CANopen FD conformance testing – today and tomorrow

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This paper presents the current state of CANopen FD conformance testing at CAN in Automation (CiA). CiA working group SIG testing works on next generation conformance test plan. The test plan should cover all necessary test cases to evaluate compliance of a designed CANopen FD device. Since the CiA 1301 conformance testing is required for any CANopen FD device, the test plan should cover every aspect and diversity of requirements to each kind of devices such as master-capable and slave devices. The conformance testing utilizes the lower test concept such as testing a device as a black box and testing only conformance of the implemented communication protocols and object dictionary to CiA 1301 specification. The upper test requires an application related simulator and therefore is not a part of a CANopen FD conformance testing. It is considered to describe test cases in CiA 1310-1 test plan specification in a scripting language such as JavaScript or PythonScript.

When it all started…

Ever since introduction of CANopen technology, CiA put a value into a testing of the CANopen devices. In order to satisfy market requirements for the CANopen device testing, the testing was designed ISO 9646-conform. Additionally, to make testing attractive to the wide number of users, as well as increasing efficiency of the testing and reduce testing efforts, there are only absolute necessary tests of the communication behavior of CANopen devices. Beside that the device testing as a ISO 9646-conform black box testing, allowed to limit test interactions and reduce the test bench to the setup such as test tool and device under test (DUT).

In this case the black box testing has the aim to compare the conformance of a device with a specification CiA 301. The DUT is a "black-box" in such a way that its communication behavior can be observed but no internal structure is known. The conformance test bench includes the lower test and the DUT (see figure 1). The test tool software performs lower test. The upper test such as interoperability as well as performance testing are out of scope of conformance and therefore not handled in the paper.
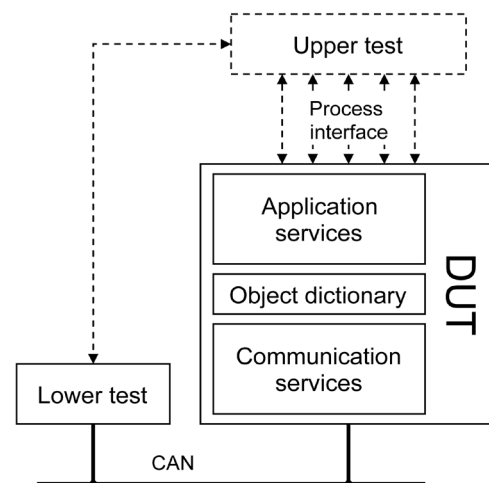

Figure 1: DUT test interface

The following items were involved in a creation of the test bench or used in there to test CANopen conformance of a CANopen device:
- CiA 301, which served as a base for CANopen device conformance testing;
- CiA 310-1 test plan for a CiA's CANopen conformance test software;
- Standardized device description file in the EDS format (CiA 306-1);
- Standardized CiA profile databases in CODB file format (CiA 306-2);
- CANopen Testing Interface (COTI) as a hardware-independent CAN API;
- Software tool for checking device description in EDS format (Vector Informatik GmbH).

While some of the items are known or the reader is well aware of their usage, the relation of the others such as EDS, CODB, COTI and Software tool for checking device description in EDS format to the testing requires some explanation. In the following the explanation is provided.

Standardized device description file in the EDS format

The test tool software uses an EDS file to collect parameter information supported by the device for comparing it with the parameters implemented in the device as well in various tests requiring parameter data.

Standardized CiA profile databases in CODB file format

A CODB file represents a CiA profile specification in a standardized parameter database format. The software tool for checking device description in EDS format uses CODB files to test, if the parameters, described in the EDS file, are conform to a CiA specification. Since CiA 301 conformance is tested, only CODB file for CiA 301 is used in testing. Currently CODB files for most of CiA device profile specification with the status DSP are available.

COTI

The COTI allows exchanging data between the test tool software and low level drivers of a CAN hardware interface. Every CAN hardware interface manufacturer has to provide a COTI library for its hardware interface to make the test tool work. The COTI specification was made available for CAN hardware interface manufacturer.

Software tool for checking device description in EDS format

This additional software tool is embedded in the testing software in agreement with Vector Informatik GmbH. The tool provides EDS checking capabilities, which testing software does not have.

