To serve the rapidly increasing bandwidth requirements in automotive networks, Atmel (recently acquired by Microchip Technology) has developed the ATA6560 and ATA6561 high-speed CAN FD transceivers that provide an interface between a CAN-protocol controller and the physical two-wire CAN network. The transceivers target use in automotive applications requiring speeds as high as 5 Mbit/s and the ability to provide differential transmit and receive capability to a micro-controller with a CAN-protocol controller. Due to their excellent electromagnetic compatibility (EMC), the devices guarantee operation as fast as 2 Mbit/s without a common-mode-choke (CMC). Radiated-emission test passed at 2 Mbit/s without a CMC.

The ATA6560 and ATA6561 transceivers provide choices for all types of high-speed CAN networks, especially in nodes requiring a low-power mode with wake-up capability via the CAN network. They provide improved electrostatic-discharge (ESD) performance; a low quiescent current; passive behavior to the CAN network when the supply voltage is off; the ability to directly interface with micro-controllers with voltages of 3 V to 5 V (ATA6561). They also offer three operating modes and dedicated fail-safe features. Figures 2 and 3 show the typical application circuits for the CAN transceivers, which are available in SO8 and DFN8 packages with wettable flanks, allowing an automatic optical inspection of the solder joints.

Automotive-grade MCU with CAN FD controller

In addition to offering CAN-FD-capable transceivers, Atmel was among the first to introduce automotive-grade micro-controllers (MCUs) with embedded CAN FD controllers. The SAMV7x MCUs are micro-controllers based on 300 MHz ARM Cortex-M7 processor cores, which bring industry-standard 32-bit processing performance, improved accuracy, increased power efficiency, and higher levels of system integration — including up to 2 CAN FD controllers — to automotive applications. The MCU leverages Atmel’s 17-year history as an ARM-core licensee with 8-bit embedded flash micro-controllers to create solutions for tomorrow’s demanding automotive networking, touch interfaces, and connectivity applications.

References

Classical CAN and CAN FD

Today’s cars are becoming increasingly complex and are undergoing a continuous addition of features. These factors have led to the need for more electronic control units (ECUs) in vehicles, and this combination of requirements can push a CAN's communication bandwidth to its limit. Solving this problem by using multiple CAN buses or by switching to another protocol requires a lot of system-design effort and the replacement of hardware and software. CAN FD extends the Classical CAN standard (Figure 1) and permits significantly higher data rates, enabling faster firmware upgrades and leaving most of the software and hardware, especially the physical layer, unchanged.

CAN FD improves the bandwidth usage of the CAN protocol, the dominant bus system in the automotive industry. To achieve the increase in the protocol's bandwidth efficiency, CAN FD frames support dual-bit-time capability and normal bit time during the arbitration phase. The bit time is identical to that of the current CAN protocol. This time includes those fields in which multiple devices can transmit simultaneously: at the arbitration start and acknowledgement end. Those fields are the start-of-frame (SOF) bit, the 12-bit arbitration field, three control bits, the acknowledge bits, the acknowledge delimiter bit, the 7-bit end-of-frame (EOF) field, and the 3-bit interframe space.

Further, CAN FD allows a reduced bit time in the data phase and other fields, and the timing requirements for these fields are less stringent because CAN FD guarantees that only one device communicates on the bus. These fields are: a control bit; a 4-bit DLC (data length code); payload data; and a CRC-field (cyclic redundancy check), which, depending on the data length, is 21 or 25 bits. CAN FD also increases the payload capacity. The data-field length increases from 8 bytes to 64 bytes, improving the efficiency of the CAN protocol. To take advantage of this improvement, the system software also requires updating.

All the benefits of the 32-bit ARM Cortex-M7 processor core embedded in the MCUs can quickly be diminished without the right peripheral functions and mix of peripherals, and SAMV7x MCUs include a variety of peripherals to meet the functional needs of automotive electronic control modules while also ensuring reliable operation across the entire automotive temperature range in compliance with the AEC-Q100 specification. Among the list of embedded peripherals are one or two (depending on device variant) CAN FD controllers.

In addition to CAN FD network support, the MCU also supports interfacing to several other automotive networks, making it a suitable choice for connectivity bridging or gateway applications. The network interface options include:

- High-speed USB: The MCU supports high-speed USB host or device mode operation, with an integrated PHY for reduced system cost;
Ethernet media access controller (GMAC): The GMAC supports all features required of an Ethernet media access controller;

Media LB: The Media LB peripheral included on the MCU provides efficient access to a 3-wire Media LB

The introduction of CAN FD will not affect today’s vehicle networks, such as LIN (local-interconnect network) and Most (media-oriented systems transport). However, migration paths are necessary to include CAN FD into current CAN networks. A CAN-FD-compliant node can accept Classical CAN frames and CAN FD frames without any errors, but a Classical CAN node will generate an error frame on the network in the presence of CAN FD frames. OEMs can use any of several approaches to ease migration efforts to a true CAN FD network.

