An Automatic Recording Weather Station

E. Desa[1], A. P. Selvam[1], R. G. Prabhu Desai[1],
M. R. Nayak[1] and S. Tengali[1]

ABSTRACT

This paper describes the Automatic Weather Station erected by the First Indian Antarctic Expedition. A simplified block diagram of the system electronics presents an overview of the sensors and associated electronic hardware. A detailed flow-chart of the acquisition and storage software is also presented together with details of the processor module, analog board, clock and power supply circuits and tape recorder interface. Finally, a typical print-out obtained at the site of erection, Dakshin Gangotri, is reproduced.

INTRODUCTION

An automatic recording weather station has been designed and installed at location Dakshin Gangotri (Latitude : 11°38' 13.618"S Longitude : 70°45' 12,963"E), during the First Indian Antarctic Expedition 1981-82.

The station was programmed to interrogate meteorological sensors every 2^{13} sees (2 hours 16 minutes 32 seconds) and record their values. The values were stored on an incremental cassette recorder with a total capacity of 1.6 Mega bits equivalent to a 5 month capacity at the set interrogation interval.

The electronics was based on Intel's 8085[(1)] microprocessor which was programmed to sample each sensor four times and compute an average value. The reference voltages as well as the temperature of the electronics package were also recorded. The Analog to Digital Converter (ADC) used was Intersil's 7107. The use of the 7107, and that of a high stability reference voltage source LM 299A[(3)] , gave the system a theoretically good performance. Military specifications integrated circuits (ICs) were used where available. The system was powered by sealed lead-acid GEL cells and secondary charging was achieved via normal lead-acid batteries of high capacity.

Mechanically, the station consisted of a 4 meter long aluminium pipe of 4.5 inch diameter which was mounted on a steel tetrapod and stabilised by 4 stainless steel guy wires. The electronics was based within a 0.5 inch thick black High Density Polyethylene (HDPE) cylinder of external diameter 30 cms and a height of 60 cms. The intervening spaces were filled with expanded polystyrene foam. The initial results obtained at site showed that the interior temperature was maintained at about 10°C above the outside ambient. The sealed lead-acid GEL cells were contained in a second HDPE cylinder and were totally sealed with connections brought out via 'O' ring fitted underwater connectors.

The data recorded on tape during the short sojourn at Dakshin Gangotri, was retrieved prior to departure and a new tape loaded. The meteorological values recorded showed good correlation with the values broadcast by the Russian Station located about 10 kms distance from Dakshin Gangotri. A print-out of the recorded data is given in Table 1 alongwith the transmitted Russian Station values for approximately the same period and location.

SYSTEM HARDWARE: ELECTRONICS AND SENSORS

A block schematic of the system electronics is shown in Fig. 1 and a photograph of the electronics situated in the insultated housing is shown in Plate 1.

ELECTRONICS

Binary Clock Board

The binary clock was permanently powered and was switch selectable on the board to provide a pulse every 2^n seconds, n was chosen as 13 as this gave a timing closest to the standard meteorological synoptic

i National Institute of Oceanography, Dona Paula, Goa-403 004.

observation period of 3 hours. The interval was actually 2 hours 16 minutes and 32 seconds. A block schematic of the board is shown in Fig. 2- It was not possible, in the short time-frame available for fabrication, to construct a clock board which would operate at 3 hour intervals.

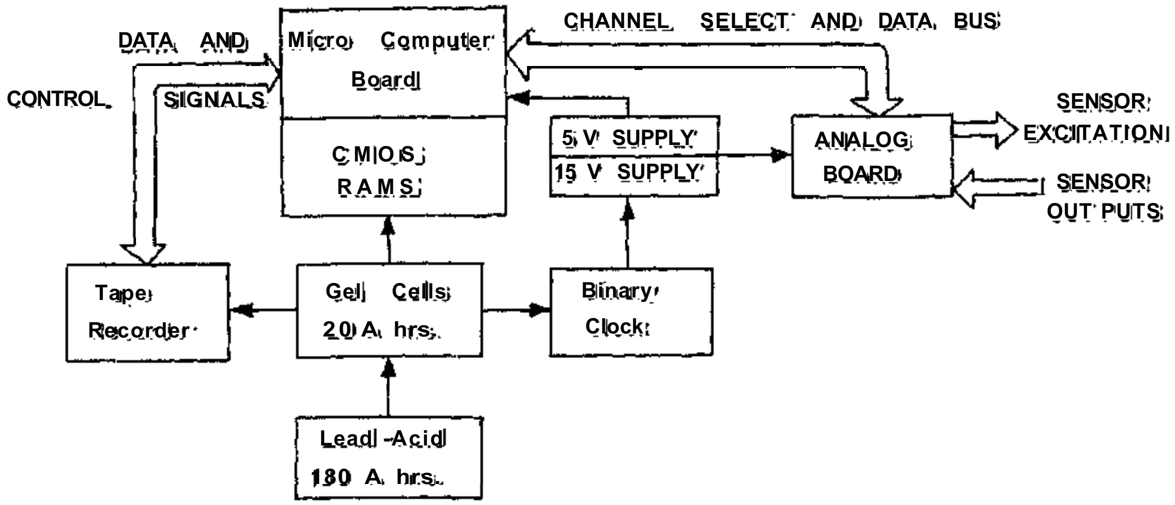

Fig. 1 : Block schematic of system electronics.

