

BridgeVIEW™ and LabVIEW™

Third-Octave Analysis Toolkit Reference Manual

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About This Manual

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


Organization of This Manual

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*, describes 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 application under Windows 95 and Windows NT environments.
- 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

The following conventions are used in this manual:

bold	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.
<i>bold italic</i>	Bold italic text denotes a note, caution, or warning.
monospace	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.
[]	In Help window pictures of VI inputs and outputs, square brackets enclose parameters whose values you rarely need to set.
<>	Angle brackets enclose the name of a key on the keyboard—for example, <shift>.
-	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.
	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

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

- *BridgeVIEW User Manual*
- *G Programming Reference Manual*
- *LabVIEW Function and VI Reference Manual*
- *LabVIEW User Manual*

Customer Communication

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

This chapter describes the contents of the *Third-Octave Analysis Toolkit*, describes toolkit installation, and explains how you can use this program. The Third-Octave Analysis Toolkit can act as an add-on toolkit for LabVIEW or BridgeVIEW, 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.

Package Contents

Your Third-Octave Analysis Toolkit contains the following materials.

- Third-Octave Analysis Toolkit disks
- *Third-Octave Analysis Toolkit Reference Manual*

Installation

This section contains instructions for installing the Third-Octave Analysis Toolkit on the Macintosh, Power Macintosh, Windows 95, or Windows NT.

You must use the analyzer with one of the National Instruments Data Acquisition (*DAQ*) devices. The Third-Octave Analysis Toolkit only can 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 have these built-in filters.

Macintosh or Power Macintosh

Complete the following steps to install the toolkit.

1. Insert disk 1 of the Third-Octave Analysis Toolkit into your 3.5-inch disk drive.
2. Double-click on the Third-Octave Analysis Installer icon when it appears on your desktop.
3. 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 installed the necessary hardware already, refer to the user manual for your DAQ device for device configuration instructions.

Once you have completed 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.llb`. You can run and modify the Third-Octave Analyzer in `octave.llb` from LabVIEW.

Windows 95 and Windows NT

Complete the following steps to install the toolkit.

1. Insert disk 1 of the Third-Octave Analysis Toolkit into your 3.5-inch disk drive.
2. From the File Manager, open the appropriate disk drive and run `setup.exe`.
3. 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 installed the necessary hardware already, refer to the user manual for your DAQ device for device configuration instructions.

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

After you finish installing the Third Octave Analysis Toolkit, the following files and directories are installed.



Note

xxx denotes your installation directory.

<code>xxx\octave.exe</code>	The stand-alone application.
<code>xxx\lvsrc\octave.llb</code>	The LabVIEW source code for <code>octave.exe</code> . (You can run and modify <code>octave.llb</code> from LabVIEW.)
<code>xxx\daqdrv</code>	The <i>DLL</i> necessary to run <code>octave.exe</code> .
<code>xxx\aweight.dat</code>	An example weighting file.
<code>xxx\channel4.ref</code>	An example reference file.
<code>xxx\cvsrc\instr</code>	Contains the instrument driver for third-octave analysis with LabWindows/CVI.
<code>xxx\cvsrc\example</code>	Contains a LabWindows/CVI example that calls the third-octave analysis instrument driver.
<code>xxx\winsrc\windll</code>	Contains 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?

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 also is expressed in b octaves often:

$$\log_2\left(\frac{f_{i+1}}{f_i}\right) = b,$$

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

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 roughly can be 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 $2^{-1/6}(2^{1/3} - 1)(fm)$, 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
28	630	-1.9
29	800	-0.8
30	1000	0

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)
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 f_s , define $\Delta f = f_s/51200$, 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 95 or NT, first configure your data acquisition (DAQ) device using the NI-DAQ Configuration Utility. On the Macintosh, be sure your DAQ device is 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.

