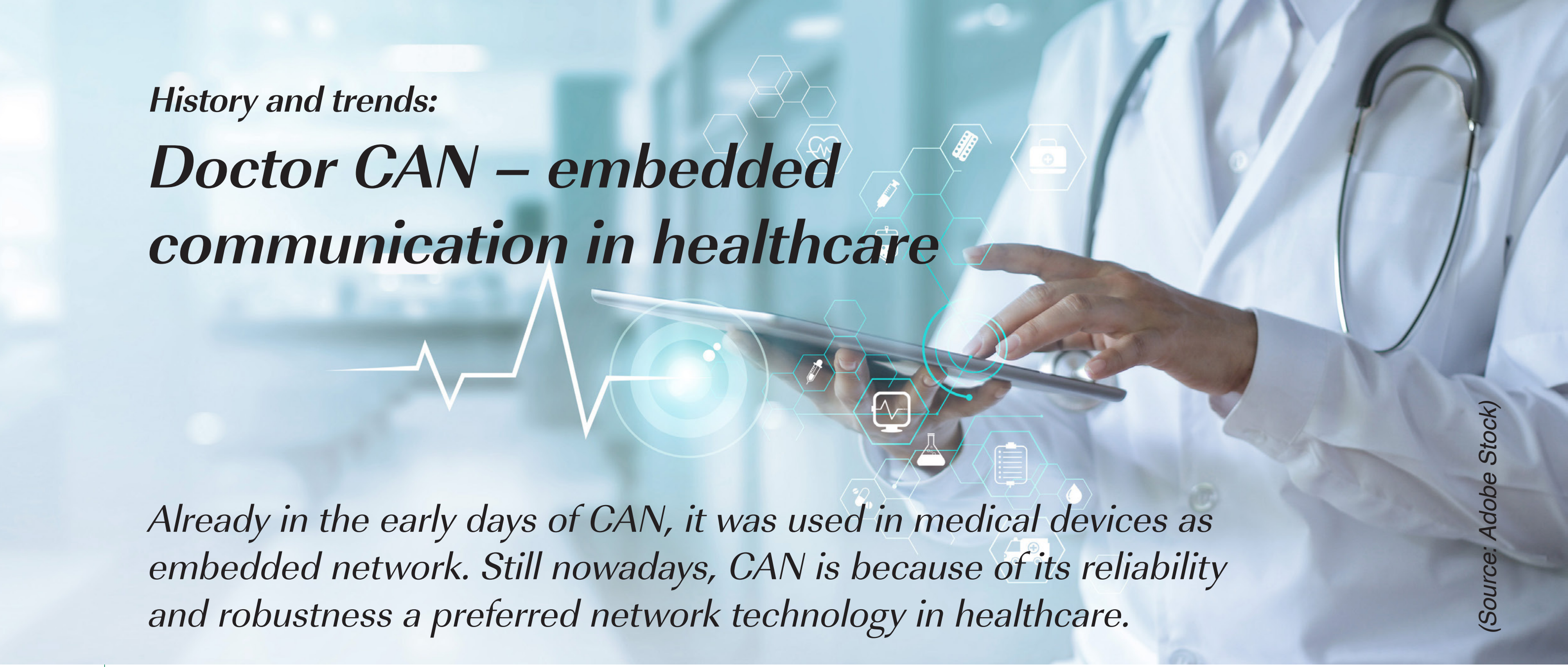
History and trends:

Doctor CAN – embedded communication in healthcare



(Source: Adobe Stock)

Already in the early days of CAN, it was used in medical devices as embedded network. Still nowadays, CAN is because of its reliability and robustness a preferred network technology in healthcare.

CAN has been used in medical devices since a long time. Today, CAN networks are used also in intensive care units including patient beds, in operating rooms, and in other healthcare equipment. Most of these CAN networks are embedded or even deeply embedded. Open networks are used for example to connect medical imaging systems to contrast media injectors.

