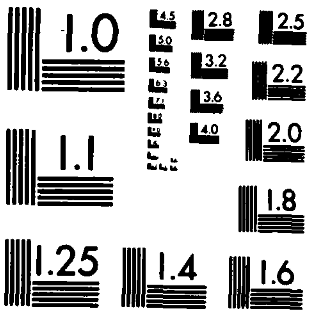
AD-A123 979 A PORTABLE MEASUREMENT AND RECORDING SYSTEM FOR SHIP MOTION DATA OR OTHER..(U) NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER SAN DIEGO CA R A NEWMAN JAN 83 1/1

UNCLASSIFIED NPRDC-TN-83-2 F/G 14/2 NL

END
DATE
FILMED
83
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

NPRDC TN 83-2

JANUARY 1983

AD A123979

A PORTABLE MEASUREMENT AND RECORDING SYSTEM FOR SHIP MOTION DATA OR OTHER ANALOG SIGNALS

NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER
SAN DIEGO, CALIFORNIA

NAVY PERSONNEL RESEARCH
AND
DEVELOPMENT CENTER
San Diego, California 92152

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

NPRDC Technical Note 83-2 January 1983

A PORTABLE MEASUREMENT AND RECORDING SYSTEM FOR SHIP MOTION DATA OR OTHER ANALOG SIGNALS

Richard A. Newman

Reviewed by
E. A. Koehler

Released by
James F. Kelly, Jr.
Commanding Officer

Navy Personnel Research and Development Center
San Diego, California 92152

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER NPRDC TN 83-2	2. GOVT ACCESSION NO. AD-A123979	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A PORTABLE MEASUREMENT AND RECORDING SYSTEM FOR SHIP MOTION DATA OR OTHER ANALOG SIGNALS		5. TYPE OF REPORT & PERIOD COVERED Technical Note Jul 1977-Nov 1980
		6. PERFORMING ORG. REPORT NUMBER ~~17-21-4~~
7. AUTHOR(s) Richard A. Newman		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Navy Personnel Research and Development Center San Diego, California 92152		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 525-024-03.01
11. CONTROLLING OFFICE NAME AND ADDRESS Navy Personnel Research and Development Center San Diego, California 92152		12. REPORT DATE January 1983
		13. NUMBER OF PAGES 20
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the development of a portable measurement and recording system for ship motion data or other analog signals.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FOREWORD

This effort was conducted in support of exploratory development task area work unit 525-024-03.01 (Critical Task Performance Measurement), under the sponsorship of the Naval Sea Systems Command. The overall objective of the work unit was to develop a capability for measuring task performance in critical tasks in the operational ship environment and to use this capability to obtain data on the effects of environmental factors (e.g., ship motion) on performance.

The purpose of the work described here was to develop the instrumentation for measuring ship motion at the time and place of human performance measurement. The equipment was designed to be adaptable to making other environmental and/or performance measurements as the program progressed. Although the project was terminated in late 1980, the portable measurement and recording equipment for ship motion data had been secured. In mid 1982, this equipment was transferred to the Naval Biodynamics Laboratory, New Orleans, for its use in other motion measurement related projects.

Special acknowledgement is due Mr. Richard Chalmers, Environmental Test Branch, Naval Ocean Systems Center, for his assistance in obtaining the hardware components described in this report.

JAMES F. KELLY, JR.	JAMES W. TWEEDDALE
Commanding Officer	Technical Director

SUMMARY

Problem

[illegible] ability to assess crew performance [illegible] severely limited by the difficulty of making simultaneous measurements of [illegible] and the environment. This is especially true when ship motion data are required. The measurement of ship motion is complicated, requiring up to three simultaneous reference coordinate systems, and motion measurements must often be made in high sea state conditions that are destructive to equipment and unpleasant for both ship personnel and researchers.

Objective

The primary purpose of this effort was to develop a portable ship motion measurement and recording system that could be used in conjunction with performance tests developed as part of the Critical Task Performance Measurement (CTPM) project. This system was to be small, to make few demands upon ship resources, and to be capable of measuring the motions of small craft operating in high sea states. In conjunction with this hardware development, an overall implementation plan was to be developed for its use in performance testing.

Approach

The functional requirements of a working system, data on environmental and operational hazards to the equipment, and ship/test compatability requirements were determined. Selection of the general technology to be applied involved consideration of size, weight, power consumption, cost, and low reliability of analog instrumentation. As a result, it was decided to use a microprocessor-based system designed around commercial components.

