Trends and Applications of **USB in Automotive**

**FTF-AUT-F0335**

Arturo Inzunza | Automotive Applications Engineer

APR. 2014
Agenda

• USB Introduction
• Current uses in Auto
• Future uses in Auto
• USB in Freescale automotive MCU’s and MPU’s
• Conclusions
Introduction – USB

• USB is one if the most widespread communications protocol, cables and connectors standard today.

• Billions of computers and embedded systems (~ 8 by 2010) use this standard to inter-communicate even when the vendor is different.

• USB has replaced several different interfaces, not only communication interfaces, but also power interfaces.

• Its original objectives:
  – Standard interface for peripherals
  – Ease of use
  – Port expansion
Introduction – USB Now

• USB has new objectives:
  – Higher performance
  – Smaller form factor
  – Embedded flexibility
  – Wider applications range

• The automotive market is starting to look at USB as a potential interface on the vehicle. Not only for external user interface but for internal communications as well.

• The protocol its widely known, offers flexibility and several standard solutions exist.
Objectives

After completing this session, you will be able to:

• Understand the USB current features

• Evaluate potential uses of USB on an automotive environment

• Discuss future applications of USB

• Identify Freescale devices that provide USB functionality
USB Introduction – Operating Modes

- USB is a Master-Slave architecture

- Two main roles:
  - Master is called Host
  - Slave is called Device

- Third role is Hub
  - Special device
USB Introduction – Operating Modes - Host

• A Host is in charge of starting all communications.

• The different types of Devices are sorted in “Classes”.
  – Common classes are: CDC, MSD, HID, etc.

• The Host needs “Drivers” that support specific classes therefore can understand and use devices of those specific classes.

• The Host needs to maintain a schedule and well defined timings to address all the known connected Devices on the network.

• Originally only PCs were hosts. Communication between two devices was impossible without a PC.
USB Introduction – Operating Modes - Device

- A device provides functionality to the host.

- It requires less processing power as it only replies to Host’s queries.

- Hubs are special types of devices (class 0x09)

- Only one device is connected with the host at any given time.

- What if the two devices want to talk to each other?

### USB Device Classes

- Audio
- Communications
- HID
- Physical Image
- Printer
- Mass Storage Hub
- CDC-Data
- Smart Card
- Content Security
- Video
- Personal Healthcare
- Audio/Video Devices
- Diagnostic Device
- Wireless Controller
- Miscellaneous
- Application Specific
- Vendor Specific
USB On-The-Go (OTG)

• Defined as a supplement to USB 2.0.

• Allows non-PCs to communicate to each other.

• An OTG device can act as a Host or as a Slave depending on the situation.

• Operating mode is commonly defined by the cable used…
USB On-The-Go (OTG)

• Most smart phones have OTG AB connectors allowing flexibility.

Micro-A
- ID pin grounded
- Indicates OTG should be Host.

Micro-B
- ID pin floated
- Indicates OTG should be Device.
USB Speeds

• USB has evolved and currently is on revision 3.1

• USB 1.x
  – Low Speed (LS) → 1.5 Mbps
  – Full Speed (FS) → 12 Mbps

• **USB 2.0**
  – High Speed (HS) → 480 Mbps

• USB 3.0
  – Super Speed USB (SS) → 5 Gbps

• USB 3.1
  – Super Speed+ USB (SS+) → 10 Gbps
Current Uses in Auto

Infotainment User Interaction
Infotainment User Interaction

• Infotainment and head system units require simple methods for the user to provide custom content.

• Currently is common to have Music and Video in a USB thumbdrive or cellphone.

• Several OEM and aftermarket head units have USB ports for the user to load their music files to the system.

• These USB ports on the head units normally support the MSD and the Audio classes.
Infotainment User Interaction

- There are solutions for older Head Units that don’t have USB using the CD player or extension port.

- Currently, head units support up to USB 2.0, no more speed is needed as music and video is buffered.

- But users are starting to get more and more media to the car and some OEMs have upgraded their Head Units with hard drives.

- USB 3.0 will be integrated to future head units to reduce the time required to move files to the on-board infotainment hard drive.
Current Uses in Auto

Power Source
USB as Power Source

- USB has replaced several interfaces, including common power delivering interfaces.

- Several portable devices manufacturers are switching to USB charging as it provides standard and widely spread port.

