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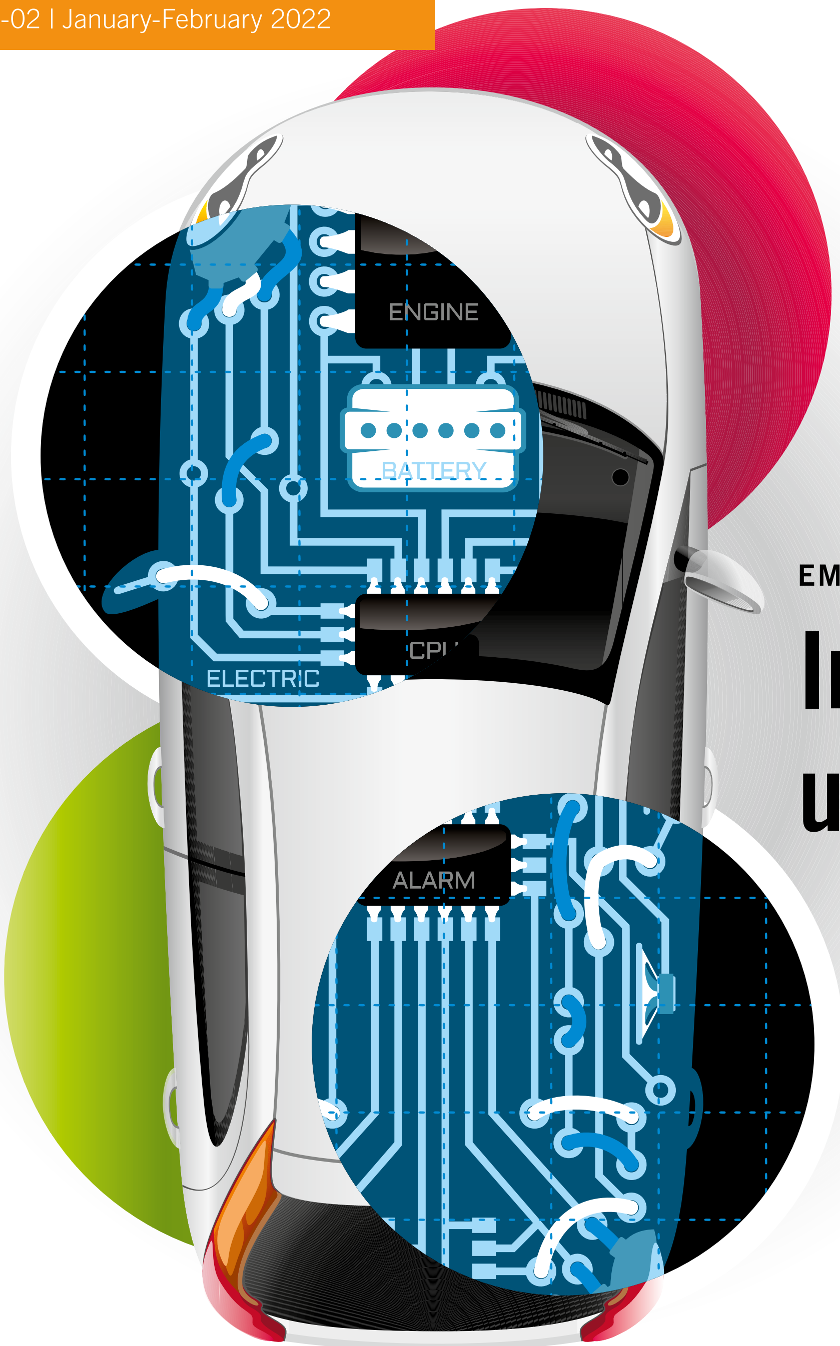

