SMD

IM-SG

Impedance Meter / Signal Generator Owner's Manual

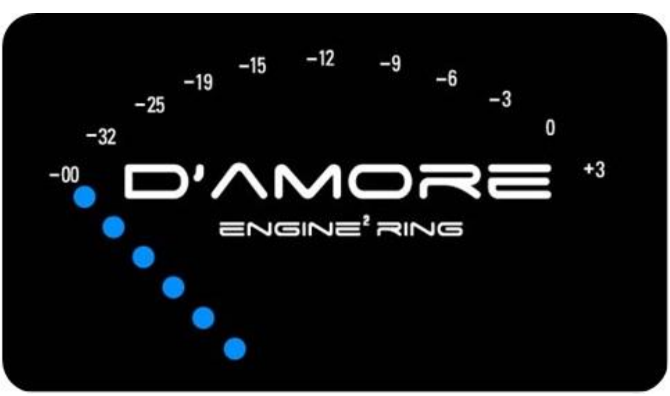

Table of Contents

The Purpose and Benefit of the IM-SG

The D'Amore Engineering IM-SG was designed to test the impedance of raw speaker drivers, loaded speaker enclosures, passive crossover networks, audio signal cables, speaker wires, and multi-speaker systems over the entire audio frequency range. In addition it can also be used as a stand-alone signal generator for both sine wave and pink noise for system tuning.

What is Included?

- The IM-SG
- Impedance test harness
- Y-adapter
- This manual
- Pride of ownership

About the Design

The IM-SG combines 4 powerful analog blocks in one package: A continuously variable audio frequency sine wave generator (you can't do that in digital ☺), pink noise generator, analog audio amplifier, and a precision balanced instrumentation amplifier to measure voltage and current. Combine all of this with a powerful digital microprocessor to do the math, and we have a very powerful and useful tool. There are many possible uses for the IM-SG. Some of the more common uses will be discussed in this manual. You may be able to find other uses.

Specifications

- **Impedance Measurement Range**
  1 ohm-100 ohms with 0.1ohms resolution
- **Low Impedance Measurement Range**
  0.00 ohm- 0.99 ohms with 0.01 ohms resolution
- **Operating Range of Battery**
  9.5 Volts - 6.4 Volts
- **Sine Wave Generation Frequency Range**
  greater than 8Hz - 20kHz in two ranges
- **Frequency Measurement Accuracy**
  greater than 99.5%
- **Impedance Measurement Accuracy**
  greater than 99% from 0 ohms - 30 ohms
  greater than 96% from 30 ohms - 99 ohms
- **Pink Noise Generation Flatness**
  20 Hz - 20 kHz +/- 2.0dB
- **Sine Wave Generation Frequency Response**
  8 Hz - 15 kHz +/- 0.8dB
  8 Hz - 20 kHz +/- 1.5dB
- **Battery Voltage Low Warning**
  7.2 Volts
- **Generator Output Voltage (unloaded)**
  725 mV RMS
- **Output Impedance of Signal Generator**
  10 ohms

Power Requirements

Pull the silicon rubber boot off of the unit by starting at one end and pulling off towards the other end. On the back side you will see the battery compartment. Slide battery compartment cover off towards bottom end of unit to reveal the 9V battery compartment. Insert a fresh 9V battery, make sure the wires are routed around the battery. (If they are under or on top of the battery the door may not close properly) You are ready to go. **Do not run this unit off of any power source other than a 9V battery. Wall adapters are electrically noisy, as are vehicle electrical systems.**

General Notes for using the IM-SG

The Off button - Hold for 3 seconds to put the IM-SG to sleep

The On button - Hold for 1 second to wake the IM-SG

When the IM-SG is powered up, it will display the condition of the 9V battery. It has 3 different messages depending on the condition of the battery.

Battery Good *- The battery's voltage is greater than 7.2 Volts.*

Battery Low Replace Soon *- The battery's voltage is between 6.4 Volts - 7.2 Volts.*

Battery Bad Replace Now* *- The battery's voltage is below 6.4 Volts and accuracy cannot be guaranteed.*

** The accuracy of the IM-SG is not affected by the condition of the battery unless the battery voltage is below 6.4 Volts. In this case, it will not proceed to boot up, but instruct the user to replace the battery instead. This insures accuracy at all times.*

Range button* - Press to cycle through the modes
(Low Range > High Range > Pink Noise)

Low Range = approximately 8 Hz - 600 Hz

High Range = approximately 600 Hz - 20 kHz

Pink Noise = All frequencies from 20 Hz - 20 kHz

** The Range button only cycles through the modes if the impedance being measured is over 0.50 ohms.*

General Notes for using the IM-SG *continued*

The rotary knob - Rotate slowly to sweep through the frequency range.

The display - The display shows the generator frequency "f" and the measured impedance "Z" simultaneously.

Harness Compensation

If making critical measurements, like those needed when trying to derive Thiele/Small parameters for a speaker driver (Page X), the IM-SG can compensate for harness impedance to obtain the highest accuracy possible.

1. Turn on the IM-SG by holding the **On** button for 1 second.
2. Adjust frequency to approximately 500 Hz.
3. Connect the test harness to the IM-SG and short the red and black test leads together by clipping them together.
4. Wait for Impedance reading to settle, it should settle to less than 0.50 ohms, if not you may have a defective harness. The reading must settle to below 0.50 ohms to continue.
5. Press and hold the **Range** button for 3 seconds.
6. The IM-SG will display "CALIBRATED", the impedance should now read 0.00 ohms or -0.00 ohms. A lower case "c" is displayed next to the Ω symbol to indicate that the reading is now compensated for test harness impedance!
7. Compensation is canceled by powering the IM-SG off and then back on.

General Notes for Measuring Raw Speaker Drivers (out of box)

When measuring raw speaker drivers it is important that the room in which the speaker is being tested is quiet and the air in the room is still. If a fan is blowing and air is moving in the room it will cause inaccurate readings. *Remember, a speaker moves air, and air moves a speaker.*

When testing a woofer, it is best if the woofer is away from boundaries and has adequate airflow at the back side of the magnet if the speaker magnet is vented. If the magnet vent is blocked, or if the woofer has boundaries such as sitting on a table, it can cause inaccurate readings.

One accurate method for testing woofers is to suspend them between two wood studs that are suspended parallel to the ground between two tables. If this is just not practical, you can set the woofer on a sturdy table and place something under two sides of the magnet; making sure the magnet vent is not blocked off.

Midrange and tweeter speakers can be measured while sitting on a table, or by holding them in the air away from obstacles.

