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A FIELD-DEPLOYABLE DIGITAL ACOUSTIC MEASUREMENT SYSTEM

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ABSTRACT

A field-deployable digital acoustic measurement system has been developed to support acoustic research programs at the Langley Research Center. The system digitizes the acoustic inputs at the microphone which can be located up to 1000 feet from the van which houses the acquisition, storage and analysis equipment. Digitized data from up to 12 microphones is recorded on high density 8mm tape and is analyzed post-test by a microcomputer system. Synchronous and non-synchronous sampling is available with maximum sample rates of 12,500 and 40,000 samples per second, respectively. The high density tape storage system is capable of storing 5 gigabytes of data at transfer rates up to 1 megabyte per second. System overall dynamic range exceeds 83 dB.

INTRODUCTION

Researchers at the National Aeronautics and Space Administration, Langley Research Center, are engaged in acoustic research directed toward understanding and reducing noise generated by aerospace vehicles. The research encompasses both theoretical and experimental studies and involves numerous field tests and measurements of noise signatures from various types of vehicles. This paper describes a new field-deployable, digital acoustic measurement system developed to provide an acoustic measurement capability in support of this research. The need to replace the analog acoustic measurement systems, which have been used very successfully for many years, with digital systems was driven by several factors: first, the reduced availability of test vehicles for extended test periods and the limited life cycle of some components of many of the research vehicles being tested have made it essential that test time be reduced to a minimum; second, there is a need to reduce the time between completion of field tests and publication of the results. These requirements are more easily realized if the data is digitized during acquisition and processed post test in the field. Field processing allows alteration of the test plan after each day's testing, if needed, to fill out the test matrix and eliminates redundant tests that might be conducted if results were not available. Currently, Langley has four field instrumentation vans: three with analog instrumentation and one with digital instrumentation. Each van has acquisition, monitoring, and recording equipment for 12 microphone channels. Two new vans with digital instrumentation are being built. In addition to normal acoustic data, test vehicle position is measured using tracking instrumentation, local atmospheric conditions are acquired from a weather station set up at the test site, and earth acoustic impedance is measured. With the addition of the new digital system, all of the data including the non-acoustic data is in digital form which allows the integration of all data elements to be easily accomplished.

SYSTEM OVERVIEW

Figure 1 is a block diagram of the digital acoustic instrumentation system. The system is composed of acquisition and recording systems and a basic monitoring system with oscilloscopes, spectrum analyzer, meters, strip chart recorder, etc. The acquisition system has four elements: the remote digitizers located at the microphones to digitize the microphone analog outputs, the encoder/decoder subsystem, the display and control subsystem, and the digital acquisition-to-tape interface. All of these elements except the microphones and remote digitizers are in an instrumentation van that can be located up to 1000 feet away. The instrumentation vans are positioned at large distances from the microphones to reduce noise pickup from the van power generators and to avoid interference with the measurement. Using the analog systems, the long transmission lines from the microphones to the instrumentation van have created problems at times because the long lines act as antennas and pick up radio frequency signals which are demodulated by the analog instrumentation. The frequency of the demodulated signal falls in the audio band and appears as interfering noise to the acoustic measurement, in effect reducing the dynamic range of the measuring system. Since the digital system digitizes the data at the microphone and only digital data is transmitted on the transmission lines, the effects of the demodulated radio interference are negligible. Digitizing the data at the microphone has allowed a significant increase in the dynamic range (30-40dB) of the measurement, and this increased dynamic range has all but eliminated the need for operator gain changes to maintain a good signal-to-noise ratio. The other major system element is the recording system which is also located in the instrumentation van and is composed of a data conversion/buffering subsystem, the tape drive subsystem, and a digital-to-analog conversion subsystem. The digital recording system was developed as a low-cost alternative to the traditional digital instrumentation recorder, primarily because of the numbers of recorders required and the cost of the recorders. The new data recorders are relatively low cost and provide a significant new capability that is not available commercially. In the following paragraphs, the acquisition and recording systems will be discussed separately and in detail.

