

A²B and Ethernet in Automotive Applications: What, When, and How

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Introduction

The number of electronic systems in cars has increased in recent years, reaching higher levels of complexity with the adoption of new technologies for infotainment and advanced driver-assistance systems (cameras, radar, lidar, etc.), along with multiple sensors for many different purposes (stability, speed, acceleration, etc.).

We can differentiate between high and low bandwidth technologies. Typically, sensors require a low bandwidth. The most common accelerometers used in cars have an output data rate (ODR) of a few kHz. When it comes to infotainment, audio and video data require a data rate in the range of several Mbps.

However, what is really raising the bar is the adoption of HD multicamera systems for parking assistance, 360° vision systems (also known as bird's-eye view or surround view monitor systems), radar (RF microwave), and lidar (optical) to enhance advanced driver-assistance systems (ADASs). The coexistence of all these systems is a key factor in the development of autonomous vehicles, but it represents a big challenge for any communication bus.

Traditional buses used in automotive are:

- ▶ Local interconnect network (LIN): with a speed of up to 20 kbps, it is mainly used within subsystems where low cost is essential and the speed/bandwidth ratio is not important.
- ▶ Controlled area network (CAN): with a transmission rate of up to 1 Mbps, it is mainly used for communication between the electronic control unit (ECU) and sensors in start/stop systems, parking assist systems, and electric park brakes.
- ▶ FlexRay: faster than CAN (up to 10 Mbps), it is more expensive. It was initially adopted for x-by-wire (drive-by-wire, steer-by-wire) systems and conceived to accommodate multiple network topologies.
- ▶ Media oriented systems transport (MOST): with a maximum speed of 150 Mbps, it's designed to transport audio, video, voice, and data signals. It defines all seven layers of the ISO/OSI model, from the physical level up to the application layer. It is a proprietary solution.

With such evolution in network technology, another aspect has become important. Many different buses used for different subsystems include very complex (and expensive) cabling. Size and weight are new challenges in automotive applications because meeting new environmental regulations means developing new systems that can, for example, reduce CO₂ emissions. In such a landscape there's no easy answer to the need for a high bandwidth, low latency, deterministic, robust, and cheap communication bus.

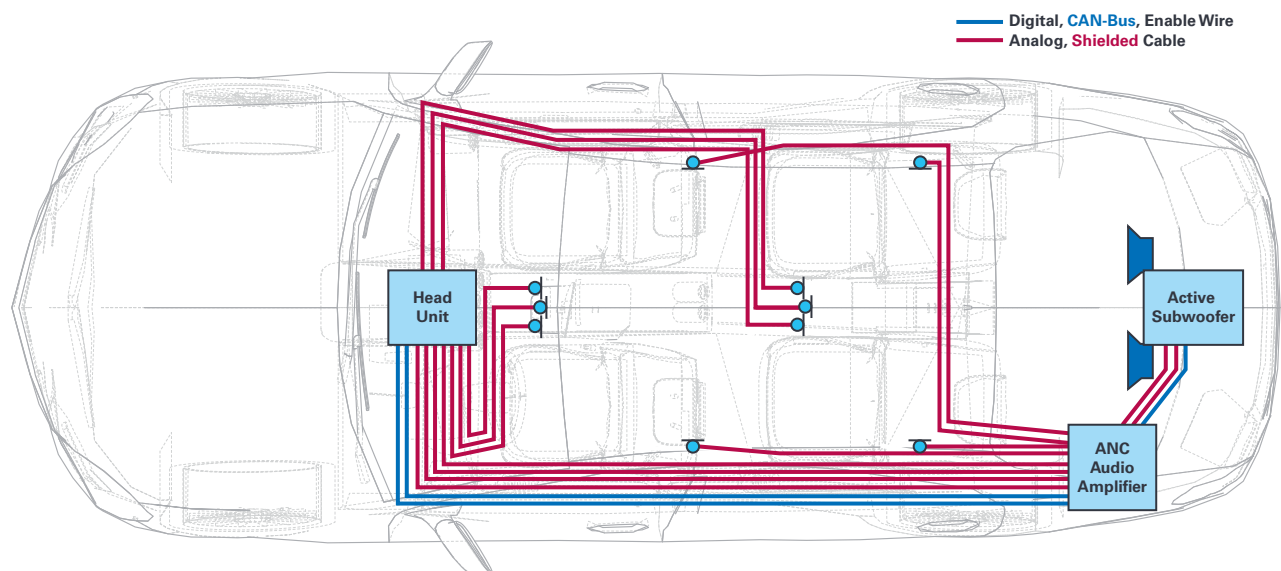


Figure 1. Traditional in-car cabling for audio systems.

