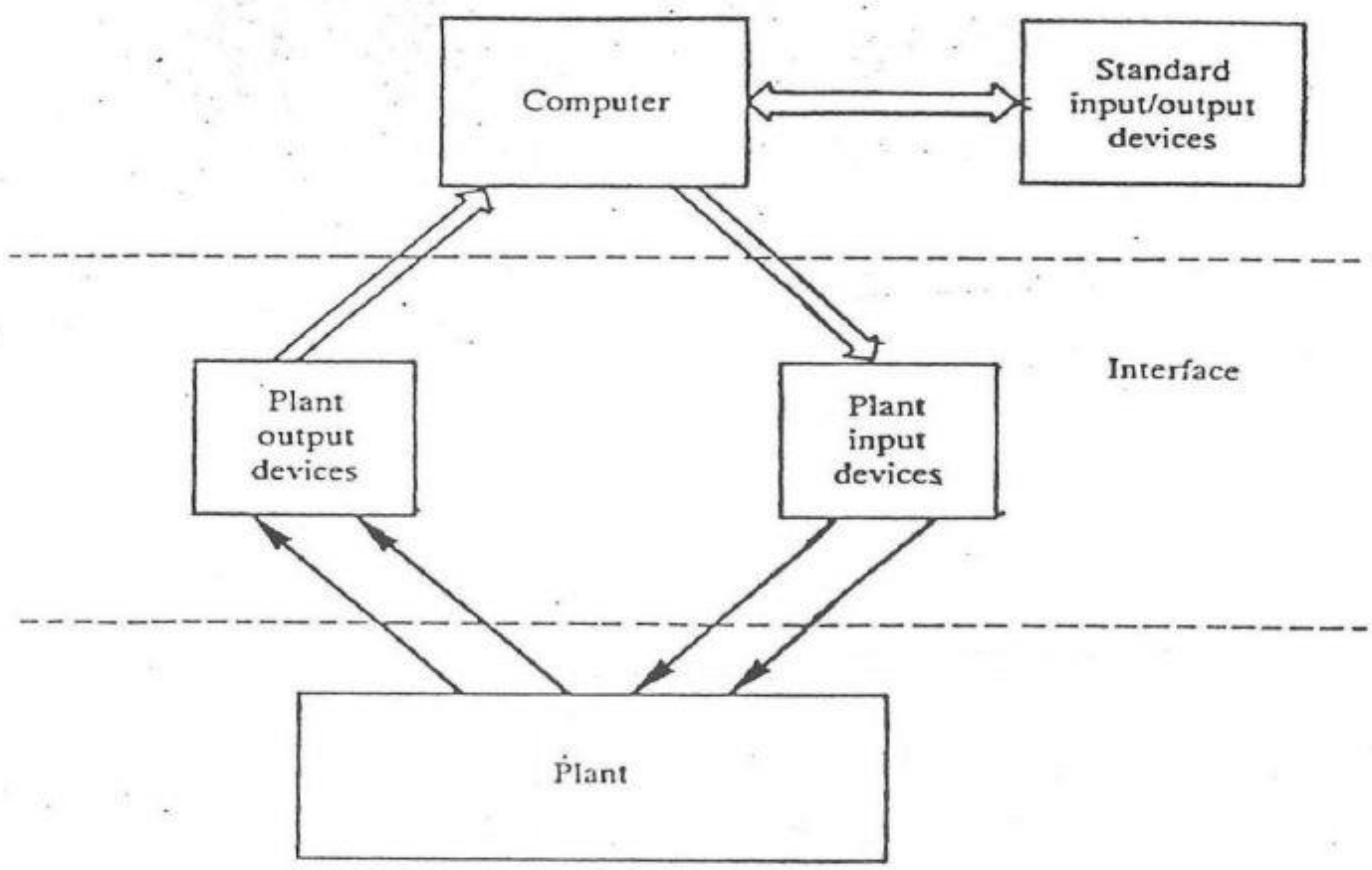

Fig. Generalized computer control system.

Each of the various types of device will required software to operator it; again we will represent this software as input and output tasks. The generalized picture of computer control system is shown below.

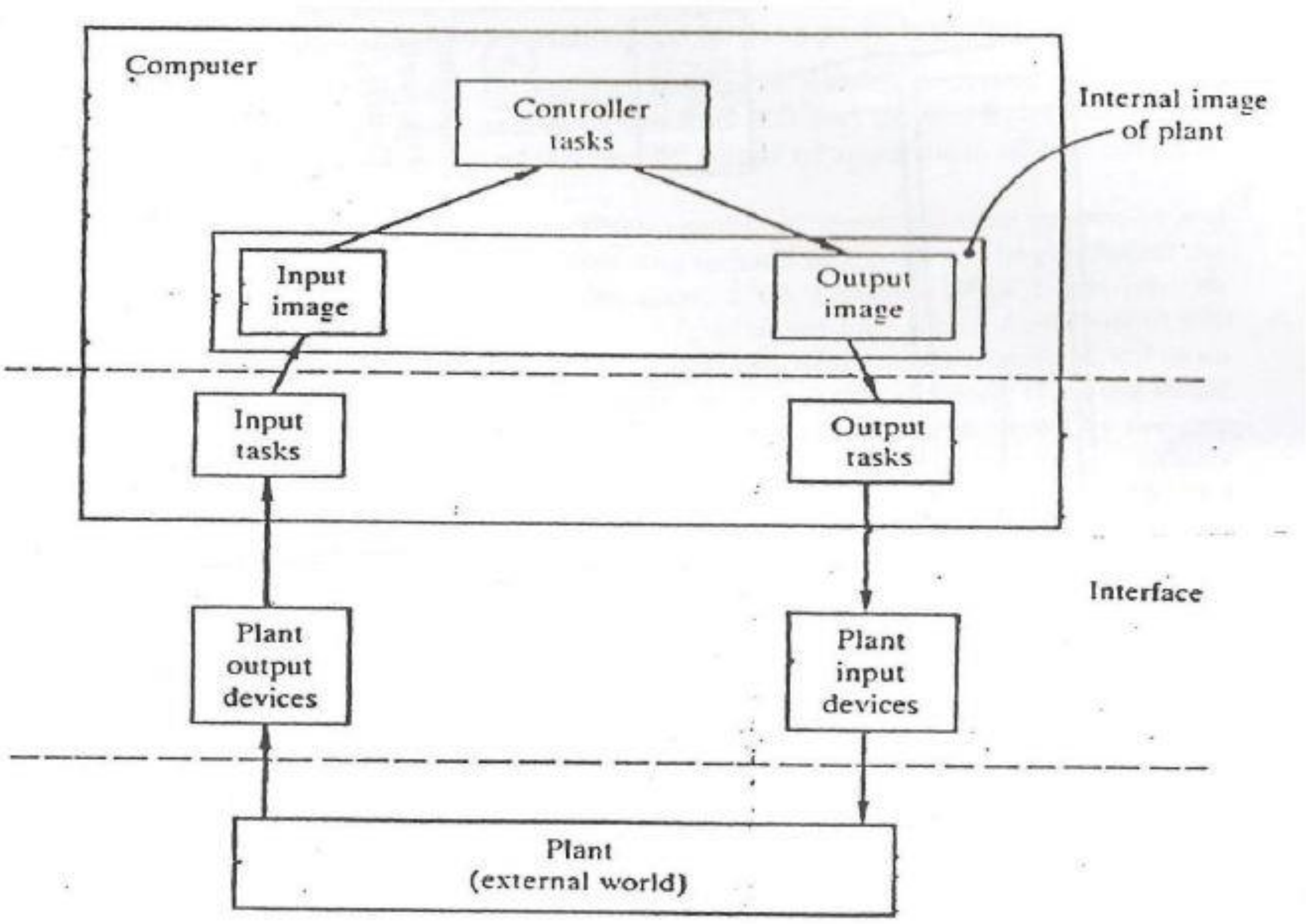

Fig. Generalized computer control system showing hardware and software interface.

The computer input devices plus input software provide the information to create " input image " of the plant. The input image is a snapshot of the status of the plant and this snapshot is renewed at specified interval. The output image represents the current of set of outputs generated by the control calculations. The output image will be updated periodically by control tasks. It is the job of the output task to convey the output image to the plant. The control tasks can thus be considered as operating on an internal image (or model) of the plant. The simple mode of computer described above divides the task to be performed into three major areas: plant input tasks, plant output tasks, and Control tasks; and it is assumed that communication with the operator is treated as part of the plant input and plant output tasks. However, in many applications communication will extend beyond simple indication and switches. Control of the system may be shared between several computers and hence information may have to be transmitted between computers. The model must therefore be extended to included communication tasks as shown in figure.

