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How to make remarkable sound of electrical vehicles inside out with active sound design

How to play the audio files in this document?

1. Open the file in Adobe Acrobat **Reader**
2. Click on the loudspeaker icon  and play the sound
3. If that doesn’t work, change the following settings:
    - In the menu, select **Edit** -> *Preferences*
    - Left menu: chose **Security (Enhanced)**
    - Under **Sandbox Protections**, uncheck the box for Enable Protected Mode at Startup
    - Under **Enhanced Security**, uncheck box for Enable Enhanced Security
    - Click OK and restart Adobe Reader

Why adding sounds to the vehicle?

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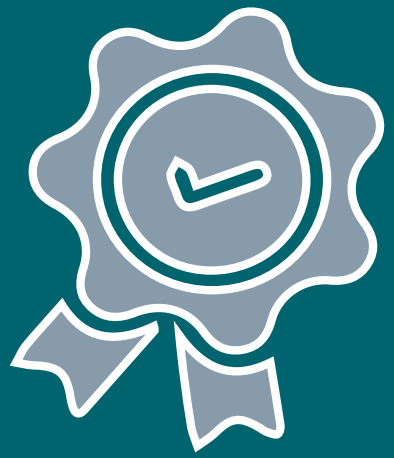
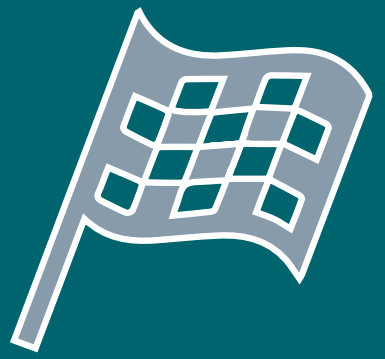
BECAUSE YOU MUST



ENSURE COMPLIANCE

BECAUSE YOU CAN

PROTECT BRAND REPUTATION



STRIVE UNIQUE BRAND VALUE

REDUCE COSTS

DESIGN

From brand sound to drivable sound model
Granular synthesis | Order synthesis

VALIDATE & TUNE

Validation in the vehicle
Real-time sound tuning

DEPLOY

Integration in production vehicle
Ready for mass production

Interior sound

Brand sound exploration

Active sound model creation

In-vehicle validation

Sound quality analysis

Audio amplifier tuning

Vehicle audio integration

Exterior sound

AVAS

Brand sound exploration

AVAS model creation

Frontloading compliance

In-vehicle AVAS tuning

Vehicle integration

Regulation validation

Industrialization

DESIGN

From brand sound
to pedestrian warning system

VALIDATE & TUNE

Upfront compliance to standards
Real-time sound tuning

DEPLOY

Integration in production vehicle
Minimum noise certification

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Brand Sound Exploration

What direction to take in sound design?

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Exploration

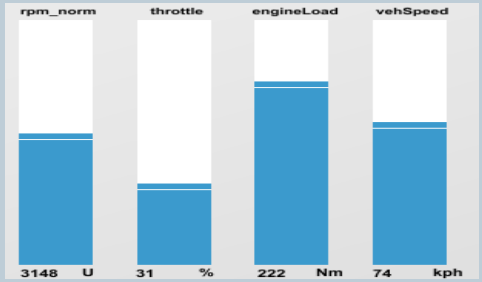
Towards rules

From Jury

Software based Active Sound Design in early stage

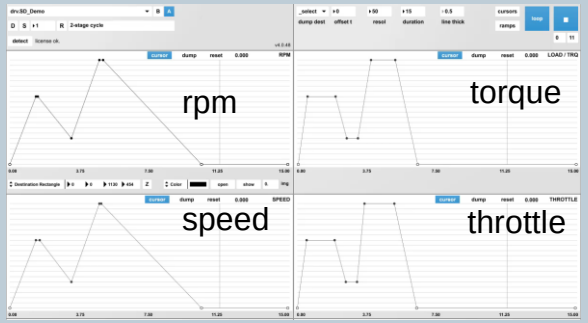
Vehicle input parameters during sound model creation

Manually enter parameters



- ✓Fast & Easy
- ✓Hard to compare during design (no loop)
- ✓Potential artificial scenarios

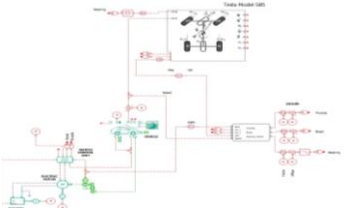
Use Driver profiles



- ✓Easier for comparison during design
- ✓Realistic scenarios

Define driving profiles:

1. Basic anchor points
2. Models



3. Measure

DIGITAL BUS

Toolset with different approaches and layers for designing the sounds

Classical Sounds, e.g. engine order alike?

How to do design very creative sounds

Be able to spice up the sounds?

Without sounding artificial

Sequence of layers that generate final sound

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Classical approach

Advanced approach

Including perception of power into the sound generation

Overcoming monotonic pitch increase with speed through shepard layer

Makes sure low frequent content remains in place

Two approaches for SPEED based layer

First approach: Order Synthesis as “traditional” approach

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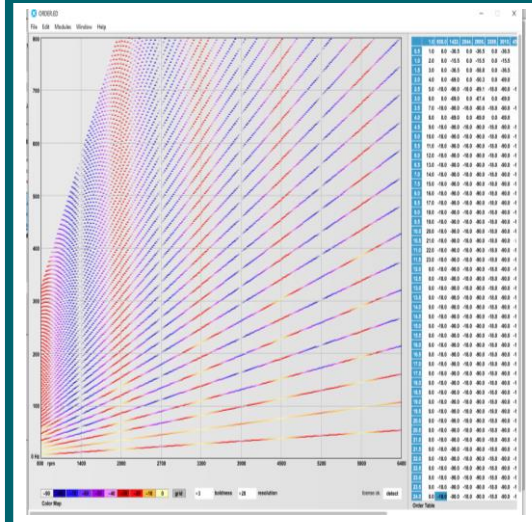
Order synthesis

Classical NVH sound generation



- Mimic or enhance orders of an internal combustion engine
- Generate sounds known by the listener
- Possibility (must) to create multiple layers based on different vehicle load cases

Order Synthesis +

Additional signal manipulations parametrized in perceptions

Added Variance
Increasing liveliness and natural Roughness - Dirtyness

Complex Sound Signature
Replication of brand identity

Standard ASD off → **Sporty moderate ASD** → **Race full ASD**

“Even without any real combustion engine orders present, this synthesis sounds very natural & authentic, where others we tested keep sounding synthetic”

Two approaches for SPEED based layer

Second approach: “the sky is the limit” with granular synthesis

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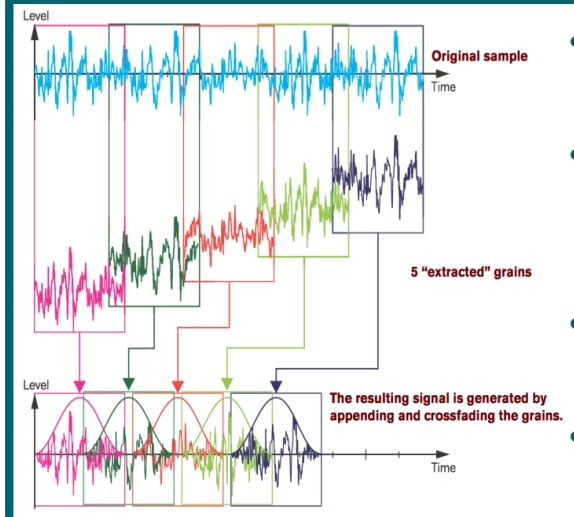
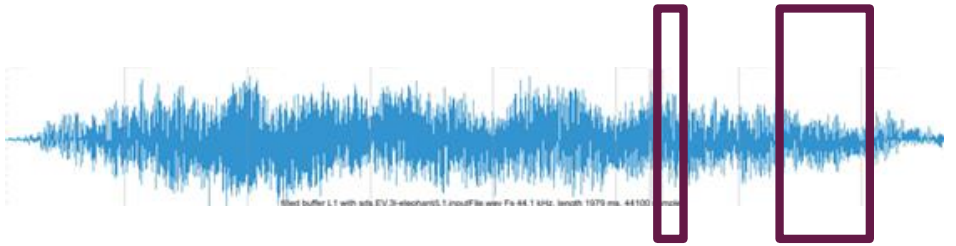
Granular synthesis

Music industry sound generation parametrized for NVH



- Generate a sound that is *rich* and *alive*
- Possibility to generate complex signatures in multiple layers
- Sound generation not linked to classical vehicle
- Requires more experience on sound design



Preloaded Sound Sample

Replay of Grains from sample with varying parameters, such as duration, pitch (function of Speed), position, …

+ randomization to make sound real and alive

Example

Creating and tuning sounds with Granular synthesis

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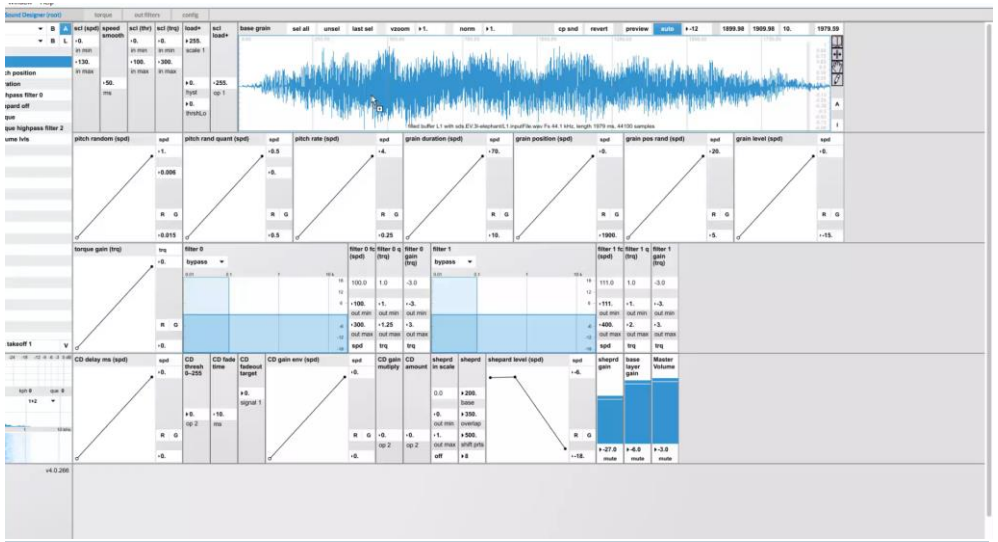
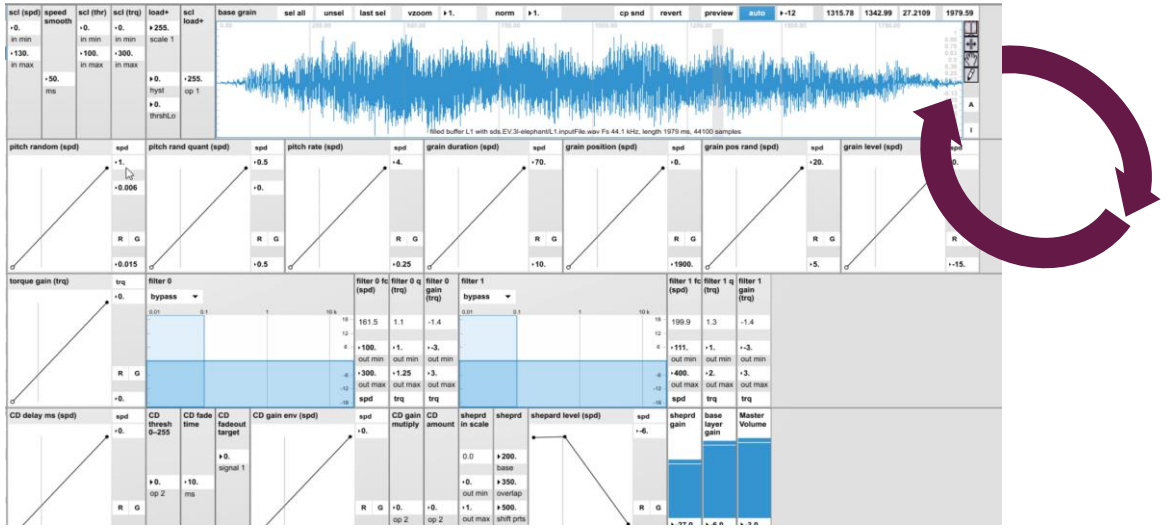
Starting from … an elephant sound





✓Initial sample sound combined with default settings
✓Initial pitch rate definition
✓Initial grain position & duration.