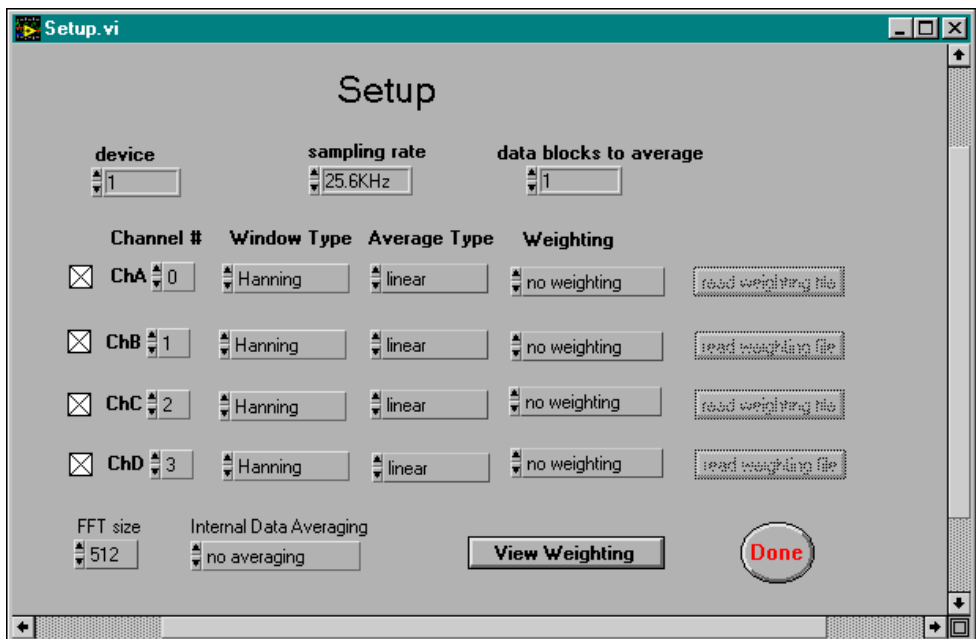


Figure 2-1. Third-Octave Analyzer Setup Dialog Box

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 the NI-DAQ Configuration Utility. 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 Q , then $S_p(k)$ is the instantaneous power output of data block p , and the averaged power output after the number of Q data blocks is $S_Q(k)$.

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

$$S_Q(k) = \frac{1}{Q} \sum_{p=0}^{Q-1} S_p(k)$$

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

$$S_p(k) = (1 - \alpha)S_{p-1}(k) + \alpha S_p(k),$$

where $\alpha = \frac{1}{Q}$ and $0 < \alpha < 1$

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-weighting` tells the analyzers to mimic human hearing responses to acoustical signals. Refer to Table 1-1, *Filter Bands for ANSI S1.11*, in Chapter 1, *Overview of the Third-Octave Analysis Toolkit*, for a list of default A-Weighting values incorporated in the analyzer. You also can 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.

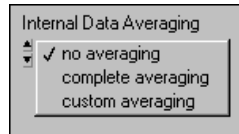
FFT size is the size used to compute *FFT* internally. It has two options 512 and 256. Using 512-point FFT gives more accurate results but takes twice the memory and runs slower than using 256-point FFT. **FFT size** defaults to 512.

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 the **Set Internal Averaging Setting** dialog box appears, as shown in Figure 2-2.

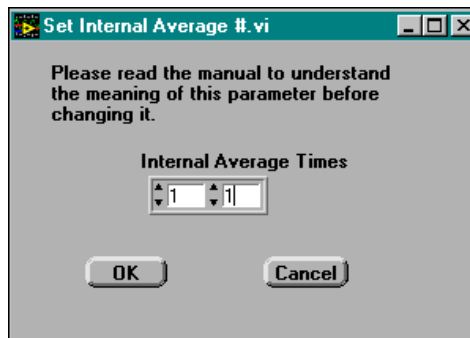


Figure 2-2. Internal Data Averaging Setting Dialog Box

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 or **Cancel** to go back to the original setting.

Running the Third-Octave Analyzer

When you finish setting all the parameters on the Setup dialog box, 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. Only one, two, or three graphs appear 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.