EMBEDDED SYSTEMS

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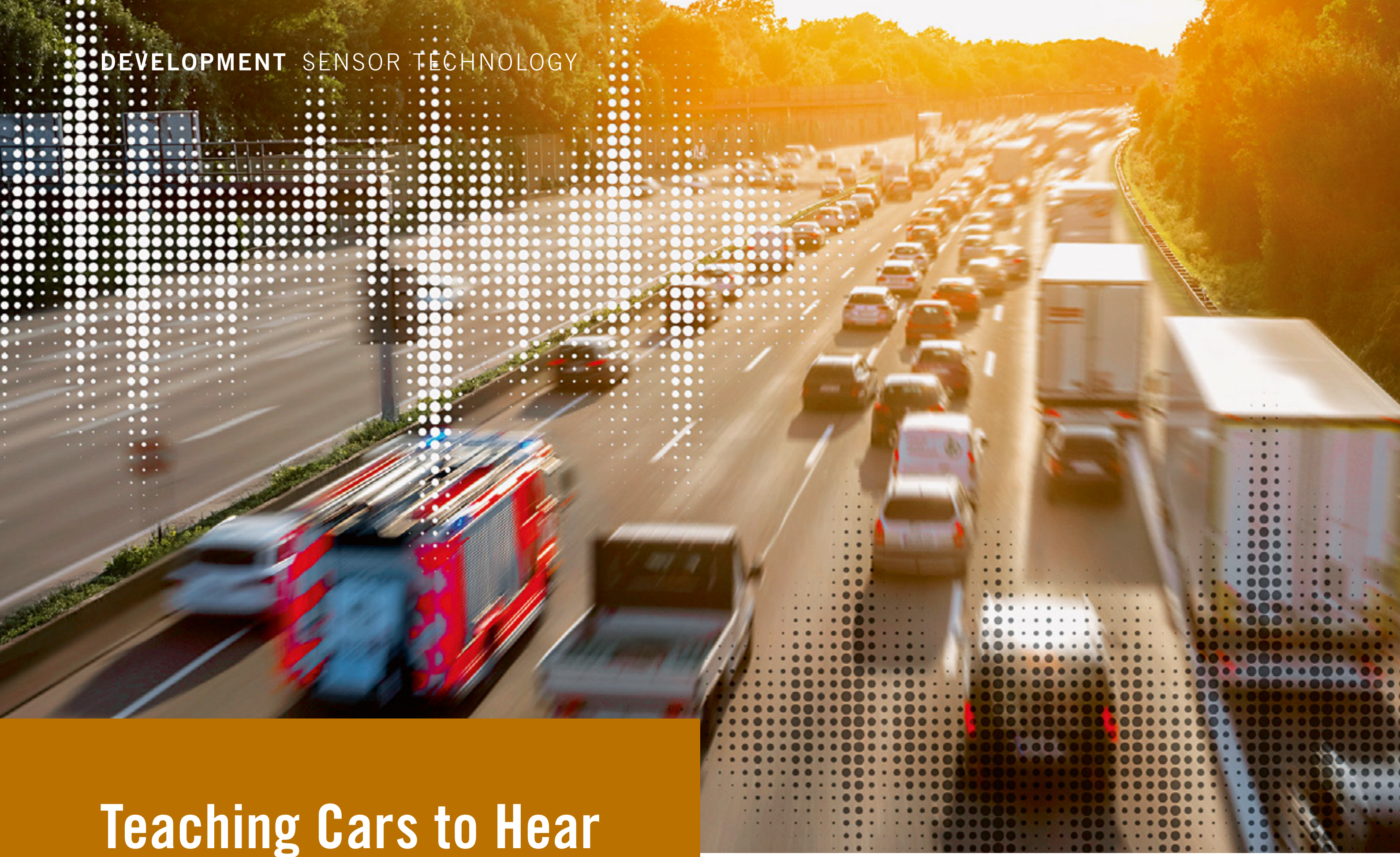

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Teaching Cars to Hear

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Visual sensors can only detect objects in their direct line of sight. MEMS microphones are not subject to this limitation. Infineon and Reality AI recommend these components – together with machine learning methods – as a useful addition for future driver assistance systems. For example, they can help ADAS perceive emergency vehicles with warning signals earlier.

