



SigCalRP User's Guide

TDT

SigCalRP User's Guide – Version 4.2

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Chapter 1 Introduction

Welcome to SigCalRP calibration software for SigGenRP projects. We hope you will find this software friendly and useful. As always, we welcome your comments on how to improve our software to make it more useful for your research.

SigCalRP Overview

SigCalRP is designed to make speaker calibration and generation of SigGen normalization files a simple process. SigGen normalization files can be used to flatten non-linear frequency responses of speakers.

SigCalRP Capabilities

SigCalRP plays out a series of tones and measures the sound pressure level (SPL) from a signal that is recorded using a calibrated microphone and digitized by an A/D converter. SigCalRP will then automatically calculate a normalization file that maximizes the signal to noise ratio of the D/A converter, while avoiding clipping.

SigCalRP gives you two ways to normalize a signal:

- ✓ normalization file in SigGenRP
- ✓ normalization with a PA5 programmable attenuator (only use with tone signals)

Each method has inherent advantages and disadvantages and only one method of normalization should be used. One of the keys to successful calibration is knowing the limitations of hardware, and how to avoid common pitfalls. These are briefly described in this manual and more information on System 3 hardware is available in the TDT System 3 Manual.

Hardware Support

SigCalRP supports TDT's System 3 RP family of Real-Time Processors as well as the RX6, RX8 and RZ6 processors:

RP2 Real-Time Processor
RP2.1 Enhanced Real-Time Processor
RV8 Barracuda
RL2 Stingray Pocket Processor
RA16 Medusa Digital Bioamp
RM1 Mini Processor
RM2 Mobile Processor

RX6 Piranha Processor
RX8 Multi I/O Processor

RZ6 Multi I/O Processor

Before You Begin:

Before you begin you should have a basic knowledge of:

SigGenRP concepts: you should be familiar with generating signals using the Frequency method in SigGenRP.

Your RP device: you should read the sections of the TDT System 3 Manual for your processor device. Each device has different maximal sampling rates, and may have different maximum input and output voltage levels.

Chapter 2 The Software Interface

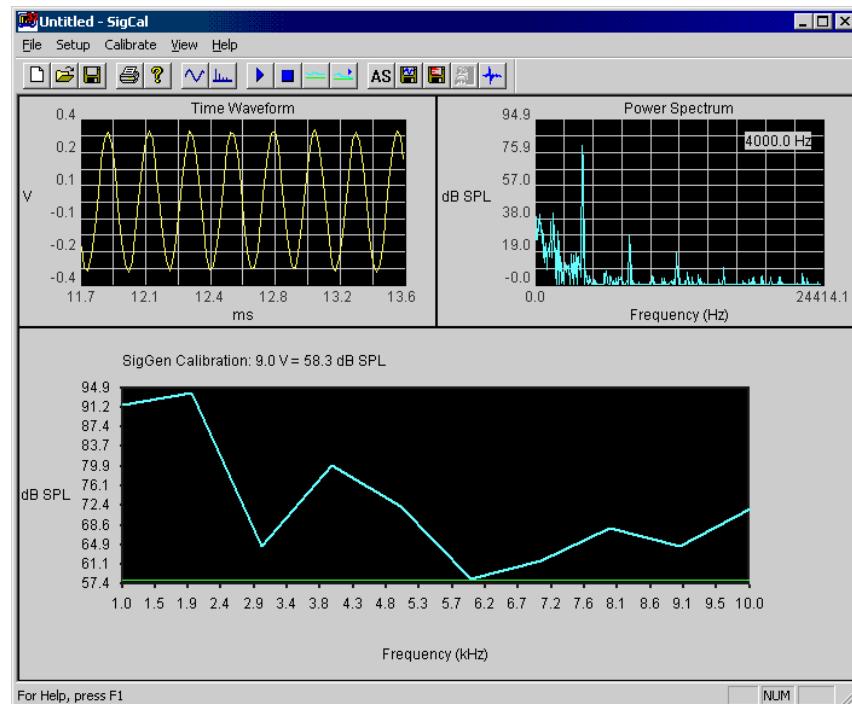
This chapter introduces the SigCalRP interface, menus, and dialog boxes.

