Conformance Test of In-Vehicle Communication Protocols – Why?

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ABSTRACT

Actually automotive industries is in a dilemma: Further customer satisfaction requires further features to be built into cars and this requires more electronics in cars. All this currently happens at a rapidly increasing pace thus increasing networked cars electronic control systems complexity correspondingly. Networking obviously requires interoperable communication modules consisting of communication hardware and software. And here is the problem: As network protocols are specified mostly in natural languages such as English, no precise and non-ambiguous specification exists. For this reason, implementers may understand the same specification differently. And as a result the implementation of the same protocol may behave differently under certain operational conditions. As a consequence mixed suppliers control modules may not be able to communicate properly.

Conformance testing is the solution to this problem. The following paper explains the general procedure on how to derive conformance tests under the constraints of verbal non precise device specification. All this is explained with the example of deriving and implementing tests for CAN protocol transceivers. C&S Group developed a more general procedure to derive tests and methods to implement them on the basis of a standard ISO tester architecture. Last but not least a road map is given on the conformance tests implemented for various vehicle communication protocols by C&S Group.

INTRODUCTION

Networking nowadays is a standard technology applied in cars. There are various kinds of communication protocols applied, each meeting the different application requirements in terms of safety, body electronics, power train, x-by-wire, etc. The goal of networking is to provide a means to exchange variables between distributed control applications. As such a door controller may read the position of a switch and exchange the proper value with the seat positioning controller thus moving the seat properly. Obviously controllers are provided by various module manufacturers communication modules which are supplied by various software and hardware manufacturers. Given that the final user expectation would be that all these applications can communicate with no problems it is essential that the underlying communication components are all “interoperable”.

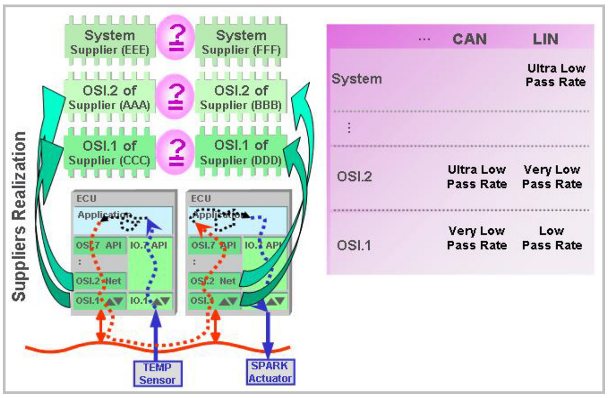
But interoperability of communication components may be a problem: Although standards exists in SAE and ISO very often these standards are not precise enough. Standards are mostly written in natural languages thus containing specifications which are ambiguous, incorrect or contradictory. Taking this into account there is a high risk that mixed components networked systems may end up in communication problems. This is even more true today, as networks tend to integrate plenty of nodes, i. e. 30 and more within one network branch.

A very effective countermeasure to this dilemma are conformance tests, checking the properties of components against a “well defined” set of test cases and thus ensuring that different suppliers’ devices are properly interoperable under operational conditions as specified by the tests.

Over recent years various efforts have been undertaken to specify and implement such kind of interoperability tests. C&S Group has been working on such tests for various protocols such as CAN, eBUS, TTCAN, FlexRay, LIN, etc. In the meantime some of the specifications have become standards such as ISO 16845 CAN (layer 2) Conformance Test.

DISTRIBUTED SYSTEMS WITH MIXED SUPPLIERS COMPONENTS REQUIRE INTEROPERABILITY/CONFORMANCE TESTS

Figure 1 depicts the typical problem in distributed systems: As corresponding layers – this is demonstrated with the OSI communication layers – in distributed systems are typically composed from various suppliers, the question arises whether the corresponding layers behave “similar”. As the specifications given are usually not precise – mostly they are given in a non-precise natural language – there is a high risk that corresponding layers, which are sourced by different suppliers may not be compliant. Especially fig. 1 demonstrates drastically how high the risk of non-compliance and thus interoperability problems is: Most of the implementations of suppliers do not pass the first test run. What if no conformance tests had been applied!?



	...	CAN	LIN
System			Ultra Low Pass Rate
⋮			
OSI.2		Ultra Low Pass Rate	Very Low Pass Rate
OSI.1		Very Low Pass Rate	Low Pass Rate

Figure 1: OSI COM Layers – Interoperable?

Having these bad experiences in conformance testing in mind, obviously these tests are a must in order to enhance electronic system quality.

As a consequence these considerations are applicable to any supplied module which may be characterized as follows:

- The module is applied in distributed systems as a corresponding module in different systems nodes
- This module is expected to provide a corresponding, distributed behavior in the various nodes.
- This module typically will be sourced by different suppliers.

