Measurements with CLIO 12 for crossover simulation with VituixCAD

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Contents

Measurement gear

- Microphone CLIO MIC-01, MIC-02 or MIC-03 with calibration file
- CLIO fw-02 audio interface with USB interface
- PC with Windows 10-11
- CLIO mic cable, impedance measurement cable, USB-cable, signal cable and speaker cable
- CLIO QCBox 5 or integrated amplifier or power amplifier
- Turning table; manual or automatic for example Outline ET-series
- Wireless keyboard is very handy with manual turning table.

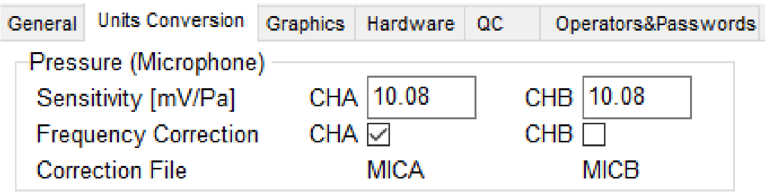
Preparations

Copy microphone calibration file (with max 100 frequency points) to directories:

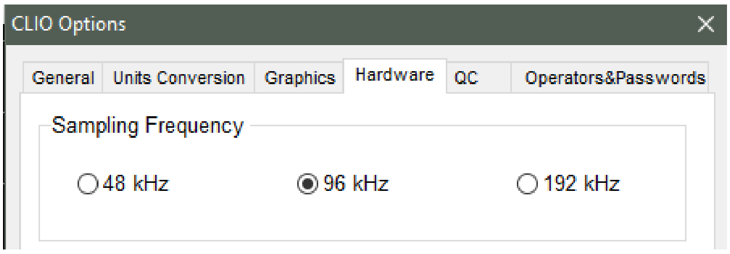
- C:\Program Files (x86)\Audiomatica\CLIO12 as MICA.cal
- User Documents\VituixCAD\Projects\Mics with original name (*serial-number*.cal).

Connect power supply to CLIO fw-02 and let it warm up. Proceed audio interface calibration via *Main menu -> Calibration* if not yet executed. Validate calibration on regular basis. See ‘Calibration validation’ section in user manual for more information.

Set *Sensitivity [mV/Pa]* of the microphone and check *Frequency Correction CHA* to *CLIO Options -> Units Conversion*. For example, my MIC-01 is 10.08 mV/Pa in calibration chart.



Select *Sampling Frequency 96 kHz* via *CLIO Options -> Hardware* or hardware control toolbar (bottom) of the main window. This ensures that measured frequency range covers internal range of VituixCAD (5-40k) without forced extrapolation.

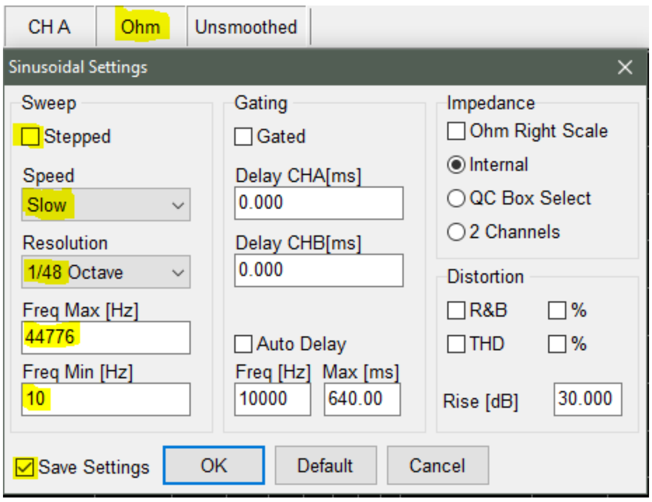


Impedance measurements with CLIO fw-02

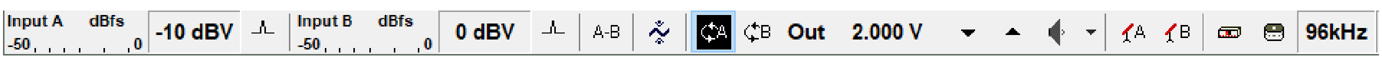
Measurement connection. See user manual for more information.

Note that DUT should be installed in the box/baffle while impedance measurement for XO simulation. Not free air.

Impedance responses can be measured with MLS&Chirp or Sinusoidal analysis. These instructions are for ***Sinusoidal***. Accept the following settings with *Save Settings* checked. Y axis unit should be *Ohm* and *Unsmoothed* before measurements are executed.



Adjust initial sensitivity of input A to -10 dBV, normal polarity, output A connected to input A, Out level 2.0 V, phantom power off, sampling frequency 96 kHz:



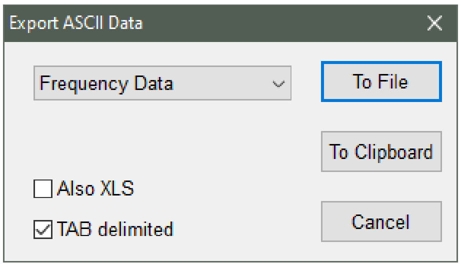
Make test measurements with driver connected to adjust Input A sensitivity and Out level so that Input A dBfs bar visits green zone, but does not clip up to red which would ruin the measurement. Suitable level is individual for each driver due to radical differences in maximum impedance. Environment should be as silent as possible, and cone should “breathe” normally – as during listening.

1) Measure impedance response of one woofer if all drivers have own box with same volume (and tuning). If drivers share the same box volume, they should be measured together in series or parallel - like in the final connection. Magnitude is scaled in Drivers tab of VituixCAD to represent single driver; 2 in parallel -> Scaling=2.0, 2 in series -> Scaling=0.5 etc.

2) Measure impedance response of one mid-range driver if all drivers have own box with same volume. If drivers share the same box volume, they should be measured together in series or parallel - like in the final connection. Magnitude is scaled in Drivers tab to represent single driver.

