

A SHIP-BORNE METEOROLOGICAL STATION FOR GROUND TRUTH MEASUREMENTS

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ABSTRACT

Oceanographic upwelling studies required ground truth measurements of meteorological parameters and sea surface temperature to be made from a research vessel which did not have the necessary facilities. A ship-borne station was therefore designed to sense and store standard meteorological parameters with special reference to wind data. The system was based on a 16 bit microprocessor. Commercial sensors with half bridge outputs were used. All sensor outputs were converted to engineering units using best fit third order polynomials prior to storage. The system was calibrated in the laboratory and also after installation. Results obtained from the system met the required specifications. The exercise of constructing a weather station has demonstrated that with the high performance components available, and modular software construction in a Higher Level Language, it is possible to design equipment specially tailored to ones needs, rapidly and cost effectively.

INTRODUCTION

Many oceanographic research vessels have a permanently fitted suite of meteorological sensors and desk top or mini computers for data acquisition, processing and storage. Occasionally however, marine research requiring weather data is carried out from chartered or other vessels not having fitted equipment, and in such cases it is necessary to temporarily install a station for specific studies. At an oceanographic station, the characteristics of such a data acquisition system would typically allow it to sample air and sea surface temperatures, barometric pressure and humidity, and store values averaged over a few minutes. Average and gust wind speed and wind direction would be acquired over shorter time intervals and be stored as vector components together with ship's speed and heading. A temporary station is also likely to be used in more than one type of environment, and the

software should be modular and in a Higher Level Language so that different users of the station can configure the acquisition routines to particular requirements.

We describe here a ship-borne meteorological station originally designed to collect ground truth data for intercomparison with remotely sensed data, and incorporating the characteristics outlined above.

The ship-borne meteorological station was developed around the Intel SDK-86 board. It also contained an Analog Interface board incorporating a 12 bit, analog-to-digital converter and interfacing to standard half-bridge sensors. An I/O Extender board was also designed incorporating an interrupt controller, a serial port, and a real time clock, and interfacing to a satellite navigator, a 1 Hz clock and the SDK-86 board.

The software routines sampled the air and sea surface temperatures, barometric pressure and humidity every 10 secs for 10 minutes, and stored the average value for each parameter. The wind speed and direction sensors were similarly sampled and the six samples per minute were vector averaged and stored along with data on the ship's drift and heading from the satellite navigator. Ten wind vectors were therefore stored per acquisition period.

Raw sensor outputs were converted to engineering units. Converted data was stored on high density tapes. The programme used modular routines written in PLM-86, thus permitting the user to modify them when required. The sensors were calibrated using environmental chambers for the air temperature and humidity, and a precision water bath for the sea surface temperature. The barometric pressure was calibrated against a standard barometer, whilst the wind sensor was calibrated in a modified wind tunnel against a standard anemometer.

The meteorological station was installed on Research Vessel Sagar Kanya (see Plate 1 below) for comparison with the standard meteorological equipment fitted on-board. The meteorological equipments on RV Sagar Kanya were duplicated on both sides of the base of a wind weather radar dome (above the ship's bridge), and we fixed our portable station adjacent to the starboard set of sensors.

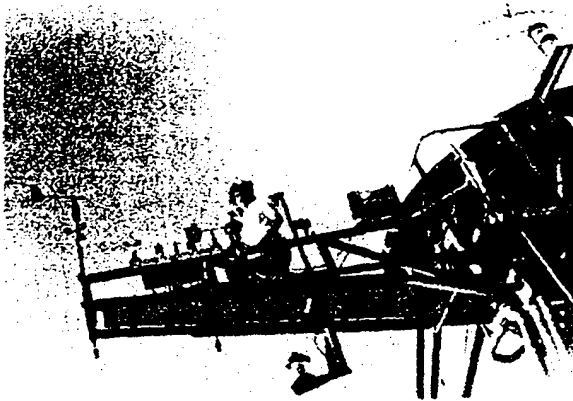


PLATE 1

At sea, hourly independent measurements of air and sea surface temperatures, barometric pressure and humidity were made to monitor the performances of the permanent and the portable stations.

