

# Third-Octave Analysis Toolkit

## *Reference Manual*

**National Instruments Corporate Headquarters**

6504 Bridge Point Parkway

Austin, TX 78730-5039

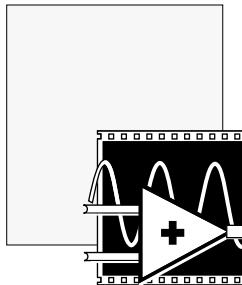
(512) 794-0100

Technical support fax: (800) 328-2203

(512) 794-5678

**Branch Offices:**

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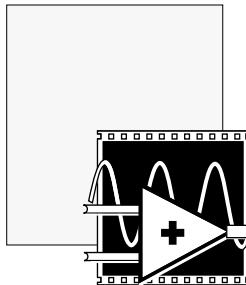
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# About This Manual

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This manual describes the Third-Octave Analysis Toolkit package. You can use this program to analyze acoustics and audio signals.

## Organization of This Manual

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This manual is organized as follows:

- Chapter 1, *Overview of the Third-Octave Analysis Toolkit*, describes the contents of the Third-Octave Analysis Toolkit, describes toolkit installation and explains how you can use this program.
- Chapter 2, *Operating the Third-Octave Analyzer*, describes the stand-alone Third-Octave Analyzer application and explains the program features.
- Chapter 3, *Third-Octave Analysis Toolkit Design*, describes the design specifications and algorithms of the Third-Octave Analysis Toolkit.
- Chapter 4, *Third-Octave Filters VI*, contains the description for the Third-Octave Filters VI and its parameters.
- Chapter 5, *Building Windows Applications for Third-Octave Analysis*, describes how to build a third-octave analysis applications under a Windows environment.
- Appendix A, *Error Codes*, lists the error codes returned by the Third-Octave Filters VI and the C function call.
- Appendix B, *References*, lists the reference material used to produce the VI in this manual.
- Appendix C, *Customer Communication*, contains forms you can use to request help from National Instruments or to comment on our products and manuals.
- The *Glossary* contains an alphabetical list and description of terms used in this manual, including abbreviations, acronyms, metric prefixes, mnemonics, and symbols.

# Conventions Used in This Manual

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The following conventions are used in this manual:

<b>bold</b>	Bold text denotes menus, menu items, or dialog box buttons or options. In addition, bold text denotes VI input and output parameters. In the Help window pictures of VI inputs and outputs, boldfaced parameters are parameters whose values you must specify.
<i>italic</i>	Italic text denotes emphasis, a cross reference, or an introduction to a key concept.
<b><i>bold italic</i></b>	Bold italic text denotes a note, caution, or warning.
<b>monospace</b>	Text in this font denotes text or characters that you should enter literally using the keyboard. Sections of code, programming and syntax examples, and the proper names of files also appear in this font.
<b>[]</b>	In Help window pictures of VI inputs and outputs, square brackets enclose parameters whose values you rarely need to set.
<b>&lt;&gt;</b>	Angle brackets enclose the name of a key on the keyboard—for example, <shift>.
<b>-</b>	A hyphen between two or more key names enclosed in angle brackets denotes that you should simultaneously press the named keys—for example, <shift-delete>. Key names are lowercase.



## Warning:

*This icon to the left of bold italicized text denotes a warning, which alerts you to the possibility of damage to you or your equipment.*



## Caution:

*This icon to the left of bold italicized text denotes a caution, which alerts you to the possibility of data loss or a system crash.*



## Note:

*This icon to the left of bold italicized text denotes a note, which alerts you to important information.*

## Data Types

Each VI description gives a data type picture for each input and output parameter, as illustrated in the following table.

Control	Indicator	Data Type
		Signed 8-bit integer
		Signed 16-bit integer
		Signed 32-bit integer
		Unsigned 8-bit integer
		Unsigned 16-bit integer
		Unsigned 32-bit integer
		Single-precision floating-point number
		Double-precision floating-point number
		Extended-precision floating-point number
		String
		Boolean
		Array of signed 32-bit integers
		Cluster
		File Refnum

Abbreviations, acronyms, metric prefixes, mnemonics, symbols, and terms are listed in the *Glossary*.

## Related Documentation

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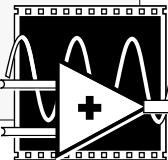
The following documents contain information that you may find helpful as you read this manual:

- *LabVIEW Analysis VI Reference Manual*
- *LabVIEW Data Acquisition VI Reference Manual*
- *LabVIEW Tutorial*
- *LabVIEW User Manual*

## Customer Communication

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National Instruments wants to receive your comments on our products and manuals. We are interested in the applications you develop with our products, and we want to help if you have problems with them. To make it easy for you to contact us, this manual contains comment and technical support forms for you to complete. These forms are in Appendix C, *Customer Communication*, at the end of this manual.



# Overview of the Third-Octave Analysis Toolkit

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The Third-Octave Analysis Toolkit can act as an add-on toolkit for LabVIEW or as a stand-alone application. The toolkit also provides the instrument driver for LabWindows/CVI users and dynamic link libraries (DLLs) for Windows users. This chapter describes toolkit installation and explains how you can use this program.

## Package Contents

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Your Third-Octave Analysis Toolkit should contain the following materials.

- The Third-Octave Analysis Toolkit diskettes
- *Third-Octave Analysis Toolkit Reference Manual*, part number 320952A-01

## Installation

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This section contains instructions for installing the Third-Octave Analysis Toolkit on the Macintosh or Power Macintosh and in Windows or Windows NT.

You must use the analyzer with one of the National Instruments Data Acquisition (DAQ) devices. The Third-Octave Analysis Toolkit can only analyze signals correctly when the signal does not have any aliasing, so you should use a device that has a built-in anti-aliasing filter. The National Instruments Dynamic Signal Acquisition (DSA) boards, such as the AT-A2150 or AT-DSP2200 for PC users and the NB-A2150F for Macintosh users, have these built-in filters.

## Macintosh or Power Macintosh

Complete the following steps to install the toolkit.

1. Insert diskette 1 of the Third-Octave Analysis Toolkit into your 3.5-inch diskette drive and double-click on the Third-Octave Analysis Installer icon when it appears on your desktop.
2. Follow the instructions on your screen.

You must have a National Instruments DAQ device installed in your system to run the Third-Octave Analyzer. If you have not already installed the necessary hardware, refer to the user manual for your DAQ device for device configuration instructions.

Once you have complete the on-screen installation instructions, you are ready to run the Third-Octave Analyzer.

The installer not only installs the stand-alone application, the Third-Octave Analyzer, but it also installs the LabVIEW source code library, `octave.11b`. You can run and modify the Third-Octave Analyzer in `octave.11b` from LabVIEW.

## Windows and Windows NT

Complete the following steps to install the toolkit.

1. Launch Windows.
2. Insert diskette 1 of the Third-Octave Analysis Toolkit into your 3.5-inch diskette drive.
3. From the File Manager, open the appropriate diskette drive and run `setup.exe`.
4. Follow the instructions on your screen.

