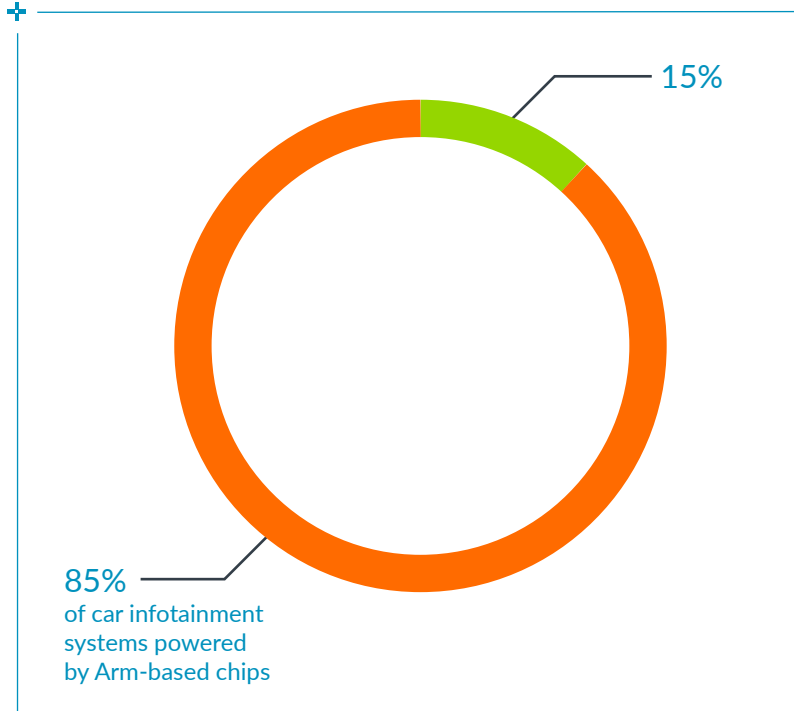


Then, Now and the Future of the Car Cockpit



January 2019





Introduction

As we enter the era of advanced driver-assisted systems (ADAS) and head toward autonomous vehicles, technology continues to transform the automobile cockpit. Vehicles today use technology and features only science fictions writers might have dreamt up just a few years ago. And as the digital revolution continues, Arm experts expect vehicle interiors to change more in the next ten years than they have in the past 50 years.

For decades, Arm architecture has been a key enabler of automotive technology, with more than 85 percent of infotainment systems and many under-the-hood applications powered by Arm-based chips. To highlight how dramatically cockpit technology has changed in the past few decades, here's an overview of technology hotspots in cockpits of the past, present, and future.



The Instrument Cluster

Past

Digital speedometers arrived in the late 1970s as options, or as standard in some luxury brands. Due to reliability and visibility issues, however, adoption was limited and most instrument clusters remained back-lit analog gauges driven by stepper motors designed specifically for pointer control.

In the early 1990s, the Driver Information Center (DIC) with an integrated LCD display became a more common feature in the instrument cluster. The DIC communicated important information about the vehicle, but were only offered by a few vehicle manufacturers.

Compute Requirements

A microcontroller drove the stepper motors for gauges and the DIC.

Arm Solution

Not applicable.

Present

High-end and premium vehicles often use full-color thin-film-transistor (TFT) liquid crystal displays (LCD) in digital clusters to provide a signature user experience. The cluster electronic control unit must have safety mechanisms to correctly display safety relevant content (tell-tales), and more safety information is shown to the driver through advanced driver-assistance system (ADAS) features.

In-Vehicle Infotainment (IVI) system features, such as navigation, audio, and telephony data, are often integrated into the digital cluster. Here, dynamically reconfigurable clusters let the driver personalize the user interface (UI). Some vehicle manufacturers integrate the instrument cluster application into a digital cockpit domain controller alongside other workloads on a mixed-criticality platform.

