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A Sophisticated, Multi-Channel Data Acquisition and Processing System for High Frequency Noise Research

David G. Hall and James Bridges
Sverdrup Technology, Inc.
Lewis Research Center Group
Brook Park, Ohio

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A SOPHISTICATED, MULTI-CHANNEL DATA ACQUISITION AND PROCESSING SYSTEM FOR HIGH FREQUENCY NOISE RESEARCH

David G. Hall and James Bridges

Sverdrup Technology Inc.
Lewis Research Center Group
2001 Aerospace Parkway
Brookpark, OH 44142

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I. ABSTRACT

A sophisticated, multi-channel computerized data acquisition and processing system has been developed at the NASA Lewis Research Center for use in noise experiments. This technology, which is available for transfer to industry, provides a convenient, cost-effective alternative to analog tape recording for high frequency acoustic measurements. This system provides 32-channel acquisition of microphone signals with an analysis bandwidth up to 100 kHz per channel. Cost was minimized through the use of off-the-shelf components. Requirements to allow for future expansion were met by choosing equipment which adheres to established industry standards for hardware and software. Data processing capabilities include narrow band and 1/3 octave spectral analysis, compensation for microphone frequency response/ directivity and correction of acoustic data to standard day conditions. This system has been used successfully in a major wind tunnel test program at NASA Lewis to acquire and analyze jet noise data in support of the HSCT (High Speed Civil Transport) program.

II. INTRODUCTION

In response to recent interest in high speed civil transport aircraft, NASA Lewis is conducting a program to develop various enabling technologies. Wind tunnel testing with reduced-scale models of various jet nozzles is included in this effort. In the case of a typical full-sized civil transport engine, most of the jet noise occurs at frequencies between 50 Hz and 10 kHz. With a reduced-scale model, this noise shifts to proportionately higher frequencies. Testing of a typical 1/8 scale model requires sound measurements from approximately 400 Hz to 80 kHz.

The data system described in this paper was developed to alleviate deficiencies noted during jet noise research at NASA Lewis during 1989/1990 (ref 1). At that time, high frequency jet noise data was recorded on analog tape and played back at reduced speed to be digitized by an existing low speed data system. Narrow band spectral estimates were produced and transferred to Personal Computers and then processed to obtain 1/3 octave files with corrections for atmospheric absorption, model scaling and microphone effects. The time from tape recording to final output was typically 2 to 3 days. Results from previous tests were not always available when they were needed to make decisions about subsequent model configurations.

A new data system was developed, using all-digital techniques to consolidate the acquisition and processing functions, reduce analog tape usage, and provide next-day analysis results. General system design requirements included:

a) 32 analog inputs with a frequency response of 0 to 100 kHz.
b) Magnetic disk storage for at least 50 test conditions.
c) Incorporation of standard hardware and software.
d) Portability.
e) Provisons for future upgrades.
f) Minimize cost through the use of off-the-shelf components.

The system was designed to allow use in a wide variety of research disciplines.

III. SYSTEM REQUIREMENTS

The detailed system requirements began with the need to acquire 32 analog signals with frequency content from 0 to 100 kHz. A rate of 250 kHz per channel was chosen as a practical minimum. Overall system throughput was calculated as 8,000,000 samples per second. Additional requirements were to provide simultaneous sample and hold on all channels with at least 70 dB of dynamic range. A 12-bit Analog to Digital Converter (ADC) was selected. In addition, acquisition time had to be minimized due to high temperature gases in the model.

Research was conducted to find an existing data acquisition product which would meet these requirements and stay within the prescribed budget. None were found. The existing systems all featured a design whereby the ADC output was transferred directly to magnetic disk storage through a host computer, immediately following conversion. The speed of the disk drive interface limited the throughput to approximately 2,000,000 samples per second for all available systems within the budget.

A decision was made to develop a new system which avoided the disk interface bottleneck. The ADC function would be performed in a separate CAMAC (IEEE-583) subsystem, containing high speed semiconductor memory to temporarily store the digitized signals. This memory bank would be transferred, following completion of each test condition, to disk storage on a host computer using a GPIB (IEEE-488) interface when time was not critical.

IV. SYSTEM CONFIGURATION

The host computer system was procured from Concurrent Computer Corporation (model SLS-5550-02 with additional options). A block diagram is shown in figure 1. The CAMAC/ADC subsystem was supplied by DSP Technology Incorporated (see fig. 2).

The host computer is a table top Multibus system with an MC68020 CPU running at 20 Mhz. It includes a Vector Accelerator option (rated at 14 Mflops), a 663 Mbyte hard disk for on-line data storage and a magnetic cartridge tape drive (150 Mbytes/cartridge) for archiving. The color graphics CRT (640x480 resolution) is linked to a dedicated graphics processor. This system also includes an auxiliary data acquisition subsystem based on the STD+ bus with a low speed ADC and a clock driver module. Host/CAMAC communication is accomplished via a Multibus to GPIB interface (National Instruments model GPIB-796).

