Get on the fast-track to automotive system innovation with Texas Instruments

Heinz-Peter Beckemeyer,
Director, Automotive Systems
Texas Instruments
It’s probable that in your lifetime, you will drive or ride in a self-driving car. This car will almost certainly be loaded with electronic conveniences and safety devices to make your trip enjoyable, and it may well be an electric vehicle (EV).

How long before such vehicles are widely available is much debated, but both car manufacturers and technology suppliers are committed to making self-driving cars happen.

Self-driving electric cars merge two complementary technical developments with a lot of momentum behind them: autonomous operation and an affordable EV with fast recharging and an extensive range. When you add in the ongoing trend to use advanced electronics to make traveling safer, more comfortable and connected, the result will be a revolution in transportation in just a few design generations.

It is easy to view self-driving EVs as the all-encompassing dream – the pinnacle of the automotive market. However, those involved in vehicle manufacturing know this dream is only possible via many small steps in technology development. Automated driving depends on scores of electronic systems for sensing, communication and control throughout the vehicle.

Electronic systems throughout the vehicle control the motor, powertrain, steering and suspension, as well as operating the dashboard instrumentation, navigation, entertainment consoles and speakers, cabin and exterior lighting, heating, ventilation and air conditioning (HVAC), automatic seats, windows and mirrors. Advanced electronics save weight, improve operation, increase energy efficiency and make cars safer, more comfortable and convenient. They are also essential to the gradual introduction of autonomous driving, the change from combustion to electric propulsion and the ongoing improvements to the travel experience.

The varied transportation market

The worldwide production of cars and light trucks – more than 93 million units in 2016 – should exceed 105 million units in 2021, according to LMC Automotive. Today, market analyst firm Strategy Analytics says the average automobile contains about $324 worth of semiconductor components, pushing beyond $361 in 2021. A steady increase in electronic systems and components represents the fastest-growing automotive parts segment.

While new feature introductions first appear in premium automobiles, they tend to migrate in a few design cycles toward mid-sized and then economy vehicles. In some cases, legislation or regulations speed up the technology dispersal to promote safety, energy economy or reduced emissions.

![Figure 1. As global vehicle production and more electronic systems are added to vehicles, the average amount of semiconductor content per vehicle will steadily increase.](image-url)
Although cars, SUVs and pickup trucks make up the vast majority of the transportation market and thus tend to drive innovation, other forms of transportation require advanced electronic technology as well. These include industrial transportation and personal, recreational, and other heavy vehicles such as commercial trucks, motorcycles, buses, construction and farm equipment. Innovative technology tends to migrate from the automotive sector to these other transportation areas, but in some cases the flow can work in reverse.

Transportation also goes beyond vehicles – to roadways, parking lots, conventional service stations and recharging stations for the EVs and plug-in hybrid electric vehicles (HEVs) that are becoming more common. Starting with expressways and major intersections, monitoring sensors and cameras are appearing on city roads, along with communications via the cloud to control stations and eventually the vehicles themselves. These environmental changes will affect driving habits, and automakers will need to accommodate consumer expectations with the design of their products. Because semiconductor manufacturers like Texas Instruments (TI) supply technology for a variety of transportation types and infrastructures, the company is in a good position to help automakers harmonize their design efforts with developments in the larger transportation environment.

**The driving forces in the automotive market**

Automated driving and vehicle electrification are both multistage and multi-generational. To track developments in automated driving, SAE International created the J3016 standard to define five levels ranging from none at all (level 0) to fully self-driving (level 5), with different degrees of nonhuman control in between. Many features in the lower levels have already appeared in production vehicles, including dynamic stability control (level 1), adaptive cruise control and lane keeping (level 2), while limited self-driving for situations such as automated parking or driver incapacitation in emergencies (level 3) is on the horizon.

Along with advanced information and warning features, these driving aids are collectively known as advanced driver assistance systems (ADAS) and they promote safety and convenience. The success of ADAS is extremely important to the automotive industry; according to Strategy Analytics, these systems will grow to an estimated market of more than $37 billion by 2021.

