The ARM® Connected Car

Chris Turner
Senior Product Marketing Manager, CPU Group
Agenda

The ARM Connected Car

- Automotive Trends and Technologies
- Computation and Communications Towards Autonomous Driving
- ARM’s Processor Portfolio for Automotive Electronics
- The Roadmap for Functional Safety
- Extending the ARM Ecosystem for Automotive
The Road Ahead

Full autonomous driving may be years away but semi-autonomous is just round the corner

- Expect initial deployments in cities and major highways
- Legislation changes required – already initiated
- Consumer acceptance to be determined
- Significant societal and economic benefits
- Hazardous consequences if things go wrong

- ARM technology solutions:
  - Sensing
  - Computation
  - Control
  - Connectivity

Phase 1. Passive safety help using telematics and emergency calls
Phase 2. Active safety and driver assistance for obstacle detection and collision avoidance
Phase 3. Cooperative safety using vehicle communications to other vehicles and highways infrastructure
Phase 4. Autonomous driving and achieving the goal of zero collisions
Advanced Driver Assistance Systems (ADAS)

Available today and evolving fast

- Safety and convenience features
  - e.g. park assist, adaptive cruise control, lane keep assist, auto emergency braking
- Complementing established systems
  - Vehicle stability, electric power steering
- 360° degree sensing
  - Rapidly improving capabilities, performance and reliability
- Increasing sensor processing
  - Computer vision, feature recognition
- Safety-related applications
  - Functional safety, legislative requirements

Lidar
Mono/stereo camera systems
Near-field radar
Ultrasonic parking
Longer distance radar
Mobile Phones Connect to the Car

Integrating cell-phones with in-vehicle infotainment (IVI) displays

- Porting the cell-phone interface into the car display
- Limited integration with vehicle electronics. Some telematics.

Examples are:
  - MirrorLink™
  - Android™ Open Automotive Alliance
eCall - Saving Lives
Emergency call 911, or 112 in EU

- Carried by cell phone network
- Activate on airbag deployment
- Basic data, e.g. location, sent by SMS
- Public Safety Access Points respond
- Voice call to vehicle occupants
- ARM Powered® devices and modules
- Legislation and deployment in progress
Cooperative Intelligent Traffic Systems, C-ITS

The driver for deployment of V2X

- Smart City: communicating traffic signals
  - Pacing speed between traffic signals
  - Controlling eco engine stop-start
  - Emissions reduction, fuel saving

- Tipping point penetration can enable:
  - Longer range communication for accident avoidance and congestion management
  - V2V, starts with braking/turning signal

- Trials: Ann Arbor MI, Frankfurt, Vienna
  - ITS cooperative corridor scheduled 2015

- Semi-autonomous driving / platooning
  - Fusion with ADAS sensors
Dedicated Short Range Communications

Car-to-car, car-to-highway, vehicle-to-vehicle, vehicle-to-highway, V2V, V2H, V2X

- Wireless access in vehicular environment
  - 5.9 GHz band allocated for US and EU
- New 802.11p protocols standardized
  - Rapid connection setup and teardown
  - Expect future integration with regular WiFi
- NHTSA proposes for new vehicles in 2017
  - Basic Safety Message
  - Roadside Alert Message
  - Probe Vehicle Message

- Forming a long range network
  - Video or radar only see a few seconds away in line of sight

National Highway Traffic Safety Administration: www.safercar.gov/v2v
In-vehicle Networks

High data rate for sensors, communications, computation and control/actuation

- Current networks are challenged by increasing data and do not provide flexible topologies
  - FlexRay®, CAN bus, LIN bus
  - MOST (Media Oriented Systems Transport)

- New One Pair EtherNet (OPEN)
  - Robust low cost connector and physical interface
  - Network saves cost and weight for automotive
  - BroadR-Reach® offered as a standard
  - Add AVB (audio-video bridging) for QoS
  - Packet-based network scales outside the vehicle

360° camera system

Infotainment

V2X
The Connected Car

Wide variety of mobile communications – informing, assisting and enhancing road safety

- Infotainment communication
  - IVI radio and cell phone, GPS, DAB, HD radio, TMS info, in-car hotspot

- Telematics
  - eCall, insurance, theft tracking, black box, tolling, parking, servicing

- Intelligent traffic system
  - Road safety, congestion, emissions

- Enabling wireless technologies
  - Digital broadcasting
  - 2G, 3G, LTE/4G, SMS
  - LTE Cat0 for M2M/MTC/IoT
  - DSRC, 802.11p for V2X
The Autonomous Driving Future

Ubiquitous availability and safety could be a challenge

- Road and traffic conditions. Weather. Hazards ahead
- Immediate locale. Do I go forward, turn left or right?
- Recognise vehicles, kerbs, pedestrians nearby. The unexpected!
- Machine learning. Sharing experience locally and upstream
- My current speed and trajectory. Match to others. Platooning
- Acceleration, steering, braking actuation. Vehicle stability
- Pre-crash panic. System reset. Hand control back to a human!
Rapid Growth in Automotive Processing and Software

