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HYDROLOGICAL APPLICATIONS OF MICROPROCESSORS

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ABSTRACT

Microprocessors and microcomputers are increasingly being used in a number of hydrometeorological data collection systems. Almost all modern data acquisition systems use microprocessors for collection and analyses of the data. The report introduces concepts of microprocessors and microcomputers for actual field users. Review of applications of microprocessors for data measurement and processing in the fields of hydrology, meteorology, oceanography, geophysical exploration etc. is also presented in the report. Some typical applications have been included to familiarise readers with the latest uses of the microprocessor technology.

1.0 INTRODUCTION

We are in the midst of an era in electronics that requires intelligent instruments,machines and systems in all technological and scientific fields. These systems obtain their intelligence from microprocessors, microcomputers, and other large-scale integrated circuits operating under control of programs stored in memory. Microprocessors are new and facinating logic devices that are having pronounced effects on our lives. Every day new applications are being found and new microprocessor-based products are being developed.

1.1 About Microprocessor

A microprocessor is a logic device that is able to function, sequentially, as an indefinite variety of logic devices. This capability exists because the microprocessor is essentially a computer. The word computer usually identifies that part of a computer system that actually computes. The rest of the computer system provides an interface between human operator and the computer. Thus, the computer may be visualized as the 'brain' of the computer system. In a computer some of the electronic logic is the brain of the computer, while rest is nothing more than depositories and conduits for information flowing to and from the brain. The electronic logic that constitutes the brain of the computer is frequently referred to as the Central Processing Unit (CPU). Nowadays vast quantities of electronic logic are created as microscopic circuits on tiny pieces of silicon, referred to as chips. These chips are mounted in Dual In-line Packages(DIPs). Today the word ' micro-processor' describes a single chip, packaged in a DIP, containing the logic of central processing unit, plus various amounts of the ' depository and conduit' logic that must surround a CPU.

1.2 Elements of a Microprocessor

Typical elements for microprocessor are shown in Figure 1. These are as follows:

Arithmetic Logic Unit(ALU):

This forms heart of the microprocessor and performs the various arithmetic and logical operations e.g. incrementing, decrementing, addition, subtraction, complementing etc.

Registers:

The ALU in a microprocessor is capable of little more than those operations referred above. A microprocessor gains its additional power by attaching several storage registers to the ALU. The ALU can operate on data from only one or two of the register at a time. Some of these registers are more versatile than the rest and are labeled ' acummulators'. 'Multiplexers' are used to transfer register contents between different registers.

Programme Counter (PC):

This counter keeps track of the sequence of operations for all microprocessor circuits; that is, the number in the

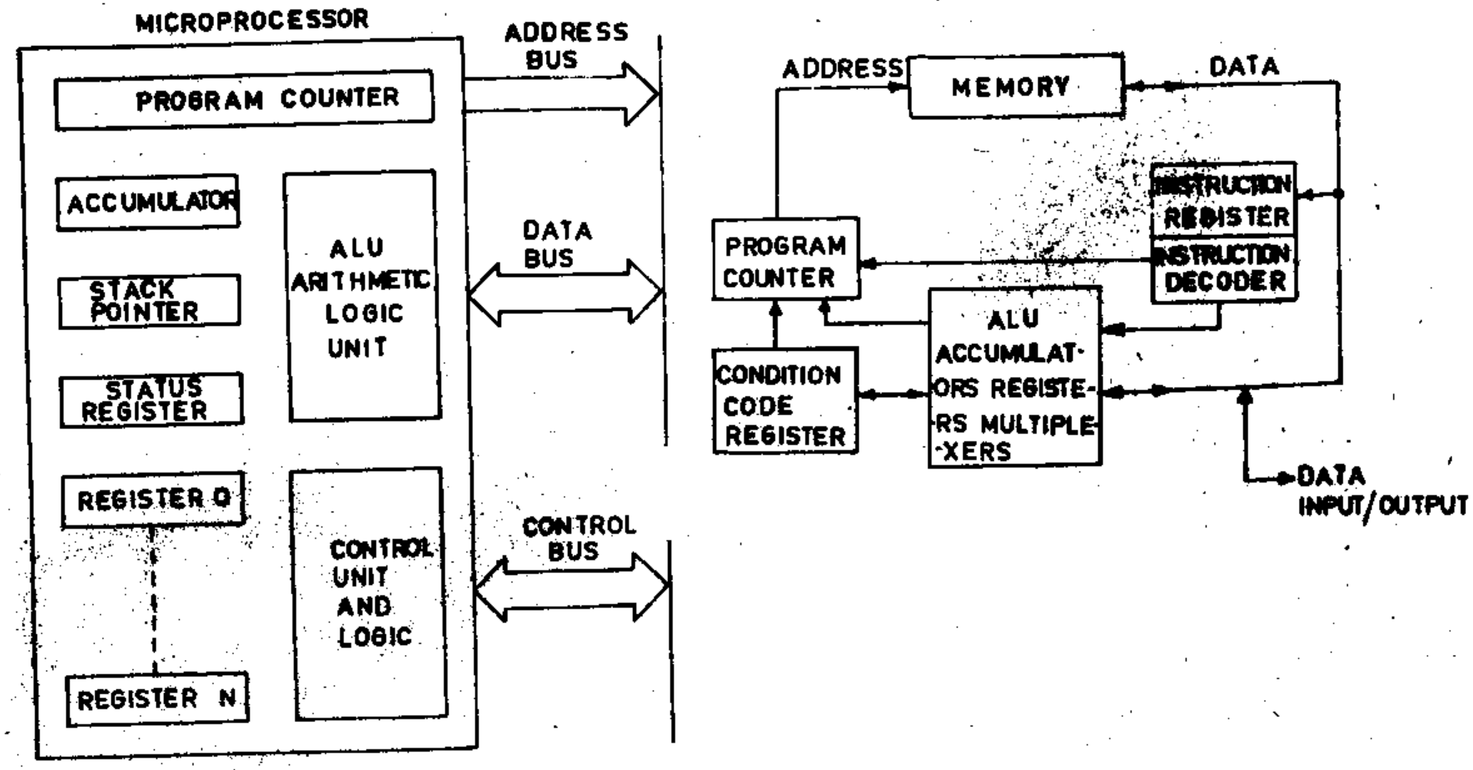

Fig.1 - Elements of a Microprocessor

program counter is the line number being executed in the program.

Memory and Instruction Register:

The program counter does not directly sequence the ALU through various operations. As the program counter sequences through the numbers associated with a program stored in a memory, the data word at each corresponding memory location is sequentially presented to the instruction register. Here the data word is temporarily stored while the instruction decoder determines which operation the ALU and/or the program counter must perform.

