

WEATHER STATION FOR SCIENTIFIC DATA COLLECTION

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ABSTRACT

A state of art automatic weather station has been developed primarily to support research programs on oceanographic and climatic studies. The basic system includes a suite of sensors for measurement of wind velocity, air temperature, barometric pressure, solar radiation and relative humidity. The system has been designed for meteorological measurements on land and from oceanographic ships. Innovative mechanical packaging and use of surface mount device (SMD) technology has resulted in an extremely portable and compact package, facilitating ease of installation and handling. The data acquisition unit incorporates a 32 bit microcontroller, Motorola MC68832. Use of FLASH memory devices support *in situ* software programmability. The basic system supports options for data retrieval using UHF/VHF transceivers. The paper describes the design aspects and analysis of a typical data set collected using the weather station.

INTRODUCTION

Surface meteorological parameters play a key role in oceanographic studies of air-sea interaction, ocean dynamics, upwelling, heat exchange and in engineering studies involving coastal erosion and structural designs. We need accurate and reliable systems for measurements and continuous monitoring of meteorological parameters. Several systems have been built at the National Institute of Oceanography (NIO) Goa, to meet in-house requirements and have been reported by Desa et al. (1983), Prabhu Desai et al. (1986,1991).

Automatic weather station NIOAWS-96, has been primarily developed at NIO specifically to acquire good quality reliable data from scientific research vessels, floating platforms and from coastal places. In order to provide a reliable and acceptable data set to the oceanographic community the sensor suite has been selected based on extensive studies undertaken in-house and elsewhere and also based on the reported performances of the sensors and meteorological systems in field. Significant work has been reported by Hosom et al. (1995), Cresenti et al. (1989b), Weller et al. (1990) and Payne (1995) on sensor performances and development of meteorological systems for oceanographic applications.

A second objective has been to provide ease of operation in terms of installation, routine maintenance and calibration. Meteorological systems are generally found to be difficult to handle, especially on board ship. The main reason for this being the complicated assembly of sensors and long cables routed through a ship's superstructure from the mast to the data acquisition and display systems. This approach makes calibration and maintenance so difficult

that systems often remain un-utilized and ignored. The mechanical packaging of sensors, electronics and interconnection therefore requires careful consideration.

The design considerations and features of NIOAWS-96 are discussed in the following sections.

DESIGN CONSIDERATIONS

Mechanical packaging

Fig.1 is an engineering drawing of the NIOAWS-96. The sensors and electronics are packaged inside a single housing. The main cylindrical tube contains the data logging electronics and barometric pressure transducer. The barometric pressure transducer is packaged inside a smaller cylindrical tube with the endplate carrying connectors for other sensors, power supply, etc. The side arms on the main cylinder carry sensors for wind, air temperature, relative humidity and solar radiation. The underwater type connector at the bottom of the unit is provided to carry power and RS-232 signals for communication with the data logger. The integration of sensors and electronics inside a single package has eliminated the use of lengthy sensor cables and the radio frequency interference which is usually associated in the ship board environment. Compact packaging has facilitated the eased installation and maintenance procedures.

Data acquisition electronics

The data acquisition unit is based on a Tattletale Model 8 logger from Onset Corp. USA. Model 8 Logger is a miniature card of 3" x 2" x 0.5" and is based on a Motorola embedded controller MC68332. The peripherals on board include a 12 bit analog to digital converter, a hardware real time clock, FLASH EPROM memory of 256K byte and 256K byte CMOS static memory.

The Motorola MC68332 is a powerful and versatile embedded controller, consisting of a 32 bit Central Processing Unit (CPU), System Integration Module (SIM), 16 channel Time Processing Unit (TPU) and Queued Serial Module(QSM).The SIM module supports system protection logic and test debug environment. The TPU is a dedicated micro-engine independent of the CPU and allows any of its 16 channels to be configured for a variety of time functions, such as simple transition counter, pulse width modulation, quadrature decode, motor control etc. Each of the port lines can be configured for universal asynchronous receive/transmit (USART) functions. The QSM module supports enhanced serial communication interface (SCI) and a queued serial peripheral interface (SPI).

The 68332 controller works on a 40 kHz crystal and internal frequency synthesizer allows one to configure the operating frequency from 160 kHz to 16 MHz. Operating frequency control allows the control of power consumption by reducing the frequency. The processor can also selectively shut down various internal subsystems and can be programmed to go to its lowest power stop mode reducing power drain to 200 μ a. The controller can be awoken on a hardware interrupt signal or from a real time clock.