✓Pitch rate adjustment
✓Grain position change
✓Grain duration change

After first design iterations ready for in-vehicle testing

Overview of all layers

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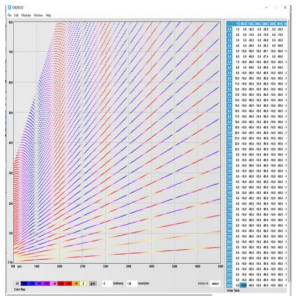
Speed Layer

Traditional Approach

Order synthesis

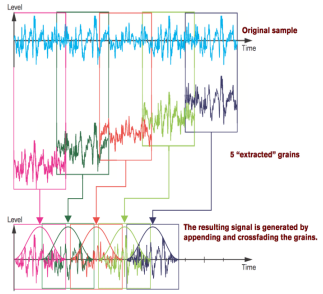
Classical NVH sound generation



Sky is the limit

Granular synthesis

Music industry sound generation parametrized for NVH



Including combinations of both

Torque layer: to emphasize dynamic behavior of the vehicle, in function of engine load

Shepard Layer: overcome monotonic pitch increase with speed. Low frequency content remains present.

DESIGN
From brand sound to drivable sound model
Granular synthesis | Order synthesis

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Validation in the vehicle
Real-time sound tuning

DEPLOY
Integration in production vehicle
Ready for mass production

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Audio amplifier tuning

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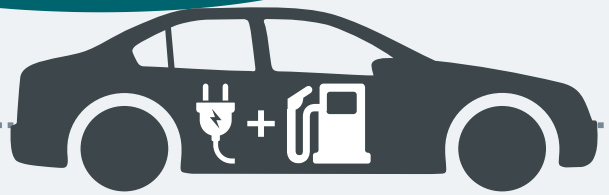

Exterior sound

AVAS

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Frontloading compliance

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Industrialization

DESIGN
From brand sound
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Integration in production vehicle
Minimum noise certification

What sounds good in the studio must be validated in the vehicle unit

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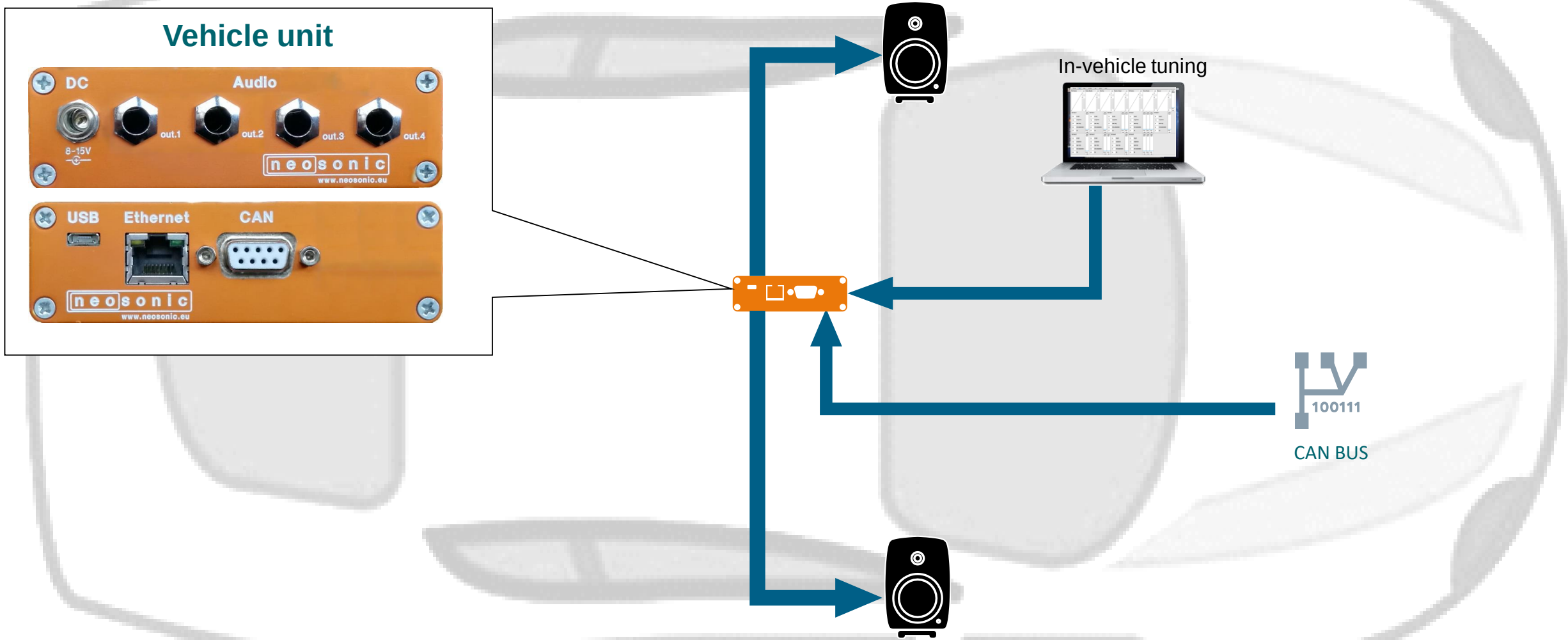
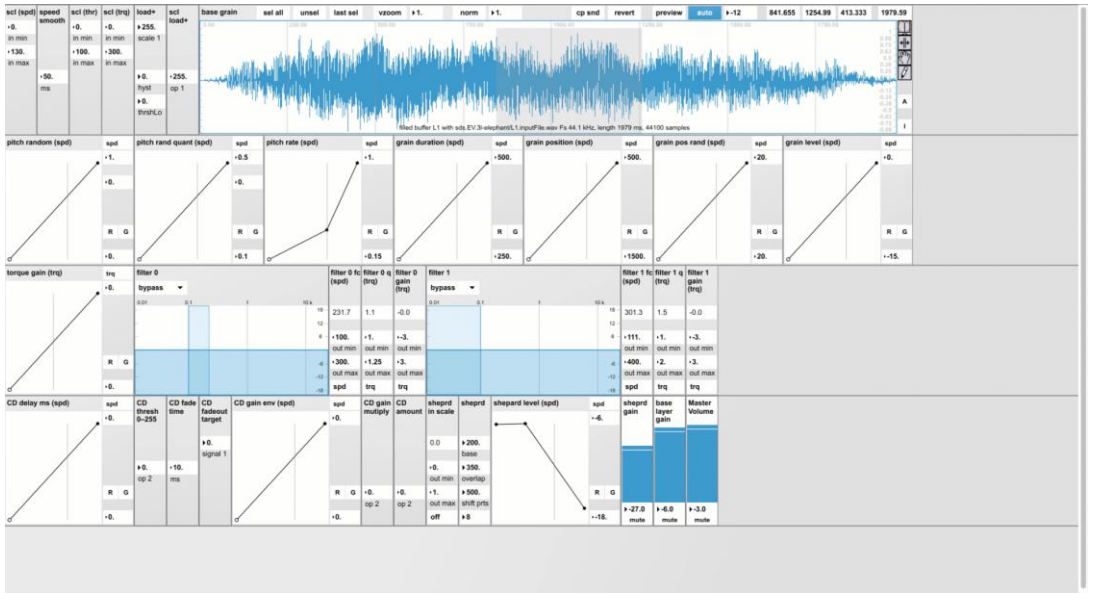
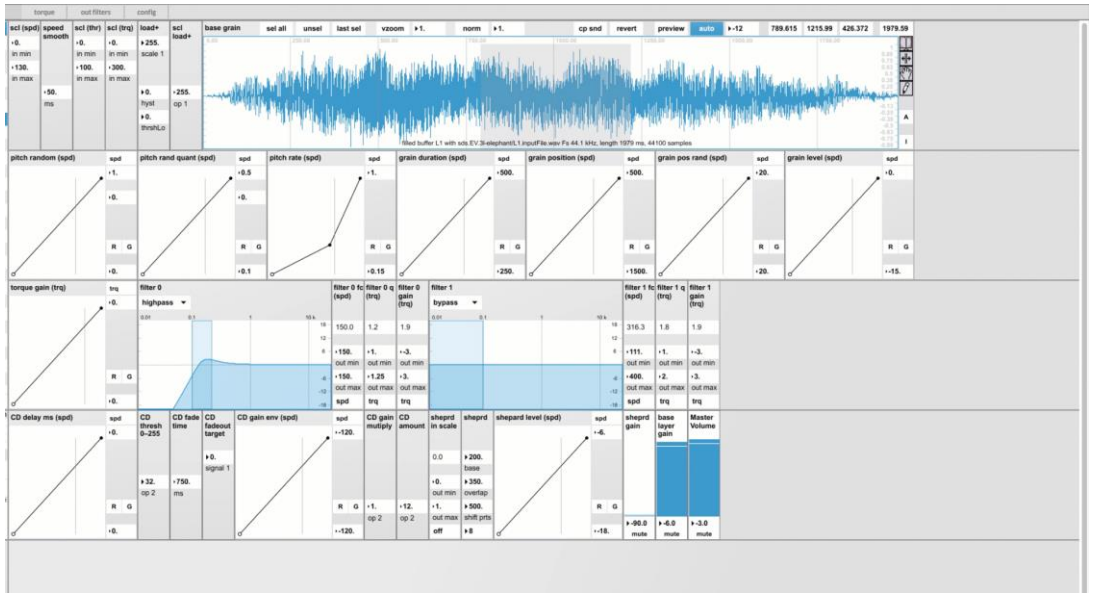


