The Polish company DCD-Semi provides the DCAN FD IP core for implementation of standalone CAN (FD) controllers. The company’s CAN-All ecosystem considers automotive safety standards and expands towards CAN XL.

In 1997 at a computer expo Bill Gates did say a joke: “If GM had kept up with technology like the computer industry has, we would be driving 25-S cars that got 1000 miles to the gallon”. GM did not wait with a response saying that with the same car characteristics “your car would crash twice a day”. 20 years ago, both statements built tensions between the automotive and computer industries. Nowadays we can see a different relationship between them. Every modern car is equipped with an on-board computer, multiple sensors, cameras, and safety systems. Lights, brakes, engine(s), even air-conditioning – all of these devices built in modern cars – are supervised by sensors and controlled by micro-controllers. And, this is where the CAN network is a vital part of (almost) every automotive being.

CAN was originally designed to significantly save on copper, because it did reduce the number of connections between devices, creating a global net inside the vehicle. Its story begins in the Robert Bosch company in 1983. By now it was further developed and standardized. In 2012, an improved version of CAN, the CAN with Flexible Data-Rate has been released to support greater loads without extending transmission time. Currently, another CAN successor is under development. CAN XL, supporting even greater loads and introducing new transmission features, such as PWM coding – seems to become “apple of daddy’s eye” not only for automotive.

CAN did expand over the physical layer. Today when saying CAN, you may expect both hardware and software, covering the physical layer, data link layer, and application layer. More medium-dependent interface sub-layers may also be introduced. CAN is a complete environment, providing many standard mechanisms ensuring faster product development. The end-user may easily replace an old CAN controller without reinventing the design because the succeeding CAN protocols are all backward compatible.

Automotive IP cores provider

DCD-Semi (Poland) masters automotive IP cores (e.g. DCAN FD) since 1999. That’s why the CAN-ALL ecosystem is a natural step of development based on experience gained with the biggest and the most innovative automotive companies. During these two decades the company developed more than 70 different architectures, which were successfully implemented in more than 750 000 000 electronic devices around the globe.

CAN-ALL is already proven in dozens of events and production designs. The verification is based, on more than two decades of market experience and thousands of automotive implementations with such companies as Volkswagen and Toyota.

The DCAN-FD IP core is designed in accordance with the ISO 11898-1:2015 standard. It does support CAN FD frames and the Classical CAN frames to provide backward compatibility. The IP supports up to 64-byte data frames. A CAN FD frame consists of the arbitration phase and the data phase. Between them, there is a dedicated BRS (bit rate switch) bit, which enables to increase the data bit rate while transferring payload. The bit rate switch takes place exactly between segment 1 and segment 2 of the BRS bit. This functionality is fully supported by the DCAN-FD. The data-phase bit rate may be up to 8 Mbit/s. The DCAN offers an advanced hardware frame filtering with multiple filter banks. To enable maximal throughput the IP can be equipped with multiple transmission buffers, so that the next CAN frames may be loaded while the current one is transmitted. The IP is also capable of receiving multiple frames inside the internal FIFO memory before reading them. This functionality might be also
used with a DMA (direct memory access) controller. All CAN frame types are supported: data frame, remote frame, error passive and error active frames, as well as the overload frame. For the transfer error detection and handling, the DCAN offers a sophisticated error management logic as a self-test capability. It can be both an active CAN participant and a listener. After multiple transmission errors and reaching of the error passive state, a device is cut-off from the network to avoid disturbance of the CAN traffic. To achieve a lower power consumption while CAN is in the idle state, the IP can be set to sleep mode and waked up, if a transfer occurs.

Additionally, the IP core offers many more features and can be tailored to the project needs, basing on customer’s design requirements. The company’s experience and the team spirit have led to creation of an advanced, fast, architecture-independent IP core design.

**Functional safety – 21\textsuperscript{st} century approach to system design**

Even the best engineer makes mistakes. Over the decades of car manufacturing (Benz Patent Motor Car, model no. 1 was reported in July 1886) did happen a lot. Many people died, but the lessons have been learned. The carmakers introduced hydraulic brakes for better deaccelerating, seat belts and airbags for better driver and passenger protection, lidars, cameras and blind-spot motors for the safety of all road users. Now, different introduced AI (artificial intelligence) applications should help the driver. Nowadays the manufacturers have to think about pedestrians’ safety, too. The scope of the car-influenced elements expands pretty fast. In 1934 GM performed the first crash test to gain better real-life information about car safety. Vehicle safety standards evolved, and today’s cars are safer than ever before. This wouldn’t be possible without a tight cooperation between the automotive and electronics industry.

The biggest issue is that one cannot rely on the design itself. It can work as designed but still lead to an accident, because of the wrong design assumptions. A car can be stuffed with plenty of safety features, but their cooperation can fail. The vehicle can have advanced software supervising system, but the bad coding practices or compiler bugs can still lead to an unexpected behavior.

**Figure: 2 Over the decades carmakers introduced a lot of measures to save lifes (Source: Autoweek.com)**

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To change the whole conception, design, manufacturing, and decommissioning process (the product lifetime) the ISO 26262 standard has been introduced. The main goal is to mitigate risks (systematic failures and random hardware failures) by providing appropriate requirements and processes.