Even today, autonomous shuttle buses are already on the road on some fixed routes in public transport. The first robo-taxis are expected to be in use in Germany from 2022. Self-driving cars also aim to provide a cost-effective transportation solution for seniors who can no longer drive themselves but live in residential neighborhoods that can only be reached by car. On the way to a fully autonomous vehicle, Advanced Driver Assistance Systems (ADAS), which already relieve the driver of some tasks, are standard in many modern vehicles. Some suppliers are already focusing on Level 3 of automated driving, which includes hands-off and eyes-off paradigms, but still requires the driver to intervene in certain hazardous situations. Sensor technology is a key component of platforms for automated driving: Only if the vehicle correctly captures all important data from the environment it can draw the right conclusions and react accordingly. Existing automotive environment sensing solutions typically use cameras or active sensors such as lidar, radar, or ultrasonic sonar. These approaches can be costly and are subject to significant limitations because targets must be in a clear line of sight to the sensor. Furthermore, the target must be specifically illuminated by light or another energy source; dust, weather and obstacles will affect the sensors.

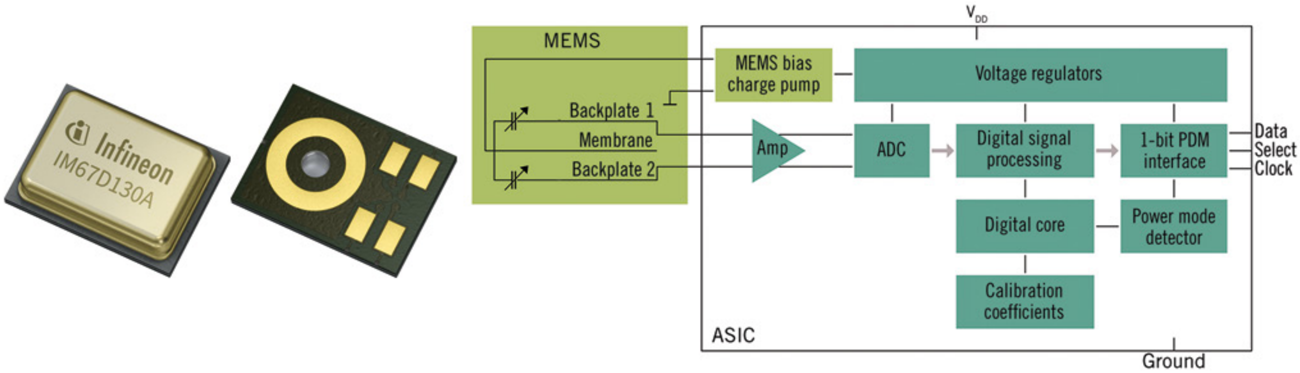

FIGURE 1 The automotive-certified MEMS microphone Xensiv IM67D130A is designed to help simplify design-in and certification (© Infineon)

COMPLETE THE EYES WITH EARS

The aforementioned sensors correspond to the eyes of a human driver. Unlike these, the driver's ears are not limited to target objects within his line of sight. For example, the driver hears the sirens of emergency vehicles or police, long before the vehicles enter the line of sight. Passive audio detection and localization of other road users can thus usefully complement other ADAS sensors. The sensors required for this – MEMS microphones – are cost-effective and can be easily integrated in vehicles. The associated possibilities go far beyond the detection of emergency vehicles. Machine learning algorithms can be used to identify different types of vehicles, bicycles, and pedestrians, determine the angle of arrival and the estimated distance, and decide whether the road user is moving away or approaching. Hearing vehicles meet new Euro NCAP standards for vehicle safety regarding obstructed vision and can thus contribute to the increased safety of vulnerable road users. One example is the Autonomous Emergency Braking (AEB) system "Cyclist" [1], which performs emergency braking in the event of crossing cyclists. Consider the scenario where the cyclist is initially obstructed by vehicles parked on the nearside: by the time visual sensors detect the cyclist, it would be too late to avoid collision. However, low-latency passive audio-based detection and localization can provide advance warning about the cyclist outside the field of view.

