Evolving Automotive Safety Requirements Demand Faster, More Efficient RADAR Processing Solutions

NXP MCUs strike the optimal performance-per-watt balance for hardware-accelerated, high-resolution RADAR systems designed for safer, smarter vehicles

INTRODUCTION

The old axiom that "safety sells cars" has never held truer than it does today. Heightening consumer awareness for advanced, high-tech safety features is being met with intensifying regulatory efforts led by global New Car Assessment Programs (NCAPs) to minimize driver and passenger safety threats. In the evolution from current generation L2-class vehicles to fully autonomous L5 vehicles, safety concerns are understandably top-of-mind for consumers and automotive OEMs alike as the margin for safety system error grows ever smaller.

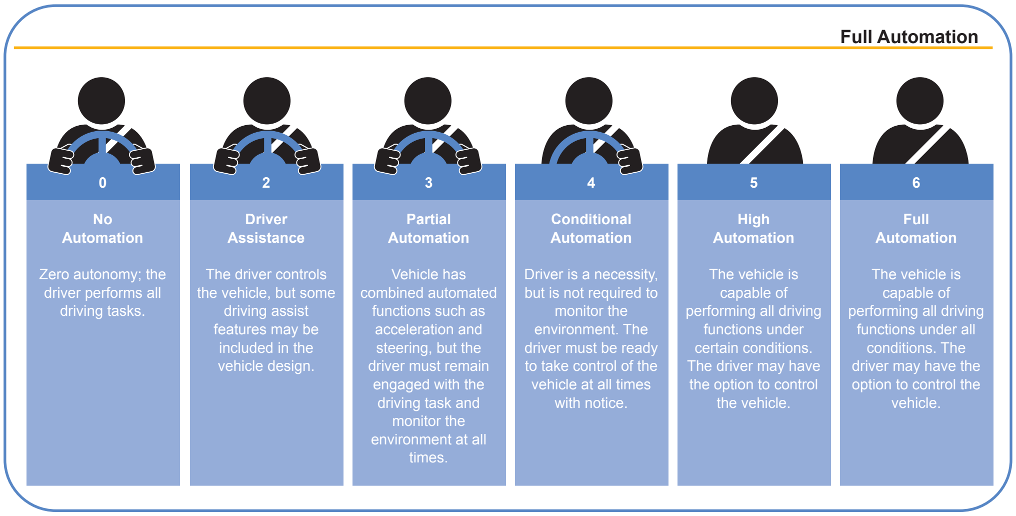

Figure 1. Society of Automotive Engineers (SAE) Automation Levels (Source: National Highway Traffic Safety Administration (NHTSA))

Automotive OEMs and tier-one suppliers are racing to meet these expanding requirements while driving safety feature costs downward to enable commercial price points that consumers find palatable, sharpening their respective competitive advantages while accelerating overall market adoption. At the vehicle sensor level, this requires a careful price/performance balance among camera, RADAR and LiDAR technologies, taking into account their relative strengths and weaknesses.

All three technologies have demonstrated their unique value for automotive safety applications, and no single technology is complete in its ability to enable autonomous driving or advanced driver assistance system (ADAS) functionality. But where costs are concerned, LiDAR sensors will remain largely cost prohibitive until the advent of L4 and L5 vehicles makes this technology indispensable for meeting the requisite liability and insurance thresholds. In addition to streamlining onboard laser and optics costs, mechanically rotated LiDAR implementations will also need to evolve in a manner that eliminates the reliability challenges inherent to moving part-based assemblies.

For the foreseeable future, RADAR and camera sensors will comprise the optimal sensor complement for vehicle safety applications, providing the affordability, reliability and combined functionality needed to enable the next generation of safer, smarter cars. And while camera sensors are essential for object recognition and classification, RADAR sensors are immune to camera sensor deficiencies that limit their effectiveness in low light and inclement weather conditions, while providing the high-precision, vehicle-to-object distance, depth and velocity ranging capabilities that cameras cannot.