Automotive Audio Bus (A²B)

One of the major contributions to the total cabling weight comes from car audio systems because analog wiring requires expensive shielded cables for each audio source/sink (loudspeaker). Moreover, active noise cancellation (ANC) and road noise cancellation (RNC) systems require several microphones inside the car, adding many other inputs to the audio network.

The actual cabling inside a car for a traditional audio system is well represented by Figure 1.

Automotive Audio Bus (A²B[®]) is an innovative technology from Analog Devices that allows the implementation of in-line topology with a single master connecting to up to 10 slaves daisy chained. With a speed of 50 Mbps, A²B is optimized for audio applications. Connectivity is dramatically simplified by using an unshielded twisted pair (UTP) cable, reducing the total weight of the harness by up to 75%. The distance between nodes can be as long as 15 m, while the maximum network length is 40 m. The same UTP supplies power (phantom powered configuration), up to 300 mA—ideal for digital microphones.

It is always possible to provide slave nodes with a local power supply, in case the power budget provided by the master is insufficient. The bus allows a bidirectional, master-to-slave and slave-to-slave communication, bringing up to 32 channels downstream and upstream (12, 16, and 24 bits). Most importantly, a 2-cycle latency is guaranteed, providing latency-sensitive applications such as ANC/RNC with a deterministic support. The bus is capable of transporting I²C messages, allowing the configuration over distance of ADCs/DACs at slave nodes.

What really simplifies the configuration of an A²B network is SigmaStudio[®], a graphical design environment supporting SigmaDSP[®] and SHARC[®] DSP families. An A²B transceiver (AD2428, AD2427, and AD2426) provides I²S and PDM interfaces. Typically, an I²S interface is used for connecting to ADCs and DACs, while digital microphones use PDM.

One of the major concerns in automotive applications is related to electromagnetic compatibility (EMC). A²B has passed the most stringent automotive EMC and electromagnetic interference (EMI)-compatibility tests using just a 2-wire UTP cable. RNC applications require accelerometers and microphones distributed around and inside the vehicle. The use of analog parts is cost-prohibitive as it would require additional circuitry (analog-to-digital converters), wiring, and connectors. The A²B technology simplifies this architecture with a novel approach to audio sources and sensors.

Ethernet in Automotive

Ethernet is a very popular networking technology and possesses a large ecosystem. However, its use in the automotive field is limited so far to a few applications such as diagnostics, in-vehicle infotainment systems, and connectivity to sensors. Its rival for in-car applications is likely MOST, which can compete in terms of speed.

Although Ethernet has the potential to become the definitive answer to the huge demand for bandwidth arising with the newest technologies (radar and lidar, for example), there are several aspects still limiting its adoption in cars.

Traditional Ethernet cables used for 100-Base-TX, based on two differential pair wires and isolated by transformers, are too expensive for automotive applications. Moreover, a Cat-5 cable doesn't meet automotive EMI standards, making the 100-Base-TX Ethernet useless for in-car communications other than diagnostics and firmware updates.

For vehicle-to-vehicle (V2V) or vehicle-to-everything (V2X) communications, in-car data transport must be supported in terms of synchronization, traffic shaping, and fixed latency. Ethernet doesn't have this kind of support, unless new protocol stacks are implemented.

Let's consider the physical layer first.

With the aim of meeting the requirements in terms of weight, EMI, and cost, the Institute of Electrical and Electronics Engineers (IEEE) defined a new standard called 802.3bw, also known as 100-Base-T1. IEEE 802.3bw is a 100 Mbps standard based on a UTP cable that is bidirectional and that meets strong automotive emissions requirements. EMI is reduced by using the basic principles of superposition, specific encoding, and scrambling schemes.

Weight and cost are lower when an unshielded 2-wire cable is used instead of the traditional Cat-5 cable. Technologies like power over Ethernet (PoE) provide power along with data, sharing the same wires. However, PoE requires at least two pairs of wires for providing power, clearly in contrast with the need to reduce the number of wires.

This is why IEEE defined the standard 802.3bu, also known as power over data lines (PoDL). PoDL can provide power over a single pair of wires, adding some complexity to the transceiver schematics.