In-vehicle tuning

Creating and tuning sounds with Granular synthesis



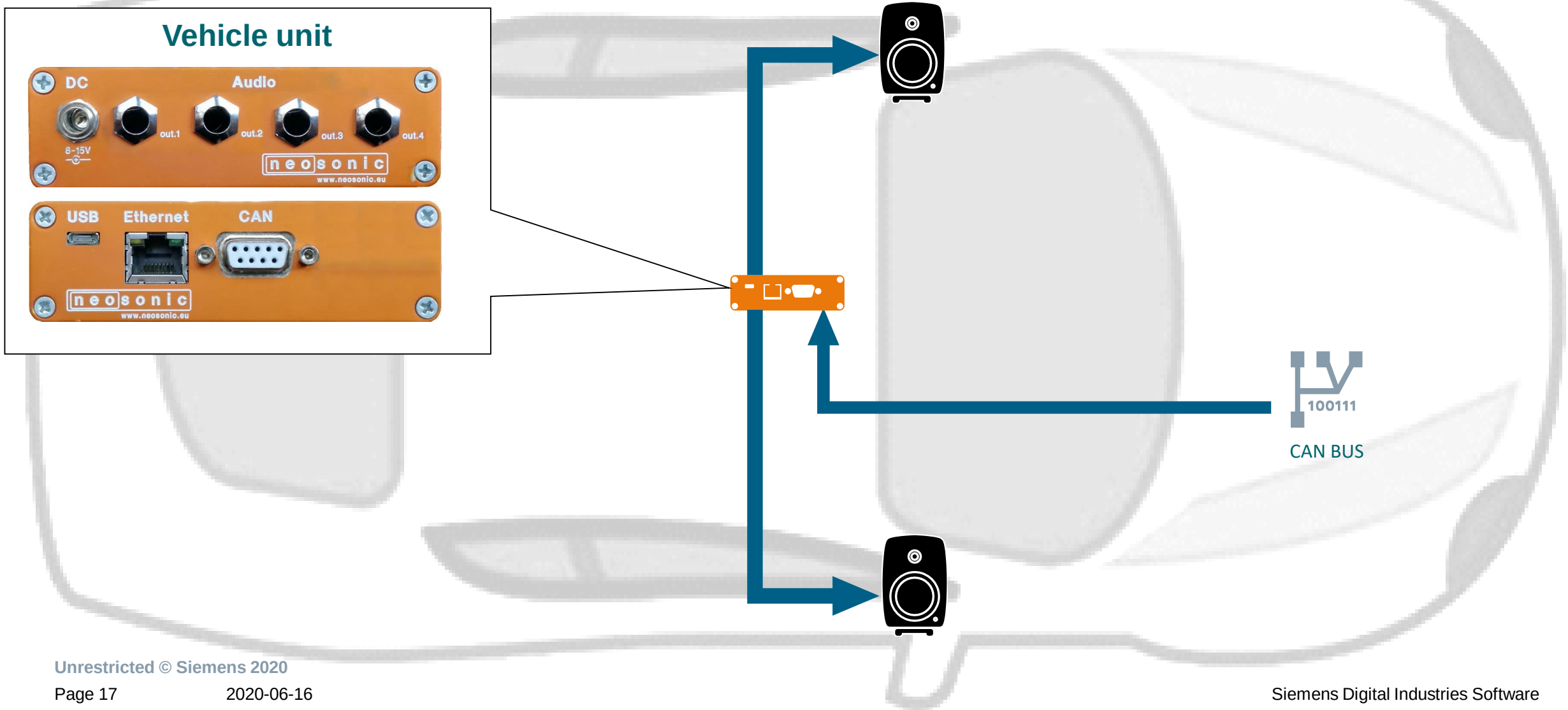
- ✓Filtering in function of speed and torque
- ✓Shepard layer modification
- ✓Constant drive gain



- ✓Torque layer adjustments
- ✓High-pass filter in torque layer
- ✓Grain duration change

Final designed sound ready for industrialization

After tuning – leave the in-vehicle unit in the vehicle for final validation



Tuning on a driving simulator

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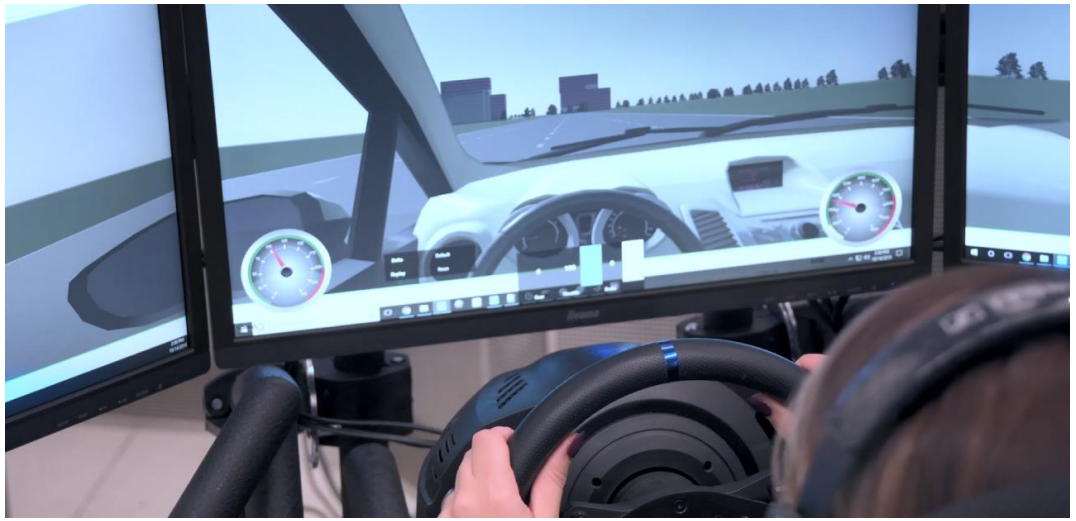
Can you evaluate & tune the Sound model without having a prototype available?

Could you evaluate sound model for another variant of the vehicle without having this available?

What would be the impact of control parameters on the sound?

Towards the driving simulator



Active Sound Design on the vehicle simulator

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USER

Performance Model

Definition of vehicle driving behavior
From classic towards complex xEV driveline

Rpm, speed, torque

Rpm1, speed, torque, %pedal, gear, .. Rpm 2, ..

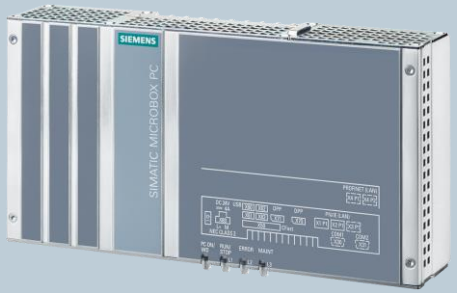
NVH Model

Definition of sound built up from different noise component

Road
Powertrain
Wind

g(t)

Evaluate driving alternatives by tuning Simcenter Amesim models



Throttle, Gear

Can

Sound Design hardware

Sound

or Simcenter Testlab Sound Designer on pc

How to measure the ASD results?
Binaural recordings

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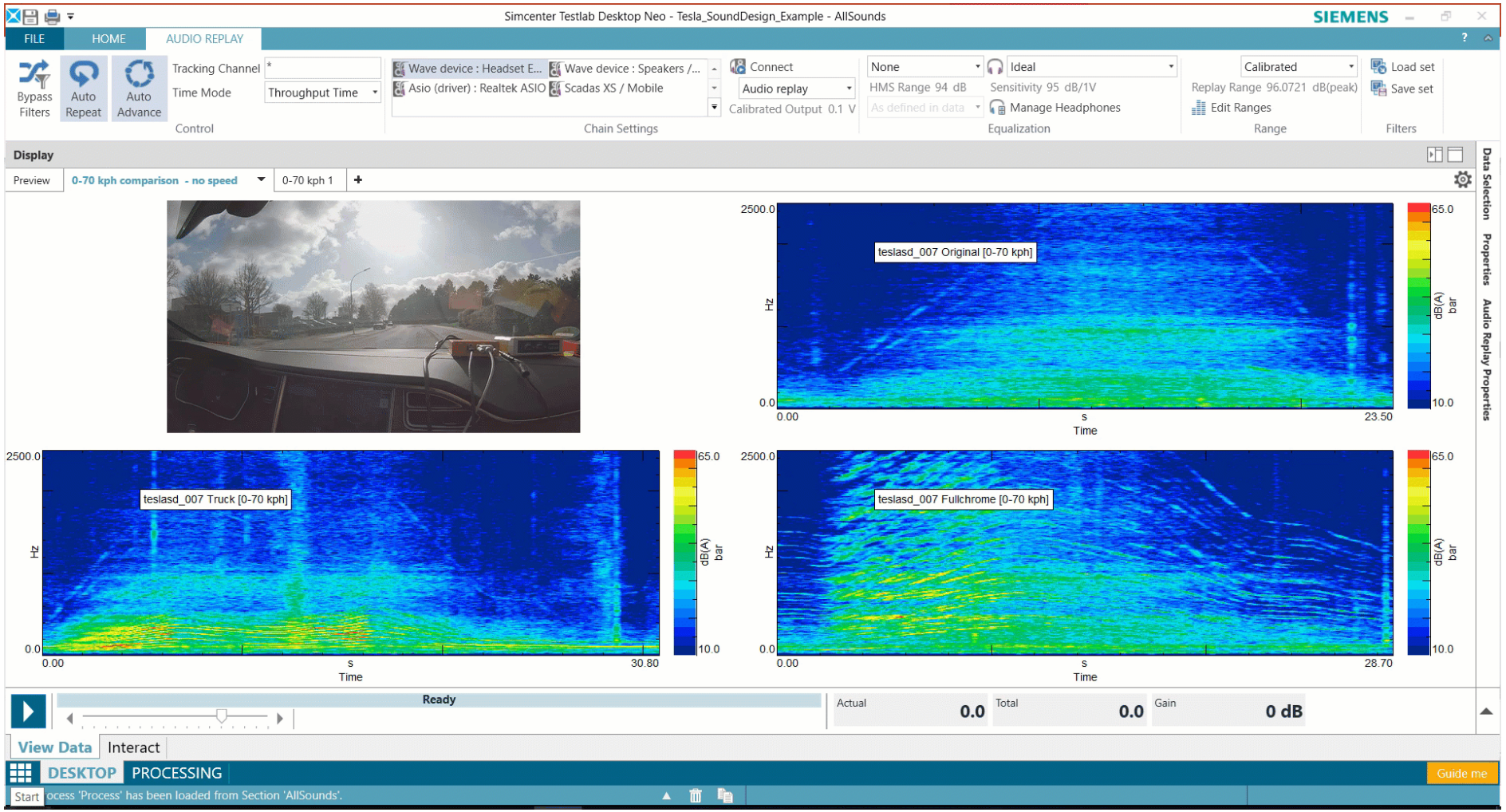
Requires artificial head or a binaural headset

Measure audio in combination with other vehicle signals (CAN-BUS, Engine speed, GPS, etc.)

