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ALDAS User's Manual

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SUMMARY

The Acoustic Laboratory Data Acquisition System (ALDAS) is an inexpensive, transportable means to digitize and analyze data. The system is based on the Macintosh II family of computers, with internal analog-to-digital boards providing four channels of simultaneous data acquisition at rates up to 50,000 samples/sec. The ALDAS software package, written for use with rotorcraft acoustics, performs automatic acoustic calibration of channels, data display, two types of cycle averaging, and spectral amplitude analysis. The program can use data obtained from internal analog-to-digital conversion, or discrete external data imported in ASCII format. All aspects of ALDAS can be improved as new hardware becomes available and new features are introduced into the code.

1.0 INTRODUCTION

The helicopter industry requires a more detailed analysis of acoustics data than it did in the past, for correlation with increasingly sophisticated methods of acoustics prediction. Increasing concerns about the ability to detect helicopters, and the increased ability to predict precise spectra, have generated the need for a low-cost, transportable, easy-to-use, digital acquisition and analysis package. Typically, acoustics data has been acquired on analog tape and then either analyzed directly with an analog-output narrow- or octave-band analyzer, or digitized with a minicomputer-based system and analyzed through software.

The analog-output analyzer imposes many user and operational limitations. These limitations include strictly controlled input duration and output resolution, and a restricted number of input channels—typically only one or two input channels are available at a time. Another limitation is that although most analyzers can transport the results to other types of machines, they frequently cannot transfer the exact set of analyzed data for further analysis or display.

The minicomputer-based technique overcomes many of the limitations of the analog-output devices. It is versatile, it can handle simultaneous input data channels, and the data can be saved and used by other applications or machines. However, the minicomputer-based system is not easily transportable and can be expensive. The Acoustic Laboratory Data Acquisition System (ALDAS) incorporates the advantages of the minicomputer system while overcoming its two major limitations.

2.0 SYSTEM SPECIFICATIONS

ALDAS is primarily geared for the in-flight acoustics data acquired by the YO-3A Acoustics Research Aircraft (ref. 1). The YO-3A aircraft is essentially a quiet microphone platform that acquires and records data while flying in formation with the research aircraft. ALDAS specifications are listed in table 1 and explained below.

Table 1. ALDAS system requirements

	System requirements	System specifications
1.	4-channel simultaneous digitization	4-channel simultaneous digitization
2.	16-bit digitization on all channels	3 channels at 16 bits 1 channel at 12 bits
3.	0 to 45,056 samples/sec	0 to 50,000 samples/sec
4.	Easily transportable system	Macintosh II–based system
5.	Easy-to-use system	System uses Macintosh interface standards
6.	3,604,480 samples of data accessible	Currently can access 1,500,000 samples but will be upgraded in future to 7,675,000 samples
7.	Data interchangeable with other systems and codes	Imports and exports ASCII data files

1. Four-channel simultaneous digitization. The YO-3A has three microphones, one on each wingtip and one on the vertical tail tip. Since flight data is unsteady in nature (no matter how "steady" the flight condition), the acoustics data must be digitized so that no phase shift exists between microphones. In addition, the YO-3A acoustics data and the helicopter data are related by a common time code or once-per-revolution pulse (1P), which is recorded on both aircraft. It is necessary to digitize the time code or 1P at the same time as the three acoustics signals in order to tie the data together. Thus, the requirement for the number of simultaneous channels is four.

2. Resolution: three channels at 16 bits, one channel at 12 bits. Acoustics data, by its nature, is composed of many waves, with a wide variation between wave amplitudes. This variation results in amplitudes at the off-harmonic frequencies that are much lower than those at the harmonic frequencies. To guarantee that the noise level in the acoustics data is low enough to allow the low-amplitude variations to be resolved, 16-bit analog-to-digital resolution is required. However, since only three channels are needed for the microphones on the YO-3A, and the fourth channel is for the 1P or time-code pulses, the resolution for the fourth channel does not have to be as great. Although 16 bits is desirable, 12-bit resolution is adequate for the fourth channel.

3. Data acquisition rate: 0 to 50,000 samples/sec. ALDAS should be usable for a wide range of aircraft tests, yet maintain an adequate resolution in the time axis. A data-acquisition rate of

4096 samples/rev is assumed to be adequate for all rotorcraft applications of the data, and rotation rates of 4.5 to 11.0 rev/sec are typical for full-scale rotorcraft. This yields a maximum sample-rate range requirement of 0 to 45,056 samples/sec.

4. Macintosh II–based system. Frequently, acoustics testing takes place at remote sites. The ability to reduce the acoustics data at these sites between flights is useful to ensure that the test acquires the best available data set. Thus, ALDAS must be easily transportable and must not have special environmental requirements or an extensive setup time.

5. Macintosh interface standards. The system should be easy to use.

6. Number of accessible data samples: currently 1,500,000 samples, but will be upgraded in the future to 7,675,000 samples. ALDAS must be able to handle several seconds of data per channel for all channels concurrently. Typically, to eliminate unsteady effects, several cycles of data are averaged to yield a representative cycle, but plotting several cycles of the raw data aids in tracking anomalies in the averaged cycle. Data sets of up to 45,056 samples per second per channel for 20 seconds and four channels, or up to 3,604,480 samples of data, should ideally be accessible at a time.

7. Imports and exports ASCII data files. Data must be interchangeable with other computer systems and codes.

3.0 SYSTEM DESCRIPTION

ALDAS consists of three parts: the microcomputer, the analog-to-digital boards, and the acquisition/analysis software. The data can enter ALDAS from an external ASCII file, an analog tape recorder, or directly from the microphone outputs.

The microcomputer chosen was the Macintosh II series because it is easy to use, has good graphics capability, is widely available at low cost, and can be easily transported. The original system, which was developed for the Macintosh II, was easily converted when the Macintosh IIx was introduced. Although the Macintosh II is perhaps underpowered in CPU, clock speed, and memory capacity for this application, the Macintosh IIx and future machines show excellent growth in CPU capability, with the advantage of maintaining software compatibility with earlier machines. The current 8-Mbyte-RAM limit of the machine does not meet the maximum data-samples requirement. However, the release of the Macintosh Operating System 7.0, and the introduction of 4-Mbyte SIMMs as well as virtual memory configurations, will overcome this limitation in the near future.

The analog-to-digital boards selected were the GW Instruments MacAdios II motherboard with three GWI-HAD daughter boards. These boards most closely met the system requirements at the time of procurement. (New products and improvements are continually being introduced, many of which might readily be used for ALDAS and perform as well, or better than, the current configuration.) The software developed for ALDAS can be easily modified to accommodate different brands of analog-to-digital boards. The MacAdios II motherboard is a 12-bit internal board that has a

maximum rate of 144,000 samples/sec. The daughter boards are 16-bit with a maximum rate of 50,000 samples/sec, and they physically mount on the motherboard. These boards can be externally triggered, can run on an external clock, and can acquire the four channels of data simultaneously.

The acquisition/analysis software, or ALDAS Program, was written in Lightspeed Pascal to conform to the Macintosh User Interface Guidelines (ref. 2). This program controls the analog-to-digital boards, the import/export of ASCII data, the analysis of data, and the display of raw or analyzed data. General ALDAS Program features are

- Automatic calibration of channels

- Scrollable data-viewing windows for up to four data sets

- Automatic input of user-selected data points into data lists

- Two methods of averaging

  — using on-input low-high trigger

  — using user-selected start points in time history

- Digital filtering using two data-window types

- Spectral analysis using eight data-window types

- Graphics output to printer

- User-selectable

  — data type (choices are Acoustics and General)

  — viewing resolution of data

  — x and y display units on data plots

  — channel combinations for analog-to-digital conversion

- Can save data in ASCII format for input to other programs

- Can import data in ASCII format

- Can save and recall digitizing settings

The remainder of this manual will concentrate on the discussion of these features and instructions for their use.

4.0 ALDAS PROGRAM USER INSTRUCTIONS

These user instructions will start with general information about the Macintosh interface and then follow the functional lines of the program, starting with data acquisition, display, and analysis. This organization was chosen to give the user a feel for how to apply, as well as how to use, the program.

4.1 General Menu and Dialog Information

Like any Macintosh application, the ALDAS Program relies on commands found in menus, or their keyboard-command equivalents, to initiate actions. The ALDAS Program uses three types of menus, shown in figure 1: pull-down, hierarchical, and pop-up. Pop-up menus appear only in dialog boxes and windows; pull-down and hierarchical menus are activated from the ALDAS Program's main menu, which appears when the program is started.

(a) Pull-down.

(b) Hierarchical.

(c) Inactive pop-up.

(d) Active pop-up.
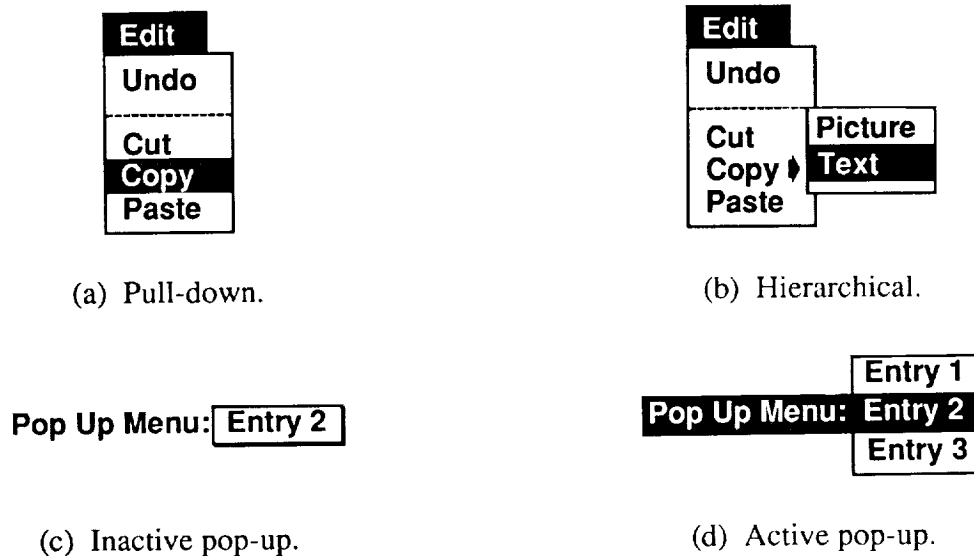
Figure 1. Menu types.

A composite of the pull-down and hierarchical menus for the ALDAS Program is shown in figure 2. The keyboard-command equivalents for the menu items are indicated to the right of the menu commands and are summarized in table 2. If a solid right arrowhead (▶) is in the keyboard command location, then a hierarchical menu is present and can be activated by dragging the mouse pointer over the arrowhead. An ellipsis (...) after a menu item indicates that choosing that command will activate a dialog box (described below). The absence of an ellipsis is an indication that the command will usually be performed without a dialog box. However, some graphics options are not compatible with some data types, and the combination of a commanded option and an incompatible data type will force a dialog box to appear.

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Table 2. ALDAS program keyboard commands

Character key	Command key combination			
	⌘	⌘-Option	⌘-Shift	⌘-Option-Shift
1,2,3,4	Bring plot window x to front	Activate x list window	[Reserved for system]	Bring x list window to front if list active
C	Copy			
E	Save as ASCII data			
I	Import ASCII data			
N	Amplitude Spectrum Analysis Go	Amplitude Spectrum Analysis Options dialog box		
P	Print front graph			
Q	Quit			
T	Time History Go	Time History Options dialog box		
V	Paste			
X	Cut			

File Edit Font Size Acquire Analyze Plot Special Windows

Window 1 ⌘1
Window 2 ⌘2
Window 3 ⌘3
Window 4 ⌘4

Save Settings ...
Load Settings ...
Print Settings ...
- - - - - - - - - -
Save as ASCII ... ⌘e
Import ASCII ... ⌘l
Print Graph ⌘p
- - - - - - - - - -
Quit ⌘q

About ALDAS ...
- - - - - - - - - -
DAs

List 1 ▶
List 2 ▶
List 3 ▶
List 4 ▶
- - - - - - - - - -
FFT Windows ▶
FFT Options ...
Edit Info ...

Activate ⌘-O (1,2,3,4)
Bring To Front ⌘-O-S (1,2,3,4)
- - - - - - - - - -
Clear Cells

Rectangular
Hanning
Tenth Cos Taper
Quarter Cos Taper
Kaiser-Bessel
Parzen
Welch
Blackman Harris

Time History ▶

Go ⌘ t
Options ... ⌘-O t

Average ...
Amp. Spectrum ▶
Digital Filter ...

Go ⌘ n
Options ... ⌘-O n

Calibrate ...
Digitize ...

Figure 2. ALDAS Program menu choices.