Make sure the speaker is not connected to an amplifier or damage to the IM-SG could occur!

Finding the Resonant Frequencies of a Vehicle or Room (For max SPL)

1. Connect IM-SG to any auxiliary input of a source unit or amplifier to use the IM-SG as a signal generator. Turn the volume of the source unit or amplifier gain down.
2. Turn on the IM-SG by holding the **On** button for 1 second.
3. Power on the audio system
4. Increase volume to a moderate level
5. Starting at around 20 Hz, slowly turn the frequency control up. Sweep between 20 Hz - 80 Hz while listening carefully.
6. There will be one or more frequencies that play louder than the others. Note these frequencies.
7. This allows the SPL competitor to select tones or music that has frequencies that match the frequencies found using the IM-SG to achieve the highest SPL score in competition.

Finding the Resonant Frequencies of vehicle parts (finding rattles)

Most of the interior and exterior parts of a vehicle, and even furniture and other items in a living room can be subject to mechanical resonance. A door panel for instance, at some frequency it has a natural resonance frequency, or a frequency at which it will start to vibrate due to its physical properties. These can be very hard to find playing music because the rattle of this component may only occur once in a while, or only with specific music. With the IM-SG it is easy to find such rattles. Once these rattles are found they can be made quiet by tightening something that is loose, or by applying a damping material such as the popular adhesive mats.

1. Connect IM-SG to any auxiliary input of a source unit or amplifier to use the IM-SG as a signal generator. Turn the volume of the source unit or amplifier gain down.
2. Turn on the IM-SG by holding the **On** button for 1 second.
3. Power on the audio system
4. Increase volume to a moderate level
5. Starting at around 20 Hz, slowly turn the frequency control up. Sweep between 20 Hz - 150 Hz while listening carefully.
6. It is likely to find many different things rattling, each at their own frequency. If no rattles are found, increase the volume and repeat step 5. Use caution not to damage speakers from overheating. Have fun finding and correcting all of those rattles!

Using the IM-SG to tune the response of an audio system

By using the IM-SG with an audio spectrum analyzer (RTA) or with a inexpensive handheld SPL meter, it is possible to analyze the frequency response of an entire audio system and correct the response with equalization or by swapping phase of individual speakers, or by adjusting crossover points.

RTA Method

1. Connect IM-SG to any auxiliary input of a source unit or amplifier to use the IM-SG as a pink noise generator. Turn the volume of the source unit or amplifier gain down.
2. Turn on the IM-SG by holding the **On** button for 1 second.
3. Power on the audio system
4. Press the *Range* button twice to activate Pink Noise mode.
5. Increase volume of source unit to a moderate level
6. Place the RTA's microphone in the listening position
7. View the system's frequency response on the RTA
8. Look for holes or peaks in the frequency response of the system. Many times just swapping the phase of the rear channels or subwoofer channel will clear up some of these.
9. Adjust tone controls and equalization to flatten any peaks or dips in the system's frequency response.

Using the IM-SG to tune the response of an audio system - continued

SPL Meter Method

1. Connect IM-SG to any auxiliary input of a source unit or amplifier to use the IM-SG as a sine wave generator. Turn the volume of the source unit or amplifier gain down.
2. Turn on the IM-SG by holding the **On** button for 1 second.
3. Power on the audio system
4. Increase volume of source unit to a moderate level
5. Place the SPL meter's microphone in the listening position
6. Slowly sweep the frequency on the IM-SG while viewing the SPL meter. Look for holes or peaks in the frequency response of the system. Many times just swapping the phase of the rear channels or subwoofer channel will clear up some of these.

Adjust tone controls and equalization to flatten any peaks or dips in the system's frequency response.

Checking the Impedance of Speaker Cables or Signal Cables

With the IM-SG's low impedance mode and harness compensation it is easy to test the impedance of power wire, speaker cables, signal cables, and more. A few examples are listed below.

Testing Power Cable

1. Follow the instructions on Page 7 for to calibrate the IM-SG to compensate for test harness impedance.
2. Connect one end of the test harness to one end of the power cable, and the opposite end of the test harness to the other end of the power cable. It doesn't matter that you cannot fit the entire cable end inside the small alligator clips on the test harness. Just make a good connection to a number of strands that comfortably fit the alligator clip.
3. Set the frequency to around 50 Hz
4. If the wire gauge is 4 AWG or larger, it might be hard to measure unless measuring a complete spool of at least 100 feet because the resistance is so small.
5. It is a good way to compare two different types of wire as long as both spools are the same length.

Testing Speaker Cable

1. Follow the instructions on Page 7 for to calibrate the IM-SG to compensate for test harness impedance.
2. Connect the test harness to the positive and negative wires of the speaker cable at one end. Short the positive and negative wires at the opposite end of the cable.
3. Set the frequency to around 1 kHz

Checking the Impedance of Speaker Cables or Signal Cables - continued

4. Wait for the impedance reading to settle before reading it
5. This is a good way to compare two different types of wire as long as types are the same length.
6. Vary the frequency, see how it performs across the whole audio spectrum

Testing RCA cables

1. For this measurement the IM-SG does not have to be calibrated for harness compensation as the harness will not be used for this test
2. Connect one end of the RCA to be tested to the IM-SG directly. Short the other end of the RCA cable by using a shorting plug.
3. Set the frequency to around 1 kHz
4. Wait for the impedance reading to settle before reading it
5. This is a good way to compare two different types of wire as long as types are the same length.
6. Vary the frequency, see how it performs across the whole audio spectrum
7. Also try shaking the cable around to check for intermittencies in the cable. If the RCA has any breaks in the cable or connectors the impedance will jump up quickly.

Checking the Final Speaker Load on an Amplifier

With the IM-SG it is possible and useful to test the impedance of a speaker system be it a component set, an individual speaker, or a multi subwoofer setup.

1. To measure the f_B, make sure the room or area around the subwoofer is quiet and free from moving air.
2. Connect the test leads to the speaker system, if it has multiple voice coils they all need to be connected. A parallel connection will work fine. **Make sure there is no amplifier connected or damage to the IM-SG could occur!**
3. Turn on the IM-SG by holding the **On** button for 1 second.
4. After the unit is operating, turn the frequency down as far as it goes. Then slowly sweep the frequency all the way through the audio range while watching the impedance.
5. This is a good way to look at the impedance rise of the subwoofer system and to make sure the minimum impedance of the subwoofer system does not drop below safe limits for the amplifier.

