TENMA®

# Speaker Measurement Interface


# Instructions for Installation and Use

## Note:

This document was created solely for the purpose of providing this information on the Tenma and MCM Electronics Websites. Actual instructions, in electronic help-file format are included with the product.

**Model #72-850**

www.mcmelectronics.com

www.tenma.com

# Software Installation

**Software Installation**

The Tenma Speaker Measurement Interface software can be installed by directly copying files from the CD, or by using the installation file W2INST.EXE. There are no Windows registry entries made and the only drivers required should already be available if you meet the following requirements.

Windows 98 Second Edition (with USB service packs installed)
Windows ME
Windows 2000
Windows XP

NOTE: Windows 95 and Windows 98 prior to Win98SE are not supported since these operating systems do not support USB.

**Windows Generic USB Driver Installation**

When you plug the Tenma Speaker Measurement Interface into your system you may find that the drivers are already installed and there is nothing to do. If not, Windows will identify that a 'USB Audio Codec' has been installed and the new hardware wizard will start. Following the wizard's instructions will eventually configure the Windows default driver for USB Audio Devices. This may require you to install drivers from the Windows installation CD. The steps you will follow will roughly be the following.

NOTE: When the Tenma Speaker Measurement Interface is first identified and software is installed, Windows may try to redirect your PC's default sound output to the Tenma Speaker Measurement Interface by making it the default sound interface. You will want to disable this. Here are the installation steps for each of the operating systems the Tenma Speaker Measurement Interface is designed for.

**Installing the Tenma Speaker Measurement Interface in Windows XP**

1. Connect the Tenma Speaker Measurement Interface to an unused USB port on your PC. The New Hardware Installation dialog box opens and a USB audio device is installed.
2. Click Start, then click Control Panel. The Control Panel window opens. If your Control Panel is in Category View, click Sounds, Speech, and Audio Devices. The Sounds, Speech, and Audio Devices window opens.
3. Click Sounds and Audio Devices. The Sounds and Audio Devices Properties dialog box opens.
4. Click the Audio tab.
5. In the Sound Recording section, click the arrow button to open the Default device list, and then select your original sound card. Repeat for the Sound Playback section.

**Installing the Tenma Speaker Measurement Interface in Windows Me**

1. Connect the Tenma Speaker Measurement Interface to an unused USB port on your PC. The New Hardware Installation dialog box opens and a USB composite device is installed.
2. When a wizard opens for USB audio device, click "Next".
3. Click Search for the best driver for your device, then click Next twice.
4. When the location of the driver is displayed, click Next, and then click Finish.
5. Click Start, Settings, then click Control Panel. The Control Panel window opens. If you do not see the Sounds and Multimedia icon, click view all Control Panel options.
6. Double-click Sounds and Multimedia. The Sounds and Multimedia Properties dialog box opens.
7. Click the Audio tab.
8. In the Sound Recording section, click the arrow button to open the Preferred device list, and then click on your original sound card. Repeat for the Sound Playback section.

**Installing the Tenma Speaker Measurement Interface in Windows 2000**

1. Connect the Tenma Speaker Measurement Interface to an unused USB port on your PC. The New Hardware Installation dialog box opens and a USB composite device and a USB audio device are installed.
2. Click Start, Settings, then click Control Panel. The Control Panel window opens.
3. Double-click Sounds and Multimedia. The Sounds and Multimedia Properties dialog box opens.
4. Click the Audio tab.

6\. In the Sound Recording section, click the arrow button to open the Preferred device list, and then click on your original sound card. Repeat for the Sound Playback section.

**Installing the Tenma Speaker Measurement Interface in Windows 98SE**

1. Connect the Tenma Speaker Measurement Interface to an unused USB port on your PC. The New

Hardware Installation dialog box opens automatically, followed by a USB composite device, and then click on Next.

2. Click Search for the best driver for your device, then click Next twice.
3. When the location of the driver is displayed, click Next, and then click Finish.
4. When another wizard opens for a USB audio device, click Next.
5. Click Search for the best driver for your device, then click Next twice.
6. When the location of the driver is displayed, click Next, and then click Finish.
7. Click Start, Settings, then click Control Panel. The Control Panel window opens.
8. Double-click Multimedia. The Sounds and Multimedia Properties dialog box opens.
9. Click the Audio tab.
10. In the Sound Recording section, click the arrow button to open the Preferred device list, and then click on your original sound card. Repeat for the Sound Playback section.

**WINDOWS NT IS NOT A SUPPORTED PLATFORM!**

Though a Windows NT compatible USB codec driver may exist, Windows NT is now considered a legacy operating system that has been superseded by Win2K and WinXP. Windows NT also does not autodetect or autoinstall new hardware, making driver installation difficult or impossible.

## Hardware Connections

**WARNING**

**DO NOT CONNECT ANYTHING EXCEPT A DRIVER TO THE TENMA SPEAKER MEASUREMENT INTERFACE**

**Power Requirements**

Basic Thiele Small testing and parameter extraction does not require more than a few milli-amps of current, which is easily powered by the USB port.  The Tenma Speaker Measurement Interface does not need an external power supply.

**Connecting a Driver**

The provided test lead with a banana jack at one end and alligator clips at the other will be used to connect drivers to the Tenma Speaker Measurement Interface.  Calibration resistors (and shorts) are also used during the calibration routine.  These will be connected directly to the Tenma Speaker Measurement Interface, or to the end of the test lead depending on the parameter being measured.

**Connecting lineout to an amplifier for breaking in a driver**

Before testing a driver, it is often desirable to break the driver in for an hour or two.  Basically 'fresh' driver parameters are not the same as when the driver has been exercised for some time possibly leading to wrong assumptions in the box design.  This is most easily accomplished, and with far less voice coil heating, by using a test tone that is equal to the free air resonance of the driver.  A line level output has been provided that can be connected to an amplifier to provide the necessary test tones.  The test tone frequency and amplitude can be controlled using the frequency and amplitude buttons in the control window.

Note:  Since the Tenma Speaker Measurement Interface is sharing PC resources, you may experience dropouts if the operating system becomes overloaded.  Adding a pre-amplifier or an integrated amplifier with a volume control may be desired since this would allow you to set the output level to maximum and then cut back the level manually.

# Making a Test Bench

**Making a Test Bench**

When viewed electrically an electromechanical device such as a loudspeaker driver will exhibit impedance and phase variation where resonance occurs. Driver resonance is created when kinetic energy is stored in the drivers moving mass and potential energy is stored in the drivers suspension (spring). Energy is also lost to electrical and mechanical resistances affecting the magnitude peaks in the impedance curve. This Tenma Speaker Measurement Interface software then converts this information into parameters that can be fed into a box simulation software package.

To accurately measure these parameters you will need to create a suitable test bench where outside influences do not disturb the Tenma Speaker Measurement Interface as it is performing tests. There are two basic setup configurations that you can use, each with pro's and cons.