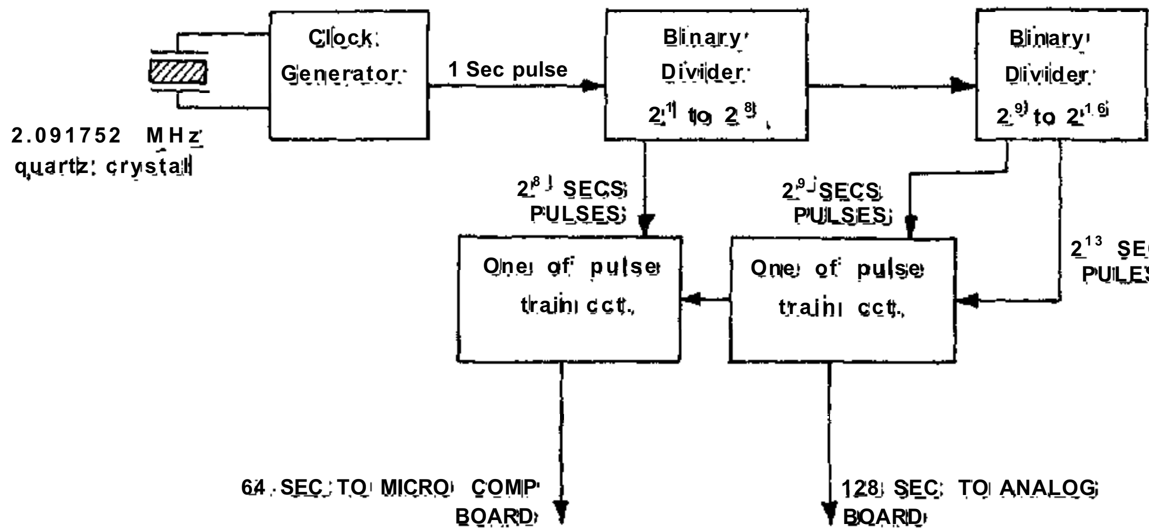

Fig. 2 : Block schematic of binary clock board.

Power Supply Board

The power supplies were all situated on one standard card and a schematic is shown in Fig. 3

From Fig. 2, it is seen that battery power is provided at all times to the CMOS binary clock board, the CMOS RAMS on the micro-computer board and to the tape drive. The total consumption for these three circuits was of the order of 200 micro-amps (μA). The circuit used military specifications voltage regulators where possible The tape drive unit was permanently powered up as it was a low drain system (60 μA) and moreover it tended to write a random garbled character every time it was switched on. This error was avoided by continuously powering the recorder.