Finding the f_S of a Raw Speaker Driver

The f_S is the speaker's natural resonant frequency. This will give you some idea of the usable bandwidth of the speaker. Generally the speaker will not produce usable output below the frequency of f_S.

1. To measure the f_S, make sure the driver is ready to be measured (read General notes for measuring raw speaker drivers on page 8).
2. Connect the test leads to the speaker, if it has multiple voice coils they all need to be connected. Connecting the coils in parallel will work fine.
3. Turn on the IM-SG by holding the **On** button for 1 second.
4. After the unit is operating, adjust the frequency to the low end of the f_S range in the chart below. Then slowly raise the frequency until the peak in impedance is found. If you go too far and pass the peak, just back down the frequency until the peak in impedance is found. Figure 1 shows the impedance curve for a 15 inch woofer we tested. We measured the f_S to be 24Hz.
5. Record the Frequency where the Impedance reaches its maximum value within the range of interest. This Frequency is the f_S.

Typical values for f_S are listed in the table below to give you an idea of where to look for it.

Speaker Type	f_S Range
Subwoofer	10 - 50 Hz
Midbass	20 - 150 Hz
Midrange	30 - 900 Hz
Tweeter	400 Hz - 5 kHz

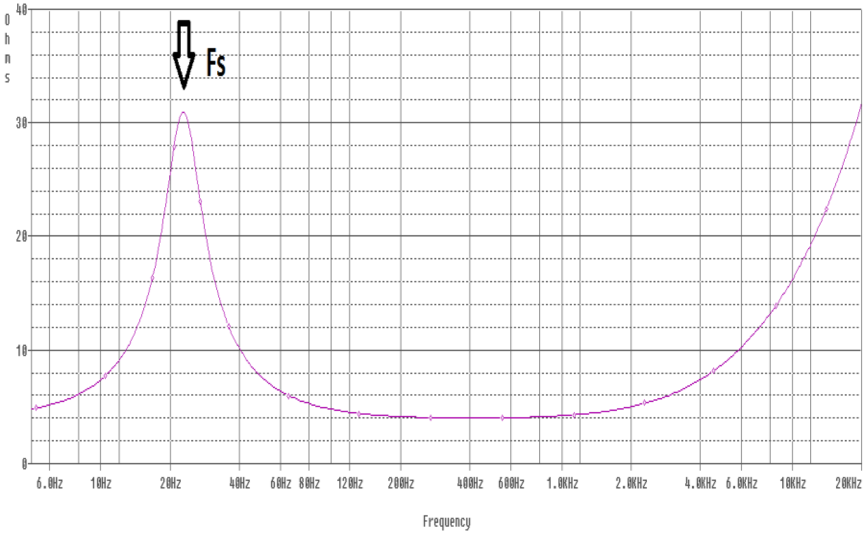

Figure 1, Impedance curve of a single 4 ohm voice coil, 15 inch subwoofer. Notice the f_S at 24 Hz.

The Significance of f_S

Subwoofer - The f_S value of a subwoofer is the frequency at which the cone naturally resonates, or vibrates at. This is **one** of the factors that determine how low a subwoofer will play. Example: A subwoofer with an f_S of 35 Hz is going to have a harder time trying to reproduce a 25 Hz tone than a subwoofer with a f_S of 20 Hz would. The f_S is also one of the main factors that go into calculating subwoofer enclosure volume and tuning frequency.

Midbass / Midrange - The f_S value of a midbass or midrange speaker can be looked at as a limit for where the highpass crossover should be set. Example: A 6.5 inch midrange was measured to have an f_S of 60 Hz. This speaker should be crossed over (high pass filtered) higher than 60 Hz to protect the driver from over excursion and damage. We suggest setting the high pass filter on midbass drivers $^1/_2$ octave to 1 octave higher than the driver's f_S for best power handling. Use $^1/_2$ octave higher if using a 24dB/Octave crossover, and 1 octave higher if using a 12dB/Octave crossover. *This is not law by any means, just a suggestion and very good place to start. If the midbass driver has its own sealed or ported enclosure it's possible that lower crossover frequencies can be used.*

24dB/octave Example: For $^1/_2$ octave higher, take the measured f_S and multiply by 1.41. So for measured f_S of 60 Hz, crossover should be set at 60 Hz X 1.41 = 85 Hz.

12dB/octave Example: For 1 octave higher, take the measured f_S and multiply by 2. So for measured f_S of 60 Hz, crossover should be set at 60 Hz X 2 = 120 Hz.

The Significance of f_S - *Continued*

Tweeter - Most tweeters have a measureable f_S frequency. *There are some types of tweeters, (ribbons for instance) that have an almost flat impedance across its operating range. For this type of tweeter, follow manufacturer's recommendations for crossover frequency.* For all moving coil type tweeters, we can measure the f_S just like a subwoofer or midbass driver; you just have to look for it more carefully. Typically, the impedance peak is not as high as a subwoofer or midbass driver. Figure 2 shows the impedance curve of a common 1.0 inch tweeter.

Figure 2 shows the impedance peak to occur at 1.59 kHz. This is the f_S for this tweeter. This information is useful for determining a safe crossover frequency for this tweeter.

We suggest setting the high pass filter on tweeters 1 octave to 2 octaves higher than the driver's f_S for best power handling. Use 1 octave higher if using a 24dB/Octave crossover and 2 octaves higher if using a 12dB/Octave crossover. *This is not law by any means, just a suggestion and good place to start.*

24dB/octave Example: For 1 octave higher, take the measured f_S and multiply by 2. So for measured f_S of 1.59 kHz, crossover should be set at 1.59 kHz X 2 = 3.18 kHz.

12dB/octave Example: For 2 octaves higher take the measured f_S and multiply by 4. So for measured f_S of 1.59 kHz, crossover should be set at 1.59 kHz X 4 = 6.36 kHz.