System Description

The sensors are 12 piezoresistive linear accelerometers. Their output goes through anti-aliasing filters to analog amplifiers. The frequency range of the filtered response is from DC to 50Hz. High rate of change of acceleration (jerk) impulses from ship slamming or other impulse loading can also be recorded. Accelerations of under 0.1g are reliably measurable.

The filtered and amplified signals from the accelerometers are converted to digital form by an analog to digital converter, and stored on digital tape under control of a microcomputer program. Software control provides considerable flexibility. The system records the data from the 12 channels on cartridge tape and permits recording of data at two locations.

Conclusions

1. The measurement system is fully able to perform the required functions. Pending verification on a ship, there are no reasons why the system should not function properly in its proposed environment.

2. The design of the hardware and the flexibility of the software control make it possible, by replacing the accelerometers with appropriate sensors and signal conditioners, to use this system for many other types of measurement.

CONTENTS

LIST OF FIGURES

INTRODUCTION

Problem

The Navy's ability to assess and measure crew performance under operational conditions is presently limited, especially under conditions of high sea state. Where ship motion is severe, measurement of performance is even more difficult, and, at present, motion and task performance are not measured simultaneously.

The measurement of ship motion is complex, requiring the consideration of three coordinate reference systems, and has usually been performed using analog recording on instrumentation tape recorders. Experience in past programs has shown that, in addition to large size and ship support requirements, analog recording system reliability in high sea states is poor.

Objectives

The primary objective of this effort was to develop a ship motion measurement and recording system that could be used in conjunction with the performance tests developed as part of the Critical Task Performance Measurement (CTPM) project. This system was to (1) be small, permitting installation and use in small craft such as the 65 ft. patrol boats, (2) have minimal requirements for ship power or other ship support, (3) be capable of measuring the large motion and high accelerative loading of small craft operating in a high sea, (4) be more reliable than present systems, and (5) be less likely to lose data than the conventional large analog recording systems.

In conjunction with this hardware development, an implementation plan was developed for use in performance testing, so as to assure that the motion data could be correlated and coanalyzed with the data obtained from the performance tests.

Background

The measurement of ship motion, using accelerometers and rate gyros, is not new, although it is not done as a routine function on all new ship designs. The most common way of performing this task is to place the sensors at the center of gravity (CG) of the ship and at any special points of anticipated mechanical stress, such as the bow. Data are usually recorded on an analog instrumentation tape recorder. These measurements are normally done in support of ship engineering studies, and there are usually few limits on the size of the sensors or on the size and space required by the signal conditioning and recording equipment. It is not unusual to have one or more 6-foot racks of equipment with accelerometers that weigh up to 1 pound (or more) each, in use. Despite the use of heavy duty equipment, experience in prior programs has shown that the conventional systems are sometimes unreliable, and they may be out of operation for significant portions of an at-sea test. This is especially true when the test environment involves high sea states. In some cases, the size and weight of the equipment seems to work against the reliability of the system, as the mass/inertia relationships of large ship motions in heavy seas, which show frequent directional reversal, result in mechanical strain on the equipment. The use of large inertial mass on a tape drive to help maintain constant tape speed, which is common in instrumentation recorders, may now work against accurate recording in the environment of reversing directions of acceleration.

Also significant is the difference in motion at the CG and at the location of the human task performer. In theory, if the location of the personnel relative to the CG is known, it is possible to determine the motion of the task site, given the motion at the CG.

In practice, there are a number of factors that tend to prevent this. Most significant is the nonavailability of motion data from the CG, and the lack of accurate dimensional data to permit coordinate referencing. In the real world, it makes more sense to measure the motion at the point at which the task is performed. Some of the implications of motion on task performance, including motion-induced mechanical and physiological effects on performance, are discussed in an earlier document (Newman, 1976).

Another aspect of the measurement problem is that the motion applied to the human body, either at the feet (standing) or at the base of the spine (seated) is not the motion to which the motion-sensitive sensory mechanisms of the inner ear respond. The human body is not a rigid structure. It is an active biomechanical system that may dampen motion (passively or by muscle actions) at some frequencies or resonate to motion at others. Further, due to the off-center-pivot location of the head on the neck, linear motion applied to the body may be translated into rotational motion of the head. This makes it desirable to measure head motion directly, and to calculate the transfer function between applied motion and head motion. This data may have significance in the design of ships and equipment.

These factors led to a consideration of alternative methods of obtaining data on ship motion. One promising approach appeared to be use of the small, easily packaged, and low-cost microprocessors now available. Data could be collected, digitized, and recorded on digital tape. A small portable system could be built that was less susceptible to some of the problems of environmentally-induced data loss. In addition, using this approach, simultaneous measurement of applied motion and head motion might be possible.