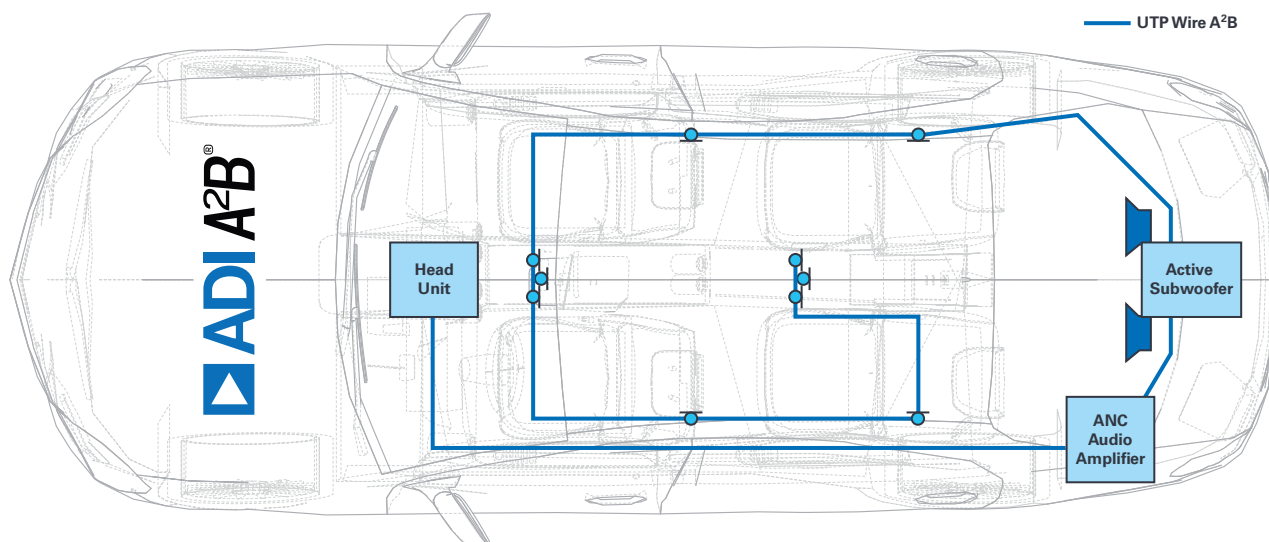


Figure 2. In-car cabling for audio systems simplified by A²B technology.

As already stated, to support automotive applications, Ethernet needs additional SW providing determinism. This can be achieved by the Audio Video Bridging (AVB) protocol, developed within the IEEE 802.1, the organization in charge of the second layer in the ISO/OSI model.

AVB is a SW technology providing time synchronization and traffic shaping. With these fundamental concepts, Ethernet can bring audio and video content reliably. AVB led to the definition of a set of protocols known as time-sensitive networking (TSN), focused on the industrial and automotive markets, providing Ethernet with real-time support.

To summarize, IEEE 802.3bw plus TSN can be a suitable solution for deterministic communication within a car, replacing traditional buses. Moreover, 100-Base-T1 is evolving to a new 1000-Base-T1 standard that can reach 1 Gbps. However, such systems are complex, and these technologies are not mature enough for wide deployment within the automotive market.

Possible Scenarios

While the automotive market is starting to adopt A²B for audio transport in cars, Ethernet is still far from massive implementation when it comes to conveying data from different bus systems.

Applications like ANC, hands-free systems, noise generation for electric vehicles (EV), and emergency call (eCall) systems benefit from the simplification introduced by A²B technology. Moreover, in the future, it could be possible to bring the information from digital sensors directly to the A²B, simplifying the architecture of RNC systems.

However, A²B has a limitation in bandwidth related to the bus speed. Ethernet could reach the speed of 1 Gbps once the 1000-Base-T1 matures; with this bandwidth it could easily bring different kinds of data, from sensors to audio/video streams.

Autonomous driving is pushing for even further performances, heading to multigigabit network connectivity. So, which kind of scenario should we expect for the next few years?

A²B is an easy to implement technology, bringing power and data over the same UTP, with a deterministic support for fixed latency.

Ethernet, with the incumbent 100-Base-T1 (and 1000-Base-T1 in the future), will be a convergent technology allowing the aggregation of multiple data buses, but with an increased complexity for adding power (PoDL) and SW determinism (TSN).