**Vertical Orientation (Cone is facing upward)**

Simply laying a driver down on a bare concrete surface and performing tests is definitely easy to do, but if this is not possible, a suitable stiff and heavy bench may work. The Tenma Speaker Measurement Interface can also help you identify these problems by examining the phase of an arbitrary sweep. In this case a resonance is first seen as a kink in the phase plot, and if very bad, a kink in the impedance plot.

As an example, consider a flimsy table surface. If a driver weighing 5kg (including magnet and frame) is placed on a 4ft by 4ft 'table' of 1/2 inch particle board, we would expect to see some sagging as the driver weight pushes down on the table surface. If we assume the table sags 10mm, and the table surface also has a weight of 5Kg, we could infer that this setup might resonate at about 10Hz. Clearly a 10Hz resonance would be too close to the resonant frequency we are trying to test, so this would be unacceptable. A smaller table will improve stiffness, raising the table resonance.

Table resonance can also increased by moving the driver to one of the table corners with a table leg directly underneath. In this case the springiness of the table leg, which is extremely high, moves the resonance up in frequency. A brace put under the table will also raise the resonance.

Adding mass to the table also tends to help. Though this lowers the resonant frequency, the ability of the driver to couple energy into the table mass is lower. If you think about this, this is the same strategy you may use when building the final cabinet. Old speaker cabinets also make good test benches.

**Horizontal Orientation (Cone is facing sideways)**

In practice no suspension can allow a cone to move indefinitely to either side of the rest position, bringing up the possibility of non-linearity. Horizontal testing is arguably more difficult to set up, but it does have the advantage of not depressing the driver suspension when a test mass is added, and therefore should be more linear.

This small advantage is however offset by the fact that there are few reasonable ways to build a suitable open-air rigid frame to mount a driver to. One such example that works reasonably well is to mount the driver between two old (massive) speaker boxes.

Another nuisance is the only reasonable way to increase the drivers moving mass is to add something like clay or soft caulking to the driver cone. Not only is weighing clay prone to measurement errors, but also if you place the clay on the front side of a paper or composite cone you will likely stain the cone. Worse, some cone materials can even be damaged.

**RECOMENDATION: Use the vertical orientation and solid test mass method first. The few minutes it takes to run the test will be well worth the effort.**

## Pulldown Menus

The Pulldown nenu options will change depending on which window is active.  Here is a listing for each pulldown menu.  A series of notes follows the list to help detail some of these features.

**Frame Menu (no active child window)**

File
- Save WOO File
- Load WOO File
- Export ASCII file
- Export to BassBox
- Export to LMS
- Show Results
- Show TS Control
- New Title
- Exit

Options
- Clear Values on start
- Clear Values now
- Config buffers and settling
- New CalR
- New Rset

Help
- Help
- About

**Results Window (Text Display of converted data)**

File
- Save WOO File
- Load WOO File
- Export ASCII file
- Export to BassBox
- Export to LMS
- Show Results
- Show TS Control
- Print
- New Title
- Exit
- Close results

Window
- Cascade Shift+F5
- Tile    Shift+F4
- Arrange Icons
- Close All

Options
- Clear Values on start
- Clear Values now

Results
- F6  Q, Fs, Le
- F7  Vas,Mass,BL,Cms
- F8  Box measurements
- F9  Calibration
- F11 Arbitrary 1 Sweep
- F12 Arbitrary 2 Sweep
- Use vented box info to to refine Vb and Fb
- Convert Vented Box info to Vas data
- Copy Test to Arb Buffer
  - <sub menu>

| | |
|---|---|
| Help | Opens the WT2.HLP help file |
| About | Opens the About Dialog |

**Thiele Small Data and Control**

File

- Save WOO File
- Load WOO File
- Export ASCII file
- Export to BassBox
- Export to LMS
- Show Results
- Show TS Control
- Print
- New Title
- Exit
- Close results

Window

- Cascade Shift+F5
- Tile    Shift+F4
- Arrange Icons
- Close All

Options

- Sweep start      <sub menu>
- Sweep end        <sub menu>
- Sample Rate      <sub menu>
- I drive          <sub menu>
- Frequency output <sub menu>
- Sweep points
- Sweep ratio
- Search pivot ratio
- Clear Values on start
- Clear Values now
- Calibrate coarse (default)
- Calibrate full
- Measure Revc
- Ellipse/Oval Calculator

Results

- F6  Q, Fs, Le
- F7  Vas,Mass,BL,Cms
- F8  Box measurements
- F9  Calibration
- F11 Arbitrary 1 Sweep
- F12 Arbitrary 2 Sweep
- Use vented box info to to refine Vb and Fb
- Convert Vented Box info to Vas data
- Copy Test to Arb Buffer
  - <sub menu>

Help

- Help        Opens the WT2.HLP help file
- About       Opens the About Dialog

**NOTES**

WOO and CFG files are identical.  These files are used to save and load all sweep data, calibration and configuration information in binary form.  If you save and then re–import a WOO/CFG file, the present calibration data will be overwritten.

Export to ASCII, BassBox and LMS files contain human readable information that can be imported to other programs.  The most comprehensive is the ASCII export.  However this file format should be considered more of a log file than an export file as it can change in structure.

When all child windows are closed, the options pulldown will contain advanced options for setting the digital filtering buffers and the calibration values.  Not much checking is done here, so be careful if you make adjustments.

Adjusting CalR value is probably the most useful advanced option because it allows values other than 10.0 ohms. Though the Tenma Speaker Measurement Interface typically resolves 10 milliohm variations from 1-20Khz, accuracy is only as good as the calibration resistor. If you can measure your calibration resistor to a higher accuracy (precision bridge for example) and enter that value here, or use an entirely different value. However, do keep in mind that many precision resistors will be inductive. Also, the last used CalR and Rset values are kept in the CFG and WOO files. If you reload an old WOO file, these values must be re-entered.

The Rset value is more of a manufacturing value for a particular WT2 model. This value is used to set the maximum current output from the internal current driver. If your company needs a modified WT2 contact C&S Audio. DO NOT MAKE THE CHANGE YOURSELF AS THIS WILL OBVIOUSLY VOID ANY WARRENTEE!

The system response of a driver that has been installed in a box reveals a number of parameters that can be used to refine the box tuning. Essentially the physical effects of box loss, damping material over stuffing, vent placement and others affect the actual box volume and tuning. That is, the physical box construction you begin with will be an approximation of the desired box and NOT the box you desired. Measured in the box data (Ha and Alpha) and previous Vas information can be used to refine your box tuning. See 'Measure Vented Box' for more details.

Similarly measured box data can be used to create Vas data. This assumes the actual box volume and tuning are well known. Again, physical box effects can result in an actual box that differs from its predicted characteristics. This option is most often used in manufacturing where attaching weight to a driver would not be acceptable.