Dialog boxes are the way that certain options are chosen and control data is input to the ALDAS Program. The two types of dialog boxes are modal and modeless; their formats are shown in figure 3. Modal boxes have no title bar across the top and require an action such as clicking on the Continue or Cancel button before anything else can be done by the machine. In contrast, modeless dialog boxes have a title bar across the top and act as normal windows, so actions not associated with the dialog box can be performed even though the dialog box is active.

Channel 1
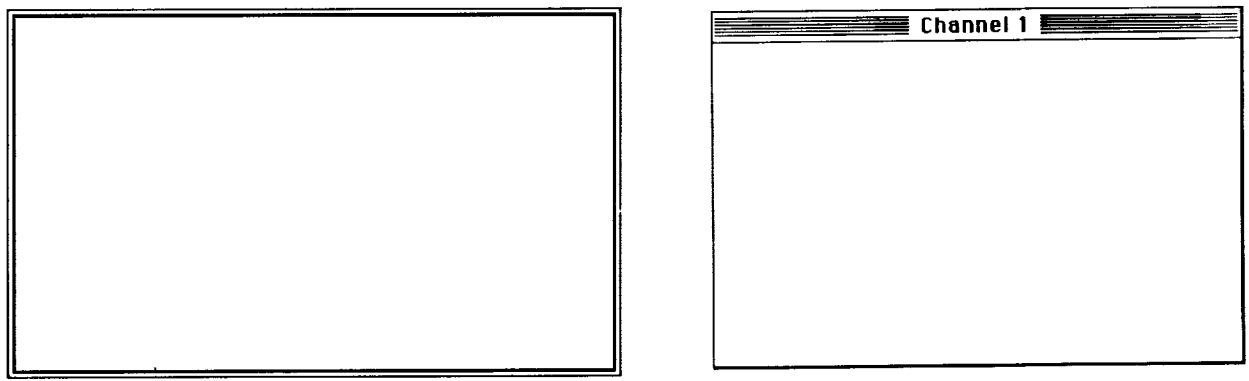
(a) Modal. (b) Modeless.

Figure 3. Dialog box formats.

Windows and dialog boxes contain several types of input fields and controls: editable text fields, check boxes, radio buttons, control buttons, pop-up menus, and scroll bars. Figure 4 shows what each of these looks like (except pop-up menus, which were shown in figure 1). The insertion cursor can be moved among editable text fields within a window or dialog box by pressing the tab key or clicking on the desired field with the mouse. Check boxes and radio buttons are turned on and off by clicking on them. Control buttons are activated when they are clicked on. Pop-up menus appear when the mouse button is depressed and the pointer held over the menu indicator. The Cancel button always closes the dialog box it is in without taking any action or retaining the values entered in that dialog box.

Static Text   **Editable Text**

(a) Text fields.

☐ **Channel 3**   ☒ **Channel 1**

(b) Check boxes.

○ **Time**   ◉ **Points**

(c) Radio buttons.

(**Go**)   (**Cancel**)

(d) Control buttons.

(e) Scroll bar.

Figure 4. Standard Macintosh input fields and controls.

4.2 Data in the ALDAS Program

Data can be input into the ALDAS Program via two methods: importing ASCII data, and converting analog data (from a tape recorder or from microphone outputs) to digital. Data, once it is in ALDAS, is considered to be either of general or acoustics type. The general data type can have any units, whereas the acoustics data is defined to be in pascals. Both data types are stored in integer form and use a linear calibration function as well as decibel gains and attenuations for conversion from integer counts to real data.

4.2.1 Importing ASCII Data– Data from sources other than ALDAS can be imported through the use of an ASCII input file, which must be in the form of one value per line, each line ending in a carriage return. The procedure for importing data is as follows:

1. Choose Import ASCII from the File menu (see fig. 2). This activates the dialog box shown in figure 5.

Figure 5. Import ASCII dialog box.

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2. In the editable fields, enter information pertaining to the data to be input. In the Number Samples field, enter the number of lines of ASCII data in the input file. The Sample Rate is in samples/sec. The Number Samples and Sample Rate fields must be nonzero to perform the data input.

3. Click on either the Acoustic Data or General Data radio button to set the data type. This data type can be changed later (see section 4.5.2).

4. Click on either the Real Data or Integer Data radio button to tell the input routine which is being imported. If Real Data is checked, the program will calculate a slope and intercept for the data set and convert the real values to integer count values in the range ±32,700. If Integer Data is checked, the program will save the integer values of the input stream and use the slope and intercept entered in the dialog box.

5. To import the data after entering the information, click on Continue. To close the dialog box without performing any action, click on Cancel.

When the Continue button is clicked, the Open File dialog box is activated.

1. Enter the requested information about the file from which the data is being imported.

2. Click on Continue.

ALDAS then reads the number of lines indicated in the Number Samples field and performs the operations indicated by the choice of Real Data or Integer Data. A File dialog box is activated to open the output file.

1. Enter the requested information about the file in which the imported data is to be stored.

2. Click on Continue.

The program then stores the data in the ALDAS-formatted file indicated in the File dialog box.

4.2.2 Analog-To-Digital Conversion— Analog-to-digital conversion is done in two steps: acoustic calibration (section 4.2.3) and data acquisition (section 4.2.4). When making analog-to-digital conversions, the ALDAS Program drives the GW Instruments boards. However, with minimal program changes, other brands of analog-to-digital boards could be substituted. The following aspects of the conversion should be considered when making these program changes.

For helicopters, whose data is normally considered on a per revolution basis, data analysis involving fast Fourier transforms (FFT) is easier if the number of samples/rev is a power of two. Figure 6 shows the number of samples/rev versus rotor rpm for a sample rate of 50,000 samples/sec. The dashed lines indicate the samples/rev values that are a power of two. As can be seen, for normal helicopter revolution rates (206 to 310 rpm), there is no problem getting up to 8192 samples/rev. However, for tilt-rotor rates (516 to 660 rpm) and model-scale rates (1345 to 3300 rpm), a set of digitizing boards with a higher samples/sec capability will be required to obtain high-resolution data.

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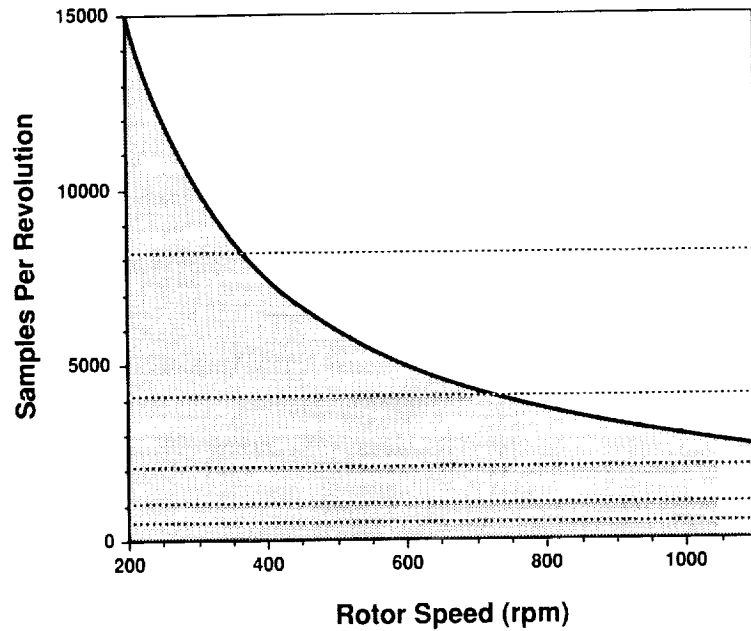
Figure 6. Samples/rev envelope for a rate of 50,000 samples/sec.

Also to be considered in obtaining a power-of-two samples/rev value is the discrete nature of the determination of the sample rate for the GW Instruments boards. The sample rate (in samples/sec) is determined by the equation

$$\text{Sample Rate} = \frac{1,000,000}{(\text{range})(\text{mult})}$$

where

$$\text{range} = 1; 10; 100; 1000; 10,000$$

$$\text{mult} = 2, 3, 4, ..., 6553$$

In most cases, the calculated sample rate will not be exactly the desired rate. The ability to connect an external clock to the boards allow this shortcoming to be overcome.

Another consideration when configuring the analog-to-digital conversion is the voltage ranges of interest. The available ranges for the GW Instruments boards are ±10, ±5, and ±2.5 v; they are selected by jumper blocks on the boards. If the input voltage exceeds the voltage range selected on the digitizing boards, a band-edged signal results. Conversely, if the input voltage is very low compared to the voltage range, low resolution and a low signal-to-noise ratio results. The normal practice is to leave the boards set at a nominal value and use amplifiers to adjust the input voltage for optimal performance.

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4.2.3 Acoustic Calibration– The first step in analog-to-digital conversion is calibration. The ALDAS Program performs an automatic acoustic calibration of a chosen channel, given a sine wave calibration signal of a known frequency and amplitude. The acoustic calibration procedure is as follows:

1. Choose Calibrate from the Acquire menu (see fig. 2). This activates the Cal Options dialog box shown in figure 7.

Figure 7. Calibration Options dialog box.

2. Click on the radio button of the channel to be calibrated.

3. Enter the calibration value in decibels, the calibration frequency in hertz, and the calibration gain in decibels. (Note that attenuation is negative gain.)

4. To choose an analog input signal, check Analog; to choose data input from an ALDAS-formatted data file, check File. (Normal operating procedure is the Analog option.)

5. To start calibration after entering the information, click on Start . To close the dialog box without performing any action, click on Cancel.

When the Start button is clicked, the ALDAS Program takes 20,000 samples of the input signal at 20,408 samples/sec. The computer performs the acoustic calibration of the input signal by first finding the root mean square (rms) value of the input sine wave amplitude,

$$rms = \frac{\displaystyle\sum_{i=1}^{cycles} Maximum_i - \sum_{i=1}^{cycles} Minimum_i}{2(cycles)} \ (0.707107)$$

where cycles is the number of sine wave cycles in the input signal, and $Maximum_i$ and $Minimum_i$ are the maximum and minimum amplitudes of each cycle in counts. The calibration slope is then calculated from this averaged rms value using

$$Slope = \frac{10^{(CalAmp+CalGain)/20}(0.00002)}{rms}$$

where CalAmp is the Calibration Value and CalGain is the Calibration Gain in decibels from the Cal Options dialog box. The calibration intercept is then calculated by multiplying the slope by the mean signal value. Once the calibration has been calculated, the program performs a fast Fourier transform (FFT) on the first 8192 points using a Hanning window (see appendix A for FFT window information) to determine the quality of the calibration. Then a subset of the input data, the results of the FFT, and statistical information on the quality of the calibration mean, amplitude, and frequency are displayed in a calibration plot window, as shown in figure 8. The calibration slope and offset are automatically copied to the appropriate digitizing channel; however, it is advisable to print the calibration graph for permanent record using the Print Graph command on the File menu (see fig. 2).

4.2.4 Acquisition– Data is digitized through the use of the analog-to-digital conversion boards; the procedure is as follows:

1. Choose Digitize from the Acquire menu (see fig. 2). This activates the Digitize Options dialog box shown in figure 9, and up to four channel dialog boxes, one of which is shown in figure 10. The Digitize Options dialog box has two similar forms. In the default form, the per revolution options are activated (fig. 9(a)); in the other form, these options are deactivated (fig. 9(b)).

2. Check the appropriate boxes, as described below:

Channel boxes: Used to select the channels to digitize. A channel dialog box is activated for each selected channel.

/Rev Options box: Turns on the per revolution data-input options when checked. When not checked, data input is continuous with time.