You must have a National Instruments DAQ device installed in your system to run the Third-Octave Analyzer. If you have not already installed the necessary hardware, refer to the user manual for your DAQ device for device configuration instructions.

Once you have configured your DAQ device by running `WDAQCONF.EXE` and completed the on-screen installation instructions, you are ready to run the Third-Octave Analyzer.

You will have the following files and directories installed after you finish the installation.

**Note:** *xxx* denotes your installation directory.

<code>octave.exe</code>	the stand-alone application
<code>xxx\lvsrv\octave.llb</code>	the LabVIEW source code for <code>octave.exe</code> (You can run and modify <code>octave.llb</code> from LabVIEW.)
<code>daqdrv, lvdevice.dll</code>	(Windows only) the DLL necessary to run <code>octave.exe</code>
<code>aweight.dat</code>	an example weighting file
<code>xxx\cvisrc\instr</code>	contains the instrument driver for third-octave analysis with LabWindows/CVI
<code>xxx\cvisrc\example</code>	contains a LabWindows/CVI example that calls the third-octave analysis instrument driver
<code>xxx\winsrc\windll</code>	contains 16- and 32-bit DLLs, which have third-octave analysis functions
<code>xxx\winsrc\example\vb</code>	contains an example that calls the third-octave analysis function from Visual Basic.

## What Is an Octave Analyzer?

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An octave analyzer is a parallel-connected filter bank with a set number of filters. Each filter is tuned to a special frequency band and has a designated center frequency and bandwidth. The following formula determines the center frequencies of a pair of two adjacent filters:

$$\frac{f_{i+1}}{f_i} = 2^b,$$

where  $f_i$  is the designated center frequency in the  $i$ th filter band, and  $f_{i+1}$  is the designated center frequency of the next higher band. The parameter  $b$  is the bandwidth designator for the particular octave analyzer of interest; therefore,  $b = 1$  for an octave analyzer,  $b = 1/3$  for a one-third octave analyzer, also called a third-octave analyzer,  $b = 1/6$  for a one-sixth octave analyzer, and so forth. Notice that the following equation is also often expressed in  $b$  octaves:

$$\log_2 \frac{f_{i+1}}{f_i} = b,$$

where  $\log_2$  represents the base 2 logarithm.

In the case of a third-octave analyzer, the center frequencies of any two adjacent filters are related by a factor of  $2^{1/3}$ , or one-third of an octave.

## Introduction to the Third-Octave Analysis Toolkit

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Third-octave analysis is a special type of octave analysis widely used in acoustical analysis and audio signal processing.

You can use the Third-Octave Analysis Toolkit to analyze *stationary* acoustic and audio signals. Because the frequency contents and average properties of a stationary signal do not vary with time, the spectrum of the signal also does not change over time. For example, the speech waveform of a conversation or the noise from a vehicle can be roughly regarded as a stationary signal. You should not use the Third-Octave Analysis Toolkit with transient signals.

The Third-Octave Analysis Toolkit meets the conditions for Order 3, Type 3-D one-third octave filters as defined in the ANSI S1.11-1986

standard. Table 1-1 shows the filter band center frequencies in Hertz as defined by this standard. You can see in this table that the center frequency increases at a logarithmic rate. For a given filter in the filter bank, the bandwidth of the filter is determined by  $(2^{1/3} - 1)(fm)$ , where  $fm$  is the designated center frequency. Because  $fm$  increases logarithmically, the bandwidth also increases logarithmically.

**Table 1-1.** Filter Bands for ANSI S1.11

ANSI Band Number	Center Frequency (Hz) 1/3 Octave	A-weighting (dB) (Factor to mimic human hearing)
7	5	Data is out of the dynamic range of the analyzer.
8	6.3	
9	8	
10	10	-70.4
11	12.5	-63.4
12	16	-56.7
13	20	-50.5
14	25	-44.7
15	31.5	-39.4
16	40	-34.6
17	50	-30.3
18	63	-26.2
19	80	-22.5
20	100	-19.1
21	125	-16.1
22	160	-13.4
23	200	-10.9
24	250	-8.6
25	315	-6.6
26	400	-4.8
27	500	-3.2

**Table 1-1.** Filter Bands for ANSI S1.11 (Continued)

ANSI Band Number	Center Frequency (Hz) 1/3 Octave	A-weighting (dB) (Factor to mimic human hearing)
28	630	-1.9
29	800	-0.8
30	1000	0
31	1250	+0.6
32	1600	+1.0
33	2000	+1.2
34	2500	+1.3
35	3150	+1.2
36	4000	+1.0
37	5000	+0.5
38	6300	-0.1
39	8000	-1.1
40	10000	-2.5
41	12500	-4.3
42	16000	-6.6
43	20000	-9.3

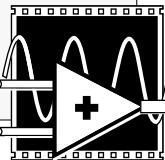
The Third-Octave Analyzer uses 1,000 Hz as its reference frequency.

The following describes how the analyzer calculates its center frequencies.

Define an array as *CF*.

$$CF = \{20, 25, 31.5, 40, 50, 63, 80, 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, 4000, 5000, 6300, 8000, 10000, 12500, 16000, 20000\}$$

If the sampling rate is 51200 Hz, the center frequencies are the same as in Table 1-1 from ANSI Band number 13 to 43, thus from 20 Hz-20000 Hz is the same as the array *CF*. If the sampling rate is *fs*, define  $\Delta f = fs/51200$ , then the *i*th center frequency is  $CF[i]/\Delta f$  where  $CF[i]$  is the *i*th element in the array *CF*.



# Operating the Third-Octave Analyzer

This chapter describes the stand-alone Third-Octave Analyzer application and explains the program features. For information on the analyzer algorithm, refer to Chapter 3, *Third-Octave Analysis Toolkit Design*.

## Setting Up the Third-Octave Analyzer

In Windows, first configure your data acquisition (DAQ) device using WDAQCONF . EXE. On the Macintosh, your DAQ device should already be configured. Then, run the stand-alone application by clicking the Third-Octave Analyzer icon, or by launching LabVIEW and opening the Third-Octave Analyzer VI found in *octave.11b*. The analyzer opens a setup panel first, as shown in Figure 2-1.