Frequency and current drive can be entered from the pulldown, or from a button in the control window. If the button is used, clicking on the center of the button will open a dialog box (enter any value) while clicking on the button edge will shift the value up or down, somewhat like a slider.

The number of sweep points and sweep ratio determine how granular the final data display will be. Choosing more points, or a smaller ratio will produce a finer display at the expense of speed.

The search pivot ratio option sets final 'bombout' point when the search algorithm has decided it is close enough to move on. A larger value here will result in less time iterating the Fs and 3db down points.

Two calibration options are given. The only difference is that in full calibration mode, the test lead wires are measured independently giving slightly better results. An interesting option is to perform calibration without the test leads (zero length) and then measure things like speaker cables. The Tenma Speaker Measurement Interface is able to resolve resistance and reactance in leads as short as one foot.

The Ellipse and Oval Calculator is a tool that might be useful when working with non round drivers. This tool assumes a mathematically correct ellipse. If the driver is not a perfect ellipse you will need to calculate an effective diameter by hand.

## Measuring Drivers Overview

**WARNING**

**DO NOT CONNECT ANYTHING EXCEPT A DRIVER TO THE TENMA SPEAKER MEASUREMENT INTERFACE**

**THE TENMA SPEAKER MEASUREMENT INTERFACES DIFFERENTIAL CURRENT SOURCE OUTPUT (BANANA JACK) CANNOT BE SAFELY CONNECTED OR GROUNDED TO EXTERNAL EQUIPMENT OR DEVICES (SUCH AS AN OSCILLOSCOPE) WITHOUT RISKING DAMAGE TO THE DEVICE. LOUDSPEAKERS, RLC NETWORKS AND CROSSOVER CIRCUITS OR HAND HELD METERS (WHICH ARE FREE FLOATING RELATIVE TO GROUND) ARE THE ONLY ACCEPTABLE LOADS**

The process whereby the Tenma Speaker Measurement Interface measures a woofer is fairly complex. Any woofer behaves electrically like a tuned circuit consisting of a capacitor, inductor and resistor in series. This circuit will ring at a frequency with a unique Q. The Tenma Speaker Measurement Interface injects a sinusoidal signal that excites this resonant behavior and measures the extent to which that behavior is exhibited.

Another way to look at this is that the impedance of the woofer changes with frequency. The Tenma Speaker Measurement Interface measures this impedance and interprets the results of the measurements in terms of Thiele/Small woofer parameters.

The Tenma Speaker Measurement Interface uses a small signal to perform its measurements, so you may not hear the Tenma Speaker Measurement Interface working. As drive level increases, especially when testing small diameter drivers, the resonance frequency also increases. The measurements being made are for use with small signal mathematical models, so the measurement voltage should be small!

As the Tenma Speaker Measurement Interface sweeps from low to high frequency it will automatically find and measure woofer resonance and other test points that are used to calculate the Thiele/Small model. What it does in the middle is based on an algorithm that accurately collects all of the pertinent data as quickly as possible. You can follow along as the Tenma Speaker Measurement Interface shows you what it is doing. The method used by the Tenma Speaker Measurement Interface is identical to the method you would use to measure fs, Qts and Vas if you were using a high precision frequency generator, AC voltmeter and phase meter. This is called the constant-current method of measuring woofer properties.

### About Woofers And What We Are Measuring

A woofer's impedance curve always looks like a bell curve or a camel hump. In general, a larger magnet in the woofer will produce a taller hump in the impedance curve. This is exhibited by a lower Qts, all else being equal. You can therefore think of Qts as a measure of the strength of the woofer magnet. A woofer with a smaller magnet will have a Qts greater than 0.7. Woofers with Q's greater than 0.7 are generally difficult to get any reasonable bass response out of in a reasonably sized enclosure. Woofers with large magnets tend to have a low Qts. Some woofers with large magnets can have a Qts as low as 0.20. Though typically very efficient, these woofers tend to have "too much" magnet and also tend to have difficulty producing low bass.

Vas can be thought of as a measure of how stiff the movement of the woofer cone is relative to the air around it. Vas is defined as the volume of air having the same compliance as the suspension system of the woofer. The units are usually specified as either cubic feet or liters. The Tenma Speaker Measurement Interface gives you the results of Vas in both units.

Vas is used, along with Qts to determine what volume of an enclosure you should build to get optimal performance from your woofer. The Tenma Speaker Measurement Interface is unique in that it takes the guesswork out of the whole process and puts a tool in your hands that will perform verifiable, repeatable measurements of a woofers' behavior both before and after the woofer is put into a box.

### Using The Tenma Speaker Measurement Interface

There are two main windows where data and information are entered and displayed. Each will have its own menu system. The 'Tenma Speaker Measurement Interface Data and Control' window is where the Tenma

Speaker Measurement Interface hardware is controlled and data is returned. A text area at the top displays condensed Thiele/Small and Box test results. Buttons for initiating tests are at the upper left with frequency and level controls at center left. Impedance and phase information is then displayed at the lower left.

**Calibrate**

Clicking on the calibrate button initiates the default calibration process. The software then leads you through several configurations of attaching the included 1% accurate 10-ohm resistor, short and test cable. As you go through the calibration steps information displayed will indicate the test frequencies and measurements that are made. The 10-ohm resistor that is supplied is accurate to 1% and is non-inductive. If wish greater accuracy, you may supply a 10 ohm resistor that is more accurate than 1% but be careful of wire-wound resistors as this will cause high frequency errors. When calibration is complete, the test lead resistance will effectively be nulled from the circuit. A slightly more accurate calibration that measures test lead inductance as a separate entity can also be performed using the pull down option menu. Calibration data is kept and will reload from WT2.CFG each time the software starts but can be rerun at any time.

**Fs, Qts Test**

The Tenma Speaker Measurement Interface automatically measures fs and Qts of a raw driver or a closed box system. When testing the fs of a raw driver, tradition dictates that the driver be suspended in the air at least three feet from nearby objects. This can be done by placing two 1" x 2" lumber slats horizontally three feet off the ground, with the driver placed between the boards and clamped in place. If this is not practical, testing the driver while it sits on a tabletop will only slightly affect the accuracy of the measurement. Attach a driver to the test leads and choose this menu item. The test begins by measuring Revc.

A raw driver and a closed box system look exactly alike to The Tenma Speaker Measurement Interface. You can test a raw driver, design and build a closed box system, and retest the system for fc and Qtc. If the fc and Qtc are not to your liking, you can modify the box and quickly re-test the system. This is very educational. Many large boxes are so flimsy that Qtc is not at all what you predicted it would be. If this happens, try stiffening the box walls with braces and constructing cross braces that connect the baffle, back wall and the sidewalls together. This brace resembles an X and can be secured where the braces cross. You will find that this greatly improves the behavior of the closed box system.

