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DATA ACQUISITION SYSTEM

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Data acquisition systems are used for collection, pre-processing and storage of signals. They provide an accurate, real-time analysis alongwith data collection and transmission for applications in hydrometeorology, agricultural engineering, geophysics and related areas. Modern microprocessor-controlled systems can be classified as central data acquisition systems and remote data acquisition systems. The former type is suitable for central station applications, while the latter type is ideal for remote applications e.g.the automatic hydrologic and weather stations. Modular structure of these systems provides enormous expansion capabilities. Additional input/output devices, storage processing and communication facilities can be conveniently hooked up with these systems. The report describes general configurations of the two types ,i.e. Micromet and Auto Met.V,System,of data acquisition systems alongwith their typical applications. Automatic hydrologic system is described in more detail as it is being procured for installation at the National Institute of Hydrology. Some advanced, mostly electronic, hydrometeorological sensosrs have also been described as they form important components for use with such acquisition systems.

1. INTRODUCTION

Data acquisition systems are designed to accept multiple data input signals, to process the data according to user-selected functions, and to output the data in a meaningful form to divices such as printers and recorders. These systems provide an accurate, real time analysis alongwith data collection and transmission for aplications in hydrometeorological studies, agricultural studies , geophysical studies and various industrial purposes.

Data acquisition systems are categorized in two basic classes: analog systems and digital systems, depending upon the mode of handling of the signal. The type of data acquisition system, whether analog or digital, depends largely on the intended use of the measured input data. In general, analog data systems are used when wide bandwidth is required or when lower accuracy can be tolerated. Digital systems are used when the physical process being monitored is slowly varying (narrow bandwidth) and when high accuracy and low per-channel cost is required. Digital systems range in complexity from single-channel measuring and recording systems to sophesticated automatic multichannel systems that measure a large number of input parameters, compare against reset limits or conditions, and perform computations and decisions on the input signal. digial data acquisition systems are in general more compelex than analog systems, both in terms of the instrumentation involved and the volume and complexity of data they can handle.

A typical data acquisition system consists of individual sensors with necessary signal conditioning, multiplexing, data conversion, data porocessing, data handling and associated transmission, storage and display systems. In order to optimize the characteristics of a system in terms of performance handling capacity, and cost, the relevant sub-systems may often be combined. The analog data is generally acquired and converted to digital form for the purposes of processing ,transmission, display and storage.

Processing may consist of a large variety of operations from simple comparison to complicated mathematical multiplication. It can be for such purposes as collecting information (averages, statistics, etc.) ,converting the data into useful form for using data for controlling a process, performing repeated calculations to seperate out signals buried in noise, generating information for displays, and a variety of other goals. Data may be transmitted over long distances (from one location to another) or short distances (from a test site to a nearby computer). The data may be displayed on a digital display device or as a part of a cathode ray tube (CRT) presentation. The same may be stored in either raw or processed form, temporarily (for immediate use) or permanently.

The characteristics of data acquisition systems depend both on the properties of the analog data itself and on the processing to be carried out. Based on the environment, a broad classification divides data acquisition systems into two categories viz., those suited to favourable environments(minimum radio frequency intereference and electromagnetic induction) and those intended for hostile environments. The former category may include, among others, laboratory instrument applicoations, high sensitivity calibration tests and research or routine investigations. In these systems, the designer's task is oriented more towards making sensitive measurements rather than to the problems of protecting the integrity of the analog data. The second category specifically includes measurements protecting the integrety of the analog data under the hostile conditions present. Situations of this nature arise in industrial process control systems, aircraft control systems, hydrometeorological and geophysical systems.

Measurements under hostile conditions often require devices capable of wide temperature range operation, excellent shielding, redundant paths for critical measurements, and considerable processing of the digital data. In addition, digital conversion of the signal at early stages, thus making full use of high noise immunity of digital signals, as well as considerable design effort in order to reduce common mode errors and avoidable interferences, can also enhance performance and increase reliability. On the other hand, laboratory measurements are conducted over narrower temperature range, with much less ambient electrical noise, employing high sensitivity and precision devices for higher accuracies and resolution.

The important factors that decide the configuration and the sub-systems of the data acquisition system are (i) resolution and accuracy,(ii) the number of channels to be mentioned, (ii) sampling rate per channel, (iv) signal conditioning requirement of each channel, and (v) cost.

2.0 REVIEW

Data acquisition systems are used to measure and record signals obtained in basically two ways : (a) signals originating from direct measurement of electrical quantities, these may include dc and ac voltage, frequency, or resistance, and are typically found in such areas as electronic component testing, environmental studies, quality analysis work etc. (b) signals originating from transducers, such as strain gauges, thermocouples etc.

Data acquisition systems can be categorized into two major classes : analog systems and digital systems (See figure 1). Analog systems deal with measurement information in analog form. An analog signal may be defined as a continuous function, such as a plot of voltage versus time, or displacement versus pressure. Digital systems handle information in digital form. A digital quantity may consist of a number of discrete and discontinuous pulses whose time relationship contains information about the magnitude or the nature of the quantity. An analog data acquisition system typically consist of some or all of the following elements:

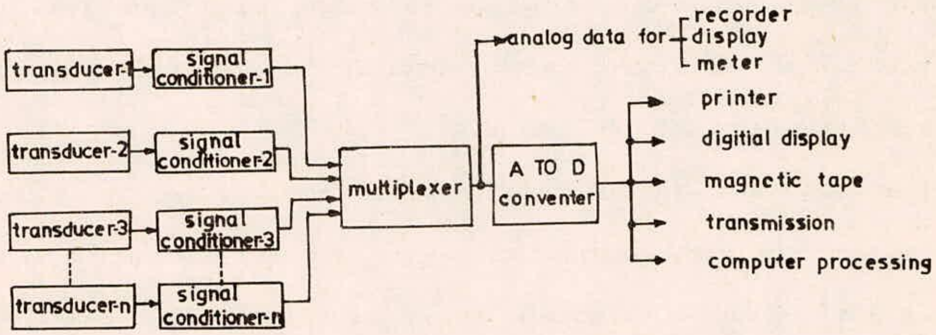


Fig.1. Generalized data acquisition system

(a) Transducers for translating physical parameters into electrical signals,

(b) Signal conditioners for amplifying, modifying, or selecting certain portion of these signals,

(c) Visual display devices for continuous monitoring of the input signals. These devices may include single or multichannel cathode ray oscilloscopes (CROs), storage CROs, panel meters, numeric displays, and so on,

(d) Graphic recording instruments for obtaining permanent records of the input data. These instruments include stylus-and-ink recorders to provide continuous records on paper charts optical recording systems such as mirror galvanometer recorder and ultraviolet recorders, and

(e) Magnetic tape recording sytstem for acquiring input data, preserving their original electrical form, and reproducing them at a later date for more detailed analysis.

A digital data acquisition system may include some or all of the elements shown in figure 2. The essential functional operations within a digital system include handling analog signals, making the measurement, converting and handling digital data, and internal programming and control. The function function of each of these system elements is listed below:

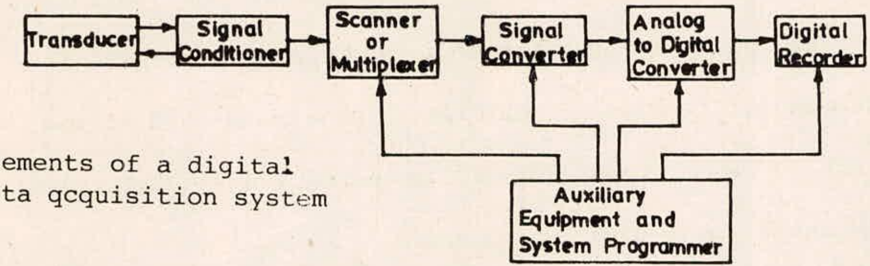


Fig.2.Elements of a digital data qcquisition system

(a) Transducer - translates physical parameters to electrical signals acceptable by the acquisition system. Some typical parameters include temperature ,pressure, acceleration, weight,displacement, velocity etc.; electrical quantities such as voltage, resistance, or frequency, may also be measured directly,

(b) Signal conditioner - generally includes the supporting circuitary for the transducer. This circuitary may provide excitation power, balancing circuits, and calibration elements

(c) Scanner, or multiplexer - accepts multiple analog inputs and sequentially connects them to one measuring instrument,

(d) Signal converter - translates the analog signal to a form acceptable by the analog-to-digital converter,

(e) Analog-to-digital converter (ADC) - converts the analog voltage to its equivalent digital form. The output of the ADC may be displayed visually and is also available as voltage outputs in discrete steps for further processing or recording on a digital recorder,

(f) Auxiliary equipment - these comprise of instruments for system programming functions and data processing. Typical auxiliary functions include linearizing and limit comparison. These functions may be performed by individual instruments or by a digital computer,

(g) Digital recorder - records digital information on punched cards perforated paper tape, magnetic tape, cassette tape, typewritten pages, or a combination of these systems. The digital recorder may be preceded by a coupling unit that translates the digital information to the proper form for entry into the particular digital recorder selected.

Modern data acquisition systems utilize a modular, systematic approach to the collection and retrieval of hydrometeorological data. The same basic elements are used in every environmental monitoring system. The specific application dictates the actual components and system complexity. This modular approach facilitates construction and maintenance, it also allows additions to or changes in a system as the application changes. Two basic system configurations utilising the modular concept, as shown in figure 3, can be classified as Central Data Acquisition System and Remote Data Acquisition System.

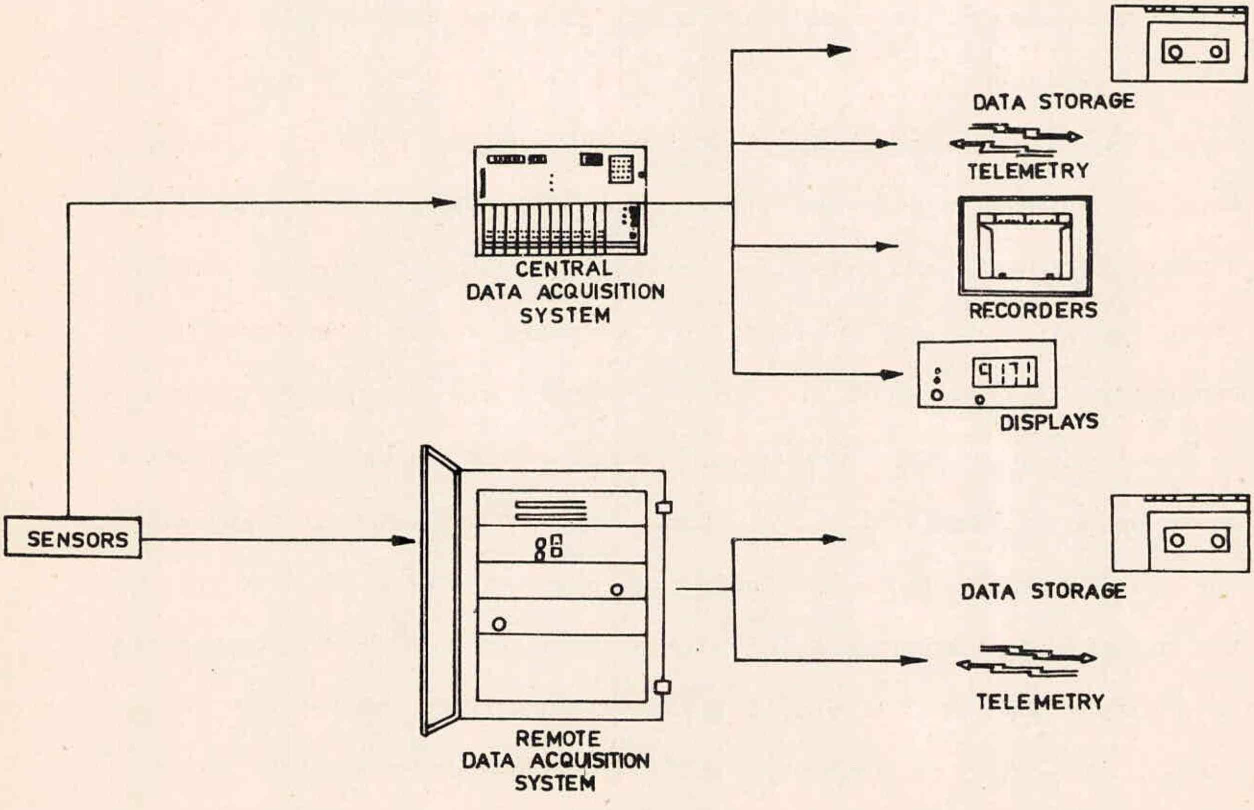


Fig.3.Basic Configuration of D.A.S.

3.0 METHODOLOGY

3.1 Central Data Acquisition System

The central data acquisition system (e.g.M733) of Quali Metrices Inc.) is based on a modular concept. The approaoch employs a backplane bus structure and single function, plug-in hardware cards. Standard cards are provided with each system, and optional cards are added according to user requirements. Additional cards can be added to a working system as processing requirements change, allowing the expansion of a simple system into a more complicated one. This approach simplifies system maintenance, as a malfunctioning component can be easily identified and replaced.