The CAMAC subsystem, supplied by DSP Technology, consists of two "crate" chassis using standard 19-inch rack mounting. Each crate contains a CAMAC/GPIB interface for communication with the host computer. The first crate provides 32 anti-aliasing amplifier/filter channels with gain and cutoff set by the host computer. The second crate contains a 32-channel ADC and an 8-Msample memory module. Digitization is controlled by the clock module in the host computer. Each ADC channel has an individual sample and hold amplifier. Maximum throughput is 250 k samples per second per channel. Signals from 0 to 100 kHz may be analyzed.

V. DATA ACQUISITION SOFTWARE

All data acquisition software in this system is implemented in the C programming language. The host/CAMAC interface software works by issuing function calls to GPIB library routines. The syntax for these function calls was originally developed by National Instruments Corporation. They are commonly referred to as "IBIC" functions.

CAMAC subsystem operation is controlled through an acquisition parameter file, specified by the user when the program is started. An example is shown in figure 3. Data sampling occurs in bursts, with N samples per channel in each burst (N is typically selected as a multiple of 2 to permit Fast Fourier Transform analysis). A data frame consists of one or more sampling bursts. The maximum number of frames is limited only by the capacity of the CAMAC memory.

The first few lines in the acquisition parameter file control the burst/frame sampling. ADC channels are activated as a group, with 1,2,4,6...32 used during each burst. The number of channels is the same in each burst. The "Time of Experiment" field may be used to insert a pause between frames. If this field is zero, continuous acquisition is performed. The user specifies the number of samples per channel for each burst (referred to as N above), and the analysis bandwidth (cutoff freq). The software calculates the actual sampling rate as three times the cutoff frequency or 250 kHz, whichever is less. Following the ADC clock data, one line is required in the parameter file for each active channel to specify:

a) ADC offset.
b) ADC counts/volts conversion.
c) Programmable amplifier gain.
d) Microphone serial number.
e) Engineering units/Volts conversion factor.
f) Microphone location.

Item c) is used for CAMAC setup. The others are used during data analysis.

After the GPIB controller in each crate is initialized, the software interrogates the other slots in each crate, executing a setup routine for each module found, in accordance with the data in the parameter file. The program then prompts the user for keyboard input of a "Reading Number" which it uses to form the name of the data file being created.

After entry of the reading number, the host begins to send clock pulses from the clock driver module to the CAMAC ADC. If more than one digitizing frequency/frame was specified in the parameter file, the host software issues GPIB commands to change the anti-aliasing filter cutoff between each burst. The CAMAC system digitizes the active channels and stores them in the local memory buffer. When all the required samples are converted, the host computer transfers them to disk storage via the GPIB at a rate of approximately 400 k samples/second. The program then prompts the user for the next reading number.

VI. POST-ACQUISITION DATA PROCESSING

Data processing is performed on the host computer using the IDARS software package supplied by Creare Incorporated in combination with some specialized routines. The IDARS software is used in most of the Concurrent Computer Corporation systems at NASA Lewis for signal processing. The following functions are implemented:

a) De-multiplexing. This function takes the raw data file transferred from the CAMAC system as input and creates an individual output file for each active ADC channel with conversion to engineering units. If more than one digitizing rate per frame was used, a separate file is generated for each rate.

b) Calculate a narrow band spectral density for each file using an FFT algorithm.

c) Apply amplitude compensation based on frequency and microphone/model location for:

i) Anti-aliasing filters.
ii) Microphone windscreen/directivity.
iii) Microphone frequency response.
iv) Test facility cable frequency response.

d) Calculate 1/3 octave power levels, normalizing all channels to a common distance based on microphone locations. Frequency-dependent atmospheric absorption effects are removed and output files are generated for plotting.

VII. OUTLOOK FOR TECHNOLOGY TRANSFER AND FUTURE UPGRADES

The system described in this paper could easily be modified to include expanded capabilities or to support experiments in other fields besides acoustics.

Expansion of the CAMAC subsystem could be accomplished by adding additional crates. One advantage of specifying CAMAC-compliant hardware for the ADC subsystem is the large number of potential vendors (over 50 identified).

The host computer could be enhanced by substituting a higher performance unit from Concurrent Computer Corporation. Substitution of a different brand of host computer is feasible as well, since the C programming language and IEEE-488 interface are available with many different brands of computer. Modifications to the software described in this paper would affect the IEEE-488 and ADC clock control subroutines. Various versions of the Creare IDARS analysis software are compatible with other host computers. A general purpose signal analysis package which permits the user to write customized processing functions could be substituted for the IDARS software as well.