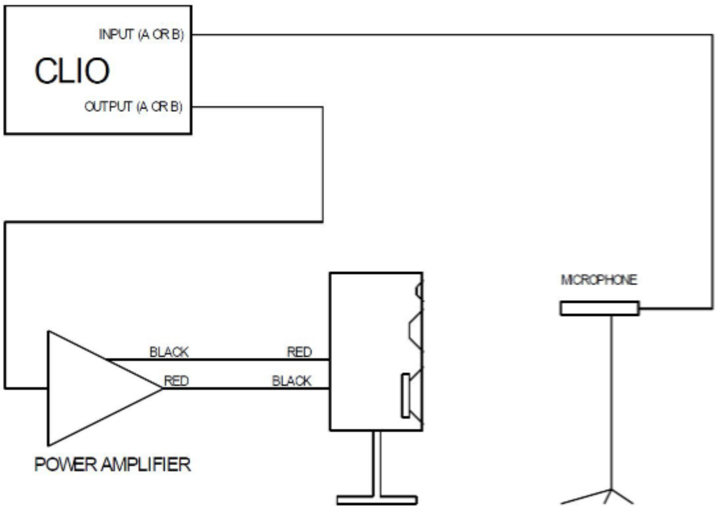
3) Measure impedance response of tweeter.

Save each successful impedance measurement to Documents\VituixCAD\Projects*projectname*\Impedance*drivername*_ZR.sin file for backup. Export ASCII Data as Frequency Data to *drivername*_ZR.txt file to the same directory (because VituixCAD does not support .sin files).

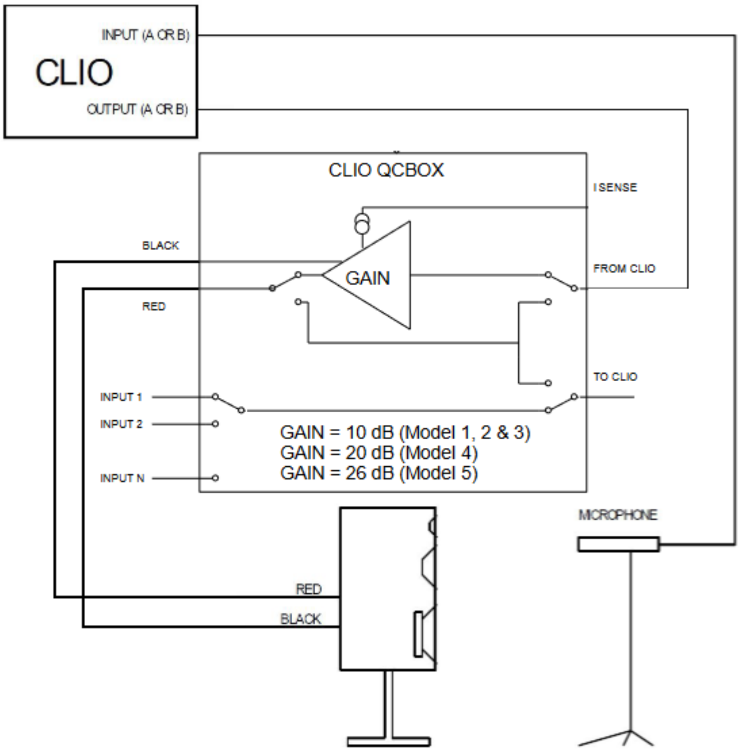


Gear setup for acoustical frequency response measurements

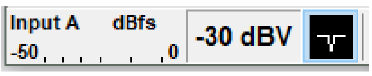
Connection with integrated or power amplifier:



Connection with QCBox 5 as power amplifier:



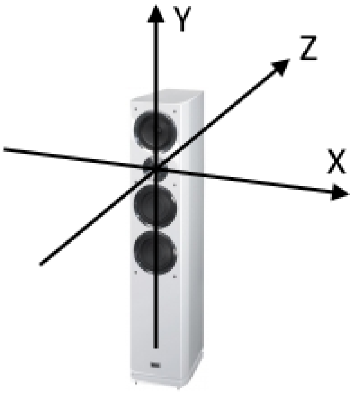
Note! Polarity of CLIO microphone signal is inverted compared to sound pressure deviation from environment. Polarity while acoustical frequency response measurements can be inverted with speaker cable such as both images above, or with inversion switch in hardware control toolbar of CLIO software:



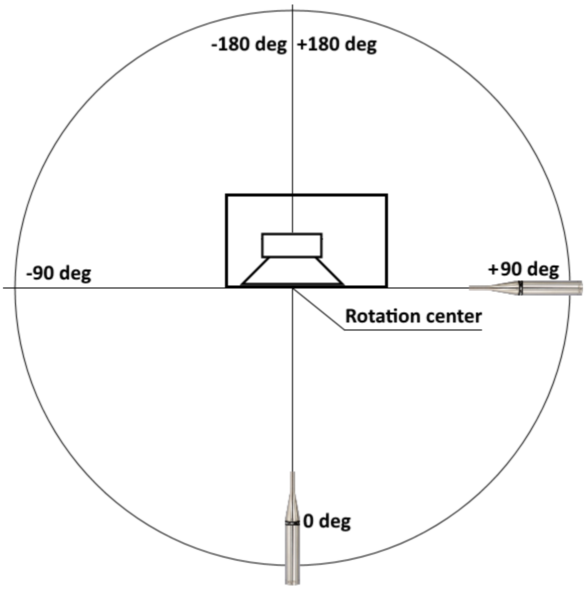
Terminology

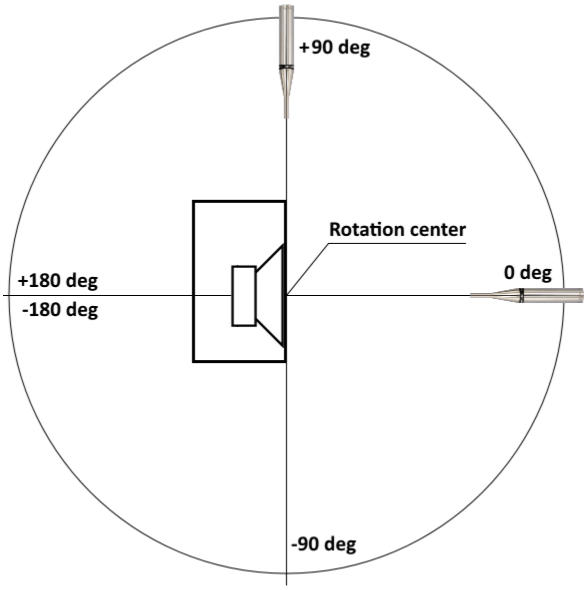
Few terms need to be defined first:

- X-axis is horizontal from left (-) to right (+) when observer is in front of speaker.
- Y-axis is vertical from floor (-) to ceiling (+).
- Z-axis is horizontal from microphone (-) through center point of DUT to front wall (+) when measuring on-axis response, 0 degrees hor & ver.