Condition Code Register(CCR):

While the ALU is performing its task, the special-purpose register called the condition code register (CCR) becomes activated. Each bit in this register represents a terse summary of various types of results possible during ALU operations. This register is also called the 'status' or 'flag' register by various manufacturers.

Control Section:

Microprocessors contain some supervisory logic called the control section. This section usually consists of the program counter, instruction register and instruction decoder. The control section links all diverse registers in the microprocessor to perform the requirements of a particular instrcution.

Index Register:

As an aid to efficient programming, one or more index registers are included in most newer microprocessors. The usefulness of the index register allows a programmer to automatically scan through one section of memory (for exampl picking up entries from a table of data) while the program counter is executing instructions in the main program.

Stack Pointer(SP):

The stack pointer (SP) is another register whose potenti can be fully realized only by good programming. The stack pointer can address any section of memory space. It provides an easily programmable means of storing and retrieving succes ive data words.

Input-Output:

Microprocessors have an internal data bus that transfers information between various registers. Bidirectional buffers are required to transfer this low-level bus to or from the higher-power-level outside circuits. Most of the internal registers also contain a set of bidirectional buffers for moving data to or from the device over the internal data bus. This type of buffer is also used outside the micro-processors to move data between the microprocessor and other devices.

External Memory:

A microprocessor stores nearly all its permanent and temporary data and instruction in devices outside its package. A microcomputer chip might store all or most of the temporary data and instructions inside the chip and many microcomputers also contain Read only-Memories(ROMs) (either permanently programmed or user-alterable) for holding nonvolatile data and instructions.

1.3 Evolution of Microprocessor

The complexity of integrated circuit (IC) devices has doubled approximately every year since the first device was developed in the early 1960s. Projections indicate that, if the present trend continues, devices containing hundreds of millions of transistors and other discrete components per chip will be available in the 1990s. Figure 2 shows the maximum number of components (transistors, diodes,capacitors, and resistors) on state-of-the-art IC chips for the past 25 years.

In the early 1960s, the first gate was fabricated by using a chip of silicon. As more gates were added to ICs over the years, the functions performed by these devices grew more complex. In just a few years after the first chip was developed, nearly all the logic and arithmetic functions performed by today's microcomputer devices were available to a user on a large assortment of IC devices. The arithmetic logic unit (ALU) chip developed in the 1960s could add, substract, rotate, and shift, just as a microprocessor or microcomputer device can today. However, not until the early 1970s was then ALU combined (on a single chip) with a sequential circuit (flip-flops,shift registers, and so on) to make a microprocessor. This had not been possible until the IC developers were able to place at least 1000 transistors on a single chip. It took only some more years until input-output (I/O circuits), read-only-memory (ROM), random-access-memory (RAM) and clock circuits were also placed on the chip; the device was then called a microcomputer.

1.4 Concept of Microcomputers

Microcomputers essentially comprise of a central processing unit (CPU), data storing and handling devices and various input-output (I/O) devices. Standard memory chips (Random Access Memories or RAMs and Read only Memories or ROMs), cassette-tapes and floppy diskettes are different means of storing and handling of data in microcomputers. Strip chart recorders and printers are also utilized as means of data storage. Keyboard, light emitting diode (L.E.D.) or liquid crystal display (L.C.D.) type of displays, video display unit (VDU) monitor, analog to digital (A/D) and digital to analog (D/A) converters, interfaces for transmission of data (e.g. MODEM) and signal conditioners are some of the commonly used input-output devices.

The CPU is the part of the machine which performs mathematical functions, controls the execution of program statements and directs the storage and retrieval of data. Detailed operation of the components of a CPU have already been described in section 1.3. Efficiency of a microcomputer depends on capabilities of the software , which transforms the microcomputer into an easily usable tool capable of undertaking a wide variety of tasks. Typical configuration of a microcomputer is shown in Figure 2.

