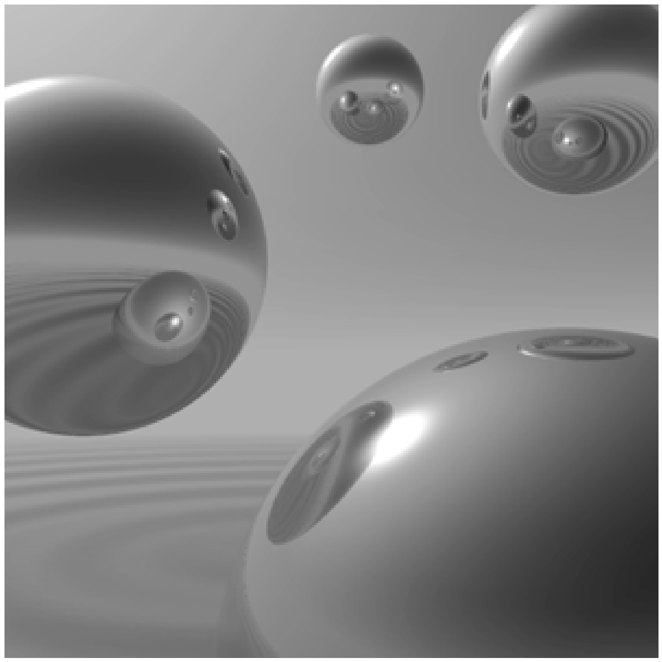

SigCal User's Guide

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SigCal32 User's Guide – Version 3.0

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Contents

Preface

SigCal was written to make the process of calibrating speakers and using normalization files with SigGen an easy matter. 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. For more information you should refer to the guide ‘DSP Applications Using System II’, which can be found in the System II manual.

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.

Organization of the Manual

- *Chapter 1* Introduction
  Installation of SigCal and hardware configuration.

- *Chapter 2* SigCal Overview
  An overview of the windows and menus in SigCal.

- *Chapter 3* Using SigCal
  Instructions on how to use SigCal to calibrate your speaker and generate normalization files for use with SigGen.

Chapter 1 Introduction

What Is SigCal?

SigCal 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.

SigCal Capabilities

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

Hardware Support

SigCal supports TDT's System II instrumentation, including any combination of TDT's D/A and A/D converters. The D/A and A/D can be triggered either from software or from the TG6 timing generator.

Before You Begin

What You Need

See your Microsoft Windows documentation.

- Windows fundamentals

  You should be comfortable with Windows basics: starting Windows; using the mouse; manipulating windows; opening, closing, and saving files.

See the SigGen manual.

- Basic SigGen concepts

  If you are going to be using SigCal with SigGen, you should be familiar with generating SigGen signals using the Frequency method.

Installing the Software

Requirements

In order to run SigCal, you must have the following:

- Microsoft Windows 95
- A monitor with at least VGA resolution graphics. Super VGA (1024 x 768) resolution graphics highly recommended
- TDT's AP2 Array Processor
- TDT's XBUS hardware including
    - D/A converter
    - A/D converter
    - TG6 timing generator (optional for trigger D/A and A/D)
- Speaker
- Calibrated microphone and microphone amplifier

Installation

To install SigCal

1. Make sure your TDT hardware (including AP2 Array Processor and XBUS devices) is installed and functioning properly.

   Refer to the *System II Installation Guide*.
2. Insert the SigCal diskette into drive A: or B:.
3. Run **setup.exe** to start the installation program.

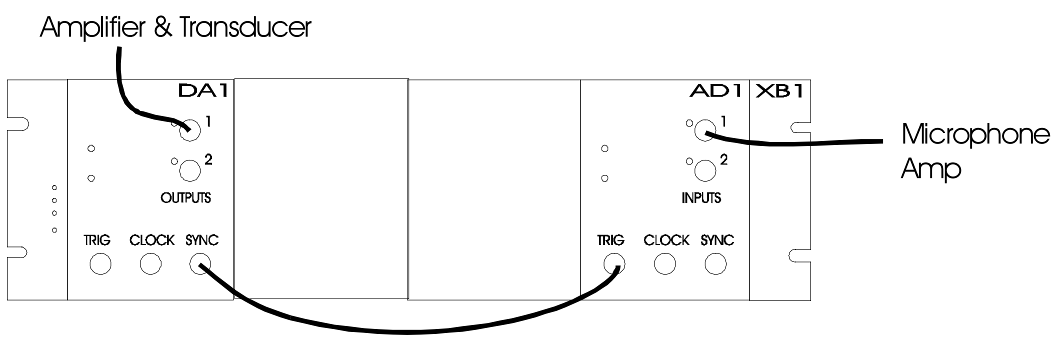
Hardware Configuration

SigCal can trigger sound presentation and data acquisition either from software or from hardware with a TG6 Timing Generator. You will have to connect the rest of your system the same way that you will be using it with your other software. Use the same filter, attenuator, and amplifier settings that you would normally use.