Rotation: Horizontal plane (top view) Vertical plane (side view)





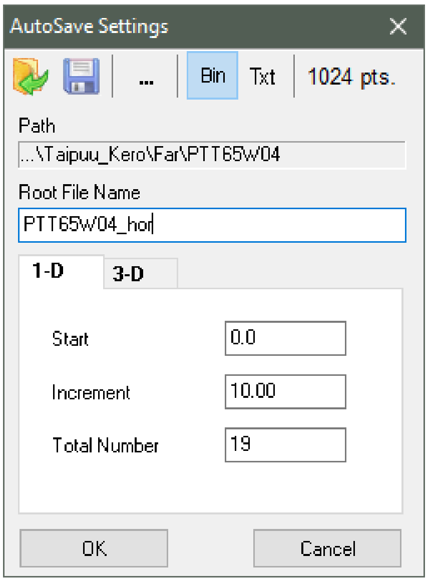
Mechanical setup

Prepare turning table with angle scale 0…+/-180 deg, step ticks 5 deg.

Line lasers help aligning mic and DUT. 3D laser such as Bosch GLL 3 below or above the mic aligns $X_{MIC} = X_{DUT}$ and Z_{MIC} i.e. measurement distance. 2D laser such as Bosch GLL 2-15 by the side aligns $Y_{MIC} = Y_{DUT}$ and Z_{DUT} i.e. baffle surface while on-axis measurement. Three laser beams cross at mic head, and three beams at rotation center of DUT.

Wireless keyboard on turning table helps pressing **G**o button after each rotation of manual turning table.

AutoSave Settings



Select with […] button where far field measurements are saved. Recommended directory is Documents\VituixCAD\Projects*projectname*\Far*drivername.* Selected directory is shown in *Path* text box.

Check *Bin* to save files in binary format. VituixCAD is used to convert IR measurements from .mls files to frequency responses as txt or frd files so uncheck *Txt*, and *pts.* can be anything.

Enter *Root File Name*. Format for dual plane far field measurements is *drivername* and plane keyword separated with _ or space. For example, PTT65W04_hor is PTT65W04 in horizontal plane.
Note! *drivername* should not contain plane keyword - especially “ver”. For example “Driver1_hor” is illegal causing association to vertical plane.

Enter *Start* angle and *Increment* in degrees, and *Total Number* of measurements. For example

- Start=0, Increment=10, Total Number=19 equals to 0...+180 deg with 10 deg steps, totally 19 measurements
- Start=-170, Increment=10, Total Number=36 equals to -170...+180 deg with 10 deg steps, totally 36 measurements.

Accept settings with OK button and reopen AutoSave Settings window. Save AutoSave Settings with *Save* (disk) button to measurement directory as *drivername*_hor.asd (or *drivername*_ver.asd) file for backup and later use in case you need to repeat the sequence.

Far field measurements

Result as USPL in dB/2.83V/1m

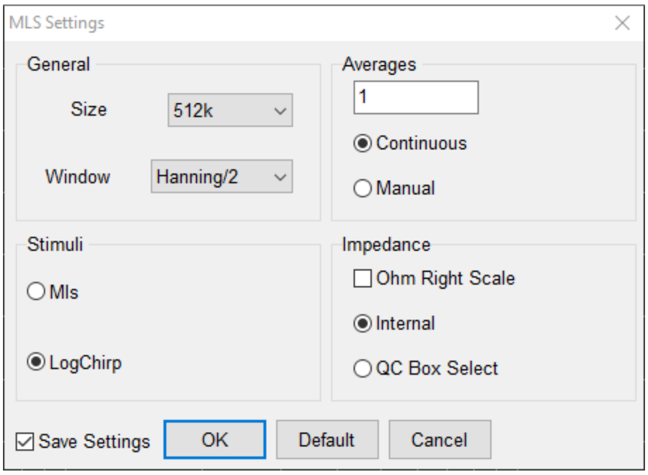
Output voltage of power amplifier should be known to measure voltage sensitivity USPL in dB/2.83V/1m. You can measure exact net gain from CLIO fw-02 output to power amplifier’s output for both MLS signal and LogChirp or Sinusoidal analysis. *Out* level visible in hardware control toolbar of CLIO 12 software exists at the **balanced** outputs of CLIO fw-02. Level at the unbalanced outputs is half = 6.02 dB lower.

Example: Nominal gain of power amplifier is 26 dB. Measured actual may be a bit different, for example 25.78 dB. Total net gain from Out level control to output terminals of QCBox 5 using **unbalanced** cable is 25.78 – 6.02 = 19.76 dB. So output of 2.83 V_{RMS} requires 10^(-19.76/20)*2.83 V_{RMS} = 0.291 V_{RMS} with Out level control in hardware control toolbar.

SPL-calibrated mic at 1000 mm from DUT gives result in dB/2.83V/1m with LogChip and Sinusoidal. MLS has 3 dB lower signal level.

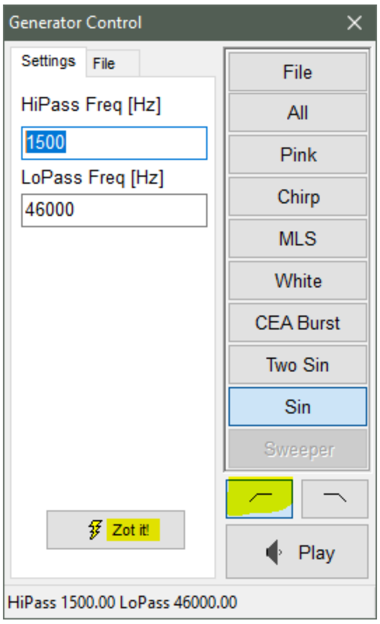
Settings

Far field responses are measured with ***MLS & LogChirp*** function. Accept the following MLS Settings with *Save Setting* checked. See user manual for more information.



Measure far field responses with 2.83 V_{AC} at driver’s terminals if sensitivity of driver is low...normal 80...90 dB/2.83V/1m.
Voltage should be significantly lower - for example 0.5 V_{AC} with very sensitive PA drivers to avoid exceeding 100 dBSPL. Measurement can be scaled back to USPL (dB/2.83V/1m) with Convert IR to FR tool in VituixCAD.

