



## Microprocessors Design Aspects for Coastal Oceanographic Instruments

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### ABSTRACT

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A large class of coastal oceanographic instruments involve the acquisition and storage of data in the field over varying periods of unattended operation. Considerable flexibility in the design of such instruments is obtained through the use of microprocessor techniques. A well designed general purpose microcomputer board serves as the common element in several special purpose instruments, each having its own software invoked features. The data from a number of instruments can be logged, controlled and processed by common microprocessor based control units thereby speeding up design and development work.

Other advantages of microprocessor based systems for coastal oceanographic work are the ability to manually enter heading data with few circuit complications for each set of readings and also the ability to use common data display peripherals to service a large number of unattended field recording units. In this short paper some examples are used to illustrate these aspects.



### INTRODUCTION

Oceanographic instrumentation for coastal research has benefitted from the introduction of the microprocessor and its progressively wider usage in the field of marine instrumentation. Microprocessors have been used in the four major fields of data collection, processing, transmission/reception and storage. Oceanographic instrumentation has several special requirements. These are: low power and military specifications for operation in the hostile marine environment, low chip count for increased reliability, ease of reconfiguration to meet changing needs of the experimenter at sea, capability of data processing and reduction to save power when transmitting or storing, programming capability for intelligent operation in remote locations, and ability to function as stand alone or integrated into an intelligent network to meet changing requirements at sea.

### DISCUSSION

#### Power Consumption

Oceanographic instruments deployed in remote coastal locations are critically dependent on their power supplies. In order to reduce battery capacity, low power consumption is essential. Since remote sensors are normally sealed units, heat dissipation should be minimum to maintain electronics compartment temperature at a reasonable level. Another aspect particular to this type of instrumentation is that generally the parameters measured are quasi-stable functions with variations in the millisecond to second range. The associated hardware may therefore have slow instruction cycle thereby reducing power along the speed-power relation.

The marine environment is a high humidity, highly corrosive environment. It is characterised by large temperature variations and

extremes of pressure. Devices (ceramic packaged against humidity) have a wide operating temperature ranges. Microprocessors thereafter called "micros" (for shorthand), and their peripheral devices available in military specifications are ceramic packaged and have normal CMOS versions. They therefore fulfill all the requirements for the marine environment.

### Chip Count

The primary requirement in a high cost area such as coastal oceanography is reliability. Some aspects of reliability are discussed in other sections whilst the advantages of low chip count are discussed here. To reduce system failures due to device failures, the simplest method is to reduce chip count. Another advantage of reducing chip count is that troubleshooting is greatly simplified which is especially important in the ocean environs where ship time is so very costly.

The present generation micros and their smart peripheral devices have reduced a typical microcomputer system to a 3 chip count. The number of components required for an "average" system has been falling every year and will continue to do so with time. New CPU's currently available have on-chip select logic, DMA capabilities and with a timer included (INTEL 80186). The general purpose CPU card used in the National Institute of Oceanography (N.I.O.) has a 10 chip count giving it the capability of 4K EPROM, 1K RAM, 48 I/O lines and with spare decoded lines available for off-board expansion.

### Reconfigurability

Different experimenters look at oceanic parameters from different angles depending on the model they wish to verify. It is therefore important that a basic measuring instrument should be easily reconfigured to suit different experimental needs. It may be necessary for instance to incorporate different storage devices in equipment from experiment to experiment or change the software to access sensor data differently. For a device to be acceptable for oceanographic work, therefore, it should allow for easy adaptation to a standard bus structure and it should also be possible to work

in a High Level Language (HLL) to speed turn around development time.

Microcomputer hardware designed around standard bus structure such as the S-100, Multibus, or Versabus will allow the add-on of a wide range of commercially available memory and I/O controller devices to meet any particular application depending on the complexity of the system. This will greatly reduce the turn around time spent on PCB design, layout and testing. With the standard bus structure, popular firmware components such as a BASIC Interpreter or CPM operating system are easily incorporated in a system. These firmware components allow faster development from a High Level Language. Reconfiguring such a system (e.g. changing the storage of data from EPROMs, *i.e.* floppy disc or magnetic tapes) will be merely a matter of replacing the standard cards on the bus and selecting the appropriate device driver routines.