Software Triggering

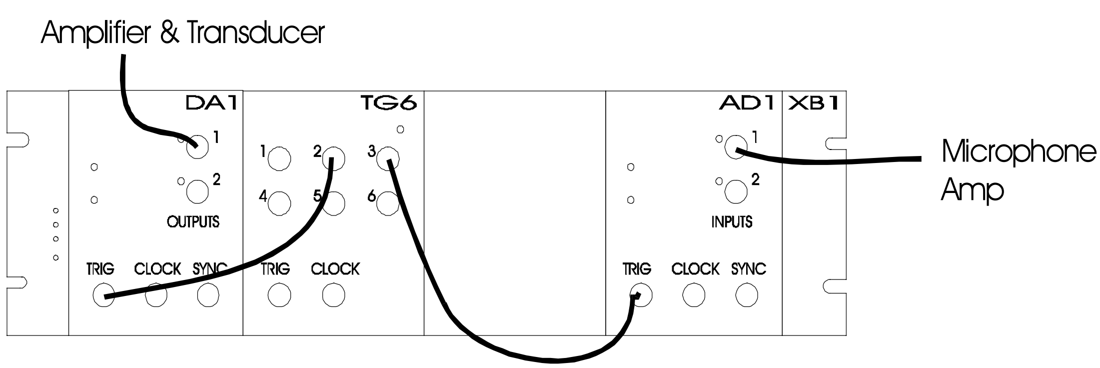
The D/A will be triggered by software. If you use a DD1 or PD1, no hardware connections need to be made.

If you have separate D/A and A/D modules, then the SYNC output of the D/A needs to be connected to the TRIG input of the A/D module.



TG6 Triggering

The D/A and A/D can also be triggered by the TG6. Channels 1, 2, and 3 of the TG6 will send out simultaneous trigger pulses, and these can be connected to the TRIG inputs of the D/A and A/D as desired. The standard SigGen Solutions configuration with TG6 channel 2 to the D/A TRIG and TG6 channel 3 to the A/D TRIG input will work, so that you don't have to change connections between programs.