SigCalRP Plots

The main SigCalRP workspace, shown below, is divided into three plot areas.

- ✓ The **Time Waveform** shows the time domain plot of the recorded signal.
- ✓ The **Power Spectrum** shows the frequency domain plot of the recorded signal.
- ✓ The **Calibration** plot shows the speaker calibration, normalization curve, normalization curve test data, and total harmonic distortion (THD) measurements.

To inspect different frequencies after the calibration is completed, right-click on the calibration plot. The Time waveform and Power spectrum will be updated for the frequency that is clicked.



Screen Controls

Zooming the Time and Frequency Plots

Zoom in on a plot by clicking the left mouse button and dragging to the right. To zoom out, click the right mouse button while it is in the plot area.

Zooming the Calibration Plot

The dB SPL scale may be manually zoomed out by left-clicking in either the upper or lower part of the scale to change the maximum and minimum plot values.

Right-click in the scale to zoom in on the plot.

Autoscale may also be used to automatically scale the plot.

Moving the Normalization Line

The green normalization line may be moved by pressing and holding the left mouse button while dragging the line to a new position.

Inspecting Individual Frequencies

To inspect the time and frequency plots of different frequencies, right-click the frequency you wish to view in the calibration plot. The current frequency being displayed is shown in the upper right corner of the frequency plot. Only the last 100 frequencies tested are stored in memory.

Menus

File Menu

The File menu includes commands for opening and saving SigCal files. SigCal files have the .cal extension and contain all of the SigCalRP settings as well as the data for SigCal files that have been run. Note that the functions to export normalization files and to export calibration data to an ASCII file are found under the Calibrate menu.

New Opens a new SigCal file with no calibration data. Previous SigCalRP settings are maintained.

Open/Save/Save As These commands will open and save all of the settings and calibration data in a SigCal file. The most recent SigCal files are shown at the bottom of the File menu.

Print/Print Setup These commands are used to print the current SigCalRP screen. The size of the plot on the printer is directly proportional to the size of the SigCalRP window. So, to increase the size of the plot, maximize the SigCalRP window.

Exit Exits the SigCalRP program.

Calibrate Menu

Start Once the [calibration signal](#) and [acquisition](#) have been configured, Start plays the calibration tone series and begins acquisition and analysis. While calibration is in process, the signal values can not be changed. Click Stop before changing any settings.

Stop Stops calibration procedure. If a calibration series is not complete, there may be invalid data for the rest of a series. When generating normalization files, be sure to run the calibration through the entire frequency series.

Test Norm Runs through the calibration series and applies the normalization data to the calibration tones. This allows you to test whether the normalization file will work in SigGenRP. The dotted lines produced by the test normalization series should be close to the green normalization line.

Iterate Runs through the calibration series and applies the normalization data to the calibration tones. The normalization data will then be adjusted to account for any deviations from the normalization line. Iterate may be run several times in a row to try to improve matching to the normalization line.

Autoscale Autoscale will scale the left hand y axis to the minimum and maximum of the calibration curves.

Save Norm Saves normalization data to a SigGenRP normalization file (*.nrm).

Export Calibration Data Saves calibration data to an ASCII text file that may be imported to a spreadsheet. The calibration data includes the SigGenRP calibration value, the calibration without normalization calculated from both the time signal and power spectrum. The total harmonic distortion measurement, and the normalization curve. If a test normalization is run, these data are also saved to the data file.

Export Raw Data Saves raw data from time signals and power spectra from all of the frequencies tested to two separate files. The time signal data are saved as volts and the power spectra as dB SPL. It takes several seconds to save the data. A maximum of 100 time and frequency buffers may be saved. If more frequencies were tested, only the last 100 will be saved.

Save SigGen File If a SigGenRP variable is used to generate the tone frequency series, the calibrated value determined by SigCalRP can be saved to that SigGen file or a new SigGen file. For example, if SigCalRP determines that 9.0 V = 105.5 dB. This calibration may be saved to the SigGen file by choosing Save SigGen file. This would modify the calibration values that you see in the SigGenRP Signal dialog box (opened by choosing Signal from the Modify menu in SigGenRP).

