Sample Rate Conversion Library for dsPIC® User's Guide

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Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our web site (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXXXXA", where "XXXXXXXX" is the document number and "A" is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before you use the Sample Rate Conversion Library for dsPIC®. Items discussed in this Preface include:

- Document Layout
- Conventions Used in this Guide
- Warranty Registration
- Recommended Reading
- The Microchip Web Site
- Development Systems Customer Change Notification Service
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

This document describes how to use the Sample Rate Conversion (SRC) library with the dsPIC33E family of devices. The document layout is as follows:

- **Chapter 1. "Introduction" –** This chapter provides an overview of the SRC library.
- **Chapter 2. "Installation" –** This chapter describes the installation procedure for the SRC library.
- **Chapter 3. "Application Programming Interface (API)"** – This chapter outlines how the API functions provided in the SRC library can be included in your application software via the Application Programming Interface.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Italic characters	Referenced books	*MPLAB® IDE User's Guide*
	Emphasized text	...is the *only* compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic text with right angle bracket	A menu path	*File>Save*
Bold characters	A dialog button	Click **OK**
	A tab	Click the **Power** tab
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
`Plain Courier New`	Sample source code	`#define START`
	Filenames	`autoexec.bat`
	File paths	`c:\mcc18\h`
	Keywords	`_asm, _endasm, static`
	Command-line options	`-Opa+, -Opa-`
	Bit values	`0, 1`
	Constants	`0xFF, 'A'`
`Italic Courier New`	A variable argument	*`file`*`.o`, where *`file`* can be any valid filename
Square brackets [ ]	Optional arguments	`mcc18 [options]` *`file`* `[options]`
Curly brackets and pipe character: { | }	Choice of mutually exclusive arguments; an OR selection	`errorlevel {0|1}`
Ellipses...	Replaces repeated text	`var_name [, var_name...]`

	Represents code supplied by user	`void main (void)`
		`{ ...`
		`}`

Notes	A Note presents information that we want to re-emphasize, either to help you avoid a common pitfall or to make you aware of operating differences between some device family members. A Note can be in a box, or when used in a table or figure, it is located at the bottom of the table or figure.	**Note:** This is a standard note box. **CAUTION** **This is a caution note.** **Note 1:** This is a note used in a table.

WARRANTY REGISTRATION

Please complete the enclosed Warranty Registration Card and mail it promptly. Sending in the Warranty Registration Card entitles you to receive new product updates. Interim software releases are available at the Microchip web site.

RECOMMENDED READING

This user's guide describes how to use the Sample Rate Conversion Library for dsPIC®. The following are available and recommended as supplemental reference resources.

dsPIC33E/PIC24E Family Reference Manual Sections

Family Reference Manual sections are available, which explain the operation of the dsPIC33E device family architecture and peripheral modules. The specifics of each device family are discussed in the individual family's device data sheet.

MPLAB® C Compiler for PIC24 MCUs and dsPIC DSCs User's Guide (DS50001284)

This document details the use of Microchip's MPLAB C Compiler for dsPIC Digital Signal Controllers to develop 16-bit applications.

MPLAB® IDE User's Guide (DS50001519)

Consult this document for more information pertaining to the installation and implementation of the MPLAB IDE software, as well as the MPLAB Editor and MPLAB SIM Simulator software that are included with it.

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- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
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The Development Systems product group categories are:

- **Compilers** – The latest information on Microchip C compilers and other language tools. These include the MPLAB® C compiler; MPASM™ and MPLAB 16-bit assemblers; MPLINK™ and MPLAB 16-bit object linkers; and MPLIB™ and MPLAB 16-bit object librarians.
- **Emulators** – The latest information on the Microchip in-circuit emulator, MPLAB REAL ICE™
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debugger, MPLAB ICD 3.
- **MPLAB IDE** – The latest information on Microchip MPLAB IDE, the Windows® Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB SIM simulator, MPLAB IDE Project Manager and general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include the MPLAB PM3 device programmer and the PICkit™ 3 development programmers.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: http://www.microchip.com/support

DOCUMENT REVISION HISTORY

Revision A (September 2011)

This is the initial release of the document.

Revision B (July 2013)

Document title was changed and all references to PIC32 were removed. Refer to the *"Sample Rate Conversion Library for PIC32 User's Guide"* (DS60001190) for this content.

