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CAN Conformance:

Methodology and Tools.

ABSTRACT

The development of distributed architectures that rely on communication protocols for data exchanges between remote ECUs produced by different equipment manufacturers, sets new problems for car manufacturers who have the responsibility of the whole system.

At each communication level, the car manufacturers have to be sure that the protocol implementations are compliant with the chosen standard.

The CAN standard is a Data Link Layer protocol generally implemented in ASICs. So, there is a need for tools verifying during the design process that all the components produced, today and in the future, by a lot of different silicon suppliers, are and will be compliant with the CAN standard.

AUTOMOTIVE NETWORKING

In Western Europe, more than 13 million cars are built every year. Modern vehicles require an increasing amount of electronics especially to implement safety and comfort functions. More and more formerly mechanical functions are now replaced by electronic systems.

As the electronic systems grow in number and complexity, the duplication of resources in different pieces of equipment (ECUs : Electronic Control Unit) becomes costly and the requirements on powerful communication mechanisms and on-board networking become obvious.

After having equipped a limited number of cars, all the European car manufacturers are now fully committed to use networking technologies for the new car generations. The potential market for nodes is therefore very high and the future electronic systems will be significantly influenced by this technology.

The European industry has a leading position in this field since the CAN standard has been chosen by the majority of car manufacturers for different types of applications. Beyond the automotive world, this kind of network finds increased interest in the sensor / actuator field for industrial applications. The number of companies, around two hundreds, that participate in organisations like the CiA (CAN in Automation) is a clear proof of this interest.

THE NEED FOR CONFORMANCE TESTING

One of the main advantages of the multiplexed wiring resides in the fact that the CAN protocol used in that frame, is becoming a world-wide standard used by the majority of the car manufacturers.

Contrarily to the multiple types of intersystem links more or less complex between the different ECUs in a car (digital I/O, PWM I/O, Analog I/O, KWP2000, ...), where it is possible for the equipment manufacturers to meet one specification (so one standard) by link and by car manufacturer, the CAN allows to reduce this diversity to just one and unique standard.

However, car manufacturers have to work with different equipment manufacturers to develop their own ECUs. And these same equipment manufacturers themselves have to work with different silicon suppliers.

In these conditions, where several different companies interfere at different levels of the communication protocol (physical layer, Data Link Layer, transport layer, interaction layer), car manufacturers, who have the responsibility of the whole systems, need to guarantee the perfect interoperability of the different ECUs connected on the network.

De facto, the car manufacturers have to be sure that the protocol implementations are compliant at each communication level. The first step to provide this conformance is the availability of a clear and unambiguous specification of the standard protocol. The following step is the possibility of verifying and certifying the implementation of the protocol. Since the CAN standard is a Data Link Layer protocol generally implemented in ASICs, this by more and more various silicon makers using different design tools, there is a need for conformance tools allowing verifications during the main steps of the design process and guaranteeing the conformance with the CAN standard of all produced components, today and in the future.

For these reasons, it is necessary to develop a methodology and the associated tools allowing car manufacturers to have interoperable equipment and silicon founders to develop compliant components used with these pieces of equipment.

THE CAN CONFORMANCE TESTING METHODOLOGY

The selected methodology has been based on a very pragmatic approach that can be directly used by the automotive industry. This methodology ensues the three following steps (see figure 1):

- The Test Plan document definition,
- The Test Plan CAD implementation,

- The Conformance Tester design.

