Requirement Specification for Transceiver Simulation Models

Transceiver Model Specification

V 1.0

Document history

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Contents

1 Targets

In this specification the demands on the simulation models of the transceivers for vehicle networks as well as the required scope of services through the semiconductor manufacturers are described.

1.1 Aim and Motivation

The simulation models of the transceivers are supposed to be used for the simulation of the physical level of vehicle networks.

The simulations should give early indications over:

- the influence of different topologies on the system operation,
- the evaluation of the functionality in case of changes to the system,
- requirements for future transceivers,
- the impact of specific limiting conditions in the automotive environment,
- the interaction of system components (e.g. the influence of additional components on transceiver functions),
- the system operation for specified “worst case scenarios” or at the system boundary.

The simulation contributes to the system reliability. Changes to the vehicle topology and the demands on components (e.g. transceivers) are avoided.

The actual specification focuses on CAN-Transceivers. The intention is to extend the specification to cover LIN also. Therefore, some parameters for LIN are already included. FlexRay is out of scope for the moment

1.2 Use of the Simulation

The simulation is used for the inspection of the system operation of the communication layer of networks in standard and worst case scenarios. The simulations are performed including dynamic behaviour in the time domain. The focus is on the validation of topology, circuit influences on the signal integrity, delay times and the interactions with bus drivers.

In this context, the simulated network architecture primarily consists of the physical layer, which may optionally be extended by parts of the Medium Access Control sub layer (data link layer, please refer to the related network specification e.g. ISO 11898 / -1).

On one hand complete vehicle networks including specific constraints should be simulated, on the other hand individual system parts for investigations of basic influences are evaluated. The specific constraints include e.g.:

- different bus topologies
- system variables
- termination concepts
- EMC arrangements
- partial network use
- mixed transceiver networks
- variations of the supply voltage
- ground shift
- different transceiver states (normal mode, sleep mode, etc.)

Beside the simulation with its typical technology parameters (typical values according to data sheet), the simulation of defined worst case scenarios should also be possible. Affected values are e.g. delay times, static power consumption of the device in different states or operational modes, and signal symmetry (e.g. temporal shift of the signal edges).

2 Simulation Environment

The models have to be executable in the following simulation environment. The test and evaluation of the transceiver simulation models will be executed in a defined test bench. The test bench is specified in a separate document.

2.1 Description Languages

The following Description Languages should be used for modeling:

- VHDL-AMS (IEEE 1076.1-1999)
- MAST *(optionally allowed for the intervening period, until full coverage of IEEE 1076.1-1999 has been achieved by the tool suppliers)*
- In the future, simulations shall use only the hardware description language standard IEEE 1076.1-1999. Currently the VHDL-AMS standard is not completely covered by any simulation tool available and some components are written in other languages included as “dll”-library for example. For the intervening period until full coverage of VHDL-AMS is achieved, models are delivered specifically for any of the simulation tools.

The models can be delivered as:

- clean model description source code
- precompiled library (for each simulation language specified above, including simulator specific symbols (see ch. 4.2)
- encrypted model description source code (at future revisions of VHDL-AMS)

3 Model Requirements

3.1 Simulator operating modes

The transceiver model must support following simulation types:

- **DC Analysis (Operating Point)**
  The DC Analysis computes the state of the system at time 0. This analysis is the initial point for subsequent analyses.
  In detail, this analysis defines the steady state of a nonlinear system at time 0. All time varying parameters and their derivates are set to 0. All dynamic elements are ignored and effectively removed from the circuit (capacitances are removed from the circuit, inductances are short circuited and time dependent sources removed). Noises and AC sources are removed too.

- **Transient Analysis (Time Domain Analysis)**
  The Transient Analysis computes the systems behaviour as a function of time. The calculated datapoints in the time domain are time steps. The values of each time step are used for determining an initial guess at the next solution point in the simulation. The results are similar as the measurements were shown on oscilloscope.
  Specific measurements are rise time, fall time, slew rate, period, frequency, duty cycle, pulse width, delay, overshoot, undershoot and settle time.

- **Statistical Analysis (Monte Carlo)**
  The Monte Carlo Analysis defines statistical method for the investigation of a circuit. At this type of analysis, component parameters are randomly varied within user specified tolerance ranges. The Monte Carlo method defines a set execution runs with basic analysis types with the parameter sets being varied (e.g. Transient Analysis).
  The correlation between variations of performance parameters and variations of independent component parameters are computed. These results are used to define a statistical sensitivity to determine how much the percent change in performance can be correlated with a percent change in each parameter. The parameters are randomly varied in their tolerance band.
  For Monte Carlo analysis, the external transceiver model parameter shall be varied only.

- **Parameter Sweep Analysis (Vary)**
  This analysis uses a deterministic method to identify the impact of individual parameters on system performance by changing only one parameter at a time by a small and fixed amount. With that, the perturbation is measured to the measured performance.
  The design parameters are changed by a small amount for calculating the effect of performance measure. It helps to determine and isolate components which contribute to specific unwanted measures, e.g. voltage overshoot.

