CAN-based Protocols in Avionics

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Abstract	This application note provides an overview of communication protocols used in CAN-based avionics networking.

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1.0 Overview

With the increasing functionality of electronics in planes the avionics data busses play a more and more important role. Well-established data busses such as ARINC 429, MIL-STD1553 and some more provide reliable and safe communication. Their behavior with all advantages and all issues is well-known. For some applications they will remain, for others the bandwidth and addressing capabilities are not sufficient any more.

New concepts have been developed and deployed to overcome the limitations. As a general concept the Integrated Modular Avionics IMA is introduced, and as Aircraft Data Network ADN the high-speed real-time and safe data bus ARINC 664 AFDX® is introduced.

Many systems and sub-systems use the Controller Area Network CAN for the communication between several internal electronic devices. CAN defines only the Physical Layer and Data Link Layer. If functions such as network management or transport layer are required, they need to be defined by so-called Higher Layer Protocols – in the following abbreviated just as protocol.

This application note provides some aspects of typically used protocols and their use cases. It provides some criteria to ask the right questions on the selection of a protocol.

2.0 Proprietary Protocol versus Standardized Protocol

There is a very simple rule:

Design follows Requirements

Applied to a sub-system without direct external communication this will typically lead to a communication design which is appropriate from the requirements' point of view and as lean as possible. As an example take a simple sensor, that transmits a single value cyclically in a CAN message. The receiver electronics just filters on that message, and reads the value. Such a communication is simple to program and simple to test. The Failure Mode and Effects Analysis are simple to perform and the treatment is straight forward. Such a communication design is very efficient. It is called layer 2 communications.

As an opposing example assume, that the sensor needs calibration data or software configuration that shall be downloaded and flashed via the bus. The data amount exceeds the payload of a single message and several commands are required for applying the calibration data or software. The result is the design of a transport protocol and a command interface. This is very complex to design, implement and test, and proving the quality of the protocol and its implementation needs high efforts. Furthermore other avionics may require similar concepts; service tools will be required, which can run the protocol. In this case the standardization of such a Data Loader and the underlying transport protocol will save significant costs. An example for a standard dealing with such a scenario is ARINC 826 (details see below).

3.0 Important Protocols

The following will give a brief overview about some of the important CAN-based protocols used in avionics.

3.1 ARINC 825

ARINC 825 "General Standardization of Controller Area Network Bus Protocol for Airborne Use" is a protocol specification for the aviation industry, managed by www.arinc.com.

It specifies both the fundamental communication within CAN-based sub-systems, and between CAN sub-systems which for example are interconnected by AFDX®. It offers addressing mechanisms, communication mechanisms, a service structure, profile descriptions and much more.

The importance of this protocol is shown by the fact that Airbus and Boeing initiated the CAN Technical WG of the AEEC to specify methods and a protocol for the general use of CAN, including interoperability between sub-systems. This activity led to ARINC 825. For many sub-systems of the Airbus A350 the technical design directives already request the use of ARINC 825.

3.2 ARINC 826

ARINC 826 "Software Data Loader via CAN Interface" is a protocol specification for the aviation industry, managed by www.arinc.com.

The general specification for Software Data Load in avionics is ARINC 615A. For use via CAN networks a subset was used and optimized for the characteristics of CAN. The basic identifier structure is based on ARINC 825 and a transport and command protocol specification for this application was added.

Sub-systems of the new Airbus A350 already implement ARINC 826.

3.3 ARINC 812

ARINC 812 “Definition of Standard Data Interfaces for Galley Insert (GAIN) equipment, CAN Communications” is a protocol specification for the aviation industry, managed by www.arinc.com.

Airliner galleys need to be designed for easy configurability by airlines, high interoperability between different aircraft types and inserts of different suppliers, and with high requirements on the power management. For this Airbus and Boeing together with many suppliers specified ARINC 810 and ARINC 812. ARINC 810 defines mechanical and electrical characteristics such as form factor, connectors and CAN as the interface data bus. The protocol to be used is defined in ARINC 812.

Originally ARINC 812 was developed independent from ARINC 825. The current draft provides interoperability with ARINC 825. A release date of this draft is not known yet.

3.4 CANopen

The “CANopen Application Layer and Communication Profile” is a specification family managed by CAN in Automation e.V. (www.can-cia.org).

CANopen is one of the most wide-spread protocols in many application fields. Many hundreds of module providers and users are the base for steadily improvement. CANopen is designed for very flexible configurable embedded networks. It specifies the basic communication mechanisms and device profiles, but also application profiles with specific support for selected application fields.

This high flexibility has the disadvantage of a high complexity. Even if usage in several SIL3 applications is known, this requires high efforts for proving the safety requirements. Using CANopen in high DO178B Design Assurance Levels should be considered only if strong reasons justify the high efforts.

A clear advantage is the availability of controllers, actors and sensors in the industrial market. For many sub-systems in a plane it is appropriate to use such modules from the general industrial market. Typical examples are catering elevators, water-waste-systems, and other cabin equipment. But also some few critical systems like a cabin fire extinguishing system partially use CANopen sensors.

3.5 CANaerospace

CANaerospace was developed by the company Stock Flight Systems (www.canaerospace.com). Key protocol applications are in engineering simulators, simulation cockpits, experimental aircraft, and – especially in the Italian field – drones (UAVs).