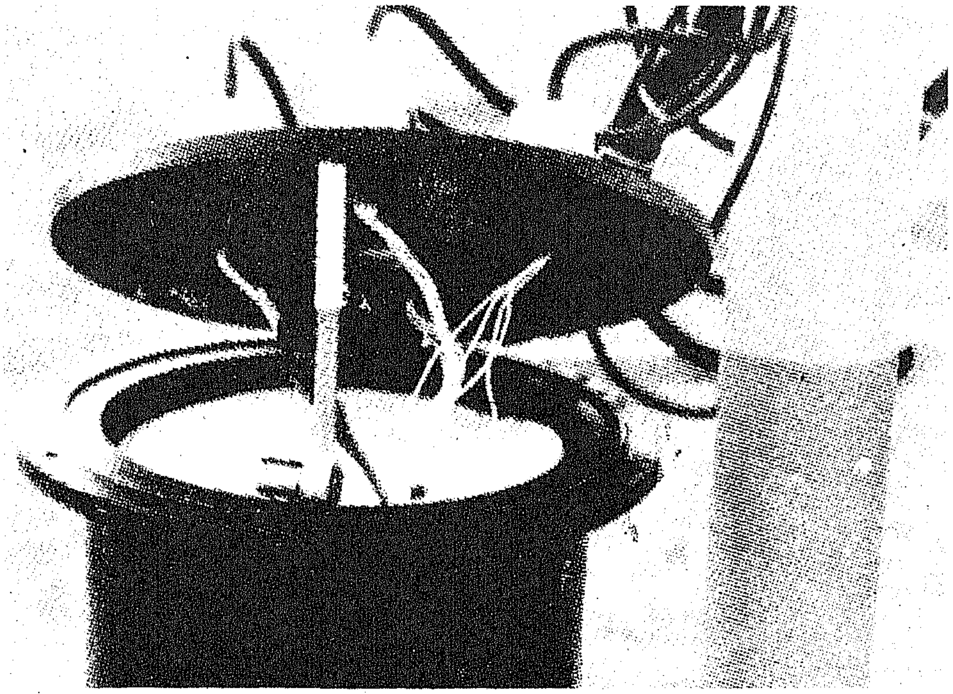

Plate 1 ;. H. D. P. E. bin seen with electronics and insulation

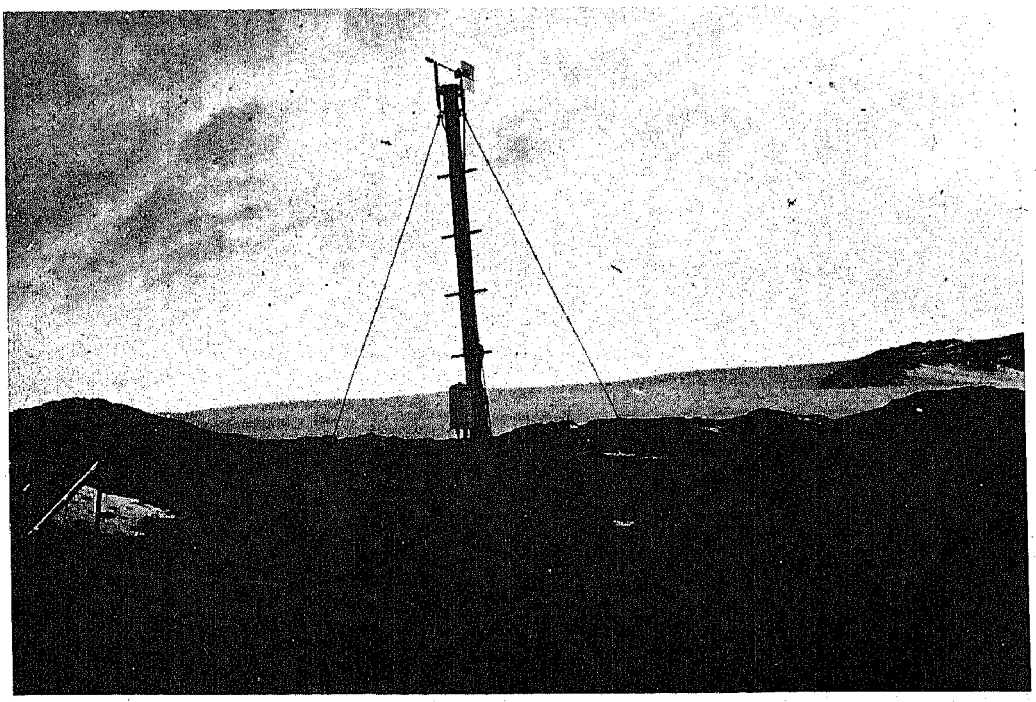

Plate 2 : View of weather station

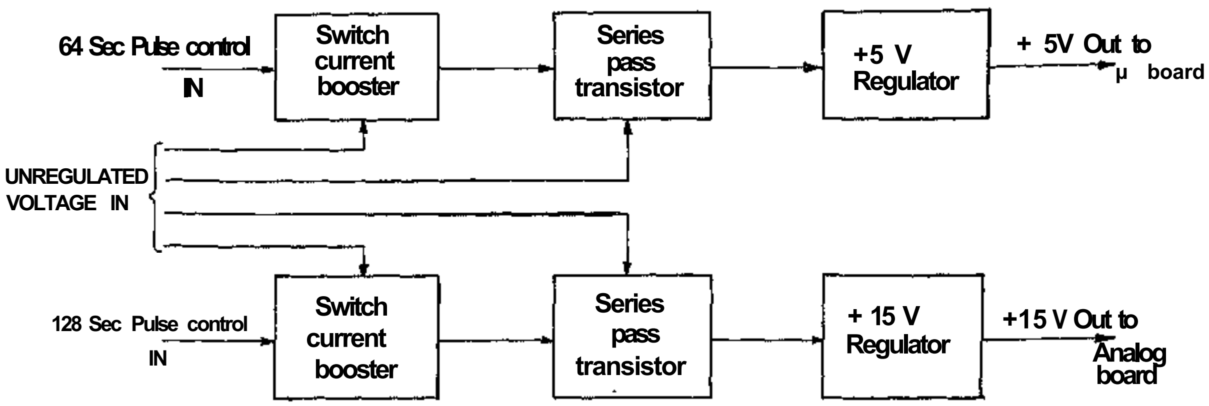

Fig. 3 : Block schematic of power supply board.