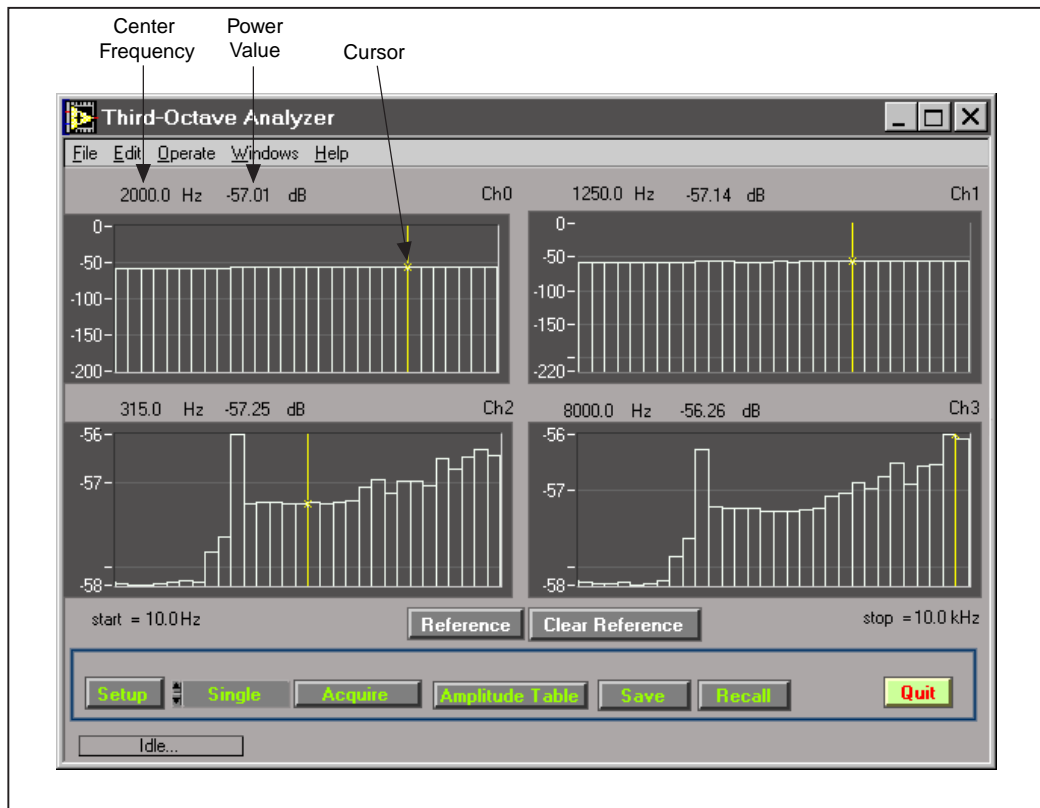


Figure 2-3. Four-Channel Third-Octave Analyzer Panel

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 dialog box.

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 **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.

Reference 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 that show the value of reference and the difference of reference with the actual power value at each frequency band.

Clear Reference clears the reference signal for the analyzer.

Figure 2-4 is the front panel for one channel with a reference signal.

