CHAPTER - I

INTRODUCTION TO DAS

CHAPTER-1

INTRODUCTION TO DATA ACQUISITION SYSTEM

1.0 HISTORY

In the Ferroelectricity Laboratory of Physics Department of Shivaji University, Kolhapur several experiments can be carried on the ferroelectric materials for the research and development purposes. These experiments are like D.C.Electrical Conductivity Measurement, Thermoelectrical Power Measurement, Studies of Pyroelectric Properties, Solid-state Battery Formation, etc. The Electronic Laboratory of this Department also conducting several experiments on the Temperature measurements, Semiconductor device characteristics measurements, etc. The scientific data of all these experiments are recorded manually on the paper with time. Such recording is lengthy and it has certain drawbacks. Some experiments in the ferroelectricity lab. are very long. It requires approximately three hours. This becomes tiresome, time consuming work and there may be a possibility of errors.

If the data is recorded digitally, does not have such limitations. So, it is an attempt to design the **DATA ACQUISITION SYSTEM USING COMPUTER**, for these experiments. Some times all the recorded data may not be essential for analysis purpose; the data which is required for further analysis must be recorded. In the present work totally four experiments have undertaken. These are: i) Temperature measurement, ii) Electrical field for Conductivity measurement, iii) Thermoelectric Power measurement, and iv) Semiconductor device characteristics measurement. Using software data files are prepared and graphs are plotted according to the need of the application.

In this work, mV/mA input interfacing card along with PC-XT is used. The software is developed in the higher level language, Turbo C. The total software is carried out in the four cases. The data can be recorded on the hard disk or on a floppy disk.

1.1 INTRODUCTION

Data acquisition systems are used for collecting the input data in analog or digital form as rapidly, accurately and economically as possible. In analog recording of instrumentation system the analog signals are recorded in basically two different ways -

1) Signals which originates from DIRECT MEASUREMENT of electrical quantities. These signals may be d.c. or a.c. voltages, frequency or resistance etc.

2) signals which originates from use of TRANSDUCERS.

The analog data is generally acquired and converted into the digital form for the purpose of i) Processing, ii) Transmission, iii) Display, & iv) Storage etc.

There are two types of Instrumentation Systems.

1) **ANALOG SYSTEMS**- These systems deal with information in

analog form. An analog signal may be defined as continuous function, such as a voltage versus time, displacement versus force.

2) **DIGITAL SYSTEMS**- A digital quantity may consist of a number of discrete or discontinuous pulses whose time relationship contains information about the magnitude and the nature of the quantity under measurement.

Depending up on the two categories of the instrumentation system there are two main types of data acquisition systems:

i) Analog data acquisition system and

ii) Digital data acquisition system.

Components of Analog data acquisition systems :

An analog data acquisition system typically consists of the some or all of the following elements.

1) **Transducer** - The definition of transducer is that, a device which converts the energy from one form to another. It is desirable that an emf. obtained from the transducer is proportional to the quantity being measured; is used as an input to the data acquisition system. Therefore, transducers such as thermocouples, strain gauges bridges, piezo-electric devices and photosensitive devices are used.

2) **Signal Conditioning Equipment**- Any equipment that assist in transforming the output of transducer to the desired magnitude or form required by the next stage of the data acquisition system. It also produces the required conditions in the transducer so that they work properly. It includes devices for amplifying, refining,or selecting certain positions of these signals.

Examples of signal conditioning equipment includes, known constant voltage sources for strain gauge bridges, zero bridge balance device for strain gauge circuits, temperature control devices for thermocouple junctions, voltage amplifiers and Servo systems.

3) **Calibrating equipment**- Before each test there is a precalibration and after each test there is a postcalibration. This usually consists of a millivolt calibration of all input-circuits and shunt calibration of all bridge type transducer circuits.

4) **Integrating equipment** - It is often desirable to know the integral or a summation of a quantity. There are several ways of determining the time integral of a quantity. An analog integrating circuit can be used for a quantitative test. It has the possible danger of becoming overloaded and also its accuracy is low. Therefore digital techniques are normally used for integration purposes.

5) **Visual Display Devices** - These are required for continuous monitoring of the input signals. These devices includes panel mounted meters, numerical displays, signal or multichannel CRO's etc.

6) **Analog Recorders**- It includes strip chart recorders, oscillograph, magnetic tape recorders and cathode ray oscilloscope with photographic equipment.

7) **Analog Computer** - The function of data acquisition system is not only to record data acquired by the transducer and sensors but also to reduce this data to the desired form. Analog computer may be used as a reduction device. The output voltage of an analog computer can either be recorded in analog form or be

converted to a digital form for recording and further computations.

8) **High-speed Cameras And TV Equipment**- In many industrial process, engine testing and aerodynamic testing, it is not possible for the test operator to have ~~of the~~ a view of the equipment being tested. Therefore, closed circuit TV is used to enable the operator to make visual observations of the test. Also high speed cameras are employed to obtain a complete visual record of the process for further analysis.

Components of Digital Data Acquisition System:

A digital data acquisition system may include some or all of the components shown in the fig.(1.1). The essential functional operations of a digital data acquisition systems are : a) handling of analog signals, b) making the measurement, c) converting the data to a digital form and handling it, and d) internal programming and control.

The various components and their functions are given bellow.

1) **Transducer** - They convert a physical quantity to an electrical signal which is acceptable by the acquisition system. These parameters are like temperature, pressure, acceleration, displacement, velocity, weight, etc. And some electrical quantities such as voltage, resistance, or frequency may be measured directly.

2) **Signal Conditioning Equipment** - It includes the supporting circuitry for the transducer. This circuitry may provide excitation power, balancing circuits, and precalibration and post-calibration elements. Voltage amplifiers, servo systems etc. are

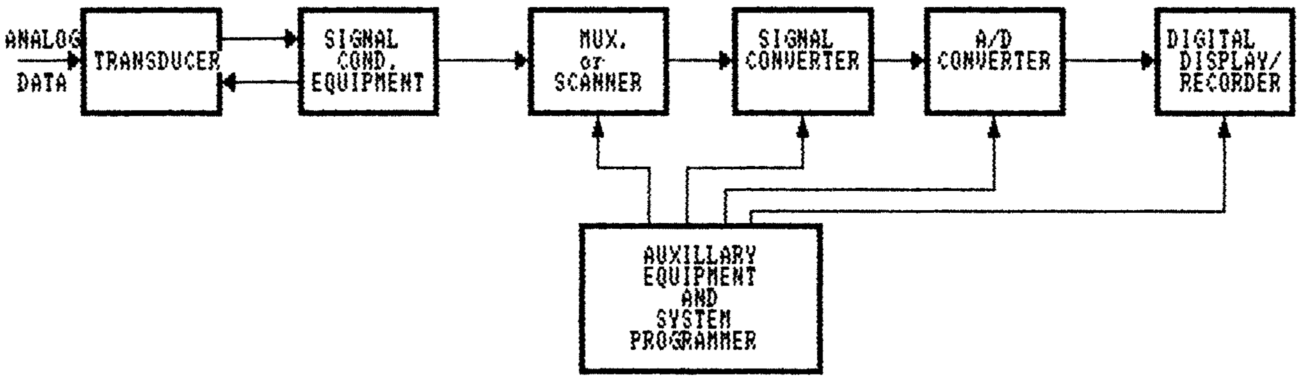

FIG.(1.1) COMPONANTS OF DIGITAL DAS.

the examples of the signal conditioning equipment.

3) **Multiplexer or Scanner** - Multiplexer is a process of sharing a single channel with more than one input. The multiplexer accepts one or more than one analog inputs (multiple analog inputs) and connects them sequentially to one measuring instrument. Another name of the multiplexer is a scanner.

4) **Signal Converter** - A signal converter translates the analog signal to a form acceptable by the analog to a digital converter. An example of signal converter is an amplifier for amplifying the low level signal voltages produced by transducers.

5) **Analog to Digital Converter** - An A/D converter converts the analog voltage to its equivalent digital form. The output of an A/D converter may be fed to digital display devices for visual display or may be fed to digital recorder for recording. It may be fed to digital computer for data reduction and further processing.

6) **Auxiliary Equipment** - This contains devices for system programming functions and digital data processing. Some of the typical functions done by the auxiliary equipments are linearization and limit comparison of signals. These functions may be performed by individual devices or by digital computer.

7) **Digital Recorder** - Records of information in digital form may be had on punched cards, perforated paper tapes, type written pages, or magnetic tape or a combination of these systems.

8) **Digital Printer** - After all the tests have been completed and the data generated, it becomes necessary to record the numbers and in some cases reduce the data to a more meaningful form. A

digital printer can be specified to interface with an electronic instrumentation system in order to perform this work, and thus provide a high quality hard copy for records and minimizing the labor of the operating staff.

The type of data acquisition system to be used depends upon the application and intended use of recorded input data. Analog data acquisition systems are used when wide frequency width is required or when lower accuracies can be tolerated. Digital data acquisition systems are used when the physical quantity being monitored has a narrow bandwidth i.e. when the quantities varies slowly. Digital systems are also used when high accuracy and low per channel cost is required. Digital data acquisition systems are in general more complex than analog systems, both in terms of instrumentation involved and the volume and the complexity of the data they can be handle.