Save Variable Schedule File Saves a variable schedule file that contains two variables: Freq and CalAtten. This schedule file can be used to calibrate a frequency series in SigGenRP through the use of a programmable attenuator. It is not useful for non-tonal signals, like noise. The schedule file will list each frequency tested and the amount of attenuation needed to calibrate that frequency. The schedule file will also contain header information about the calibration values that should be set in SigGenRP (note: these will not be set automatically), and the date and time the schedule file was saved.

View Menu

Time Signal SPL When checked, plots the SPL measured from the time domain signal in yellow. This SPL measurement will often be higher than the SPL measurement from the power spectrum (shown in blue) due to background noise outside the frequency band measured.

THD When checked, the THD values are plotted as brown squares on a scale of 0 to 2%. If Normalization Curve is also plotted, the THD scale will not be shown. THD is calculated using the first four harmonics of the test signal.

Normalization Curve When checked, the normalization data that are applied to the test signal are plotted as a purple line. The y scale for the normalization curve is shown on the right and is automatically scaled.

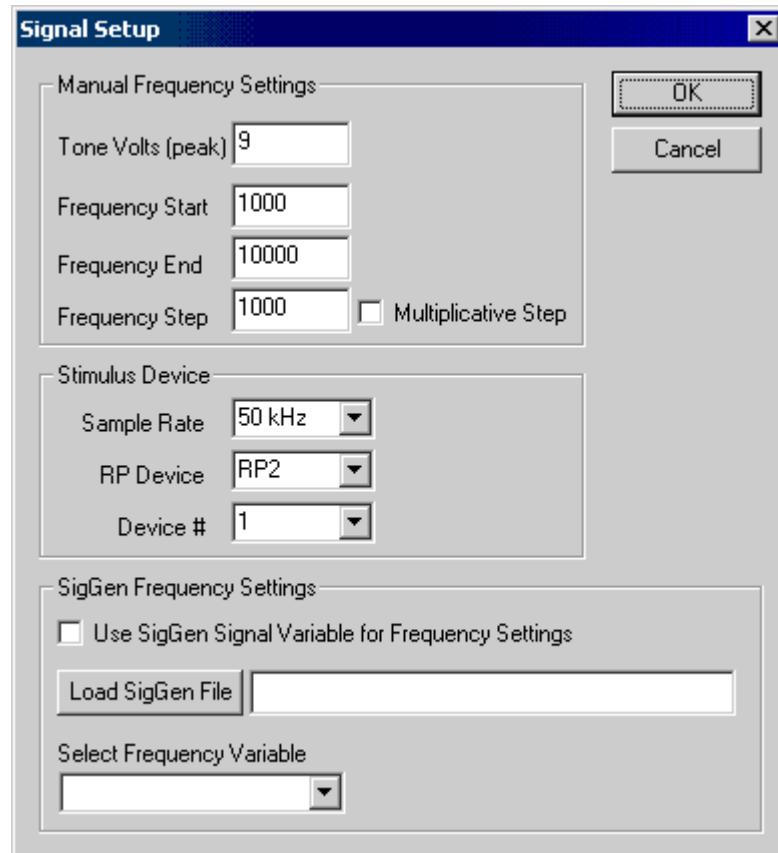
Toolbar Shows the toolbar.

Status Bar Shows the status bar.

Setup Dialogs

Signal Setup

The Signal Setup dialog box is used to setup the calibration tone voltage and frequency series. The frequency series can be set through the Manual Frequency Settings or by using a frequency variable from a SigGen file.



Manual Frequency Settings

These settings are used to produce a series of tones whose SPL will be measured.

Tone Volts (peak)

The peak voltage (i.e. not rms voltage) of the calibration tones. The D/A have a maximum peak voltage of 10V. This value is used for generating the test signals for either the Manual Frequency Settings or SigGen Frequency Settings.

Frequency Start

The first frequency of the calibration tone series.

Frequency End

The last frequency of the calibration tone series.

Frequency Step

The step value used to generate the tone series. The tone series may consist of a maximum of 1000 frequencies.