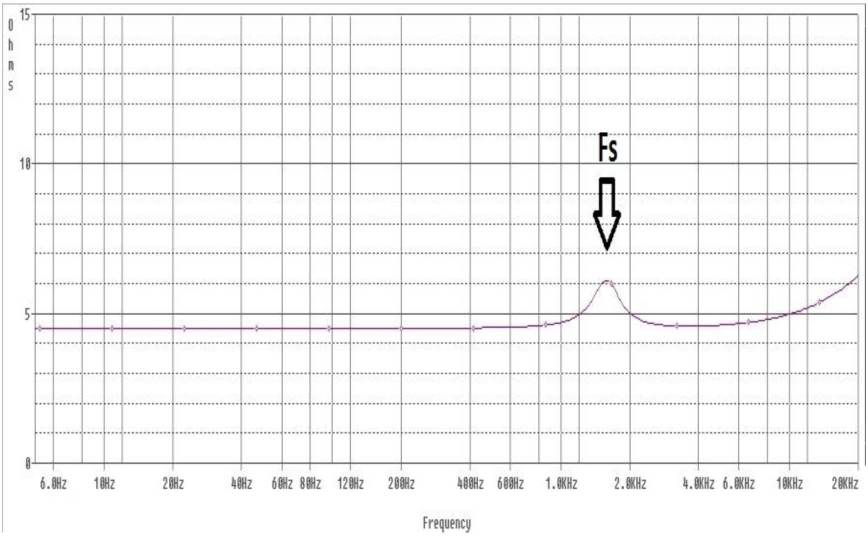

Figure 2, Impedance curve of a typical 4 ohm, 1" tweeter. Notice the f_S at 1.59 kHz

Finding the f_C of a Sealed Box Subwoofer System

1. The f_C is the driver's natural resonant frequency while in the sealed enclosure. This will give you some idea of the usable bandwidth of the speaker. Generally the output of the sealed subwoofer system will start to decrease as the frequency goes below f_C.
2. To measure the f_C, make sure the room or area around the subwoofer is quiet and free from moving air.
3. Connect the test leads to the speaker system, if it has multiple voice coils they all need to be connected. A parallel connection will work fine. **Make sure there is no amplifier connected or damage to the IM-SG could occur!**
4. Turn on the IM-SG by holding the **On** button for 1 second.
5. After the unit is operating, turn the frequency down as far as it goes. Then slowly raise the frequency until the peak in impedance is found. If you go too far and pass the peak, just back down the frequency until the peak in impedance is found. Figure 3 shows the f_C of the same 15 inch woofer we tested in the *Finding the f_S of a Raw Speaker Driver* section, but now in a 2 cubic foot sealed box. We measured the f_C to be 40 Hz.
6. Record the Frequency where the Impedance reaches its maximum value. This Frequency is the f_C.

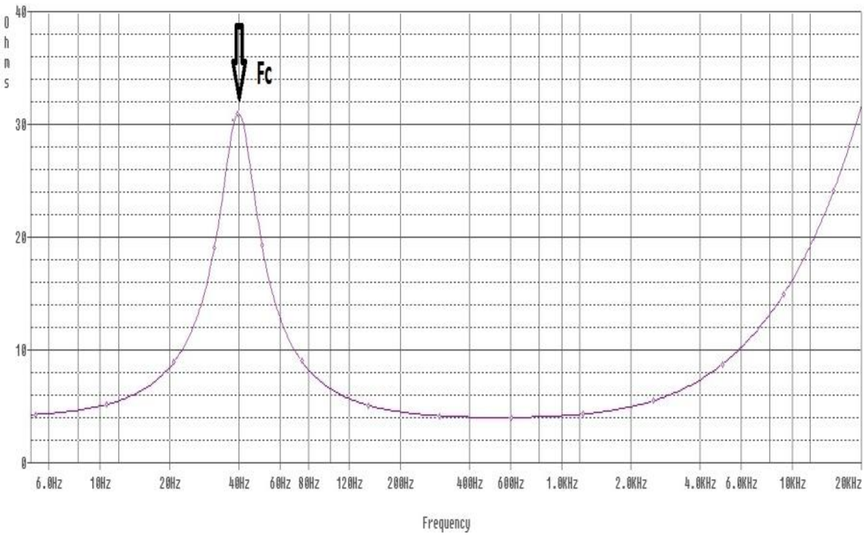

Figure 3, f_C of a single 4 ohm, 15 inch subwoofer in a 2 cubic feet sealed box.

Finding the Q_{TC} of a Sealed Box Subwoofer System

The Q_{TC} of a sealed subwoofer box system will give you some idea of how the frequency response of the system might be. The effects of different Sealed Box Subwoofer Q_{TC} values are shown in the chart below. Typical range of Q_{TC} is 0.7 - 1.2.

0.7 <-----------------------------0.9------------------------------> 1.2

Lower Bass <---------------------------------------> Punchy Bass

Larger Box <---> Smaller Box

More Cone Excursion <-----------------> Less Cone Excursion

To find the Q_{TC} of a sealed box subwoofer, we need to know f_S and the Q_{TS} of the raw driver (see page 33 to measure these or use manufacturer's specs). We also need to know the f_C of the sealed subwoofer box system (page 14). Once the f_S and Q_{TS} of the driver is known, and f_C of the sealed subwoofer system is known; it is easy to find the Q_{TC} of the sealed enclosure using the formula below.

$$Qtc = \frac{(fc\ X\ Qts)}{fs}$$

Figure 4 shows the same 10 inch subwoofer driver in three different sealed boxes. The blue trace is a box with a Q_{TC} of 0.7. The pink trace is a box with a Q_{TC} of 0.9. The green trace is a box with a Q_{TC} of 1.2.

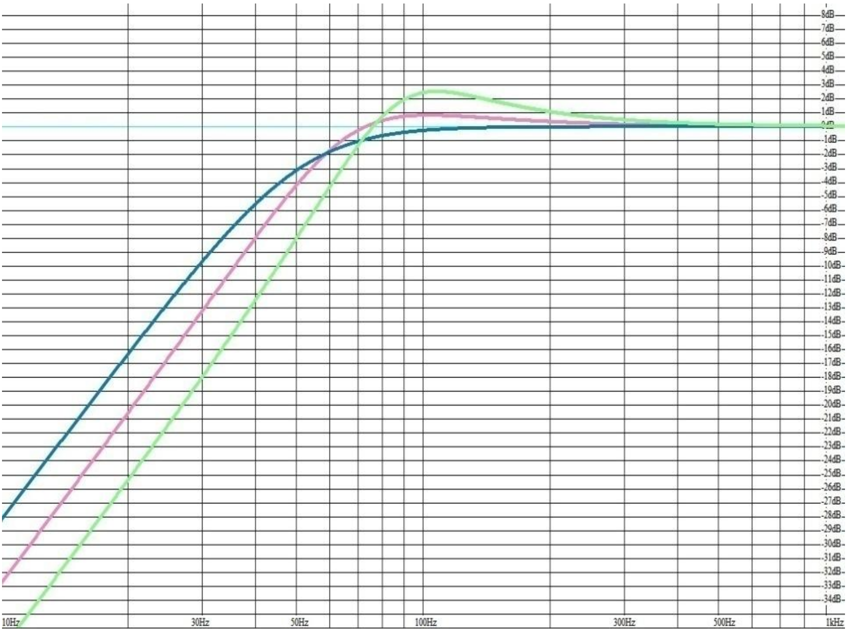

Figure 4

For a given driver, the Q_{TC} of the sealed subwoofer box system will be affected directly by the volume of the enclosure. The larger the enclosure, the lower the Q_{TC} value will be. The box can be stuffed with polyester stuffing or lined with fiberglass insulation to make adjustments to the enclosure's Q_{TC} value.