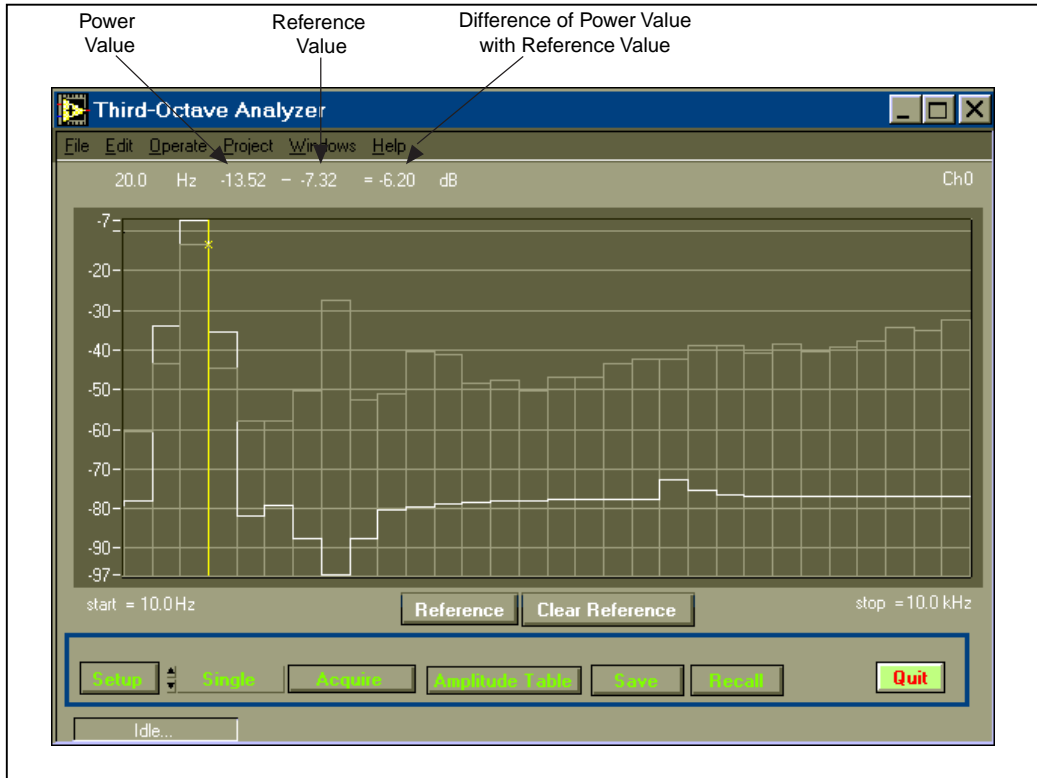


Figure 2-4. One-Channel Third-Octave Analyzer Panel with Reference Signal

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

This chapter describes the design specifications and algorithms of the Third-Octave Analysis Toolkit. ANSI Standard S1.11 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 S1.11 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

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

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:

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

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 1.3 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 51,200 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.

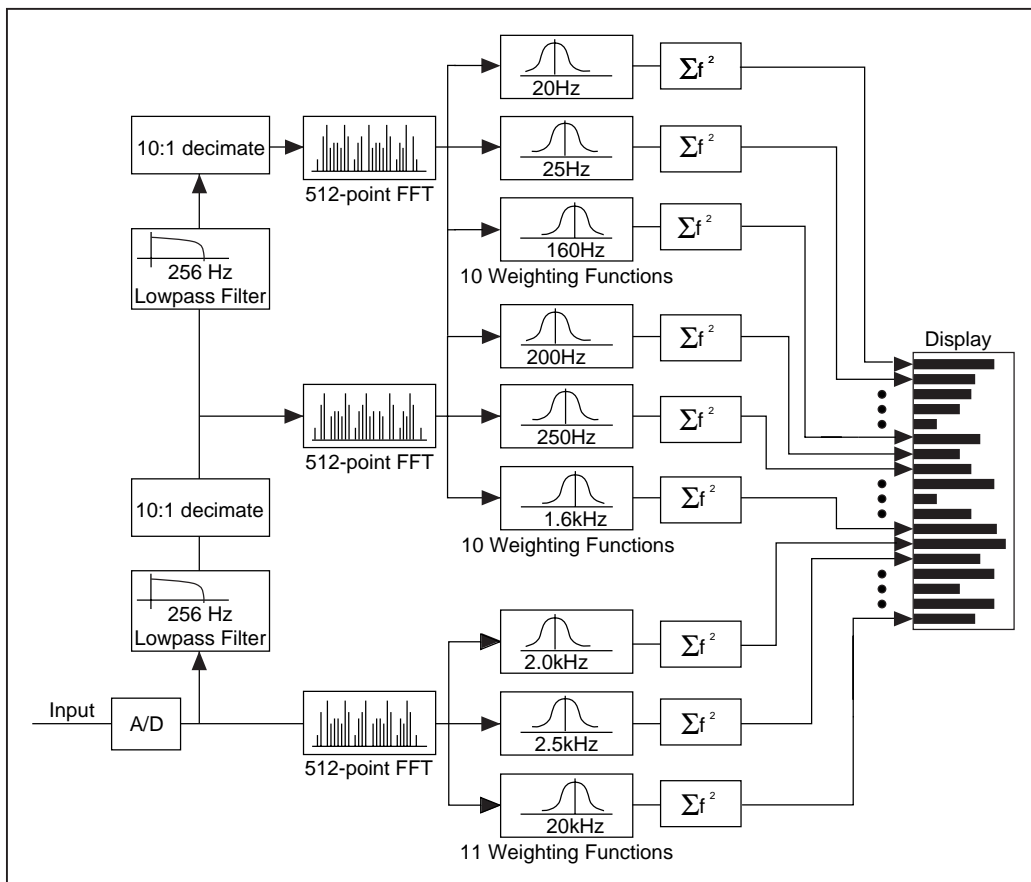


Figure 3-1. Multistage Third-Octave Analyzer Design Using FFT

With the analyzer, you also can choose to have 256-point FFT. This is not as accurate as using 512-point FFT, but it requires 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.