The M733 accpets inputs from a variety of hydro-meteorological sensosrs through signal conditioning modules. Data can be output to devices such as a cassette type recorder, a digital printer, a multitrack tape recorder, or a variety of telemetry systems. Possible system configurations are shown in fig.4. Sensors are connected directly to specialized signal conditioning modules for input to the system. These modules standardize the input signals and make them available for interrogation by a communication module, the interface between the signal conditioning and the data acquisition system. The communications module and its associated signal conditioning modules can be located at the site or placed at a remote site many kilometers away. If remote installation is required, the communications link may be either dedicated telephone lines or radios. Input to the M733 can also occur through a standard RS232C terminal or a computer link. This input type

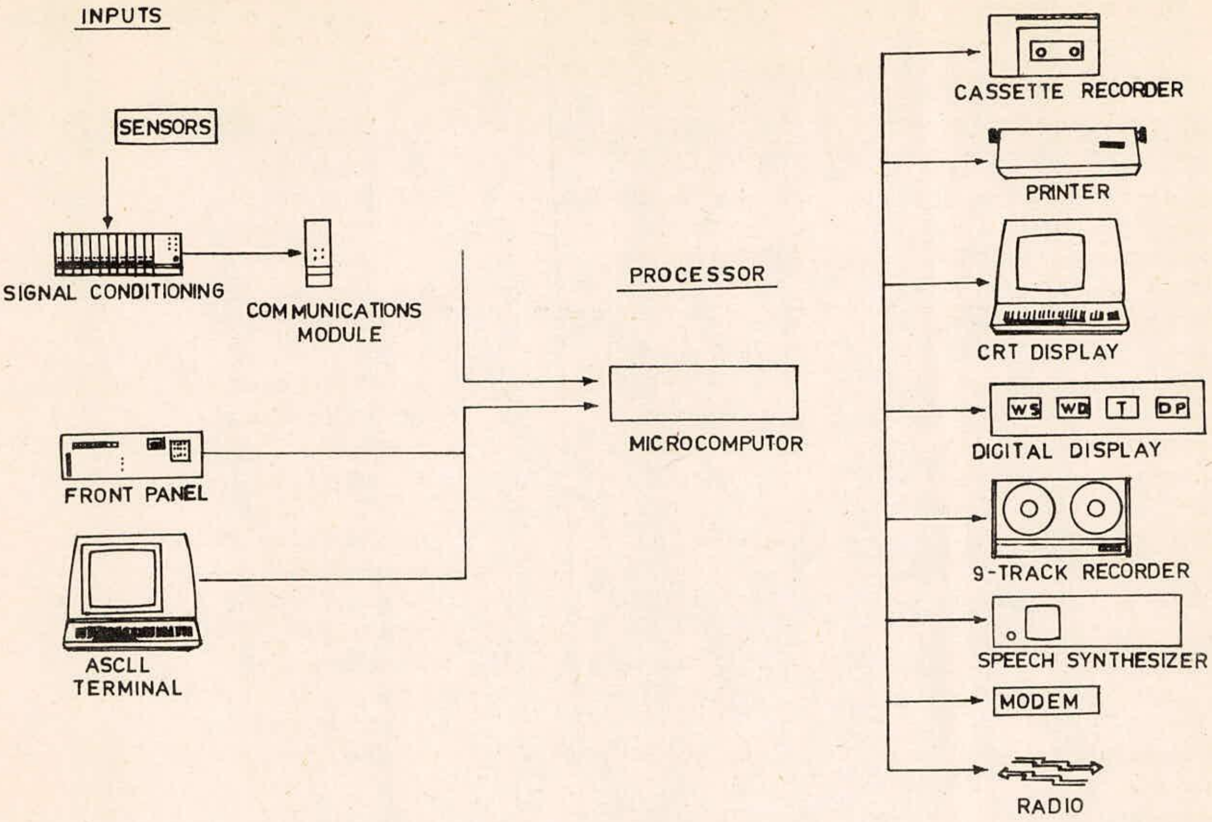


Fig.4 Central Data Acquisition system

uses standard ASCII characters at baud rates from 110 to 19,200.

The standard sensor input signal conditioning modules are listed in table 1. All standard modules have four analog outputs. The first is a 0 to 5 VDC switched output that is used for automatic interrogation by the M733 system through the communications module. When the M733 addresses the module, this output is switched onto the analog signal bus. This bus is common to all signal conditioning modules and terminates at the A/D converter in the communications module. The other three module outputs are available to drive external recorders or displays. Two low impedance voltage outputs are provided: 0 to 5 VDC and 0 to 1 VDC(recorder output). A current output is also provided, either 0 to 1 mA or 4 to 20 mA. A vareity of special function modules can also be included to extend the capabilities of the signal conditioning system. These include special input modules, calculating modules, and

TABLE 1

STANDARD SENSOR INPUT MODULES

Measurement	Standard Range	Input Transducer
Wind speed	0-100 mph	DC generator
Dual-range wind speed	0-50/0-100 mph	DC generator
Wind speed	0-100 mph	AC generator
Dual-range speed	0-50/0-100 mph	AC generator
Wind speed	0-100 mph	HF tachometer
Dual-range wind speed	0-50/0-100 mph	HF tachometer
Wind speed	0-100 mph	Light chopper
Dual-range speed	0-50/0-100 mph	Light chooper
Forward and reverse wind speed	± 60 mph	DC generator
Dual-range forward & reverse wind speed	± 30/±60 mph	DC generator
Wind direction	0-360°	5K-ohm single wiper pot
Wind direction	0-360°/540°	5K-ohm single wiper pot
Elevation	±50° elevation	1K-ohm pot
Solar radiation	0-2ly	Thermopile or silicon cell
Temperature	-40 to 50°C or -40 to 120°F	4-wire thermistor
Temperature	-40 to 50°Cor -40 to 120°F	100-ohmplatinum resistance sensor
Delta temperature (requires 1460 for reference)	±5°C,±10°C,or ±15°C	4-wire termistor
Delta temerature (requires 1465 for reference)	±5°C,±10°C,or±5°F	100-ohm platinum resistance sensor
Relative humidity	0-100%	Thin film capacitor, 3.6 VDC excitation
Dew point temperature	-40 to 50°C or -40 to 120°F	Thermistor
Dew point temerature	-40 to 50°C or -40 to 120°F	Platinum resistance sensor
Event accumulation (precipitation)	0-100 or 0-1000 counts	Contact closure
Water level	0-5' to 0-100 m	Potentiometer, 1K-ohm std.
Soil moisture	100%-dry(0-5 V)	Resistive element
Low rainfall event accumulation	0-100 or 0-100 counts	Light chopper
Event duration	On or off	Contact closure
Atmospheric pressure	600-1100 mb	Piezoresistive diaphragm
Atmospheric pressure	600-1100 mb plus any 100 mb span	Piezoresistive diaphragm
Atmospheric pressure	600 to 1100 mb	Variable-capacitance cylinder
Ceiling height (requires 2 card slots)	0-5100'	2-digit BCD input
Visibility	Depends on sensor (0-5 miles max.)	0-10 mA input.

display modules.

The M733 microcomputer consists of several standard hardware cards which plug into an STD bus backplane. A variety of optional hardward cards may be added, depending on the application requirements.

The central processing unit is the 780 microprocessor. In this system, it controls data acquisition(scan interval and channel number), converts raw data to engineering units, and performs the user-specified mathematical functions. In addition, this processor automatically calibrates the associated signal conditioning units once a day and corrects for sensor nonlinearities and drift. It will also set and check alarm points, check signal status flags in order to accept or reject data, and format reports and summaries for output. The CPU card includes 8K of random access memory(RAM) for working storage. A total of 32K of read-only-memory(ROM) is provided on two cards to support the operations of the CPU and the standard software. This memory is in a non-volatile, permanent form.

A real-time clock provides the system with the Julian date plus hours, minutes and seconds. It includes on board battery back-up to keep the clock running for up to a week after a power failure. The clock card also features a watch-dog circuit which restarts the system if the program gets trapped in an endless loop. A power fail detection circuit disables input to this and other battery-backed boards during power-line transients.

Standard inputs and outputs to the M733 processor occur through a serial input/output (SIO) card. Each SIO card has two ports, one with full RS232 capabilities(data and control) and a second with RS232 levels on data lines only (control lines are TTL levels). This port can also be configured for 20mA loop current operation. Both ports are capable of full duplex operation, and baud rates may be independently selected for each. Each port can also be configured for either terminal or communication functions.

The software for use with these microcomputers comprises of three standard programs. All three have similar concepts but differ in the types of calculations performed and data processed. For each data channel, the user can select scan order, calculation type, report interval, output units(Metric or English),alarm, limits, and operation mode (e.g.in or out of service, high or low calibration mode).

(i) The standard meteorological program can scan multiple signal conditioning racks and collects upto 18 channels of data. The number of input channels which may be accomodated is determined by the number of output channels required and the number of calculation options per input channel. Calculation options include instantaneous data, accumulated data, averages, standard deviation, maximum, minimums, time of event, and alarm checking. The program also performs engineering unit conversions and output formatting.

(ii) The air quality monitoring program provides control commands to air quality analyzers as well as collecting air quality and meteorological data. The program can scan upto 12 data channels, usually consisting of 4 to 6 met. channels and 6 to 8 air quality channels. These can be located at upto four stations, one local and three remote. Status flags are monitored along with the data input signal, and the data is processed based on the condition of the status flags. Seven calculation options are provided, including standard and vector averages and sigmas.

(iii) The standard airport program brings together all the environmental parameters required to operate an airport safety. Data collected includes meteorological information (wind speed and direction, temperature, barometrie pressure) along with visual limitations, cloud height, and runway conditions. Calculation options include QNH,QFE, visibility, runway visual range and speed and direction of peak gusts.

The outputs from this system are taken in form RS232 serial outputs and a high speed parallel output using tape input/output cards. The D/A module converts the digital output of the micro computer into an analog output suitable for recording on a strip chart recorder. Each module includes 4 D/A converters, accomodating 4 channels of data. The module plugs into a standard signal conditioning rack and receives input from the M733 on backplane bus. The analog outputs are available on the rear panel terminal strip. The output may be either 0-1 VDC or 0-5 VDC.

The distributer module allows a single RS232 port to drive upto three standard RS232 lines with no signal degradation. This module may also be used to allow three RS 232 inputs to enter the microcomputer through a single port, e.g.,three different remote signal conditioning racks. An addressable communications switching unit(ASCU) provides more input/output options.

The various output and peripheral devices which can be used with microcomputer system are cassette tape recorder, terminal printer, video display terminal, telemetry systems and track tape recorder units. Seven telemetry options include modems for communication via dial-up phone lines or dedicated lines,speech synthesizer and radio transceivers.

3.2 Remote Data Acquisition System

The remote data acquisition system (e.g. Model Macro 20 of Qualimetrics, Inc) is utiliszed specifically for unattended operation in remote locations. It is built from low power (CMOS) microprocessor-based components and can include solar panel to recharge the battery. Two various of this data acquisition system are available : The Model 1160 which mounts in a standard 19-inch wide equipment bay and the Model 1161 which comes installed in a weather proof enclosure. This system has 20 standard input channels from analog or digital sensors. It processes and stores the data according to user-selected programsand outputs the data to a recorder on site and/or to remote devices via telemetry. The figure (5) outlines the basic system configuration and identifies the different output devices.

Each Macro 20 includes a standard input board which accept the sensor output signals directly and prepares them for processing. This board accomodates 16 differential analog inputs over 4 different DC voltage ranges: ± 50 mV, ± 200 mV, ± 500 mV, or ± 2V. Scaling resistors can be added to the input board if the desired input does not fall within one of these ranges. The input board also accepts 4 digital inputs from pulse-or contact output sensors. Each of these input channels will accomodate upto 65, 536 counts per scan interval. Six status signal can also be input. The variety of input signals accepted includes a wide selection of sensors. These include anemometers, pyranometers, thermistor probe, humidity probe, rain gauges, soil moisture sensor etc.

The Macro 20 processor board includes a microprocessor, a real-time clock, and the memory required to support the system. Standard software consists of 17 calculation types, including averages, maximums,

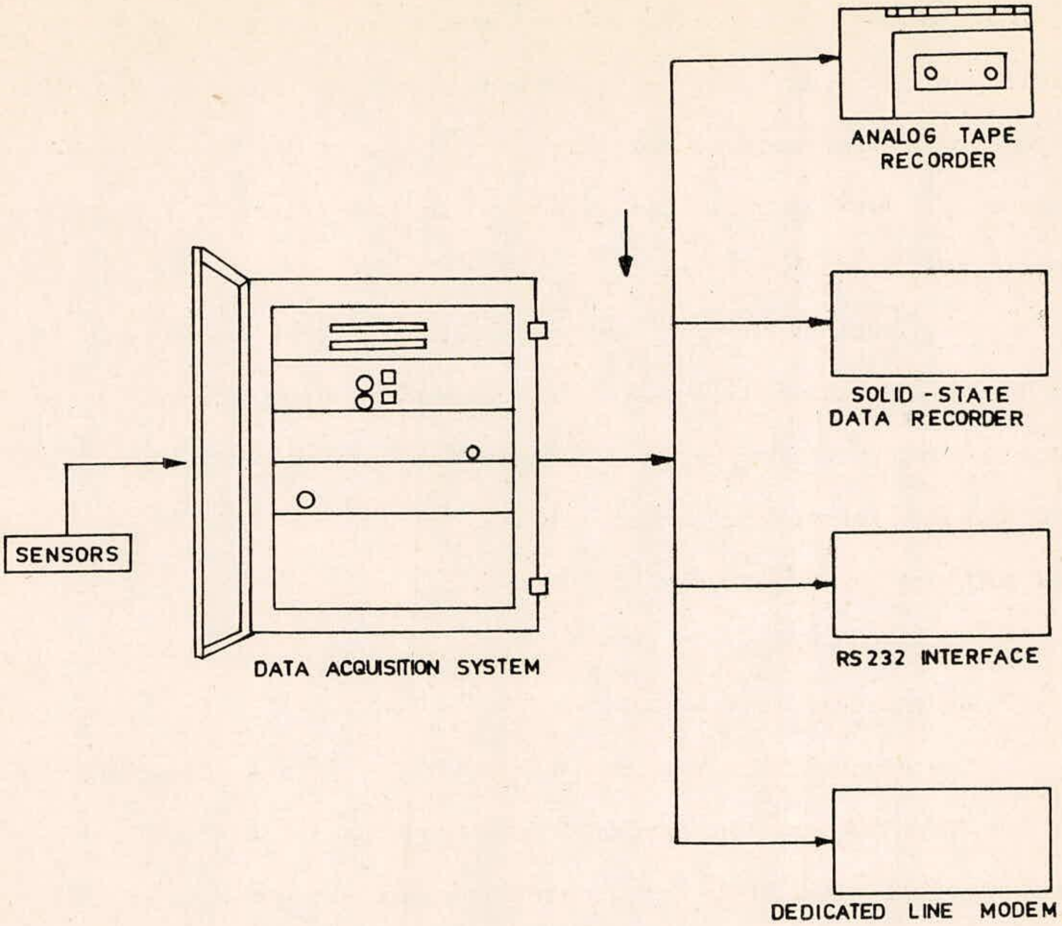


Fig.5.Remote data acquisition system

minimums, standard deviations, or instaneous values. Upto 4 calculations can be selected for each data channel Second level calculations can be performed on already processed data. Inputs are made through a 16-key keypad. Programs may also be input through the RS232 port, or they may be read off of one of the recorder output devices.