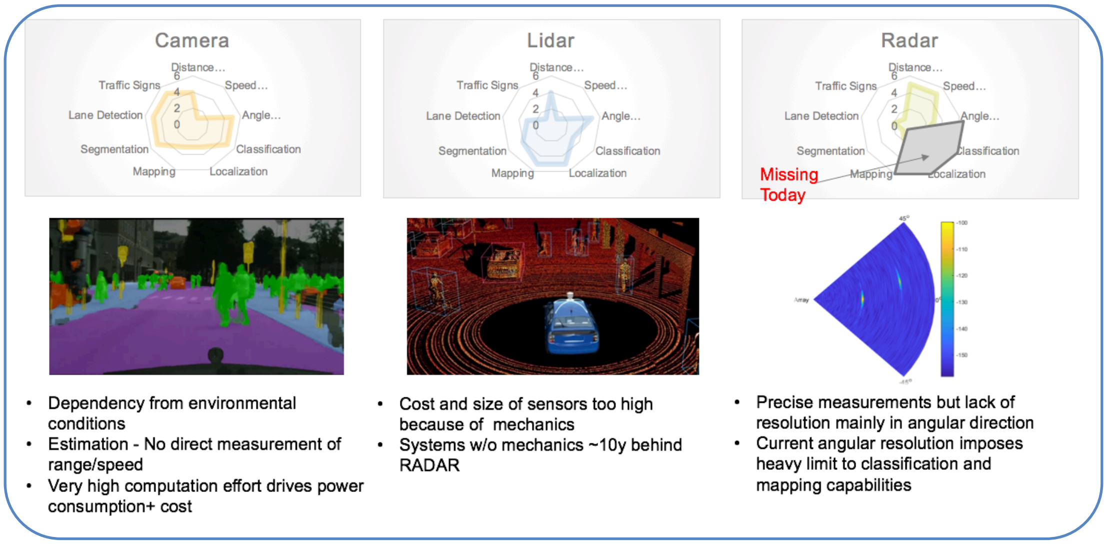

Figure 2. Sensor Capabilities for Today's Autonomous Driving.

Camera and RADAR sensors are similar at the processor level in that they impose significant computational workloads. Shrinking pixel size and increasing pixel density can readily improve camera-based image resolution. Achieving higher-resolution RADAR sensors, however, introduces exponentially larger demands on the underlying processing platform.

Here we'll assess some of the technology trends, challenges and opportunities fueling the automotive industry's continued innovation in — and growing reliance on — high-resolution RADAR for advanced vehicle safety features.

Figure 3. Radar scene

HIGH-SPEED PROCESSING FOR HIGH-RESOLUTION RADAR

As regulatory bodies phase out vehicle RADARs operating in the increasingly congested 24 GHz band, they've simultaneously opened up millimeter wave (mmW) frequencies for automotive RADAR in the 77 GHz band (77-81 GHz) leveraging frequency-modulated continuous wave (FMCW) RADAR. This expansion of available frequencies enables up to 5 GHz of sweep bandwidth where previously 24 GHz narrow-band RADARs were limited to 200 MHz — a significant difference in available frequency width. This change translates to 25x improvements in range resolution, the latter of which determines how far apart objects need to be before they are distinguishable as distinctly separate objects, allowing better detection and tracking capabilities among tightly clustered, adjacent objects. The ability to discern between multiple objects (e.g., a vehicle and a pedestrian), becomes paramount for higher order, automated decision-making based on the known movement patterns and attributes of these two "object" classes.

Automotive RADAR is fundamentally optimized to calculate range, velocity/Doppler, direction of arrival and elevation parameters. To achieve a higher resolution RADAR capability across any one of these parameters, trade-offs in other parameters may be required if the underlying processing performance and/or memory are constrained.

Radar Functionality

Measure:

- Distance to object
- Relative radial velocity
- Angle of arrival
- Radar cross section (object size)

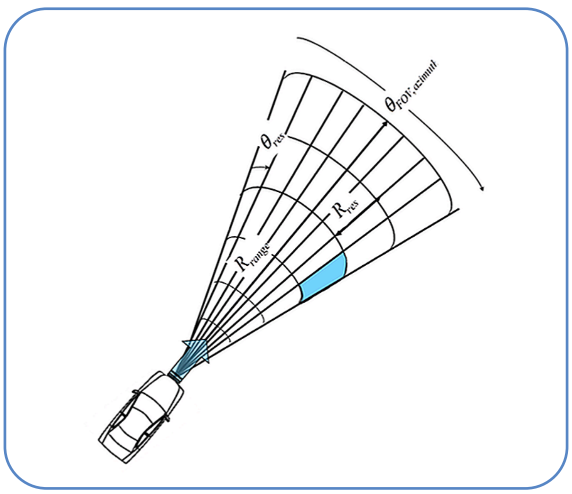

Figure 4. Radar Functionality

Automotive suppliers are steadfastly committed to improving RADAR resolution. Managing the trade-offs however, remains a significant challenge, particularly in regard to angular resolution, a critical capability for distinguishing cars in neighboring lanes, and an essential feature for adaptive cruise control (ACC), and automatic emergency braking (AEB) applications. The ability to detect and distinguish pedestrians among adjacent, larger targets can also stress the azimuth resolution capability of the sensor.