AUTOMOTIVE-QUALIFIED MEMS MICROPHONE

Infineon Technologies has partnered with Reality AI to develop an advanced sensing solution giving vehicles the sense of hearing. This solution uses Xensiv MEMS microphones in combination with Aurix microcontrollers and Reality AI's automotive See-With-Sound (SWS) system. This also resulted in a product

FIGURE 2 Various use cases for MEMS sensors inside and outside the vehicle (© Reality AI)

development program for tier-1 and tier-2 suppliers enabling them to create their own versions of the system. The Xensiv IM67D130A, **FIGURE 1**, is the first automotive-qualified MEMS microphone (AEC-Q103-003) on the market, helping to simplify the design-in efforts for the industry and reduce the risk of qualification fails. The MEMS microphone is specified for operating temperatures from -40 to +105 °C. Thanks to its high acoustic overload point of 130 dB SPL, it is capable of capturing distortion-free audio signals in noisy environments. This combination of cost-effective, automotive-grade components enables a new sensory input that can be manufactured on a large scale for tier-1s and OEMs in the automotive industry. The automotive microphones enable the use of sound as a complementary metric in outdoor applications for ADAS, such as detection of sirens or road conditions. The microphone is also well suited for in-cabin applications. The high Signal-to-Noise Ratio (SNR) of 67 dB, in combination with the low Total Harmonic Distortion (THD), enables optimal speech quality and best speech intelligibility for applications based on automatic speech recognition. MEMS microphones in vehicles thus enable further applications, **FIGURE 2**. Inside the vehicle, high-quality MEMS microphones are used, for example, in hands-free kits, e-call systems and for active noise cancellation.

Exterior use cases that cannot be solved by means of conventional sensors to date include:

- Use case 1: As described earlier, there are scenarios where an ADAS cannot easily see other road users, such as emergency vehicles, due to road layout or objects blocking vision.
- Use case 2: Sudden changes in road conditions which cannot be heard by tire and road noise only can lead to physical instability of the vehicle, posing a potential safety risk.
- Use case 3: Vehicles can detect people, but there is no easy way to enable efficient interaction (e.g., control and communication for vehicle access).
- Use case 4: Detecting break-ins or low-speed accidents at the vehicle can provide useful information for insurance or car rental companies. This concerns vandalism (e.g., scratches, broken windows) or minor collisions (e.g., with cars, bicycles, pedestrians) and hit-and-run situations.

In addition, monitoring the vehicle's engine, braking, and other sounds can be used for predictive maintenance purposes.

CHALLENGES IN AUDIO ENVIRONMENT DETECTION

Audio environment detection for cars is not an easy task. Since the system relies on the sound emitted by the targets rather than the illumination of the targets with a known energy source, a wide variation in target types must be considered. In addition, background noise, reflections, and absorption of sound cause additional challenges to the system. Another challenge with using audio sensors is their placement on the vehicle. The body of the vehicle itself shades the sound field, so while a small array on the roof of the vehicle could provide 360° coverage, it would be less effective for nearby targets that are below the level of the roof. A series of arrays mounted on the vehicle, e.g., on roof corners, bumpers or mirrors, would provide better coverage of nearby noise and a broader basis for localization, **FIGURE 3**. Reality AI's design is based on pairs of microphones that can be placed at arbitrary fixed distances from each other on the vehicle, allowing different manufacturers to set up different configurations. Infineon's automotive-qualified Xensiv IM67D130A also scores here. The sensitivity of each individual microphone is calibrated within very narrow limits and thus offers ideal conditions for optimized algorithms for multi-microphone arrays.