Proccesed data is stored in one or two internal buffers, each holding 1365 data points. One buffer stores data to be output to an on-site recorder. This data is output as a block when the buffer gets full. Block recording saves time and power. The other buffer is accessible via RS232 or a modem.

This data acquisition system has three output ports. One allows direct connection of an analog tape recorder. A second port supports a solid state data recorder and the third port provides an RS 232compatible output which can be connected to an RS 232 interface and /or a dedicated line modern. All three output ports may be activated simultaneously. Data outputs can occur at a user-selected interval and/or hourly and/or daily.

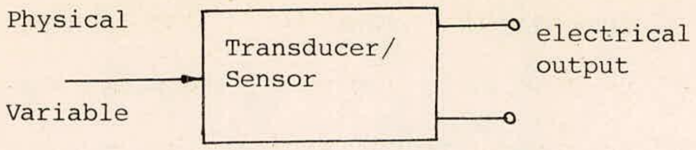
The various output and peripheral devices which can be used with this microcomputer system are dedicated line modern, solid-state data recorder, analog tape recorder and tape/memory module recorder. The RS 232 interfaces provide output to devices like telemetry units and printers.

3.3 Hydrometeorological Sensors

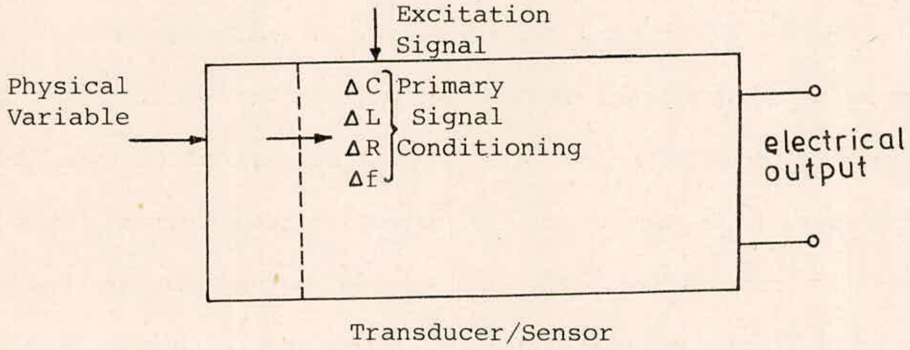
Transducers or sensors are said to be the front-end element of any data acquisition system. Their function is to transform or convert physical data from the non-electrical domain to the electrical domain. These can be further classified as analog sensors and digital sensors. Digital type of sensors convert physical data directly to the digital data domain i.e. in 0 and 1 form, whereas analog sensosrs transform into analog form i.e. continuous/intermittent waveform.

Two broad classes of sensors can be identified as active and passive sensors. As shown in figure 6, active sensors incorporate some signal conditioning devices like filters, ampfliers etc. Passive sensors are those of self-generated output type, not involving any signal-conditioning.

First type of sensors are called single-stage device since the physical parameter is converted directly to the electrical form. In contrast, the latter type includes basically two-stage devices. The first stage involves the transformation of the physical variable to



(A) Passive type of sensor



(B) Active type of sensor

Fig.6. Two classes of sensors; C= capacitor, L = inductor, R= resistor, f = filter

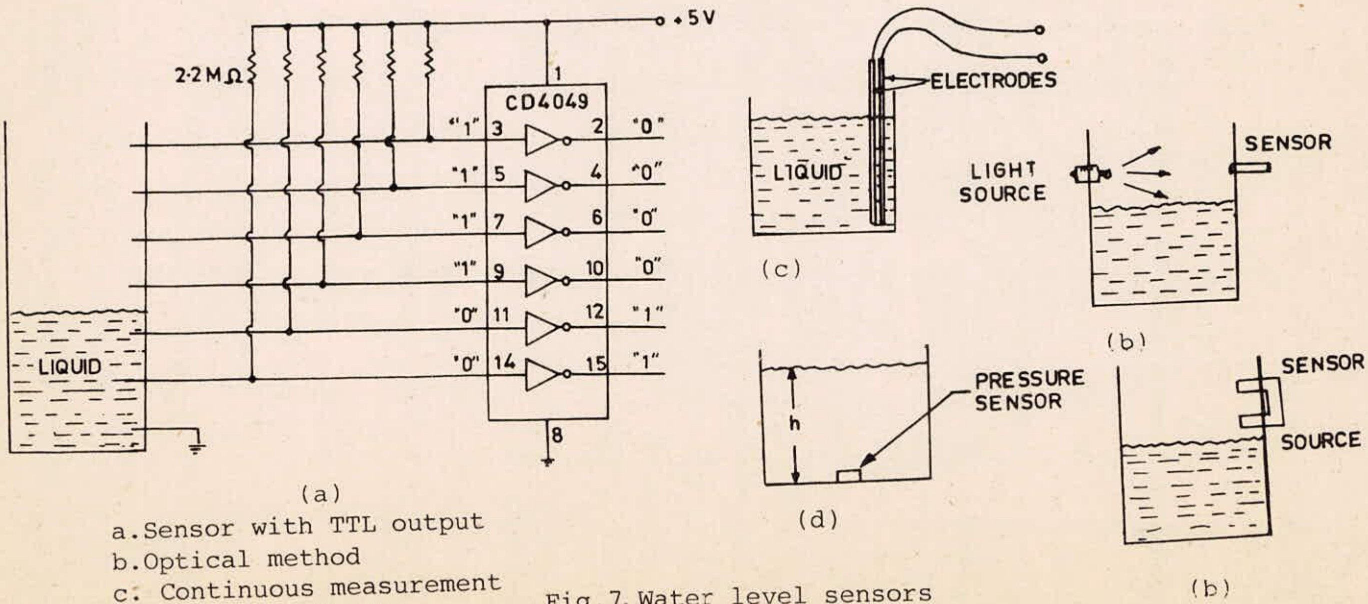
an analog parameter such as resistance, capacitance, inductance, frequency or charge. The second stage, which requires an external excitation signal, is the primary analog signal conditioning module wherein the analog parameter is converted to a current or a voltage. This second stage is now commonly provided by manufactures to facilitate the use of their products. There is some additional cost for this primary signal conditioning, but the result is a device having, in most cases, a voltage output, for example, in the volt rather than the millivolt range. This increased output level facilities interfacing these sensors to the data acquisition systems.

In the following paragraphs some modern state-of-art sensors which can be utilized in hydro-meteorological data acquisition systems, have been described.

3.3.1 Level sensing transducers

Direct measurement of ground water level in observation wells can be done either manually operated or by automatic recording measurements. The simplest method of manual measurements is by suspending a weighted line(e.g.a steel tape) from a defined point at the surface. Electrical contact methods involve the lowering of one or more elctrodes to water level, contact with the water closes the circuit and is indicated by warning light, buzzer or meter. The water level can also be measured by some principle electrochemical effect of two dissimilar metals immersed in water and by detecting the current flow so generated by a micro-ammeter. Another common method is to measure the position of a float. A float linked to a counter-weight by a cable over a pulley indicates the level changes in a well by indicating the rise or fall of the counter-weight, measured with respect to a fixed mark on the cable. The design of such a system involves choosing a displacement transducer and designing the methcnical linkage from this transducer to the float.

For liquids that show some electrical conductivity, a scheme of level detection is illustrated in figure 7a. The technique relies on



a.Sensor with TTL output
b.Optical method
c. Continuous measurement
d.Pressure method

Fig.7. Water level sensors

the conductivity and on the high input impedance of such devices as the MOSFET. The CD 4049 is a CMOS buffer that produces TTL voltage levels at its outputs. In the absence of any liquid in the tank, all the buffer inputs are held high by the 2.2 M resistors. When the level reaches the wire to a particular input, the input is pulled low by the conduction of current through the liquid, and the buffer output in question goes high. The liquid is then known to be between the highest sensor with a high output and the lowest sensor with a low output. If a continuous rather than a quantized measurement of the liquid level is required, then a pair of parallel electrodes running the full depth of the container is needed, as shown in figure 7c. The conductance between the two electrodes is then directly proportional to the depth of the liquid. Alternating current is passed between the two electrodes for taking the measurements.

If the problem is to determine when a liquid is above or below a certain level, optical sensors can be used to detect whether a light beam has been interrupted by the liquid. Two of the possible configurations are shown in figure 7 b(A). A sensor/source pair such as the MCT 8 (optical proximity switches) would make a suitable detector for the arrangement in figure 7 b (B). This device need not be mounted within the tank, as in the diagram, but could be mounted around a sight gauge attached to the tank.

For insulting fluids, an arrangement such as the one depicted in figure 7c can be used. In this case, the measured quantity is the capacitance between the electrodes rather than the conductance. A convenient configuration could be a pair of concentric cylinders which are open at the bottom. The liquid partially fills the space between the two cylinders and increases the capacitance of the probe as the liquid level rises. Any AC method, using variable area capacitance transducer alongwith an AC bridge circuit can be used to obtain an electrical output, needed to measure the capacitance of the probe

The pressure in a fluid is related to its height, h, above the point of measurement by the formula:

$$P = P_o + \rho g h$$

Where Po is the pressure at the surface of the fluid (normally atmospheric), is the density of the fluid, and the g is the acceleration due to gravity. If a pressure transducer, reading gauge pressure is mounted at the bottom of a tank (see figure 7 d), it will provide a measure of depth for a liquid of known density. If the transducer is always to be used with same fluid, its output can be calibrated in terms of depth rather than pressure units.

Sonic echo methods are also used for depth measurements. In this method a sound pulse is transmitted and time required for its echo to return from the surface is measured. The sound may be transmitted from the bottom of a container so that the elapsed time is directly proportional to the depth of the liquid. Alternatively, sound may be projected from above a surface, so that the elapsed time is directly proportional to the distance of the level being sensed below the transducer. The latter approach is a non-contact method and is particularly useful when corrosine or otherwise harmful liquids are being sensed. Commercial ultrasonic water level measuring equipment are available from many manufacturers. For example, Polaroid markets a relatively inexpensive ultrasonic ranging kit that can sense the surfaces within the range of 0.9 to 35 ft.

3.3.2 Flow measuring sensors

Flow meters are basically divided into mechanical and electrical types. In mechanical types, the most common method followed for flow measurement is to place an obstruction in the flow pipe so as to produce a secondary effect such as the torque developed on vanes or the pressure difference across an orifice plate. The electrical potential developed in a coil by a liquid moving in a magnetic field, frequency of rotation of a turbine, change in velocity of sound in a moving fluid, and change in resistance of an element placed in the fluid path are some of the basic principles used in an electrical type of flow meter.

Various flow meters can be classified under the following types, depending upon the physical principles of operation as well as other characteristics:

i. Head type flow meters based on differential pressure measurements. Examples are orifice plate, venturi tube, flow nozzle and pilot tube,

ii. Electromagnetic flow meters,

iii. Rotameters (variable area meters),

iv. Mechanical flow meters,

v. Anemometer-positive displacement type, and turbine,

vi. Ultrasonic flow meters,

vii. Vortex flow meters

Relative characteristics of the various types of flow meters are given in table 2.

In electrical type of sensors, recently there have been many improvements. In the following paragraphs, some of these sensors are described. Pressure difference methods:

a. Pilot tube. When there is a fluid flow past the Pilot tube, as shown in figure 8c, the pressure P_b, at the impact hole is

TABLE 2.COMPARISON OF FLOW METERS

Type of flowmeter	Fluid Application					Performance					Remarks
	Liquid-non-corroosive	Liquid corrosive	Liquid viscous	Range m^3/s	Rangeability	Linearity	Repeatibility " F.S.	Accuracy %F.S.	Pressure loss	Immunity to viscosity effects	
Orifice	A	A	L	$1x10^{-7}$ to 5	4	S	0.1	2	High	Good	Low cost;not recommended for sluries.
Venturi	A	A	L	-do-	5	S	0.1	2	Medium	-do-	High cost;handles suspended solids;good for large flows.
Flow Nozzle	A	A	L	-do-	4	S	0.1	2	-do-	-do-	Recommended for high pressure/temperature stream flow; limited to moderate pipe sizes.
Pitot tube	NA	NA	NA	-	5	S	[illegible].05	1	Nil	Poor	Mostly for aerodynamic measurements.
Rotameters	A	A	L	$1x10^{-7}$ to 5	5	0.1%	0.5	2	Low	-do-	Low cost;handles wide variety of corrosives; limited to small pipe sizes and capacities.
Electromagnetic	A	A	A	$5x10^{-2}$ to 5	10	0.2% F.S.	0.1	0.5	Nil	Good	Only for conductive fluids;high cost;large pipe sizes and capacities;available in several materials of construction
Positive displacement	A	A	A	$5x10^{3}$ to 1	10	0.2% F.S.	0.1	0.5	Low	-do-	Good accuracy,especially for low flow rates; easy to instal and maintain;moderate cost; limited pipe size.