Fragile DUTs such as ribbon tweeters can be protected with high-pass filter configured via ‘Generator Control’ panel. Click high-pass button, enter HiPass Freq [Hz], any higher value to LoPass [Hz] and click *Zot it!* button.



High-passed stimuli can be compensated with A/B function in Calculator tool. B response is transfer function of high pass filter (2nd order Butterworth). Another option is MLS signal which is gentler than sine for HF radiators due to spectrum of white noise.

Set initial sensitivity of mic input A to -30 dBV in hardware control toolbar. Invert polarity of mic signal if speaker cable is not crossed. Phantom power on. Make test measurement and reduce sensitivity if dBfs bar clips to red.

Measurements

Measure far field responses of woofer and mid-range driver and tweeter at 1000 mm in horizontal plane around the speaker. Large constructions and deep horns may need longer than 1000 mm for example 3x baffle width to capture far field response closer to response at typical listening distance. Long panels/ribbons should be measured at typical listening distance which could be difficult…impossible indoors. Measure single side 0, 10, 20, …, 180 degrees in horizontal plane if speaker is horizontally symmetrical. Very asymmetrical constructions such as classic 3-way should be measured to both negative and positive off-axis angles: -170, -160, …, 0, …, +170, +180 degrees. Wall speakers should be measured and simulated to half space, and corner speakers to quarter space (see VituixCAD Options). Full-range horn speakers can be measured to half space only due to low pressure at rear side. Angle step of 5 degrees produces more accurate average. That could be useful with radiators having dense on-axis response deviations such as compression driver in a horn.

Basic rules

- All far field measurements should have the same signal level from power amplifier to maintain sensitivity differences. Volume of integrated amplifier should not be touched between measurements of different drivers. Exception is very sensitive drivers which could require e.g. 0.5 V_{RMS} signal, and scaling back to 2.83 V (+15 dB) for crossover simulation.
- 1st order reflections should be avoided or delayed. Measure drivers at elevation of close to half of room height. Center point of DUT is for example 125 cm from the floor and ceiling. >150 cm from DUT to the walls, and >150 cm from the mic to the walls. Absorb with large and soft pillows on the floor and ceiling if possible, to enable time windows longer than 4 ms.
- Saved measurement filenames (.mls) must have valid coding for plane and off-axis angle. CLIO's 1-D style <name-prefix> <angle*100>.mls is perfect for VituixCAD. For example M15CH002_hor 11000.mls equals M15CH002 to horizontal angle of +110 degrees.
  Another valid format is CLIO's 3-D balloon style <name-prefix> <polar*100> <azimuth*100>.mls.
  Single axial measurement (without off-axis responses) could also have plane and angle coding with "hor 0" though it's not anymore mandatory with VituixCAD 2.0.
- Elevation of mic is at the center point of driver under test. Turn speaker back/front if front baffle is tilted. Tilt turning table front (rear up) with ground plane measurement to aim driver's axis towards the mic while hor

0 deg measurement.
Exception: Mid and tweeter can be measured at common mic elevation = average Y of center points if the drivers are small and close to each other, baffle is straight (non-stepped) and vertical plane is not measured i.e. drivers are circular and hor/ver difference in baffle diffraction is ignored on purpose.

- Rotation center on X-axis while off-axis measurement sequence is at the center point of driver under test.
- Rotation center on Z-axis while off-axis measurement sequence:
  a) Rotation center on Z-axis is common for all drivers if drivers are installed in straight non-stepped baffle. Rotation center is typically on surface of front baffle for the tweeter. Z=0 mm for all drivers in crossover simulation regardless of difference between baffle surface and acoustical center.
  b) Rotation center on Z-axis varies with stepped baffle. Drivers on each baffle level has own rotation center on Z-axis. Distance from each baffle level to microphone should be constant, typically 1000 mm. Differences in baffle levels on Z-axis are entered to the simulator as Z mm of driver instance in XO, e.g. tweeter Z=0 mm, mid-range Z=-20 mm, woofer Z=-100 mm.
- Asymmetrical rectangular radiators such as AMTs and ribbons as well as elliptical and rectangular horns with height <> width should be measured in both planes.
- All drivers should be measured to same off-axis angles. Subwoofers too if they are included in the same construction and project, and power and DI responses are simulated with the other drivers (*).
- If vertical plane is measured, off-axis angles should be equal to horizontal plane to avoid mirroring from horizontal to vertical and vice versa (*).

(*) Last two rules have not been mandatory for a long time with VituixCAD 2.0 if *Mirror missing* and *Interpolate* are checked and *Angle step* >= 5 deg in Options window, but common directions for all drivers and both planes make measuring easier and faster due to file naming system with AutoSave Settings.

Possible exceptions

Measurement of vertical plane can be skipped if the driver and possible wave guide/horn are circular i.e. directivity of radiating surface in vertical plane is equal to horizontal plane. Skipping of vertical plane could cause small hump (<1 dB) to power response at diffraction peak frequency if baffle height is longer than width. In that case sound balancing should be weighted by axial response around diffraction peak frequency (wavelength = baffle width).

It's also possible to save time if construction contains several drivers of the same model. Different locations on the baffle usually cause small deviations (<1dB) to on-axis response and tiny deviations (<0.5 dB) to power and directivity index responses compared to full data if at least baffle width is common for all driver instances.

Timing differences

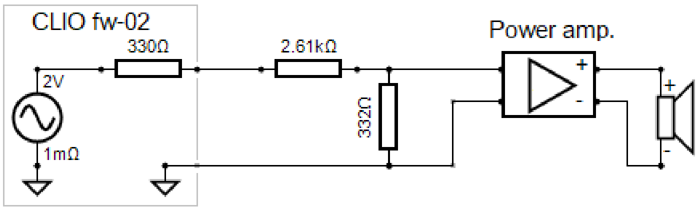
Phase response includes timing difference between rotation center (=center of DUT on baffle surface) and actual (frequency-dependent) acoustical center of the driver. Phase response includes also extra travel distance from radiator's throat via possible wave guide/horn and around box edges including delayed diffractions when speaker is rotated >90 deg while off-axis measurement sequence.
Therefore so called 'Z difference' between the drivers or baffle surface and assumed/measured acoustical center of the driver should never be entered to Z mm coordinate of driver instance in crossover simulation with unidirectional drivers such as boxed speakers and horns to avoid geometry calculation error which would cause immediate response summing error to off-axis directions.

