WHITE PAPER

Matthew Watson
Product Line Manager,
Automotive Infotainment Processors
Texas Instruments

Scott Linke
System and Architecture Manager,
Automotive Infotainment Processors
Texas Instruments

Andy Gryc
Product Marketing Manager,
Automotive
QNX Software Systems

In-Vehicle Connectivity is So Retro

Image is of the head unit for the QNX reference vehicle, a specially modified Jeep Wrangler.

Introduction

Automotive infotainment consumers may assume in-vehicle connectivity is a new, emerging capability, and that it only means being connected to the Internet. How quickly our definitions evolve. Few consumers likely consider CAN communication a high-tech topic, but in infotainment systems, CAN and other internal connectivity protocols such as MOST, Ethernet and USB provide important backbones that enable key features in cars today. Bluetooth® technology once defined "wireless" connectivity in the car. Now, this definition has expanded to include smartphone tethering, in-vehicle Wi-Fi® access points, vehicle-to-vehicle communication, Near Field Communication (NFC) and more.

Over the past 10 years, Texas Instruments Incorporated (TI) and QNX Software Systems Limited have worked closely to enable innovative, connected automotive infotainment solutions. Many of these systems were groundbreaking in their time, even if they have been superseded by systems being deployed in today's cars. This paper provides insight into the ongoing refinement and innovation that drove the evolution of these systems, and will continue to drive future offerings. Innovation can result not only by introducing new means for in-vehicle systems and carry-in electronics to interact, but through "less-glamorous" but critical ways such as reducing system cost, size and power. Connectivity will also be discussed with respect to both in-vehicle systems and external devices.

Bluetooth technology and compressed audio on OMAP™ 1 processors

With the launch of OMAP 1 processors in 2002, TI introduced a family of single-chip automotive devices that enabled a rich multimedia experience (CD-DA and CD-ROM/DVD-ROM/USB/SD with MP3, WMA, and AAC audio decoder support). These devices also provided connectivity to early *Bluetooth* technology-enabled phones to offer hands-free calling capabilities in cars. These solutions are still in production and on the road in 2012, providing a feature-rich, entry-level infotainment experience. Key innovations in OMAP 1 processors, which were enabled in conjunction with QNX Software Systems, include the ability to integrate multimedia functions and an application-based processor into a single system-on-chip (SOC). This solution accelerated audio codecs and processing using TI's C55x digital signal processor (DSP), and leveraged a straightforward API from ARM® Holdings' ARM926 general purpose processor to the DSP in order to coordinate communication.

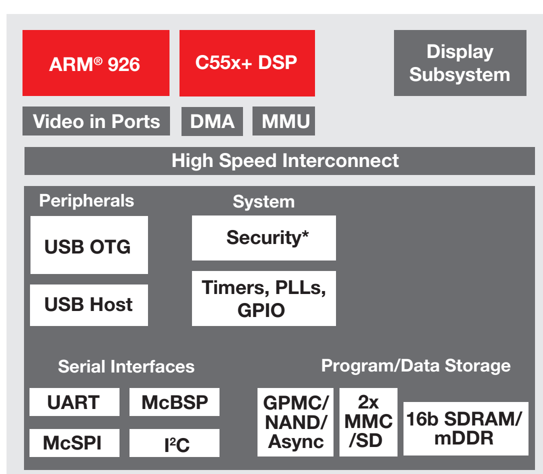

Figure 1: Simplified OMAP 1 processor block diagram.

Enhanced multimedia and software-defined radio on the Jacinto 1-DDR

After launching five OMAP 1 processor derivatives, TI introduced the Jacinto 1 family of devices in 2006. This new family of devices provided the next major leap in infotainment integration. Compared to the OMAP 1 family, the Jacinto 1 family offered a much lower cost point for enabling additional features such as compressed video playback from DVD or local USB/SD storage, *Bluetooth* A2DP audio streaming support for Apple iPods®, and digital terrestrial radio baseband demodulation (DAB in Europe and HD Radio™ in the United States). Additionally, the Jacinto 1-DDR device offered the ability to drive two high-resolution color displays for user interfaces or video playback, giving OEMs more flexibility in placing information on screens.

Jacinto 1 devices also replaced the C55x DSP with the powerful TI C64x+ fixed-point DSP. The C64x+ DSP's performance allowed graphics acceleration, compressed audio decoding, voice recognition and radio demodulation to run concurrently. This concurrency significantly extended the reach of what was possible with a single, isolated ARM CPU.

