

SONIC SOLUTIONS

---

---

# **SonicStudio 5**

## **Sample Rate Conversion**

### **(SS-500 & SS-520)**

©1996 Sonic Solutions. All rights reserved.

SonicStudio 5, Sample Rate Conversion (SS-500 & SS-520)

This manual, as well as the software described in it, is furnished under license and may only be used or copied in accordance with the terms of such license. The information in this manual is furnished for informational use only, is subject to change without notice, and should not be construed as a commitment by Sonic Solutions. Sonic Solutions assumes no responsibility or liability for any errors or inaccuracies that may appear in this book.

Except as permitted by such license, no part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, recording, or otherwise, without the prior written permission of Sonic Solutions.

SONIC SOLUTIONS, INC. ("SONIC") MAKES NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, REGARDING THE APPLE SOFTWARE. SONIC DOES NOT WARRANT, GUARANTEE, OR MAKE ANY REPRESENTATIONS REGARDING THE USE OR THE RESULTS OF THE USE OF THE SONIC SOFTWARE IN TERMS OF ITS CORRECTNESS, ACCURACY, RELIABILITY, CURRENTNESS, OR OTHERWISE. THE ENTIRE RISK AS TO THE RESULTS AND PERFORMANCE OF THE SONIC SOFTWARE IS ASSUMED BY YOU. THE EXCLUSION OF IMPLIED WARRANTIES IS NOT PERMITTED BY SOME STATES. THE ABOVE EXCLUSION MAY NOT APPLY TO YOU.

IN NO EVENT WILL SONIC, ITS DIRECTORS, OFFICERS, EMPLOYEES, OR AGENTS BE LIABLE TO YOU FOR ANY CONSEQUENTIAL, INCIDENTAL, OR INDIRECT DAMAGES (INCLUDING DAMAGES FOR LOSS OF BUSINESS PROFITS, BUSINESS INTERRUPTION, LOSS OF BUSINESS INFORMATION, AND THE LIKE) ARISING OUT OF THE USE OR INABILITY TO USE THE APPLE SOFTWARE EVEN IF SONIC HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. BECAUSE SOME STATES DO NOT ALLOW THE EXCLUSION OR LIMITATION OF LIABILITY FOR CONSEQUENTIAL OR INCIDENTAL DAMAGES, THE ABOVE LIMITATIONS MAY NOT APPLY TO YOU.

Sonic, Sonic Solutions, the Sonic logo, SonicStudio, Audio 2000, Sonic DVD Creator, DVD Production Alliance, DVD Ready, DVD Toolmakers Guild, High-Density Audio, TimeTwist, Varispeed, MediaNet, and SonicOMF are trademarks of Sonic Solutions.

NoNOISE is a registered trademark of Sonic Solutions.

Dolby Digital is a trademark of Dolby Laboratories, Inc.

QuickKeys is a registered trademark of CE Software, Inc.

JL Cooper is a registered trademark of J. L. Cooper Electronics, Inc.

Apple, the Apple logo, Finder, Macintosh, Quadra, and Quicktime are registered trademarks of Apple Computer, Inc.

Acrobat is a trademark of Adobe Systems, Inc.

NuBus is a trademark of Texas Instruments.

All other company or product names are either trademarks or registered trademarks of their respective owners.

Written and designed at Sonic Solutions, 101 Rowland Blvd., Novato, CA. 94945, USA

Printed in the USA

Sonic Part Number 820012B (12/96)

# Contents

---

1 Basic Sample Rate Conversion (SS-520)	
Introduction .....	1-1
2 Varispeed Sample Rate Conversion (SS-500)	
Introduction .....	2-1
Recording with Sample Rate Conversion .....	2-2
Background Sample Rate Conversion .....	2-7
Varispeed on Playback .....	2-9
The Filter Parameters Dialog Box .....	2-10
Summary .....	2-13
References .....	2-13

## Sample Rate Conversion

---

# 1 Basic Sample Rate Conversion (SS-520)

---

## Introduction

SonicStudio™ systems equipped with the SS-520 Basic Sample Rate Option allow you to convert between the two sample rates most often used in professional audio, 44.1 kHz and 48 kHz.

## Converting Sample Rate

In professional digital audio, there are two sample rates in use.

- 44.1 kHz is used by the Compact Disc system. All CD masters must be produced at this rate.
- A rate of 48 kHz is used in many other types of digital recording, including DAT and Digital VTRs such as D1 and D2.

