eVADER system integration into Nissan LEAF vehicle

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eVADER technical direction - Concept

The alert sound will be emitted by a Beamforming Loudspeaker Array (directed towards the detected Vulnerable Road User). The sound beam can be rotated from one side of the vehicle to the other within ~0.5s if required.

Default condition: broad beam at lower sound level

Alert sound directed toward pedestrian at increased sound level, dependent on risk estimation.

Extract from WP4 Continental
eVADER will have an Environmental Perception System (EPS) based on existing ADAS [Advanced Driver Assistance Systems] able to detect any Vulnerable Road User (VRU) - **WP4 leader Continental**

In addition a Location Based System (LBS) will use GPS position, time of day and a database of hotspots, critical areas and speed limits, to support risk estimations when no VRU is detected.
The eVADER pedestrian alert system will be built into a Nissan LEAF vehicle for evaluation and testing – WP6 leader Nissan

Systems for integration:
- External microphones
- EPS system, camera & radar
- LBS system, GPS
- Risk Estimator computer
- Beamforming loudspeaker array
- Beamforming controller and internal alert sound generator
- Communications on dedicated eVADER CAN bus

Source: WP6 Leader Nissan
eVADER - system overview

eVADER system process:
Pedestrian detection > Risk estimation > Pedestrian Alert sound Generation

Source: WP4 Leader Continental & TNO
eVADER system integration schematic

Source: WP6 Leader Nissan
Pedestrian Detection & LBS system hardware

- Stereo Camera MFC310
- Front Radar ARS351
- Eberspacher Flexcon Midget
- Vehicle to CONTI CAN Gateway
- LBS (Squarell GPS)

CONTINENTAL
eVADER Can Bus Router & VSound DSP Unit

Source: WP6 Leader Nissan
Risk Estimator & Interaction Manager

PCAN Pro Router

EVADER CAN BUS HS 500K

Craneboard - TNO

- Risk estimation
- Ped. filtering
- Driver behavior
- V Sound RP feedback
- LBS algorithms
- Environmental noise level
- Risk estimation
- Interaction manager

Source: WP6 Leader Nissan
Special windscreen ordered with masking profile to match Pedestrian Detection Camera
Objective

eVADER system will monitor street ambient sound levels to allow for compensation in the alert sound level to help audibility.

Selected microphone

Knowles Sisonic microphone (MEMS):
• Low cost
• Robust, tolerant of environmental conditions and vibration.
**Stage 1:**
Evaluation of various potential microphone mounting positions on the vehicle.

**Considerations:**
Influence of disturbing noise sources, such as wind generated noise, motor / Powertrain noise, tyre noise. Environmental effects protection / disturbance of microphones.
e.g. High Powertrain noise disturbance was a feature of mic no. 1, 2 and 3.
High wind noise was a feature of 4 and 8.

**Stage 2:**
Evaluate vehicle microphone levels relative to potential pedestrian position at kerb-side. Establish strategy / algorithm which can give ambient noise level estimations closest to actual kerb-side noise levels.
eVADER Beamforming loudspeaker array

System requirements:
- Minimise number of acoustic sources (6)
- Frequency range 300Hz to 1.2kHz
- SPL up to 90dBA at 1 metre
- Directivity only required in horizontal plane
- Beam steering nominally ±60 degrees
- Angular tracking speed ~300 deg/sec
- Non uniform loudspeaker array

TNO evaluated a range of potential beamforming algorithms. The ‘sound power minimization’ algorithm was chosen for eVADER as it provides narrow beams and allows flexible real-time implementation.

Source: WP3 Leader TNO with LMS
Loudspeaker specifications:
• Visaton FRS 5 X - 8 Ohm
• Diaphragm diameter: 5 cm

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
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<tbody>
<tr>
<td>Rated power</td>
<td>5W</td>
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<tr>
<td>Frequency response</td>
<td>120-20000 Hz</td>
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<tr>
<td>Resonance frequency</td>
<td>190 Hz</td>
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Amplifier specifications:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Operating voltage</td>
<td>6 - 18 Vdc</td>
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<tr>
<td>Output power</td>
<td>2 x 10 Watt</td>
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<td>Frequency range</td>
<td>40 - 16,000 Hz</td>
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<tr>
<td>Loudspeaker impedance</td>
<td>2 - 8 Ω</td>
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<tr>
<td>Sensitivity</td>
<td>80mV</td>
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</tbody>
</table>
LMS evaluated the beamforming system performance using FEM & BEM modelling techniques. Influence of ambient temperature, humidity, ground reflections and beam scattering from parked vehicles have been considered.

Example: Beamforming Directivity performance as a function of frequency for a 30 degree orientated alert signal at distance of 20m from the bumper loudspeaker array.

Source: WP3 Leader TNO with LMS
Bumper & loudspeaker test system prepared by Technical University of Darmstadt – using CAD data supplied by Nissan
Prototype beamforming loudspeaker array installed on Nissan Leaf
First evaluation of prototype eVADER real-time Beamforming system.