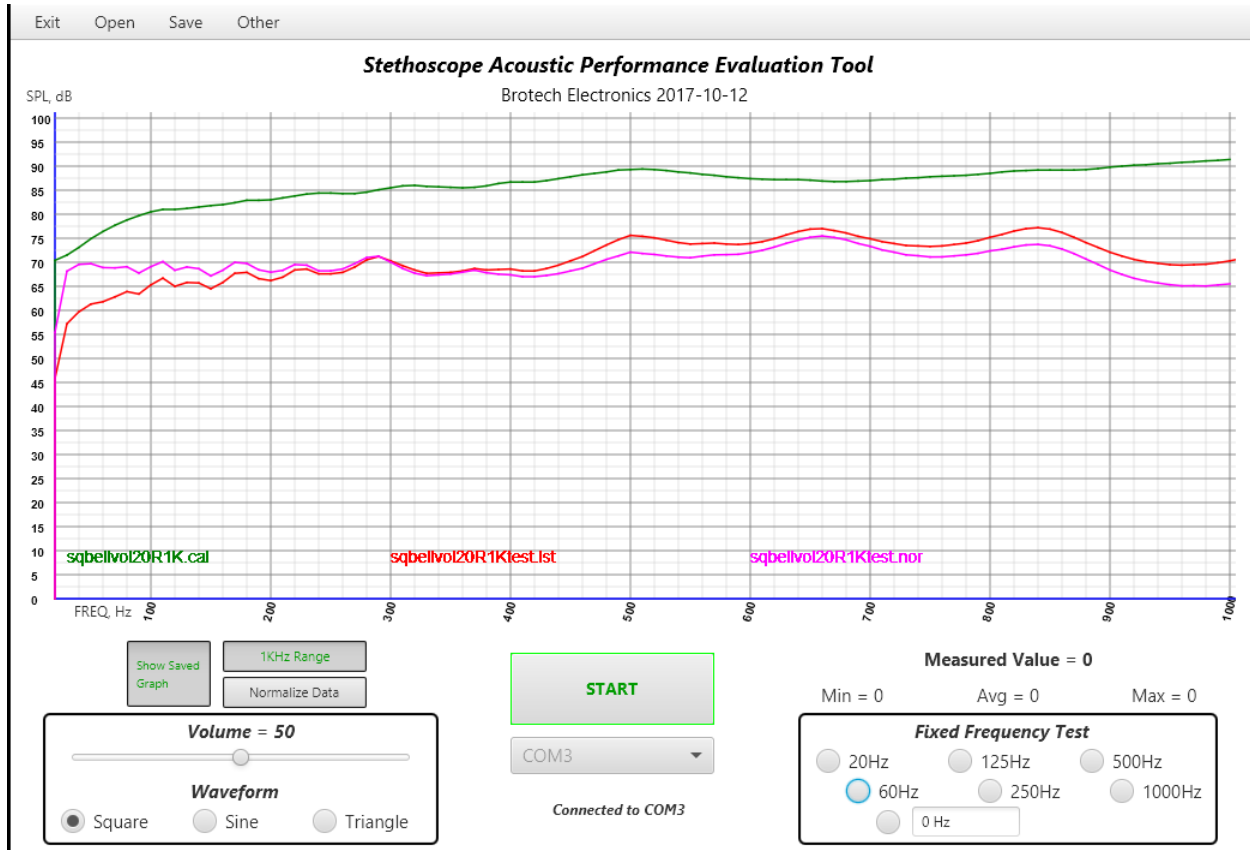


Brotech Electronics

Stethoscope

Acoustic Performance Evaluation Tool



The Brotech Electronics Stethoscope Acoustic Performance Evaluation Tool is a versatile Engineering and Quality Assurance test tool that can be used to measure, compare and evaluate acoustic performance of a stethoscope. It consists of custom desktop computer software and customized hardware mounted in an ambient noise-reduced enclosure (image below). The software communicates with the custom hardware through a USB Serial Communications port (Com Port).

Fundamentally it works by supplying an audio signal to the stethoscope chestpiece, while monitoring amplitude at the binaural: scope performance may be gauged by frequency response and amplitude. The amplitude is measured in calibrated decibels (dB).