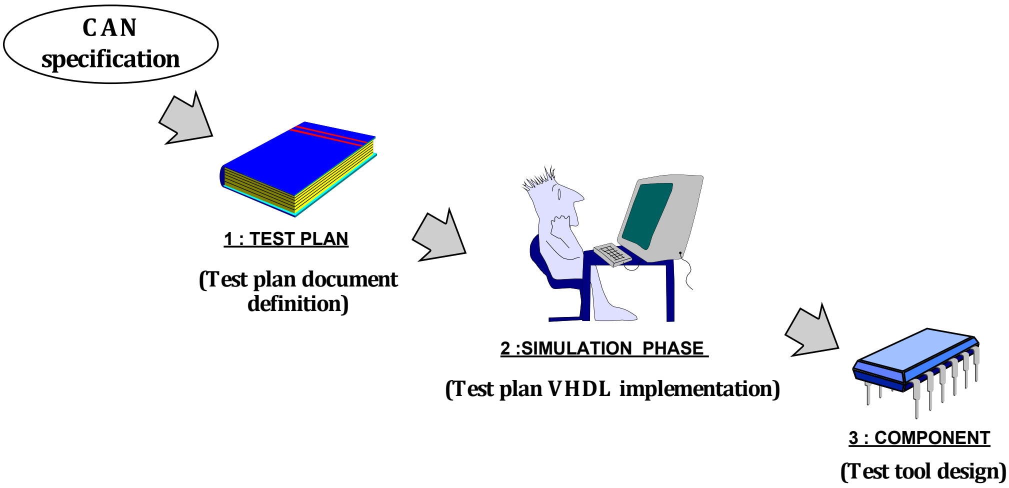

Figure 1 : CAN conformance testing methodology

Test Plan Document

From the CAN specifications [1], the goal of the first step is to write the CAN Test Plan document [2], [3]. This document describes the tests that an implementation in conformance with the standard has to comply with. The test method follows the recommendations of the ISO 9646 standard concerning the co-ordinated test method.

The architecture of the Test Plan is given in figure 2. The design, called Implementation Under Test, is tested by the Test Plan through the CAN network. The Upper Tester function has to be developed by the designer in order to place at the Test Plan disposal the relevant information concerning the transmission and to co-ordinate the tests between the Test Plan and the Implementation Under Test. The design of this very simple function is made easy thanks to the Upper Tester Specification document delivered with the Test Plan.

The test architecture takes into account the different options specified in the standard in order to be able to adapt the whole list of tests to the capabilities of the component.

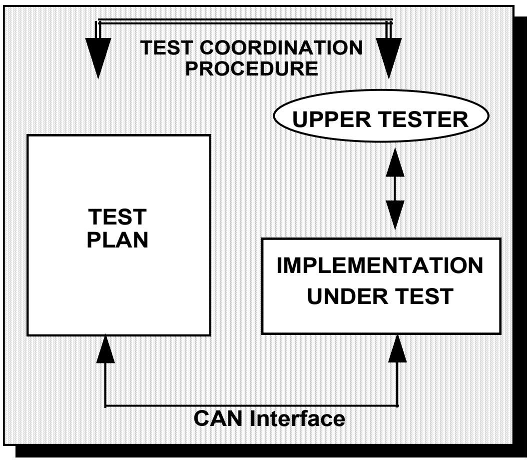

Figure 2 : Test architecture

The CAN Test Plan document includes a comprehensive list of tests, around 200 tests, that verify the implementation of all the functions of a logical CAN interface. Seven test classes have been defined :

- Valid frame format class,
- Error detection class,
- Error frame management class,
- Overload frame management class,
- Passive error state class,
- Error counters management class,
- Bit timing class.

The first version of the Test Plan has been released and is available for any company that would be interested in this document.

Computer Aided Design Phase

The second step of the methodology includes the implementation of the CAN Test Plan in VHDL (VHSIC Description Language), a world-recognised description language for ASIC design.

After having compiled the Test Plan with the model of the Implementation Under Test, this tool allows the designer to verify as early as the simulation phase if its component is compliant with the standard or not. This kind of tool avoids design mistakes coming from a misinterpretation of the standard and saves money since these mistakes are detected before the foundry. Such an automatic tool also enhances the design quality level thanks to the implementation of non-regression tests.

The Test Plan architecture is shown in figure 3. The left part of the figure describes the Configuration step. Thanks to the CAN component characteristics (bus speed (date rate), acceptance filters (identifiers), device configuration sequence, ...) provided by the designer, this module generates, among the generic test list described in the reference files, the exhaustive list of the CAN tests (component files) the design will have to comply with. The Configuration software is written in C++.