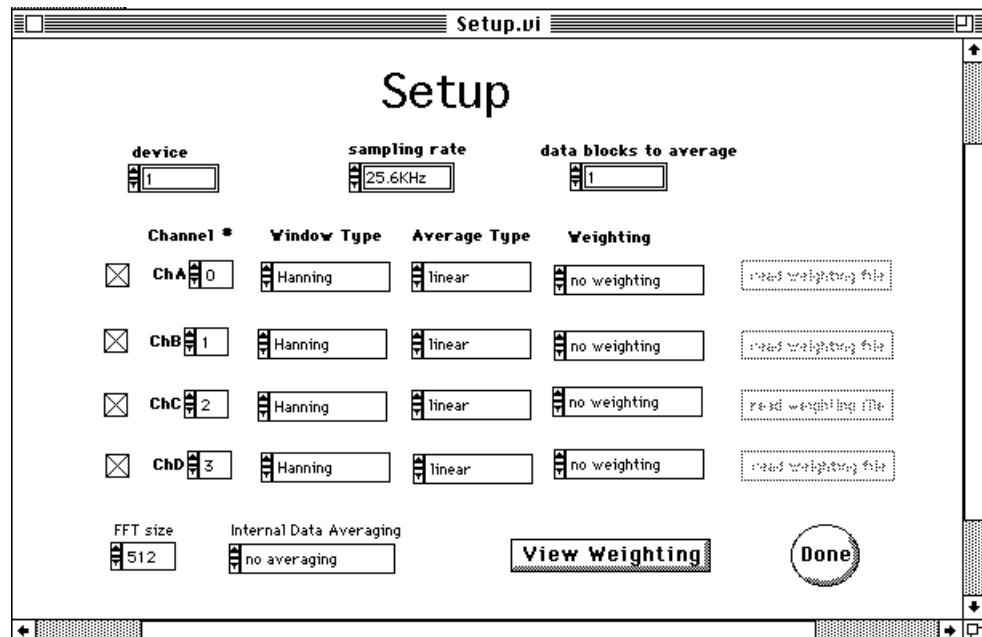


Figure 2-1. Third-Octave Analyzer Setup Panel

The following paragraphs describe the Setup front panel parameters and buttons that you can customize for your application.

**device** assigns an identification number to your device.

In Windows, you assign this number to your device when you run WDAQCONF .EXE. For the Macintosh, the **device** parameter indicates the physical slot number into which you plug your device. You can find this number by opening NI-DAQ in the control panels folder.

**sampling rate** designates the rate at which your device samples. The Third-Octave Analyzer offers three sampling rates: 12.8kHz, 25.6kHz, 51.2kHz. The corresponding data frequency ranges analyzed are: 5Hz-5kHz, 10Hz-10kHz, and 20Hz-20kHz.

**data blocks to average** indicates the number of data blocks the analyzer averages before the final display. The analyzer acquires  $M$  data points each time for each channel (where  $M=54,280$  if **FFT size**=512 and  $M=28,680$  if **FFT size**=256). After it analyzes the data block, the analyzer acquires another  $M$ -point data block and analyzes it. The Third-Octave Analyzer repeats this process the number of times that you have designated in this parameter. The final power output is the average of the power output from each block. Notice that the analyzer does not continuously acquire the data block, which should be satisfactory for stationary signals.

**Channel #** indicates which channels you want to acquire data from and analyze. You can choose up to four channels and the **Channel #** can be the same in every control. Each channel has a check box. If you do not need to use a channel, click inside the box until the check disappears to disable all the parameters associated with that channel.

**Window Type** selects one of four commonly-used windows (Rectangular, Hamming, Hanning, and Blackman) for each channel. The window reduces the truncation effect. The **Window Type** parameter defaults to the Hanning window.

**Average Type** indicates what type of average the analyzer uses to average the data block. The two types of possible averages are *linear* or *exponential* averaging.

If **data blocks to average** is  $M$ , then  $S_p(k)$  is the instantaneous power output of data block  $p$ , and the averaged power output after the number of  $p$  data blocks is  $S_p(k)$ .

The following formula defines the linear averaging, also called *true* or *additive* averaging.

$$S_M(k) = (1/M) \sum_{p=0}^{M-1} S_p(k)$$

The following is the formula for exponential averaging (also referred to as *discount* or *RC* averaging).

$$S_p(k) = (1 - \alpha)S_{p-1}(k) + \alpha S_p(k) \quad , \text{ where } \alpha = 1/M$$

$$0 < \alpha < 1$$

The analyzer defaults to linear averaging.

**Weighting** designates the weighting types. The human sense of hearing responds differently to different frequencies and does not perceive sound equally. Choosing **A-Weighing** tells the analyzers to mimic human hearing responses to acoustical signals. Refer to Table 1-1 in Chapter 1, *Overview of the Third-Octave Analyzer*, for a list of default A-Weighting values incorporated in the analyzer. You can also choose **no weighting** and **custom weighting**. When you choose **custom weighting**, you must read your weighting file. This file is a spreadsheet file with two columns, where the first column is 31 center frequencies and the second column is 31 corresponding weighting values. An example of a weighting file is `aweight.dat`. Make sure the weighting value corresponds correctly to the right frequency. The analyzer adds the weighting value to the final power value before display.

**View Weighting** displays a table which shows all the weighting values at each frequency for each channel.

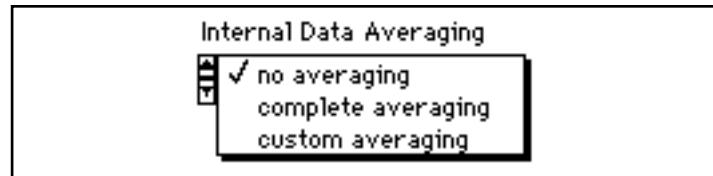
**FFT size** is the size used to compute FFT internally. It has two options 512 and 256. Using 512-point FFT gives more accurate results but takes twice the memory and runs slower than using 256-point FFT. **FFT size** defaults to 512.

**Internal Data Averaging** indicates the input data in one block needed to be averaged.

A block of data that is acquired each time is just enough for computing the outputs of the first 10 third-octave filters in the lower frequencies, but it is more than enough for computing the outputs of the 21 higher

frequency bands. This parameter controls how to compute the power in the 21 third-octave filters in the highest frequencies.

There are three **Internal Data Averaging** parameter options.



- `no averaging` means the analyzer uses only the minimum points of the data to compute the octave outputs in the 21 highest frequency bands and throws all the rest of the data away. If your signal is almost stationary, use this option.
- `complete averaging` means the analyzer uses all the data points to compute the octave outputs in the 21 highest frequency bands. No data is thrown away. This option results in a slower execution time, so you should select it when the signal is not completely stationary.
- `custom averaging` allows you to choose other internal averaging settings. The `no averaging` and `complete averaging` are the two extreme cases of the **Internal Data Averaging**.

When you choose `custom averaging`, an edit button appears at the right of the **Internal Data Averaging** control. When you click the edit button another panel pops up, as shown in Figure 2-2.

