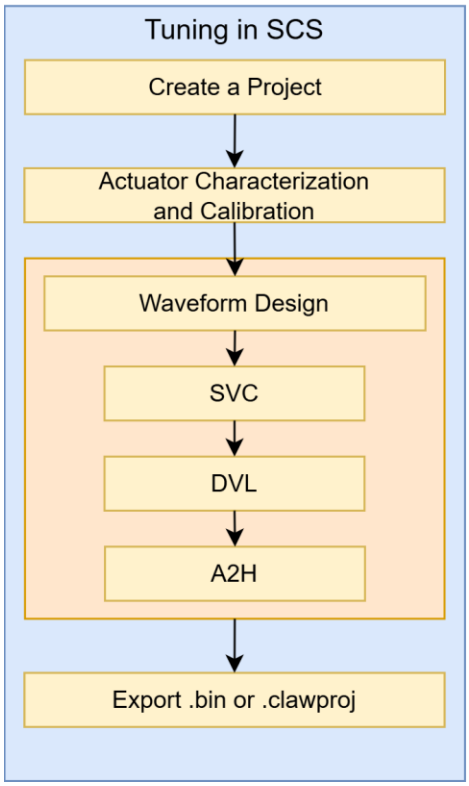
CS40L5X SCS User Guide

Introduction

This document outlines the tuning tools and features included in CS40L5X Tuning Workspace. These tuning tools utilize the Cirrus Logic® SoundClear® Studio (SCS) platform and allow the user to tune Sensorless Velocity Control (SVC), Dynamic Voltage Limiter (DVL), and Audio-To-Haptics (A2H) haptic algorithms. This document also covers the process of using the SCS tools to create and test haptic waveforms for a desired use case.

The Tuning Workflow is demonstrated in the flowchart below. This document covers each step through the Tuning workflow and details the customization process.



This document references information covered in the CDB40L5X Configuration User Guide. Contact your Cirrus Logic representative for a copy of the CDB40L5X Configuration User Guide.

Table of Contents

1 Hardware Components

1.1 Lochnagar and CDB40L5X

To use the SCS tools for the CS40L5X devices, consult the CDB40L5X Haptic Studio Guide. This document outlines the process of setting up the Cirrus Logic Lochnagar 2 and CDB40L5X-Q100 evaluation system. Contact your Cirrus Logic representative for a copy of the CDB40L5X-Q100 User Guide.

1.2 Accelerometer Input

Many features of SoundClear Studio (SCS) rely on measuring the acceleration of the mechanical system caused by driving an LRA from the CS40L5X device. To measure this acceleration, our tools require an accelerometer connected to the mechanical system connected to channel 1 of the PORT1 IN input of the Lochnagar 2 (see image below for the location of the PORT1 IN input of the Lochnagar 2).

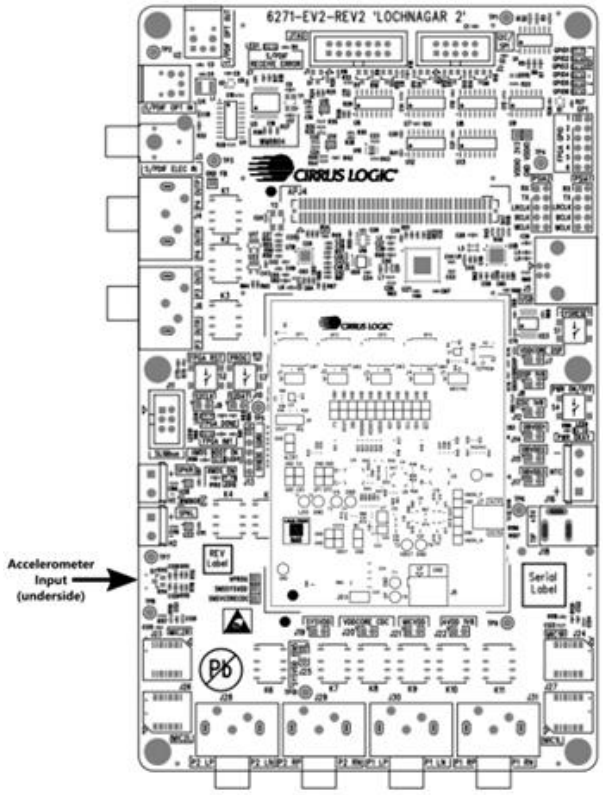


Figure 1 Lochnagar Accelerometer Input

Cirrus Logic uses the Brüel and Kjær (B&K) 4535-B-001 tri-axis accelerometer with the 1704 pre-amplifier for acceleration measurement. However, any similar accelerometer setup (e.g., with a single-axis accelerometer) should work. The tools assume the 10 mV/ms^{-2} conversion sensitivity of the B&K accelerometer by default; the sensitivity can be adjusted if necessary to align with a different accelerometer - see Section 2.7 to configure the accelerometer sensitivity.

2 Software Setup

2.1 SCS Installation

SoundClear Studio (SCS) is a platform that allows communication to supported Cirrus Logic devices. In the process of getting a new computer set up for the CS40L5X tuning, the following components must be installed.

- SoundClear Studio
- CS40L5X Tuning Base BSP
- SCS Haptics Tuning Dependencies Installer:
  - FTDI CDM Driver
  - Lochnagar 2 VCOM Driver
  - Cirrus Logic USB Audio Driver
  - Cirrus Logic Platforms INF
  - MATLAB 2021a runtime

The Cirrus Logic CS40L5X SCS software can be installed through the CS40L5X Tuning Installer. The Tuning Installer supports all CS40L5X devices and will install SoundClear Studio and all required BSPs for tuning and configuration. Using the installers will create a "sandboxed" instance of the tool, that will show up as the application "CS40L5X Tuning" in Windows.

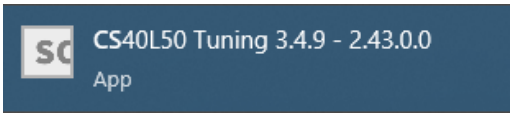


Figure 2 Sandboxed Instance of Tuning Workspace

This installer can be downloaded from Cirrus Logic's Software Delivery Portal. Contact your Cirrus Logic representative for access to the portal and these pieces of software.

2.2 Sound Card Configuration

To ensure proper operation of the SCS tools, the Windows sound card playback and recording devices must be configured as shown below in the following figures. These settings can be managed under the Sound Control Panel on the Windows device settings. For both devices, ensure both options under "Exclusive Mode" are checked, the level is set to 100%, and that all enhancements are disabled.

Playback: Set "Lochnagar USB Audio 2.0" as the default playback device, and under the Advanced tab, set the default format as 24 bit, 48000 Hz (Studio Quality).

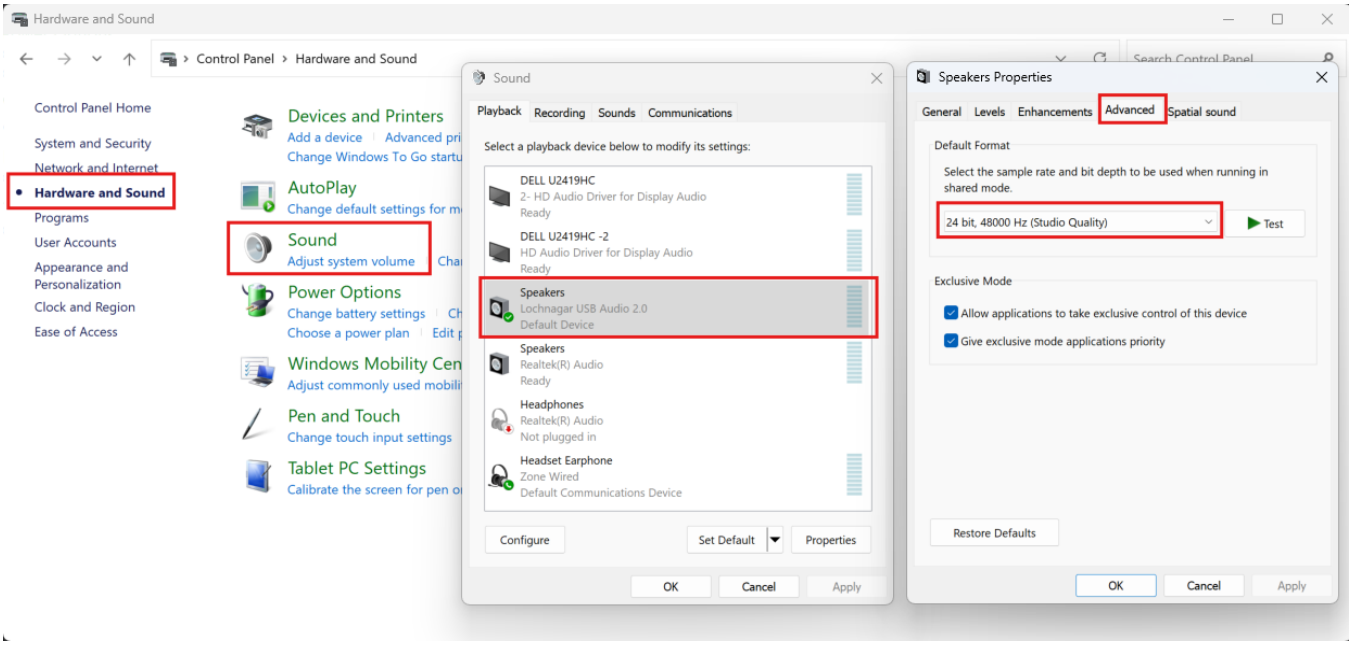


Figure 3 Sound Card - Playback Settings

Recording: Set "Lochnagar USB Audio 2.0" as the default recording device. Under the Advanced tab, set the default format as 16 channel, 24 bit, 48000 Hz (Studio Quality). Ensure "Listen to this device" is unchecked on all recording devices.

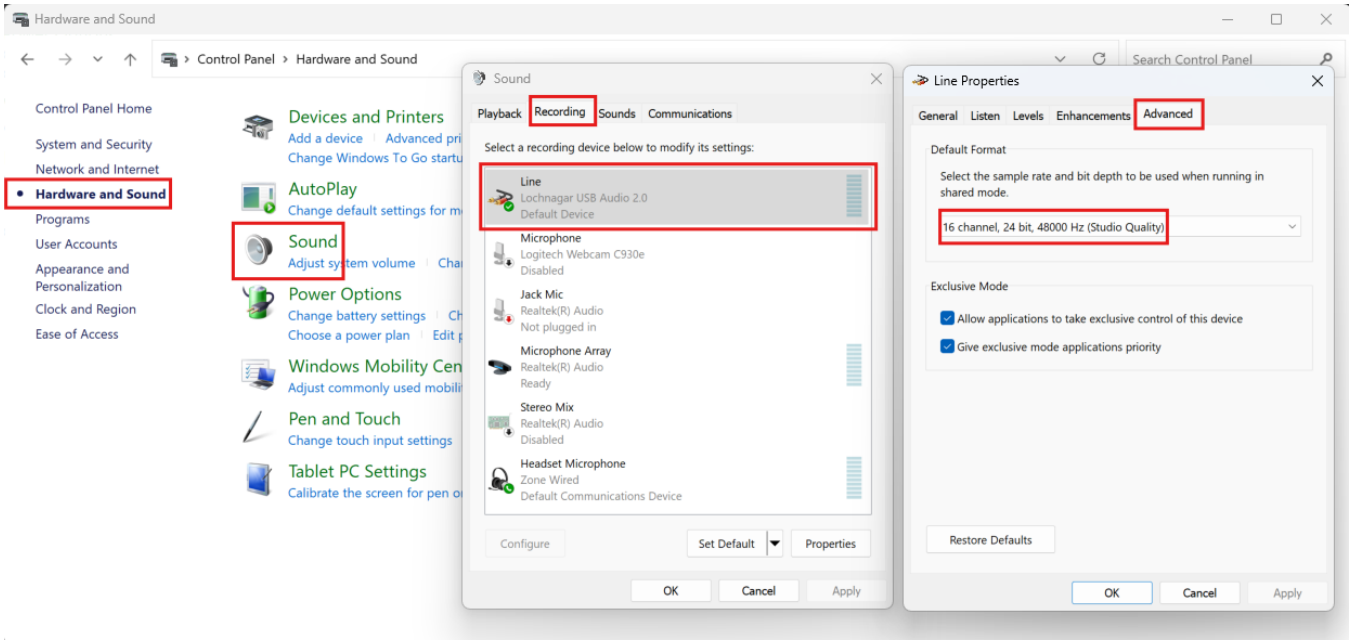


Figure 4 Sound Card - Recording Settings

2.3 Lochnagar 2 Basic Guide

The Lochnagar 2 board should be configured and connected as described below.

1. All shunts should be in their default position on the LN2 and CDB40L5X as indicated in the images shown.

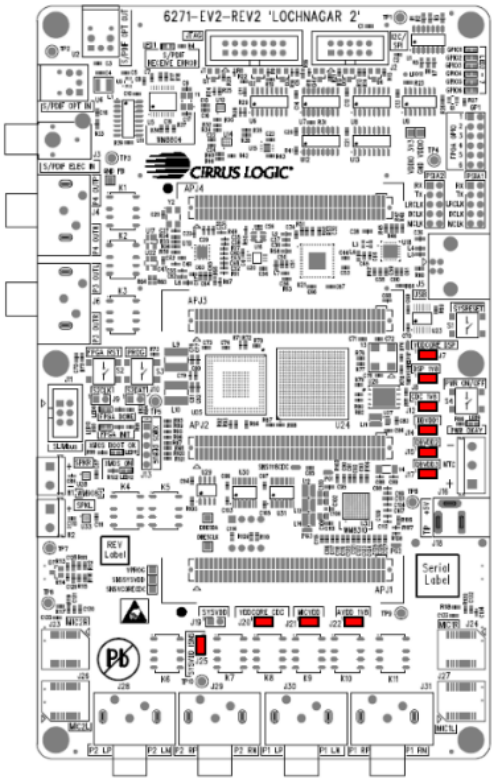


Figure 5 Default Shunt Configurations for LN2

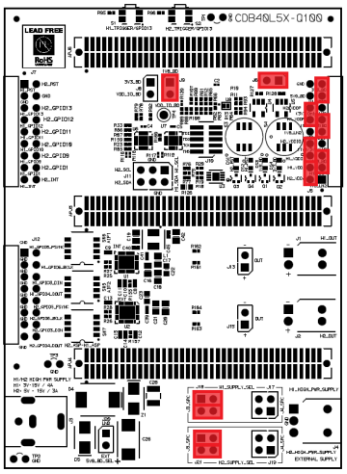


Figure 6 Default Shunt Configurations for CDB40L5X

2. Mount the CDB40L5X to the LN2 connectors. Notice the keyed orientation of the connectors. All power must be off when the CDB40L5X is mounted to the platform.
3. Connect the appropriate power supply into the barrel jack connector on the CDB40L5X. It is recommended that the voltage level and current capability of this supply matches the supply that will be used in the target system.
   - For Internal boost configuration, this should match the target system VDD_B supply.
   - For External boost configuration, this should match the target system VDD_AMP supply.
4. Turn on the power supply.
5. Plug in the USB-B port of the LN2 to the computer. Wait several seconds for the USB devices to enumerate. When LN2 is connected to the computer for the first time, the associated drivers are installed.