Real-time stereo audio replay

Application Example: Electric Vehicle

Original – combustion sound – granular synthesis sound



Original EV sound is very silent

Make it sound like an ICE using order synthesis

Use granular synthesis for a more complex sound

Sound Quality Analysis

Subjective evaluation of Active Sound Design

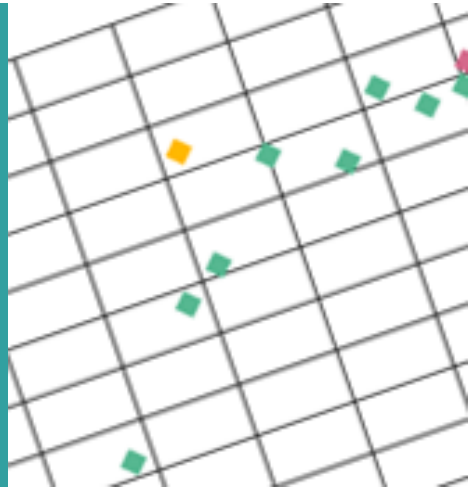
Easy platform to design the correct test

Powerful analysis tools to understand the results

Jury Testing

Use sounds measured with Testlab or imported from an external source

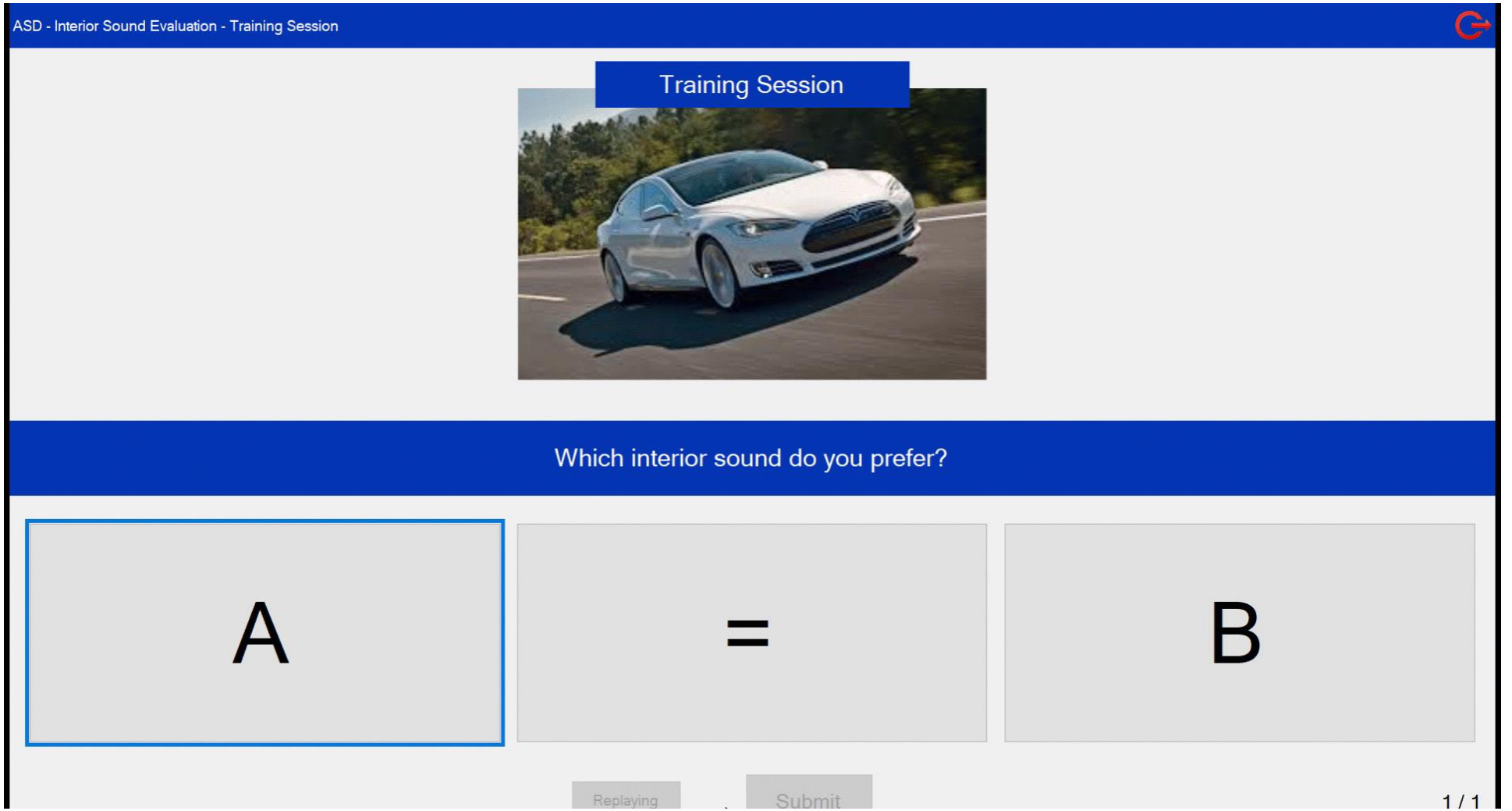
Support for A/B comparison, Semantic Differential and Category Judgement with statistical questions and reference answers



Connect to an unlimited number of Jurors and watch their answers in real time

Improve result quality with automatic checks on concordance and consistency
1-click export to Excel to further analysis

Jury Testing to get customer feedback on Active Sound Design Preference



DESIGN

From brand sound to drivable sound model
Granular synthesis | Order synthesis

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Validation in the vehicle
Real-time sound tuning

DEPLOY

Integration in production vehicle
Ready for mass production

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Specific AVAS challenges

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Creating AVAS sounds that resonate the **right brand values**

PROTECT BRAND REPUTATION

Identify right AVAS **speaker locations**

SMARTER DECISIONS

Ensure compliance with regulation

ENSURE COMPLIANCE

Acoustic Vehicle Alert System

Mandatory for new vehicle types since 2019-2020

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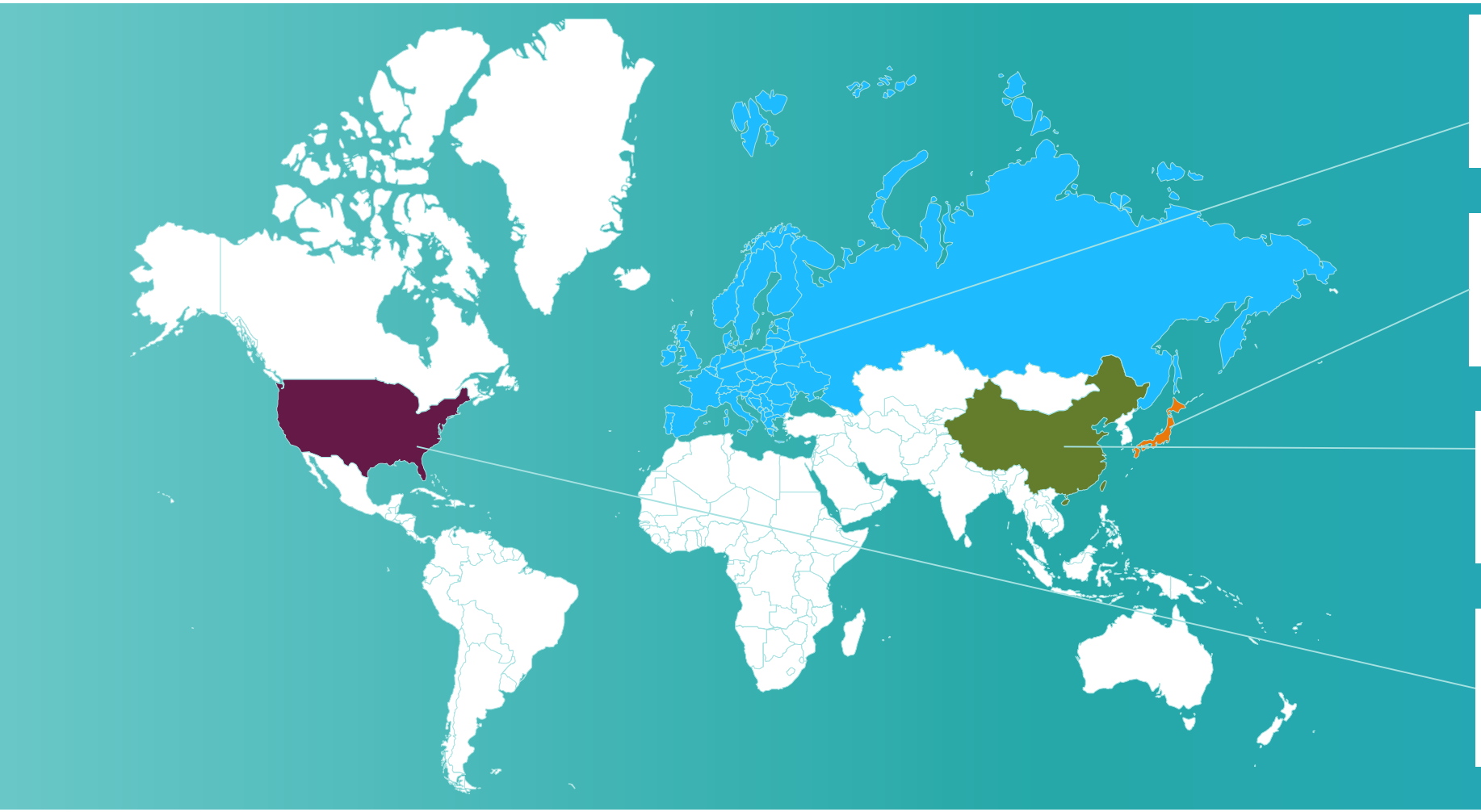

EU – Mid 2019
UN/ECE R138

Japan
Aligned UN/ECE R138

China – Mid-2019
GB/T 37153
UN/ECE R138 +2dB

USA – Mid 2020
FMVSS 141

AVAS design starts with compliance in mind

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Any great AVAS sound needs to comply to standards
2 main standards: Europe ECE R138, US FMVSS 141

Operational conditions
- ECE R138: 10 kph, 20 kph, 6 kph reverse
- FMVSS141: in addition: 0kph, reverse

Processing
- Minimum noise levels per octave band
- Pitch shift
- Volume change

ECE R138

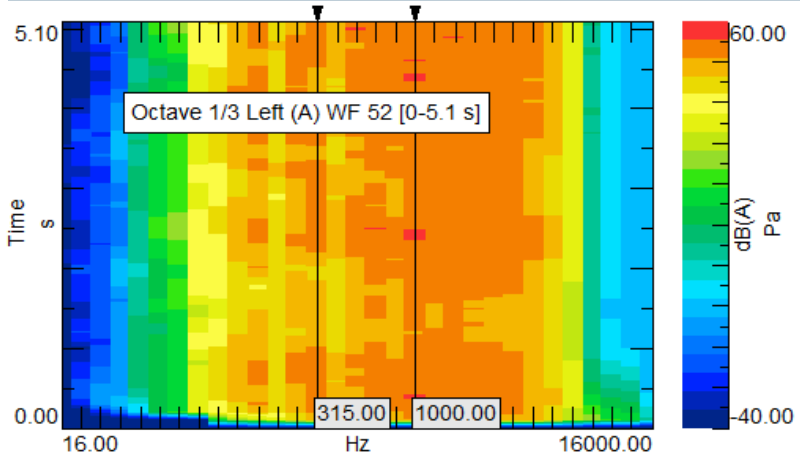
When tested under the conditions of Annex 3 paragraph 3.3.2, the vehicle shall emit a sound