DAT tapes may be recorded at either sample rate, but many DAT machines (particularly consumer models) record *only* at 48 kHz. Many producers and engineers prefer to record at this rate as well.

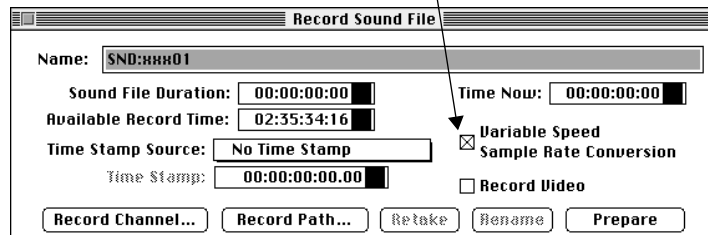
Source material recorded at the 48 kHz rate must be converted to 44.1 kHz before it can be transferred to Compact Disc. This is a digital signal processing operation performed at the time the material is transferred into the system.

## Sample Rate Conversion

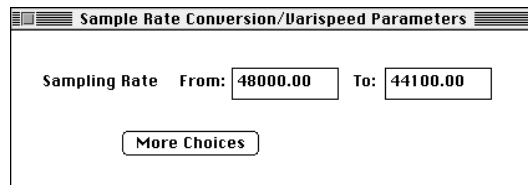
---

In systems equipped with SS-520, Basic Sample Rate Conversion, the Record Sound File dialog includes an additional checkbox:

### Sample Rate Conversion / Variable Speed Checkbox

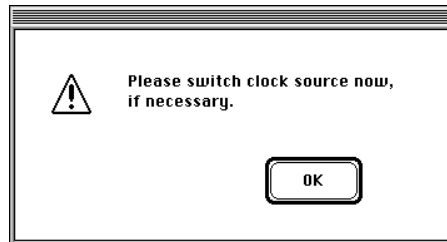


When this box is checked, a small dialog opens to specify conversion from 48 to 44.1 kHz or vice-versa.



For CD mastering, 48000 to 44100 is the usual requirement. After selecting the conversion and closing the dialog, the recording process continues normally.

When the Pause button on the armed Transport Panel is pressed to start the recording, the system brings up a Warning message that advises the user to check the clock source.



At this time, make sure that the material being loaded is indeed at the source sample rate specified.

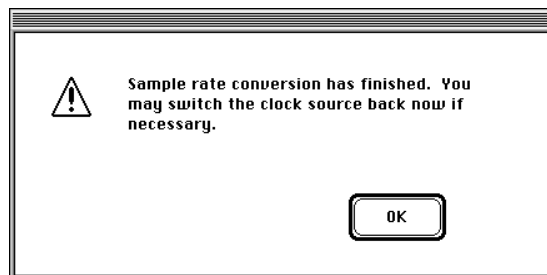


---

**CAUTION** All active audio inputs to the Sonic system must be locked to a common sample clock.

---

At the end of recording, the system again prompts the user to switch the sample rate.



If the system remains at the same sample rate as the input, the recorded file will play back with a speed and pitch change proportionate to the conversion rate. In this mode, the conversion serves as a Varispeed function.

## Sample Rate Conversion

---

## 2 Varispeed Sample Rate Conversion (SS-500)

---

### Introduction

While loading sound to or from SonicStudio, it is sometimes necessary to alter the sampling rate to convert between sample rates used by different media, such as 48 kHz for DAT and 44.1 kHz for Compact Disc. This type of processing can also be used to alter the playback rate, thereby changing the pitch and length of the material

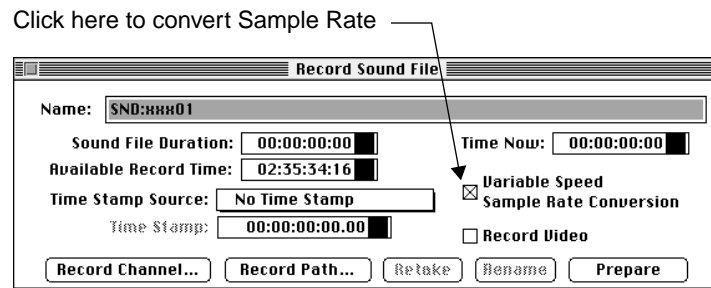
There are three ways to use the Sample Rate Conversion software:

- Record with Sample Rate Conversion by selecting Variable Speed Sample Rate Conversion in the Record Sound File dialog.
- Play back audio with rate conversion by choosing the command Varispeed on Playback under the Play menu.
- Process a file on the sound disk to create a new file converted to the target rate.