2.4 Device Bring-Up

Once the CS40L5X device has been powered up, the CS40L5X will appear in the Navigator:

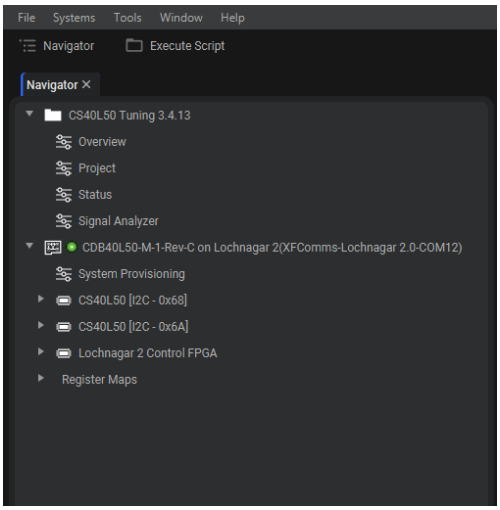


Figure 7 Navigator

2.5 Basic Overview

Below is the basic layout of a SoundClear Studio upon first opening:

- The "Tuning" folder contains all panels used for tune creation and testing:
  - Overview - create new project, access recent projects, etc.
  - Project - details of a project file
  - Status - status of devices and log history
  - Signal Analyzer - monitor signals and take measurements
  - Blocks - individual tuning panels for Calibration, Wavetable Editing, Streaming, as well as SVC, DVL, A2H algorithms (appears when a project is opened)
- Each device has various tools and panels:
  - CS40L5X I2C-0x68/0x6A - audio serial port and digital path configurations, logging, and provisioning
  - Lochnagar 2 or UAP FPGA - configuring the given platform's control FPGA settings and configurations
  - Register Maps
- The Navigation column can be opened or closed via the button above the left column
- The “Execute Script” button gives the functionality to execute python scripts directly from the Tuning Workspace

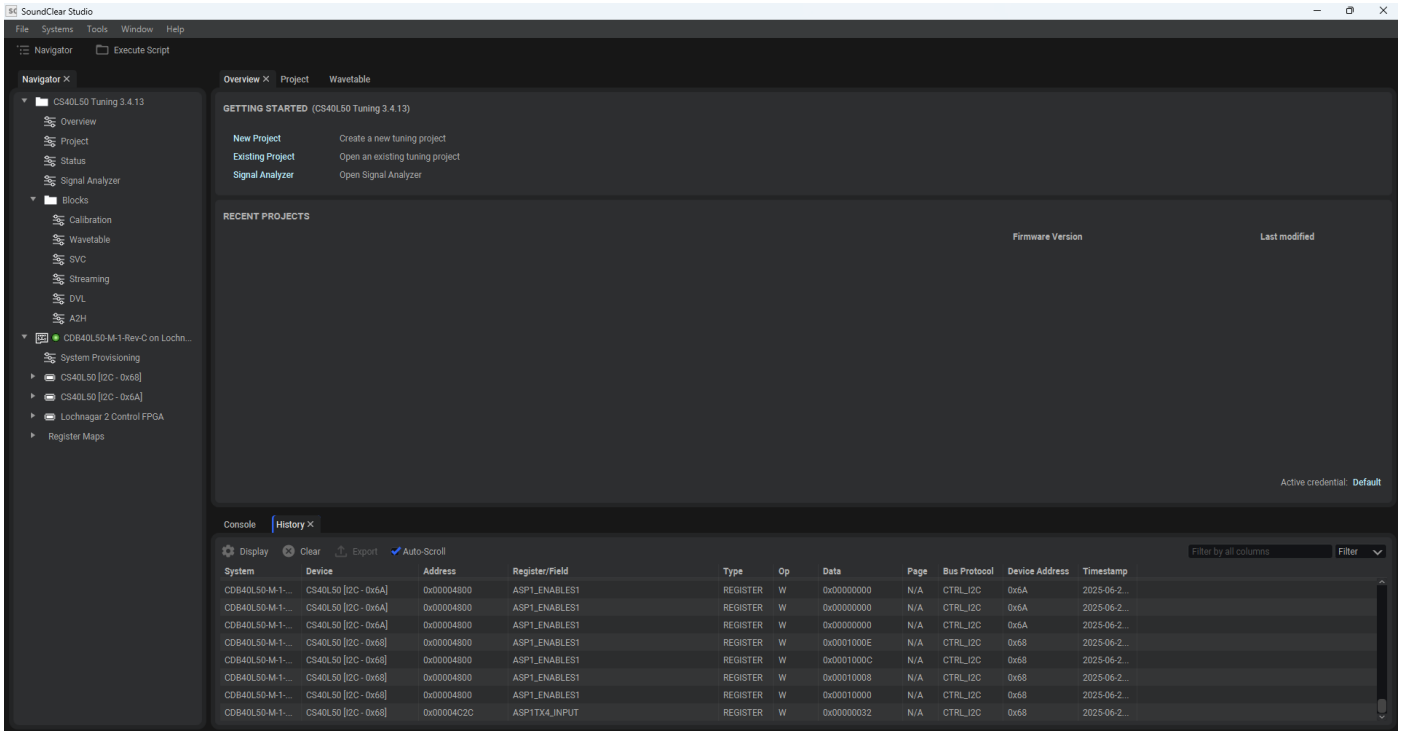


Figure 8 Overview of SCS

2.6 Updating Individual Board Support Packages

The Tuning Support packages will install the necessary Board Support Packages (BSPs) required for tuning a CS40L5X device. Additional or updated BSPs can be installed and uninstalled in the "Files" Menu.

Installing a new package:

- Files > Install Package > select the desired .scspkg file to install
- Validate BSP and press "Install"
- The new BSP will appear in the "Navigator" panel. There can be multiple versions of the Tuning BSP installed for situations when different projects require different BSPs. It is important to realize that each "Overview" panel corresponds to its respective BSP.

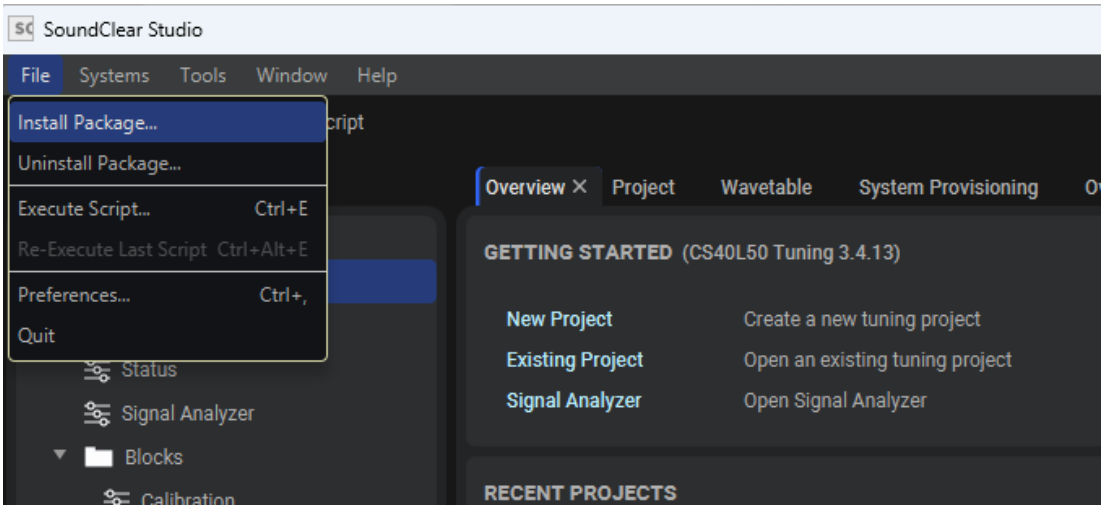


Figure 9 Installing BSP Packages from the Tools Menu

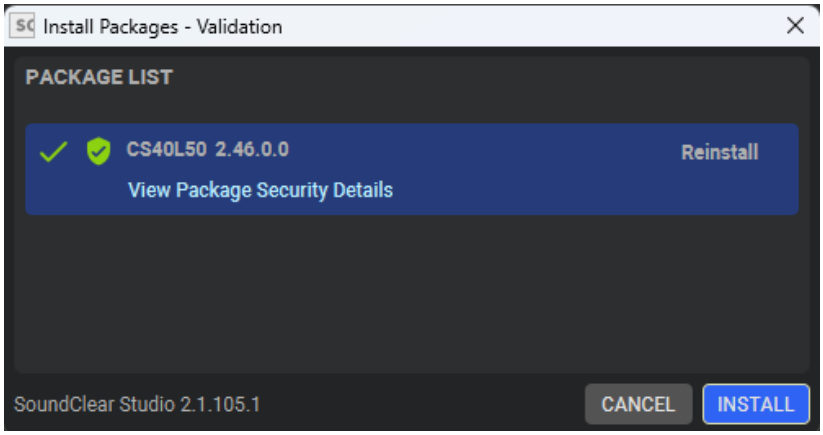


Figure 10 Validating before Installing BSP

Uninstalling a package:

- Files > Uninstall Package > select desired package(s) to uninstall
- If a package is a dependency of another BSP, a message indicating this will be displayed in the "Package Details" area of the window and the uninstall is not allowed.

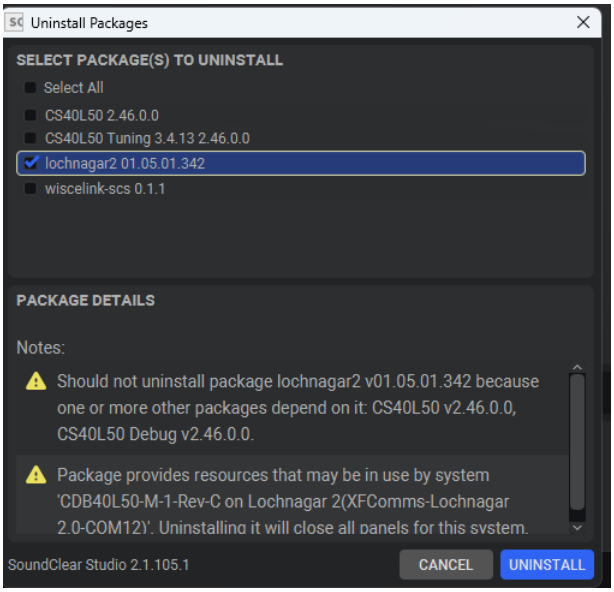


Figure 11 Selecting a BSP to Uninstall

2.7 Creating a New Claw Project

New projects can be created from a quick link in the "Getting Started" section of the CS40L5X Tuning > Overview panel or can be created directly from the CS40L5X Tuning> Project panel. Select the file path where you wish to store the project and which firmware to use.

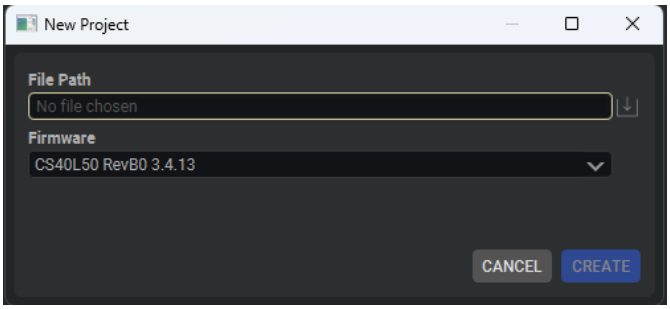


Figure 12 Creating a New Project

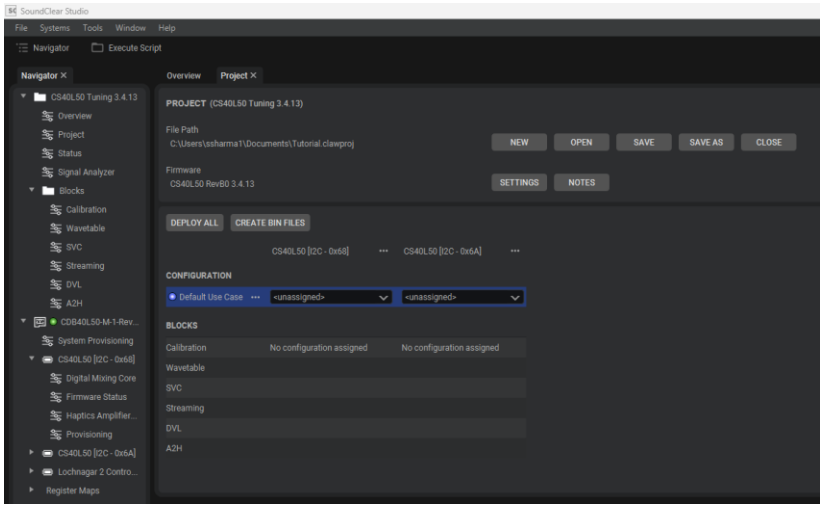


Figure 13 New Project Default Page

SoundClear Studio creates a new project, and the connected system is ready to be configured. Navigate to the "Settings" button and ensure that the Accelerometer sensitivity is correct for the connected model:

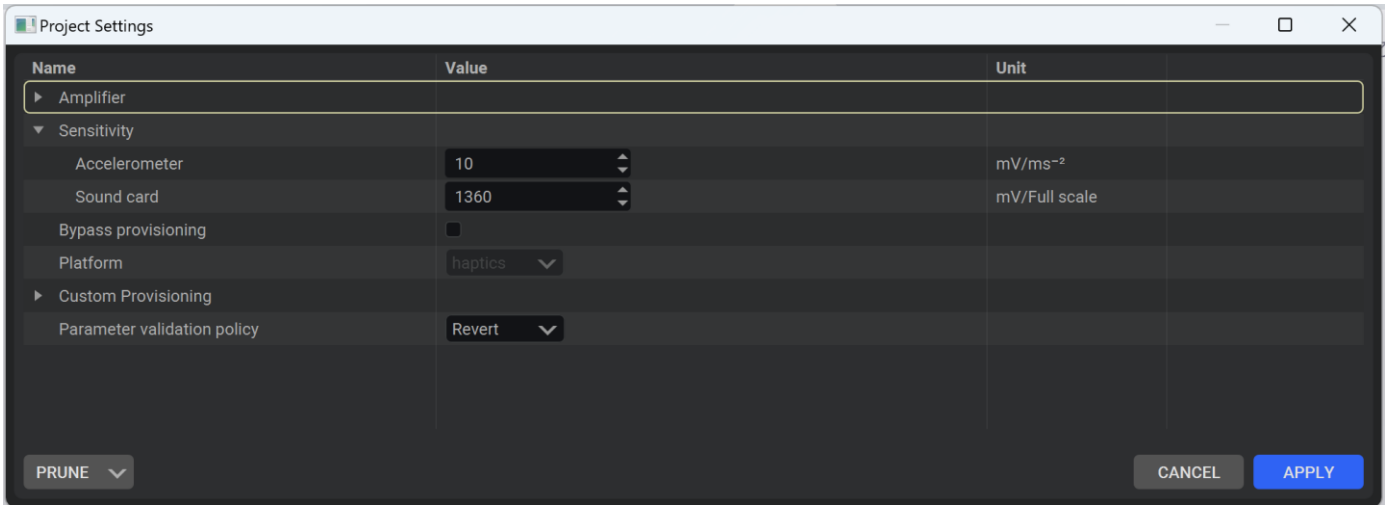


Figure 14 New Project Settings Page

2.7.1 Creating a Virtual System

A virtual system can be created when hardware is not required for the tuning goals. A virtual system has the same functionality of a real project, but does not receive any feedback from a hardware system. To create a virtual system of an existing Project, right-click on the project in the Navigator tab and click "Copy to Virtual System".

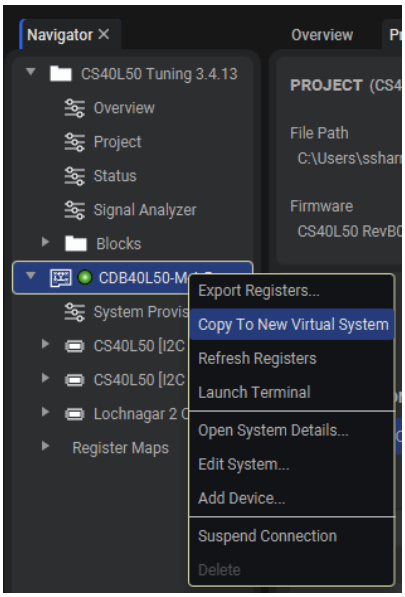


Figure 15 Virtual System of Existing Project

Alternatively, a new virtual system can be added from the Navigator tab if no hardware is connected and no existing project is open.

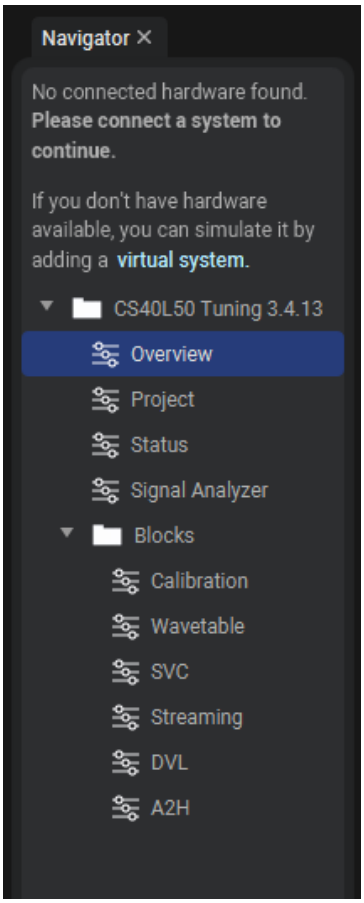


Figure 16 Add Virtual System from Navigator

Any changes made in a Virtual system can be saved as presets that can later be applied to a real system.

2.7.2 Configurations, Devices, and Presets

The following definitions are applicable in SoundClear Studio and throughout this document.

- Each CS40L5X available on the given tuning platform is considered a **Device**.
- Each device can be assigned a DSP tuning **Configuration**.
- Each configuration consists of tuning blocks (SVC, DVL, etc.) with a number of tunable parameters. The tuned parameter values for each block are considered **Presets**.

A configuration is a container of presets that can be applied to a device all at once. Different combinations of presets can be created for different configurations, and configurations can be applied across multiple devices on the hardware. Single configurations cannot be exported out of a Tuning Project, that is the purpose of a claw project. A claw project will hold all associated configurations to the device.

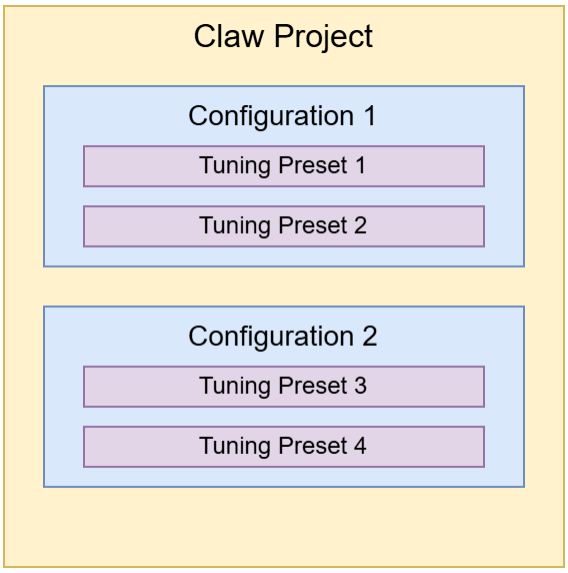


Figure 17 Claw Project Hierarchy

2.7.3 Assigning and Unassigning Configurations to Devices

For each use case, connected devices can be assigned a configuration using the drop-down box of the given device from the Project panel.

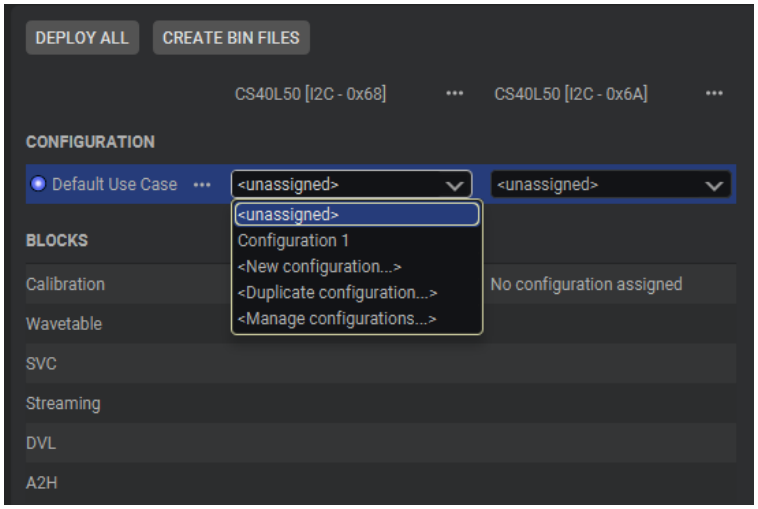


Figure 18 Configuration Assignment Drop-Down

2.7.4 Adding and Removing Configurations

Once a project is created, configurations can be created and modified as desired. Below is an example of a default two-channel system.