CAN is used in medical devices such as X-ray machines, magnetic resonators, angiographs, computer tomographs, and others. These devices may implement cascaded CAN networks for embedded and deeply embedded control applications. Sub-systems with a standardized CANopen interface include collimators and dosemeters. Also, medical imaging devices may be connected to contrast media injectors by an open CANopen-based network. CAN networks can also connect all devices and units inside operating rooms to enable fast and monitored plugging together of operating gear so as to avoid any omissions and to check on the functionality of all devices. Intensive care units (ICU) are another use case for CAN in healthcare. CAN is used as deeply embedded network for internal control purposes. The interconnection of ICUs via CAN networks is a further application area. Some sophisticated patient beds use an embedded CAN control system for the motion controllers and the different user interfaces. The beds additionally provide a CAN interface to connect for example a blood-pressure monitor.

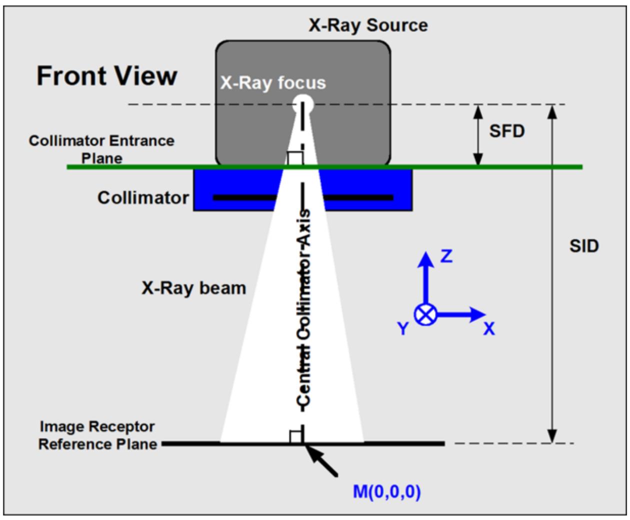


Figure 1: Collimator coordinate system, whereby the individual coordinates are as seen from a front view (Source: CiA)

Philips Medical Systems was one of the early adopters of CAN communication in X-ray devices, computer tomography, and other medical devices. As an early CAN in Automation (CiA) member, the healthcare company supported the development of the CAN Application Layer (CAL) released by CiA in 1993. It was a pure application layer (layer-7) approach, which was the predecessor of the CANopen application layer and communication profile. In 1993, Siemens implemented CAN networks with proprietary higher-layer protocols in its computer tomography systems.

CAL was also used by Karl Storz, a Swiss company, for its endoscopy devices. Mid of the 90ties, endoscopy pioneer Richard Wolf, a German company, connected its products via embedded CANopen networks. Additionally, the company linked operating (OR) tables, surgical lights, and other devices from third-party suppliers by means of a second CAN interface.

CANopen profiles for medical devices

With the introduction of CANopen, Siemens (nowadays Siemens Healthineers) and GE Healthcare migrated from proprietary CAN-based embedded networks to this application layer. CiA members developed CANopen profiles for automatic X-ray collimators (CiA 412-2) and dose measurement systems (CiA 412-6).

The CiA 412 CANopen profiles for medical devices specify general definitions (Part 1), the CANopen interface for automatic X-ray collimators (Part 2) as well as for dose measurement systems (Part 6). Using standardized CANopen interfaces, device manufacturers may supply diverse markets with medical devices implementing the same electronic interface according to CiA 412 and can simply vary the appropriate application software. A system designer may choose between CANopen devices from different manufacturers implementing the same profile-compliant ▷