### Data Processing and Reduction Capability

Remote oceanographic systems that need to transmit data must necessarily, have processing and reduction capabilities at site. This is so because transmission of data is expensive in terms of both money and power. For a semiconductor device to be useful in oceanographic applications it must have good processing capabilities. Signal processing requirements vary from fairly simple calculations such as linearisation of transducer outputs to online high speed digital signal analysis from seismic sources or computation of satellites fixes from doppler counts. Simple applications involving the monitoring of data acquisition, transducer linearisation and spectral analysis of slowly varying signals etc., have been the areas of single-chip microcomputers and eight-bit processors.

With the advent of high speed 16-bit microprocessor supported with number crunching co-processors the computation time of microprocessors are superior to or compatible with the minicomputers such as PDP-11 and HP 1000. With these capabilities 16-bit and 32-bit microcomputers will undertake the complex real time computations tasks such as Fast Fourier Transforms (FFT), Kalman filtering, matrix inversion and other signal analysis, algorithm and

will make their appearance in GPS receivers, Integrated Navigations Systems (INS), etc.

### Programming Capability

Sensors and data acquisition packages left on moored or drifting buoys far from shore as well as recording/listening packages left on the seabed are classed as remotely located sensors. Such units are normally inaccessible and to ensure their uninterrupted operation they have to be integrated with processors to make them "intelligent." Software routines can be written that allow the remote device to trouble-shoot and, if hardware redundancy is incorporated in the design, rectify itself.

Power is a limiting factor in the design of coastal oceanographic instrumentation and programming can easily be done on micros that will check battery voltages prior to other tasks. Thus if the battery voltage has fallen below a set level the system can avoid sampling erroneously. Other software checks can be incorporated which allow reference voltage changes affecting sensor outputs to be corrected. Sensor addressing can be changed by the program to select redundant sensors if the parameter to be measured shows output beyond a specified range. The micro is capable of all these tasks and on this basis is a prime candidate for use in coastal applications.

### Multiprocessor Capability

Oceanographic work is work in new environs. Thus the experimental needs change with data collected, model results obtained, and unforeseen natural changes. Investigations conducted with experiments in attendance would not be a remote situation, but would be defined as in-situ field observation. In a typical situation, that of an integrated datalogger on-board a research vessel, it may at some stage be found necessary to incorporate new measuring devices, remove all or unnecessary ones and generally restructure the system. The device being introduced should have the capability of operating as stand alone or integrated into a multiprocessor network. These changes in the system should be easy to implement and the only change required should be in the executive routine which controls the several different devices of the network. The added devices

should have built-in protocol lines allowing it an access to the main bus at the correct times. All the above requirements are architecturally met by microprocessors and the "smart" peripherals now available. Access to the bus, compatibility with bus lines, protocol procedures etc; are standard and widely used. Incorporation of new devices to an already existing system presents no problems and the only change to be incorporated is the modification of the executive routines.

### SOME DESIGN ASPECTS

Oceanographic instrumentation for coastal applications as most other types of instrumentation encompasses a wide range of complexity—from small stand-alone systems to large numbers of microcomputers in multiprocessor configurations. It would be, therefore, more meaningful to ask a series of questions at the onset of development to determine which guidelines are to be followed. Amongst the more obvious queries would be: Will the system be operated remotely or attended, have a degree of man-machine interaction, need to be compatible within a larger network, have to do any signal or data processing, transmit/receive data, and store/display data? These questions are answered below:

#### Remote or Attended Operation

The remotely operated instrument presents the greatest challenge to instrumentation engineers. Such a system would have to have software functions written in that would let it compare sensor outputs to a look-up-table of acceptable values. If a sensor output fell outside its limits, the micro would be programmed to remember this and try a fixed number of times and if the sensor did not recover, then it could be programmed to switch-on a second similar sensor. It should also be able to check its scratch-pad memory and its I/O devices, and take corrective action, if necessary, in a rapidly changing environment; it should be able to keep sensor outputs dynamically operating in the required range-altering sensor excitation or introducing divider networks for optimum Analog to Digital Conversion (ADC) performance. As power supply is the most critical parameter, it should monitor and record key supply levels

and adjust computation to cater for this and also for A/D drifts. Finally, it should have a built-in protocol shut-down service that would conserve battery power and memory space when either a sensor or the supply levels went outside their limits.