Improper siting of a meteorological station is known to cause large measurement errors in both temperature (Goerss & Duchon, 1980) and wind (Kahma & Lepparanta, 1981). Goerss & Duchon, 1980 have observed deviations upto 2°C during 24 hours observations between dry bulb readings taken at the ship's bridge and that recorded off a boom from the ship's prow. In order to ascertain the conditions existing on RV Sagar Kanya, dry and wet bulb temperatures were recorded hourly at 3 different locations on the ship. These were at the main wood covered deck, the metal ballon deck, and at the wind weather dome which were at 4.6, 13.5 and 22.6 meters above the sea surface respectively. Similarly, Kahma & Lepparanta, 1981 showed that errors as large as 35% can arise from mast mounted wind sensors placed above the ship's bridge. This was not verified, though anomalies in the wind field pattern were noticed around the dome where the vessel's wind sensors were located.

All sensors were calibrated and temperature and wind speed calibration curves have been plotted. An intercomparison of the dry bulb temperatures from RV Sagar Kanya thermometers and our station are illustrated, and show good agreement. The large variations in dry bulb readings at different locations on the vessel have been plotted as an indicator to the importance of proper station siting. The portable nature of the weather station would not encumber proper siting, affording simultaneously a cost effective technique to obtain good quality data.

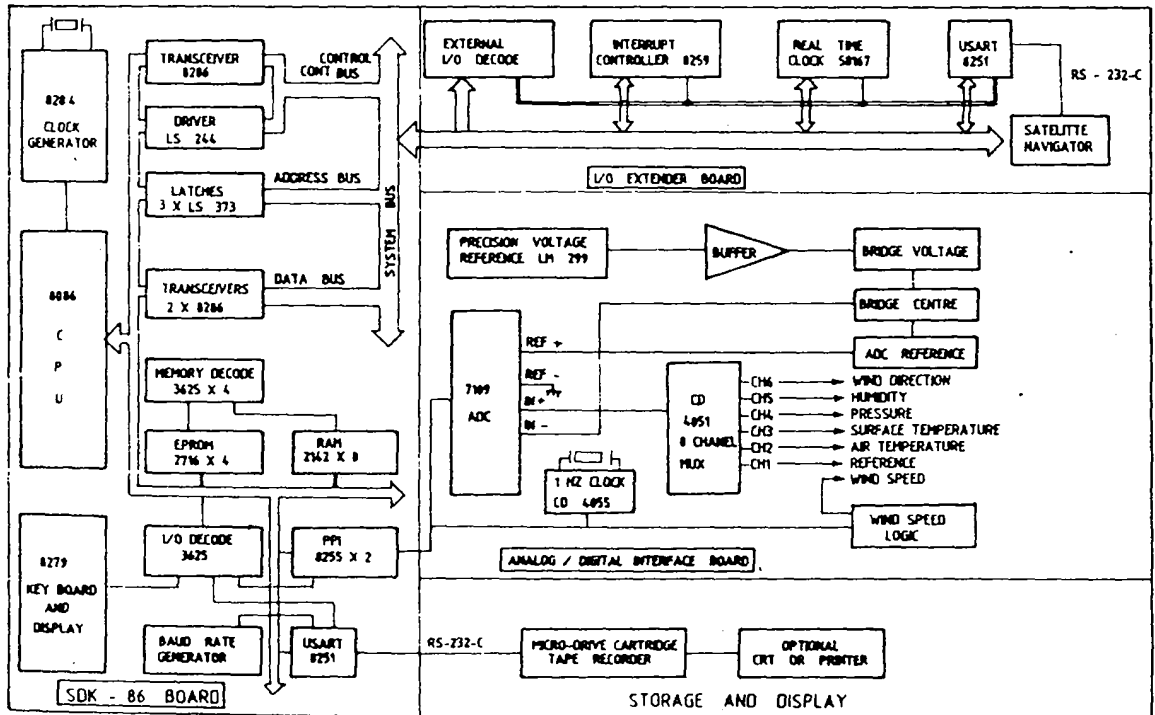


FIG. 1. SCHEMATIC HARDWARE BLOCK DIAGRAM.

STATION DESCRIPTION

Software

The meteorological station was based around Intel's SDK-86 board and is schematically presented in Figure 1. An Analog Interface board and an I/O Extender board were connected to the SDK-86 to allow interfacing to the sensors and the tape recorder. These are described below.

SDK-86 board

The SDK-86 board used the 16 bit 8086 microprocessor. The CPU was configured in a minimum mode, and operated at 4.9 MHz with no wait states. The 8K on-board EPROM held the program source code, including the routines for conversion to engineering units. The 4K RAM held all sensor data acquired during the 10 minute period.

