Reasons for System Simulation with CANoe J1939
Version 1.1
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Application Note AN-ION-1-3400

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1.0 Overview

For years, world-wide passenger car network development has taken advantage of a powerful and comprehensive simulation and analysis tool by Vector called CANoe. J1939-users can finally benefit from the car industry’s experience.

CANoe J1939 provides the user with an extensive simulation and development environment for J1939 systems. In the design phase of a J1939 system, the developer has the ability to simulate the remaining behaviour of the network, observe the bus load, and determine the necessary performance of the hardware which is being developed. The CANoe J1939 tool makes it easy to generate a complete simulation. Hereby the user is completely supported by the extensive J1939-specific services. Therefore, the application of CANoe J1939 leads to significant time and cost savings throughout the entire J1939 project.

CANerator J1939, the J1939 network configuration tool from Vector is integrated in CANoe J1939. It is used to create the project for the J1939 system that is to be simulated. CANerator generates a CANoe database and a
device model for each simulated device. Due to the fact that all communication relevant values are given, the device models can represent all bus communication. It is not necessary for the user to write code that simulates the communication, this code is generated automatically. Due to the flexible interface of the environment variables and callbacks, the user can concentrate on the programming of the application. The simulation and visualization of external influences such as I/O values, temperatures, encoder values etc. take place via operating panels. The generated models can be gradually replaced with real J1939 devices. Each of the real devices are then simulated in real-time with the existing devices. This is referred to as the remaining bus simulation. In the final phase of development, when all necessary devices are physically available, CANoe J1939 provides the required analysis of the J1939-System.

2.0 Basic Concept of System Modelling

CANoe is a universal development, test and analysis environment for CAN bus systems, which is made available to all project participants over the entire development process. The system producer is supported in functional distribution, functional checking and integration of the overall system. The supplier obtains an ideal test environment by simulation of the remainder of the bus and environment.

The development process is based on a phase model which differentiates between three development stages (see Figure 1).

Phase 1: Requirements analysis and design of the networked system

First, the party responsible for design distributes the overall functionality of the system among different network nodes and refines the design to the level of the network node. This includes defining messages and selecting the baud rate of the bus. Finally the bus behavior of individual network nodes must be specified, e. g. in the form of cycle times or more complex protocols. Then this information can be evaluated first by the simulation tool to provide initial estimates of bus load and the latency times to be expected at the prescribed baud rate. Afterwards, this specification can also be utilized for testing in subsequent phases.
For a more accurate study, a dynamic functional model of the overall system is created. This involves specifying the behavior of the network nodes with regard to input and output variables and the messages to be received and transmitted. Especially useful here is an event-driven model with a procedural description of behavior. For example, the model may describe how - after receiving a message (Event) - the received data are to be further processed (procedural) and how the result is to be output as a control variable.

The user must also specify the input variables to the simulation tool, so that the time behavior of network nodes and the accumulation of messages can be simulated. The results of the simulation serve to validate the design and can later be used as a reference after implementation.

Phase 2: Implementation of components with simulation of remainder of the bus

After the first phase has been completed the design and development of individual network nodes is usually performed by all participants, independently and in parallel. The models for the other network nodes can now be used to simulate the remainder of the bus for testing of a developed network node. The tool requires an interface to the real bus for this, and it must be able to conduct the simulation in real time.

Phase 3: Integration of the overall system

In this last development phase all real network nodes are connected to the bus in a step-by-step manner. To accomplish this it must be possible to "disconnect" the models one-by-one in the simulation of the remainder of the bus. The tool serves increasingly as an intelligent analysis tool which observes the message traffic between the real network nodes on the bus and compares the results with the specified requirements.
The behavior of network nodes with regard to input and output signals is described with the help of environment variables. CANoe differentiates between discrete and continuous variables. Switch positions can be represented as discrete environment variables. With continuous environment variables, dimensions such as temperature or engine RPM can be described.

The control panels provide a user-friendly interface to the environment variables. The user can create the panels independently with the help of the Panel Editor. During the simulation values of environment variables can be displayed (lamps, counters) and interactively modified (switches, potentiometers).