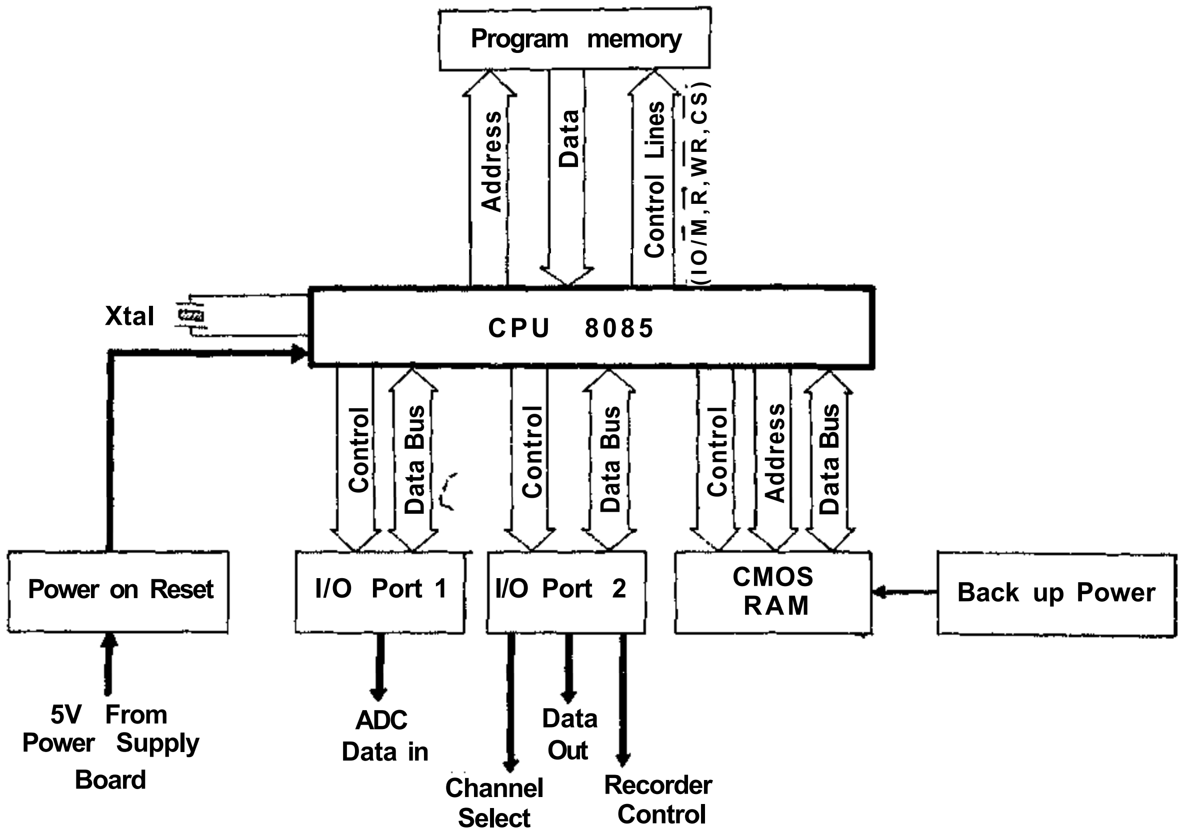

Fig. 4 : Block schematic of micro computer board.

tended to write a random garbled character every time it was switched on. This error was avoided by continuously powering the recorder.

Micro-computer Board

A schematic of the micro board is shown in Fig. 4. The board can accommodate 6K bytes of Programmable Read Only Memories (PROM) and 1K bytes of static Random Access Memory (RAM). It contains 2 programmable Peripheral Input Output (PIO) ICs and extra decoded I/O lines are also available. The system software required only 2K bytes of programme memory and 256 bytes of RAM.

Analog Board

A schematic of this board is shown in Fig. 5. The regulated 15 V supply to this board was further regulated to 5 V for the 7107 ADC[2] and for the 4 to 16 line decoder. The 4 lines from the micro-comp board were decoded to different CMOS switches. These switches returned sensor voltage outputs to the ADC. An integration network was also provided to smoothen out rapid fluctuations of sensor output (especially important for the wind speed and wind direction sensors). The program averaged each sensor output from 4 consecutive readings. This averaged value was recorded on the tape.