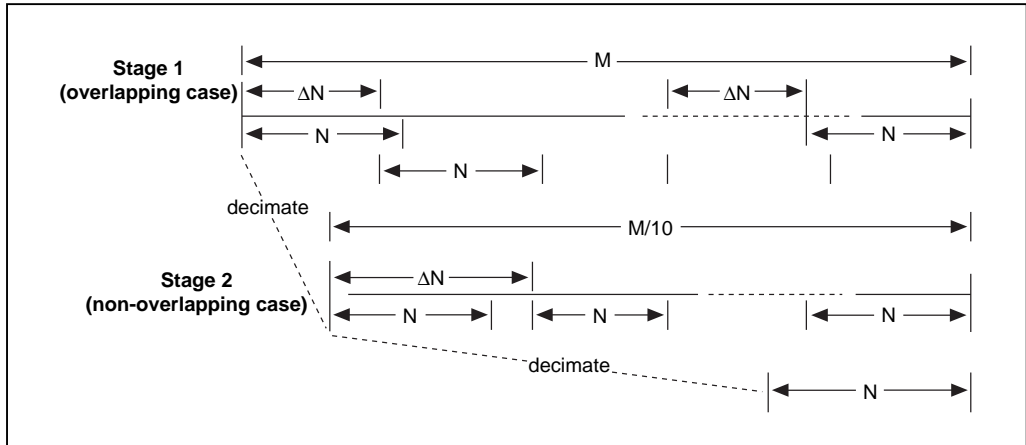


Figure 3-2. Internal Data Averaging Procedure

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 percent data is overlapping. So for the second stage, if the second element in **Internal Data Averaging** is set to 15, then $\Delta N = 5400/15 = 360$. Now there is also $512 - 360 = 152$, and again, about 30 percent data is overlapping.

In most application, 30 percent 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

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**

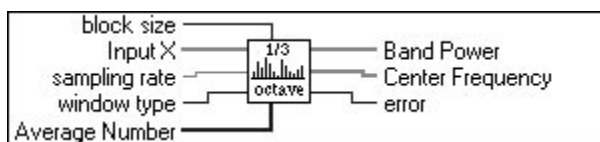
Sub-Type Designator D, in Type 3-D, means that there are >100 millibels for composite bandwidth error.

Third Octave Filters VI

This chapter describes the *Third-Octave Filters VI* and its parameters.

Third-Octave Filters VI

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 determines 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 being analyzed. 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.

I32

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.

I32

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.

DBL

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

DBL

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.

I32

error

See Appendix A, [Error Codes](#), for a list of error codes.

Building Windows Applications for Third-Octave Analysis

This chapter describes how to build a third-octave analysis application under Windows 95 and Windows NT environments.

Third-Octave Analysis Applications in LabWindows/CVI

This section describes the instrument driver for LabWindows/CVI included with the Third Octave Analysis Toolkit, and provides information on running Third-Octave Analysis applications in LabWindows/CVI.

Third-Octave Analysis Instrument Driver

The Third-Octave Analysis Toolkit provides an instrument driver, `octave.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

Name	Type	Description
input	double array	The input data array.
nx	long integer	The size of the input data array. nx = 28680 if FFTSize = 512 and nx = 54280 if FFTSize = 256.
fs	double integer	The sampling rate of input.
winType	long integer	The type of window that applies to the input array.
FFTSize	long integer	The FFT size used to compute the third-octave outputs, which can only be 256 or 512.
aveNum	long array	The internal averaging information.
outputNum	long integer	The size of output arrays, which must be 31.
Power	double array	The outputs of the 31 third-octave filters.
CenterFreq	double array	The center frequencies of the 31 third-octave filters.

Output

Name	Type	Description
Power	double array	The outputs of the 31 third-octave filters.
CenterFreq	double array	The center frequencies of the 31 third-octave filters.