Electronic Control Units (ECU) shift to central domain controllers over in-car networks

In-vehicle Infotainment
Audio, Visual, Maps, Traffic, Mobile phone integration, SIM, Toll payment, Google services, seat back display

Dashboard
Instrument display surface, Head-up display, IVI display

Car-to-car
Vehicle-to-Vehicle
Vehicle-to-Infrastructure

Advanced Driver Assistance System
Radar/image processing, Collision avoidance, Emergency braking, Adaptive cruise control, Lane departure warning, Parking assistance

Gateways
GSM 3G 4G LTE, Bluetooth®, WiFi, CAN, LIN, Flexray, TTP

Body Electronics
Heating, Ventilation, AC, Lighting, Electric seat, Windows, Mirrors, Cameras, Seat belt, Air bag, Comfort, Convenience

Hybrid Electric Vehicle
Battery management
Motor control

Connected Car
Car-to-car, Crash alert, Service, Maps
Insurers’ black box

Powertrain
Engine Control Unit, Sensors, Gearbox

Chassis
Braking, Steering, Stability, ABS, VSC, EPS

Body control

Powertrain

Chassis / Safety

IVI / Connectivity
Growth Forecast for Automotive Processors
Processor-based SoCs or MCUs (excluding power devices, sensors, analog)

- Vehicle manufacturing growth
- Increase in devices per vehicle
- Strong growth in ADAS
- New connectivity, V2X
- Semi-autonomous robotics
- More ASIL qualified devices
- Device complexity increase
- 8 and 16-bit obsolescence
- Increasing device ASP

![Worldwide Automotive SoC Consumption, millions](chart)

Source: ARM estimates based on various data points
Energy-efficient Processors for Automotive

Low power processing is increasingly important, especially for hybrid/electric vehicles.

Cortex® -M processors
- Smallest footprint / lowest power

Cortex-R processors
- Actuation, fast control
- Extended Functional Safety
- Fast response / Real-time control

Cortex-A processors
- Computation, robotics
- Computer-vision

RTOS
DSP
Linux®, QNX
ARMv8-R

Higher performance
Cortex-M Processors Used Throughout Vehicles
Lighting, HVAC, comfort, convenience, sensing, motor control, IVI audio etc.

- Cortex-M4
- Cortex-M3
- Cortex-M0+
- Cortex-M0
- Cortex-M7

Highest performance with larger memory systems

Blended MCU and DSP

Energy-Performance Balance

Most Widely Licensed

Scalable & Compatible ISA
Cortex-A Processors for IVI and ADAS

In-vehicle infotainment, computer-vision and displays
Cortex-R Processors for Control and Actuation

**Cortex-R4 (2005)**
- High-performance, real-time, deeply embedded, ARMv7-R
- Deterministic event response
- Soft and hard error management
- Synthesis configurable feature set

**Cortex-R5 (2010)**
- Low Latency Peripheral Port
- Accelerator Coherency Port
- Dual cores in split or lock-step
- Bus error management
- Smaller Floating Point Unit
- Enhanced memory protection
- Functional safety support

**Cortex-R7 (2012)**
- Large performance increase
- Out-of-order execution
- Higher clock frequency
- MultiProcessor Core x1 or x2
- ACP and MPCore coherency
- Quality of Service features
- Extended real time memory
- Enhanced error management
- Integrated interrupt controller

**ARMv8-R Architecture**
- Virtualisation support for multiple guest Operating System partitions
- Task and application consolidation
- Strict isolation for high availability, responsiveness and functional safety support

**Functional safety**

**Communications baseband**

**Automotive / Industrial**

**Magnetic and solid state storage**
The ARMv8-R Architecture
Innovation for the next generation of automotive and industrial, processing and control

- Automotive software complexity is increasing
  - Could be upwards of 100 million lines of code running on as many as 100 ECUs by various suppliers
  - Safety and security events must be managed reliably
  - Increasingly significant part of development cost
  - Software issues can cause expensive recalls and have the potential to damage an automotive brand

- ARMv8-R processor architecture supports:
  - Improved software quality and reliability
  - Lower R&D cost with increased software re-use
  - Reduced production cost through ECU consolidation
**ARMv8-R Architecture**

Will introduce real-time virtualisation to ARM Cortex-R processors

- **New Privilege Level (PL-2) within Cortex-R processors**
  - Exclusive access to a second stage Memory Protection Unit, interrupt controller configuration etc. (‘bare metal’ support)

- **Provides a ‘sandbox’ for handling safety and security events**

- **Supports ‘virtualisation’, i.e. software separation, for multiple ‘guest’ OSs and their tasks**
  - Enabling OS and task consolidation with isolation
  - Managed by a hypervisor running at PL-2