<table>
<thead>
<tr>
<th>Hybrid electric vehicles</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Start/stop</strong></td>
<td>Stops engine when the car stops; starts when foot is removed from brake</td>
</tr>
<tr>
<td><strong>Micro hybrid</strong></td>
<td>Regenerative braking and recharging</td>
</tr>
<tr>
<td><strong>Mild hybrid</strong></td>
<td>Includes a 12-V battery for compatibility with existing electrical systems, plus a 48-V battery to run the starter/generator, fuel pump, water pump, cooling fan and other functions, such as an electric supercharger/turbocharger</td>
</tr>
<tr>
<td><strong>Full hybrid (HEV)</strong></td>
<td>Operates from a combination of a battery and a combustion engine</td>
</tr>
<tr>
<td><strong>Plug-in hybrid (HEV)</strong></td>
<td>Allows extending fuel efficiency by recharging from a wall socket</td>
</tr>
<tr>
<td><strong>Electric vehicles</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Pure electric (EV)</strong></td>
<td>Fully electric operation. HEVs and EVs require batteries rated at 400 V or more to propel the car.</td>
</tr>
</tbody>
</table>

*Table 1.* The six types of vehicles with varying degrees of electrification.
Informational ADAS, such as rear-view or surround-view camera systems with displays, provide drivers with a better field of view and allow them to see into blind spots. Machine vision-based systems process information from a variety of sensors to identify objects and dangerous environments surrounding a vehicle, and warn the driver with visual, haptic or acoustic signals. ADAS takes it a step further and can perform simple maneuvers for the driver, like steering the vehicle back into the center of the lane or completely stopping the car if a pedestrian steps in front of it. For highly automated and fully automated systems in a vehicle (also called self-driving cars), many sensors and subsystems will have to work together to transmit, combine and process all available information (also called sensor fusion) in real-time. This can make decisions not only to affect steering, acceleration and braking, but also route planning.

Vehicle electrification has similar levels of limited to fully electric operation, giving consumers a selection as they become accustomed to the technology. Generally, the automotive industry distinguishes the EV categories listed in Table 1. Each category includes the features in those above it, and each in turn saves an increased amount of combustible fuel. Of those listed, mild hybrids and plug-in hybrids are predicted to be the fastest-growing categories in the next few years.

Vehicle electrification through these stages complements the development of automated driving because both depend on advanced electronics deployed throughout the vehicle. In some cases, both electric drive and automated driving may use the same systems for acceleration and stopping; in other cases, they may share sensing, computing and communication resources for operation and diagnostics. Moreover, ADAS-activated automation often achieves the goal of energy efficiency, which is a central purpose of electrification. For example, adaptive cruise control helps maintain a uniform fuel usage that is more efficient than frequent acceleration and braking. Another ADAS feature, the replacement of external side mirrors with cameras and in-car displays, not only increases driver awareness and safety but also impacts energy reduction by removing two sources of air drag.

A third major trend in automotive electronics is the ongoing development of greater comfort, convenience and connection to the world outside the vehicle, going back to the earliest installation of car radios. With increased freedom from the strains of driving, consumers will want their traveling experience to be more enjoyable in terms of climate control, sound, light, communications, and at-hand or voice-activated conveniences.

In general, these types of systems fall into two groups: those in the instrument cluster and dashboard that provide information and entertainment, and those in the car body and lighting that facilitate comfort and convenience. In both areas, advanced electronics have brought greater traveling satisfaction to drivers and passengers, and will continue to do so.

In the following sections, we will explain the systems and technology requirements for the major development areas in automotive electronics:

- Vehicle sensing, intelligence and control for ADAS, to enable a smarter and safer driving experience.
- Next-generation integrated cockpit systems to create more interactive, not distractive, driving experiences.
• The building blocks for greater intelligence in body electronics systems, and more complex lighting to optimize passenger safety, comfort and convenience.

• Power management, sensing and motor control technologies for electric powertrain subsystems to electrify automotive systems from the car to the grid.

**ADAS paves the way to autonomous vehicles**

Providing the pathway to vehicle automation, ADAS technology is based on extensive sensing and imaging from cameras, ultrasound, radar and LIDAR. The more ADAS technologies, the greater the need for high-bandwidth communications, high-performance image (and other signal) processing, and intelligent control. The information has to be processed immediately, so functional acceleration and low-latency communication is especially important, as is using as few wires as possible to save space and especially weight.

Cameras produce a vast amount of video data, requiring algorithms to filter and condition that data. These algorithms also search for and recognize objects of importance such as traffic lights, lane markings, pedestrians and other vehicles. All of this takes place in real time, along with determining whether the car should swerve, slow, stop, etc., and initiating the action. The combination of video, data from other sensors and control decision-making demands heterogeneous processing solutions that often integrate general-purpose and specialized core processors in the same device.