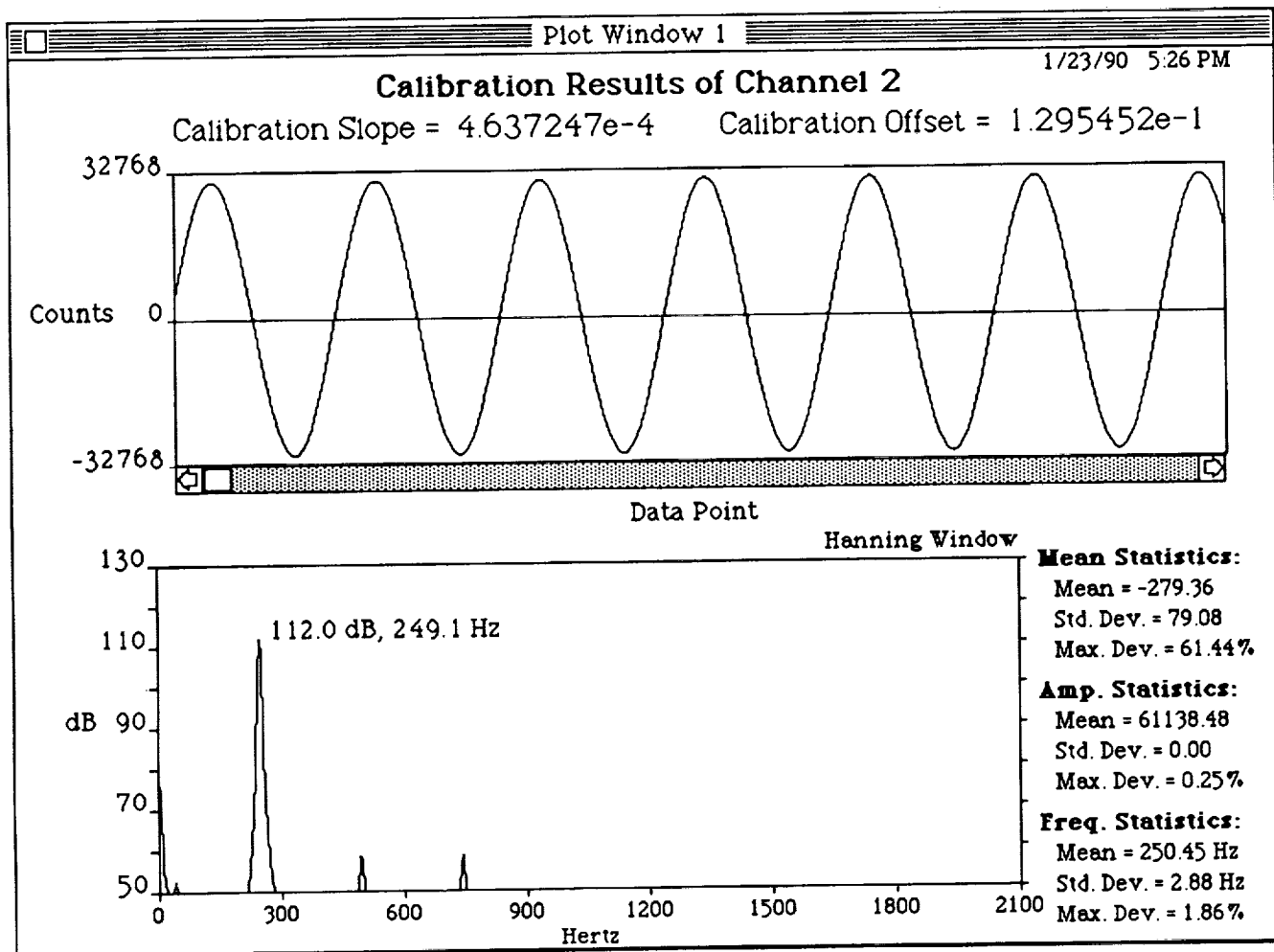Pulse Trigger box: Triggers data acquisition externally on a low-to-high pulse when checked.

1/23/90 5:26 PM

Calibration Results of Channel 2

Calibration Slope = 4.637247e-4   Calibration Offset = 1.295452e-1

Figure 8. Calibration plot window.

Digitize Options

Sample Rate:	41666	Samples/Second
Sample Length:	0.200	Seconds/rev
Filter Rate:	10000	Hertz
Samples:	8192	/rev
# cycles	1	

☒ Channel 1   ☐ Channel 3

☐ Channel 2   ☐ Channel 4

☒ /Rev Options   ☐ Pulse Trigger

Start Time: DD/MON/YR HR:MN:SC

(Prepare For Digitizing)   (Cancel)

Digitize Options

Sample Rate:	41666	Samples/Second
Sample Length:	0.200	Seconds
Filter Rate:	10000	Hertz
Samples:	8192	

☒ Channel 1   ☐ Channel 3

☐ Channel 2   ☐ Channel 4

☐ /Rev Options   ☐ Pulse Trigger

Start Time: DD/MON/YR HR:MN:SC

(Prepare For Digitizing)   (Cancel)

(a) Per revolution options on.   (b) Per revolution options off.

Figure 9. Digitize Options dialog box.

3. Enter the requested information in the editable fields, described below:

Sample Length: The duration in seconds of each revolution when /Rev Options is checked and of the total input data when /Rev Options is not checked.

Filter Rate: The analog antialiasing-filter value.

Samples: The number of samples/rev when /Rev Options is checked, and the number of samples of the total input data when /Rev Options is not checked.

cycles: The number of rotor revolutions to digitize when /Rev Options is checked.

Start Time: A reference date and time, input by the user. This can be the time the data was either acquired or digitized.

4. Enter the information for individual channels through the Channel dialog boxes, as shown in figure 10. There is a separate dialog box for each channel; the data fields for these dialog boxes are self-explanatory. If a channel was calibrated using the ALDAS Program acoustic-calibration procedure described in section 4.2.3, the calibration-slope (Cal Slope) and calibration-gain (Cal Gain) fields will contain the ALDAS values. These values can be altered by the user.

5. Click on the Prepare for Digitizing button in the Digitize Options box. This initializes the proper variables and activates the Prepare for Digitizing dialog box shown in figure 11.

Channel 1

Comments:

Channel 1

Data Saved in File: Channel 1

Analog Gain: 0   Decibels

Attenuation: 0   Decibels

Digital Gain: 1.0   Times

Cal Slope: 1.0

Cal Gain: 0

Intercept: 0.0

⦿ Acoustics Data   ◯ General Data
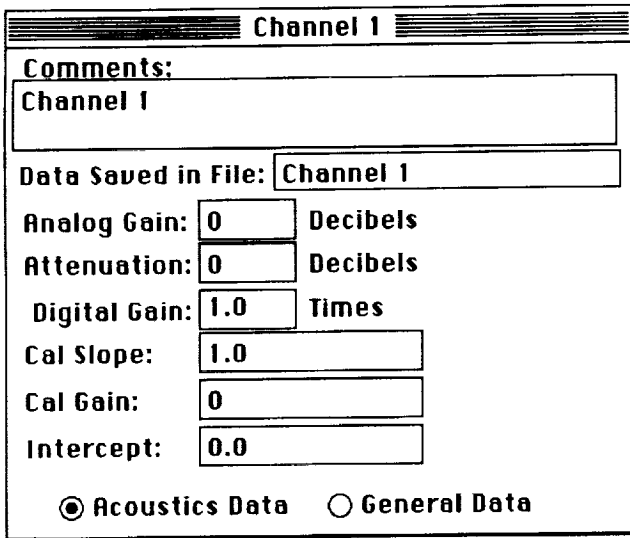
Figure 10. Channel dialog box.

⚠ Ready to start acquiring data!

[Acquire Data]   [Cancel]
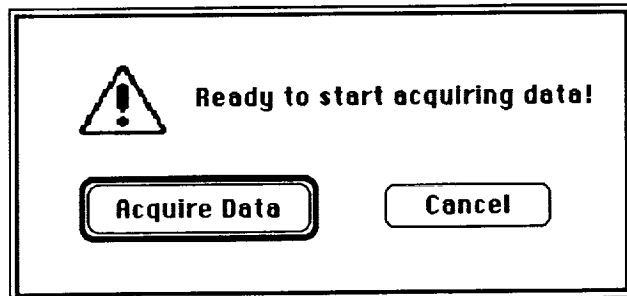
Figure 11. Prepare-for-digitizing dialog box.

6. To begin data acquisition, click Acquire Data or press the return key. To close the dialog box without performing any action, click on cancel.

When the ALDAS Program finishes acquiring the data, one of two things will happen:

1. If /Rev Options was not checked, a File dialog box will be activated, allowing the program to ask where to save the data and giving the user a chance to change the raw-data file name.

2. If /Rev Options was checked, the dialog box shown in figure 12 will be activated. Click on the appropriate command button. If requested, the program will average the data on a cycle-by-cycle basis to derive an averaged cycle and will save that averaged data. This option should only be used if the rotor rpm is *very* constant or if the Pulse Trigger option was checked in the Digitize Options dialog box. The command buttons control the following actions:

[Save Averaged Data Only]

[Save Raw Data Only]

[Save Both]

[Cancel]
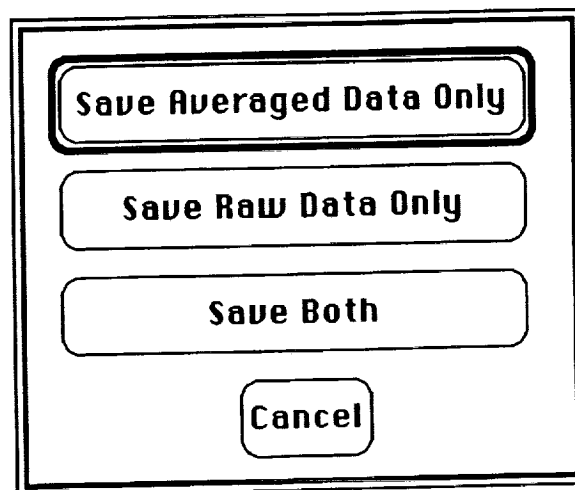
Figure 12. Post-digitizing dialog box.

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Save Averaged Data Only: Saves only the averaged cycle of data.

Save Raw Data Only: Saves the raw data only as a continuous stream; does not average the data. Note that the data is saved as a continuous data stream with a constant time base even if the data is discontinuous, because the Pulse Trigger was activated.

Save Both: Averages the raw data and saves both raw and averaged data.

Cancel: Returns control to the Digitize Options dialog box without saving any data.

When raw data is saved, the program inserts "Raw-" into the beginning of the file name. For averaged data calculated by this method of averaging, the program inserts "Ave-" into the beginning of the file name. Information from the dialog boxes is saved along with the data, and control returns to the Digitize Options dialog box. The method of viewing this information and displaying the data will be covered in section 4.3.

Since it is time-consuming to set up the digitizing parameters, a means of saving, restoring, and printing these values has been included in the ALDAS Program. These functions are controlled by the Save Settings, Load Settings, and Print Settings menu choices on the File menu (see fig. 2).

Save Settings: Saves the current digitizing settings in the designated settings file.

Load Settings: Restores the digitizing settings from a designated settings file to the current settings file.

Print Settings: Prints the parameters for the current digitizing settings for all four channels.

Care should be taken when using saved settings if the configuration of the input source has changed, because this may cause the calibration values to be different than those saved.

4.3 Data Display

All data either acquired, imported, or calculated by the ALDAS Program can be viewed in a graphical form through the use of data plot windows, which are described in section 4.3.1. Data plot windows are activated by choosing Amplitude Spectrum in the Analyze menu (see section 4.4.2) or Time History in the Plot menu (see section 4.3.2). There can be up to four data plot windows open on the desktop at any time. These windows can contain raw time-history data, a frequency spectrum, or averaged time-history data. In general, the user can choose the x and y data units for the plot requested. The axis units are chosen via the radio buttons contained in the Display Options dialog box, which is activated from the Options submenu and shown in figure 13. The x-axis choices are Points, Time, and Frequency, and the y-axis choices are Counts, Pascals, decibels, and General. Only the x and y choices that apply to the type of data being displayed will be shown to the user.
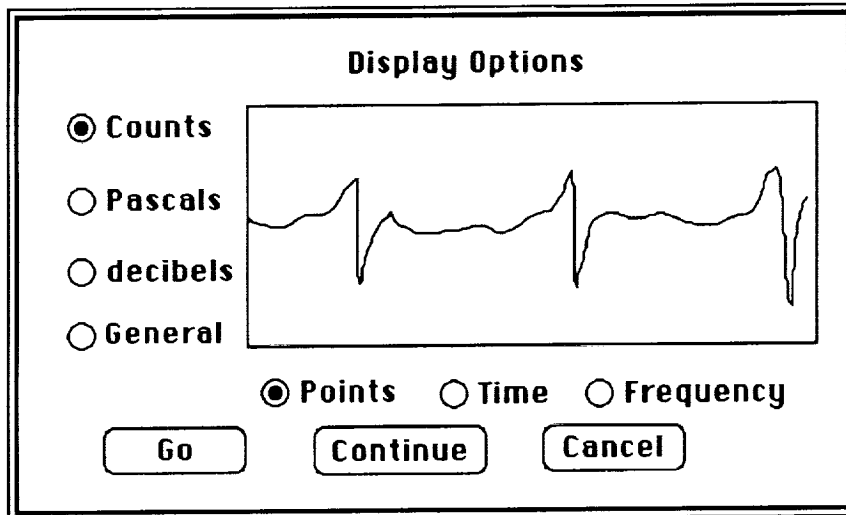
Figure 13. Display Options dialog box.

A useful side effect of the four data plot windows is the ability of the program to show a data stream in two or more data plot windows at once, in either the same or different axis units. This allows easy comparison of different parts of the data stream (see section 4.3.1), especially on a system that has a large monitor.

An active data plot window that is hidden may be brought to the front by choosing the desired window from the Windows menu (see fig. 2). Only the data plot windows that are activated are accessible in this manner.