1. Create **<New configuration...>** and name them accordingly
2. Using the drop-down menu, assign a configuration for each CS40L5X

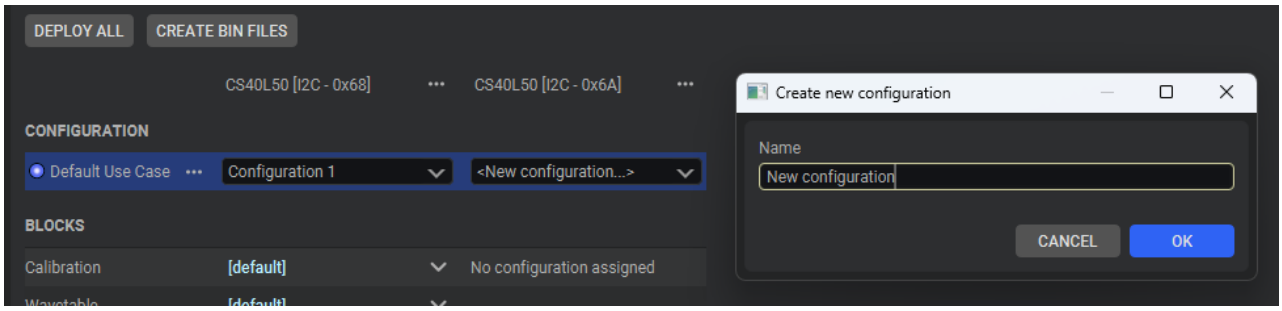


Figure 19 Creating a New Configuration

For further management of configurations (i.e. renaming, comparing, importing, exporting, deleting, etc.) click on **<Manage configurations...>** option in the "Configuration Assignment" drop-down or by clicking the <...>. In this example, there is the default "Configuration 1" at a default stage where none of the blocks have been altered yet. Different presets can be assigned from either the configuration manager or from the Overview Panel.

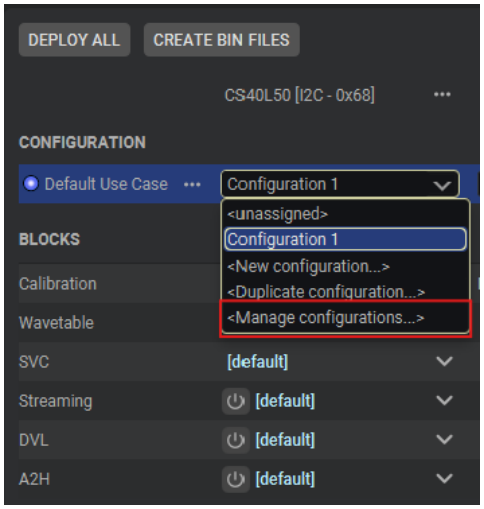


Figure 20 Accessing Configuration Manager

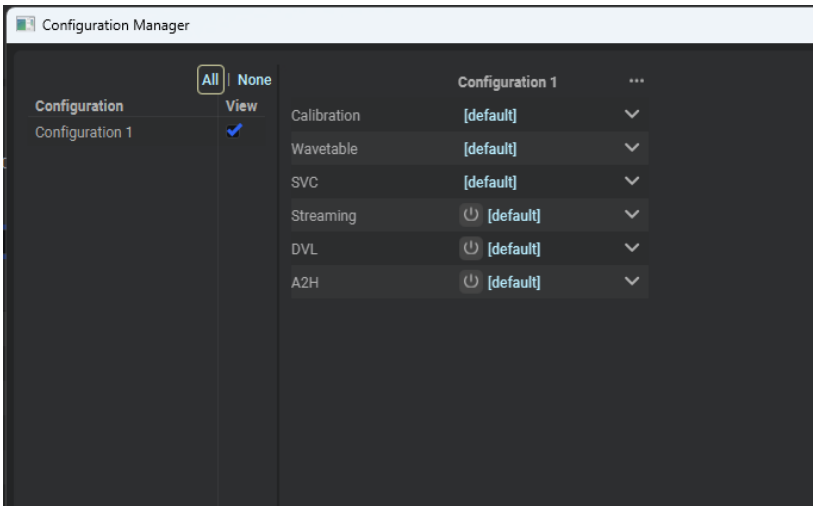


Figure 21 Configuration Manager Panel

2.7.5 Provisioning a System and Deploying Configurations

When a new configuration is assigned to a device, SoundClear Studio automatically provisions the device (load firmware, route audio, and amp gain as configured in the Project Settings) and deploys the selected tuning-block configuration. Custom provisioning scripts may be selected in Project Settings.

During the tuning process, the **Deploy All** button will turn blue when SoundClear Studio detects that there may be changes in the project that are not reflected in the device's current state. Clicking the "Deploy All" button will re-deploy the device configuration to the connected system.

As an example, double click on any of the blocks to make changes to the configuration. Notice that any unsaved changes in a preset that have not yet been applied are indicated by an asterisk. Once saved, the preset is ready for deployment. The "Deploy All" button turns blue as a reminder to re-deploy the new configurations to the connected system.

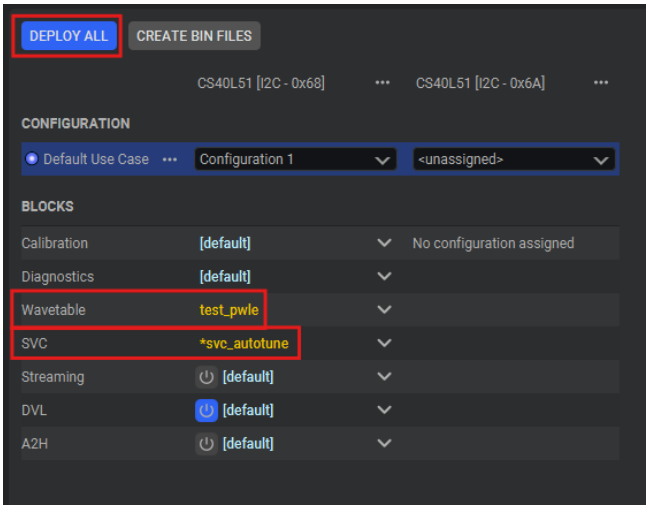


Figure 22 Deploy All Button

2.7.6 Hardware Configuration Panel

Blocks represent each of the Tuning tools available for the device. A user can select different presets from this menu to tailor a Configuration setting. By double clicking a preset, SCS will navigate the user to the respective Tuning Tool. By double clicking the power symbol, Streaming, DVL, and A2H can be enabled straight from this menu.

The Deploy button within the Hardware Configuration panel will re-deploy all DSP blocks for devices using the selected hardware configuration preset, and then issue the required mailbox commands to apply the power-on write sequencer contents. When any new presets are applied that have yet to be deployed, the Deploy button will appear in blue to indicate that changes have not yet been applied.

3 General Features during Tuning

There are six Tuning Blocks available in a Tuning workspace for CS40L5X devices: Calibration, Wavetable, SVC, Streaming, DVL, and A2H. This section outlines initial steps and tools available under each tuning tab.

3.1 Calibration

The first step before starting any Tuning is to calibrate the actuator connected to the system. The calibration section allows the user to trigger a characterization signal to determine the F_0 for a given input amplitude. The inputs to the F_0 calibration are as follows:

- **Frequency Span**: The range of frequencies from the Frequency Center that the plugin will sweep to find the F_0.
- **Frequency Center**: The center of the frequency range to be swept, this value should be the value specified in the actuator datasheet to give a valid starting point for the plugin to reference.
- **Amplitude**: The amplitude of the signal ran by the plugin to determine the F_0. Note that F_0 shifts in response to a differing chirp amplitude.
- **Re_{DC} Estimate**: The Re_{DC} estimate of an actuator to determine the F_0. Re_{DC} is automatically updated when a Calibration is started, but can also be manually inputted to adjust Le and F_0.

The Calibrate button (shown below) executes the chirp calibration and provides an updated F_0, Re_{DC}, and Le value when completed.

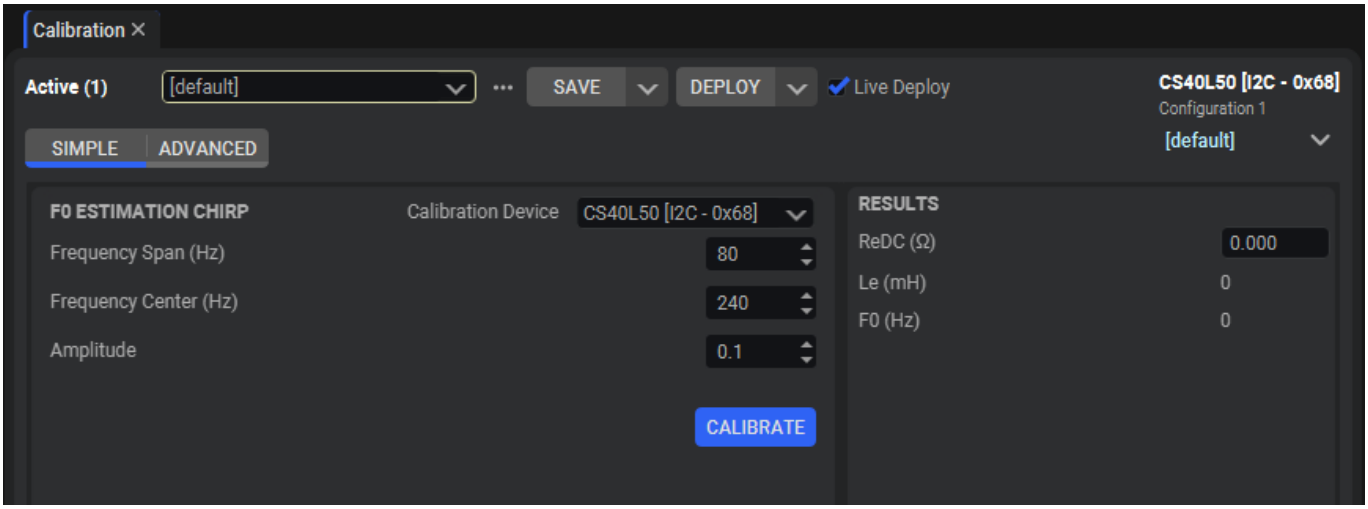


Figure 23 Calibration Tab

3.2 Compare Mode

The Compare Mode tool is available in the ••• menu of the tuning parameters section.

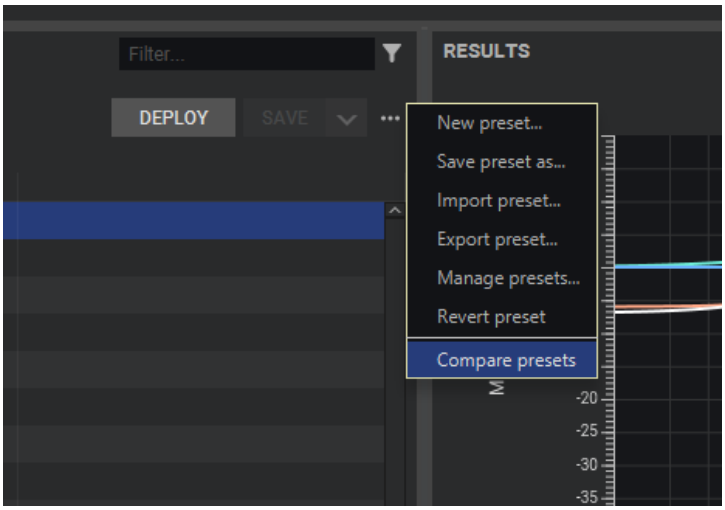


Figure 24 Toggle Compare Mode using the Compare Presets Option

This tool adds a second value column into the tuning parameters table and can compare between the following:

- Current preset and last saved version of that preset
- Current preset and default preset
- Current preset and another preset

When comparing two presets, any differing values are outlined in blue.

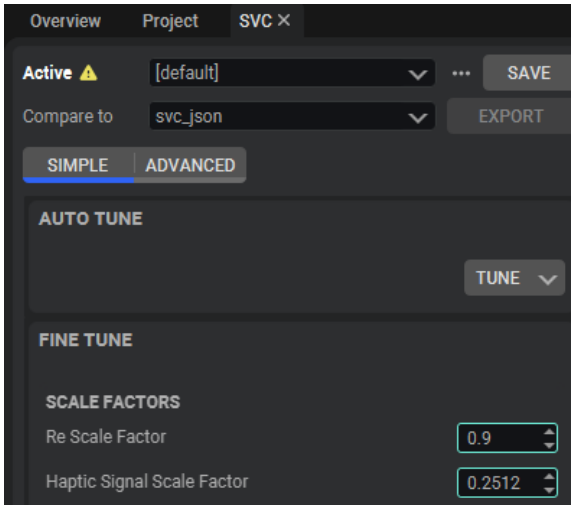


Figure 25 Differing Values in Compare Mode

3.3 Sharing Tunings, Exporting, and Compiling

There are three main formats for files to be shared across users and deployed to production systems: clawproj files, preset files, and bin files.

3.3.1 Sharing Projects as .clawproj Files

A clawproj file contains the entire SCS Tuning project, including all presets, configurations, and device assignments. Clawproj files can be shared across different users, provided both users have the required BSPs installed on their computers. Clawproj files can be created, opened, and saved from the Project panel.

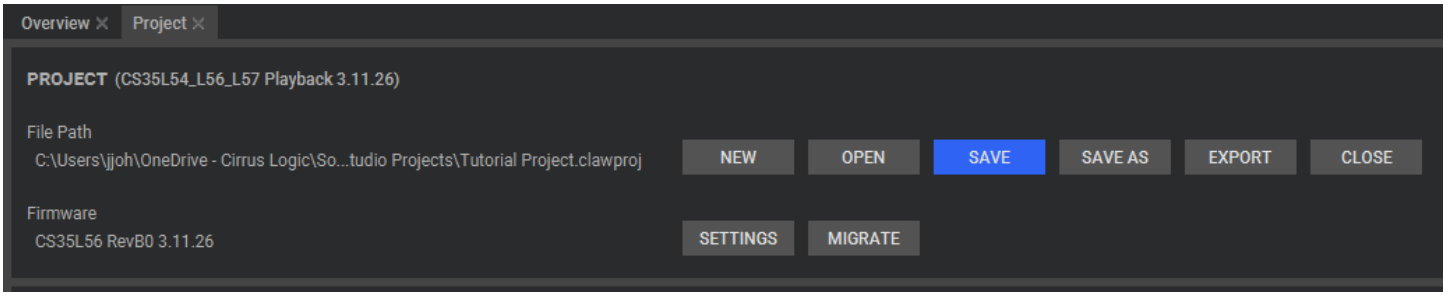


Figure 26 Saving a Project in the Project Panel

3.3.2 Exporting and Importing Preset Files

A preset file contains the tuning parameter values for one tuning block. The preset parameters for an individual tuning block can be exported or imported from within the respective block's tuning panel. The presets for an entire configuration can also be batch-exported from the project panel.

To export a single preset of a block, navigate to the desired tuning block and select the "Export preset..." option from the "Tuning Parameters" ••• menu. Presets can be individually imported in the same method that they were exported. They can be imported individually through the "Import preset" option in the tuning parameters ••• menu.

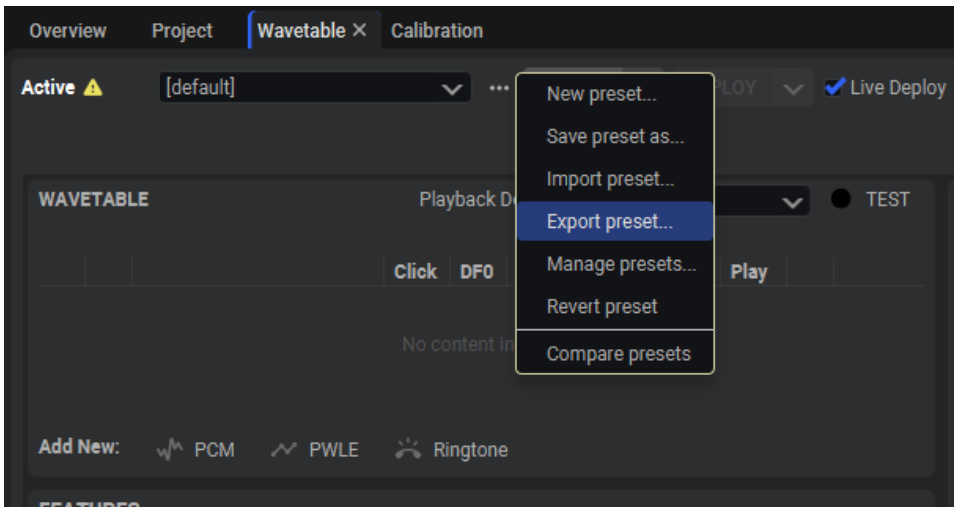


Figure 27 Export Preset from Tuning Parameters Menu

Alternatively, select the "Manage presets..." option from the dropdown arrow from the Project Tab to launch the "Preset Configuration Manager" window. Right click on the desired preset and select the "Export" option.