So with the released specifications it was just a matter of time to develop each single piece of software providing the functionality of the conformance testing. To simplify the design of a device description files for every CANopen device to be tested, the software tools were developed for automatic generation of the EDS files. Such tools could include CODB files for already released device profile specifications. Since CODB format represents the object dictionary entries, it can be used to generate/convert the object dictionary entries in various other formats such an EDS one. Due to the fact that object description take the most of EDS file, this effectively saves the time to write the object dictionary entries for EDS file manually. For example a CODB file for CiA 401 can be converted into CiA 401 EDS generic template, which can be modified into CiA 401 digital input device description by just selecting the related CANopen indexes. The EDS generated from such a template would require just to modify the non-object dictionary related parts of EDS format. This also can be automatized by including the EDS format editor in such an EDS generator tool. That said also generation of device configuration files with EDS-based DCF format as well as XML-based device description as specified in CiA 311 were possible. But that is not a topic being considered in this paper.

Furthermore, the object dictionary entries can be retrieved from the CODB format to compare with the provided EDS entries during EDS checking as well as to use in any conformance tests where the operation with the entries is required e.g. read the object content using SDO services. With working EDS checking tool, CODBs and COTI nothing stood in the way of creation of the conformance test tool.

Creation of a CANopen conformance test software

The CANopen conformance test software designed by National Instruments in the version 1.0 was the final result of the test tool development. Then the software was given to CiA for further maintenance and development. Till 2013, CiA used for CiA

conformance testing, the version 2.0. In 2013, a new version, developed by CiA members, was released. This version 3.0 is now the test tool version that is used by CiA office, for CANopen conformance testing. The test tools from version 1.0 to 3.0 allowed to test all CANopen protocols, object dictionary entries as well as the communication state machine (Finite State Automaton – FSA). Also device behavior during its operation can be tested to the certain degree due to the configurable timing constraints for PDO, Error control within the test tool.

With emerging of the new technology such as CANopen FD, the need for testing conformance remain but the new tool capable of handling the CANopen FD traits had to be developed.

CANopen FD designs have to be tested

The test tool for CANopen FD is currently in the stage where the test plan is still in the development. This means the testing of the CANopen FD devices using a CANopen FD test tool will not be possible for a while. To overcome this limitation IG CANopen FD already prepared the test procedure for a manual conformance assessment. Any device manufacturer starting with CANopen FD can use it to pre-test the device for a conformance to CiA 1301. CiA shall use it as a mean for the CANopen FD certification till the test tool is available. The test bench for this time includes the CiA 1301 specification and a test procedure for a manual conformance assessment. So new developed CANopen devices can already be manually tested for conformance to CANopen FD and certified by CiA.
CiA pursues the following CANopen FD testing goals on request from our members:

- Make the transition from CANopen to CANopen FD testing simple and cost-effective;
- Ensure comprehensibility and repeatability of the tests.

To satisfy the both goals, basic principles of the development of the CANopen test bench also used for creation of the CANopen FD test bench. The following items are involved

in a creation of the test bench or used in there to test CANopen FD device conformance:

- CiA 1301, which serves as a base for CANopen FD device conformance testing;
- CiA 1310-1 test plan for a CANopen FD conformance test software (work in progress);
- Device description file in the XML-based format (CiA 1311-1) (work in progress);
- Device's XDD schema validation and checking tool (not yet started);
- Standardized profile databases in XML-based file format (considered).

Based on the listed items, the upcoming CANopen FD test tool (CiA) will support XML-based device description and therefore requires an XDD validation and checking instead of EDS checker. It is unknown though how the XML tool for XDD validation and checking be connected to the test tool software. The creation of CiA 1301 and further CANopen profile databases in CODB file format has not been considered yet.

Similarities and differences between CANopen and CANopen FD testing

To answer the question we should elaborate what is done by now and what is still to do step by step starting with the list of items required for the creation of the test bench.

CANopen FD current testing-related development state

CiA 1301 specifies few mandatory bit-timing settings effectively force testing of all devices with the correct bit timing.

CANopen FD communication FSA provides more details on states and state transitions offering developers a deep view on what FSA does. Thus the testing of FSA is transparent.

CANopen FD testing-related technology migration concerns

Protocols and services such as NMT, Boot up, Heartbeat, and SYNC are not changed in their core therefore their testing does

not differ much from that in CANopen. The same applies to PDO. SDO protocols and services do not exist in CANopen FD, they are replaced with much advanced USDO thus an USDO testing comes additionally into a play. EMCY protocols and services are changed in their core however retaining the CANopen EMCY message structure within the CANopen FD EMCY message therefore additional testing for the changed EMCY behavior is required in comparison to the CANopen testing. Object dictionary in CANopen FD is mostly the same however the key parameters such as device type and error behavior parameters are different now this does not affect testing much though. Yet further EMCY testing is required due to the changed error handling and its parameters (see CiA 1301).