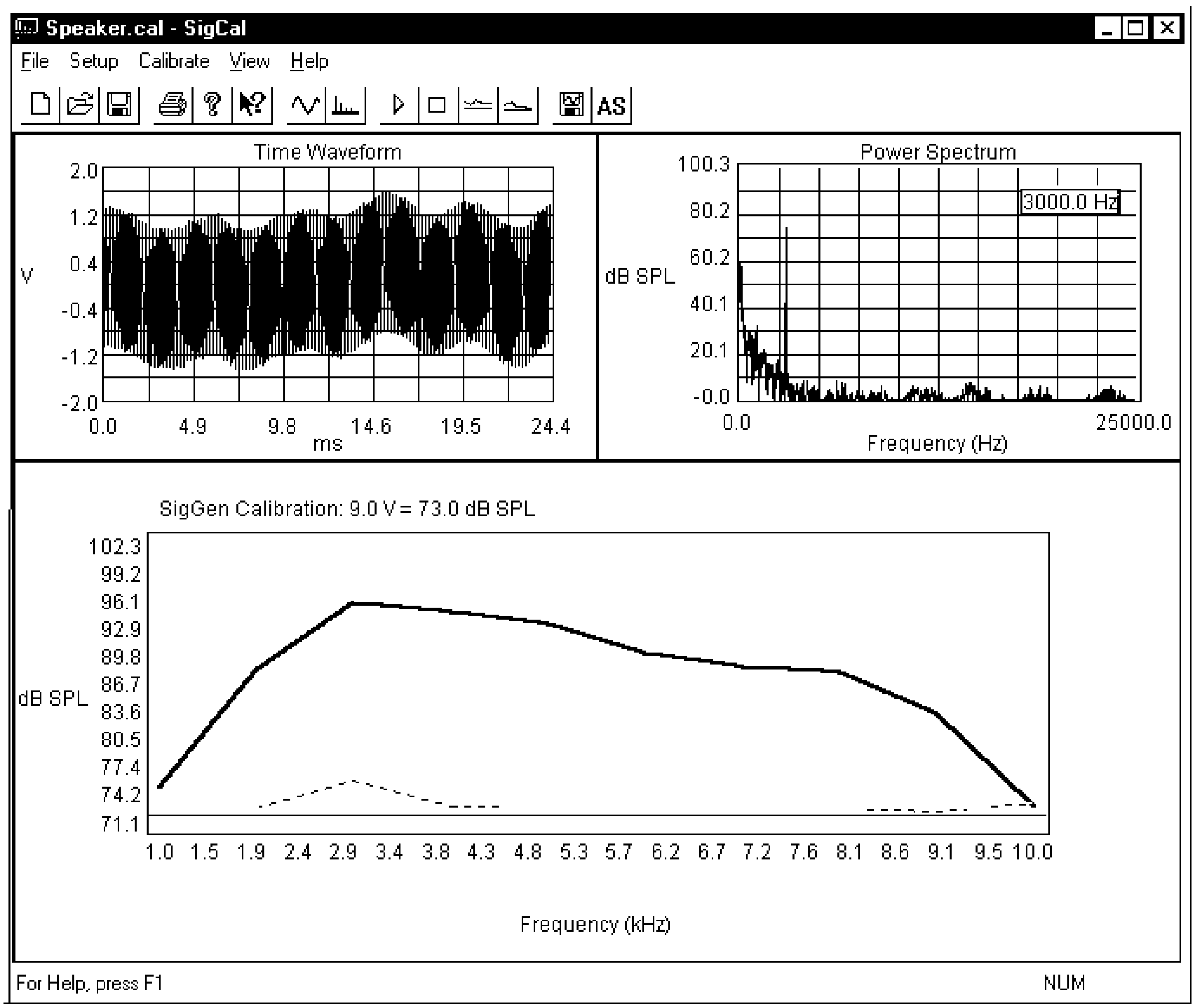
Chapter 2 SigCal Overview

SigCal Plots

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.



File Menu

The file menu has commands for opening and saving SigCal files. SigCal files have the .cal extension. SigCal files contain all of the SigCal 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 SigCal 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

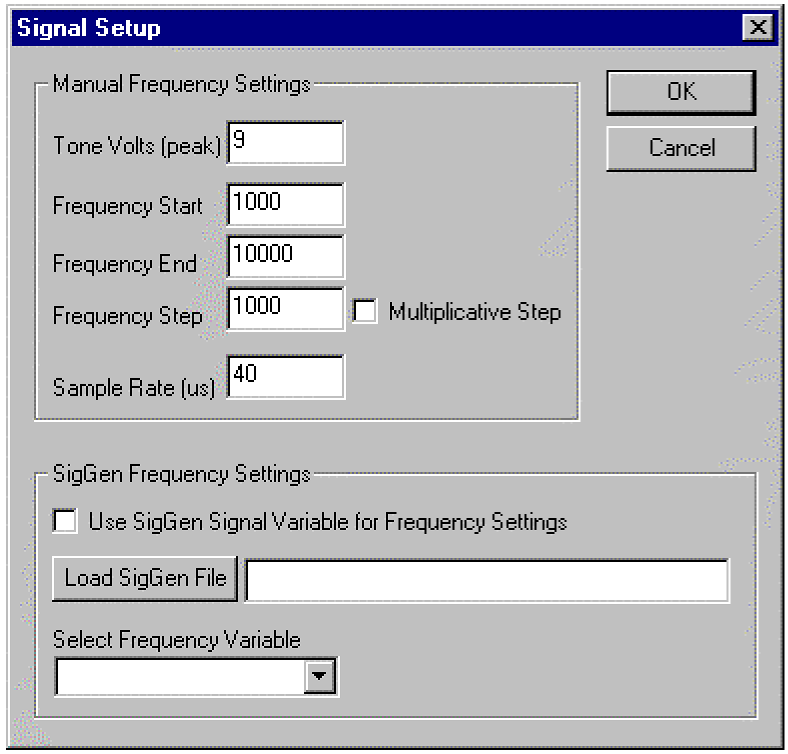
These commands will setup printing of the current SigCal screen. The size of the plot on the printer is directly proportional to the size of the SigCal window. So, to increase the size of the plot, maximize the SigCal window.