ACQUISITION SYSTEM

The acquisition system can be operated in either a synchronous mode, where the output of each microphone is sampled at the same instant of time, or in a nonsynchronous mode where the sample rate is the same for all microphones but there is no time correlation between samples. In the synchronous mode, sample time is controlled from the instrumentation van; and in the nonsynchronous mode, sample time is controlled by circuitry in each remote digitizer. The major elements of the acquisition system are the remote digitizers, the encode/decode subsystem, the display and control subsystem, and the digital-to-analog converter subsystem. Each of these elements will be discussed.

Remote Digitizers

The remote digitizer is shown in block diagram form in figure 2. This remote electronic system is powered by two 6 volt sealed lead acid batteries driving a DC to DC converter which supplies several voltages to the electronics. The microphone is a condenser type with an integral preamplifier. The output of the microphone preamplifier is input to a digitally controlled variable gain amplifier with gains of 1 to 128. The output of the amplifier is low-pass filtered and sampled either in a synchronous mode with the sample time controlled remotely from the instrumentation van or nonsynchronously, where the sample time is controlled in each remote digitizer by a precision clock in the logic control circuitry. The sampled analog data is converted to digital nonreturn to zero (NRZ), offset binary format by the analog-to-digital converter. The digital data is then converted to a serial data stream, encoded in a Manchester II code and transmitted to the instrumentation van. The Logic Control Circuitry controls the entire process.

Encode/Decode System

The encode/decode subsystem (figure 1) is located in the instrumentation van. When in the synchronous data mode, the system encodes the gains to be set on the variable gain amplifier in the remote digitizer in a Manchester code which is sent to each remote digitizer each time it is commanded to sample the microphone data. Communications between the instrumentation van and the remote digitizer can be half-duplex or full-duplex. Only half-duplex has been used in the system to date because of the lighter, smaller cable requirements. The subsystem also decodes the Manchester coded data received from the remote digitizer in both the synchronous and nonsynchronous modes of operation.

Display and Control System

The display and control subsystem (figure 1) is used to display the amplitude of the data from each channel, set the gain of variable gain amplifier in the remote digitizer, detect and alert the operator of overload conditions in the remote digitizer, and alert the operator of any faults in the communication of information and data between the instrumentation van and the remote digitizer. The display and control chassis is pictured in figure 3.

Digital-to-Analog Conversion System

Each data channel has a digital-to analog converter to allow the operator to monitor the data from each microphone. The D/A converter for each channel monitors the data between the encode/decode system and the acquisition/tape interface. Converting the data to analog at several points in the serial path of the acquisition and recording system allows the operator to isolate system electronic problems to specific elements of the system.

Acquisition to Tape Interface

The 12 microphone data channels and 8 additional channels of information, i. e., time code, run number, voice annotation, etc., are put into the proper format and clocked into the recording system by this interface. There are 20 parallel channels for transfer of NRZ serial data. Each channel is composed of three signals: data, clock and strobe.

Acquisition System Specifications

The following table lists the most important features and specifications for the acquisition system.

Table 1. Acquisition System Features and Specifications

Sample Modes: Synchronous and Non-synchronous.

Sample Rates: Half-Duplex, synchronous, 12,500 samples/second maximum. Half-Duplex, non-synchronous, 40,000 samples/second maximum. Full-Duplex, synchronous and non-synchronous, 40,000 sample/second maximum.

Digitization: 16 Bit, Offset Binary.

Gain Range: 102-142 dB (128 to 1). Gain controlled from instrumentation van in synchronous mode of operation.

Cable Length: 2000 feet with bit rate of 330,000 bits/second. 1000 feet with bit rate of 1,000,000 bits/second.

System Clock: Variable, 4×10^6 to 12×10^6.

Cable Type: Half-Duplex, single twisted, shielded pair. Full-Duplex, two twisted, shielded pairs.

Dynamic Range: >83 dB.