Chapter 1. Introduction

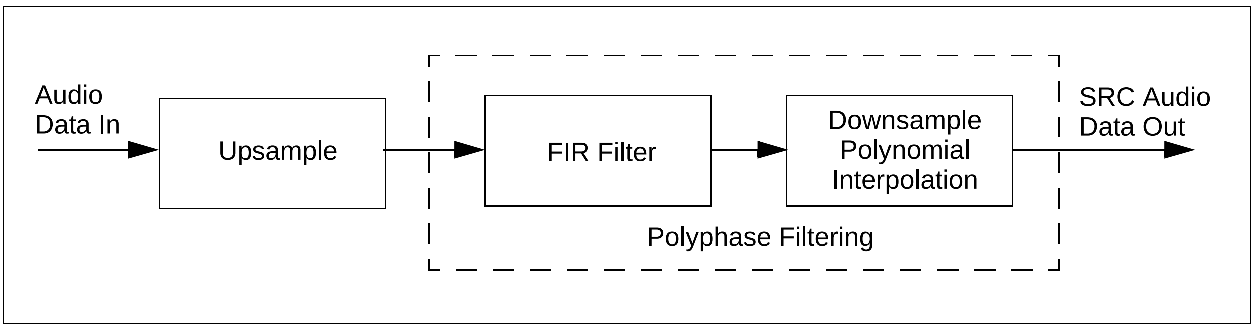
The Sample Rate Conversion Library for dsPIC®, which can be used with Microchip's dsPIC33E family of devices, provides the ability to upconvert the sampling rate of real-time 16-bit stereo audio data. At run-time, the input sampling rate can be selected between 32 kHz or 44.1 kHz, with a fixed output sample rate of 48 kHz.

1.1 ALGORITHM OVERVIEW

The SRC algorithm converts real-time 16-bit audio data sampled at 44.1 kHz or 32 kHz, to a sampling rate of 48 kHz. The size of the input audio data in 1 ms interval will be 32 samples for 32 kHz input, and 44 or 456 samples for 44.1 kHz input. The output consists of 48 stereo samples per 1 ms interval.

Figure 1-1 shows the various blocks of the SRC algorithm. The incoming audio data passes through an upsampler or an interpolation stage. The signal then passes through an anti-aliasing low-pass filter followed by a downsampler or decimation stage.

FIGURE 1-1:



1.1.1 32 kHz to 48 kHz Sample Rate Conversion

The input is upsampled by a factor of 3 followed by a Finite Impulse Response (FIR) filter to smooth the signal. A gain factor is applied to the smoothed signal to compensate for the loss caused by inserting the zeros.

The resulting intermediate signal is then downsampled by a factor of 2 to obtain an output audio signal at a sampling rate of 48 kHz. Since downsampling creates redundancy in the filtering of the sample that is decimated, the filtering of this sample can be skipped, resulting in significant instruction cycle execution savings. This is a simplified form of the polyphase filtering technique, which improves the speed of the SRC.

In this mode, every 1 ms of audio frame is expected to have 32 stereo samples since the sample rate is 32 kHz.

1.1.2 44.1 kHz to 48 kHz Sample Rate Conversion

The input is upsampled by a factor of 2, by inserting a zero after every input sample followed by a FIR filter, which is applied to smooth the signal. A gain factor of 2 is applied to the smoothed signal to compensate for the loss caused by inserting the zeros.

Polynomial interpolation is used to reduce every sequence of 147 samples at 88.2 kHz to 80 samples at 48 kHz. This ensures the sampling rate of the output audio data to be 48 kHz. Polyphase filtering is also employed in this mode to reduce redundancy.

In this mode, the first nine audio frames are expected to contain 44 stereo samples and the tenth frame is expected to contain 45 stereo samples.

1.1.3 Filter design

For 32 kHz input, a low-pass filter is utilized with a very steep roll-off to limit aliasing effects. The corner frequency lies below one-sixth of the intermediate sample rate. This is below the Nyquist frequency, so that aliasing effects should not be a problem when downsampling. The corner frequency used here is 14.5 kHz, which may be desirable when optimizing the filter design to adjust the corner frequency so that the first stop-band null covers the input Nyquist frequency.

The overall processing load is dominated by the FIR filter; however, there is a trade-off between processing load (i.e., filter length) and the quality of the outputs.

For 44.1 kHz input, the corner frequency of the low-pass filter lies below one-fourth of the intermediate sample rate. The greater processing load at this frequency requires a shorter filter length. The corner frequency used here is 19.7 kHz.

A more aggressive optimization of the filter is needed, which can be provided by an equiripple design technique.

The code uses polynomial interpolation to convert intermediate data at 88.2 kHz to output data at 48 kHz.

Chapter 2. Installation

This chapter describes the installation procedure for the Sample Rate Conversion Library for dsPIC® and includes resource usage.