Turbine meter	A	L	L	$5x10^3$ to 1	15	0.2% F.S.	0.2	0.5	do	do	Excellent repeatability limited range for viscous materials;easy to install and maintain
Hot wire/ Film	NA	NA	NA	-	4	S	0.02	0.2	NIl	Poor	Applicable for aerodynamic measurements and flow in water channels.
Ultrasonic	A	NA	NA	$5x10^{-3}$ to 1	25	0.5% F.S.	0.1	1	do	Good	Applicable to sonically conductive liquids.
Vortex	A	A	L	$5x10^{-3}$ to 0.1	25	0.5% F.S.	0.1	0.5	Low	-do-	High Cost; handles variety of chemicals, including sluries;good response speed;applicable for gas mass flow measurements.

A-applicable NA-not applicable S-square root relationship L-limited application.

(After Rangan et.al.1983)

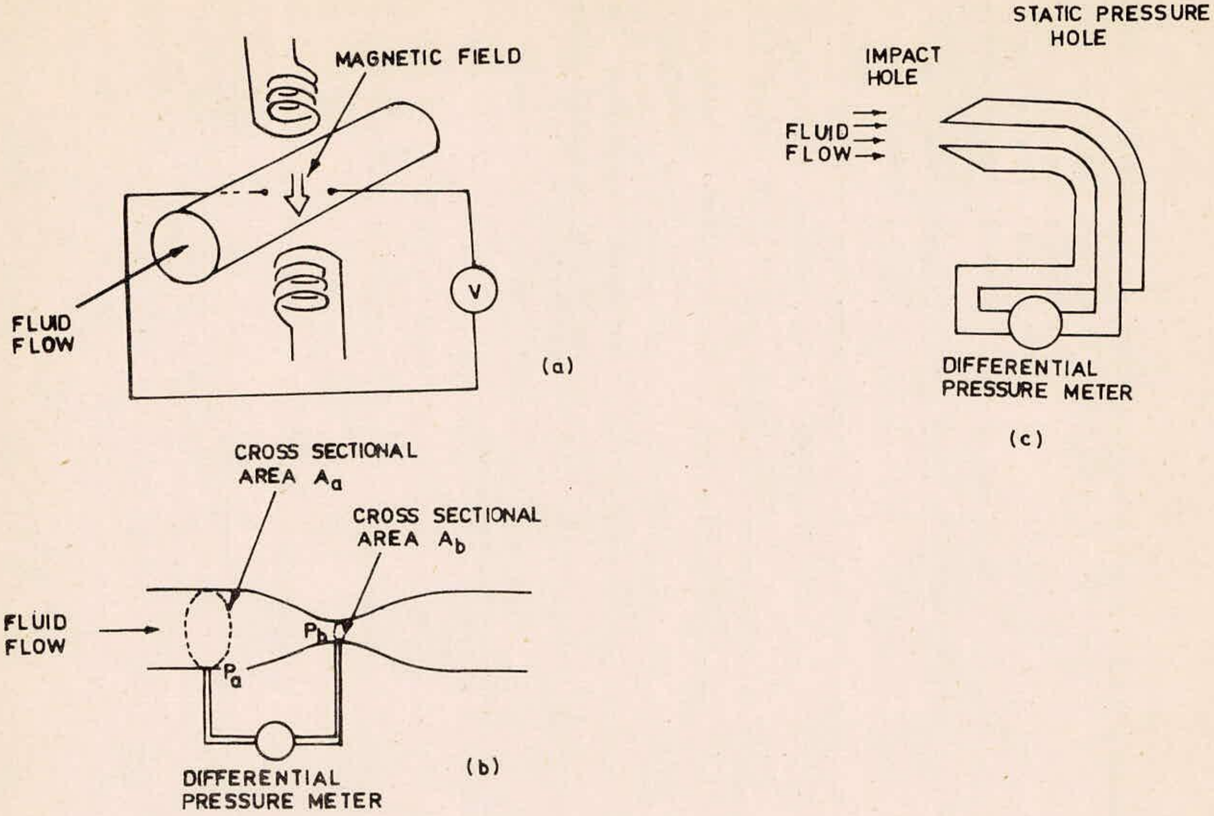


Fig.8.Water flow sensors

higher than the pressure P_a, at the static hole by an amount that is directly proportional to the square of the fluid velocity, i.e.

$$V^2 = k(P_b - P_a)$$

In the formula, k is a constant that is dependent only on the fluid density. In such cases, an integrated circuit pressure gauges, available commercially, can be used in the differential configuration to derive an electrical signal that is proportional to the square of the velocity of the fluid. Taking the square root of this signal provides a voltage which is proportional to the fluid velocity.

National Semiconductor markets a series of IC pressure gauges, at the heart of which lies a piezoresistive circuit consisting of a wheatstone bridge diffused into a water of silicon. This water is a diaphram that distorts under the influence of the pressure to be measured. The distortion changes the values of the resistors in the bridge and the out of balance voltage becomes a measure of the pressure. An output voltage of about 1 mv/psi is produced. The sensor, complete with signal conditioning circuitary, is available as the LX 14XX, LX 16XX, and LX 17XX series. They require only a single 9-volt to 15-volt DC power supply for their operation.

This method is insensitive at low fluid velocities, due to the low pressure differentials generated across the pilot tube. An air speed of 16 m/sec, for example, sets up a pressure difference of only about 0.04 psi. A water speed of 1.6 m/sec sets up a pressure difference of about 0.4 psi.

b. Venturi tube. When fluid flows along a constricted tube, as shown in figure 8b, the pressure P_a, upstream of the constriction will be higher than the pressure P_b, at the constriction. The pressure difference is proportional to the square of the fluid velocity upstream of the constriction according to the equation:

$$P_a - P_b = k\,(V_a^2 - V_b^2)\,\left[\left(\frac{A_a}{A_b}\right)^2 - 1\right]$$

where k is a constant that depends on the density of the fluid. Here also, an IC differential pressure transducer can be used to provide the velocity-dependent electrical signal. This method is much more sensitive than the Pilot tube, but at the expense of severely obstructing the fluid flow and wasting some of the head pressure.

Electromagnetic induction method:

This method places no obstruction in the path of the fluid flow, and produces a direct electrical output. If a magnetic field is applied across the direction of flow of a conductive fluid, then a voltage, V, will appear across that fluid at right angles to both the direction of flow and the applied magnetic field, as shown in figure 8a. The size of this output voltage is given by:

$$V = Blv$$

where B is the magnitude of the magnetic field in test (= 10^4 gauss),l, is the distance between sensing electrodes in medtres, and v is the velocity of the fluid in ms^{-1}

This method is not very successful if the conductivity of the fluid is less than 10^{-5} mho cm^{-1}. Also, the voltage measuring equipment must have a high input impedance, especially for low values of conductivity. Whereas, this method has the particular advantage that it is unaffected by changes in viscosity, density, temperature and consistency of the fluid; even turbulent flow does not affect its output. The inclusion of suspended solids in the fluid is also no problem.

3.3.3 Radiation sensors

Sensors used to measure radiations in the visible and near infrared regions of the electromagnetic spectrum are described in the following paragraphs.

(a) Photodiode

The semiconductor PN junction, when used as a rectifier, shows a small, temperature-dependent reverse current originating from minority carriers. The latter are created close to the depletion layer by thermal excitation and are swept across the junction by the combined effect of the barrier potential and the reverse bias voltage. This reverse current can be increased by shining light onto the diode to create minority carriers at a higher rate. The reverse current then becomes a measure of the incident light intensity. Since all semiconductor diodes are subject to this effect, manufacturers package them in opaque encapsulation. Scarping the paint off a glass-encapsulated diode allows the photodiode effect to be observed. However, if a predictable response is required of the diode as a photodetctor, then it is advisable to obtain a device which is actually marketed as a photodiode. Normally the reverse current is directly proportional to the light intensity, with a proportionality constant of about 0.8 A(mW/cm^2). Alternatively, the photodiode can be used as a photovoltaic device, in which the incident light causes a voltage to be developed across the diode. In this case, the open circuit voltage developed is logarithmically related to the light intensity.

(b) Phototransistor

Under the normal bias arrangements for a transistor, the collector-base junction is a reverse-biased PN junction. The collector-base junction is therefore capable of acting as a photodiode, with any light falling on the transistor increasing the collector-base reverse leakage current. Once this current enters in the base region, it behaves as normal base current and is amplified by the transistor action. If I_r is the current which flows from collector to base due to phtodiode effect, then the resulting collector current, Ic, is given by:

$$I_C = (h_{FE} + 1)\ I_\gamma$$

Phototransistor has a much greater sensitivity than a photodiode, although it has a similar response. The phototransistor is operated with the base connection open (figure 9b). The irridiation can then be thought of as providing a base current(I_{CEO}) of about 0.5 A(mW/cm^2). Greater sensitivity is obtained by using monolithic Darlington pair of transistors

The resulting devices, such as the FPT400 and FPT560 from Fairchild corporation are known as Photodarlingtons.

(c) Light-dependent resistor(LDR)

When light falls on a semiconductor, the photon energy may be sufficient to promote valence electrons into the conduction band. The resulting increase in the number of charge carriers increases the conductivity of the semiconductor, so that a block of semiconductor material can be used as a light dependent resistor. The most popular material for the manufacture of LDRs is cadmium sulphide (CdS) because its spectral response curve, peaking in the green, approximates that of the human eye. Because of this and its low cost, small size, and low power consumption, the LDR finds extensive use in camera light meters. However, the nonlinear relationship of resistance to light intensity together with the temperature senstivity and "memory" of LDRs makes them less popular for other light measurements. On the other hand, the large change in resistance between the "light" and "no light" conditions(typically from 100 Q to 1 MQ) makes the device useful in switching or chopping applications. The temperature dependence of the LDR(up to 0.5% of the "light" resistance per ^{o}C) can be reduced by incorporating two of them into a Wheatstone bridge arrangement so that one is shielded from the light for temperature compensation as shown in Fig.9a. However, there is nothing that can be done about the "memory" effect, wherein exposure to strong light can affect measurements taken several hours later.

(d) Photovoltaic cells

The photodiode and phototransistor can be used as photovoltaic cells in that a voltage can be developed across the device when it is illuminated. The incident radiation creates electron-hole pairs in a semiconductor near a junction, and charge seperation occurs as the minority carriers thus created are swept across the junction under the effect of the barrier potential. The difference lies in the internal resistance of the device when it is regarded as a voltage generator. The voltage generated by a photovoltaic cell is dependent on the band gap of the material. A silicon photocell develops around 0.6V, a gallium arsenic(GaAs) cell develops around 0.9 V under open-circuit conditions. The short-circuit current developed in a photovoltaic cell is linearly related to the intensity of the light failling on the device. However, the linear dependence of output current on illumination intensity is disturbed if the resistance of the measuring device is too high. Measuring the current output of the cell directly with a microammeter provides a simple light measuring system, but it leads to a fatigue effect as the output will drop over a period of time under constant illumination. So that the results are more reproducible, the output voltage needs to be measured with a high impedance device.

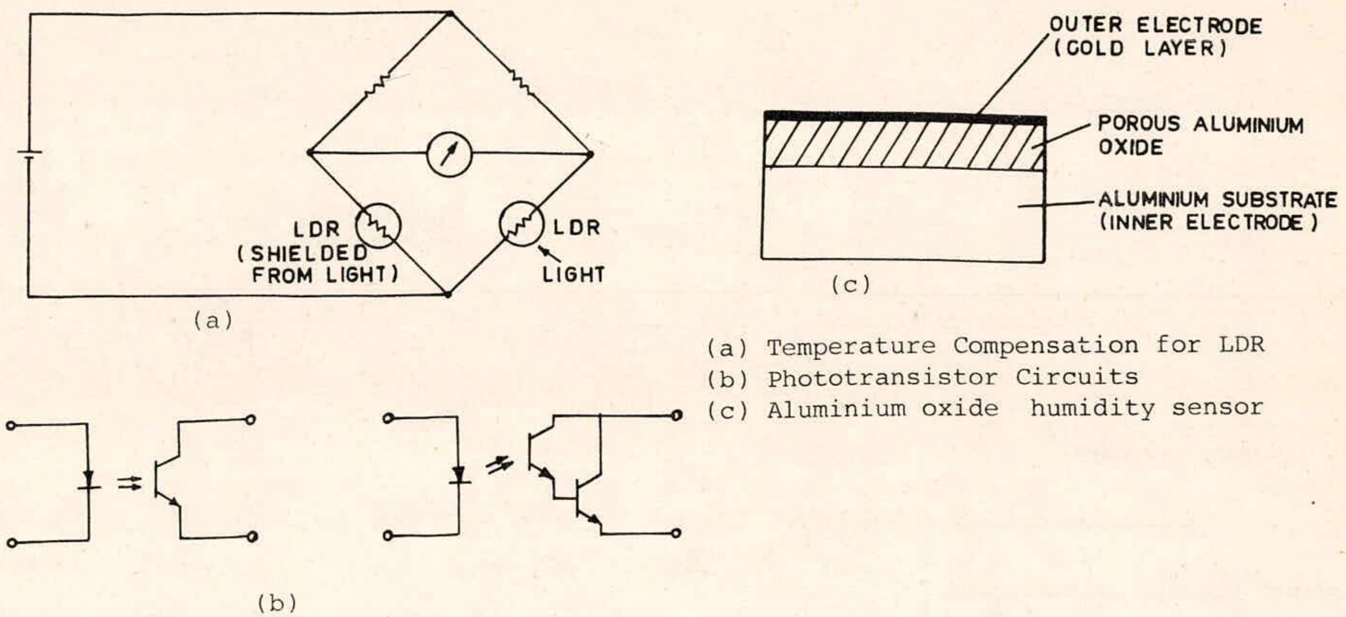
3.3.4 Humidity Sensors

Humidity measurements in terms of electrical output can be done in many ways. Two examples are replacing the liquid-in-glass thermometers of the wet and dry bulb hygrometer by thermistors, and coupling an annual hair, which expands and contracts with changing humidity, to a displacement transducer. Similarly, dew point measurements may be automated by optical sensing of droplet formation on a surface cooled by the thermoelectric effect.