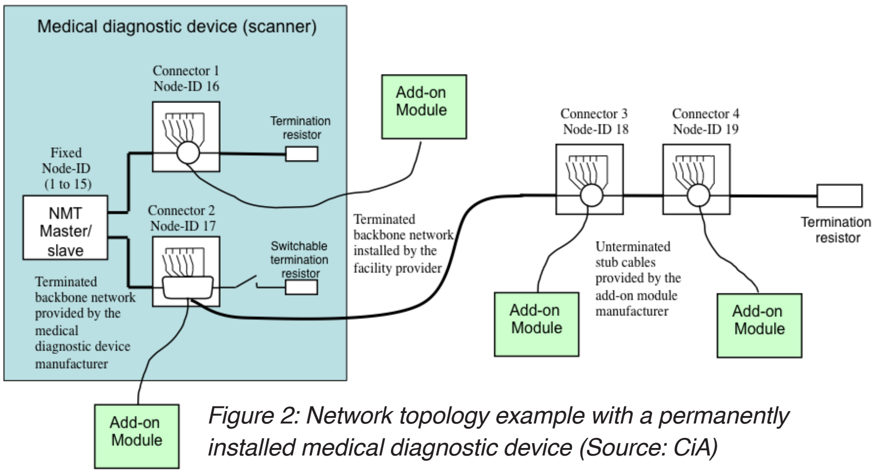


Figure 2: Network topology example with a permanently installed medical diagnostic device (Source: CiA)

functionality. For development, analysis, and maintenance of the devices, CANopen tools can be used.

The CiA 412-2 document for automatic X-ray collimators, represents the CANopen device profile for generic X-ray collimators, and as such describes the generic subset of collimator functionality. A collimator has three basic functions for which the profile specifies the appropriate configuration, application, and diagnostic parameters. The main function limits (or collimates) the X-ray beam (e.g. rectangular collimation) issued by an X-ray emitting source (X-ray tube) to a defined (receptor) format. Filters may be applied to influence spectral characteristics of the X-ray beam. The visual simulation of the X-ray beam is the third specified functionality. Some automatic X-ray collimators support local control functionality. The defined collimator functionality coordinates (X, Y, s, ω, D) may be controlled either in position or velocity mode. Devices compliant to this profile are required to support the emergency message (CiA 301). The defined device errors are sorted in warnings, recoverable errors, and non-recoverable errors.

The introduced collimator device FSA (finite state automaton) specifies the application behavior as well as the corresponding state transitions of the collimators. As a collimator is usable with local control even when the CAN network does not work properly, the communication FSA (CANopen NMT server FSA, CiA 301) and the collimator FSA are very loosely coupled. Also defined is a coordinate FSA applicable for the symmetric rectangular collimation sets, the quadrangle collimation sets, the circular collimation sets, as well as the spatial filter sets. The third specified FSA (homogeneous filter FSA) has the same states as the coordinate FSA with a different definition for some states. In addition, the X-ray visualization FSA is defined. Further, the profile provides some use case scenarios e.g. coordinate motion between the defined limits, changes of the SID (source image distance) value, etc. The CiA 412-2 pre-defines one RPDO containing the collimator command and the target x-y-position value as well as one TPDO providing the collimator state and the actual x-y-position value.

The CANopen dose measurement system (CiA 412-6) measures the X-ray dose and the dose area product. In addition, the dose area product rate, dose rate, RD (reference distance) entrance/skin dose, RD entrance/skin dose rate, MD (measured distance) entrance/skin dose, MD entrance/skin dose rate, irradiation time, chamber temperature, as well as the air pressure values are measured. The actual measured values (called field values) are converted to values with a real physical dimension (called process values). The profile specifies all required objects to fulfill this conversation and to represent the mentioned values in a standardized manner. Additionally, CiA 412-6 introduces an FSA for the dose measurement systems. The profile defines one RPDO and two TPDOs respectively transferring the control word (RPDO1) and the status word (TPDO1) as well as the current process value (TPDO2). Profiles for X-ray generators (Part 3), patient tables (Part 4), and X-ray stands (Part 5) are also intended in the future.

Nowadays, many of the medical device suppliers use CANopen as embedded network for different purposes in X-ray machines, in computer tomography, and angiography. This includes United-Imaging Healthcare, a Chinese CiA member, which has equipped its products with CANopen networks to integrate devices from several suppliers, especially motion controllers and I/O modules.