As more ADAS features appear, there will be a greater need to fuse the electronic functions – both to save space, weight, cost and functional resources – and to provide redundant sensing and imaging for greater reliability. For instance, a video camera trained on the road ahead has limited visibility at night or in fog, rain or a dust storm. However, augmented by other sensors such as radar and LIDAR, a “look-ahead” system can compensate for the limitations of the camera.
Fusion drives the integration of separate components, sometimes onto a single chip, and other times into a multichip module. Semiconductor providers must have a wide range of process and packaging technologies to help shrink the components most effectively.

**Infotainment and cluster systems enable an interactive experience**

Infotainment systems combine a variety of technologies in a central location to aid drivers and provide information and entertainment. Traditional instrument gauges are giving way to digital cluster displays with as-needed alerts and on-demand information in intuitive formats. For instance, ADAS functions may alert drivers that other vehicles or objects are in the roadway through an aerial display, while a head-up display (HUD) projected on the windshield keeps the driver’s eyes on the road.

HUDs are gaining traction; consumers are only beginning to realize their potential for high-resolution projection, as they bring sharper images with more information in formats that help keep the driver’s eyes from tiring. On the other hand, many drivers have become accustomed to following spoken navigation instructions, and voice messages can reinforce alerts when the driver overlooks warning lights. On the steering column, touch and gesture sensors enable intuitive user interfaces, and when coupled with tactile feedback can enhance experience and driver awareness.

Changes in infotainment systems connect the larger world to the vehicle. Emerging, integrated entertainment, multimedia and informational functions mimic the utility and familiarity of a smartphone. Audio systems support a greater selection of listening options, and enhanced acoustics and speakers make the sound in the cabin more satisfying. Whatever the success of infotainment features, the design goal is to make them interactive, not distractive, so that the driver can stay focused on driving.

*Figure 3. Once consisting of little more than a radio, infotainment and cluster systems have grown to now include HUD and eventually gaming and other rich entertainment experiences.*
As the nerve center of the car, infotainment and cluster systems require connection to the ADAS, powertrain and convenience systems. Flexibility is key to the processing solutions on which infotainment and cluster systems depend: flexible communications because data connections may vary, flexible configuration to support hardware differences among car models, and flexible software that permits adaptation to various trim lines and design cycles. With flexibility comes scalability so that the same microprocessor family can support multiple vehicle types.

The long-term growth of electronic functions will come over time, helping reduce design times with proven development tools and software reuse. Additional needs include highly efficient power supplies to support low-power and multi-rail requirements, high-speed serial receivers for minimizing communications wiring, sensors to monitor light dimming and cabin temperature, and a variety of other functions that promote comfort, convenience and safety.

**Body electronics and complex lighting drive comfort, convenience and safety**

The wide range of conveniences included in vehicle body electronics depend on miniaturized, cost-efficient sensors. Many positioning features, such as those that report an unclosed door or move a seat automatically, depend on position sensors that are integrated along with other circuitry. Touch-sensing buttons or panels, sometimes aided by haptic feedback, can replace spring-activated switches that wear out. Door locks and alarms operate with wireless switching, as well as being tripped by door positioning and seat pressure sensors.

Introductions in voice-activated controls that promote an interactive human-machine interface (HMI) are based on human voice recognition systems, working in tandem with processing of voice commands. Along with these and other sensors are small motors, solenoids and other actuation devices driven by compact circuitry. For technology developers, highly visible conveniences in body
electronics pose space, weight and cost challenges; however, most of which can be easy to solve with innovative technology and ideas.

Adaptive lighting systems have generated some of the most exciting innovations in the automotive industry. Until the last decade, most headlights only had static, on/off functionalities and the majority used incandescent bulbs. Now debuting in high-end vehicle models, adaptive headlight systems comprise light-emitting diode (LED) or Xenon headlights that dynamically adjust beam direction and intensity. An LED matrix manager enables adaptive headlight technology to provide better roadway illumination.

Within the cabin, digital light adjustment techniques can change the ambiance of the cabin, while exterior illumination improves as manufacturers change traditional lamps to LEDs.