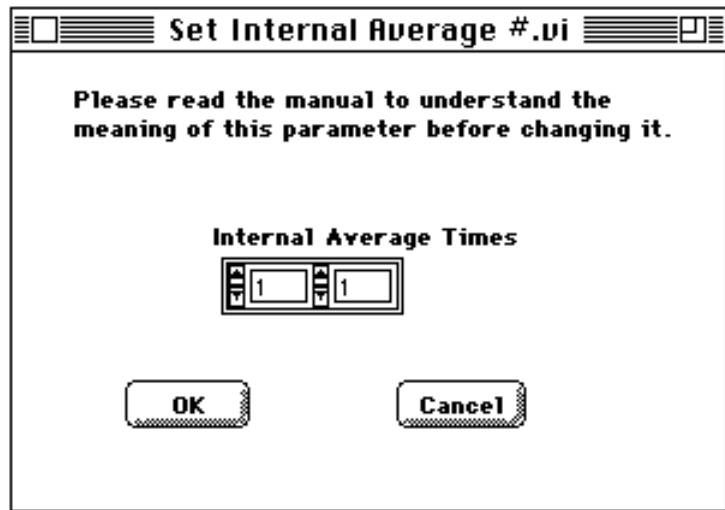


Figure 2-2. Internal Data Averaging Setting Panel

**Internal Average Times** indicates the number of blocks of data to be averaged in the higher frequency bands. The first number in the control should be in the range of 1-150, and the second number should be in the range of 1-15. The lower limit on both controls (1) corresponds to no averaging and the upper limit (150 for the first control and 15 for the second control) is complete averaging. Any number in between these two numbers is partial averaging. The more the averaging, the slower execution time. Refer to the *Internal Data Averaging* section in Chapter 3, *Third-Octave Analysis Toolkit Design*, for more details.

Click OK to accept the new internal average settings and Cancel to go back to the original setting.

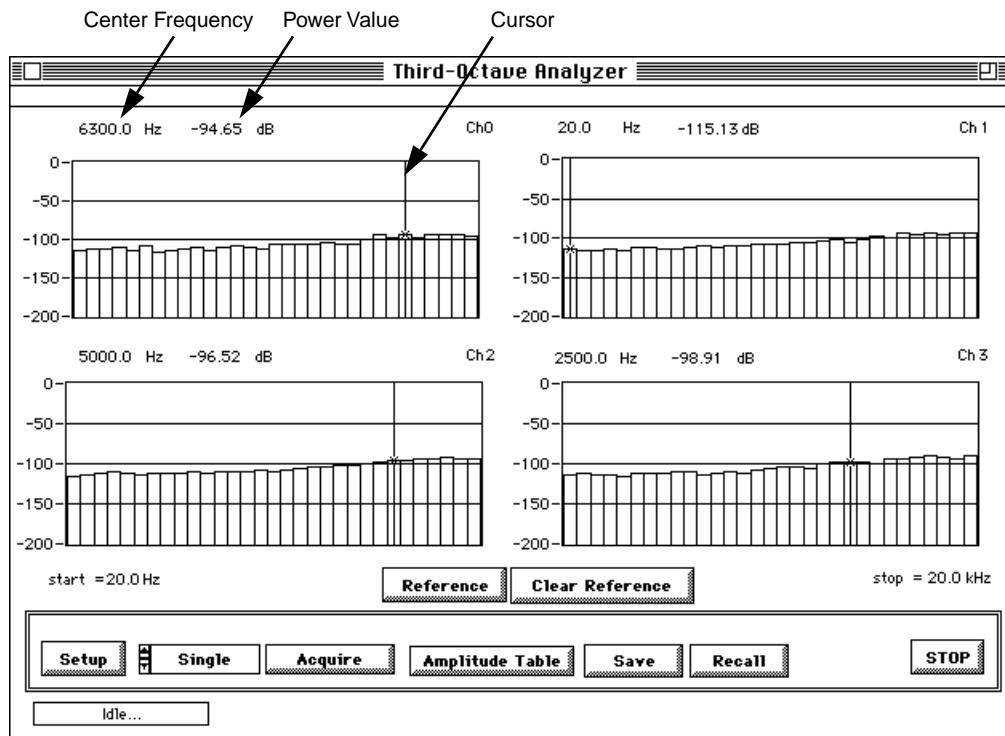
## Running the Third-Octave Analyzer

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When you finish setting all the parameters on the Setup panel, click the Done button. Then, the analyzer begins to acquire data, performs third-octave analysis, and displays the power results on the front panel. The analyzer shows both the power values and the corresponding center frequencies.

The Third-Octave Analyzer only displays the graphs for the channels you choose. Figure 2-3 shows a four-channel analyzer panel. You will only get one, two, or three graphs if you only choose 1, 2, or 3 channels.

You can use the Operating tool to position the cursors (shown as thin vertical lines with an asterisk in each channel chart in Figure 2-3). Move the cursors left and right to display the power value in each band. Two indicators show the center frequency of each band and the corresponding power value.



**Figure 2-3.** Four-Channel Third-Octave Analyzer Panel

The following sections define the several control buttons on the Third-Octave Analyzer front panel that you can select to perform functions.

**Setup** opens the Setup panel.

**Acquire** acquires and analyzes a block of data. The analyzer does not start acquiring data until you click on this button.

You can select single or continuous mode to acquire data. Choose the mode by clicking on the up or down arrows on the control to the left of the Acquire button until the desired mode appears in the control. When you select **Single**, every time that you click the Acquire button, the analyzer acquires and analyzes a new data block. When you choose the

**Continuous**, the analyzer starts to acquire and analyze data when you click the Acquire button. When one block of data finishes, the analyzer acquires the next block of data and analyzes it, until you click on the Stop Acquire button. (The Acquire button, which is shown in Figure 2-3, becomes the Stop Acquire button during an acquisition.)

**Amplitude Table** shows a table with all 31 bands of output power values for each channel.

**Save** saves the 31 bands of power values in a spreadsheet format where each column represents 31 bands of power value for each channel.

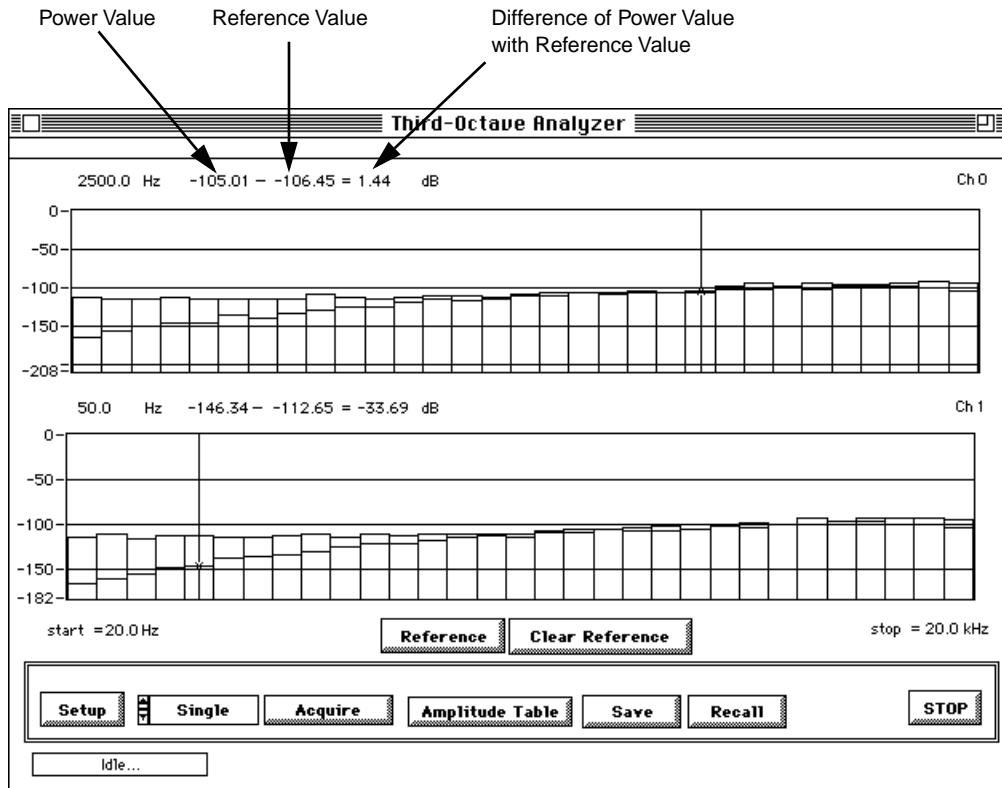
This button saves the power amplitude as well as some status information, such as channel numbers, window type, average type and weighting values.