In the digital domain, sample rate conversion and variable-speed playback are identical operations. Both change the sample spacing or clock frequency of the digital audio. SonicStudio performs a set of numeric calculations, equivalent to digitally filtering and resampling the audio data, to translate from one rate to another.

## Recording with Sample Rate Conversion

When recording with the Record Sound file dialog, the user can specify Sample Rate Conversion (or SRC) by using the checkbox Variable Speed/Sample Rate Conversion.

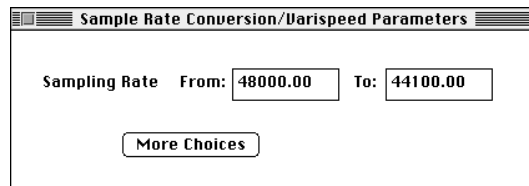


Note that sample rate conversion on record is a real-time processing function that occupies a substantial share of the SSP-3 card's capability. Because critical DSP resources are consumed, it is not possible to read or generate Time Code when recording with SRC.

Before initiating sample rate conversion, make sure that the Time Code read and generator are disabled in the Time Code Read/Write Preferences dialog.

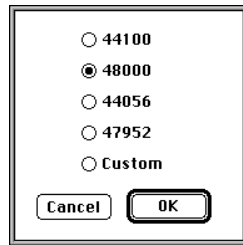
## Specifying Conversion Ratio

When the user clicks on the Sample Rate Conversion checkbox, a dialog opens to define the ratio of conversion.



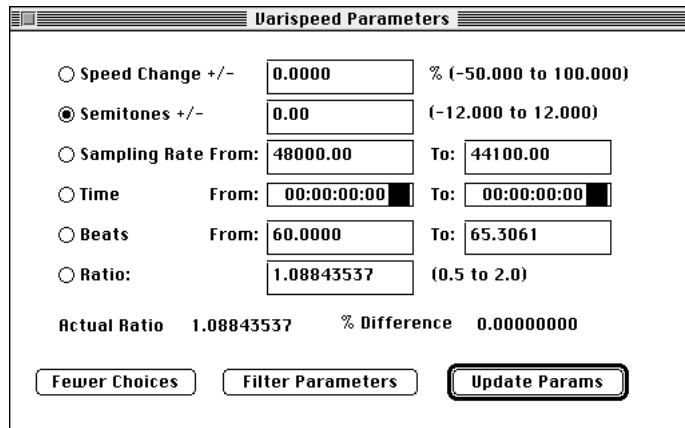
The user may specify any ratio desired. The default setting, 48000.00 to 44100.00 is commonly used in transferring digital audio tapes for mastering to Compact Disc.

When either of the rate fields ("From" or "To") is clicked with the mouse, it opens a menu of commonly used sample rates.



If the sample rate needed for the "From" or "To" entries is not found in this list, select Custom and enter the desired values in the Sample Rate Conversion dialog. (Hit the Delete key on the Mac keyboard to clear the old value before typing in the new value.)

To specify the conversion in another form, such as ratio, use the button More Choices. This expands the Sample Rate Conversion/Varispeed Parameters dialog to express the ratio of conversion in several forms.



Besides conversion from one defined sample rate to another, the change in rate may be expressed in terms of:

- A percentage speed change
- Pitch transposition in musical semitones
- Change from original play time to new time
- Change from original to new tempo, expressed as beats-per-minute
- A direct ratio

Values may be entered in any of these forms. In all cases, the range of values in all forms is from one-half the current sample rate/play speed to twice that.

Note that for all fields in this dialog, it is necessary to clear the current value (hit Delete on the keyboard), before entering the new value.

After entering a new value, click the Update Params button to translate the last entered value into all of the other forms displayed in the dialog. If the entered value is out of range, or is not valid for the type of data used by that field, the system will alert the user with an error message.

### Filter Parameters

Sample rate conversion consists of a high-precision digital filter and a resampling function. There are several parameters associated with the filter portion of the process, and these may be specified by the user.

The filter parameters are the same whether the SRC function is used for sample rate conversion on input or output, and a detailed description of these is provided in the last section of this manual. In most applications, the default settings of these parameters will deliver optimum performance.