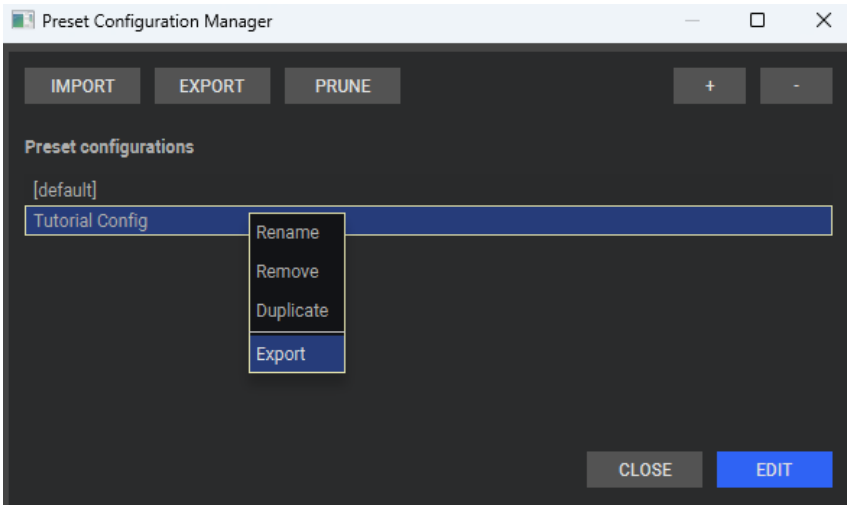


Figure 28 Export Preset from Preset Configuration Manager

To export an entire configuration's preset files, go to the Project panel and select from the ••• menu associated with the desired device and configuration. Select a folder to export to, and all non-default presets for that configuration will be saved into the target folder. This feature is helpful when many tuning blocks have been modified for the configuration, and they need to be collectively exported. Presets can also be batch-imported into the active configuration from the Project panel using the ••• menu for the associated device. When batch-importing presets, all selected presets from a target folder will be imported into the configuration.

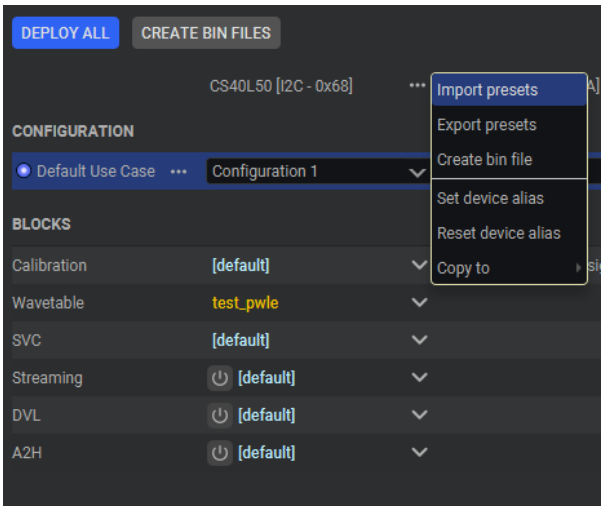


Figure 29 Batch Importing Presets into a Configuration

3.3.3 Creating a bin File

A bin file contains the configuration tuning parameters for a specific use case. The bin file is used by the driver to apply the same configuration in the target application.

To create a bin file, the desired configuration must be assigned to a device in the active use case. Create the bin file in the Project panel by selecting the "Create bin file" option under the ••• menu for the associated device. Additionally, pressing the "Create Bin Files" button boxed in red will create bin files for the entire project file.

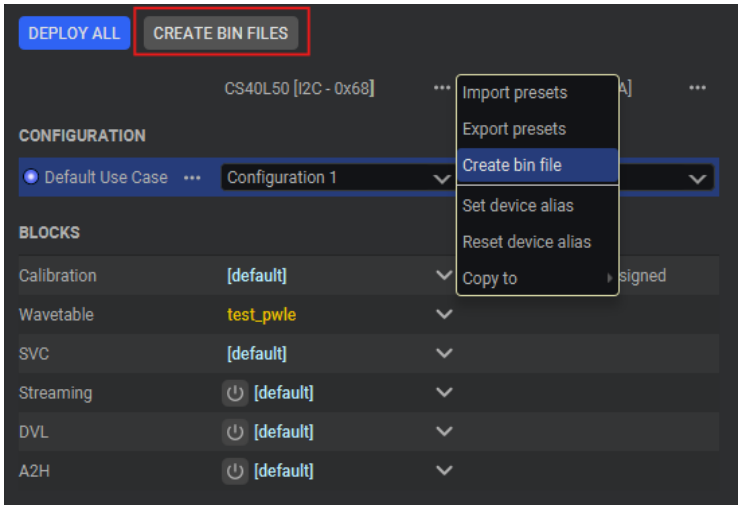


Figure 30 Creating a bin File from the Channel Menu

4 Wavetable Editing and Playback

The CS40L5X supports playback of several custom-defined haptic effects. These effects are stored in the device memory in a structure referred to as the haptic wavetable. To interact with the haptic wavetable, the Haptics Control software provides the "Wavetable Editing" tab.

The Wavetable Editing tab allows the creation and manipulation of three different types of haptic waveforms:

- **PWLE Effects**: A piecewise linear envelope (PWLE) which specifies the amplitude envelope of a variable-frequency sine wave over time. These waveforms are useful for long-duration and low-resolution effects like buzzes.
- **PCM Effects**: A waveform which specifies the voltage values to output over time, as a pulse-code modulated (PCM) signal. These waveforms are useful for clicks, and for other short, finely tuned effects. PCM files must be 8-bit .wav format.
- **Ringtones / Composite Effects**: A waveform which comprises a series of PCM / PWLE effects, with delays inserted between and amplitude adjustment as needed. These waveforms are useful for creating long effects which combine and/or repeat other effects.

When the tool is initially loaded, the CS40L5X wavetable is empty. The Wavetable Editing tab is shown in the image below.

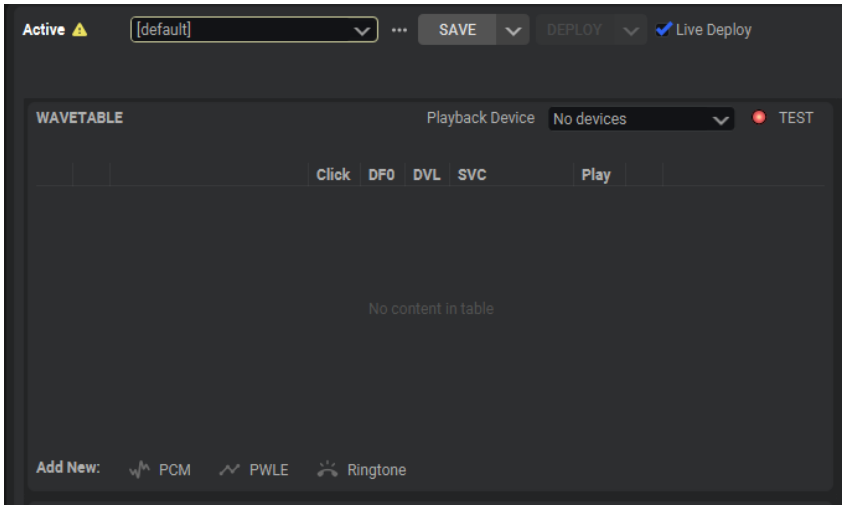


Figure 31 WaveTable Display

4.1 Creating PWLE Waveforms

PWLE waveforms can be added to the wavetable either as previously saved preset files, or else can be created directly with the plugin.

4.1.1 Creating New PWLE Waveforms

To create a new PWLE waveform to modify and play out, click the "PWLE" button below the wavetable display.

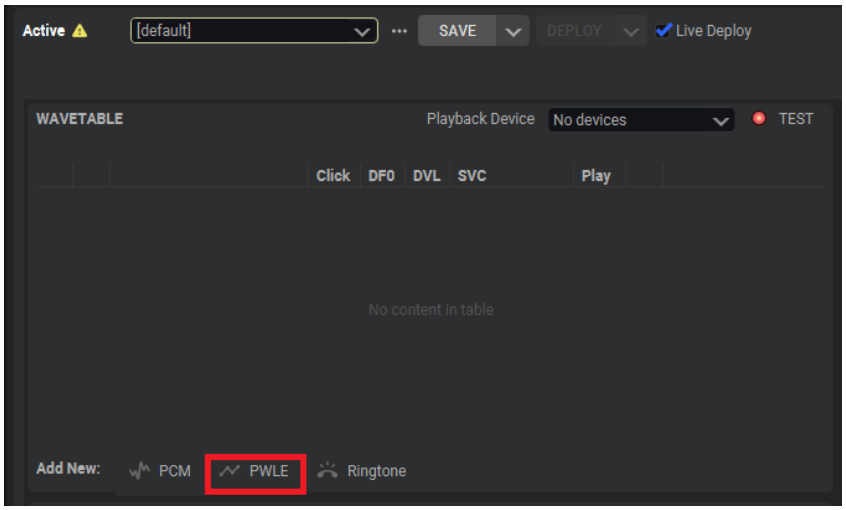


Figure 32 Add PWLE into WaveTable

The panel display is shown in the following figure:

Figure 33 PWLE Modification Interface

A PWLE waveform is a series of instructions which define how a sine wave is modulated during playback to produce a desired haptic effect. The PWLE waveform is composed of a number of sections. Each section is specified by a number of parameters which define how the waveform is played out during that section.

4.1.1.1 Section Parameters

The PWLE waveform can be customized by changing the following parameters:

- **Time (ms)**: The length of time this section plays for.
- **Indefinite**: Sets whether this section plays indefinitely until a stop command is sent.
- **Level**: The level (relative to full-scale) of the sine wave amplitude at the end of the section. Note the level transitions are linear.
- **Frequency**: The frequency (in Hz) of the sine wave to play during the section.
- **F_0**: If enabled, the waveform frequency is set to the actuator's measured F_0 rather than the user-specified value. To ensure the correct F_0 value is used for the actuator, click the "Load" button; this loads the calibration file generated from the Calibration tab – see Section 3.1 for more information.
- **Chirp Mode**: Selects whether the section should play at the specified frequency for the whole section, or change the frequency linearly from start to end. If Chirp Mode is enabled, the start frequency is that of the previous section; the specified frequency defines the end frequency for the section.
- **FHC:** Sections with FHC enabled are defined by the number of half cycles instead of by time.
- **Repeats**: The number of times the PWLE waveform is repeated. A value of 0 indicates the PWLE should play once and finish.
- **Wait Time (ms)**: The number of milliseconds to wait between repetitions of the PWLE waveform

4.2 Adding PCM Waveforms

To add a PCM waveform to the wavetable, follow this procedure:

1. Click the "PCM" button below the wavetable display.
2. Navigate to the desired PCM file. (Note that PCM files must be 8-bit .wav format, with sample rate of 4 kHz, 8 kHz, 24 kHz, or 48 kHz)
3. Select "Open" for the PCM file.

The chosen waveform is loaded to the wavetable using the name of the PCM file.

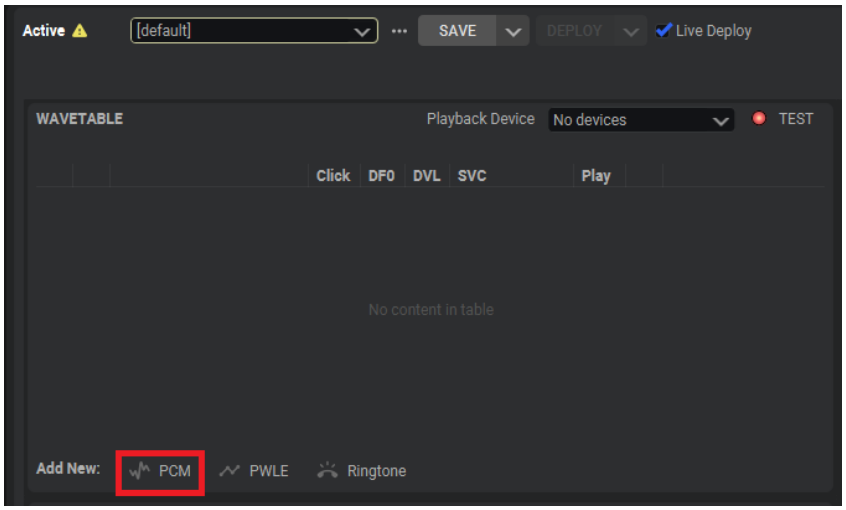


Figure 34 Add PCM into WaveTable

4.2.1 Changing PCM Waveform Sample Rate

The wavetable supports waveforms at sample rates of 4 kHz, 8 kHz, 24 kHz, or 48 kHz. To change the sample rate a waveform is stored at, first select the waveform to be changed. Navigate to the Waveform Information Panel and select the desired sample rate from the drop-down menu.

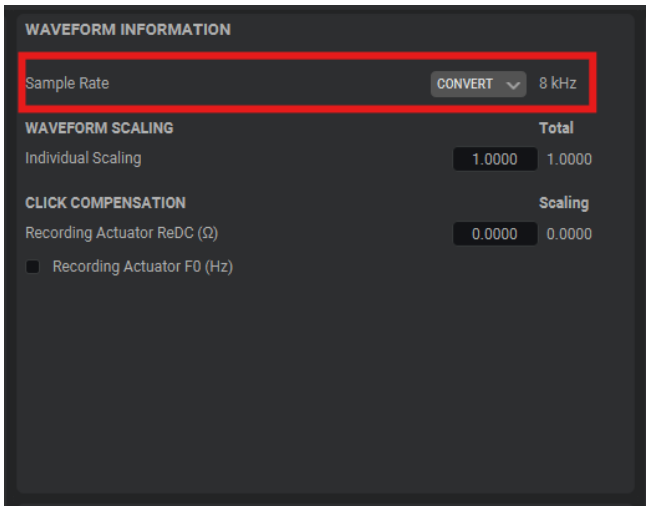


Figure 35 Convert Sample Rate of a PCM Waveform

4.2.2 Click Compensation

The click compensation enables a previously tuned waveform to be adapted for a different actuator. By compensating for F_0 and/or ReDC, the original waveform is adjusted to match the characteristics of the new actuator.

Figure 36 Click Compensation Panel in Waveform Information Panel

To enable F_0 click compensation for a specific waveform, check the "Click" box for the desired waveform. To disable Re_{DC} click compensation for a specific waveform, set the "Recording Actuator Re_{DC}" field to 0.

The click-compensation tuning parameters are described in the following table.

Table 1 Click Compensation Parameters

Section	Parameter	Description
Recording Actuator	F_0	The F_0 of the LRA used for the reference waveform
	Re_{DC}	The Re_{DC} of the LRA used for the reference waveform
Click Compensation Factors	F_0 Scale Factor	The scaling factor between the reference F_0, and the current LRA. (This field is populated automatically from the other input data.)
	Re_{DC} Scale Factor	The scaling factor between the reference Re_{DC}, and the current LRA. (This field is populated automatically from the other input data.)

4.2.3 F0 and ReDC Compensation

Since most clicks are designed for a specific frequency at F0, it is important for part-to-part variations to be accounted for. For example, if a click is designed for a specific F0 of 100Hz, but the F0 of the LRA is 90Hz, this may result in a reduction in the strength of the effect because the click is played off resonance of the LRA. But, if the waveform were to speed up or slow down, the resulting effect would shift the F0 of the waveform to then align with the F0 of the LRA. The benefits of this F0 alignment usually results in improved and consistent click strength, and improved braking. The F0 Compensation algorithm scales the waveform playback speed up/down based on the ratio of the "Current Actuator F0", and the "Recording Actuator F0". The ratio is displayed in the "Click Compensation Factor F0" field.

Re_{DC} Compensation adjusts for part-to-part variations in Re_{DC} between LRAs. This is done to maintain a consistent current through the coil between devices. For example, if a click is designed for a specific Re_{DC} of 10Ω, and the Re_{DC} of the LRA is 11Ω, the current flow in the coil is reduced, resulting in a potentially weaker effect. The Re_{DC} Compensation algorithm scales the waveform up/down based on the ratio of the "Current Actuator Re_{DC}", and the "Recording Actuator Re_{DC}". The ratio is displayed in the "Click Compensation Factor F_0" field.

4.3 Creating Ringtone/Composite Waveforms

Ringtones (also referred to as "composite waveforms") are scripts which instruct the firmware to play out specific effects in a particular order, with particular delays, and for a certain number of loops. Each ringtone is specified as a text string, where each playback instruction is separated by a comma. The syntax for each instruction is as follows:

- <n>: Wait n ms. For example, an instruction of "10" selects a firmware wait time of 10 ms.
- <n>.<m>: Play waveform at index n, scaled to m% of its full-scale. For example, the instruction "1.50" plays the waveform at index 1 at 50% scaling.
  - Only integer % values are permitted
  - Only PCM or PWLE waveforms can be called through this interface
- <n>.<m>.<k>: Play waveform at index n, scaled to m% of its full-scale, for k ms. For example, the instruction "1.50.600" plays the waveform at index 1 at 50% scaling for 600 ms.
  - A waveform with duration shorter than k ms is looped until k ms has elapsed
  - This specification is required for PWLEs with indefinite sections
- !!: Specifies the start of a local loop.
- <n>!!: Specifies the sequence since the previous "!!" command should be repeated n times. For example, "2.100, !!, 1.50, 5!!," specifies that the following should occur:
  a. Index 2 played out at 100% amplitude
  b. Index 1 played out at 50% amplitude
  c. Step 2 is repeated 5 more times (for a total of 6 iterations)
- <n>!: Specifies the ringtone should be repeated n times. For example, "2.100, !!, 1.50, 5!!, 10!," specifies that the previous example should be repeated 10 more times (for a total of 11 playback iterations)

4.4 Haptic Event Configuration

The Haptic Events section shows the waveforms associated with GPI events. By default, the Waveform Index columns show the ROM waveform that is played when a particular GPI is pressed or released. The mapping can be edited by selecting the desired entry and replacing it with the ROM or RAM waveform index of choice. A dropdown menu is used to switch between ROM and RAM waveforms. For further information detailing the ROM index, refer to the CS40L5X Configuration User Guide. The Waveform Index columns also show the attenuation level for each respective GPI trigger event. A dropdown menu allows the attenuation for each event to be configured in the range 0 dB to –7 dB.