Stuffing usually lowers the Q_{TC} value as well as flattening the impedance curve slightly. Experiment and have fun!

Finding the Volume of a Subwoofer Enclosure (V_b)

By taking some measurements with the IM-SG and knowing two of the T/S parameters of the driver, it is possible to find the exact volume of a subwoofer enclosure. For this method to work, the enclosure has to be completely sealed. As such it may not be possible to use this method on a ported enclosure unless it is possible to seal off the port completely.

1. Find the V_{AS} and the f_S of the raw driver (see page 33 to measure these or use manufacturer's specs).
2. To measure the volume of a enclosure, V_b, make sure the room or area around the subwoofer is quiet and free from moving air.
3. Connect the test leads to the speaker system, if it has multiple voice coils they all need to be connected. A parallel connection will work fine. **Make sure there is no amplifier connected or damage to the IM-SG could occur!**
4. Turn on the IM-SG by holding the **On** button for 1 second.
5. After the unit is operating, turn the frequency down as far as it goes. Then slowly raise the frequency until a **first** peak in impedance is found. If you go too far and pass the peak, just back down the frequency until the peak in impedance is found. This frequency peak is $\mathbf{f_C}$, the resonant frequency of the sealed box subwoofer system. This is the same measurement as the procedure on page 21. We found the f_C of our test driver mounted in the test box to be 40 Hz.

6. Now using the V_{AS} of the raw driver, the f_S of the raw driver, and the f_C of the subwoofer/box system we can determine the volume of the enclosure using the following formula.

$$V_b = \frac{V_{AS}}{((\frac{f_C}{f_S})^2 - 1)}$$

7. On our sample 12 inch subwoofer driver used in the **Finding the Thiele / Small (T/S) parameters of a driver** section we measured the f_S to be 27.1 Hz. We also measured the V_{AS} to be 1.98 cubic feet.
8. Plug the V_{AS}, f_S, and f_C into the equation above.

$$V_b = \frac{1.98}{((\frac{40}{27.1})^2 - 1)}$$

9. Solving for V_b we get 1.68 cubic feet. This is the exact volume of the enclosure!

Try adding polyester box fill material or similar and remeasuring the f_C. Chances are adding some fill material will lower the f_C and thus increase the apparent box volume. In this same test box we added 1 lb of fill and remeaured our f_C to be 37 Hz. Thus our appearent box volume increased to

$$V_b = \frac{1.98}{((\frac{37}{27.1})^2 - 1)}$$

$V_b = 2.29$ cubic feet! A nice gain from just a bag of fill!

Finding the Tuning Frequency of a Ported Subwoofer Box System (f_B)

The f_B is the resonant frequency of the ported subwoofer enclosure. Measuring this will give you some idea of the usable bandwidth of the speaker and also if the target tuning frequency when constructing the enclosure was met. *Generally a infrasonic filter (subsonic filter) should be used on ported subwoofer enclosures. The frequency of said filter should be set just below the f_B frequency.*

1. To measure f_B, make sure the room or area around the subwoofer is quiet and free from moving air.
2. Connect the test leads to the speaker system, if it has multiple voice coils they all need to be connected. A parallel connection will work fine. **Make sure there is no amplifier connected or damage to the IM-SG could occur!**
3. Turn on the IM-SG by holding the **On** button for 1 second.
4. After the unit is operating, turn the frequency down as far as it goes. Then slowly raise the frequency until a **first** peak in impedance is found. If you go too far and pass the peak, just back down the frequency until the peak in impedance is found. Let us call this frequency peak f_L.
5. Continue increasing the frequency slowly until a **second** peak in the impedance is found. Let us call this frequency peak f_H. Ported enclosures have two impedance peaks, see Figure 5.
6. Now slowly decrease the frequency, you are looking for the **minimum** impedance that is between f_L and f_H.
7. The frequency at which this minimum impedance occurs between f_L and f_H is called f_B. This is the tuning frequency of the ported subwoofer enclosure.

Finding the Tuning Frequency of a Ported Subwoofer Box System (f_B) - continued

8. Figure 5 below shows the impedance curve of a 12 inch woofer in a ported box tuned to 30 Hz. The minimum impedance between the two peaks is f_B, the tuning frequency. This is the frequency at which the port has the highest air velocity, and the subwoofer has the lowest excursion.

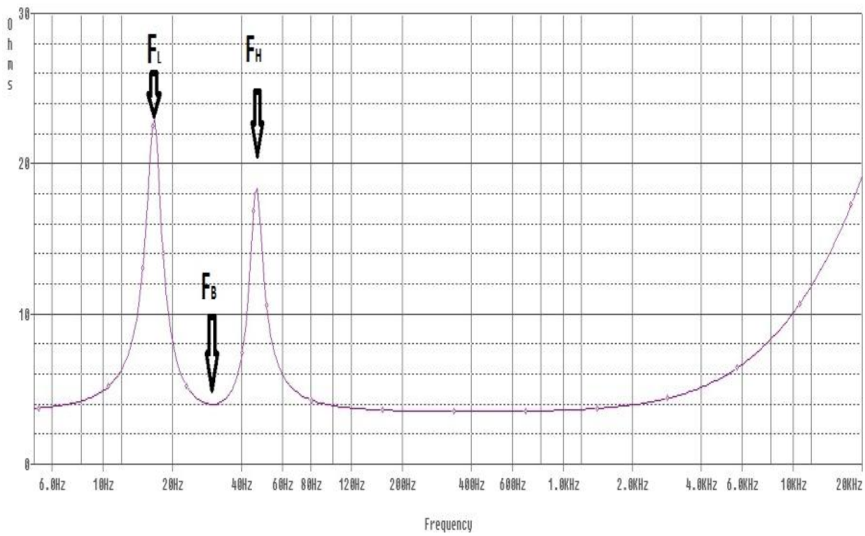

Figure 5

To prevent excessive cone excursion and potential damage to the subwoofer is it advisable to use a infrasonic (subsonic) filter set approximately $^1/_2$ octave below f_B. To calculate this, multiply f_B by .707 Thus in this example 30 Hz X .707 = 21.2 Hz.