Bandwidth: Two fixed bandwidth, 8-Pole Butterworth low pass filters, 1000 Hertz cut-off and 10,000 Hertz cut-off.

Data Encoding: Manchester II code.

Battery Life: 20 hours with 1-2 hours reserve before recharging.

Auxiliary Signal Input: +/-10 volts.

LED Bar Display: Displays amplitude with peak hold and incorporates LED to indicate loss of Manchester signal from remote digitizer.

Modular Construction: Construction modularized to allow upgrades such as improved A/D converter and allow the system to be used for other data acquisition application.

Control: Manual or computer control of gains and sample rate. Computer to provide a data monitoring capability in the future.

Data Monitoring: D/A converter for each data channel.

Data Channels: 12.

RECORDING SYSTEM

The recording system uses 8mm helican scan, cartridge tape drives to store 20 channels of acoustic data and test information on a single track on the recorder. Figure 4 is a photograph of the tape drive system. One tape drive is used to record the primary data tape, and the second drive is used to simultaneously record a backup tape. The second drive also provides redundancy in case of drive or electronic failure. Each tape drive has its own microprocessor controller and electronics. Data compression systems are combined with the tape drives to provide several possible configurations and data transfer rates. Although all of the various configurations have not been tested, the expected transfer rates for some of the configurations with and without data compression are given in table 2. The recording system includes the data conversion and buffering subsystem, the tape drive subsystem, and the digital-to-analog conversion subsystem. Each of these subsystems will be described.

Data Conversion and Buffering Subsystem

This subsystem accepts 20 parallel channels of serial data coming from the acquisition system and converts the data in each channel to a parallel format. The parallel 16-bit-wide data samples for each channel are loaded into 2000 byte First In First Out (FIFO) speed matching buffers. The data in the FIFO's is output to the tape drive subsystem. Also included in this subsystem is a digital-to-analog converter that can be switched to any data channel. This provides a data monitoring as well as troubleshooting capability.

Tape Drive Subsystem

The tape drive subsystem, pictured in figure 4, is composed of 8mm tape drives, microprocessor controllers, Small Computer Systems Interface (SCSI) controller, logic to activate the front panel switches controlled by the microprocessor, run number switch, logic to detect loss of a channel or data dropout, and logic and display of the time remaining on the tape. In the record and playback modes, the microprocessor is used to activate the front panel switches in a set sequence to reduce the possibility of pressing the wrong switch. When a tape is loaded, it is checked to see if it has been used. If data is present, the system will only allow playback of the tape. The 8mm drives use the Small Computer System Interface (SCSI) and the electronics are included in each drive. The tape drive subsystem electronics interface to the SCSI bus through a SCSI integrated circuit controlled by the microprocessors. In the record mode, the microprocessor initiates data transfer from the FIFO's to the microprocessor bus; but once started, the SCSI integrated circuit continues data transfer from the microprocessor bus to the SCSI bus in a Direct Memory Access (DMA) mode until the stop switch is activated. Transfer rates up to 2 megabytes/second are possible with the SCSI controller and electronics used although the tape drives will not accept data at this rate. The tape subsystem has a playback mode primarily for setup and troubleshooting. During playback the data is demultiplexed and input into digital-to-analog converters. Data compressors not shown on the block diagram in figure 1 are connected between the SCSI bus output of the SCSI integrated circuit and the SCSI bus input to each tape drive. Since the data compressor resides on the SCSI bus, it is not shown as a separate subsystem.

D/A Conversion Subsystem

The digital-to-analog conversion subsystem is used to monitor the digital data going onto the tapes during the record mode and coming off the tapes during the playback mode. Since the 8mm drives do not provide a true read-after-write capability, the data is monitored at the last available point before being recorded. The tape drives perform internal read-after-write to do error correction as the data is recorded. This provides a very low bit error rate for the recorded data. Reliability is provided by using redundant tape drives, monitoring of the data on the SCSI bus, and error correction.

Table 2. Recording System Features and Specifications

Tape Drives: 8mm Helican Scan, cartridge tape.