Hygroscopic sensors are simple in operations and give direct output. Some substances, such as phosphorous pentoxide, lithium chloride, calcium chloride, and zinc chloride, absorb moisture from the air and change their conductivity. This enables a resistance measurement to provide a reading of atmospheric humidity. The sensitive element is designed to maximize its surface area and therefore the speed and sensitivity with which it responds to atmospheric changes. Unfortunately, these devices also tend to be very sensitive to temperature and therefore must be used with care.

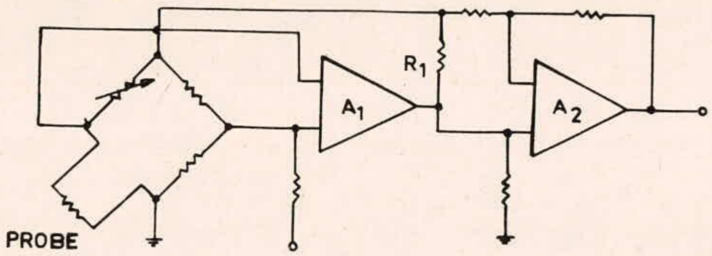
Ion exchange materials, such as sulphonated polystyrene, can also be used to produce electrical output in the form of a resistance change. A capacitance change is also possible and may be preferable in some circumstances, because a small change in moisture content of the material can lead to a large change in its dielectric constant.

Another transducer that can sense humidity as either a resistance value or a capacitance value uses a porous coating of aluminium oxide on an aluminium substrate as shown in figure 9c. Moisture in the air permeates the pores in the aluminium oxide, reducing the resistance of the layer and increasing its dielectric constant.

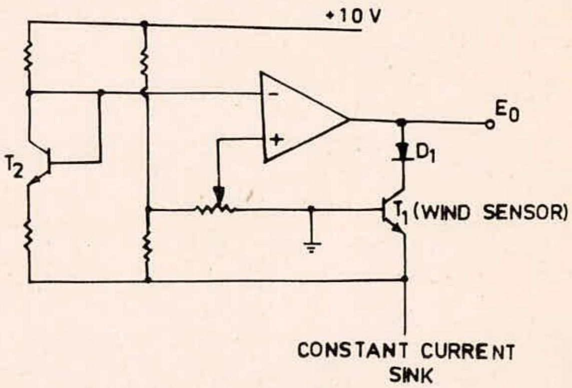


(a) Temperature Compensation for LDR
(b) Phototransistor Circuits
(c) Aluminium oxide humidity sensor

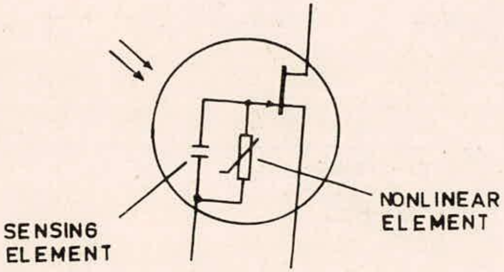
Fig.9. Humidity and radiation sensors



(a) A1, A2 are amplifiers



(b)



(c)

(a) Hot-wire anemometer
(b) Transistor anemometer
(c) Pyroelectric detector

Fig. 10. Temperature and wind sensors

3.3.5 Wind Sensors

The traditional method of measuring windspeed, the rotating cup anemometer, produces an electrical output via a tacho generator A single bit optical shaft encoder and a ratemeter are also used in place of tachogenerators. Solid State electronics is utilized in modern "hot-wire" anemometers. In this instrument, an electrically heated element loses heat at a rate which is determined by its surroundings, which in turn is controlled by the wind speed. Basic circuitory of this type of anemometer is given in figure 10a. Here the probe is run at constant temperature and power variation required to keep the temperature constant is measured. Amplifier A1 detects any out-of-balance condition in the wheatstone bridge and corrects this by providing more or less current (via R1) to the probe, thereby heating or cooling it. Amplifier A2 is configured as a differential amplifier to amplify the voltage across R1 as a measurement of wind speed. The output voltage, EO, then needs to be processes through linearizing and off setting circuitory.

A further variations is to use a transistor as the sensor with the temperature dependance of the base-emitter voltage, V_{BE}, being the important property. A bead type transistor is suitable, and the effects of ambient temperature variations can be offset by using a second transistor of the same type which is shielded from the wind. One such circuit is shown in figure 10b. T1 is the wind sensor and T2 is used to correct for the ambient temperature variations. The transistors are run at essentially constant current to eliminate the dependance of V_{BE} on the emitter current. The Op Amp-adjusts the collector voltage of the sensor transistor T1 and therefore its power dissipation to keep T1 at a constant temperature above ambient(as sensed by T2). The diode D1 is present to provide an approximate V_{BE} drop. Thus the voltage measured at the Op-Amp output (relative to earth) is approximately equal to V_{CE} of the sensor transistor T1.

3.3.6 Temperature Sensors

Besides conventional type of sensors, as described in a report by Seth and Goyal, 1985, there are some sensors which do not require physical contact with the surface.

One of the traditional noncontact methods of measuring temperature is to focus the radiation from the body of interest onto a blackened disc. Its temperature change is then gauged using a thermopile, which is simply a number of thermocouples connected in series. This has been the basis for some commercially available instruments such as the Leeds and Northrup Rayotube detector, which reads temperature differences of 200-5000°F and has an output of approximately 24 mV at 1260°C. The response of the detector is surprisingly quick,with a time constant of 0.05 second.

Pyroelectric substances are now being used in place of the blackened disc and termopile. A pyroelectric substance shows a temperature-dependent electrical polarization which is normally set during the manufacturing process. When used as the dielectric in a capacitor, the pyroelectric substance will produce a change in charge on the electrodes of the capacitor as its temperatur changes. Mullard, Plessey, and Eltec all manufacture temperature detectors from thin slices of ceramic pyroelectric material. The detectors are mounted in a TO-5 type of encapsulation, together with a JFET for impedance matching. The equivalent circuit of the Mullard devices is shown in Fig.10C.

4.0 APPLICATIONS

As described in Section 3, the two main variants of data acquisition systems are, namely, central data acquisition system and remote data acquisition system. Former comprises of all the components i.e. sensor(s), signal conditioners,display and storage devices etc., placed at the experiment site. The latter utilizes only sensor(s) alongwith pre-amplifiers at the experiment site, which is generally remote from inhabitation, and the rest of the components are kept at some convenient location such as a laboratory etc. In general, remote type of systems are more compact, light weight and portable in nature. The three applications described in this section typically exemplify these two types of data acqauisition systems. The systems described under sections 4.1 (Auto Met V) and 4.2 (A.H.S.) are examples of central type and remote type of data acquisition systems, respectively. Micro Met system, described under section 4.3, is an example where the system can be used in either of the two modes, depending upon the application. Auto Met V and Micro Met systems are commercially available from M/s Teledyne Geotech, Inc. and the details provided for these systems have been taken from their catalogues, etc. The automatic Hydrologic Station (A.H.S.) is being procured from M/s Companie Industriele Radioelectrique (C.I.R.), Berne, Switzerland, for installation at National Institute of Hydrology, Roorkee. Details provided for this system have been taken from the literature provided by C.I.R., Berne, Switzerland.

4.1 Auto Met V System

The Auto Met V of Teledyne Geotech, Inc., consists of an 8-bit parallel central processor with upto 64 K bytes of memory, 32 parallel digital outputs, 32 parallel digital inputs with 12-bit analog-to-digital (A/D) conversion accuracy's and priority level interrupts. Memory and input/output expansions are possible using multilevel addressing techniques. The system operates as a single, self-contained unit collecting data from meteorological instruments, air quality analyzers or any similar signal sources. It may also be used as a master terminal unit (MTU) in a system with multiple remote data terminals. In such a system the remote terminals can be almost any unit using digital telemetry. Model MDS 888 or Model TC-10/85 microcomputer systems are such units from Teledyne Geotech Inc.

4.1.1 MDS-888 Remote Terminal Unit

The Model MDS-888 (Figure 11) is a small scale remote terminal designed for use in systems with a small number of data channels at each remote location, where a high speed data rate and computational capability are not required. These are configured from a group of functional modules that are assembled into a unit using inter connecting cables. The various modules available are:

a. Transient protection modules

Three stage transient protection is available on all status, accumulator and analog inputs. This includes gas discharge tubes from each active input line to ground plus diode protection and TC filtering Transient pulses with fact rise tuner and/or high levels are supressed by these modules without damage to the protection circuits or to the low level MDS-888 logic circuits.

b. Analog input modules

Analog input modules may be of the current or voltage type. Each analog multiplexer and analog-to-digital converter module handles

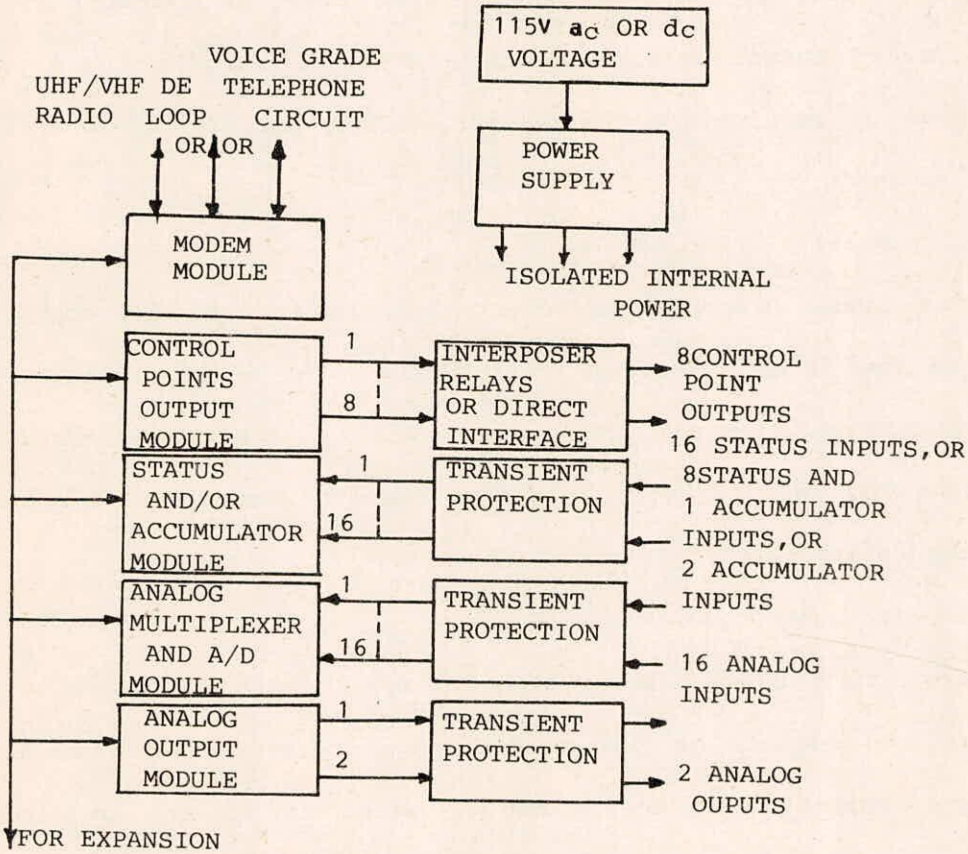


FIG.11.BLOCK DIAGRAM OF MDS-888

upto 16 signals, with eight or ten bit resolution. The binary number of the selected analog input is transmitted through the communications system without scaling.

c. Analog output modules

These also may be of the current or voltage type. These outputs may be electrically isolated or non-isolated from the internal power source. Analog outputs are held at a constant value until a new binary number is received by the MDS-888. Eight bit digital-to-analog converter is used.

d. Status accumulator input modules

Status inputs are used to detect the condition of dry contacts external to the remote terminal unit (RTU). The 8-bit accumulators count 255 contact closure before overflowing. A division network divides down the rate of input pulses to prevent accumulator overflow between consecutive interrogations of the RTU.

e. Control point ouput modules

Control point outputs are provided through small relay for switching low level signals or through interposer relay for upto 10 Amps load. The control point module may be wired to operate in either a latching or a momentary mode of operation. The momentary mode uses a timing circuit that allows the selection of a wide range of accurately timed closures.

f. Internal power supply module

Standard power supply options include configurations for ac or dc power inputs. The dc inputs incorporate a switching regulator that allows operation over a wide range of voltage input. Standard dc voltage inputs are 12 V, 24 V and 48 V. Voltages derived for use inside the MDS-888 are electrically isolated from primary input voltage.