Exit

Exits the SigCal program.

SetUp Menu

Signal



Overview

Use this dialog box 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.

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.

MANUAL FREQUENCY SETTINGS

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

Frequency Start

The first frequency of the calibration tone series.

Frequency End

The last frequency of the calibration tone series.

Frequency Step

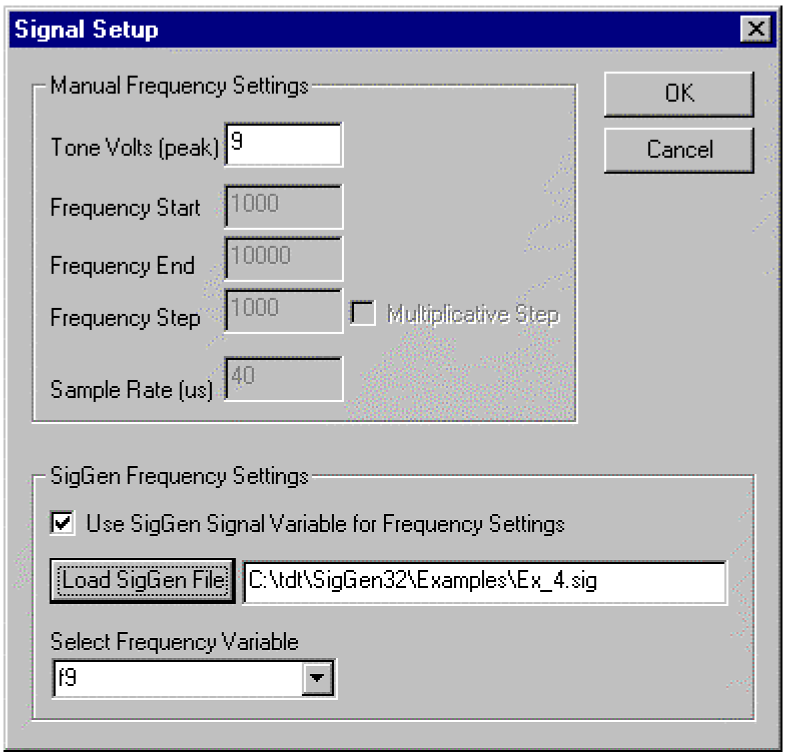
The step value used to generate the tone series. The tone series may consist of a maximum of 1000 frequencies.

If Multiplicative Step is not checked, the value is a linear step. 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.

If Multiplicative Step is checked, the value will be used as a multiplier. For example if Frequency Start is 100, Frequency End is 6400, and Frequency Step is 2, the frequency series will be: 100, 200, 400, 800, 1600, 3200, 6400.

Sample Rate (µs)

The sample period for the D/A and A/D converters. The maximum frequncy that may be used for the frequency series is one-half of the sample rate. For example, for a sample period of 20 µs, which corresponds to a 50 kHz sample rate, the maximum frequency that may be played is 25 kHz.



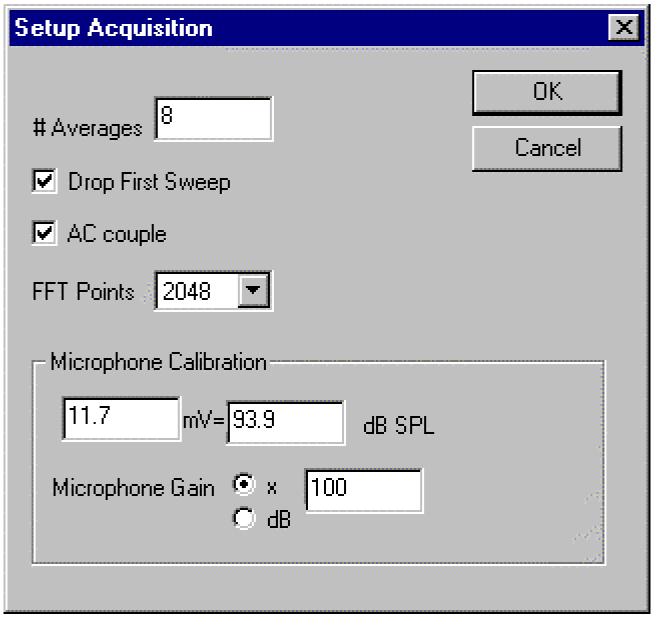
SigGen Frequency Settings

A frequency series may also be specified by loading a SigGen Signal and choosing a variable that contains the values of the frequencies you want tested.