- **Fast interrupt response and rapid context switching**
  - New fast and flexible MPU programming model

- **Enhanced AArch32 32-bit instruction set (A32 and T32)**
Using Privilege Level 2 to Enhance Safety and Security
Additional ARMv8-R Privilege Level used in systems – even without virtualization

- High availability
  - Safe and Secure Monitor can monitor and restart RTOS if necessary

- Functional safety
  - Host and isolate both on-line and off-line BIST software at PL2
  - Additional PL2 software e.g. scrubbing RAMs for errors
  - Isolated monitoring and handling of system safety events
  - Stage 2 MPU protects against random and systematic errors

- Authentication
  - Collaborate with Security Processor (HSM)
  - RTOS calls for support via HVC

- Firmware management
  - PL2 and S2 MPU can protect software code
  - Safe and reliable mechanism for firmware updates

- Safe and Secure Monitor code is smaller and highly verified
Fault Detection and Correction Features
A selection of hardware features from the ARM Cortex processor portfolio

- Timing protection
- Lock-step copy of logic with timing separation
- ECC protection for both soft and hard errors
- ECC and parity bus protection scheme
- System MPU
- Performance monitoring
- Error logging and reporting
- Precise exception handling
- Instruction and data trace with memory reconstruction
- ROM data overlay
- On-line Memory BIST interface for testing and ‘scrubbing’
Functional Safety

ARM support for ISO 26262, IEC 61508 etc.

- Processor IP is a safety element out of context
  - Standards treatment enables the supply chain

- Standard level of support for functional safety
  - For selected ARM Cortex-M and Cortex-A processors
  - Intended for less critical applications, typically ADAS and sensors
  - Target systems have requirements up to ASIL B / SIL 2

- Extended level of support for functional safety
  - For selected ARM Cortex-R and Cortex-M processors
  - Intended for any functional safety applications, including powertrain, chassis, industrial
  - Target systems have requirements up to ASIL D / SIL 3
Enabling Safety-related Applications
Extended level support for Functional Safety

- Processors with fault detection and correction
- Systematic IP development and test process
  - Requirements capture and tracking
  - Comprehensive traceability information
  - Capture and retain evidence for assessment
- Safety manual, FMEA, SW BIST program
64-bit Processing Solutions with ARMv8-A
Combining scalable performance for sensing with high level functional safety for actuation

- **ARM Cortex-A53**
  - Cortex-A53 MP4 at 625 MHz on 28 nm delivers ~ 10,000 DMIPS

- **ARM Cortex-A57**
  - Cortex-A57 MP4 at 1 GHz on 28 nm delivers ~ 16,000 DMIPS

- Data exchange could be via coherency ports on each processor’s snoop control unit
- Automotive SoC implementations for long-term reliability in extreme temperatures
Developing and Debugging Automotive Software

ARM processors supporting the rapid evolution of automotive electronics

- **Architecture**
  - Consistent processor architecture across a wide range of right-sized processors incorporating solutions for safety and security

- **Software**
  - Rapidly growing and evolving automotive software complexity
  - Faster product cycles, consumer demand, revisions and upgrades
  - New techniques, e.g. model-based programming/autocoding
  - AUTOSAR®, GENIVI® – developing software standards and interoperability

- **Hardware**
  - Choice and diversity across the ARM silicon partnership serving the automotive supply chain
Towards an ARM Automotive Ecosystem

Some of the ecosystem partners working with ARM on ARMv8-R for automotive

- Real-time hypervisors, schedulers, Operating Systems, comm stacks, AUTOSAR, tools
In Conclusion
From mobile to automobile

- ARM architecture is perfectly positioned to deliver the full range of processor devices for cars of the 2020s

- ARM’s partnership and ecosystem fits the global automotive supply chain, offering a diversity of solutions in a rapidly-evolving market

- ARM’s processor and IP portfolio, including functional safety, addresses the automotive electronics market with right-sized energy-efficient solutions
Thank You


http://community.arm.com/community/news/blog/2014/02/27/armv8-r-architecture-wins-hardware-award-at-embedded-systems-conference

http://community.arm.com/groups/processors/blog/2013/10/23/armv8-r-architecture-innovation-for-embedded-systems

http://community.arm.com/groups/processors/blog/2013/10/24/software-consolidation-with-the-armv8-r-hypervisor

http://community.arm.com/groups/processors/blog/2013/10/25/armv8-r-architecture-for-next-generation-automotive

http://community.arm.com/groups/smart-and-connected/blog/2014/04/07/connected-car-update

The trademarks featured in this presentation are registered and/or unregistered trademarks of ARM Limited (or its subsidiaries) in the EU and/or elsewhere. All rights reserved. Any other marks featured may be trademarks of their respective owners.

© Copyright ARM Ltd 2014