Furthermore, the ability to accurately gauge tunnels, bridges, signposts and attendant vehicle clearance leeway can have significant ramifications for capabilities targeting small obstacle detection on roadways. This new ability may introduce a more stringent requirement for enhanced resolution in elevation detection and leverage sensors with true 2D angle measurement capabilities (azimuth + elevation).

Manufacturers can achieve this goal by using the multiple input multiple output (MIMO) technique. In this technique, virtual antennas arrayed around a vehicle behave like N x M receive antennas from only N physical transmit and M physical receive antennas. The benefit of this method is that it doesn't add significant cost to the system, but it does achieve a significant improvement in angular resolution while minimizing the number of transmitted RADAR chirps. Chirp reduction translates to a faster scan time and eliminates some of the deteriorating effects that impact sensor latency and thereby enhances object detection agility and ADAS response time.

"Range walk," another effect in which a target in motion will sway the attendant range bin in between chirps, results in a blurring of Doppler measurements and a reduction in detection and tracking precision. It's possible to counteract these effects by generating faster chirp rates, but this chirp rate increase requires faster sampling in order to sustain the range resolution capability. Higher sampling rates stress the memory bandwidth of the underlying processor and require faster Doppler FFT processing, introducing significant demands on onboard memory capacity, among other penalties.

The processor performance demands imposed by MIMO beamforming across the virtual antenna array fundamentally require a highly capable processing platform with ample memory, bandwidth and signal processing capabilities in order to realize the aforementioned improvements in angle resolution.

The radar has two major functional blocks:

- RF Sensor (the RF "Front End")
  - Antennas
  - Signal creation and transmission
  - Signal reception and signal conditioning
  - Analog-to-digital sampling
- Computational (RADAR MCU)
  - Convert sampled signal into frequency information
  - Identify "targets"
  - Calculate 1) distance, 2) relative radial velocity and 3) angle of target
  - Advanced functions such as classification and tracking

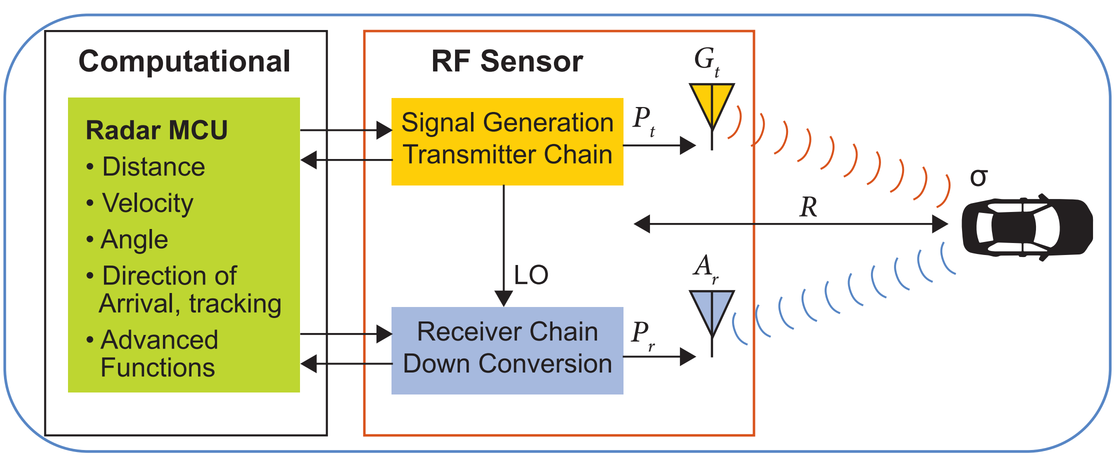

Figure 5. Functional blocks of radar.

Every new automated decision-making capability introduced into the RADAR sensor signal chain increases computational workload. These demands will only grow as heightening safety standards around the globe are met with increasingly adept RADAR sensor implementations. Global NCAP mandates, for example, are expected to establish and enforce stringent safety rating requirements in 2020 for advance RADAR-driven capabilities. These capabilities range from cross-traffic AEB and occluded object classification to pedestrian detection in low light.