OEMs should note that new ECUs deployed in the network must be CAN-FD-compliant, meaning that both the CAN controller and the CAN transceiver must be FD-compliant and still operate within the Classical CAN communication-frame format. Also, when upgrading the software, OEMs should integrate new CAN drivers that will have only minimal or no effect on the upper layers. Further, limiting the payload to 8 bytes can restrict any software changes to the CAN driver only, and achieving higher data rates requires a software update to incorporate the CAN FD frame format. OEMs can realize a true CAN-FD-compliant network by using software updates to support payloads as large as 64 bytes for high bandwidth efficiency, by using CAN-FD-qualified transceivers for much higher data rates or by implementing both of these methods.

To address the needs of complex automotive real-time embedded systems, the core and peripherals of an MCU must be tied together by a coherent system architecture that is optimized for managing real-time events common to embedded systems while minimizing processing latency. The SAMV7x MCUs include features to do this.

Multi-layer bus: A high speed multi-layer bus matrix is at the heart of the system architecture. The multi-layer bus matrix connects the elements of the system (e.g. the core, the system RAM, the Flash memory) through multiple master and multiple slave ports. This arrangement allows for concurrent accesses from different masters to different slaves. As an example, the CPU can access the Flash at the same time that data is being transferred from the CAN controller to the system RAM.

Direct memory access: An additional system architectural feature included in automotive ARM products to further reduce the processor load to service peripherals is the use of direct memory access (DMA) technology. DMA allows for transfers between peripherals and memories or between memories without CPU involvement. Once configured, DMA transfers are typically triggered automatically by hardware events. Each available CAN FD controller integrates its own DMA controller, which operates as a master on the multi-layer bus. This configuration allows seamless “behind the scene” movement of entire CAN messages to the system RAM without any processor core involvement.

Tightly coupled memory: In addition to instruction and data caches, the MCUs include an SRAM architecture. This architecture allows the available SRAM to be...
Faster software downloads: CAN FD speeds up the end-of-line programming of vehicles’ ECUs. General Motors states that, with the use of CAN FD, the ECU programming time is only one-third or even one-fifth of the current programming time [1]. Likewise, diagnostics and software upgrades in repair garages are also faster.

Error status: A transmit-node error may result in a sudden stop of the message, thus affecting safety-critical systems. Every CAN FD message includes the condition of the transmit node in the error-status-information (ESI) bit. In this way, the receiver can monitor the transmit node and take fail-safe actions before any issues occur.

Increased data payload: CAN FD allows messages as long as 64 bytes to avoid splitting long messages. This feature results in a simplified transport layer of the CAN stack and requires no implementation of complex flow-control mechanisms involving multiple messages.

Faster communication between ECUs: The increasing amount of automotive features leads to an increase in data exchange among the automotive ECUs. With its higher bandwidth, CAN FD can handle the higher amount of data and it enables speeds similar to those of Flexray.

Reduced bus loads: As a result of the higher communication speed, the ECUs can send and receive data more quickly using CAN FD frames rather than the Classical CAN frames. This feature directly reduces bus loading. For example, an instrument cluster can inform a driver of many vehicle parameters. It drives three to seven gauges, controls 20 to 30 telltale devices, generates chimes, and displays signal warnings to indicate status or system malfunction. This node receives and transmits information via many CAN messages from multiple ECUs. Because CAN is a priority-based protocol, it delays lower priority messages and increases bus loading. These issues result in a reduced response time and the CAN load on such a system can be 75% to 80%. CAN FD alleviates this problem by reducing the load by more than 75%.

Transmission-line length: Networks in trucks or articulated buses can be as long as 9 m to 20 m. The arbitration field limits the speed of the entire network. The J1939-14 standard defines a maximum bitrate of 500 kbit/s. However, CAN FD enables much higher speeds. The arbitration fields may remain at 500 kbit/s, whereas the data payloads can be at much higher data rates, thus increasing the throughput of the network.

CAN FD use cases

Faster software downloads: CAN FD speeds up the end-of-line programming of vehicles’ ECUs. General Motors states that, with the use of CAN FD, the ECU programming time is only one-third or even one-fifth of the current programming time [1]. Likewise, diagnostics and software upgrades in repair garages are also faster.

Error status: A transmit-node error may result in a sudden stop of the message, thus affecting safety-critical systems. Every CAN FD message includes the condition of the transmit node in the error-status-information (ESI) bit. In this way, the receiver can monitor the transmit node and take fail-safe actions before any issues occur.

Increased data payload: CAN FD allows messages as long as 64 bytes to avoid splitting long messages. This feature results in a simplified transport layer of the CAN stack and requires no implementation of complex flow-control mechanisms involving multiple messages.