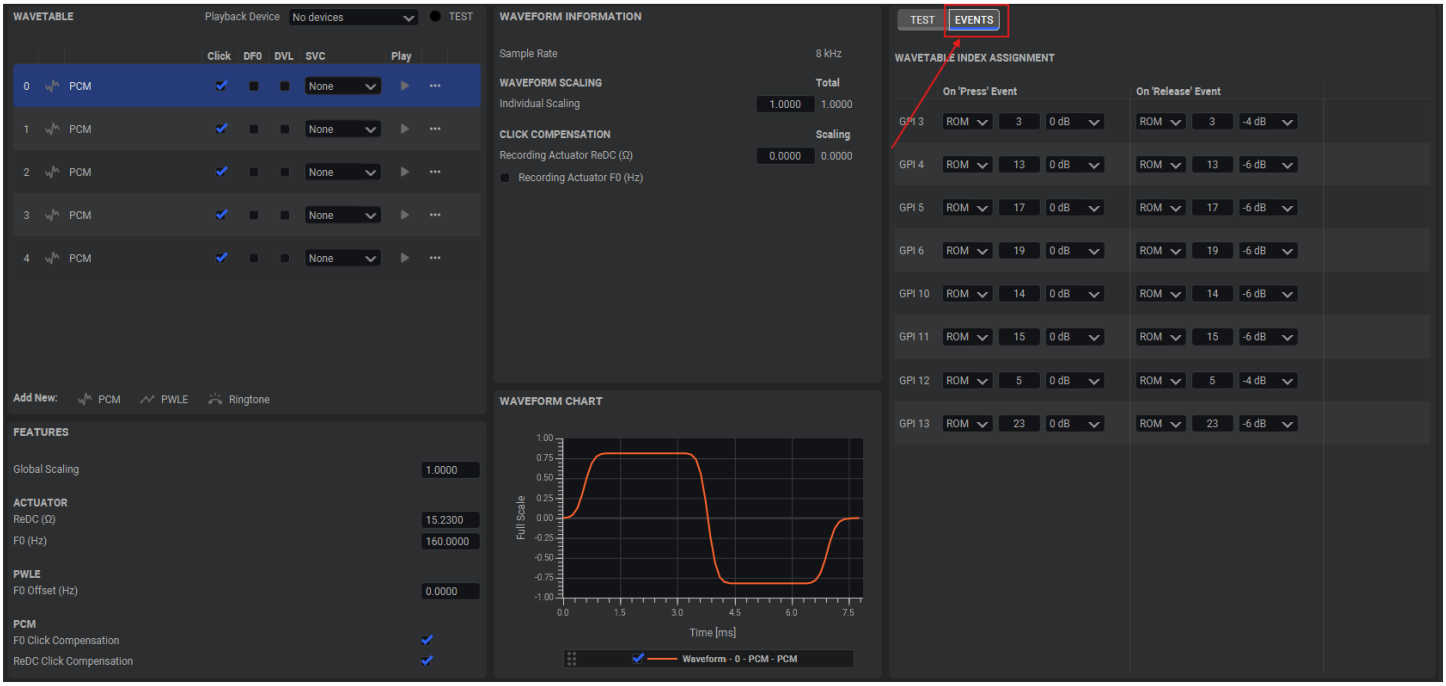


Figure 37 Haptic Events Configuration

4.5 Test Waveforms

To evaluate the performance of different haptic effects, select the Test button above the wavetable and ensure that a Playback Device is configured and selected in the drop-down menu. This will enable waveforms to appear in the Test tab on the right. Select the waveforms to be played by checking the boxes under the "Test" column in the wavetable. Click the "Play" icon to deploy and record a desired waveform. Each one of the effects will play out, their signals recorded, and the graphs are populated with the relevant signals. To monitor the data, select the graphs to be displayed with the checkboxes above the plots. By default, all graphs of Acceleration, RE, VMON, and IMON are displayed.

Each waveform recording will appear as a check-boxed list underneath the Test tab. From the list, select each waveform to compare. The associated waveforms acquired over the course of playback are overlaid to show differences between the two waveforms / configurations. The color code indicates which wavetable index relates to the provided data.

For example, below are two buzz PWLE Waveforms of differing amplitudes. In the Wavetable, the PWLEs are configured as indicated in the Waveform Information Panel:

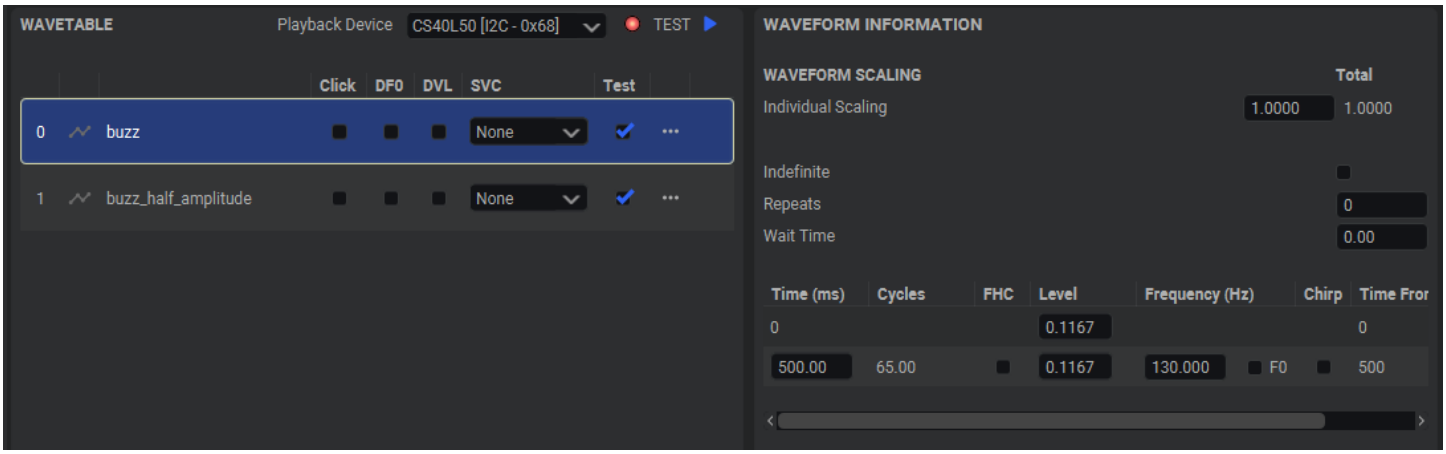


Figure 38 buzz Waveform Information

The first buzz waveform plays at the actuator's resonant frequency at its rated voltage for 500 ms.

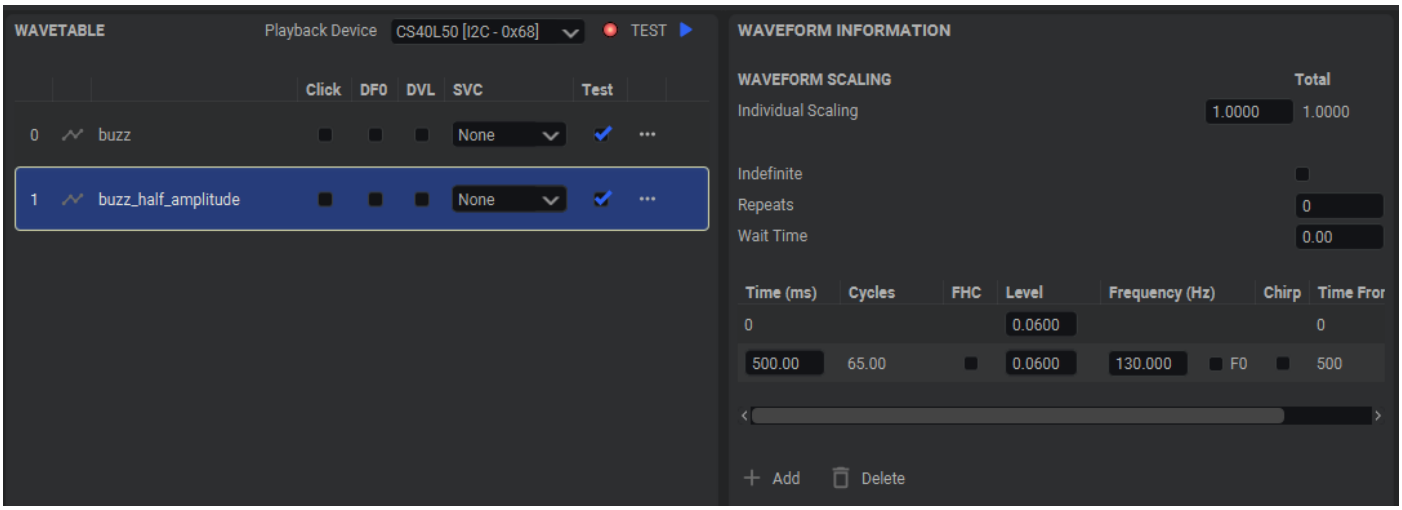


Figure 39 buzz_half_amplitude Waveform Information

The second buzz plays at half of the actuator's rated voltage at its resonant frequency for 500 ms. To compare these two waveforms, the Test button above the table is enabled (indicated by the Red circle), and both waveforms are selected under the Test column. The Play icon is pressed, and the following two waveforms appear in the Test panel.

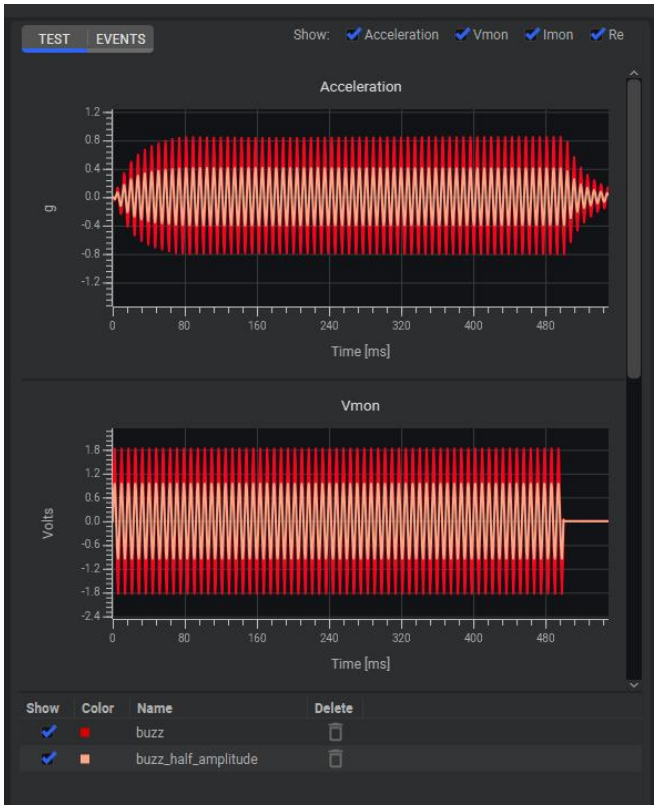


Figure 40 Comparing Two Buzz PWLE Waveforms

The red waveform corresponds with buzz_ol and the peach waveform corresponds to buzz_half_amplitude. The red waveform Vmon peaks at 1.8 V and Acceleration at 0.8 g, and the peach waveform peaks at half that at 0.9 V and 0.4 g respectively. The waveforms can also be individually inspected by selecting the desired one to appear from the list below the graphs.

4.6 General Wavetable Editing Features

In addition to specific manipulations to the different waveforms, the user can perform the following operations on the wavetable as a whole:

- Saving the wavetable
- Loading a wavetable from an existing file
- Changing the global scaling factor for the wavetable

4.6.1 Saving the Wavetable

To save a wavetable for future use, follow this procedure:

1. Click the "Export Preset" button from the ••• menu. This opens the File Explorer.
   – The wavetable must have at least 1 waveform
2. Navigate to the directory where the wavetable files will be saved.
3. Enter the desired name for the saved file in the "File name" field of the File Explorer and click the "Save" button.

4.6.2 Loading the Wavetable

To load a previously saved waveform or set of waveforms, follow this procedure:

1. Click the "Import Preset" button on the ••• menu. This opens the File Explorer.
2. Navigate to and select the desired wavetable preset file.
3. Click the "Open" button. This closes the File Explorer and loads the wavetable into the device.

4.6.3 Changing the Scaling Factor

The WaveTable tab includes tools to scale the amplitude of the haptic waveforms. It is recommended to refer to the actuator datasheet to avoid exceeding the rated input voltage. Scaling levels can be applied on a waveform-by-waveform basis or else applied to all waveforms in the wave table at once. To scale an individual waveform, enter the scaling factor into the Individual Scaling Factor control and click "Enter". To scale all waveforms at once, enter the scaling factor into the Global Waveform Scaling Factor control and click "Enter".

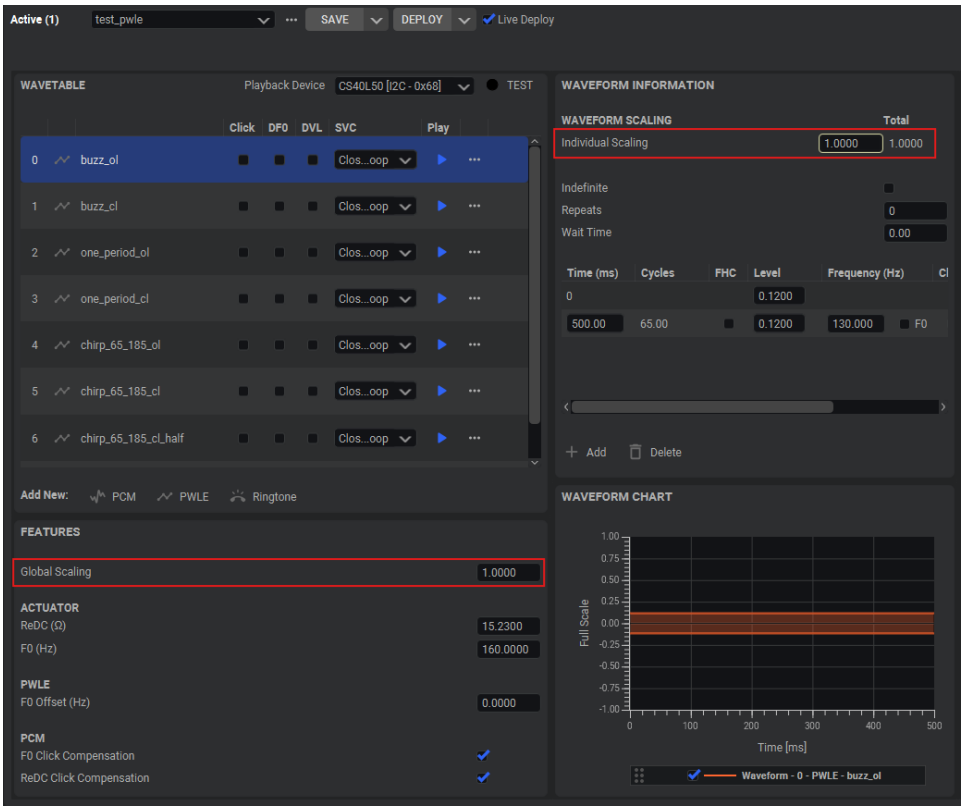


Figure 41 Waveform Scaling Controls

4.6.4 Waveform Menu Options

A number of waveform options are accessed by selecting a checkbox in the wavetable. These options are summarized as follows:

- **Toggle Click**: Select whether to apply Click Compensation to the desired waveform. Note: This is only applicable to open-loop style PCM waveforms, this does not work with Sensorless Velocity Controlled (SVC) enabled waveforms or PWLE/Ringtone waveforms.
- **Toggle Dynamic F_0**: Select whether this waveform should have the Dynamic F_0 algorithm applied to it.
- **Toggle DVL**: Select whether this waveform should have the Dynamic Voltage Limiting algorithm applied to it. Changes to the DVL algorithm can be made in the DVL Tuning Block.
- **SVC:** Select from the drop-down menu the desired setting of the SVC algorithm. Changes to the SVC can be made in the SVC Tuning Block.
- **Test**: Enable the Test button to record and collect Acceleration, Vmon, Imon, and Re data. This graphical data will only appear when the Test button is enabled.

5 SVC Tab

The SVC configuration tab allows the user to characterize the actuator and tune the SVC algorithm performance according to the system requirements. This section provides a walkthrough of the actuator characterization process and the SVC auto-tuning procedure.

5.1 Tune SVC

5.1.1 Open SVC Configuration Tool

Open the SVC configuration tab and click on the "Tune" button. This launches the SVC configuration tool, enabling the actuator characterization and the SVC auto-tuning procedure.