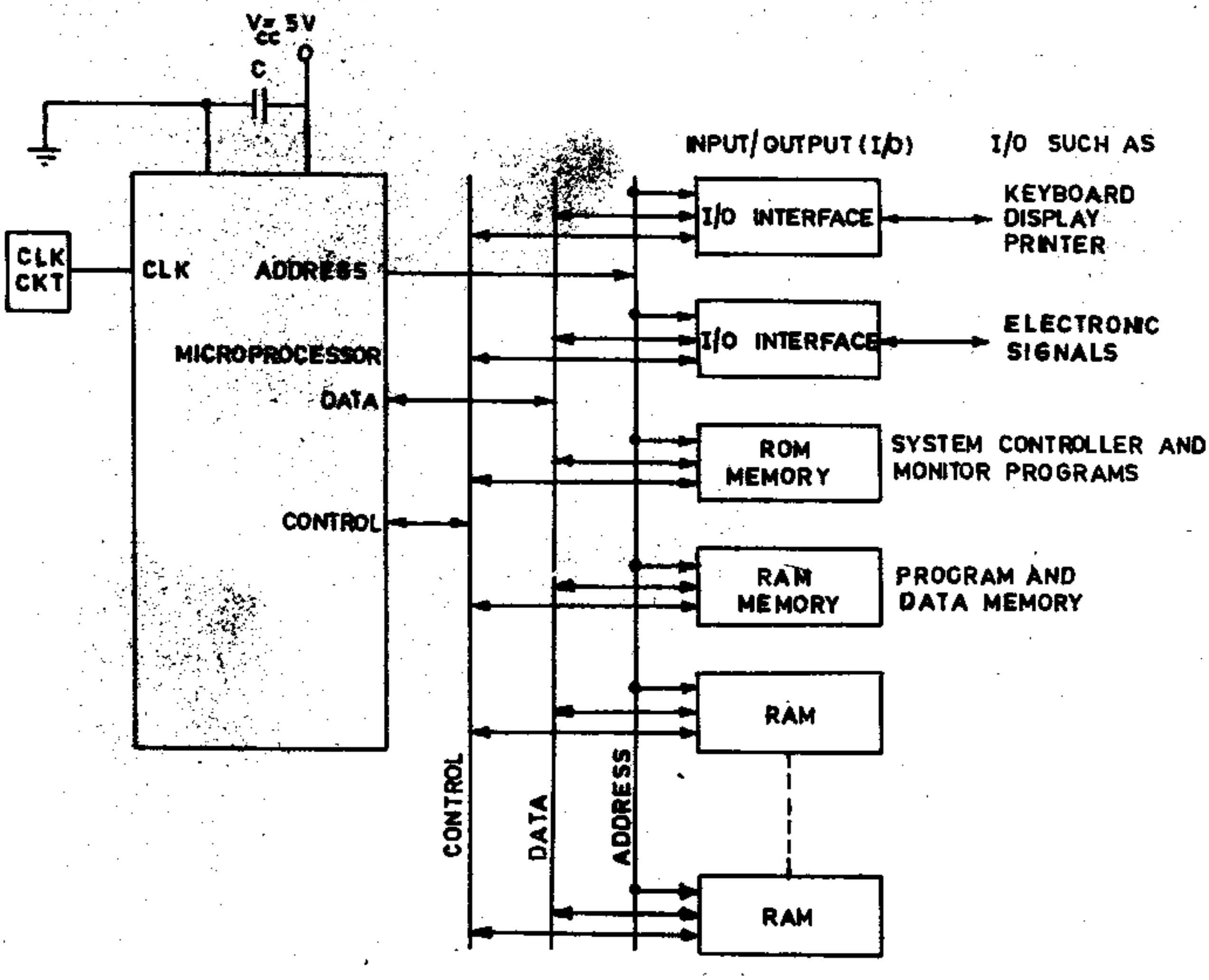

Fig.2 - General Configuration of a Micro-computer

2.0 REVIEW

2.1 General Electronic Instrumentation

Electronic instruments can be classified according to types such as simple display V/s calculating, and analouge V/s digital. A 'simple display' is one that takes an electrical signal either natural or from a transducer that represents some physical parameter such as a voltage, and displays it with no more processing, except possibly amplifications or filtering. A ' calculating instrument' provides some signal processing that may include linear amplification, non-linear amplification, scaling,filtering, logarithmic or antilog amplification, integration, differentiation, level shifting, summation, multiplication, division, etc. It is in the latter type that microprocessors have come in for immense use.

With the advent of microprocessors, a single instrument can now do the job which computers use to do earlier (Nayar 1983). Oscilloscopes, for example, are becoming more sophisticated and complex with knobs and switches are being replaced by keyboards. Results are not only displayed by a wavefrom on a scope, but also by digital read-out of actual values. Likewise data recorders, digital voltmeters,capacitance bridges,IC testers etc. are feeling the impact of microprocessors.

In many specialised applications, instruments are required to be controlled from remote locations. With microprocessors, the instrument can itself operate and control various operations as programmed in the software. The number of front-panel controls are reduced by incorporating features such as autoranging or automatic gain control. Modifications and improvements in the instrument to suit specific requirements can be made simply by altering the software.

Microprocessors enable an instrument to interact with the operator in simple ways. This makes the instrument easier to use, shortens the time needed to learn operating procedure, reduces operational errors and makes the results more consistent. As an example, earlier versions of frequency counters had direct reading counters upto 100 MHz and with heterodyne convertors or transfer oscillators beyond 100 MHz. Now automatic microwave frequency counters count upto GHz range and can perform offset functions.

Microprocessor-based instruments can be made capable of self-automatic calibration and self-trouble shooting diagnosis. It refuses to make a measurement if it finds a faulty module and by indicating which module is malfunctioning, it can reduce repair time considerably. Tests can be initiated automatically when a hardware error is detected or at any convenient time in the instrument's operation or alternatively by operator's request from the keyboard. One such task for improvement in performance of instruments could be error correction, for example in a digital voltmeter, the microprocessor can frequently measure the internal reference standard voltage, find out error in reading and apply that as a correction to the readings resulting in unprecedented accuracies. It can also find out if the measured values fall within the present limits and flash a warning if the limits are exceeded. Instruments can be made to perform arithmetic on their basic measurement results, e.g. to gain resolution by averaging several successive readings.

2.2 Hydrological Instrumentation

Hydrological instruments are basically classified as surface water instruments and ground water instruments. Conventional instruments have been described in a report by Seth and Goyal (1985). During the last fifteen years there were considerable improvements in both types besides development of completely new instruments. Appreciable improvements have occurred in technology of the following:

(i) Ultrasonic flow metering

(ii) Electromagnetic flow metering

(iii) Optical velocity measurements

(iv) Frictionless contacts and electronic counters in current meters

(v) The moving boat technique

(vi) Telemetry

(vii) Transducers (pressure or capacitance gauges)

(viii) Remote sensing, and

(xi) Digital recorders.

Latkovich(1985) has described some recent developments in hydrologic instrumentation at U.S.Geological Survey of United States. He describes some material developments e.g. fibreglass wading rod, polymer (plastic) sheaves, pulleys and sampler components,; polymer bucket wheels for current meters etc. A microlprocessor controlled current meter digitizer (CMD) is also reported. It automatically records the current meter revolutions, keeps track of time and converts the results into real-time velocities. Meter-rating equations are pre-programmed into the CMD's memory for instant recall, dependent on the mode of recording (automatic or manual) and the type of meter being used.

An automated discharge- measurement program is also reported to be tested and evaluated with the objective of developing an'electronic note book recording system . The microcomputer software program, when housed in hardware, would enable entries for a complete discharge measurement with options for air and wet line corrections, ice measurement computations, weighted gauge-height computations and so forth as well as all the notes normally written in the measurement note sheet. The results would be printed out on an expensive, portable printer carried in the field.

The USGS is also developing a microprocessor-controlled ground water level recording system to monitor levels in small diameter (2-inch) observation wells. A Minimum Data Recorder (MDR) is being developed to record the daily average water level and maximum and minimum (time-tagged) levels for the period of record. It will operate unattended for at least 12 month period and cover a total range of water levels from 0 to 20 ft. by using a pressure-transducer. Other potential applications for the MDR would be in surface water hydrology; recording flood hydrographs for small drainage-area discharge determinations and short-term, reconnaisance-type streamflow appraisals.

The most rapid development is observable in the field of real-time data collection, where the progress in data trsnsmission technology was a revolutionary one. Real time observations are often essential in up-to-date water management systems and in some special needs e.g. flood forecasting. Now-a-days even satellites are being used for data collection from remote areas.

Ghanekar et al.(1984) have described a satellite-based data collection system for real-time flood forecasting applications. The system, using INSAT 1 satellite, was proposed to be set up for collecting vast amount of hydrometeorological data from the Yamuna catchment area. Data on (i) stage or river water level,(ii) discharge or river flow rate, (iii) rainfall (iv) temperature and snow accummulation is required on near real-time basis during the flood season and at larger intervals on other days during the year.

Satellite receives data from sensors through the Data Collection Platforms (DCPs). Each DCP collects data from 10 sensors, and records information every hour in Data Conversion Storage and Transmission Sub-system (DCSTS).Each group of DCPs transmits data to satellite during ten minute interval allotted to each group. Data formatting and pre-processing before transmission is done by using microprocessors. Use of microprocessors saves transmission-time by compressing the data.

