CAN FD Light - From lighting to lightweight

CAN FD Light is a network aimed at sensor / actuator communication in automotive and non-automotive applications. The need and the advantages for a lightweight CAN-based network is proven in lighting systems for modern cars.

The necessity for a lightweight CAN FD network became evident during the development of a system for modern car rear lights. During the development phase the usefulness of a "CAN FD Light" with rear lighting being a frontrunner surfaced while looking at the future trends in car communication systems and other fields in the industry. Communication systems with a central controller and small actuator and sensor devices have been around for many years already. The need to drive hundreds of light sources in a dynamic way and the safety and reliability requirements plus the cost pressure inherent to the automotive industry extended the scope of this kind of system.

Today, car rear lights consist of a few drivers for the light sources that are locally controlled by a light controller, which is usually placed closely to these drivers. The light controller communicates by a CAN or LIN network with the domain controller responsible for lighting e.g. the body domain controller. This is shown in figure 1.

The light control part of the body domain controller consists among others of a micro-controller (e.g. 32-bit MCU), CAN/LIN transceivers, smart high-side drivers to control the power supply of the light module, and its associated power-management device. The light module embeds a small micro-controller for generating the light patterns and to communicate with the body domain controller, DC/DC-convertors to generate the voltages needed for the light sources (LEDs), a simple communication interface like e.g. I²C and a power-management device for supply. The light sources are switched by high-side or low-side driver circuits.

Newer and future rear lights show dynamic light patterns that can be used for safety like warning the driver in the car behind of upcoming traffic hazards or for enhancing the design of a car for individualization or branding. Light is a very appealing design element for vehicles. For these uses of light, several hundreds of individual light sources must be controlled, each with its own intensity resolution of at least eight bits at a refresh rate in the range of several milliseconds. Since the light sources are now distributed over the rear of the car, the light module cannot be placed next to the drivers anymore. This means that a reliable and safe communication is needed that provides a high bandwidth at a high level of immunity against the distortions faced in the harsh environment of a car.

Since the light module cannot be placed anymore close to the drivers, a valid question to ask is: Why not using the body domain controller directly for controlling the light drivers? This change in the architecture can be seen in figure 2.

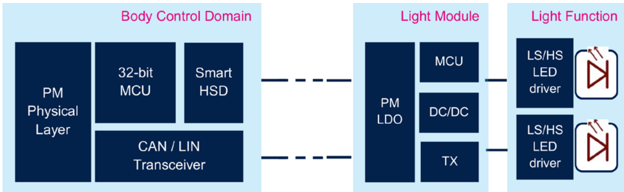

Figure 1: Classic light control (Source: STMicroelectronics)

With a new robust and reliable network, the embedded light module can be spared, and its tasks be taken over by the powerful body domain controller. This not only enhances the functionality of the rear light, but also reduces the system cost and enables easier updates using wireless technologies ("Over-the-air"). Inside the light functions remain only the drivers that communicate directly with the domain controller without the need for any software.

When looking beyond the needs for rear light the same architectures can be seen in other areas of the car. Figure 3 shows the evolution from the flat network architecture towards the domain and zone architectures. Besides the various domain and zonal controllers that are interconnected by high bandwidth networks like Ethernet "clouds" of sensors and actuators exist, that are connected to these controllers. This is very similar to the described rear light network, which makes a lightweight CAN FD network applicable in various sections of the car.

System costs

A network for communication between a controller and many small devices like actuators and sensors must be reliable and cost efficient. The network protocol must be embedded in these devices without the use of a micro-controller and software. Also, external costly components must be spared. One of the most expensive components in a communication system, is the crystal for generating ▷

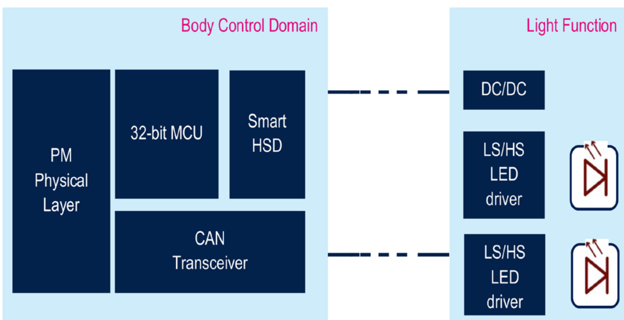

Figure 2: Future light system (Source: STMicroelectronics)