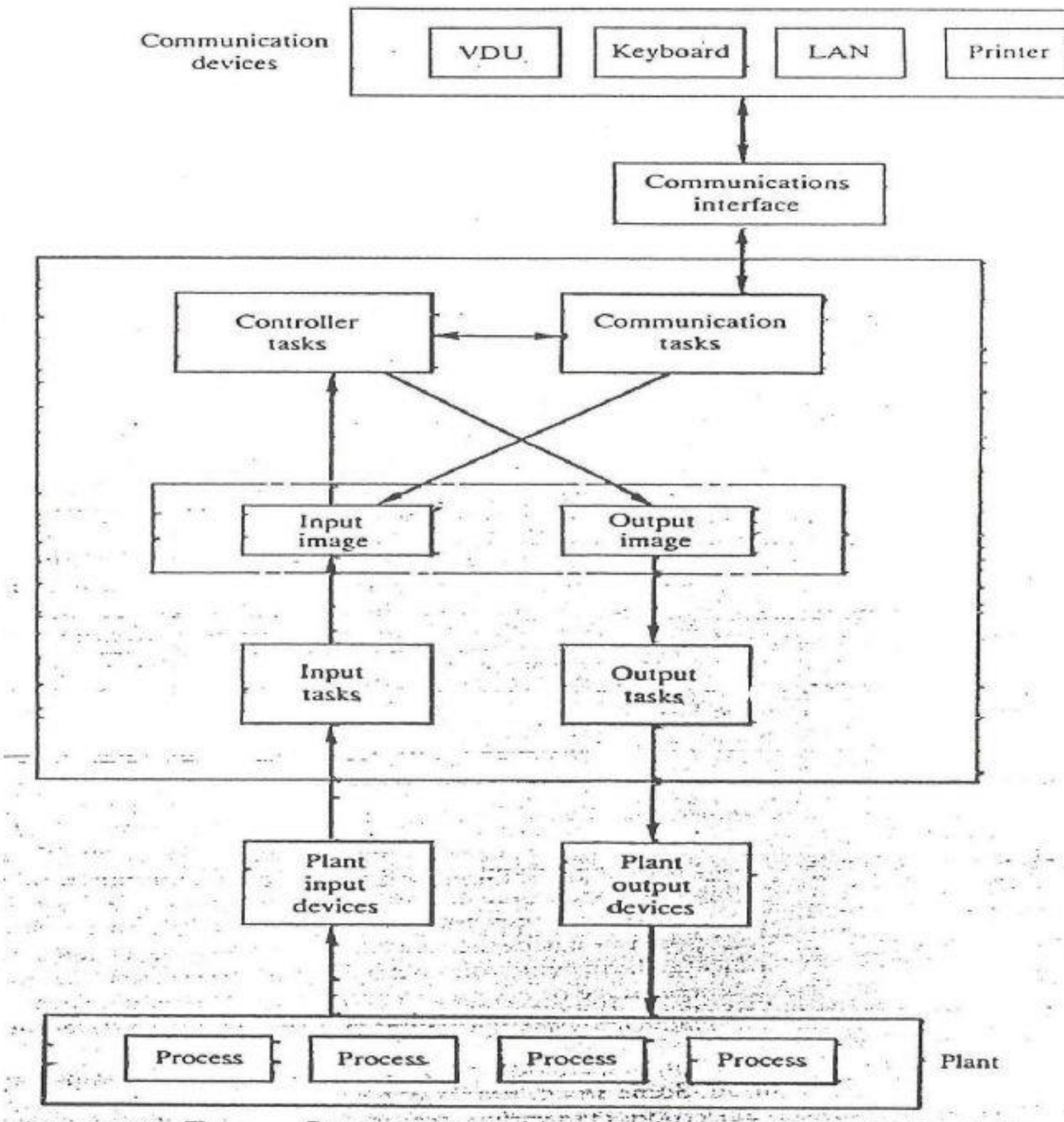

Fig. Computer control system showing communication tasks.

Clasification of real time system

The real time system will be used to refer to system in which:

1. The order of computation is determined by the passage of the time or by events external to the computer ; and
2. The result of particular calculation may depend upon the value of the variable 'time' at the instance of execution of the calculations or the time taken to execute the computation.

1. Clock based system:

A process plant operates in real time and thus we talk about the plant time constants, these may be measured in hours (chemical process) or millisecond (aircraft system). For feedback control system the required sampling rate will be dependent on the time constant of the process to be controlled. The shorter the time constant of the process, the faster the required sampling rate.

The computer which is used to control the plant must therefore be synchronized to real time or natural time and must be able to carry out all the required operations measurement, control and actuation within each sampling interval.

The completion of the operation within the specified time is dependent on the number of operation to be performed and the speed of computer. Synchronization is usually obtained by adding to the computer system a clock – normally referred to a " real – time " clock and using a single from this clock to interrupt the operations of the computer at some predetermined fixed time interval.

2. Sensor-based system:

The actions of the system will be not at particular times or time interval, but in response to some event (Ex. turn off a pump when the level in a liquid tank reaches a predetermined value). Sensor-based systems are used extensively to indicate alarm conditions and initiate alarm actions. (Ex. too high temperature or too great pressure).

Sensor-based system normally employ interrupts to inform the computer system that action is required. Some small, simple systems may use polling that is the computer periodically asks(polls) the various sensors to see if action is required.

3. Interactive System:

Interactive system probably represent the largest class of real time system and cover such systems as automatic bank tellers, reservation systems for hotels, etc. The real time requirement is usually expressed in terms of the average response time not exceeding a specified value . For example, an automatic bank teller system might require an average response time not exceeding 20 sec. Although this type of system superficially seems similar to the sensor based system - that is, it apparently responds to a signal form the plant (in this case usually a person) - it is different in that it responds at a time determined by the internal state of the computer.

Classification of Programs:

1. **Sequential "single tasking"**

In classical sequential programming action are strictly ordered as a time sequence: the behavior of the program depends only on the effects of the individual actions and their order; the time taken to perform the action is not of consequence, therefore, requires two kinds of argument:-

1- that a particular statement defines a stated action.
2- that the various program structures produce a stated sequence of events.

2. **Multi-tasking**

The design and programming of large real-time (and large interactive) systems can be considerably eased if the background portioning can be extended into multiple partition to allow the concept of many active task. The implication of this approach are that each task may be carried in parallel and there is no assumption made at the design stage as to how many processors will be used in the system.

The system must be :-

1- create separate tasks
2- schedule running at the tasks (on a priority basis)
3- share data between tasks
4- synchronize tasks with each other
5- prevent tasks corrupting each other
6- control the starting and stopping of tasks

Concepts of computer control

There are several different computer activities carried out

1. Sequence control.
2. Loop control.
3. Supervisory control.
4. Data acquisition.
5. Data analysis.
6. Human or Man-Machine interface (MMI).

The overcall objectives of the control of these processes can by summarized as: **Safety, Product specification, Environment, Ease of operating, and Economics**.

Sequence Control:

Although Sequence control will occur in same part most systems it often predominates in batch systems and hence a batch system is used to illustrate it. Batch system are widely used in the food-processing and chemical industries where the operations carried out frequently involve mixing raw materials , carrying out some process and then discharging the product. Typical example of simple complete processing plant is shown in figure bellow:

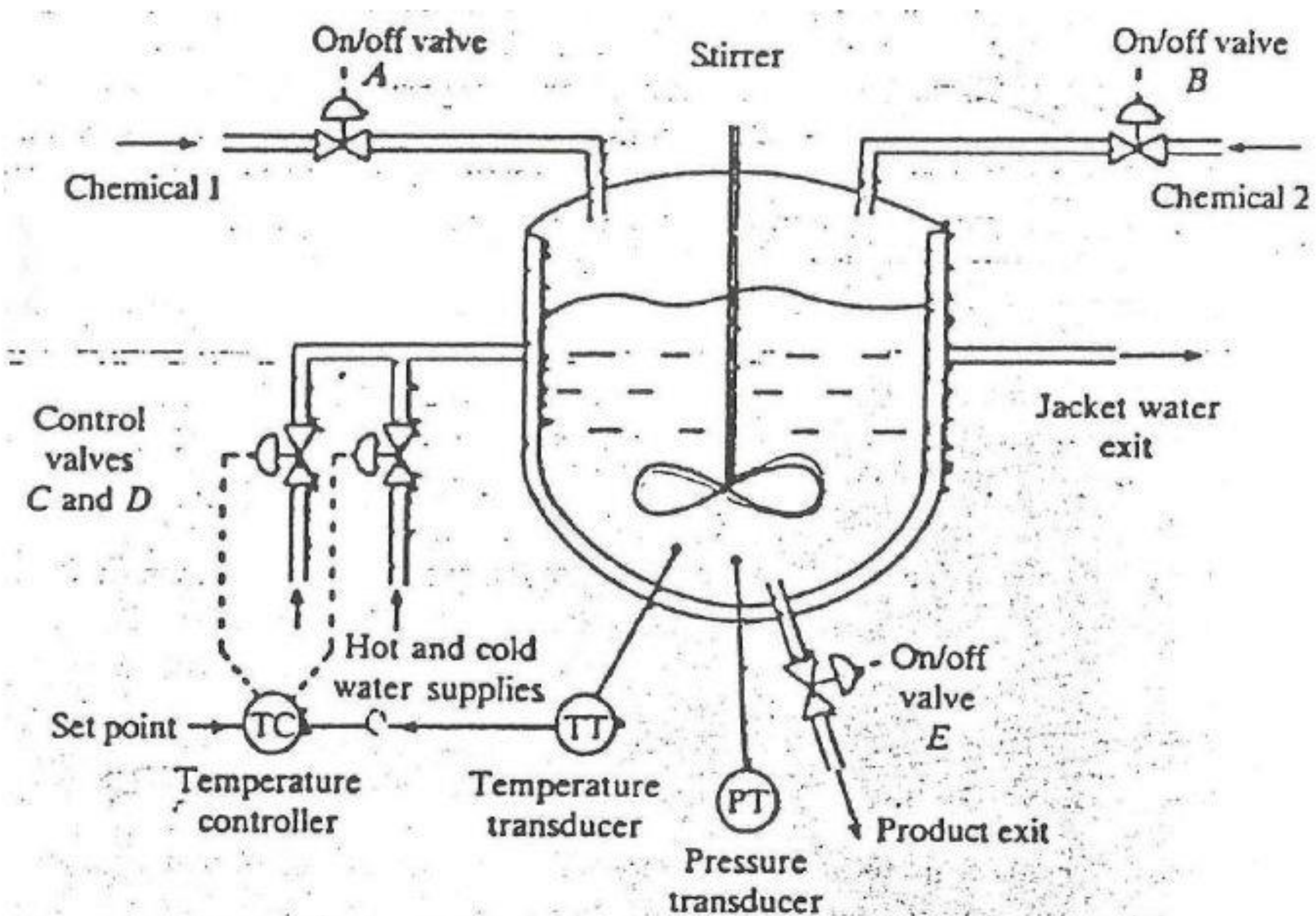

Fig. A simple chemical reactor vessel

In this plant a chemical is produced by the reaction of two other chemicals at a specified temperature. The chemicals are mixed together in a sealed vessel (the reactor) and the temperature of the reaction is controlled by feeding hot or cold water through the water jacket which surrounds the vessel. The water flow is controlled by adjusting valve C and D. The flow of material into and out of the vessel is regulated by the valve A, B and E. The temperature of the contents of the vessel and the pressure in the vessel are monitored.