4.0 Selection Criteria

4.1 Technical Differences

The different protocols have been designed focusing on different requirements. So there is no best or good or bad protocol. They all have their strength for certain applications. In the following the characteristics of CAN itself are assumed to be known.

4.1.1 Bandwidth Utilization

Protocol	Characteristics	Comment
ARINC 825, ARINC 812	• Uses 29 bit identifiers • Payload transports several signals • Provides very efficient transport protocols for any size of data	Usage of 29 bit identifiers wastes bandwidth in comparison to 11 bit identifiers. The incorporation of channel / service / addressing schemes in the identifier mitigates this, when implementing complex network structures. Transporting several signals per message allows the system designer to optimally design the usage of bandwidth in relation to the system requirements.
ARINC 826	• Uses ARINC 825 communications • Provides very efficient transport protocols for any size of data	No usage in normal operation required. For download / upload services the transport protocol is very efficient.
CANopen	• Normally uses 11 bit identifiers • Payload transports several signals • Provides efficient transport protocols for any size of data	Usage of 11 bit identifiers saves bandwidth in simple systems. In more complex systems this forces complex actions for realizing higher services (refer to CiA® DS-302), using bandwidth. Transporting several signals per message allows the system designer to optimally design the usage of bandwidth in relation to the system requirements.
CANaerospace	• Uses 11 bit identifiers • Payload normally transports only one signal • Provides an efficient transport protocol for up to 1020 byte	Usage of 11 bit identifiers saves bandwidth. Transporting one signal per message allows slightly more efficient implementation in the microcontrollers, but wastes much bus bandwidth.

Table 1 - Protocol Bandwidth Utilization

4.1.2 Timing, Predictability

Protocol	Characteristics	Comment
ARINC 825	• Time Triggered Bus Scheduling (derived from CANaerospace)	Describes a method, how the system designer can design a predictable network with a bandwidth utilization of up to 50%. The LRU implementer needs to consider a set of measures to ensure that the designed communication will also work under fault conditions. These measures are not described in the specification.
ARINC 826		No usage in normal operation required.

Protocol	Characteristics	Comment
CANopen	• Provides several communication services and modes with and without real-time functions	The normal usage of CANopen provides very quick response times, but formally it is event driven and not predictable. The service SYNC together with sync-driven PDOs allows designing a predictable network. Handling fault conditions is only partially specified – the responsibility stays to the network designer and device implementer. The service SRDO allows to set-up full predictable and SIL3-safe networks. **Attention**: Only a few selected specifically designed CANopen devices fully support the SRDO service. The SYNC service is supported by some more devices, but most of them not to the extend that allows predictable networks.
CANaerospace	• Time Triggered Bus Scheduling	Describes a method, how the system designer can design a predictable network with a bandwidth utilization of up to 50%. The LRU implementer needs to consider a set of measures to ensure that the designed communication will also work under fault conditions. These measures are not described in the specification.
ARINC 812		For the application of Galleys full predictability is not required.

Table 2 – Timing, Predictability

4.2 Applications

Some of the protocols are designed for specific systems, sub-systems or applications; others are for more general use.

Protocol	Applications	Comment
ARINC 825	• general use • IMA sub-network	Has specific strengths if several applications or functions communicate via the same network or if an application or function communicates via different sub-networks. Is specifically designed to support the IMA concept.
ARINC 826	• software download / upload via CAN	
ARINC 812	• galley	De-facto standard for the Galley Master (MGCU) and the inserts (GAIN)
CANopen	• general use	Provides low-cost availability of industrial components (specifically sensors)
CANaerospace	• engineering simulators • simulation cockpits • experimental aircraft, UAV	Flexible and efficient for easy use in engineering and experimental phases

Table 3 - Applications

4.3 Supply Chain / Joint Projects

The usage of standards significantly reduces efforts at project partners. This applies for

- same understanding of interfaces
- reduction of different interpretation of the specifications
- re-use of technologies across project borders
- less cost in setting-up second sources

Anyhow it needs to be considered, that standards have to fulfill more generic requirements, fitting to several applications. Therefore they may be more complex than a specifically designed protocol.

4.4 Development Support and Competencies

When selecting a protocol it is important to get development assistance. The following questions should be answered:

- Are development tools available? Because of the complex character of some of the protocols layer 2 based CAN tools may not be enough. Specific tools with protocol support will decrease efforts in simulation, development, testing and bug-fixing. If these tools support all of the typical protocols, the learning curve in efficiently using the tools is lower, even if in a new project another protocol is used.
- Do I need to implement the protocol myself? Or are there commercial high-quality protocol stacks available?
- Are training classes available?
- Do I need technical consulting services? If so, which companies can provide that know-how?
- Do I need further external services? Which companies can provide know-how and resources?

5.0 Conclusion

Selecting a protocol is a complex task. Considering the criteria given above will help in finding the right questions.

6.0 Additional Resources

The following material may provide further information:

VECTOR APPLICATION NOTES
AN-AND-1-100 Business Introduction to CAN
AN-AND-1-101 Technical Introduction to CAN
AN-ION-1-0103 Protocol Selection Guide
AN-ION-1-1100 Introduction to CANopen
AN-AON-1-1101 Introduction to CANopen Documentation Family

They are available for download in the download center at www.vector.com.

7.0 Trademarks

All mentioned names are either registered or unregistered trademarks of their respective owners.

AFDX® is an Airbus‘ registered trademark.

8.0 Contacts

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