For processing the audio signal, Reality AI uses Infineon's Aurix TC3x MCU family. The multi-core architecture of the scalable MCU family contains up to six independently operating 32-bit TriCore processor cores and up to 16 MB flash memory with functional safety up to ASIL D according to the ISO 26262 2018 standard as well as Full EVITA (E-safety Vehicle Intrusion Protected Applications) embedded security in the hardware security module. With rich in-vehicle connectivity buses, data security and functional safety, the Aurix TC3xx microcontrollers are suitable for safety-critical applications such as airbags, braking systems and power steering. They are already used in many radar- or camera-based driver assistance sys-

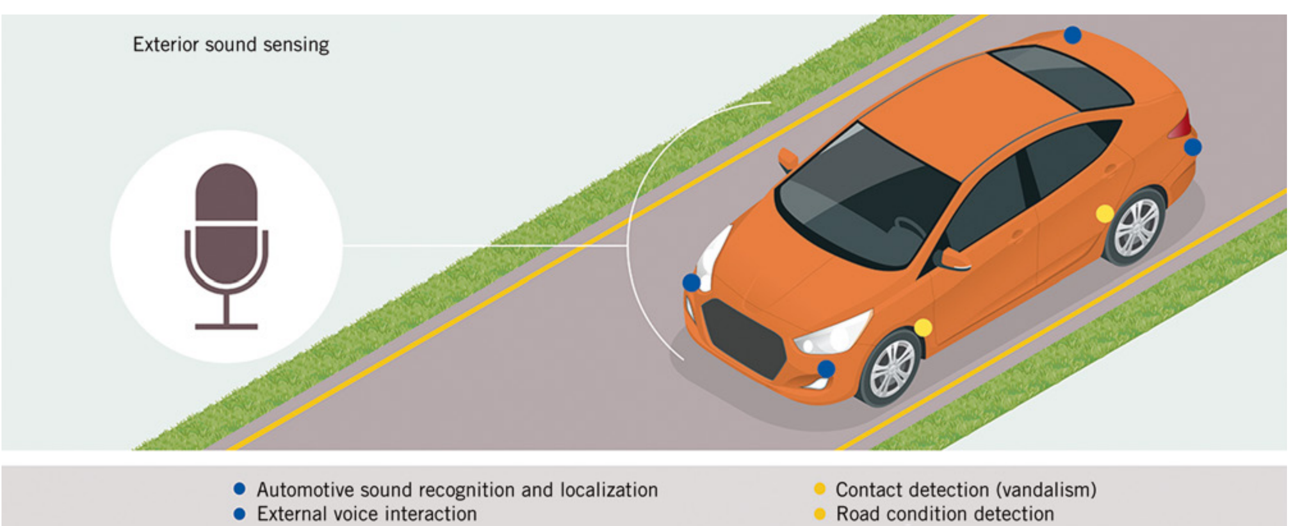

FIGURE 3 Example sensor array for outdoor application (© Reality AI)