The procedure for the operation of the system as follows:-

1. open valve "A".(To charge the vessel with chemical 1).
2. Check the level of the chemical, (by monitoring the pressure in the vessel), when correct amount of chemical has been admitted, close valve "A".
3. Start the stirrer.
4. Repeat stage "1&2" with valve "B" (to admitted the second chemical).
5. Switch ON the three-term controller and supply a set point so that the chemical mixed is heated up to the required reaction temperature.
6. Monitor the reaction temperature, when it reaches the set point, start a timer to time the duration of the reaction.
7. When the timer indicates that the reaction is complete switch off the controller and open valve "C" cool down the reactor contents. Switch off the stirrer.
8. Monitor the temperature, when the contents have cooled , open valve "E" to remove the product from reactor.

   When implement by computer all of the above actions and timings would be based upon software.

Loop control (Direct digital control (DDC)):

In DDC the computer is in the feedback loop. A consequence of this is that the computer becomes a critical component and great care is needed to ensure that, in the event of the failure or multi functioning of the computer, the plant remains in a safe condition.

The advantages claimed for DDC over analog control are:-

Cost: in the early days the breakeven point was between 50-100 loops; with the introduction of microprocessors a single loop DDC unit can be cheaper than an the analog unit.

Performance: digital control makes it possible to use improves the accuracy of the controller and provides a wider range of control settings.

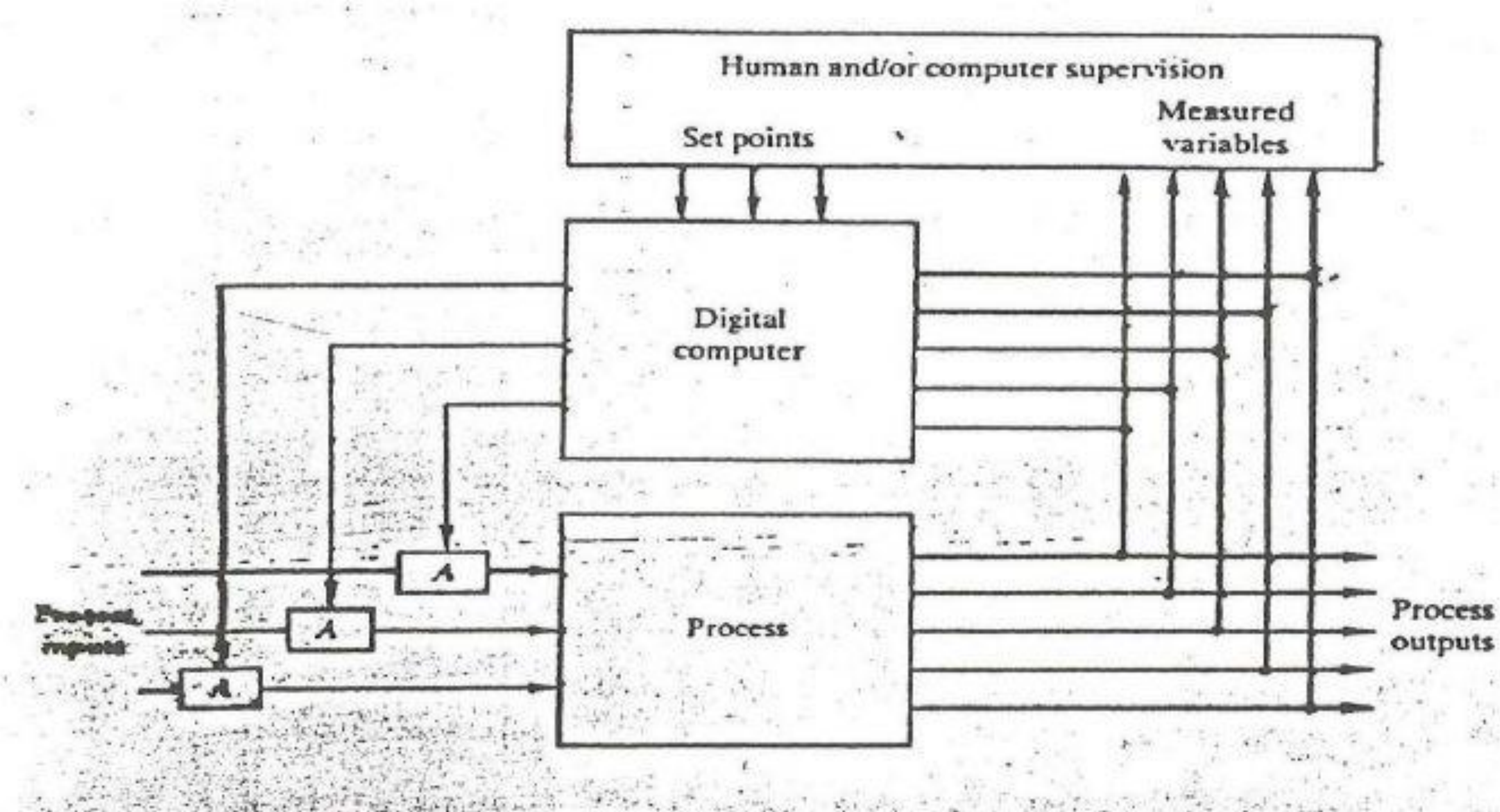

Fig. Direct digital control.

DDC control may be applied either to a single loop system implemented on a small microprocessor or to a large system involving several hundred Loops. The loops may be cascaded that is, with the output or actuation signal of one loop acting as the set point for another loop. Signals added together (rat loop) and conditional switches may be used to alter signal connections.

The latter is used in aircraft control, for example when control parameters are changed with alterations in altitude and aircraft speed. Adaptive control using self-tuning is illustrated in figure below and uses identification techniques to achieve continual determination of the parameters of the process being controlled; changes in the process parameters are then used to adjust the actual controller.

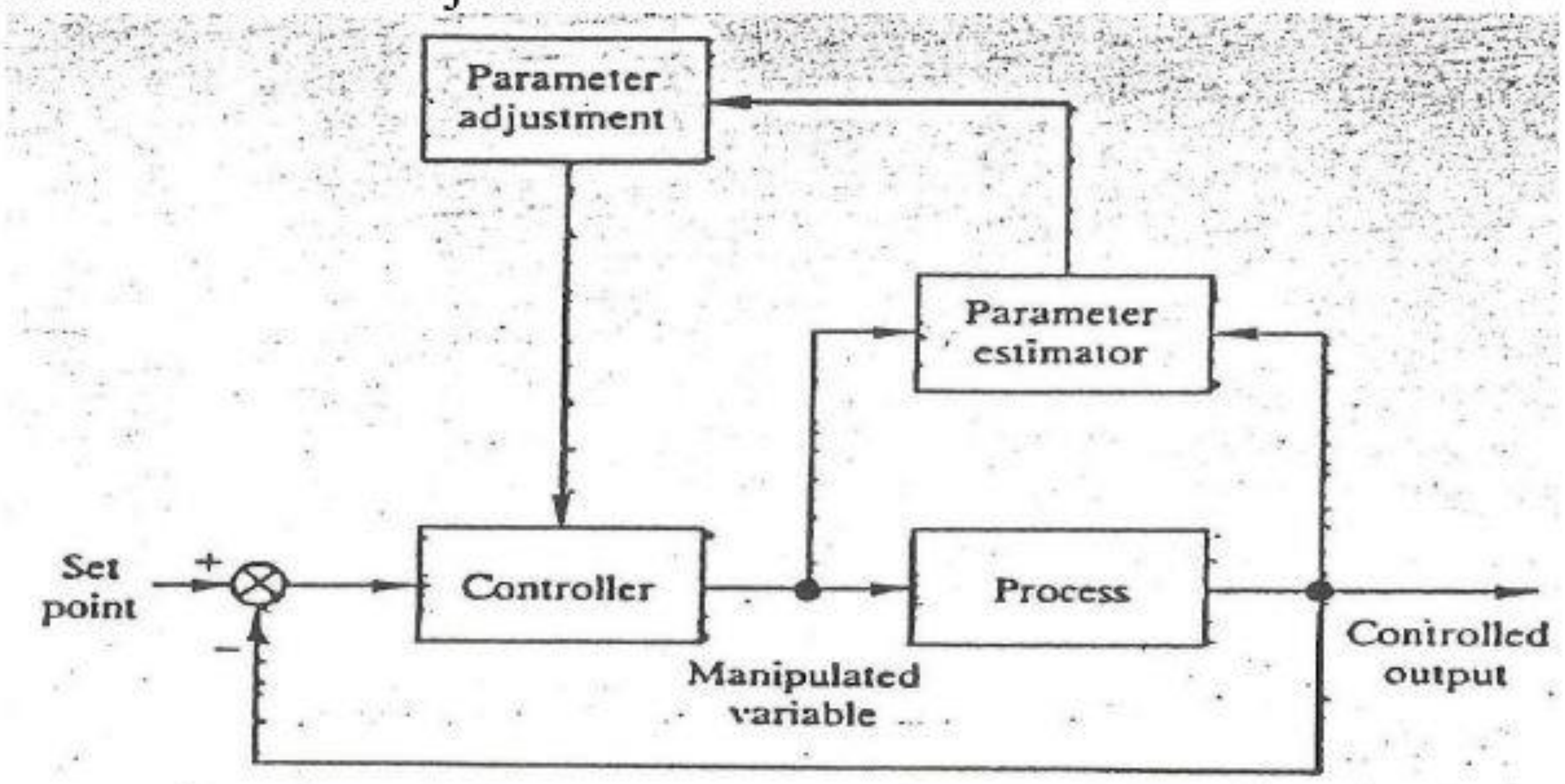

Fig. Self-tuning adaptive control.