Transfer Rates: Uncompressed data, 250 kilobytes/second. With upgraded tape drives, 500 kilobytes/second. Compressed data and upgraded tape drives, 2 megabytes/second.

Storage Capability: Upgraded drives, no compression, 5 megabytes. Upgraded drives with data compression, minimum of 10 megabytes.

Redundancy: Dual tape drives and electronics.

Control: Each tape drive is controlled by a separate 68000 microprocessor. The front panel switches are controlled to prevent nonallowable switch sequences. Recorded tapes are automatically prevented from being overwritten. Loss of a data channel during acquisition is automatically detected, an LED is turned on, and saturation levels are stored on tape for the failed channel.

Housekeeping Data: Gains, run number, time code, and voice annotation.

Multiplexed Channels: 20.

Data Monitoring: D/A converter for each data channel.

Bus: Small Computer Systems Interface (SCSI).

Display: Time remaining on the tape, channels deactivated or failed, and data tape loaded.

Data Buffering: 2 kilobyte FIFO buffer on each channel.

Data Interface: Serial or parallel.

CONCLUSION

A field deployable, digital acquisition and recording system has been developed that is very versatile and although specifically developed to satisfy the requirements for an acoustic measurement system, can be applied to other measurement needs. The system was designed to allow improved components to be incorporated as they become available and are needed, and also to allow the acquisition and recording systems to be used independently of one another or with other systems. The acquisition system has operated very successfully in several field tests. The recording system is currently being integrated with the acquisition system and being tested in the laboratory. The first field test of the complete acquisition and recording system is scheduled for January 1991. Future additions to the system will include computer monitoring of data channel, automatic activity logging, and expanded tape annotation.