CANopen for medical diagnostic add-on modules

Some medical scanner devices need to communicate with contrast media injectors. For this purpose, CiA members specified around 2011 the CiA 425-2 profile. The SIG (special interest group) contrast media injector is still adding new features and updates. The scope of the group is the enhancement and maintenance of profiles for medical add-on devices such as contrast media injector. ▷

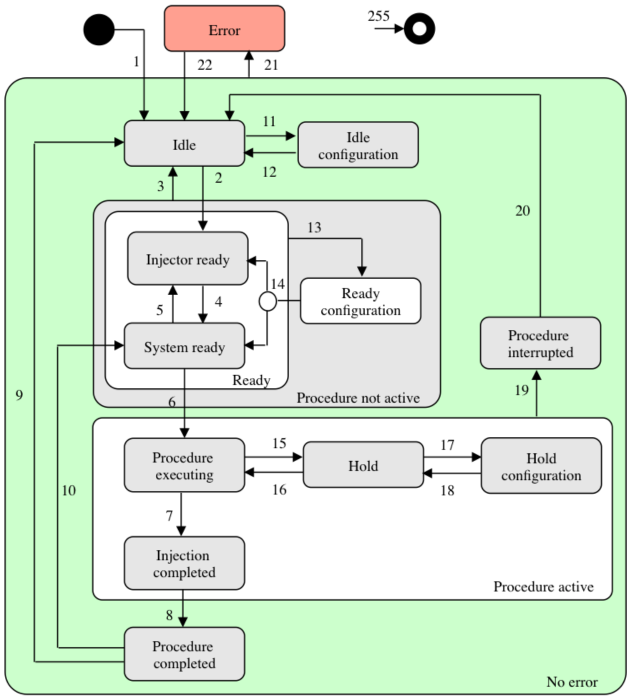


Figure 3: Injector state machine; FSA (finite state automaton) (Source: CiA)

Figure 4: The Econ100 from HMS/Ixxat used for mammography (Source: IMS/HMS/Ixxat)

The CiA 425 profile specifies the CANopen communication between medical sub-systems (diagnostic devices) and their add-on modules. It covers the general definitions (Part 1) and the CANopen interface for injector devices (Part 2). Injectors from different manufacturers implementing this profile may be attached to a diagnostic device via a standardized CANopen interface. Thus, a diagnostic device manufacturer does not need to hold several spare injectors available. The same injector interface implementation may be also used in diverse diagnostic devices of one manufacturer.

The physical device interface complies with IEC 60601-1 for medical electrical equipment. CANopen-related physical layer accords to CiA 301 verson 4.2.0. Bit rate of 250 kbit/s is supported. Four connectors are specified. Five of the connector pins are used for geographical node-ID assignment. Medical diagnostic devices use the node-IDs 1 to 15. Geographical addressing is not mandatory for permanently connected nodes. Here the node-ID setup is internally done by hardware or software. The network installer has to ensure, that a node-ID is not used twice. Typically, the medical diagnostic device provides the CANopen NMT (network management) manager capability and the add-on modules provide the NMT server functionality.

The CANopen injector interface (CiA 425-2) specification is used to connect automatic and semi-automatic injectors to the CANopen network allowing operation of third-party products. It covers injectors connected to such medical diagnostic systems as angiography, computer tomography, magneto resonance, ultra-sonic, etc. The injector may provide up to eight configurable pistons. Each injector implements a certain compatibility class (0 to 5) showing the diagnostic device's capability to control the injector. This reaches from injector monitoring (class 0) to real-time adjustment of the injector parameters. The higher class provides the functionality of the lower class. If required, the injector may use the safety-related communication according to EN 50325-5.

Figure 5: The Accutron CT-D CT861-2 double-head injector with a support arm (Source: Medtron)

Figure 6: With its surgical microscope with integrated OCT camera, Zeiss gives surgeons better insights into the transparent structures of the eye during surgery. A CAN interface is used in the panel PC. (Source: Zeiss)

The specified state machine (FSA) defines injector's application behavior. It is also specified on which events certain FSA transitions and actions are executed. The injector may be operated by local commands (not specified) or via CANopen network by the control word sent from the medical diagnostic device. The injector reports its state in the status word. The FSA is also controlled by detected errors.