Return Value

Name	Type	Description
status	long integer	Refer to error codes in Appendix A, <i>Error Codes</i> .

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

$f_s = 25600\text{Hz}$, then $i = 2$, and the frequency range is $10\text{Hz}–10000\text{Hz}$. The recommended f_s should be chosen from 12800Hz , 25600Hz , or 51200Hz and the corresponding frequency ranges are $5\text{Hz}–5000\text{Hz}$, $10\text{Hz}–10000\text{Hz}$, and $20\text{Hz}–20000\text{Hz}$.

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 the [Internal Data Averaging](#) section in Chapter 3, *Third-Octave Analysis Toolkit Design*, for more information.

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

Depending on the CVI compatibility mode that you selected (Borland, Msvc, Symantec, or Watcom) during your CVI installation, you must copy the appropriate `Octave.obj` file from the `xxx\cvsrc\instr\win32\` folder to the `xxx\cvsrc\instr` folder.

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

Third-Octave Analysis Applications in Windows

Third-Octave Analysis Toolkit provides a 32-bit dynamic link library (DLL), `octave32.dll`, for Windows 95/NT users. This DLL is located in the `winsrc\windll` subdirectory of your installation directory.

The function prototype in these DLLs is:

```
long 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

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.

For Windows 95/NT, copy `octave32.dll` from the `winsrc\windll` folder to your `Windows\System` folder.

Error Codes

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.

References

This appendix lists the reference material used to produce the VI in this manual.

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

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



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Canada (Ontario)	905 785 0085	905 785 0086
Canada (Quebec)	514 694 8521	514 694 4399
Denmark	45 76 26 00	45 76 26 02
Finland	09 725 725 11	09 725 725 55
France	01 48 14 24 24	01 48 14 24 14
Germany	089 741 31 30	089 714 60 35
Hong Kong	2645 3186	2686 8505
Israel	03 6120092	03 6120095
Italy	02 413091	02 41309215
Japan	03 5472 2970	03 5472 2977
Korea	02 596 7456	02 596 7455
Mexico	5 520 2635	5 520 3282
Netherlands	0348 433466	0348 430673
Norway	32 84 84 00	32 84 86 00
Singapore	2265886	2265887
Spain	91 640 0085	91 640 0533
Sweden	08 730 49 70	08 730 43 70
Switzerland	056 200 51 51	056 200 51 55
Taiwan	02 377 1200	02 737 4644
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Company _____

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Computer brand _____ Model _____ Processor _____

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 _____

National Instruments hardware product model _____ Revision _____

Configuration _____

National Instruments software product _____ Version _____

Configuration _____

The problem is: _____

List any error messages: _____

The following steps reproduce the problem: _____

Third-Octave Analysis Toolkit

Hardware and Software Configuration Form

Record the settings and revisions of your hardware and software on the line to the right of each item. Complete a new copy of this form each time you revise your software or hardware configuration, and use this form as a reference for your current configuration. Completing this form accurately before contacting National Instruments for technical support helps our applications engineers answer your questions more efficiently.

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DMA channels of hardware _____

Base I/O address of hardware _____

Programming choice _____

National Instruments software _____

Other boards in system _____

Base I/O address of other boards _____

DMA channels of other boards _____

Interrupt level of other boards _____

Other Products

Computer make and model _____

Microprocessor _____

Clock frequency or speed _____

Type of video board installed _____

Operating system version _____

Operating system mode _____

Programming language _____

Programming language version _____

Other boards in system _____

Base I/O address of other boards _____

DMA channels of other boards _____

Interrupt level of other boards _____

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Glossary

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

Numbers/Symbols

° degrees

% percent

A

ANSI S1.11-1986 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.

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.

T

Third-Octave Filters VI Main VI of the Third-Octave Analyzer, which computes the outputs of 31 third-octave filters.

Third-Octave Analysis Toolkit Toolkit that includes the Third-Octave Analyzer, Third-Octave Filters VI, the Third-Octave Analysis Instrument Driver, and the executable programs necessary to use the toolkit with LabVIEW and BridgeVIEW.

Third-Octave Analyzer Stand-alone application or VI that includes the Third-Octave Filters VI as a subVI and analysis tools, including the Third-Octave Analyzer Panel.

V

VI Virtual instrument.

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