APPROACH

Functional Requirements

While the newly available microprocessor-based technology appeared to be a solution to the problems, this could not be determined fully until a set of functional requirements was developed that could be used as criteria for determining hardware and system performance. The primary requirements for the system are listed below:

Frequency: DC to 50 Hz.--All directions of motion.
Anti-aliasing Filters: Required--Either hardware or software.
Sensitivity: .05 g or better, with .01 g resolution--All six degrees of freedom.
Max. G Load: 5 g impulse.
Sampling Rate: 40 samples/channel/second minimum.

Number of Channels: 12

A/D Conversion Accuracy: 0.1% (1 part in 1000) or better.
Data Storage Medium: Tape--Cassette or cartridge.
Recording Time: 10 minutes continuous, minimum.

Weights:
- Sensors: 30gm max/sensor.
- Package: 20Kg max. each.

Packaging:
- Number: 3 max.
- Size: Not over 65cm in any dimension.

Shock: Survive 75cm drop; 10 g impulse.
Water and Spray Resistant.

Power: 117 VAC nominal voltage, 10 amperes max. or battery pack (rechargable).

The use of 12 data channels was necessary if six degree-of-freedom measurements were to be performed at two locations for development of transfer function data. Although recording 12 channels of data instead of six imposed no significant problem from the A to D conversion and recording aspect, there was a problem in obtaining sensors that could be used for a head motion sensing system. Sensing of linear motion is not a problem, as small, light weight, sensitive accelerometers are available. It is in the area of rotational measurement that difficulties arise. Most low g sensors of rotation use a large inertial mass to detect the low rates of accelerations involved. Since these units can weigh a pound or more, this would result in a head-mounted system of at least 4 to 5 pounds. Such weights are much too great, as they represent a very significant proportion of the total weight of the head, and must result in a significant change in the head response to motion. A weight limit of 1 pound for the head-mounted system, including sensors and mount, was established as a reasonable criterion.

Since it did not seem feasible to do this with conventional measurement of rotational motion, an alternative method was developed that involved using six linear accelerometers arranged in pairs on each of the three axes of the head-reference system (Figure 1). By comparing the motion from different axis locations, the rotational motion could be derived. Light weight, adjustable mounting could be used to position the sensors. Given the ability to provide a satisfactory head-mounted set of linear accelerometers, it was necessary to confirm the correctness of the proposed mathematical analysis and that numerical solutions were possible using conventional computer capability. An analysis was performed and the appropriate equations were derived for both the combined rotational/linear sensor case and for the all-linear sensor case, using a rigid head mount for the sensors (de Grassie, 1975).

In the course of the analyses, it also became obvious that the availability of commonly used components for most of the system gave an inherent flexibility that should be considered in its design. In particular, use of different sensors with the digital recording capability should have wide application. The possibilities will be discussed in the hardware description.

Environmental Criteria

Weight, size, and power requirements were primary considerations. The use of a microprocessor-based system has significant advantages in all three of these areas relative to the large, heavy, high power consumption of analog instrumentation recording systems. Although battery packs were available, they were not used in this implementation, since 60Hz 60CY power is available in the ships and patrol boats for which system use was initially planned. Although system requirements specify that packaging should be water and spray resistant, cost considerations prevent designing to the existing MilStd requirements. Further, since this is research equipment that will not be subject to some of the extremes of handling and exposure that ship operational equipment may experience, MilStd level design should not be needed.

The packaging also takes into consideration electrical and electronic interference, and the aluminum cases and the interconnecting cables provide shielding to minimize interference either to or from ship equipment.