The programmable injection protocol is a sequence of configured phases (injection, test bolus, delay, and wait) with defined actions. The injection and test bolus phases require configuration of total volume, total flow rate, and piston ratio. Optionally, the rise time and pressure limit may be configured. The diagnostic device controls and monitors the phase processing by means of the control word respectively the status word. The injector may support three operation modes (monitor, tracking, and control). The CiA 425-2 further defines the RPDO 1 and TPDOs 1 to 4, the complex data types, and the required application objects. Additionally, to the mentioned above, the latter include the current and configured values, physical units (specified according to CiA 303-2) and limitations for volume, pressure, and flow rate related to the corresponding phase types. Time-related values, piston attributes, configured language, supported CiA profile version, as well as the device's (diagnostic device and injector) description are specified within certain objects. The CAN Newsletter magazine published several articles regarding injectors:

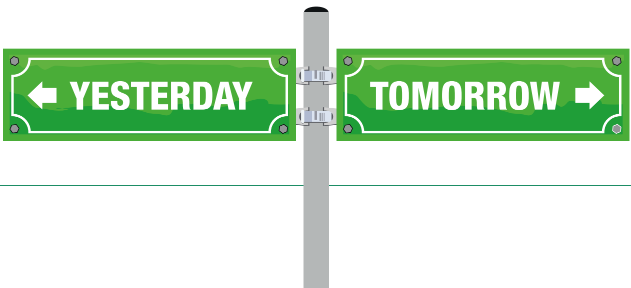
- CANopen object dictionary of an injector (CAN Newsletter 1/2021)
- Injector and scanner communication (CAN Newsletter 4/2020)
- Implementing a CANopen injector FSA (CAN Newsletter 3/2020)

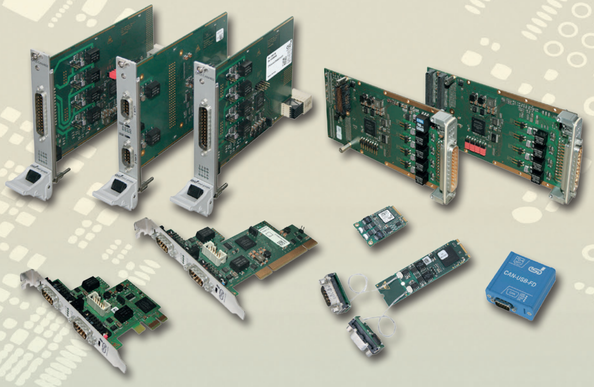
Figure 7: CAN is also used in dentist instruments as well as in dentist chairs to move the patient in position. (Source: Adobe Stock)

Application examples

Already in 2005, the CAN Newsletter magazine reported about Medtron implementing CANopen in its contrast media injectors. In 2021, the CAN Newsletter Online published an article about CANopen-based CT imaging. Medtron and Siemens designed the Accutron CT-D CT861-2 injector communicating with Siemens Somatom go CT scanners via a CANopen interface. The double-head injector is needed for clinical CT (computer tomography) imaging procedures. It is mountable on the gantry by means of a Siemens support arm in which the power supply cable is routed. The company's CANopen interface Class IV allows a wireless synchronization of the injector and the scanner system to achieve a workflow. By mounting the injector onto the gantry, it is available next to the CT scanner table. This integration also enables a positioning closer to the patient. Medtron works in the field of medical engineering. It manufactures contrast medium injectors used across the globe within the imaging systems, such as magnetic resonance imaging, computed tomography, and angiography. The German company is also contributing to the development of the CiA 425-2 profile specification for CANopen injectors.