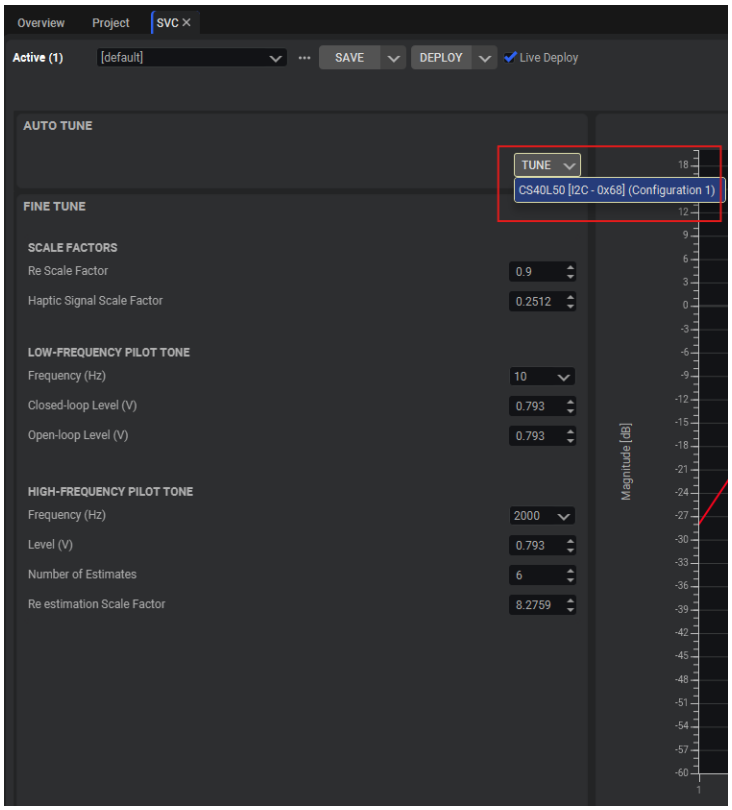


Figure 42 Tune SVC for LRA

5.1.2 Actuator Characterization

On the SVC configuration tool, select the "Browse" button and create a new folder. This folder stores all the files created during the characterization procedure and contains the SVC configuration file.

Once the new folder has been created, select the appropriate actuator model, LRA or Voice Coil Motor, and click on the "Start Characterization" button. During the characterization process, the device estimates the actuator parameters using various test signals, which will be audible. At the end of the characterization process, the actuator parameter table shows the electrical, mechanical, and derived parameters. SCS saves the characterization results automatically to the file created at the beginning of this step. The actuator characterization process takes a few minutes; it is recommended to keep the setup uninterrupted during this process.

Note: Before starting the SVC characterization process, ensure the Windows sound card is configured according to the Sound Card Configuration section.

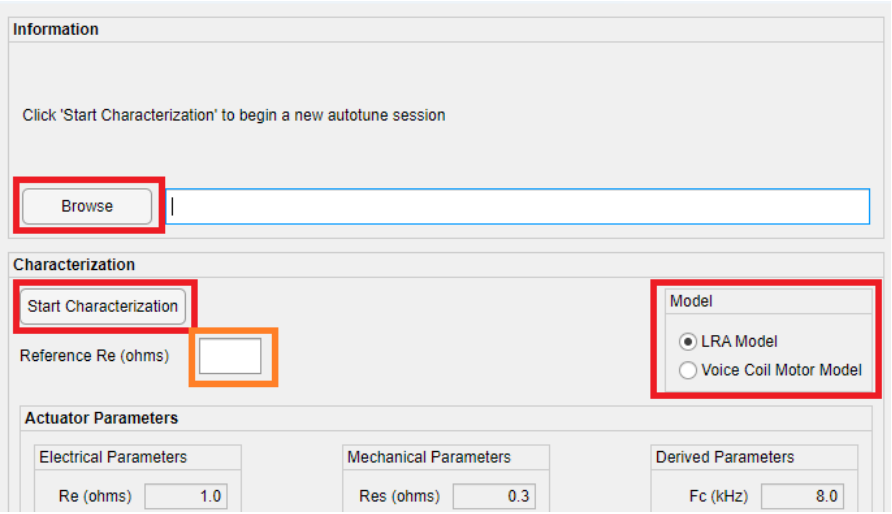


Figure 43 LRA Characterization

5.1.3 SVC Auto-Tuning

After the actuator characterization is complete, click on the "Autotune SVC for Actuator" button to start the SVC auto-tuning procedure. This procedure performs the actuator variation study, closed-loop analysis, and ReDC estimation tuning. The duration of this procedure depends heavily on the host system's performance. In some cases, this could take more than the 10 minutes indicated on the selection.

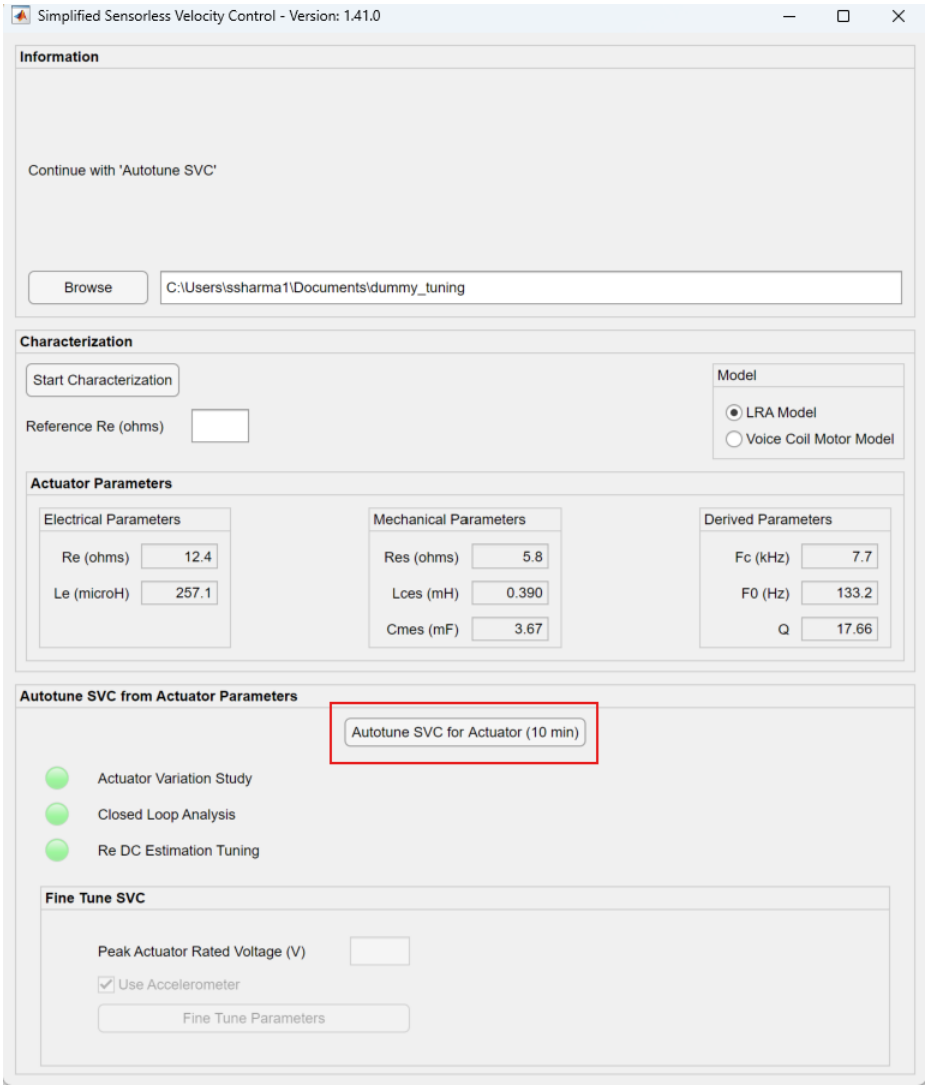


Figure 44 SVC Autotune

5.1.4 SVC Fine Tuning

Once the "Autotune SVC" procedure is complete, input the Peak Actuator Rated Voltage and click on the "Fine Tune Parameters" button to start the fine-tuning process. This step takes a few minutes to complete; after this, the user can close the SVC configuration tool.

The SVC plugin automatically saves the tuning file and applies it to the device after the SVC auto-tuning procedure is complete. The SVC configuration file is saved as a .json file, which could be used for future tuning of the SVC algorithm.

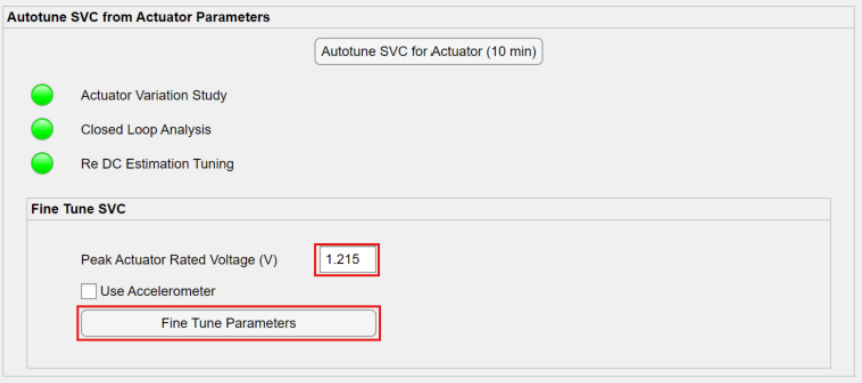


Figure 45 SVC Fine Tune

5.2 Fine Tune Parameters

The SVC configuration tab allows the users to manually tune basic parameters that could be used to optimize the Re DC estimation and SVC algorithm performance for a given LRA.

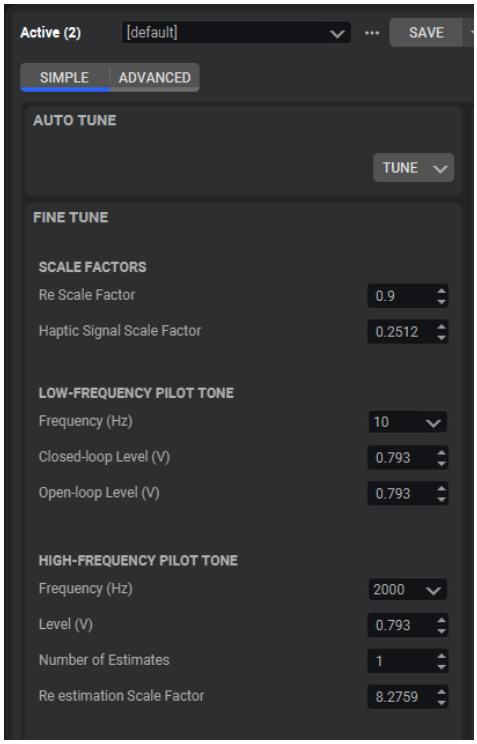


Figure 46 Overview of SVC Fine Tune Parameters

The parameters available to fine tune are described as shown.

Table 2 SVC Fine Tune Parameters

Fine Tune Configuration	Parameter	Description
Scale Factors	Re Scale Factor	The Re scaling factor scales the strength of the coil impedance cancellation applied by the SVC algorithm.
	Haptic Signal Scale Factor	The scale factor for the haptic signal
Low-Frequency Pilot Tone	Frequency	The frequency of the low-frequency pilot tone.
	Closed-loop Level	The Closed-loop level of the low-frequency pilot tone.
	Open-loop Level	The Open-loop level of the low-frequency pilot tone.
High Frequency Pilot Tone	Frequency	The frequency of the high-frequency pilot tone.
	Level	The voltage of the high-frequency Pilot tone, ranging from 0 - 6.34 V.
	Number of Estimates	The number of 48kHz samples of the High Frequency Pilot Tone.
	Re estimation Scale Factor	The scale factor for converting high pilot tone RE estimation to Ohms.

5.3 Enabling SVC in the Wavetable

Once a tuning has been saved and applied to a device, it can be enabled on a haptic waveform in the Wavetable tab. Returning back to the Wavetable tab, select the functionality of SVC to be applied onto the device from the dropdown menu under the SVC column.

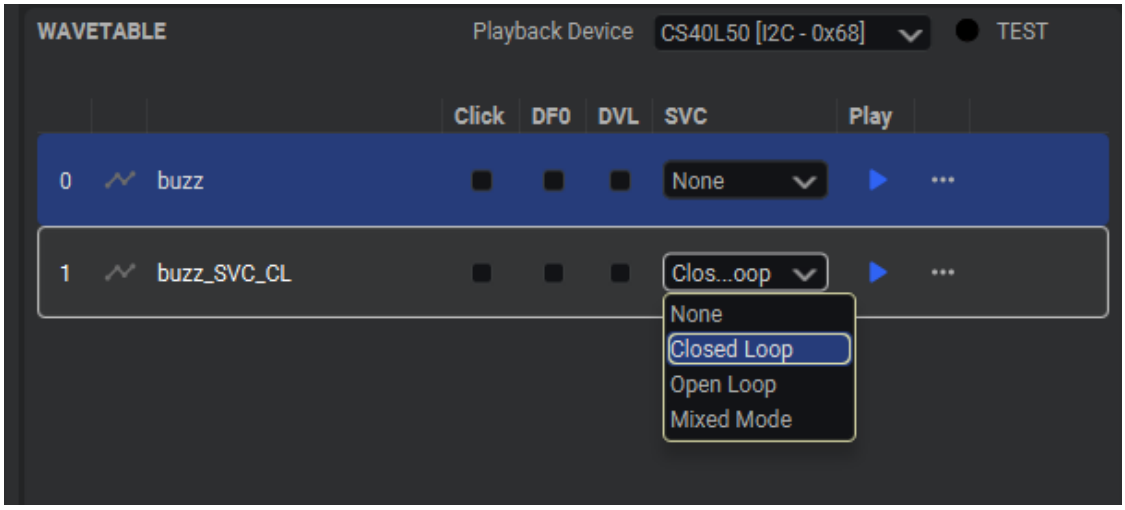


Figure 47 SVC Options

There are four different SVC options to choose from, as described in the table below.

Table 3 SVC Option Descriptions

SVC Option	Description
None	Disables SVC
Closed Loop	Enabled SVC, optimizes ramp-up and braking time
Open Loop	Disables SVC, but still plays pilot tones
Mixed Mode	Disables SVC during ramp-up, enables SVC during braking

Closed-Loop mode enables the best performance of a haptic waveform. This mode helps to optimize the ramp-up and braking time of a given waveform by automatically applying overdrive at the beginning of the waveform playback and applying the required braking signal at the end of the waveform. The following plot shows the performance comparison between a waveform played with the SVC closed-loop mode enabled (red waveform) against a waveform played with the SVC disabled (peach waveform).

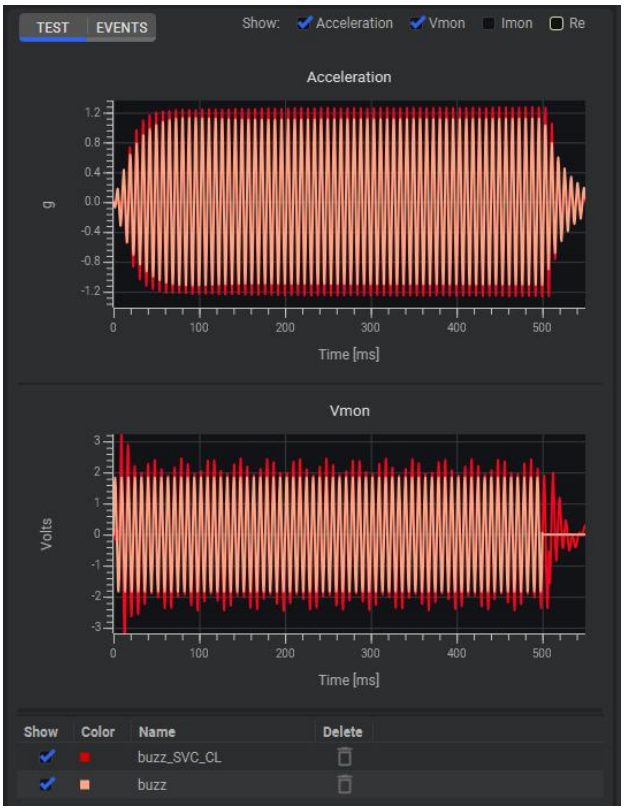


Figure 48 Comparing SVC OFF and ON

In this example, the SVC closed-loop waveform reaches the maximum acceleration in about 50 ms and brakes in about 50 ms. In contrast, the waveform with the SVC disabled takes approximately 70 ms to reach maximum acceleration and brakes in about 70 ms. Since the SVC closed-loop algorithm helps regulate the signal by directly controlling the bEMF, the acceleration is consistent over time while the acceleration of the waveform with the SVC disabled decay as the LRA coil impedance starts changing.

6 Streaming Tab

The Streaming tab allows the user to enable SVC streaming over I2S. Click the checkbox next to the Name to enable SVC over I2S.

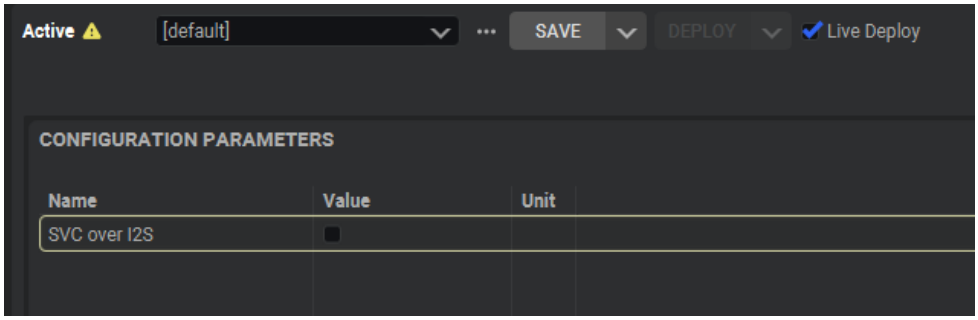


Figure 49 Enable SVC via I2S

7 DVL Tab

The Dynamic Voltage Limiter (DVL) is a DSP firmware algorithm that enables adaptable and frequency-dependent voltage limiting in CS40L5X devices. LRAs exhibit high sensitivity within a narrow frequency range around the resonant frequency (F0) and much lower sensitivity at frequencies away from the resonance. Accordingly, the DVL enables users to set frequency-dependent voltage limits. The DVL also detects and manages SVC overdrive and braking conditions that can result in large voltage swings.

For more information about DVL, see AN0578R1 - Dynamic Voltage Limiter (DVL) User Guide.