If the system is to operated in an attended mode, the system software should begin by check-summing its program memory and scratch-pad and flashing an appropriate signal if malfunction occurs, software should be so written as to allow the system to maintain its own troubleshooting diagnostics and inform the user accordingly. An attended system is inherently capable of greater tasks than a remote system as it can be programmed to signal the user when it has been led up an unwanted path. Attended system software should be in a high level language to allow rapid modification to routines depending on the experimental requirements. Interactive graphics capabilities with the refinements of colour and dimensional displays are useful and necessary in many attended system configurations. Most multi-bus, multi-processor configurations are implemented in attended system operation.

### Man-Machine Interaction

This aspect would mainly be invoked for attended system operation. There are two main methods of communications to the user, visually and audibly. All the comments made previously on attended system operation are applicable here. In addition, it may be added that the current trend towards self instruction of the user by the computer is advantageous, in large, replacing manuals. Menu driven programs ensure lower operator errors and with the reliability of processor systems increasing, operator errors are the main cause of system malfunctions. The software for attended systems should be user friendly, menu driven, self diagnosing and communicative. Lower reliability hardware may be used in interactive systems as the software can be made sufficiently powerful to allow the user easier troubleshooting.

### Compatibility in Larger Networks

If a projected system is to be compatible within a larger network of processors then its hardware conception becomes radically differ-

ent from a system meant for stand-alone functions only. A system may be designed for initial stand-alone operation and future incorporation in a micro computer network. For operation in a multibus, multiprocessor system it is essential to implement one of the standard buses mentioned previously. Besides the data line, handshaking lines indicating the status of the data bus and protocol lines establishing the master-slave hierarchy as well as determining which bus connected devices may transmit, receive or do both, have to be implemented. A larger system can then be compounded from groups of different microbased instruments of varying architecture. The system control would reside with an executive responsible for task identification, data control and other house-keeping chores.

### Data Acquisition

This is usually one of the basic tasks of an instrument in any field. Sensors available for different parameters come with a variety of outputs—though they may basically be divided into analog and digital types. The digital types may communicate directly to the bus on an appropriate enabling signal. The analog signals would be multiplexed through a common A/D converter onto the bus. A/D converters are available in single chip, lower power, micro compatible forms making their circuit incorporation simple. It is usually the case in marine instrumentation that most coastal parameters are quasi-stable, round robin selection is adequate. It may however occur, as in the case of satellite navigation data, that the data appears asynchronously and is of the highest priority. Such situations are easily accommodated in the interrupt structure of the processor. Some parameters exist, such as wind speed and direction, where instantaneous values are important but not acceptable for an overall reading. In such cases, integrated values over several minutes can be collected using software delay loops and sub-routines to calculate running averages (from acquired data) to prevent register overflow.

### Signal and Data Processing

Signal processing, arise from the trivial gain adjustments, sensor voltage excitation correc-

ion, A/D drift corrections would involve use of available packages for floating point double precision arithmetic, Fast Fourier Transforms, digital filtering etc. With the present availability of super stable reference voltage sources, 16 bit A/D converters and auto-zero front-end and operational amplifiers, signal processing is becoming more and more to mean the use of software routines designed to reduce voltage levels or binary digits to engineering units data.

In coastal oceanography more than other fields, data processing capabilities in a system are important (especially so far remotely operated devices) as both money and power are saved if the data can be processed prior to storage or transmission. With the present high cost of satellite data transmission, each unnecessary transmitted character costs about 10 cents. It is important, therefore, to reduce data to the most significant form prior to transmission. Storage of data is equally expensive, as times between servicing of remote devices should be kept as long as possible considering the high cost of ships time required for recovery.