TABLE 3. COMMUNICATIONS FORMAT

REQUEST FOR DATA FROM MTU

BYTE \ BIT	7	6	5	4	3	2	1	0
0	SYNC							
1	DIR	FUNCTION				R/W	C.P.ENABLE	
2	NO.OF POINTS				ANALOG SUBFUNCT			
3	CRC CODE						STOP	

SYNC = ALWAYS 1
RTU ADDRESS= INTEGER RTU SCANNING(0-127)
DIR=ALWAYS 1
FUNCTION=0.6 ANALOG INPUT
7.9 STATUS INPUT
14-15 ACCUMULATOR INPUT
R/W=0 READ DATA
C.P.ENABLE='11' IS CONTROL POINT SAFETY CODE OTHERWISE 0
NO. OF POINTS=INTEGER NUMBER OF POINTS TO SEND BACK
ANALOGSUBFUNCTIONS 0-7 INTEGER FOR ANALOG INPUT CHANNEL
CRC CODE=CYCLE REDUNDANCY CHECK CODE (6 BITS)
STOP=00

REPLY MESSAGE FROM RTU

BYTE \ BIT	7	6	5	4	3	2	1	0
0	SYNC	RTU ADDRESS						
1	DIR	FUNCTION				R/W	D_1	S_0
2	D_9	DATA						D_2
3	CRC CODE						STOP	

SYNC = ALWAYS 1
RTU ADDRESS= INTEGER RTU RESPONDING(0-127)
DIR = ALWAYS 0
FUNCTION= SAME AS ABOVE
R/W = 0
DATA = 10 BIT INTEGER IF ANALOG INPUT
8 BITS FOR STATUS INPUT(RIGHT-TO LEFT) OR
ACCUMULATOR INPUT
CRC CODE=CYCLE REDUNDANCY ERROR CHECK CODE(6 BITS)
STOP = 00

Contd..

WRITE DATA TO ANALOG OUTPUT
OR CONTROL POINT FROM MTU

<table>
<tr><th>BIT</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td>0</td><td>SYNC</td><td colspan="7">RTU ADDRESS</td></tr>
<tr><td>1</td><td>DIR</td><td colspan="3">FUNCTION</td><td>R/W</td><td>D_1</td><td colspan="2">D_0</td></tr>
<tr><td>2</td><td colspan="8">D_9 DATA D_2</td></tr>
<tr><td>3</td><td colspan="6">CRC CODE</td><td colspan="2">STOP</td></tr>
</table>

SYNC = ANALYSIS 1
RTU ADDRESS = INTEGER RTU SCANNING(0-127)
DIR = ALWAYS 1
FUNCTION=10 CONTROL POINT OUTPUT
12-13 ANALOG OUTPUT
R/W = 11 IS CONTROL POINT SAFETY CODE
FOR 10 BIT DIGITAL TO ANALOG CONVERTER,
THE TWO BITS ARE USED FOR THE LEAST
SIGNIFICANT BITS.
DATA=0.255 INTEGER FOR 8BIT ANALOG OUTPUT
0-1023 INTEGER FOR 10 BIT ANALOG OUTPUT
USING EXTRA TWO BITS(ABOVE)
0-7 BIT FLAG FOR CONTROL POINT OUTPUT SELECT
CRC CODE= CYCLE REDUNDANCY CHECK CODE(6BITS)
STOP=00

Communication options available with the system are of three general types:

(a) DC loop communication at 30 or 75 baud on commercial telegraph lines,

(b) Voice grade communication on leased telephone circuits at 300 or 1200 baud, and

(c) Data transmission using UHF or VHF radio links.

The MDS-888 system remains in a quiscent state until called upto to perform a function. Depending upon the communication system used, this may involve a request for data through a communication circuit and/or a transmission to be initiated based on a change of a status input. The most common configuration uses the unit in a polled mode of operation so that a request for data is made on the receive line of the communication circuit and the data are returned on the transmit line. The typical communications format is given in table 3. Other formats may also be accomodated since the communication module is microprocessor based.

4.1.2 TC-10/85 Microcomputer System

The TC-10/85 system utilizes an INTEL 8085 microprocessor and is capable of performing a varied and complex set of tasks. It contains the following elements on a single card:

(a) Central processing unit (CPU, INTEL 8085) with associated interrupt, clocks, and external logic,

(b) Erasable Programmable Read Only Memory(EPROM),

(c) Random Access Memory (RAM),

(d) Input-Output(I/O) ports through which the CPU communicates with external devices and modules,

(e) Analog-to-Digital(A/D) 12-bit conversion hardware with 8 channel multiplex,

(f) Digital input and digital output logic for 4 input and output channels,

(g) An interface to an operator entry unit to permit operator interaction.

The microprocessor contained on the main logic board controls the operation of the system(CPU, memory, input-output devices, etc.) in response to a program stored in EPROM. It communicates with other modules or devices on the same board and other optional boards via a parallel data bus. Figure 12 illustrates block diagram of a TC-10/85 unit with a complete set of modules to provide a mixture of digital and analog inputs and outputs. The system may be configured to accomodate a minimum of 8 analog and 4 digital inputs along with 4 digital outputs upto a system that might contain from 100 to 200 digital and analog inputs and outputs.

The TC-10/85 main logic board, is the nucleus of the Data Acquisition and Control system. This module utilizes an 8085 microprocessor alongwith necessary memory, clock and bus generation logic to support the microprocessor. The board also contains an eight-channel analog-to-digital(A/D) converter, four channels of digital input, four channels of digital output, and a bidirectional serial interface to the Operator Entry Unit(OEU). It communicates with any expansion modules over a parallel I/O and a memory expansion bus and is designed to serially interface to the OEU. An optional arithmetic processor may be provided on the main logic board to improve the performance of the TC-10/85 system. This improves the speed and arithmetic

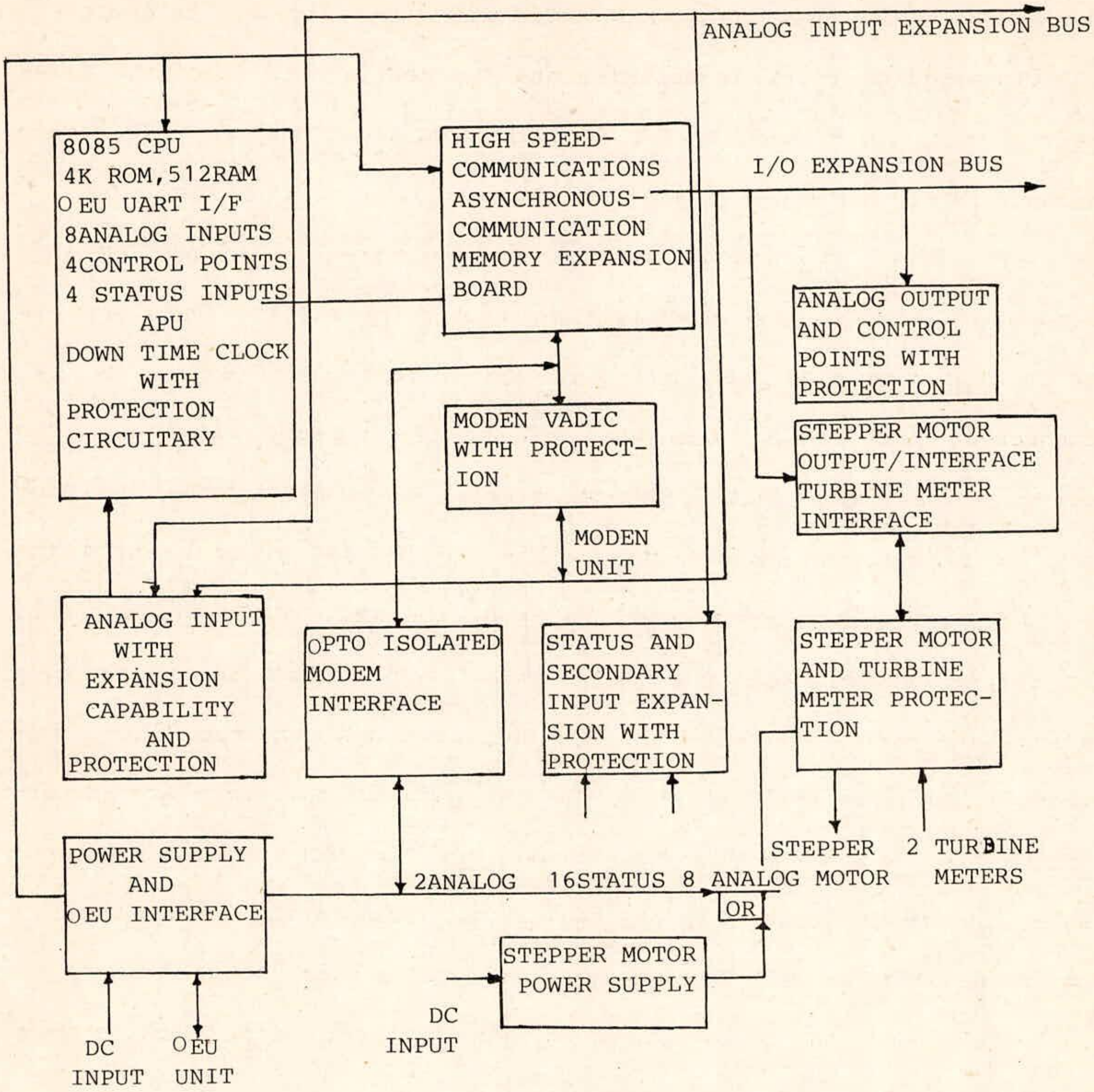


Fig.12. Block Diagram of TC-10/85 Unit

capability of the system to permit application to analytical and diagnostic problems. The arithmetic commands available with arithmetic processing unit are add, subtract, multiply, divide, trignometric functions,square root, logarithms, and exponentiation. Execution times vary from 8.5 microseconds for 16 bit fixed point add to 2670 microseconds for 32 bit floating point e^x.

The operator entry unit (OEU) is used to enter information into memory or retrieve and display data stored in memory. The unit may be located upto 1500 feet away from the TC-10/85 unit. It may be disconnected from the TC.10/85 when not in use thereby allowing it to serve several main units. The receptacles accomodating the OEU plug may be placed near transducers which are mounted remotely from the TC-10/85 unit. By inserting the plug of the OEU into the receptacle at the transducer location, the operator can display transducer data which have been digitizedby the A/D converter and converted into engineering units by the processor. This permits to calibrate transducers through the A/D and engineering conversion. The OEU uses a microprocessor to handle keyboard scanning, display generation, and communications handling as well as conversion of data formats.

Communication capabilities in the TC-10/85 unit needs certain information to be specified, such as:

(a) communication media-wire, radio, microwave, etc.,

(b) quality, type of channel-voice grade, class, condition, etc.,

(c) speed of transmission(bit, baud rate),

(d) type of transmission(asyhchronous/synchronous)

Based upon these specifications, different communications options can be provided in the system. This involves provision of (i) communications interface, (ii)moderm and moderm interface, and (iii) moderm transient protection.

The TC-10/85 unit may be expanded beyond the basic unit to include additional inputs and outputs. Each analog input expansion board provides eight additional single-ended analog input channels for the microcomputer. The expansion channels are buffered and then multiplexed onto an analog input expansion bus which, in turn, is fed to channel seven of the existing eight analog inputs on the main logic board. When the first expansion board is added to the TC-10/85, the low pass filter is removed from channel seven on the main logic board, and is added to the first expansion board. The first expansion board, or primary expansion board, then has ,input channels and the main logic board has 7 for a total of 16. Any additional expansion boards have eight channels. Each analog output board provides two analog output channels for the microcomputer. Each channel has a digital holding register which drives a digital to analog(D/A) converter with 0-5 VDC output. The available configuration options are either 8,9 or 10 bit linearity and either 1 or 2 output channels.

An optional communications interface module permits connecting the TC-10/85 unit to a central supervisor. This option enables the operation of single or multiple TC-10/85 unit(s) to be monitored and controlled by a central supervisor which may also be a TC-10/85 unit.

4.2 Automatic Hydrologic Station

The National Institute of Hydrology, Roorkee is establishing an Automatic Hydrologic Station (A.H.S.), which consists of a variety of meteorological, micro-meteorological and hydrological sensors alongwith a Data Acquisition System (D.A.S.). The main aim of the A.H.S. is observation and automatic recording of short time interval data for establishing inter-relationship between different components of hydrologic cycle, e.g. precipitation, evapo-transpiration, soil moisture, surface runoff, infiltration etc. The measured data would be used to develop and validate models which describe inter-component relationships.

The block-diagramatic representation of the A.H.S. is shown in figure 13. Each station (A.H.S.) is composed of:

(i) TELEDAT 2000 Data Acquisition Station,

(ii) a set of meteorological sensors,

(iii)a telescopic mast (10m) for meteorological sensors, and

(iv) Lysimeter sensors equipment.

The proposed configuration of the A.H.S. is shown in figure 14.

4.2.1 Sensors

The set of meteorological sensors include one number each of sensors for (i) air temperature, (ii) humidity, (iii) wind direction and speed, (iv) global radiation, (v) sunshine duration, (vi) air pressure, and (vii) rain.

Sensors for the lysimeter equipment would be measuring (i) air temperature, (ii) humidity, (iii) wind direction and speed, (iv) balanced radiation, (v) global radiation, (vi) ground temperature (at different depths), (vii) conductivity (at different depths), (viii) weight, (ix) rainfall, and (x) water flow.

Three additional sensors for water flow measurements would be provided for related hydrological measurements.