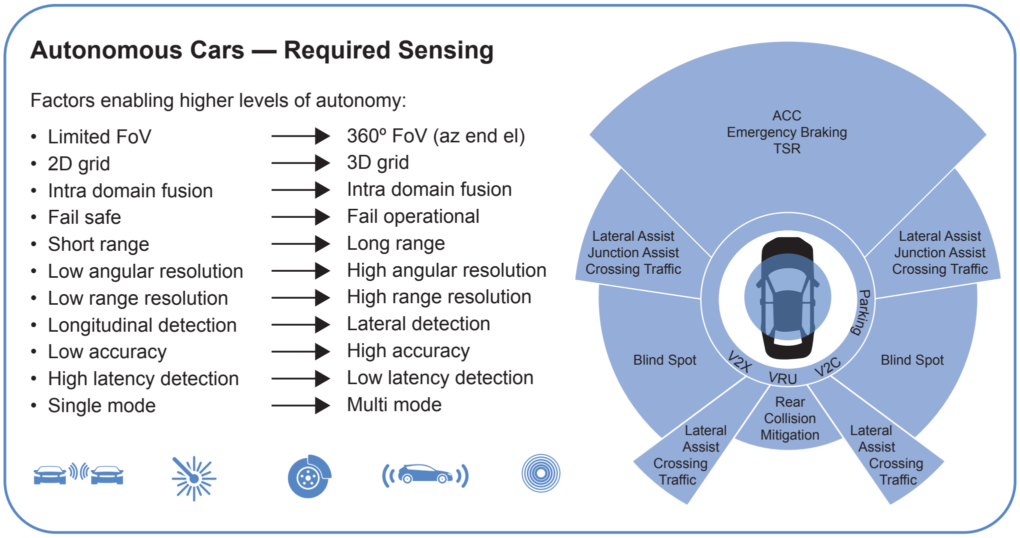

Figure 6. Sensing required for Autonomous vehicles.

At the processing layer, this increasing reliance on RADAR-based safety features has shined a spotlight on the performance capabilities of today's automotive RADAR processors. This focus on automotive RADAR processor performance has exposed several key architectural differences among competing offerings. Automotive OEMs and tier-one suppliers must be aware of these differences to ensure that they're leveraging all available RADAR processing power as efficiently as possible to maximize ADAS responsiveness for optimal driver and passenger safety.

UNRIVALED PERFORMANCE AND UNPRECEDENTED POWER EFFICIENCY

Power efficiency is a critical consideration for every automotive sensor application. Whether powered by fossil fuel or electricity or a combination of the two, the thermal management constraint is particularly pronounced for vehicles leveraging multiple RADAR transmitters, given their associated RF power outputs and limited mounting and thermal dissipation outlets. Power dissipation and thermal management considerations compound the power efficiency challenge as onboard vehicle sensor networks grow increasingly dense, with fewer airflow/cooling outlets available to system designers.

Therefore, it's imprudent to address increased RADAR performance requirements by simply expanding the number of power-hungry, general-purpose processor cores beneath the sensor. The RADAR sensor processing pipeline requires the utmost attention to performance-per-watt metrics, and it's in this domain that NXP has established clear advantages compared to competing approaches.

As a technology and market leader in automotive RADAR processing, NXP's highly integrated RADAR processors offer customers a scalable family of hardware- and software-compatible products featuring S32R27 and S32R37 RADAR MCUs. These devices offer significant performance-per-watt improvements over a traditional DSP[1] by integrating a highly-efficient, specialized hardware accelerator — NXP's proprietary Signal Processing Toolbox (SPT). In combination, these capabilities enable longer range, higher resolution and accuracy for RADAR-driven, safety-critical applications such as collision avoidance, lane change assist, autonomous emergency braking.

[1] Based on NXP benchmarking and publicly available competitive information

NXP's S32R27 and S32R37 solutions are 32-bit Power Architecture® based MCUs designed to address advanced RADAR signal processing capabilities, meeting the high-performance computational demands required by modern beamforming and fast chirp modulation RADAR systems by offering unique signal processing acceleration together with a powerful multi-core architecture.