**Vas Test**

Vas is the most controversial woofer property. Vas is difficult to measure because it is dependent on the properties of the air in which it finds itself. The nominal density of air is 1.18 kilograms per cubic meter but that is only a nominal figure and can vary widely based on elevation above sea level, humidity and temperature. This also means the measured Vas will likely be different than the manufacturer supplied Vas. Vas can be directly measured using the Delta Mass method, or indirectly (you will need to do some calculations) using the Vented Box Test.

**Delta Mass**

The easiest and quickest method for measuring Vas is the Delta mass method. You start by measuring the raw woofer for fs and Q. Then add a known mass to the woofer cone and choose the Vas test. The preferred method is to use modeling clay of a known weight, or if you don't have access to an accurate scale, you can use nickels, which happen to uniformly weigh 5 grams each thanks to the U.S. Mint. The added mass should be 75% of the moving mass (Mm). The Tenma Speaker Measurement Interface finds a new lower fs and this is called fsa. Measure from the middle of one side of the surround to the middle of the other side of the surround in inches. Enter this diameter when prompted.

Because the "Mms" is calculated within the "Measure Vas" option we recommend the following procedure: 1. Run the initial test using the recommended mass listed below. 2. After the initial test, find Mms. 3. Take 75% of Mms and using this mass, run another test.

| Driver Size | Delta Mass |
|---|---|
| 5¼" | 20g |
| 6½" | 40g |
| 8" | 60g |
| 10" | 80g |
| 12" | 100g |
| 15" | 120g |
| 18" | 140g |

**Delta Compliance, Vented Box**

Delta compliance means change in spring constant. The woofer has a spring constant that we measure with fs and Q. We add another spring in series with the woofer in the form of a box and re-measure the system. In the case of a vented box, all we need to measure is alpha that is defined as Vas/Vb where Vb is the volume of the vented box. To calculate Vas we merely do the following Vas=alpha*Vb. The accuracy of the measurement relies on knowing Vb very closely. Alpha can be measured in the vented 'Box Test'. Normally the vented box test is used after a box is built to see how closely the measured box results match the simulation and is not normally used to calculate Vas (but this does make a good check).

**Box Test (Measure Vented Box)**

This menu item causes The Tenma Speaker Measurement Interface to measure fsb, fm, alpha and ha of a vented system. These parameters are usually a target of the simulated design. Being able to measure them allows you to see how close you are to achieving what you set out to do, and which way you might want to adjust the box volume (or tuning) to get closer to your design goal.

Fm is the measured in the box tuning frequency. If Fm is greater than the value called for in the box simulation program, the port length needs to be increased, port diameter decreased, or the box made larger. If Fm is lower than expected, port length can be decreased, a larger diameter port can be used, or the box volume can be made smaller.

Alpha is Vas/Vb. If you wanted alpha to be .8 and you measure it to be .7 that means that Vb is too large. Adding a solid object to the inside of the box (say a wood brace) will make Vb smaller and therefore alpha larger. The reverse also applies but is more difficult to do since this requires building a new box, or making the box appear larger by 'overstuffing' the box with damping material. Another option orienting the driver (and port) to face the floor or solid wall. In this case the air immediately in front of the driver (and port) adds an extra 'air mass' to both the driver and port. With the Tenma Speaker Measurement Interface, this is relatively easy to measure. If you have access to alignment tables, you can also use the box test parameters to determine an expected response. Typically it is easier to simply re-enter the measured values into the box simulation program to see how the system is actually working.

Q loss is the figure of merit for a vented box system. A typical 'good' Q loss is around 7. If Q loss is less than 3 then the assumptions of loudspeaker design do not hold. You must get Q loss above 3 to have a shot at getting the system to behave correctly. Large lossy cabinets are the place where you are most likely to find low Q loss. If Q loss is greater than 7, this indicates that the port resonance is likely undamped and may ring producing coloration.

Things that cause Q loss to be low (QL<7)

A large enclosure with thin and lossy walls will likely radiate energy from the enclosure walls as they flex. In this case the cure is to stiffen the walls with braces or to glue additional walls to the outside of the enclosure

The enclosure is well built, but is either too large, or the damping material inside is absorbing too much energy. This may be the result of overstuffing a small enclosure with damping material to make it appear larger. If not, decrease the box volume by adding internal solid fill material like bracing, which can only help.

The woofer is leaky. Paper cone drivers are very bad for this. You can cure the problem by sealing the cone and dust cap with some waterproof sealant. Parts Express' "The Wet Look" sealant #340-510 is ideal for this application. This unfortunately will lower fs and raise Qts so you will want to run parameter tests again after applying the sealant. It may also close off the voice coil from being able to let heat escape. If you run a lot of power, always try to buy woofers with vented pole pieces. This allows you to seal the cone and not burn up the voice coil.

Things that cause Q loss to be high (QL>7)

When the box is large and non lossy, the port tuning frequency Fb will be undamped leading to ringing and coloration. Either the box is too big, or there is too little damping material. Adding damping material may make the box look larger, but it will also lower QL.

**Inspecting Results**

Condensed cumulative results are shown in the 'Tenma Speaker Measurement Interface Data and Control' or individually in greater detail in the 'Test Results' window. Results are given in Thiele/Small form and in MKS form. The Thiele/Small parameters are fs, Qms, Qes, Qts, Vas and efficiency. This collection is enough to satisfy any table driven design methodology or any computer aided design program. The MKS parameters are Mmd in grams, Cm in microns per Newton and Rm in MKS mechanical ohms. These units are helpful for electrically equivalent circuit simulation programs, or variations of Spice circuits. There is a very good article on this in Speaker Builder Magazine issue #3 of 1991 about using Spice for driver modeling.

**Arbitrary impedance plots (2 available)**

Arbitrary impedance plots provide simple sweeps over a frequency range and detail of your choice. These extra sweeps can be used to measure and compare raw drivers, in the box drivers, crossovers inductors and more. For example, a leaky closed box system will have the multiple "camel hump" look of a vented system with the first hump being at a very low frequency. Keep in mind that increasing the number of points in the sweep will increase resolution, but will take some time to complete.

Note: Data displayed in the 'Test Results' window is limited to 50 lines and may exceed screen length. If you want to see all the data taken, use the 'Results' pull down menu and select 'Log All Now". All data, from all tests will be written to the selected file in ASCII text format.

## Driver Break-In

**Connecting lineout to an amplifier for breaking in a driver**

Before testing a driver, it is often desirable to break in a driver for an hour or two. Basically 'fresh' driver parameters are not the same as when the driver has been exercised for some time possibly leading to wrong assumptions in the box design. This is most easily accomplished, and with far less voice coil heating, by using a test tone that is equal to the free air resonance of the driver. A line level output has been provided that can be connected to an amplifier to provide the necessary test tones. The test tone frequency and amplitude can be controlled using the frequency and amplitude buttons in the control window.