In the following the basic conformance test technique is described in general, based on the C&S developed methodology SOVS = System Operational Variable Space. It will be explicitly explained with the example of CAN Protocol Transceiver Tests.

CONFORMANCE TESTS SPECIFICATION – BASIC TECHNIQUE

Baring in mind the constraint of insufficiently specified components and the requirement that these components should be interoperable, one way out of this dilemma is to apply “sufficiently exhaustive” conformance tests to verify the desired interoperability of components. As no sufficiently detailed and formal description of the component exists a so called Black Box Test Technique is applicable. Test stimuli are applied from outside of the component – which is referred to as Implementation under Test IUT – to the accessible inputs, the responses are read from the outputs of the IUT and compared to what is understood from the specification.

In a first step**,** in order to derive a first guess of a sufficiently exhaustive set of test cases an empiric driven selection of a set of test cases, representing practical conditions under which a component would work later on, is a recommendable practical approach. In a second step, the individual elements of the above set are organized in such a way that they would each result in the parameterized product of a set of – mostly desired – orthogonal vectors. These vectors may be defined application driven. The parameterized product of the vectors defines the so called System Operational Variable Space – SOVS, comprising all possible operational conditions - known so far - under which IUT is expected to be functional in the specified way. In a third step**,** a subset of the SOVS is selected empirically, driven from application experience, or even formally. This subset is then expected to be Sufficiently Exhaustive Minimal Set of (conformance) Test Cases

SEMSTC on one hand, while comprising not too many test~~s~~ cases on the other hand resulting in a still acceptable test time.

Obviously the approach mentioned above is a practically viable procedure to derive a sufficiently exhaustive set of test cases. But this procedure of course incorporates the risk that the selected subset of tests does not sufficiently cover the behavior of the component. There are several ways to optimize the selection of test cases – see below:

- The selection of the of SEMSTC should be supported by formal methods
- The application of the SEMSTC in conjunction with the practically gained experience, that in real application cases it is detected that tested components show deficiencies in their desired interoperability, will lead to an iterative optimization process influencing the re-specification of the test cases and the component. The newly detected problem is analyzed leading to:
    - A redefinition of the SOVS, their parameters and SEMSTC in such a way that the new case systematically is a member of the sets mentioned above.
    - A redefinition of the component specification leading to a more precise, more detailed, more formal result, without necessarily being too stringent to the implementers. Based on that, "more" formal methods could be applied to derive tests which would then lead to a better SEMSTC. The Black Box Test Method would then turn more into a Gray Box Test Technique.

CONFORMANCE TESTS SPECIFICATION – EXAMPLE: CAN TRANSCEIVERS

The Transceiver is the interface between the analog signal transmission over the physical communication media and the digital "world" towards the higher OSI-layers. The latter could comprise – as ~~it~~ is the case for CAN – lines for digital signals such as Receive_Data, Transmit_Data, Error_Signal, etc. Towards the physical media there may be analog lines such as CAN_High, CAN_Low, etc. The redundancy of these lines is used for differential mode signal transmission which provides a good means for high common mode noise injection immunity. In case of a failure – short circuit or broken wire – the redundancy is used together with the failure detection mechanism of the fault tolerant transceiver, to switch off the defect line, communicate with a reduced signal to noise ratio and signal the error to higher layers. Finally there are power supply lines that supply the component with energy. There are means provided to switch the component from normal mode into low power or power off mode. For more details refer to [4].

SYSTEM OPERATIONAL VARIABLE SPACE - As an example for the purpose of doing interoperability tests on standard transceiver components a SOVS is given, derived from experience, see table 1. This experience has been gained from practical applications at the automotive companies sites' and the experience in testing and organizing tests within the research work at C&S Group.[1] For further details refer to [5], [6].

Transceiver-SOVS =	{ System Configuration } x { Communication } x { Power Supply } x { GND Shift } x { Op. Modes } x { Failure }

Table 1:
Transceiver System Operational Variable Space

The individual vectors can be broken down into parameters as shown in tab. 2.

System Configuration	
Baud rate	.... 5 kBd ...... 125 kBd
Termination	Calculated total termination = ... 100Ω ......
Topology	Bus, ring, star, mesh, ...
Composition	Homogeneous, heterogeneous (ratio), ...
Number of nodes	1, 2, ...40, ...
Environmental conditions	Temperature (...20°C...), moisture, shock, ...
......	

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[1] Funded to C&S Group as a research grant by Audi, BMW, DaimlerChrysler, PSA, Volkswagen

Communication	
Nodes' interaction	• Logical ring: • node x receives token • node x transmits token to node x+1 • after 1 cycle all nodes transmit 1 message leading to an arbitration conflict • ... • Arbitrary communication .... • ....
Identifier	Any, special, ...
Data	Any, nodes reference, ...
......	