In 2018, the CAN Newsletter magazine reported about CAN devices from HMS/Ixxat which were used in mammography. MS used the Ixxat Econ100 embedded controller in their Giotto Class mammography machine. The machine can move around the patient taking X-ray photos from several different positions, providing physicians with better pictures for detecting breast cancer. The moving parts of the Giotto Class are mainly controlled using the CANopen protocol. The Econ100 manages the internal communication network and the logic control unit for about twenty different electronic boards. It controls movement, X-ray emission, data acquisition, visualization, and safety chain inside the machine. The controller features a Xilinx Zynq SoC – dual-core Cortex A9 processor as well as two CANopen ports which make it possible to configure ▷





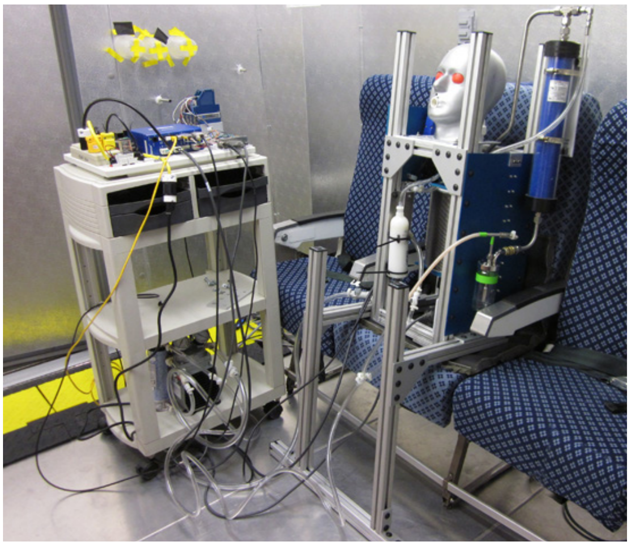


Figure 8: The cough simulator in action (Photo: Kvaser)

communication at two different bit rates - to adjust to different stub lengths within the network. It offers two independent CAN networks with CANopen as higher-layer protocol for communication.

The Callisto Eye from Zeiss also uses a CAN interface. The panel PC is part of the Opmi Lumera 700 from Zeiss, which is an operating microscope suited for every ophthalmic surgery specialty. The assistance functions of Callisto Eye are surgeon-controlled – with either the foot control panel or handgrips.

Also in many dentist chairs, CAN-based motion controllers are applied to move the patient in position. Additionally, the dentist instruments are controlled via additional CAN networks. For example, Austrian CiA member, W&H Dentaltechnik, has equipped a range of its dentist instruments with CANopen interfaces. Such CANopen interfaces are not yet standardized by means of CiA profiles. The mechanical interfaces are already internationally standardized.

Coughing with CAN: In 2017, Niosh (USA) has developed a cough simulator to study how diseases like influenza can spread via airborne droplets. This simulator uses Kvaser's CAN-based Leaf Light HS v2 interface (Figure 8). It is a high-speed USB interface for CAN that offers loss free transmission and reception of basic and extended CAN frames on the CAN network. In this application case it connects the motor and the computer, transmitting control commands from a custom-built National Instrument's Labview program, and sending back motor position feedback. The list on applications of CAN in healthcare is long and impossible to mention all. CAN is not often visible, but there in so many fields. ◀