A data plot window can be printed when it is the front window. All information shown in the window is printed. This printout is performed by choosing Print Graph from the File menu (see fig. 2).

4.3.1 Common Data Plot Window Elements– Certain controls and indicators are common to all data plot windows, independently of the type of data displayed. These common elements are shown in figure 14, a screen image of one data plot window, and described below.

Cursor button: Toggles the cursor on and off when clicked. When the cursor is on, a vertical cursor line appears in the plot frame; it follows the mouse pointer when the mouse pointer is in the plot frame. In addition, above the Cursor button, the x and y values of the intersection of the data trace and the cursor line are displayed in the plot's x and y units.

Viewing Resolution radio buttons: Indicate the decimation factor, for the x axis, of the data displayed. For example, if 1/2 is checked, every other point is plotted; if 1/4 is checked, every fourth point is plotted. This allows the user to examine the data for trends and choose where to look in more detail.

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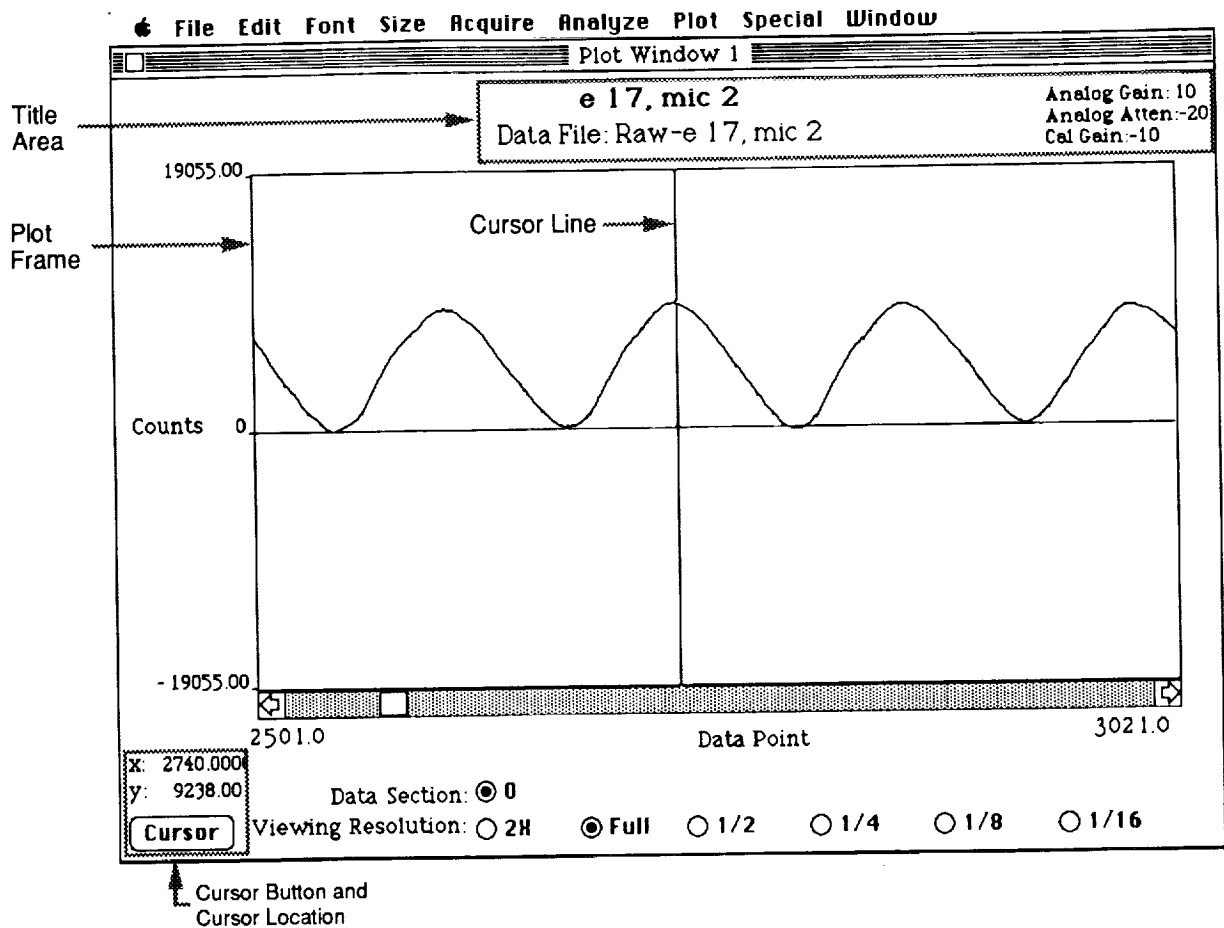
Figure 14. Common data plot window elements.

Data Section radio buttons: A dynamic set of radio buttons that indicate which 32,767-point section of data is currently displayed in the plot frame. For example, if a data set has 68,054 data points, it will be divided for display into three sections: section 0, points 0 to 32,767; section 1, points 32,768 to 65,534; and section 2, points 65,535 to 68,054. Three corresponding Data Section radio buttons, labeled 0, 1, and 2, will appear below the plot frame. If the plot frame were displaying points 33,767 through 34,287, the button labeled 1 would be checked. You can change sections of data by clicking the radio button for the section you want. These buttons do not affect the stored data, as the full set of data is stored in RAM at this point. In addition, any action such as filtering, averaging, or fast Fourier transforming ignores these section boundaries, and the data is treated as one continuous set.

Horizontal Scroll Bar: Acts like any standard Macintosh scroll bar and, in effect, translates the plot frame over the data. The numbers just below each end of the bar are the starting and ending x-values viewed in the plot frame, in the units indicated.

Title Area: Displays the file name for the data shown in the plot window, and the comments stored with the data during data import (section 4.2.1, fig. 5) or data acquisition

(section 4.2.4, fig. 10). In addition, the analog gain, analog attenuation, and calibration gain in decibels is shown if the data type is Acoustics. When the data in the window is the result of an FFT, the name of analysis window used is also shown in this area.

4.3.2 Displaying Time History Data– To create and display a plot of raw, averaged, or digitally filtered time-history data:

1. Choose Time History from the Plot menu (see fig. 2). A hierarchical menu is displayed with two choices, Go and Options.

2. To define, or redefine, the units for the plot's x and y axes, choose Options. This activates the Display Options dialog box shown in figure 13.

   a. Choose the desired x and y units by clicking on the appropriate radio buttons. The x-axis choices are Points and Time, and the y-axis choices are Counts, Pascals, decibels, and General.

   b. Click on the appropriate command button. The three command buttons are

      Go: Accepts the radio button inputs, closes the dialog box, and creates and displays a plot.

      Continue: Accepts the radio button inputs and closes the dialog box, but does not create a plot.

      Cancel: Closes the dialog box without accepting the radio button inputs or creating a plot.

3. To create a plot using the currently defined x and y units, choose Go from the Time History submenu. (Note: Axis units can also be defined when FFT results are plotted, but different choices are allowed. For example, an FFT plot can have frequency on the x axis (see section 4.4.2); a time history plot cannot. If the currently defined x unit is Frequency and you choose Go from the Time History submenu, a time-history Display Options box will be activated automatically. Choose new units for the x axis, and click the appropriate command button.)

4.3.3 Data Lists– Specific data points can be selected from the data plots and listed in data lists, which are viewed in data list windows. There are four data list windows, corresponding to the four data plot windows; data selected from a given plot window goes to the data list of the same number. Choosing a list from the Special menu (see fig. 2) activates a hierarchical menu, whose options are

   Activate: Activates the data list and makes it visible as the front window.

   Deactivate: Deactivates the data list and hides its window.

   Bring to Front: Brings a data list window to the front when it is active but hidden.

   Clear Cells: Deletes all data in that data list and resets the data point number to 0.

To transfer data from an active data plot window to a data list (fig. 15):
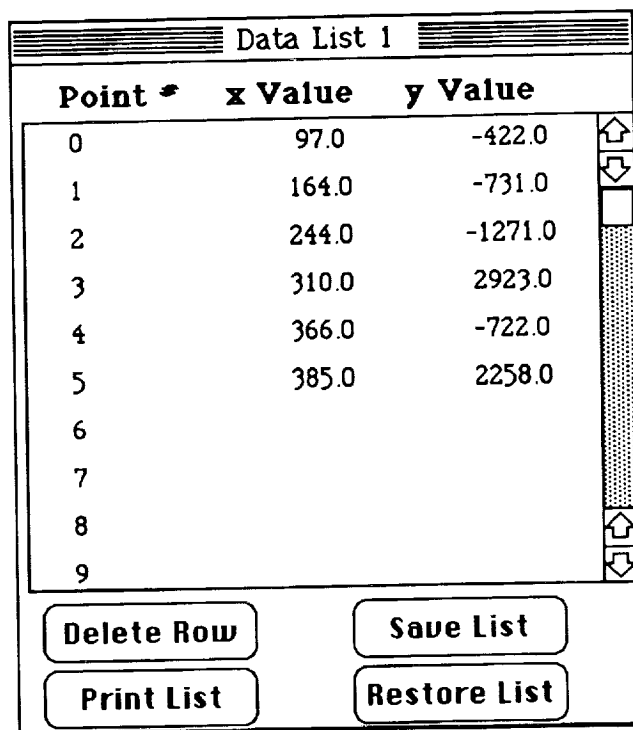
Figure 15. Data List window.

1. Activate the data list. (Choose a list from the Special menu (see fig. 2); a hierarchical menu is displayed. Choose Activate.)

2. Choose the corresponding data plot window from the Window menu (see fig. 2); this brings the data plot window to the front.

3. If the cursor in the data plot window is off, turn it on by clicking on the Cursor button.

4. Position the cursor line on the x value desired (see section 4.3.1).

5. Click the mouse with the arrow pointer inside the plot frame. This will transfer the x and y data values shown above the Cursor button to the next available row in the data list.

6. To add points to the data list, repeat steps 4 and 5.

The maximum number of rows in a data list is 200; note that the first row is numbered 0. To get data values from several data traces to reside on the same data list, display each data trace in the same data window sequentially and choose the values desired.

The command buttons in the data list window are

Delete Row: Deletes the row in which a cell is selected, decrements the point numbers by one, and moves the data in the list up to fill in the deleted row.

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Print List: Prints the data in the list, with the point numbers.

Save List: Activates a file dialog box and saves the data list to the text file indicated.

Restore List: Activates a file dialog box and restores the data from the selected text file to the current list, overwriting the data in the list.

4.4 Data Analysis

Several types of analyses can be performed after the data has been acquired. At present, these analyses consist of averaging, calculating an amplitude spectrum, and digital filtering. In future releases of the ALDAS Program additional types of analysis will be added, including octave and third-octave algorithms.

4.4.1 Averaging– The ALDAS Program provides two methods of performing cycle-oriented averaging. The first method is performed at the time of acquisition and was explained in section 4.2.4. The second method allows the user to control the parameters of the cycle averaging in more detail—the procedure is as follows:

1. Load the starting points of all cycles to be averaged into a data list (see section 4.3.3.) *The x units of the plot from which these points are taken must be points.* (For selecting the units, see section 4.3.2.)

2. Choose Average from the Analyze menu (see fig. 2). This activates the Average Options dialog box shown in figure 16.

3. Enter the requested information in the editable fields and select the appropriate pop-up menu. The options are described below:

Offset: The number of points that will be added to the starting point of each cycle. Its purpose is to shift the resultant cycle so as not to mask the event that is being used as the trigger for the starting point. Negative offsets are permissible except when the combination of the first point in the data to be averaged and the offset is negative.

points: The number of points that will be averaged in each cycle.

cycles: The number of cycles to be averaged. The program automatically fills in the number of cycles contained in the data list; however, any number less than this is also permissible.

Starting Cycle: The cycle at which averaging starts. This can be used in conjunction with "# cycles" to average a subset of the cycles named in the starting-point data list. The default value is 0, the number of the first cycle on the data list.