Power Supply	....

Ground Shift	....

Operational Modes	....

Failure	

Single bus failure	• no failure
	• short circuit:
	  • CL_Vx(up)@Rx with:
	    • Vx = [.. -3V .. +18V ..]
	    • Rx = [.. 0Ω .. 50kΩ ..]
	  • CH_Vx(up)@Rx
	  • ....
	• open circuit:
	  • CL_OW@Rx(up)
	  • CL_OW@Rx(down)
	• ......

1,5 bus failures	• apply CL_BAT + CL_CH then remove CL_BAT • apply CL_GND + CL_CH then remove CL_GND • ...
2 bus failures	• apply CL_BAT + CL_CH • apply CL_GND + CL_CH • ...
n bus failures	• ...
Location of failure	At node 1, 2, ...
....	

Table 2:
System Operational Vectors and their Parameters

SUFFICIENTLY EXHAUSTIVE MINIMAL SET OF TEST CASES - The individual test cases then would result from – theoretically – the combinatorial product of any set of values assigned to the parameters defining the vectors. Apparently this would lead to a very large number of test cases which would be difficult to execute in a reasonable amount of time. Therefore a reduced subset of vector ranges must be carefully selected. This selection is empirically driven from experience, reducing the combinatorial product to a "realistic worst case" test scenario SEMSTC. In this case the group of automotive companies funding the C&S research work agreed on the following reductions:

- System Configuration = constant standard network with 100 kBd, .. , 40 nodes, ..
- Communication = constant standard with a fixed functionality logical ring communication ….
- Failure = reduced parameter sets such as: single and 1.5 failure types only, location of failure between node 39 and 40, …

In this case the number of combinations shrinks down significantly because the are only 4 of the 6 vectors to be varied combinatorially as 2 of the vectors are kept constant. Furthermore the numbers and the variation range of the parameters have significantly shrunk. All this led to the final specification of transceiver conformance tests; for more information see [5].

Table 3 shows a typical example for a test~~s~~ case specification "Test case 4.3.6.7: CH_Vx(down)@Rx". This case checks the behavior of the IUT in case of a short circuit failure. Therefore the IUT first is set into an initial state (repetitively) in which a specific condition is applied to the IUT: short circuit resistor and voltage against which the short circuit is applied. Then the actual test step is applied, which is a standard communication round, passing a token from one node to the next throughout the standard test network. After each test step(s) the behavior of the network is checked, i.e. if an error is detected by the transceiver and into which state it is switched. The responses read are compared to the operational requirements and thus a decision is taken whether the test has passed or failed.

All the individual tests are specified to be carried out as so called homogeneous tests. This means, that all tests as specified above are carried out on a homogenous standard network which consists of 40 nodes with all transceivers being of the same brand. Then a second test run is performed with a first step inhomogeneous standard network where the specific transceiver under tests is checked with regard to its interoperability against a so called “golden node transceiver”, which currently is a Philips 1054 type. Finally a third test run is executed in an inhomogeneous standard network, where the device under test is mixed with 3 other types of transceivers. This gives an additional higher degree of confirmation of interoperability of mixed systems proper operation.

Typically set up and execution of these tests takes approximately 2 months. In order to shorten the time for the first feed back to the semiconductor manufacturer within a time frame of one week a first rough run through a shortened set of homogeneous tests is performed. As such some (mayor) deficiencies or malfunctions may be detected in an early phase and the semiconductor manufacturer may already work on corrections of the device at this early point of time.

TESTER IMPLEMENTATION – The principle of the realization of the tester is then shown in figure 2: A tester supervisor – typically a PC – holds all the software for the test cases and the software to perform offline check of test results with the required operation. Furthermore the supervisor controls the so called upper and lower tester which serve as the interfaces towards the device under test. These interfaces implement all the physical signal adaptation as well as the time buffering. As such they contain e.g. the programmable devices to provide the varying short circuit resistors, the correspondingly varying voltage generators, the memorizing oscilloscopes, etc. The IUT finally is implemented through a standard network of 40 nodes. Each ~~nodes~~ contains one transceiver – IUT – which itself communicates with a CAN node and a micro controller. The micro controller runs part of the upper tester software which implements the token passing mechanism, the signal evaluation logics and the communication path to the supervisor.