Another key innovation TI and QNX Software Systems enabled on Jacinto 1 devices was the DSP Link Inter-Processor Communication (IPC) component. This link tied the ARM CPU and DSP together to enable a zero-overhead interface for controlling applications and peripherals with DSP acceleration. DSP Link IPC software represented an evolutionary step up from the Jacinto 1 processor's cousin, the OMAP 1 processor. The range of software mechanisms in DSP Link expanded to support several distinct methodologies for information transfer. It also enabled disparate features such audio codecs, graphics acceleration, radio demodulation to execute simultaneously on the DSP, while allowing ARM software to control these features from the user application seamlessly and with low latency.

Jacinto 1 processors further offered the ability for hardware to route and process video from external sources, such as cameras or DVDs, directly to the displays. Previous architectures could only perform routing or multiplexing video feeds along with a User Interface (UI) through software algorithms or by using a separate hardware device. Using software to blend UIs with camera or video overlays, perform transparencies, or perform color space operations could add significant software processing overhead, while adding a separate hardware device increased bill-of-materials (BOM) costs. Jacinto 1 devices removed the need for both of these solutions by leveraging hardware features for graphical manipulations such as color-space conversion or alpha blending. This advancement freed the ARM CPU from those graphical duties, allowing it to be used for additional software capability for OEM differentiation.

QNX Software Systems contributed software infrastructure components to Jacinto 1 systems that supported the device's features. Examples include multimedia frameworks that used DSP codecs accessible through DSP Link, and integrating DSP-accelerated graphics features from third-party companies into QNX Software Systems' OpenGL® ES drivers.

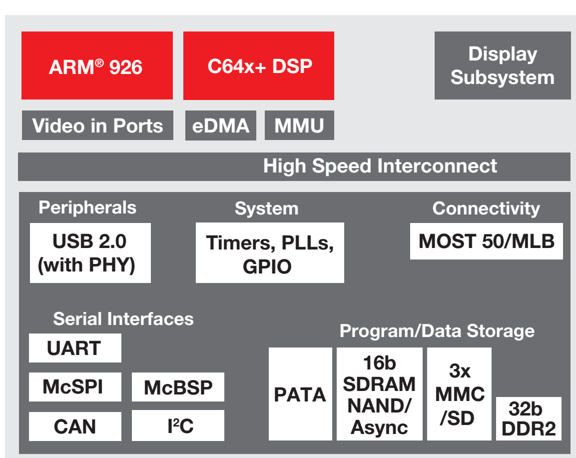

Figure 2: TI's Jacinto 1-DDR processor diagram

Jacinto 3 family boosts graphics and user experience in the age of smartphones

TI launched its OMAP 3 processors and Jacinto 3 family of devices in 2008, both of which included the ARM® Cortex™-A8 core and Imagination Technologies PowerVR™ SGX graphics. These systems offered the same connectivity options as the Jacinto 1-DDR solution, but provided a significant boost in terms of user experience through rich graphics and low-latency touch screen support.

Software provided the evolutionary step forward. Jacinto 3 devices were powerful enough to run an entire infotainment software stack on a single chip. The days of systems requiring a collection of separate CPU, GPU and DSP parts were finally over. QNX Software Systems leveraged Jacinto 3's power and their preceding 10 years of automotive development to create the first QNX CAR™ application platform, which significantly reduced the first-level integration efforts required to deliver automotive infotainment products. The QNX CAR application platform rolled all the separate software components into one package, including all major pieces required for a "modern" infotainment system. Fitting all infotainment capabilities into a single software architecture on a single chip reduced project BOM costs, and the pre-integrating software components reduced development costs.

This solution was an unprecedented success for multiple automotive Tier-1 suppliers. One supplier was even able to shorten the development cycle from three years to a mere 14 months from concept to production!

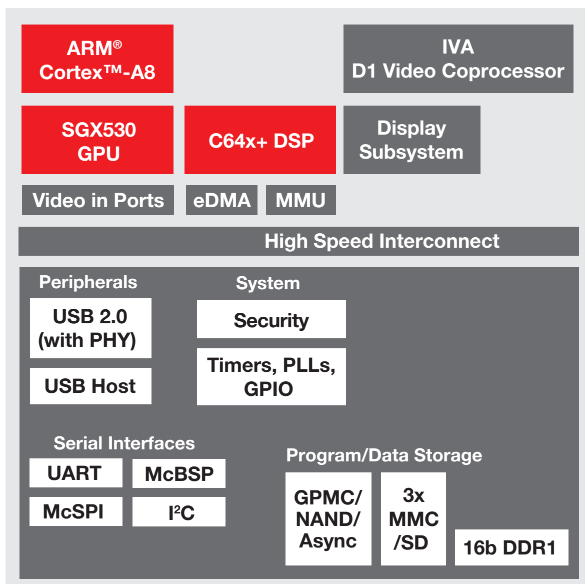

Figure 3: TI's Jacinto 3 processor diagram

Jacinto 4 and 5 family adds multimedia, cloud connectivity, and enhanced vehicle communication

The Jacinto 4 and 5 families of processors arrived in 2010. These chips made the next step in multimedia possible: full high-definition, 1080p video decode/encode and display. They also brought another DSP upgrade to the C674x+ floating-point DSP. These chips are in systems on the road today, offering users an affordable, full-featured connected infotainment experience.

