Tonochi's Audio Room – Supplemental Information

MEASUREMENT METHODS

2020/03/02

△1: 2019/08/12
Measurements are input directly to Excel spreadsheets

Tonochi methods for measurements

Some of Tonochi Methods are a bit different from the industrial standards, which are specified by organizations like ANSI and JEITA. I devised the ways even amateurs can carry out. Although the accuracy is slightly lower than the professional methods, I suppose Tonochi Methods are effective to find out faults and causes of degradation of sound quality.

Some data measured with Tonochi Methods would be worse, compared to the industrial standards. The purpose of Tonochi Methods is not to obtain magnificent data but find out causes of degradation of sound quality. I think the industrial standards specify conditions so that manufacturers can easily get excellent data.
The fuel efficiency data printed on catalogs of automobile are far better than the actual fuel efficiency. This is because the method and condition are specified so as to get good data. I suspect that the same thing goes in the audio industry (sorry if I am wrong).

Here I describe Tonochi's unique methods for measurements on audio equipment and system. Measurements on small parts like resistors and capacitors are not described here.

Contents

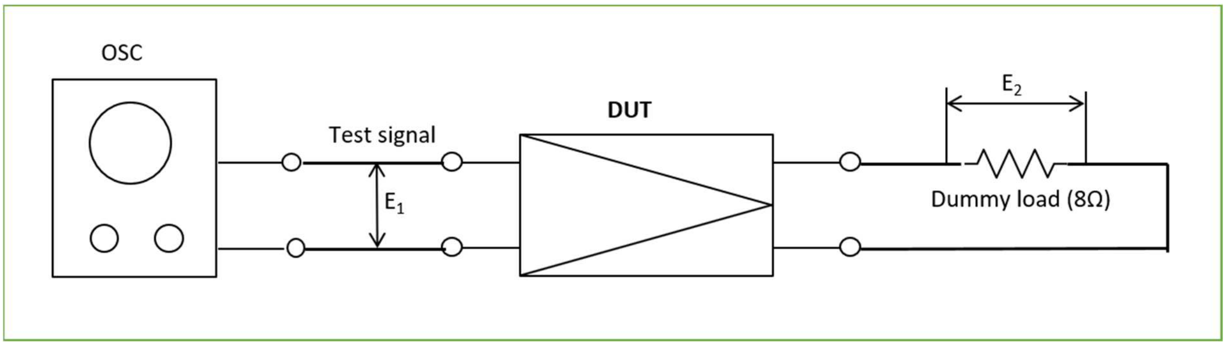
Measurements on Power Amplifiers

Note that DUT (Device Under Test) stands for the power amplifier to be measured.

Frequency Response

Apparatus

The output voltage E_2 (RMS) is measured with a digital oscilloscope. A DMM is not used, because the error is too large in RF range.
The dummy load is 8 ohm non-inductive resistor.



Conditions

- The test signal is sine wave ranging 1Hz-1MHz.
- Frequency step: standard step - 1.0, 1.25, 1.6, 2.0, 2.5, 3.15, 4.0, 5.0, 6.3, 8.0, 10, 12.5, …
- Each channel is measured separately for stereo amps; the other channel's input is short-circuited to ground
- The attenuator of DUT is set to maximum (0dB)
- The output power of DUT: 0.01W, 1W, 1/2Max （1kHz）

Procedure

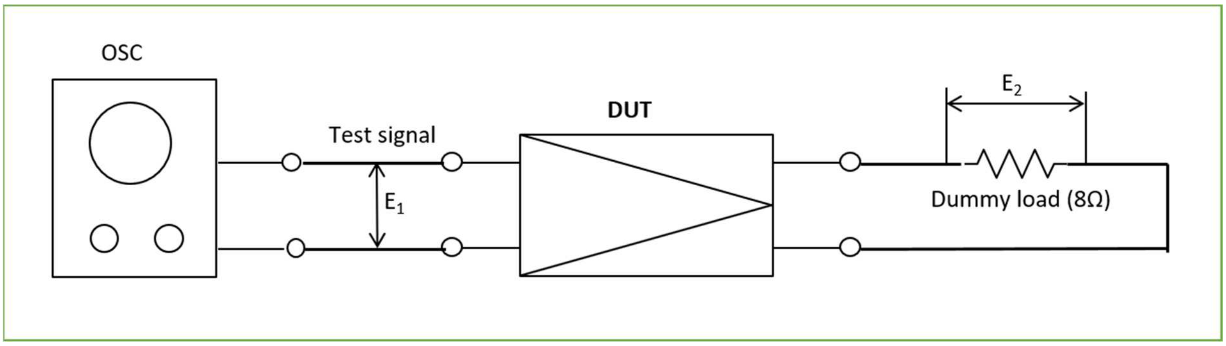
1. Turn on DUT and wait 5 minutes for warming-up.
2. Adjust the oscillator so that the output of DUT becomes 1W （E_2=2.83V） at 1kHz.
3. Measure E_2 at each frequency~~, and write it down on the measurement sheet.~~△1 In the meantime, check the DC voltage and the waveform. If any problem is found, save the waveform.
4. Repeat step-2 and -3 for the output of 0.01W （E_2=0.283V） and the half of the maximum output.
5. ~~Input the measurement data in the Excel sheet to visualize them.~~ △1
6. Calculate the gain of DUT using the data at 1kHz: Gain[dB] = $20\log(E_2/E_1)$

Maximum Output Power

Apparatus

The output voltage E_2 (RMS) is measured with a digital oscilloscope.
The dummy load is 8 ohm non-inductive resistor.

The temperature of the output transistor (if possible) or the heatsink is measured with DMM.



Conditions

- Test signal: sine wave of 20Hz, 100Hz, 1kHz, 10kHz, 40kHz
- Duration: 1 minute
- Three channel combinations for stereo amps: L-ch only, R-ch only, and L + R
- When a single channel is measured, the other channel's input is short-circuited to ground
- If DUT has an input attenuator, set it to maximum (0dB)

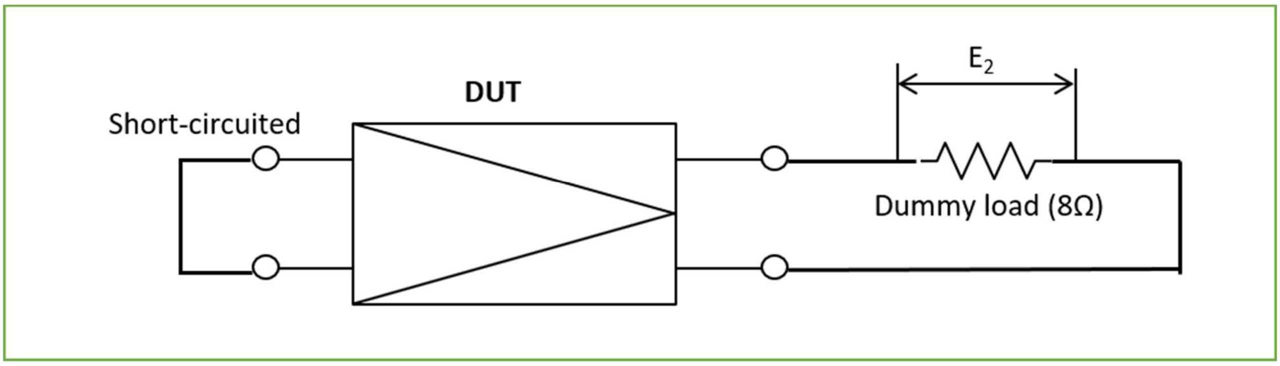
Procedure

1. Turn on DUT and wait 5 minutes for warming-up.
2. Turn up E_1 gradually, while observing the waveform, until E_2 is distorted. Turn down E_1 very slightly and keep the level.
3. Check that the waveform and the temperature keep normal for one minute.
4. Record E_2 as the maximum output if the waveform and the temperature are normal after one minute elapsed.
5. If the waveform is distorted, turn down E_1 until E_2 becomes normal. Record the lowered E_2 as the maximum output.
6. If the temperature is still going up and it approaches the limit, turn down E_1 until the temperature becomes stable. Then, record E_2 of that moment as the maximum output.
7. ~~Input the data to Excel sheet to calculate~~△1 the output power [W]: $P[W] = E_2^2/8$

Residual Noise

Apparatus

The output voltage E_2 (RMS) is measured with a digital oscilloscope.
The dummy load is 8 ohm non-inductive resistor.
The industrial standard specifies that the input of DUT is short-circuited to the ground by 600 ohm resistor, but in Tonochi Method the input is short-circuited with a commercially available shorting plug.