<table>
<tr><td rowspan="3">Constants</td><td colspan="2">Power Supply = 12V / GND Shift = 0V / Op. Mode = Normal</td></tr>
<tr><td>Test procedure:</td><td>Short Circuit Failure (CL_Vx, CH_Vx)</td></tr>
<tr><td>Operating area:</td><td>Short Circuit Operating Area</td></tr>
<tr><td>Initial State</td><td colspan="2">
System Configuration: constant as specified in <i>Standard Net</i>
Communication: constant as specified in <i>Standard Net</i>
Op. Mode : Normal Mode
Power Supply: 12V
GND Shift: 0V
<u>resistor range for error generator R/U:</u>
rx_start : 0Ω
rx_stop : 50KΩ
rx_next : depending on steps
<table>
<tr><th colspan="2">range</th><th>step</th></tr>
<tr><td>0Ω -</td><td>10Ω</td><td>1Ω</td></tr>
<tr><td>10Ω -</td><td>50Ω</td><td>5Ω</td></tr>
<tr><td>50Ω -</td><td>250Ω</td><td>10Ω</td></tr>
<tr><td>250Ω -</td><td>1.000Ω</td><td>50Ω</td></tr>
<tr><td>1.000Ω -</td><td>10.000Ω</td><td>1.000Ω</td></tr>
<tr><td>10.000Ω -</td><td>50.000Ω</td><td>10.000Ω</td></tr>
</table>
<u>voltage range for error generator R/U:</u>
vx_start : 16V
vx_stop : -3V
vx_next : depending on steps
<table>
<tr><th colspan="2">range</th><th>step</th></tr>
<tr><td>16V -</td><td>-3V</td><td>0.1V</td></tr>
</table>
</td></tr>
<tr><td>Test Steps</td><td colspan="2">execution of communication as specified in <i>Standard Net</i></td></tr>
<tr><td>Response</td><td colspan="2">test results must match the operating areas as defined for short circuit failures</td></tr>
</table>

Table 3: Test Case “Short Circuit”

All tests are executed fully automatically. This is a very important feature for any conformance tests as such tests do not depend on the actual condition of a tester person and his capability to observe and evaluate test measurement results. As such, repeatability of tests is ensured at any time and any place. The results are all registered on the PC. If a problem has occurred the operator of the tester is alarmed to check the problem and communicate it to the supplier of the IUT. Along with that the actual test scenario is delivered which informs the manufacturer of the possibly faulty component and enables him to check for the problem and take countermeasures. At the end a final test report is produced by the tester which together with a summarizing Authentication Report is handed over to the manufacturer of the component.

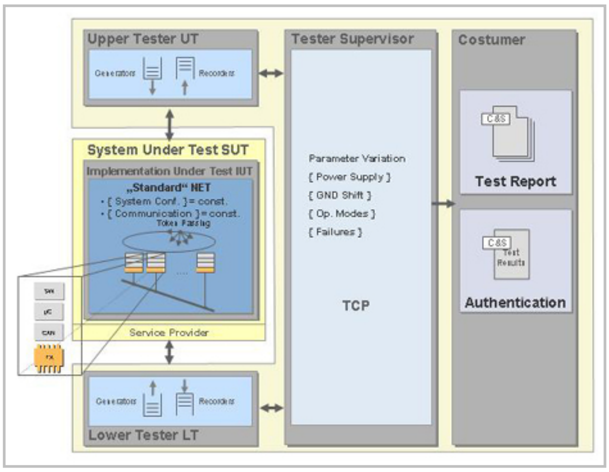


Figure 2a: Transceiver Tester Architecture

Figure 2b: Transceiver Tester Implementation

CONFORMANCE TESTS – FURTHER OSI-LAYERS AND PROTOCOLS

Specification of conformance tests and the design of the corresponding tester as it is done at C&S Group follows a very straight forward and well structured process.

CONFORMANCE TESTS SPECIFICATION – Given the constraints above that the specification of the device under tests – DUT – typically is given in a verbal manner, the following procedure is basically the standard principle and process applied by C&S:

1. Definition of System Operational Variable Space
    - Preface:
        - All the following definitions and specifications are of course derived from the specification of the behavior of the device under test – DUT.
        - If this specification shows deficiencies, ambiguities, incorrectness~~'s~~, contradictions, etc. additional specifications through SOVS must clarify the problems.
        - As the latter refinement / enhancement step is very essential to the interoperability of a "standard" component this critical procedure must always be done in consensus with a group of involved and competent partners, i.e. a standardization~~s~~ organization or a corresponding group.
    - Definition of vectors of SOVS for DUT
    - Definition of relevant parameters for each vector
    - Definition of value ranges for all parameters
    - Definition of responses of DUT
2. Definition of Sufficiently Exhaustive Minimal Set of Test Cases
    - Definition of a reduced, practically "sufficiently" worst case value range of parameter values
    - Specification of granularity of steps "practically" sufficient to check variable~~s~~ ranges of parameters
    - Derive individual test cases and specify them in a (semi-) formal repetitive form based on a standard procedure:
        - Specify test environment constants
        - Specify set up step, which initializes the device under test into a well defined internal state
        - Specify a (or a sequence of) test step(s)
        - Specify the required responses of DUT
3. Update of test specification
    - Field experience typically observes special cases where the observed behavior may deviate from expectation and requirements. If these cases can be reproduced and if they can be considered relevant to the operational area of the devices then correspondingly modified and/or further test cases must be specified. As this

procedure is very sensitive towards the mixed systems interoperability standards, a group's consensus – as said above – is a must before modifications are introduced.