The MC68332 processor can therefore accommodate requirements of a wide variety of applications. The model 8 logger is programmed using the Aztec 'C' compiler. The built in monitor program allows the download of code and burn in of the onboard FLASH memory. This allows software updates to be made with ease and to download different application programs depending on the requirements of data acquisition.

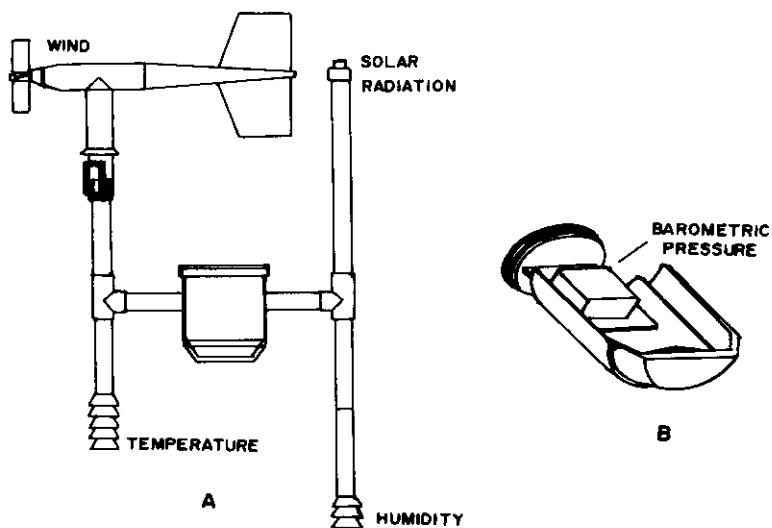


Fig.1(a) Schematic drawing of AWS (b) Inside view of electronic unit

Signal conditioning

Fig.2 shows the schematic configuration of the AWS electronics. The system is powered from an 8 to 12 volt supply. The signal conditioning circuit consists of power control and regulator that powers up the circuit and data logger. The TT8 data logger controls the switching on and off of the power.

The wind speed sensor outputs a sinusoid whose frequency and amplitude is proportional to wind speed. The limiter circuit in Fig. 2 is essentially a back-to-back diode, which clamps the input voltage. The comparator converts the sinusoidal signal into a square wave at a threshold level corresponding to 0.5m/s of wind speed. The built-in hysteresis in the comparator avoids false triggering. The comparator output is connected the TPU lines of TT8 which is configured as transition counter.

The barometric pressure transducer has a serial output and is directly interfaced to the TT8 TPU channels configured as USART. Necessary handshake signals are also generated using TPU channels.

The analog signal conditioning circuitry involves simple level shifting, amplification and input filtering to avoid pickup and radio frequency interference. The signal conditioned analog output is converted to digital form using 12 bit ADC (MAX-186) on-board the TT8 data logger.

On first power-up, the data logger waits for 30 s for user entry to initialize setup parameters such as time, sampling and averaging intervals etc. If setup is not initialized during this interval the data logger proceeds with its default setup values. The default setup samples all sensors once every 10 seconds. The output values are dumped on a serial port. Between sampling times the processor goes into its sleep mode reducing current consumption from 20 ma to less than 0.5 ma. During sleep mode the TPU unit is configured to count input transitions to accumulate wind speed pulses. Vector averaged values of wind and average values of sensor outputs are stored in internal memory at the end of acquisition interval.

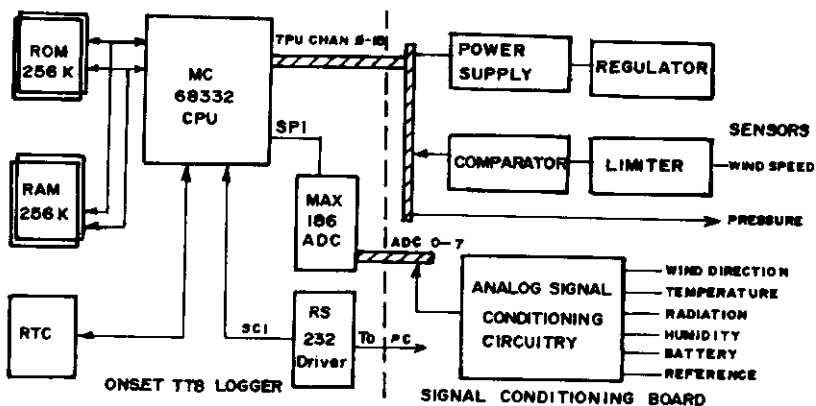


Fig. 2 Schematic diagram of AWS electronics

The data can be downloaded from the logger using standard XMODEM protocol. The system has a storage capacity for approximately 6 months of data at hourly recording intervals. Data is usually retrieved using a notebook computer in field installations. Use of surface mount devices have resulted in compact packaging. The signal conditioning and data logger are stacked one above the other. The entire electronics of the NIOAWS-96 occupies a space of 2"x3"x1".