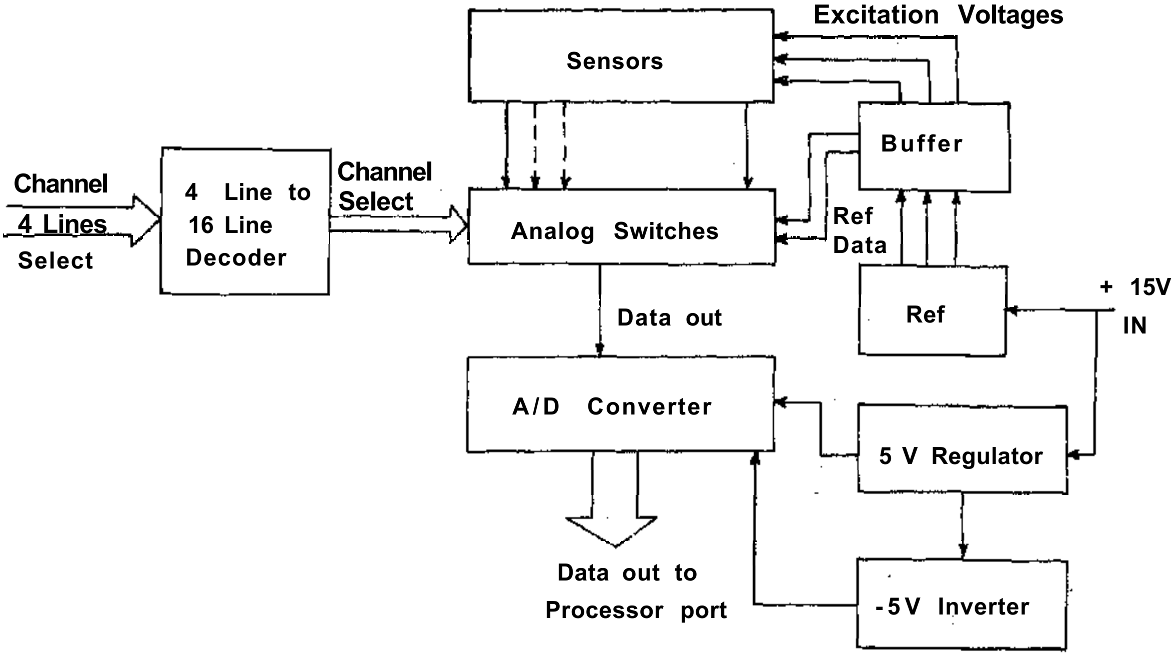

Fig. 5 : Block schematic of analog board.

A voltage divider network from the reference was also provided to allow the ADC to record variations of the reference. A thermistor, with its linearising elements was provided on board and allowed convenient monitoring of the temperature of the system electronics.

Tape Reader Interface Board

A schematic of this circuit is shown in Fig. 6. Since the voltage levels from the micro-comp board were TTL levels and the recorder operated on CMOS logic, an interface board for level conversion was required. The incremental tape recorder, Memodyne Cassette Recorder type 211[4] was formated for an 8 bit word, 64 words per file and a file gap word of 16 bits. The maximum writing speed attainable was 100 bits per second.

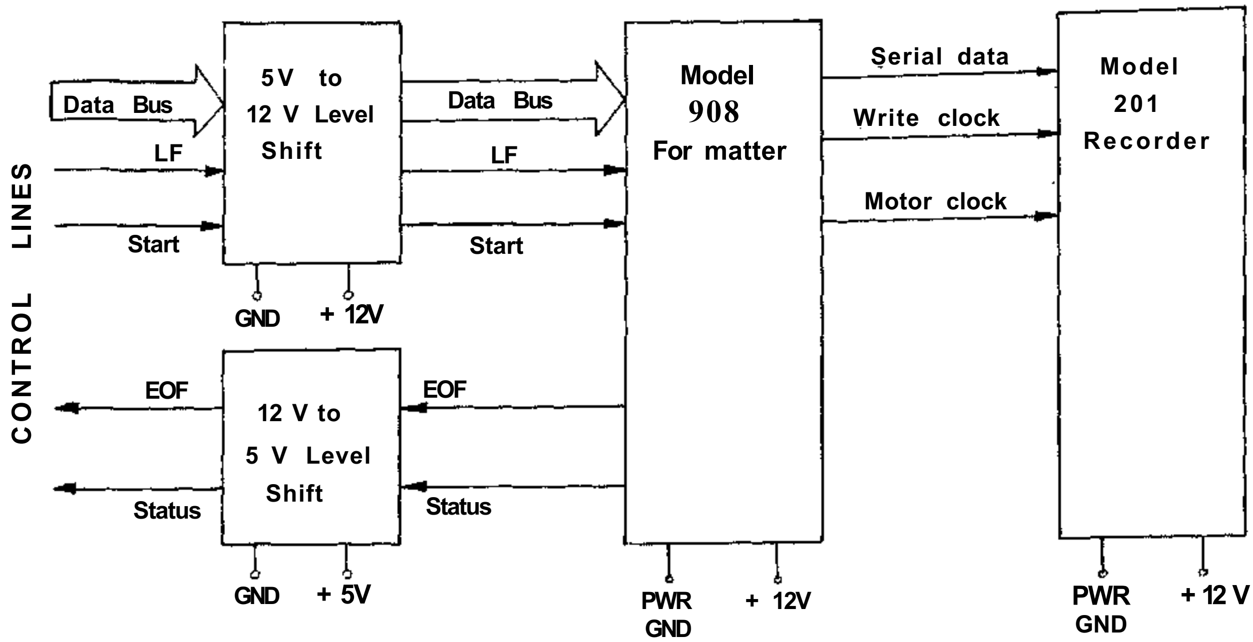

Fig. 6 : Block schematic of tape interface board.