- Field experience is typically reported to the C&S group for further process by:
  - automotive manufacturers and suppliers systems experience
  - semiconductor manufacturers experience
  - C&S test executions and networked system design.

CONFORMANCE TESTS IMPLMENTATION – The conformance tester itself consequently realizes in a structured way the above mentioned specification of the tests

1. Analysis of the functional and performance requirements of all individual tests
2. Group the test cases into classes with
   - High time resolution requirements
   - Medium time resolution requirements
   - Low time resolution requirements
   - Off line parts of the tests. This typically comprises test case generation and evaluation of the observed results of the tests
3. Assume a standard tester architecture corresponding to ISO 9694 Coordinated Test Method to be applied for implementation of the tests. This consists of the following 3 levels – see fig. 2 and 3:
   - Supervisor, which typically is a PC. The PC can be considered as an off-line device as compared to the real time requirement given by the test cases' specification. As such the PC:
   - stores all the test cases
   - controls and downloads the test stimuli to the upper and lower testers
   - stores all the test results delivered by the upper and lower tester
   - evaluates the results of the test measured with the results required and thus prepares the final test record with the detailed and global results "test failed/passed".
   - upper tester, which is the "upper OSI layer" interface between the DUT and the supervisor. This interface must provide the correspondingly required electrical and real time capabilities.
   - lower tester, which is the "upper OSI layer" interface between the DUT and the supervisor. This interface must provide the correspondingly required electrical and real time capabilities.
4. Map the classes onto the above mentioned blocks of the standard tester architecture consisting. This process shall be guided by the constraints in order to facilitate the design and achieve optimal flexibility, minimum development costs and best quality:
   - Shift as much functionality as possible into software, running on standard hardware for the supervisor, the upper and lower tester
   - Apply standard off-the-shelf hardware for the implementation of the required features and real time constraints. Standard hardware typically is a PC and measurement tools such as programmable data generator and analyzers, voltage generators, oscilloscopes, etc. Standard Communication between the blocks should be implemented on standard protocols such as Ethernet, IEC 488, etc.
   - Minimize the hardware to be designed especially for this purpose
5. All tests are executed fully automatically. This is a very important feature for any conformance tests since then such tests do not depend on the actual condition of a tester person and his capability to observe and evaluate test measurement results. As such repeatability of tests is ensured at any time and any place while a good quality is guaranteed.

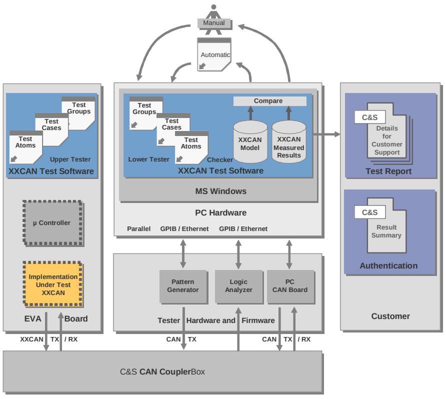


Figure 3a: C&S CAN Tester Architecture

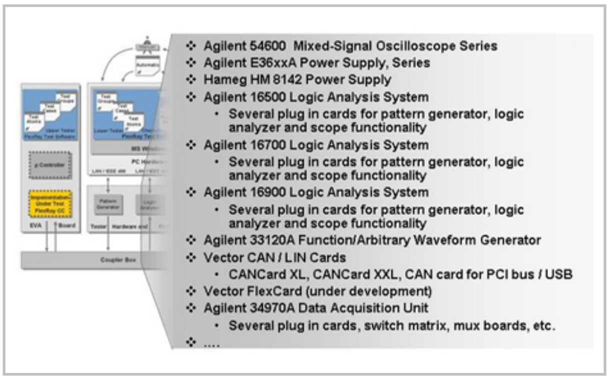
Figure 3b: C&S CAN Tester Implementation

CONFORMANCE TESTS IMPLEMENTATED AT C&S – In 1995 C&S group was founded at the University of Applied Sciences in Wolfenbuettel, Germany. This was due to Motorola, charging C&S with a first research project to specify and implement the first time conformance tests for CAN OSI layer 2. This project – especially together with Robert Bosch GmbH and Dassault Electronique - finally lead to the actual ISO CAN test standard ISO 16 845. In the meantime C&S has evolved into the mostly required test site world wide. Some automotive manufacturers do not accept CAN devices delivered by their module supplier unless they have been tested by C&S. Furthermore C&S has been asked to re-use its communication protocol conformance test knowledge to apply it to other CAN OSI layers and to other types of protocols. All of these activities have been done in very close cooperation either with automotive manufacturers and/or semiconductor manufacturers.

