CANopen-based Transducer Network

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Abstract

The CANopen device profile for transducer submitted to IEEE for standardization can be used to describe multi-sensor devices. Using this profile, the system designer can design cascaded networks. Each device may provide up to 199 sensors and actuators. The multi-channel CANopen transducer module may use embedded communication links as defined in IEEE 1451. The CANopen devices provides compatibility to the Transducer Electronic Data Sheet (TEDS) as defined in IEEE 1451.

1. Introduction

Sensor elements in embedded systems are usually connected via non-standardized interfaces to a microcontroller-based controller. In order to reduce the integration effort that is necessary especially in sensor-intensive applications, the CAN in Automation (CiA) international users' and manufacturers' group has developed a CANopen device profile (DS 404) for transducers and closed-loop controllers. The profile describes the interfaces for CAN-based sensors, actuators and PID-controllers. The internationally standardized CANopen protocol (EN 50325-4) provides communication services, with which the devices can exchange process data, receive configuration data, and transmit diagnosis data. The digital I/O functions correspond to a sub-group of the CANopen device profile for generic I/O modules (DS 401).

2. CANopen object dictionary

Sensor data that are available after the A/D conversion are saved to the CANopen Object Dictionary of the device. The entries in the CANopen Object Dictionary can be accessed (read/write) via the network via a 24-bit address (16-bit index and 8-bit sub-index). Stored in the CANopen Object Dictionary are the scaling parameters for linearization, offset, auto zero, and automatic calibration of these field values. The parameters are configurable via the SDO services (Service Data Objects) via the CAN network. Process data are written to the Object Dictionary after scaling also. The analog input values are storeable in four different formats, each of which is assigned a specific area in the CANopen Object Dictionary:

- Floating integer (field value (FV): 6100h, process value (PV) 6130h)
- 16-bit integer (FV: 7100h, PV: 7130h)
- 24-bit integer (FV: 8100h, PV: 8130h)
- 32-bit integer (FV: 9100h, PV: 9130h)

Up to 199 analog input channels can be implemented in a device. The process value of the first sensor channel is sent by default in a Process Data Object (PDO). This PDO contains also the corresponding status (e.g. no error, positive or negative overload) and possible emergency messages. System developers may implement further PDOs in multi-channel devices, or they may use the optionally available multiplexed PDOs. For these just a CAN identifier is necessary, which must, however, contain the 24-bit multiplexer (16-bit index and 8-bit sub-index) in the CAN message.

The device profile just supports a simple linear scaling of the sensor data. This linear scaling is implemented with two parameterizable calibration points (Input_Scaling_1_FV/Input_ Scaling_1_PV and Input_Scaling_2_FV/Input_ Scaling_1_PV). The sensor manufacturers may implement the applicable objects for more complex linearization functions in the manufacturer-specific area of the Object Dictionary. They may also reference a specific sensor type for each analog input channel (see table 1).

Table 1. Supported sensor element types

Thermo element Type J
Thermo element Type K
Thermo element Type L
Thermo element Type N
Thermo element Type R
Thermo element Type S
Thermo element Type T
PT100 element
PT200 element
PT500 element
PT1000 element
PT5000 element
Infrared sensors
Voltage sensors
±10-V Signals
0-to-10-V signals
±1-V signals
0-to-1-V signals
±100-mV signals
0-to-100-mV signals
Current signals
4-to-20-mA signals
0-to-20-mA signals
Frequency sensors
Strain gauge
Strain gauge bridge
Strain gauge half bridge
Strain gauge quarter bridge
LVDT sensor
Pressure sensor
Temperature sensor
Potentiometer

The device profile also describes analog outputs. This means that multi-channel transducers can be described, which provide analog inputs as well as analog outputs. Several of those transducer I/O modules (TIOM) can be connected via the CAN network to a closed-loop controller (CLC). CANopen even provides for the possibility that several CLC-devices exist in the very same network. The analog I/O channels can then be assigned via configuration. The CLC-devices can pre-process the data if the applicable PID controllers are implemented. These networked CLC-devices again can act as TIOM modules in a higher hierarchic CANopen network, meaning they provide analog inputs and outputs to the higher hierarchic network. Thus multi-layer network cascades can be realized. In theory in the topmost network a maximum of 199 times 126 (25,074) sensors and a maximum of 1999 times 126 (25,074) analog actuators are describable. In practice this is not yet possible since the commonly available CAN transceiver allow just up to 64 devices in a network. The maximum number of analog channels is thus 12,537. The CLC-device(s) can be replaced by an ASAM controller in the topmost CANopen network. ASAM controllers are programmable devices that are used in test stands for motors and gearboxes. The International Standardization Organization (ISO) is standardizing ASAM-based measuring systems.