The example in Figure 2 is intended to clarify the functions which CANoe provides for simulation and testing of CAN bus systems.

By pressing the pushbutton on the left control panel the discrete environment variable "Pushbutton" is set to the value 1. The bus node on the left reacts by sending out a message on the CAN bus. The bus node in the middle receives this message and sets the discrete environment variable "Light" to 1. This causes the small lamp in the middle control panel to light up.
Analogously, the user can also adjust the potentiometer in the middle control panel, whereby the value of the continuous environment variable "Potentiometer" is modified. This causes the middle network node to place a message on the bus with the new data. This message is received by the network node on the right. There a new value is calculated from the signal contents for the environment variable "Engine RPM". Finally, this causes the display of engine speed to be updated on the right control panel.

The behavior presented in the previous sections can be described very easily with functions available in CAPL. By this method it is possible to implement a simulation of complex systems with relatively little effort.

### 3.0 Advantages of System Simulation

#### 3.1 Modelling a System

For building a complete communication system it is necessary to plan carefully the communication relationship between all devices. This sometimes is done on plain paper – without any possibility of further electronic processing. Many system designers do this process with some kind of a database. This allows to make further processing, such as generation of the documentation. Anyhow, this does not allow to use CAN-specific know-how. With a specific CAN simulation tool, the semantics of the communication can be planned and described.

There is already a de-facto industry standard to describe the communication matrix – the so-called CANdb database. Building a network description simply means to select the appropriate PG. Afterwards the communication relationships between the devices are defined.

#### 3.2 Evaluation of Communication Channels

Defining the complex communication between many devices is a hard error-prone work. Using a simulation tool allows to immediately test the communication channels.

If communication related errors are detected in the final phases of a project this will cause a lot of time and trouble. Very often this affects not only the system provider but also the suppliers. CANoe J1939 helps avoiding that by detecting errors already before suppliers are involved and before the concrete implementations are started.
3.3 Busload
Simulating the communication system allows to get statements about the busload already in the planning phase of the project. This will avoid unpleasing surprises in the integration phase.

3.4 Device Performance
The simulation helps in detecting load or even overload situations. Besides the general busload this affects the performance of the Devices’ micro-controllers. Some implementations of Devices will show problems only in critical load situations.

Searching this kind of problems in an integrated system is very time consuming, since it is not easy to reproduce the unique situation. If found, solving the problem in the Device’s implementation may require a re-design of the software which will shift delivery dates significantly.

A big medical manufacturer detected sporadic problems in some of its components. With the help of generating a reproducible background busload (see also 5.7) these problems could be identified as performance problems.

3.5 Distributed Development Process with Suppliers
A typical system development acts in a way, where interfaces between the suppliers are specified, then the suppliers develop the devices, perform self-defined tests and then deliver to the OEM. The OEM integrates the devices – and nothing will work. Finding the problems is hard and time-consuming, and it will be nearly impossible to uniquely identify the responsibilities.

Giving the system model to the suppliers will enable them to develop their devices in the environment of the complete system. By performing the real-time remaining bus simulation, the behaviour can be tested extremely close to the real system.

Many big car manufacturers world-wide as well as several agriculture manufacturers have chosen this concept. This lead to a revolutionary increase of their development process. It is unthinkable now, how development of the CAN system could work without CANoe.
4.0 Reference Applications

4.1 Automotive Body Electronics

Originally CANoe had been developed in close co-operation with the research and pre-development departments from DaimlerChrysler and others. They provided their experience as input for the requirement analysis. Meanwhile CANoe has proven it’s concept in most European and many world-wide designs for networking the Body Bus Electronics.

![Automotive Example](image)

Figure 3: Automotive Example

4.2 Agriculture Electronics

The agriculture market consists of many manufacturers of tractors and harvesters and many manufacturers of equipment machines – the so-called implements. They are faced with the problem that the farmers will try to attach any implement with any tractor. Having solved most mechanical and electrical interface problems the next step had been the electronical interfacing. Started in the late 80’s with CAN and the protocol LBS they have reached a high-sophisticated CAN-based bus system called ISO11783 or short ISOBUS, which is based on J1939.

