ElectronicDesign

TOP TIPS

Sensor Technologies Fueling the Autonomous Vehicle Roadmap

1 Evolving Towards the Autonomous Vehicle

Tomorrow's fully autonomous vehicles require numerous integrated sensor technologies to accurately assess a driving situation and determine what action is needed. Image sensors, radar, light detection and ranging (LiDAR), and ultrasonic sensors are among the major sensor types being developed by OEMs and Tier 1 suppliers. The sensor technologies already available in today's vehicles represent SAE Level 2 autonomous solutions. A full range of sensor types—as well as sensor fusion—will be required to evolve into the fail-safe Level 5 AV of tomorrow.

2 Image Sensors

Since back-up cameras were developed, we've seen the technology advance to forward cameras and now surround-view applications. Going beyond object detection, the industry is moving rapidly to adopt multi-camera systems and AI-based processing methods to create 360° hemispheric views of the vehicle and its surroundings.

Forward-facing camera systems enable Advanced Driver Assistance System (ADAS) functions such as lane-keeping assistance and traffic sign recognition. Forward-facing dual (stereo) cameras can present an essentially 3D image that provides the information necessary to calculate the distance to a moving object, making it applicable for active cruise control and forward collision warning. Augmented with positional graphics relative to steering wheel movement, camera systems are now widely used in parking-assist applications.

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Beyond What Meets the Eye

The requirements for image sensors go beyond merely representing images clearly on a screen. All objects need to be identified correctly in the system for the right automated response or alert to occur. Due to the limitations of the technology, image sensor data is increasingly being combined with radar and other sensors to provide a more robust and reliable data stream across a wider variety of conditions, such as rain, snow, fog, darkness and bright sun. Images captured in low-light conditions have a low signal-to-noise ratio, which makes it difficult to distinguish between a "signal" (for example, obstacles in the road) and system "noise" that degrades structural elements such as edges. It is especially difficult for cameras to track moving objects during these and other less-than-ideal environmental conditions.

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Radar: Measuring Range and Velocity

Radar detects objects by measuring the time it takes for transmitted radio waves to bounce back from any elements in their path. Radar is well suited to seeing and tracking other cars as each radar hit returns not just a distance but also how fast the obstacle is moving. This is commonly referred to as the Doppler effect, the change in frequency of a wave in relation to an observer who is moving relative to the wave source.

Radar for ADAS functions works at 77GHz, which offers higher resolution and greater accuracy for speed and distance measurements than the older 24GHz. And with a wavelength of 3.9 mm, the antenna can be small. Radar's other key advantage for ADAS is its ability to function effectively in poor weather.

This rendering depicts just a few ADAS functionalities that combine image sensors, LiDAR and radar technologies to assess a vehicle's true surroundings.

A radar system's ability to detect an object largely depends on reflection strength. This is influenced by factors such as the object's size, distance, absorption characteristics, reflection angle, and the radar's transmission power. This makes detecting small objects with radar relatively difficult. An ADAS-equipped vehicle must account for pedestrians, animals, bicycles, motorcycles, and other objects that either have relatively few hard or metallic shapes and/or enough mass to reflect radar signals reliably.

5 LiDAR: Seeing Things in a Different Light

Light Detection and Ranging (LiDAR) works on essentially the same principle as radar but uses lasers to generate a high-resolution 3D image of the surrounding environment. The sensor sends out short pulses of laser light and times how long it takes to see the reflection. LiDAR sensors can identify details in an object measuring only a few centimeters at more than 100 meters, and can identify the presence of an object up to 200 meters away. LiDAR works well in all light conditions and is unaffected at night, but performance starts to diminish in the snow, fog, rain, and dusty conditions.

When it comes to identifying objects in the vicinity of the vehicle, other sensor systems are preferable. And despite LiDAR's ability to detect extreme detail, it can't, for example, "read" the letters on a road sign or identify road markings since they're flat (2D). LiDAR also requires a huge amount of processing power to interpret and translate up to a million measurements every second into actionable data.

6 Ultrasonics: Bringing Sound Into the Picture

Ultrasonic sensors use reflected sound waves to calculate the distance to objects. The latest generation of the ultrasonic sensor enables automatic and remote parking in small parking spaces. It is also well suited to supporting emergency braking functions at low speeds through presence detection of close objects, and reacts fast to obstacles that appear suddenly such as pedestrians.

Ultrasonic sensors have a relatively short effective operating range—around 2 meters—so they are typically used in low-speed systems. In addition to parking applications, they have also found a place in more complex ADAS functions such as blind-spot monitoring. Ultrasonic sensors are also unaffected by nighttime and other challenging light conditions, such as bright or low sunlight, filling an important gap left partially unfilled by other sensor types.

7 Sensor Fusion: One Plus One Can Equal Three

Vision systems, radar, LiDAR, and ultrasonics are just a few of the sensor technologies we'll find in tomorrow's vehicles. But since each sensor alone has its limitations, a way to combine data from across the sensor range will be a critical enabler of the fully autonomous vehicle. Known as sensor fusion, this technology is the best way to determine, for example, if what's appearing on radar is the same as what is being "seen" in LiDAR or on camera. By synthesizing data from all on-board sensor technologies, sensor fusion can significantly increase the accuracy of system responses. If successful, sensor fusion will enable tomorrow's AV to truly replicate—or even surpass—the capabilities of the human driver.