CAN & CAN FD Connection via Ethernet

PCAN-Ethernet Gateway FD DR

The PCAN-Gateway product family from PEAK-System is designed for the transmission of CAN messages over IP networks. With a single gateway connected to a CAN bus, users can access the CAN bus using the LAN interface of their computer. In addition, different CAN buses can be connected over IP using this technology. The devices are configured via a convenient web interface. Alternatively, the JSON interface allows access via software.

The new PCAN-Ethernet Gateway FD DR is the first model supporting the modern standard CAN FD in addition to classic CAN.

Specifications:

- AM5716 Sitara with Arm® Cortex® M15 core
- 2 GByte Flash and 1 GByte DDR3 RAM
- Linux operating system (version 4.19)
- Two High-speed CAN channels (ISO 11898-2)
  - Comply with CAN specifications 2.0 A/B and FD
  - CAN FD bit rates for the data field (64 bytes max.) from 20 kbit/s up to 10 Mbit/s
  - CAN bit rates from 20 kbit/s up to 1 Mbit/s
- Galvanic isolation of the CAN channels up to 500 V against each other, against RS-232, and the power supply
- Connections for CAN, RS-232, and power supply via 4-pole screw-terminal strips (Phoenix)
- LAN interface
  - Data transmission using TCP or UDP
  - 10/100/1000 Mbit/s bit rate
  - RJ-45 connector with status LEDs
- Monitoring and configuration of the devices via the web interface or JSON interface
- Software update via the web interface
- Reboot or reset of the device to a previous software version with a reset button
- Plastic casing (width: 45.2 mm) for mounting on a DIN rail (DIN EN 60715 TH35)
- LEDs for device status and power supply
- Voltage supply from 8 to 30 V
- Operating temperature range from -40 to 70 °C (-40 to 158 °F)

Further PCAN-Gateway Models:

- PCAN-Ethernet Gateway DR - CAN to LAN gateways in DIN rail casing with Phoenix connectors
- PCAN-Wireless Gateway DR - CAN to WLAN gateways in DIN rail casing with Phoenix connectors
- PCAN-Wireless Gateway - CAN to WLAN gateways in casing with flange and D-Sub or Tyco connectors

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PEAK-System Technik GmbH

Otto-Roehm-Str. 69, 64293 Darmstadt, Germany
Phone: +49 6151 8173-20 - Fax: +49 6151 8173-29
E-mail: info@peak-system.com

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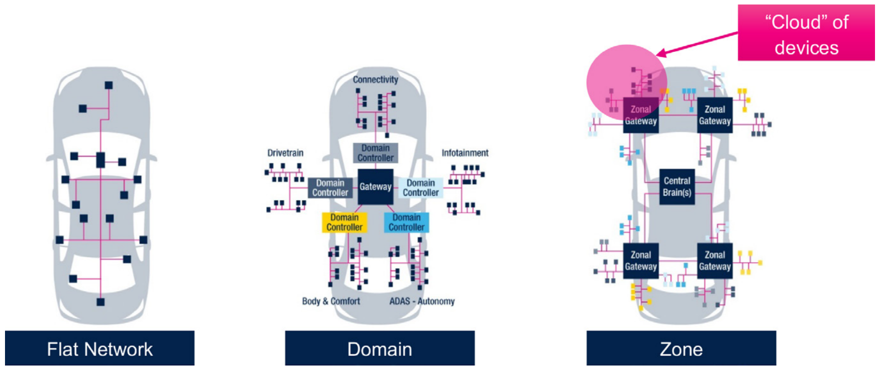

Figure 3: Car network evolution (Source: STMicroelectronics)

the accurate clock frequency to sample the received data-frame and to generate the frame to be transmitted. This crystal cannot be placed at each small communicating device since it would increase the system cost drastically.

Besides the reliability and cost constraints, a network used in the car must not require a new infrastructure at the car makers. It must build on existing tools, software, measurement, and development equipment already available at the development, manufacturing, and service sites. In addition, the transceivers used for this network must already be proven to operate in the automotive environment.