1.2 WORK PERFORMED BY DATA ACQUISITION SYSTEM :

The acquisition and control of analog or digital data on pressure, flow, temperature, current, contact status etc. are widespread needs in process industry. Data acquisition systems are used for sensing a number of these signals emanating from the plant and converting them into a suitable form for the storage and processing. The processed information enables the operator to : i) Ensure that the plant is running smoothly,

ii) take control action for regulating the plant, and

iii) take corrective action in case of emergencies.

With the advent of microcomputer, storage and processing of information has become an inexpensive proposition so much so that it has become flexible to dedicate the microcomputer entirely to the DAS. This has made DAS more compact, versatile and reliable. We know that in digital data acquisition system the function of auxiliary equipment is performed by the digital computer i.e. microcomputer. A data acquisition system utilizes a few basic capabilities of computer to be performed four major categories of task which are given below :

i) Data acquisition,

ii) Data storage and retrieval,

iii) Data reduction, and

iv) Data presentation.

1.2.1 Data Acquisition - The data can be read under the control of the computer (auxiliary equipment). This not only results in a substantial saving of time and effort, but number of errors can be reduced which are present in the data. When data are expected at irregular intervals, the computer can continuously scan all the input sources and accept data when they are actually produced.

For analog data the computer controls the sampling and digitizing process and it also controls the identification and information of the data. For some irregular and also in case of emergencies the computer can be programmed to reject unacceptable readings and computer provides automatic calibration of the input data.

1.2.2 Data Storage and Retrieval - Computer has a large capacity of memory, so its ability is to store and retrieve large quantity of data. Instead of computer, the storage of large amount of data is space and time consuming. For manually collecting some types of information, almost it impossible. The digital computer, however can serve as an automated filling system in which information can be automatically entered as it is generated. These files can be stored and updated whenever necessary. Any or all of the information can be retrieved on command whenever desired and can be manipulated to provide output reports in tabular or graphic form to meet the need of user.

1.2.3 Data Reduction and Transformation - Analog signal is quiet useless if it is required from the computer in raw form. To obtain useful information from any input signal, some form of data reduction or transformation is necessary to represent the data as a set of specific parameters. These parameters can then be analyzed, compared with other parameters or otherwise manipulated. The size and complexity of the transformation and the reduction problems are such that manual methods would be completely impractical.

1.2.4 Data Presentation - The very important use of this system is to present the results of measurement and analysis to its user in the most meaningful form. A data acquisition system using computer provides information in a number of useful forms. Here we get table printouts, graphs and charts can be produced automatically, with futures as clearly labeled using both alphabetic and numeric symbols. If the necessary computer peripherals are available, plots and cathode ray display can also be generated. In addition computer can be programmed to organize the data or presentation in most meaningful form possible. Thus providing the user with a clear and accurate report of his results.

1.3 BASIC CHARACTERISTICS OF DAS

There are so many types of raw informations just like d.c. voltage, a.c. voltage, varying frequencies, time etc. These raw informations must be processed through the four basic steps which are given in the above section. If many sources of each type of data signal exists in one system; a basic decision must be made at the design of the instrumentation system. Here collecting the data rapidly from the many sources, the data channels must be time-shared or to be multiplexed. Here decision will be taken that how many channels will be provided for series or parallel gathering of data from various sources.

The specific configuration of any given data acquisition system concerning the choice of parallel and time-sharing depends up on the characteristics :

1) Rate of processing information - The first of these performance specifications involves the number of data words per unit time.

2) Accuracy with which operations are performed - It involves the error rate per unit data word.

3) The quantity of data to be acquired - This factor can be expressed in terms of total data words per run, or per test.

Here we can say, these three system characteristics are the key factors in determining the configuration of the DAS and the overall cost of the system.

1.4 OPTIONAL UNITS OF DAS

We have discussed the analog and digital components of the data acquisition system. These all are the basic measuring and recording units in the data acquisition system. Instead of these units DAS includes one or more optional units. These units are used in those systems in which the output data are required in meaningful form for operating personnel.

These units are scaler and offset corrections performs the operation

$$Y = ax + b \qquad \text{..............................*}$$

where, x is the data constant, a and b are the constants that converts x into the engineering units such as degree F.

Optional units are as follows -

1) **Programming** - This units control system operating modes, select signal flow path through the system. It gives (furnishes) instructions or (and) stored data as required by each unit in the system.

2) **Clock** - Clock provides real or arbitrary time in digital code to recording system.

3) **Manual data insertion** - Provides means for operators to insert identification or other data into data recording.

4) **Data identification** - Data identification unit provides digital information to recording system to identify data channel number, frame number, run number; where frame number includes one sample of all data channels and a run is associated with separate

distinct test channel number typically is omitted if a record of the data channel sequence is available.

5) **Analog transmission and termination** - To transmit analog data over extended distances system of cables, connectors and so on are required.

6) **Raw - Data ordering** - Patch board or other similar apparatus for ordering the interconnection of the transducer to the scanner (multiplexer) units.

7) **Sequence control** - Equipment controlled by the programming unit for operating scanners and auxiliary selector units and for controlling the sequence in which data channels and auxiliary equipments are selected.

8) **Analog filtering** - Analog filtering units are used either before or after the low level scanners. These are used to reject noise and power-supply-included voltages.

9) **Sampling** - For sampling a data at a known instant of time or for holding the peak value of a.c. inputs for duration of the sampling period, analog samples and hold equipments are used.

10) **Visual readout** - Equipment for visually displaying the output of the translator or the digital quantity generated or stored in one of the units.

11) **Scaler and offset conversion and control** - A memory in which the constants are stored, required to perform the operation y = ax + b where, y = digital output, x = raw input data, a = scaler constant, and b = offset constant. In addition equipment used in conjunction with sequencer and program units to select for a particular data channel, the appropriate constant and to perform the indicated operation.

12) Operator control unit - This panel contains all the operator controls.

13) External reference - External referencing equipment is used for referencing the translator or analog - to -digital converter to an external source to permit measurement in the form of ratios.

1.5 DESIGNATION OF DAS IN THE MARKET

DAS is a some kind of system that is used to acquire data. The question is not really trivial because there are number of products on the market that qualify for the designation "data acquisition system ". One kind of DAS is a rack - mounted device intended to accompany a minicomputer or large microcomputer in a 19 - inch instrument rack. In another case, the DAS is a printed circuit board that plugs into a microcomputer or minicomputer and serves to convert analog voltage or current levels into binary words. Still another DAS may be a hybrid function module that is complete within itself and needs only mounting on a printed circuit board or in a cabinet to function with a microcomputer system. A last category of DAS is an integrated circuit that contains almost all of the components needed to make it work but may steel require some external circuitry.

In general, however, we can define the data acquisition-system as a device or circuit that converts analog data into digital format and is ready for direct interfacing with a micro/mini computer. The DAS may also contain DACs, as well as ADCs, so that an analog signal may be created from a digital output on the computer. That DAC feature, however, is an option that is not totally necessary to our definition. The DAS may be a single channel affair or it may be multi-channel. Eight and sixteen channel DASs are readily available and some manufacturers offer DAS in up to 64 channels such a DAS will convert up to 64 independent channels of analog data into binary format and input it into the computer.

1.6 STRUCTURE OF DAS

There are different types of data acquisition systems. DAS can be designed according to the user's applications. But it is possible to generalize the DAS with the essential elements. These elements basically consists of multiplexer, buffer amplifier (Instrumentation amplifier), sample and hold (S/H) circuits, Analog to digital converter (A/D), tri-state d rivers, address decoder, control logic circuitry and the computer. All these components are operate under the control of the auxiliary equipment i.e. the computer, which automatically maintains the correct order of events. The DAS system also contains interfacing circuits. Hence we can say that DASs are small modules containing circuits. This modules accepts number of analog inputs and these are called channels. Channels are either differential voltage signals (two inputs) or single ended voltage signals (referred w.r.t.ground). Fig.(1.2) shows the data acquisition system arrangement which use the microcomputer for timing and control of the conversion process as well as channel selection.