**Break-In Level and Frequency**

When a driver is driven with a frequency at its resonance point two things occur. First, the cone and suspension system act like an oscillating spring and mass, requiring very little energy to be applied to achieve a substantial excursion. Second, the electrical impedance of the driver is at its maximum at the resonance point. Therefore, driving the driver at this frequency will achieve the greatest amount of mechanical motion for the least amount of electrical heating energy in the voice coil.

**WARNING**

**IT IS VERY EASY TO MECHANICALLY OVERDRIVE THE DRIVER AT ITS RESONANCE POINT. DO NOT ALLOW THE DRIVER TO BOTTOM OUT OR BECOME MECHANICALLY NOISEY. AT THIS POINT THE DRIVER IS EITHER OVERDRIVEN OR MAY NOT BE CAPABLE OF THIS EXCURSION**

**START WITH A MODERATETLY LOW LEVEL FOR AT LEAST THE FIRST 15 MINUTES AND THEN WORK YOUR WAY UP IN POWER. THE RESONANCE POINT SHOULD BE VISABLE TO THE NAKED EYE. IF NOT, OCCASIONALY RECONNECT THE DRIVER TO THE TENMA SPEAKER MEASUREMENT INTERFACES LEADS AND RERUN THE Q TEST TO FIND THE RESONANCE.**

**UNDER NO CIRCUMSTANCES SHOULD THE TENMA SPEAKER MEASUREMENT INTERFACES TEST LEADS BE CONNECTED TO THE AMPLIFIER.**

NOTE

Since the Tenma Speaker Measurement Interface is sharing PC resources, you may experience dropouts if the operating system becomes overloaded. Adding a pre-amplifier or an integrated amplifier with a volume control may be desired since this would allow you to set the output level to maximum and then cut back the level manually.

# Calibration

**Calibration**

A fast default calibration method as well as a more comprehensive calibration procedure that takes into account test lead inductance has been provided. In both cases several calibration steps will be needed for the Tenma Speaker Measurement Interface to fully compensate for internal and external influences.

**Fast Calibration (Button default)**

Begin: Scaling compensation K is set to 1, Cable resistance and inductance is zeroed and phase compensation is set to nominal.

Step 1: The test leads are connected to the Tenma Speaker Measurement Interface, Rcal is connected to the end of the test leads, and a 10KHz test signal is applied. The resulting output will be used to compute the scaling factor K where Vout=K*Idrive*(Rcal), the cable resistance and a rough phase compensation at 10Khz.

Step 2: The calibration resistor at the end of the test cable is removed and replaced by a short. The 10KHz test signal is still applied. The residual signal that is measured is the internal inter channel leakage. K, cable resistance, phase compensation and leakage are now computed.

Step 3: The short is removed and Rcal is connected to the end of the test lead. A 1Hz test signal is now used to compute the low frequency difference between the voltage and current side of the internal transconductance amplifier.

NOTE: Fast Calibration is generally good enough for most tests. If the test lead is omitted from the procedure (CalR and Shorts are directly connected), it is possible to measure cable resistance and inductance by connecting a cable and then shorting the far end.

**Full Calibration - From Options Pull Down Menu**

Full calibration goes a few steps more than Fast Calibration by breaking out the cable resistance and inductance as separate entities. Results are typically slightly better.

Begin: Scaling compensation K is set to 1, Cable resistance and inductance is zeroed and phase compensation is set to nominal.

Step 1: 100Hz Rcal at end of test lead measures Vout = K*Idrive*(Rcal + Rlead)

Step 2: 100Hz short at end of test lead measures Vout = K*Idrive*Rlead. K and Rlead are now computed

Step 3: 10Khz short directly connected to the Tenma Speaker Measurement Interface output measures internal leakage from the voltage sense side to the current sense side of the circuit.

Step 4: 10Khz Rcal directly connected to the Tenma Speaker Measurement Interface output measures and fine-tunes the phase error at 10Khz.

Step 5: 10KHz short at end of test lead measures the complex impedance of the test lead. Since Rload is zero, this is a measure of cable inductance.

Step 6: 10Khz Rcal at end of test lead measures and calibrates true load phase, minus the effect of the cable inductance and resistance.

Step 7: 1Hz Rcal at end of test lead performs low frequency gain compensation where the voltage and current sense converter is beginning to roll off. This extends the Tenma Speaker Measurement Interfaces useful measurement range to below 1Hz.

Note: Performing a full calibration with a zero length cable will allow you to measure and test cables and connectors. With care these results can be compared.

## Measure Q and Rdc

**Step 1**
If you have not recently calibrated the Tenma Speaker Measurement Interface, do so now as this test requires precisely measuring resistance.

**Step 2**
Place or mount the driver you want to test on a suitable test bench. Connect the calibrated test lead to the Tenma Speaker Measurement Interface, followed by connecting the test lead far end to the driver.

**Step 3**
In the 'Options' pull down menu, select a suitable 'Sweep Start' and 'Sweep End' point for the driver being tested (you can always rerun this test). If you are not sure, 10Hz and 20Khz will do just fine, but will take some extra time to complete the test.

**Step 4**
Also in the 'Options' pull down menu, select either 'Sweep Points' or 'Sweep Ratio' to set how rapidly you would like the search algorithm to fill in the graph. Keep in mind that more points will generate a smoother graph but will take longer to complete.

At this point don't worry about the other entries in the Options pull down menu, as they are not important.
NOTE: If you change the sampling rate, calibration will become invalid.

**Step 5**
Click on the button labeled "Q test". The Tenma Speaker Measurement Interface begins by measuring Revc resistance from 1 and 2 Hz measurements. This allows the Tenma Speaker Measurement Interface to operate within its usable frequency range while applying noise rejection filtering. A pair of complex impedances is returned which are then used to extract the true DC resistance.

**Step 6**
After accepting the measured Revc value, multiple search algorithms are executed to find the following points in this order

- Fs, which coincides with Zero phase and Zmax
- F_low, is the frequency below Fs where Ro=Rdc*sqrt(Zmax/Rdc)
- F_high, is the frequency above Fs where Ro=Rdc*sqrt(Zmax/Rdc)
- F_min - Frequency above F_high where phase is zero
- Sweep to Fmax completes the plot
- Test at 1Khz - Computes Le at 1Khz

## Measure Vas, Delta Mass

**Measuring Vas**
Vas can be thought of as a measure of how stiff the movement of the woofer cone is relative to the air around it. Vas is defined as the volume of air having the same compliance as the suspension system of the driver in cubic feet or liters. The Tenma Speaker Measurement Interface gives results of Vas in both units. Vas and Qts are then used in a separate box simulation program to determine the optimal box volume and tuning for your woofer.

Since Vas computations rely on the results returned in the Q test, this test should be performed after the Q test has been completed.