Near field measurements

Level reduction

Near field responses of active cones, passive cones and ports should be measured with significantly lower signal level compared to far field to avoid distortion/compression, clipping and mechanical hitting to microphone. Suitable reduction compared to far field measurements is 15…30 dB depending on radiating area and number of ports/cones; larger total area -> less reduction required. Level is reduced primarily with *Out* level in hardware control toolbar in CLIO software though output level requirement could be below 30 mV if gain of power amplifier is high and driver is sensitive. Alternatives maintaining full level setting resolution and source S/N are volume potentiometer of amplifier or attenuating cable between CLIO fw-02 and power amplifier.

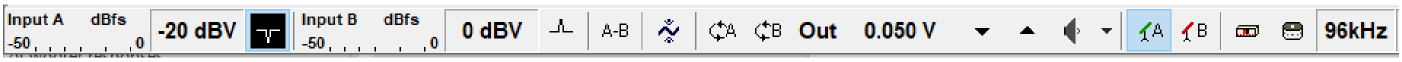
Unbalanced cable with attenuation of 20 dB:



Settings

MLS Settings are the same as with far field measurements.

Set initial sensitivity of mic input A to -20 dBV. Invert polarity of mic signal if speaker cable is not crossed. Phantom power on. Make test measurement and reduce sensitivity if dBfs bar clips to red.



Measurements

Measure near field response of one woofer cone at 5 mm from center of dust cap. Measure at 5 mm from cone close to phase plug if the driver has phase plug. If two woofers have shared box, feed signal to both woofers and isolate the other cone (which is not under test) by locating thick pillow between the drivers. Goal is to prevent midrange frequencies going from the other driver to mic too much. Do not brake the cone or block air flow to avoid changing system resonance which would cause some error to result.

Measure near field response of reflex port(s) or passive radiator(s). Mic in the center of vent at baffle surface if vent is not rounded. If vent has rounding, penetrate few millimeters inside, where tube with constant diameter begins. Not too deep.

Measure near field response of one mid-range driver at 5 mm from center of dust cap. Measure at 5 mm from cone close to phase plug if the driver has phase plug.

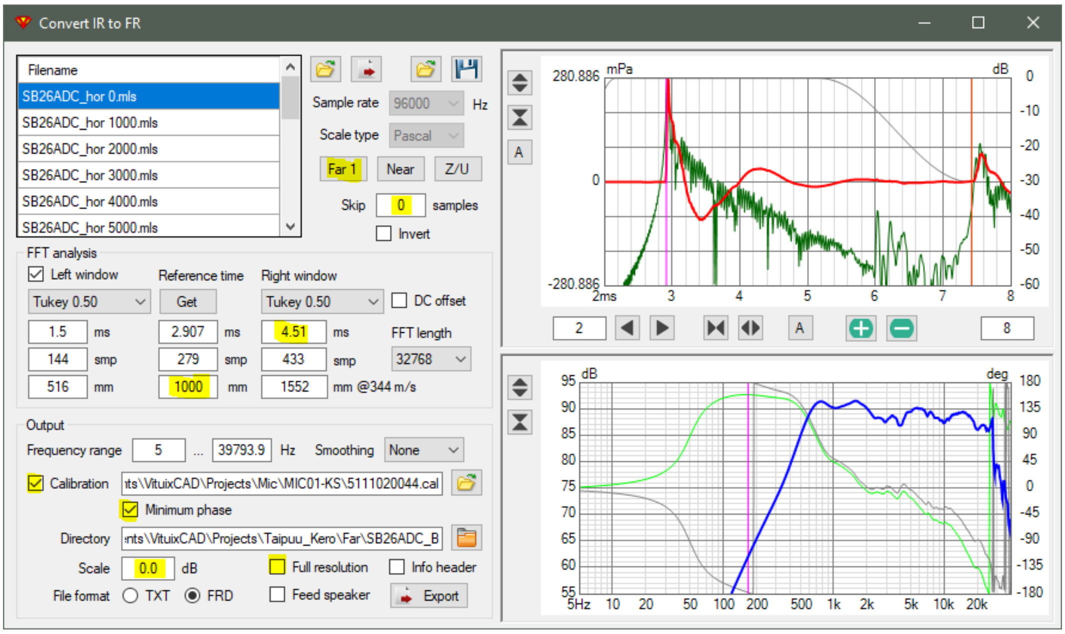
Post-processing example: 2-way with two passive radiators

Exporting far field responses

Export far field responses of tweeter

Open ***Convert IR to FR*** tool in VituixCAD 2.0.

Open far field measurements of the tweeter to the file list with *Open* button. Select axial response; _hor 0.mls.



Click ***Far 1*** button to set default values for the 1st far field export (tweeter's).
Verify that Skip samples is 0.
Verify that ETC curve is visible in time domain (upper) chart. Verify that Normal phase and Minimum phase curves are visible in frequency domain (lower) chart.

FFT analysis group:

- Enter measurement distance (from rotation center of DUT to mic) in millimeters to the lowest *Reference time* text box. Adjust reference time until normal phase curve is close to minimum phase curve at 10 kHz if signal path contains DSP gear/app. with latency.
- Adjust ***Right window*** with red cursor in IR graph to the beginning of the first reflection. Should be 3.5-6 ms.

