REVOLUTIONIZE THE AUTOMOTIVE COCKPIT

Texas Instrument – April 2017
SIGNIFICANT TRENDS IN AUTOMOTIVE ...

**GREENER**
Fuel economy electrification hybridization...

**SAFER**
L1 & L2 ADAS, automation...

**CONNECTED**
Integrated cockpit, sensors, V2X...

**FOUNDA TIONAL SHIFTS IN THE AUTOMOTIVE INDUSTRY**

- **Vehicle hardware** as differentiating factor ➔ **Software**
- Long development cycles ➔ **Shorten cycles**
- Human operated, stand-alone ➔ **Assisted & connected**
- OEM at the center of high tech components ➔ **Gravity shifting to electronics**

Sources: IEEE, Automotive Designline

Boeing 787 Dreamliner
Average Luxury Vehicle

6.5M LINES OF CODE
100M LINES OF CODE
Cockpit Display Revenue

$10B in 2016
$18.4B in 2021
13% CAGR

Steady growth in Automotive semiconductor content

Sources: Automotive News, IHS Automotive – Jun 2016

Market Share/Segment

2016

Head-up display, 7%
Instrument Cluster, 42%
Center Stack, 51%

Driver Domain, Safety & Innovation

CONNECTED CAR

Electronics Control Unit (ECU)

• Automotive Processors are fundamental enabler for smarter, safer and connected vehicles
• ECU integration **mandatory** to meet features at cost point of future Digital Cockpit

Revolutionize Digital Cockpit

• Instruments panels: hybrid & digital reconfigurable clusters with more complex content
• Bigger displays, new ergonomics, augmented reality HUD, connected cars and more …
New technology available is up to 4x more important as a trigger than better brand image.

With new technologies at affordable cost. They aren't willing to pay much with only 27% willing to pay over $2,500.
... AND REFLECTED IN TECHNOLOGY DEPLOYMENT

**ECUs/car**
- 40-50 IN 2005
- 80-100 IN 2015

**AVERAGE/car**
- $334 IN 2014
- $362 IN 2018

**6.5M LINES OF CODE**
- Boeing 787 Dreamliner

**100M LINES OF CODE**
- Average Luxury Vehicle

Sources: WindRiver, newelectronics

Complex problem becoming more complex

Steady growth in Automotive semiconductor content

Source: Gartner IHS, Bank of America Merrill Lynch

Sources: IEEE, Automotive Designline

Semiconductor technology in general and Automotive Processors in particular have become a fundamental enabler for smarter, safer and connected vehicles

The "basic package" is expanding
WHAT DOES IT MEAN FOR AUTOMOTIVE PROCESSORS?

End-user wants

- New technologies at affordable cost
- Optimize total cost of ownership
- Richer features than previous car
- Safer driving experience

Car OEM focus on

- Benefit from technology improvements
- Automative quality
- Electronic systems reliability
- Personalize HD virtual dashboard
- Augment road perception
- Enhanced perception inside the car

Auto Processor

- Optimized eBOM via integration and SW platforming
- Heterogeneous architecture for best concurrencies: safety, security and performance
- Differentiate via image, signal & vision processing capabilities

- $
JACINTO HETEROGENOUS ARCHITECTURE
ONE SIZE DOESN'T FIT ALL

Choose the right core for the right job

Optimize entire platform around programmer productivity on the MPUs

Offload the majority of “work” to specialized processors. Provide tools & SW to manage complexity

Single to multi-cores MPU enable performance scalability and concurrrencies

Separate MPU clusters facilitates multi-OS and multi-domain software architecture

Greater power efficiency than solution using general-purpose processors

Auxiliary MPUs support real-time, safety OS and/or interrupt-intensive tasks

Image, signal and vision co-processors for simultaneous IVI and InfoADAS features

MPU : Microprocessor
GPU : Graphics Processor
DSP : Digital Signal Processor
AMPU : Auxiliary Microprocessor
HWA : Hardware Accelerator
JACINTO PROCESSORS INTEGRATION
DESIGNED FOR AUTOMOTIVE SAFETY & ROBUSTNESS

- High-performance graphics engine, can be virtualized using OpenGL ES client-server model
- Cluster QoS supported via prioritization of 3D processing thread at macro-tile boundary

- Optimize entire platform around programmer productivity on the MPUs
- High-level OS (HLOS), HMI
- HW virtualization support to run cluster processing functions in separate virtual machine (VM)
- Hypervisor

- Separation between HLOS & safety OS
- Robustness & safety features (frame-freeze, video watchdog, etc.)
- Offload interrupt heavy processing & Ctrl functionality (automotive stacks etc.)