Conditions

- Any filter like an A-curve filter is not used
- If DUT has an input attenuator, set it to maximum (0dB)

Procedure

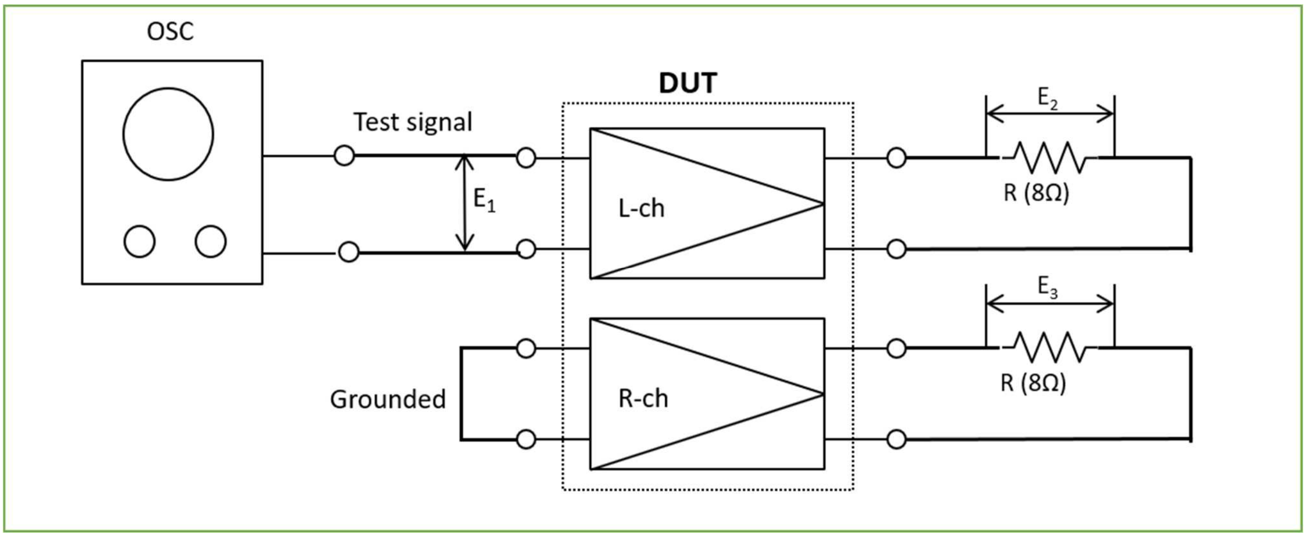
1. Turn on DUT and wait 5 minutes for warming-up.
2. Record not only the voltages (E_2) but the waveforms.

Channel Separation (Crosstalk)

This measurement is applicable to stereo amplifiers only.

Apparatus

The output voltage E_2 (RMS) is measured with a digital oscilloscope.
The waveforms are also observed and recorded.
The dummy load is 8 ohm non-inductive resistor.



Conditions

- Test signals: 20Hz, 1kHz, 20kHz sine waves
- The output of DUT: 1W (E_1=2.83V)
- Directions: both L→R, R→L
- If DUT has an input attenuator, set it to maximum (0dB)
- The input of the channel to be measured is grounded

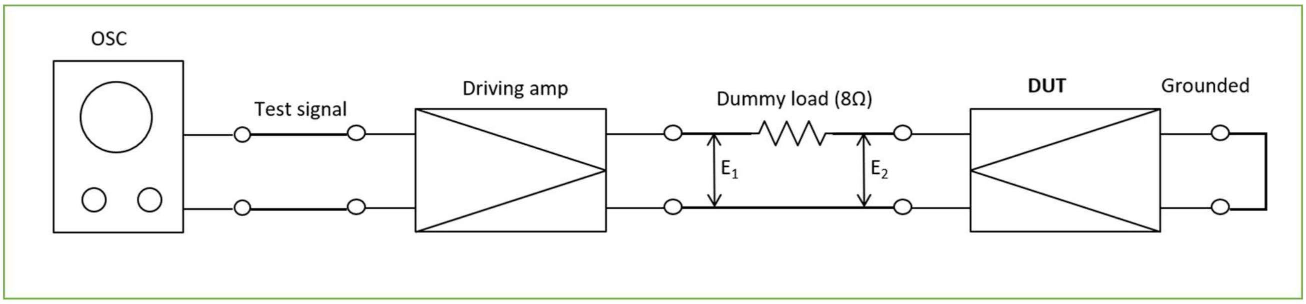
Procedure

1. Turn on DUT and wait 5 minutes for warming-up.
2. Adjust E_1 so that the output of DUT becomes 1W (E_2=2.83V).
3. Measure ~~and record~~ E_3. △1
4. ~~Input the data to the Excel sheet to calculate~~ △1 the channel separation: CS[dB] = 20log(E_2/E_3)

Damping Factor (DF)

Apparatus

The output voltage E_2 (RMS) is measured with a digital oscilloscope.
The dummy load is 8 ohm non-inductive resistor.
Another power amplifier (called driving amp) is used to drive the load.



Conditions

- Test signals: sine waves of 20Hz, 1kHz, 20kHz
- The output of the driving amp: 1W (2.83V)
- If DUT has an input attenuator, set it to maximum (0dB)
- Each channel is measured separately for stereo amps; the other channel's input is grounded

Procedure

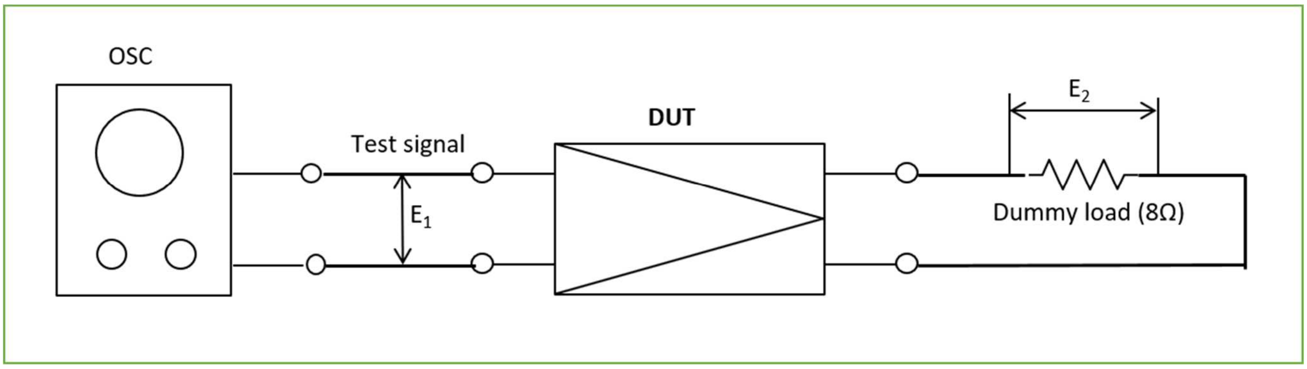
1. Turn on DUT and wait 5 minutes for warming-up.
2. Adjust the oscillator so that E_1 becomes 2.83V (1W).
3. Measure ~~and record~~ E_2. △1
4. ~~Input the data to the Excel sheet to calculate~~△1 DF = E_1/E_2 - 1

Linearity

Gains at the output power of 0.01W to the maximum are measured.

Apparatus

The input voltage E_1 and the output voltage E_2 (both are RMS) are measured with a digital oscilloscope.
The dummy load is 8 ohm non-inductive resistor.



Conditions

- Test signals: sine waves of 100Hz, 1kHz, 10kHz
- The output of DUT: 0.01W, 0.1W, 1W, 10W, and max
- If DUT has an input attenuator, set it to maximum (0dB)
- Each channel is measured separately for stereo amps

Procedure

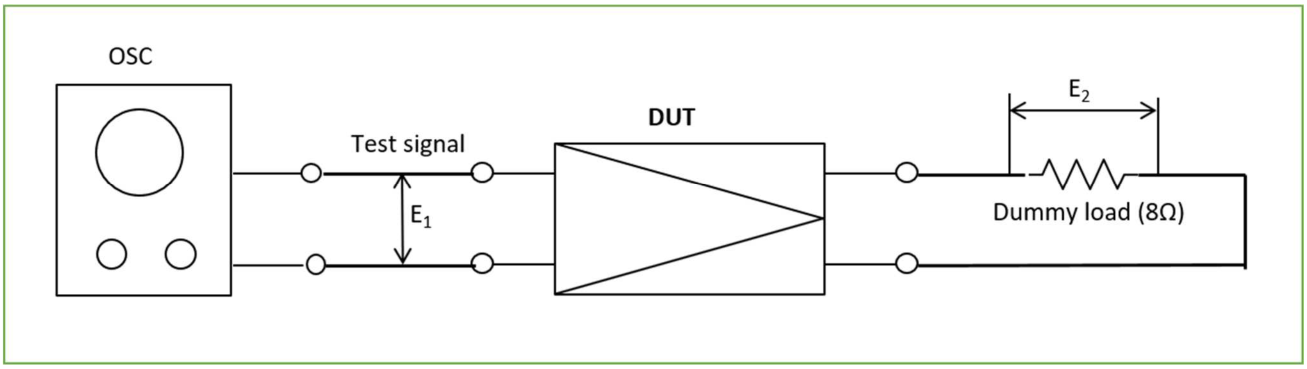
1. Turn on DUT and wait 5 minutes for warming-up.
2. Adjust E_1 so that E_2 becomes 2.83V (1W).
3. Measure E_1~~, and record it~~. △1
4. Repeat the step-3 for E_2=0.283V（0.01W）, 0.894V（0.1W）, 8.94V（10W）.
5. Adjust E_1 so that E_2 becomes the maximum, and record E_1, E_2.
6. ~~Input the data on the Excel sheet and make the graph of linearity.~~ △1

FFT Analysis

The response of DUT against a sine wave is analyzed by FFT to obtain the distortion ratios (THD, THD+N and IMD) and signal/noise ratio (SNR).

Apparatus

The output voltage E_2 (RMS) is measured and analyzed with a digital oscilloscope.
The dummy load is 8 ohm non-inductive resistor.