As such, for instance the Low Speed Fault Tolerant CAN Transceiver Tests have been developed in the ICT consortium under the support of Audi, BMW, DaimlerChrysler, PSA and Volkswagen; the High Speed CAN Transceiver Tests have been sponsored by Ford_US, a further High Speed Transceiver Test will be specified in the ICT group. The TTx protocol tests are done in cooperation with semiconductor manufacturers. LIN tests are specified under the umbrella of the LIN Consortium and in special cooperation with car and semiconductor manufacturers. Further protocol tests have been developed for instance for eBUS protocol together with corresponding industries; others on request.

The high quality requirements to the test house, regarding conformance tests can only be met, if the following conditions apply:

- High volume of test experience – C&S provides more than 10 years of experience with a volume of more than 20 man*years of expertise
- Systematic approach to specify the required test cases – C&S SOVS methodology
- Test tools must be based on a systematic re-use basis – C&S tools architecture shown in fig. 3a follows the ISO test standard ISO 9646. The C&S implementation strictly applies remotely programmable, calibrated, standard off-the-shelf measurement tools in conjunction with a well structured test control architecture; see fig. 4 a and 4b.



- Agilent 54600 Mixed-Signal Oscilloscope Series
- Agilent E36xxA Power Supply, Series
- Hameg HM 8142 Power Supply
- Agilent 16500 Logic Analysis System
  - Several plug in cards for pattern generator, logic analyzer and scope functionality
- Agilent 16700 Logic Analysis System
  - Several plug in cards for pattern generator, logic analyzer and scope functionality
- Agilent 16900 Logic Analysis System
  - Several plug in cards for pattern generator, logic analyzer and scope functionality
- Agilent 33120A Function/Arbitrary Waveform Generator
- Vector CAN / LIN Cards
  - CANCard XL, CANCard XXL, CAN card for PCI bus / USB
- Vector FlexCard (under development)
- Agilent 34970A Data Acquisition Unit
  - Several plug in cards, switch matrix, mux boards, etc.
- ….

Figure. 4a: Modular tester implementation based on standard, calibrated measurement tools

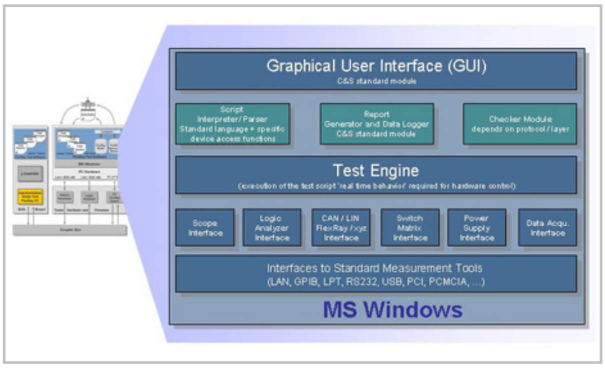


Figure 4b: Modular tester implementation based on strictly structured software modules supervisor schematics

Tests are all performed in real time. That is why a high number of tests can be executed in a rather short time frame, usually in less than 2 months. This is the reason why simulation phases, which typically have been carried out at the semiconductor manufacturer's site and which are supposed to be quite exhaustive, cannot cover as many test cases as testing which is carried out in real time. The difference is in the range of several tenth of orders of magnitude. Therefore the devices under test – DUT – must be provided so that they can be run in real time. Therefore typically device manufacturers supply test modules either in an early design phase in an emulated form, for instance in an emulator box – such as Quick Turn Box – or as an FPGA-based implementation. As testing includes a customer coaching process possible malfunctions are discussed with the supplier who then can easily modify his implementation and deliver an updated solution for the continuation of the test procedure. The final test though typically is carried out on (first) silicon.

CONFORMANCE "?" TESTS – WIRING TOPOLOGIES COMPLIANCE

Another area of high criticality is the "compliant" layout of the wiring harness. Various suppliers' transceiver characteristics combined with different OEMs electronic coupling circuits and related wiring topologies very often lead to unexpected behavior of the physical communication, if the manifold of parameter tolerances and shifts over time, temperature, etc. have not been considered sufficiently. Therefore, C&S has been developing since 1999 a simulation technology based on MAST and VHDL-AMS language to simulate the signal communication behavior upfront and verify it in technical mock ups; see fig. 5.