**Step 1**
Clicking the "VAS test" button will bring up a dialog box where you are allowed to enter the cone diameter, mass added and DC resistance if desired. When entering values be sure to hit the enter key (not the continue button) to make each entry valid. You will notice that when you hit the enter key, converted values are also updated. For example, if the delta mass value is entered in grams, ounces and equivalent mass in US mint nickels are updated.

The effective piston diameter of a driver includes the cone as well as that part of the suspension that moves with the driver cone. Since the suspension does not move at the basket edge, but does move with the cone at the cone edge, the effective piston area is increased to include the halfway point of the suspension. Effective cone diameter is therefore measured between the halfway points of the suspension and is entered either in inches or millimeters.

**Step 2**
After adding the mass and accepting the entered values the Tenma Speaker Measurement Interface searches for the new resonance peak. When this is found, Vas, BL, Mm and Cms are calculated and displayed in both the Test Results and WT2 control window. Vas data can also be viewed at a later time using the results pull down menu.

**Optimizing the Test Mass**
At this point a ballpark value for Mm will be given and an optimal value for delta mass can be determined. The desired test mass should be approximately 75% (77.78% would be exact) of Mms and result in a 25% decrease in the resonant frequency. Either add or subtract some mass and repeat step 1.

1. Run the initial test using the recommended mass listed below
2. Go to "Inspect Results" and find Mms
3. Rerun the test using a test mass equal to 75% of Mms

| Driver Size | Delta Mass |
|---|---|
| 5¼" | 20g |
| 6½" | 40g |
| 8" | 60g |
| 10" | 80g |
| 12" | 100g |
| 15" | 120g |
| 18" | 140g |

## The Delta Mass Method of Calculating Vas

The easiest and quickest method for measuring Vas is the Delta mass method. After completing the Q and Revc test, this test uses a known test mass to modify the free air resonance of the driver. Solid or 'sticky' weights like modeling clay or soft caulking can be used. Weight accuracy will be important, so if you don't have access to an accurate scale, you will want to start by using nickels that happen to have a uniform weight of 5.00 grams, thanks to the U.S. Mint.

The test mass should be approximately 75% of the driver moving mass (Mms) and result in a 25% decrease in resonance. Getting a weight that is close to this value may take a few test runs. Weight is entered in grams, ounces or nickels. Making the driver cone heavier will cause the measured resonance to go down. This allows the Tenma Speaker Measurement Interface to compute the driver suspension stiffness (Kms=1/Cms) and the moving Mass (Mms) using the equation for a spring and mass resonance. Here the equivalent mass and spring oscillator resonant frequency is given by.

Fs = 2*pi * sqrt(Kms/Mms)

Here is how this works. Starting with the equation for 'Free Air Resonance' Fs, suppose we add a second mass Ma. We would expect a new resonant frequency Fsa for the added mass Ma. If Fs and Fsa are known, these two equations can then be juggled around a bit giving equations for Mms and Kms as shown.

1) Fs = 2*pi * sqrt(Kms/Mms) Nominal free air resonance
2) Fsa = 2*pi * sqrt(Kms/(Mms+Ma)) Test mass modified resonance

3) Mms = Ma*Fsa^2/(Fs^2 - Fsa^2) (1) and (2) solution for Mms and Kms
4) Kms = Mms*(2*PI*Fs)^2

**Preferred Mass Ratio**
When too little weight is used, the change in frequency is small leading to systematic math errors. On the other hand, if too much weight is used, the suspension spring stiffness will increase leading to errors. The industry accepted ratio should yield F1/F2=1.25. When measuring Vas is complete, the report file will include information at the bottom indicating if you are too high or too low with your added weight.

**What to use for a mass**
As long as the amplitudes are kept small, and the resonance is low, almost anything can be used. The only criteria is that the test mass does not itself add any other appreciable resonance.

**Easy Nickel Method**
The weight of freshly minted US Nickels is tightly controlled at 5.00 grams each making them excellent weights for woofer testing. Occasionally very large drivers require a large number of nickels that cannot be easily added around the dust cap without stacking them. A solution is to glue together small stacks of nickels.

**Modeling clay (be careful!)**
If you have an accurate weight scale, modeling clay stuck to the driver cone will also work. However, keep in mind that for a paper cone can be blemished, so put the clay on the backside. You should also take note that by mashing the clay onto the cone, you can also easily damage the cone. Additionally, measurement errors can occur during the weighing of the clay. This is why, at least initially, the recommended method is to add a solid mass (Nickels) to the cone.

**<u>Vertical vs. Horizontal Test Benches, and Solid vs. Sticky Weights</u>**
Arguably the simplest method is to simply place the woofer on a solid concrete floor and use solid test mass weights such as Nickels. When properly run, the results will be quite good with only small errors arising from suspension non-linearity. Basically, as the cone becomes slightly depressed from the cone and test mass, the free air resonance will slightly increase.

**<u>Delta Compliance, Box Method</u>**
The other variable in the resonance equation that can be modified is the spring constant Kms. In this case by placing the driver in a sealed box the trapped air in the box will act like a spring increasing Kms and increasing Fs.

However, the sealed box method requires knowing the box volume, driver backside volume, box loss, mass loading and a few other miscellaneous parameters to an accuracy at least as good as the results we desire. Achieving both accuracy and repeatability is therefore difficult at best if you attempt to start from this direction. Additionally, the test box may never get used.

After measuring Qts and Vas, a driver and box combination is typically modeled on a computer to achieve a desired goal. Often the initial box alignment has some errors. Luckily these can be measured and corrected using information gathered using the "Measure Vented Box" test. An interesting parameter that is returned is Alpha=Vas/Vb. This is interesting in that it either helps to nail down the effective box size Vb if Vas is known precisely, or Vas if Vb is known precisely. In either case, the measured value for alpha should match that of the loudspeaker design program.

## Measure Vented Box

**Box Test**

After installing the driver in a rough aligned box, click on the 'Box Test' button. The Tenma Speaker Measurement Interface now performs a search and sweep, finding an impedance peak below the box tuning frequency, Z min (roughly at the box tuning frequency) and Zmax above the box tuning frequency. The parameters fsb, fm, alpha and ha of the vented system are then measured. These parameters are usually a target of the simulated design. Being able to measure them allows you to see how close you are to achieving what you set out to do, and which way you might want to adjust the box volume (or tuning) to get closer to your design goal.

**Using Box Test Data**

Measuring Q and Vas, Box simulation, and finally building a tuned box does not always result in a perfectly aligned box. Variations or miscalculations of the back volume of the woofer, tuning port dimensions, internal bracing, overstuffing, wall and floor loading and a host of other variables can all affect the outcome. The 'Vented Box Test' returns information that can be used to realign the box and achieve a desired result.

Alternatively, if a well-known test box is used, vented box results can be used to calculate Vas. This in turn allows all other parameters returned in the Vas test to be computed. You must previously run the Q/Revc tests to perform this calculation.