Conditions

- Test signals: sine waves of 100Hz, 1kHz, 10kHz
- The output power of DUT: 1W, 10W, and max
- If DUT has an input attenuator, set it to maximum (0dB)
- Each channel is measured separately for stereo amps
- Any filter like A-curve filter shouldn't be used

Procedure

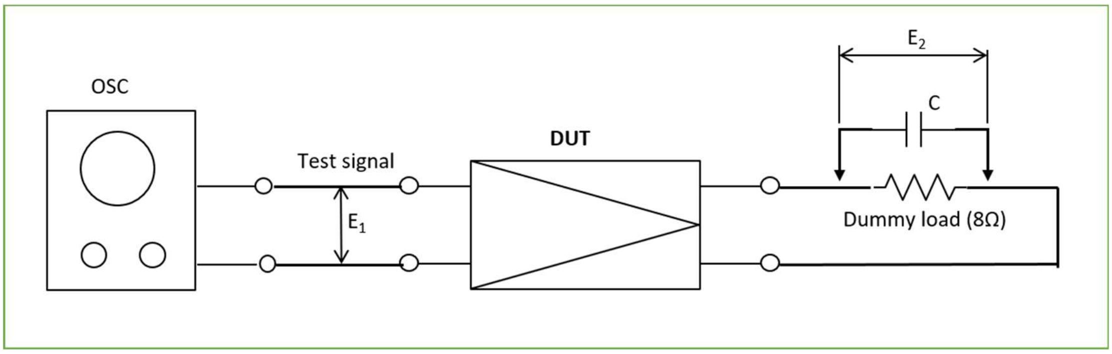
1. Turn on DUT and wait 5 minutes for warming-up.
2. Set the frequency to 1kHz.
3. Adjust E_1 so that E_2 becomes 2.83V (1W).
4. Measure E_2, and analyze it with FFT.
5. Repeat the step-4 for E_2=8.94V（10W） and E_2=max.
6. Repeat the step-3-5 for f=100Hz and 10kHz.
7. Save the data together with waveforms.

Square Wave Test

DUT's transient response and stability are checked by observing waveform of square wave response.
In addition to the measurement, this test includes adjusting DUT to minimize overshooting and ringing.

Apparatus

The waveforms of E_2 is observed with a digital oscilloscope.
The dummy load consists of 8 ohm non-inductive resistor and capacitor C (=0.47uF).



Conditions

- Test signals: square waves of 100Hz, 1kHz, 10kHz
- The output power of DUT: 1W, 10W
- Load: w/ C (=0.47uF), and w/o C
- If DUT has an input attenuator, set it to maximum (0dB)
- Each channel is measured separately for stereo amps
- The input of the other channel is short-circuited to ground

Procedure

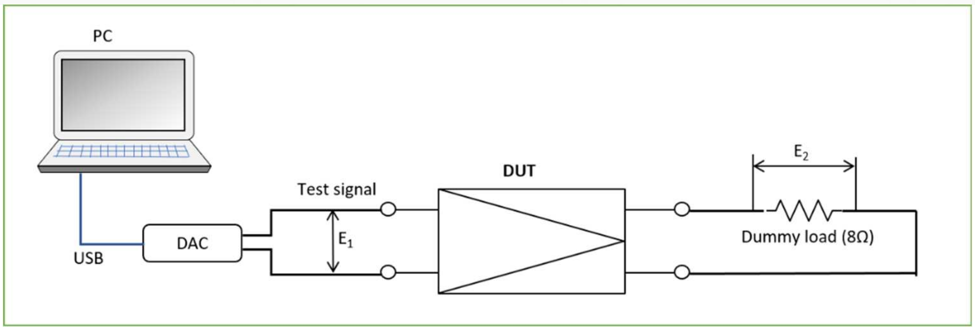
1. Turn on DUT and wait 5 minutes for warming-up.
2. Remove C.
3. Set the frequency to 1kHz.
4. Adjust E_1 so that E_2 becomes 2.83V(=2.83V_{peak}) (1W).
5. Observe the waveform of E_2, and save it as a file.
6. Repeat the step-5 for E_2=8.94V(=8.94V_{peak})（10W）.
7. Repeat the step-4 to -6 for f=100Hz and 10kHz.
8. Attach C and repeat the step-3 to -7.
9. If overshooting and/or ringing is observed, change some parts like the lag compensation capacitor to eliminate overshooting and ringing.

Impulse Response Test

DUT's transient characteristic and stability are checked by observing waveforms of impulse response.

Apparatus

The waveforms of E_2 is observed with a digital oscilloscope.
The test signal is generated by PC. The resolution must be 192kHz/24bit or higher.
The dummy load is 8 ohm non-inductive resistor.



Conditions

- Test signal: impulse of 50us in width
- The output power of DUT: 2.83V_{peak} (1W)
- If DUT has an input attenuator, set it to maximum (0dB)
- Each channel is measured separately for stereo amps
- The input of the other channel is short-circuited to ground

Procedure

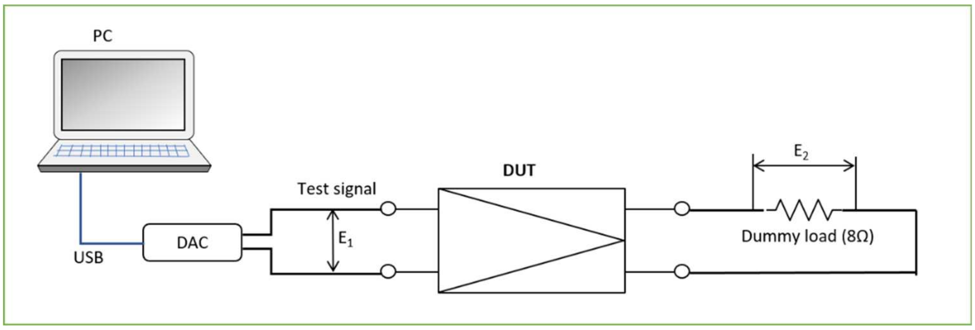
1. Turn on DUT and wait 5 minutes for warming-up.
2. Generate square wave and adjust E_1 so that E_2 becomes 2.83V_{peak}.
3. Generate impulse of the same peak level as the square wave, and observe and save the waveform of E_2.

Tone Burst Wave Test

The purpose of this test is to confirm low dynamic distortion and high stability of DUT by using tone burst waves in full magnitude.

Apparatus

The waveforms of E_2 is observed with a digital oscilloscope.
The test signal is generated by PC. The resolution must be 192kHz/24bit or higher.
The dummy load is 8 ohm non-inductive resistor.



Conditions

- Test signal: tone burst wave in duty ratio of 1:12
- The frequency the sine wave: 20Hz, 160Hz, 800Hz, 2.5kHz, 6.8kHz, 20kHz (800Hz and 6.8kHz are the crossover frequencies of Gaudi II)
- The output of DUT: maximum
- If DUT has an input attenuator, set it to maximum (0dB)
- Each channel is measured separately for stereo amps
- The input of the other channel is short-circuited to ground

Procedure

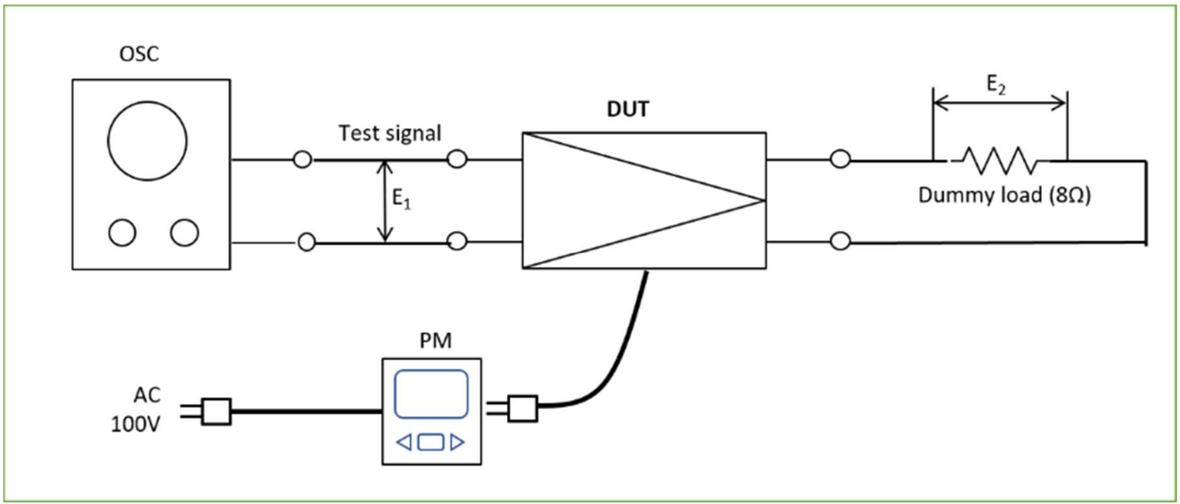
1. Turn on DUT and wait 5 minutes for warming-up.
2. Adjust E_1 so that the output of DUT becomes maximum.
3. Make PC generate tone burst wave.
4. Observe the waveform of E_2, and save the data.

Power Dissipation

Apparatus

The power dissipation is measured with a power meter.

The test signal is sine waves.
The dummy load is 8 ohm non-inductive resistor.



Conditions

- Test signal: sine waves of 20Hz, 1kHz, 20kHz
- The output of DUT (E_2): zero, 1W, maximum, plus power-off (standby) state
- If DUT has an input attenuator, set it to maximum (0dB)
- If DUT is a stereo amp, both channels operate

Procedure

1. Turn on DUT and wait 5 minutes for warming-up.
2. Set the frequency of E_1 to 1kHz.
3. Adjust the voltage of E_1 so that E_2 becomes 2.83V (1W).
4. Read the indication of the power meter.
5. Repeat step-4 for the output of zero and maximum.
6. Repeat step-3 to -5 for frequencies of 20Hz and 20kHz.
7. Read the indication of the power meter when DUT is off (standby).