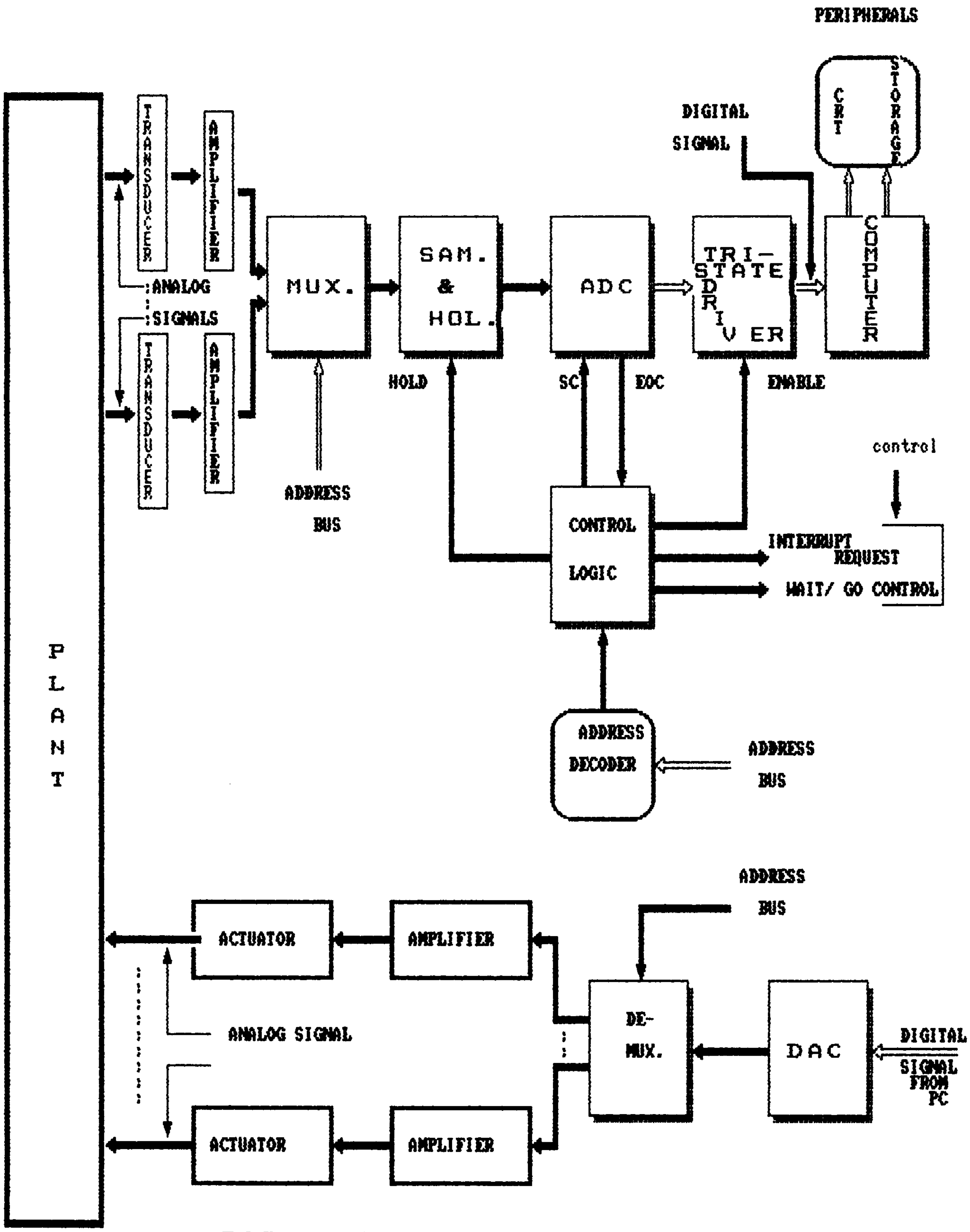

FIG.(1.2) DAS ARRANGEMENT BOCK DIAGRAM.

Sharing of the same sample and hold circuit and ADC for a number of analog signals reduces cost and the selection of the next channel during the conversion improves efficiency. It may be noted that independent signal conditioning is required for each input channel. The addition of signal processing linearizers and programmable gain amplifiers is thus possible. The digital output is available in various binary formats at TTL or CMOS logic levels. An alternative approach using parallel conversion transfers the multiplexing task from the analog to digital domain.

It permits the use of slower and low cost ADCs and eliminates the sample and hold circuits. The analog multiplexer is also eliminated. The configuration is schematically shown in the fig.(1.3) for parallel conversion.

The deciding cost of ADCs and the higher performance of source conversion will result in increased application of this configuration.

The paragraphs bellow presents the general description of each block of DAS.

1.6.1 TRANSDUCERS: Transducers are required to obtain physical quantities from the plant for purpose of monitoring control, and protection. They converts signals from one form to another employing various physical effects. Most transducers provides their outputs in electrical form which are analog equivalents of non electrical quantities. A variety of transducers are available depending on the nature of physical quantities to be measured. For example, thermistor can be used for measurement of temperature, since the resistance varies with temperature. A strain gauge which is based on the principal of resistance variation

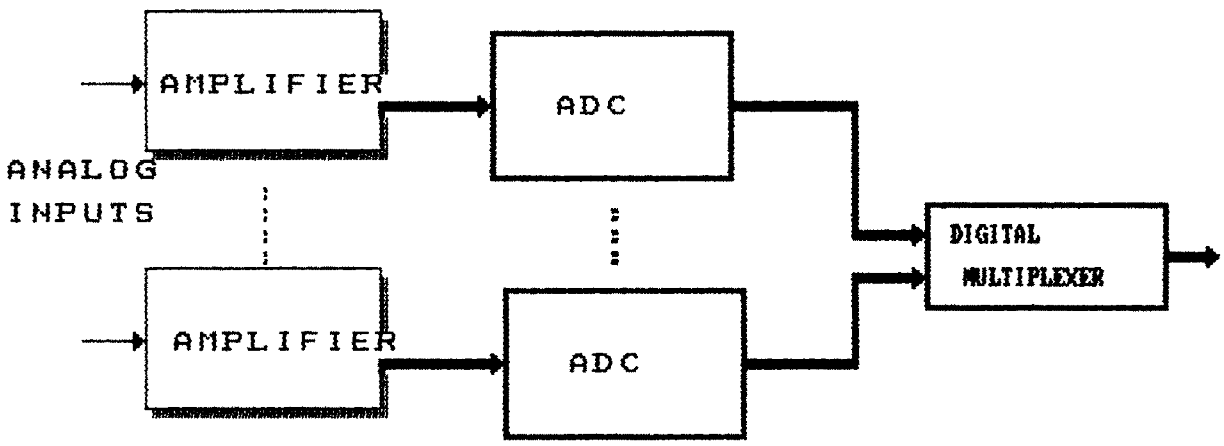

FIG.(1.3) PARALLEL CONVERSION.

when a thin wire is stretched can be used to measured strain. Strain gauges can also provide a means of determining the force or pressure. The full range of physical effects and types of transducers is very extensive. Most transducers produce nonlinear output signals and therefore required " Calibration and Linearizing circuits " or " Computer based software components " to provide the actual value. The output of transducer located in a noisy environment may require filtering before it can be used by the amplifier.

There are number of measuring devices that provide a digital output in the form of pulses or sequences of 1's and Ø's. The pulse count or the pattern of 1's and Ø's can be used as a measure of some physical quantity. Such devices are called digital transducers. They offer higher resolution, higher accuracy and greater reliability as compared to analog transducers. Some transducers which are used generally are temperature transducers, strain gauges, pressure and flow transducers, digital transducers. In todays instrumentation system digital transducers are used for variety of applications.

1.6.2 AMPLIFIERS (INSTRUMENTATION AMPLIFIERS): The out put from the measuring transducers very varied in type and output levels. The following are typical of those encountered in process instrumentation schemes.

1) High level signals from the pressure transducers (i.e.Ø-5 v; Ø-1Ø mA);

2) Low level signals from thermocouples (Ø-1Ø mv); and

3) Contact state from switches, relays (Ø-5Ø v).

Since the desired voltage levels for most analog multiplexers, sample and hold circuits and ADCs are usually between 5-10 v ; hence dc operational or instrumentation amplifiers have to be employed. The purpose these amplifier is to perform one or more of the following functions -

1) Magnitude amplification of the signal,

2) buffering of the signal,

3) conversion of current into voltage signal, and

4) separation of differential signal from unwanted common mode signals.

There are some instrumentation amplifiers. These are -

i) Differential-Input operational amplifier,

ii) Single-ended - Single-input amplifier,

iii) A transistorized chopper amplifier,

iv) A chopper stabilized amplifier, and

v) DC instrumentation amplifier etc.

If instrumentation amplifier is required to have analog signals of differing ranges, connected to the multiplexer input then a programmable gain amplifier would be preferable where a gain would be set in accordance with the multiplexer selection address. The use of the programmable gain amplifiers removes the necessity to standardize on the analog input ranges. The differential gain of most amplifier can be programmed through software or adjusted with resistor typically over a range of 1 to 1000 ohms. If there is a great difference between various input signal levels, some signal conditioning may be required prior to application of the signal to DAS.

1.6.3 MULTIPLEXER (ANALOG MUX.):

An analog multiplexer operates on S/H circuit which hold the required analog voltage long enough for A/D conversion. It consist of an array of parallel electronic switches (e.g.FETs) connected to a common output line. Popular switch configuration includes 4, 8, and 16 channels which are connected in single (single-ended) and dual (differential) configurations.

The multiplexer also contains a decoder-driver circuit which decodes a binary input word and turns on the appropriate switch. This circuit interfaces with standard TTL inputs and drives the multiplexer switches with proper control voltages. For an 8 - channel analog multiplexer a one-of-eight-decoder is used.