CANopen FD upcoming testing-related features

Introduction of the planned multi-object USDO access or any further USDO protocols and services leads to the specification of further test cases and thus to the modification of the test tool software.

During IG CANopen FD meeting on September 2019 the following was considered on request from CiA business committee "…Therefore all experts are requested to analyze and remove all attributes of CANopen FD that would limit the performance of CAN XL, if CANopen FD would be used as higher-layer protocol". If CANopen FD becomes THE higher layer protocol for both CAN FD and CAN XL, the automatic testing with the test tool become somewhat complex. In that case the CANopen FD test tool before and after CAN XL introduction in CANopen FD will be different. This means two tools have to be maintained to satisfy testing of only CAN-FD-based or only CAN-XL-based CANopen FD devices.

CANopen FD device description current development state

The EDS format is not used for CANopen FD device description. The XML-based device description is used instead.

Technology migration concerns for device description

The CANopen FD XML-based device description remains /ISO15745-1/ compliant as in CiA 311. The device description is reduced to mandatory features of CiA 311. The device description is extended though with CANopen FD specific features such as nominal and data bitrates and data object properties such as USDO access, modification etc. CiA 1311-1 describes the XML-Schema of the CANopen FD devices. The XML components of the schema are described in a table-based form for better readability (see Table 1).

Table 1: Example of XML component description in CiA 1311-1

Component properties		Documentation
Key	**Value**	
name	bitratesAndClock	This attribute indicates the attribute group for supported bitrates and base clock corresponding to each listed bitrate.
component	attribute group	
type	xsd:attributeGroup	
use	required	
multiplicity	4..*	

The schema files are designed but in a standardized XSD file format using "Russian doll" structure as it was done in CANopen XML format specification CiA 311 which is also standardized in ISO15745-1Amd.

Beside that there are very few changes triggered due to CANopen FD specifics (see above). The description becomes pretty slim and targets non-modular CANopen FD devices.

The testing of such a simplified description could prove to be much easier than that of EDS used in CANopen tech-nology. Modular device functions are excluded in the work in progress draft specification.

CANopen FD device description upcoming features

It is not known if any modular device concept will be introduced. It is not known if any other features new or these from CiA 311 will be added.

Development state of CANopen FD parameter databases and their formats
It has not been decided yet in which format the CANopen FD parameter databases will be provided for device description validation and testing as well as a parameter database for test tool software.

Technology migration concerns for CANopen FD parameter databases

Since XML-based device description is used in CANopen FD, the role of CODB parameter databases, designed for CANopen testing in a special VBA-generated csv-similar file format, is unclear. Their re-use in CANopen FD has not yet been decided. Since XML-based file requires a schema validation, a XML-based CiA 1301 parameter database can be used for validated device description and testing device features and parameters.

Additionally XML-based CiA 4<xx>-F<y> parameter databases can be used for testing device parameters against its device description. As mentioned previously, it has not yet been decided which database format shall be used in testing.

CANopen FD test plan current development state

CiA 1310-1 specifies the test cases for CiA 1301 testing in a special format. The test plan is ISO 9646-conform and is structured similar to a CANopen test plan such as device description test, protocol tests, object description tests, and FSA tests. The test procedure description is done also in CiA's pseudo-code. The important difference between CANopen and CANopen FD test description lays in the new test case description format. It contains the test case identification as a unique name and number. Additionally, test case settings and settings for the device under test are provided. The test case procedure is written in atomic steps. Thus, the test tool designer knows what is to program to each step. On the other hand, the user of the test tool software knows what is to expect from the test tool in each test case step and can easily recognize, if the DUT causes the erroneous behavior. Each test

case description provides also an iteration of the whole case or single steps and finally post condition for the testing

The test plan distinguishes between the non-destructive and destructive tests for each protocol or function test. The non-destructive test functionality assumes the correct behavior of the device and destructive one triggers device responses to the incorrect external requests or trigger conditions. Current state is the USDO test case specification for upload and download USDO expedited unicast and broadcast and segmented unicast services. The test cases for other tests were not fully revised. An example of a test case is provided in the figure 2.

CANopen FD test plan migration concerns CiA 310-1 test plan was specified as a very generic one allowing some interpretation and high flexibility for the test programming. CiA 1310-1 on the other hand has clear structure and comprehensive test case description including test purpose and defined information on requirement(s) to be tested. CiA 1310-1 has couple hundred pages more than its CANopen predecessor mostly due to the thorough test case description and page layout but its readability and usability is higher.