Measurements on Preamplifier

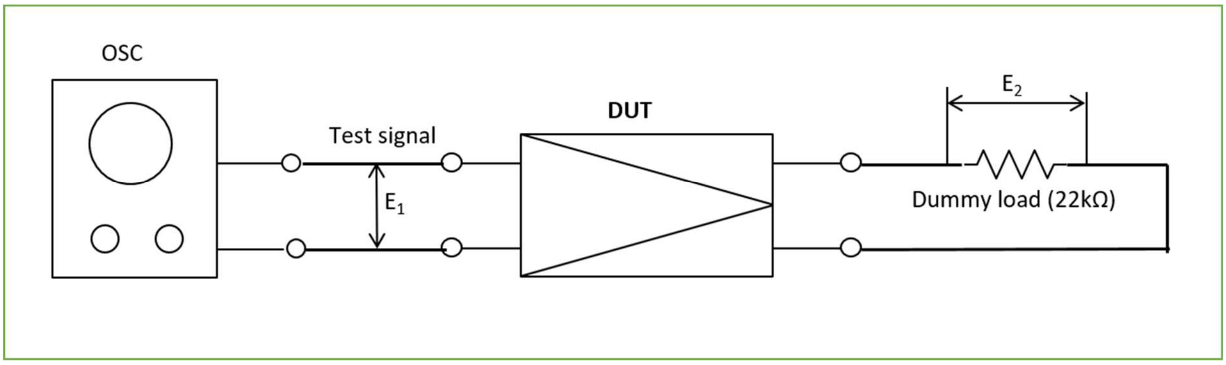
The DUT stands for preamplifier in the following measurements. In addition to preamplifiers, the DUT includes crossover networks, phono EQ amplifiers and digital audio players.

Frequency Response

For preamplifiers that include phono EQ, the measurement is made for not only PHONO IN → PRE OUT but also PHONO IN → EQ OUT.
For crossover networks, the measurement is made for each output (HIGH, MID, LOW).

Apparatus

The digital oscilloscope is used to measure the AC voltages (rms). The DMM is not used because it doesn't cover frequencies higher than audible band.
The dummy load is 1W metal film resistor of 22k ohm (Dummy Load Cable).



Conditions

- Test signal: sine waves ranging 1Hz-1MHz
- Frequency step: standard (1.0, 1.25, 1.6, 2.0, 2.5, 3.15, 4.0, 5.0, 6.3, 8.0, 10, 12.5, …)
- Each channel measured separately: the input of the other channel is short-circuited to ground
- The volume control of DUT (if available): max (0dB), -20dB, -40dB, -60dB
- The output of DUT: 1V (@1kHz)

Procedure

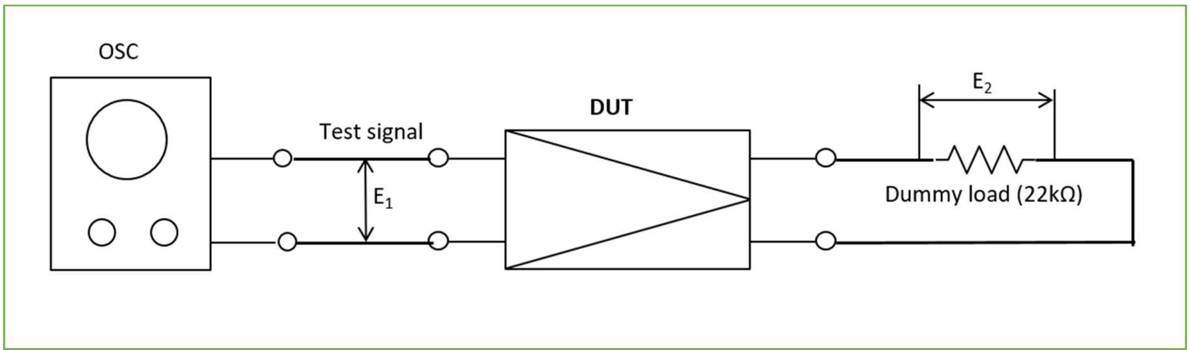
1. Turn on DUT and wait 5 minutes for warming-up.
2. Set the frequency to 1kHz, and adjust E_1 so that E_2 becomes 1V.
3. Measure E_2 at each frequency~~ and record it~~. △1
4. ~~Input the data to Excel sheet and make graphs.~~ △1
5. ~~Calculate~~ the gain ~~from the data measured~~ at 1kHz: Gain[dB] = 20log(E_2/E_1) △1

Maximum Output

The system design specifies that the maximum output of the preamplifier is 2V (rms), so the only check point is to confirm that the maximum output level is 2V or higher. But the real maximum value is measured to confirm the adequate and stable operation of the preamplifier.

Apparatus

The digital oscilloscope is used to measure the AC voltages (rms). At the same time, the waveform is observed and recorded.
The dummy load is 1W metal film resistor of 22k ohm (Dummy Load Cable).



Conditions

- Test signal: sine waves of 20Hz, 1kHz, 20kHz
- Each channel measured separately: the input of the other channel is short-circuited to ground
- Both channels measured at the same time
- The volume control of DUT (if available): max (0dB)

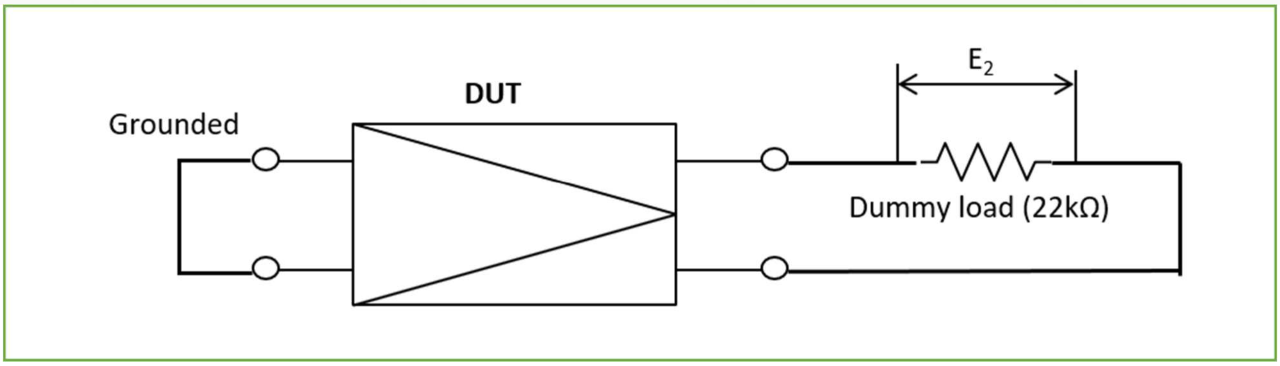
Procedure

1. Turn on DUT and wait 5 minutes for warming-up.
2. Increase E_1 gradually while observing the waveform of E_2 until it's distorted.
3. Turn down E_1 slightly.
4. Measure E_2 after one minute elapsed.

Residual Noise

Apparatus

The digital oscilloscope is used to measure the AC voltage (rms) and DC voltage. In addition, the waveform is observed and saved.
According to the industrial standard, 600 ohm resistor is connected to the input of DUT, but, in Tonochi Method, the input is grounded with a short plug.



Conditions

- Any filter like the A-curve filter isn't used
- The volume control of DUT (if available): max (0dB)
- The input is grounded

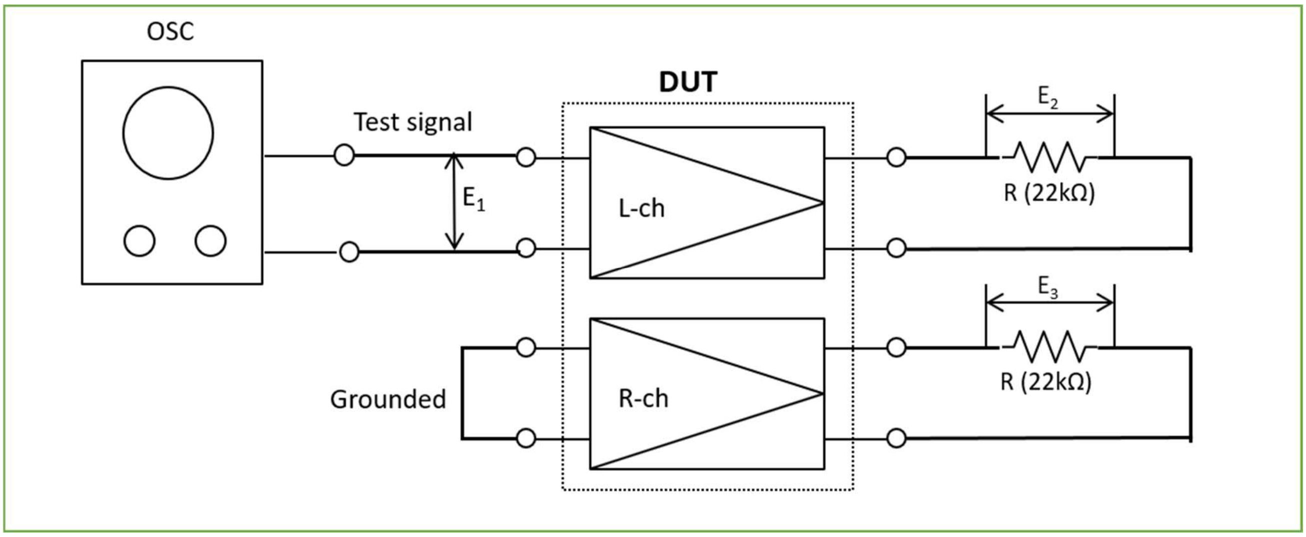
Procedure

1. Turn on DUT and wait 5 minutes for warming-up.
2. Measure AC and DC voltages, and waveform of E_2.

Channel Separation (Crosstalk)

Apparatus

The digital oscilloscope is used to measure the AC voltages (rms). In addition, the waveform is observed and saved.