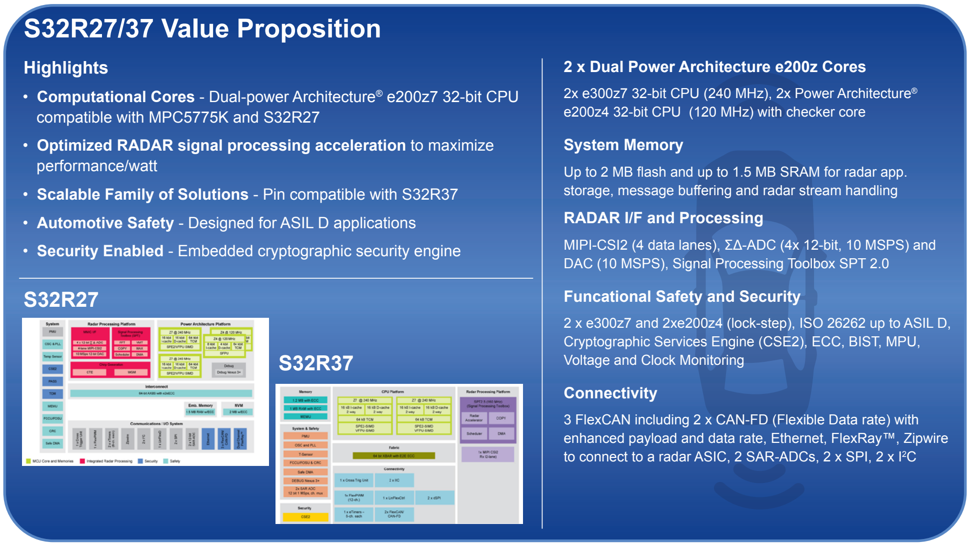

Figure 7. Value proposition for NXP Radar devices.

NXP Automotive RADAR MCU Target Applications

NXP S32R27 and S32R37 – Low- to mid-range RADAR, including side-looking and surround sensors, lane change/keeping assist (LCA, LKA), blind spot detection (BSD), rear-traffic-crossing alert (RTCA).

NXP S32R27 Additional Capabilities – Long-range RADAR, including forward-looking sensor, adaptive cruise control (ACC), autonomous emergency braking (AEB), pedestrian protection.

NXP's SPT supports high-performance RADAR signal processing using its powerful, dedicated engine integrating signal processing operations, providing all the required hardware modules to help engineers with:

- ADC sampling within a programmed capture window
- Hardware acceleration for fast Fourier transform (FFT), histogram calculation, 2D peak search, and mathematical operations on vector data
- High-level commands for signal processing operations
- Compression/decompression for DMA data transfers
- CPU interrupt notification and a watchdog

The SPT is a part of a highly optimized RADAR processing subsystem and utilizes an advanced, high-performance master bus and a peripheral bus. The system bus master interface is used for fast data transfers between external memory and local RAM, while the purpose of the peripheral interface is to set configuration, get status information, basic control of SPT and trigger interrupts and delivering superior automotive RADAR processing performance. The SPT programmable direct memory access (PDMA) is a key element supporting the transfer of data streams into and out of the SPT core. With a strong focus on the automotive RADAR application domain, NXP uses its deep system understanding to optimize where it is necessary while providing just enough flexibility for customers.

THE ROAD AHEAD

Where driver, passenger and pedestrian safety measures are concerned, every millisecond of vehicle response time is critical. As the demand for higher resolution RADAR sensors increases unabated for advanced automotive safety features, performance requirements dictate that the underlying processing platform strikes the optimal balance of compute agility and power efficiency.

NXP's comprehensive portfolio of automotive RADAR MCUs – in combination with its industry-leading SPT hardware acceleration capability – comprises a uniquely scalable, streamlined and highly integrated solution specifically designed to enhance RADAR resolution and sensor data fusion for the next generation of safer, smarter vehicles. NXP will continue to innovate specific intellectual property that keeps pace with growing L3+ requirements, enabling tier one suppliers to build the highest performance RADAR solutions in the industry.

To learn more about NXP's automotive RADAR processing solutions, visit **www.nxp.com/radar** or contact us at **www.nxp.com/contactus**

Contributor

Wim Rouwet
Systems and Architecture Engineer

How to Reach Us:

Home Page: **www.nxp.com**
Web Support: **www.nxp.com/support**

USA/Europe or Locations Not Listed:
NXP Semiconductors USA, Inc.
Technical Information Center, EL516
2100 East Elliot Road
Tempe, Arizona 85284
+1-800-521-6274 or +1-480-768-2130
www.nxp.com/support

Europe, Middle East, and Africa:
NXP Semiconductors Germany GmbH
Technical Information Center
Schatzbogen 7
81829 Muenchen, Germany
+44 1296 380 456 (English)
+46 8 52200080 (English)
+49 89 92103 559 (German)
+33 1 69 35 48 48 (French)
www.nxp.com/support

Japan:
NXP Japan Ltd.
Yebisu Garden Place Tower 24F,
4-20-3, Ebisu, Shibuya-ku,
Tokyo 150-6024, Japan
0120 950 032 (Domestic Toll Free)
www.nxp.com/jp/support/

Asia/Pacific:
NXP Semiconductors Hong Kong Ltd.
Technical Information Center
2 Dai King Street
Tai Po Industrial Estate
Tai Po, N.T., Hong Kong
+800 2666 8080
support.asia@nxp.com

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