It is important to note that the SigGen signal will not be used in the calculation. Instead, a series of tones will be generated with each tone's frequency specified by a SigGen 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 SigGen variable and listed in the manual settings section.

Acquisition



Overview

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.

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.

Microphone Calibration

Enter the value for the microphone calibration here as the number of millivolts produced by the microphone for a given SPL.

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.

Calibrate Menu

Once the calibration signal and acquisition have been configured, choose Start from the Calibrate menu. SigCal will play the series of tones and automatically generate the calibration curve, and SigGen normalization data.

Start

Starts playing of the calibration tone series and acquisition and analysis. While calibration is in process, the signal values can not be changed. Press 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 calibration series and applies the normalization data to the calibration tones. This allows you to test whether the normalization file will work in SigGen. 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 SigGen 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 SigGen 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, be patient. 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 SigGen variable is used to generate the tone frequency series, the calibrated value determined by SigCal may be saved to that SigGen file or a new SigGen file. For example, if SigCal 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 SigGen).

Save Variable Schedule File

SigCal will save a variable schedule file that contains two variables: Freq and CalAtten. This schedule file can be used to calibrate a frequency series in SigGen 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 SigGen (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 5%. If Normalization Curve is also plotted, the THD scale will not be shown.

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.

Screen Controls

Zooming the time and frequency plots

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

Inspecting individual frequencies

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

Toolbar

The toolbar has shortcuts to all of the menu items. Place the mouse cursor over a toolbar item for information on its function.

Chapter 3 Using SigCal

Calibration Fundamentals

TDT D/A Converter

It is important to understand how the TDT D/A converter (DAC) generates signals and how to best take advantage of the DAC for high signal quality. The DAC can generate a maximum signal of +/- 10V peak-to-peak. This signal is generated digitally with 16-bits, meaning there are 65536 discrete values that the DAC can generate. This gives the DAC about a 96 dB theoretical dynamic range between the smallest and largest signal that can be produced.

It is best to try to generate the largest signal possible out of the D/A. This will give you the best signal to noise ratio, and also lets you take advantage of the full dynamic range of the DAC. Chapter 1 of DSP Applications using System II in the System II manual has a complete technical discussion of this issue.

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 SigGen, 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 96 dB, this is the theoretical maximum range that a normalization curve could have before there was clipping or no signal was produced by the D/A. However, if you normalize down 90 dB, that only gives you 6 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 20 dB. SigCal has built in warnings for indicating that a signal will clip or be too small.

Using a PA4 Programmable Attenuator to Calibrate a Tone Series

If your SigGen signal consists of a single tone where the frequency may vary over separate SGI's, then you could use a PA4 to calibrate your signals instead of a normalization file.

The advantages of using a PA4 for calibration include:

- You can use either the Time of 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 PA4 to calibrate the signal over a larger range.

SigCal will generate a Variable Schedule File containing values that should be sent to the PA4 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. 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.