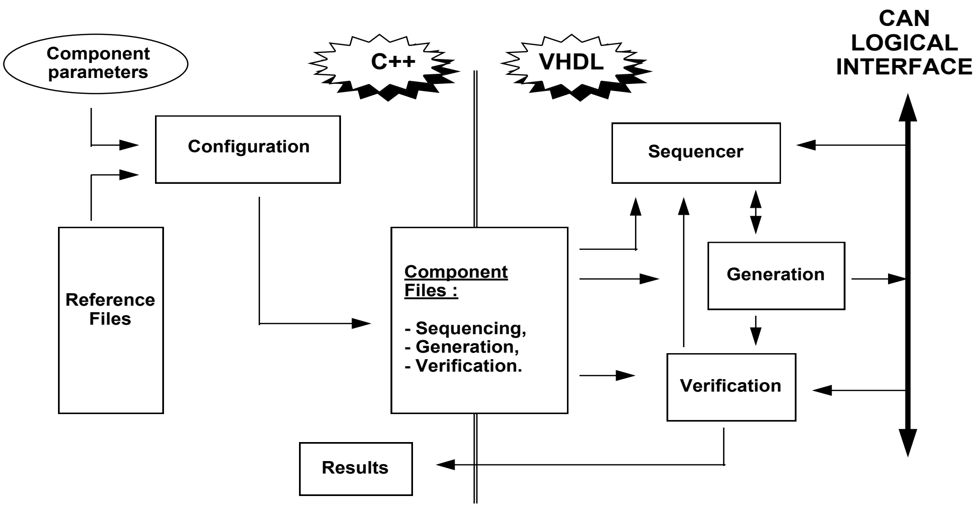

Figure 3 : CAN test plan architecture

The right part of the figure shows how the VHDL part of the Test Plan uses the component files to sequence the different tests, to generate the patterns to the Implementation Under Test and to verify the compliance with the standard by comparing the sampled data coming from the Implementation Under Test with the verification file.

The verification of the CAN conformance is achieved in real-time while the simulation is running. A dedicated VHDL variable, visualised in the simulation window (see figure 4) switches to the wrong state when a non-compliant event occurs. The simulation gives the exact position and the explanation of the non-conformance problem. A global report file is also generated at the end of a batch simulation. This batch mode is well adapted for non-regression test phases. The designer can visualise afterwards the sequences that failed.

The first version of the Test Plan will be delivered by the end of 1996 to the REALNET project partners to test the CAN cell and the CAN component models. Thanks to this experience, the Test Plan package will be available for other companies. It will run under the main VHDL environments available on the market and the configuration software will be compatible with standard UNIX workstations.

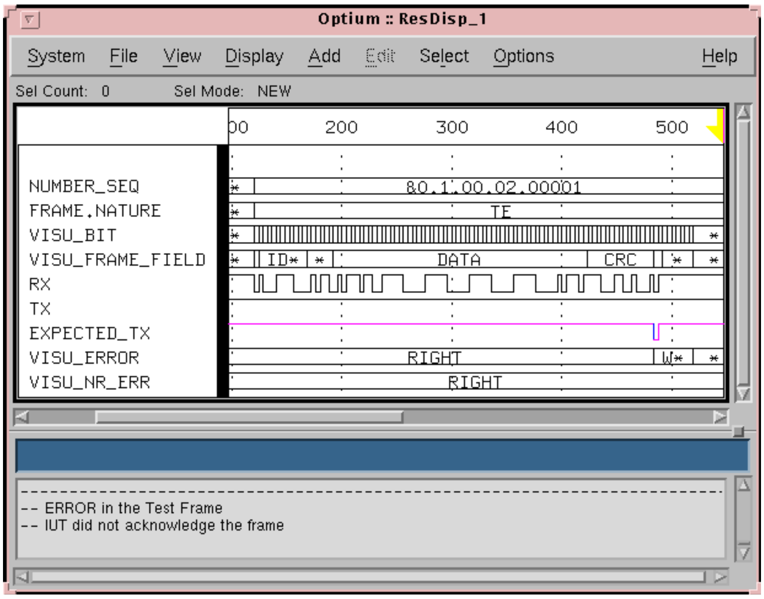

Figure 4 : Example of simulation results (test error detected)

Conformance tester

The goal of the last step is to develop a PC-based conformance tester to perform the Test Plan on a real component.

