In-Vehicle Connectivity is So Retro

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 Many of these systems were groundbreaking in their time, even if they have been superseded by systems being deployed in today’s cars.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.
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](image-url)
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!

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

![Figure 3: TI’s Jacinto 3 processor diagram](image-url)
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.

![TI's Jacinto 4 processor diagram.](image)

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.
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
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 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.
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