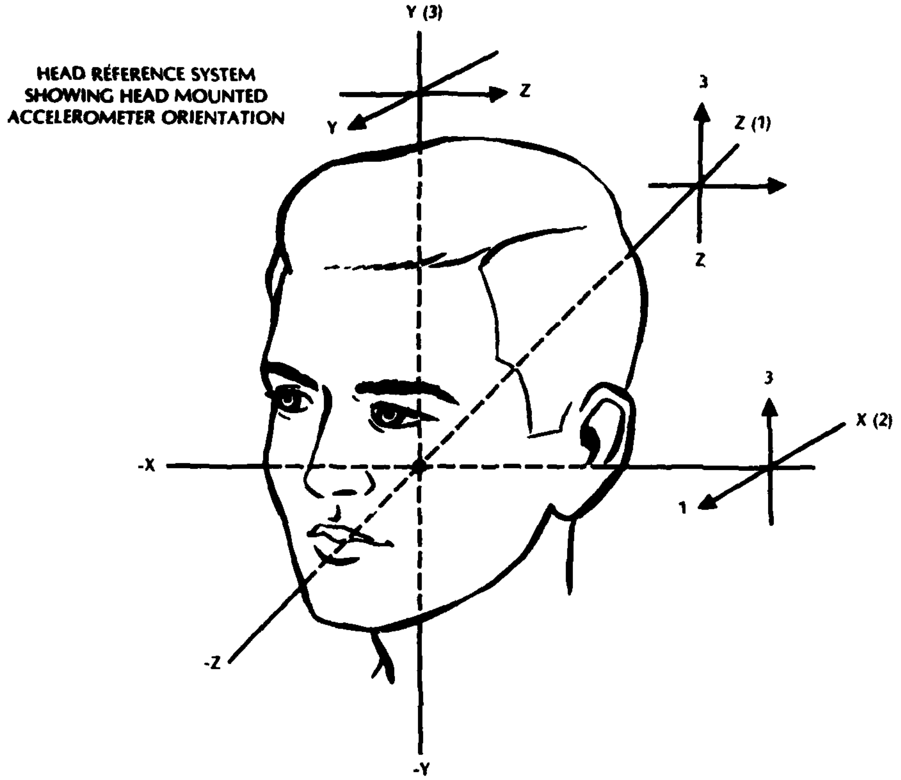


Figure 1. Head reference system showing head-mounted accelerometer orientation.

This approach, and consideration of the factors discussed above, have resulted in the design of the hardware described in the next section. This design should also have application to other difficult data collection environments. Figure 2 is a block diagram of the system.

EQUIPMENT DESCRIPTION

The major measurement/recording system components are described in the following paragraphs and listed below:

Analog Equipment

Accelerometers: Endevco model 2262-25 piezoresistive low g (12 ea).
Sensitivity--20mV/g.
Frequency response-- ± 5% DC to 750Hz.
Weight--28 gm ea. without cable.

Anti-aliasing filters: Frequency Devices, Inc. model 721L6L-20AO Low Pass (12 ea.)--six pole Bessel, 20Hz corner frequency.