Setting time is an important specification for analog multiplexer. It is measured from the time a channel is switched on and depends on the RC time constants formed by the device capacitance and its ON resistance. Using the CMOS switch shown in fig.(1.4) the setting time constant is 1.125 μs for a 16-channel multiplexer. A typical value for setting time for a 20 V step to 0.01 % accuracy is 5 μs. The total leakage current for the 15 off-channel, one ON-channel condition is 15*5 =75 nA. This current is drawn by the 50 PF capacitor of the ON-channel. The voltage OFFSET is approximately 116 μV which is much less than 1/2 LSB (1.245 mV) of a 12 bit ADC. " Crosstalk" is the ratio of the output voltage to the input voltage with all channel connected in parallel and OFF.

A S/H circuit follows the multiplexer in order to

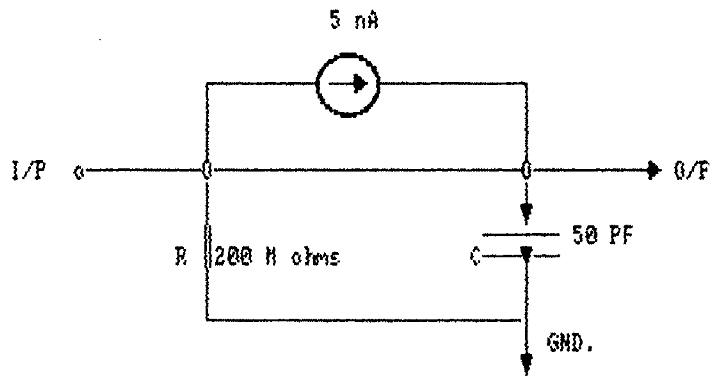

FIG.(1.4) CMOS SWITCH.

minimize the error introduced by the change in the signal value. When the multiplexer switches input channels, the S/H circuit can be commanded to "hold" the signal level during digitization. Multiplexer setting time is thus arranged to occur during the digitization time of ADC. It may be noted that this is only possible when the S/H circuit is employed. After digitization is over, the S/H circuit is gated back to the "sample" mode.

Modern analog multiplexer having high speed and reliability are available as large scale integrated (LSI) circuits and can have as many as 16-channels on a single chip. When specifying multiplexer for a specific application, the following parameters must be considered. These are -

1) Number of channels (4,8,16),

2) Voltage range (+/-5 to +/-10 V),

3) Crosstalk (less than +/- 0.005% for FET switches),and

4) settling time (typically 5 µs).

1.6.4 SAMPLE AND HOLD CIRCUITS:

Microcomputer based data acquisition system (DAS) and direct digital controller (DDC) require a sample and hold circuit (S/H) if reasonable conversion speed and accuracy are to be maintained. Sample and hold circuits greatly reduce errors caused by the input waveform variations while conversion is taking place in ADC. They freeze fast-changing signals during conversion.

Consider a sinusoidal voltage waveform which is shown in fig. (1.5) being converted by an ADC having a conversion time 'tc'.

During the time tc the sine wave varies by V, the digital output from the ADC will therefore be equivalent of some

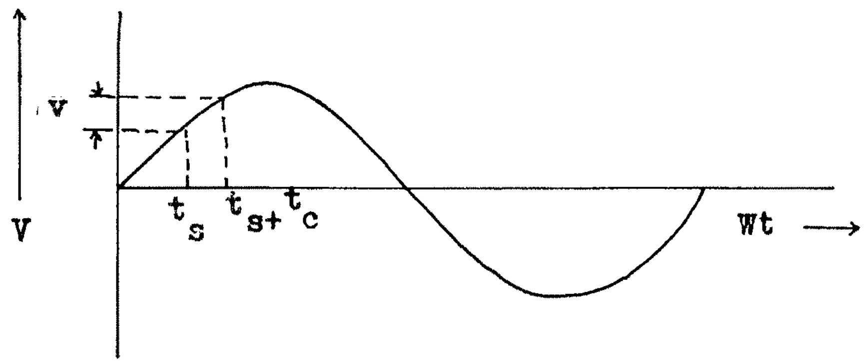

Fig.(1.5) Conversion of Sinusoidal Waveform.

analog value of the voltage during tc instead of being the digital equivalent of the analog quantity at the starting instant ts. It may be noted that if the conversion period tc converts a zero-crossover point on the waveform, the sign of the digital output from the ADC is the most likely to be erroneous. The time uncertainty results in errors between successive points on the waveform. It can be easily verified that error is a function of the highest input frequency and the uncertainty time. Here we can give percentage error = $2 \pi f tu \times 100 \%$

where, f is the maximum input frequency and tu is the uncertainty time. For an ADC having conversion time of 0.5 uS, the maximum input frequency which can be digitized with an accuracy of 0.1 % is 31.8 Hz.

The uncertainty time of conversion can be minimized with the use of a sample/hold circuit which increases the bandwidth of the system for the same accuracy. The S/H circuit is simply a memory device in which an input voltage is acquired and then stored on a high quality capacitor. For the sample and hold circuit shown in fig.(1.6). A1 is an input buffer amplifier with a high input impedance so that the source which may be an analog multiplexer is not loaded. Several hold-mode specifications are also important. The hold-mode drop is the output-voltage change per unit time when the sample switch is open. This drop is caused by the leakage current of the capacitor and the switch and the output amplifier A2 bias current. It may be noted that the drop is only of consequence in a long hold interval. Hold mode feed through is the fraction of the input-signal that appears at the

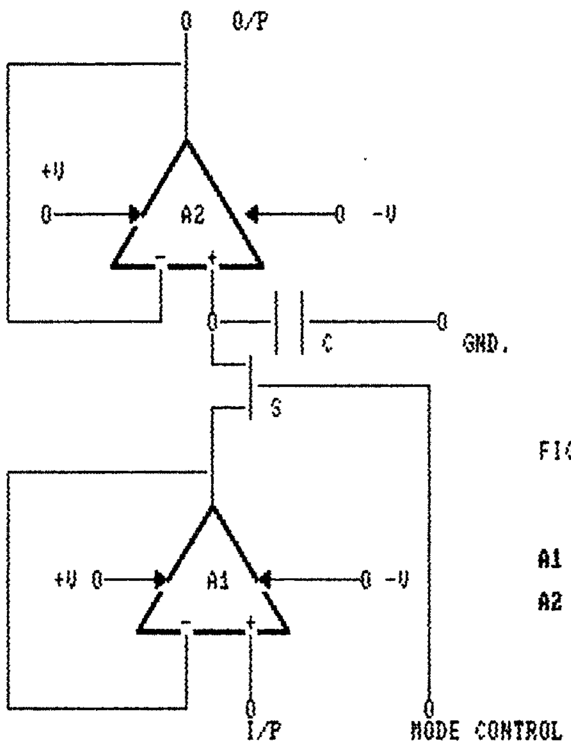

FIG.(1.6) A SAMPLE/HOLD CIRCUIT

A1 - INPUT BUFFER AMPLIFIER.

A2 - OUTPUT BUFFER AMPLIFIER.

output during hold time.

It is important to know the aperture time since it determines the input bandwidth. If the system is being developed from the modules, the acquisition time will have to be considered as this can affect the throughput rate of the whole system. This time is added to ADC conversion time in order to determine the through put rate. Care should be taken to ensure that the drop is such that the voltage decay is less than one bit during the conversion time.

1.6.5 ANALOG TO DIGITAL CONVERTER (ADC) : Analog to digital converter is an important part of data acquisition system. There are great many types of commercially available analog to digital converters (ADCs). ADCs can be categorized into those which require a ADC in their mechanization and those which do not. However, all these operate by comparing the unknown voltage (Vin) against the known reference voltage V_R. They differ in mechanism used for generating V_R. The A/D converter is a member of the family of action/status devices. There are two control lines:

i) the start conversion (SC) or called as action I/P line,

ii) the end of conversion (EOC) or called as status O/P line.

Conversion Process : a) First the unit is activated by placing the signal high;

b) On activation, the unit places the EOC signal low.

The output of A1 must be capable of driving the hold capacitor with enough drive current to change it rapidly. The hold capacitor should have low leakage and low absorption characteristics. The sample and hold circuit uses a FET switches, which rapidly switched ON or OFF by a drive circuit which interfaces with TTL inputs. A2 is the output amplifier which buffers the voltage on the hold capacitor.

There are two modes of operation for a sample and hold circuit : in sample mode (or tracking mode) when the switch is closed, and hold mode is when the switch is open. The mode control is TTL compatible with logic "1" for sample command and logic "Ø" for hold command. In the hold mode, the output is frozen at the value that existed when the switch is opened. The time elapsed between the command to hold and the opening of the FET switch is called the aperture time; it is generally much less than a microsecond. For an ADC using an sample and hold circuit, the aperture time becomes the uncertainty time, thus allowing higher frequency components to be digitized with the same accuracy. Assuming an FET switch with an aperture time of 1ØØ ns, the highest input frequency that can be digitized now becomes 1.6 KHz.