Compute Requirements

An application processor with an integrated 3D-graphics engine supports a rich 3D user experience. An instrument cluster electronic control unit typically has an ISO 26262 Automotive Safety Integrity Level (ASIL) B requirement.

Arm Solution

Cortex-A, Mali GPU, Mali DPU.

Future

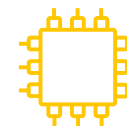
The number of displays in the cockpit have significantly increased, and all vehicle instrument clusters are digital. Vehicle manufacturers include the instrument cluster application as part of the digital cockpit domain controller alongside multiple mixed-criticality workloads on the same electronic control unit.

Increasingly, car makers are able to differentiate their brand and provide a signature user experience, while dynamically reconfigurable clusters allow the driver to personalize the UI.

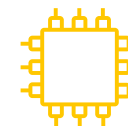
Compute Requirements

An application processor with integrated 3D-graphics engine supports a rich 3D user-experience. An Instrument cluster ECU typically has ISO 26262 Automotive Safety Integrity Level (ASIL).

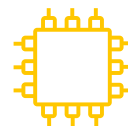
Arm Solution



Cortex-A



Mali GPU



Mali DPU

Heads-Ups Display (HUD)

Past

As early as 1988, some vehicle manufacturers were producing limited-capability, monochromatic HUDs to present data in a way that didn't force the driver to look away from the usual viewpoint.

Offered as optional, these HUDs displayed a digital speedometer on the windshield, but were widely regarded as more of a novelty, and did not gain huge acceptance.

Compute Requirements

A microcontroller-based electronic control unit was used to drive the heads-up display.

Arm Solution

Not applicable.

Present

For several years, HUDs have been common in premium vehicles, and include speedometer, tachometer, and navigation aids. Some vehicle manufacturers offer integrated night vision sensor systems that also are displayed on the HUD.

In addition, there are many aftermarket HUD solutions available today. These are typically integrated into the same electronic control unit as the digital instrument cluster application. Some vehicle manufacturers have started to integrate the HUD application into a digital cockpit domain controller alongside other workloads on a mixed-criticality platform.

Compute Requirements

A microcontroller-based electronic control unit with graphics-generating IP drives a simple HUD display, and an application processor with integrated 3D graphics engine supports a rich 3D user experience.

Arm Solution

Future

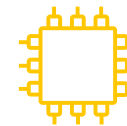
Augmented reality HUDs (AR-HUD) are common, and vehicle manufacturers see them as a way to help drivers build trust in new ADAS and automated driving features. AR-HUDs offer enhanced vision systems by integrating advanced driver-assist systems (ADAS) with autonomous features, such as navigation aids and lane-keep assist alerts, in real time. These are displayed on a large portion of the windshield.

Safety-relevant content is rendered in real time with low latency. ADAS visual alerts on larger AR-HUD displays require head or eye tracking and image distortion correction. Holographic projection is becoming increasingly available.

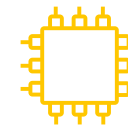
Compute Requirements

An application processor with an integrated 3D-graphics engine supports a rich 3D user-experience.

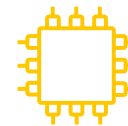
Arm Solution



Cortex-A



Mali GPU



Mali DPU

Center Stack/Head Unit

Past

Some premium vehicle designs had console display units with small digital displays. Console display units typically provided dual-zone automatic climate controls, but the majority of vehicles used rotary dials, knobs and switches.



Compute Requirements

A microcontroller-based electronic control unit processed center stack control inputs and drive servos for climate control.

Arm Solution

Cortex-M.

Present

Modern mobile phone electronics with touchscreen UIs have influenced IVI technology in many ways. Vehicle manufacturers offer the latest infotainment features in a standard center display, while some premium vehicles offer multiple displays with the latest smartphone app integration and wireless charging pads.

Furthermore, some premium vehicles offer a center display with a touchscreen interface for features such as seat position, media playback, and climate controls. Premium vehicles also are designed with an integrated SIM card and offer services such as WiFi connectivity, real-time traffic information, and intelligent voice assist.