The model reference technique is illustrated in fig below, it is relies on the ability to construct an accurate model of the process and to measure the disturbances which affect the process.

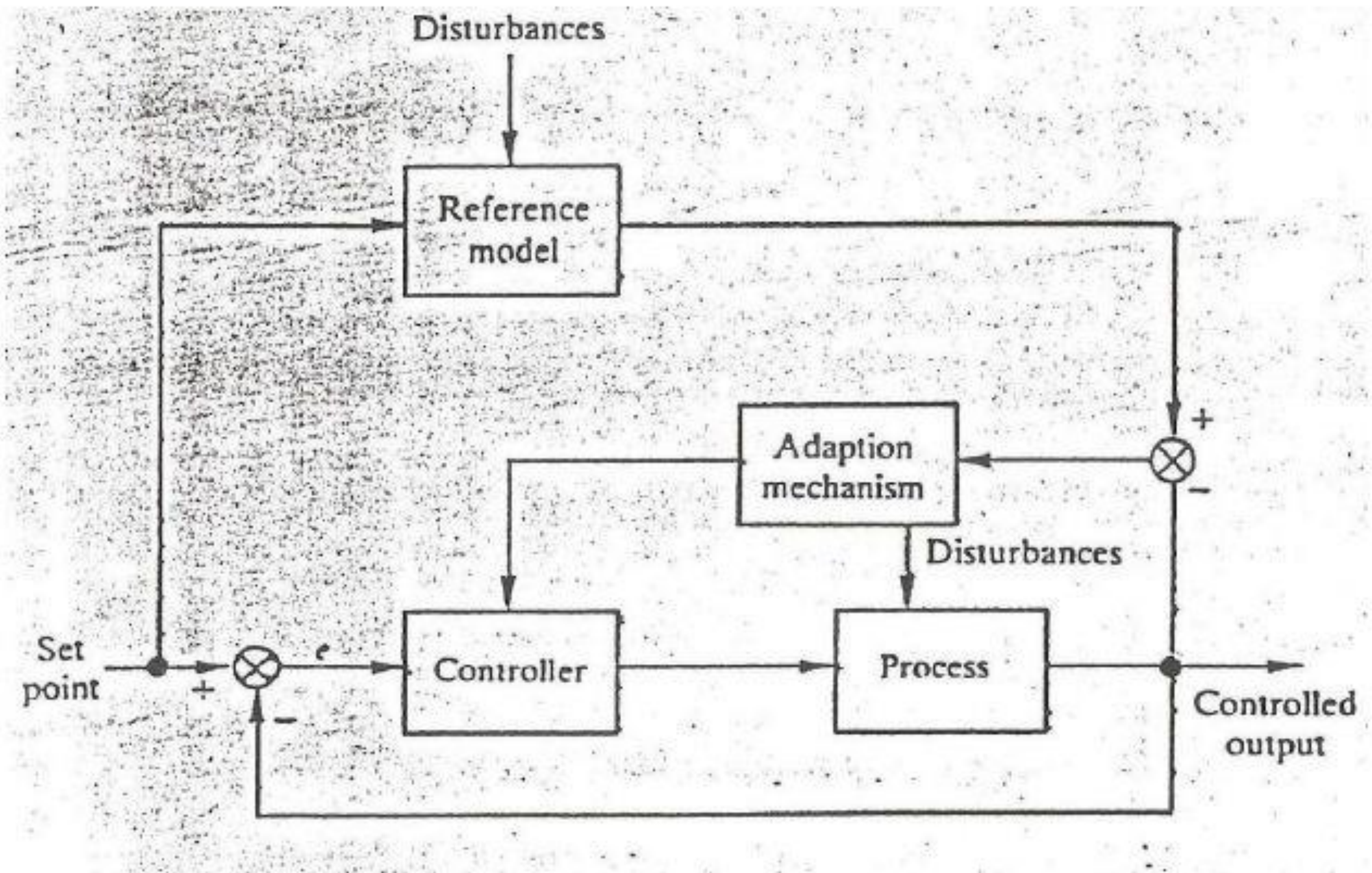

Fig. Model-reference adaptive control.

Supervisory control:

The adoption of computers for process control has increased the range of activities that can be performed, for not only can the computer system directly control the operation of the plant, it can also provide managers and engineers with a comprehensive picture of the status of the plant operation.

It is in their supervisory role and in the presentation of information to the plant operation – large rooms full of dials and switches have been replaced by VDUs and keyboards that the major changes have been made.

The main reasons for this were that computer in the early days were not always very reliable and caution dictated that the plant should still be able to run in the event of a computer failure, and that computers were very expensive and it was not economically viable to use a computer to replace the analog control equipment in current use.

A computer system used to adjust the set points of existing analog control system in an optimum manner(to minimize energy or to maximize production) could perhaps be economically justified.

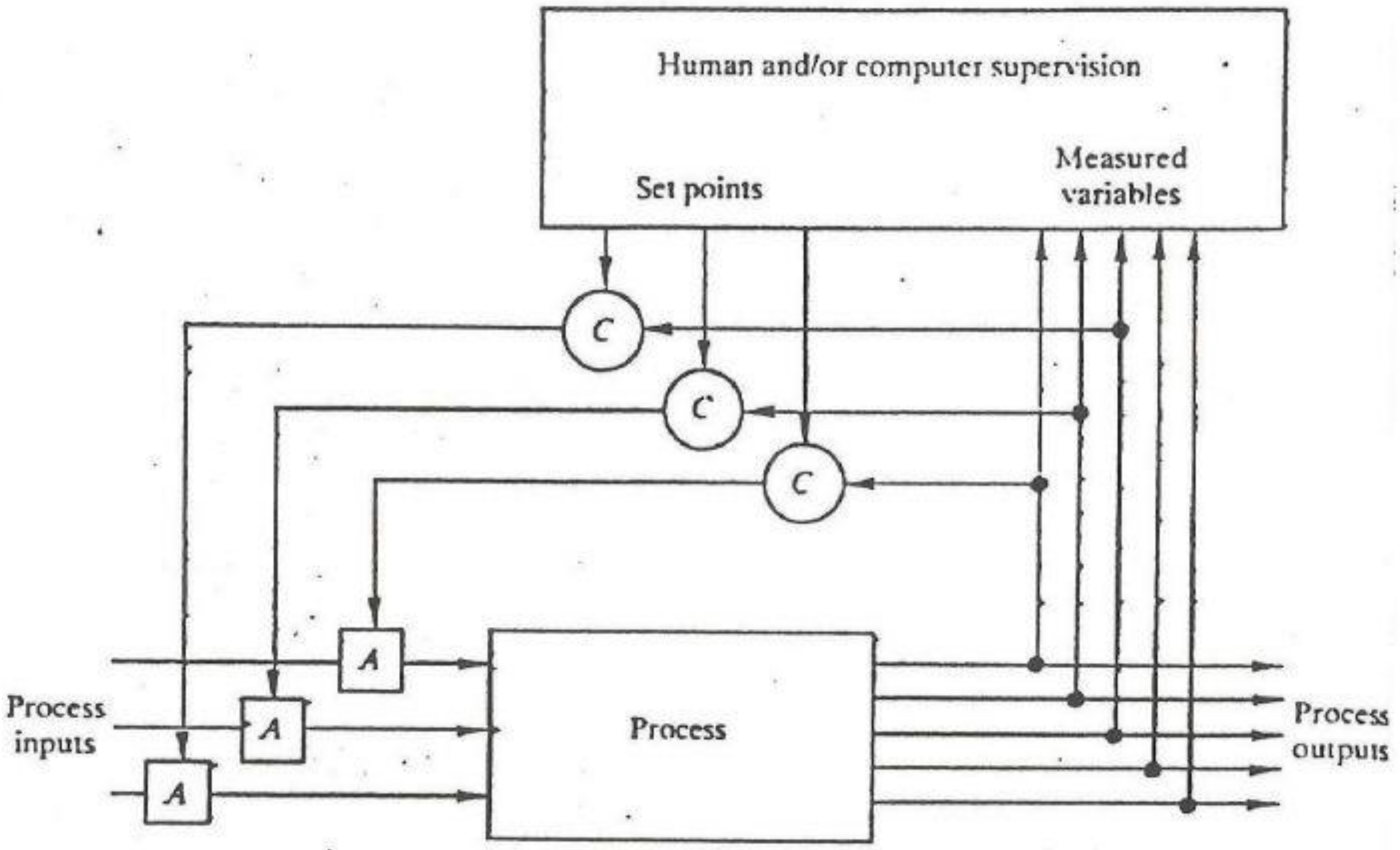

Fig. Supervisory control.