Key QNX and TI innovations on the Jacinto 4 and 5 platforms focused on delivering improved and additional connectivity, with MOST MLB, Ethernet AVB, PCIe and SATA, thus providing connectivity to a broader range of networks and peripherals. TI also introduced an automotive version of its single-chip, multi-standard WiLink™ 7Q combo connectivity solution. For the first time, Wi-Fi, *Bluetooth* and GPS technologies were married on a single automotive-qualified chip, interfaced to a Jacinto processor.

A unique addition to Jacinto 4 and 5 devices was a set of dual ARM Cortex-M3 CPUs (along with a dedicated L1 cache), which could be dedicated to software services with high interrupt loads or real-time latency requirements, offloading the main CPU. A single Cortex-M3 core could manage decoding a video stream and producing video frames, so that the load on the main CPU was reduced to file I/O (reading the movie file from SD card) and audio decoding. TI further improved performance by advancing the previous DSP Link (ARM-DSP) inter-processor communication API to include the Cortex-M3 cores (SYSLink) along with hardware mailboxes and spinlocks.

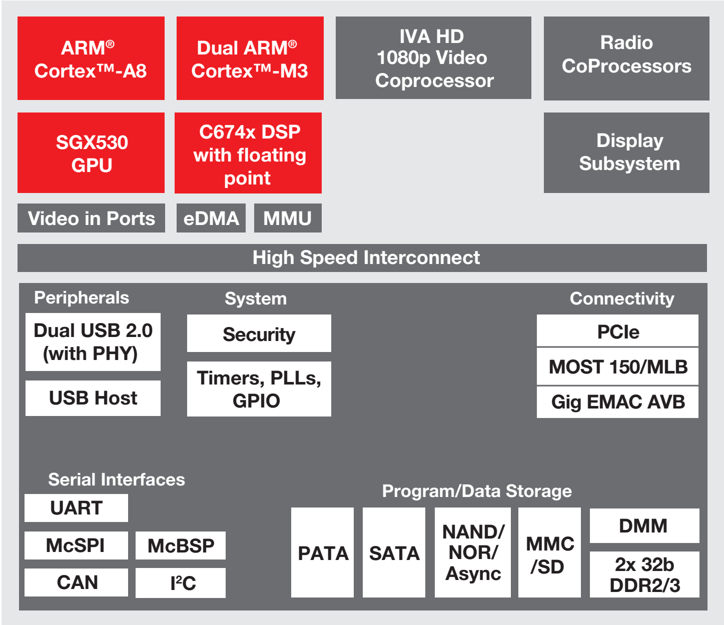

Figure 4: TI's Jacinto 4 processor diagram.

Building on the success of the QNX CAR application platform, QNX Software Systems began its next-generation implementation using Jacinto 4 and OMAP 4 processors as initial hardware platforms. The QNX automotive team adapted codecs for the QNX multimedia engine to take full advantage of the new capabilities provided in SYSLink, improving the engine's performance.

QNX Software Systems leveraged Jacinto 4's features to create the QNX CAR 2 application platform, a further evolution in the infotainment software environment. QNX CAR 2 uses a modular architecture designed to support multiple user interface technologies, including HTML5. Underlying software services are insulated through a Persistent Publish/Subscribe (PPS) technology that unifies the services layer. This modularity offers developers greater customization options than do more rigid architectures, while reducing the overall development time required to bring an automotive infotainment system to market.

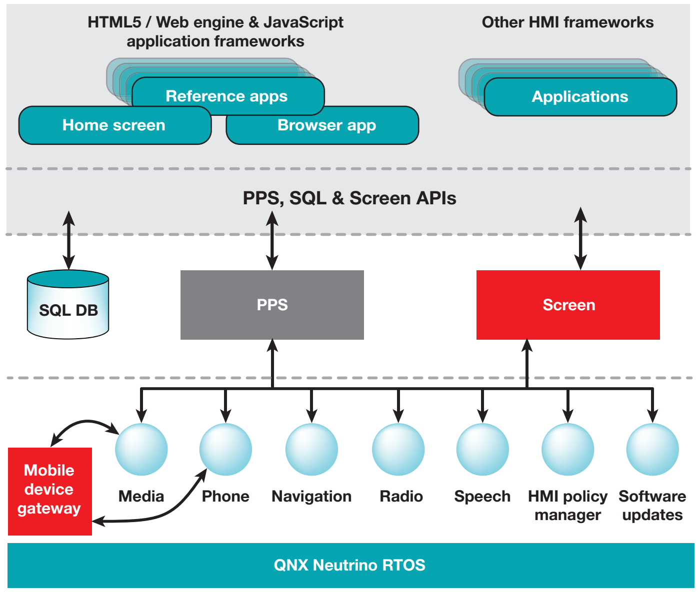

Figure 5: A high-level view of the QNX CAR 2 software architecture.