**Recall** recalls a previous status and data. The recalled file has the same formats as using the Save button to save a file. If the current status differs from the recalled status, the analyzer loads the recalled status and displays the recalled results. When you acquire a new data block, the analyzer still uses the recalled status until you run the Setup again.

**STOP** stops the analyzer.

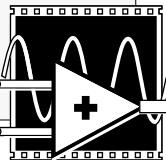
**Clear Reference** clears the reference signal for the analyzer.

**Reference** clicking this button results in the analyzer prompting you to load your reference file, which should be the same file format to which you save your data. The analyzer plots the reference on the same graph with the power value. When you have the reference signal, each plot has two more indicators which show the value of reference and the difference of reference with the actual power value at each frequency band. Figure 2-4 is the front panel for two channels with reference signals.



**Figure 2-4.** Two-Channel Third-Octave Analyzer with Reference Signals

The indicator box in the bottom left corner of the analyzer shows the status of the analyzer. In Figure 2-4, you can see that the status of this VI is **Idle**....



# Third-Octave Analysis Toolkit Design

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This chapter describes the design specifications and algorithms of the Third-Octave Analysis Toolkit. ANSI Standard S1.1 defines clear specifications for octave band filters. Octave band filters can be either passive or active analog filters that operate on *continuous-time signals*, or analog and digital filters that operate on *discrete-time signals*. Traditional octave analyzers typically use analog filters, but newer analyzers most often use digital filters.

Digital octave filters are designed in several ways. A set of bandpass filters (usually IIR filters) can be designed directly from the time domain at different center frequencies and bandwidths. In particular, ANSI S1.1 uses Butterworth filters to define the order and attenuation of the octave filters. Digital octave filters can also be designed in the frequency domain using the fast Fourier transform (FFT). Many instrument manufacturers use a spectrum analyzer to synthesize the octave analyzer. The Third-Octave Analysis Toolkit also follows this approach.

## Algorithm Description

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In the frequency domain approach to octave analysis, you first collect a block of data. Then, you apply the FFT to the data to obtain the spectral information. Because the spectral information appears in a discrete format, several discrete spectral values (or *bins*) are weighted and then summed to obtain the power for each of the 31 filters. You can obtain these same results by using a third-octave filter. The number of bins used for each octave filter varies depending on the center frequency of the octave filter. Typically, higher frequencies require more bins than the lower frequencies.

Table 3-1 shows the three possible sampling rates used by the Third-Octave Analyzer.

**Table 3-1.** Third-Octave Analyzer Sampling Rates, ANSI Bands, and Center Frequencies

Sampling Rate	ANSI Band	Center Frequencies
12.8 kHz	7–37	5 Hz–5 kHz
25.6 kHz	10–40	10 Hz–10 kHz
51.2 kHz	13–43	20 Hz–20 kHz

Each sampling rate covers 31 ANSI third-octave bands, as listed in Table 3-1. The AT-A2150 and NB-A2150F dynamic signal acquisition (DSA) devices and the AT-DSP2200 digital signal processing (DSP) devices have these software-selectable sampling rates, which makes them ideal for implementing the Third-Octave Analyzer.

## Multistage Decimation Techniques

---

Given an  $N$ -point FFT and a sampling frequency  $f_s$ , you can find the frequency resolution by using the following formula.

$$f = \frac{f_s}{N}$$

Assume you have selected  $f_s = 12.8$  kHz for  $N = 512$ . Therefore:

$$f = \frac{12.8\text{kHz}}{512} = 0.025 = 25\text{Hz}.$$

A 25-Hz frequency resolution is sufficient for higher-frequency bands but not for lower-frequency bands. For example, the center frequencies for ANSI bands 7 and 8 are only 3 Hz apart. Therefore, you must reduce  $f$  for lower-frequency bands.

You can reduce  $f$  by increasing  $N$  or by reducing the sampling frequency  $f_s$ . Increasing  $N$  dramatically increases the time needed to compute the FFT and makes the Third-Octave Analyzer impractical. Therefore, you should reduce the sampling frequency for lower-frequency bands.

Most data acquisition (DAQ) devices have a limited choice of sampling frequencies, and at any given time, only one sampling frequency is chosen. The hardware sampling frequency should be selected according to the highest center frequency that you analyze, as shown in Table 3-1.

After you select the hardware sampling rate, the Third-Octave Analyzer uses a lowpass filter to remove unwanted high frequencies, and then takes every 10th data point to lower the sampling frequency. This process is called *decimation*. For example, a 100-point data block would contain only 10 points following decimation. Table 3-2 shows how different sampling rates apply to the different third-octave filters. This table also shows the frequency resolution in each group, assuming that you used a 512-point FFT size.