Multiplicative Step Check Box

Not checked... the step value is a linear step. **Note:** the Frequency End value is inclusive.

For example, if Frequency Start is 1000, Frequency End is 10000, and Frequency Step is 1000, the frequency series will be: 1000, 2000, 3000, ..., 10,000.

Checked... the step value will be used as a multiplier. **Note:** the Frequency End value is non-inclusive.

For example, if Frequency Start is 100, Frequency End is 6401, and Frequency Step is 2, the frequency series will be: 100, 200, 400, 800, 1600, 3200, 6400.

Stimulus Device Setup

These setting are used to configure the RPx device that will be used to generate the signals. It will load the appropriate RPvds file to the device for stimulus generation. The same or different RPx device may be used for acquisition.

Sample Rate

The sample rate for the D/A and A/D converters (they both must be the same for calibration). The maximum frequency that may be used for the frequency series is one-half of the sample rate.

RP Device

Selects the RP Device type.

Device #

Selects the device by logical index number. Device numbers can be viewed using the zBusMon utility.

SigGen Frequency Settings

A frequency series may also be specified by loading a SigGenRP signal and choosing a variable that contains the values of the frequencies you want tested. It is important to note that the SigGenRP signal will not be used in the calculation. Instead, a series of tones will be generated with each tone's frequency specified by the selected SigGenRP variable. The amplitude of the tone is set in the Tone Volts edit box in the Manual Frequency Settings section. When a SigGen file is used the manual settings that can not be adjusted are grayed out. The sample rate is set to the sample rate specified in the SigGen file. The start and stop frequencies are determined from the SigGenRP variable and listed in the manual settings section.

Use SigGen Signal Variable for Frequency Settings Check Box

Enables or disables the use of SigGen Frequency Settings.

Not checked... The settings in the Manual Frequency settings area are used.

Checked... Frequency settings will be loaded from the specified file and variable.

Load SigGen File

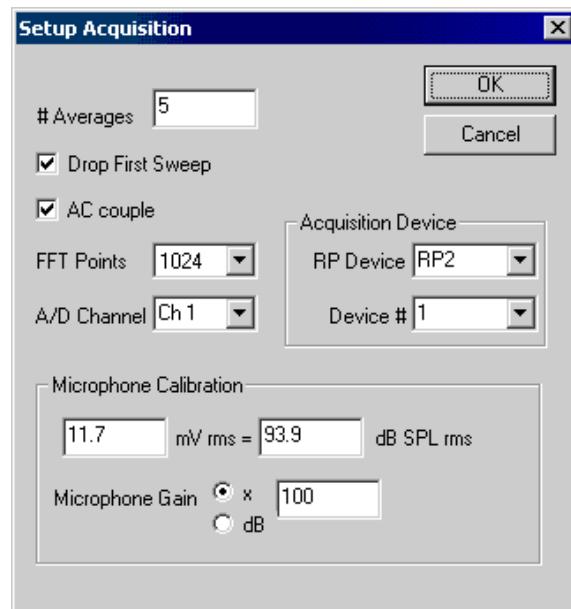
Specifies the SigGen File to be used to select a variable.

Select Frequency Variable

Specifies the variable to be used for the frequency settings.

Acquisition Setup

The Setup Acquisition dialog box is used to configure the A/D converter, configure options for averaging, and to set the microphone calibration and gain.



Averages

Enter the value for the number of sweeps that will be acquired and averaged to obtain the calibration measurement. More sweeps will reduce the influence of background noise that is not produced by the transducer.

Drop First Sweep

Check this box to drop the first sweep and not include it in the overall average. Since the D/A and A/D start converting simultaneously, the time it takes the signal to reach the microphone will be recorded as no signal, if the first sweep is included. By dropping the first sweep, the effect of this travel time on the calibration value is minimized.

AC couple

Check this box to remove any DC shift from your signal. This is done mathematically after the signal is acquired.

FFT Points

This is the number of points used by the inverse FFT to generate the signal and the number of points used by the FFT to calculate the power spectrum. A larger number of FFT points will produce a longer test signal with greater frequency resolution.