**Alpha = Vas/Vb (box fine tuning)**

Alpha is Vas/Vb. If you wanted alpha to be .8 and you measure it to be .7 that means that Vb is too large. Adding a solid object to the inside of the box (say a wood brace) will make Vb smaller and therefore alpha larger. The reverse also applies but is more difficult to do since this requires building a new box, or making the box appear larger by 'overstuffing' the box with damping material. Another option is orienting the driver (and port) to face the floor or solid wall. In this case the air immediately in front of the driver (and port) adds an extra 'air mass' to both the driver and port. With the Tenma Speaker Measurement Interface, this is relatively easy to measure. If you have access to alignment tables, you can also use the box test parameters to determine an expected response. Typically it is easier to simply re-enter the measured values into the box simulation program to see how the system is actually working.

**Using Fm and Fsb to find the actual port frequency (box fine tuning)**

Fm is the vented box frequency where impedance is minimal and phase is zero. Depending on the modeling program, some programs will indicate this frequency as the port Helmholtz frequency Fh. Fsb is a calculated frequency that other modeling programs will place Fh. Qloss can also affect Fsb and Fm so be sure to use this parameter in your modeling program if possible. Checking the phase and impedance of your simulated box should indicate which of the two should be used. If this is not possible, target a frequency that is the average of Fsb and Fm.

If Fh is greater than the value called for in the box simulation program, the port length needs to be increased, port diameter decreased, or the box made larger. If Fh is lower than expected, port length can be decreased, a larger diameter port can be used, or the box volume can be made smaller.

**Q loss (total box loss)**

Q loss is the figure of merit for a vented box system. A typical 'good' Q loss is around 7. If Q loss is less than 3 then the assumptions of loudspeaker design do not hold. You must get Q loss above 3 to have a shot at getting the system to behave correctly. Large lossy cabinets are the place where you are most likely to find low Q loss. If Q loss is greater than 7, this indicates that the port resonance is likely undamped and may ring producing coloration (avoid this as well).

Note: Qes and Revc must be accurate to achieve a good measure of Qloss

Things that cause Q loss to be low (QL<7)

A large enclosure with thin and lossy walls will likely radiate energy from the enclosure walls as they flex. In this case the cure is to stiffen the walls with braces or to glue additional walls to the outside of the enclosure

The enclosure is well built, but is either too large, or the damping material inside is absorbing too much energy. This may be the result of overstuffing a small enclosure with damping material to make it appear larger. If not, decrease the box volume by adding internal solid fill material like bracing, which can only help.

The woofer is leaky. Paper cone drivers are very bad for this. You can cure the problem by sealing the cone and dust cap with some waterproof sealant. Parts Express' "The Wet Look" sealant #340-510 is ideal for this application. This unfortunately will lower fs and raise Qts so you will want to run parameter tests again after applying the sealant. It may also close off the voice coil from being able to let heat escape. If you run a lot of power, always try to buy woofers with vented pole pieces. This allows you to seal the cone and not burn up the voice coil.

Things that cause Q loss to be high (QL>7)

When the box is large and non lossy, the port tuning frequency Fb will be undamped leading to ringing and coloration. Either the box is too big, or there is too little damping material. Adding damping material may make the box look larger, but it will also lower QL.

## Other WT2 Capabilities

**WARNING**

**DO NOT CONNECT ANYTHING EXCEPT A LOUDSPEAKER DRIVER TO THE TENMA SPEAKER MEASUREMENT INTERFACE**

**THE TENMA SPEAKER MEASUREMENT INTERFACES DIFFERENTIAL CURRENT SOURCE OUTPUT (BANANA JACK) CANNOT BE SAFELY CONNECTED OR GROUNDED TO EXTERNAL EQUIPMENT OR DEVICES (SUCH AS AN OSCILLOSCOPE) WITHOUT RISKING DAMAGE TO THE DEVICE. LOUDSPEAKER DRIVERS, RLC NETWORKS AND CROSSOVER CIRCUITS OR HAND HELD METERS (WHICH ARE FREE FLOATING RELATIVE TO GROUND) ARE THE ONLY ACCEPTABLE LOADS**

### Tenma Speaker Measurement Interface Hardware

The Tenma Speaker Measurement Interface output is a combined precision current source and phase meter that is able to scan arbitrary frequencies from 1 to 20Khz. Impedances can be measured to the accuracy of the calibration resistor from zero ohms to several kilo-ohms typically to better than a tenth of an ohm of absolute error. Also over this range, phase accuracy is typically better than a tenth of a degree with any significant deviation limited to the extreme limits.

Loudspeaker drivers are however bi-directional transducers that not only convert electrical energy into mechanical energy but they can also transform mechanical and acoustic energy into electrical energy. Although the Tenma Speaker Measurement Interface performs filtering to remove most of these signals, some signal contamination can occur when a noisy environment or vibration is present.

### Measuring High Impedance Values

Ohms law states that voltage (V), current (I) and resistance (R) are related by the equation V=I*R. Therefore if an open circuit were applied to a true current source, an infinite voltage would be produced no matter how small the current (I) is. The Tenma Speaker Measurement Interface output is of course limited to its internal drive voltages and is only able to drive approximately +/-1V. Never the less, we can use our understanding of Ohms law and the real world hardware within the Tenma Speaker Measurement Interface to solve for R in terms of V and I.

R=V/I Equation used to find R (and complex impedance Z)

Noting that V is limited to +/-1V, each setting for Idrive will therefore have a usable impedance range before clipping occurs. For example, if Idrive were set to 1mA, the maximum measurable impedance would be 1K ohms. The table below gives the maximum measurable impedance for each current setting.

| Idrive | Zmax |
|---|---|
| 5mA | 200 ohms |
| 1mA | 1K ohm |
| 100uA | 10K ohms |
| 10uA | (typically not usable) |

In reality the variables V and I will have finite precision as well as internal offsets that will limit the range over which R (and complex impedance Z) can be measured. This puts a practical limit for the Tenma Speaker Measurement Interface at somewhere near 10K ohms.

### Q, VAS and Box Search Tests

The Tenma Speaker Measurement Interface precisely measures both impedance and phase. Special search routines in the software are then used to zero in on phase or impedances as needed. This is different from an arbitrary sweep in that it allows the Tenma Speaker Measurement Interface to precisely measure and zero in on a specific point along a curve rather than attempting to compute where a point is likely to be from points around it.

The Tenma Speaker Measurement Interface software performs two basic free air (not mounted) woofer tests, plus an additional test after the woofer has been mounted in its nominally aligned, but not fine tuned box.

**Environmental Factors That Effect Testing**

You should also keep in mind that driver parameters are highly dependent on temperature, humidity, driver orientation and a host of other environmental factors. It is advised that tests be made in succession to minimize environmental factors.