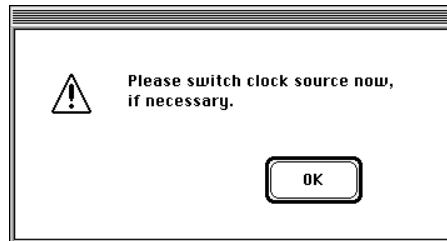
### Percentage Difference

Sample rate conversion is a digital process whose resolution is controlled by the arithmetic capabilities of the computing engine that performs the process. The SSP-3 computes and stores data to 24-bit accuracy.

When the parameters are updated, the system computes the difference between the conversion requested and that which the SSP-3 can perform in real time. This difference is display in the field "% difference."

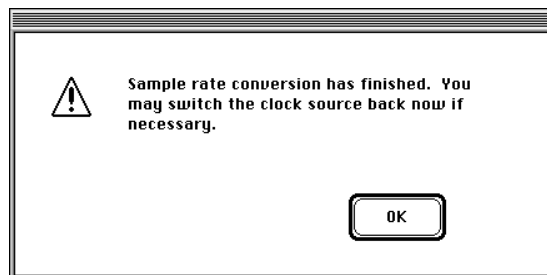
## Performing the Conversion

Once the desired values are entered, the user closes the Sample Rate Conversion dialog by using the close box in the upper left corner, then starts the recording normally. After preparing the files, the system alerts the user before beginning actual recording.



The alert instructs the user to switch the clock source. In most cases this simply means to make sure that the source sample rate is the same as that specified for the conversion.

At the end of recording, the system again prompts the user to switch the sample rate.



## Sample Rate Conversion

---

If the system remains at the same sample rate as the input, the recorded file will play back with a speed and pitch change proportionate to the conversion rate. The system should be switched back to the target sample rate before playback.

This may be done by:

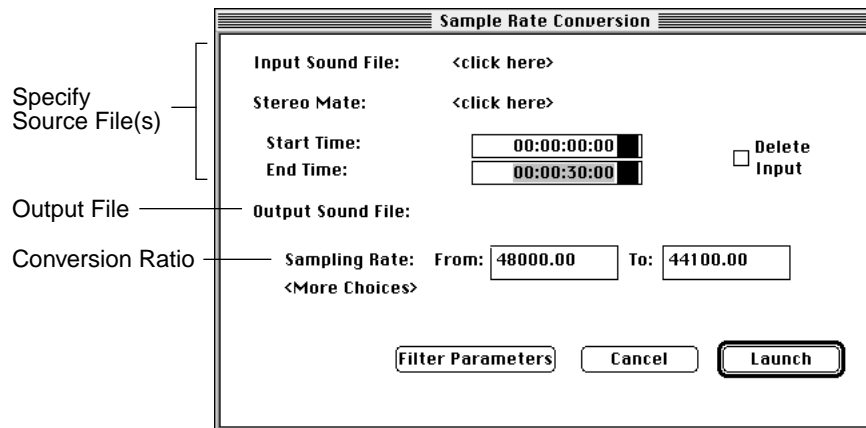
- Switching the input to a digital audio source at the target rate, or
- Switching SonicStudio to internal clock, by switching all inputs off in the Audio I/O Preferences dialog, as described in the Sonic Studio *Reference* manual.

For the latter case, a sample rate of 44.1 kHz or 48 kHz may be selected by using the Audio I/O Parameters field of Audio/I/O Preferences, as described in the manual titled *Reference*, Chapter 5, *Dialog Reference*.

Once the recording process is complete, the sound file with sample rate conversion is stored on the Sound Disk, with its sample rate information set to the value specified in the conversion.

## Background Sample Rate Conversion

Sample Rate Conversion can also be performed as a background processing function.



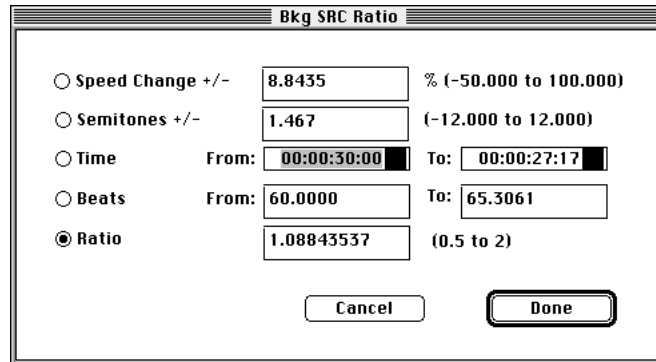
The command Bkg Sample Rate Conversion is found in the DSP menu. It brings up a dialog to specify the source file, the conversion ratio, and (optionally) the filter parameters that apply. You start by specifying the sound file to be processed by clicking in the designated place in the dialog. If the specified file is stereo, the system asks whether both files are to be processed.