SENSORS

The sensors used were:

(a)	Wind speed	Monitored at 5 metres above surface.
(b)	Wind direction	
(c)	Humidity	Monitored at 3 metres above surface.
(d)	Air temperature	
(e)	Surface temperature	Monitored at surface
(f)	Electronic Housing temperature	Monitored inside the HDPE housing.
(g)	Reference voltage levels.	

The excitation voltages for the various sensors were carefully chosen in order to make the decoding algorithms as simple as possible. These are discussed later. The excitation voltages were all present at the respective sensors from the start of the warm-up period. The sensors were however sequentially selected and digitised over a period of approximately 2 secs per sensor.

Wind Speed

The wind speed sensor was a cup anemometer from R.M. Young and Co.[5]. It utilised a d.c. tachometer generator whose analogue output voltage was directly proportional to wind speed. The voltage output of the generator was 2.40 volts±10% at 1800 r.p.m. which from the calibration chart correspond to 51 miles per hour (mph). The output signal of the sensor contained a ripple voltage which was smoothed out by connecting a large capacitor (1000 μF) across the output terminals. The expected speeds of 102 mph gave a sensor output of 4.8 V, which was divided down by a factor of 2.4 to lie within the ADC operating range. The sensor output, in volts, therefore, multiplied by 51, gave the wind speed in mph.

Wind Direction

The wind direction sensor was a wind vane utilising a precision conductive type potentiometer. The vertical shaft holding the vane was connected to the potentiometer via a flexible coupling.

The potentiometer was excited by a reference voltage of 360 mV and the output in millivolts was therefore directly proportional to bearing.

The wind speed and direction sensors were mounted at the top of the weather mast on a cross-arm with one sensor at each end. The photograph on Plate 2 shows this clearly. The zero position of the wind vane was first marked in the laboratory. A north sighting at Dakshin Gangotri was taken and the vane marking aligned accordingly.

Humidity

The humidity sensor[6] was a thin film capacity sensor which had a 0% to 100% relative humidity (RH) range with a response time of about 1 sec and a fairly linear temperature dependence of 0.05% RH/°C. The sensor was excited with a stable D.C.reference voltage of 3.6 volts for which the rated output was 1 mV per percent of RH. Since the probe could not be operated single ended, differential readings of the high and low humidity outputs were made. The difference in millivolts was the direct readout of the relative humidity. The humicap sensor was enclosed in a sintered filter and the probe together with the air temperature monitor were placed in a cylindrical Stevenson's box.

Temperature

The temperature measurements were made using the Omega Engineering Inc.[7] thermistors. The sensor was encased in a stainless steel penetration probe tube which was mounted inside the Stevenson's Box. A second probe was fixed to the mast close to ground level to monitor surface temperatures. Linearising elements were soldered on to the analog board. The thermistor element were connected to give out a single ended negative slope output. The equation governing the temperature (T) to voltage out (Vo) was given by $T = (+0.86507 V_{in} - Vo)/0.0053483 V_{in}$ where V_{in} was the excitation voltage.

If Vin was chosen as 1870 mV, then the voltage output when subtracted from 1618 mV gave a value which was 10 times the temperature value in degrees Celsius.

An element similar to that used for external air temperature measurement but without the steel casing, was used within the HDPE housing. This allowed monitoring of the housing temperature and reassured us that with the insulation and the heat generated during acquisition, the electronics was maintained at typically 10°C above the external ambient temperature. Thus the outside temperature could fall to about — 40°C before affecting the electronics.

The resistance elements along with the composite thermistors provided linear outputs in the range 0°C to +50°C. In order to estimate temperatures below 0°C, a look up table of the thermistor resistance values with negative temperatures was used. The thermistor elements were operational to -30°C and had an accuracy of ±0.15°C

Hardware C. P.

The only other hardware were the cable and connectors. The cable used was teflon wire in a proved underwater polypropylene braid. The sensor leads terminated in standard underwater connectors to take into account possible snow burial and subsequent remelt. The connectors were additionally secured to their counterparts with heavy duty nylon lock nuts. All cables were strapped to supporting structures with nylon lock straps so that any movement in high velocity winds would not snap the cables which could become brittle in sub-zero temperatures.

The lid of the HDPE housing was screwed down with stainless steel lock nuts and a neoprene rubber O-ring ensured water tightness.

Both HDPE bins housing the eletronics as well as the sealed GEL cells, were securely fixed to the tripod which itself terminated in large rectangular wooden feet buried in the rocky soil of Dakshin Gangotri.

SYSTEM SOFTWARE

A flow chart of the software followed by the processor is shown in Fig. 7. The micro-computer board was powered 64 sec. after the analog board. This time was sufficient for stabilizing the reference voltage, operational amplifiers and the sensor outputs.