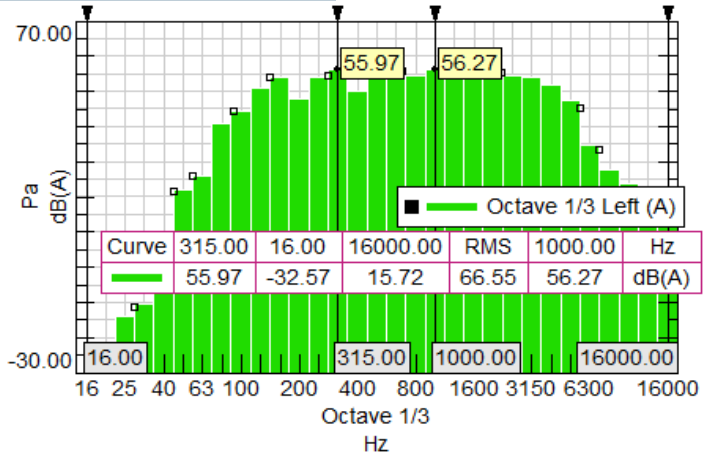
(a) That has a minimum overall sound pressure level for the applicable test speed according to Table 2 of paragraph 6.2.8.;

(b) That has at least two of the one-third octave bands according to Table 2 of paragraph 6.2.8. At least one of these bands shall be below or within the 1,600 Hz one-third octave band;

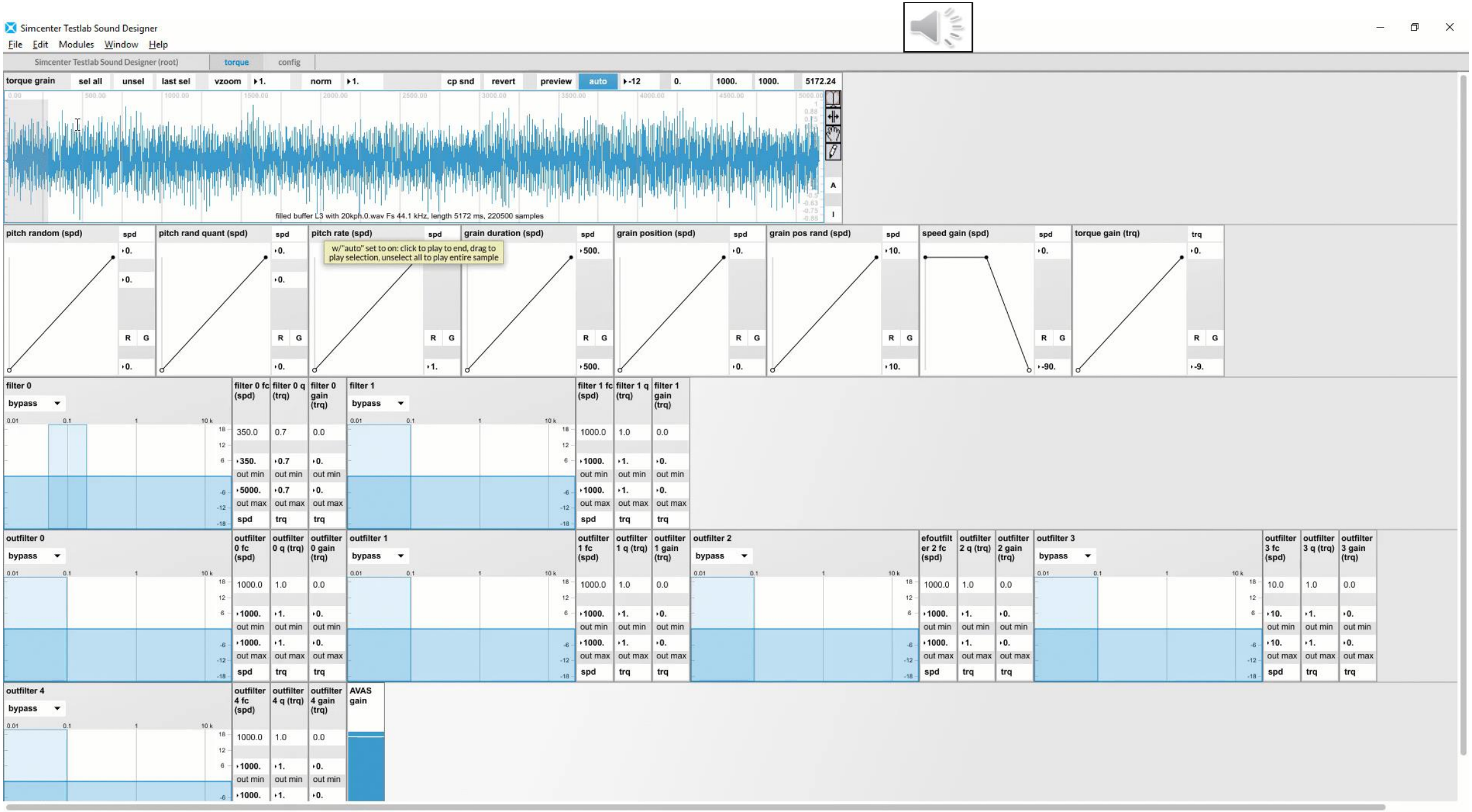
(c) With minimum sound pressure levels in the chosen bands for the applicable test speed according to Table 2 of paragraph 6.2.8., column 3 or column 4.

Frequency in Hz		*Constant Speed Test paragraph 3.3.2. (10 km/h)*	*Constant Speed Test paragraph 3.3.2. (20 km/h)*
Column 1	*Column 2*	*Column 3*	*Column 4*
Overall		50	56
1/3rd Octave Bands	160	45	50
	200	44	49
	250	43	48
	315	44	49
	400	45	50
	500	45	50
	630	46	51
	800	46	51
	1,000	46	51
	1,250	46	51
	1,600	44	49
	2,000	42	47
	2,500	39	44
	3,150	36	41
	4,000	34	39
	5,000	31	36





→OK – 66.55dB(A) > 50|56 dB(A)
→OK: all bands, focus on 315Hz + 1000Hz
→OK
315Hz: 55.97dB(A) > 44|49 dB(A)
1000Hz: 56.27dB(A) > 46|51 dB(A)


Simcenter Testlab Sound Designer
File Edit Modules Window Help
Simcenter Testlab Sound Designer (root)
torque
config
torque grain
sel all
unsel
last sel
vzoom
norm
cp snd
revert
preview
auto
5172.24
filled buffer L3 with 20kph.0.wav Fs 44.1 kHz, length 5172 ms, 220500 samples
pitch random (spd)
pitch rand quant (spd)
pitch rate (spd)
w/"auto" set to on: click to play to end, drag to play selection, unselect all to play entire sample
grain duration (spd)
grain position (spd)
grain pos rand (spd)
speed gain (spd)
torque gain (trq)
filter 0
filter 0 fc (spd)
filter 0 q (trq)
filter 0 gain (trq)
filter 1
filter 1 fc (spd)
filter 1 q (trq)
filter 1 gain (trq)
outfilter 0
outfilter 0 fc (spd)
outfilter 0 q (trq)
outfilter 0 gain (trq)
outfilter 1
outfilter 1 fc (spd)
outfilter 1 q (trq)
outfilter 1 gain (trq)
outfilter 2
efoutfilter 2 fc (spd)
outfilter 2 q (trq)
outfilter 2 gain (trq)
outfilter 3
outfilter 3 fc (spd)
outfilter 3 q (trq)
outfilter 3 gain (trq)
outfilter 4
outfilter 4 fc (spd)
outfilter 4 q (trq)
outfilter 4 gain (trq)
AVAS gain
bypass

Specific AVAS challenges

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Creating AVAS sounds that resonate the **right brand values**

PROTECT BRAND REPUTATION

Identify right AVAS **speaker locations**

SMARTER DECISIONS

Ensure compliance with regulation

ENSURE COMPLIANCE

Granular synthesis

Using simulation in the AVAS Development
Pedestrian Safety / AVAS

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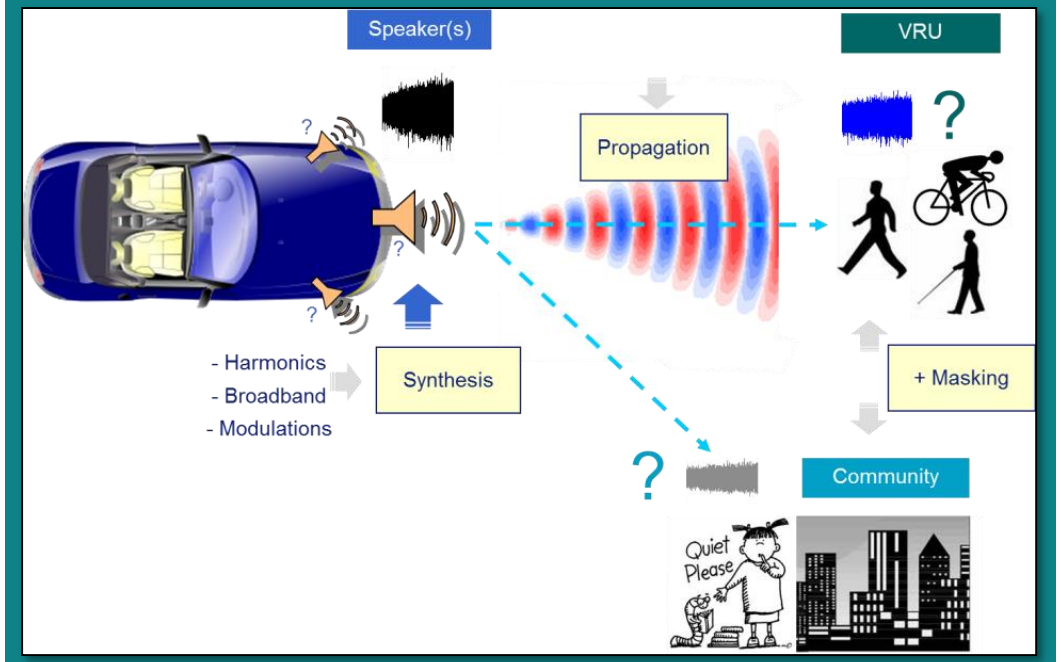
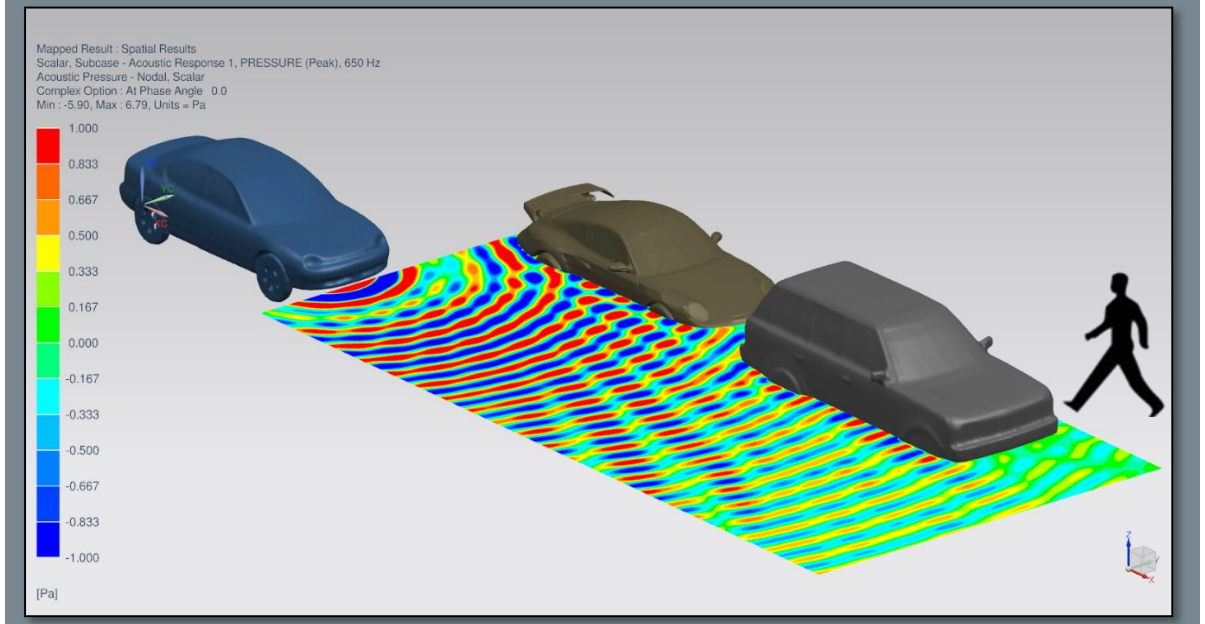
Challenges:

- ✓ Estimate sound Signature
- ✓ content
- ✓ propagation
- ✓ directivity

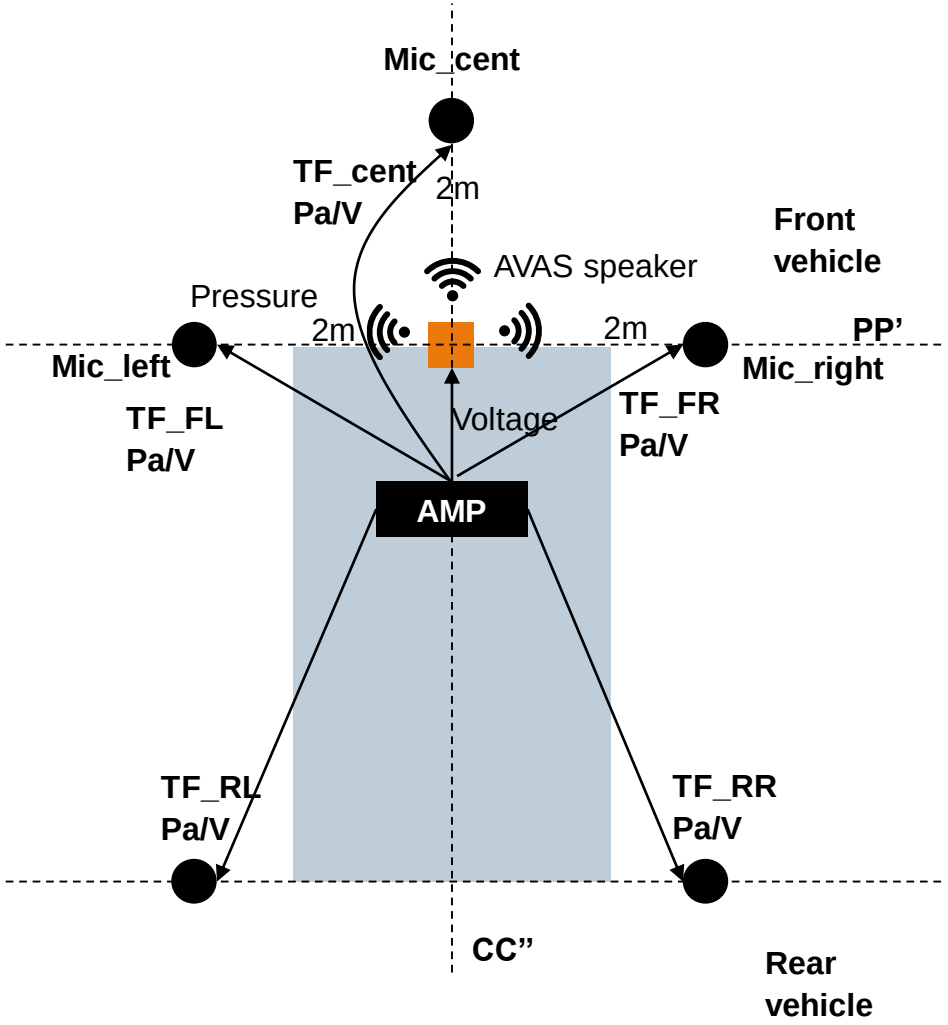




Solution: Fast Multipole BEM

- ✓ Scattering on parked vehicles + ground reflection
- ✓ Can sound be sufficiently heard by people between / behind the car?

Frontload AVAS compliance
Measure transfer functions



Transfer functions:
- From Voltage output of the AMP for the Speaker
- To the pressure response at the PBN microphones

ECE R138
- left & right microphone, at 2m from CC'

FMVSS141
- additional center microphone, on CC' line, at 2m distance
- center microphone only used for stationary directivity test

Reverse
- For reverse testing the vehicle is repositioned with the rear at PP' line

Frontload AVAS compliance

Evaluate PBN prediction with transfer functions

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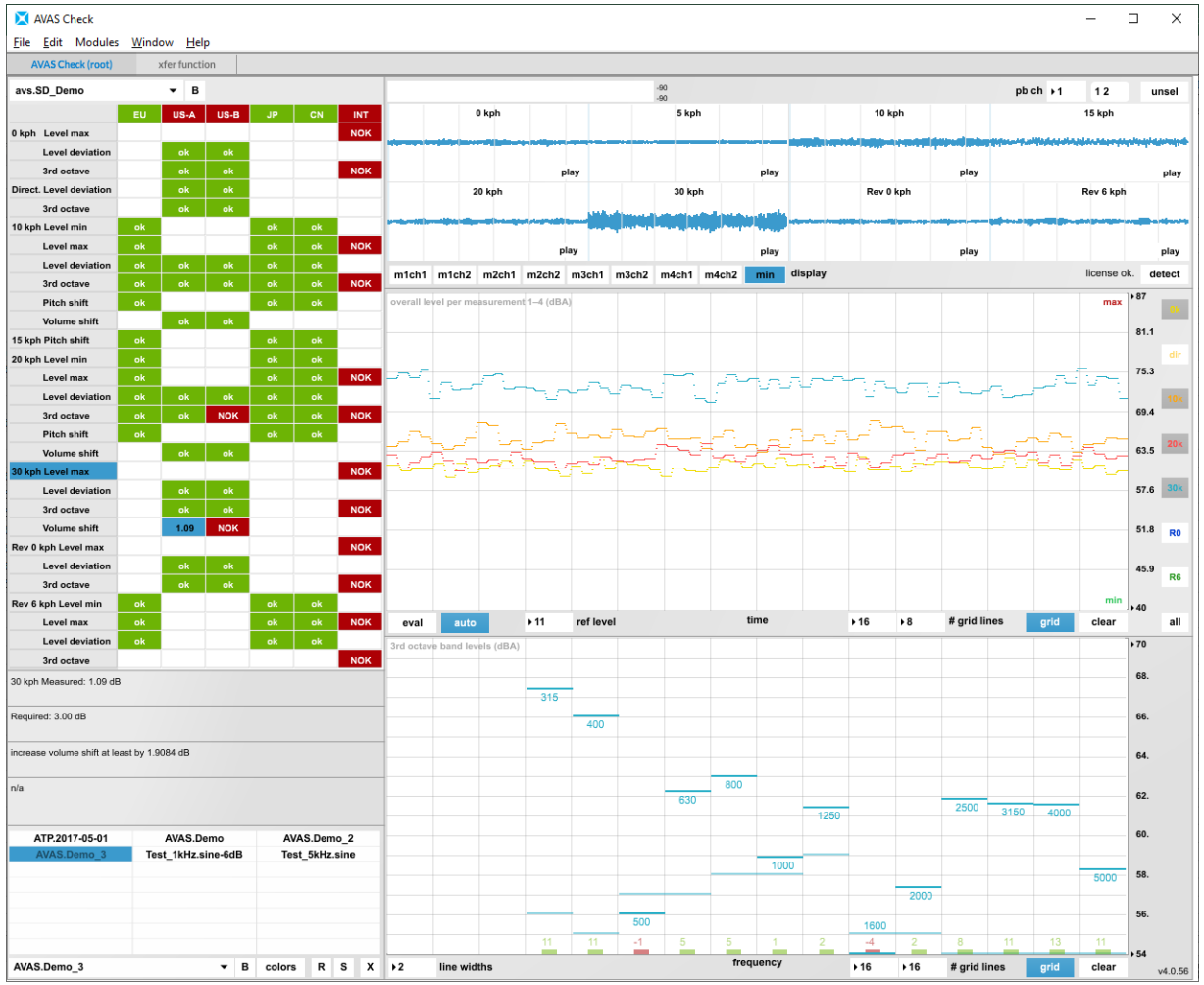
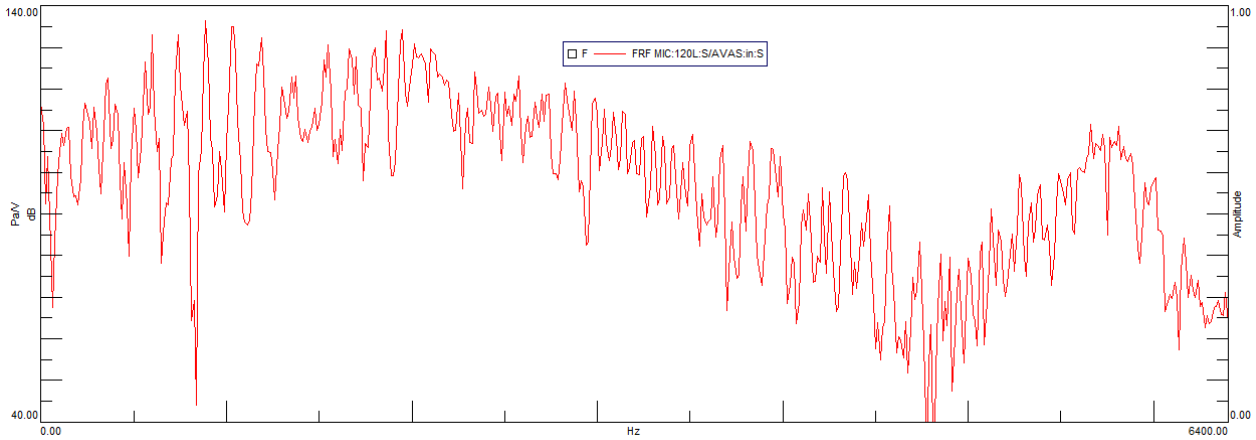
Ingenuity for life





Transfer functions:

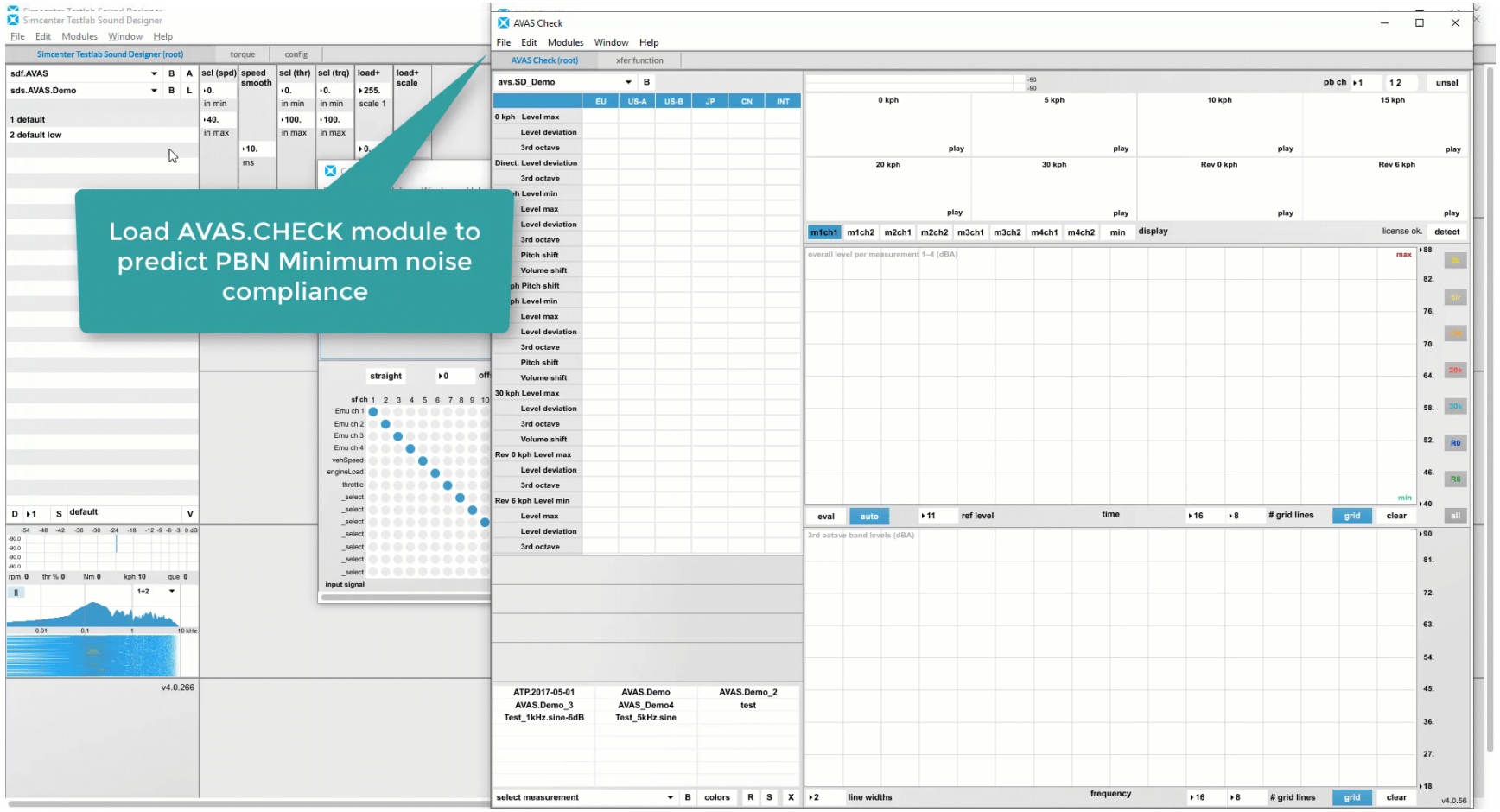
- From Voltage output of the AMP → Speaker
- To the pressure response at the PBN microphones

The AVAS.CHECK

- predicts the sound at the PBN mics
- evaluates if the criteria of R138, FMVSS141, GB/T 37153 + Japanese standards are met.

Frontload AVAS compliance [video]

Evaluate PBN prediction with transfer functions



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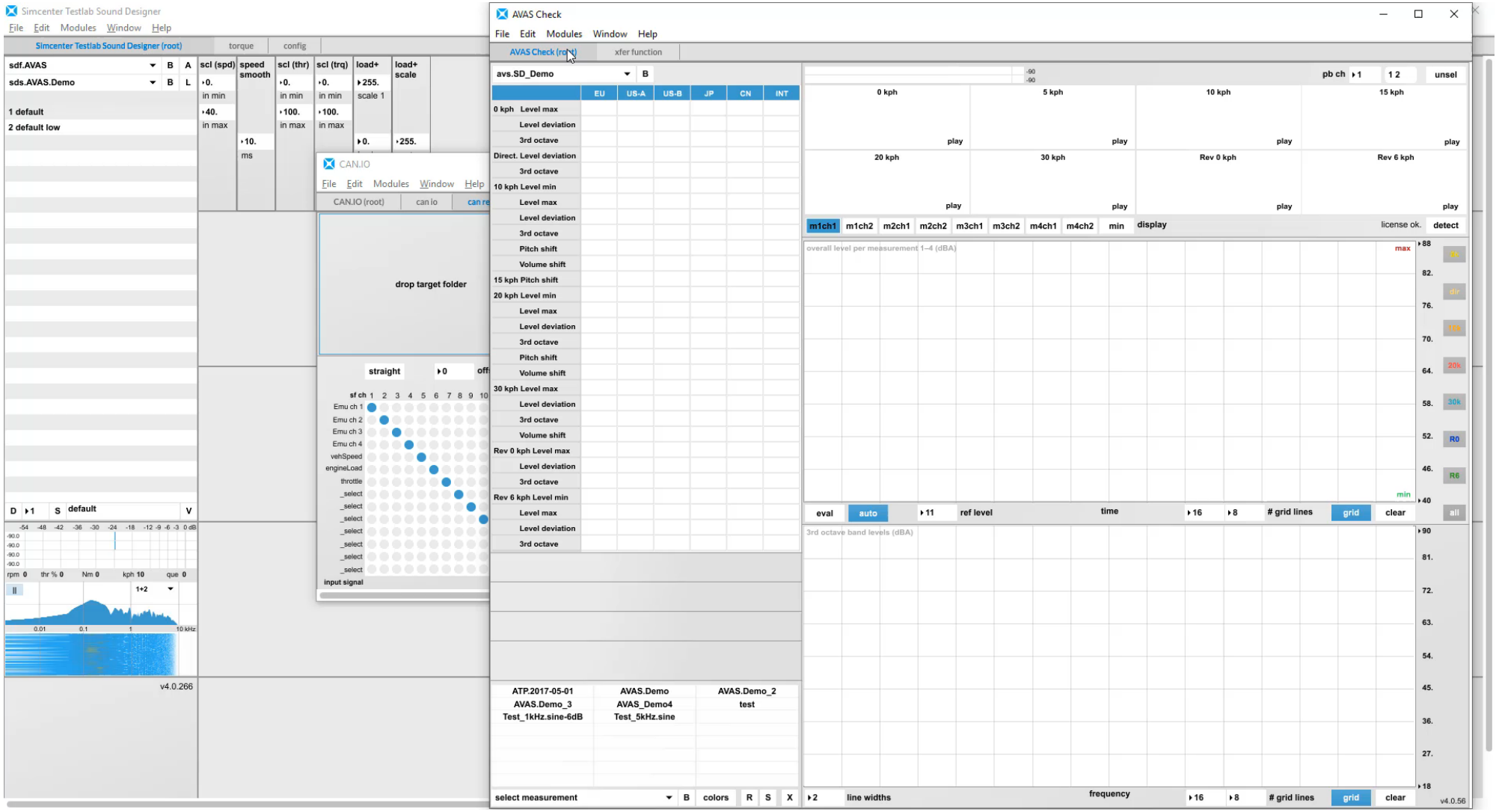
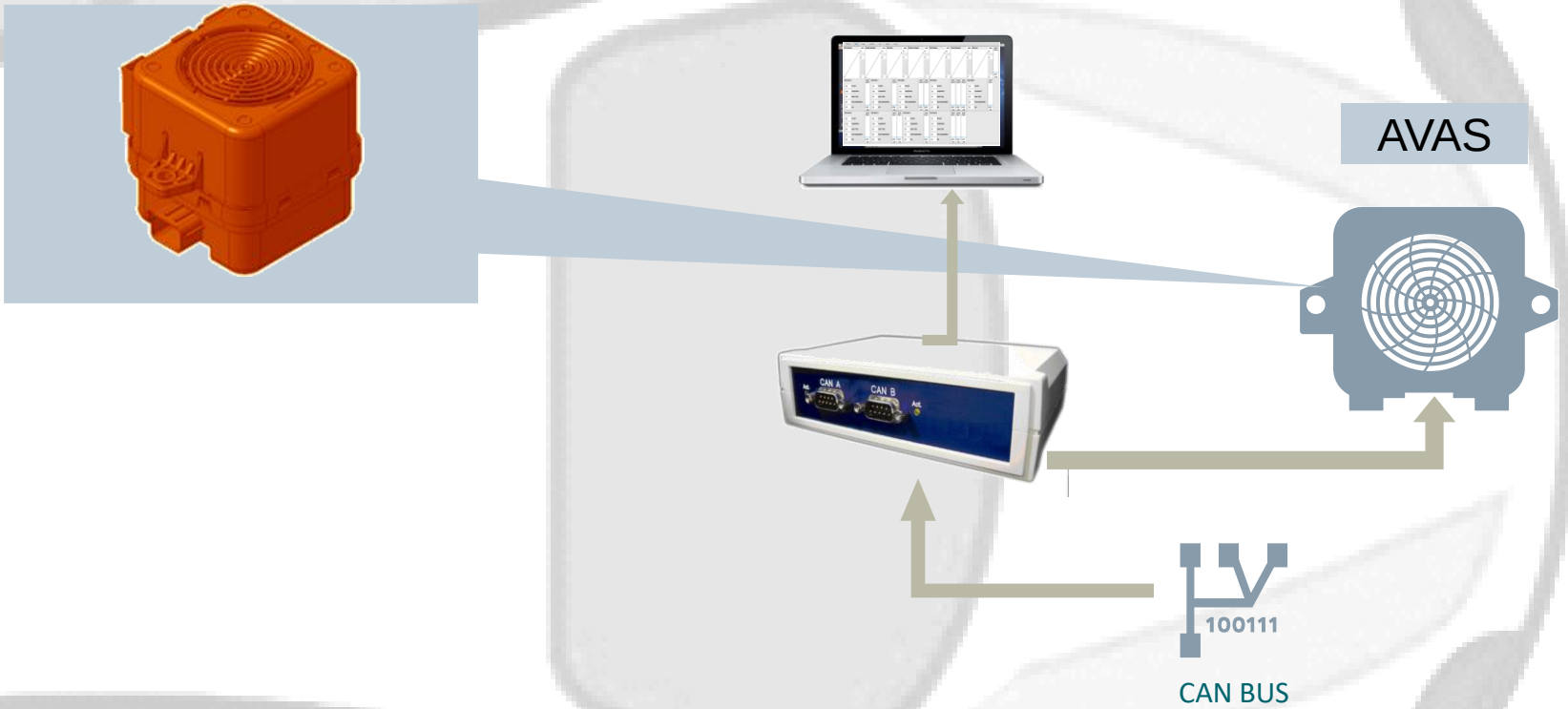