Human or Man-Machine Interface(MMI):

The key to the successful adoption of a computer control scheme can frequently be the facilities provided for the plant operator. It is important that he is provided with a simple and clear system for the day-to-day operation of the plant.

All the information relevant to the current state of it is operation should be readily available and facilities to enable interaction with the plant to change set points, to manually adjust actuators, to acknowledge alarm condition, etc. should be provided.

To exact nature of the displays is usually determined by the engineer responsible for the plant or part of the plant.

Addition displays, including trends and summaries of past operations, are frequently available to the engineer, often in the form of hard copy, in addition the plant engineer (maintenance engineer) will require information on which to base decisions about maintenance schedules and instrument actuator and plant component replacements.

Computer hardware requirement for R.T application

Although almost any digital computer can be used for real time computer control and other real time operations, they are not all equally easily adapted for such work. A process control computer has to communicate both with plant and personal; this communication must be efficient and effective and processor must be capable of rapid execution to provide for real time action

A characteristic of computer used in control systems is that they are modular; they provide the means of adding extra units, in particular, specialized input and output devices, to a basic unit. The capabilities of the basic unit (in term of its processing power, storage capacity, I/O bandwidth and interrupt structure), determine the overall performance of the system. The arithmetic and logic (ALU), control, register, memory and I/O units represents a general purpose digital computer. A simplified block diagram of the basic unit is shown in figure bellow:

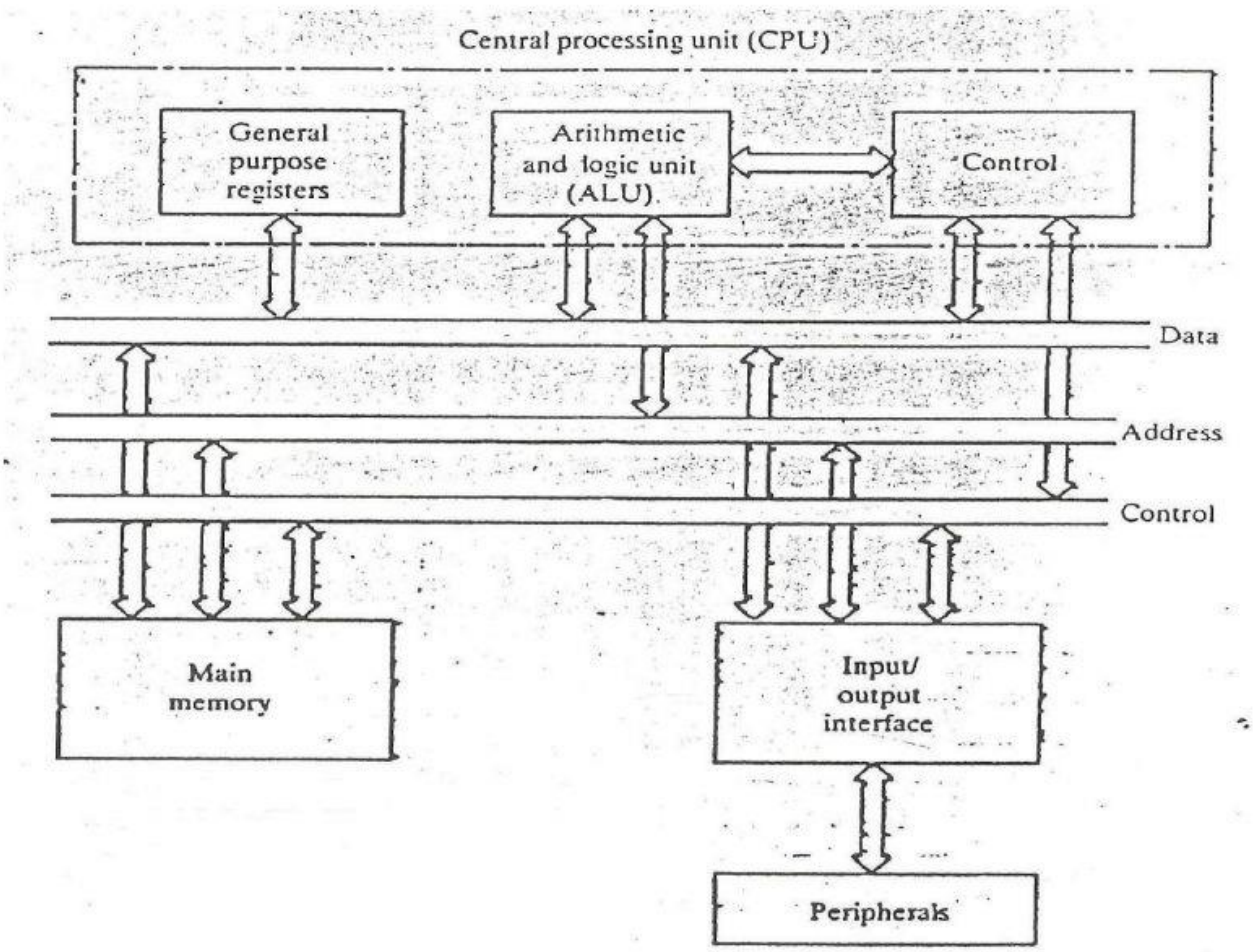

Fig. Schematic diagram of a general purpose digital computer.

General purpose computer:

1. **Central processing unit (CPU)**

The ALU together with the control unit and the general purpose register make up the central processing unit. The ALU contains the circuits necessary to carry out arithmetic and logic operations (adding, subtraction, comparing, multiplication and division, etc.).

The control unit continually supervises the operations within the CPU, it fetches program instructions from main memory, decoders the instructions and up the necessary data paths and timing cycles for execution of the instructions. The important features of the CPU which determine the processing power available and hence influence the choice of computer for process control include:-

1. Word length
2. Instruction set
3. Addressing methods
4. Number of registers
5. Information transfer rates
6. Interrupt structures

The word length used by the computer is important both in ensuring adequate precision in calculations and in allowing direct access to a large area of main storage with in one instruction word.

Word length	integer range	memory size
8	-128 +127	256
16	-32768 +32767	64 K
32	-4294967296 +4294967295	8 M

Formula is integer range (-2^n) ⟶ $(2^n - 1)$ n:- No. of bits in a word

The basic instruction set of the CPU is also important in determining its overall performance.

Features which are desirable are :-

1. Flexible addressing modes for direct and immediate addressing.
2. Relative addressing modes.
3. Address modification by using of index register.

4. Instructions to transfer variable length blocks of data between storage unit or location with in memory.
5. Single commands to carry out multiple operations.

These features reduce the number of instructions required to perform 'housekeeping' operations and hence both reduce storage requirements and improve overall speed of operation by reducing the number of access to main memory required to carry out the operations . Another area which must be considered carefully when selecting a computer for process control is information transfer, both within the CPU, between backing store and the CPU, and with the I/o devices.

2. Storage

The storage used on computer control systems divided in to two categories: fast access storage and auxiliary storage.

The fast access memory is that part of the system which contains data, programs and results which are currently being operated on.

The auxiliary storage medium is typically disk or magnetic tape. These devices provide bulk storage for programs or data which are required infrequently at a much lower cost than fast access memory. The penalty is a much larger access time and the need for interface boards and software to connect them to the CPU.

3. Input and Output

The I/O interface is one of the most complex areas of computer system; part of complication arises because of the wide variety of devices which have to be connected and the wide variation in the rates of data transfer.

A printer may operate at 300-band rate where as a disk may require a rate of 500 k bands. The devices may require parallel or serial data transfer may require A/D or D/A conversion or conversion to pulse rate .

The I/O system of most control computers can be divided in to three section: process I/O, operator I/O and computer I/O . It is modern practice that all these devices (a typical range is shown in figure) share the same bus system and hence the CPU treats all devices in the same way and all the devices have to conform to the bus standard.