SHIP BOARD SYSTEM CONFIGURATION

The ship board system uses a personal computer for data acquisition. The NIOAWS-96 is interfaced to a serial port of a personal computer. The personal computer is also interfaced to Log/Gyro and global positioning system (GPS) receiver. For installation on-board research

vessel Sagar Sampada we have used standard NMEA outputs from the ship's GPS receiver. For installations on board coastal research vessel Sagar Pashimi and Sagar Purvi we have used a 10-channel GPS receiver card Magellan AIV10V.

The GPS output is used to tag the data set with position information. The ship speed and heading information is used to compute true wind vector. PC based data acquisition software is implemented to run in a Windows environment with a graphical user interface to display the data. NETBIOS based communication support is provided so that in a local area network environment meteorological data can be monitored in real time from any node in the network.

Sensors used with NIOAWS-96

The details of specifications of sensors used with NIOAWS-96 is given in Table 1. The descriptions of the sensors and its characteristics are highlighted below.

Table 1. Specification of the Meteorological sensors used with NIOAWS

Sensor	Specifications	
Wind speed	Range	0 - 60m/s
	resolution	0.1 m/s
Wind direction	range	0 - 360 °
	resolution	1 °
Air temperature	range	0 - 45 °C
	accuracy	± 0.15 °C
Barometric pressure	range	800 - 1060 mbar
	resolution	0.01 mbar
Solar radiation	range	0 -200 mw/m ²
	accuracy	5 %
humidity	range	0 - 100 % RH
	accuracy	3 %

Wind speed and direction: R. M. Young propeller model 5103 is used. This sensor is widely used on oceanographic buoys and ships. The sensor consists of integrated vane and propeller in one unit. The sensor uses a 18 cm diameter 4 blade helicoid propeller molded from polypropylene. The sensor is rugged, lightweight and corrosion resistant. The sensor uses sealed bearings and a linear potentiometer for direction sensing. A six pole magnetic disc attached at the end of the propeller induces an AC signal in the coil of frequency proportional to the wind speed. The sensor produces 3 sinusoidal pulses for each rotation of the sensor. The vane position is transmitted by a 10K precision conductive plastic potentiometer.

In addition to being compact, corrosion resistant and rugged in nature the sensor has better performance in respect of over-speeding due to inertia and cosine response

Air temperature: YSI 44202 thermistor is used as a temperature-sensing element. The thermistor is sealed inside a stainless still probe. The thermistor is supplied with matched resistors for use with a simple network that generates linear output with temperature. The

temperature output is mounted inside a sunshield similar to Stevenson Grid to avoid heating from direct sun. The accuracy of temperature measurement is within ± 0.1 .

Barometric pressure: The pressure sensor is from Atmospheric Instrumentation Research, USA. The Intellisensor model AIR -SB2 series sensor is used. The sensor uses a capacitive sensing element of sealed aluminum with an integrated thermistor. This is an intelligent sensor and has a built in microprocessor which takes care of temperature compensation, multiple sampling and averaging and conversion of the signal output in engineering units. The sensor works on 8 to 10 volt supply and draws 6 ma current in active mode and about 10 μ a current in standby mode. The sensor provides output in TTL serial format. The sensor has an accuracy of 0.5 mbar.

A total of 7 sensors were tested. The manufacturer's calibration was verified with test and calibration facility at Institute of Tropical Meteorology at Pune. Amongst 7 sensors the first two that were procured in 1994 showed substantial drifts from the original calibration and the rest of the 5 were within ± 0.5 mb from the original calibration values.

Solar radiation: The solar radiation is measured using LI-200SA Pyranometer from Licor Inc. USA. The pyranometer sensor consists of a cosine collector, a visible light bandpass filter and a silicon photo-diode sensor. The sensor has an accuracy of 5%.

Relative humidity: Humidity measurements from unattended platform are known to be very difficult especially in the marine environment. We have selected humidity sensor from Rotronic, USA. This sensor was evaluated to be one of the most reliable sensor amongst commercially available sensors in a study undertaken by Crescent et al. (1989d) at Woods hole oceanographic Institution, USA.