In some vehicles, smartphone projection solutions take advantage of mobile phone apps to project on the center display. Drivers can customize menu preferences, seat positions, and so on, and save those settings to a specific user profile.

Compute Requirements

Premium vehicles require a multi-CPU Systems-on-Chip (SoC) with a graphics processing unit (GPU). The platform runs an RTOS or general-purpose OS (Linux and Android) and a center display user interface.

Arm Solution

Cortex M, Cortex A, Arm Mali GPU, DPU, Arm CryptoCell, Arm TrustZone.

Future

The cockpit now has one seamless widescreen display of multiple high-resolution screens. Safety continues to be a main focus as relevant driver Information is collected, prioritized, and instantly presented. ADAS features provide additional data, and sensor imagery is augmented with detected objects to aid driver vision.

A configurable digital UI is integrated into the center console and has touchscreen controls. Services and applications are provided using native Android or iOS IVI systems.

Advanced artificial intelligence (AI) models learn driver preferences and can display information accordingly, as well as adjust menu structures. Driver personalization settings with biometric authentication allow the driver and passengers to transfer their customized display profiles and preferences from vehicle to vehicle.

Compute Requirements

Premium vehicles require a multi-CPU SoC with multiple GPUs for high-resolution center console displays. The platform runs an RTOS or general-purpose OS (Linux and Android) to provide a user interface with multiple displays.

Arm Solution

Cortex M, Cortex A, Arm Mali GPU, DPU, Arm CryptoCell, Arm TrustZone.

Sideview Mirror

Past

Mirror positions could be adjusted with simple electrical motor controls to give the driver the best possible view.

Present

Sideview mirror positions are adjustable with motor controls, and multiple driver mirror positions can be saved as a profile on the key fob. Some vehicles manufacturers install auto-dimming sideview mirrors with electrochromic technology.

Additional safety features include sideview mirrors with sensors for blind spot object detection and in-mirror alerts.

Future

The physical sideview mirror has completely gone, and vehicle manufacturers integrate a digital sideview mirror application into a digital cockpit domain controller. High dynamic range cameras around the vehicle use augmented reality (AR) overlays to alert for detected objects and send blind-spot warnings. These blind-spot warnings alert the driver by audio, on the instrument cluster, and via the HUD.

Compute Requirements

A simple microcontroller was used to control both left and right mirror positions.

Compute Requirements

Radar proximity sensors on each side of the vehicle provide data for real-time object detection, and the driver is immediately alerted to detected objects. Sideview mirrors with ADAS features have an ISO26262 Automotive Safety Integrity Level (ASIL) B safety requirement.

Compute Requirements

Radar sensors and camera video process blind-spot object detection, while left and right sideview video with detected object overlays are displayed. This requires a multi-CPU application processor with integrated image signal processor (ISP) and 3D-graphics engine with a software stack for real-time safe application rendering and display. A sideview mirror system has a min ISO 26262 Automotive Safety Integrity Level (ASIL) B requirement.

Arm Solution

Cortex-M.

Arm Solution

Cortex-M.

Arm Solution

Cortex-A, Mali ISP, Mali GPU, Mali DPU.



Rearview Mirror

Past

Anti-glare rearview mirrors (sometimes referred to as day/night mirrors) were standard equipment, designed to reduce the brightness and glare of high-beam headlights from vehicles approaching from behind. These day/night rearview mirrors were manually operated by using a lever to change the mode. Around 1990, some early automatic-dimming rearview mirrors were installed on certain vehicles.



Compute Requirements

An 8/16-bit MCU is used for automatic-dimming electronics.

Arm Solution

Cortex-M.

Present

Automatically dimming rearview mirrors detect glare and dim the mirror to protect the driver's vision. Some rearview mirrors incorporate camera displays when the vehicle is in reverse to increase driver visibility. Intelligent rearview camera displays in the center console have started to replace or augment mirrors, with cameras mounted on the bumper to give the driver an unobstructed rearview display.