Conditions

- Test signal: sine waves of 20Hz, 1kHz, 20kHz
- The output of DUT (E_2): 1V
- Measurement is bade in both ways (L→R、L←R)
- The volume control of DUT (if available): max (0dB)
- The input of the channel to be measured is grounded

Procedure

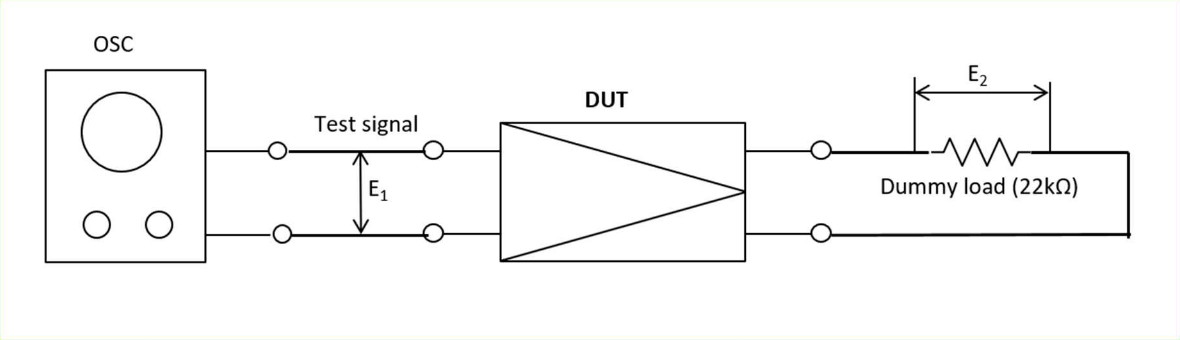
1. Turn on DUT and wait 5 minutes for warming-up.
2. Adjust E_1 so that E_2 becomes 1V.
3. Measure ~~and record~~ E_3. △1
4. ~~Input the data on Excel sheet to calculate the channel separation:~~ △1 CS[dB] = $20\log(E_2/E_3)$

Linearity

Gains at the minimum output level (-80dB: 0.2mV) to the maximum will be measured.

Apparatus

The digital oscilloscope is used to measure the AC voltages (rms).



Conditions

- Test signals: sine waves of 100Hz, 1kHz, 10kHz
- The output of DUT (E_2): 0.2mV（-80dB）, 2mV（-60dB）, 20mV（-40dB）, 200mV（-20dB）, 2V（0dB）, and max
- The volume control of DUT (if available): max (0dB)
- Each channel measured separately: the input of the other channel is short-circuited to ground

Procedure

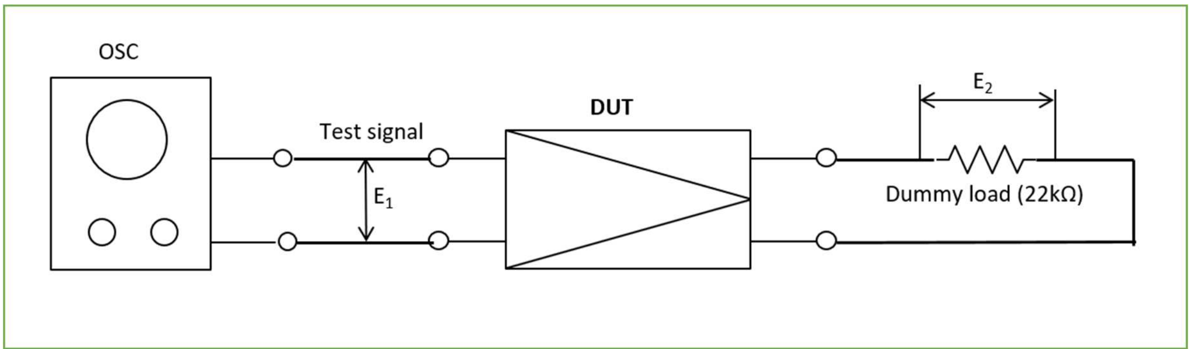
1. Turn on DUT and wait 5 minutes for warming-up.
2. Adjust E_1 so that E_2 becomes the specified level.
3. Measure ~~and record~~ E_1. △1
4. ~~Input the data on Excel sheet to draw the linearity chart.~~ △1

FFT Analysis

The response of DUT against a sine wave is analyzed by FFT to obtain the distortion ratios (THD, THD+N and IMD) and signal/noise ratio (SNR).

Apparatus

The output voltage E_2 (RMS) is measured and analyzed with a digital oscilloscope.



Conditions

- Test signals: sine waves of 100Hz, 1kHz, 10kHz
- The output of DUT (E_2): 2V
- The volume control of DUT (if available): max (0dB)
- Each channel measured separately: the input of the other channel is short-circuited to ground
- Any filter like the A-curve filter

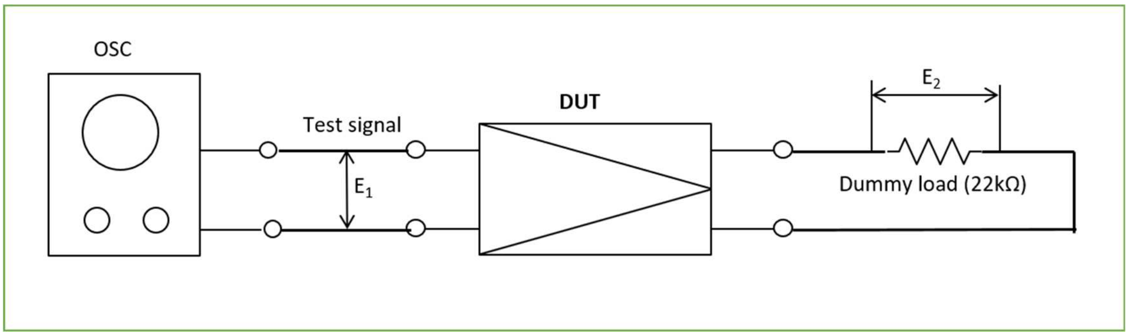
Procedure

1. Turn on DUT and wait 5 minutes for warming-up.
2. Adjust E_1 so that E_2 becomes 2V.
3. Analyze E_2 with the FFT feature of the digital oscilloscope.
4. Save the measured data along with waveforms.

Square Wave Test

DUT's transient response and stability are checked by observing waveform of square wave response.

Apparatus
The digital oscilloscope is used to observe the waveform of E_2.

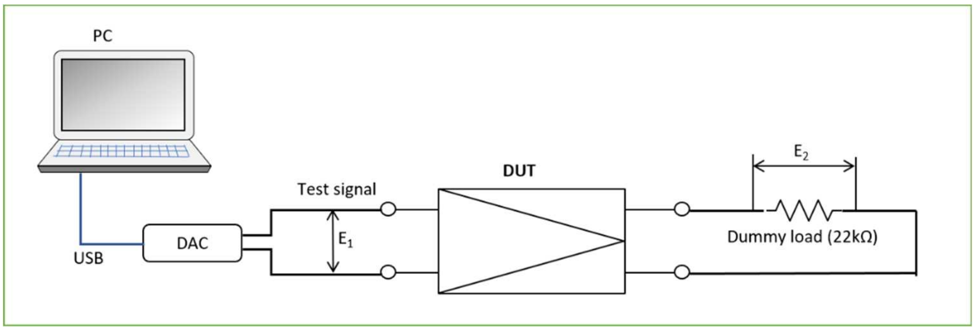


Conditions
- Test signals: square waves of 100Hz, 1kHz, 10kHz
- The output of DUT (E_2): 2V
- The volume control of DUT (if available): max (0dB)
- Each channel measured separately: the input of the other channel is short-circuited to ground

Procedure
1. Turn on DUT and wait 5 minutes for warming-up.
2. Adjust E_1 so that E_2 becomes $2V_{rms}$ ($=2V_{peak}$).
3. Observe the waveform of E_2 and save it.

Impulse Response Test
DUT's transient response and stability are checked by observing waveform of impulse response.

Apparatus
The digital oscilloscope is used to observe the waveform of E_2.
The test signal is generated by using PC and USB DAC. The resolution is 192kHz/24bit or higher.

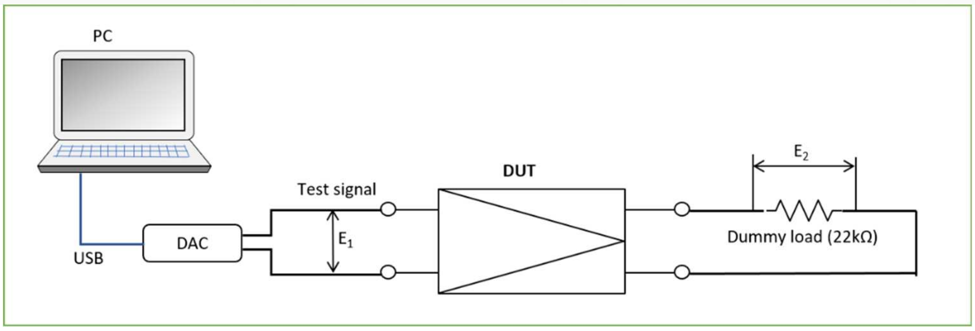


Conditions
- Test signal: impulse whose width is 50us
- The output level of DUT (E_2): $2V_{peak}$
- The volume control of DUT (if available): max (0dB)
- Each channel measured separately: the input of the other channel is short-circuited to ground

Procedure
1. Turn on DUT and wait 5 minutes for warming-up.
2. Adjust E_1 so that E_2 becomes $2V_{peak}$.
3. Observe the waveform of E_2 and save it.

Tone Burst Wave Test
DUT's dynamic distortion and stability are checked by observing waveform of tone burst wave response.

Apparatus
The digital oscilloscope is used to observe the waveform of E_2.
The test signal is generated by using PC and USB DAC. The resolution is 192kHz/24bit or higher.