Faster communication between ECUs: The increasing amount of automotive features leads to an increase in data exchange among the automotive ECUs. With its higher bandwidth, CAN FD can handle the higher amount of data and it enables speeds similar to those of Flexray.

Reduced bus loads: As a result of the higher communication speed, the ECUs can send and receive data more quickly using CAN FD frames rather than the Classical CAN frames. This feature directly reduces bus loading. For example, an instrument cluster can inform a driver of many vehicle parameters. It drives three to seven gauges, controls 20 to 30 telltale devices, generates chimes, and displays signal warnings to indicate status or system malfunction. This node receives and transmits information via many CAN messages from multiple ECUs. Because CAN is a priority-based protocol, it delays lower priority messages and increases bus loading. These issues result in a reduced response time and the CAN load on such a system can be 75% to 80%. CAN FD alleviates this problem by reducing the load by more than 75%.

Transmission-line length: Networks in trucks or articulated buses can be as long as 9 m to 20 m. The arbitration field limits the speed of the entire network. The J1939-14 standard defines a maximum bitrate of 500 kbit/s. However, CAN FD enables much higher speeds. The arbitration fields may remain at 500 kbit/s, whereas the data payloads can be at much higher data rates, thus increasing the throughput of the network.
The FDF (FD format) bit distinguishes between a CAN FD frame and a Classical CAN frame. The Classical CAN frame format is dominant, and the CAN FD frame format is recessive. Dominant means, “do not switch to a higher bit-rate—that is, maintain the same bit rate in the arbitration and the data phases,” and recessive means, “switch to a higher bit-rate.” With the ESI bit, dominant is the error-active node. The BRS (bit-rate-switch) bit allows the CAN FD rate to immediately start at the sampling point of the BRS. A recessive error indicates the passive node. The res (reserved) bit follows the FDF bit and is reserved for future protocol expansions. In this field, dominant is the standard value. In this field, an FD-enabled receiver detects a protocol-exception event, during which it detects the res bit as recessive instead of the expected dominant value. A modified CRC (cyclic redundancy check) maintains the same hamming distance for the longer frames as Classical CAN frames. For CAN FD frames, the CRC field also contains the bit-stuff count.

Features of CAN FD

The FDF (FD format) bit distinguishes between a CAN FD frame and a Classical CAN frame. The Classical CAN frame format is dominant, and the CAN FD frame format is recessive. Dominant means, “do not switch to a higher bit-rate—that is, maintain the same bit rate in the arbitration and the data phases,” and recessive means, “switch to a higher bit-rate.” With the ESI bit, dominant is the error-active node. The BRS (bit-rate-switch) bit allows the CAN FD rate to immediately start at the sampling point of the BRS. A recessive error indicates the passive node.

The res (reserved) bit follows the FDF bit and is reserved for future protocol expansions. In this field, dominant is the standard value. In this field, an FD-enabled receiver detects a protocol-exception event, during which it detects the res bit as recessive instead of the expected dominant value. A modified CRC (cyclic redundancy check) maintains the same hamming distance for the longer frames as Classical CAN frames. For CAN FD frames, the CRC field also contains the bit-stuff count.

lower priority through the multi-layer bus matrix. The no-wait-state nature of the tightly coupled memory makes it ideal for functions that must operate on data at a high frequency and with tight latency requirements – for example, digital signal processing functions operating on audio or video streams. Applications with a high percentage of such high-frequency time-critical operations would configure the available SRAM with more tightly couple memory (and therefore less system memory) compared to applications that have fewer of these types of operations.

Clocking options: All automotive ARM core devices include multiple clock options, ranging from external crystals to high frequency internal RC oscillators with high accuracy to low power internal RC oscillators. For the real time clock and calendar there is a dedicated 32-KHz low-power crystal oscillator. Phase or frequency locked loops are included to multiply the selected clock source to the needed operating frequency. And finally, the clock source to each peripheral can be individually gated. The combination of all these features allows the device to be configured to meet the performance-power consumption trade-off required by the application.

CAN FD provides an increased throughput at costs comparable to those of currently available CAN networks,
as well as additional bandwidth and higher speeds. For automotive applications, CAN FD targets an average data rate of 2 Mbit/s with currently available CAN transceivers, resulting in the ability to carry the same effective payload as a low-speed Flexray network. At the same time, CAN FD maintains the reliability of Classical CAN due to changed CRC polynomials.

ATA6560 and ATA6561 CAN FD transceivers suit the CAN FD world and Classical CAN applications. The devices provide an easy migration path from Classical CAN systems to CAN FD systems because there is no need to change CAN application software, except for configuration software. The ARM Cortex-M7 core based SAMV7x microcontrollers combine industry standard 32-bit ARM M7 core processing performance along with innovative peripherals, including CAN FD, and system architecture features to create products that meet the challenging real-time performance demands of automotive applications.

Authors
Daniel Yordanov
Berthold Gruber
Tim Grai
Microchip Technology
info@microchip.com
www.microchip.com