The rearview mirror location also is used for microphone integration to support hands-free, voice recognition, and a telematics communication unit (TCU). A TCU provides many safety and security features supported by using GPS to pinpoint the car's location. These features include: emergency vehicle response in the event of an accident, stolen-vehicle assistance, remote door unlock, navigation assistance, and many more. Increasingly, the area behind the rearview mirror also is used for lane departure warning systems.

Compute Requirements

A 16/32-bit MCU supports automatic-dimming electronics, and a 16/32-bit MCU drives the rearview camera safety display with dynamic parking guidelines. This is an ISO 26262 ASIL B safety requirement. The TCU uses a 32-bit MCU for mobile communication to a centralized service.

Arm Solution

Cortex-M.

Future

Rearview mirrors have become intelligent displays for some vehicle manufacturers, while others choose to integrate the rear- and sideview display on the console.

Quality 360-degree, high-dynamic range (HDR) cameras are commonplace and combine a camera sensor with image-processing capabilities for picture clarity with minimal glare and lighting artifacts, even from main-beam headlights. Vehicles with ADAS features use augmented reality (AR) overlays to alert drivers to detected objects.

Compute Requirements

A 16/32-bit MCU is required to drive rear view camera intelligent safety display with dynamic parking guidelines. This is an ISO 26262 ASIL B safety requirement. The TCU requires a 32-bit MCU for mobile communication to centralized services.

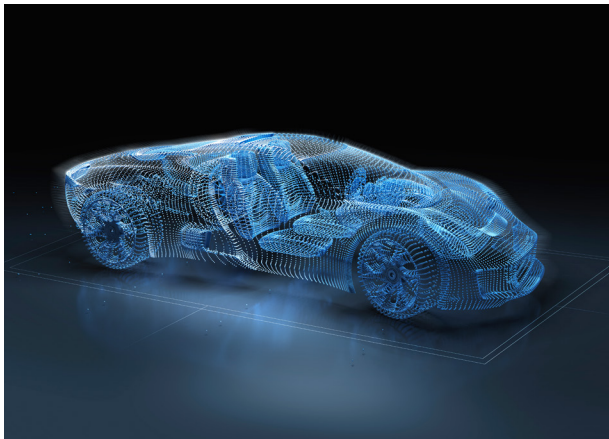
Arm Solution

Cortex A, Mali ISP, Mali GPU, Mali DPU.

Driver/Cabin Monitoring

Past

Cabin monitoring systems were not deployed by vehicle manufacturers until recently. Some after-market camera recording devices were available in the early 90s.



Present

Active real-time driver monitoring (DM) systems use sensors in the steering wheel or an inward facing camera to track driver alertness and help ensure the driver stays engaged during vehicle operation. This safety feature alerts the driver to signs of drowsiness or distraction, and is crucial for vehicles with semi-autonomous/ADAS driving features.

The DM system prompts the driver repeatedly, via visual and audible warnings and by small auto-braking events, if it detects signs of distractedness. The driver can then restore full control of the vehicle and rest if needed.

As another driver assistance feature, some manufacturers use a child/passenger monitoring system that gives front-seat passengers and the driver a view of what's going on in the back seats from the center display.

Future

ADAS and autonomous vehicle features will become very common in most vehicles. Active real-time driver monitoring systems continue to provide a vital safety feature for transfer of control to the driver as needed.

Other applications for DM systems include:

- + Driver identification and authentication
- + Heart rate measurement
- + Head position tracking for real-time augmented reality (AR) HUD display correction
- + Human-machine interface control functions using the eyes
- + Gesture recognition
- + Driver impairment level detection

These technology innovations contribute to the more robust safety solutions needed for the next generation of ADAS and autonomous driving functions.

Compute Requirements

None.