Rotronic meteorological Probe MP-100 is a combined humidity and temperature probe exclusively designed for outdoor applications. It uses capacitive sensor. The principle of operation of this sensor is based the variation of dielectric properties of solid polymer in relation to ambient relative humidity. Depending on the temperature and on the amount of water bound by the polymer the dielectric properties of the polymer vary. Active part of the sensor consists of a polymer foil which is sandwiched between two electrodes forming a condenser. The sensor is protected by a porous teflon foil. The humidity probe is mounted inside a sunshield (Stevenson grid) which protects the sensor from direct heating and allows the air to circulate freely through it.

The humidity probe requires a supply voltage of 4.5 to 24 volts and draws about 10 ma of current. The sensor output is in the range of 0 to 1 volt. We have used seven probes and their performances have been good including installations on board ship.

Typical data set collected using NIOAWS-96

The first version of NIOAWS-96 was installed at NIO in June 96. Subsequently two more systems were installed on board coastal research vessels Sagar Pashimi and Sagar Purvi in November 96 and in May 97.

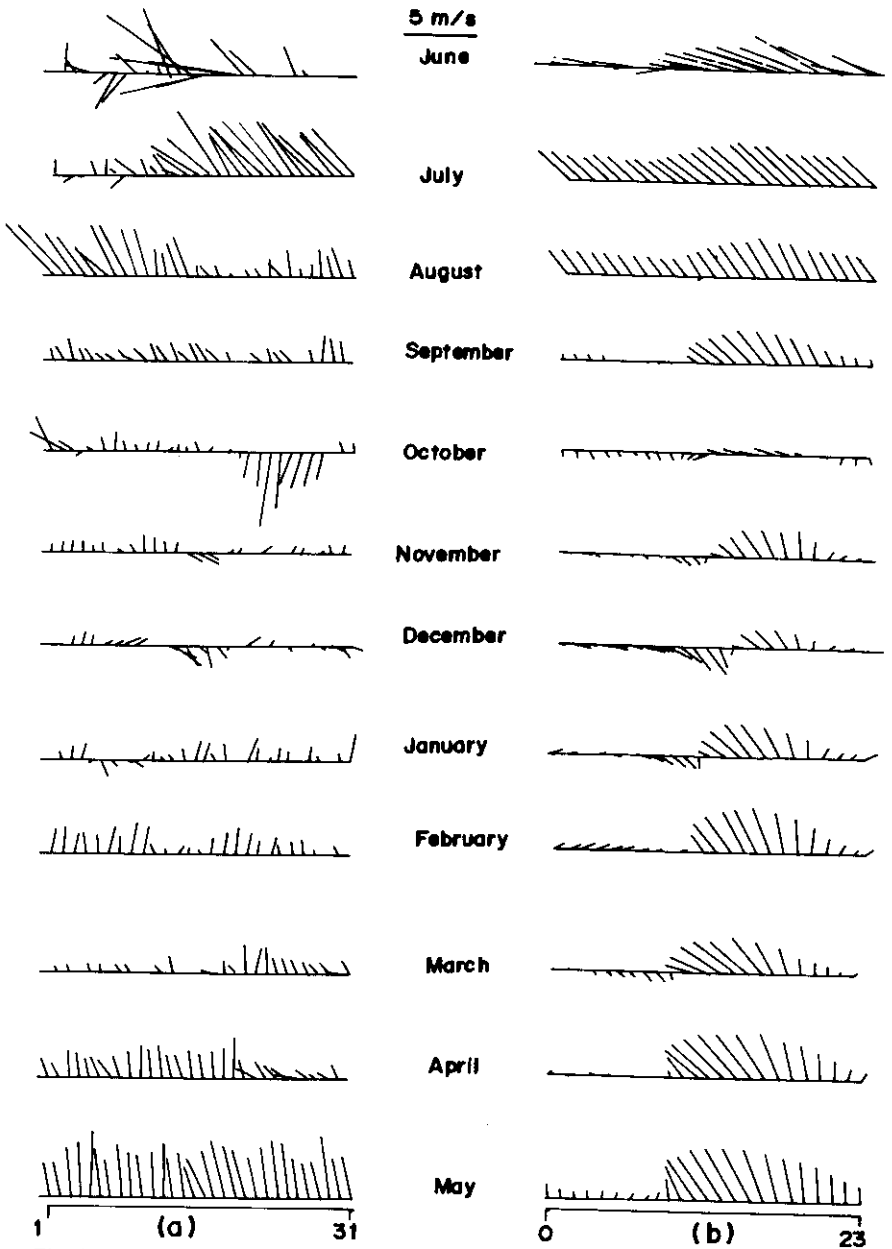


Fig. 3 (a) Stick plot of daily averaged winds and (b) stick plot of mean hourly averaged wind for different months from June 1996 to May 1997

The wind data collected over one year from June 96 to May 97 from the AWS installed at NIO is presented below. The wind speed pulses were accumulated continuously and wind direction sensor was sampled every 10 s. The vector averaged values of wind speed and direction was recorded at every 10 minute interval.