Conditions

- Test signals: burst wave repeating one cycle of sine wave in the duty ratio of 1:12
- Frequencies of the sine wave: 20Hz, 1kHz, 20kHz
- The level of DUT's output (E_2): $2.83V_{peak}$
- The volume control of DUT (if available): max (0dB)
- Each channel measured separately: the input of the other channel is short-circuited to ground

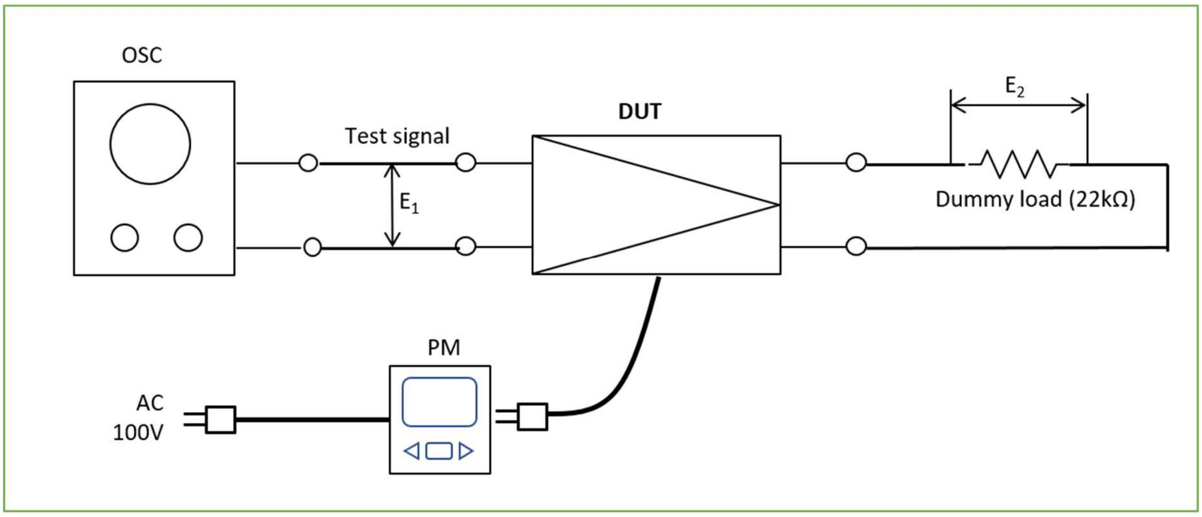
Procedure

1. Turn on DUT and wait 5 minutes for warming-up.
2. Adjust E_1 so that E_2 becomes $2V_{peak}$.
3. Observe the waveform of E_2 and save it.

Power Dissipation

Apparatus

The power dissipation is measured with a power meter.
The test signal is sine waves.



Conditions

- Test signal: sine waves of 20Hz, 1kHz, 20kHz
- The output of DUT (E_2): zero, 2V, maximum, plus power-off (standby) state
- If DUT has volume control, set it to maximum (0dB)
- If DUT is a stereo amp, both channels operate

Procedure

1. Turn on DUT and wait 5 minutes for warming-up.
2. Set the frequency of E_1 to 1kHz.
3. Adjust the voltage of E_1 so that E_2 becomes 2V.
4. Read the indication of the power meter.
5. Repeat step-4 for the output of zero and maximum.
6. Repeat step-3 to -5 for frequencies of 20Hz and 20kHz.
7. Read the indication of the power meter when DUT is off (standby).

Loudspeaker Measurements

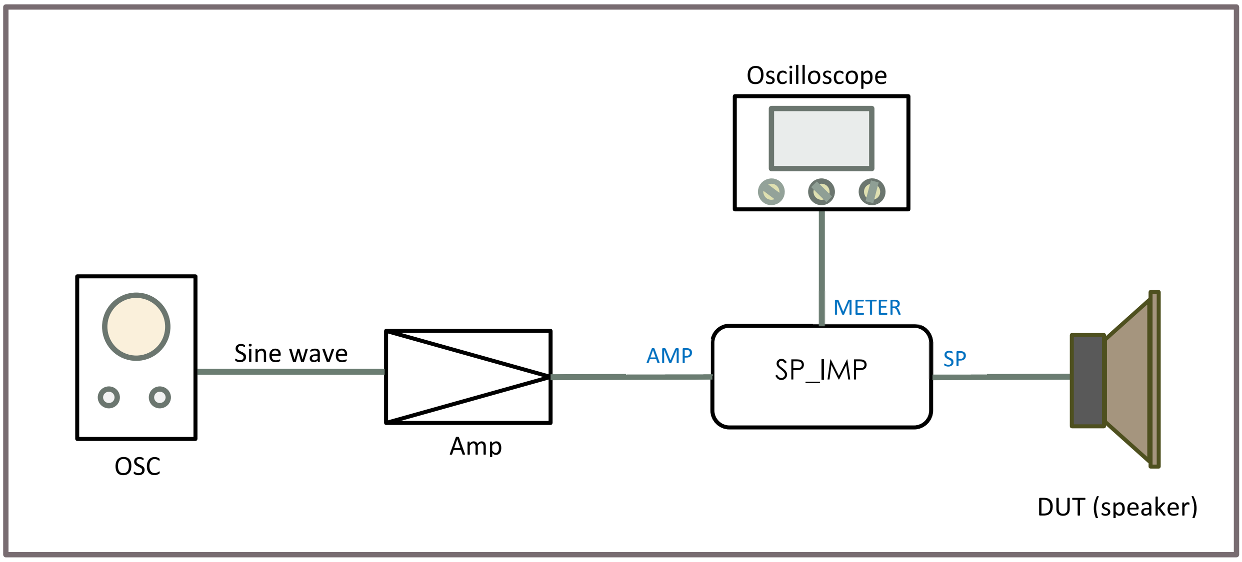
The DUT in the following measurements are woofers and full-range loudspeaker units (LS units). Squawkers and tweeters are not measured independently, but measured on the system level.

Impedance Curve

The voice coil impedance curve is measured.

Apparatus

The oscillator, power amplifier, DMM, and my original device SP_IMP are used.
For the specification of SP_IMP, see the "Supplemental Info – Measurement Instruments".



Conditions

- Test signal: sine waves of 20, 22, 25, 27.5, 31.5, 35, 40, 45, 56, 63, 70, 80, 89, 100, 110, 125, 140, 160, 175, 200Hz; up to 20kHz in 1/3 octave step
- The SPL of DUT: approx. 70dB (@1m) (shouldn't be precise)

Procedure

1. Set VR of SP_IMP to zero.
2. Set the frequency to 200Hz.
3. Turn up the output of OSC gradually until the SPL reaches 70dB.
4. Adjust the frequency.
5. Read the voltage with ~~DMM~~ oscilloscope while toggling SW, and adjust VR of SP_IMP so that the readings become the same value in either way SW is selected.
6. Read the indication of the knob of VR, and save the value (this value indicates the voice coil impedance).
7. Repeat the step-4 through -6 for all the other frequencies.

Frequency Response

DUT's frequency response is measured by sweeping sine wave in the full audio band (20Hz-20kHz).

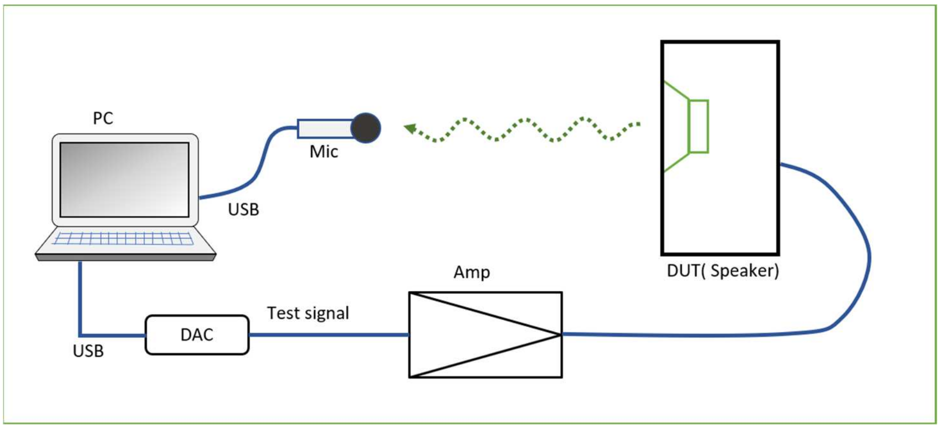
The measurement is conducted semi-automatically by using PC and a measurement app. As of June 2019, Room EQ Wizard (REW) is supposed to be the app. It could be replaced by some other app in the future.
Quasi-anechoic measurement is made with a postprocessing technique that eliminates echoic components from the floor, walls and ceiling.

The procedure specified here is based on an application report published by Texas Instruments (reference-35). For details, please see the reference listed in the "References" section in "Misc Info" page (https://nobody-audio.com/English/misc_en.html).

Apparatus

PC with the measurement app installed, USB DAC, a microphone and power amplifier are used.

- Signal generation: the measurement app (Room EQ Wizard, as of June 2019)
- Connection of test signal: the output of USB DAC is connected to the input of the amplifier
- Measurement instruments: microphone (USB type, calibration data available) and the measurement app
- Others: microphone stand



Conditions

- Test signal: sine wave of 20Hz-20kHz sweep
- SPL of DUT (loudspeaker): approx. 80dB (@315Hz)
- The height of the driver (LS unit) of DUT: midpoint between the floor and ceiling
- Calibration data is read by REW to calibrate the data

Procedure

The measurement consists of two steps: near-field and far-field measurements. The near-field applies to the low band, and the far-field applies to the high band.