Why CAN FD?

While new driver and sensor devices with a new communication protocol can be developed within the regular product upgrade cycle, the hardware inside of the domain controller cannot so easily be changed. Therefore, the network must be able to work with the existing network support the micro-controllers already provide.

While taking all these considerations into account the choice was made to implement a network based on the well-known and widely used CAN FD.

CAN FD provides a bandwidth of 1 Mbit/s, which is more than sufficient for small sensor and actuator networks including dynamic rear light applications. As shown in figure 4, a CAN FD frame provides a data-size of 64 bits per frame with minor control bit overhead. An eleven-bit field for frame identification and, with the inherent bit-stuffing rule a guaranteed edge density for synchronization.

As bus network it is cost-efficient and with one frame, data to several devices can be sent. The frame is protected by a cyclic-redundancy-check (CRC), that has proven its reliability for years in many applications and products.

Hardware protocol controllers inside of existing micro-controllers are on the market, so the domain controllers are not burdened with software running on their cores to realize the network protocol. And, since CAN FD is widely used in the industry, experience and a large tooling environment ▷

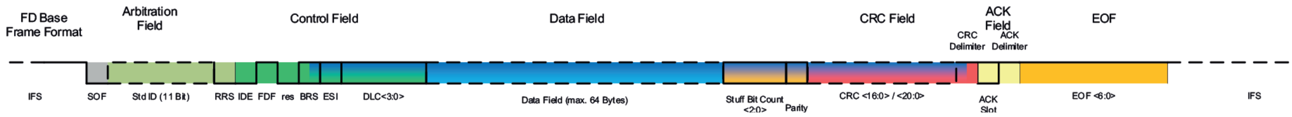

Figure 4: CAN FD base frame format (Source: STMicroelectronics)

including software exist in development, manufacturing, and service areas.

CAN FD is a very flexible network and offers features that are not necessarily needed for communication with small devices. The access to the network is determined by priority which is encoded in the identifier of the frame. Also, errors detected by one network participant are advertised to the entire network by error frames. These features, require due to their synchronization needs an accurate clock that is usually generated using crystals or ceramic resonators, which are as automotive grade quite costly. By replacing these features the crystal and buffer memory, which is necessary in case arbitration is lost, can be removed.

CAN FD Light

The resulting network is a lightweight CAN FD Light network in which the controller, e.g. the domain or zone controller, controls the entire communication. It sends data to the devices on the network and requests data from them. Only one device answers to such a request. With this strict communication flow arbitration is not needed anymore and since the data flow is clearly identified error frames for advertising errors are not required. The data flow is unidirectional in case the controller sends a dedicated frame to one device and the addressed device is the only one to answer to this frame. The controller is a device with an accurate clock, and it is the only device putting a frame on the network, which excludes phase and frequency shifts introduced by the arbitration. Therefore, the small sensor and actuator devices can synchronize to the controller while receiving the frame. The edge density needed is guaranteed by the CAN FD bit-stuffing rule. This communication scheme ensures the identification of sender and receiver on the network. Communication interrupts can be clearly identified, and error frames are not necessary.

Because the CAN FD network is a bus network broad- and multicast frames sent by the controller to all or several devices are possible, but no answer is expected. A very high network utilization of up to 100 % is feasible because no bandwidth must be reserved to allow unexpected higher priority frames accessing the network. The entire communication flow is deterministic.

Further simplifications to the CAN FD protocol are the restriction to the standard eleven-bit identifier, sticking to the CAN FD format (i.e. no Classical CAN format), and using the same data-rate for the data-phase as for the rest of the frame. As a result, the bits controlling these features are set to fixed values. Sending an acknowledge is not required, but some CAN FD protocol controllers may need it, so they do not transmit error frames.

With these modifications and simplifications, a lightweight protocol controller can be implemented entirely in hardware in small devices without the need for costly external components such as crystals.

Summary

The transceiver is a standardized Classical CAN, CAN FD, or CAN SIC (signal improvement circuitry) transceiver depending on the used data-rate and the network properties. In summary, this lightweight CAN FD Light provides a high bit-rate of up to 1 Mbit/s or even beyond with a very high network-utilization at a competitive cost. On the controller side, existing hardware protocol controllers for CAN FD can be used while at the driver device side a fully monolithic hardware solution without expensive external components is integrated.