A/D Channel

Selects which A/D channel is used to acquire the signal.

Acquisition Device

This section is used to select which device is used for acquisition. The same device may be used for both acquisition and stimulation, except when the sample rate is 200 kHz.

Microphone Calibration

Enter the value for the microphone calibration here as the number of millivolts produced by the microphone for a given SPL. This value is typically provided by the microphone manufacturer.

Microphone Gain

Enter the amount of gain on the microphone before the signal is sent to the A/D converter. Do not enter any gain that is already accounted for by the microphone calibration you entered.

The gain value may be specified as either linear by checking 'x' or as logarithmic by checking 'dB'. For example a value of 100 with 'x' checked corresponds to 100x gain. A value of 100 with dB checked corresponds to 100 dB gain.

SigCalRP assumes that the microphone response is flat.

SigCalRP uses this value to calculate the voltage output of the microphone and then uses the microphone calibration data provided above to determine the dB SPL at the microphone tip.

~

Chapter 3 Running a Calibration

Calibration Fundamentals

D/A Converters

It is important to understand how the D/A converter (DAC) on your real-time processor generates signals and how to best take advantage of the DAC for high signal quality. Different processor devices have different bit resolutions and different maximum voltage outputs.

We will discuss the RP2.1, RX6, and RZ6 here, because they are commonly used to generate stimulus signals.

The RP2.1, RX6, and RZ6

The RP2.1 ,RX6, and RZ6 DACs can generate a maximum signal of +/- 10V peak-to-peak. This signal is generated digitally with 24-bits, meaning there are 2^{24} discrete values that the DAC can generate to represent different voltages. This gives the DAC about a 144 dB theoretical dynamic range between the smallest and largest signal that can be produced. In practice, the signal to noise ratio on the RP2.1 is about 105 dB.

It is best to try to generate the largest signal possible out of the DAC. This will give you the best signal to noise ratio, and also lets you take advantage of the full dynamic range of the DAC.

Signal-to-Noise Ratio

All electrical systems have some level of noise in them. The noise coming out of the DAC is the same whether you are generating a 9 V or a 9 mV signal. Therefore, the signal to noise ratio of your signal will be higher the closer you get to the 10V maximum of the DAC.

Clipping

If you try to generate a signal larger than 10V, the DAC will clip the signal. That is, the peaks of the signal that exceed 10V will be set to 10 V, and your signal will not be faithfully reproduced.

How Normalization Files Work

The purpose of normalization files is to flatten the frequency response of the speaker by adjusting the voltage of the digital signal that is played out of the D/A converter. In SigGenRP, the normalization curve is added to signals generated in the frequency domain to produce the normalized time signal, which is then played.

Since the dynamic range of the DAC is 144 dB, this is the theoretical maximum range that a normalization curve could have before there was clipping or no signal was produced by the DAC. However, if you normalize down 90 dB, that only gives you 54 dB worth of dynamic range. A tone could then only be made with a handful of discrete values, and its quality would be diminished. Thus, it is best to normalize over a smaller range of the DAC, around 30 dB. SigCalRP has built in warnings for indicating that a signal will clip or be too small.

Using a PA5 Programmable Attenuator to Calibrate a Tone Series

If your SigGenRP signal consists of a single tone where the frequency may vary over separate SGI's, then you could use a PA5 to calibrate your signals instead of a normalization file.

The advantages of using a PA5 for calibration include:

- ✓ You can use either the Time or Frequency methods of signal generation in SigGen.
- ✓ The signal-to-noise ratio of all of the frequencies tested will be the same.
- ✓ You can play a large signal out of the DAC and use the wide dynamic range of the PA5 to calibrate the signal over a larger range.

SigCalRP will generate a Variable Schedule File containing values that should be sent to the PA5 at each frequency to calibrate the signals.

Configuring Signals and Acquisition

Signal Setup

Open the [Signal Setup](#) dialog from the Setup menu to configure the range of frequencies that will be tested. The default test level is 9 V to maximize the dynamic range of the DAC. Set the start and stop frequencies to cover the entire range that you will want to use. Use a large step value for a quick first run to see how flat the speaker is over that frequency range. This can later be set to a smaller value to produce the normalization file.