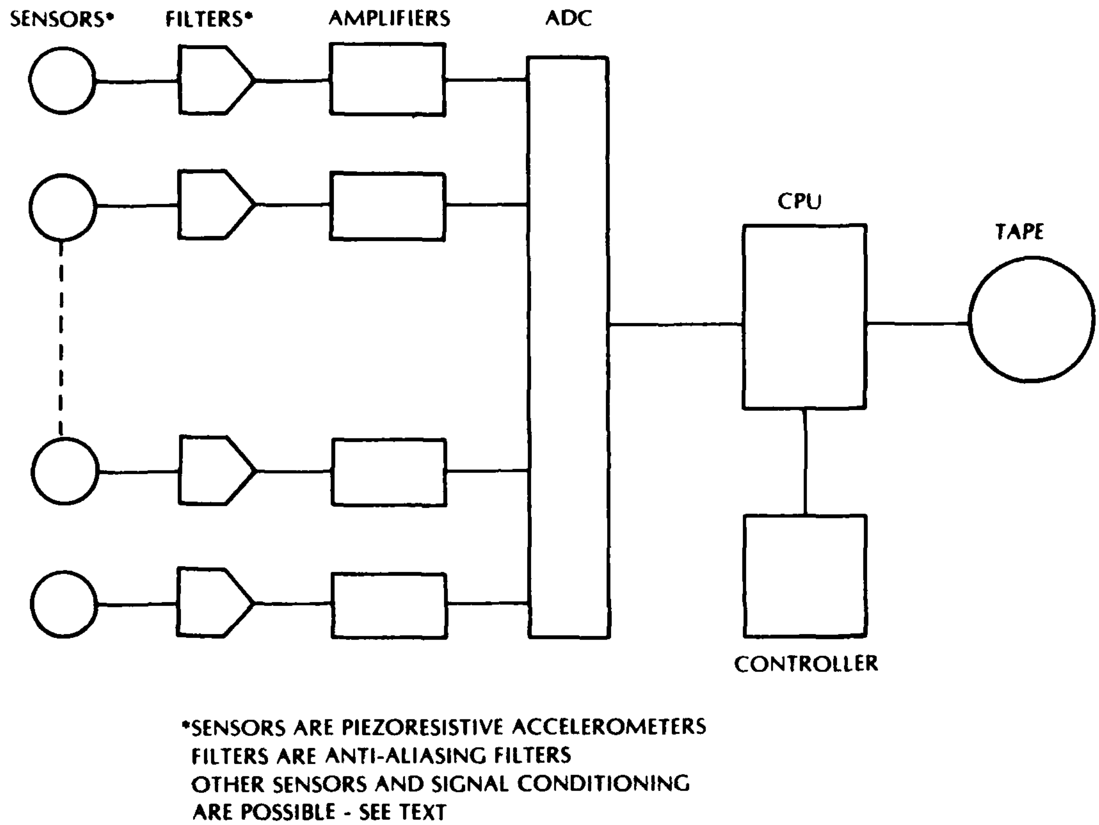


Figure 2. Block diagram of ship data measurement and recording system. See text for detailed description of characteristics.

Analog Amplifiers: Ectron model 418 differential DC amplifiers (12 ea.).
Frequency response--DC to 3kHz ± 5%.
Gain--10-1000 switch selectable plus vernier.
Noise--Under 2 microvolts ref. to input.

Analog to digital converter: Sinetrac ST-800 32-channel single-ended, 16-channel differential.
Resolution--12 bit.
Conversion time--50 microsec. per channel.

Digital Equipment:

Processing Unit: Intel SBC 80/20, incl 4Kbyte ROM, 1 Kbyte RAM data buffer.

Tape Recorder: Alloy Engineering DEI cartridge drive/DMB-1 controller.
8 bit digital recording system.

Control Box: DataWare custom unit.

Environmental Package Cases: Zero Mfg. custom cases.

Power supplies, cables, data tapes as required.

Analog Equipment

Accelerometers

Because of the low levels of acceleration involved and the need for lightweight accelerometers or rate gyros to permit head mounting of the system, the number of accelerometer types available has been very limited. Normal low g rate gyros and rotational accelerometers are usually relatively large and heavy, using the inertia of a large mass to obtain the sensitivity to low accelerative loads. To measure head response to acceleration, it is necessary to limit the mass of the instrumentation placed on the head to a small percentage of the head mass. Cost and availability factors made acquisition of small rotational accelerometers or rate gyros infeasible. For the linear dimensions, equipment is available.

By using pairs of linear accelerometers mounted along the axes of the head reference system and by appropriate geometric translation and subtraction of the paired outputs, the rotational component of motion can be calculated. This permits using the lightweight linear accelerometers for all channels of the system.

The units selected were Endevco model 2262-25 low g piezoresistive linear accelerometers. These have a nominal resolution of 0.05g, and weigh 28 grams each (one ounce). They provide an output of 20mV/g, essentially flat up to 750Hz. At the high end, they are rated at 25 g, which is desirable for measurement of slamming. Achievable resolution depends, to a great degree, on the noise characteristics of the analog system. Cable length also affects resolution and sensitivity and must be considered.

Anti-aliasing Filters

Anti-aliasing filters are a necessity if a time/frequency domain analysis of the signal is to be performed. In most cases, this function is performed by a hardware filter, but it is possible to use computer software for the purpose. These requirements are dealt with in many texts on signal analysis, Fourier transforms, spectral analysis, etc. (e.g., Inbar, 1975; Brigham, 1974). Since the frequency range of interest and the data sampling rate of the recording system were relatively low, the corner frequency selected for the filtering was 20Hz. The unit selected (Frequency Devices, Inc. model 7 1L61-20AO) is a low-pass filter, using a Bessel six-pole configuration. Attenuation characteristics are listed below:

Freq. (Hz)	Atten. (db) (theoretical)
0	0.00
2	0.03
5	0.19
10	0.73
20	3.01
40	14.17
60	30.70

These filters are active and require a power supply.

Amplifiers

The signals are amplified by Ectron model 418 differential DC amplifiers. These are low noise (peak noise referenced to input at 10Hz bandwidth is 1 microvolt), high gain (10 to 1000, switch selectable), high impedence input devices. They can provide up to 10 volts output, and can accept up to 0.5 volts input without significant distortion. Zero offset and common mode rejection of over 100 db are also features of this unit. The outputs go to the analog to digital converter (ADC), which serves as the data input to the rest of the system.

Analog to Digital Converter (ADC)

The ADC in use is a Sinetrac model 800, with capability for up to 32 channels of single-ended input or, as used here, up to 16 channels of differential input. It has a range of alternatives for input level and, in this system, can be strapped for either ± 10v or ± 5v. Conversion rates and channel sequencing are under software control. The unit is 12-bit resolution (1 in 4096) and conversion time/channel is under 50 microseconds. In a 6 or 12 channel system, this minimizes the time offset and phase shift that must be compensated for in the analyses, especially at the low frequencies considered in this development. At 50Hz, converting 16 channels will result in phase skewing of not over a total of 15 degrees. The ADC can accept any type of input signal that can be matched to the frequency and voltage requirements (10 volt max), making the system highly flexible.