Next-generation connected infotainment solutions

QNX Software Systems and TI continue to drive connected infotainment solutions forward as we look towards model year 2016 vehicles and beyond. TI leverages an ARM Cortex-A15 foundation for automotive infotainment in its OMAP 5 processors, along with the latest-generation Jacinto 6 processors. Based on the OMAP 5 architecture, Jacinto 6 includes significant performance improvements as compared to the previous-generation Jacinto 5: CPU, graphics (using Imagination Technologies' PowerVR SGX544MP2), multimedia, and software-defined radio. Jacinto 6 also provides additional and improved interfaces, including support for high-definition surround view cameras, multiple concurrent HD displays, USB 3.0, PCIe2, and SATA.

The QNX CAR 2 application platform is the first comprehensive infotainment platform to be offered on an ARM Cortex-A15 device. The capabilities of the QNX CAR 2 platform continue to evolve and will expand to support the added hardware functionality the OMAP 5 platform and Jacinto 6 processors provide.

The Jacinto 6 platform's inclusion of multiple camera inputs allows designers to create infotainment systems that support Advanced Driver Assistance and Safety (ADAS) features, with cameras used for adaptive cruise control, lane departure warnings, drowsy driver warnings, and many other features. Because versions of the QNX® Neutrino® RTOS are safety-certified for high-reliability systems, systems combining OMAP 5 processors, QNX infotainment, and ADAS can meet industry requirements to continue consolidating costs while bundling even more advanced multimedia and safety features.

The following connectivity enhancements can be enabled cost-efficiently with TI's Jacinto 6 platform and QNX platform solutions:

- Ethernet AVB and/or MOST MLB 150 multimedia interfaces connecting in-vehicle subsystems
- Wireless connectivity via TI's WiLink 7Q and WiLink 8Q combo connectivity solutions for devices designed to support (with wireless streaming and projected-mode) standards such as Wi-Fi CERTIFIED Miracast™. The WiLink 8Q family reaches new levels of cross-platform scalability and is tested following AEC-Q100 qualification.
  - NFC
  - GNSS (GPS + GLONASS)
  - *Bluetooth*/*Bluetooth* low energy
  - Wi-Fi
- Multi-video input or surround-view camera interfaces and processing
- Multi-instance digital radio support
- Multiple HD displays

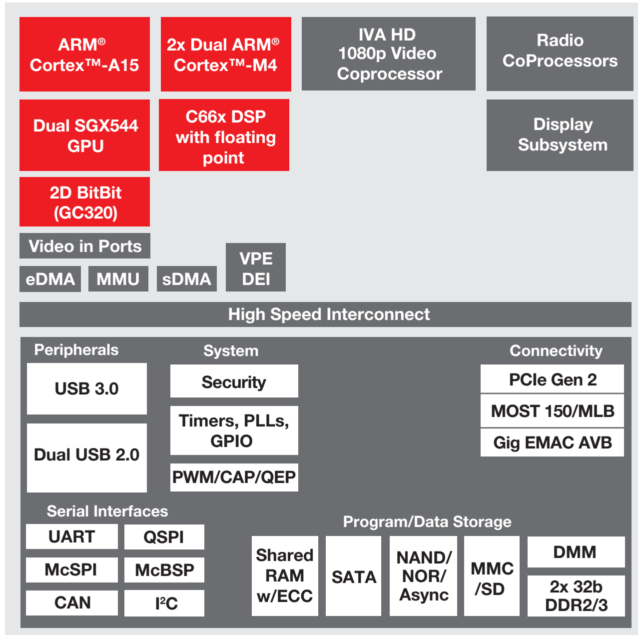

Figure 6: TI's Jacinto 6 processor diagram.

The Future

What will the future hold for automotive infotainment systems in 2018, 2020 and beyond?

The trends of device consolidation and feature expansion will surely continue and likely accelerate. Full cockpit displays and of the fusion of safety and infotainment features are very probable outcomes of these trends. The needs for greater device connectivity and further shortening of software development cycles will also continue, driven by the need for automotive technology to match the speed of innovation and adoption of consumer electronics. The expansion of ADAS functionality, ultimately culminating in fully autonomous vehicles, is a natural conclusion of consumers' wanting more of their day-to-day technology to be brought into the driving experience.

One given is that TI and QNX Software Systems will continue to pioneer, partner and collaborate on the definition and delivery of hardware and software that will provide best-in-class performance and cost effectiveness.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265