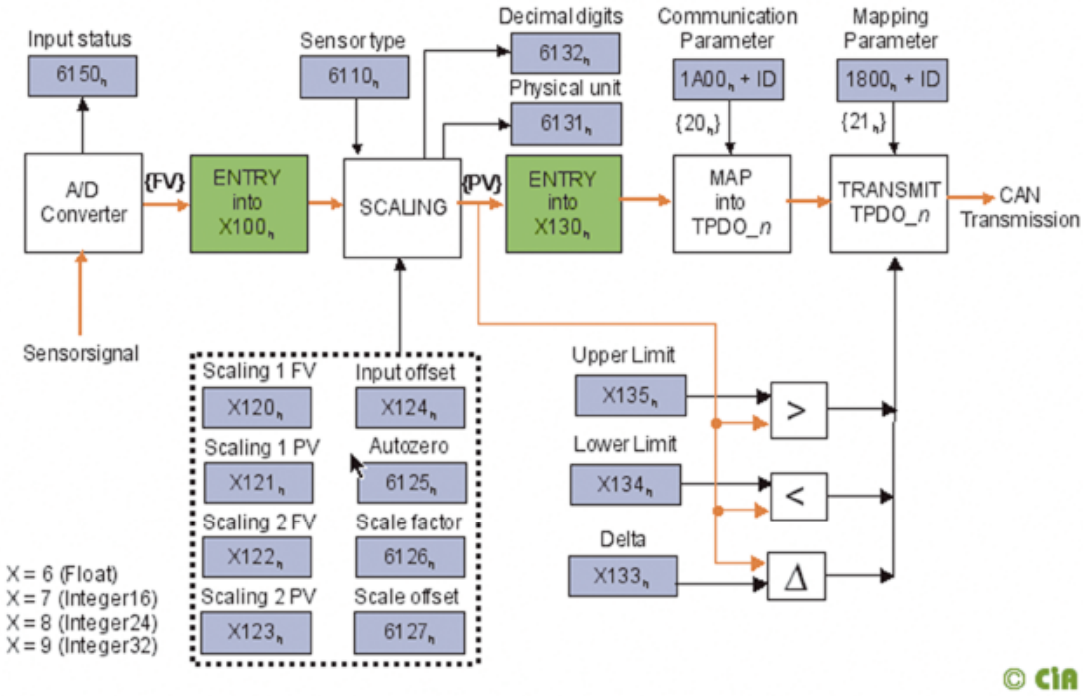

Figure 1. Block diagram of an analog sensor input

3. Applications

Several companies have implemented the CANopen device profile already. It is also recommended by Euromap (European Committee of Machinery Manufacturers for the Plastics and Rubber Industries) as embedded sensor network for extruders (Euromap 66). Beside PID controllers, especially pressure and temperature controllers that implement the profile are available. Typical applications for these sensors are in maritime electronics and in railways, in off-road vehicles and in process automation. CiA members are working on an intrinsically safe transmit method to be able to use these CANopen networks in explosive environments, too. This method will be based upon 3.3-V transceivers and 3.3-V micro-controllers. The device profile for transducer and closed-loop controllers has been submitted for standardization with the IEEE (p1451.6), where it is supposed to be functionally extended. This extension concerns especially the names of the sensor manufacturers, the product name of the sensors and an optional sensor serial number. This is also true for the actuator elements, of course.

4. Standardization

Within the IEEE standardization an intrinsically safe physical transmit method is aimed at so that the transducer modules are also applicable for use in explosion-risk facilities. Emphasis is put on the fact that commonly available transceiver and other affordable elements are used. It is likely that the energy saving e.3-V technique is going to be used. The first ISO 11898-2-conform CAN transceivers are already available.