Digital Equipment

Processor

The processor consists of an Intel SBC 80/20, 8080A based microprocessor with the necessary supporting chips (clock, I/O interface etc.) on the same board. The control software is contained in 4 Kbytes of ROM, and there is a 1 Kbyte RAM used as a data buffer. When operating, the system reads the ADC, transfers the data to the buffer, and, when the buffer is full, dumps the contents to the digital tape cartridge unit for storage. The DMB-1 tape controller and system board built by DataWare to interface with the control box for the system are in the card cage with the processor and the ADC. The overall function of the system is quite simple and, except for some checking done as part of the operating system, it serves exclusively as a data transfer mechanism, formatting the 12 bits of data into two 8-bit bytes to be compatible with the tape unit. The four bits remaining may be used for channel number, time code, other desired purpose, or not at all.

Cartridge Tape Recorder

The Alloy Engineering DEI tape cartridge drive uses commercially available 450 foot data tapes as the storage medium. Four data tracks are available, and each is sequenced automatically by the system software. Data is stored in 8-bit bytes, so that 2 bytes are required for each datum. All data are stored under software control in records of 1024 bytes, divided into 32 blocks of 32 bytes each. Each block contains the 24 bytes of ADC data and record identification. There are 6 unused bytes at the end of each block. Blocks are numbered through 65535, and then restart at 0. Recording time for each is approximately 20 minutes, so that up to 80 minutes of data can be recorded continuously. Maximum data transmission rate from the CPU to the tape is 19 Kbaud/s.

Software

The software to control the system was written by DataWare Development Inc. It has two major components in addition to the operational control--the data recording and data playback routines. The data recording routine controls the ADC so that a sample is collected every 20msec. (50/sec), the data (in two's complement format) is transferred to the data buffer, and the buffer is dumped when full onto the tape. At the end of each track, an automatic rewind occurs and some data are lost if in recording mode at that time. Use of the record numbering system also serves as a time reference. All data recording, readback, and control/monitor software is written in 8080 assembly code.

In addition to the recording and playback software, there is a self test that is initiated when the system is started. If there is an error in the system or a faulty tape in place, the system will indicate a test failure. If the test is passed, a ready light lights and the start button can be pushed to initiate data collection. A stop button and a reset button are the only other controls normally used. System operation was deliberately kept simple, so that operator error possibility is minimized when the system is being used under difficult conditions. Software routines have been documented in the user's manual. Since most functions are software controlled, modification for use with other sensors, control interfaces, or output interfaces is feasible.

Power Supplies

Five power supplies are used in the system, all of which use nominal 117/VAC input voltage. Combined current drain is under 10 amperes. This is the only ship support requirement. The supplies have their own voltage regulation and, as all operational votages are DC, small frequency deviations from 60Hz are not a problem. The voltages supplied are:

Transducers:	10V
Filters:	±15V
Amplifiers:	28V
Computer:	±15V
Tape Deck:	15V

These voltages are the design values but, in all cases, the equipment can operate with voltage variations of at least 20 percent. The power supply design offers good isolation from the AC mains, so that no significant difficulty with interference from mains transmitted signals is anticipated.

Packaging

The shielded aluminum cases designed for transport and for protection in the ship environment also serve to minimize risk of unwanted signals entering or being emitted by the measurement/recording system. Signal input/output connections are coaxial and all openings, such as cooling air fan vents, are shielded. The cases are moisture resistant but not fully waterproof. Requirements for meeting MilStd specifications such as salt spray and temperature were not imposed. The cases were obtained from Zero Mfg.

Figure 3 shows system component connections.