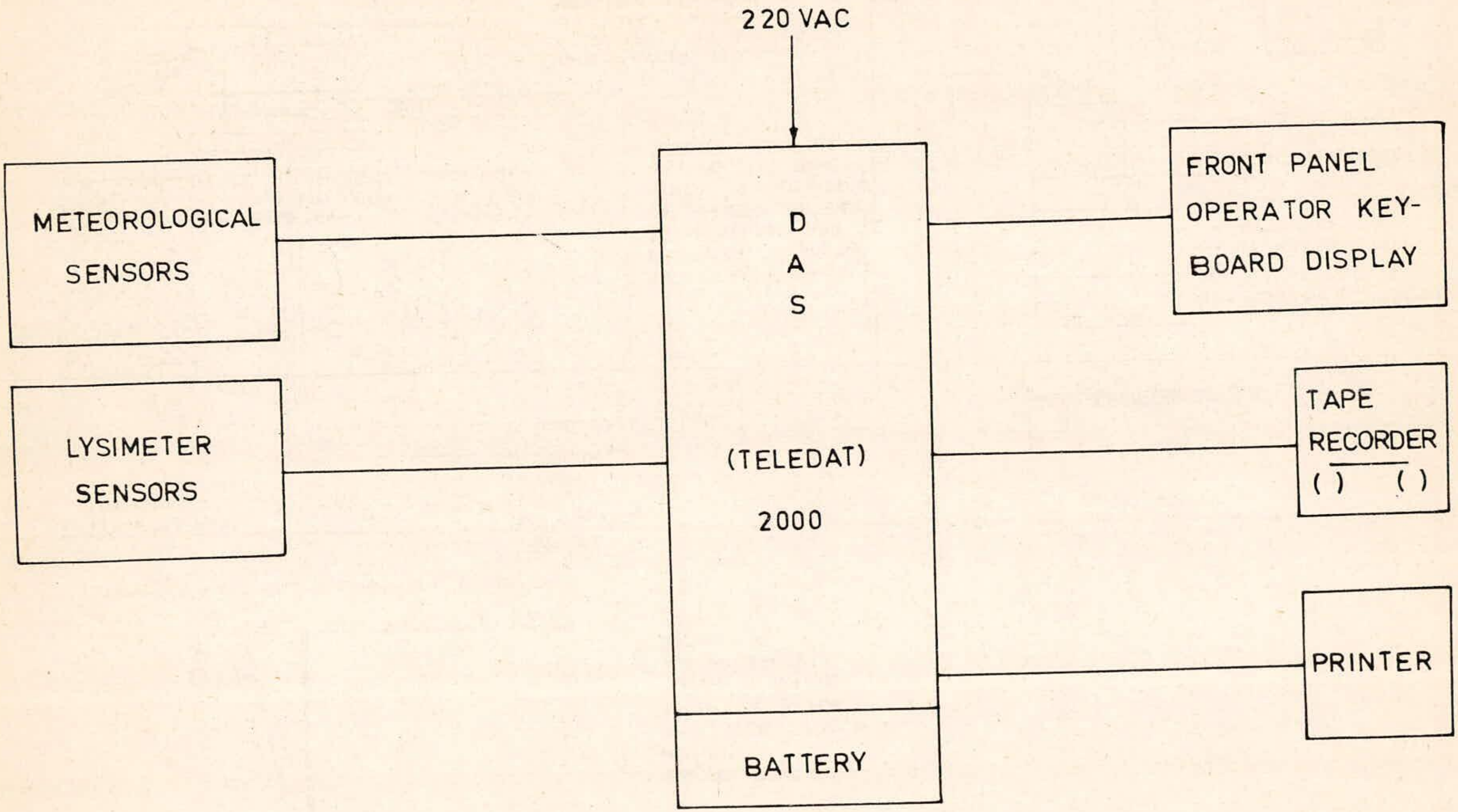


Fig.13. Block diagram of automatic hydrologic station(AHS)

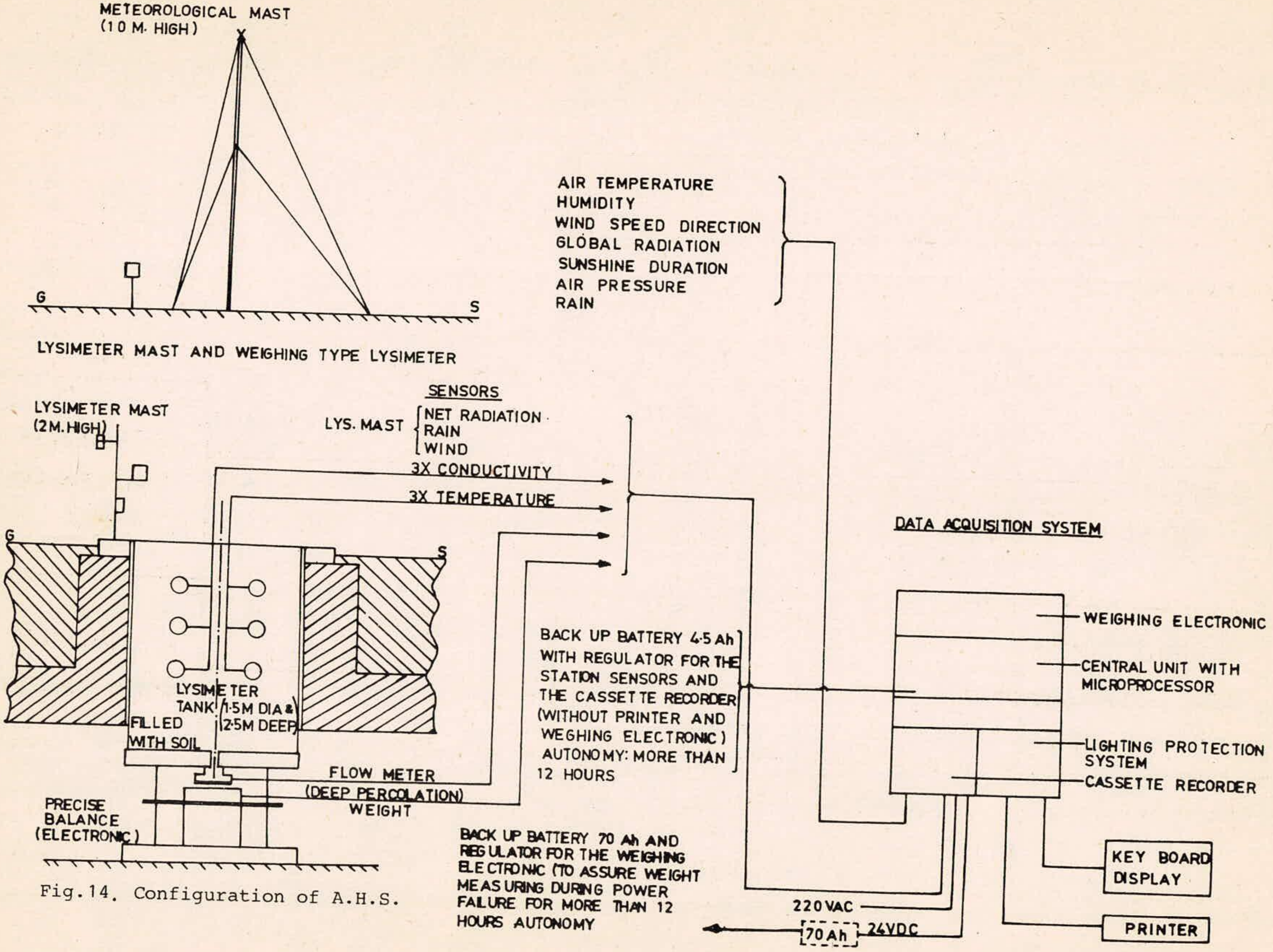


Fig.14. Configuration of A.H.S.

4.2.2 TELEDAT 2000 Data Acqusition Station

The TELEDAT 2000 station is composed of, apart from a rain proof housing with sensor connectors, (i) "Bus" Card, (ii) power supply card, (iii) CPU and peripheral input/output (PIO) card, (iv) operator front panel keyboard and display, (v) control module card, (vi) 4x10 K bytes memory cards (EPROM and RAM), (vii) analog interfaces for 8 sensor signals each, (viii) digital interfaces for 4 digital sensor signals and 4 logic lines each (ix) analog-to-digital (AD) converter, of 12 bits, (x) 2x universal asynchronous receiver/transmitter (UART) cards for V24 (RS232) communication lines, (xi) several cards for lightning and high frequencies protection, and (xi) a rack for mounting all these cards etc.

The processor used in the TELEDAT 2000 system is a RCA CDP 1802 CMOS microprocessor. The software is resident into several EPROM chips of 2K bytes each, provided with the system. An inbuilt clock, with a period of 4 seconds, governs all the cyclic activities of the station, e.g. (i) sensors sampling period, (ii) message generation intervals, (iii) message output sequences, etc. A capability of adjusting its clock for ± 8 to 20 seconds per day makes the station's sensors sampling error less than 0.03%.

Analog interfaces are used to multiplex and get analog data from a maximum of eight sensor lines per interface. A 12 bit AD conveter, with 20 ms conversion time, converts these signals for futher processing. The offset of the AD converter is measured each time an acquisition cycle is performed, thereby compensating the conversion characteristics variations. Likewise, digital interfaces are used to multiplex and count for pulsed signals from sensors with 8 bits resolution (or two pulsed signals with 10 bits resolution) and four parallel logic signals from sensors. The input pulsed signals can be from very low frequencies to a maximum of 10 KHz. The parallel signals are binary coded into a 4 bits word. At each minimum sampling period (i.e. 4 seconds), the state of the counters and the 4 parallel signals are latched, and the counters are reset to be ready for the next sampling period.

The communication modes provided with the system are (i) two UART interfaces for V 24 serial communication line. Out of these, one is used for the printer, and the other is dedicated to the tape recorder, (ii) two 8 bits parallel lines for front panel operator keyboard and screen display.

The D.A.S. periodically interrogates the interfaces to collect the values given by local sensors, to process them, and format them into a message that will be recorded on a magnetic (cassette) tape and can be taken as print-out (through printer). The periodicity of the acquisition is a function of the kind of parameter which will be measured. It may be 30 miunutes for physical parameters with slow cariation e.g. temperatures, humidity, air pressure, etc., whereas it may be as frequent as 4 seconds for physical parameters with fast variation like wind, rain, sunshine, etc. Table 4 shows, for each parameter, the acqusition time interval, the processing and the corresponding message content.

4.2.3 Processig details

As stated above, the values coming through periodical interrogation of the sensors are processed by the CPU and them formatted into an ASCII message indexed by the TIME (DATE, TIME and station

TABLE 4

Acquisition time-interval, processing and message content of A.H.S.

Meteorological Sensors

Measurement	Interval	Processing	30 minutes message Content
Air Temperature 2 sensors	30 mn.	Analog Signal conversion in degrees	- Present value
Humidity 2 sensors	30 mn	Analog signal conversion in (%)	- Present value
Global Radiation 2 sensors	4 Sec.	Analog signal Summation for 24 h. Conversion in (Wh/m^2) From 0 h to 24 h.	- Present value of the amount
Wind speed 2 sensors	Interface counter checked every	Digital signal Average of Wind East and North components calculation (in m/s)	- East, North Comp. (30 mn. average) - Max. speed during last 30 mn.
Wind Direction 2 sensors	4 sec.	Analog signal Used for east, north components calculation	- - -
Rain 3 sensors	Interface counter checked every 4 sec.	Digital signal Conversion to (mm) and values summation from 0 h to 24 h.	- Present state of the amount
Sunshine duration 1 sensor	4 seconds	Logic signal Conversion to (mn) Summation of the values from 0 h to 24 h.	- Present state of the amount
Air pressure 1 sensor	30 mn.	Analog signal Conversion to (mb)	- Present value

Continued

LYSIMETER SENSORS

Ground Temperature 6 sensors	30 mn	Analog signal Conversion in degres	- Present value
Weight 1 sensor	30 mn.	Analog signal Weight variations Conversion to (Kg)	- Present value
Conductivity 6 sensors	30 mn	Analog signal Conversion to (micro-siemens) unit	- Present value
Water flow 1 sensor	Interface counter checked every 4 sec.	Digital signal conversion to (dm^3) and values summation from 0 h to 24 h	- Present state of the amount
Balanced Radiation 1 sensor	4 sec.	Analog signal Summation for 24 h Conversion in (Wh/m^2) from 0 h to 24 h.	- Present value of the amount

OTHER SENSORS

Water level 3 sensors	30 mn.	Analog Signal Conversion to (m)	- Present value
Station Battery voltage	30 mn.	Analog Signal	- Station power supply status