A S/H thus increase the input band-width capability by reducing the uncertainty time. A number of parameters, including the aperture delay are used in characterizing S/H performance. Probably the most important of these is the acquisition time which is defined as: " The time interval for which a signal must be applied for sampling to the desired accuracy". Thus it is the time required, (after the sample command is given), for the hold capacitor to charge to a full scale voltage change and it remains within a specified error (generally Ø.Ø17) band around the final value which will remain in this state until the conversion process is complete. When EOC becomes low the SC signal is placed low.

c) When the EOC signal returns to a high state, the conversion process is complete and the digital representation of the analog input is available on the output data signal line.

The types of the analog to digital converters are : 1) successive approximation, 2) dual slope, 3) voltage to frequency, 4) RAMP time and 5) parallel method. But these ~~are~~ fall into two categories: One is the successive approximation type, which can digitize the twelve bit input only in two microseconds: and the other is the integrating type, here several hundred millisecond time is required ~~to~~ for the same task. While selecting the ADC the conversion time must be taken in account but it does not affect the software, all ADC generate a status bit which depends upon the logic state signals either a conversion is in process or the end of conversion.

CONVERTER SPECIFICATIONS - Deciding the sort of ADC or DAC system required for a particular application can be confusing if specification terms are not understood in relation to the needs. Both DACs and ADCs are available in wide range of process and specifications. Some important specifications for ADC and DAC systems are i) resolution, ii) accuracy and iii) speed.

1.6.6 DIGITAL TO ANALOG CONVERTER (DAC): It can be broadly classified in three categories:Current output, voltage output and multiplying type. The current output DAC, as the name suggests, provides current as the output signal. The voltage output DAC internally converts the current signal into voltage signal. The voltage output DAC is slower than the current output DAC because the delay in converting the current signal into the voltage signal. However, in many applications, it is necessary to convert current into the voltage by using an external operational amplifier. The multiplying DAC is similar to the other two types except its output represents the product of the input signal and the reference source and the product is linear over a broad range. Conceptually, there is not much difference between these three types; any DAC can be viewed as multiplying DAC.

D/A converters are available in integrated circuits. Some are specially designed to be compatible with the microprocessor. Typical applications include digital voltmeters, peak detectors, panel meters, programmable gain and an attenuation and stepping motor-drive.

1.6.7 DE-MULTIPLEXER : We have discussed the analog multiplexer. Here the working of de-multiplexer is apposite to that of the multiplexer. De-multiplexer have one input and many outputs. It connects the input signal to one of the out put channel depending upon the channel address on the channel address line.

1.6.8 ACTUATOR : We know the function of transducer. Function of the actuator is apposite to that of the transducer. Signals coming from the amplifiers are in the electric form. There is necessity to convert these signals in its original form when input signal is controlled through the DAS. Therefore actuator is essential in this system. It converts the electrical signals into its original analog form.

1.6.9 TRI-STATE DRIVERS : Many types of interfacing devices are necessary to interconnect the components of a bus oriented systems. The devices used in the todays microcomputer systems are designed using MLSI technology. In addition, tri-state logic devices are essential to proper functioning of the bus oriented system, in which the same bus lines are shared by several components.

The tri-state logic devices have three states : logic-Ø and high impedance. The term TRI-STATE is a trade mark of National Semiconductor and is used to represent three logic states. A tri-state logic device has third line called ENABLE as shown in the DAS arrangement block diagram Fig.(1.2). When this line is activated, the tri-state device functions the same way as ordinary logic devices. When the third line is disabled, the logic devices goes into high impedance state, as if it were disconnected from the system. Ordinarily, current is required to drive a device in logic Ø and logic 1 state. In the high impedance state, practically no current is drawn from the system. Example of the tri-state inverter is that the "Tri-State inverters with active high and active low enable lines". When the enable is high, the circuit functions as an ordinary inverter and when the enable line is low, the inverter stays in the high impedance state. Tri-state inverter can be also used with active low enable line. When the enable line is high, the inverter stays in the high impedance state.

Some A/D converter have in-built tri-state drivers. However, because of their limited drive capability, they can be used on lightly loaded buses, for heavily loaded systems, as in desk-top microcomputers the in-built drivers are permanently enabled and separate tri-state drivers employed for the data bus isolation. In microcomputer systems the peripherals are connected in parallel between the address bus and the data bus. However, because of the tri-state interfacing devices, peripherals do not load the system buses.

The microprocessor communicates with one device at a time by enabling the tri-state line of the interfacing device. Tri-state logic is critical to proper functioning of the micro-computer.

1.6.10 CONTROL LOGIC : It is a control section of the system. The control logic provides the necessary interface between the computer system bus and the elements of the acquisition unit in providing the necessary timing control. It is to ensure that the correct analog signal (channel) is selected and sampled at the correct time, initiates the A/D conversion process, signals to the computer on completion of conversion, as well as providing for the modes of operation. The data acquisition operation takes in two modes:

a) The WAIT/GO mode: -When the acquisition unit is activated the control logic causes the computer to enter a wait state, until the conversion of the analog data is completed.

b) The INTERRUPT mode: -Where on activation of the DAS, processing of the computer continuous until the control logic generates an interrupt for the computer indicating that the conversion of the analog data is complete.

1.6.11 ADDRESS DECODER : The decoder is a logic circuit that identifies the each combination of the signals present at it's inputs. This module of the DAS accepts input from the computer via the address line (16-bit for a typical 8-bit microprocessor) which serves to select a particular analog channel to be sampled. For e.g., if the input to a decoder has two binary lines the decoder will have four output lines. The two lines can assume four combinations of input signals- 00, 01, 10, 11 with each combination identified by the output lines 0 to 3. If the input is 11 (in binary), the output line 3 will be at logic one, and the other will remain at logic 0. This is called decoding. Various types of decoders are available ; 3 to 8, 4 to 16 and 4 to 10. In addition, some decoders have active low output lines as well as Enable lines. The decoder will not function unless it is enabled by a low signal.

1.6.12 PERIPHERAL UNITS :The CPU communicates with the input-output devices to accept or send data. The I/O devices are known as peripherals. However, the memory is also included in this term. Peripheral units are the support equipment to communicate computer operations to the outside world. These include the operator console where the programs are entered and through which commands can be given to initiate specific actions such as calculations and data outputs by the computer. The console usually has a CRT/keyboard and a typewriter unit for input and output. The other storage devices are magnetic tape etc.

1.6.13 SIGNAL CONDITIONER : These equipments are used to match the input requirement for the converter with the electrical output available from transducer or direct. The signal conditioning equipment may be required to linear processes like amplification, attenuation, comparison, integration and differentiation. They are also required to do non-linear process like modulation, demodulation, sampling, filtering, clipping etc. Separate signal conditioning is required for separate channel.

1.6.14 COMPUTER : Computer works as auxiliary equipment in the system. The development in the field of minicomputer have completely revolutionized the field of logging. They provide much higher scanning speeds, more sophisticated scaling, greater number of operating functions in addition to on line control facilities. Minicomputers & microcomputers are extensively used in " Process Control Instrumentation ".

The computer works as a central element in the system. All control and automatic operation of DAS is done by the computer through the necessary programming.

1.6.15 WORKING OF THE SYSTEM : A block diagram of multichannel DAS having single A/D converter preceded by a multiplexer is shown in fig.(1.1). The individual analog signals from plant are applied directly or after signal conditioning to the multiplexer. For the channel selection computer sends the address via address- decoder to the multiplexer, which will connect a particular input channel depending upon the decoder address. Here instrumentation amplifier adjust its output with the input range of the A/D converter. The output of the amplifier through multiplexer is connected to the S/H circuit. When the computer executes the sample command, the control logic gives a sample signal to the S/H circuit. We know that in the sample mode the S/H

circuit acquire the analog data or it becomes transparent to the analog signal. The computer then initialize the A/D converter module and gives a start conversion (SC) signal through control logic. At the instant of this signal the S/H circuit goes in HOLD mode, thus there is holding of sampled analog signal up to the next sample pulse.

The S/H circuit freeze the fast moving signals, so that the level at a chosen instant can be converted to the digital form. While getting the SC signal the A/D converter starts its conversion. When it finishes its conversion process, it sends out an end of conversion (EOC) pulse. This pulse is read by the computer ; computer enables the tri-state drivers through the control logic and tri-state logic becomes able to transfer the data on the data bus of the computer. The digital representation of analog input signal is available on the computer data bus. Computer process on the digital data and send it to the output peripherals. Peripherals are like printers, CRT, or memory for storage purpose.

For next channel selection computer sends next address to the multiplexer and repeats the above mentioned procedure for all selected channels.

Above all procedure is suitable for the plant, if it is running smoothly. But sometime if the plant is running irregularly then there is necessity to take control action for regularity of the plant. There is also necessity to take corrective action in case of emergencies. This can be done by blocks which are presents at the bottom of the DAS arrangement block diagram. These are DAC, De-multiplexer, Amplifier, Actuator, etc.