- Automotive peripherals
- Purpose-built automotive processors from inception to ensure auto certifications & the specific needs of car OEMs/Tier1s are met

- Multi HD display
- Display write-back path

- High memory bandwidth for best-in-class HMI, HD display support and improved auto concurrencies
- DDR Error Correction
- DSP cores and HW accelerators (HWA) for automotive differentiation / innovation

- Numerous HW & SW security features provide Secure Boot & Trusted Execution Environment

MPUs

GPUs

Display

AMPs

DSPs & HWAs

RAM

DDR EMIF

Serial connectivity

System services

Vehicle connectivity

Security

Serial connectivity

Vehicle connectivity

JACINTO PROCESSORS INTEGRATION
DESIGNED FOR AUTOMOTIVE SAFETY & ROBUSTNESS
## Jacinto 6 Family
**Scalable and Software Compatible Processors for Digital Cockpit**

<table>
<thead>
<tr>
<th></th>
<th>MPU</th>
<th>DSP &amp; HWA</th>
<th>GPU</th>
<th>Multimedia</th>
<th>Display &amp; Capture</th>
<th>Memory</th>
<th>Auto Peripherals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>“Jacinto 6 Plus”</strong> DRA7xx</td>
<td>ARM A15 Dual Core MPU</td>
<td>2x Dual Core Aux CPU</td>
<td>3D GPU 2x SGX544 2D GPU GC320</td>
<td>IVA HD 1080p Video, VPE</td>
<td>Display Subsystem 3 LCD</td>
<td>Capture 2x VIP 2x CSI2</td>
<td>DDR3/3L 32b 512KB-2.5MB L3 RAM CAN FD, DCAN PCIe eAVB</td>
</tr>
<tr>
<td><strong>“Jacinto 6”</strong> DRA74x/75x</td>
<td>ARM A15 Dual Core MPU</td>
<td>2x Dual Core Aux CPU</td>
<td>3D GPU 2x SGX544 2D GPU GC320</td>
<td>IVA HD 1080p Video, VPE</td>
<td>Display Subsystem 3 LCD</td>
<td>Capture 2-3x VIP</td>
<td>DDR3/3L 32b 512KB-2.5MB L3 RAM 2x DCAN 2x PCIe eAVB</td>
</tr>
<tr>
<td><strong>“Jacinto 6 Eco”</strong> DRA72x</td>
<td>ARM A15 Single Core MPU</td>
<td>2x Dual Core Aux CPU</td>
<td>3D GPU SGX544 2D GPU GC320</td>
<td>IVA HD 1080p Video, VPE</td>
<td>Display Subsystem 2 LCD</td>
<td>Capture 1x VIP 2x CSI2</td>
<td>DDR3/3L 32b S12K8 L3 RAM 2x DCAN PCIe eAVB</td>
</tr>
<tr>
<td><strong>“Jacinto 6 Entry”</strong> DRA71x</td>
<td>ARM A15 Single Core MPU</td>
<td>2x Dual Core Aux CPU</td>
<td>3D GPU SGX544 2D GPU GC320</td>
<td>IVA HD 1080p Video, VPE</td>
<td>Display Subsystem 1 LCD</td>
<td>Capture 1x VIP 1x CSI2</td>
<td>DDR3/3L 32b S12K8 L3 RAM 2x DCAN PCIe eAVB</td>
</tr>
</tbody>
</table>
INNOVATE BEYOND INFOTAINMENT
DIFFERENTIATE VIA IMAGE, SIGNAL AND VISION PROCESSING

MODERN AUTOMOTIVE COCKPIT

1. IVI options available with high volume deployment of color display systems

INFORMATIONAL ADAS:
Enhance the driver’s experience

Leverage sensors both inside & outside the vehicle with IVI system to AUGMENT existing infotainment products with informational ADAS features

1. Increasing deployment of cameras and sensors in the vehicle to support advanced safety capability (ADAS)

(1) : No active role in the control of the car (i.e. non-safety critical)
INFOTAINMENT TO INTEGRATED DIGITAL COCKPIT

More complex content to be seamlessly blended in full HD, including endless media selections from any source, 3D navigation, ADAS and augmented reality views with the ability to morph size, shape and colors according to the task at hand and driving priorities.