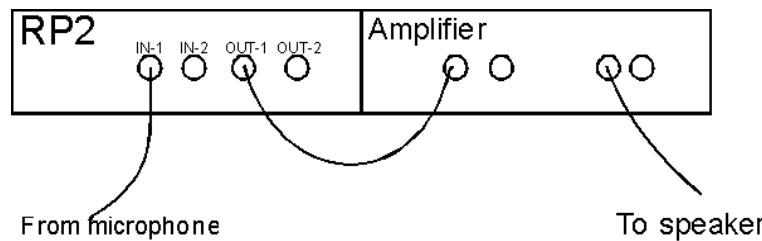
Acquisition Setup

For the initial run, use the default settings in the [Acquisition Setup](#) dialog. This will allow you to quickly estimate how flat the speaker is. For the final run, you can increase the number of averages and FFT length to get a more precise calibration.

Enter the microphone calibration for your microphone and amplifier. It is important that you have a microphone with a known calibration. The accuracy of the calibration depends on the accuracy of the microphone.

Hardware Configuration

The figure below shows a typical hardware setup using an RP2 to perform the calibration of a speaker. Other hardware setups are possible.



There are generally two signal paths:

- ✓ Signal Presentation: This is the path from the processor device Output to the speaker or other transducer. There may be other modules in this path, such as an HB7 Headphone Buffer or SA1 Speaker Amplifier.
- ✓ Signal Acquisition: This is the path from the microphone (or other measurement device) to the processor device Input. There may be other modules in this path, such as the MA3 microphone amplifier.

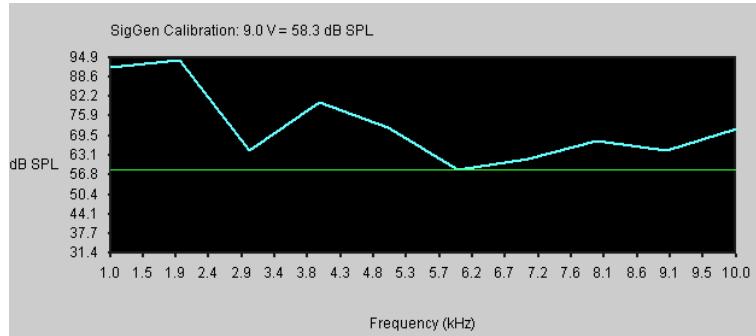
Running the Calibration

Once the signal and acquisition are configured, make sure the TDT hardware is configured as you will use it in your experiment. Connect the DAC to the amplifier and speaker that will be used in your experiment. Connect the microphone to the microphone amplifier and then to channel 1 of the A/D converter.

Run the Calibration

To start the calibration, choose Start from the Calibration menu, or click on the Play button on the toolbar. The calibration may be run several times if you need to adjust the speaker amplifier, microphone amplifier, or experimental setup.

Setting the Calibration Level



The calibration level is the value that will be used to calculate the normalization curve. It is represented by a green line on the calibration plot. If the SPL at a given frequency is greater than the calibration level, this will result in a negative normalization value. Likewise, if the SPL is less than the calibration level, this will result in a positive normalization value that will be added to the signal to boost it so that it equals the calibration value.

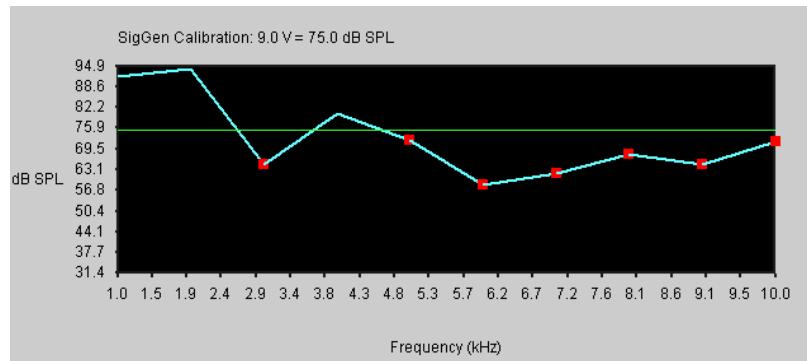
After the calibration is run, the calibration level will be automatically set as high as possible so that the resulting normalization curve does not produce clipping in the DAC when it is used in SigGenRP.