Compute Requirements

Real-time, low-latency processing is required for advanced facial analysis algorithms and deep learning workloads that use CPU, DSP, GPU and FPGAs.

Compute Requirements

For future innovations, camera sensor input and processing will be required, as well as real-time, low-latency processing for advanced facial analysis algorithms and deep learning workloads that can take advantage of CPU, DPS, GPU and FPGAs.

Arm Solution

Not applicable.

Arm Solution

Arm Cortex A, Arm Mali ISP, GPU.

Arm Solution

Arm Cortex A, Arm Mali ISP, GPU.

Human Machine Interface

Past

Center console features used rotary dials, knobs and switches, with driver input required for most functions. These manual functions included:

- + External/interior Lighting
- + Windshield wipers
- + Central locking system
- + Climate controls
- + Seat adjustments
- + Radio reception
- + Tire Pressure Monitoring



Compute Requirements

A body control module provides the processing for many if not all of these functions.

Arm Solution

Cortex-M.

Present

Inspired by modern mobile phones, multi-touch screen input on the center display is very common. This works well for several types of applications, including navigation/maps. Intelligent voice assistants are available in premium vehicles for a more natural way of communicating with the vehicle. Users can operate their vehicle and access functions and information by simply speaking to the vehicle.

Gesture controls in premium vehicles allow drivers to navigate through menus by swiping a finger up and down, left and right. This can be done without having to take hands off the steering wheel. The center stack rotary knob/controller is popular in some premium vehicles, and can be used by the driver without taking eyes off the road.

Some premium vehicles offer a touchpad as an alternative user input device for center display menu navigation and also for character input. However, driver input is still required for certain functions, such as vehicle immobilizer, remote keyless entry, and a passive start/entry system.

Compute Requirements

A body domain controller provides the same processing functions as well as some additional I/O for control functions.

Arm Solution

Cortex-M, Cortex-R.

Future

Multi-touch screen input continues to be one of the main forms of user input, while intelligent voice assistant technology becomes increasingly sophisticated. As its popularity increases and user experiences improve in the home smart-speaker market, adoption in vehicles soon follows.

Users can select the same intelligent voice assistant in their vehicle that they have grown accustomed to at home. Other than touch input, the most common HMI with the vehicle will be natural language communication.

Gesture-based controls may be integrated so the driver can provide gesture controls (such as swiping) to command the center display menus using fingers, while still keeping hands on the steering wheel.

Compute Requirements

Body domain control processing combines with IVA machine learning workload processing.

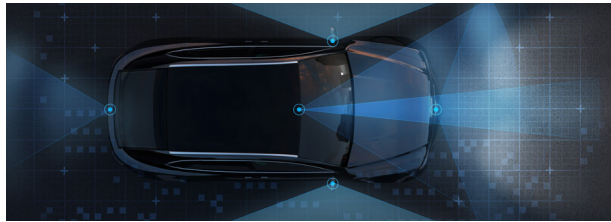
Arm Solution

Cortex-M, Cortex-R.

Steering Wheel

Past

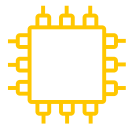
Vehicles have used steering wheels since the 1890s with slight changes in styling and materials. Designs changed as vehicle manufacturers began to integrate cruise control, audio controls, wiper controls on or around the steering wheel. Still, the modern steering wheel performs the exact same basic function as the original.



Compute Requirements

The body control module provides the I/O and processing needs for control functions.

Arm Solution



Cortex-M

Present

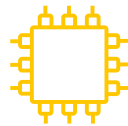
The majority of vehicles still have a legacy steering wheel with a mechanical linkage between the steering wheel and the rack. However, a small number of vehicles are designed using high availability servo-electric power steering (EPS) which allows for steer-by-wire. These systems use electronics and actuators on the steering column and rack. ADAS/autonomous steering features require this technology.