Traditional instrument cluster & center-stack give:

- reliable vehicle and safety information
- access to favorite media content and more

New ergonomics made possible to further improve their focus and attention on the road, including augmentation with Head-Up Display (HUD) to show relevant driving information in the driver's direct field of vision.

Ultimately, display in the center field of vision relevant information and safety contents according to current driving situation which will pave the way to autonomous driving.
JACINTO AUTOMOTIVE PROCESSORS

AUTOMOTIVE DIGITAL COCKPIT

- Head-up display including augmented reality processing
- Reconfigurable Digital Cluster with driver monitoring systems
- Audio Amplifier
- Feature-Rich In-Vehicle-Infotainment (IV)
- Head Unit Co-Processor
- Rear Seat Entertainment
- In-Vehicle-Infotainment with informational ADAS including surround view (SRV), front and interior cameras processing, and driver identification systems

150+ million Auto Processor SoCs on the road in more than 35 OEM brands

Texas Instruments strong history with signal processing has produced strong results in the automotive industry, and will continue to enable the leading integrated digital cockpit and autonomous driving solutions of the future.
“JACINTO 6 ENTRY” DIGITAL CLUSTER + DISPLAY AUDIO
FEATURE-RICH, SINGLE DISPLAY FOR THE ENTRY SEGMENT

WiFi Smartphone Screen Replication

Latest Digital Radio and Audio Features

Fast Boot by Texas Instruments

AGL Platform

“Jacinto 6 Entry” DRA71x
Digital Cluster and Display Audio on Single 1920x720 Display

YouTube video - Click Here

Jacinto “wall” / scalability – Click Here
**“JACINTO 6 ENTRY” DIGITAL CLUSTER**

**ASIL-B CERTIFIABLE DIGITAL CLUSTER AT A LOW COST**

**1920x720 at 60fps**
- Performance at entry segment cost

**Fast Boot Features**

**CAN stack on ARM Cortex M4**

**ASIL-B Certifiable**
- Mentor Nucleus® RTOS on ARM Cortex-M4
- Mentor Connected OS™ (Linux)

YouTube video - [Click Here](#)

Rightware HMI on Jacinto 6 SoCs – [Click Here](#)
"JACINTO 6 PLUS" DIGITAL COCKPIT
PERFORMANCE AND INTEGRATION DRIVEN BY A SINGLE SOC

- Fully Reconfigurable Digital Cluster
  - Linux-based
  - 1920x720 @ 60fps

- ASIL-B Certifiable
  - Optional ARM Cortex-M4 based Safety RTOS

1080p 15.6” Infotainment
- Android N OS
- Latest Digital Radio and Audio features

Hypervisor with GPU Sharing

Surround View Based on DSP + ISP

Single “Jacinto 6 Plus“ Processor
Multi OS/Hypervisor
Enabling ADAS to Autonomous Driving

Texas Instrument – April 2017
### Levels of Autonomous Driving

<table>
<thead>
<tr>
<th>SAE Level</th>
<th>Name</th>
<th>Narrative Definition</th>
<th>Execution of Steering and Acceleration/Deceleration</th>
<th>Monitoring of Driving Environment</th>
<th>Fallback Performance of Dynamic Driving Task</th>
<th>System Capability (Driving Modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
<td>the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
<td>the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
</tr>
</tbody>
</table>

2014: Level 2 enabled by TI ADAS SoCs. In one vehicle there are up to 10 TI ADAS SoCs, in front camera, multiple radar, fusion, night vision, rear camera and 360 surround view cameras.
ADAS to Autonomous

ADAS – Driver Assist to Limited Driver Substitution

- Discrete signal processing with 1-4 sensors per SoC and limited fusion on big ARM SoCs
- Traditional Detection and Classification moving to Deep Learning
- Isolated compute provides security

Autonomous driving through connected/collaborative technology

- Shift towards centralized signal processing
- Multi-Modal Sensor Fusion provides Robustness and Redundancy
- Heavy use of Deep Learning
- Connected compute needs active security