In-vehicle AVAS Tuning in real-time



Specific AVAS challenges

SIEMENS
Ingenuity for life

Creating AVAS sounds that resonate the **right brand values**

PROTECT BRAND REPUTATION

Granular synthesis

Identify right AVAS **speaker locations**

SMARTER DECISIONS

Optimize through Simulation
&
Test Prototype iterations

Ensure compliance with regulation

ENSURE COMPLIANCE

Frontload compliance
&
Execute homologation test on final design

DESIGN

From brand sound to drivable sound model
Granular synthesis | Order synthesis

VALIDATE & TUNE

Validation in the vehicle
Real-time sound tuning

DEPLOY

Integration in production vehicle
Ready for mass production

Interior sound

Brand sound exploration

Active sound model creation

In-vehicle validation

Sound quality analysis

Audio amplifier tuning

Vehicle audio integration

Exterior sound

AVAS

Brand sound exploration

AVAS model creation

Frontloading compliance

In-vehicle AVAS tuning

Vehicle integration

Regulation validation

Industrialization

DESIGN

From brand sound
to pedestrian warning system

VALIDATE & TUNE

Upfront compliance to standards
Real-time sound tuning

DEPLOY

Integration in production vehicle
Minimum noise certification

From Development to Production
Transfer to Tier-1 audio HW & final tuning

SIEMENS
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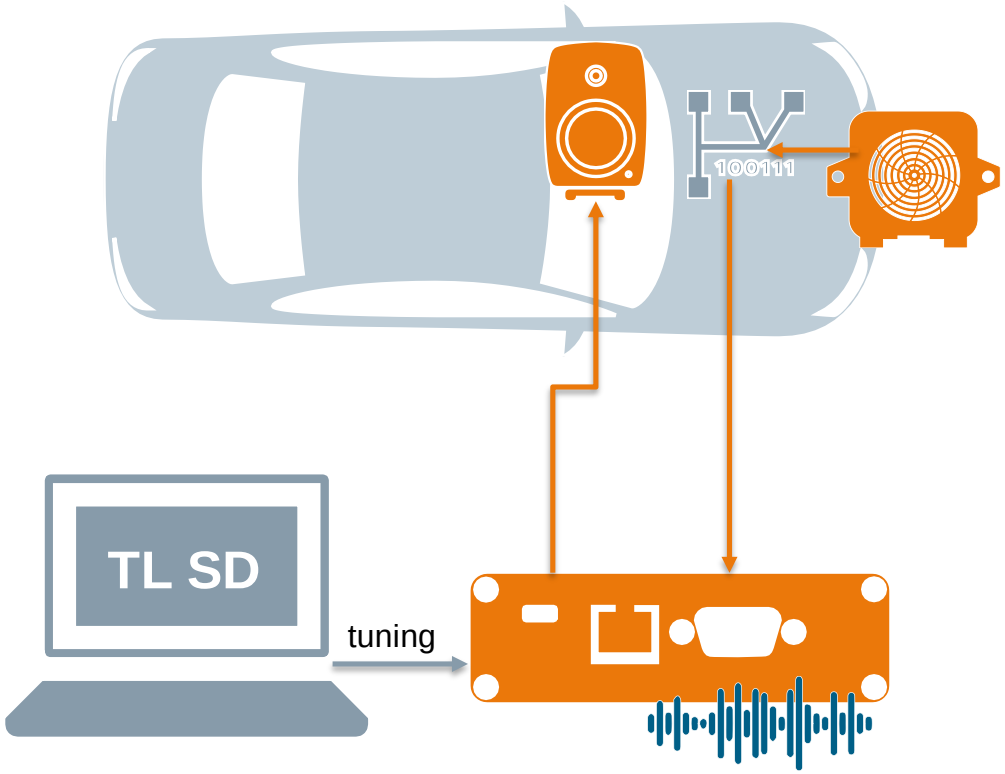

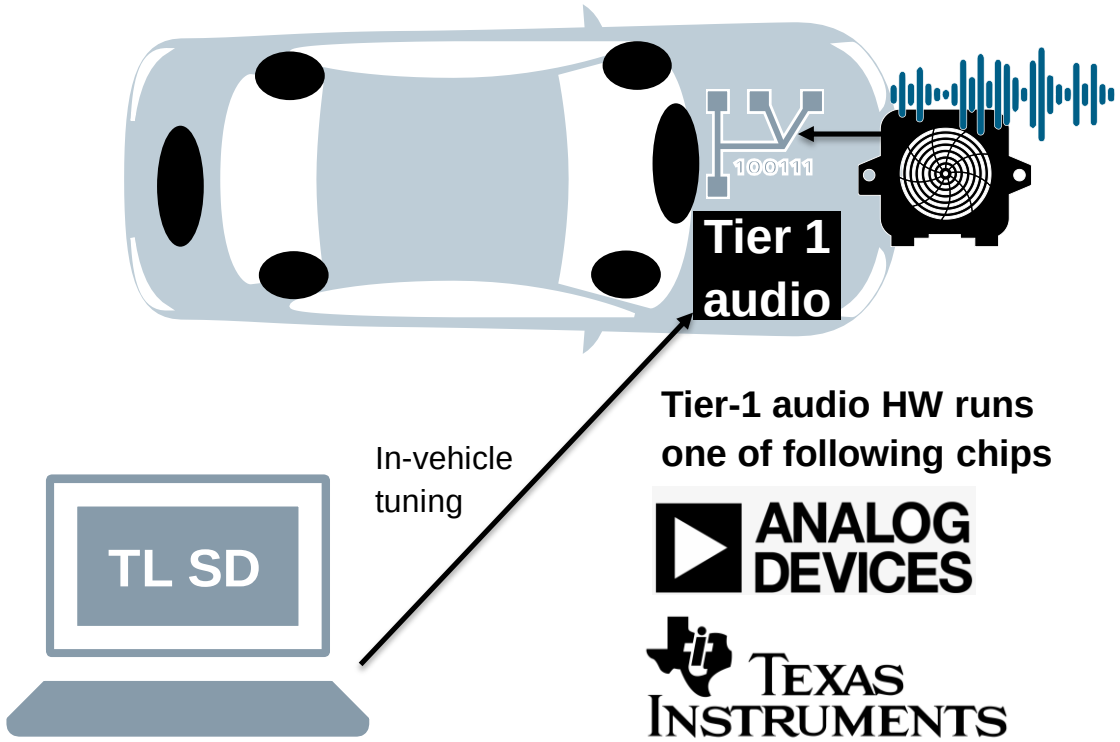

Tier-1 audio HW runs one of following chips

ANALOG DEVICES

Texas Instruments

NXP

Warning sounds for AVAS

Pass the minimum pass-by noise threshold

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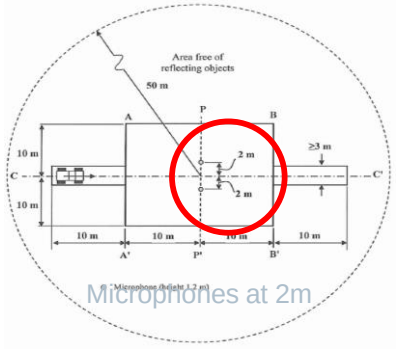
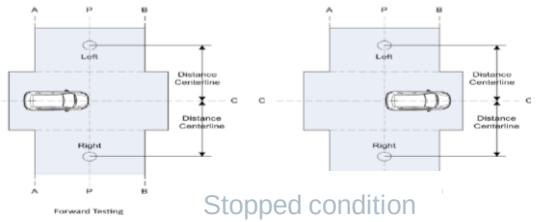
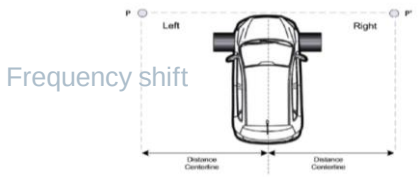


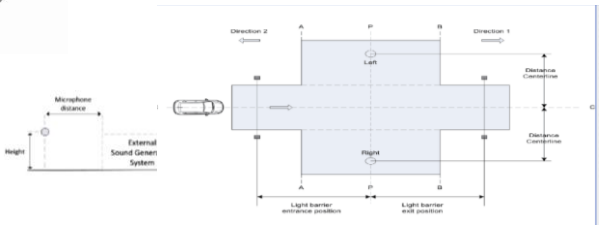
Microphones at 2m



Stopped condition

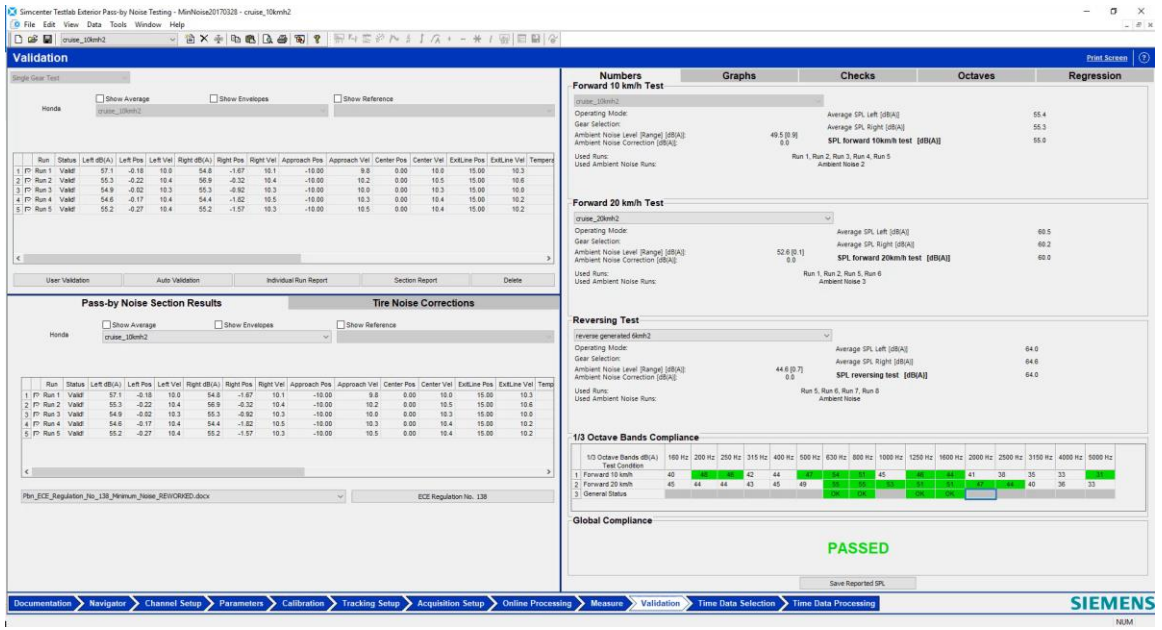


Frequency shift



Slow speed cruise

- Test in full confidence according to standard UNECE R138
- Testlab talks language of the standards, guided from set-up to report
- Supported both in-room or exterior



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Active Sound Design Development
Know-how and tech transfer

SIEMENS
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Simcenter Engineering services complement the Hard- and Software offering with dedicated Services for AVAS and Interior Active Sound Enhancement

Modular offering:

- Onsite commissioning and user training
- Branding, Benchmarking, SQ Analysis and Target Sound Definition
- Development of base sound profiles
- In-vehicle Tuning and Evaluation Workshops
- Final Validation and Certification for AVAS

THANK YOU