7.1 Tuning DVL

The DVL Tuning tool provides access to high-level tuning parameters to adjust the DVL algorithm. In this tab, users can adjust DVL configuration parameters by inputting values specific to the tuning. The resulting Magnitude Response is displayed on the graph to the right of the parameters. In the example tuning shown below, DVL limits the voltage at the resonant frequency.

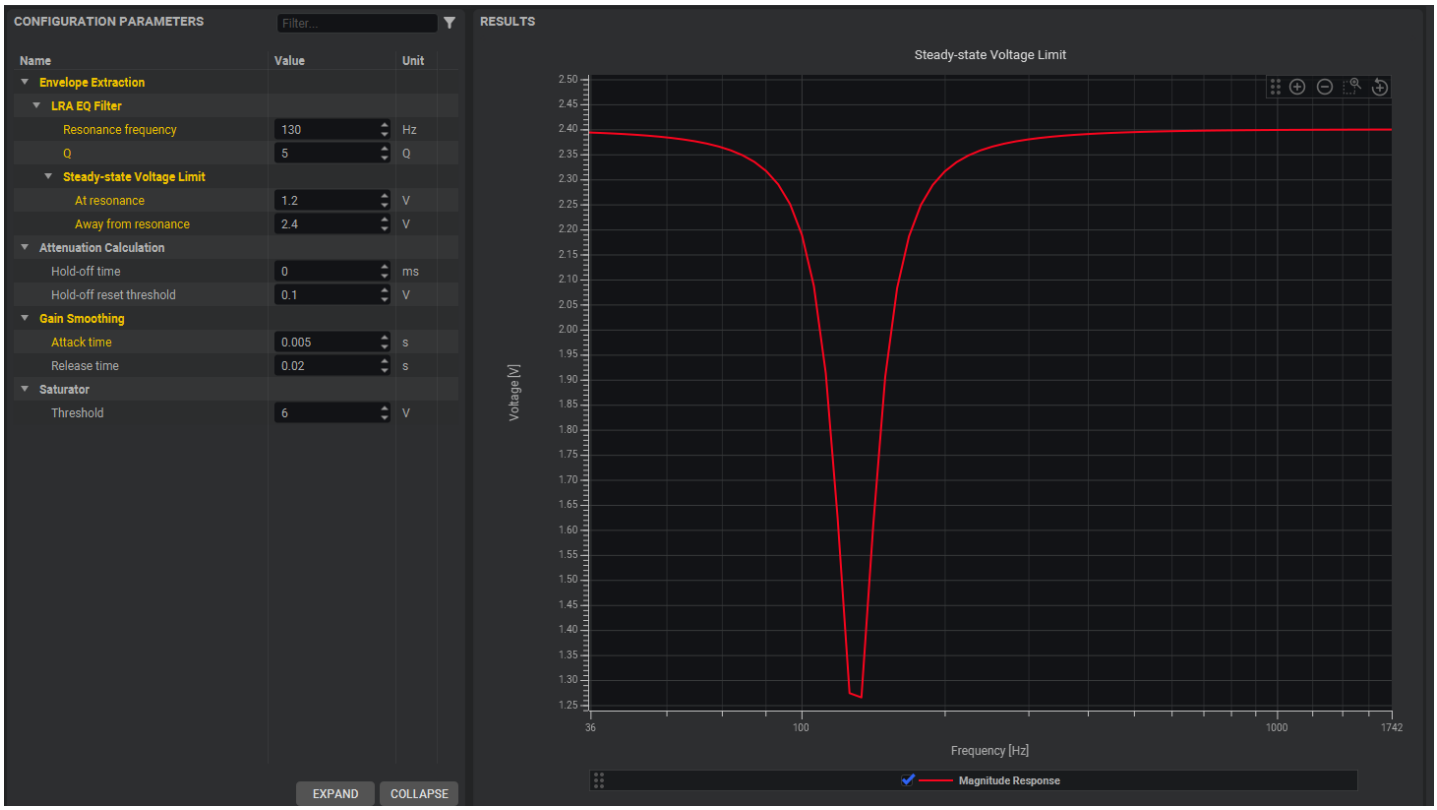


Figure 50 Overview of DVL Tab

The configuration parameters are described as shown in the table below:

Table 4 Configuration Parameters for DVL

Configuration Parameter Section	Sub-Block	Parameter	Definition and Guideline
Envelope Extraction	LRA EQ Filter	Resonance Frequency	The nominal resonant frequency of the LRA.
		Q	The LRA Q factor.
	Steady State Voltage	At resonance	The rated voltage at F0 of the LRA.
		Away from resonance	This setting should be based on guidance from the actuator vendor and is usually around double the rated voltage.
Attenuation Calculation		Hold-off time	The time which after the signal level rises above the threshold voltage before gain starts to be reduced.
		Hold-off reset threshold	The magnitude threshold below which the hold-off counter is reset.
Gain Smoothing		Attack time	The attack time for the gain limiter when gain is increasing
		Release time	The release time for the gain limiter when gain is decreasing
Saturator		Threshold	The threshold above which level is saturated. The output never exceeds this level.

7.2 Enabling DVL Tuning in the WaveTable

To enable and test DVL, check the DVL box in the Wavetable Tuning Tab and ensure that the Test button is enabled.

For example, compare two chirp waveforms, one at rated voltage and the other at full scale. DVL should be applied on the chirp at full-scale, and as a result it will limit the voltage around the resonant frequency significantly.

The first chirp ranges from 65 to 300 Hz at the rated voltage without DVL applied:

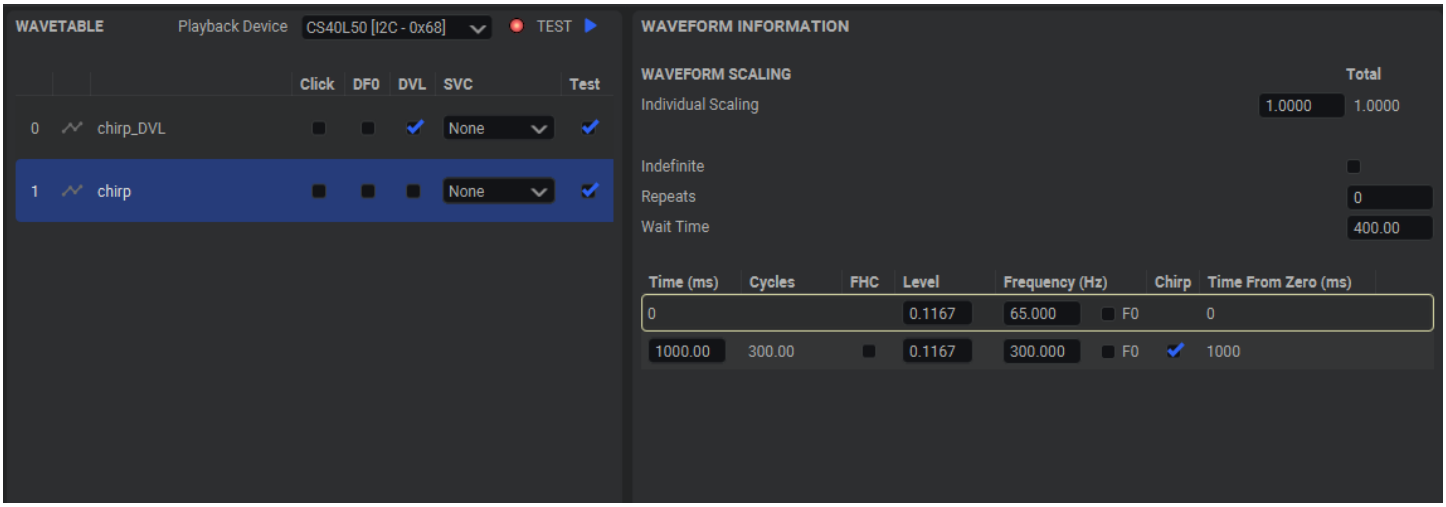


Figure 51 chirp Waveform Information

The second chirp ranges from 65 to 300 Hz at the full-scale voltage with DVL applied. Full scale voltage is beyond the limits of this actuator. DVL limits the voltage to be within this actuator's limits:

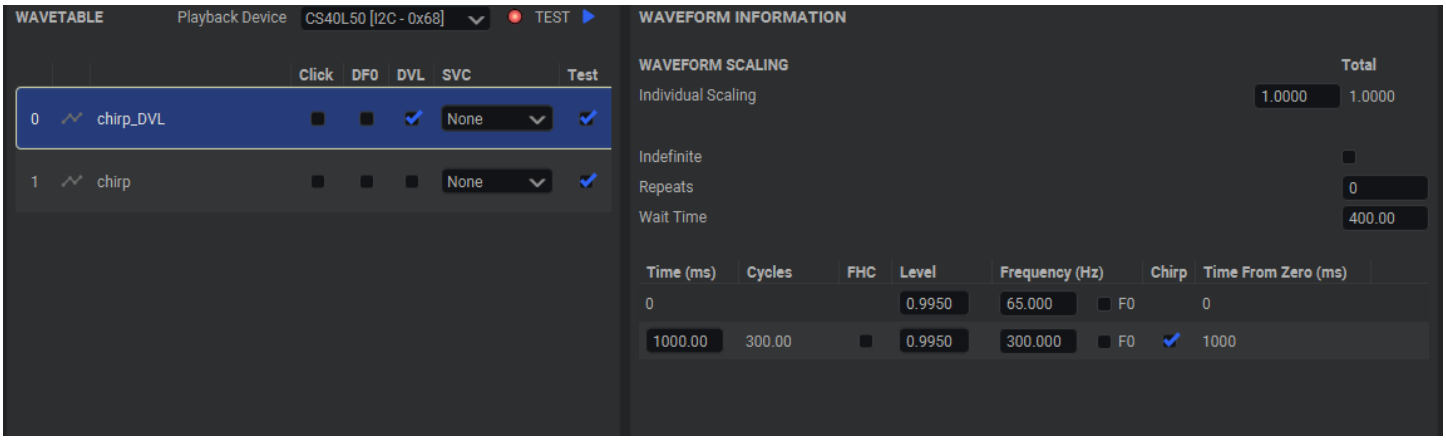


Figure 52 chirp_DVL Waveform Information

The DVL function is illustrated in the following figure – the peach waveform is the chirp at rated voltage without DVL applied, and the red waveform is the chirp at full scale with DVL applied. The red waveform limits the full-scale voltage within the actuator's limits by applying the DVL algorithm.

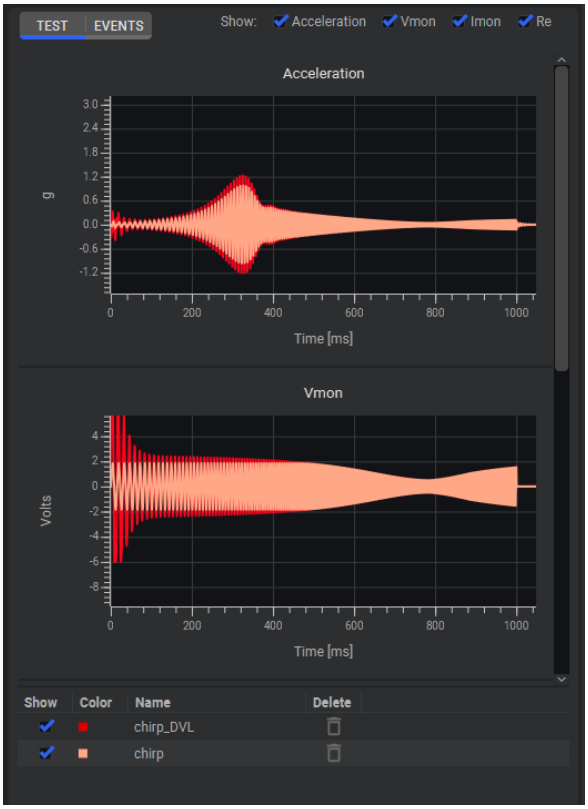


Figure 53 Comparing NO DVL and DVL

8 A2H Tab

The Audio to Haptics (A2H) algorithm is a real-time process in which an audio stream from a video game, ringtone, or other application is analyzed. Haptic feedback is triggered when the audio has a haptic-worthy event. The parameters of the algorithm can be tuned specifically to the actuator that is in the system to offer peak performance. The A2H Tuning Tool allows a user to tune algorithm parameters. The graphs on the right display the magnitude response of the Sideband and Crossover Tunings. For more information about A2H, see *AN0573R2 - Audio To Haptics (A2H) User Guide*.

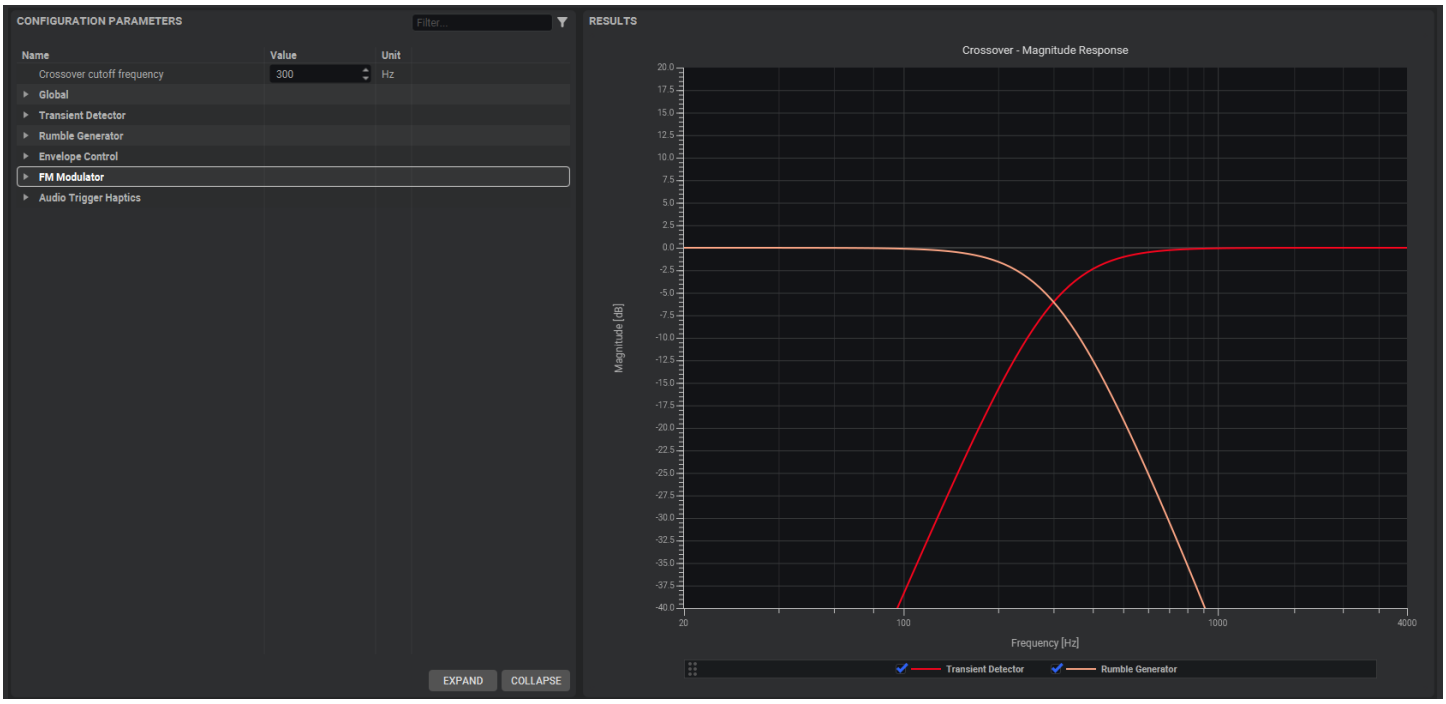


Figure 54 Overview of A2H Tab

The table below provides all tuning parameters available for A2H.

