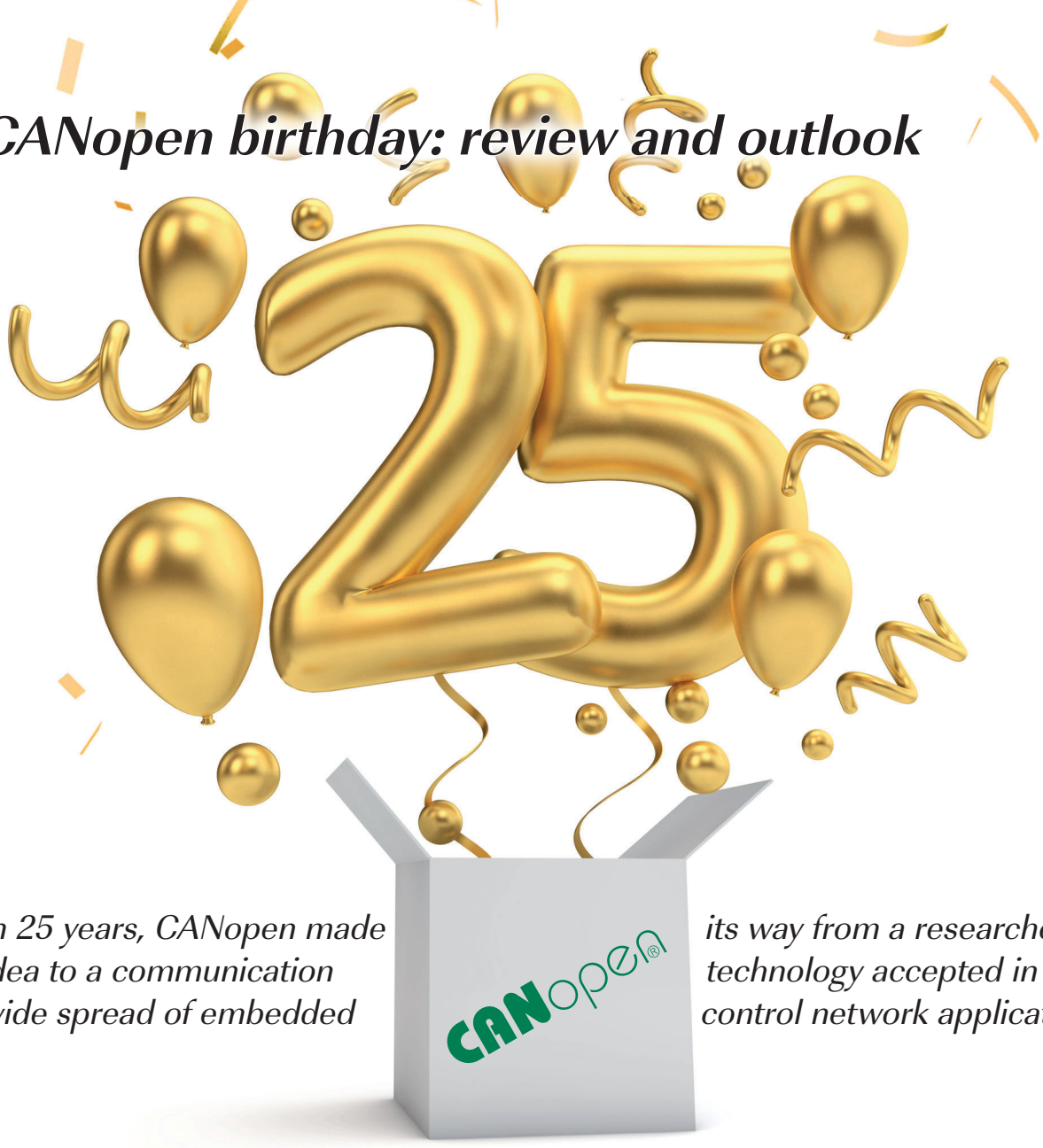
CANopen birthday: review and outlook



Source: Adobe Stock

In 25 years, CANopen made its way from a researchers' idea to a communication technology accepted in a wide spread of embedded control network applications.