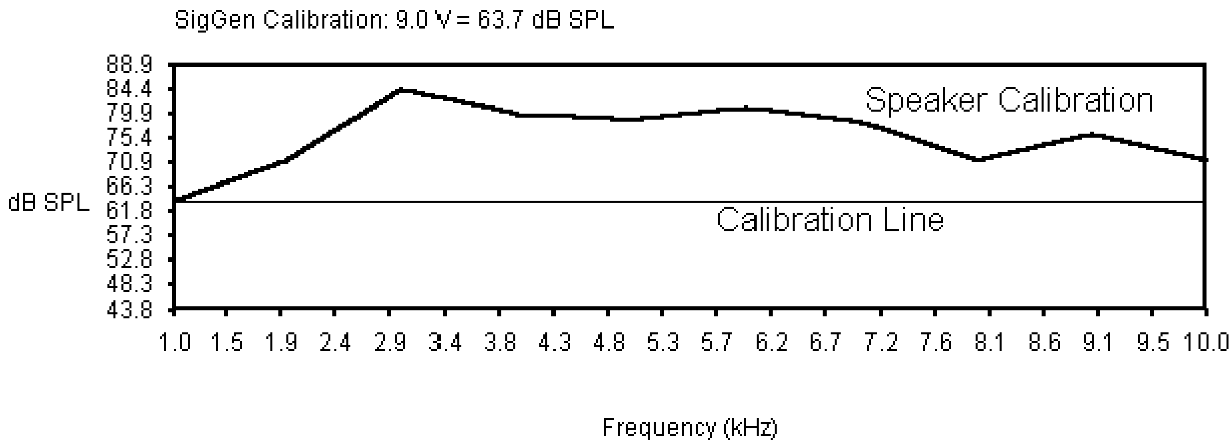
Running the Calibration

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. If you are using a TG6 to trigger the DAC and ADC, connect the TG6 to the TRIG inputs on the DAC and ADC. If you are not using a TG6, connect the SYNC of the DAC to the TRIG of the ADC. There is a diagram in Chapter 1 illustrating these connections.

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.

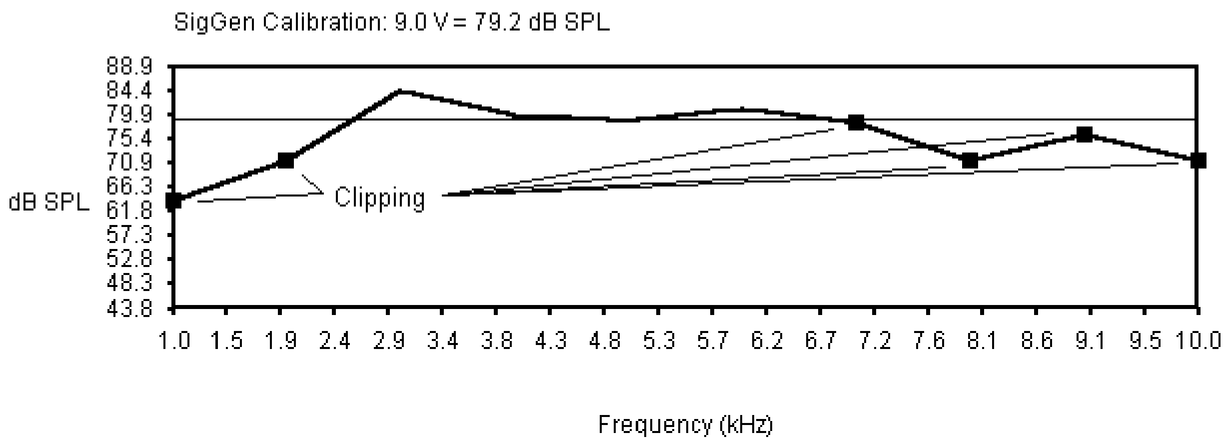
After the calibration is run, the calibration level will be automatically set as high as possible so that the resulting normalization curve does not produce clipping in the DAC when it is used in SigGen.

The calibration level will give you the calibration value to use in SigGen. 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

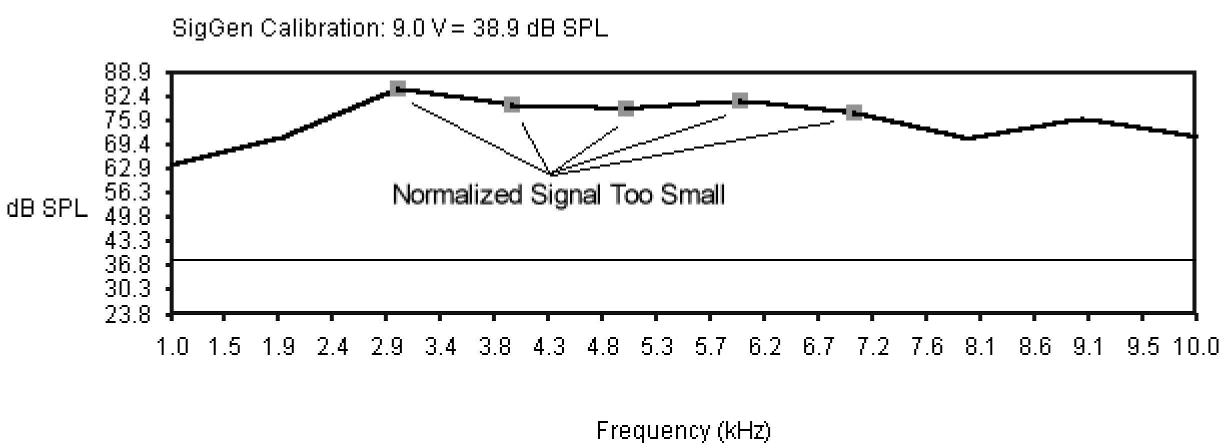
In most cases you will find that the calibration level is set just as you need. To change the calibration level, left-click on the green calibration line and drag it to a new value. A new normalization curve will be calculated based on the calibration line.