The serial port on the SDK-86 was connected to a Micro-Drive Cartridge Recorder which was written to after data acquisition. Data was communicated to the recorder at 2400 baud. One of the two available parallel ports was used to address the multiplexer on the Analog board. This port also received parallel data from the ADC. One line of this port was used to send a pulse train to read the contents of the wind speed sensor register. This was a digital sensor storing wind data in a 10 bit shift register. The second port was reserved for expansion.

The SDK-86 also has a keyboard and display which was programmed to store information such as day, date, time, station number and cruise number. The 8 LEDs displayed time but if required, any sensor could be monitored by pressing a designated key and the latest value of the sensor was then continuously displayed. The keyboard was serviced every 1 second by the main program. A VDU was connected in parallel with the Recorder port, so that data being written onto tape could be viewed.

Analog interface board

The Analog Interface board contained the analog circuitry, ADC, analog multiplexer, voltage reference source, and a 1 Hz quartz clock used as a time interrupt for sensor servicing. As a majority of the sensors were half-bridge types, the design of the Analog board was considerably simplified. The balanced half-bridge sensors had a full scale output of 1/22 of the bridge excitation voltage centred at 1/2 the bridge voltage. The ADC 7109 used had true differential floating inputs and references, and 13 bit resolution. The full scale input was set at 204.8 mV, which allowed the sensor output to be digitised with no amplification. The high common mode rejection and the differential input facility meant that the standing half-bridge voltage could be subtracted by the ADC itself with no additional circuitry. The sensor outputs were multiplexed through an 8 channel IC, CD 4051, with channel address selection from the parallel port of the SDK-86.

Even though the ADC was a ratiometric type, a precision voltage reference, LM 299, was used to derive the bridge excitation as well as the reference voltage. The half bridge voltage input to the ADC was also derived from this reference.

The 1 Hz clock was derived from a 21 stage divider circuit and was used to interrupt the processor and set it on its round robin programme.

The wind speed sensor measured the arithmetic mean of the wind in periods between 8 secs and 3 hours, and the maximum sustained wind speed over a 2 second period within the 10 sec sampling interval. As vector winds were important, the wind speed was sampled close to the sensor response time of 8 secs, together with wind direction. These readings formed the wind vectors which were vector averaged. The 12 volt pulses from the wind speed sensor were translated to TTL levels for further processing by the CPU.

I/O Extender board

This interface board contained a real time clock, a serial port, and an interrupt controller. The serial port, Intel 8251, received data from a single channel Tracor Satellite Navigator at 110 baud. This was allotted the highest priority. The navigator was set to transmit dead-reckoning data every minute.

The serial 1 Hz clock interrupt, and the asynchronous navigational data stream were prioritized by the interrupt controller, Intel 8259. This meant that different tasks such as data acquisition and processing, keyboard and navigational data servicing, and tape recording could proceed until interrupted.

Software

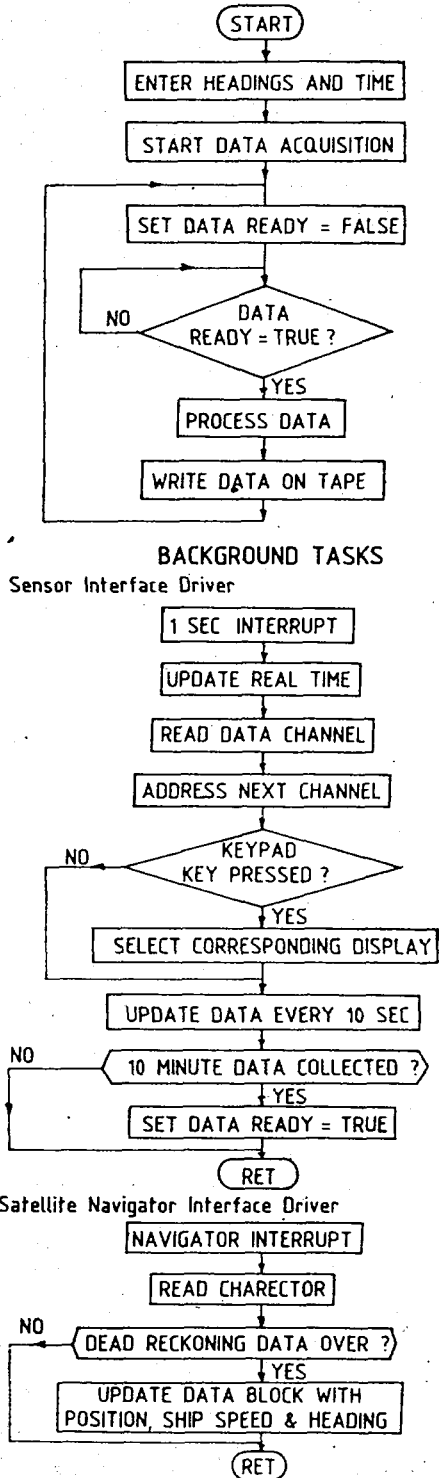
The program was written in PLM-86 an efficient High Level Language available on Intel's Microprocessor Development System.