After selecting the source file, you can optionally define a Start and End time so that only part of the file will be processed.

Background SRC creates a new file. The name for the output file is defined by clicking next to Output Sound File.

If sound disk space is at a premium, you can select the Delete Input option. In most cases, this is not recommended, as it may be desired to process again or return to the original file for other reasons.

By default, the conversion ratio is defined as "From" and "To" sample rates. By clicking where it says <More Choices>, you can specify conversion as a raw ratio, as a pitch interval, as a change from one tempo to another, and so on.



Once the source and output files, conversion ratio, and other optional parameters have been selected, click on the Launch button.

## Background and Foreground Processing

The mode of processing depends on system configuration. If the system includes a second SSP or USP board dedicated for NoNOISE and effects processing, sample rate conversion will be placed into the background queue. Its progress can be viewed by opening the Background Manager dialog box.

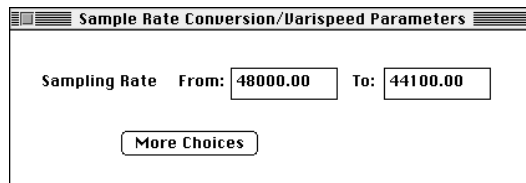
If there is no separate processing card in the system, the Background Manager dialog box opens automatically, and remains open (with user actions other than Abort locked out) until the conversion operation is complete. The resulting sound file can then be opened and used for editing.

## Varispeed on Playback

Varispeed on Playback uses (almost) the same dialog as recording with sample rate conversion. This function is selected by choosing the command Varispeed on Playback from the Play menu.

<b>All</b>	
<b>Reel Rock</b>	⌘/
<b>Varispeed On Playback</b>	
<b>Stop Play</b>	
<b>Reserve Bandwidth</b>	

For playback use, the small dialog box is equipped with an additional button to switch variable speed in and out. The user can start playback, then open the Varispeed dialog box, and switch processing in and out by using this button.



In the large form of the dialog box, this button replaces the Update Parameters button. The displayed parameters are updated whenever processing is switched in or out.

## The Filter Parameters Dialog Box

The process of sample rate conversion begins by applying a high-precision digital filter to create a "decimated" version of the original audio data. This version is then resampled at the target sample rate to create an accurate interpolation between data points.

The low-pass filter that is used for decimation is very precise. The user has a great deal of control over the actual realization of this filter.

The large form of the Sample Rate conversion/Varispeed Parameters dialog box includes a button labeled Filter Parameters. This button opens a dialog box to set different aspects of the filter implementation.

	Default	(Range)
DC level Gain:	0.9000000	0.9 (0.0 to 1.0)
Filter Frequency 3db point: (Relative to Source)	0.9070295	0.907 (0.0 to 1.0)
Filter Sharpness Beta: (for Kaiser Window)	10.00000	10.0 (15.0 to 2.0)
Window Size: (Number of Multiplies)	29.000000	29.0 (2.0 to 48.0)

Cancel OK

### DC Level Gain

The decimation filter used in sample rate conversion is an FIR type, a multi-tap delay that approximates the response of the ideal filter. Because the decimation calculations must be performed in real time, the number of taps available for the filter is limited, and the (theoretically infinite) impulse response must be abbreviated.

For computational efficiency, SonicStudio uses a direct truncation of the ideal prototype response. This type of filter is very accurate, but exhibits amplitude ripple near the cutoff frequency that is known as the "Gibbs Phenomenon."

As a result of this ripple, source material containing high frequencies recorded at high signal levels may exhibit clipping as it passes through the decimator. The DC Level Gain parameter reduces gain at the input of the conversion to prevent this clipping. This reduces the overall level of the converted audio.

If the source material does not contain strong high frequencies, the DC level Gain may be set to a value of "1," resulting in unity gain, without adversely affecting audio.

### Filter Frequency 3 dB Point

The maximum value for the cutoff frequency of the decimation filter is the Nyquist frequency of the source, which is 1/2 the sample rate. The actual cutoff frequency used for the filter is expressed as a multiple of the Nyquist rate.