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 (giving a dynamic range of 56 dB), green squares will be placed on the curve.

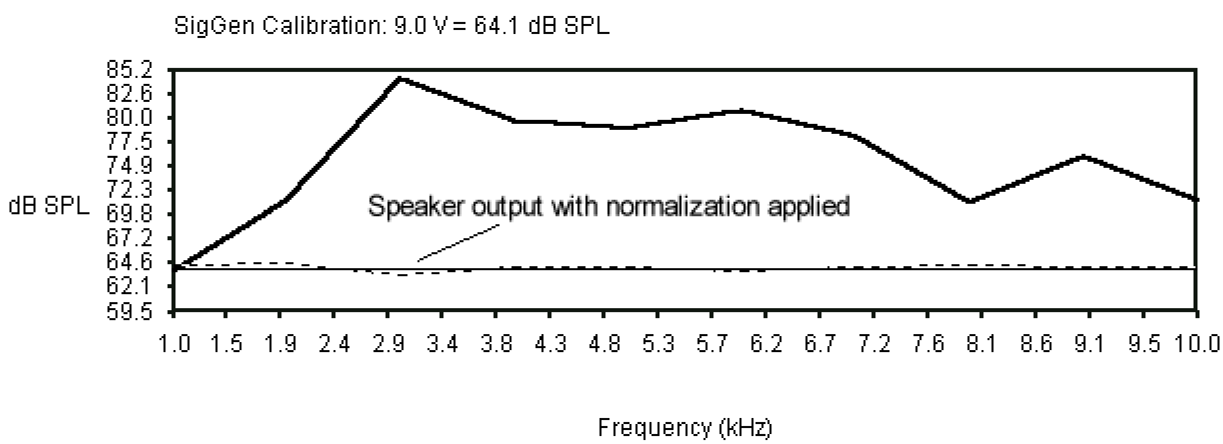
Viewing the Normalization Curve

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.

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 PA4 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.

Saving the Normalization File for use in SigGen

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 SigGen 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 you are generating 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 SigGen to the value determined by SigCal. If a SigGen variable is used to generate the tone frequency series, the calibrated value determined by SigCal may be saved to that SigGen file or a new SigGen file from SigCal. For example, if SigCal 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 SigGen). If you did not use a SigGen file to set up the frequency series, you would have to manually enter this calibration in SigGen.

Calibration of Tone Signals

Normalization files are of most utility for non-tonal signals. If you are using single tones as your SigGen stimuli, then you will obtain better signal quality if you use the PA4 Programmable Attenuator to equalize the different frequencies. SigGen Normalization files adjust for the transducer variability by decreasing the signal amplitude output by the D/A. When tones are used, since you are only playing one frequency, you can use the PA4 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 SigCal to save these values to a variable file for use in SigGen. The values saved to these files will be the attenuations that need to be applied at each frequency to calibrate the signal. In SigGen use this variable file to attenuate each frequency appropriately as shown in the example below.

Using a Variable File in SigGen to Calibrate Tones

In this example one wishes to use five different frequencies in a tone pip experiment. However, each tone is calibrated to account for transducer variability across frequency. The tones we want to use are listed below:

Frequency	Transducer Sensitivity	Attenuation Setting
1000 Hz	98.0 dBSPL/vrms	8.0
1400 Hz	96.5	6.5
2000 Hz	93.8	3.8
2700 Hz	92.0	2.0
3500 Hz	91.1	1.1

To get the tone pips to play out at a calibrated level we need to attenuate the low frequency tones so that they match the level of the highest frequency tone. The last column shows some attenuation settings that could be used to normalize the transducer to have a uniform sensitivity of 90.0dB SPL/vrms. These will be calculated for you by SigCal.