**The electrification of powertrain subsystems progresses quickly**

While the powertrain is all but invisible to drivers and passengers, it remains the most fundamental technology in the automobile. China, and several countries in Europe, are planning to ban vehicles with internal combustion engines (ICE) between 2030 and 2050. Thus, the changeover of subsystems from ICES to electric motors is progressing quickly. The industry demands innovative electronics solutions for the high-powered drive and fast charging needed for HEVs and EVs, for making fuel-powered engines operate more efficiently, and reducing weight in areas such as power steering.

Required semiconductor functions range from varied forms of sensing through amplification and signal conversion to communications and processing of signals and control algorithms. In addition to the specific performance requirements of these components, automotive electronics face unusually harsh environmental factors on the roads, including grime, shaking and high temperatures. Chips must be tested for the excessive heat, and printed circuit boards (PCB) for the vibration characteristic of automotive environments, along with the automotive qualification of each integrated circuit (IC) for use in these conditions.

*Figure 5. Internal combustion engines may be a feature of the past as automakers focus more on HEVs and EVs with longer ranges.*
Power management, important in all electronic systems, is far more challenging under the hood than elsewhere in the car. Wildly differing voltage levels, ranging from 3 V to more than 800 V, may need to be supported, and electronic power supplies must accommodate the rise and drop in battery voltages caused by various charging and load conditions. Maximum voltages that surpass the capabilities of silicon require new compound power transistor materials. High voltages and associated high currents require ICs built with reinforced isolation techniques to protect circuitry and people from overloads and dangerous discharges.

Precise motor control is essential to powertrain electrical subsystems. A motor creates every electromechanical rotation, from low-power motions in compressors, fans and blowers to high-powered wheel propulsion in HEVs and EVs. DC motors in a vehicle have different power and control requirements, with the most demanding applications requiring robust sensing; high-performance signal-processing algorithms; and precise control of voltage inputs to achieve the desired outputs of torque, speed and position. Steady electrical operation also means that DC motors have to run for longer hours than they once did, creating new reliability issues. Powertrain technology suppliers need extensive expertise in sensing, power management and motor control to bring innovative solutions to automotive OEMs.

**TI accelerates innovation in automotive system designs**

TI understands the requirements of automotive systems manufacturers and automakers, and applies its advanced technology using a system-based approach to address the full range of automotive needs and challenges. A 35-year relationship with the automotive industry gives TI valuable insights for creating today’s solutions, and unique foresight into addressing the challenges ahead. In virtually all areas of ADAS, infotainment, body electronics, lighting and powertrain subsystems, TI products and support help automakers reach new levels of performance and functionality. TI also supports designs for industrial and personal transportation and the infrastructure, rounding out the company’s technology base in the complete transportation environment. Across all sectors and market trends, the following six technologies are accelerating innovation in automotive systems.

**Sensing and signal conditioning.** System intelligence begins with gathering data via sensors and cameras, then amplifying and converting this analog information for digital processing. TI sensors cover a wide range of conditions including position, proximity, temperature, pressure, light, sound, fluids, speed and materials. TI also offers ultrasound and radar solutions and supports video cameras and LIDAR for ADAS sensing at a distance. Sensor ICs may also integrate signal conditioning and communications; some add processing and communications depending on requirements. TI leads the industry in analog front-end (AFE) functions that condition signals, offering a broad portfolio of discrete and integrated solutions for interfacing the analog real world to the digital world of embedded processing and control.

TI’s AWR millimeter wave (mmWave) radar sensor family delivers up to three times more accurate sensing than previously available mmWave solutions. These single-chip devices combine mmWave radar plus communications, along with a microcontroller (MCU) and digital signal processor (DSP), enabling designers to implement intelligent, contactless sensing to help vehicles detect and avoid other cars, people or objects.
For motors, TI was the first to offer a resolver sensor interface with an integrated power supply, exciter amplifier and functional safety features to enable smaller, more reliable and more accurate rotary position-sensing designs. Many automotive systems require functional safety features, which are enabled through TI's SafeTI™ design packages. Using SafeTI components like sensors, motor drivers, MCUs and power products help designers meet industry-standard functional safety requirements while managing both systematic and random failures.