Likely, a mixed solution based on A²B for audio transport and sensors, and a backbone implemented with a high speed Gb Ethernet for cameras, lidar, and radar, could fit most of the future mid-term needs of the automotive industry.

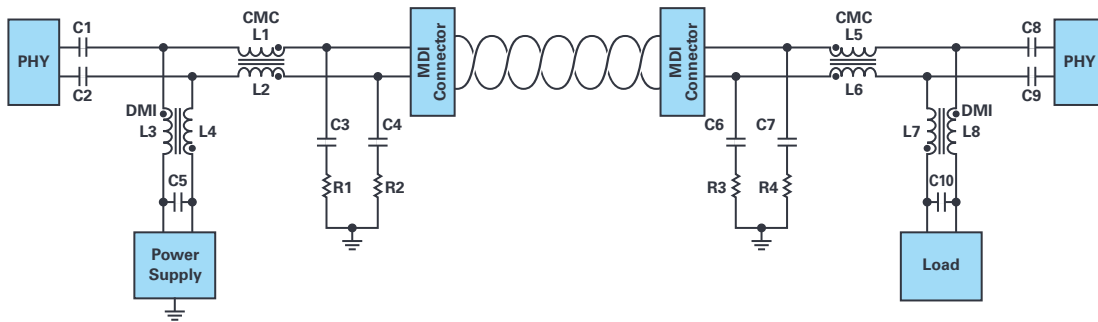


Figure 3. Basic PoDL architecture: data and power share the same differential channel.

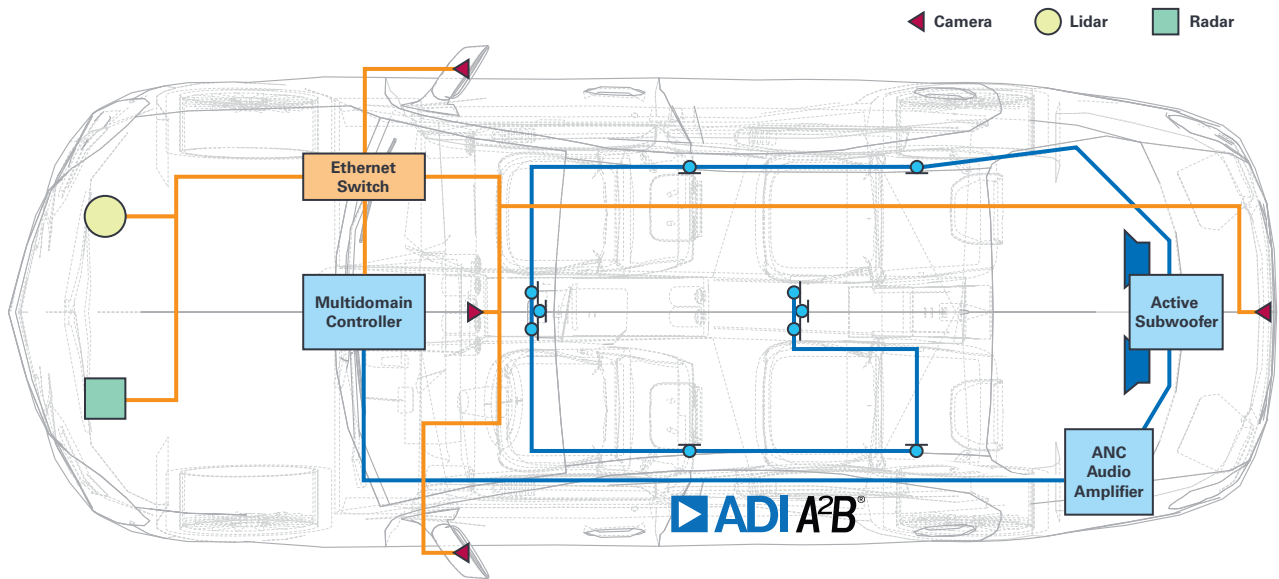


Figure 4. Multidomain architecture.

About the Author

Matteo Crosio began his career at Analog Devices in 2011 as a field applications engineer based in Italy, after 10 years covering different technical roles in the semiconductor industry. With a mixed-signal background in aerospace and telecom applications, Matteo brings solid experience as a hardware and FPGA designer, with a special focus on time synchronization. As part of the European sales organization, he now supports the EMEA region on wired communication technologies. He can be reached at matteo.crosio@analog.com.

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