Some vehicle manufacturers have integrated vibrating alerts and a flashing LED bar into the steering wheel. Automated vehicle driving features use these to communicate alerts such as lane-keep assist and driver monitoring.

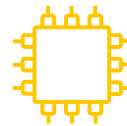
Compute Requirements

Drive-by-wire capable systems have high-robustness and functional safety requirements. Driver alerts are driven by ADAS/autonomous drive electronic control units.

Arm Solution



Cortex-M



Cortex-R

Future

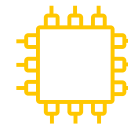
Some vehicle manufacturers deploy vehicles with collapsible or retractable steering wheels. Steering wheels and pedals are considered optional for SAE Level 5 fully autonomous vehicles and robo-taxis.

SAE Level 5 is the goal of vehicle manufacturers for self-driving vehicles. A Level 5 vehicle is capable of complete hands-off, driverless operation under all circumstances, and there are no provisions for human control.

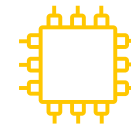
Compute Requirements

Drive-by-wire capable systems have high-robustness and functional safety requirements. Driver alerts are driven by ADAS/autonomous drive electronic control units.

Arm Solution



Cortex-M



Cortex-R

Rear Passenger Seat

Past

Portable VHS tape and DVD players with an integrated mini TV gained popularity for rear-seat entertainment. These were either strapped onto the backrest of the front seat or included a dropdown screen installed in the roof of the vehicle.

Compute Requirements

VHS video or DVD playback subsystem in the vehicle.



Arm Solution

Not applicable.

Present

Vehicle manufacturers offer rear-seat entertainment (RSE) systems with multiple separate 9" or larger color tilt-adjustable screens. These systems provide passengers with remote-control functions for built-in TV, radio, Blu-Ray/DVD player, navigation and internet connectivity, independent of the driver.

Compute Requirements

The following components are required for RSE systems:

- + Blu-ray/DVD player controlled by the center display and/or an integrated rear seat entertainment control panel
- + Digital and I/O requirement to allow control by driver and passenger both in front seat and rear seat entertainment controls
- + Multi-CPU compute in the IVI platform for media playback/streaming to multiple displays in the vehicle
- + Robust platform security for secure boot, secure keygen, secure key storage, DRM protection

Arm Solution

Cortex M, Cortex A, Arm Mali GPU, DPU, Arm CryptoCell, Arm TrustZone.

Future

The arrival of 5G connectivity, the next generation of cellular infrastructure, allows passengers and commuters to be more productive while in a vehicle. 5G technology not only speeds up communication and reduces latency, but it also keeps devices constantly connected. All the luxuries of an office environment, such as high-speed downloads and video conferencing, will be available to vehicle passengers.

Advanced passenger personalization settings with biometric authentication allow customized profiles for each entertainment display in the vehicle. This authentication allows user preferences and services (e.g. streaming media account authentication) to migrate from vehicle to vehicle. Native support for passenger smartphone screen mirroring is built in to rear seat/passenger entertainment displays and allows passengers to mirror their mobile phone onto vehicle entertainment displays.

Compute Requirements

Digital and I/O requirement allow entertainment control by the driver and passengers from the front and rear. The IVI/entertainment platform must provide multi-CPU compute for UHD media playback/streaming to multiple displays in the vehicle. Robust platform security is needed for secure boot, secure keygen, secure key storage, and DRM protection.

Arm Solution

Cortex M, Cortex A, Arm Mali GPU, DPU, Arm CryptoCell, Arm TrustZone.

Gearbox

Past

A manual transmission, also known as a manual gearbox or “stick shift,” is a type of transmission that uses a driver-operated clutch, usually engaged and disengaged by a foot pedal (or hand lever) for regulating torque transfer and gear ratio from the engine to the transmission. Although some manual transmission steering column gear selectors were available, the majority were center console gear selectors.

An automatic transmission is a type of vehicle transmission that can automatically change gear ratios as the vehicle moves. Automatic transmission gear selectors started out on the steering column but eventually migrated to the center console.