The calibration level will give you the calibration value to use in SigGenRP. For example, if a 9V test signal was used, the calibration may say 9V = 110 dB. As you adjust the line, you will see this calibration value change.

Changing the Calibration Level

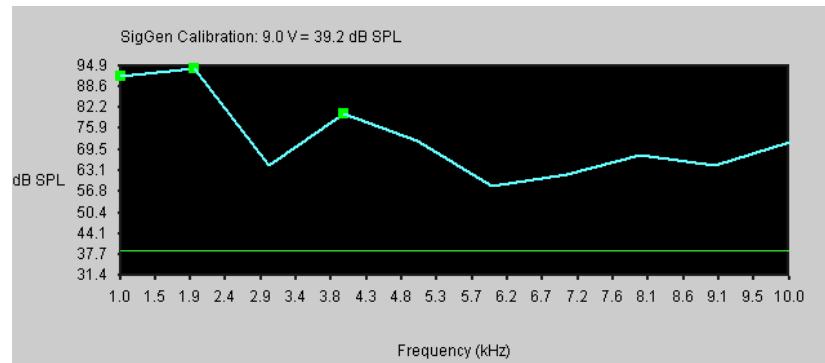
In most cases you will find that the calibration level is set just as you need. To change the calibration level, left-click on the green calibration line and drag it to a new value. A new normalization curve will be calculated based on the calibration line.

Clipping



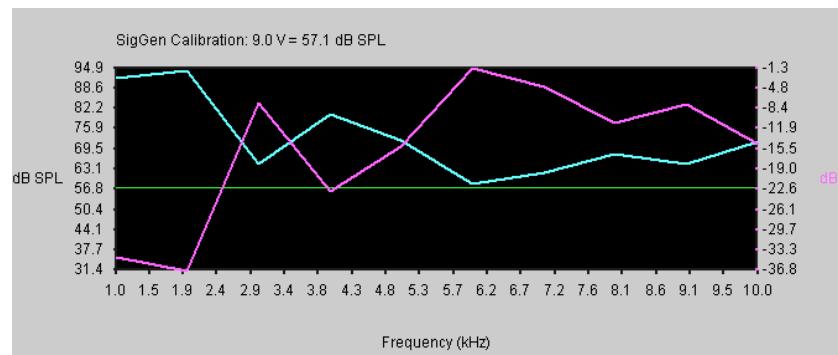
If you set the calibration level too high, so that the normalized signal would be clipped (i.e. the normalization curve would cause the signal to be larger than 10V), red squares will be placed on the calibration curve at frequencies that will be clipped.

Too Much Attenuation



If you set the calibration level too low, so that the output signal would be less than 0.1 V, green squares will be placed on the curve.

Viewing the Normalization Curve

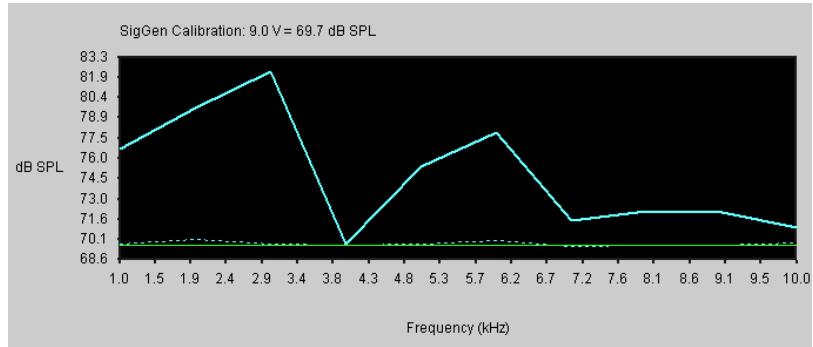


To view the normalization curve, select Normalization Curve from the View menu. The normalization curve will be autoscaled so that it is maximized on the plot. The scale for the normalization curve is labeled on the second y axis, and will be plotted in a fuschia color.