Brown et al(1985) have reported another such system for flood warning applications. The system,basically an event monitoring and early warning system for local areas, consists of a microcomputer based central receive station and upto 300 remote stations. Remote site packages include instruments for measuring the desired remote parameters and telemetry equipment and accessories. The user may select instruments for measuring stage, rainfall, and/or other desired telephone,GOES satellite, local recording or a combination of these. The microcomputer based central receive station features simultaneous data acquisition and display, real-time direct read-out,colour display and data base options, and telephone dial-in/dial-out options. Flood warning software like rainfall-runoff simulation, flow forecasting, and local audible alarms can be incorporated in the system.

U.S.Geological Survey is modernising its national hydrologic data collection network for acquiring data on the quality and quantity of surface and ground waters in the United States. The U.S.G.S. is using commercially available microprocessor technology systems to support-hydrologic data collection and telemetry via geostationary satellites (Paulson, 1984a). The system,known as Adaptable Hydrologic Data Acquisition System (AHDAS), will be supporting national network of the Geological Survey which caters to the needs of over 800 Federal,State and local cooperating agencies.

The AHDAS system comprises of (Figure 3) two basic modul..r units. The first, known as a field component(FC) is a battery-ope1 ted microcomputer that,through a set of interface modules allows it to receive data from a wide variety of hydrologic and meteorological measurement systems(for details of interface modules, see table 1). Through additional interfaces its memory can be expanded, and it can communicate data to existing telephone or satellite communications systems.

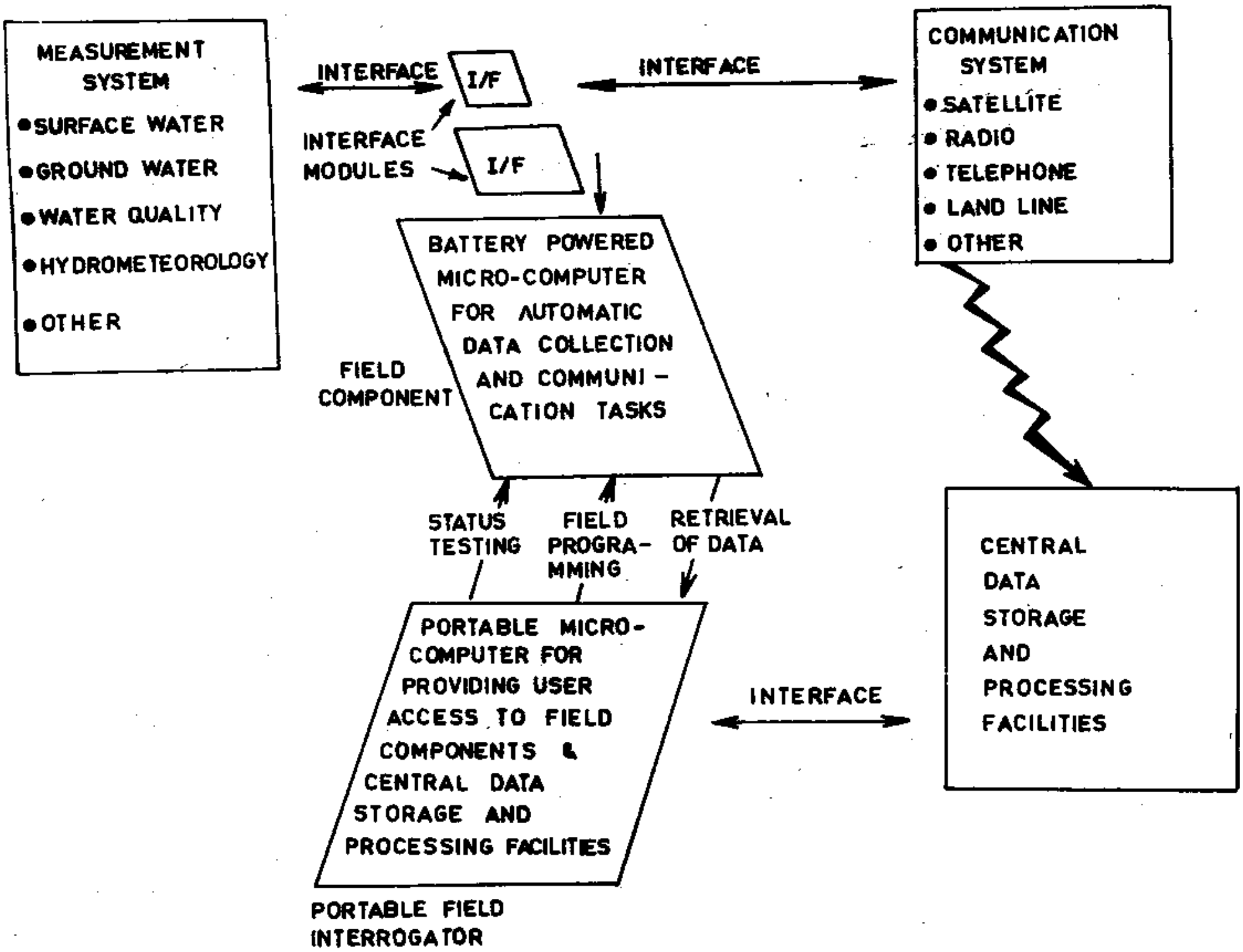

Fig.3 - Block Diagram of AHDAS

The additional module will permit the FC to conduct numerous logical and control functions found in commercially available Data Collection Platforms, and it will allow the FC to communicate with the GOES sattelite by merely adding a transmitter board.

Table 1. Interface modules for AHDAS

Name	FUNCTION
. Water Stage	- Access up to three shaft encoders used for water level - Control and sense status of peripheral systems such as samplers, pumps etc. - Compatible with commercially available DCP's.
. Rainfall	- Access up to three " tipping-bukcet" raingages. - General purpose event counting.
. Analog Input	- Eight channels of Analog to Digital conversion (0 to 5 volt,single-ended). - Space for custom pre-conditioning circuits provided on the printed circuit board.
. Memory Expansion	- Forty-eight K-bytes (48K) per module (three times basic FC memory capacity) - Modules may be stacked.
Telephone Communicator	- Answers telephone/dials telephone numbers and transmits selected data. - Standard telecommunications or synthesised

voice.

. Advanced Satellite Communicator	- Provides advanced satellite real-time data communication capability.

The second AHDAS component is the portable Field Interrogator (PFI) which is a portable battery-powered microcomputer that sllows field personnel to interact with the FC. The FC has no control switches and the PFI is required for the routine retrieval of data for programming the operations of the FC, and for testing the status of the FC.