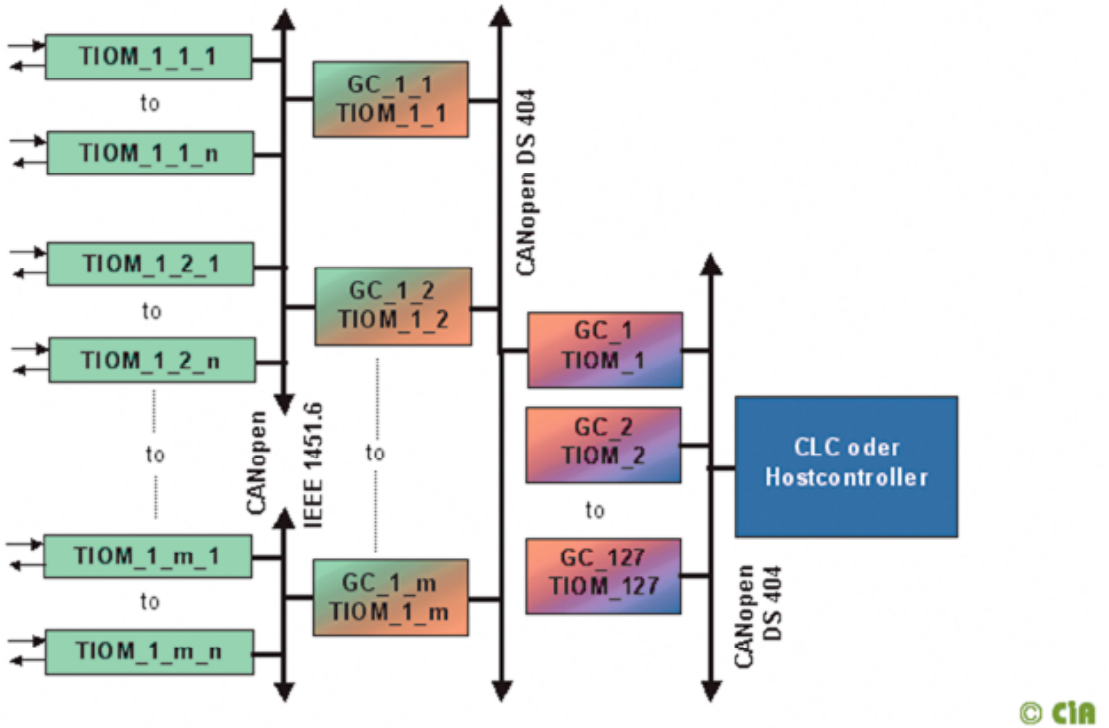

Figure 2. Cascading CANopen transducer network in several layers

The IEEE p1451.6 transducer specification will also include all those objects that should be accessible for the deeply embedded sensor interfaces within the TIOM. These deeply embedded interfaces (SPI, multi-drop, or wireless) are defined in other parts of IEEE 1451. These other parts introduce Transducer Electronic Data Sheets (TEDS). The necessary TEDS entries are represented in the CANopen Object Dictionary by means of objects and the corresponding descriptions within the CANopen EDS.

The definitions given in the IEEE p1451.6 will also be compliant to the German standardization activities initiated by the non-profit AMA organization. The SPI interface defined by AMA is quite similar to the IEEE approach as well as the AMA-TEDS specification. The CANopen/IEEE specification allows integration of several network levels. The cascaded networks provide the possibility to structure systems requiring a huge number of transducers. The single or multiple sensor and actuator devices may be implemented using standard micro-controllers with integrated CAN modules. The transducer devices may be based on the standard ISO 11898-2 transceiver chips or on the specific transceiver circuitry for an intrinsically safe physical layer that is under development within the corresponding IEEE task force.

5. Summary

The enhanced CANopen profile for transducer as submitted for IEEE standardization provides the capability to describe cascaded networks. Therefore it is dedicated for applications in which many sensors and actuators have to be connected. The CANopen devices following this profile are compliant to the other IEEE 1451 specifications as well as the standardization activities under development within the AMA manufacturers organization located in Germany.

6. References

/1/ EN 50325-4:2002 – Industrial communictions subsystem based on ISO 11898 (CAN) for controller-device interfaces – Part 4: CANopen

/2/ ISO 11898-1:2003 – Road vehicles - Cotroller area network (CAN) - Part 1: Data link layer and physical signalling

/3/ ISO 11898-2:2003 – Road vehicles - Cotroller area network (CAN) - Part 1: High-speed medium access unit

/4/ http://www.motion.aptd.nist.gov/ - National Institute of Standards and Technology, IEEE 1451 Website