CANopen FD test plan upcoming features

SIG testing developing CiA 1310 considers using a scripting language for description of the test cases and as an internal scripting interface in the test tool to allow the user to program specific use cases to test certain functions. Such a language could be Python. There is already a TTCN-3 descriptive language allowing ISO 9646-conform test cases description with communication devices and systems specifics but it is not open source or a fully blown programming language such as Python.

CANopen FD test tool software current development state

The development has not yet been started because the prerequisites are not fulfilled. The prerequisites are a released test plan (CiA

1.1.1 USDO 1.25

illustrates the USDO upload expedited unicast client request to read invalid (nonexistent) data element. illustrates the corresponding USDO upload expedited unicast server response. specifies the test case.
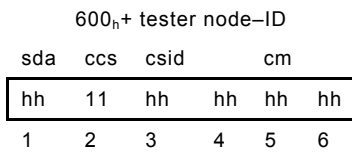
600_h+ tester node–ID

sda	ccs	csid		cm	
hh	11	hh	hh	hh	hh
1	2	3	4	5	6

Figure 1 — USDO upload expedited unicast client request

580_h+ DUT node–ID

cda	scs	ssid		sm		sac
hh	7F	hh	hh	hh	hh	34
1	2	3	4	5	6	7
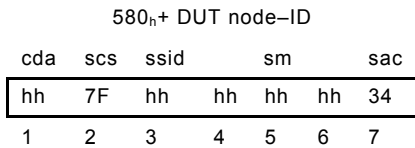
Figure 2 — USDO upload expedited unicast server response

Table 1 — USDO test 1.25

Item	Description
Number – Title	CT_1.1.25-01 - USDO upload expedited unicast with the invalid (nonexistent) data element of the valid (existing) data object
Purpose	This test shall verify the USDO abort protocol unicast if invalid (nonexistent) data element of a valid (existing) data object. (destructive testing)
Reference	/CiA1301/ Version 1.0.0, see sub-clause 8.5.3.3.2
Prerequisites	Input variables: one $sda, one random $crNodeID ≠ $sda, $ccs=$7F_h$, one $ssid ≠ 0, $scs, one $cm data object with the (nonexistent according to XUT) data element.
DUT setup	DUT is in the NMT state pre-operational.
Test case procedure	step 1: Generate request to read a data element {USDO upload expedited unicast request}($crNodeID, $sda, $ccs, $ssid, $cm) step 2: Receive response to the request from step 1 {USDO abort server to client}($crNodeID, $cda, $scs, $ssid, $cm, $sac) step 3: Compare $scs if other than $7F_h$ ERROR step 4: Compare $sac if other than 34_h, ERROR
Test iterations	??Repeat for non–existent (invalid) data element of the existing/non–existing variable/array/record data object. Monitor $sac.
Post–condition	DUT is in the NMT state pre-operational.
Notes	

Figure 2: Example of a test case procedure in CiA 1310-1

1310-1), optionally test tool implementation hints, derived from CiA 1310-1, a released XML-based device description (CiA 1311-1), a released CiA 1301 profile database (CiA 4xx profile database, not yet discussed).

At the moment, it is also unknown, if the test tool has to be loosely coupled from the hardware interface(s) or not.

CANopen FD test tool migration concerns

The migration path is still unknown. CiA business committee has not decided yet, if the test tool will be bound or not to the hardware interface(s), so the fate of COTI is yet unknown.

CANopen FD test tool upcoming features

It has not been decided yet what the features will be. A scripting interface to design own tests could be useful. Test tool internal error messages should be provided somewhere. Test tool user manual is necessary to understand what is the test tool doing. Testing of Safety devices, modular devices is not ensured since no such functionality is currently specified.

Summary

The CANopen FD test bench is a work in progress. The test tool for CANopen FD is currently in the stage where the test plan is still in the development but IG CANopen FD provides a manual test procedure to use for testing in the meantime.

Meanwhile, the test plan is being specified in CiA 1310-1, the device description in CiA 1311-1. The approach to the design of the test plan is slightly different than in CANopen. The unique test cases with atomic steps are being designed for tests. The end user can compare the test results up to the single test case step. The test cases will offer comprehensibility and repeatability and so will do their implementation in the test tool.

References

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[5]   CiA 1301, Version 1.0.0, CANopen FD application layer and communication profile

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