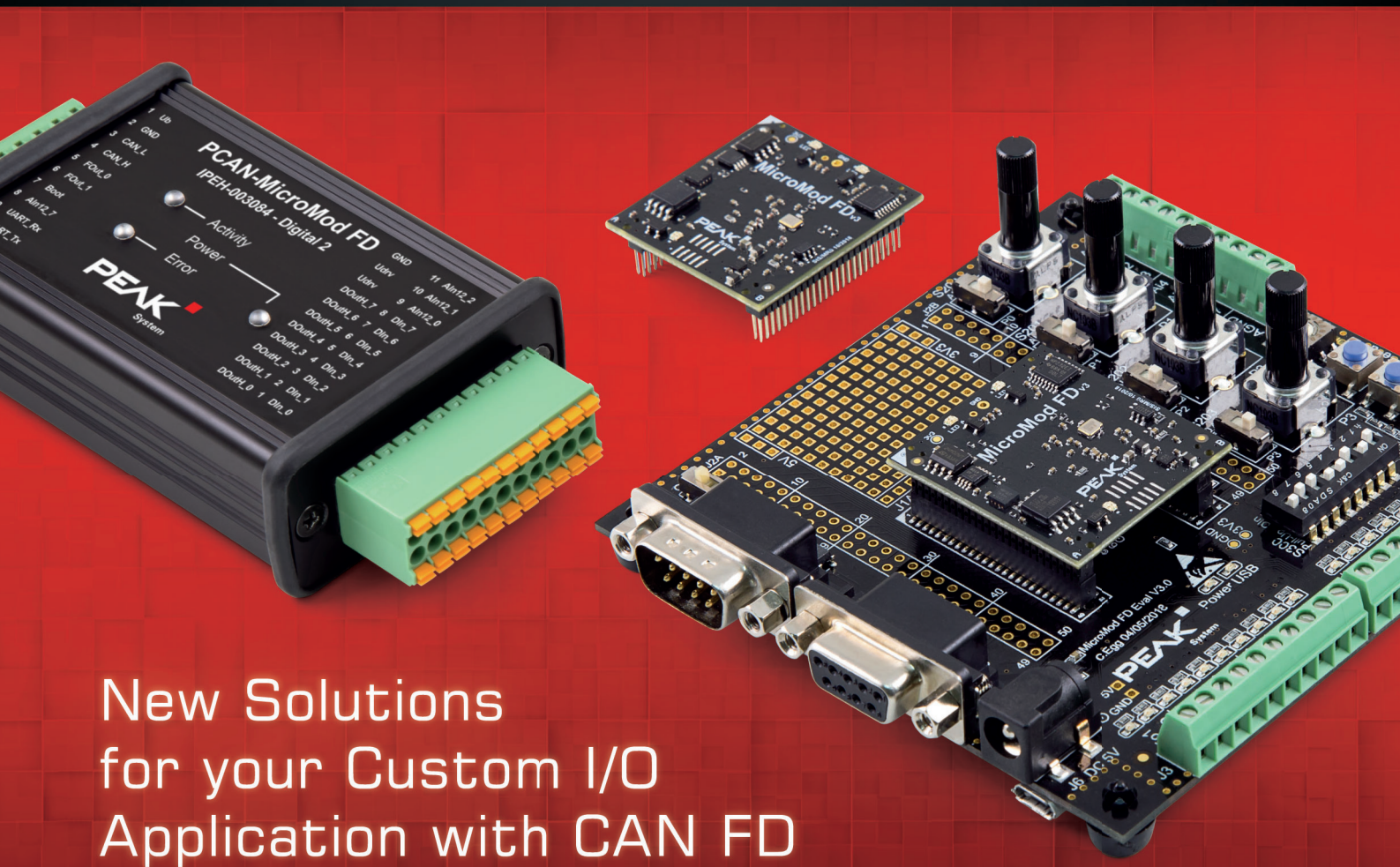
In the year 1994, Disney's Lion King with songs from Elton John hit cinema screens. Steven Spielberg won his first directing Oscar for Schindler's List. Nelson Mandela became South Africa's first black president. The IRA declared cease-fire in Northern Ireland. The Internet got real in 1994 with the founding of both Yahoo and Amazon. The Playstation was launched at the tail end of 1994 as well as the CANopen application layer. In the beginning, the title of the CiA (CAN in Automation) specification was a little bit bulky: CAL-based communication profile. The first release end of November comprised just 60 pages.