Above discussed method of data acquisition is relatively slower than the systems where sample and hold outputs or even A/D converter outputs are multiplexed, but it has the obvious advantage of having lower cost due to the sharing of a majority of subsystems. In cases where signal variations are extremely slow, sufficient accuracy in measurement can be achieved even without the sample and hold (S/H) circuit.

1.7 SAMPLING

Most signals of practical interest, such as speech, biological signals, radar signals, solar signals and various communication signals such as audio and video signals, are analog. To process analog signals by digital means signals, it is first necessary to convert them into digital form i.e. to convert them to a sequence of numbers having finite precision. This procedure is called A/D conversion, and the corresponding devices are called A/D converters.

Analog to digital conversion is a two step process. These are :1) Sampling and

2) Quantization and coding.

Basic parts of an analog to digital (A/D) converters are given in the fig.(1.7). Sampling is the process of the conversion of a continuous time signal into a discrete time signal obtained by

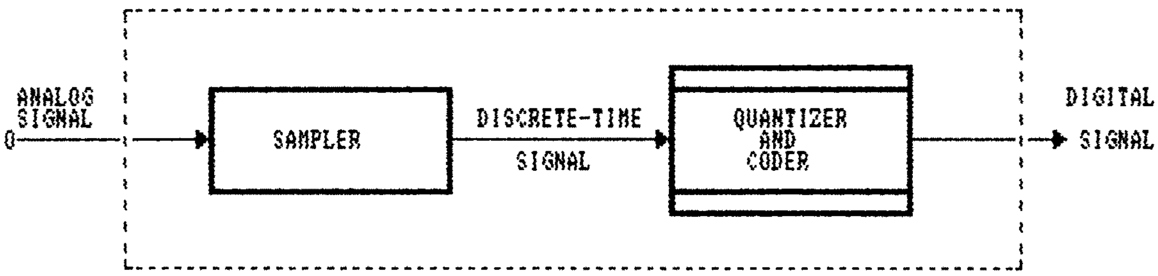

FIG.(1.7) A/D CONVERTER.

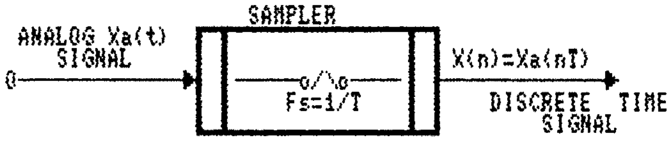

FIG.(1.8a) DISCRETE TIME SIGNAL OBTAINING.

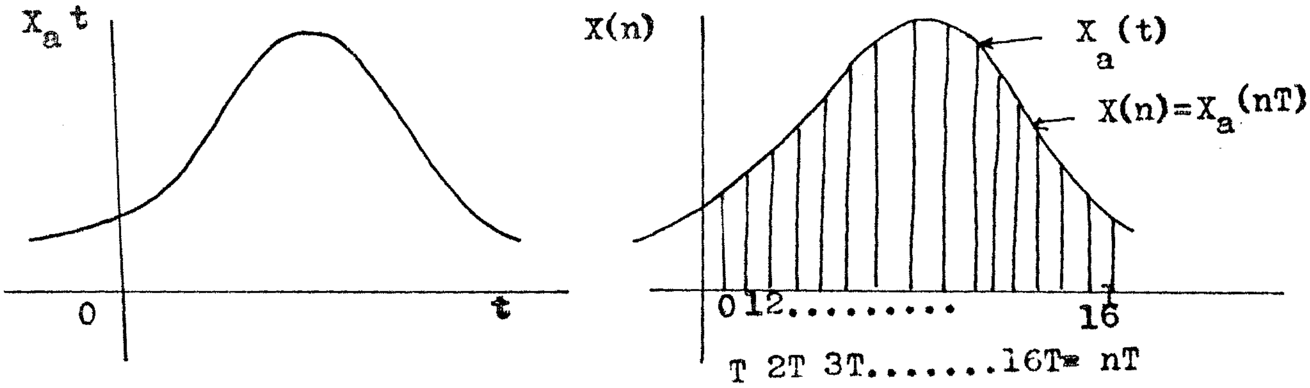

Fig. (1.8 b) Periodic Sampling of an analog signal.

taking "Samples" of the continuous time signal at discrete time instants.

Quantization is the conversion of a discrete time continuous valued signal into a discrete time, discrete valued (digital) signal. The value of each signal sample is represented by a value selected from a finite set of possible values. In the coding process each discrete value is represented by a b-bit number, which may be denoted as $X_q(n)$. The difference between the un-quantitized sample $X(n)$ and quantized output $X_q(n)$ is called quantization error.

There are many ways to sample an analog signal. But the "Periodic or Uniform sampling" method is most often used in practice. This is described the relation

$X(n)=X_a(nT)$........... $-\infty<n<\infty$

where $X(n)$=discrete time signals obtained by "taking samples" of the analog signal $X_a(t)$ every T seconds.

This procedure is shown in fig.(1.8 a & b). The time interval T between successive samples is called the sampling period or sample interval and its reciprocal $1/T = Fs$ is called the sampling rate (samples per second) or the sampling frequency (Hz). Periodic sampling establishes a relationship between the time variable t & n of continuous time & discrete time signals respectively. Indeed, these variables are linearly related through the sampling period T or equivalently, through the sampling rate $Fs = 1/T$, as $t = nT = n/Fs$.

SAMPLING THEOREM : Given any analog signal, how should we select the sampling period T or equivalently, the sampling rate Fs ? To answer this question, we must have some information about the characteristics of the signal to be sampled. In particular, we must have some general information concerning the frequency content of the signal. Such information is generally available to us. For e.g., we know generally that the major frequency components of a speech signal fall bellow 300 Hz. On the other hand, television signals, in general contain important frequency components up to 5 MHz. The information con tent of such signals is contained in the amplitude, frequencies and phases of the various frequency components. On the other hand, detailed knowledge of the characteristics of such signals is not available to us-prior to obtaining the signals. In fact, the purpose of processing the signals is usually to extract this detailed information. However if we know the maximum frequency content of the general class of signals (e.g. the class of speech signals, the class of video signals etc.), we can specify the sampling rate necessary to convert the analog signals to digital signals.

If all the frequency components of analog signal are represented in sampled form without ambiguity, and hence the analog signal can be reconstructed without distortion from the sample values using an "appropriate" interpolation (D/A conversion) method. The appropriate or ideal interpolation formula is called the " **SAMPLING THEOREM** ".

PROOF OF THEOREM : If the highest frequency contained in an analog signal Xa(t) is Fmax = B and the signal is sampled at a rate Fs>2Fmax = 2B, then Xa(t) can be exactly recovered from its sample values using the interpolation function

$$g(t) = \sin 2\pi Bt / 2\pi Bt \qquad \ldots\ldots(1)$$

Thus Xa(t) may be expressed as

$$Xa(t) = \sum_{n=-\infty}^{\infty} Xa(n/Fs)\, g(t-n/Fs) \qquad \ldots(2)$$

where Xa(n/Fs) = Xa(nT) =X(n) are the samples of Xa(t).

When the sampling of Xa(t) is done at the minimum sampling rate Fs = 2B, the reconstruction formula in equation (2) becomes

$$Xa(t) = \sum_{n=-\infty}^{\infty} Xa(n/2B) \frac{\sin 2\pi B(t-n/2B)}{2\pi B(t-n/2B)} \qquad \ldots\ldots\ldots(3)$$

The sampling rate F_N =2b=2 Fmax is called the NYQUIST RATE.

The NYQUIST RATE is F_N = 2 Fmax.

1.8 TYPES OF DAS

There are many different types of DASs in the market. But according to their applications in the industries, these systems can be put in the three major categories.

These are: i) Random channel DAS,

ii) Parallel conversion DAS, and

iii) Multiplexed DAS with memory.

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i) **RANDOM CHANNEL DAS** : Fig.(1.9) shows the functional block diagram of a random channel DAS. In this type of data acquisition system, for selecting a particular channel, computer addressed to the multiplexer and analog multiplexer set to the desired channel. The sample and hold circuit take the desired signal from the multiplexer and hold it. Analog to digital converter digitized this analog signal. After that ready signal is passed to the computer data bus via tri-state bus drivers. If the incoming data is 12-bit and the data bus is 8-bit, the data words must be broken down into 2-bytes and addressed separately.

ADVANTAGES: Design of this DAS is simple, straightforward, and comparatively low cost.

DISADVANTAGE: In this system the computer must either enter a wait mode while data is not ready or it can proceed with assigned task but repeatedly looking for a data-ready signal and return for the data.