Finding the Tuning Frequency of a Passive Radiator Subwoofer Box System (f_B)

Finding the tuning frequency of a passive radiator subwoofer box system (f_B) is exactly the same procedure as finding the tuning frequency for a ported box. Follow the instructions for **Finding the Tuning Frequency of a Ported Subwoofer Box System** on page 18. **Make sure there is no amplifier connected or damage to the IM-SG could occur!**

Referring to Figure 5, f_B represents the tuning frequency of the system. This is the frequency at which the passive radiator has the highest excursion and the active driver has the lowest excursion.

To prevent excessive cone excursion and potential damage to the subwoofer is it advisable to use a infrasonic (subsonic) filter set around $^1/_2$ octave below f_B. To calculate this, multiply f_B by .707 Thus in this example 30 Hz X .707 = 21.2 Hz.

Finding the Resonant Frequency of a raw Passive Radiator (f_P)

1. Connect IM-SG to any auxiliary input of a source unit or amplifier to use the IM-SG as a signal generator. Turn the volume of the source unit or amplifier gain down.
2. Connect a subwoofer to the amplifier's outputs
3. Turn on the IM-SG by holding the **On** button for 1 second.
4. Power on the amplifier
5. Increase amplifier gain or volume to a moderate level
6. Hold the loose (not in box) passive radiator very near the cone of the subwoofer
7. Sweep the frequency of the IM-SG between 8 Hz and 60Hz until the passive radiator cone starts to vibrate from the sound the subwoofer is producing.
8. Adjust the frequency on the IM-SG up or down until the frequency is found that causes maximum cone vibration of the passive radiator. This frequency is the passive radiator's natural resonant frequency, called f_P.

Finding the characteristics of a 4th order Bandpass Box (single reflex)

1. With the IM-SG, it is possible to find the port tuning frequency and the approximate bandwidth of a single reflex bandpass subwoofer system.
2. To measure the impedance characteristics of the subwoofer system, make sure the room or area around the subwoofer is quiet and free from moving air.
3. Connect the test leads to the speaker system, if it has multiple voice coils they all need to be connected. A parallel connection will work fine. **Make sure there is no amplifier connected or damage to the IM-SG could occur!**
4. Turn on the IM-SG by holding the **On** button for 1 second.
5. After the unit is operating, turn the frequency down as far as it goes. Then slowly raise the frequency until a **first** peak in impedance is found. If you go too far and pass the peak, just back down the frequency until the peak in impedance is found. Let us call this frequency peak $\mathbf{f_L}$. See figure 6
6. Continue increasing the frequency slowly until a **second** peak in the impedance is found. Let us call this frequency peak $\mathbf{f_H}$. Single reflex bandpass enclosures have two impedance peaks, see Figure x.
7. Now slowly decrease the frequency, you are looking for the **minimum** impedance that is between $\mathbf{f_L}$ and $\mathbf{f_H}$.
8. The frequency at which this minimum impedance occurs between $\mathbf{f_L}$ and $\mathbf{f_H}$ is called $\mathbf{f_B}$. This is the tuning frequency of the ported chamber.

Finding the characteristics of a 4th order Bandpass Box (single reflex) - continued

9. $\mathbf{f_L}$ and $\mathbf{f_H}$ tell us about the usable bandwidth of the system. Output of the subwoofer will start to decrease at frequencies below $\mathbf{f_L}$ and subwoofer output will decrease at frequencies higher than $\mathbf{f_H}$.

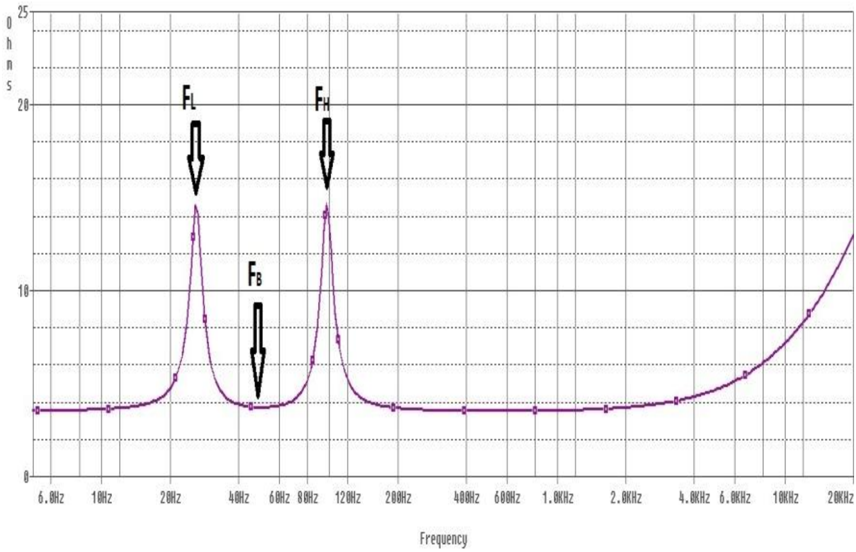

Figure 6, the impedance curve of a single 4 ohm voice coil subwoofer in a single reflex bandpass enclosure (4th order). Bandwidth is approx 30 – 90 Hz

Finding the Thiele / Small (T/S) parameters of a driver (Advanced Topic)

You don't need more equipment and a computer to do this. With the IM-SG, a small digital postage scale, and some play dough; it is possible to derive all of the T/S parameters that are needed to design a perfect custom subwoofer enclosure specific for your driver. This is important as manufacturer's published T/S specs can be off by 20% or more due to manufacturing tolerances.

If you are afraid of a calculator you may want to avoid this section and use the software available on our website.

Make sure the driver is ready to be measured (See General Notes for Measuring Raw Speaker Drivers page 8).

1. Using a digital voltmeter, zero the probes, and then measure the DC resistance of the driver. Record this value. We will call this R_E. On our 12 inch woofer example we measured R_E = 3.4 ohms.
2. Calibrate the IM-SG to compensate for the harness (Page 7)
3. Connect the IM-SG test leads to the speaker, if it has multiple voice coils they all need to be connected. Connecting the coils in parallel will work fine.
4. Turn on the IM-SG by holding the **On** button for 1 second.
5. Adjust the frequency on the IM-SG to the low end of the f_S range in the chart on the next page. Then slowly raise the frequency until the peak in impedance is found. If you go too far and pass the peak, just back down the frequency until the peak in impedance is found. Figure 8 shows the impedance curve for a 12 inch woofer we tested. We measured the f_S to be 27.1Hz.