Although the system provides for setting of this parameter from 0 to 1.0, normal values are in the range of .9 to 0.95. For example, the default of 0.9070295 is set up for conversion from 48 kHz or 44.1 kHz source material. The minimum cutoff frequency of the filter in kilohertz then is:

$$(44.1 * 0.5) * 0.9070295 = 20.000 \text{ kHz}$$

A slightly lower factor could be used at 48 kHz sample rate, while keeping the filter cutoff at or above 20 kHz.

### Filter Sharpness Beta

In a digital filter of the type used for sample rate conversion, there is a trade-off between the sharpness of the filter and the amount of attenuation in the stopband. SonicStudio uses a *Kaiser window* implementation that has a constant,  $\beta$  (Beta) and defines this trade-off.

Lower values for the Beta parameters mean a sharper cutoff, but less attenuation in the stopband, while lower values translate into a more gentle rolloff, with more optimal stopband attenuation.

A low value for Beta can result in aliasing problems caused by the reflection of signal components below the Nyquist frequency into the trans-Nyquist region. Setting the Beta to a high value, on the other hand, broadens the transition band, and could cause problems with frequencies near the filter cutoff point, but below the Nyquist frequency.

### Window Size

The window size presents a three-way trade-off between the accuracy of conversion ratio, filter response, and signal processing power required.

The greatest accuracy of conversion ratios is provided by low window size. Higher values yield better performance in the decimation filter, but at the expense of a larger error factor (% difference) in the conversion factor realized versus that requested.

In addition, higher values for Window Size consume larger amounts of processing power. Depending on the conversion ratio requested, this can result in the SSP-3 engine being unable to deliver the requested conversion in real time.

## Summary

The SS-500 Sample Rate Conversion option provides complete variable-rate processing that may be used to convert from one sample rate to another, or to change the rate (and hence pitch) on playback. The user may specify the ratio of conversion in any of several forms. Sample Rate Conversion can operate as a foreground or background operation.

In comparison with most sample rate converters, SonicStudio permits user-modification of the parameters of the decimation filter used as the first stage of processing. This makes it possible to avoid problems of high-frequency clipping and aliasing that occur with difficult source materials.

## References

1. L.R. Rabiner and B. Gold, *Theory and Application of Digital Signal Processing*, Prentice-Hall, New Jersey, 1975.
2. R. Crochiere and L.R. Rabiner, *Multirate Digital Signal Processing*, Prentice-Hall, New Jersey, 1983.

## Sample Rate Conversion

---

# Index

---

## **A**

---

Audio I/O Parameters field 2-6

## **B**

---

Background Manager dialog box 2-8  
background processing 2-8  
background sample rate conversion 2-7  
beta, constant 2-11  
Bkg Sample Rate Conversion command 2-7

## **C**

---

conversion ratio 2-12

conversion ratio, specifying 2-2

## **D**

---

dc level gain 2-10  
DC Level Gain parameter 2-11  
Delete Input option 2-7  
difference, percentage 2-4  
DSP menu 2-7

## **F**

---

filter frequency 2-11  
filter parameters 2-4  
Filter Parameters button 2-10  
filter sharpness 2-11  
FIR, conversion type 2-10  
foreground processing 2-8

## **G**

---

Gibbs Phenomenon 2-10

## **K**

---

Kaiser window 2-11

## **L**

---

Launch button 2-8

## **M**

---

More Choices button 2-3

## **N**

---

Nyquist frequency 2-11, 2-12

## **P**

---

parameters, filter 2-4  
percentage difference 2-4  
performing the conversion 2-5  
playback, and varispeed 2-9

## **R**

---

ratio, specifying conversion 2-2  
Record Sound File dialog box, illustrated 2-2  
recording with sample rate conversion 2-2  
references, listed 2-13  
ripple 2-11

## **S**

---

Sample Rate Conversion checkbox, using 2-2  
Sample Rate Conversion dialog box, illustrated 2-2  
sample rate conversion, background 2-7  
sample rate conversion, overview 2-1

sample rate conversion, recording with 2-2  
sample rate conversion, summary 2-13  
sample rate, listed 2-3  
specifying conversion ratio 2-2  
SRC function 2-4  
SSP-3, and window size 2-12  
summary 2-13

## **U**

---

Update Parameters button 2-9  
Update Params button 2-4

## **V**

---

varispeed on playback 2-9  
Varispeed Parameters dialog box, illustrated 2-3

## **W**

---

window size 2-12