A software enhancement is in work to perform automatic control of the gain of the anti-aliasing amplifier/filters. This gain is currently set at a fixed value in the acquisition parameter file. In the future, the system will monitor the voltage level on each channel and modulate the gain to insure an optimal dynamic range setup. Gains will be updated approximately once per second prior to the start of data recording, but will be fixed during recording.

VIII. CONCLUSION

The system described in this paper has been used to reduce the use of analog tape recording of jet noise data at NASA Lewis in support of the HSCT program. Data processing time has been reduced from 2 or 3 days to a few hours, providing timely support for test program decision making. Standard hardware/software were incorporated to insure long term maintainability and multiple options for future performance upgrades. The technology developed for this system (particularly the data acquisition software) is a good candidate for transfer from NASA Lewis to private industry.

REFERENCE

1. E.A. Kresja, B.A. Cooper, D.G. Hall and A. Khavaran. "Noise Measurements From an Ejector Suppressor Nozzle in the NASA Lewis 9- by 15-Foot Low Speed Wind Tunnel," NASA TM-103628 (1990). Also, AIAA Paper 90-3983 (1990).

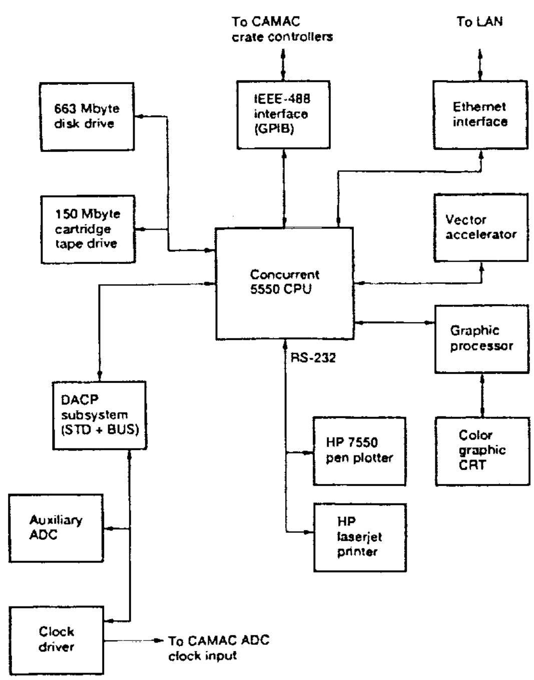

Figure 1.—Host computer system.

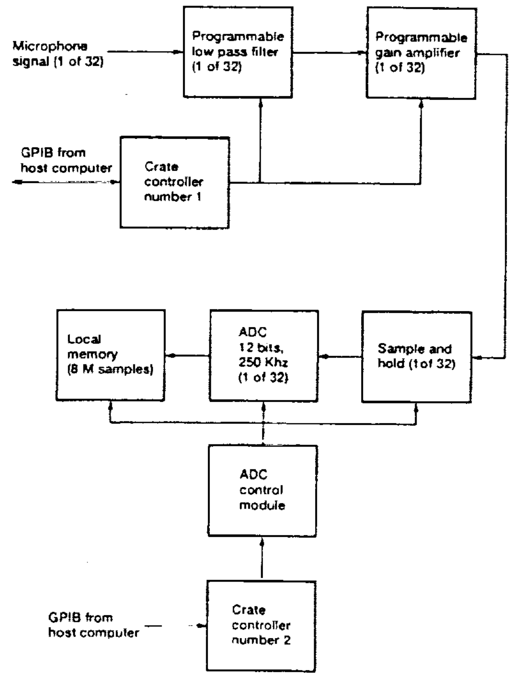

Figure 2.—CAMAC subsystem.

Parameter Structure

Number of frames:	40	Number of bursts:	2
Number of channels:	20	First channel:	0
Time of experiment:	67.385787		

	Sample per burst	Cutoff frequency	Sample frequency
Burst 1:	2048	80000.000	240000.000
Burst 2:	2048	6000.000	18018.018

Amplifier Structure								
	Bits at 0V	Bits/V	Gain 1402	BKSN	EU/V	xloc	yloc	zloc
ch01:	2048	409.600	5.000	1572531	3.048e+01	−98.60	117.00	0.06
ch02:	2048	409.600	5.000	1518373	3.080e+01	−65.50	112.90	0.12
ch03:	2048	409.600	5.000	1518421	3.081e+01	−40.20	109.90	0.09
				•				
				•				
				•				
ch32:	2048	409.600	5.000	800489	3.080e+01	33.90	39.97	0.03

Figure 3.—

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David G. Hall and James Bridges

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Lewis Research Center Group
2001 Aerospace Parkway
Brook Park, Ohio 44142

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