Finding the Thiele / Small (T/S) parameters of a driver - continued

Speaker Type	f_S Range
Subwoofer	10 - 70 Hz
Midbass	20 - 150 Hz
Midrange	30 - 900 Hz

6. Record the frequency where the impedance reaches its maximum value within the range above. This Frequency is the f_S.
7. Record the impedance at f_S. We will be calling this (R_E + R_{ES}). We measured 38.3 ohms on our sample 12 inch woofer.
8. Now we need to calculate R_C with the following equation

$$R_C = \frac{(R_{ES} + R_E)}{R_E}$$

   On our sample we measured (R_{ES} + R_E) to be 38.3 ohms, and we measured R_E to be 3.4 ohms. Plug that into the equation above and it looks like this:

$$R_C = \frac{38.3}{3.4} = 11.26$$

9. Now we need to calculate R_O with the following equation

$$R_O = R_E \text{ X } \sqrt{R_C}$$

Finding the Thiele / Small (T/S) parameters of a driver - continued

R_O represents an impedance that we are going to try to find with the IM-SG. This impedance will happen twice, once at a frequency lower than the f_S and once at a frequency higher than the f_S. We are going to call these f_L and f_H respectively. See figure 8 for a graphical representation. Plugging in our numbers from our test woofer we get:

$$R_O = 3.4 \text{ X } \sqrt{11.26}$$

Solving for R_O we get 11.41 ohms. This is the impedance we are going to search for, below the f_S frequency to find f_L and above the f_S frequency to find f_H.

10. Slowly sweep the frequency down to find f_L. It will be lower in frequency than f_S was and will occur at R_O ohms. See figure 8. Record the frequency you found as f_L. We measured f_L to be 15.3 Hz on our 12 inch woofer.
11. Now slowly sweep the frequency up, higher than the f_S frequency. We are looking for the frequency that is at R_O ohms on the other side of the peak now. We call this frequency f_H. Record the frequency you found as f_H. We measured f_H to be 43.6 Hz on our 12 inch woofer. Refer to figure 8.

    Congratulations, at this point you have found and recorded f_S, f_L, f_H, R_{ES}, R_E and R_O! Now with a little math we can find Q_{MS}, Q_{ES}, and Q_{TS}.

Finding the Thiele / Small (T/S) parameters of a driver - continued

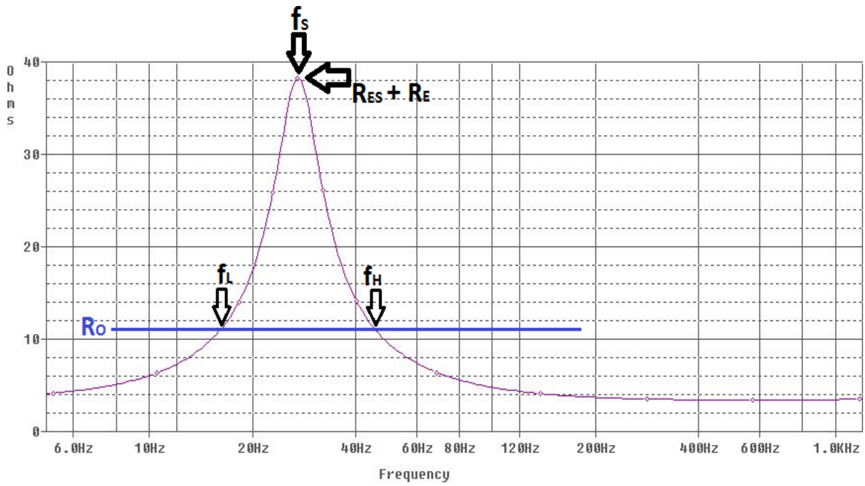

Figure 8, finding f_L and f_H

12. To find Q_{MS} plug in the recorded values for F_S, R_C, F_H, and F_L into the equation below.

$$Q_{MS} = \frac{f_{s\ X}\sqrt{R_C}}{(f_{H} - f_{L})}$$

Using numbers from our 12 inch woofer example =

$$Q_{MS} = \frac{27.1\ _X\sqrt{11.26}}{(43.6 - 15.3)}$$

So, Q_{MS} = 3.21

Finding the Thiele / Small (T/S) parameters of a driver - continued

13. Now calculate and record Q_{ES} using this formula

$$Q_{ES} = \frac{Q_{MS}}{(R_C - 1)}$$

Using the measurements from our test woofer we get:

$$Q_{ES} = \frac{3.21}{(11.26 - 1)}$$

So, Q_{ES}= 0.31

14. Now calculate and record Q_{TS} with this formula

$$Q_{TS} = \frac{(Q_{MS}\ X\ Q_{ES})}{(Q_{MS} + Q_{ES})}$$

Using the measurements from our test woofer we get:

$$Q_{TS} = \frac{(3.21\ X\ 0.31)}{(3.21 + 0.31)}$$

So, Q_{TS} = 0.28

We are almost done, now we are going to find V_{AS}. Get out your scale and play dough.

Finding the Thiele / Small (T/S) parameters of a driver - continued

15. To measure the V_{AS} we need to add some mass to the cone and re-measure the f_S with the mass on the cone. We found that play dough or modeling clay works well because it is easy to make various weights and it molds easily onto the cone. It is important that the mass doesn't rattle on the cone or vibrate independently from the cone, so press it into the cone and distribute it evenly. If it rattles it will be difficult to measure because the impedance reading on the IM-SG won't be stable. Select an appropriate mass from the chart below. Use the postage scale to measure the mass in grams.

Speaker Diameter	Approx. Mass to Add to Cone
5.25 inches	30 grams
6.5 inches	50 grams
8 inches	80 grams
10 inches	150 grams
12 inches	200 grams
15 inches	300 grams
18 inches	500 grams

16. Find and record f_{MA}: Once the mass is firmly on the cone, use the IM-SG to find the new resonant frequency with the mass added. This is where the impedance peaks. We will call this frequency f_{MA}. This number should be at least 25% lower than f_S. If not, add more mass and repeat.
17. Record the weight of the mass used in step 16 as *MA,* in grams.

Finding the Thiele / Small (T/S) parameters of a driver - continued

For our sample we used 135 grams and measured the new impedance peak to be 21.3 Hz. So MA = 135 and $f_{MA} =$ 21.3 Hz.