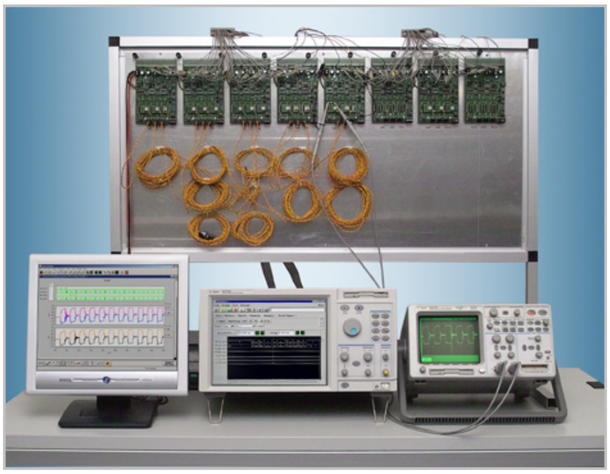
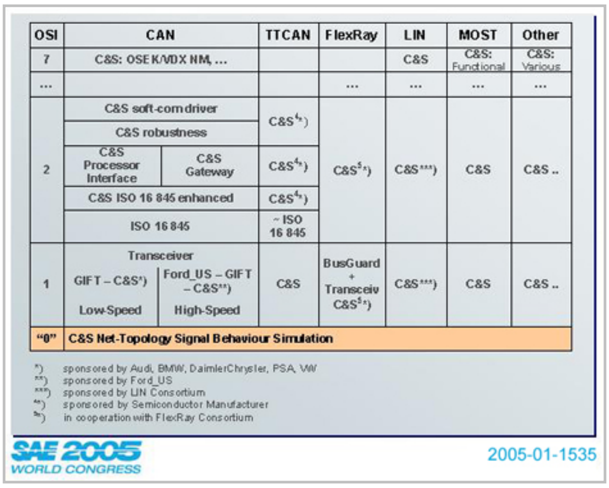


Figure. *5*: C&S Tester Realization – Signal Analysis for LIN, CAN, FlexRay…Transceiver-Topologies

Within the next years C&S may be able to work through the industrial standardization group GIFT – Audi, BMW, DC, PSA, VW, Ford, Infineon, Freescale, Philips, STMicroelectronics, and invited guests such as Bosch, Renault, TI, Maxim, etc. – towards standardized ways to judge the quality of a wiring harness up front.



OSI	CAN		TTCAN	FlexRay	LIN	MOST	Other
7	C&S: OSEK/VDX NM, ...				C&S	C&S: Functional	C&S: Various
...				...	...	...	...
2	C&S soft-com driver		C&S^{4}*)	C&S^{5}*)	C&S***)	C&S	C&S ..
	C&S robustness						
	C&S Processor Interface	C&S Gateway	C&S^{4}*)				
	C&S ISO 16 845 enhanced		C&S^{4}*)				
	ISO 16 845		~ ISO 16 845				
1	Transceiver GIFT – C&S*) Low-Speed	Ford_US – GIFT – C&S**) High-Speed	C&S	BusGuard + Transceiv C&S^{5}*)	C&S***)	C&S	C&S ..
"0"	C&S Net-Topology Signal Behaviour Simulation						

*) sponsored by Audi, BMW, DaimlerChrysler, PSA, VW
**) sponsored by Ford_US
***) sponsored by LIN Consortium
^{4}*) sponsored by Semiconductor Manufacturer
^{5}*) in cooperation with FlexRay Consortium

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The actual C&S capability in protocols conformance testing is shown in table 4.

Table 4: Overview on Existing Communication Protocol Conformance Tests

CONCLUSION

Conformance testing is a good way – and maybe the only way – to actually safeguard interoperability in networked systems with mixed suppliers' communication modules~~,~~ since a mixed suppliers' modules system is a must from the OEMs' point of view~~,~~ because of their second source policy.

Although conformance tests specification and the related tester implementation are living from the engineering genius and practical experience, the back bone of the process is based on a very structured approach, the System Operational Variable Space. As such the overall procedure is a mix of an empiric and systematic process.

The reason to all this is due to the dilemma that there does not yet exist a "precise" specification of the device to be tested. The solution could be to require formal, executable specification from which in an automatic, formal process test cases could be derived. Although nevertheless this is a very desirable situation because of many reasons, it bears several problems. Very often first inventers of a new solution do not want to be too clear outside of their company. They want to maintain their advantage against their competitors as long as possible; by the way, this is a push-pull situation because standardization of communication interfaces of course requires an "open" standard as soon as possible. Furthermore formal specifications do not guarantee that some "clever" implementers realize some features in an optimized way which un-willingly results in possible interoperability conflicts. This has been the case for instance with OSEK/VDX Network Management implementations. Although the underlying specification is written in a formal language, C&S group detected some severe problems in OSEKs derived test specification.