The flow chart describing the software is given in Figure 2. On power-up or reset, the user was prompted to enter heading information, after which the display could be used to view either the time, or the latest values of any selected sensor.

Data Acquisition

Each sensor was interrogated once in 10 secs for 10 minutes, except the keyboard which was serviced every second after sensor data had been acquired. At the end of this period, the data was stored on tape, all the CPU counters were reset, and the acquisition process was repeated. The third order polynomials used to linearise the outputs required 10 bit data and sensor outputs were suitably truncated before processing. The sequence of channel selection is given in Fig. 1 and described below. Before the CPU exited from servicing a sensor, the following sensor was addressed. This permitted about 0.8 sec settling time for the next channel.

Fig 2. FLOWCHART



Channel 0 was the offset of the ADC when subjected to a common mode signal. This offset was subtracted from the other channels. Channel 1 was a voltage equal to the simulated full scale output from a sensor, and drifts from full scale were used to correct the sensor channels. Channels 2, 3, and 4 were air and sea surface temperatures and barometric pressure respectively. The wind direction compass was energised when the barometric pressure was selected to allow the free floating magnet assembly about 2.8 secs to stabilise. Channels 5 and 6 were humidity and wind direction respectively. Channel 7 was left for expansion.

Average and gust wind speed was acquired on the 9th clock interrupt. The 10th interrupt was used to write wind data into an array, and to add the latest data frame to the sum of previous data frames.

Provision was made to input gyro values at the end of an acquisition period. This was an optional, manual entry mode in case the navigational link malfunctioned.

The last step of the program, prior to resetting, was the writing of processed data to tape, using the serial link on the SDK-86 board.

RESULTS

The ship-borne meteorological station was calibrated, and results indicated the following system performance:

	Range	Accuracy
Air and Sea Surface Temperature	0-40°C	± 0.10°C
Barometric Pressure	920-1060 mB	± 0.5 mB
Wind Speed	0.5-50 m/sec	± 0.5m/s
Wind Direction	0-360°	± 3°

As previously mentioned, improper siting of the station could cause errors in the measurement of air temperature and winds. These are discussed below.

Temperature

The calibration curve of the platinum resistance thermometer is given in Figure 3. The maximum deviation recorded was ± 0.10°C. The air temperature sensor was fixed near the permanent star-board sensors of RV Sagar Kanya. The differences between the two thermometers after correction for offset are plotted in Figure 5a. Since the station was portable (operable from 12V DC, and easily moved), we further investigated likely alternate sites for the station.

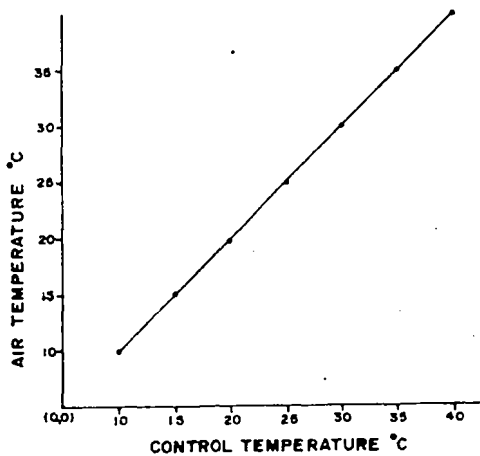


Fig. 3. TEMPERATURE CALIBRATION CURVE

Over the same 24 hours period therefore, temperatures at different locations on the vessel were plotted in Figure 5b. The differences recorded could be due to a variety of reasons, amongst them being the effect of ship's heating (Goerss and Duchon, 1980). The temperatures recorded at the monkey deck follow the trends of Fig 5a, as the location was close, (about 5 meters below) the installed suite of sensors. Improper siting can therefore lead to large differences in the recorded temperatures and the portable nature of the station would allow its placement in the most appropriate location.