In order to maintain coherence in the whole CAN conformance process, the tester is based on the same architecture and uses the same database as the CAN VDHL Test Plan model. The only differences take place in the distribution of the functions between hardware and software to take into account the real-time aspects tied with the real component test. The Upper Tester has to be implemented in a hardware environment. The architecture of the tester is described figure 5.

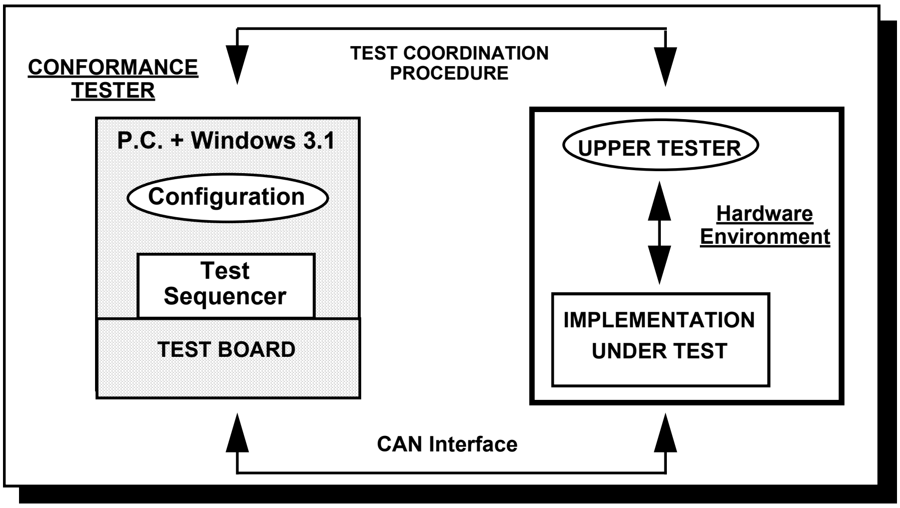

Figure 5 : Tester architecture

The Configuration software developed for the Computer Aided Design environment is installed on the PC and the tests can be easily defined by the user through a Man - Machine - Interface developed under Windows. The different tests programmed are executed thanks to the Test Sequencer that drives a specific PC Test Board. This board executes in real-time the tests defined by the user and reports the results of the tests that are displayed to the user or stored in a report file.

For the car manufacturers, the conformance tester is the mean tool. This one will allow, as a matter of fact, to verify and guarantee the conformance of the chips.

CONCLUSION

As the needs of these tools are obvious for founders, car manufacturers as well as suppliers, a consortium including Motorola GmbH (leader), Magneti Marelli SpA, GIE PSA Peugeot Citroen, Renault and Dassault Electronique has been constituted in order to fulfil the REALNET project.

The European Community selected the REALNET project under the aegis of the ESPRIT Framework 4th programme - Open Microprocessor systems Initiative (OMI).

The REALNET project contributes to the goals of OMI by providing effective tools and cell that allow to develop CAN components rapidly and with a high-level of quality. Beyond the automotive world, other industrial sectors will take advantage of the REALNET project results

The main objectives of this two-year programme are :

- To develop the conformance methodology and the associated tools for the Controller Area Network (CAN) standard,
- To develop a CAN interface cell to be included in the European Library (ELI),
- To validate the approach by developing a demonstrator devoted to the automotive industry.

Although the REALNET project will only be completed by the end of 1997, the Test Plan document [2], [3] is already available under NDA. The first version of the VHDL model will be delivered at the start of 1997.

The first version of the tester will be delivered mid 1997 to the REALNET project partners to test the component including the CAN cell. Thanks to this experience, the tester will be available for other companies.

References

[1] CAN Specification-BOSCH- Version 2.0, and BOSCH « C » Reference model.

[2] REALNET CAN VALIDATION TEST PLAN Organisation and methods NE 759 894 Issue 1.00, June 1996.

[3] REALNET CAN VALIDATION TEST PLAN Test list NE 759 895 Issue 1.00, June 1996.