- USB considers scenarios where the attached devices are self-powered or require power from the bus.

- USB 2.0 specifies a fixed current flow. A host can’t be powered through the bus.
USB as Power Source

• USB 2.0 indicates that a host may provide up to 500 mA of current (2.5 W) to a device, provided such current budget is available.

• Initially a device is allocated 100 mA, and may then negotiate for more power up to 500 mA.

• In 2007 a special specification was released called “USB Battery Charging Specification”. It allows…
  – Charging Downstream Ports: Ports for charge and data transfer
  – Dedicated Charging Ports: Only charging is available

• DCP allow up to 1.5 A of current without digital negotiation.
USB 3.x as Power Source

- Tablets and larger portable devices require more current than the USB 2.0 standard allows.

- USB 3.0 increased the maximum current on a standard port to 900 mA (4.5 W) after negotiation.

- Along with USB 3.0, another specification was created called “USB Power Delivery Specification”. Current direction is no longer fixed.
USB 3.x as Power Source

• USB Power Delivery spec introduces the “Power Profiles” term.

• These power profiles are optional but allow using USB to power much more energy demanding devices.

<table>
<thead>
<tr>
<th>Voltage</th>
<th>1.5 A</th>
<th>2.0 A</th>
<th>3.0 A</th>
<th>5.0 A</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 V</td>
<td></td>
<td>P1, P2, P3, P4, P5 (10 W)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 V</td>
<td>P2 (18 W)</td>
<td>P3, P4 (36 W)</td>
<td>P5 (60 W)</td>
<td></td>
</tr>
<tr>
<td>20 V</td>
<td></td>
<td>P4 (60 W)</td>
<td>P5 (100 W)</td>
<td></td>
</tr>
</tbody>
</table>

• USB Power Delivery capable devices will be included in the car to provide mobile devices charging capabilities.
Future Uses in Auto

Wireless Communications: Safety
USB as V2V and V2I Interfaces

• One of Freescale’s key development areas is Advanced Driver Assistance Systems (ADAS).

• 76% of the vehicle accidents in U.S. roadways could have been avoided with active safety systems.

• Several transportation agencies on the globe, for example the Intelligent Transportations Systems (ITS) program of the U.S. Department of Transportation are working on:
  - V2V: Vehicle to Vehicle Communications
  - V2I: Vehicle to Infrastructure Communications
Vehicle-to-Vehicle (V2V) Communications

• Vehicle-to-Vehicle communications will enable cars, trucks and motorcycles to share:
  - Sender’s position
  - Sender’s speed
  - Lane change events
  - Send threat or hazard indications
  - Send threat or hazard position estimation
  - Timestamps

• Receiving vehicles will be able to use this information and assess which preventive action is required:
  - Auditive and/or visual alerts to the driver
  - Automatic Speed reduction or Cruise Control Disable
Vehicle-to-Infrastructure (V2I) Communications

• Besides from vehicles, there are other hazards for a driver on the road.

• Accidents related with pedestrians, bicycles, animals, traffic, speed limits, etc. Can be addressed with a “Smart infrastructure”

• Communication with infrastructure provides the driver information on
  – Accidents on the road
  – Speed limits
  – General intersection safety (Signal Phase and Timing [SPaT] information)
Vehicle-to-Infrastructure (V2I) Communications

• While the main objective of V2I is increasing road safety, it offers improvements on:
  – Manage congestions
  – Reduce delays
  – Reduce emissions
  – Allow infrastructure monitoring
  – Parking space identification

• The ITS has already allocated the 5.9 GHz band to implement the WAVE (Wireless Access in Vehicular Environments)

• Standard IEEE 802.11p describes the implementation of WAVE.
IEEE 802.11p

- V2V but specially V2I connections last only seconds.

- The IEEE 802.11p amendment makes changes to the MAC to allow data transfer without authentication.

- Commercially available IEEE 802.11 radios (as the ones used in WiFi) can be used for V2V or V2I communications.

- Next generation automotive gateways will have USB connectivity as a port for wireless expansion.

- V2V and V2I can be integrated without hardware modifications to gateway designs featuring USB.
Future Uses in Auto

Wireless Communications: IoT
Besides from security, there are many applications that require user on-demand data.