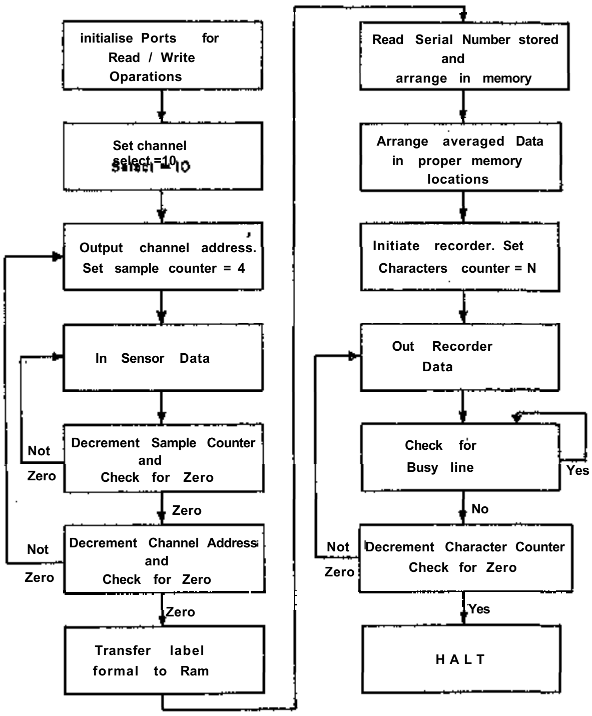

Fig. 7 : Flow chart of system software.

On initial power up, the program initialised the different I/O ports for Read and Write operations. The first channel, given the highest decoded address, was selected and the appropriate CMOS switch closed. After acquisition the sensor data was added to its last value and this process repeated 4 times for each sensor channel including the reference voltages. After an averaged value had been calculated, it was stored in memory and the next channel selected.

The channels were selected in the following order:

(a) Reference high, R1 : Should normally be 1870 mV (equal to the thermistor excitation voltage.)

(b) Reference medium, R2 : Should normally be 360 mV (equal to the wind vane excitation voltage.)

(c) Reference low, R3 : Should normally be 0 mV (equal to the ground level at the ADC common.)

(d) Wind speed, WS : Should normally lie in the range 0 to 2V. Multiplication by 51 gives the wind speed in mph

(e) Wind direction, WD : Should normally lie in the range 0 to 360 mV. Corrections can be applied from the appropriate difference of R2 and R3

(f) Air temperature, BH : After subtraction from 1618 and appropriate scaling from R1 and R3, the result when divided by 10 gives the temperature in degrees Celsius

(g) Surface temperature, AT : The algorithm used for this is as for the parameter BH.

(h) Electronic package housing temperature, BT : As for BH above

(i) Upper and Lower humidity Levels, ST and HU : Subraction of HU from ST gives the percentage relative humidity

After all 10 channels have been selected, the processor moves to the next phase of arranging the data contiguously in memory with the correct channel label preceeding each data set.

The processor first moved the channel labels together with an appropriate number of blank spaces between labels. The averaged data was then moved into the spaces between the labels. The value of the serial number of the present block of data was read from a specified memory location. This serial number was also incremented so that on the next power up the serial number would be known. It was found essential to maintain track of the serial number as the real time of data acquisition could be calculated from it. Furthermore, if the tape recorder happened to intermittently malfunction, the time tag on the recorded data values would not be lost.

TABLE 1

Raw data output and data translated to engineering units

LABELS	SNo	RI	R2	R3	WS	WD	BH
	AT	ST	BT	HU	Ot	D2	03
OATA	4080	1873	0361	0001	136	274	1872
	1873	1859	1482	1456	XXXX	YYYY	ZZZZ
SETS	4081	1873	0361	0001	120	250	1613
	1613	1354	1506	1202	XXXX	YYYY	ZZZZ

Data Translated to Engineering Units r

Reference High Voltage: RI: 1872 V	—
Reference M«dium: R2: .360 mV	-
Reference Low: R3:000V	—
Wind Speed : WS: 74 mph	13.5 mph
Wind Diraction : WD: 250^{0} (WSW)	Westerly
Air Temperature :BH:-09-5^{0}C	-2^{0} c
Surface Temperature: AT:-0-5°C	-
Humidity: ST-HU-100: 52% RH	60%RH
Electronics Bin Temperature:BT: +11.2°C	
NIO Weather Station Data	Russian Station Broadcast

It will be noticed from the Table 1 print out that the last three channels are labelled D1, D2 and D3 and contain XXXX, YYYY and ZZZZ. These characters were written into every data block as they helped in the following ways:

(a) To know if the system powered down before the data stream was over.

(b) To isolate blocks of data.

(c) To allow for future expansion of upto 3 digital channels with only minor software and hardware changes.

Having arranged the averaged data in contiguous memory preceeded by the correct labels, the program moved to the final phase of writing onto tape.

The appropriate I/O port was initialised and the data assembled in byte form at the tape reader interface. A pulse forming the write command was generated and the data byte transferred to tape. This program loop was executed for the specified number of characters after which the processor came to a halt and was powered down by the power supply board.