The CiA document based on the results of the Esprit 7302 European research project. Moog (Ireland) leaded this research activity, which was participated by ADL Automation (France), Bosch (Germany), JL Automation (United Kingdom), STA technology center (Germany), and the University of Newcastle upon Tyne (United Kingdom). The research project was titled ASPIC (Automation and Control Systems for production Units using an Installation Bus Concept). The research results were discussed within CiA. After revising and extending the research report, CiA released the CAL-based communication profile in November 1994. CAL (CAN Application Layer) was the application layer developed by CiA and published as CiA 200 series.

Already six weeks later, in January 1995, CiA released the version 1.1. It provided the missing definitions of data types. End of 1995, after gaining some experiences when implementing prototype devices, the version 2.0 was launched. It was numbered as CiA 301. The next CiA 301 version, version 3.0, published in October 1996, was implemented in real products used in industrial machines. This document was titled CANopen CAL-based communication profile for industrial systems.

The next big step was the release of version 4.0 named CiA 301 CANopen application layer and communication profile. It provided four pre-defined TPDOs and RPDOs, Heartbeat functionality, and many other functional improvements. Especially, medical device manufacturers and military equipment suppliers requested them. This CANopen specification was also the base for the EN 50325-4 standard.

The following CiA 301 versions introduced minor improvements, functional extensions, and corrections as well as clarifications. One of the functional extensions is the Sync counter allowing a more flexible use of the unique Sync protocol triggering PDO communication. The newest CiA 301 specification is the version 4.2.0 released in 2011. This means the CANopen base specification is very mature and stable.



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PCAN-MicroMod FD Analog 1:

- 8 analog inputs (16 bit, adjustable range)
- 4 analog inputs (12 bit, 0 - 10 V)
- 4 analog outputs (12 bit, adjustable range)
- 4 digital inputs (pull-up or pull-down)

PCAN-MicroMod FD Digital 1 / Digital 2:

- 8 digital inputs (pull-up or pull-down)
- 3 analog inputs (12 bit, 0 - 10 V)
- Digital 1: 8 digital outputs with Low-side switches
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One key of the success: standardized profiles

From the very beginning, there were standardized CANopen device profiles. Already pre-developed were the profiles for modular I/O devices and electrical drives. After reviewing them, CiA published them. The first implemented I/O profile was CiA 401 version 1.3 released in 1995. The CiA 402 motion control and drive profile was partly based on the Drivecom profiles by Phoenix Contact. The first version was published in May 1997 as well as the CiA 406 CANopen device profile for encoders. The CiA 402 profile is internationally standardized in IEC 61800-7-201 and IEC 61800-7-301.

Standardized device profiles enable off-the-shelf interoperability between host controllers and CANopen NMT slave devices. Products compatible with standardized profiles are also partly exchangeable, when they support the same optional functions. The list of CANopen device profiles is long, but not complete. There are still specific device functions, which have not been standardized. The last released device profile, CiA 461, specifies weighing devices.

Device profiles do not support pre-defined cross-communication between CANopen NMT slave devices. This needs to be configured by the system designer. In order to provide a pre-defined system approach, CiA developed CANopen application profiles. The first one was the CiA 407 application profile for passenger information. It was submitted for European standardization and is available as EN documents 13149-4/5/6 (Public transport – Road vehicle scheduling and control systems – General application rules for CANopen transmission buses/CANopen cabling specification/CAN message content). The most successful CANopen application profiles are the CiA 417 profile family for lift control systems and CiA 422 profile family for refuse collecting vehicles (also standardized in EN 16815).

CANopen profiles are also used on other communication technologies. Ethercat, Powerlink, Safetynet, and Varan support CiA profiles more or less officially. Other proprietary network technologies make also use of the CiA profile specifications.

Conformity tests are optional

CiA provides since many years a CiA 301 conformance test plan and a tool, implementing it. This CiA CANopen Conformance tool is available for members free-of-charge. Conformance testing is not mandatory. This has advantages and disadvantages: On the one hand nobody has to spend money for testing, but on the other hand some CANopen named devices contain just traces of CANopen functions. Especially, in the early days, there were many so-called CANopen master devices on the market, which were not compliant to CiA 301. Of course, they were able to control and manage CANopen NMT slave devices. But they were by themselves no CANopen devices. They even did not implement an object dictionary.