- Up to date GPS maps
- Up to date Points of Interest
- On-Demand music streaming
- Traffic information for smarter routing
- Real-time weather information
- …

That is from the end-user point of view… how about the OEMs?…
USB Enabling the Internet of Things in Auto

• OEMs could benefit from this:
  − Diagnostic data reporting
  − Remote troubleshooting
  − Service reminders
  − Selective message delivery (e.g. callbacks)

• Picture an Automotive Upgrade Store…
  − Maps for other countries
  − Maximum speed lock (for teen drivers)
  − Performance unlock
  − …

• And of course, deliver firmware updates, firmware fixes, etc.
USB Has Several Applications

• The connection to the internet can be done via a 3G or LTE USB modem.

• But, in this scenario the infotainment system needs a modem (+enablement around it) and the body module needs another one.

• USB can be used as a “peripheral sharing” enabler.

• BOM and implementation costs can be reduced by allowing two modules to share high-speed peripherals on a dedicated link.
USB as Peripheral Sharing Link

- Only one modem required on the car. It is shared between the Body/Gateway (for FOTA updates) and the infotainment system.
Future Uses in Auto

Inter-Chip Communications
Inter-Chip Communications

- USB provides standard means to use bus as an inter-chip bus.

- Normal USB connections are like this...

![Diagram showing USB connections between host and device]
Inter-Chip Communications – IC_USB

• Standard USB can’t be used for inter-chip communications (PHYs are needed).

• The USB-IF improved USB2.0 with the Inter-Chip USB specification.

• No plug-N-play capability

• Supports LS and FS.

• Compatible with standard USB software and stacks.

• Currently used on phones…
Inter-Chip Communications – High Speed Inter Chip USB

- High Speed Inter Chip USB or HSIC USB is the next step in inter-chip communication and allows HS only.

- Also was an incremental spec of the USB 2.0 standard.

- It completely modifies the transmission scheme removing the differential pair and using a serial interface.

- Uses two pins: Strobe and Data.

- Strobe is the clock (at 240 MHz) and Data is sampled in DDR mode.
HSIC - Signals

End of Idle
Data sampled at rising edge
Data sampled at falling edge
Last data sample
Start of Idle
Resume
Start of Idle

STROBE
Idle Phase

DATA
'0' '1' '1' ...

1.2 V
HSIC - Connections

- Only 480 MHz supported.
- There are HSIC-to-ULPI transceivers that provide HSIC functionality to standard USB 2.0 devices.
- Standard USB software and stacks apply.
USB as Inter-Chip link

• No PHY is needed for reliable high speed link on a PCB.

• Standard USB stacks can be seamlessly used.
HSIC Characteristics

- The smaller size of the HSIC physical transceiver make it easier to integrate to an embedded processor.

- The Host and Device role is decided on the SW implementation. There is no hardware negotiation of the role.
Inter-Chip Communication - SSIC

- USB 3.0 replaced HSIC with SSIC (Super Speed Inter-Chip) USB.

- The USB-IF worked with the MIPI Alliance to include SSIC support to the M-PHY2, an already existing gigabit-speed inter-chip PHY.

- Allows data transfers of 5.8 Gbps on the third gear.

- Requires 4 signals.

- Can work on 1, 2 or 4 lanes.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-G1</td>
<td>1.25</td>
<td>1.45</td>
</tr>
<tr>
<td>HS-G2</td>
<td>2.5</td>
<td>2.9</td>
</tr>
<tr>
<td>HS-G3</td>
<td>5.0</td>
<td>5.8</td>
</tr>
</tbody>
</table>
Freescale Automotive
USB solutions
Qorivva MPC5748G MCU – Body / Gateway Controller

- 1 Host (no PHY)
- 1 OTG (no PHY)
i.MX 6 Series Processors

- 1 Host + PHY
- 1 OTG + PHY
- 2 HSIC + PHY
Conclusions
Conclusions

- The USB standard offers solutions for much more than standard host – device connectivity.

- The automotive market is starting to harvest the flexibility of USB on cars.

- USB is a great solution for remote or near inter-processor communications and peripheral sharing.

- Latest Freescale platforms include USB modules to support newer and more demanding connectivity use-cases.
Recommended!

- FTF-AUT-F0082 - Future Implications for the Vehicle When Considering the Internet of Things (IoT) (W 10:30)


- FTF-AUT-F0081 - Automotive Microcontrollers in a Fast-Changing Environment (T 4:45)