Compute Requirements

A body domain controller provides the compute to monitor gearbox health/temperature.

Arm Solution

Cortex-M.

Present

Manual transmissions remain popular in countries outside of the U.S., Canada, and Australia., while in the U.S. about 95 percent of all vehicles sold are automatic. Several vehicle manufacturers have migrated to electronic gear selectors using a dial or a row of buttons. This is required for drive-by-wire automated driving functions.

On the other hand, electric vehicles are designed with no gearbox. They have a direct connection between the electric motor and the cardan/drive shaft.

Compute Requirements

The transmission electronic control unit, sometimes referred to as the transmission control module (TCM), senses gear selector position, clutch position, brake position, engine parameters and drives transmission actuator positions. Transmission electronic control units have high-robustness and functional safety requirements.

Arm Solution

Cortex-M, Cortex-R.

Future

Manual transmission vehicles no longer exist, as all passenger vehicles with combustion engines are manufactured with an automatic transmission. An automatic transmission is required for vehicles that have ADAS/autonomous drive features and several vehicle manufacturers have migrated to electronic gear selectors using a dial or a row of buttons.

The majority of electric vehicles employ single speed direct drive transmissions. Some vehicle manufacturers design multi-gear transmissions for electric vehicles to help improve efficiency.

Compute Requirements

Most vehicle manufacturers have combined engine control/processing and transmission control in a powertrain control module (PCM). PCMs have high-robustness and functional safety requirement.

Arm Solution

Cortex-M, Cortex-R.

Cockpit Domain Controller

Past

The cockpit domain controller (CDC) didn't exist until recently.



Compute Requirements

None.

Arm Solution

Not applicable.

Present

The first vehicles with a CDC were deployed in the 2019 model year. A single domain controller powers the digital instrument cluster and infotainment display.

A CDC allows multiple cockpit domains (e.g., digital instrument cluster, infotainment system, HUD) with separate electronic control units to be integrated into one domain controller that supports multiple levels of safety and criticality. This is sometimes referred to as a mixed-ASIL system. Features required to support a mixed criticality system include:

- + 64-bit architecture
- + Efficient multi-core processing
- + Hardware accelerated virtualization
- + Robust platform security for secure boot, secure keygen, secure key storage and DRM protection
- + Safety separation (i.e., safety certifiable hypervisor that guarantees isolation (freedom of interference) between multiple domains

Compute Requirements

Application-class multi-CPU SoC with a graphics processing unit (GPU) are used to drive multiple high-resolution displays. System safety certification requires an ISO 26262 ASIL B (min) certifiable Type-1 real-time hypervisor supporting an ASIL B (min) certifiable RTOS and general-purpose OS (Linux and Android) virtual machines.

Arm Solution

Arm Cortex A, Arm Mali ISP, GPU, VPU, DPU.

Future

A digital cockpit domain controller must support multiple mixed-criticality workloads on the same electronic control unit enabled by hardware virtualization. Robust security features allow for maintenance and feature over-the-air updates to safety and non-safety virtual electronic control units.