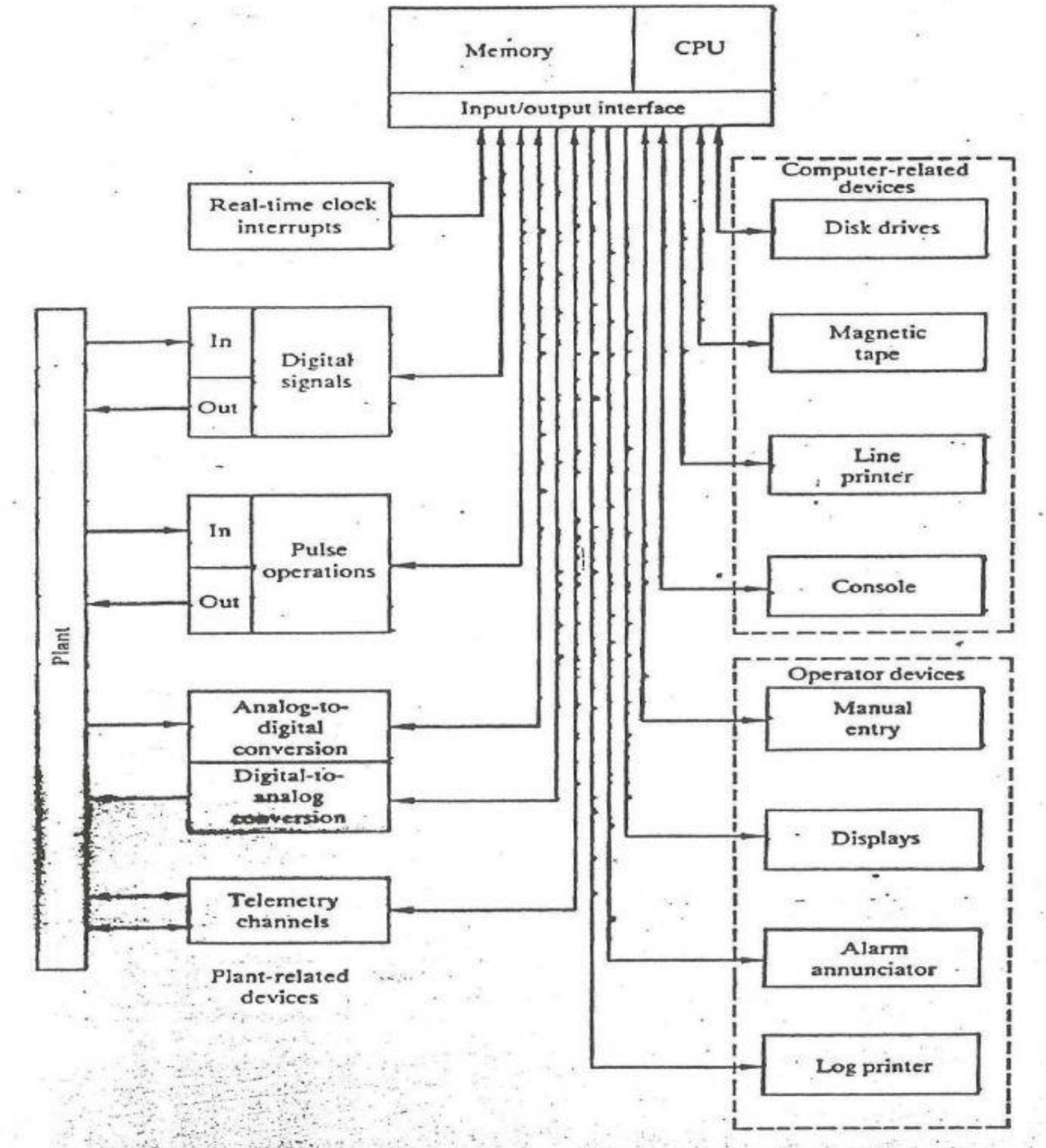

Fig. Typical interface devices.

<u>Process – Related Interfaces</u>:

Instruments and actuators connected to the process or plant can track a wide variety of form; they may use for measuring temperatures and hence could use thermo couples, resistance thermometer, etc., they could be measuring flow rate and use impulse turbines, they could be used to open valves or to control thrusters _operated heater. In all these operation there is a requirement to convert a digital quantity, in the form of a bit pattern in a computer word, to a physical quantity or to convert a physical quantity to a bit pattern.

Digital Signal interfaces:

The digital quantities can be either binary i.e., a value is open or close, a switch is on or off, a relay should be open or closed etc.

1. **read data**

A simple digital input interface is show below. It is assumed that the plant outputs are logic signals which appear on lines connected to the digital input register .

In order to read the line connected to the digital input register the computer has to place on the address bus the address of the register while some decoding circuitry is required in the interface (address decoder) to select the digital input register .

In addition to the 'select' signal, an 'enable' signal may also be required; this could be provided by the 'read' single from the computer control bus.

In response to both the 'select' and 'enable' signals the digital input register would enable its output gates to put data onto the computer data bus.

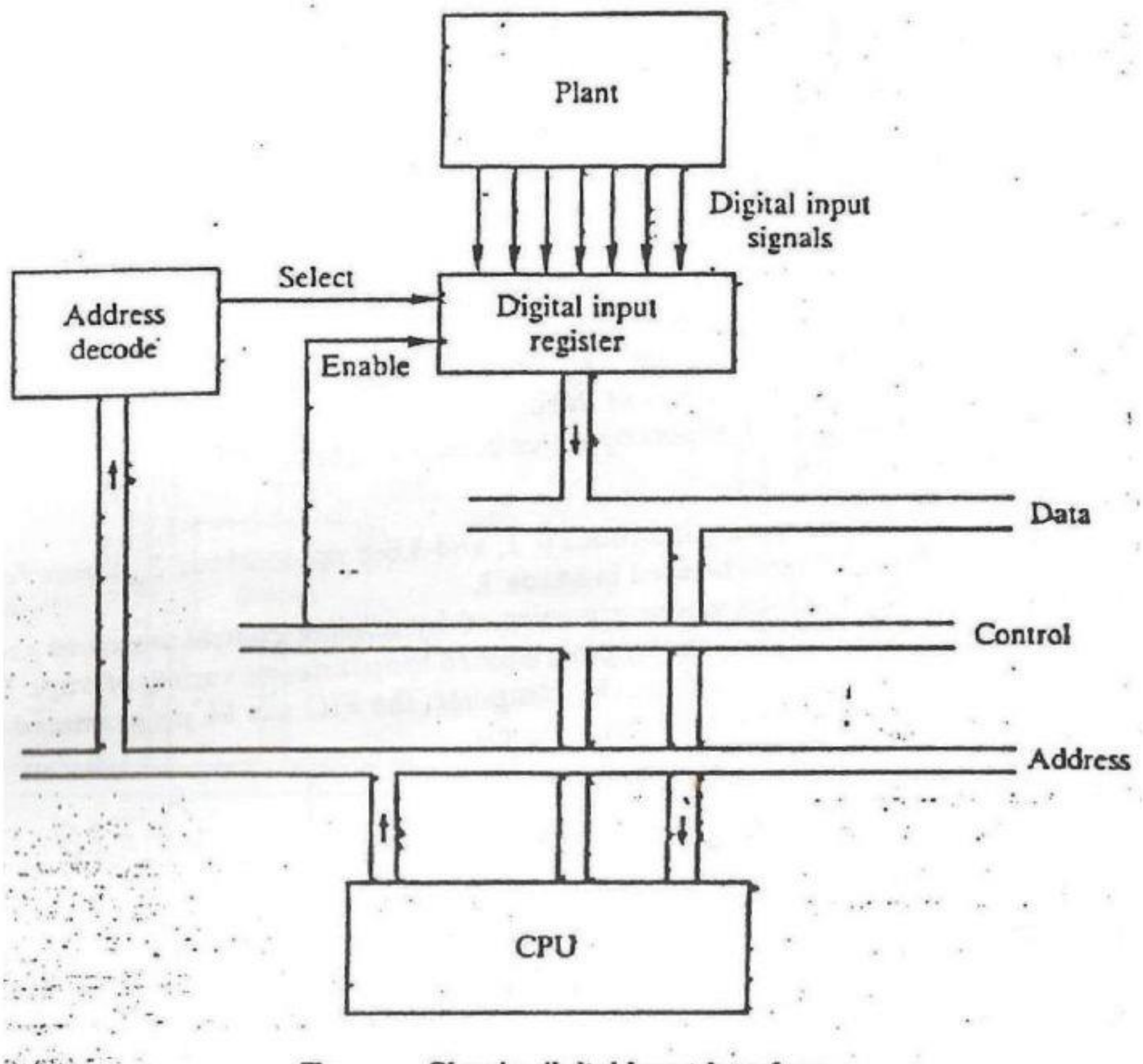

Fig. Simple digital input interface.

The timing of the transfer of information will be governed by the CPU timing. It is assumed for this system that the transfer requires three cycles of the system clock, labeled T1,T2, and T3.

The address lines being to change of the beginning of the cycle T1 and they are guaranteed to be valid by start of cycle T2; also at the start of cycle T2 the READ line becomes active. For the correct read operation the digital input register has to provide stable data at the agentive going edge (or earlier) of the clock during the T3 cycle and the data must be remain on the data lines until the negative going edge of the following clock cycle.