There are substantial benefits in using microprocessor technology for hydrologic data collection that can be derived from the flexibility and reliability it can provide. For example, data loggers are designed to collect data from many sensors, under numerous criteria, and that the data automatically can be evaluated, manipulated, statistically summarized at the hydrologic station and telemetered reliably via satellite or meteor trails from even the most remote locations.

Many data loggers are capable of initiating alert messages or changing their data collection activities based on the hydrologic conditions they are monitoring (Paulson,1984b). For example, some commercial Geostationary Operational Environmental Satellites (GOES) Data Collection Platforms(DCP) can initiate alert messages when water levels or rates of precipitation exceed specified levels. Under this mode of operations,routine data collection messages continue to be transmitted every several hours, while alert messages, transmitted at a difrerent radio frequency, are transmitted every 15 minutes. Other DCPs are being used to test another mode of operation, known as random adaptive, that alters the interval between transmissions of hydrologic data in response to the status of hydrologic conditions. Both modes of operation allow communication systems to convey critical hydrologic data in a timely way without clogging such systems with nearly useless data when hydrologic conditions are static.

Microprocessor -based data systems also can collect and store data on a non-fixed time interval, as discusssed above. A wide range of sampling schemes can be implemented by such systems to collect data at a high frequency during dynamic events and at a low frequency during more static periods.

These systems can use data from several sensors to govern the collection and transmission of data, or command an alarm or some other device. For example,data from water level and precipitation sensors can be evaluated automatically at a remote station to initiate alert transmissions, or sound an alarm for flooding conditions. Commands to an automated sampler to collect water samples of urban runoff events also could be initiated by such a system that could monitor phenomena that are of too transitory nature for effective manual sampling.

Collins (1985) has reported development of a microcomputer -based data acquisition system for collecting aquifer test data. Ground water levels and well discharges are measured using pressure transducers. Analog signals from the transducers are filtered and amplified before feeding to the microcomputer (IBM-PC compatible Colby PC transportable personal computer). Data acquisition is controlled by a BASIC programme and data are stored on floppy disk. The system could be expanded to include additional transduers, for example pH probes etc.

2.3 Meteorological Instrumentation

Precipitation data is a basic requirement in almost all the hydrologic and meteorological analysis. Accurate and cost-effective methods of measuring and processing the amount, intensity and distribution of precipitations are essential. A microprocessor-controlled system has been reported (Burgess and Hanson,1983) that stores precipitation gage data in a removable memory module for data storage and retrieval. The data stored on the removable memory module can be entered directly into a computer for storage and analysis.

The system basically consists of three sections (Figure 4) These are precipitation monitor, removable memory module and interface for data retrieval. Precipitation monitor comprises of a precipitation gauge, analog/digital converter digital check, four digit display,input/output control logic,state code logic alongwith the microprocessor. The precipitation gauge utilizes a weighing mechanism coupled to a precision potentiometer. The crystal controlled digital clock circuitory generates time of day and Julian date along with the 1-min sample interval strobe for gauge data evaluation.

The system microprocessor is a low power 8-bit CMOS integrated circuit. All data and system functions are controlled by the microprocessor in accordance with the machine-language program located in the removable memory module. The removable memory module is primarily random-access-memory (RAM) integrated circuits. A small battery is included in the

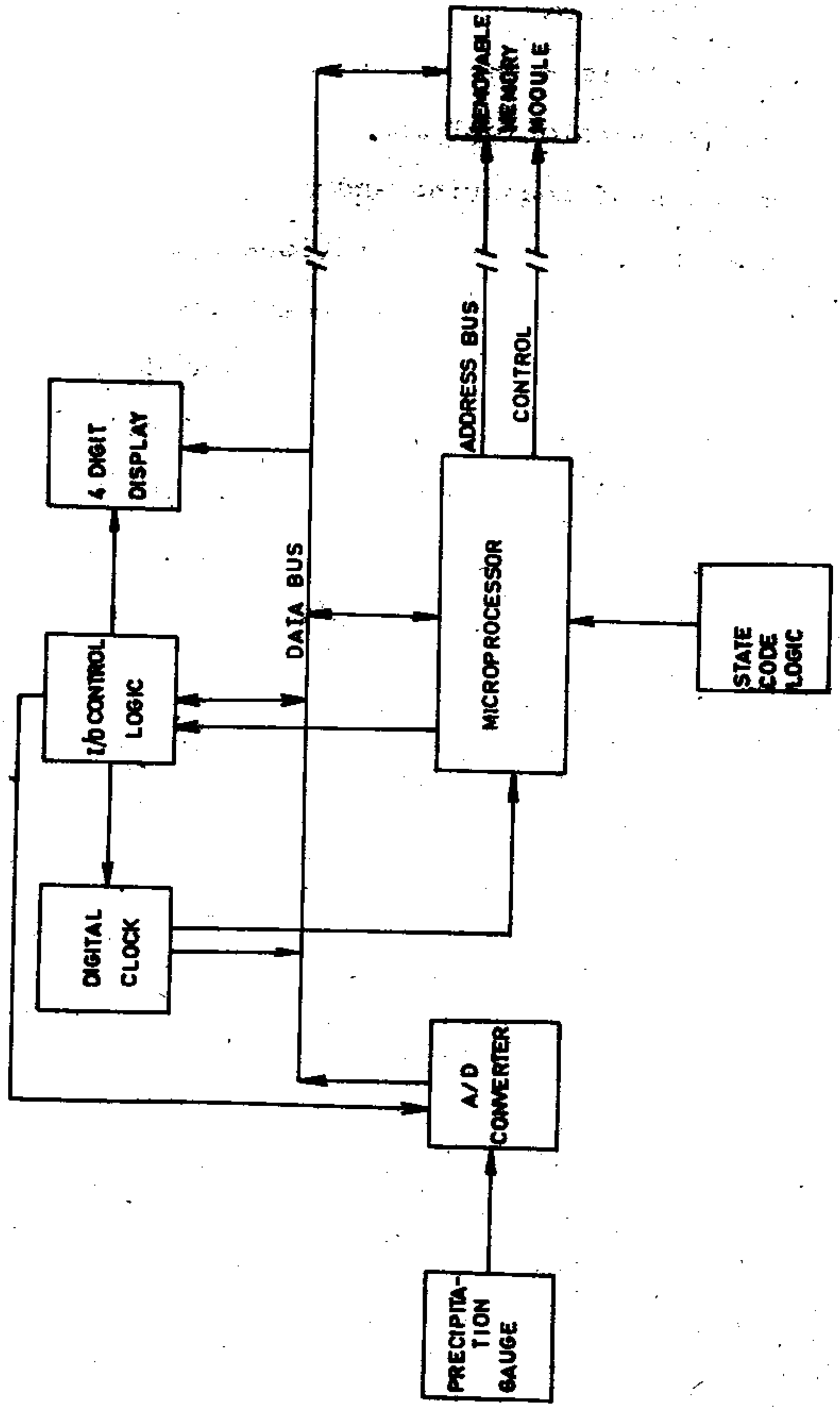

Fig.4 - Microprocessor Controlled Precipitation Monitor
(after Burgess and Hanson, 1983)

module for memory retention when the module is not connected to the precipitation monitor. The information stored in the removable memroy module is in hexadecimal code and the computer terminal operates with the ASCII code. Subroutines stored in the read-only-memory (ROM) are utilized for code conversion so that the information is properly read and recorded by the computer terminal. The main program is stored in the interface RAM section, providing data read out format for display and storage by the terminal and removable memory module erasure. The I/o control logic provides the serial data interface configuration for the computer terminal.