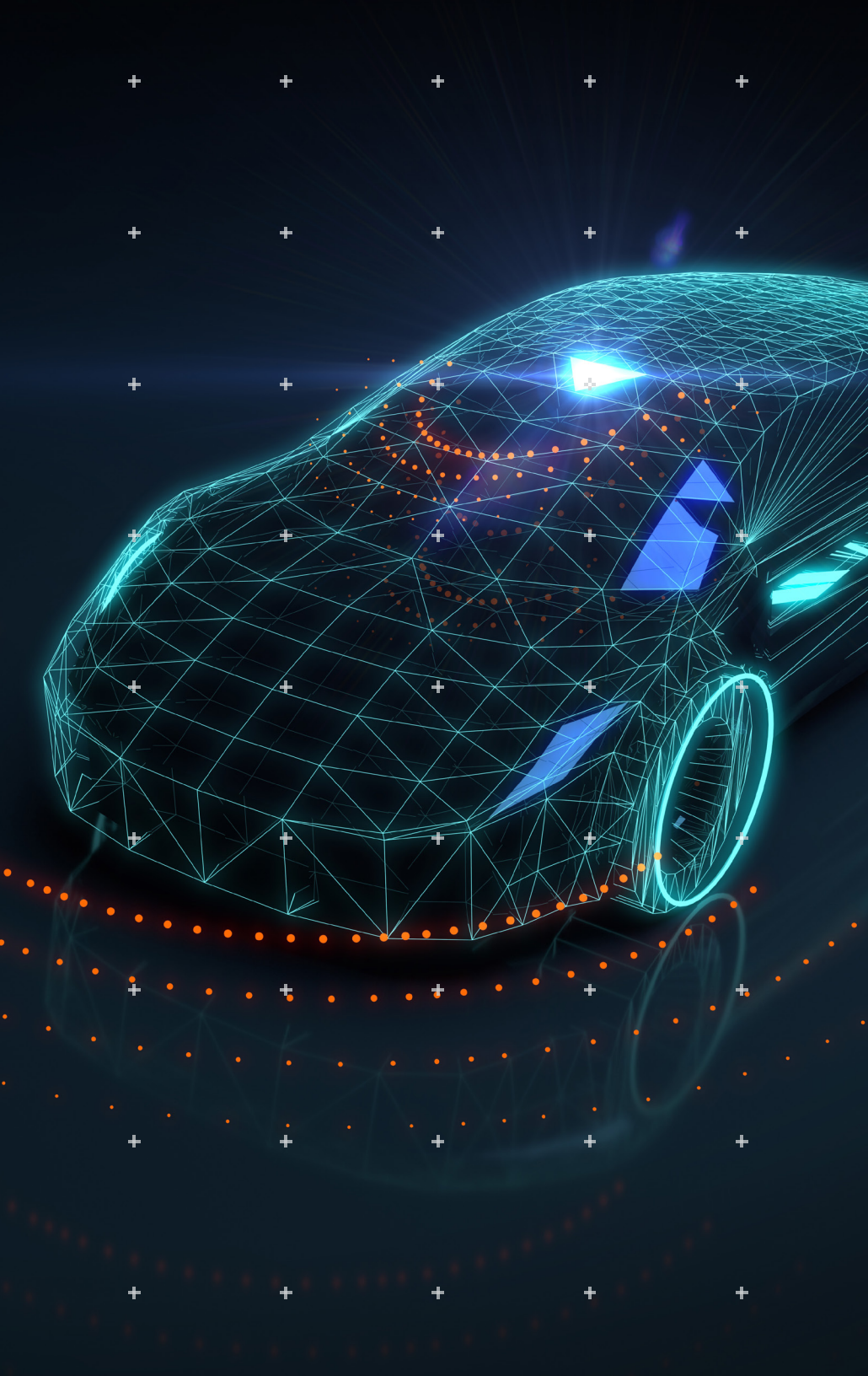


Compute Requirements

A multi-CPU application processor with integrated 3D graphics engine and a software stack for real-time virtual ECUs support safe application rendering, safe display and safe video ingest. The platform supports virtual ECUs certifiable up to ISO 26262 Automotive Safety Integrity Level (ASIL) D.

Arm Solution

Cortex-A, Mali GPU, Mali DPU, Mali ISP.



Stay up to speed on the road ahead

Without doubt, technology is helping the automotive industry deliver some of the most advanced, comfortable, and safest vehicles on the roads today. Cars are becoming large smart devices capable of much more than simply getting us from point A to B. Innovations in automotive technology are driving us toward smarter cities, cleaner environments, and safer streets.

To get the latest news and updates on Arm solutions and innovations for the automotive industry visit arm.com/automotive.