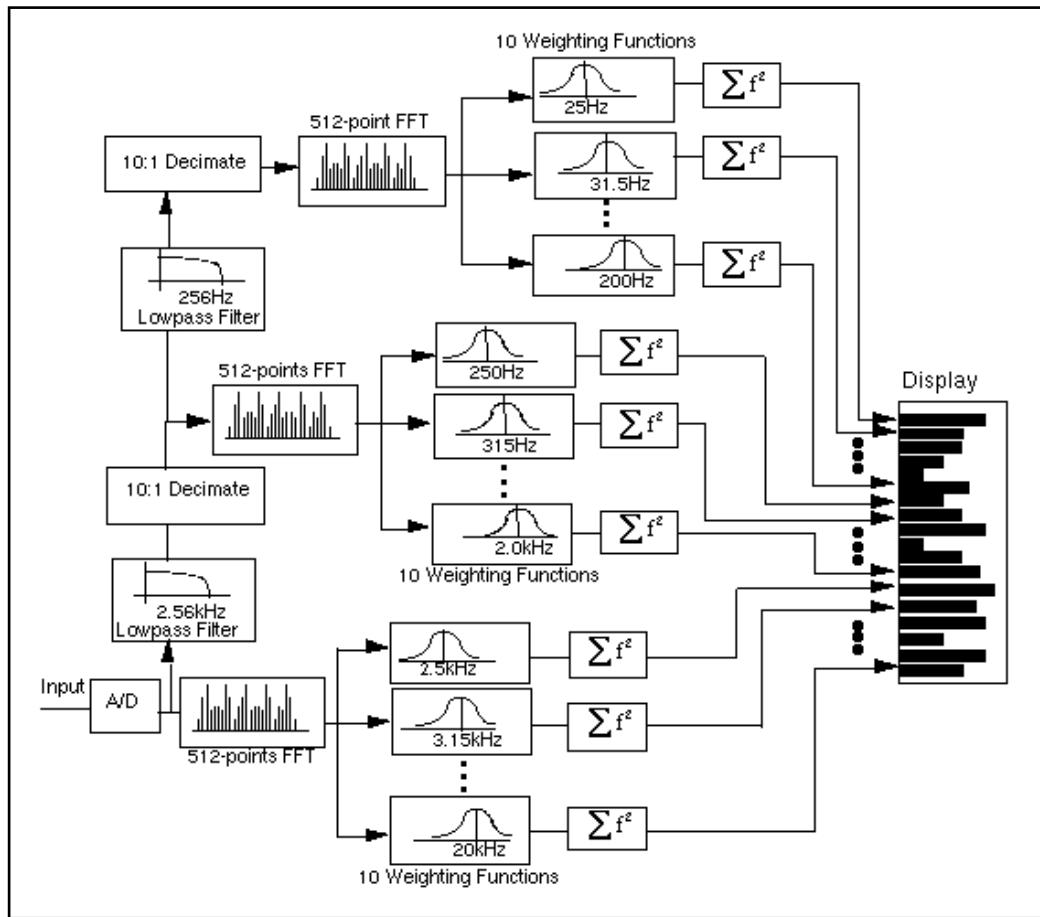
**Table 3-2.** Different Sampling Frequencies

Group	Sampling Frequencies		
Group 3 (first 10 filters)	ANSI 7–16 $f_s = 128$ Hz $\Delta f = 0.25$ Hz	ANSI 10–19 $f_s = 256$ Hz $\Delta f = 0.5$ Hz	ANSI 13–22 $f_s = 512$ Hz $\Delta f = 1$ Hz
Group 2 (middle 10 filters)	ANSI 17–26 $f_s = 1.28$ kHz $\Delta f = 2.5$ Hz	ANSI 20–29 $f_s = 2.56$ kHz $\Delta f = 5$ Hz	ANSI 23–32 $f_s = 5.12$ kHz $\Delta f = 10$ Hz
Group 1 (last 11 filters)	ANSI 27–37 $f_s = 12.8$ kHz $\Delta f = 25$ Hz	ANSI 30–40 $f_s = 25.6$ kHz $\Delta f = 50$ Hz	ANSI 33–43 $f_s = 51.2$ kHz $\Delta f = 100$ Hz

The frequencies in Group 1 are actual hardware sampling rates, while the other groups show rates obtained by using the decimation technique. The filters in Group 2 have one-tenth the sampling rate of those in Group 1, and the filters in Group 3 have one-tenth the sampling rate of the Group 2 filters. By reducing the sampling frequency in this way, there is enough frequency resolution for all the octave filters.

The size of the FFT,  $N$ , remains fixed at 512 points. When you run the analyzer, first it gathers 54,280 data points at the higher frequencies and computes a 512-point FFT. The analyzer modifies the frequency data from the FFT according to a predetermined weighting function to obtain the output of the 11 third-octave filters in Group 1. The analyzer then decimates the data block to get the data at the next lower sampling frequency and computes the second 512-point FFT. Finally, it decimates the data block again to get the data at the lowest frequencies and computes the third 512-point FFT. In this way, the analyzer obtains and

displays 31 bands of power output. Figure 3-1 shows this design procedure.

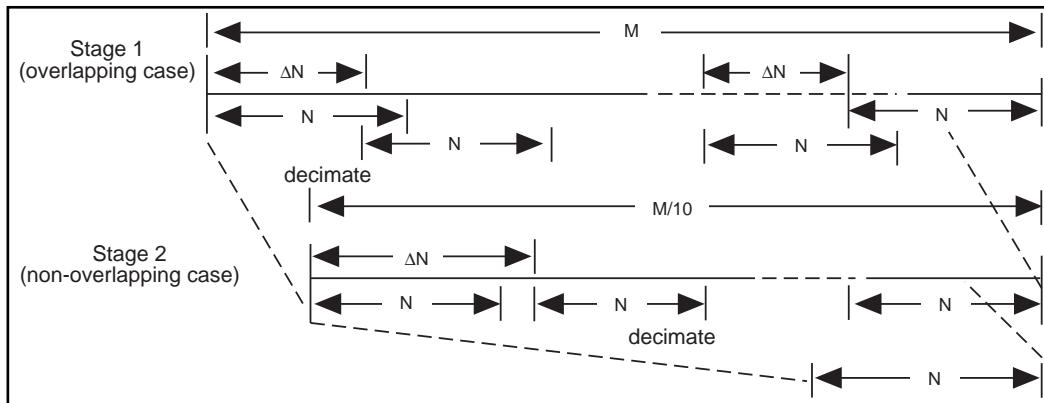


**Figure 3-1.** Multistage Third-Octave Analyzer Design Using FFT

With the analyzer, you can also choose to have 256-point FFT. This is not as accurate as using 512-point FFT, but it needs less memory and runs faster. If you choose to use 256-point FFT, the analyzer acquires a total of 28,680 points.

# Internal Data Averaging

Figure 3-2 shows a diagram how internal data points are used in each processing stage.



**Figure 3-2.** Internal Data Averaging Procedure

As described previously, there are three filter groups. The original  $M$  points are acquired by hardware ( $M=54280$  if  $N=512$ , and  $M=28680$  if  $N=256$ ). The decimation filters are successively applied to obtain approximate  $M/10$  points and  $M/100$  points in the second and third stages. In the first stage, there are roughly 100 blocks of data. In the second stage, there are approximately 10 blocks of data, each is of  $N$  points. Thus, averaging is applicable in the first and second stages. The last stage has exact  $N$  points. Therefore, no average is available at this stage.

The **Internal Data Averaging** array controls the number of averaging blocks in each stage. The first element controls the first stage and the second controls the second stage. Assuming the value of one element in the array is set to  $j$ , then  $\Delta N = M/j$  is the distance between the two adjacent  $N$ -point blocks. Total number of  $j$   $N$ -point blocks are averaged at that stage.

When  $\Delta N < N$ , the averaging is overlapping data averaging as illustrated in Stage 1 of Figure 3-2.

When  $\Delta N \geq N$ , the averaging is non-overlapping data averaging, as illustrated in Stage 2 of Figure 3-2.