Now-a-days these equipment are available commercially from international manufactures like Casella, London. Two such systems reported recently (Casella London,1985) are computerised logging systems for water level recorders and rain gauges. They provide data logging for a period of 30 days.

In water logger system, each recorder incorporates a stainless steel tape,connecting the float and weight, for relaying the water movement onto specially- designed module. The module contains a data logger and incremental shaft encoder capable of logging water level changes from 1 mm upto a maximum of 64 m with an accuracy of 1.5 mm. The logger has a port which accepts a detachable data cartridge. Each month the cartridge which collects the data is removed from the recorder and analysed by a console unit at some head office so as to provide instant reports.

Rainfall logger system employs tipping-bucket rain gauges that generate a pulse everytime a predetermined small quantity (either 0.2 mm or 0.5 mm) is received. These gauges are interfaced to a data logger, containing cartridges. These can again be analysed on console units at the head office.

Both the above systems have the similar data acquisition system(see figure 5). The data logger contains a microprocessor alongwith address decoding and data compacting firmware in order to store data in an economic manner. Data cartridges are solid state storage media capable of storing a minimum of 2K for rainfall and 4K for water level. It also contains a real time clock/calender. The console unit interrogates the data cartridges received from various locations and communicate with the associated printer, or to a mainframe computer, via a standard V24 (RS 232 C) data port. The unit also contains printer control software which immediately generates charts and graphical representation of water levels, or rainfall on Epson,or Epson compatible printers.

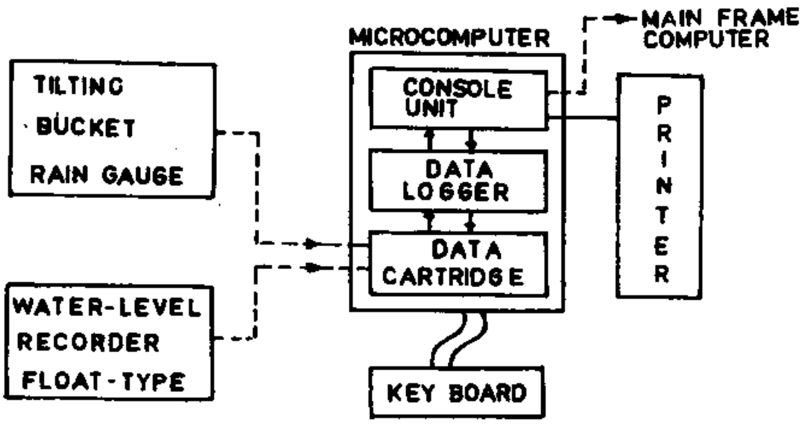

Fig.5 - Computerised Water and Rainfall Logging Systems of Cassella, London

In case a direct read out is required from a water level recorder on site at any time the data cartridge may be temporarily removed and an inspection key inserted which shows the level on a display. The complete water logger systems and rainfall logger systems cost about £ 3600 and £ 3900 respectively.

Microprocessors are now being utilized for many sophisticated operations in a system because of their multifunctional capabilities. One such field is the use in automatic weather station(AWS). The meteorologist is mainly concerned with the collection of synoptic data for forecasting purposes or with research concerning large scale air mass behaviour. In either case it is necessary to collect data from a substantial area of the globe (Strangeways,1985). An AWS essentially contains two components-field unit and base station(Figure 6). A field unit comprises of the sensors, the interface electronics for signal conditioning a data logger and one or more data outputing devices, e.g. solid state memory,magnetic tapes,telemetry etc. Base station comprises of replay unit and/or telemetry unit for inputing data, a computer for handling the raw data and various output devices like disc/tape drives, line-printers video display unit etc.

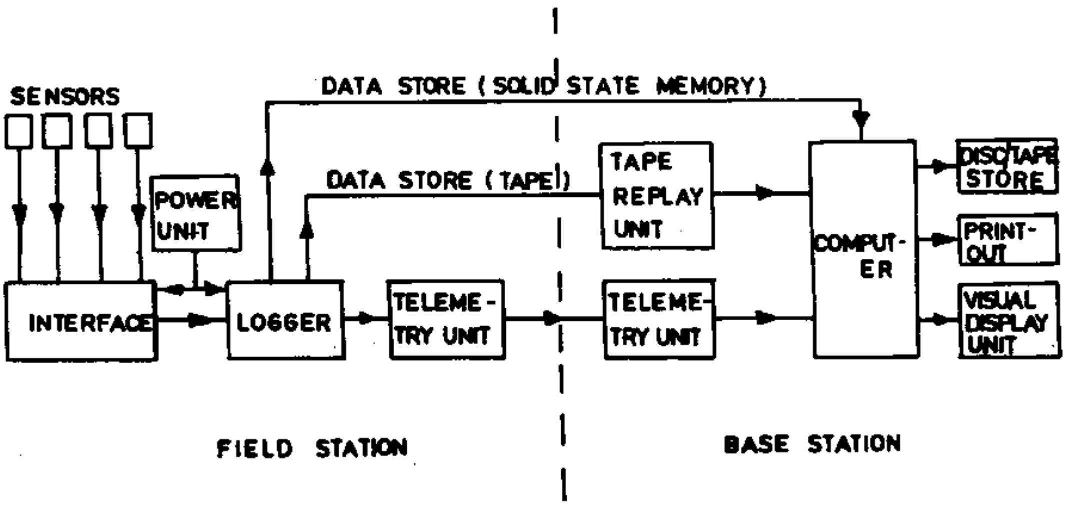

Fig.6 - Schematic of an Automatic Weather Station (AWS).