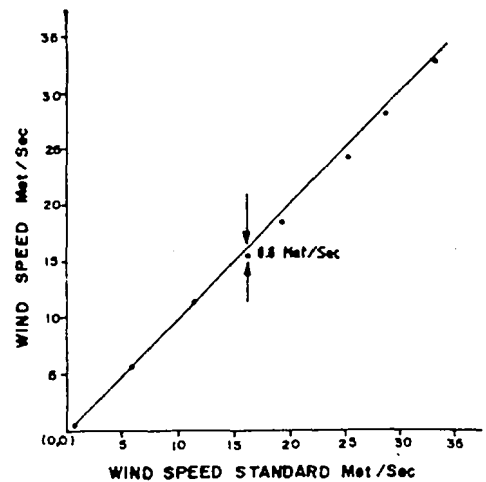


Fig 4. WIND SPEED CALIBRATION CURVE

RV Sagar Kanya had two sets of sensors installed on the port and starboard sides of the base of the wind weather radar dome. This was to allow the software to choose the sensor data not affected by the dome. It was noticed that on occasions our installed wind sensor was downwind of the dome, and recorded data on these occasions did not represent the true wind field. In the present context however, our aim was an intercomparison with the installed sensors, and the results agreed well when the winds were from starboard. However, even with sensors on both port and starboard, the measured wind field could be in large error, as reported by Kahma and Lepperanta, 1981.

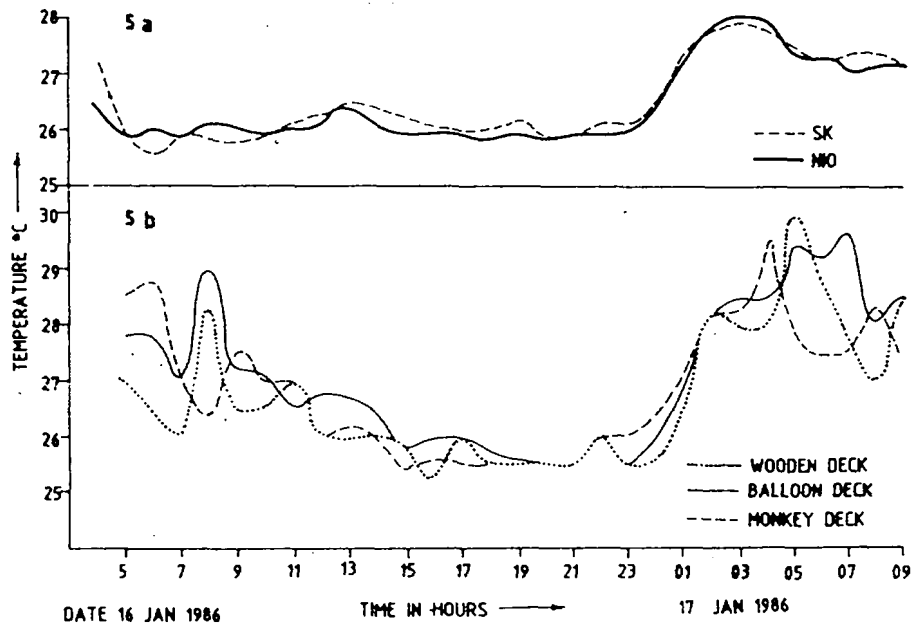


Fig. 5. COMPARISON OF AIR TEMPERATURES

CONCLUSIONS

This paper has described a ship-borne meteorological station engineered around a commercially available processor board and standard half-bridge sensors. The performance of this system, as demonstrated vis-a-vis more expensive ones, showed that good quality data could be collected at low cost. Improper siting has been shown to cause large differences in recorded air temperatures and wind data, and multiple stations as described here, could overcome some of these difficulties.

The system could be improved by including graphics display and hard copy. This would make it more versatile as the majority of processing tasks could be completed at site, and the present communication to the main computer be used mainly for updating the main data bank.

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