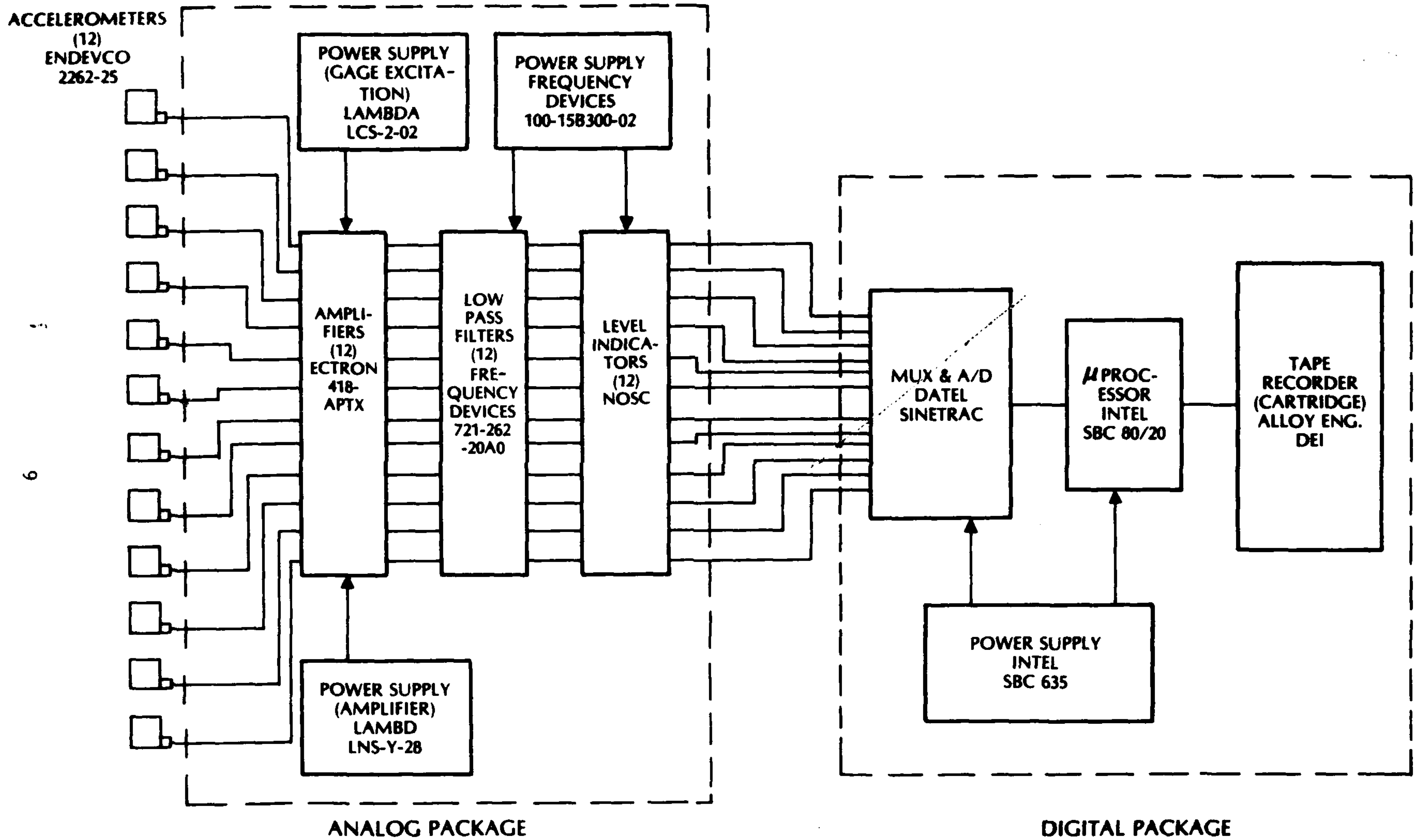


Figure 3. NAVPERSRANDCEN data acquisition system component arrangement.

SYSTEM UTILIZATION

The motion measuring and recording system was designed for use in conjunction with the performance tests developed as part of the Critical Task Performance Measurement Project. As has been discussed in the functional requirements description, it is adaptable for other uses as well. Two primary modes of use were planned. First, the two sets of sensors would measure motion at two environmental locations, such as subject's seat and a second location determined by the particular study. In the other mode, the second set of sensors is head mounted on the subject and used to determine the differences in motion at the point of application and on the head of the subject.

For the measurement of ship motion at the deck or seat, substitution of rate gyros or angular accelerometers is feasible as the weight limitations involved in head mounting do not apply. However, it is also possible to use the orthogonal pair technique required for head-mounted measurements. If rotational sensors are available, a set of calibration tests comparing the two sensing systems (colocated) should be performed.

The head-mounted system (Figure 1) will require a prior calibration under stable conditions for each subject. The mounting "frame" should be a light-weight, rigid, adjustable unit. The headbands used in industrial facilities to mount welders' helmets appear to meet the requirements. They are light (usually 30-60gms), fairly rigid plastic, with a means of adjusting to head size, both on the head circumference and over the top of the head. Each subject should be fitted with a headband, separately, with the sensor locations set using standard reference marks such as the center line of the ear canal opening and the bridge of the nose.