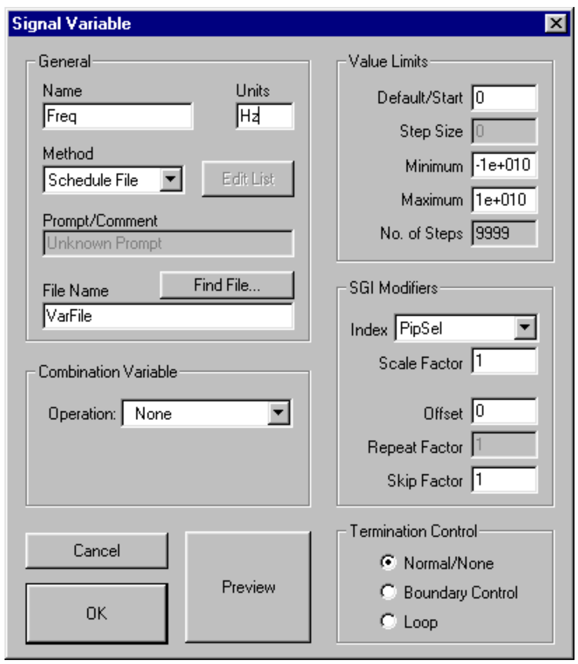
The variable file produced by SigCal has the information for both frequency and the corresponding calibration attenuation:

```
{
Freq
1
1000
1400
2000
2700
3500
}
```

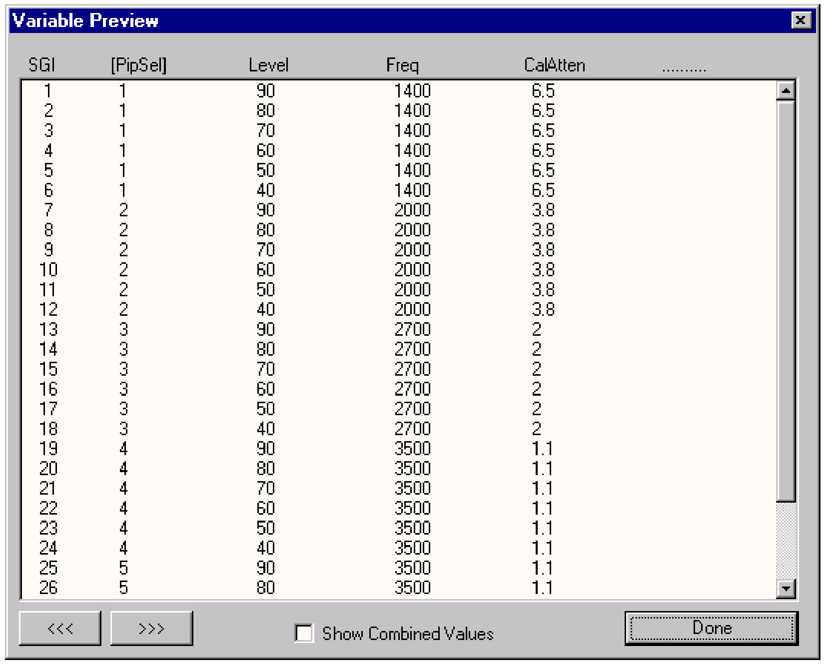
```
{
CalAtten
1
8.0
6.5
3.8
2.0
1.1
}
```

In SigGen32 make a variable called *PipSel* that goes from 1 to 5, which will be used as the SGI modifer. For example, if we want to do a frequency intensity series we need another variable called *Level* that steps through the levels we want. Then nest these variable as was done previously with SigGen.

Now make two variables called *Freq* and *CalAtten* both using the variable file above as their source. Under SGI modifiers select the *PipSel* variable with a scalar of 1.0. These variables will then use the value of *PipSel* to pick which frequency and attenuation to use.



Now click preview variables and at the bottom on the screen click the combined values button.



SGI	[PipSel]	Level	Freq	CalAtten
1	1	90	1400	6.5
2	1	80	1400	6.5
3	1	70	1400	6.5
4	1	60	1400	6.5
5	1	50	1400	6.5
6	1	40	1400	6.5
7	2	90	2000	3.8
8	2	80	2000	3.8
9	2	70	2000	3.8
10	2	60	2000	3.8
11	2	50	2000	3.8
12	2	40	2000	3.8
13	3	90	2700	2
14	3	80	2700	2
15	3	70	2700	2
16	3	60	2700	2
17	3	50	2700	2
18	3	40	2700	2
19	4	90	3500	1.1
20	4	80	3500	1.1
21	4	70	3500	1.1
22	4	60	3500	1.1
23	4	50	3500	1.1
24	4	40	3500	1.1
25	5	90	3500	1.1
26	5	80	3500	1.1