RESULTS

Since the station was a recording type, the performance of the station will not be known until the data tape has been recovered and played back. It would be useful to also have the broadcasts from the Russian Meteorological Station adjacent (10—15 km) to our own.

On Table 1, the data have been converted to engineering units utilising the conversion factors and equations described in the text. The Russian broadcast values are also recorded in table 1.

The system was tested during the cruise from the 6th December 1981 to the time when it was installed. During the month of testing, the system electronics showed no malfunctioning, but several points were noted as critical areas. These are detailed below.

Analog to Digital Converter (ADC)

The ADC used was an easily available Intersil 7.107. This ADC has proved itself in numerous commercial and laboratory applications. The probable critical areas in this IC are the negative voltage generator (obtained using a CMOS inverter) and the segment output.

Cassette Tape Recorder

The Memodyne Tape Recorder Type 211 was a proved unit for marine use in long term deployment. Being a mechanical system however, there exists the possibility that at sub-zero temperatures moving metal parts could cold weld rendering the unit non-operational.

Battery Supply

The primary battery supply for the electronics was via sealed lead-acid Gel cells. These had a capacity of 20 Amp hours and at - 20°C had a theoretical capacity of 16 Amp hours. The cells could be discharged to 80% of their capacity or 13 Amp hours. If in the battery chain however one cell malfunctioned (as is known to happen), the capacity would be drastically reduced. The Gel cells were in turn charged by ordinary truck batteries of 120 Amp hour capacity. As these had to be left open to the elements, one could derate their capacity by 60% to about 70 Amp hours for the winter season. There exists too the very real possibility of the batteries freezing and cracking their containers, in which case the system will have to run only on the Gel cells. In order to gain an idea of the worst possible conditions, the consumption per day is. calculated here.

CMOS circuitry (200/µ.A constant)	= 5 mA hours
Microcomputer board (700 mA x 64 secs x 10 times)	= 125 mA hours
Analog board (500 mA x 128 secs x 10 times)	= 178 mA hours
Tape system (200 mA x 32 secs x 10 times)	= 18 mA hours
Total consumption per day	= 326 mA hours
	40 days.

If the only Gel cells are providing power, then the upper time limit of the system is 36 days. If the lead-acid batteries are functional and capable of dicharge to 50% of their capacity, this would add another 110 days of duty. In total then, with the best possible combination, the system may function for.4 to 5 months.

TABLE 2

Sensors Specification

Sl. No.	Parameters	Sensor	Model	Range	Response Time	Linearity	Ref	Make	Accuracy
1	Wind speed	DC tachometer generator (Self generating)	3 cup Anemometer	0-102 mph	60 msec	0 To 10,000 rpm	-	R. M. young company	± 1%
2	Wind Direction	Precisious conductive plastic type Potentiometer	Windwane 6301 A	0-360°	Damping ratio 0.37	0 . 25 %	360 mV	R. M. young company	+1%
3	Humidity	Thin film capacitive	Humidity Sensing element 6061 HM	0-100% RH	About 1 sec to 90% of RH change at 20° C	About 1 %	3.6 V	Vaisala Finland	± 1%
4	Air, Surface, Housing Temperature	Thermistor	44201	0°to 100° C	About 200 msec	0.216°C	1.87 V	Omega U.S.A.	± 0.15°C

RECOMMENDATIONS

The system erected at Dakshin Gangotri was an useful first step. Based on this expedition we recommend that for future expeditions the following points should be considered.

(1) The recording system should as far as possible contain no moving parts.

(2) Because of the importance of collecting data during the winter season, the power supply should be conservatively estimated at 4 times the needed power over a period of 8 months.

(3) If the station is unattended, arrangements should be made for an adjacent manned station to visit the location regularly for data collection and transmission.

(4) Future weather stations should be linked to Satellite transmit terminals for reception via Argos. This will allow the data and the health of the system to be monitored daily.

(5) The weather mast should be 10 metres in height to enable meteorological data to be collected as per standard practice.

(6) The system should record data every 3 hours as is standard meteorological practice.

The first Indian Weather Station on Antarctica has been erected and we hope will be the forerunner of a chain of such systems regularly transmitting via satellite, meteorological, oceanographic and iceberg movement data.

REFERENCES

Intel MCS-85 Users Manual, September 1978, Intel Corporation, U, S. A.

Datel-Intersil Data Acquisition Component Handbook, 1980, Datel-Intersil, Inc., U. S. A.

National Semiconductor, Linear Databook, 1981 National Semiconductor Corporation, U. S. A.

Memodyne Corporation, Instruction Manual Model 211, 1981,

R. M. Young Company, Sensitive Wind Instruments, April 1980, R. M. Young Company, U. S. A.

Vaisala, Humicap Humidity Meter Instruction Manual, 1981 Vaisala Oy, Finland.

Omega Engineering Inc.. Temperature Measurement Handbook. 1979, Omega Engineering Inc., U. S. A.