Network reliability is assured by the deterministic unidirectional communication scheme and the frame integrity protection features already implemented in CAN FD like the cyclic redundancy check (CRC). The network topology allows broad- and multicast frames to further enhance the network utilization. The deterministic communication protocol allows on the controller and on the driver device side the reaction of expected but missed frames to inform the driver and to enter a safe state.

With these features and the cost-efficient system implementation many applications for this network exist inside the car, but also in other fields like industrial or building automation. Currently, CAN in Automation (CiA) is working on a standardization of this lightweight protocol in a special interest group.

Author

Fred Rennig
STMicroelectronics
info@st.com
www.st.com

Program of the 17th international CAN Conference

June 14, 2021	
Session I: Physical layer **Chairperson: Carsten Schanze (VW)**	
Magnus-Maria Hell (Infineon)	The physical layer in the CAN XL world
Patrick Isensee (C&S Group)	The challenge of future 10-Mbit/s in-vehicle networks
Johnnie Hancock (Keysight)	Characterizing the physical layer of CAN FD
Chat rooms with speakers, in parallel: CiA CAN Coffee (C^3)	
Session II: CAN XL data link layer **Chairperson: Reiner Zitzmann (CiA)**	
Florian Hartwich (Robert Bosch)	Introducing CAN XL into CAN networks
Dr. Arthur Mutter (Robert Bosch)	CAN XL error detection capabilities
Dr. Christian Senger (University of Stuttgart)	CRC error detection for CAN XL

June 15, 2021	
Keynote session **Chairperson: Holger Zeltwanger (CiA)**	
Carsten Schanze (VW)	Future of CAN from the prospective of an OEM
Session III: CANopen testing **Chairperson: Uwe Koppe (Microcontrol)**	
Mark Schwager (Vector)	A new approach for simulating and testing of CANopen devices
Oskar Kaplun (CiA)	CANopen FD conformance testing – today and tomorrow
Session IV: CANopen FD **Chairperson: Christian Schlegel**	
Uwe Wilhelm (Peak), Christian Keydel (Emsa)	A simplified classic CANopen-to-CANopen FD migration path using smart bridges
Alexander Philipp (Emotas)	A theoretical approach for node-ID negotiation in CANopen networks
Yao Yao (CiA)	CANopen FD devices identification via new layer setting services (LSS)
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June 16, 2021	
Session V: CAN FD lower layers **Chairperson: Dr. Frank Deicke (Fraunhofer IPMS)**	
Tony Adamson, Axel Engelhard (NXP)	CAN signal improvement and designing 5-Mbit/s networks
Fred Rennig (ST Microelectronics)	A lightweight communication bus based on CAN FD for data exchange with small monolithic actuators and sensors
Kent Lennartsson (Kvaser)	Improved CAN-driver
Session VI: Engineering **Chairperson: Kent Lennartsson (Kvaser)**	
Nikos Zervas (Cast)	Designing a CAN-to-TSN Ethernet gateway
Dr. Heikki Saha (TKE)	Automated workflow for generation of CANopen system monitoring graphical user interface (GUI)
Dr. Christopher Quigley (Warwick)	Benchmarking of CAN systems using the physical layer – car, truck, and, marine case studies
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June 17, 2021	
Session VII: Security **Chairperson: Torsten Gedenk (Emotas)**	
Thilo Schumann (CiA)	Embedded security recap
Prof. Dr. Axel Sikora (Hochschule Offenburg), Georg Olma (NXP), Olaf Pfeiffer (Emsa)	Achieving multi-level CAN (FD) security by complementing available technologies
Donjete Elshani, Vivin Richards (Infineon)	CAN XL made secure
Session VIII: CAN XL higher layers **Chairperson: Dr. Arthur Mutter (Robert Bosch)**	
Peter Decker (Vector)	IP concepts on CAN XL
Christian Schlegel	Multi-PDU concept for heterogeneous backbone networks
Holger Zeltwanger (CiA)	Standardized layer-management options for CAN-based networks
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