When trying to describe the standard in just one sentence – it ensures that the design is fully controlled at every step. Management is the key. Not only the design matters but also the project management. A project manager and competent, trained team members shall be drafted. Each product mastered within the project must be supervised: stored under a version control system, the author of each modification must be specified with the description of the change and date, the change must be reviewed by other team members. It is very important to establish best practices to be used in each project, specify the work products that need to be created, and plan each activity.

The project begins with the concept phase where proper safety goals must be defined. In the next step, proper functional safety concepts have to be defined to realize the safety goals. Then the proper functional safety requirements must be defined to realize the functional safety concepts. After that, the proper technical safety concepts must be defined to realize the functional safety requirements. Then in the next step, proper technical safety requirements have to be defined to realize the technical safety concepts. The concepts and requirements are then used for the definition of safety mechanisms and assumptions of use, emphasized further in safety metrics.
calculation. Both hardware and software mechanisms are used to achieve the desired Automotive Safety Integrity Level (ASIL) defined by the obtained metrics: Single Point Fault Metrics (SPFM) and Latent Fault Metrics (LFM). The standard determines the necessary testing and verification procedures. Further steps include production, operation, service, and decommissioning, supporting processes, and safety analyses.

The DCAN is developed as an ISO 26262 Safety Element out of context (SEooC). The SEooC (DCAN is a soft IP SEooC) is an element developed and analyzed in an assumed context of use, e.g. target FPGA board, memory used, etc. The SEooC is delivered with the complete ISO26262 required documentation. The system integrator must reevaluate the safety analysis based on the target system and the safety analysis of other system elements. The SEooC provides a deep knowledge about the DCAN IP, its failure modes, safety mechanisms that enable to reach the required ASIL level, complete Failure Modes Effects and Detection Analysis (FMEDA) with step-by-step instruction to help to integrate the IP into the customer's system and to conduct the system-level safety analysis. The conducted safety analysis depicts, that the safety metrics is fulfilled and IP reaches the ASIL-B level (SPFM > 90 %, LFM > 60 %). The goal of creating an SEooC is to shorten the product time to market. Thus, the system integrator does not need to know in detail the SEooCs used in the system, but still can calculate the system safety metrics and gets instructions on the SEooC usage and integration. It should be mentioned that the SEooC designer has a better overview of the design and can perform the element's safety analysis much faster and better.

CAN stack – modularity is a must

Modularity is a must in these days. Why? It's more than obvious: The engineer replaces a deprecated element (e.g. a Classical CAN controller) with a newer one (supporting CAN FD), instead of building a new design from scratch.

Figure 5: To replace a block in a modular system should be as simple as to play Tetris (Source: Adobe Stock)

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As far as the physical layer is concerned, it is backward compatible, but what if the design has a ready application layer? The DCAN driver enables access to the device and can be easily integrated with an existing CAN stack e.g. CANopen or even with Autosar. This stack might also be used with an already existing application. So, combining all the standard elements with standard interfaces in one design, the replacement of one block by another block offering the same functionality, but a newer or faster one, should be as simple as replacing a Tetris block with a different block (let as assume with a different color) but with the same shape.

**SocketCAN - DCAN meets Linux**

A good modularity example is the use of the Linux CAN API. SocketCAN is the official CAN API of the Linux kernel. Each Linux user-space application is developed independently from the underlying hardware. The Linux OS (operating system) offers a set of mechanisms to connect a user-space application with a kernel module. The kernel module (also called a Linux driver) is responsible for the hardware management, configuration, as well as data transmission and reception. For example, if the application needs to use the can0 device, the OS invokes the module can0 and every access is forwarded to it.

SocketCAN is the driver and the networking stack created by Volkswagen Research. It is an open-source project and takes the most opportunities from a network interface. It is not limited to the previous character device implementations. It uses the Berkeley socket API, so the use of a device is as easy as opening a socket and writing to it. The abstraction level is maintained, and the device driver benefits from the existing queuing functionality. The SocketCAN API is very similar to a typical TCP/IP layer model. The similarity to network programming is the key for programmers and saves time on learning how to use a CAN device.

Just to mention, that the available on-market CAN-FD stacks are built upon an existing CAN driver and are OS-independent, so the SocketCAN can be easily integrated into them.

**Figure 6: SocketCAN Linux driver (Source: SocketCAN public domain)**

**CAN XL – future is coming**

Controller Area Network Extra Long (CAN XL) is the upcoming third generation of the CAN data link layer. The modern, high-accuracy sensors, etc. need to transmit large data packets to the micro-controller. That is why the new CAN generation offers up to 2-KiB data packet transmission. Also, transmission speed is about to increase – large packets need to be sent faster, not blocking the network. The additional PWM (pulse width modulation) coding in CAN XL allows bit rates of 10 Mbit/s or higher. I would be more than happy to provide you more details of the latest DCD’s CAN XL solution, but as the working mode is “progress”, my colleagues could do me harm... That’s why let’s wait for a while, I believe that CiA’s anniversary party would be a good chance to share more details. The IP itself will be more secure, faster, and optimized, but still based on the best experience collected while developing DCAN and DCAN-FD.

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