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```
┌─────────────────────────────────────────────┐
│ ≣≣≣≣≣≣≣≣ Average Options ≣≣≣≣≣≣≣          │
│  ┌───────────────────────────────────────┐  │
│  │  Offset:  ┌──────┐  points             │  │
│  │           │ -50  │                     │  │
│  │           └──────┘                     │  │
│  │  # points:┌──────┐  /cycle             │  │
│  │           │ 2048 │                     │  │
│  │           └──────┘                     │  │
│  │  # cycles:┌──────┐                     │  │
│  │           │ 6    │                     │  │
│  │           └──────┘                     │  │
│  │  Starting ┌──────┐                     │  │
│  │  Cycle:   │ 0    │                     │  │
│  │           └──────┘                     │  │
│  │  Starting Points In:┌──────────────┐  │  │
│  │                     │  Data List 1 │  │  │
│  │                     └──────────────┘  │  │
│  │    ┌──────────┐   ┌──────────┐        │  │
│  │    │    Go    │   │  Cancel  │        │  │
│  │    └──────────┘   └──────────┘        │  │
│  └───────────────────────────────────────┘  │
└─────────────────────────────────────────────┘
```
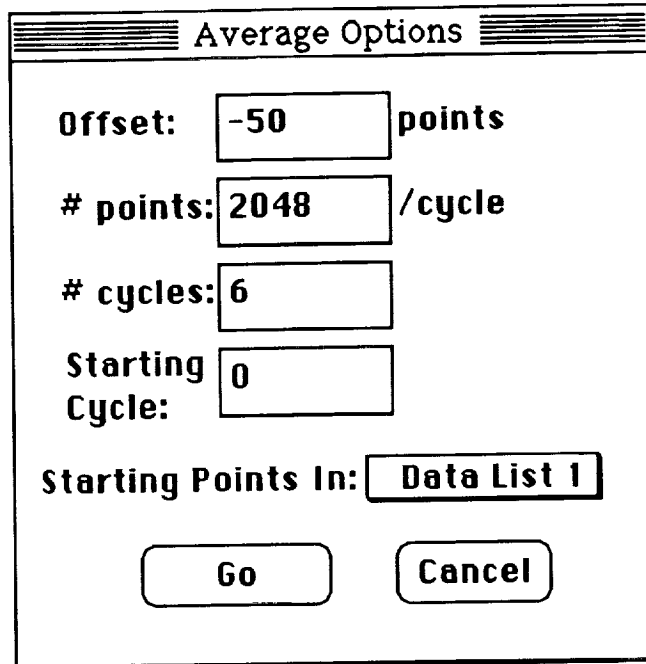
Figure 16. Average Options dialog box.

Starting Points In: A pop-up menu whose choices are the active data lists. Any or all of Data
    Lists 1 through 4 can appear. Any active data list can be chosen as the input list for the
    cycle starting points.

4. Click on the appropriate command button:

    Go: Accepts the inputs of the Average Options dialog box, activates an Open File dialog box,
        and performs the requested average on the chosen file.

    Cancel: Closes the dialog box without performing an average.

After the average has been completed, a file is created that has the same file name as the input data
file but begins with "Avg-". Note that this prefix is different than the prefix used if the data is aver-
aged during acquisition ("Ave-") (see section 2.4.2).

One of the versatile features of this method of averaging is that any set of starting points can be
used for any data trace. This means the starting points can be taken from a once-per-revolution pulse,
a time code signal, or a data trace with a distinctive event. The same points can then be used for all
the microphone data sets, which were digitized simultaneously with the cycle starting-point source
trace.

Besides smoothing the transients from a varying signal, this method of cycle averaging can be
used to cut sections of data from long data streams and save them in individual files. To do this,

choose the starting point of the cycle (that is, the starting cycle from the data list), enter the number of points to be cut, and enter 1 for the number of cycles to average.

4.4.2 Amplitude Spectrum Analysis– Spectral analysis is performed using a butterfly FFT routine, as in reference 3. The procedure is as follows:

1. Choose FFT Options from the Special menu (see fig. 2). This activates the FFT Options dialog box shown in figure 17.

```
╔══════════════════════════════════════════╗
║                                          ║
║   ┌────────────────────────────────┐     ║
║   │          FFT Options           │     ║
║   ├────────────────────────────────┤     ║
║   │                                │     ║
║   │ ◉ All data points   ○ Subset of data│ ║
║   │                          ┌──────────┐│ ║
║   │ Starting point number:   │ 1        ││ ║
║   │                          ├──────────┤│ ║
║   │ Number input data points:│ 1024     ││ ║
║   │                          ├──────────┤│ ║
║   │          Skip Factor:    │ 1        ││ ║
║   │                          └──────────┘│ ║
║   │                                │     ║
║   │      Non power of two options  │     ║
║   │ ┌──────────────────────────────┐│    ║
║   │ │ ◉ Truncate to next lower power of 2││ ║
║   │ │ ○ Fill in 0's to next power of 2  ││ ║
║   │ └──────────────────────────────┘│    ║
║   │                                │     ║
║   │ ( Cancel )      ( Continue )    │     ║
║   │                                │     ║
║   └────────────────────────────────┘     ║
║                                          ║
╚══════════════════════════════════════════╝
```

Figure 17. FFT Options dialog box.

2. Set the parameters in the FFT Options dialog box. The fields and radio buttons are as follows:

All data points: When checked, all data points in the input stream are used to perform the FFT; the non–power-of-two options apply to this field.

Subset of data: When checked, the starting point, number of input points, and skip factor are used to determine which points of the input stream are to be processed.

Starting point number: The number of the first data point to be used in the FFT analysis.

Number input data points: The number of data points on which to perform the FFT; the non–power-of-two options apply to this field.

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Skip factor: Provides a means of data decimation similar to that of viewing resolution in the Data Plot Windows (see section 4.3.1). For example, if the value is 2, every other point is taken from the input stream.

Truncate to next lower power of 2: Truncates the input stream so that the number of FFT points is the maximum possible power of two, to conform to an FFT input requirement that specifies data must have a number of points equal to a power of two.

Fill in 0's to next power of 2: Adds trailing 0's to the input stream so that the number of data points equals the next higher power of two.

3. Click on the appropriate command button:

Continue: Closes the dialog box and accepts the values within it.

Cancel: Closes the dialog box without accepting the changes.

4. Choose FFT Windows from the Special menu (see fig. 2). A hierarchical menu is displayed, listing the window functions that are available for use by the FFT. Those currently available are Rectangular, Hanning, Tenth Cosine Taper, Quarter Cosine Taper, Kaiser-Bessel, Parzen, Welch, and Blackman Harris. The equations and properties for these windows are contained in appendix A.

5. Choose the desired window function by highlighting it. The default is Hanning, and the currently selected window function is indicated on the menu by a check mark.

6. Choose Amp. Spectrum from the Analyze menu (see fig. 2). A hierarchical menu is displayed with two choices, Go and Options. These operate like the Go and Options choices in the Time History menu; the only difference is in the allowed choices of x and y axis units in the Display Options dialog box. For the Amplitude Spectrum, the x-axis choices are Points and Frequency, and the y-axis choices are Counts, Pascals, and decibels. For instructions, see section 4.3.2.

A plot window is opened automatically after a spectrum is calculated, and the results are plotted in the units requested. Figure 18 shows an FFT of a 1000-Hz calibration signal in units of decibels versus points. Notice that the frequency resolution of the x scale is given in the label, and the data window type is given in the title.

4.4.3 Digital Filtering– The ALDAS Program can digitally filter any stored time-history data using one of two types of filter windows. Low-pass convolution filtering is performed in the time domain by sweeping a filter window over the time history, as described in reference 4. Phase shift of the resultant time history is avoided by using a symmetric window that uses future points as well as past points in the data smoothing. Two filter windows, Hanning and Half Cosine Taper, are available for use in filtering. The filter cutoff frequency determines the width of the data window. The data-window is centered around the current time point. Thus, the beginning and ending data points are handled as special cases since the data window extends over the boundaries of the available data. The beginning of the time history is handled by taking the first number of points equal to the data window width divided by 2, flipping them, and appending them to the beginning of the time history.

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250 hz signal

Amplitude Spectrum

Analog Gain: 10.0
Analog Atten: 0.0
Cal Gain: 10.0
Hanning Window

x: 250.122070
y: 112.2026

Data Section: ● 0

Cursor   Viewing Resolution: ○ 2X   ● Full   ○ 1/2   ○ 1/4   ○ 1/8   ○ 1/16
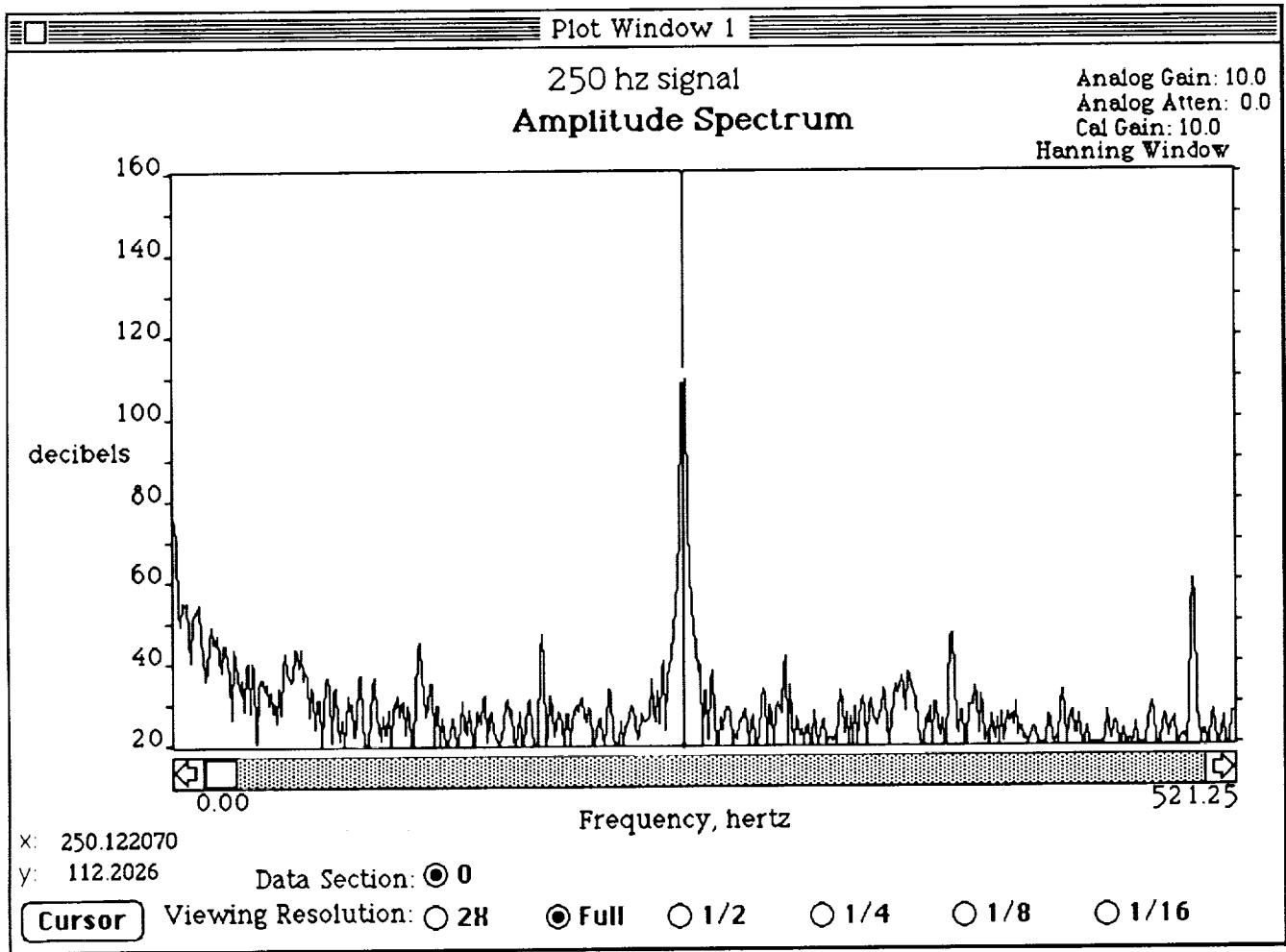
Figure 18. FFT analysis results.

This allows the filter window to be centered on the first true data point and still have the full filter data window width for computation. The end of the data is handled in a similar fashion. This concept is shown in figure 19.

To perform the filtering:

1. Choose Digital Filter from the Analyze menu (see fig. 2). This activates a standard file dialog box.

2. Use the file dialog box to choose the input file. The Filter Options dialog box shown in figure 20 is activated.
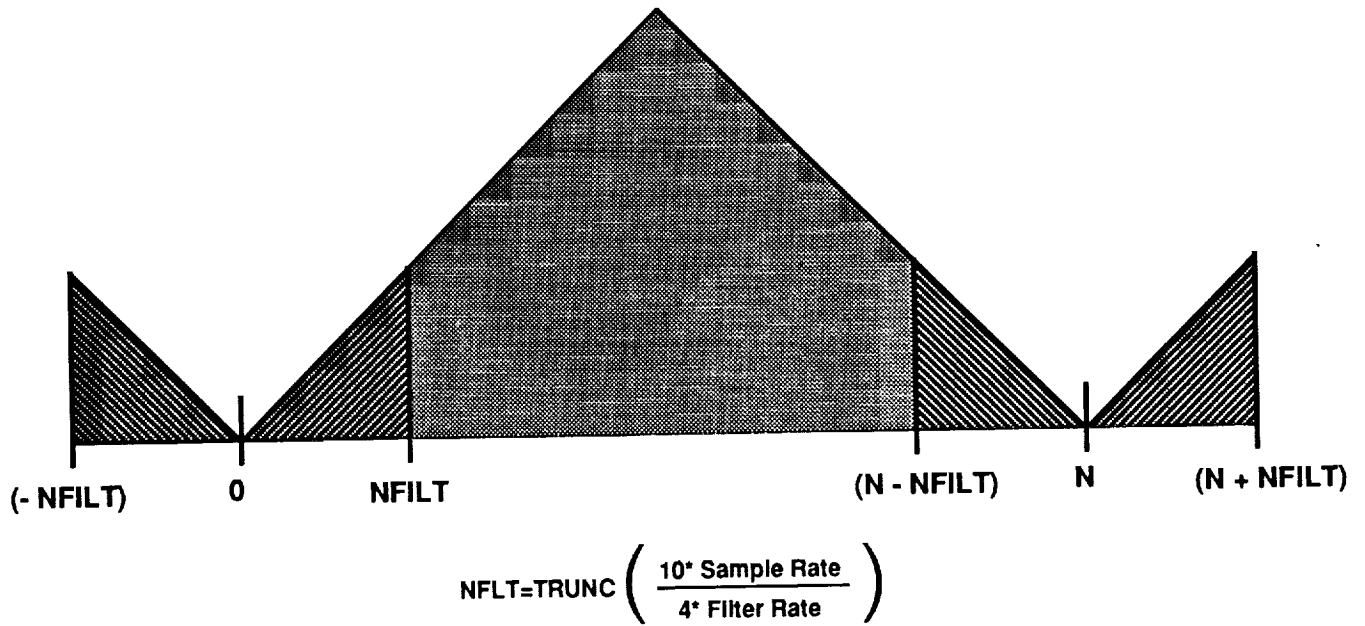
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$$\text{NFLT} = \text{TRUNC}\left(\frac{10^* \text{ Sample Rate}}{4^* \text{ Filter Rate}}\right)$$

Figure 19. Digital filtering end-point method.

Figure 20. Digital Filter Options dialog box.

3. Set the options in the Filter Options dialog box. The information and options given in this box are described below.

Input Data File: The file chosen for raw data input.

Sample Rate: The rate at which the data was sampled.

Analog Filter: The analog filter used at the time of digitization.

Digital Filter Rate: The frequency at which to apply the low-pass filter. Note that this the frequency at which the attenuation begins and is not the 3 or 6 dB down point frequencies. To calculate the 3 or 6 dB down frequencies, multiply this frequency by 1.16 or 1.23 for the Half Cosine Taper Window and 1.22 or 1.30 for the Hanning Window .

Window Type: A pop-up menu with two window choices, Hanning and Half Cosine Taper.

Change File: Button that activates a standard file dialog box and allows the user to change the input data file. The information in the Filter Options dialog box is updated to apply to the new file.

4. Click on the appropriate command button:

Continue: Performs the average. The file created by the digital filter function has the prefix "Flt-" attached to the file name.

Cancel: Closes the dialog box without performing the average.

4.5 Miscellaneous Features

Several features of the ALDAS Program do not fall under the preceding sections and are described in the following sections.

4.5.1 Saving Data as ASCII– When a data plot window is active and the front window, the data for that window can be saved as an ASCII text file. This text file can be opened by any standard word processing program on the Macintosh, imported to another application, or exported to a different computer. To save data as an ASCII text file:

1. Choose Save as ASCII from the File menu (see fig. 2). This activates the ASCII File dialog box shown in figure 21.

2. Choose the range of data to be saved by entering the first and last points of the range.

3. To include descriptive information about the data in the ASCII file, click on the Print Header Information check box. (Be sure the box has an X in it.)

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```
┌─────────────────────────────────────────────┐
│ ▤▤▤▤▤▤▤▤▤▤▤ ASCII File ▤▤▤▤▤▤▤▤▤▤▤ │
├─────────────────────────────────────────────┤
│                                             │
│  Starting Data Point:   ┌──────────────┐    │
│                         │ 1            │    │
│                         └──────────────┘    │
│                                             │
│  Ending Data Point:     ┌──────────────┐    │
│                         │ 2048         │    │
│                         └──────────────┘    │
│                                             │
│         ☒ Print Header Information          │
│       ┌──────────┐      ┌──────────┐        │
│       │    Go    │      │  Cancel  │        │
│       └──────────┘      └──────────┘        │
└─────────────────────────────────────────────┘
```
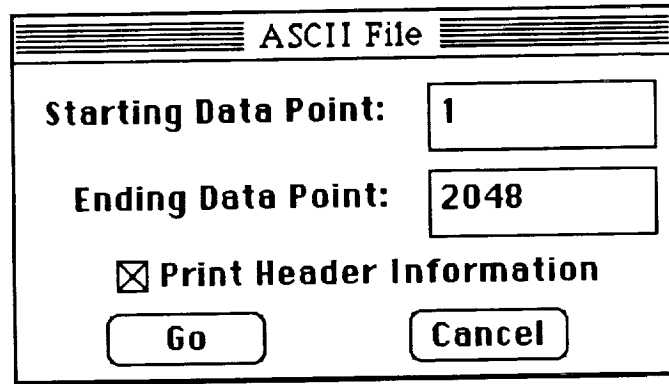
Figure 21. ASCII file dialog box.