After setting up a stethoscope in the test enclosure and sealing it, it can be used in two modes - Swept Frequency Graphing, and Fixed Frequency Testing;

Swept Frequency Graphing: In this test mode, a source frequency of Square, Sine or Triangle Wave, is swept from 5 through 500Hz in 5Hz increments, or 10 through 1000Hz in 10Hz increments. This source signal is presented at the stethoscope chestpiece, while the amplitude is measured at the

binaural. Each increment is measured, for a total of 100 samples. The data is collected and graphed in real time. It can then be saved as a data file and/or captured and saved as a graphic image.

Fixed Frequency Testing: In this mode, the user selects any of the available 6 fixed frequencies as the source signal, or manually enter any frequency from 1 thru 20kHz. The selected frequency is presented at the stethoscope chestpiece while the amplitude is measured at the binaural. No data is collected, but the sound pressure level (SPL) plus minimum, maximum and average levels, are viewable in real time.

Software Features and Controls

Menu Bar

Exit →

Exit Program: Immediately close and exit program. Will not save any currently displayed graph. (the program does not normally save any settings on exit or closing).

Open →

Graph Datafile → *[filename].lst*: Open and display any of one thru six previously saved Graph Datafiles starting from the current working directory, or change to another directory. Only files of type .lst are displayed. If the operation is cancelled, or no files selected or greater than 6 files are selected, or an invalid file type is selected, the open and display operation will fail, and an error message will report in the status message area.

Calibration Datafile → *[filename].cal*: Open and display any of one thru six previously saved Graph Calibration Datafiles starting from the current working directory, or change to another directory. Only files of type .cal are displayed. If the operation is cancelled, or no files selected or greater than 6 files are selected, or an invalid file type is selected, the open and display operation will fail and an error message will report in the status message area.

Normalized Graph Datafile → *[filename].nor*: Open and display any of one thru six previously saved Normalized Graph Datafiles starting from the current working directory, or change to another directory. Only files of type .nor are displayed. If the operation is cancelled, or no files selected or greater than 6 files are selected, or an invalid file type is selected, the open and display operation will fail and an error message will report in the status message area.

Show All Files: Open and display any of one thru six previously saved datafiles of types .lst, .cal, or .nor. starting from the current working directory, or change to another directory. Freely mix datafile types. If more than one .cal file is selected, only the first one will be used for normalized data calculations. If the operation is cancelled, or no files selected or greater than 6 files are selected, or an invalid file type is selected, the open and display operation will fail and an error message will report in the status message area.

Save →

Current Graph Data → *[filename].lst*: Save Graph Datafile of type .lst, starting at the current working directory, or change to another directory. Only files of type .lst are displayed. If the operation is cancelled, or no filename is entered, the open and display operation will fail and an error message will report in the status message area.

Current Calibration Data → *[filename].cal*: Save Graph Datafile of type .cal, starting at the current working directory, or change to another directory. Only files of type .cal are displayed. If the

operation is cancelled, or no filename is entered, the open and display operation will fail and an error message will report in the status message area.

Show All Files: Save Graph Datafile of any type .lst, or .cal, starting at the current working directory, or change to another directory. All files are displayed. If the operation is cancelled, or no filename is entered, the open and display operation will fail, and an error message will report in the status message area.

Other →

Online Help File: Display the latest version of the user manual (this pdf document). To read it, one must have a pdf reader installed and available on the local hardware, and the computer connected to the internet: the document is stored online on the Brotech Electronics website; it can also be downloaded and saved for offline reference. The manual may occasionally be updated, and the release date is indicated in the footer area.

Capture/Save Graph Image: Capture an image of and save the current program window view. The image capture includes the graph area plus the controls beneath and header on top – the entire program window (see image above). The initial save location is the current working directory, or change to another directory. The save file type is .png only – it cannot be changed, but it is a universal type opened by all viewing programs. If the operation is cancelled, or no filename is entered, the capture and save operation will fail and an error message will report in the status message area.

Set Working Directory: When the program is first installed, the default load/save directory is C:\Users\[*user_name*]\AppData\Roaming\StethEvalTool. It can be changed to any other write enabled directory (the actual installed program directory is usually not write enabled). Simply navigate to the new directory, do not enter any name, and click - Save. The working directory name will be shown in the status message area. To terminate this operation, click on cancel. On subsequent program execution, this new directory will be the default directory.