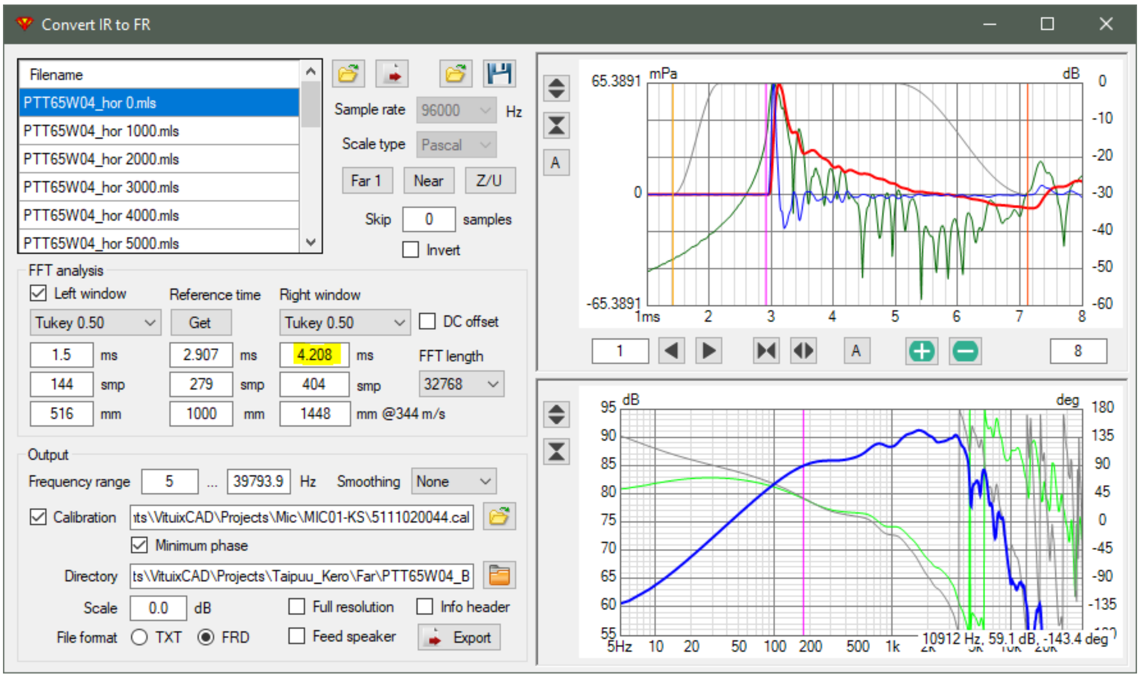
Output group:

- Select microphone ***Calibration*** file to text box with *Open* button and check Calibration.
- Check ***Minimum phase*** if you want to compensate missing phase response of calibration file.
- Change output ***Directory*** for txt/frd files if the same directory with .mls files is not okay.
- Normal scaling is 0.0 dB with all drivers measured at 1000 mm with 2.83 V_{RMS}.
  Adjust ***Scale*** dB if DUT was measured with signal level reduced from 2.83 V due to very high sensitivity, or measurement distance was an exception.
- Select ***File format*** space delimited TXT or tab delimited FRD.
- Frequency responses of deep horns could be exported with ***Full resolution*** checked. Distance between microphone and acoustical center of the driver varies quite much during rotation from 0 to 180 deg. Internal 1/48 oct. frequency resolution is able to handle about ±795 us delay variation i.e. ±273 mm variation in acoustic center compared to reference point with max. 20 kHz frequency scale. *Full resolution* export does not have this limit, but it's much slower to process in XO simulation.
- Check ***Info header*** if you want to add metadata to txt/frd files.

Scroll measurements in the file list to check that IR window settings are valid and frequency responses look okay.
Save far field frequency responses as text files with ***Export*** button.

Export far field responses of mid-woofer

Open far field measurements of the mid-woofer to the file list with *Open* button. Select axial response; _hor 0.mls.



FFT analysis group:

- Adjust ***Right window*** with red cursor in IR graph to the beginning of the first reflection. Should be 3.5-6 ms.
- Do not change other settings!

Output group:

- Change output ***Directory*** for txt/frd files if the same directory with .mls files is not okay.
- Do not change other settings!

Scroll measurements in the file list to check that IR window settings are valid and frequency responses look okay.

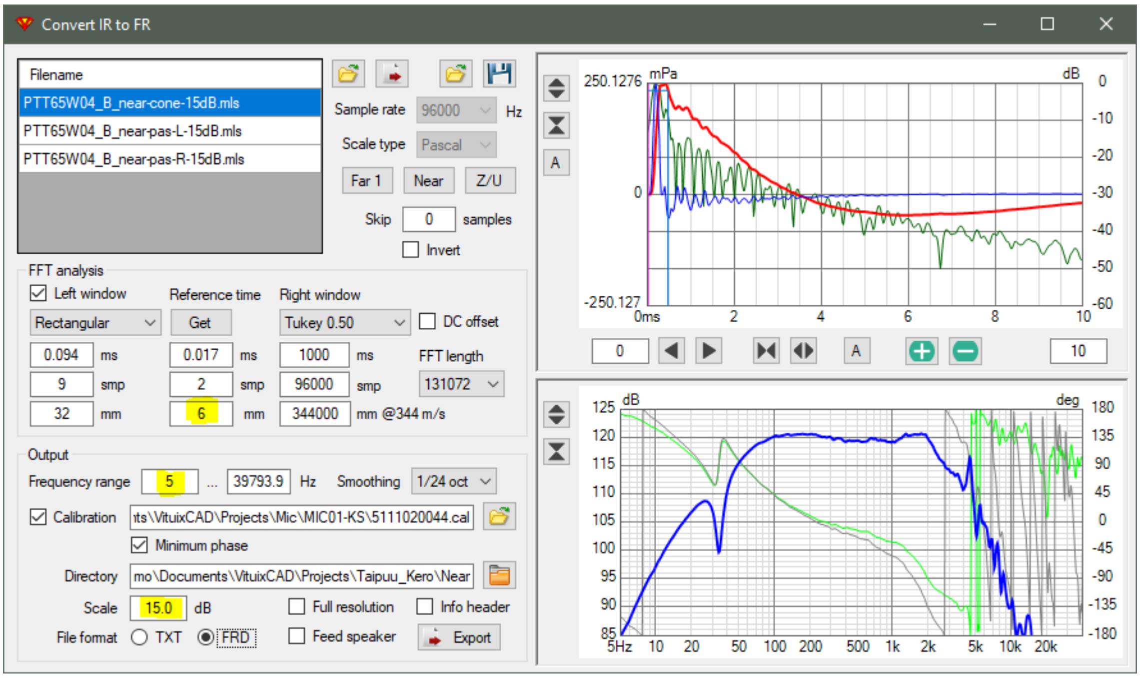
Save far field frequency responses as text files with ***Export*** button.

Exporting near field responses

Export near field response of mid-woofer and ports/passive radiators

Open all near field measurements of the mid-woofer to file list with *Open* button.

Select cone measurement from the list.



Click ***Near*** button to set default values for near field export.

FFT analysis group:

- Enter 5-7 mm (distance from cone to mic) to the lowest *Reference time* text box. Adjust reference time until normal phase curve is close to minimum phase curve at 1 kHz if signal path contains DSP gear/app. with latency.
- Do not change other settings!