Few sensors → More sensors

Fusion + Connectivity

Infrastructure Status Data

Vehicle Status Data

E-Payment Service

Weather Data

Location Data
Hi-Def Maps
Collaborative Mapping

Transit Status Information

Safety Alerts & Warnings

Signal Phase & Timing Adjusts Real-Time Conditions

Malware

Real-Time Travel Info

EcoDrive Applications
TI Enables Partial Autonomy Today
Normal Driving with 8 TDA SoCs

- TDAx ADAS Processor
- Short range radar
- Radar/Camera Fusion
- Long range/multi-mode radar
- Stereo Camera
- Infrared Camera

Multi-mode Radar

Stereo Camera

Long Range Radar with Mid-range Scan

Near/Far Infrared Camera

Short Range Radar Radar/Camera Fusion
Additional 2 SoCs for Park Assist, equals **10 TI ADAS SoCs in one car!**

- 360 Degree surround view cameras
- Smart rear view camera
TDA Family HW & SW Scalability

<table>
<thead>
<tr>
<th>Front Cam</th>
<th>360 Surround</th>
<th>Fusion</th>
<th>Smart Rear Cam</th>
<th>Radar</th>
<th>Driver Monitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td></td>
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<tr>
<td>Mid</td>
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<tr>
<td>Entry</td>
<td></td>
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</tbody>
</table>

- High:
  - TDA2xA ADAS Processor
  - TDA2xV ADAS Processor

- Mid:
  - TDA3xA ADAS Processor
  - TDA2EcoV ADAS Processor
  - TDA3xF ADAS Processor

- Entry:
  - TDA3xV ADAS Processor
  - TDA3xT ADAS Processor
  - TDA3xV ADAS Processor

Common Software & Algorithm Investment
Binary Compatible SW Across Cores
Common SoC Architecture & Tools
Distributed Processing using Common Architecture - Near Term
Centralized Processing on Common Architecture - in the Future

TI is focused on providing world class signal processing to enable ADAS today and Autonomous Driving tomorrow.
TDAX SoC Family Demos at CES 2017

- Industry-leading, integrated ISP
- Best-in-class flicker mitigation
- 3D surround view plus bonus view(s) without GPU
- Live, full-size vehicle demonstration
- Rear stitch view panorama

Augmented Around Viewing
Increased Safety via Increased Visibility

Advanced Driver Monitoring
From Fotonation

Front Camera NCAP Solutions
From KPIT & Hella Aglaia

ADAS Fusion for Safety

LED Flicker Mitigation

Deep Learning Semantic Segmentation
## Innovation across 5 key market sectors

<table>
<thead>
<tr>
<th>Advanced driver assistance systems</th>
<th>Passive safety</th>
<th>Hybrid/electric and powertrain systems</th>
<th>Body electronics &amp; lighting</th>
<th>Infotainment &amp; cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive cruise control</td>
<td>Automatic braking</td>
<td>Automatic start/stop</td>
<td>Security system</td>
<td>Entertainment system</td>
</tr>
<tr>
<td>Night vision</td>
<td>Airbag deployment</td>
<td>Battery management</td>
<td>Seat position control</td>
<td>Head-up display</td>
</tr>
<tr>
<td>Blindspot detection</td>
<td>Antilock braking</td>
<td>Electric power steering</td>
<td>Remote keyless entry</td>
<td>Navigation system</td>
</tr>
<tr>
<td>Lane departure warning</td>
<td>Tire pressure monitoring</td>
<td>Engine and transmission control</td>
<td>Lighting</td>
<td>eCall</td>
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</table>

and more…

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**Texas Instruments**
Why TI for **automotive**?

### Portfolio
- Broad and deep portfolio, **2,000+ AEC-Q100 qualified parts**
- **250+** reference designs plus tools, software
- TI.com is one-stop shop

### Innovation
- **50+** product lines innovating for automotive
- Process and packaging technology
- Kilby Labs researching new technologies

### Commitment
- Quality, reliability, safety → SafeTI™ design components and packages
- Local support, TI E2E™ Community
- Sales coverage expanded
- **30+** years of experience
Leading analog and embedded products for automotive
Thank You