18. Calculate F_{ratio} with by plugging in F_S and F_{ratio} into the equation below. Record F_{ratio}

$$F_{RATIO} = (\frac{F_S}{F_{MA}})^2$$

For our example we get:

$$F_{RATIO} = (\frac{27.1}{21.3})^2$$

So F_{ratio} = 1.62

19. Calculate and record M_{MD}.

$$M_{MD} = MA/(F_{RATIO} - 1)$$

For our example we get

$$M_{MD} = 135/(1.62 - 1)$$

So M_{MD} = 218 grams

20. Now measure the diameter of the cone from center of the surround on one side to center of the surround on the other side. Our sample 12 inch woofer measured 10.0 inches. See photo 1. Record this in inches as *D*.

Finding the Thiele / Small (T/S) parameters of a driver - continued

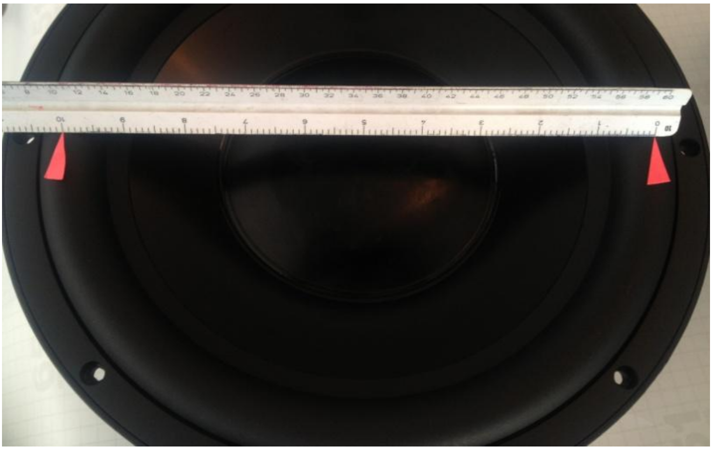

Photo 1

From the measured value of the diameter, D, we can calculate the cone area with this formula

$$Sd\ (in\ square\ inches) = (\frac{D}{2})^2 * \pi$$

So for our woofer which measured 10 inches from center of surround to center of surround we get:

$$Sd = (\frac{10}{2})^2 * \pi$$

So we get Sd = 78.54 square inches. Record this value for Sd.

Note: this is the formula for a round driver. If the driver is not round, compute the cone area as needed.

Finding the Thiele / Small (T/S) parameters of a driver - continued

21. Calculate and record M_{MR}

$$M_{MR} = \frac{Sd^{1.5}}{106.13}$$

For our example we get

$$M_{MR} = \frac{78.5^{1.5}}{106.13}$$

So M_{MR} = 6.6 grams

22. Calculate and record M_{MS}

$$M_{MS} = M_{MD} + M_{MR}$$

For our example we get

$$M_{MS} = 218 + 6.6$$

So M_{MS} = 224.6 grams, this is the moving mass of the driver

Finding the Thiele / Small (T/S) parameters of a driver – continued

23. Calculate and record C_{MS}

$$C_{MS} = 1000/((2 * \pi * f_S)^2 * M_{MS})$$

For our example we get

$$C_{MS} = 1000/((2 * 3.14 * 27.1)^2 * 224.6)$$

So C_{MS} = 0.000154

24. Calculate and record V_{AS}

$$V_{AS}\ (in\ cubic\ feet) = 2.087 * {S_D}^2 * C_{MS}$$

For our example we get

$$V_{AS}\ (in\ cubic\ feet) = 2.087 * 78.5^2 * 0.000154$$

Finally V_{AS} = 1.98 cubic feet

Finding the Thiele / Small (T/S) parameters of a driver - continued

Table of parameters found in this process, in order, from 12 inch woofer used in example.

R_E	3.4	Ohms
f_S	27.1	Hz
R_E+R_{ES}	38.3	Ohms
R_O	11.4	Ohms
Q_{MS}	3.21	unitless
Q_{ES}	0.31	unitless
Q_{TS}	0.28	unitless
M_{MS}	224.6	grams
C_{MS}	0.000154	unitless
Sd	78.5	Square Inches
V_{AS}	1.98	Cubic Feet

Notes:

Notes:

Troubleshooting:

Problem: The unit says “battery bad replace now” and won’t go to next screen

Solution: Replace battery

Problem:. It won’t switch modes from low range to high range to pink noise

Solution: Make sure the impedance being read is greater than 0.5 ohms. If not disconnect harness, change modes, then reconnect.

Problem: The Z reading says open

Solution: The impedance being measured is over 100 ohms. Test the harness by shorting the alligator clips together, if harness is good impedance should be less than 0.50 ohms. If harness is good, then reading was accurate.

Problem: The IM-SG keeps turning off

Solution: The IM-SG has an auto turn off timer; it will operate for approximately 8 minutes after the “On” button is pressed. This is to prevent it from eating your battery when you forget to turn it off. If you are in the middle of using it and need it to stay on, press the "On" button occasionally, this will reset the timer.

Problem: Some high frequency chirping can be heard when generating frequencies under 200 Hz.

Solution: This is normal and should not affect any measurements or readings.

Limited Warranty

D’Amore Engineering warrants this product to be free of defects in materials and workmanship for a period of one year.

This warranty is not transferrable and applies only to the original purchaser from an authorized D’Amore Engineering dealer. Should service be necessary under this warranty for any reason due to manufacturing defect or malfunction, D’Amore Engineering will (at its discretion) repair or replace the defective product with new or remanufactured product at no charge. Damage caused by the following is not covered under warranty: accident, misuse, abuse, product modification or neglect, unauthorized repair attempts, misrepresentations by the seller. This warranty does not cover incidental or consequential damages. Cosmetic damage due to accident or normal wear and tear is not covered under warranty. **Warranty is void if the product’s serial number has been removed or defaced.**

Any applicable implied warranties are limited in duration to the period of one year beginning with the date of the original purchase. No warranties shall apply to this product thereafter. Some states do not allow limitations on implied warranties; therefore these exclusions may not apply to you. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

If you need service on your product

All warranty returns should be sent to D'Amore Engineering accompanied by proof of purchase (a copy of the original sales receipt). Warranty expiration on products returned without proof of purchase will be determined from the manufacturing date code. Non-defective items received will be returned COD. Customer is responsible for shipping charges and insurance in sending the product to D'Amore Engineering. Shipping damage on returns is not covered under warranty.

To obtain service worldwide please e-mail D'Amore Engineering at Warranty@DAmoreEngineering.com

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