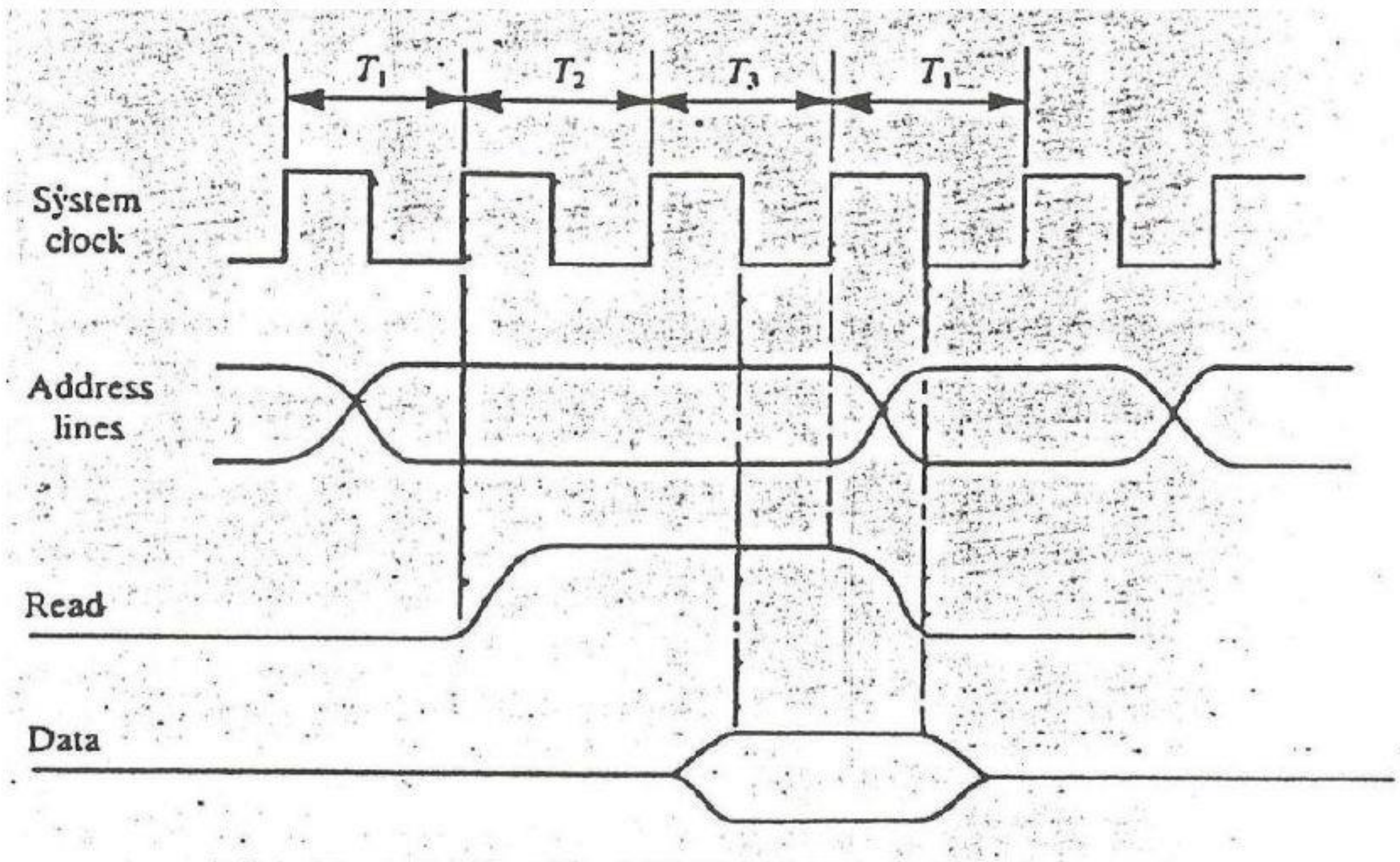

Fig. Simplified READ (INPUT) timing diagram.

2. **write data**

A simple digital output interface is shown in figure below. Digital output is the simplest form of the output; all that is required is a register or latch which can hold the data output from the computer. The 'enable' signal is used to indicate to the device that the data is stable on the data bus and can be read. The latch must be capable of accepting the data in a very short length of time (< 1 micro second).

The output from the latch is a set of logic levels (0-5) volt. If these levels are not adequate to operate the actuators on the plant, some signal conversion is necessary. This conversion is often performed by using the low level signals to operate relays which carry to higher voltage signals.

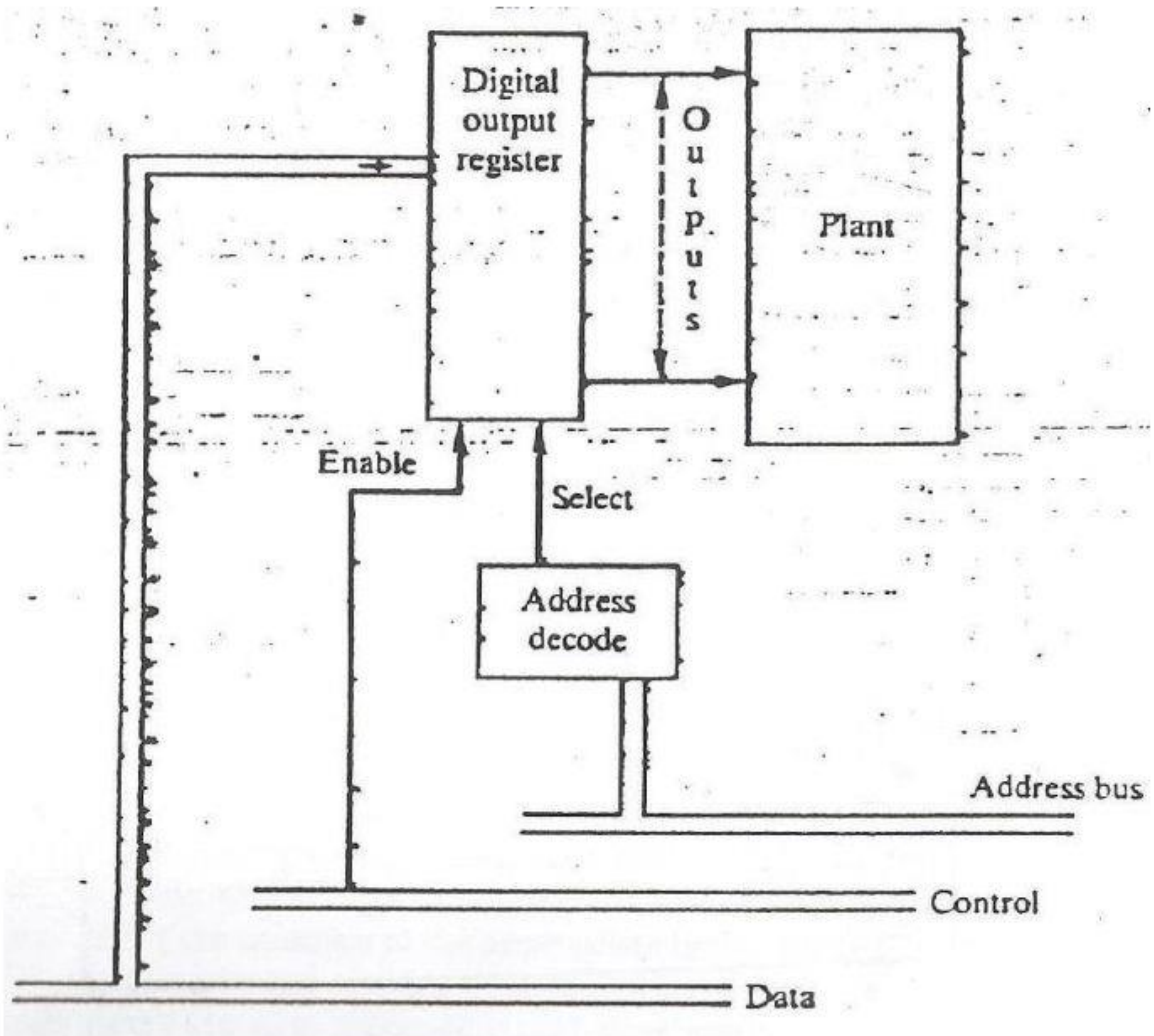

Fig. Simple digital output interface.

Pulses Interfaces:

In its simplest form a pulse input interface consists of a counter connected to a line from the plant. The counter is reset under program control and after a fixed length of time the contents are read by the computer. A typical arrangement is shown in figure, which also shows a simple pulse output interface. The transfer of data from the counter to the computer uses techniques similar to those for the digital input.

If the timing is done by the computer then the 'enable' signal must inhibit further counting of pulses.

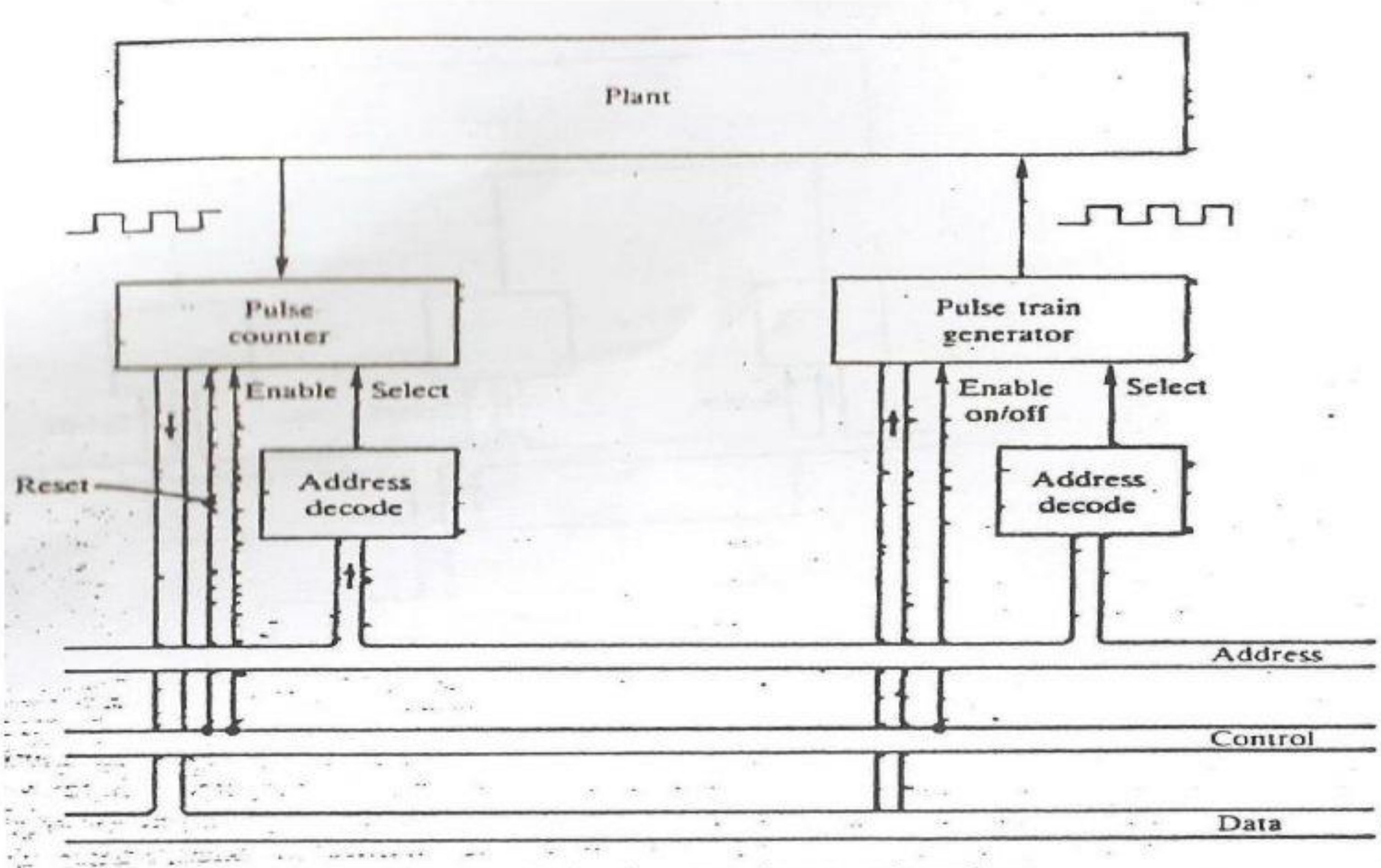

Fig. Pulse input and output interface.