For example, if  $M=54280$  and  $N=512$ , the first element in **Internal Data Averaging** is set to 150, and  $\Delta N = 54280/150=362$ . Therefore,  $512-362=150$ , so about 30% data is overlapping. For the second stage, if the second element in **Internal Data Averaging** is set to 15, then  $\Delta N = 5400/15=360$ . There are also  $512-360=152$ , so about 30% data is overlapping.

In most application, 30% of overlapping data is sufficient for spectral analysis. Therefore, 150 and 15 are used as the default settings for the **Internal Data Averaging** array as the complete averaging case in the analyzer. They are also the upper bound values for the array elements. In the case of no averaging in the analyzer, the values of both elements in the array are set to 1.

The more data blocks are averaged, the longer time is needed to compute the data.

If the signal is almost stationary, no averaging is needed. If the signal is not nearly stationary, some averaging is needed.

## Specifications of the Third-Octave Analysis Toolkit

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With the AT-A2150 or the NB-A2150F boards, the Third-Octave Analyzer can analyze up to four channels of audio signal data simultaneously. If you have a AT-DSP2200 board, the analyzer can process up to two channels of data simultaneously.

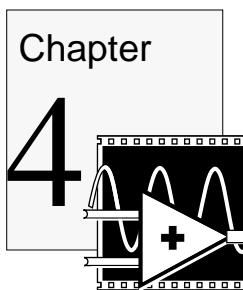
The hardware sampling frequencies are 51.2 kHz, 25.6 kHz, and 12.8 kHz. The frequency is selected using the Setup panel.

Each band filter satisfies Order 3, Type 3-D as defined in the ANSI S1.11-1986 standard. These filters are defined as follows.

- Order 3—Each filter in the filter bank has attenuation characteristics equal to or exceeding the third-order Butterworth filters, except in the passband ripples. The original Third-Octave Analyzer is defined using the analog Butterworth filter, which has a flat frequency response in the passband range. The S1.11-1986 accepts the use of a digital filter in the third-octave analyzer; therefore, passband ripples are also acceptable.

- Type 3—The Type 3-D filter meets the following ANSI standards.
  - 200 millibels for peak-to-valley ripple
  - 100 millibels for reference pass band attenuation
  - 30 millibels for linearity
  - 41 millibels for white noise bandwidth error
- The stopband attenuation is  $> 65$  dB.

 **Note:** *Sub-Type Designator D, in Type 3-D, means that there are  $> 100$  millibels for composite bandwidth error.*

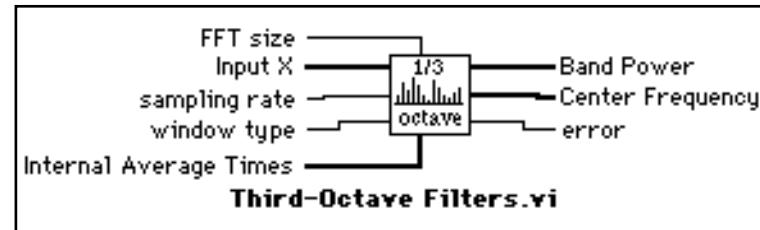


# Third-Octave Filters VI

This chapter contains the description for the Third-Octave Filters VI and its parameters.

## Third-Octave Filters VI Description

This VI is the main VI called by the Third-Octave Analyzer. It computes the outputs of 31 third-octave filters of the **Input X**.



**I32**

**FFT size** decides the fast Fourier transform (FFT) size that is used to compute the third-octave outputs. This parameter has two options you can choose: 256 or 512. Selecting a size of 512 gives more accurate results but takes more memory and runs slower than selecting a size of 256.

The **FFT size** parameter defaults to 512.

**[DBL]**

**Input X** is the input data array. The size of this input must be 28680 if **FFT size**=256 or 54280 if **FFT size**=512.

**[DBL]**

**sampling rate** is the sampling rate of **Input X**. This parameter determines the frequency range that is analyzing. Assuming **sampling rate** is  $fs$ ,  $i = fs \div 12800$ ,  $fl$  is the lower bound of the frequency range and  $fh$  is the upper bound of the frequency range, then  $fl = i \times 5\text{Hz}$ ,  $fh = i \times 5000\text{Hz}$ .

For example, if  $fs=25600\text{Hz}$ , then  $i=2$ , the frequency range is 10Hz-10000Hz. The recommended  $fs$  should be chosen from 12800Hz,

25600Hz, or 51200Hz and the corresponding frequencies ranges are 5Hz-5000Hz, 10Hz-10000Hz, and 20Hz-20000Hz.

The **sampling rate** parameter defaults to 12800Hz.



**window type** is the type of window that applies to the **Input X**. This parameter has four options you can choose.

- 0: Rectangular
- 1: Hamming
- 2: Hanning
- 3: Blackman

The **window type** parameter defaults to Hanning.



**Internal Average Times** indicates the number of blocks of data to be averaged in the higher frequency bands. This is a two-element array. The first number should be in the range of 1-150, and the second number should be in the range of 1-15. The lower bound corresponds to no averaging and the upper bound complete averaging, any number in between partial averaging. The more the averaging, the slower execution time. Refer to the *Internal Data Averaging* section in Chapter 3, *Third-Octave Analysis Toolkit Design*, for more details.



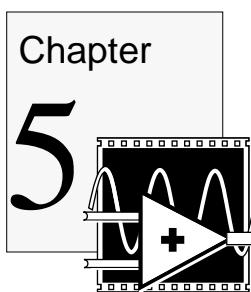
**Band Power** contains the power outputs of the 31 third-octave filters.



**Center Frequency** contains the center frequencies of the 31 third-octave filters. Refer to the *Introduction to the Third-Octave Analysis Toolkit* section in Chapter 1, *Overview of the Third-Octave Analysis Toolkit*, for how to compute the center frequencies.



**error**



# Building Windows Applications for Third-Octave Analysis

This chapter describes how to build a third-octave analysis applications under a Windows environment.

## Third-Octave Analysis Applications in LabWindows/CVI

### Third-Octave Analysis Instrument Driver

The Third-Octave Analysis Toolkit provides an instrument driver, `octinstr.fp`, for LabWindows/CVI users. You can find this file in the `cvisrc\instr` subdirectory of your installation directory.

The following is the prototype for the instrument driver.

```
long status= ThirdOctave_Analyzer(double input[], long
nx, double fs, long winType, long FFTSize, long
avgNum[ 2 ], double Power[31], double CenterFreq[31],
long outputNum);
```

### Parameters

Input	<b>input</b>	double array	The input data array.
	<b>nx</b>	long integer	The size of the input data array. <b>nx</b> =28680 if <b>FFTSize</b> =512 and <b>nx</b> =54280 if <b>FFTSize</b> =256.
	<b>fs</b>	double integer	The sampling rate of input.
	<b>winType</b>	long integer	The type of window that applies to the input array.
	<b>FFTSize</b>	long integer	The FFT size used to compute the third-octave outputs, which can only be 256 or 512.
	<b>aveNum</b>	long array	The internal averaging information.
	<b>outputNum</b>	long integer	The size of output arrays, which must be 31.