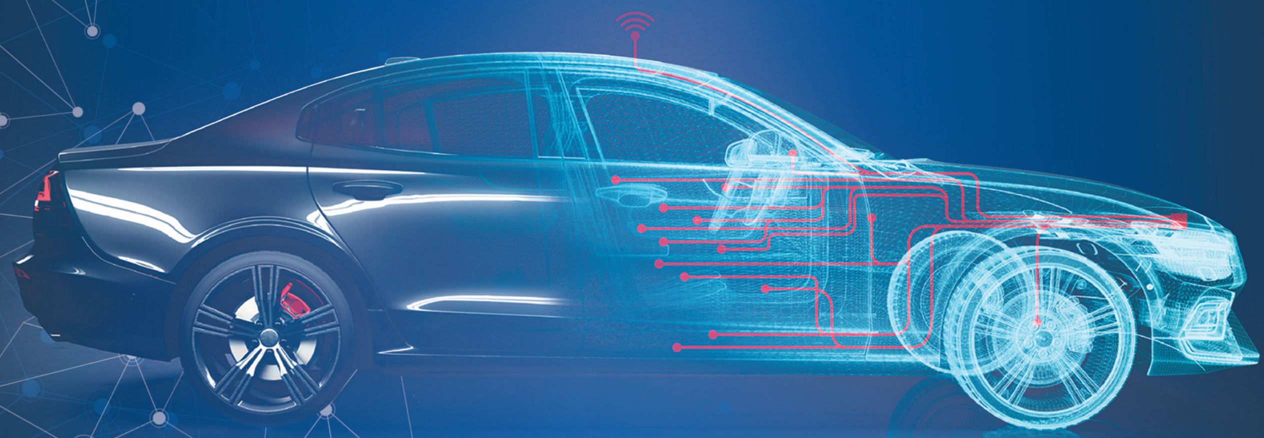
Covid-19 and CAN

The coronavirus still goes around the world. The CAN networks used in medical equipment help indirectly in the fight against it. This article in the CAN Newsletter Online collected products and developments helping.

The disinfection robots by UVD robots (Denmark) are deployed in hospitals to disinfect rooms and equipment such as patient beds. They also use embedded CAN networks.

Author

Cindy Weissmueller
CAN Newsletter
pr@can-cia.org
www.can-newsletter.org

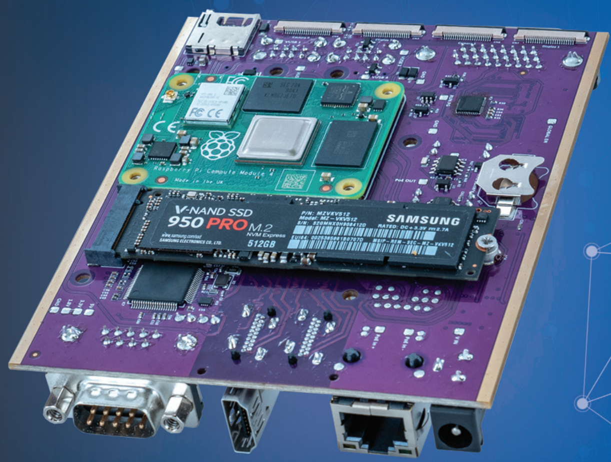


neoVI PI

Robust and Open Raspberry PI 4 Platform for CAN/CANFD Applications

Introducing the Automotive Industry's first open and robust platform for the Raspberry Pi. The neoVI PI has a built-in Raspberry Pi 4 Compute Module (RPi4 CM) that contains quad 64-bit processors and a gigabit Ethernet port, paired with Intrepid's CAN FD technology. This allows you to simulate, test and datalog with the flexibility that the Raspberry Pi 4 Compute allows.

The neoVI Pi has all the features of the RPi4 CM plus up to four CAN FD networks. he neoVI PI is designed and tested for the automotive environment. This includes a wide power supply range, EMC protection, rugged packaging and environmental testing. The neoVI PI allows you to use the Raspberry Pi 4 Compute while avoiding additional development to adapt to the automotive network environment. That makes the neoVI PI powerful enough to solve your vehicle network problems, yet small enough to fit in your backpack.



FEATURES

- Built-in RPi4 Compute Module supports all variations of EMCC, SDCard, and Wireless
- 2x internal ValueCAN4-2 for 4 CAN FD / CAN 2.0 Channels
- Intrepid Open source APIs on github/intrepidcs: libicsneo for C/C++ and python_ics for Python
- Automotive Power Supply (5-60V operation)
- 1x Native 1000BASE-T Ethernet with PoE sink support
- 4x High Speed USB Host Ports with high current sourcing
- Integrated Raspberry Pi Pico Module connected to RPi4 via USB
- M.2 NVMe slot for hosting PCIe flash up to 4TB
- Expandable IO : Internal RPi and Rpi Pico GPIO access with open connector pins for custom hardware applications
- Tested and Packaged for in-vehicle use
- HDMI connector for RPi4 OS display

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