Output group:

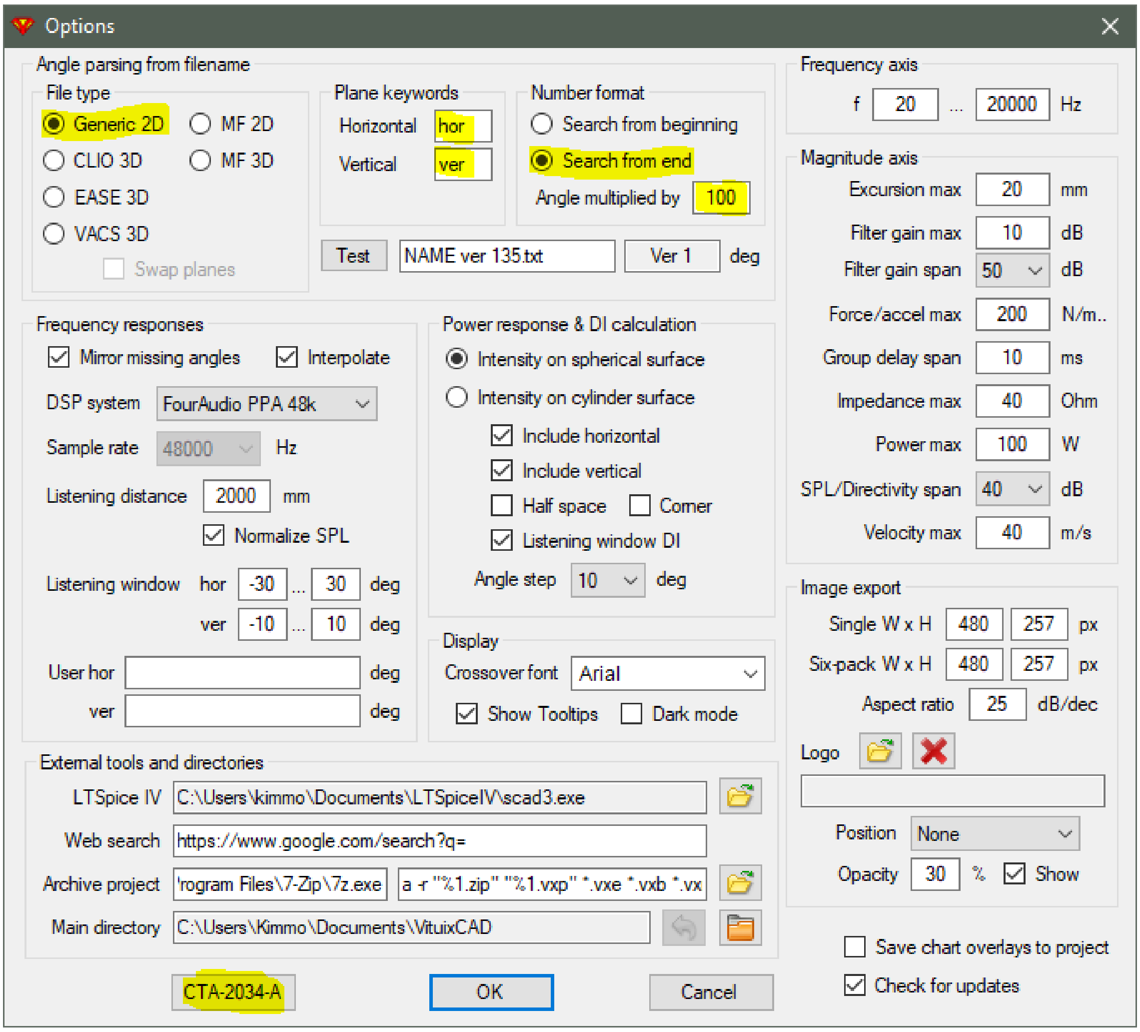
- Adjust ***Frequency range*** from the lowest reliable frequency to maximum. For example, 11 … 39793.9 Hz.
- Change output ***Directory*** for txt/frd files if the same directory with .mls files is not okay.
- Compensation of signal level reduction can be done with *Scale dB* text box. In this example, compensation of 15 dB reduction is done with Merger tool.

Scroll measurements in the file list to check that IR window settings are valid and frequency responses look okay.

Save far field frequency responses as text files with ***Export*** button.