Topics covered include:

- Installation Procedure
- Resource Usage

2.1 INSTALLATION PROCEDURE

The SRC library is available as a download from the Sample Rate Conversion Web page at www.microchip.com/SRC. After downloading and extracting the files, run the dsPIC SRC installer to install the library in the desired path.

Use the following procedure to add the library to the application:

1. In the application MPLAB workspace, right-click **Library Files** in the Project Window, and select **Add files**.
2. Browse to the location of the archive file (`libSRC_LITE_dsPIC33E_v1_0.a` or `libSRC_FULL_dsPIC33E_v1_0.a`), which is located in the `libs` folder within the installation directory.
3. Select the file and click **Open**. The SRC library is now added to the application.

2.2 RESOURCE USAGE

TABLE 2-1: PERFORMANCE AND RESOURCE CONSUMPTION FOR dsPIC33E LIBRARY MODES

SRC Library Version	SRC Mode	MIPS	Code Size (bytes)	Data Size (bytes)	SNR (dB)(1)
Lite Version	32k to 48 kHz	6.1	7624	2744	82
	32k to 44.1 kHz	9.1			82
Full Version	32k to 48 kHz	7.2	7704	2866	84
	32k to 44.1 kHz	10.1			82

Note 1: Tested with a 1 kHz full-scale sinusoidal signal.

NOTES:

Chapter 3. Application Programming Interface (API)

This chapter describes the Application Programming Interface (API) to the Sample Rate Conversion Library for dsPIC®.

Topics covered include:

- Sample Rate Conversion Library API Functions

The API functions of the SRC Library are easy to use. The prototype declaration of the API functions, the state buffer used, and buffer sizes to be used for the two SRC modes are located in the header file, `src_api.h`.

The archive file, `libSRC_x_dsPIC33E_v1_0.a (x = LITE or FULL)`, is the library file to be used in the project workspace.

EXAMPLE 3-1:

```
|
|----- h
|
|             src_api.h         (header file for SRC APIs)
|
|
|----- libs
|
|             libSRC_x_dsPIC33E_v1_0.a (SRC library archive)
```

3.1 SAMPLE RATE CONVERSION LIBRARY API FUNCTIONS

This section lists and describes the two API functions that are available in the SRC Library.

SRC_init()

Description

The API function, SRC_init(), configures the conversion mode to be used and initializes the local state buffer required by the SRC library. The SRC state contains buffer pointers, split buffers needed for the filters, and buffers for polynomial interpolation.

Prototype

```
void SRC_init(int* ptrSRC_state, int cd_flag);
```

Arguments

ptrSRC_state	a pointer to the state memory for this instance of SRC
cd_flag	SRC_32KHZ_TO_48KHZ - 32 kHz to 48 kHz conversion mode SRC_44_1KHZ_TO_48KHZ - 44.1 kHz to 48 kHz conversion mode

Example

```
#define CD_FLAG SRC_32KHZ_TO_48KHZ
.
.
.
int srcStateMem[SRC_STATE_MEM_SIZE_INT];
.
.
.
SRC_init(srcStateMem, CD_FLAG);
```

SRC_apply()

Description

The API function, SRC_apply(), is the function call that performs sample rate conversion on the input audio signal. The API takes pointer to the input buffer, pointer to the output buffer along with a pointer to the SRC state. It also takes the size of the input audio buffer as a parameter. The size of the input audio data buffer is 64 for input sample rate of 32 kHz and 88 or 90 for the input sample rate of 44.1 kHz. The sample count includes both the left and right channels of the stereo audio.

Prototype

```
int SRC_apply(int* ptrSRC_state, short* Sin, short* Sout,
   int readCount);
```

Arguments

ptrSRC_state	a pointer to the state memory for this instance of SRC
Sin	a pointer to the input buffer of size with incoming audio signal SRC_IN_PROC_SIZE
Sout	a pointer to the output buffer of size SRC_OUT_PROC_SIZE
readCount	the actual number of samples to be read from the input buffer

Example

```
#define CD_FLAG SRC_32KHZ_TO_48KHZ
.
.
.
short    Sin[SRC_IN_PROC_SIZE];
short    Sout[SRC_OUT_PROC_SIZE];
int      srcStateMem[SRC_STATE_MEM_SIZE_INT];
int      read_count;
int      write_count;
.
.
.
read_count = 64;
.
.
.
SRC_init(srcStateMem, CD_FLAG);
.
.
.
write_count = SRC_apply(srcStateMem, Sin, Sout, read_count);
```

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