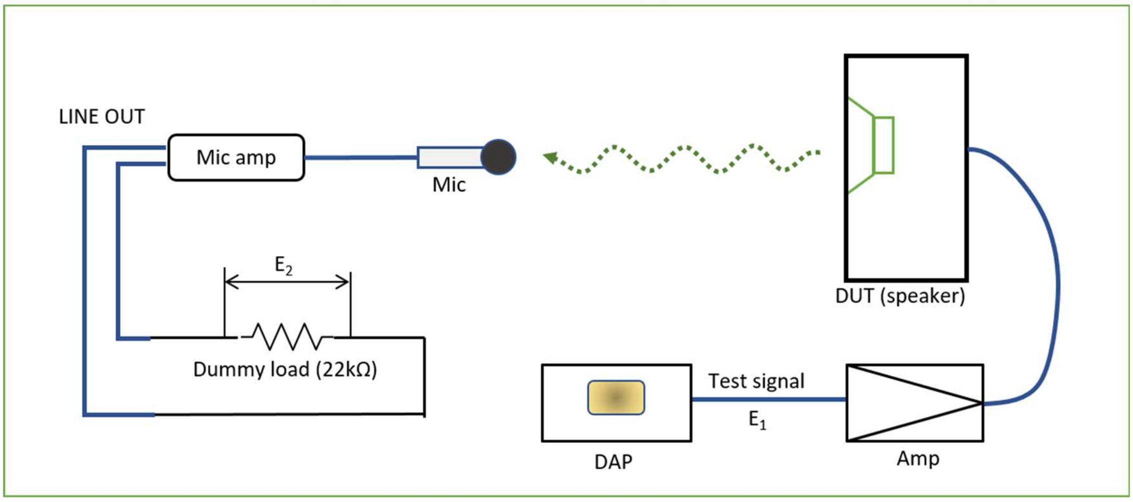
1. Calculate the boundary frequency between the high and low bands (merge frequency: f_m) according to the equation below:
   $f_m \leqq c / (2\pi a)$
   where a is the equivalent diaphragm radius, c=345[m/s] (sound velocity)
2. Calculate the distance between the LS unit and the microphone in the near-field measurement, according to the equation below:
   $d = 0.11 \times a$
3. Place the microphone at the near-field position (on the same plane as the LS unit and d[m] away from it).
4. Make DUT output sine wave of 315Hz, and adjust the volume control of the amplifier so that SPL becomes 80dB.
5. Sweep the sine wave from 20Hz through 20kHz, and make measurement.
6. Place the microphone at the far-field position (on the same plane as the LS unit and 1m away from it).
7. Make DUT output sine wave of 315Hz, and adjust the volume control of the amplifier so that SPL becomes 80dB.
8. Sweep the sine wave from f_m [Hz] through 20kHz, and make measurement.
9. Convert the measurements from frequency domain to time domain, and get the waveforms of impulse response.
10. Adjust the IR window to eliminate components of echo.
11. Merge the data of near-field and far-field and get the full-band frequency response curve.
12. Finalize the measurement by 1/24 octave smoothing.

Impulse Response

DUT's transitional performance is evaluated by observing the waveforms of impulse response.

Apparatus

- Signal generation: digital audio player with a WAV file that contains impulse data
- Power amplifier
- Measurement instruments: microphone, microphone amplifier and digital oscilloscope
- Others: microphone stand



Conditions

- Test signal: Impulse of 40us width
- The distance between DUT and microphone: 1m
- The height of the driver (LS unit) of DUT: midpoint between the floor and ceiling
- SPL of DUT: approx. 80dB

Procedure

1. Place the microphone on the same plane as the LS unit and 1[m] away from it
2. Make DUT output sine wave of 315Hz, and adjust the volume control of the amplifier so that SPL becomes 80dB.
3. Make DUT output the impulse and observe the waveform of MIC OUT (E_2), and save it.

System Level Measurements

In the system level measurements, the DUT is the whole system. It is the most important measurement in terms of evaluation of the performance of a certain audio system.

The system level measurements are carried out almost in the same way as the loudspeaker measurements. The frequency response is measured by sweeping sine wave, and impulse response is measured with 40us impulse. Their purposes are evaluation of the performance in frequency domain and the performance in time domain, respectively.
The data of the frequency response is analyzed with FFT to get distortion ratios (THD and IMD).

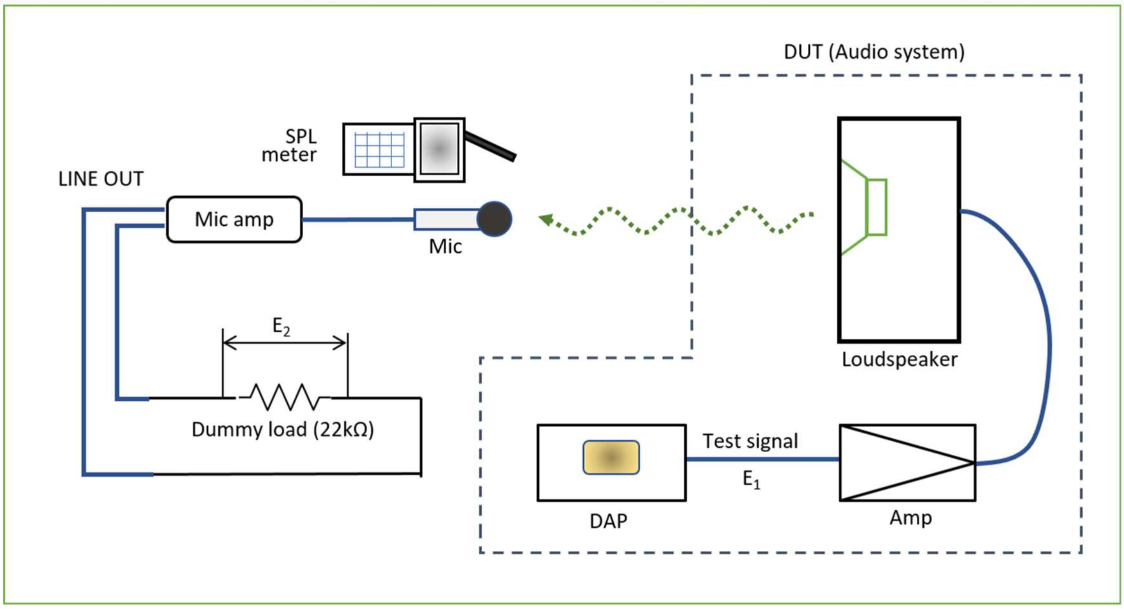
In advance of these measurements, time alignment adjustment is conducted by using single-cycle sine waves in order to align the timings of LS units (drivers). The sound waves from each LS unit must arrive at the listening position at exactly the same timing. The time alignment affects so much the frequency response and the impulse response.

Time Alignment Adjustment

The purpose of this measurement is to align the arrival timings of sound waves from each LS unit so that every sound wave arrives at the listening position at exactly the same time. Single sine waves (one cycle of sine wave) are used.

Apparatus

- Signal generation: PC and an app that generates test signals
- Signal reproduction: DAP with the WAV files which the app created
- Instruments: microphone, microphone amplifier, digital oscilloscope, and SPL meter
- Others: microphone stand, dummy load (22k ohm)



Conditions

- Test signal: single cycle sine wave
- Frequencies: 120Hz (the center of woofer band), 800Hz (the lower cross point), 3kHz (the center of squawker band), 6.8KHz (the upper cross point), 16kHz (the center of tweeter band) [*1]
- Spec of WAV file: 192kHz/24bit or higher, L+R
- SPL of DUT: approx. 80dB (@3kHz)
- Position of microphone: the listening position
- Each channel is measured independently

[*1] These frequencies are specified based on the spec of Gaudi II. They might be changed according to revision of the system design.

Procedure

1. Connect one of the DAP outputs to one of the amp inputs, and the other DAP output to A-ch of the oscilloscope (E_1).
2. Short-circuit the other input of the amp to ground.
3. Reproduce continuous sine wave of 3kHz, and adjust the volume control of the amp so that the SPL becomes 80dB at the listening position by using the SPL meter.
4. Connect the output of the mic amp to B-ch of the oscilloscope.
5. Set the trigger source of the oscilloscope to the rising edge of A-ch.
6. Reproduce single cycle sine waves, and observe the waveforms of E_1 and E_2 and save them.
7. Measure the delay time between E_1 and E_2.
8. Repeat the step-6 to -7 for all the other frequencies.
9. Adjust the delay control of the crossover network and the position of the tweeters so that all the delay times at the center frequencies become the same [*2].
10. Repeat the step-1 to -9, for the other channel.

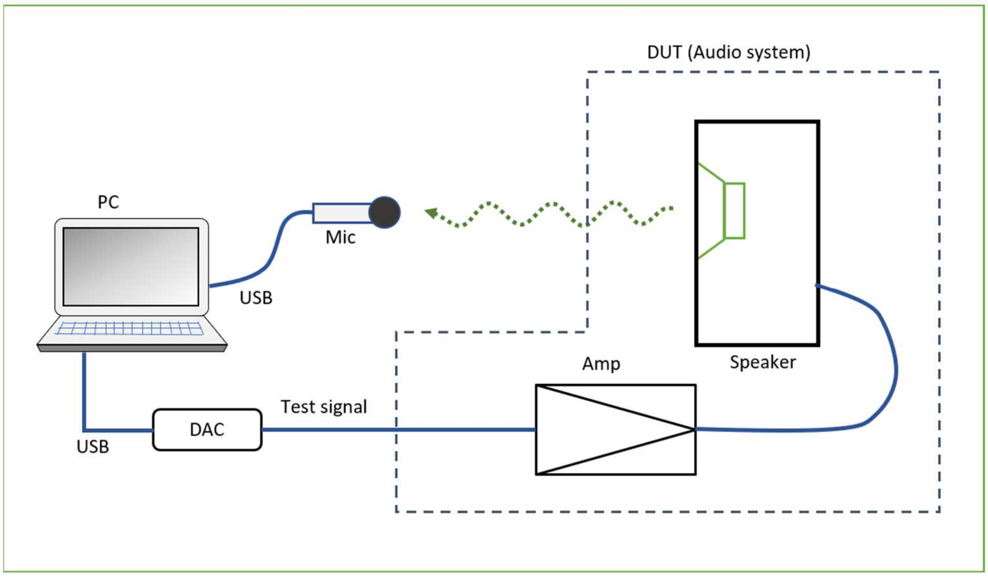
[*2] Some say the timing should be aligned at the cross points, but, in Tonochi Method, the timing is aligned at the center frequencies, because phase shifts caused by the filters in the network appear around the cross points in addition to the time difference.