4. Click on Go to close the dialog box and save the data requested in a text file. The file will have the same name as the input file, with "Txt-" as a prefix. To close the dialog box without saving the data, click on Cancel.

The ASCII text file contains two parts. The descriptive information is contained in the header part of the file and is in a free format. The data is contained in the second part of the file and is in F15.6, tab, F15.6 format, with the x value first. Figure 22 shows a text file created using this option.

4.5.2 Editing Saved Information– Certain information attached to the data can be modified. The procedure is as follows:

1. Choose Edit Info from the Special menu (see fig. 2). This activates a standard file dialog box.

2. Choose the data file to be modified or viewed. The file editing dialog box shown in figure 23 is activated.

3. To edit the information shown, click on the appropriate field. Note that the editable fields are all contained in rectangles; information that cannot be changed is also displayed in this dialog box.

4. To change the data type, click on the Acoustic Data or General Data radio button.

5. To save the changes to the file, click on Continue. A prompt is activated; click on Save.

6. To close the file and dialog box without saving any changes to the file, click on Cancel in the dialog box. If you've already clicked on Continue, a prompt has been activated; click on Cancel in the prompt box.

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```
Data from file:  Raw-250 hz
Data acquired on:
Analog Gain:                           0.0 dB
Calibration Gain:                      0.0 dB
Calibration Slope:        4.618890e-4
Calibration Intercept:    1.186870e-1
Analog Attenuation:                   0.0 dB
Digital Gain:                     1.0 times
Data digitized using:  16  bits
Sample Rate:                      25000 sps
Number of data points:         8192
Number of cycles:                 1
AntiAliasing filter rate:      10000 Hz
Seconds of data per rev:      0.330000
Comment:  250 hz sine wave
Digital filter rate:               -1 Hz
Data is for a Time History
Data type is acoustics data
x axis units are: Seconds
y axis units are: Counts
Data points:        1 to       50 follow
        0.000000   20035.000000
        0.000040   21421.000000
        0.000080   22710.000000
        0.000120   23921.000000
        0.000160   25045.000000
        0.000200   26070.000000
        0.000240   27009.000000
        0.000280   27844.000000
        0.000320   28566.000000
        0.000360   29177.000000
        0.000400   29645.000000
        0.000440   29932.000000
        0.000480   30260.000000
        0.000520   30412.000000
        0.000560   30398.000000
        0.000600   30287.000000
        0.000640   30061.000000
        0.000680   29686.000000
        0.000720   29195.000000
        0.000760   28612.000000
        0.000800   27891.000000
        0.000840   27048.000000
        0.000880   26080.000000
```

Figure 22. ASCII file format.