This type of DAS can serve any part of the data acquisition market where the task of computer is light enough enter a wait mode of data request. Such a wait period could be as low as 10 to 20 μs. The fast components that is sample and hold circuit and A/D converter are very expensive. The lower cost systems may require a wait period of 100 to 200 μs before data is available. However, at the expense of more complex software, the computer could remain busy during the period of data presentation would return for the data when mode ready available.

ii) **PARALLEL CONVERSION DAS** : Fig.(1.10) shows the block diagram

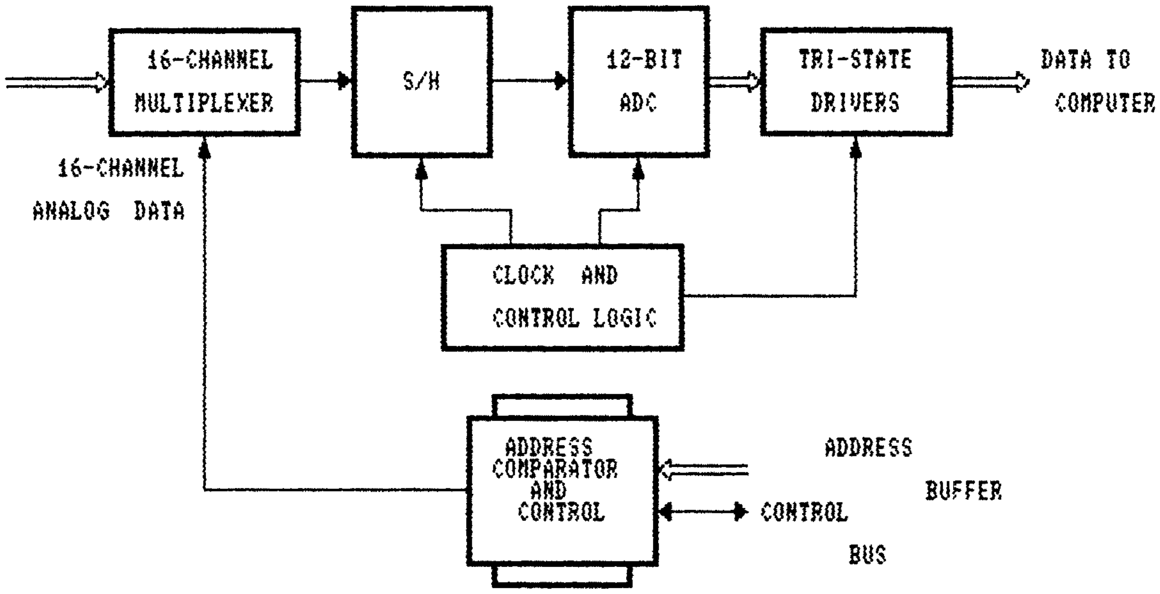

FIG.(1.9) RANDOM CHANNEL DAS.

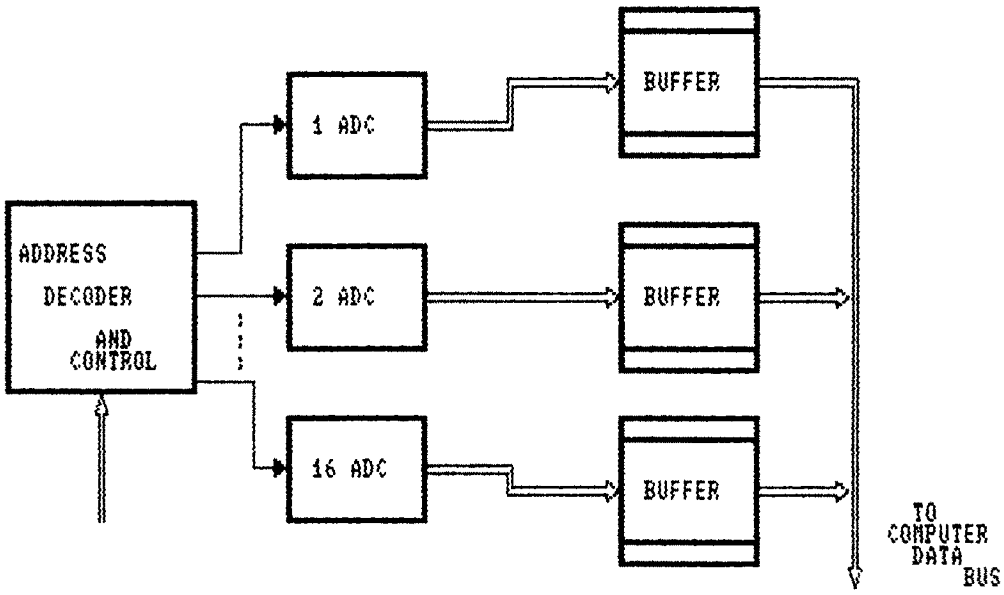

FIG.(1.10) PARALLEL CONVERSION DAS.

of parallel conversion DAS. It requires 16 A/D converters, 16-anti alias filters etc. This type of DAS does not required the sample and hold circuitry. It requires only one address decoder, these all outputs of the buffers are given to the computer data bus.

This system is based on the relative speed at which changes occur in the data, scanning rate can also be increased or decreased. The cost of the A/D converters has been reducing, and now a days it is economically feasible to employ an A/D converter for each analog input since each A/D converter is assigned to an individual channel. For that channel there is a necessity of faster A/D converter. The reduced conversion rate means that using the lower cost A/D converters and due to that the system cost may not be significantly different from the random channel DAS.

ADVANTAGES :1) Simplicity and immediate data access.

2) It provides additional advantage in industrial data acquisition systems where many strain gauges, thermocouples are distributed over large plant area.

3) The analog signals are digitized at the source, the digital transmission of data to the data center can provide enhanced immunity against line frequency and other ground-loop interferences.

iii) **MULTIPLEXED DAS WITH MEMORY** : The important characteristics of this DAS is that it contains a in built memory chip. This memory chip is interfaced to the computer system in the memory access mode without a wait period. Fig.(1.11) shows the block diagram of multiplexed DAS with memory. The restriction on the

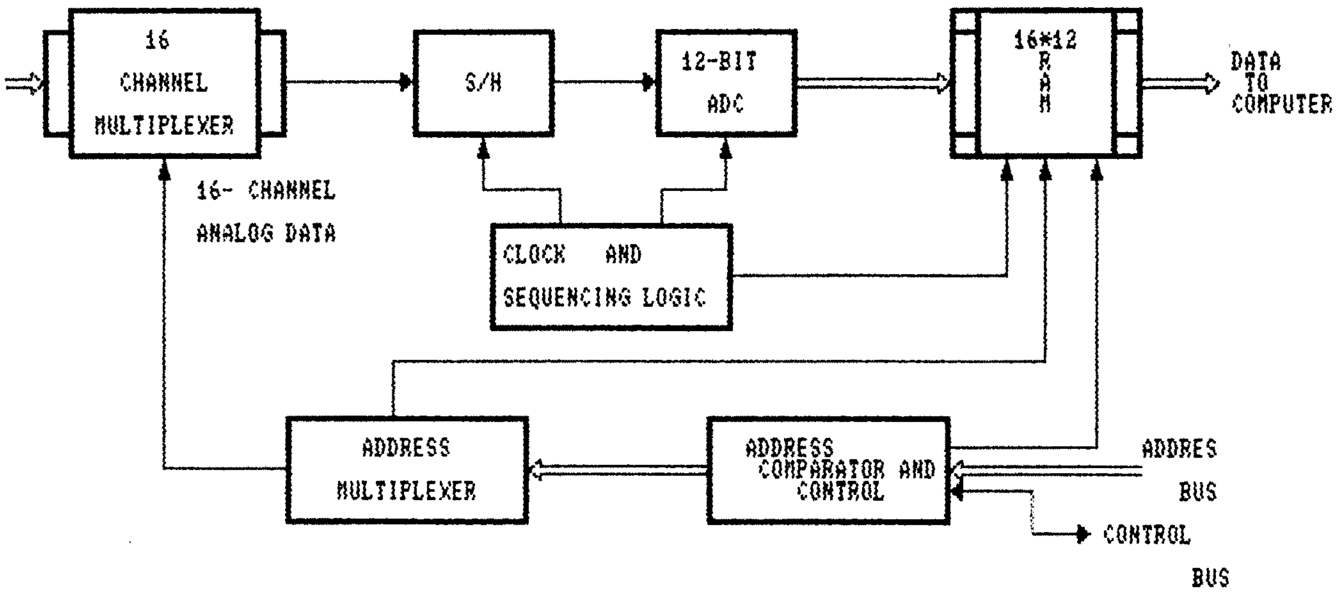

FIG.(1.11) MULTIPLEXED DAS WITH MEMORY.

bandwidth or data throughput rate exist mainly due to operating times of ADC and S/H circuit. These can be overcome by using sophisticated device available in the market. The multiplexed DAS allows the computer to operate in most efficient manner.

ADVANTAGES : i) The total package cost of this system is lower than that of the parallel conversion DAS. The required space power and overall cost per cannel is lower.

ii) There is a dedicated on-card RAM (16*12), the system does not required a special A/D converter designed with buffered output latches.

DISADVANTAGES : The accessed data may be as much as 800 microseconds old compared to a possible 1.4 microseconds with parallel conversion.