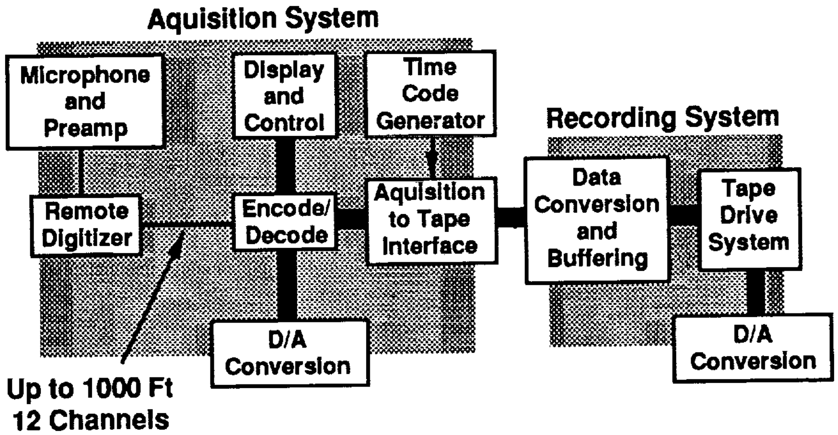

Figure 1: Digital Acoustic Measurement System Block Diagram

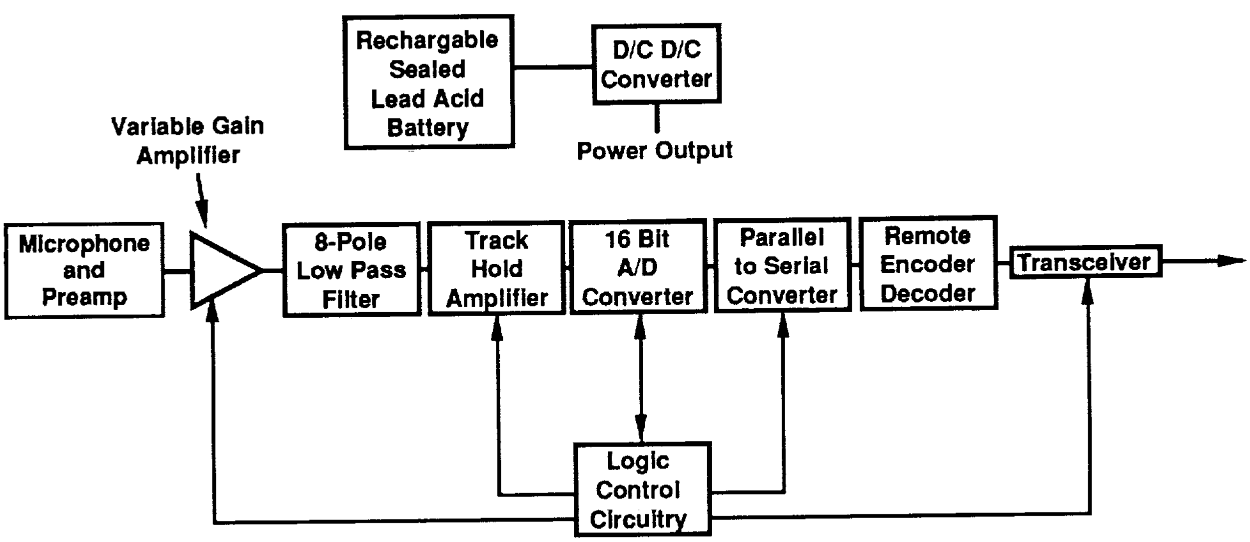

Figure 2: Remote Digitizer Block Diagram