```
┌─────────────────────────────────────────────────┐
│                                                 │
│  Info From File:                                │
│         100 hz sine                             │
│  ─────────────────────────────────────────────  │
│  Comment:                                       │
│  ┌───────────────────────────────────────────┐  │
│  │ 100 hz sine wave input                    │  │
│  │                                           │  │
│  │                                           │  │
│  └───────────────────────────────────────────┘  │
│                                                 │
│  date/time: │DD/MON/YR HR:MN:SC          │      │
│                                                 │
│  Analog Gain: │0        │  Analog Attenuation:│0│
│                                                 │
│  Digital Gain: │1.0      │      Cal Gain: │0   │ │
│                                                 │
│  Cal Slope: │ 3.058e-5 │  Cal Intercept: │2.381e-8│
│                                                 │
│  Sample Rate:  2048      General Units:│none   ││
│                                                 │
│  Points in Loop:  2048      Number of Loops:  1 │
│                                                 │
│  Analog Filter Rate:    0    A-D Bits: 16       │
│                                                 │
│  Digital Filter Rate:   250                     │
│                                                 │
│  Digital Filter Window:  Hanning Window         │
│                                                 │
│  FFT Resolution: 1.003789 Hz/Line               │
│                                                 │
│  FFT Window: Hanning Window                      │
│         ○ Acoustic Data    ◉ General Data       │
│      ┌──────────────┐   ┌──────────────┐        │
│      │   Cancel     │   │   Continue   │        │
│      └──────────────┘   └──────────────┘        │
└─────────────────────────────────────────────────┘
```

Figure 23. File editing dialog box.

4.5.3 Task Timing– The ALDAS Program indicates the progress of a requested task and an estimate of the total time that task will take through a window like that shown in figure 24. The horizontal bar is filled proportionately using the elapsed time and the total estimate of the time required that is shown below the right-hand end of the bar. Figure 25 shows the task times required in sec/point for the Macintosh II and Macintosh IIx. These times are greatly task dependent and are only accurate to ±10%. It should be noted that much of the time required to perform an FFT is used in setting up the arrays to send to the FFT routine. Thus, while a coprocessor board would speed up the analysis, the acquisition of such a board should be investigated carefully to determine if it is cost effective for the amount of time saved. Also note that as the Macintosh CPU becomes faster and more efficient, task timing will become moot, since the response time to any request will become negligible.
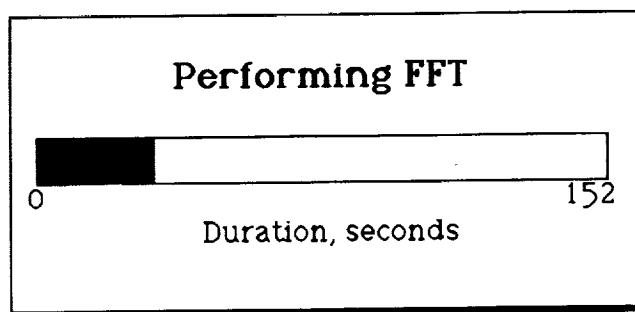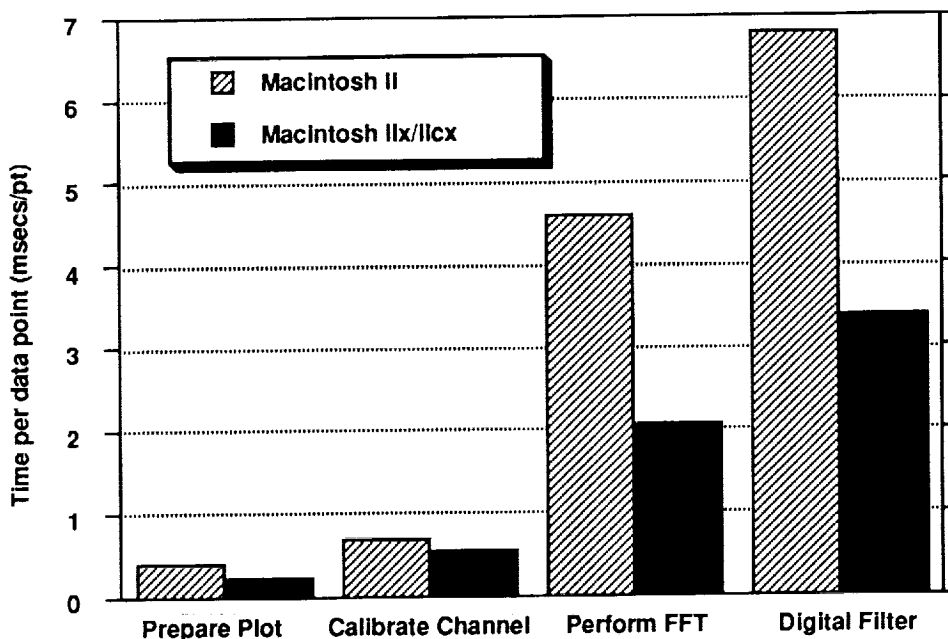
Figure 24. Task progress indicator.

Figure 25. Time required for ALDAS tasks.

5.0 FUTURE ENHANCEMENTS OF THE ALDAS

ALDAS is an evolving system, with computing power, analog-to-digital hardware, and software being upgraded as needed and as technology allows. As mentioned previously, new Macintosh systems with faster CPUs and larger memories are being developed continuously. As these new Macintosh systems become available, ALDAS will be modified to accommodate them. Likewise, the analog-to-digital capabilities that can be tied to the Macintosh are evolving, with faster 16-bit conversions and more simultaneous channels becoming available.

The ALDAS Program in its present form provides the basic requirements for acoustics data acquisition and analysis. However, it is by no means complete in its abilities. Some features that will be added in future releases are

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- octave, third-octave, and twelfth-octave analysis

- flyover types of analysis (i.e., perceived noise level)

- a real-time four-channel oscilloscope feature

- three-dimensional surface and contour graphics

- histograms

- additional spectral analysis features

- statistical functions

- the ability to calibrate data other than acoustics data

- more than four data windows

- additional data windows in amplitude spectrum analysis and digital filtering

- digital-to-analog playback capability

These additional features in the software, as well as the added capabilities provided by improved technology, will allow ALDAS to meet the needs of the acoustics community through the 1990s.

6.0 CONCLUDING REMARKS

ALDAS meets the requirements of a transportable, easy-to-use acoustics data acquisition and analysis tool. It is specifically geared to helicopter acoustics data acquired using the YO-3A aircraft, although it can be used with any analog source. The technology used for this system is rapidly advancing and the current version of ALDAS should be considered a baseline configuration to which many improvements will be made in both hardware and software.

APPENDIX A

DESCRIPTION OF DATA WINDOWS FOR FAST FOURIER TRANSFORMS