COMPARISON OF THREE TYPES OF DAS :

Sr.No.	Parallel conversion	Random addressed	Multiplexed with memory
i)	16-A/D converter.	1-A/D converter.	1-A/D converter.
ii)	16-anti-aliasing-filter.	1-S/H module.	1-S/H module.
iii)	Control circuits.	1-sixteen channel multiplexer.	1-sixteen channel multiplexer.
iv)	Additional power for extra converters.	16-anti-aliasing filters.	16-anti-alising filters.

v) Lower data bandwidth.	More complex control circuits.	One 16*12 RAM.
vi) Simple software.	longer data access time; possibly more complex software.	High speed data access; simple software.

From this comparison we can say that DAS designs might configure parallel conversion techniques, especially because of the increasing trends in reduction of the monolithic A/D converters. The multiplexed DAS with memory is simple in circuit and software design.

1.9 SELECTION FACTORS OF DAS :

For choosing the data acquisition system selection features such as conversion time, throughput, number of channels, and some other factors are easy to overspecify. But over-spaced DASs cost a lot of money. On the other hand under specified DASs are also money wasters because they will not do the job. Obviously, we must have some means for zeroing in on the specification that are most relevant(pertinent) to the job.

Some important factors for the selection of the DAS:

i) form of the DAS, ii) interfacing methods, iii) input voltage range, iv) output coding and v) throughput rate and sampling rate.

i) FORM OF THE DAS - The first job is to determine the form that the DAS will take. If we are going to need a rack mounted DAS, that can be mounted with a mini or microcomputer cabinet. Such a system would often be cheaper in long run than building an equivalent data acquisition system from one of the other products. In other cases, however we will want to buy a pre-made printed circuit board that is designed to plug into the microcomputer that we have selected or was selected for us. In still other cases, we will want to buy either an integrated circuit or hybrid function module DAS and mount it on a PC board ourselves. This is the feature that would be followed if we had a bastered computer or one that is not popular to have attracted the attention of the PC board DAS makers. We would also use this system if the DAS was to be remote or part of another instrument or system and then only the data would be transmitted to the computer.

ii) **INTERFACING METHOD** - In cases where the DAS is mounted inside the computer, plugged into the computer bus, then it is probably best to memory map the DAS. In this system, the 8 to 16 channels are treated as memory locations. In some versions, only the lowest channels need be specified because it uses the memory address boundary system. The DAS is located exactly at some 4k boundary in the computer memory space channel number 1 has the address of the boundary selected while the remaining 15 channels are automatically placed in the next 15 memory slots above the boundary.

The second interfacing method, used where memory mapping is not possible, is to connect the DAS to a series of I/O ports. This would be done in cases where the memory is full or the DAS is remote. It is not usually to good an idea to extend the data and address buses of the microcomputer indefinitely.

iii) **INPUT VOLTAGE RANGE** - If the input voltage range is excessive, then either another DAS must be selected or an attenuator provided between the signal source and DAS input channel. If, on the other hand, signal level is too low for efficient use of the admissible codes, then we must provide an amplifier for that channel. In some cases, it will be necessary to attenuate some channels, amplify others, and leave rest alone. This necessity points up the utility of DASs that contain built-in programmable gain instrumentation amplifiers. When a channel is selected, then the proper gain for that channel is also cranked into the DAS.

iv) OUTPUT CODING - Select the output code according the needs of the system. For example, we can use ordinary straight binary for unipolar systems. But if the analog signal is bipolar, then we must either apply an offset voltage that makes it uni-polar or provide the coding scheme that will account for the bipolar input voltage. There is more than one system for representing bipolar data and the one selected depends in parts on how dearly need to know the value is the exactly zero.

v) THROUGHPUT RATE AND SAMPLING RATE - The conversion time, throughput rate and sampling rate are all interrelated parameters. There are certain constraints placed upon the sampling rate. A well known theorem tells us that the sample rate must be at least the twice the highest frequency component in the waveform. For example, if the Fourier series for the waveform has the significant "harmonics" to 500 Hz, then a thousand samples per second sampling rate is needed.

Throughput rate and sampling rate can cost a lot of money. If, we have a 10 KHz waveforms then it will be necessary to have some very fast DACs. But, if most of the parameters in the system have much lower frequency component and only one or two waveforms have a high frequency content, it might be wise to use a low-rate DAS, and then buy a couple of faster A/D converters to serve only the high frequency channels. Such a procedure would usually be cheaper than specifying all 16 (or more) channels to have the sample frequency as needed for the single high frequency channel.

1.10 FACTORS REQUIRED FOR THE DAS DESIGN

Number of factors are required for designing the data acquisition system. Some important factors are given below.

1) Sample and hold - The sample and hold is used to keep the analog signal constant while the A/D converter is making the conversion. This feature is especially needed on the successive approximation form of data converter. Some systems will use a series S/H circuits, one each for the analog signals. This can be done when the conversion time to make all 16 channels into digital form is too long for the rate of change of the various data signals. This is especially necessary in some scientific experiments, such as might be found in medical laboratory.

Many of the parameters are interrelated, and in fact it is these correlations that the system user is seeking. In order to make sure that correlated data stays correlated, it is necessary to sample all lines at the same time and then make various A/D conversions. This procedure allows to have related analog data signals essentially converted at the same time. But this is not for free. In some cases, especially where a slow A/D converter is used for the number of analog channels, we see a phenomena called DATA CREEP or DATA WALK. It occurs because of the drop in the sample/hold circuits. There is problem with all capacitor stored S/H circuits is the slow discharge of the capacitor during the store mode. If this drop is sufficiently large, then we will find that the data at the last conversion in the multichannel DAS is not as valid as the first conversion. We can test for 'CREEP' by connecting all input to the same signal source, and then sampling. If there is no creep, then A/D conversion process will yield the same binary value for all parallel channels (+/- 1 LSB because of normal A/D uncertainties).

2) **Requirements of the computer** - The microcomputers have certain advantages over the other electronic circuit methods is attested to buy the fact that so many are sold. The most obvious advantage is reduced size. There are so many advantages of the microcomputer to the designing of the electronic instrumentation like data acquisition system. One principal advantage of computer in DAS is that the drift of analog circuit is eliminated.

3) **Software programming** - There are software routines which will be required for the DAS. These routines are compatible with the hardware programming and the other characteristics of the DAS. The programs may include delays waiting for the ADC to complete conversion.

4) **Hardware programming** - Data acquisition system gives many options to the user for the I/O operations. These options include

: a) Uni-polar/bipolar operations, b) address selection, c) amplifier gain, d) differential/single-ended operation and others. They are typically selected by jumpers or switches between pins of DAS or by the attachment of resistors as specified in the specification sheet of the module.

5) Overall response time - A DAS does not provide the digital conversion of data on a selected channel at the instant of the selection occurs. Rather, there is delay while the multiplexer acquires the system channel, while amplifier selects to the value on the channel, and while the A/D converter performs the conversion. This time will be important for the determination of the maximum sampling rate from the DAS. Here the time may run from tens of microseconds to hundreds of microseconds, depending on the number of bits converted, gains of the amplifiers, single-switching speed and how long it takes the computer to process the value and how many other variable channels to be sampled.

1.11 APPLICATIONS OF DAS

Data acquisition systems are widely used in the large fields for a variety of industrial and scientific areas, including the aerospace, biomedical and telemetry industries. Here use of data acquisition system depends upon the application and intended use of input data to be recorded. According to the user applications area analog DASs and digital DASs are used separately. Some time it also necessary to use of analog and digital DAS for the same application. But todays modern electronic DASs can perform thousands of measurements per second. DAS detect changes smaller than one part in one million and respond to those changes less than (1/100)th of a second.

For understanding purpose DASs applications can be broadly classified in the three main categories. There are so many applications belonging to these categories are given below :

SCIENTIFIC AND EDUCATIONAL APPLICATIONS :

i) In different remote site measurements like studies of large civil structures,measurements in open fields, remote weather stations and test in moving vehicles.

ii) In manufacturing, scientific research and development, Education and military/aerospace.

iii) Waveform digitizing, signal processing and analysis.

iv) Data acquisition, measurement and many analysis operations.

INDUSTRIAL APPLICATIONS :

i) To monitor the temperature and pressure of a process and actuate alarm when the limits are exceeded.

ii) Applications like -

a) Oil, gas and electrical distribution,

b) Power plant control system,

c) Petroleum and refinery system control,

d) Chemical process control systems,

e) Numerical machine tool control systems and

f) Medical and instrumentation systems.

BUSINESS APPLICATIONS :

i) Used to check the performance on a production line or on a maintenance facility. The applications vary from electronic component testing such as capacitor testing to large system testing like to check out all of the electronic systems on an aircraft.

ii) Task on monitoring the temperature in a large building or on oil refinery or the flammable gas concentration in a coal mine. Also in medical field the task as patient monitoring etc.

iii) Task as monitoring at many points, the condition of a process or equipment, for example; a nuclear reactor, aerodynamic structure, rocket or jet or internal combustion engine. In other words, use of multichannel DAS i.e. each point to be monitored must be measured rapidly, one after the other, in sequence. Each measurement in digital form is recorded for latter accurate analysis.

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