Pulse generators can be of two types: they can either send a series of pulses of Fixed duration or a single pulses of variable length. For the former, the computer can be used either to turn a pulse generator ON or OFF, or to lead a register with the number of pluses to be transmitted.

Analog Interfaces:

The analog signal come from example thermocouples, strain gauges, tachogenerator or any analog sensors.

The normal method of operation of an analog input interface is that the computer issues a '**start**' or '**sample**' signal, typically a short pulse (1 μ sec.), in response to which the A/D switches the 'sample-hold' into **SAMPEL** for a short period after which the quantization process commences: quantization may take from a few (μ sec.) to several (m sec.). On completion of the conversion the A/D raises a 'ready' or 'complete' line which is either polled by the computer or is used to generate an interrupt.

We can used multiplexer to switch the inputs from several input lines to a single A/D. The sequence of events is then: select the channel, send the start conversion command and wait for the conversion complete signal.

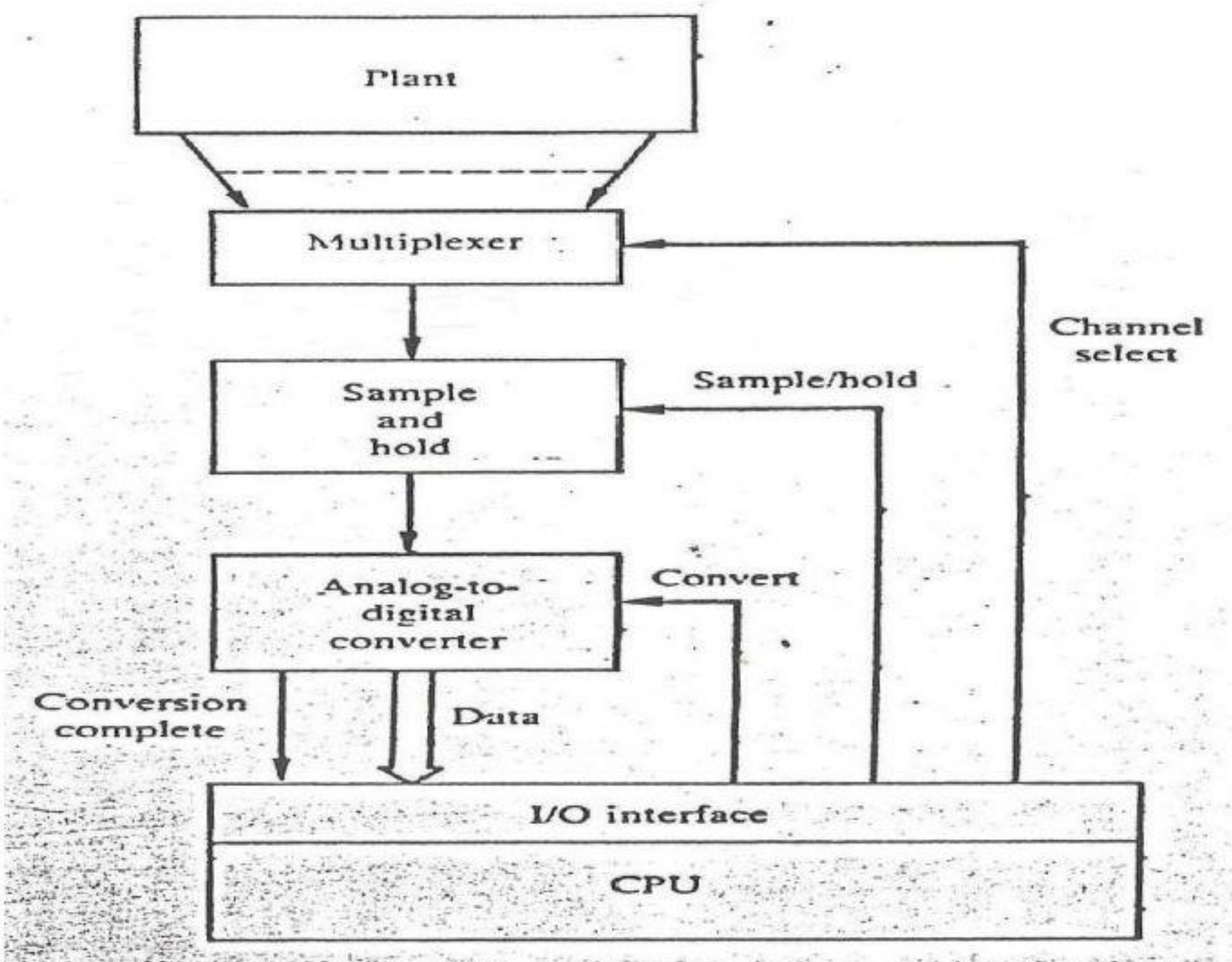

Fig. Analog input system.

The action of D/A is simpler (and hence cheaper) than A/D and as consequence it is normal to provide on converter for each output

Atypical arrangement is shown in figure below.

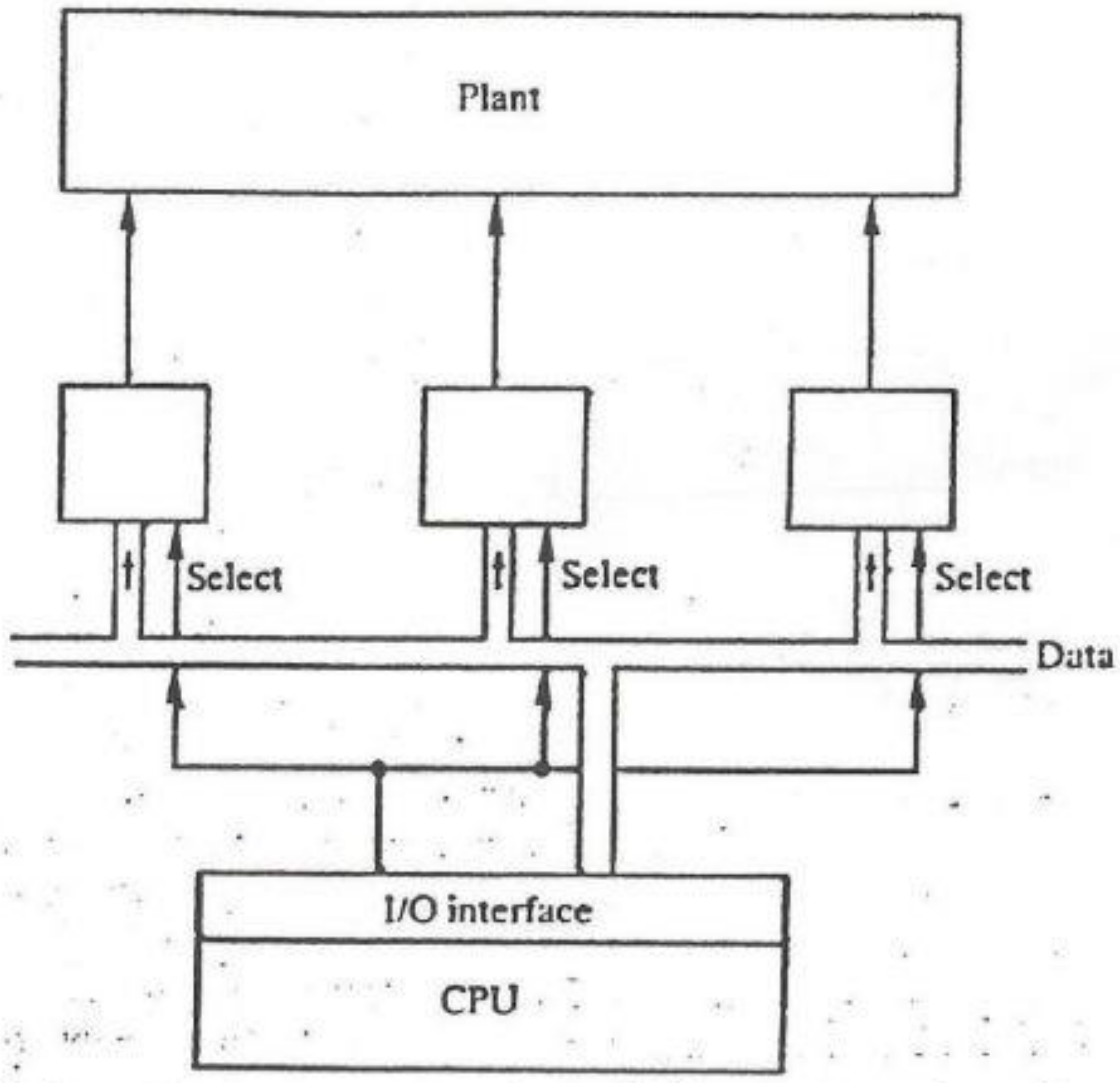

Fig. Analog output system.