For example, what would the change in voice coil resistance be for a change in temperature from 30'C to 40'C? Here the resistance property of most metals like copper and aluminum is found to be directly proportional to absolute temperature measured in degrees Kelvin.

```
R at 0'K = 0 ohms        resistance at absolute zero is zero ohms
R at 273'K = Rnom        Nominal driver resistance at 0'C
R = Rnom*Tk/273          Resistance at any temperature in K'
R = Rnom*(273+Tc)/273    Resistance at any temperature in C'
```

This equation shows that a 10'C increase in temperature will result in a 3.7% increase in resistance. This is hardly trivial given that the calibration resistor is 1% accurate. Note: Calibration resistors are made in such a way that their temperature coefficients are close to zero and are not greatly affected by temperature.

R_hot/R_cold = Rnom*(283/278)/Rnom*(273/278) = 1.037

Another example would be a change in humidity where the effective mass of a paper cone might change by 1%. Again, the ability to measure frequencies to a fraction of 1% would seem excessive.

However, if the Q and Vas tests are performed under the same conditions, many of the errors in one test, are nulled by the same error in the next test. For example, if the mass of the cone changes by 1%, it affects both the free air and delta mass resonance.

**Testing Cables**

The Tenma Speaker Measurement Interface is easily capable of testing the resistance and inductance of a reasonable length of speaker cable. Begin by aligning the Tenma Speaker Measurement Interface with a zero length test cable by not attaching it when the calibration asks for it. This will properly zero out only the internal errors leaving the test load, the cable we want to test. Next, run an arbitrary plot from 10Hz to 20Khz (the 10Hz region should be pretty flat).

Note: When Z approaches zero, phase will become less accurate. This is the result of having a small magnitude load signal.

## User Interface and Hotkeys

**Entering Frequency and Signal Amplitude**

The button interface for adjusting frequency and amplitude combines the actions of a dialog box with that of a scroll bar. If you click on the middle of the button a dialog will open allowing you to enter an exact value. If you click on the far left or right of the button, the button acts like a scroll bar adjusting the value up or down. You can also select a few predetermined values from the pull down menus.

**Function Hot Keys**

F1 Opens the help menu in 'Contents' mode
F2 Software installation
F3 Hardware installation
F4 Test Bench
F5 Measuring Drivers Overview

F6 Show Q test data and information
F7 Show Vas test data and information
F8 Show Box test data and information
F9 Show Calibration information
F11 Show arbitrary sweep #1 test data and information
F12 Show arbitrary sweep #2 test data and information

## Arbitrary Sweeps

The two arbitrary sweep buffers can be used for simple frequency sweeps where no search algorithm is used.  In this case the step ratio Fnow/Fnext is held constant.  The frequency step ratio is set in the options pulldown menu when the data and control window is active.  Use more steps (smaller ratio) to produce a smoother plot or less steps to quickly gather sparse data.

Data from other tests (Q/Fs, Vas and Box) can be copied to and from the arbitrary buffers.  Arbitrary buffer data is displayed as simple impedance data with conversions to resistance and inductance.  This data cannot be re-converted into speaker parameters.  Use the F4 and F5 hotkeys to quickly display this data.

NOTE: Arbitrary sweeps are particularly useful when measuring the resistance and inductance of resistors and cables (see Measuring Test Lead Inductance).  Keep in mind that many precision and power resistors are made from coiled wire and therefore may have measurable inductance.

## Measuring Test Lead Inductance

Test lead inductance can be significant at higher frequencies or when the test leads are appreciably long. This would for example be important when measuring crossover components, mid-ranges or tweeters. The standard Tenma Speaker Measurement Interface test leads for example have an impedance variation of ~140 milliohms at 20Khz simply by changing the wire spacing. If high frequency repeatability is a concern, switching to a test lead made from twin-conductor wire will ensure consistent wire spacing. The data below shows just how much variation the test lead wires will have.

NARROW SPACING (58 milliohm rise at 20Khz)
{bmc bmps\tl_close.bmp}

WIDE SPACING (194 milliohms rise at 20Khz)
{bmc bmps\tl_wide.bmp}

**Setup**

1) Calibrate the Tenma Speaker Measurement Interface with a 'zero length' cable. Basically when the test lead is called for during the calibration process, simply plug the calibration resistor and short directly into the Tenma Speaker Measurement Interface box.

2) Connect the test leads and short test clip end. This will allow you to directly measure the test lead resistance and inductance.

3) Change the test frequency to 20 KHz by clicking on the 'Frequency Hz' button. Clicking to the left or right of the button will shift frequency up or down, while clicking in the middle of the button will open a dialog box where you can enter an exact value.

4) Change the test lead spacing and orientation while examining the impedance and phase. Run an ARB1 or ARB2 arbitrary sweep if you want to collect and examine the data graphically.

5) Repeat with other test leads. For example, you can now measure the cables you use to connect your speakers and actually *measure* what works (and what does not)!

**Notes**

1) 36-inch (90 cm) test leads, identical to those shipped with the Tenma Speaker Measurement Interface were used to collect the data above.

2) Wire loop inductance is proportional to the area inside the loop. Wider wire spacing therefore results in higher inductance. In the experiment above, spacing was taken to an extreme.

3) Changes in contact resistance in the banana jacks and test clips can also be measured. For example, if the banana jacks have not been used much, they will develop a small amount of oxidation that can result in a few 10's of milliohms variation in resistance. Look carefully and this can be seen in the data given above. Wiggling the jacks around a bit will tend to clean the oxidation off but if it is particularly stubborn, try contact cleaner. Remember that this is a very small amount that can never be totally eliminated. IF ABSOLUTE ACCURACY IS NEEDED, YOU WILL NOT BE ABLE TO ELIMINATE CONTACT RESISTANCE. THE BEST SOLUTION IS SIMPLY DONT MOVE THE JACKS!

## Definitions

| | |
|---|---|
| Revc | Electrical resistance of voice coil |
| Fs | Free air resonant frequency of a driver |
| Qes | Electrical Q of driver |
| Qms | Mechanical Q of driver |
| Qts | Total Q of driver |
| Zmax | Impedance at resonance maxima |
| Le | Inductance measured at 1 kHz |
| | |
| Vas | Equivalent air volume of moving mass suspension |
| Diam | Effective cone diameter.  Half way point between suspension roll |
| Area | Cone area defined as Area=pi*Diam^2/4 |
| BL | Electromotive force delivered by magnet and voice coil |
| Cms | Suspension compliance: Inverse of spring constant |
| Kms | Inverse of Cms: Spring constant |
| Mms | Moving mass of voice coil, cone and suspension |
| Eff | Efficiency as acoustic output/input wattage |
| Sens | Output for 1 watt input |
| Rms | Mechanical resistance of driver |
| | |
| Fsb | Vented box tuning frequency.  Compare this to design |
| alpha | Alpha=Vas/Vb.  Use this to determine the effective box size. |
| Ha | Ha=xx/xx |
| Qloss | Box loss.  <3 lossy bad, 5=excellent, >7 probable resonances |