Controls

Show Saved Graph: Toggle on/off button used to show or hide already loaded graphs. Before it can be used, first load up to 6 previously saved graphs.

1KHz Range: Toggle on/off button used to change the horizontal scale of the graph. The scale can either be 0 thru 500Hz or 0 thru 1kHz. Rescaling the graph WILL NOT rescale a previously captured graph. If a graph was captured at 500Hz scale, it should only be viewed on the 500hZ scale to be meaningful; if a graph was captured at 1kHz scale, it should only be viewed on the 1kHz scale to be meaningful.

Normalize Data: Toggle on/off button used to normalize new data as it is captured. Before it can be used, a .cal file must be loaded. Then toggle the Normalize Data button On, and capture new data.

Start/Stop: Toggle button to Start and Stop new data capture and graphing.

Choose Port: Before any data can be collected, or any measurements made the custom hardware communications port must be selected and initialized. Use this tab to select the COM port associated with the custom hardware. It's impossible to predict exactly which port, COM1 through COMn, is the correct port, and need be discovered through trial and error. Once discovered, it will always be the same port unless other serial ports are connected to the computer beforehand. If it does not connect, the attempt will timeout at 8 seconds.

Measured Value = (and Min =, Avg =, Max =): During active capture, either graphing or Fixed Frequency Test using the radio buttons, these fields are constantly updated with new collected data. They display the current measured value, plus the minimum, maximum, and average of all data collected. This data is not stored.

Volume: Changes the amplitude or loudness of the chestpiece source signal (frequency). The volume can be adjusted during Fixed Frequency testing, or at other times the system is connected to the custom hardware, but it cannot be adjusted while graphing. This is usually set to 50 or less.

Waveform (Square, Sine, Triangle): Select from any of three waveforms as the source signal; Square, Sine, or Triangle Wave. The Square wave produces the most linear scale; the Sine Wave may be considered more realistic to real world sounds; the Triangle Wave is soft and subtle and might be used for fine analysis. In practice the distinction is difficult to measure and discern. The default is Square Wave.

Fixed Frequency Test (seven radio buttons 20Hz thru 1000Hz, 0Hz): This area consists of six radio-button selectable fixed frequencies plus a seventh user entered frequency. To start, click on any of the radio buttons; to Stop, click on another unselected radio button. One can also enter any frequency in the 0Hz field, within a practical range of 1 thru 20000. Enter numeric data only and no commas or other characters, but a decimal point can be used. Examples: 440, 1200, 60.5

Miscellaneous

Current Status: Just below the Start/Stop button and the communication port selection tab is a status message area. All system messages will appear here.

Graph Drawing Area: The graph drawing area is where all graphs are drawn and displayed. The left vertical scale shows the sound pressure level (SPL) in decibels (dB), 5dB divisions, 0 thru 100dB. The bottom horizontal scale shows the frequency that a SPL data point has been captured at. The range is 0 thru 500Hz, minor divisions of 10Hz, or when the 1kHz toggle button is on, 0 thru 1000Hz, minor divisions of 20Hz.

File Naming Convention: One can use commonly allowed characters in a filename, avoiding reserved characters (such as but not limited to / \ ? % * : | “ < > .). The length can be up to 255 characters long.

File types: The graph data file types can only be of three types. Any other type will not work. The types are;