Lab.	SENSOR TYPE	Value	Unit/message
T1	TEMPERATURE(air)	xx.x	Present value in degres
T2	TEMPERATURE(air)	xx.x	Present value in degres
T3	TEMPERATURE (ground)	xx.x	Present value in degres
T4	TEMPERATURE (ground)	xx.x	Present value in degres
T5	TEMPERATURE (ground)	xx.x	Present value in degres
T6	TEMPERATURE (ground)	xx.x	Present value in degres
T7	TEMPERATURE (ground)	xx.x	Present valu in degres
T8	TEMPERATURE (ground)	xx.x	Present value in degres
W1	WIND	xx.x	East comp(m/s)(30mn average)
		xx.x	North comp(m/s)(30mn average)
		xx.x	Max speed m/s (in last 30mn)
W2	WIND	xx.x	East comp(m/s)(30mn average)
		xx.x	North comp(m/s)(30mn average)
H1	HUMIDITY	xxx.x	%
H2	HUMIDITY	xxx.x	%
S1	SUNSHINE DURATION	xxxx.	mn/24h
P1	AIR PRESSURE	xxxx.	mb
R1	RAIN	xxx.x	mm/24h
R2	RAIN	xxx.x	mm/24h
R3	RAIN	xxx.x	mm/24h
K1	WEIGHT	xxxx.x	Kg
C1	CONDUCTIVITY	xxxxx.	micro Siemens
C2	CONDUCTIVITY	xxxxx.	micro Siemens
C3	CONDUCTIVITY	xxxxx.	micro Siemens
C4	CONDUCTIVITY	xxxxx.	micro Siemens
C5	CONDUCTIVITY	xxxxx.	micro Siemens
C6	CONDUCTIVITY	xxxxx.	micro Siemens
B1	BALANCED RADIATION	xxxx.	W.h/m^2
G1	GLOBAL RADIATION	xxxx.	W.h./m^2
G2	GLOBAL RADIATION	xxxx.	w.h/m2
L1	WATER LEVEL	xx.x	m
L2	WATER LEVEL	xx.x	m
L3	WATER LEVEL	xx.x	m
F1	WATER FLOW	xxx.x	dm3/24h
BA	BATTERY	ssxxx.	Status power & voltage*10

The Rain accumulated values, global and balanced radiation values, sunshine duration value, and water flow accumulated values are cleared each mightnight (Oh 00)

Fig.15. TYPICAL TELEDAT MESSAGE,WITH SENSOR LABEL AND UNIT

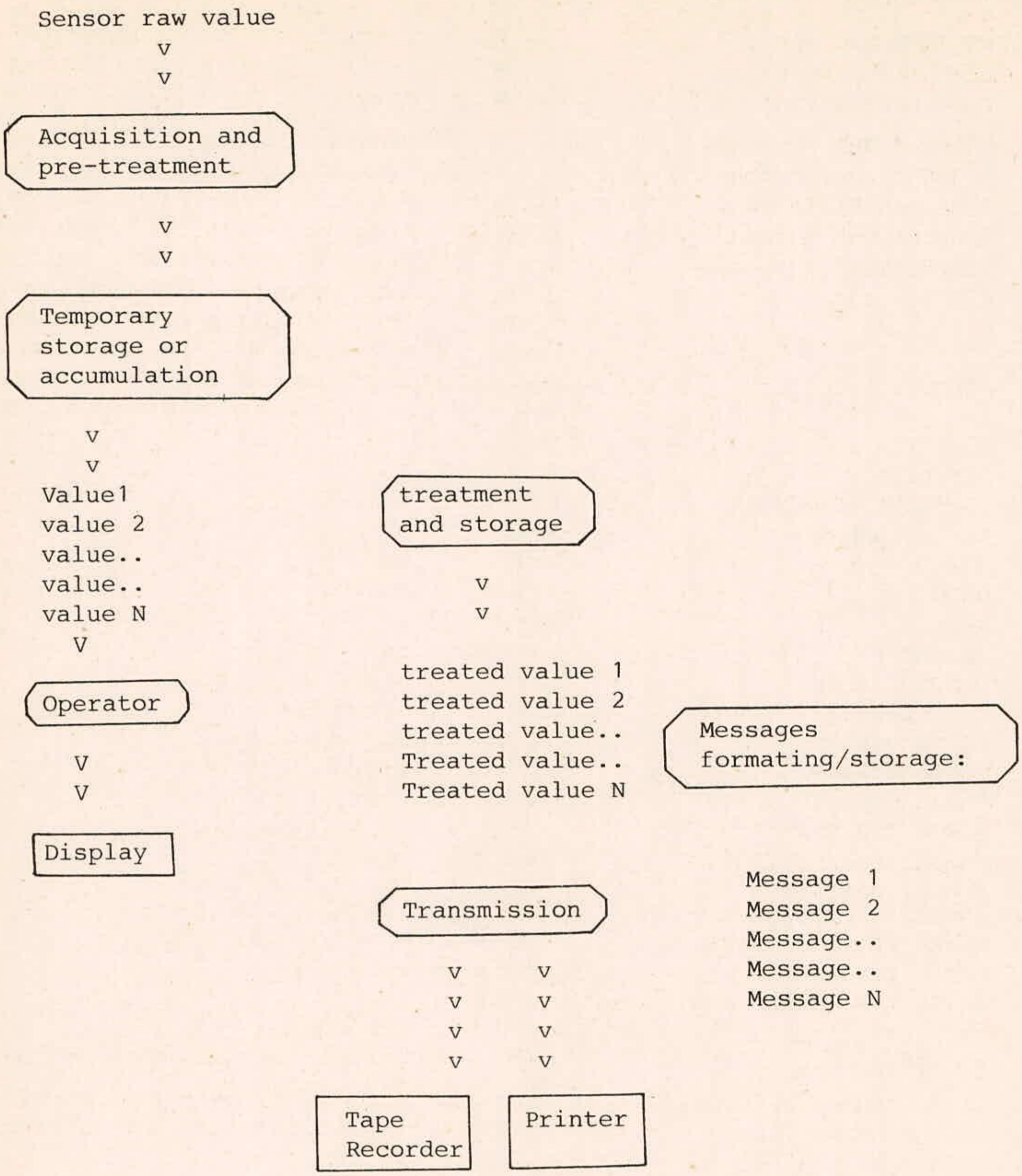


Fig.16.DATA FLOW IN TELEDAT 2000 SYSTEM

identifier, if it is a new day). The time interval to produce such message is in relation with the acquisition cycles, and generally, the message is generated when a complete sensor acqusition cycle has been executed (i.e. 30 minutes). This message (see figure 15) is stored in the station memory, sent to the printer, and recorded on to the tape if the tape recorder is ready. A maximum of 245 messages can be recorded on one side of the tape. However, a maximum of 24 messages can be stored in the TELEDAT memory if the tape recorder is not ready. When the tape is available, all the sensor messages are recorded on the tape. Schematic diagram showing data flow in the system is shown in figure 16.

4.3 Micro Met System

The Micro Met of Teledyne Geotech, Inc. is a digital data system that can be used as a small, self-contained station or as a remote terminal that communicates with a central station. It is a compact, stand alone system in which data processing, formatting and recording techniques are available (see figure 17).

The analog and digital signal conditioning circuits are built in the system so that sensor signals can be fed directly without using seperate processors. Status inputs allow various operating conditions to be monitored and flagged along with the appropriate sensor signals. A software calender clock is provided to give year, month, day and time of day to nearest second. Input/output devices include a built-in keyboard and display which can be used to select changable parameters, set clock, monitor data signals and clock and control tape transport. A magnetic tape cassette recorder allows data storage for periods upto a month and provides interim storage for data to be transmitted

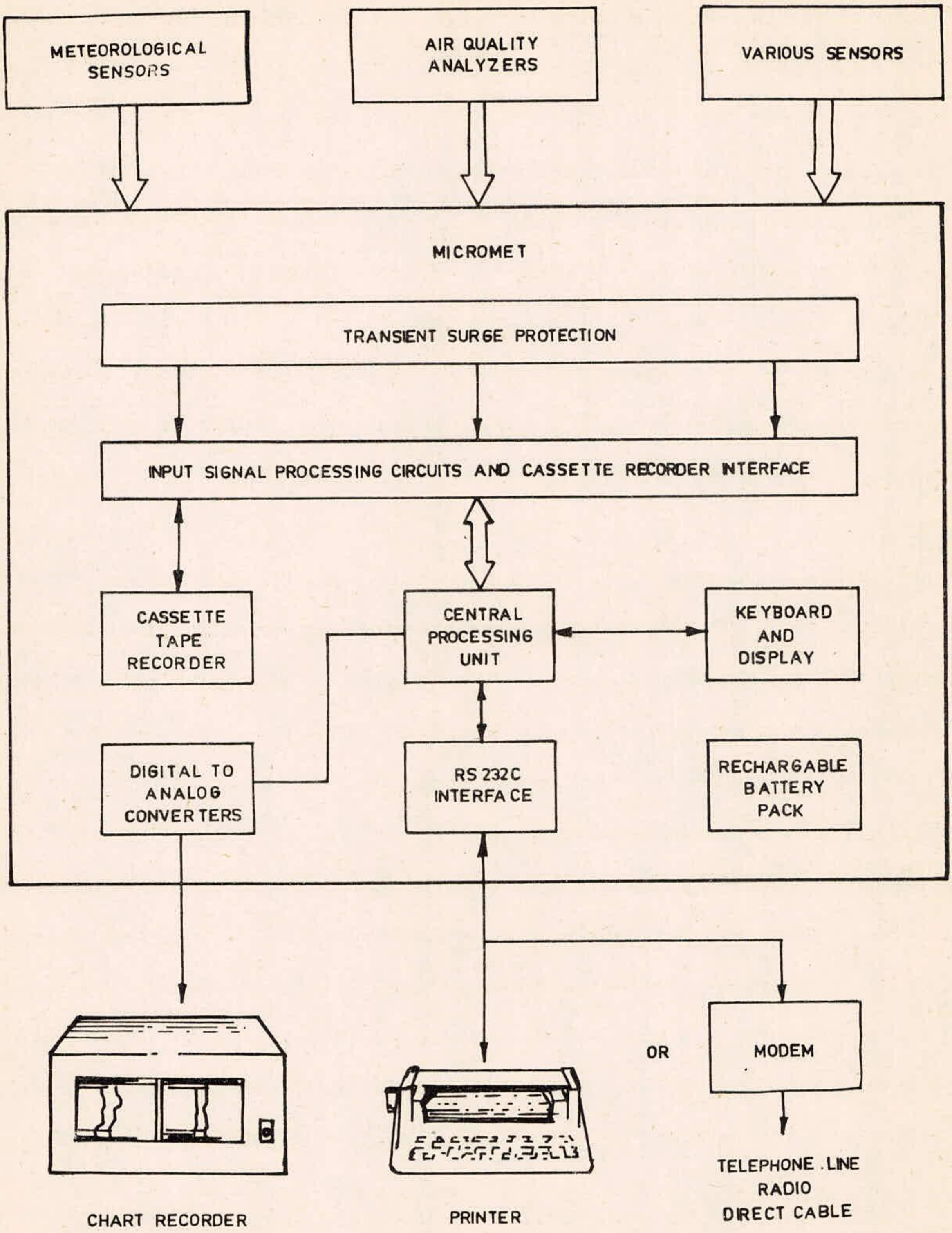


Fig.17. Functional block diagram of MICROMET

to another facility. Various computations include signal averaging, vector processing and standard deviations, maximum and minimum values and totalization (for precipitation, solar radiation and others)

The basic Micro Met accomodates one complete set of wind speed, wind direction, temperature, barometric pressure, relative humidity, solar radiation and precipitation sensosrs. Upto three additional 0.5 V signal inputs can also be accomodated. The wind speed input is a 16-bit accumulator, the wind direction input is from a 10 K potentiometer, and the temperature input is platinum RTD level compatible with built in non-linearity correction. All signals are internally conditioned and input to the digital processor. The cassette recorder records station identification number, calender date and time alongwith the processed data. Optional output devices include a printer, an auto-answer telephone terminal, and strip chart recorders. The system can simultaneously accomodate the cassette recorder option, the strip chart option,and either the printer or the communication option. The strip chart option consists of an 8 channel output module. The basic system can be expanded by including an additional I/O module, thereby doubling the number of inputs. In computations, averages are calculated for all channels except precipitation which is a total accumulation, for an operator selectable interval between 5 and 60 minutes. In addition, the peak wind speed and the standard deviation of wind direction, using vector computation, are computed for each interval. At the end of each calender day, daily values are generated for minimum and maximum temperatures, total solar radiation and total precipition.

5.0 REMARKS

Data acquisition systems are designed to accept multiple data input signals, to process the data according to user-selected functions, and to output the data in a meaningful form to devices such as printers recorders and CROs. With the advent of microprocessor technology, there has been a tremendous change in the capabilities of the data acquisition systems. Modern systems are based an modular concepts in which every function of the data acqusition process is available an individual boards that can be plugged into a chasis containing the the bus structure. This concept facilitates more or less unlimited expansion of the system capabilities. The user can define his requirements in terms of type of signal to be measured, amount of data, storage medium and seperation between data-collection and storage station. Based on these specifications, suitable hardware can be configured keeping in view the type of aplication i.e. central data acquisition or remote data acquisition.

Central data acqusition systems are utilized for applications requiring data collection from a larger area whereas remote data acquisition systems are meant for limited areal apoplications e.g. automatic weather station. Central type of systems are complicated involving more hardware as well as the variety of communication options than the remote type of systems. Both type of systems can be incorporated with processing capabilities sufficient for any pre-processing requirements. In many cases, depending upon the nature of studies, processing performed by these systems are sufficient and then they may perform like stand- alone systems.

In hydrometeorological applications, both types of systems are in use. The choice depends upon a number of factors e.g. type of signal to be monitored (analog, digital or event type), areal extent of the field, nature of terrain i.e. flat or undulating, location of the field - distance from the recording or central station, etc. Initial pre-processing of the signal can also be performed on a remote type of system. Main processing is done at the central station where facility of large computers is available. However,their capabilities are utilized mainly in collecting data from remote, inaccessible places. For example, data on precipitation, temperature, solar radiation, runoff, etc. from snow covered mountains can be effectively acquired by remote data acquisition systems. Some such systems have already been developed (for example, by Institute of Hydrology, UK, Strangeways, 1981) and other are being developed at different parts of the world. It is hoped that in near future the hydrological data networks would be provided with useful facilities like modern data acquisition systems, in order to cater to the longfelt needs of near real-time data acqusition.

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