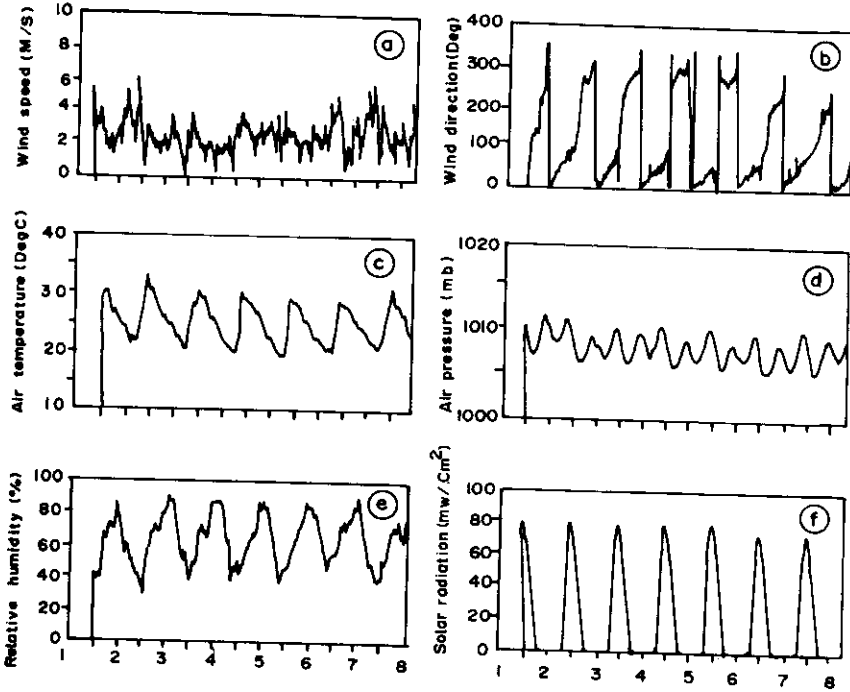


Fig.4 Plot of typical data set collected using NIOAWS-96 in January 97.

- (a) Wind speed; (b) Wind direction; (c) Air temperature; (d) Air pressure;
- (e) Relative humidity; (f) Solar radiation

Fig. 3a and 3b show stick plot of daily averaged and mean hourly averaged data for different months. Fig.3a shows prominent winds from west and northwest in June to September associated with monsoon season. From November to February winds with much lower intensity are observed. April and May show significant wind from north and northwest. In Fig.3b we see pattern of mean hourly winds in different months. From November to May we see a clear pattern of northeast winds in early hours of the day turning to southwest and then to northwest. This pattern is representative of land and sea breeze effect.

Fig.4 shows typical plots of wind speed and direction, temperature, barometric pressure, solar radiation and humidity data collected in the month of January 97 from AWS96 installed at NIO.

DISCUSSION

NIOAWS-96 has been used successfully on board ship and on land installations. The compact packaging of sensors and electronics has resulted in ease of installation and maintenance as compared to previous systems. In all we have three shipboard installations, four land based installations and additional six units are being developed for in-house environmental impact assessment (EIA) programs being undertaken at NIO.

Having gained the confidences with the basic configuration, efforts are underway for future enhancements. viz.

- i) Inclusion of compass and GPS receiver within AWS electronics unit for mobile and ship-based stations.
- ii) Inclusion of sensors for precipitation
- iii) VHF and link.

The shipboard systems presently use PCs for data logging with GPS and Log/Gyro connection. This is convenient for oceanographic research vessels. We plan to build a totally autonomous unit for ships of opportunity and mobile stations incorporating GPS receivers and compass.

Precipitation sensors are not included presently in our systems. We plan to use optical rain gauges for ship based installations and low cost tipping bucket type sensors for land based installations.

A VHF link is often desirable in remote land based stations. We have successfully tested data retrieval through a VHF link using Pacific Crest transceivers. Necessary modifications are underway to support a self-reporting capability using VHF link. The AWS at preset intervals will power the VHF unit and check for remote master computer for uploading the data.

The NIOAWS-96 is a reliable field worthy equipment. Only problem that was encountered in early design stage was that of interference in the neighborhood of strong radio transmitters. This was taken care of by using proper RC filters at the inputs. The entire electronics has been implemented in SMD components and overall reliability is satisfactory. We have not had any problems with electronics and sensors except for two AIR SB2 pressure sensors that showed substantial drifts in manufacturer's calibration.

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