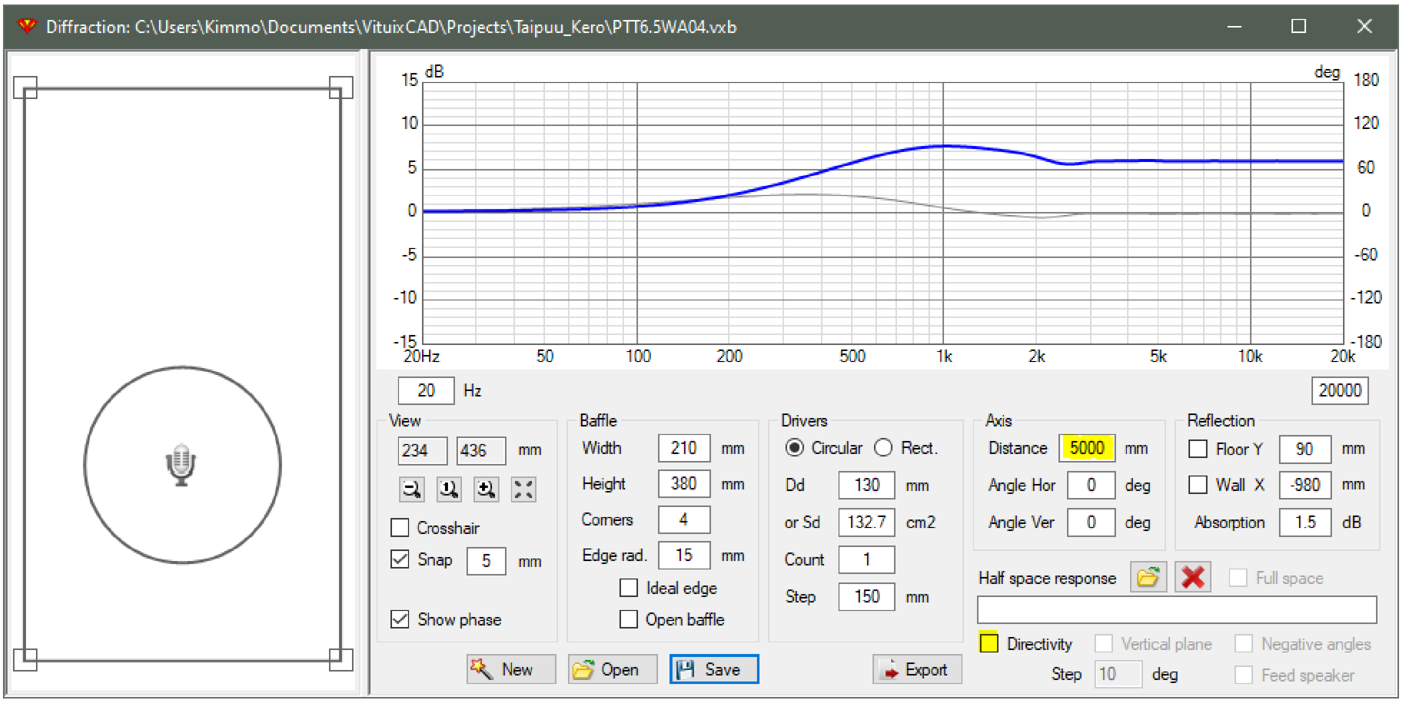
VituixCAD Options

Verify that *Number format* of angle coding is compatible with CLIO. See mark-ups in yellow.
Click CTA-2034-A button to set default parameters for directivity calculations. Accept and close with OK button.

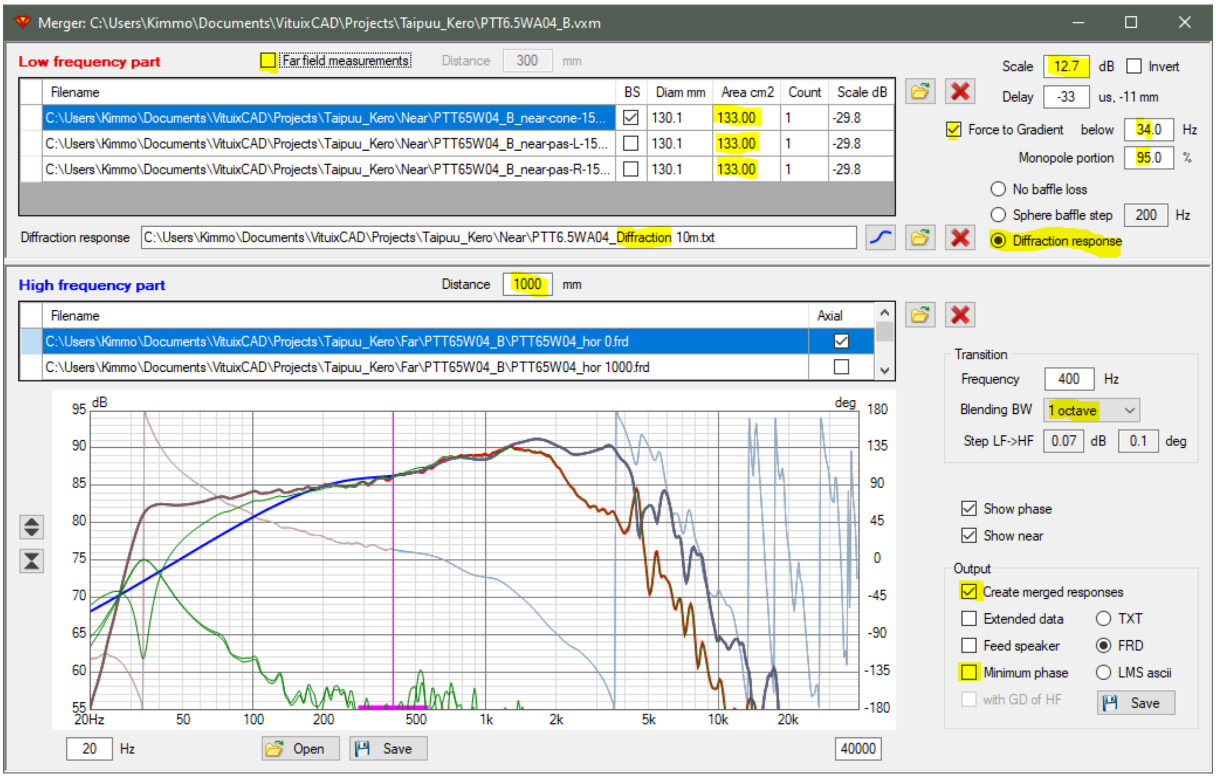


Baffle simulation with Diffraction tool

Enter Baffle dimensions and Drivers parameters and click New. Adjust location of mid-woofer, and mic to the center of it. Set *Axis Distance* to typical maximum/possible listening distance to get maximum baffle loss to exported file. Uncheck *Directivity* and export cabinet impact response to VituixCAD\Projects*projectname*\Near directory with *Export* button.



Merging near field and far field responses with Merger tool



Low frequency part

Uncheck *Far field measurements*. Load near field measurements to *Low frequency* list. Check *BS* field of cones/ports located to front baffle i.e. creating baffle step to on-axis direction. Enter *Area cm2* or *Diam mm* and *Count* for each cone and port. Enter measurement distance of HF far field responses to *Distance mm* text box.

You can force very low frequencies towards omni…cardioid…dipole with *Force to Gradient* checkbox and text boxes if actual directivity can be predicted. In this case, passive radiators on the side baffles presumably create an omni pattern below system resonance so possible directivity in time windowed far field measurements can be removed

Check Diffraction response and load simulated baffle effect response to *Diffraction response* text box.

High frequency part

Load far field measurements to *High frequency* list. Verify that program detects on-axis response i.e. *Axial* field is checked for on-axis. Select initial Blending BW = 1 octave. Set initial transition frequency to 400-500 Hz (2.0 divided by length of Right window in Convert IR to FR).

Scaling of LF part

Amplitude of near field responses in Low frequency list is adjusted manually with *Scale [dB]* until levels are equal within blending range, especially 400…700 Hz. If output signal level was reduced e.g. 15 dB for near field measurements, required LF *Scale* is close +15 dB. Not exactly because level conversion from near field to far field with radius and distance only is simplification. In this case +12.7 dB aligns total LF to (unscaled) on-axis HF quite credibly.
Delay [us] is set automatically while adjusting transition frequency. Delay is expected to be quite close to 0 us, but small deviation is not alarming at transition of 300-600 Hz.

Output

Check *Create merged responses*, uncheck *Minimum phase* and export merged responses as .txt or .frd with *Save* button in bottom right corner.

Save

Save Merger project to VituixCAD\Projects*projectname* directory for later use with Save button below the chart.

Merger video lesson (partly outdated):
https://www.youtube.com/watch?v=cUGDhpleWD0