Summing up the recommendation for future progress towards an easier way to interoperability would be to go both ways in parallel: Try to achieve formal, executable specifications for the devices. Derive from there on one hand test cases automatically. On the other hand apply the SOVS process with reduced test vector findings while shrinking the vectors parameter ranges to the "practically" sufficient worst case. Superimpose both results. Enhance them continuously by further test cases derived from special observations from practical systems applications.

As a result test specifications must be published as a standard. Furthermore these standards are obviously "living" standards, as they tend to be updated, modified, enhanced by experience.

Looking at the test cases for a device from another view angle, they could be taken as another type of specification for the component itself. Whenever device manufacturers enter the design process they usually ask for the test specification in advance. Baring this in mind test cases' specification should conform to the device specification itself. Therefore both ways correspondences should be maintained at all times. Consequently this implies that device standards would be "living" standards, too. How can we cope with that in our "traditional" standardization process ?!

REFERENCES

[1] W. Lawrenz: Networked Systems High Level Design & Test Philosophy and Tools; SAE Conference and Show Detroit, paper 950296, 27.03. - 03.03.95

[2] W. Lawrenz, editor: CAN - Controller Area Network from Theories to Application; Springer Verlag, 1997, ISBN 0-387-94939-9

[3] ISO 11898 Road Vehicle – Controller Area Network (CAN), part 1; International Standard ISO 11898, 1999

[4] Specification of a Fault Tolerant CAN Transceiver; GIFT Working Group (Audi, BMW, DaimlerChrysler, PSA, Volkswagen, Infineon, Motorola, Philips, STMicroelectronics), chaired by C&S group at Fachhochschule Wolfenbuettel, Germany, 2000, www.cs-group.de

[5] Test Specification for a Fault Tolerant CAN Transceiver; ICT Working Group (Audi, BMW, DaimlerChrysler, PSA, Volkswagen, Infineon, Motorola, Philips, STMicroelectronics), chaired by C&S group at Fachhochschule Wolfenbuettel, Germany, 2001, www.cs-group.de

[6] M. Scheurer: Entwicklung einer Methode zur systematischen Ableitung von Testfällen für Konformitätsprüfungen in der Informationstechnologie ; Diploma Thesis at Fachhochschule Wolfenbuettel, C&S group, Germany, July 2000

[7] Abramovici, M.A. Breuer, A.D. Friedman: Digital testing and testable design; Computer Science Press, 1990.

[8] A.L.Courbis, J.F. Santucci, N.Giambiasi : Automatic Behavioral Test Pattern Generation for Digital Circuits; 1st IEEE Asian Test Symposium, Hiroshima, Japan, November 1992, pp. 112-117

[9] S.J. Chandra, J.H. Patel: Experimental evaluation of testability measures for test generation; IEEE Trans. On CAD, Vol. 8, N°1, pp.93-97, January 1989.

[10] Z. Manna, A. Pnueli: How to cook a temporal proof system for your pet language; Report n°STAN-CS-82-954, Department of Computer Sciences, Stanford University , USA, 1982

[11] K.T. Cheng, A.S. Krishnakumar: Automatic functional test generation using the Extended Finite State Machine Model; 30th ACM/IEEE Design Automation Conference, USA, 1993

[12] M. Larnac, V. Chapurlat, J. Magnier, B. Chenot: Formal Representation and Proof of the Interpreted Sequential Machine Model; EUROCAST'97, LNCS 1333, Springer, Las Palmas de Gran Canaria, Spain, 1997

[13] J. Magnier: Représentation Symbolique et Vérification Formelle de machines séquentielles; State Thesis University of Montpellier II, France, 1990

[14] K. Hoffmeister: Applikations- bedingte Kommunikationsanfor-derungen im verteilten Kraftfahrzeug-Echtzeitsystem und deren Testbarkeit; Diploma Thesis at Fachhochschule Wolfenbuettel, C&S group, Germany, July 2000

[15] W. Lawrenz, Anne-Lise Courbis, Janine Magnier: Car System Conformance Testing, International Conference Systems Engineering and Information&Communication Technology, Nimes TIC 2000, September 2000

[16] W. Lawrenz: Signal Behaviour on Complex Topology Communication Networks; SAE Convergence Conference, Detroit, 18. - 21.10.2004.

[17] W. Lawrenz et al.: LIN Protocol Conformance Tests ; paper no. 2005-01-1535, SAE 2005 World Congress, 11.-14.04.2005

[18] C&S: System Operational Variable Space; internal C&S report

[19] GIFT standardization group: Pre-standardization on physical layer issues; see *www.cs-group.de*

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