Some conformance test plans for device profiles have been developed, but to implement them is costly. Testing device profiles makes only sense, when an upper tester is ▷

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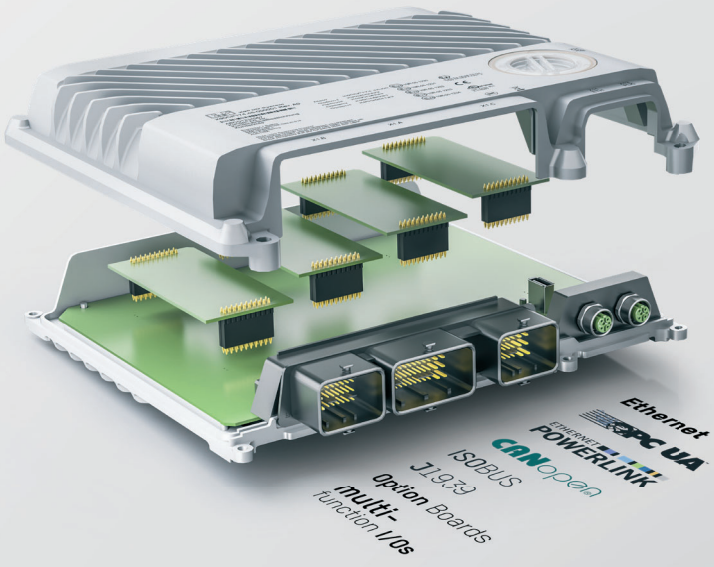

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→ Preprogrammed software components
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Figure 1: Heidelberg printing machines is one of the early users of CANopen as network to connect add-on devices to its Speedmaster machines (Source: CiA/Heidelberg)

implemented. Upper testers depend on the device-under-test. This means they are unique and cannot be used easily to test other devices.

Classic CANopen: a hidden champion

CANopen started as an embedded network in industrial machines including printing machines and textile machines. Early adapters were medical device suppliers. Today many medical devices use embedded CAN networks for different purposes. One of the most penetrated markets is construction machinery. Truck-mounted cranes, excavators, and many other earth-moving and mining machines implement embedded CAN-open networks.

This magazine is full of CANopen application reports. Professional coffee machines, subsea equipment, satellites, and service robots are just a few examples of the broad range of CANopen applications. CANopen is also used in police cars and cabs (CiA 447 series), in building doors (CiA 416 series) as well as in rail vehicles.

Besides the CiA 401 profile for modular I/O devices, the CiA 402 drives and motion control profile seems to be the most implemented one. The number of servo controllers and stepper motors supporting CiA 402 is huge. The CiA 402 specification gives the implementers some freedom to use manufacturer-specific functions. This leads to some interoperability issues, when integrating them with host controllers.

Figure 2: The Toru picker self-driving logistics robot from Magazino using CANopen motion controllers by Faulhaber is a typical example of a modern CANopen application (Source: Magazino/Faulhaber)

Figure 3: Embedded CANopen networks are also used in exotic applications such as the shown Gran Telescopio Canarias (Source: Flickr/Alberto Perdomo)

CANopen is also used deeply embedded in modular devices such as I/O modules. In such applications it acts as device-internal backbone network. Those deeply embedded networks are not visible. They are so-to-say hidden networks.

Outlook: CANopen FD application layer

With the introduction of the CAN FD data link layer protocol, CiA started to make use of the higher payload and faster transmission also for CANopen markets. The CiA 1301 CANopen FD application layer is released already. The other necessary building blocks such as electronic data sheet, layer setting services, etc. will follow soon. CANopen FD is specified in a way that it can also be used for the next CAN data link layer generation, which is currently under development in the CiA organization. It will provide payloads up to 2048 byte and will support bit-rate of 10 Mbit/s and above.