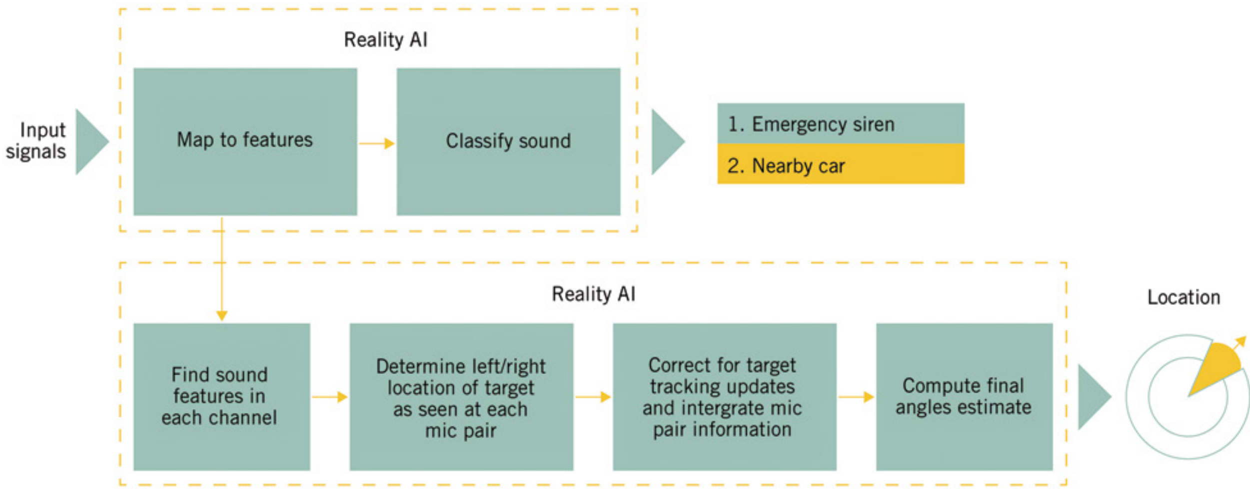

FIGURE 4 Flowchart of Reality AI's system, consisting of classifier (top) and localizer (© Infineon)

tems. Thanks to real-time capability and comprehensive security functions, they are recommended for data fusion – and thus for applications such as the signal processing for MEMS microphones.

MACHINE LEARNING FOR VEHICLE CLASSIFICATION

The system's targets include emergency vehicle sirens, cars, trucks, and other vehicles. They all represent sound classes rather than a unique, reproducible signal. This is because siren tones, for example, vary significantly around the world. There are only loosely defined standards for police, fire, and ambulance signal tones, and often each of these types of vehicles has multiple siren modes as well. For example, a vehicle may use one type of signal tone when driving down a road and another to warn traffic when crossing an intersection. A marketable product must therefore be trained to recognize this diversity.

Vehicle sounds present an even greater challenge because they are not generated by a purpose-built device such as a siren. These sounds consist of a mixture of engine, tire and road noise, braking and other sounds. All these sounds vary depending on road conditions, vehicle speed, and driver behavior. Reality AI's algorithm automatically identifies optimal features to recognize the unique signature of the target, even in scenarios that require multi-target tracking. However, before a product is launched, a wide range of vehicles must be used for training and validation. As shown in **FIGURE 4**, Reality AI's solution involves two systems working together: a classifier that detects and distinguishes target objects, e.g., sirens or cars, and a localizer that identifies the Angle of Arrival (AOA) of the sound from the detected target object. The AOA identification can be based on two parameters. The first is the relative loudness of the sounds arriving at different points on the vehicle, and the second is the phase difference in the arrival of the sounds in local sub-areas. Localization is based on signal processing techniques augmented by machine learning. Information from each pair of microphones that is in the direct path of the sound source rather than blocked by the vehicle's body is combined to provide a final estimate of the AOA relative to the vehicle.

The system evaluates the sound field several times per second and determines the probability that a target is in the sound field. For each target, the position is estimated. This information is combined to smooth the output. This reduces the number of false alarms and also suppresses noise in the AOA calculation. Once a target is detected moving in a specific angular direction, e.g., right to left or vice versa, further tracking filters are applied to predict and test AOA changes over time.

SUMMARY

Today's ADAS rely almost exclusively on cameras and lidar sensors. These have the disadvantage of only detecting objects that are in the direct line of sight. Infineon has introduced a system with Reality AI that gives cars a sense of hearing. Based on the first automotive-qualified MEMS microphones on the market from Infineon's Xensiv family and the Aurix MCUs, the system can detect and locate emergency vehicles early on. The system can also identify other road users – from pedestrians and cyclists to cars and trucks – and determine their location and direction of movement.

REFERENCE

[1] AEB Cyclist. Online: https://www.euroncap.com/en/vehicle-safety/the-ratings-explained/vulnerable-road-user-vru-protection/aeb-cyclist/, access: November 17, 2021

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