### Data Transmission/Reception

In coastal oceanographic research the transmission and reception of data is usually over several kilometers, as such, the only reliable link is via satellite. Instruments that have to communicate via satellite could either be remote devices (as in the case of buoys) or attended ones (as in the case of ship borne data loggers). In either case, the system has to be so designed for transmission as to obey the protocol procedures required by the platform transmit terminals (as in the case of buoys) or the modems (as in the case of the data logger). Hardware and software has to be implemented in a form acceptable to the protocol of the transmitting/receiving device.

### Storage and Display of Data

The storage of data for present generation coastal instruments is made in the form of magnetic tapes, floppy discs, EPROMs or RAMs. If the standard bus structure is implemented, then the switching from one type of device to another causes no problems as the peripheral is treated equally by the processor with the usual

handshaking and protocol lines, via appropriate driver routines. The display of data takes the form of output on a printer, plotter, CRT or LED display. User allows for interactive graphic displays routines the user to view the data in different presentations or clearer physical understanding of natural phenomenae.

## EXAMPLES OF INSTRUMENTS FOR COASTAL RESEARCH

We describe here a few examples of instruments designed, developed and deployed by the Institute incorporating some of the guidelines outlined above.

### Micro-Based Ship-Borne Data Logger

The system is an attended unit, with some degree of man-machine interaction, it communicates with other micro based stand alone units, acquires data from them, stores and displays this data, and finally transmits the logged data over a satellite link (DESAI *et al.* 1986). The data logger acquires data from a magnetometer, echosounder, and satellite navigator. The data logger communicates to each one over a parallel, or serial line. The system wakes up with a sign on message, checks its program and RAM memory and signals the result on the CRT. It then prompts the user via a series of questions to enter heading and other important station data. The user is also encouraged to enter a report to the Chief of the expedition and this is logged. After this stage, the logger begins a round robin search of the devices, maintaining highest interrupt priority for the navigation data. The data logger is designed around Intel's 8086 Microprocessor (INTEL, 1985). Data is temporarily stored on a 4K RAM buffer, and downloaded on a cassette when the buffer limit is exceeded. Storage of up to 1 mega byte of data is realisable. The advent of high technology satellite links such as the MX-211 ship earth station (SES) from Magnavox enables the acquired data to be transmitted to a shore station. The coded data stream is received on a similar SES, stored on floppy disk drives and decoded and formatted on an Apple Computer for user analysis.

### Data Buoy

The ocean data buoy (DATA BUOY, 1986) collects data from a single location over long

periods important for the design of offshore structures and computation of long term climatic changes. The system is a small, easily serviceable, cost-effective buoy that: is suitable for deployment in coastal areas, measures meteorological and oceanographic parameters, is wave transparent as the first step to design wave following buoys subsequently, is a recording type (on solid state memories), and served as a preliminary input to our future development phases of a wave following buoy with satellite transmitting capability.

The design philosophy followed in the electronics incorporated the use of microprocessor technology, thus reducing the chip count, decreasing throughput time, and easing design changes. The system also utilised solar panels for recharging the sealed lead acid batteries so as to increase the periods between data recovery. The data recording was done on solid state memories thus avoiding problems inherent with mechanical recorders on board a constantly accelerating platform such as a buoy.

The first test for the electronics was its deployment at DAKSHIN GANGOTRI (Antarctica at 70deG South latitude; second at Daman, India to, provide base line data for ocean engineering wave studies. Based on the successful results the buoy was moored 5 Kms off Mormugao Harbour, Goa, India in Latitude 15°25', Longitude 73°45' at a depth of 20 metres.

The design philosophy followed for the system electronics was to ensure maximum reliability in the field, a necessary criteria since access to the buoy is limited particularly during rough weather. Secondly, low-power consumption, thus enabling reserve power on the buoy to tide over the periods of inaccessibility. These two factors led to adoption of the following set of criteria: microprocessor implementation to reduce chip count, and increase flexibility in data acquisition; design flexibility to accommodate additional sensors; large rugged data storage to accommodate long-term unattended operation; solar panels, for reserve power; and computer compatible data storage and acquisition. With the above set of criteria, a single board microcomputer was designed using the Intel 8085 microprocessor. The microcomputer design was the outcome of previous experience gained from working on general purpose boards. The choice of peripheral chips allowed the ease of integration of additional sensors. The highlights of the

software were modular subroutines and on-board processing of data and storage in engineering units. The parameters included wind speed, wind direction, buoy heading, relative humidity, air temperature, sea surface temperature, and housing temperature.