Table 5 A2H Tuning Parameters

Block	Sub-Block	SCS Name	Parameter Description
Global			
		Audio Left	Audio left channel enable
		Audio Right	Audio right channel enable
Transient Detector			
		Amount of sustain to subtract from transient	Transient detector rumble generator Sustain gain before subtracting from transient
High-Pass Signal	Envelope Estimation	Rise Time	Transient detector rumble generator High Pass Envelope Estimation Smoothing Factor (Rise)
		Fall Time	Transient detector rumble generator High Pass Envelope Estimation Smoothing Factor (Fall)
Low-Pass Signal	Envelope Estimation	Rise Time	Transient detector rumble generator Low Pass Envelope Estimation Smoothing Factor (Rise)
		Fall Time	Transient detector rumble generator Low Pass Envelope Estimation Smoothing Factor (Fall)
	Smoothing	Rise Time	Transient detector rumble generator Low Pass Envelope Smoothing Factor (Rise)
		Fall Time	Transient detector rumble generator Low Pass Envelope Smoothing Factor (Fall)

Block	Sub-Block	SCS Name	Parameter Description
Automatic Gain Control		Enable	Transient detector rumble generator AGC On/Off
		Maximum Gain	Transient detector rumble generator Maximum Gain Allowed for AGC
Transient Envelope (click)		Scale Factor	Transient detector rumble generator Scaling Factor for Transients
		Amplitude Limit	Transient detector rumble generator Amplitude Limit for Transient Envelope
Rumble Generator			
		Amount of sustain to subtract from transient	Rumble generator Sustain gain before subtracting from transient
Pitch Estimation		Maximum pitch to track	Rumble generator upper pitch limit
		Rise time	Rumble generator Pitch Smoothing Factor (Rise)
		Fall time	Rumble generator Pitch Smoothing Factor (Fall)
Low-Pass Signal	Envelope Estimation	Rise time	Rumble generator Low Pass Envelope Estimation Smoothing Factor (Rise)
		Fall time	Rumble generator Low Pass Envelope Estimation Smoothing Factor (Fall)
	Smoothing	Rise time	Rumble generator Low Pass Envelope Smoothing Factor (Rise)
		Fall time	Rumble generator Low Pass Envelope Smoothing Factor (Fall)
Automatic Gain Control		Enable	Rumble generator AGC On/Off
		Maximum Gain	Rumble generator Maximum Gain Allowed for AGC
Transient Envelope (Bump)		Scale Factor	Rumble generator Scaling Factor for Transients
		Amplitude Limit	Rumble generator Amplitude Limit for Transient Envelope
Sustain Envelope (Buzz)		Scale Factor	Rumble generator Scaling Factor for Sustain
		Amplitude Limit	Rumble generator Amplitude Limit for Sustain Envelope
	Peak Tracking	Rise time	Rumble generator Sustain Envelope Peak Tracking Smoothing Factor (Rise)
		Fall time	Rumble generator Sustain Envelope Peak Tracking Smoothing Factor (Fall)
Envelope Control			
		Combined envelope gain threshold	Gain threshold for combined envelope below which the combined envelope is set to 0.
Click		Gain	Final scaling of the Click envelope.
	Compare	Rise time	Click envelope smoothing factor (rise) for comparing to Click envelope. When Click envelope compare is larger than Click envelope, the Click envelope is disabled.
		Fall time	Click envelope smoothing factor (fall) for comparing to Click envelope. When Click envelope compare is larger than Click envelope, the Click envelope is disabled.
	Enable Pulse	Rise time	Click envelope smoothing factor (rise) for enable pulse of Click envelope. Smooths the rise of the enable pulse.
		Fall time	Click envelope smoothing factor (fall) for enable pulse of Click envelope. Smooths the fall of the enable pulse.
Bump		Gain	Final scaling of the Bump envelope.
	Compare	Rise time	Bump envelope smoothing factor (rise) for comparing to Bump envelope. When Bump envelope compare is larger than Bump envelope, the Bump envelope is disabled.
		Fall time	Bump envelope smoothing factor (fall) for comparing to Bump envelope. When Bump envelope compare is larger than Bump envelope, the Bump envelope is disabled.
	Enable Pulse	Rise time	Bump envelope smoothing factor (rise) for enable pulse of Bump envelope. Smooths the rise of the enable pulse.
		Fall time	Bump envelope smoothing factor (fall) for enable pulse of Bump envelope. Smooths the fall of the enable pulse.
Buzz		Fast to slow threshold	Threshold above which Buzz Slow Rise/Fall is used and below Buzz Fast Rise/Fall are used.
		Threshold	Threshold to enable Buzz envelope. When Buzz minus Bump is larger than this threshold, Buzz envelope is enabled.
		Gain	Final scaling of the Buzz envelope.

Block	Sub-Block	SCS Name	Parameter Description
	Fast	Rise time	Fast smoothing factor (rise). Smooths Bump envelope for subtracting from buzz envelope compare.
		Fall time	Fast smoothing factor (fall). Smooths Bump envelope for subtracting from buzz envelope compare.
	Slow	Rise time	Slow smoothing factor (rise). Smooths Bump envelope for subtracting from buzz envelope compare.
		Fall time	Slow smoothing factor (fall). Smooths Bump envelope for subtracting from buzz envelope compare.
	Compare	Rise time	Smooths Bump minus Buzz before Buzz Threshold.
		Fall time	Smooths Bump minus Buzz before Buzz Threshold.
FM Modulator			
		Center frequency	FM modulator center frequency
		Output level	FM modulator output level
Bandwidth Control		Maximum frequency	FM modulator bandwidth control maximum frequency
		Gain	FM modulator bandwidth control gain value
Smoothing		Zero-crossing time	FM modulator envelope smoothing factor (at zero crosses)
		Rise time	FM modulator envelope rise smoothing factor (between zero crosses)
		Fall time	FM modulator envelope fall smoothing factor (between zero crosses)
Audio Trigger Haptics			
		Buzz effect wavetable index	Wavetable index when Buzz effect is triggered. Set it to 16777215 to disable
		Click effect wavetable index	Wavetable index when Click effect is triggered. Set it to 16777215 to disable
		Bump effect wavetable index	Wavetable index when Bump effect is triggered. Set it to 16777215 to disable
		Click and Bump effect wavetable index	Wavetable index when Click and Bump effect is triggered simultaneously. Set it to 16777215 to disable
		Buzz threshold	Threshold to trigger Buzz effect
		Buzz locking time	Time in millisecond that Buzz effect triggering is locked
		Click threshold	Threshold to trigger Click effect
		Click locking time	Time in millisecond that Click effect triggering is locked
		Bump threshold	Threshold to trigger Bump effect
		Bump locking time	Time in millisecond that Bump effect triggering is locked

9 Provisioning Tab

The provisioning panel allows for the streamlined provisioning of a system/device outside of the tuning tool, using a tuning (in compiled bin file form), the firmware file, and python scripts. This may be desirable if the user does not need to change the tuning but simply wants to apply it for testing and/or demonstration purposes.

9.1 Device Provisioning Panel

Device provisioning can be found under each specific device in the navigator. There is a separate device provisioning panel for each device.

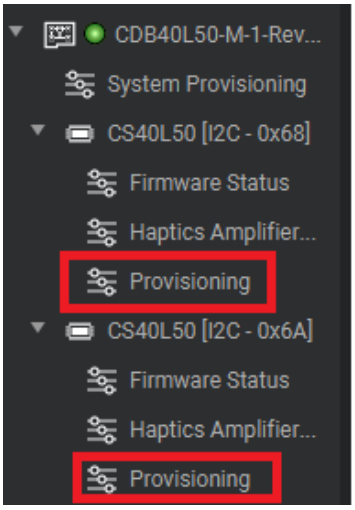


Figure 55 Navigate to Provisioning Panel Unique to Each Device

The top section of the provisioning panel allows for loading scripts at various points in system provisioning on a per-device basis.

Figure 56 Provisioning Panel - Device Panel

A number of pre-configured scripts and files are provided with the CS40L5X Jamerson BSP. If installed within a sandboxed workspace, these will be located the C:\ProgramData\Cirrus Logic\SCS\Workspaces\ folder for the appropriate version.

When starting from a blank provisioning panel, the open folder icons will open the appropriate base folder. All recommended files below will be in reference to this base folder.

Table 6 Recommended Provisioning Files

	Description	Recommended File
Host Platform configuration	Configure the Host platform (Lochnagar2) for Tuning playback.	`scripts\CS40L50_PYTHON\provisioning\host_init_ln2.py`
Firmware Load	Firmware WMFW file	`firmware\<FirmwareVersion>\*.wmfw` Firmware versions for A1 and B0 Parts will be located in different <FirmwareVersion> directories.
Device Initialization	Configure the Device (CS40L5X) for Tuning playback.	scripts\CS40L50_PYTHON\provisioning\device_init_tuning_cs40l50.py
Post-Configuration	Script to run after tuning has been deployed. Puts the device into an Active state.	provisioning\post_config_ln2_enable_asp.py
Tuning File Load	Tuning BIN file for Wavetable, SVC, A2H, DVL	Bin file generated from SoundClear Tuning or provided by a Cirrus Engineer. Must match the firmware version above.

9.2 Mailbox Panel

The mailbox panel contains convenience buttons to manually send a number of commands to the mailbox register. The mailbox panel is at the bottom of each device's unique provisioning tab.

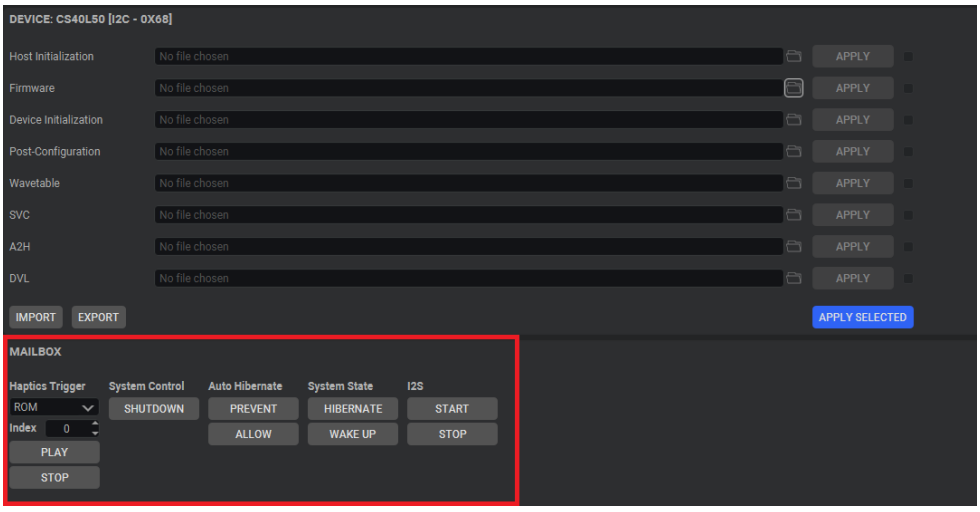


Figure 57 Navigate to Mailbox Panel

9.2.1 Convenience Buttons

A brief description of the convenience button commands is provided in the following table:

Table 7 Common Mailbox Commands

	Mailbox Command	Description
System Control	Shutdown	Shut down the haptic output path and transition to the Shutdown State. A shutdown is required before loading new firmware to DSP memory.
Auto Hibernate	Prevent	Disable automatic transition to the Hibernate State (default behavior).
	Allow	Enable automatic transition to the Hibernate State. If enabled, the device automatically enters the Hibernate State following a timeout of inactivity in the Standby State
System State	Hibernate	Shut down the haptic path and transition to the Hibernate State.
	Wake Up	Wake the device from the Hibernate State and transition to the Standby State.
I2S	Start	Start I2S streaming.
	Stop	Stop I2S streaming.

9.2.2 ROM Playback

The mailbox panel also enables playback of waveforms that are stored in the CS40L5X ROM. This feature is useful when confirming the CS40L5X is properly powered up and wired to an actuator, by allowing the user to easily trigger a predesigned haptic event. For further information detailing the ROM index, refer to Section 5.1.1 in AN0541R1 - CS40L5X Configuration User Guide.

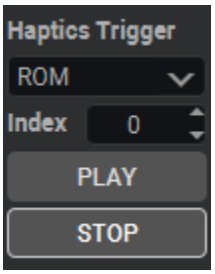


Figure 58 ROM Playback

10 Register Maps

The Register Map view allows user-initiated register read and write transactions to a connected system. Additionally, detailed information about the values of registers and fields and the ability to export and input device registers are available. Display configuration, searching, and filtering facilities are also provided.

The Register Map view consists of two main sections: a Register Toolbar at the top, and a Register Table below.

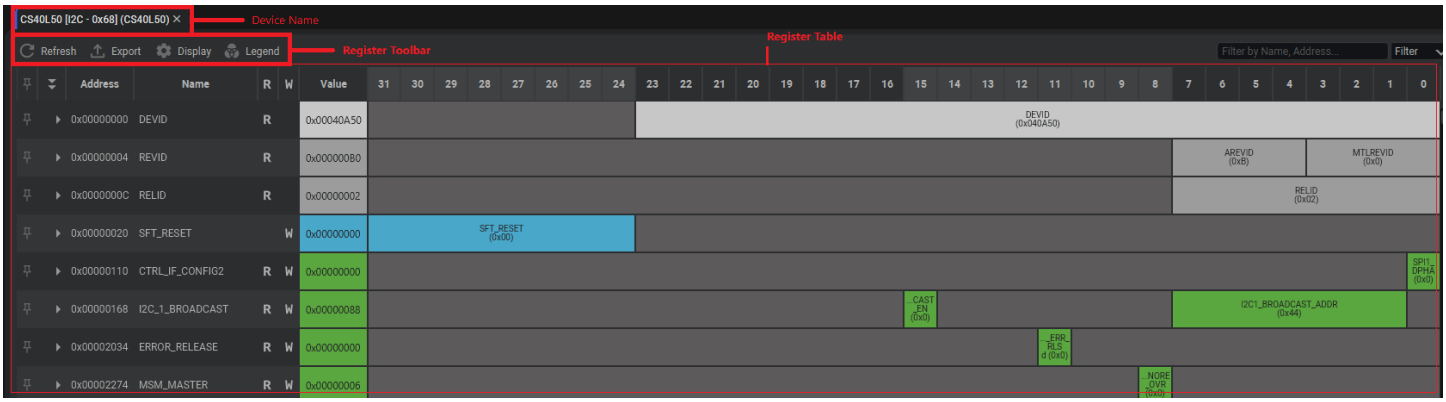


Figure 59 Overview of Register Map Panel

10.1 Register Toolbar and Table

The Register Toolbar contains a set of general buttons and a search/filter facility. The buttons are described as followed:

- Refresh – refreshes the registers from the device. If this button is blocked, it means a refresh operation is in progress.
- Export – exports all the registers in a device as a .csv file
- Display – configures the display options for register maps for all instances of the device.
- Legend – displays the legend for Register Map cells.

The search/filter bar provides the option to display or highlight specified registers and fields.

The register table displays the registers on the selected device and is divided into three sections.

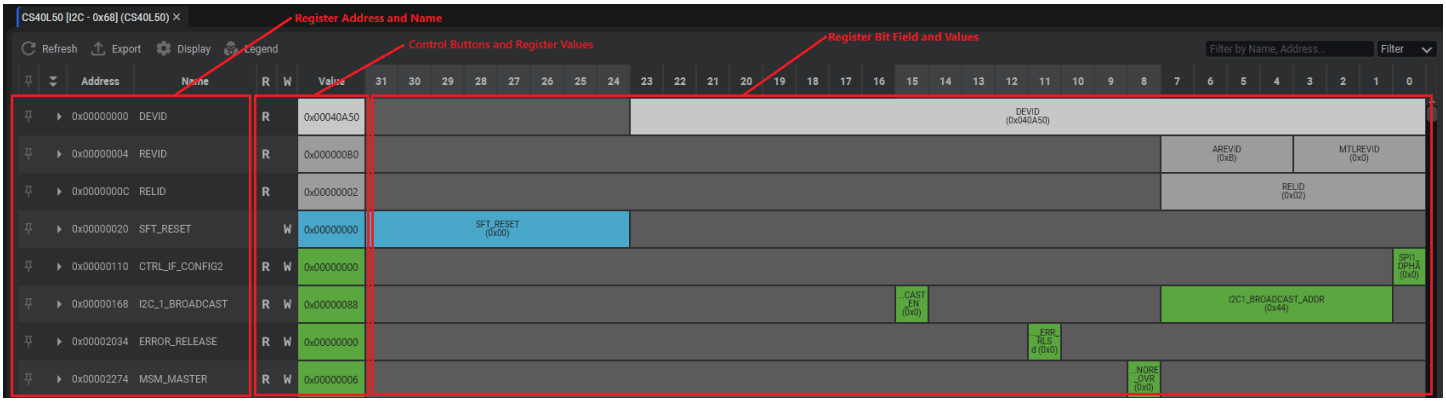


Figure 60 Register Table Sections

The leftmost section contains the address of the register and its name. Double-clicking on one of these cells of the table or clicking on the arrowhead opens the field row(s) which display the content of any fields within the register in an appropriate format. The central section contains control buttons for reading and writing to the associated field/register, and a value display. The rightmost section contains the bit values in the registers, divided into fields. When the field row is displayed, an appropriate control for updating the field value is displayed. Right-clicking a cell in any of the Address or Name columns displays a popup about the current and default values for the register or field displayed in that row. If the register or field is writable, the popup allows a new value to be entered.

The Control Buttons and Register Values section contains three columns. The left two columns display whether the register or field can be read (column R) or written (column W). If there is no button in the column, the action is not available. Clicking either of the buttons performs the read or write to/from the register or cache. The Value column displays the current value of the register or field. To edit the value of a writable register or field, double-click on the cell in the register or field's Value column. A text field is displayed, in which a new value is entered in either decimal or hexadecimal format.

The color of a cell in the Value column indicates additional information about the data in the register or field:

- Green – indicates that the data can be both read and written.
- Blue – indicates that the data is write-only. SoundClear Studio maintains an internal cache of the last values written to these bits.
- Gray – indicates that the data is read-only.

10.2 Register Map Field Values

On a row that displays a field, the field values shown depend on the size of the bit field. Some bit fields are single-bit values, while others consist of multiple bits, as shown for the fields in register ASP1_CONTROL2 at address 0x00004808.

Figure 61 Register Fields

Where a bit field is single or dual-bit and the values are pre-defined, a radio button selection is provided. The radio button labels display the definitions, as shown for bits [6:0]. Where a bit field is single-bit and is write-only, a check box is provided; selecting this sets the bit, deselecting this clears the bit. For multi-bit fields where the values are pre-defined by the data sheet, a drop-down box with the available options is provided, as shown for bits [31:24] and [23:16]. Options are selected by clicking the desired value. For multi-bit fields where the values are not pre-defined in the data sheet, a text-input box is provided for entering the desired value. Note that it is possible to enter any value; this may include reserved, undefined, or illegal values.

10.3 Errors

If any read or write access to a register fails due to a communication error, the Value field in the register table and any corresponding affected fields will have a red background.

The Value field contains the last value that was either read or written from the register. This value DOES NOT necessarily reflect the value actually in the device register. Additional details about the error can be found using the History View feature of SoundClear Studio to log accesses.

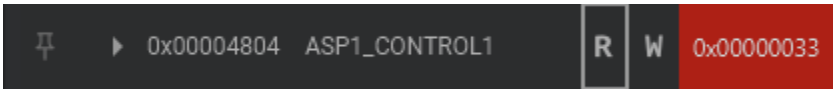


Figure 62 Error in Register Table

11 Revision History

Revision	Changes
R1 AUG 2025	• Initial release
R2 NOV 2025	• Added clarifying information regarding accelerometer setup
R3 DEC 2025	• Re-released without confidential restrictions

Contacting Cirrus Logic Support

For all product questions and inquiries, contact a Cirrus Logic Sales Representative.
To find the one nearest you, go to www.cirrus.com.