The FFT windows used in the ALDAS Program are described in detail in references 3 and 5. The equations for these windows are shown in this appendix, and some of their characteristics are listed in table A1. The correction factor, $C.F.$, is obtained from the numerical integration of the window's equation and is used to correct the amplitude of the amplitude spectrum analysis using the window. The FFT windows are shown in figures A1 through A8 along with the log magnitudes of the transform. The log magnitudes of the transform are performed on a 250-Hz generated cosine wave whose beginning and end points are 180° out of phase. For all equations, N = number of points in the FFT window.

The equations for the data windows are

1. Rectangular:

$$f(x) = x \qquad\qquad i = 0, 1, 2, ..., N-1$$

$$C.F. = 1.0$$

2. Hanning:

$$f(x) = \frac{x}{2}\left[1 - \cos\left(\frac{2\pi i}{N}\right)\right] \qquad\qquad i = 0, 1, 2, ..., N-1$$

$$C.F. = 1.632993$$

3. Cosine Taper:

$$f(x) = \frac{x}{2}\left[1 - \cos\left(\frac{2\pi i}{\alpha N}\right)\right] \qquad\qquad i = 0, 1, 2, ..., \frac{\alpha N}{2}$$

$$f(x) = 1 \qquad\qquad i = \frac{\alpha N}{2} + 1, \frac{\alpha N}{2} + 2, \frac{\alpha N}{2} + 3, ..., N - \frac{\alpha N}{2}$$

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$$f(x) = \frac{x}{2}\left[1 - \cos\left(\frac{2\pi i}{\alpha N}\right)\right] \qquad i = N - \frac{\alpha N}{2} + 1, N - \frac{\alpha N}{2} + 2, N - \frac{\alpha N}{2} + 3, ..., N - 1$$

where for one-tenth cosine taper

$\alpha = 0.2$, $C.F. = 1.069045$

and for one-quarter cosine taper

$\alpha = 0.5$, $C.F. = 1.206045$

4. Cosine Series:

$$f(x) = x\left[a_0 - a_1\cos\left(\frac{2\pi i}{N}\right) + a_2\cos\left(\frac{4\pi i}{N}\right) - a_3\cos\left(\frac{6\pi i}{N}\right)\right] \qquad i = 0, 1, 2, ..., N - 1$$

where for Kaiser-Bessel cosine series

$a_0 = 0.402430$, $a_1 = 0.498040$, $a_2 = 0.098310$, $a_3 = 0.001220$, $C.F. = 1.854381$

and for Blackman Harris cosine series

$a_0 = 0.358750$, $a_1 = 0.488290$, $a_2 = 0.141280$, $a_3 = 0.011680$, $C.F. = 1.968888$

5. Parzen:

$$f(x) = x\left[1 - \left|\frac{i - \frac{1}{2}(N-1)}{\frac{1}{2}(N+1)}\right|\right] \qquad i = 0, 1, 2, ..., N - 1$$

$C.F. = 1.728677$

6. Welch:

$$f(x) = x\left\{1 - \left[\frac{i - \frac{1}{2}(N-1)}{\frac{1}{2}(N+1)}\right]^2\right\} \qquad i = 0, 1, 2, ..., N - 1$$

$C.F. = 1.366640$

Table A1. FFT window properties

	Highest sidelobe level (dB)	Scallop loss (dB)	Worst-case process loss (dB)	6.0 dB bandwidth (bins)
Rectangular	−13	3.92	3.92	1.21
Hanning	−32	1.42	3.18	2.00
Tenth cosine taper	−14	3.25	3.45	1.35
Quarter cosine taper	−15	2.24	3.11	1.57
Kaiser-Bessel	−69	1.02	3.56	2.39
Blackman Harris	−92	0.83	3.85	2.72
Parzen	−27	1.82	3.07	1.78
Welch	−21	2.22	3.01	1.59
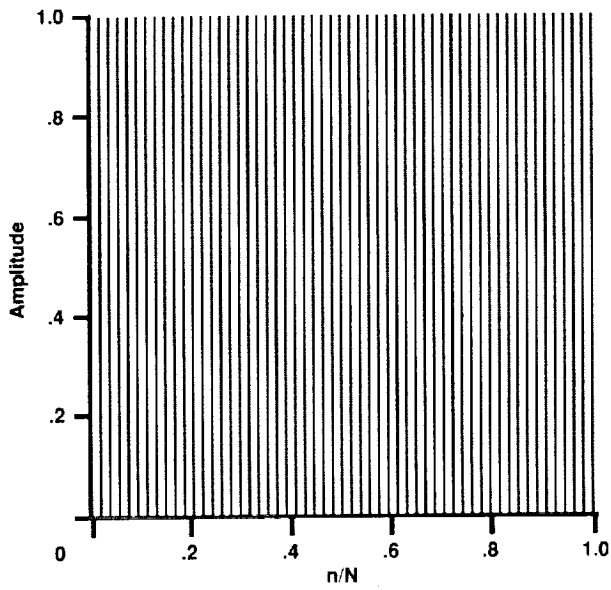
(a) Window shape.
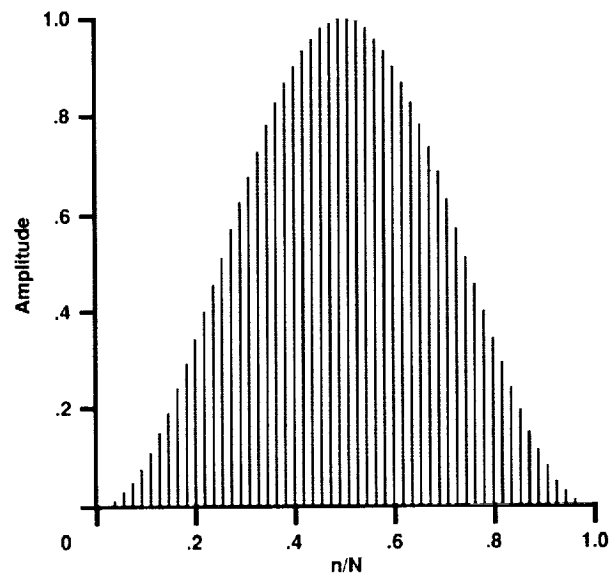
(a) Window shape.
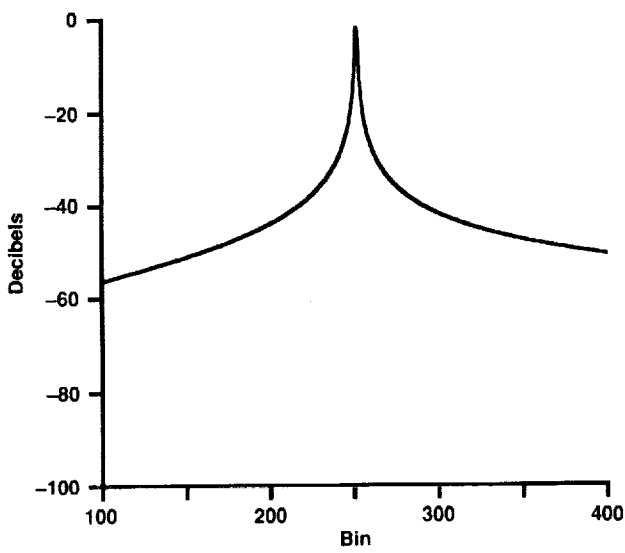
(b) RMS log magnitude of transform.
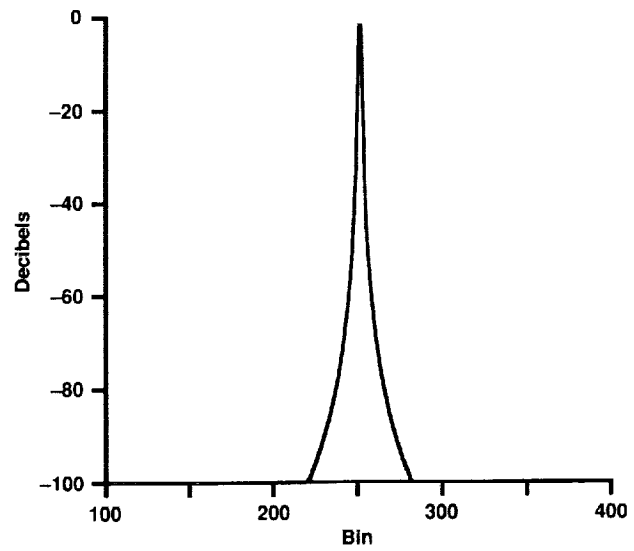
(b) RMS log magnitude of transform.

Figure A1. Rectangular window.

Figure A2. Hanning window.
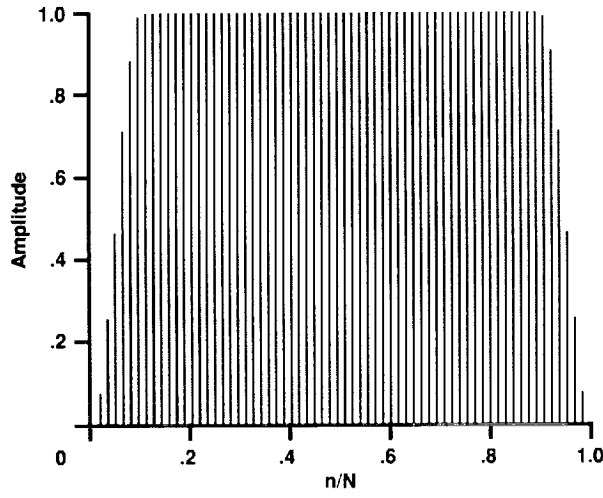
(a) Window shape.
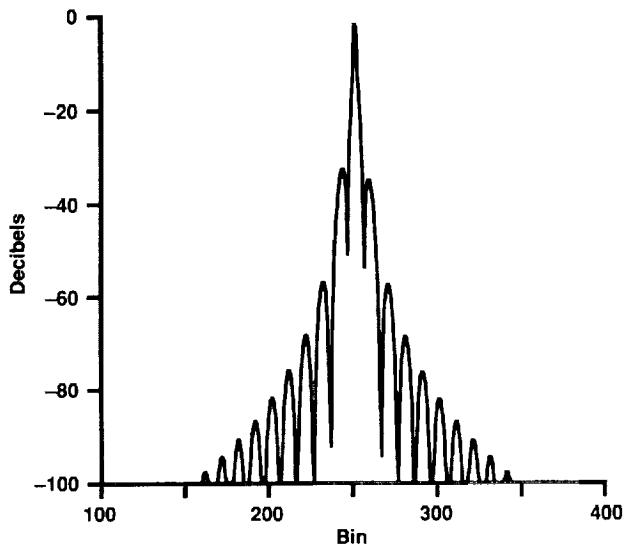
(a) Window shape.
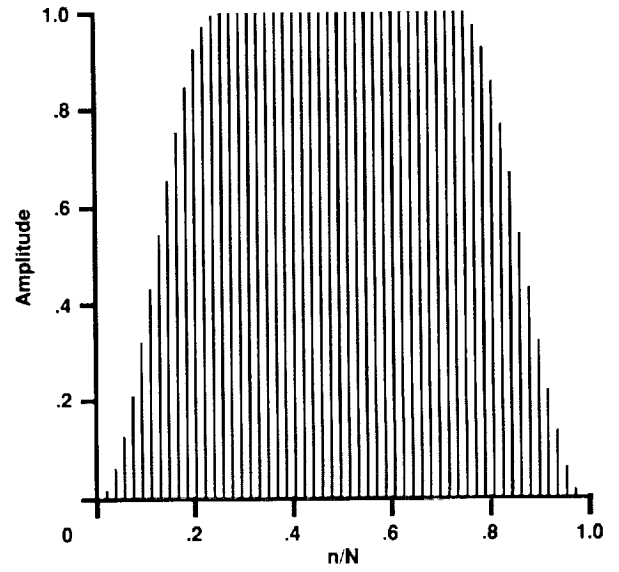
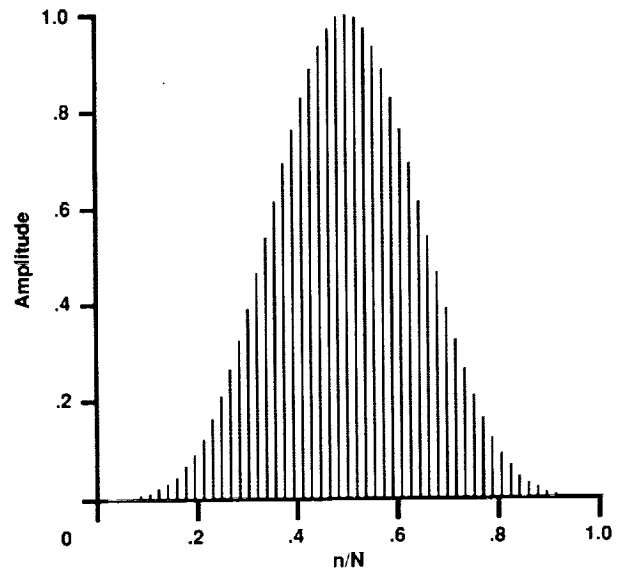
(b) RMS log magnitude of transform.
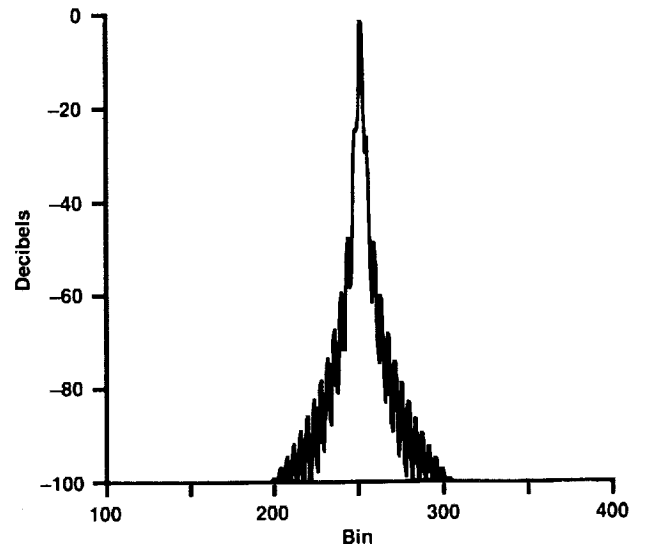
(b) RMS log magnitude of transform.
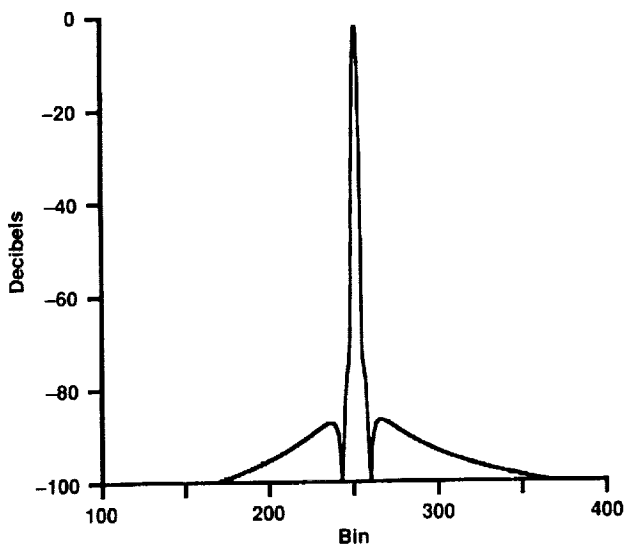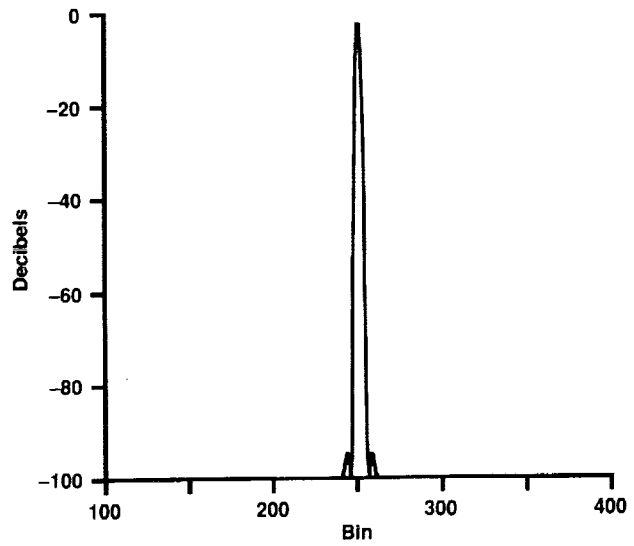
Figure A3. One-Tenth Cosine Taper window.   Figure A4. One-Quarter Cosine Taper window.
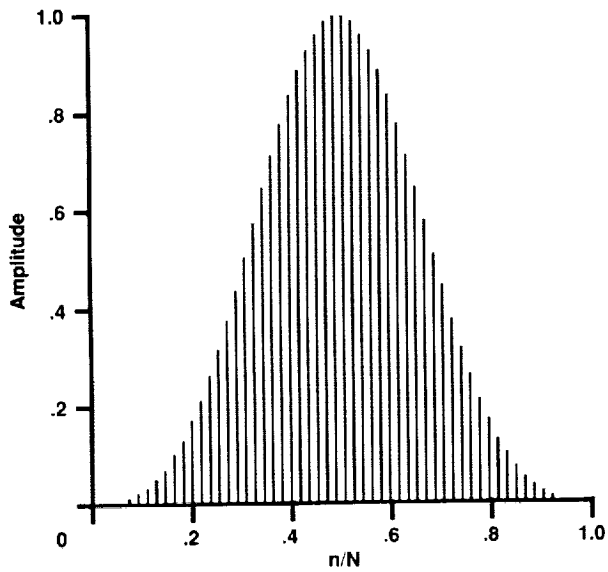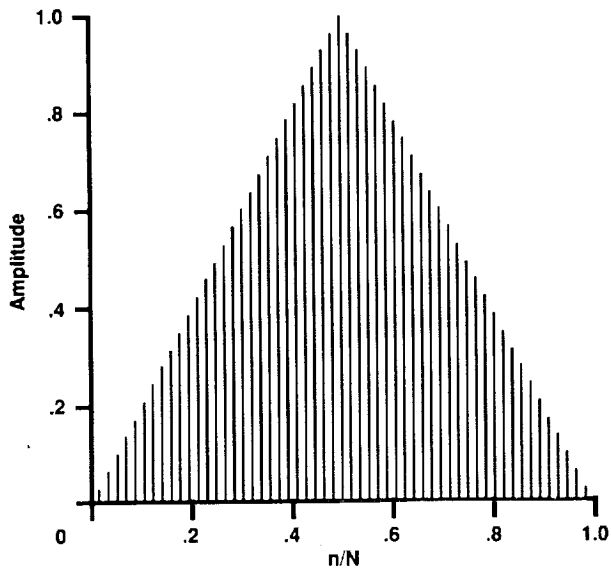
(a) Window shape.

(a) Window shape.

(b) RMS log magnitude of transform.
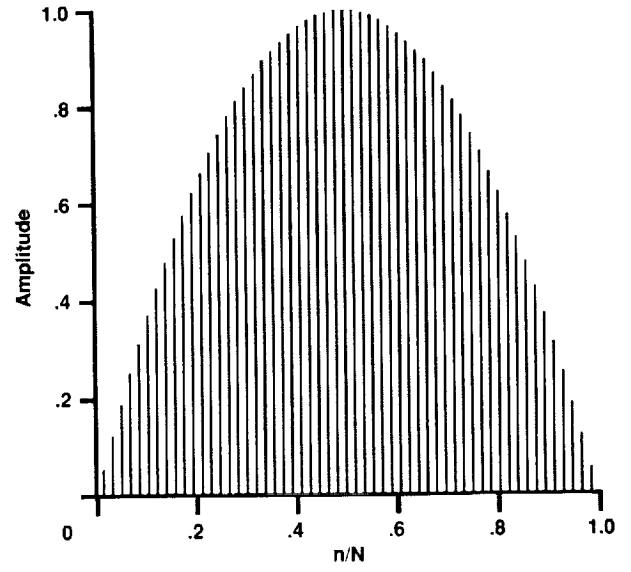
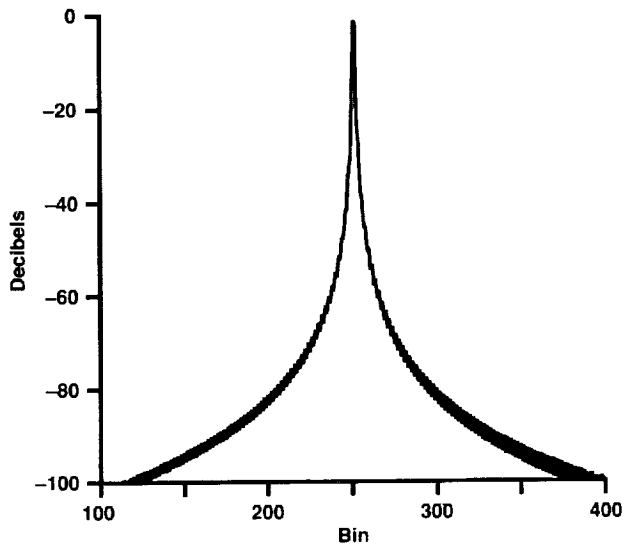(b) RMS log magnitude of transform.

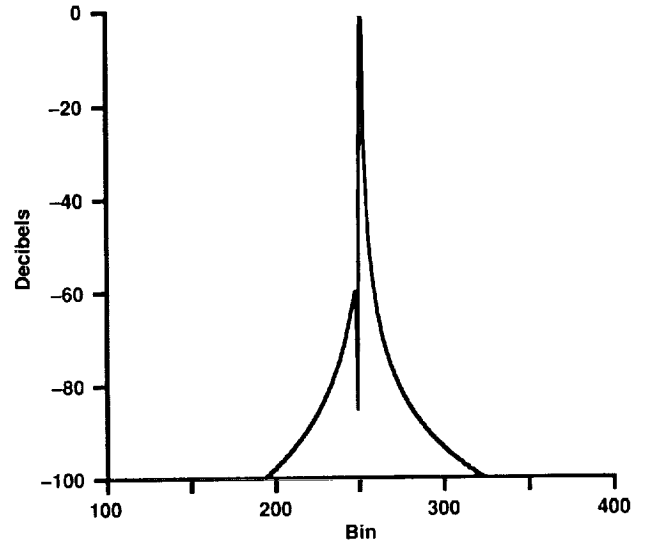Figure A5. Kaiser-Bessel window.

Figure A6. Blackman Harris window.

(a) Window shape.

(b) RMS log magnitude of transform.

Figure A7. Parzen window.

(a) Window shape.

(b) RMS log magnitude of transform.

Figure A8. Welch window.

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APPENDIX B

ACRONYMS

ALDAS   Acoustic Laboratory Data Acquisition System

CPU   command processing unit

FFT   fast Fourier transform

RAM   random access memory

rms   root mean square

SIMM   single inline memory module

1P   once-per-revolution pulse

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16. Abstract

The Acoustic Laboratory Data Acquisition System (ALDAS) is an inexpensive, transportable means to digitize and analyze data. The system is based on the Macintosh II family of computers, with internal analog-to-digital boards providing four channels of simultaneous data acquisition at rates up to 50,000 samples/sec. The ALDAS software package, written for use with rotorcraft acoustics, performs automatic acoustic calibration of channels, data display, two types of cycle averaging, and spectral amplitude analysis. The program can use data obtained from internal analog-to-digital conversion, or discrete external data imported in ASCII format. All aspects of ALDAS can be improved as new hardware becomes available and new features are introduced into the code.

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