### Micro-Based Flow Measuring Instrument

The objective of this design is to facilitate an instrument capable of current profile measurements in high velocity regimes with large sediment loads, and where rotary tidal currents are prevalent (JOSEPH *et al.*, 1986). Since the requirement is for continuous monitoring, the unit was designed to automatically acquire, process and display the three parameters, viz; flow speed, flow direction and deployment depth.

The instrument is mainly used in the study of water movement which is essential for many ocean engineering design applications. As carriers of thermal and kinetic energy, sediments, dissolved nutrients, and pollutants—water currents have an important influence on climatic, geological, biological, and pollution aspects of the environment. In addition such measurements are used as valuable tools in intelligent water resource management. As the most ocean engineering activities are in the shallow-region, in coastal areas, where surface currents differ considerably in magnitude and direction from currents at shallow depths, this focusses a need for current profiling instruments for shallow water applications (viz; coastal areas).

Comparison with Aanderaa recording current meter showed that the present instrument can measure a maximum speed of 466 cms/sec. Calibration results of 6 similar units showed that the linear response is repeatable indicating that the instrument is suitable for coastal research.

### Microprocessor-Based Tide Measuring System

Tide measuring instrument (or Tide Gauge, in brief) belongs to a class of oceanographic instruments that sample and record data unattended, for several weeks in remote coastal locations (JOSEPH and DESA, 1984). The older forms of tide gauges (mechanical pattern

gauges), required personnel to constantly attend to monitor data recording, check mechanical parts, etc. In order to avoid these shortcomings, automatic self-recording microprocessor-based Tide Gauge is designed, developed and deployed for continuous unattended recording in the Mandovi River, Goa, India.

The electronics unit is built around an 8085A microprocessor running at 4 MHz. The system contains 6K EPROM space for program code, 1K RAM for scratchpad calculations, and on-board decoding logic for up to 4 parallel I/O ports (8255) giving a total of 96 programmable I/O lines. An EPROM card contains 16K bytes of memory for data storage, a 4-digit LED, a chart recorder, and an 18-column impact printer interfaced to the single board computer via I/O ports. The remaining I/O lines are used for control functions such as status checks on front panel switches, energising a beeper mounted on the front panel of the instrument.

Tidal values can be sampled from 1 minute to 255 minutes with this program. After completion of the program, the CPU resets the flip-flop and turns off power to the processor-card, EPROM card and the sensor frequency converter card. The entire software developed for this instrument is written in 8085 Assembly Language on Intel Microcomputer Development System (MDS) and essentially consists of 3 independent modules, viz; data acquisition module, display/print module (for inspecting data on a 4-digit LED display or obtaining hard copy outputs), and the chart module for tracing the tidal oscillation onto a chart recorder.

The important outputs emerging out from this design and development include: (a) on-site calculation of tidal height directly in meters (using Intel floating point arithmetic routines to evaluate sensor polynomial), (b) use of EPROMs to store data (ideally suitable for tide measurements since tidal data is slowly changing variable due to which memory requirements are not so critical for space), (c) user friendly interfaces (for easy inspection of data on site), and no separate play-back unit is required to process the or examine the data, and (d) use of CMOS circuitry, and automatic power on/off features conserve power and satisfy the requirement for long term self recording instruments. Improvements in this unit are in progress to include a real time clock chip (MM 58167A) and a satellite transmission package

to transmit data on a near real time basis to the laboratory from the field station.