Use of a BBC microcomputer in AWS has been reported (Sparks and Sumner, 1984) under the Microcomputer environmental Probes Project (MEPP) which was undertaken at Lampeter. The University College Swansea Microprocessor Centre developed an interface box called MODAS (Modular Data Acquisition System) for interfacing a large number of analogue as well as digital sensors. Various sensors used with the AWS are as follows:

(i) Analogue inputs

Dry-bulb temperature

Wet-bulb temperature

Earth temperature at 5,10,20,30 and 60 cms

Grass temperature

(ii) Digital inputs

Wind vane delivering 16 compass points
Reed switch'run of wind' anemometer
Tipping bucket rain gauge

A display -screen provides an update of every five minutes for weather conditions. In addition, at 9.00 maximum,minimum and grass minimum temperatures and total rainfall for the previous 24 hours are calculated and archieved separately. Current values for wind direction and speed,air,dew point and earth temperatures are also stored. Dew point temperature computed using an approximation formula correct within normal temperature to about 0.5°C. Also developed with the system are two specialized groups of programs; one for archieving air and dew point temperatures, wind speed and direction and rainfall for any specified time interval greater than about 250 and the other for accessing upto eight temperature sensors, at time intervals determined by the user. Graphs and tables of processed data can be displayed using a BBC Model B micro-computer in either a high-resolution , four-colours graphics or a lower-resolution, eight colours graphics.

Another feature of the graphical presentation is to provide a wide variety of different graph combinations from the same data set using a menu system. For example,combinations of temperature, wind speed, wind direction and rainfall graphs are produced using this microcomputer software.

Apart from permanently stationed AWS, as described above, portable AWS have also been developed. These are very useful in collecting data from a wider area, under different hydrological and meteorological environments, using a single unit. One such system, namely Portable Automated Mesonet (PAM), has been reported (Brock,1975), which consists of a trailer-mounted base station and a network of remote stations. In this system, each remote station samples local sensors synchronously and transmits the data to the base station via a radio link. With the use of antennas mounted on a 50.m tower at the base station and on 12-m towers at remote stations, communication range achieved is upto 80 km.

Analog as well as digital, including event type, sensors can be interfaced with such systems. These sensors are kept in the field and interfaced with the remote unit through signal conditioners. Power for remote units is provided by batteries and/or by solar-panels, wind generators or thermo-electric generators. In order to reduce consumption these units could be made triggered type, i.e. only after receiving a command from the base station, the remote units will turn on the transmitter and send the data message. In this way power requirement can be reduced by switching off the transmitter when transmission is not required.

Base station houses equipment for data logging, data quality assurance and real-time analysis. Data, as received on receiver, passes through a central processing unit (microprocessor) for linearisation and conversion into physical units and then to industry compatible magnetic tape units. The stream of data from each sensor is examined to ascertain data quality. Cathode ray tube (CRT) may be used to display questionable data sequences. Constant operator presence is not required since the CRT displays can also be copied on hard-copy devices. A typical configuration of base station and remote-units is given by Brock (1975).

In relatively flat terrains, the data is transmitted, using line-of-sight telemetry (Goyal et al.1985). In undulating terrains, also involving larger areas, radio repearters can be used for enhancing the signals. In some cases when a remote station must be placed at very long range(i.e. across a large lake or a hill or across any other major radio obstruction) a telephone-line link could be used from the base station to a remote master station(Sinvhal and Goyal, 1985). The remote master station could poll other remote units in its vicinity.

The system is used to study sea breezes, hail storms, squall lines and regional air pollution in an area upto 160 kms in diameter. Remote stations could be located from 1 to 10 km apart and are interrogated at fixed time intervals. The data is then telemetered to the base station where it is made available for real-time analysis and display as well as recorded on magnetic tape for later analysis. Real-time analysis of the signal helps monitoring the progress of meteorological phenomena (e.g., a squall line or a sea breeze front) through the network. Microprocessors are utilised for controlling the whole operation of data acquisition alongwith providing a check on quality of the data. This is done by running programs continuously at the base station to check for bad or questionable data so that intermittent failure anywhere in the system can be called to the operator's attention.

2.4 Other Applications

There are numerous fields of applications for microprocessors. In India, as well as abroad, these are increasingly used for performing a variety of tasks involving data collection, transmission and analysis.

Smith (1981) has described a microprocessor-controlled digitizer for conductivity-temperature-depth probes which are used in oceanographic studies. Signals from Plessy Environmental systems' Model 9400 conductivity-temperature-depth (CTD) probe are multiplexed after proper filtering and subsequently frequency modulated. This data is then digitised and fed to a computer for real-time analyses. Interfacing the digitizer to the computer is done by plugging the unit to a terminal connector and writing a short program in Basic language. Use of a microprocessor reduces the amount of hardware significantly so that the entire instrument, less power supply and FM demodulators can be constructed on a board 17 cm by 14 cm. Cost of such digitizer could be well under $ 500.

Microprocessors are specially useful in applications requiring storage of data from remote locations, through unattended operations. Joseph and Desa (1984) have reported an automatic self-recording tide measuring system, based on an Intel 8085 microprocessor. Erasable Programmable Read Only Memories (EPROMs) were used for storing the tidal data. Use of a microprocessor facilitates an on site analysis and inspection of tidal data and satisfies the requirements of long term self recording instruments.

Geophysicists are also taking advantage of the modern microprocessor technology. Previously, using conventional type of geophysical instruments, most of the time in a field survey was spent in taking the measurements. Processing and interpretation of data use to be another time consuming process. Sowerbutts and Mason(1984) have reported a system for small-scale geophysical surveys. This is based on an Apple II microcomputer which was used to increase the speed of the surveys and to simultaneously record position of the survey points. Using programs written in Basic language , results of geophysical measurements are processed and plotted as profiles on the computer screen as measurements are made. This procedures enables the operator to identify and repeat any dubious readings before moving on, and provides the sort of information needed in order to consider modifying the course of a survey while in progress.

On completion of a survey, the microcomputer, is used with different programs to process, plot and interpret some or all of the survey results. Contour maps and other forms of graphical presentation of results are plotted on the computer screen, and detailed scale plots are made on paper using either a small digital plotter connected to the computer or matrix printer. These tests can be performed in the field immediately on completion of a survey, or later back at base.

Goyal et al.(1985) have utilized a microprocessor in telemetering of seismological data over short distances. In such data communication applications, use of a microprocessor drastically reduces the involved hardware. Most of the operations in the system are controlled by software thereby making the system versatile and suitable in a variety of conditions.