Output	<b>Power</b> <b>CenterFreq</b>	double array double array	The outputs of the 31 third-octave filters. The center frequencies of the 31 third-octave filters.
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## Return Value

<b>status</b>	long integer	Refer to error codes in Appendix A, <i>Error Codes</i> .
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## Parameter Discussion

**input** is the input data array. The size of **input** must be 28680 if **FFTSize**=256, and must be 54280 if **FFTSize**=512.

**nx** is the array size of **input**. The size of **nx** must be 28680 if **FFTSize**=256, and must be 54280 if **FFTSize**=512.

**fs** is the sampling rate of **input**. This parameter determines the frequency range that is analyzing. Assuming  $i=fs/12800$ ,  $fl$  is the lower limit of the frequency range and  $fh$  is the high limit of the frequency range, then

$fl = i \times 5\text{Hz}$ ,  $fh = i \times 5000\text{Hz}$ . For example, if  $fs=25600\text{Hz}$ , then  $i=2$ , and the frequency range is 10Hz-10000Hz. The recommended **fs** should be chosen from 12800Hz, 25600Hz, or 51200Hz and the corresponding frequencies ranges are 5Hz-5000Hz, 10Hz-10000Hz, and 20Hz-20000Hz.

**winType** is the type of window that applies to the input array. There are four kinds of windows from which you can choose.

- 0: Rectangular
- 1: Hamming
- 2: Hanning
- 3: Blackman

**FFTSize** is the FFT size that is used to compute the third-octave outputs. It can only be 256 or 512. Using 512-point FFT gives more accurate results but takes more memory and runs slower than using 256-point FFT.

**avgNum** indicates the number of blocks of data to be averaged in the higher frequency bands. This is a two-element array. The first number should be in the range of 1-150, and the second number should be in the range of 1-15. The lower bound corresponds to no averaging and the upper bound complete averaging, any number in between partial averaging. No averaging is used for near stationary signals and complete averaging is used for not nearly stationary signals. The more the averaging, the slower the execution time. Refer to *Internal Data*

*Averaging* section in Chapter 3, *Third-Octave Analysis Toolkit Design*, for more details.

**outputNum** is the size of output arrays of **Power** and **CenterFreq**, which must be 31.

**Power** is an array that contains the outputs of the 31 third-octave filters. It is not in the dB format.

**CenterFreq** is an array that contains the center frequencies of the 31 third-octave filters. Refer to the *Introduction to the Third-Octave Analysis Toolkit* section in Chapter 1, *Overview of the Third-Octave Analysis Toolkit*, for how the center frequencies are computed.

## Running Third-Octave Analysis Applications in LabWindows/CVI

Add the `octinstr.fp` to your project and call the above `ThirdOctave_Analyzer` function in your C code.

For an example of how to call this function, open `cvisrc\example\oct_exam.prj`.

## Third-Octave Analysis Applications in Windows

---

Third-Octave Analysis Toolkit provides a 16-bit dynamic link library (DLL), `octave16.dll`, and a 32-bit DLL, `octave32.dll`, for Windows users. These two DLLs are located in the `winsrc\windll` subdirectory of your installation directory.

The function prototype in these DLLs is:

```
long FAR PASCAL ThirdOctave_Analyzer(double *input,  
long nx, double fs, long winType, long FFTSize, long  
avgNum[2], double Power[31], double CenterFreq[31],  
long outputNum);
```

The meanings of the parameters are the same as the instrument driver for LabWindows/CVI. Please refer to the previous *Third-Octave Analysis Instrument Driver* section for the parameter description.

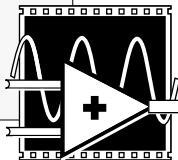
Call this function the same way in your code as you call any functions in DLLs.

# Third-Octave Analysis Applications in Visual Basic

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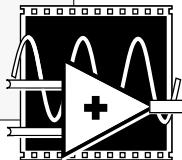
Third-Octave Analysis Toolkit also provides an example for Visual Basic showing how to call the `ThirdOctave_Analyzer` function. You can find the source codes in the `winsrc\example\vb` subdirectory of your installation directory.

Before you run this example, copy `octave16.dll` to your Windows directory.



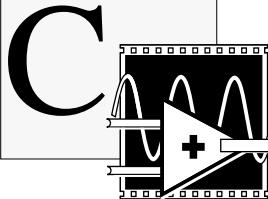
This appendix lists the error codes returned by the Third-Octave Filters VI and the C function, `ThirdOctave_Analyzer()`.

Code	Name	Description
-20001	OutofMemErr	There is not enough memory left.
-20070	SamplingRateErr	The sampling rate is not correct.
-20071	ArraySizeErr	The size of one of the arrays is not correct.



For more information on octave analysis, read the following documents.

1. ANSI S1.11-1986: Specification for octave-band and fractional-octave-band analog and digital filters.
2. R.B. Randall. *Frequency Analysis*, Brüel & Kjaer, ISBN 8-87355-07-8.



# Customer Communication

For your convenience, this appendix contains forms to help you gather the information necessary to help us solve technical problems you might have, as well as a form you can use to comment on the product documentation. Filling out a copy of the *Technical Support Form* before contacting National Instruments helps us help you better and faster.

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# Technical Support Form

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Operating system (include version number) \_\_\_\_\_

Clock speed \_\_\_\_\_ MHz RAM \_\_\_\_\_ MB Display adapter \_\_\_\_\_

Mouse yes no Other adapters installed \_\_\_\_\_

Hard disk capacity \_\_\_\_\_ MB Brand \_\_\_\_\_

Instruments used \_\_\_\_\_

Boards installed (include revision and configuration) \_\_\_\_\_

\_\_\_\_\_

LabVIEW Version \_\_\_\_\_ VI Libraries installed (other than standard libraries) \_\_\_\_\_

The problem is: \_\_\_\_\_

\_\_\_\_\_

List any error messages: \_\_\_\_\_

The following steps reproduce the problem: \_\_\_\_\_

\_\_\_\_\_

# Documentation Comment Form

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Part Number: **320952A-01**

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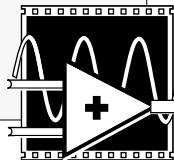
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## Glossary



# Glossary

Prefix	Meaning	Value
m-	milli-	$10^{-3}$
$\mu$ -	micro-	$10^{-6}$
n-	nano-	$10^{-9}$

## A

ANSI S1.11-1986 Standard Specifications for octave-band and fractional-octave-band analog and digital filters.

ASCII American Standard Code for Information Interchange.

## B

basis A core or fundamental function.

## D

DAQ Data acquisition.

DLL Dynamic link library.

DSA Dynamic signal acquisition.

DSP Digital signal processing.

## F

FFT Fast Fourier transform.

## *Glossary*

### **I**

IIR filters      Infinite impulse response filters.

### **M**

MB      Megabytes of memory.

### **N**

nonstationary signal    A signal whose frequency content changes within a captured frame.

### **S**

sampling rate      The rate at which a continuous waveform is digitized.

### **V**

VI      Virtual instrument.