In spring 2001 the specification achieved a more or less stable state. The goal was to present first products on a fair in autumn 2001. The system development was supported by CANoe. Public statements said “We would never have reached our challenging goal in that short time without the help of CANoe”.
4.3 Public Community Vehicles

The market for communal waste collection vehicles, street cleaning vehicles and machines for many other tasks of public community is stamped by a wide variety of different application in relatively small number of units. The manufacturers have to serve their customers by providing interfaces to all relevant truck manufacturers. This results in high efforts regarding bus communications. A group of manufacturers wants to establish a standardized interface, which in the end most likely will be a combination of ISO11992 and CANopen.

Others such as DaimlerChrysler Unimog have chosen the widespread J1939 standard family. They are using CANoe J1939/ISOBUS in their development.

4.4 Education

Several universities are using CANoe for teaching CAN and Higher Layer Protocols. Simulation is a flexible way to demonstrate and practice a series of CAN use-cases without the need of many different hardware set-ups.
5.0 Questions and Answers

This chapter gives answers on some typical questions to the usage of CANoe J1939.

5.1 What is the Relationship to Mathematical Simulation Systems?

Such simulation systems have a big strength in mathematical and logical simulation of application processes. Anyhow they lack of specific knowledge of CAN communication issues. CANoe is predestinated for this by the experience with CAN based systems of more than 10 years.

CANoe has an open interface to systems such as Matlab/Simulink. It is available for free for users with a CANoe maintenance contract.

As an example the University of Munich the project “Process security of agricultural electronic devices” built a model of a complete tractor with harrow and drilling machine was modelled, simulated and evaluated specifically regarding process safety requirements. This has been done in very close interaction between CANoe and Matlab/Simulink.

5.2 Does CANoe help me debugging my Device?

When you are developing your own devices, you generally face the task of “seeing” the first message sent from the device and then stimulating the device with messages. If this is successful, it is followed by incremental tests that add implemented functions of the device.

After turning on the J1939 device, the device should start a so-called “Address Claiming Procedure”. This can be seen in the Trace window. The results of the complete network are displayed in the scanner window.

The interactive generator block can be used for stimulation purposes. Specific individual messages can be sent here without the time and overhead involved in configuration.

5.3 Can I do Online Evaluation of Data?

Current values of messages can be observed in various display formats in the data window. If you are more concerned with the temporal flow instead, you should use the graphics window.

5.4 How do I observe Problems while fast Traffic?

CANoe allows to record the traffic to a file, which can be replayed afterwards. For data reduction it has filter and trigger capabilities. The search function allows to find specific messages or data contents on the application data level – such as “Temperature > 80 deg” - down to the bit level.

To aid you in quickly evaluating messages, you can also scroll through the Trace window without any recording. Together with the expandable node structure, this provides comprehensive information.
5.5 How do I talk with my Devices?

There is a whole series of options for interacting with bus traffic with CANoe and generating messages and/or services.

A feature known as the “interactive generator block” is most suitable for transmitting parameter groups containing process data.

5.6 Does CANoe support reproducible Stimulation?

The generator block can be used for sequences that occur frequently, for example. A list of messages that are transmitted by pressing a key or by time control is entered into the generator block.

Another possibility is the Replay block. In this case, a file in which the messages are specified is played back. For example, you can record message traffic with the logging tool, modify it offline if necessary and then enter it in Replay. If you use the ASCII format, the file can also be modified manually in an editor.

5.7 Is there a Reference Background Busload available?

For testing Devices under all circumstances one requirement is to have a reproducible bus load. One can write ASCII definition files or record existing traffic. The file can then be used for Replay.

5.8 What about Protocol Testing?

While displaying the message traffic CANoe observes the protocol in the background. It implements checks for typical implementation errors. If one of them is detected, CANoe displays a corresponding clear text message.

6.0 Contacts

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