Frequency Response (1m away from the loudspeaker)

The DUT's frequency response is measured by sweeping sine wave in the audio band (20Hz-20kHz). This measurement is similar to the one for loudspeakers.

Apparatus

- Signal generation: the PC app for measurement (Room EQ Wizard, as of June 2019) generates test signals
- Input of test signals: LINE output of USB DAC to LINE input of amp
- Instruments: microphone (including mic amp and ADC, with calibration data), PC app for measurement
- Others: microphone stand



Conditions

- Test signals: sine wave sweep (20Hz-20kHz)
- SPL: approx. 80dB (at 315Hz)
- The microphone's calibration data is given to the app to minimize the error
- Each channel is measured independently

Procedure

The measurement consists of two steps: near-field and far-field measurements. The near-field applies to the low band, and the far-field applies to the high band.

1. Calculate the boundary frequency between the high and low bands (merge frequency: f_m) according to the equation below:
   $f_m \leqq c / (2\pi a)$
   where a is the equivalent diaphragm radius, c=345[m/s] (sound velocity)
2. Calculate the distance between the woofer and the microphone in the near-field measurement, according to the equation below:
   $d = 0.11 \times a$
3. Place the mic at the near-field position (on the same plane as the woofer and d[m] away from it).
4. Make DUT output sine wave of 315Hz, and adjust the volume control of the amplifier so that SPL becomes 80dB.
5. Sweep the sine wave from 20Hz through 20kHz, and make measurement.
6. Place the microphone at the far-field position (on the same plane as the LS unit and 1m away from it).
7. Make DUT output sine wave of 315Hz, and adjust the volume control of the amplifier so that SPL becomes 80dB.
8. Sweep the sine wave from f_m [Hz] through 20kHz, and make measurement.
9. Convert the measurements from frequency domain to time domain, and get the waveforms of impulse response.
10. Adjust the IR window to eliminate components of echo.
11. Merge the data of near-field and far-field and get the full-band frequency response curve.
12. Finalize the measurement by 1/24 octave smoothing.
13. Repeat the step-3 through -12 for the other channel.

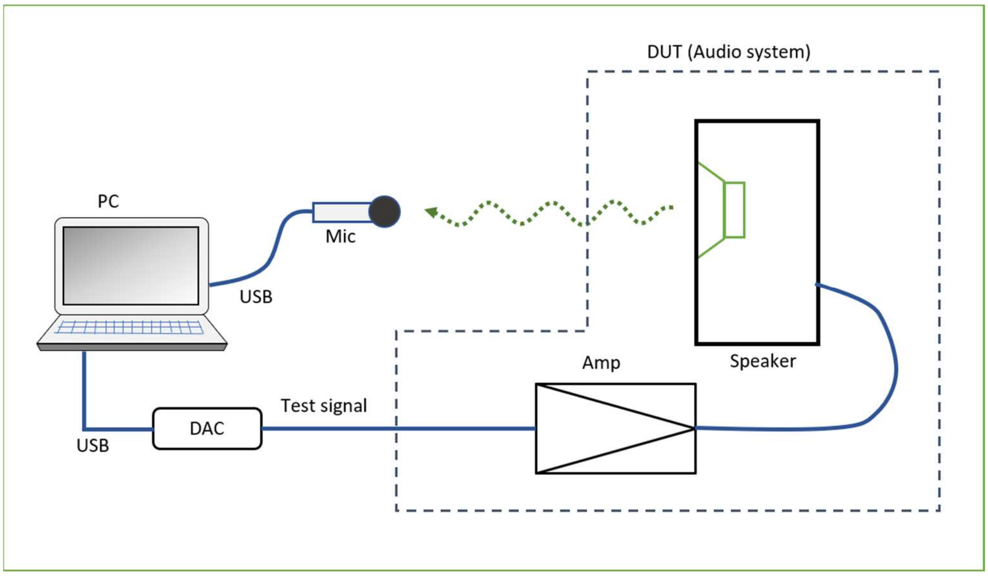
Frequency Response (at the listening position)

The DUT's frequency response is measured by sweeping sine wave in the audio band (20Hz-20kHz).
This measurement is similar to the one at the position 1m away from the loudspeakers, except that the microphone is placed at the listening position throughout the full audio band.

Apparatus

- Signal generation: the PC app for measurement (Room EQ Wizard, as of June 2019) generates test signals
- Input of test signals: LINE output of USB DAC to LINE input of amp
- Instruments: microphone (including mic amp and ADC, with calibration data), PC app for measurement

- Others: microphone stand



Conditions

- Test signals: sine wave sweep (20Hz-20kHz)
- SPL: approx. 80dB (at 315Hz)
- The microphone's calibration data is given to the app to minimize the error
- Each channel is measured independently

Procedure

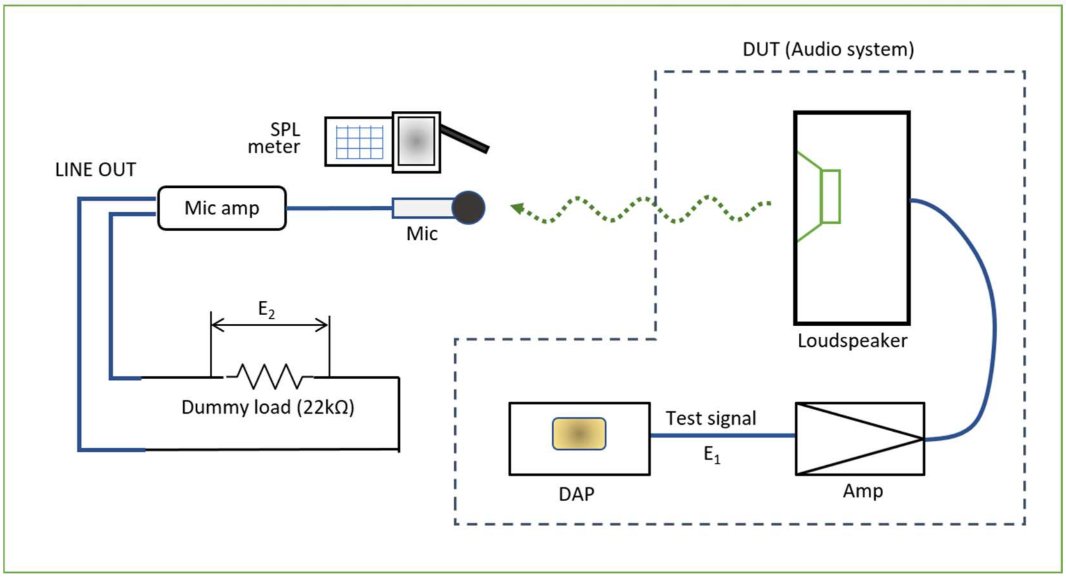
1. Place the mic at the listening position.
2. Make DUT output sine wave of 3kHz, and adjust the volume control of the amplifier so that SPL becomes 80dB.
3. Sweep the sine wave from 20Hz through 20kHz, and make measurement.
4. Convert the measurements from frequency domain to time domain, and get the waveforms of impulse response.
5. Adjust the IR window to eliminate components of echo.
6. Finalize the measurement by 1/24 octave smoothing.
7. Repeat the step-2 through -6 for the other channel.

Impulse Response

DUT's transitional performance is evaluated by observing the waveforms of impulse response.

Apparatus

- Signal generation: signal generation app on PC
- Input of test signals: digital audio player with WAV files that contains test signals
- Instruments: microphone, microphone amplifier, digital oscilloscope, SPL meter
- Others: microphone stand, dummy load for mic amp (22k ohm)



Conditions

- Test signal: Impulse of 40us width
- Mic position: 1m away from tweeter, listening position
- Resolution of WAV files: 192kHz/24bit or higher
- SPL of DUT: approx. 80dB
- Each channel is measured independently

Procedure

1. Place the microphone on the same plane as the tweeter and 1[m] away from it
2. Make DUT output sine wave of 3kHz, and adjust the volume control of the amplifier so that SPL becomes 80dB.
3. Make DUT output the impulse and observe the waveform of MIC OUT (E_2), and save it.
4. Place the mic at the listening position, and repeat step-2 through -3.
5. Repeat step-1 through -4 for the other channel.

Distortion Ratios (THD, IMD)

Distortion ratios are calculated by analyzing the data measured in the frequency response measurement. The feature of the measurement app (Room EQ Wizard, as of June 2019) is utilized.

Apparatus

Any instrument is not necessary since the existing data are used.

Conditions

- Test signal: sine wave sweep
- Mic position: 1m away from tweeter, the listening position
- Each channel is analyzed independently

Procedure

1. Load the data to the measurement app, and analyze the data.

Room Acoustics

In addition to the measurements of audio devices, it is necessary to measure the room acoustics like reverberation time, reflections of boundaries, standing waves, etc.

I am still learning techniques in this field. I haven't specified measurement methods yet.

[END OF DOCUMENT]

NOBODY Audio
Tonochi’s Audio Room - Supplemental Information