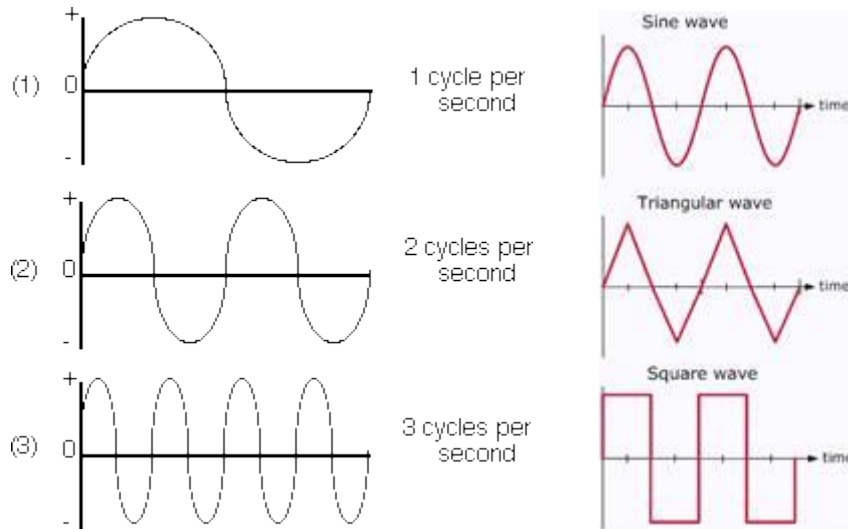
lst = common graph data file type; This is the default and most common graph data file type. All saved graphs should be of this type.

cal = calibration graph data file type; This is a unique data file containing graph normalization information. It is used to calibrate a straight horizontal line across the graph under specific waveform and amplitude conditions. When a calibration data file is loaded and active, a normalization offset will be applied to all incoming data. This is a little or never used file type. Calibration files can be made by capturing a graph with the microphone placed directly over the speaker – no stethoscope employed.

nor = normalized graph data file type; New incoming data can be Normalized by first loading a previously saved calibration file, and then applying the normalization offset by enabling the Normalize Data toggle button. When the newly captured data is saved as a .lst file, a second Normalized datafile is automatically also saved at the same time. This auto saved file will be of type .nor. A normalized file can be viewed like a standard lst file.

Basic Sound and Transmission Theory

Sound, a sound wave that may be heard consists of positive and negative air pressure waves reaching the ear, within the audible range of human hearing ~20Hz to ~15K Hz (Hertz or cycles per second). One (1) cycle consists of one positive pressure and one negative pressure transition. A single cycle may be visualized as beginning at 0 (standard atmospheric pressure) increasing to some positive pressure (positive to atmosphere), decreasing to and through 0 (to atmosphere), going below zero (negative to atmosphere pressure) and returning to 0 (atmospheric pressure).



When you hear a note or frequency of let's say, 500Hz, it means that there is a continuous stream of 500 single cycles, alternating half positive/half negative pressures, being transmitted through the air and reaching your ear – every second.

At ~20C, 68F ambient temperature and 1 atmosphere pressure (sea level), sound travels at a speed of 1125 feet per second. It travels faster if the air is denser, slower if thinner, and these properties are changeable through changes in temperature and altitude. (with cooler denser air for example, it will also sound louder because it's a more efficient transfer medium)

Besides transmission speed, frequencies have a length conventionally measured in a single cycle. So, a frequency of 1Hz, one-cycle, has a wavelength of 1125 feet; one positive transition stretched to 562.5' and one negative transition stretched to 562.5'. A frequency of 1125Hz has a wavelength of 1 foot, or 12 inches.

Higher pitch means shorter wavelength, and lower pitch means longer wavelength. That's why bass pipes on a pipe organ are the longest.

An open tube or pipe of length n , will resonate, or transmit the most energy -- be loudest -- coincident with a frequency that has the same wavelength as the tube length. So, a tube or pipe of 1 foot will have a resonant fundamental frequency of 1125 Hz. It's an inverse property where, longer length = lower resonant frequency, and shorter length = higher resonant frequency.

For a stopped pipe, or a closed system with a resonator at one end and closed or stopped at the other, the effective resonant length of the pipe is doubled and therefore the resonant frequency is halved. So, a 1 foot stopped pipe sounds and resonates as though it is a 2 foot long pipe and the resonant or fundamental frequency wavelength is 2 feet.

A stethoscope overall lengths measure 24” to 32”, and these may be considered stopped pipes; and so the effective length is doubled. Changes in length shift the resonant frequency higher or lower. Below is a table of calculated resonant frequency for stopped pipes of length 24” to 32” stepped in ½” increments. When measuring the transmitted sound pressure level of a scope, you would expect to see the highest amplitude measured at the fundamental frequency established by the overall length. As demonstrated with the Acoustic Performance Evaluation Tool, we do observe this.