**Embedded processing.** TI's embedded processor portfolio is broad and deep, including single-core MCUs and multicore processor-based systems on chip (SoCs). Specialized cores help speed video processing, and on-chip wired and wireless interfaces provide flexible communications. EVs benefit from C2000™ MCUs, which offer real-time control solutions for efficient power conversion and high-performance motor control. Also part of the SafeTI design package offering, Hercules™ TMS570 MCUs help customers meet strict industry standards for functional safety automotive applications.

The Jacinto™ family of highly integrated TDAX and DRAx SoCs are specifically built for automotive ADAS and infotainment applications, including digital cockpit, cluster, sensor fusion, park assist, camera mirror systems (CMS) and driver monitoring systems (DMS). Optimized for the performance, power and cost requirements of ADAS and infotainment systems, Jacinto processors’ heterogeneous architecture and common software platform allow OEMs to more easily differentiate their offerings with industry-leading performance and efficiency.

For ADAS applications, the Jacinto TDAX family of SoCs provides high performance and low power consumption based on a heterogeneous hardware processing platform with a common software architecture. These highly integrated SoCs enable miniaturization of camera-based vision systems for front, rear and surround views as well as night vision, plus multi-range radar and sensor fusion systems. The scalable architecture allows automakers to design ADAS features for a range of vehicles from premium to entry level, and also helps preserve OEMs’ software investment and reduce their subsequent development costs.

*Figure 6. TI’s system-based approach addresses the full range of automotive needs and challenges.*
Jacinto DRAx infotainment SoCs offer another highly integrated solution with performance and safety that enable the digital automotive cockpit. A common core platform and architecture permit maximum reuse of software and design investments and the efficient scaling of features. This platform enables manufacturers to optimize the bill of materials while leveraging image, vision and signal processing for differentiation across vehicle types.

**Connectivity.** Highly integrated vehicle systems need reliable communications. TI's in-depth expertise in communications provide solutions with robust bandwidth that meet requirements for all types of automotive systems. TI embraces the major wired transmission standards, from basic Control Area Network (CAN) to Gigabit Ethernet (GbE), Local Interconnect Network (LIN), RS-485 and RS-232 transceivers plus wireless communication protocols such as Bluetooth® and Wi-Fi®. Among notable innovations is FPD-Link™ III, the high-speed serial video communication that pairs well with Jacinto SoCs and other infotainment processors, which saves weight and space while providing the bandwidth needed for video signals in just two wires. To serve multi-camera systems, a single hub aggregates and replicates high-resolution data from up to four cameras simultaneously.

Because it is embedded into almost all modern smartphones, wearables and tablets, Bluetooth® low energy is a particularly attractive wireless technology for automotive body electronics and infotainment applications.

Bluetooth® low energy enables passive entry passive start (PEPS), including car sharing, where a driver’s smartphone functions as a virtual key; remote vehicle diagnostics or telematics information, such as sharing tire pressure, fuel level, battery status and temperature to a smart device; and also driver assistance and personalization, so a vehicle’s body control module (BCM) can activate interior and exterior lighting, personalize seat positions, and adjust HVAC or infotainment preferences as a driver nears a vehicle. In the future, Bluetooth® low energy could enable autonomous parking, where a user exits the vehicle and activates a smartphone app to allow the car to drive itself off to a parking spot nearby. This is all made possible with TI’s SimpleLink™ Bluetooth® low energy CC2640R2F-Q1 automotive-qualified single-mode Bluetooth® low energy wireless MCU solution.

**Lighting and displays.** TI’s portfolio for automotive lighting accelerates designers’ innovation in both interior and exterior illumination systems, including LED-based HUDs. TI matrix drivers offer high-performance control for multi-pixel LED front and rear lights. For both interior and exterior lighting systems, highly-efficient LED drivers can extend the life of automotive lighting designs, maintaining greater driver and pedestrian visibility (thus improving personal safety) and enhancing the overall driving experience. Exterior lighting solutions designed with TI's lighting technology enable developers to create cost-effective, customizable systems without sacrificing aesthetics.