### Electronic Bathythermograph

This is an instrument for recording sea temperature and pressure on static RAMs designed for upto an operation depth of 256 metres (coastal waters) (PESHWE et al., 1986). The instrument has basically two sub-units, viz; a sea unit (which acquires and stores the data) and a deck unit (which enables the user to read data from the sea unit and connect it to the peripherals). The sea unit is a stainless steel cylindrical housing containing battery and the electronics package. The pressure and temperature sensors are mounted at the bottom of the housing. The main connector enables the batteries to be charged, and data to be entered into and read from the system memory. The deck unit has a hexadecimal keypad, a pair of 4 LEDs and associated electronics to enable communication with the sea unit and display the respective functions. The unit also enables interface to BCD printer and an RS232C communication terminal to process the data received from the sea unit. The microprocessor used in the instrument is 8085A. The instrument successfully recorded the data during RV 'GAVESHANI' cruise giving good compatibility with data compared with digital bathythermograph readings.

### CONCLUSIONS

Microprocessors have made a tremendous impact on the oceanographic instruments. New oceanographic instruments are compact, low power, intelligent highly reliable and field-worthy in extreme weather conditions. They have capabilities to work as stand alone units or to function in an integrated network. They have processing capabilities which were once the tasks left for minicomputers. With the high end processors entering in CMOS technology, increasing memory capacity and silicon operating systems tiny personal computers will enter into the area of data acquisition of processing where the oceanographer will be able to implement a system themselves without too much assistance from electronic engineers.

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### □ RESUMEN □

Un gran número de instrumentos de oceanografía costera requieren la adquisición y almacenamiento de datos en periodos de operación no atendidos por personal. El uso de microprocesadores concede, al diseño de tales aparatos, una gran flexibilidad. Un microordenador puede servir como elemento común en varios instrumentos especiales, cada uno con su propio software. Los datos de los diferentes instrumentos pueden ser almacenados, controlados y procesados por un microprocesador común. Otra ventaja de los sistemas basados en microprocesadores es la capacidad de usar los datos en diferentes periféricos. En este Informe se recogen varios ejemplos que ilustran estos aspectos.—*Department of Water Sciences, University of Santandén, Santandén, Spain.*

### □ RÉSUMÉ □

De nombreux instruments d'océanographie côtière impliquent l'acquisition et le stockage de données sur le terrain et avec des périodes plus ou moins longues de relâche. Une flexibilité considérable dans la conception de tels instruments est obtenue par utilisation de microprocesseurs. Un micro-ordinateur domestique peut servir d'élément commun à plusieurs instruments, lesquels ont chacun leur software et leur configuration des données. Les données de certains instruments peuvent être stockées, contrôlées et analysées par les unités de contrôle d'un microprocesseur, ce qui accélère le travail. Autres avantages des systèmes à microprocesseurs pour l'océanographie littorale: permettre d'entrer manuellement des données de tête, et utiliser les périphériques des données communes pour alimenter un grand nombre d'unités d'enregistrement en attente. Illustre cet aspect de quelques exemples.—*Catherine Bressolier, EPHE, UA 910 CNRS, Montrouge, France.*

### □ ZUSAMMENFASSUNG □

Sehr viele Typen von ozeanographischen Instrumenten sind für die Gewinnung und Speicherung von Felddaten über unterschiedlich lange Perioden mit unkontrolliertem Arbeitsablauf eingerichtet. Eine bemerkenswerte Flexibilität in der Anlage solcher Instrumente wird gesichert durch die Anwendung von Micro-Computer-Techniken.

Ein sinnvoll gestalteter zentraler Micro-Computer dient als gemeinsames Teil von peripheren Instrumenten für verschiedene Spezialzwecke, die jeweils mit eigenem Programm abgerufen werden können. Die Daten mehrerer Instrumente können zerlegt, kontrolliert und umgesetzt werden durch vom universellen Micro-Computer kontrollierte Einheiten, wobei Einbauzeiten und Entwicklungsarbeit gespart werden. Andere Vorteile von auf Micro-Prozessoren gestützten Systemen für ozeanographische Arbeiten an der Küste sind: manuelle Einbringung von Haupt-Daten mit nur wenigen Durchgängen für jede Ablesung sowie die Fähigkeit, mit normalen Periphergeräten eine große Zahl unbeaufsichtigter Feldstationen zu bedienen.

In dieser kurzen Arbeit werden einige Beispiele und Illustrationen für solche Überlegungen vorgestellt.—*Dieter Kellat, Universität Essen, Federal Republic of Germany.*