Stethoscope overall length, in inches	Apparent Stopped Pipe Length	Resonant Frequency
24	48	281.25
24.5	49	275.51
25	50	270.00
25.5	51	264.71
26	52	259.62
26.5	53	254.72
27	54	250.00
27.5	55	245.45
28	56	241.07
28.5	57	236.84
29	58	232.76
29.5	59	228.81
30	60	225.00
30.5	61	221.31
31	62	217.74
31.5	63	214.29
32	64	210.94

Additionally, there can be strong harmonics of even and odd multiples of the fundamental frequency. So for length of 27", one would see the resonant fundamental of ~250Hz, plus some peaks at 500Hz and 1KHz, and in the opposite direction, 125Hz and 62.5Hz, and etceteras... this happens until the sound energy dissipates or can't be supported and the harmonic multiples fall off. Odd harmonics as well can appear at 375 Hz, 625Hz, and below and etceteras...

We can demonstrate and see this with the Acoustic Performance Evaluation Tool, observing resonant or fundamental, and the harmonic peaks as well, and we can measure their amplitudes.

Fundamentally, the resonant frequency of any Stethoscope is its overall length. This can be changed or tweaked by changing the length of the tubing. The chestpiece itself, the design or shape, bell or diaphragm, does not contribute to or affect or change or contribute to the fundamental frequency of the system.

That said, the diaphragm side will have an increased amplitude over the bell because it is larger area funneling pressure waves from the source into the tubing. The diaphragm side also acts as a mechanical filter and flattens the peaks and dips. This is known as a Q factor, which is a relative measure of how narrow in width (bandwidth) the resonant frequency appears.

The following diagram illustrates this. Notice that the amplitude and presumed resonant frequency of these graphs are all the same, but the way they arrive there is broad (wide bandwidth) to very narrow (narrow bandwidth). The high Q number would be the bell side of the stethoscope, while the low Q number would be the diaphragm side. For the diaphragm though, because the diaphragm is also wider in diameter in more efficiently captures pressure waves, and so it's usually also slightly louder than the bell - it's louder due to the larger area, and flatter in response with a wider bandwidth caused by the mechanical filtering. This bandwidth or Q factor is probably changeable depending on the natural frequency of the diaphragm and tension and pressure applied when pressed to a subject.

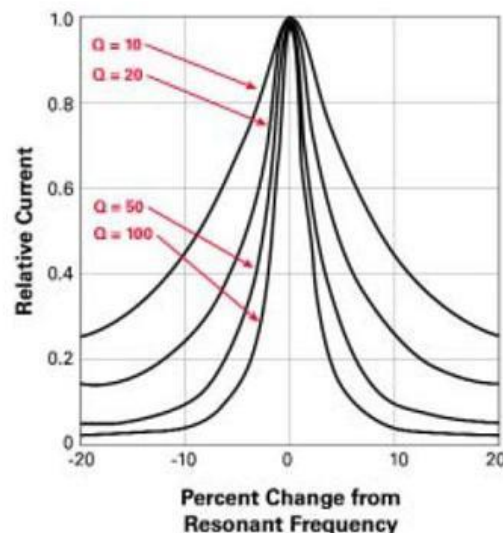


Figure 3: Q-factor percentage

Stethoscope Evaluation Tool hardware and sound-attenuated enclosure. As packaged, it consists of; custom electronic hardware, Extech 407750 customized Sound Level Meter, chestpiece weights, remote microphone for the binaural, stop plug for the binaural, cables and connections, AC/DC power supply.



Satisfaction Guarantee:

The customer has up to 30 days, to evaluate and try the Stethoscope Acoustic Performance Evaluation Tool, and if it doesn't meet your requirements you can return it for credit. The items must be returned in like-new condition. Contact us first for a return authorization (RMA). The customer pays for UPS tracked and insured shipping. Under these conditions and upon receipt of the returned hardware, a full refund will be provided, less the shipping charges.

Product Warranty:

The Brotech Electronics Stethoscope Acoustic Performance Evaluation Tool custom hardware is guaranteed free from defects in material and workmanship for a period of 90 days from date of purchase. In the unlikely event that you experience a problem, contact us and we'll try to find a resolution. If the product needs to be returned for repair, contact us first for a return authorization (RMA). The customer pays for UPS tracked and insured shipping one way.

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