Similar to automatic weather stations, described earlier, automated weather data network (Hubbard et.al.,1983) has been developed for agricultural applications. The system-called Automated Weather Data Network (AWDN), was developed at University of Nebraska. A number of weather stations are connected through AWDN, which is used to automatically collect hourly weather data from these stations. Standard weather sensors e.g. cup aneomometer, wind vane, thermistor, electronic hygrometer, silicone pyranometer, shielded thermistor for soil temperature and tipping bucket raingauges, are coupled to an on-site microprocessor alongwith solid state memory storage. The calibration constants for the various weather sensors are entered into memory for use in converting analog sensor input to digital form during the processing of incoming sensor signals. Hourly readings of the sensors are stored in the memory. A central minicomputer regularly interrogates the microprocessor, quality-checks the incoming weather data and transfers it to a larger main frame computer. Whenever suspicious data is encountered, appropriate messages are printed so that the data can be checked by a specialist. The computer then sorts the data for the most recent 24 hr. period and merges it into the data archieve. Main use of the mentioned system is in providing a near real-time data about weather-an important parameter in irrigation scheduling etc.

Irrigation management is yet another allied field of hydro-metereology in which use of microprocessors can economise the cost of equipment and make the system flexible. Efficient and effective control over the irrigation water supply to cultivative crops boosts up their productivity. The control systems supply the optimum moisture to crops at the appropriate time of their need. Microcomputer in such control system acts basically as a supervisor by continuously monitoring soil-moisture at the crop root zone and based on that, taking decisions regarding state of parameters like field capacity and wilting point. The control system measures the actual soil moisture tension at the crop root zone, compares it with a preset threshold value, decides on the amount of moisture deficit and performs irrigation to replenish the deficit in near real-time. Ehtirajan (1985) has described a microcomputer control system for irrigation management. The system is based on an Intel 8085 microprocessor. It also contains hardware sections for (i) irrigation water supply system,(ii) soil-moisture data acquisition system, and (iii) control hardware sub-system. Such electronic digital control system help increasing the irrigation efficiency and conservation of water.

Ritchey and Faivre (1985) have described an automated data-acquisition system for measurement of soil/water properties in laboratory. It is used to monitor flow through fine-grained undisturbed soil samples and was designed to measure the effective porosity and hydraulic conductivity of saturated soils. It utilizes four pressure transducers and eight water-level sensors. The data acquisition system consists of an IBM-PC compatible microcomputer and a Tecmar PC-Mate Lab Master data-acquisition circuit board. The system is controlled by a computer program written in BASIC.

2.5 Data Processing Applications

Microprocessors are effectively being used for initial, mainly on-line, pre-processing of signals before feeding into a bigger computer for final analysis. Recent advances in microelectronics have enabled the manufactures to bring up a memory of the order of 512 K bytes on single board micro-computers. This helps in performing a variety of analysis-procedures, even those involving large memory-size, on these on-line microprocessor systems. Statistical as well as other methods of frequency analyses (e.g. fast four transformation etc) digital filtering, correlation studies etc; and other numeric processing, etg. double precision operations, fast scaling, non-linear function (for example sin x, e^x) computations etc. can be easily performed on these system. Two examples of versatile single-board microcomputers, specially designed for signal processing applications, are Intel 2920 and TMS 320 series from Intel corporation, Inc and Texas Instruments, Inc. respectively.

Cole et.al.(1985) have reported on use of micro-computers in groundwater modelling. They have given a good perspective on ground water modelling using microcomputers, based on research work carried out at Battelle, Pacific Northwest Laboratory,U.S.A. A review of the work done in past, being carried out at present and that envisaged for future is outlined in the paper. Some of the numerical models, developed by Battelle-Northwest researchers, to investitate groundwater flow and contaminant transport problems are described as (i) two -dimensional flow with advective transport (PATHS), (ii) multilayer two-dimensional flow (VTT), (iii) one-dimensional radionuclide chain dècay(MMT),(iv) one-dimensional unsaturated flow (UNSATID) (v) three-dimensional fluid flow (FE3DGW), and (vi) three-dimensional transport of fluid, heat and solute. Apart from this, some computer animation software in form of films of the simulation results, have also been developed.

Microcomputer are also used for processing surface water data, e.g. water-level, flow etc. and meteorologic data,e.g. precipitation, humidity etc. This data may be in any of the several different forms(i) digital recording,(ii) analog graphic recording,(iii) hand recording,(iv) microwave telemetric recording, solid state recording. Raw data are processed and transformed according to type and method of collection. Startzman (1985) has described a computerised method to process analog hydrologic data. In this method, microcomputer software is used to digitize filter and view data from analog charts of gate operation and water level before being transmitted to a mainframe computer for data base archival.

Borehole geophysical methods find many useful applications in hydrogeological studies. They provide vital information regarding the lithology, stratigraphy and physico-chemical properties of the fluids filling the borehole and its surrounding formations. Using these parameters, areas of high porosity and permeability, which would produce the most water can be identified, as also zones of salinity; the magnitude and direction of flow through a well and regional groundwater flow patterns might also be indicated.

Microprocessor are now increasingly used for automatic processing of geophysical logging data. Here, it is not enough to have all the necessary computer programs for the processing of the lags. It is also very important to optimize the way in which these programs can be combined for fast effective evaluation of the laogs. A critical factor in this process is the general memory structure of the microcomputer (memory map), since the operator has to define the parts of the memory which will contain the data, the programs and the intermediate and final results. Tselentis (1985) has described such applications of microcomputers for processing of geophysical well logs, as applied in the hydrogeological studies. Recently,resistivity modelling techniques are also being implemented on microcomputers. James (1985) has developed algorithms for finite-difference resistivity modelling using Polozhil decomposition which can be accommodated on a microcomputer with only 256 K bytes of memory.

These recent developments in microcomputer-technology may help in establishing geophysical well logging as a low-cost quantitative investigation technique of groundwater hydrology.

3.0 REMARKS

Many applications of microprocessors and microcomputers in collection of data for hydrometeorological applications have been reviewed. Main uses of microprocessors are for (i) acquisition of data: comprising of data collection and data-transmission, and (ii) processing of data.

In many cases, recent trend is to replace conventional sensors by microprocessor-based sensors. Microprocessors are efficient in reducing volume and increasing efficiency of the sensors.

Microprocessors in data -transmission play important role, especially in flood control systems. Satellites are used as the medium and the two ends of the data acquisition systems are operated with the use of microprocessors. As a result, digital transmission is possible which appreciably reduces the loss of signal as compared to the analog transmission.

Capability of microprocessors for data processing is mainly realized in field operations where large computers cannot be used for logistic well as technical limitations. Moreover, they are effectively used for dedicated applications

Since microprocessors and associated circuitery are commercially available at very reasonable prices, their inclusion in any project for different uses does not involve heavy investments.

Microprocessor technology is a very fast developing field. Many new applications are coming up. For upto date knowledge of these as well as other applications readers are adviced to keep in touch with the research publication, journals etc. as listed at the end of the report.

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