Greater resolution and more advanced features are possible using DLP® technology, which permits the selective redirecting or dimming of portions of the headlight pattern away from other drivers’ eyes or highly reflective surfaces. In the future, DLP technology-based exterior lights may project messages that improve visual communication with pedestrians and other drivers. In HUDs, DLP technology provides higher brightness across temperature ranges that can be used to display a larger field-of-view and augmented reality graphics. This allows OEMs to design HUDs for the optimal virtual image distance to help keep driver’s eyes on the road.
Power management. One of TI’s greatest strengths is its power-management technology, with a portfolio of power conversion and regulation solutions that accommodate the full spectrum of multi-voltage subsystem electrification. Among leading products are LM53x synchronous DC/DC converters, which save space, reduce power consumption and reduce electromagnetic interference (EMI), encompassing a complete solution for automotive power design. TI battery-management devices enable systems that recharge hybrid and EV batteries. Silicon gate drivers and power transistors from TI are available for switching power supplies in 12 V and 48 V automotive electronics. For the much higher voltages needed for HEV and EV propulsion, which exceed the ordinary operating limits of silicon, TI offers gate drivers and supports other technologies.

Isolation. High levels of integration mean that signals of widely different voltages need isolation from each other for signal integrity and the protection of people and equipment. TI offers isolated solutions for stand-alone and integrated basic or reinforced isolation in its signal chain and power portfolio to prevent high voltage spikes and transients from entering low-voltage circuitry. In addition, TI’s capacitive technology isolates the signals from unwanted line noise from on-chip sources.

Support and reference designs

TI technologies are all backed by extensive development support, including reference designs, evaluation modules (EVMs) and tools to simplify development and help speed time to market. Reference designs instantiate the system-based design approach, providing automotive manufacturers and automakers with proven circuits and extensive test data that can shorten their design and validation cycles. Among the many reference designs that TI offers for automotive applications are:

- Automotive 2-Axis Power Seat Brushed DC Motor Drive Reference Design
- Automotive ADAS Reference Design for Four Camera Hub with MIPI CSI-2 Output
- Automotive Camera Module Reference Design with 1MPixel Imager, Bayer Video Output & Power over Coax
- Automotive Multiple Channel Temperature Sensing for LED Headlight Reference Design
- Automotive Reinforced Isolation CAN Reference Design
- Automotive Resolver-to-Digital Converter Reference Design for Safety Application
- Automotive Shunt-Based ±500A Precision Current Sensing Reference Design
- Automotive TFT LCD Display Solution
- Bidirectional DC-DC Converter Reference Design for 12-V/48-V Automotive Systems
- CISPR 25 Class 5 USB Type-C™ Port Reference Design with USB 3.0 Data Support
- Multiswitch detection interface (MSDI) for body control module (BCM)

Transportation into the future

The vision of self-driving EVs whisking us about our daily business may tantalize us, but automotive technologists know that transforming that vision into reality will take a while. In the meantime, developments in ADAS, powertrain electrification, infotainment and cluster, body electronics and lighting can help make designers’ automotive designs safer and make travel more enjoyable, but are also bringing
challenges with each automotive design generation. Other types of vehicles and the transportation infrastructure also feel the effect of these trends and present their own requirements.

The challenges facing the automotive industry require innovative electronics technology in power management and throughout the signal chain. Car manufacturers and Tier-1 suppliers who need advanced semiconductor solutions also need wide-ranging technology and expertise from their suppliers, plus in-depth support to help them create and release new models.

TI is a leading supplier of the advanced semiconductor technology that enables new developments in automobiles and other transportation methods. TI offers IC solutions for every electronic system in a vehicle today, managing all power-supply stages and covering the entire signal chain, from sensing through signal conditioning and processing to communication and control. TI's broad portfolio of automotive products, together with its in-depth expertise, system-based approach to design and full development support, have resulted in extensive engagements with leading automotive manufacturers in all regions of the world. These relationships, built alongside TI’s active participation in industry standards bodies and commitment to research, continue to advance the company’s development of innovative technology that brings greater value to customers. As automakers and their customers travel the road to greater automated driving, electrification, safety, comfort and convenience, innovative technology from TI will be with them all the way.

**Additional resources:**
- Learn more about how TI accelerates innovation in automotive systems: [www.ti.com/automotive](http://www.ti.com/automotive)
- Get the latest news and solutions for automotive systems on TI’s [Behind the Wheel blog](http://www.ti.com/automotive)
- View the latest automotive reference designs for [ADAS, body electronics and lighting, infotainment and cluster](http://www.ti.com/automotive), and [HEV/EV and powertrain applications](http://www.ti.com/automotive)
IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ("TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, INCLUDING BUT NOT LIMITED TO TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include, without limitation, TI's standard terms for semiconductor products (http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/sampterms.htm).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2017, Texas Instruments Incorporated