Testing the Calibration

Once the calibration has been run and the normalization curve generated, you can test the normalization curve. Select Test Norm from the Calibration menu. This will use the normalization curve to adjust the signal produced by the DAC.

The level of the sound will be plotted as a dotted line. If the normalization curve is set properly, the dotted line should closely parallel the green calibration line.



Fine Tuning the Calibration

If the calibration test shows that the normalization curve does not produce a flat response out of the speaker:

1. Check to make sure that you are not overdriving the speaker. Look at the THD levels and the power spectra to make sure that you are getting a pure tone signal, and not a lot of harmonics. If you see a lot of harmonics, you either should turn down the gain on your speaker amplifier, or attenuate the signal from the DAC by sending it through a PA5 Programmable Attenuator.
2. Make sure that the microphone is not being overdriven, and that the amplitude of the signal coming out of the microphone amplifier is at least one volt (look at the voltage on the Time Domain plot), but not more than 10V.
3. Try iterating the normalization test several times. This will adjust the normalization curve based on the deviations from the calibration level.
4. Try re-running the entire calibration with more averages and/or a longer FFT.

If you can't get one normalization file that covers the whole frequency range of the speaker without either clipping the signal or playing too small a signal out of the DAC:

1. Break your frequency range into two parts, and create a normalization file for each section.
2. You will also have to create a separate SigGen file with a different calibration for each section.

Using Normalization Files in SigGenRP

Once you have established the reasonable frequency range to use for your speaker, run the calibration with smaller steps, and test it. When you are satisfied that the normalization file produces a sufficiently flat response, save your normalization file by selecting Save Norm from the Calibration menu.

The file can then be used in SigGenRP by checking Use Norm in the Signal Parameters dialog box (opened by selecting Signal from the Modify menu), and then loading the normalization file.

Be sure that to generate signals using the frequency method in the segment dialog box. Otherwise, the normalization file will not be used.

Remember to change the calibration setting in SigGenRP to the value determined by SigCalRP. If a SigGenRP variable is used to generate the tone frequency series, the calibrated value determined by SigCalRP may be saved to that SigGen file or a new SigGen file from SigCalRP. For example, if SigCalRP determines that 9.0 V = 105.5 dB. This calibration may be saved to the SigGen file by choosing Save SigGen file. This would modify the calibration values that you see in the SigGen Signal dialog box (opened by choosing Signal from the Modify menu in SigGenRP). If you did not use a SigGen file to set up the frequency series, you would have to manually enter this calibration in SigGenRP.

Using a PA5 Attenuator for Tone Calibration

Calibration of Tone Signals

Normalization files are of most utility for non-tonal signals. If you are using single tones as your SigGenRP stimuli, then you will obtain better signal quality if you use the PA5 Programmable Attenuator to equalize the different frequencies. SigGenRP normalization files adjust for the transducer variability by decreasing the amplitude of the D/A output. When tones are used, since you are only playing one frequency, you can use the PA5 to adjust the signal level. This will provide constant signal-to-noise ratio for all of the frequencies and let you maximize the output voltage on the D/A converter.

Use the Save Variable Schedule File feature of SigCalRP to save these values to a variable file for use in SigGenRP. The values saved to these files will be the attenuations that need to be applied at each frequency to calibrate the signal. In SigGenRP, use this variable file to attenuate each frequency appropriately.

The schedule file creates two lists of values, one for frequencies and one for the normalized attenuation level. You must create two variables in your SigGen file and name them Freq and CalAtten. Set each variable to use the "Schedule File" method and enter the name of the schedule file that you saved after calibration. These two variables will use the list of values saved in the schedule file. Select Preview Variables to confirm the correct values.

Next you must link the appropriate signal parameters to these variables. In the Modify->Segment menu, the frequency of your tone segment should be set to the Freq variable. In the Attenuation box located in the Modify->Signal menu, choose the PA5 device and select the CalAtten variable from the dropdown list. See the SigGenRP help guide for more information.