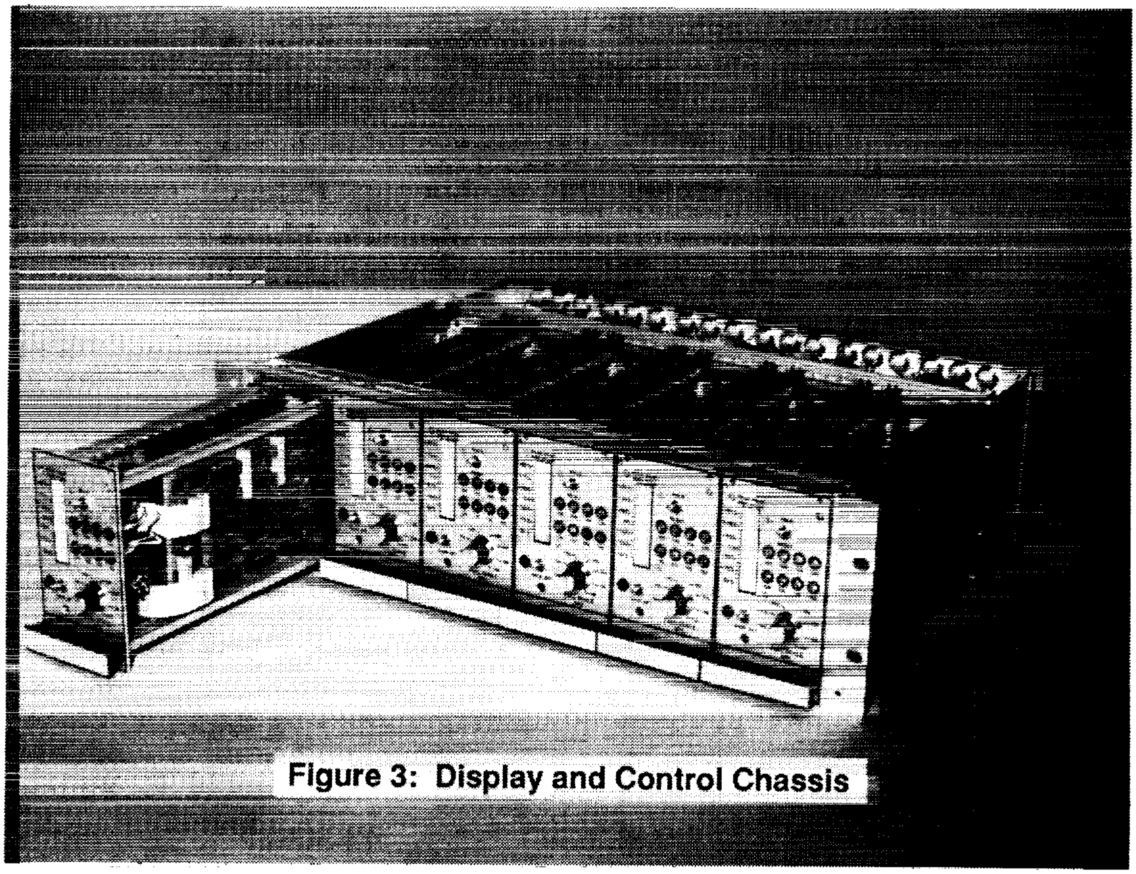

Figure 3: Display and Control Chassis

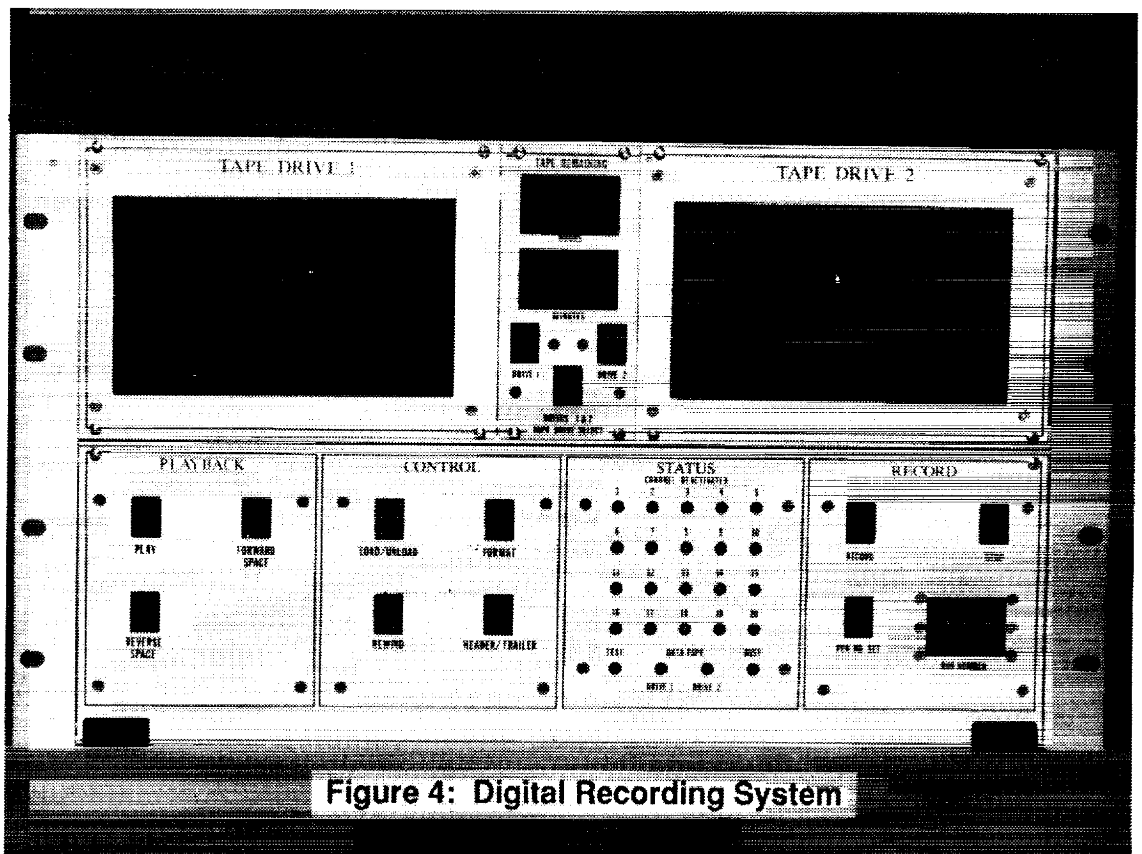

Figure 4: Digital Recording System