The accelerometers should be mounted on a small aluminum cube about 15mm (0.6 in.) on a side. This will permit transfer from one head mount to another, provide sufficiently rigid mount at the frequencies of interest, and minimize weight.

All testing should be performed on a pretest, test, posttest basis, comparing each subject's performance under control conditions with performance under ship motion conditions. Pretraining should control learning effect, as well as familiarize subjects with the measurement conditions. At present, there are no data on sufficient conditions that would permit combining data from different individuals into group data. Because of the high variability in response to motion-related effects, each subject must serve as his own control.

Data processing to derive the vectors of motion and the applied-motion/head-motion transfer function are fairly straightforward procedures. The pairs of accelerometers are compared, and the differences determined for the magnitude and direction of rotational motion around each axis. The necessary mathematical equations to describe these motions and to transfer them to head coordinates (or any other coordinates) have been developed. Numerical integration of the accelerations, to determine the velocity and position of the head and body, can also be done. Finally, the spatial vector of motion, both for the body and the head, can be obtained. These motion data can be developed for each time sample, and frequency and power/energy distributions over time can be calculated using standard analyses.

All of these data and analyses are for correlation with the data and analyses from the performance tests. Availability of computer analyses may permit correlation with specific components of motion and development of data on ship/head transfer functions.

Finally, these data can be examined for comparisons among subjects to provide a basis for defining individual differences in response to motion, and to determine whether a transfer function or other measure can be correlated with habituation to motion or specific effects of motion.

CONCLUSIONS

The system for data measurement and recording described in this report will not only meet the requirements of the program for which it was developed, but also can be used in many situations where analog data must be collected under difficult environmental conditions. The most significant features of the equipment include the following:

1. The system is small, consisting of three suitcase-sized aluminum cases of equipment, making transportation and installation simpler than for larger analog recording systems.

2. Its demands on ship support are minimal, with only 110VAC power required. By fairly simple modification, DC or other power sources can be used.

3. The minimal interface with ship electrical power and the use of shielded cases help minimize risks of interference to/from ship electronics.

4. Use of digital recording reduces risk of data loss and simplifies timing and error checking, as the "wow" and "flutter" problems of analog recording are not present.

5. The small size of the equipment cases reduce the need for environmental protection against shock, vibration, salt water spray, and moisture.

6. The "general purpose" front end makes modification for use of different sensors and signal conditioners for analog data acquisition relatively easy and quick.

7. Through the use of digital cartridge recording, data can be collected and analyzed without removing the system from the testbed. It also minimizes the interfacing needed to enter the data into a computer for analysis.

8. Software control of the system and the large number of channels add to system flexibility.

Overall, these capabilities make this a system of high potential applicability and ease of operation, especially where data collection is difficult due to the environment, limited ship support availability, and requirements for noninterference with ship systems and operations.

RECOMMENDATION

Although the motion measurement system described herein should fully meet project objectives, the state of the art in hardware development, especially in the microcomputer and recording equipment areas, has significantly advanced since the work was completed. Therefore, it is recommended that the equipment list be updated where appropriate to take advantage of recent hardware and software improvements.

REFERENCES

Brigham, E. O. The fast fourier transform. New York, NY: Prentice-Hall, 1974.

deGrassie, J. Description of head motion using linear accelerometers and rate gyros as sensors (Unpublished Manuscript). San Diego, CA: Navy Personnel Research and Development Center, 1975.

Inbar, G. F. (Ed.). Signal analysis and pattern recognition in biomedical engineering. New York, NY: John Wiley & Sons, 1975.

Newman, R. A. Ship motion effects in the human factors design of ships and shipboard equipment (NPRDC TR 77-2). San Diego, CA: Navy Personnel Research and Development Center, 1976. (AD-A031 978)

DISTRIBUTION LIST

Chief of Naval Operations (OP-115) (2), (OP-964D), (OP-987H)
Chief of Naval Material (NMAT 05)
Commander Naval Ocean Systems Center (Code 9331)
Commanding Officer, Naval Biodynamics Laboratory
Commander, Army Research Institute for the Behavioral and Social Sciences, Alexandria (PERI-ASL)
Commander, Air Force Human Resources Laboratory, Brooks Air Force Base (Scientific and Technical Information Office)
Commandant Coast Guard Headquarters
Commanding Officer, U.S. Coast Guard Institute
Commanding Officer, U.S. Coast Guard Research and Development Center, Avery Point
Commanding Officer, U.S. Coast Guard Training Center, Alameda
Superintendent, U.S. Coast Guard Academy
Defense Technical Information Center (DDA) (2)