Of course, the classic CANopen profiles need to be updated to provide PDOs with more payloads. This process has been started already. The CiA profiles will be divided in a generic part specifying the application functionality and parts describing the mapping to CiA 301 (classic CANopen) and CiA 1301 (CANopen FD). It is also intended to map the CiA profiles to the J1939 application layers on demand. The first profile supporting CANopen FD is CiA 463-F (CANopen device profile for IO-Link gateway – CANopen FD mapping). The functional behavior and parameters are specified in CiA 463-B. Other profiles will be adapted, too. ◀

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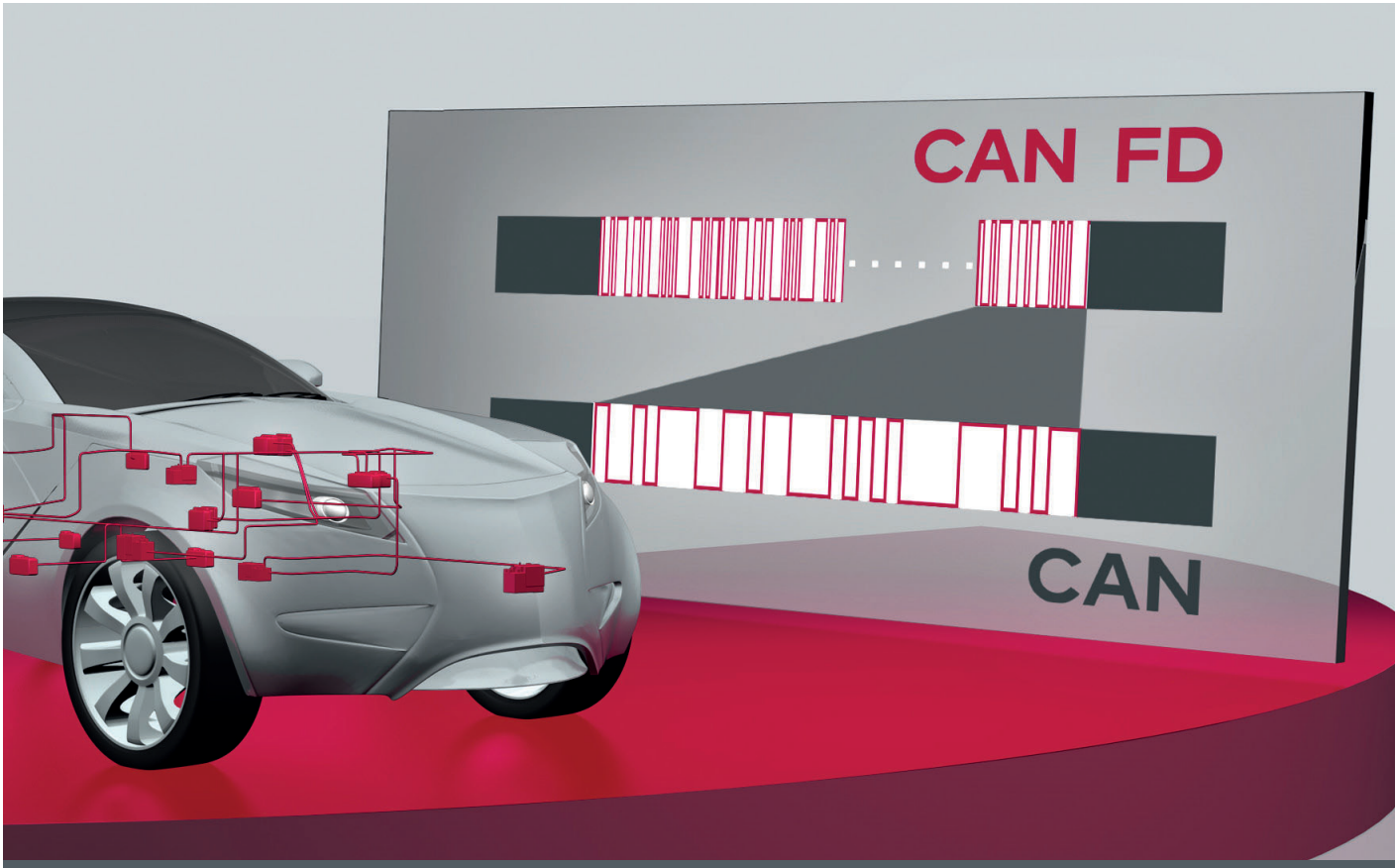

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