3.2 Validity Range

The transceiver model must correspond to the behaviour described in the data sheet within the operating range limits specified in the data sheet concerning the required function scope. Guaranteed behaviors of transceiver are described in the data sheet only. In addition, a correct impedance behaviour at the bus pins is demanded in the unsupplied state ($V_{CC} = V_{BAT} = 0$ V) (Reverse current paths).

The transceiver model must reproduce the behaviour specified in the valid data sheet concerning the subsequently required function scope.

In the case that the range of validity is exceeded after the simulation run, error or warning reports have to be issued by a monitoring system, which has to be implemented in the model. This monitoring system has to include the supply voltages, the inputs and outputs (voltage and current ranges at analogue pins and logical levels at digital pins), as well as other variables and selectable parameters (e.g. for the switching between typical and limit values for parameterization of temperature and V_{cc} range; see Ch. 3.5). This ensures, that only plausible and valid values are used and that the simulation returns realistic results. The monitoring system has to be documented how it is implemented.

DC Analysis: The error reports shall occur at the end of the analysis only.

Transient Analysis: The error reports shall occur at the end of a time step.

3.3 Functionality

For a transceiver type, two models with different functionality levels shall be provided:

- LEVEL 1
  - Bus Interface, Bus Termination (CAN-high, CAN-low, LIN Bus Lines, RTH, RTL, SPLIT)
    - Analogue interface implementation.
  - Data In- / Output (TxD_CAN, RxD_CAN, TxD_LIN, RxD_LIN)
    - Digital interface implementation.

- LEVEL 2
  - Bus Interface, Bus Termination (CAN-high, CAN-low, LIN Bus Lines, RTH, RTL, SPLIT)
    - Analogue interface implementation.
  - Data In- / Output (TxD_CAN, RxD_CAN, TxD_LIN, RxD_LIN)
    - Analogue interface implementation.

Since the different bus driver types (e.g. LIN, fault tolerant CAN, high speed CAN, high speed CAN with low power mode, FlexRay, single transceivers or higher integrated circuits) partially show significant differences regarding function, options and modes, subsequently the basic scope is described. Additional specific model requirements shall be decided by the GIFT consortium and shall be described in a separate functional requirements document. The contact persons are listed in chapter 5.

3.3.1 States / State Transitions

- Basic transceiver modes which directly result in influences to the signal behaviour at the bus lines:
  - normal mode
  - sleep mode
  - wake up
  - receive only mode
- Further states (from extended bus driver functionality, e.g. error handling, line diagnosis)
- Implementation of state transitions (e.g. from sleep to normal mode), during which correct behaviour is required (impedance, signal integrity) while the states are connected statically
- Correct internal termination and impedance behaviour at the bus pins while the power supply is switched off,
- Correct behaviour in case of lost ground connection
- If the under voltage condition is not modelled, a warning must follow

3.3.2 Diagnosis

If applicable, the following functions must be implemented:

- Detection of bus errors and indication by error pin or status (System Basis Chip, maybe digital pins)
- Handling of bus errors / single wire operation

3.3.3 Wake up

– Wake up by the bus, local wake up and control pins within the specified voltage range

– Wake up filter mechanisms

– Wake up delays / times

3.3.4 Ground shift

– Simulation of static ground shift in the range of $U_{static\_ground\_shift}$ from -1V to 6V must be possible

– Simulation of dynamic ground must be possible. See Figure 1 below. (t_{Bit} = 2µs)

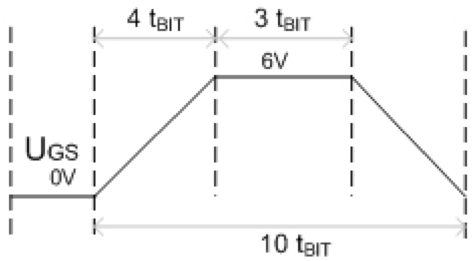

Figure 1: Dynamic GND Shift sequence

3.3.5 Voltage Sources / Voltage Control

– The functionality of INH (voltage regulator activation) must be sufficiently implemented to indicate the correct signal state

3.3.6 Delays

– Propagation delay (loop delay) (TxD → BUS → RxD) [concerning variances compare chapter 3.5]

– Other delay times (e.g. regarding mode-control, INH-pin, local wake up)

3.3.7 Currents and Powers

– Correct currents at the bus-relevant signal pins (bus pins and for LEVEL 2 models Rx, Tx pins)

– Power dissipation of the bus driver during dominant, recessive or several other operational states shall be reflected by the current of the V_{CC} (V_{BAT}) pin. The transition implementations may be simplified.

3.3.8 Further Functionalities

– Additional Functionalities of System Basis Chip:

  - The functions, relevant for the behaviour at the bus, have to be implemented. This requires the implementation of all bus-sided pins (e.g. CAN_{High}, CAN_{Low}, Split), pins to control and receive the bus signals (e.g. RxD, TxD), power supply pins (e.g. V_{SUP}, GND), pins used to signal bus errors and to control the transceiver modes.

– Dependencies / Parameterization cp. chapter 3.5

3.4 Model Interfaces (Pins and Parameter)

All real pins of single chip transceiver including all model variations must be implemented. Implementations of System Basis Chips have to conform the functionally ambit described in chapter 3.3.8.

Parameterization (cp. chapter 3.5) and model variation might request additional pins and parameters as input to the model. The parameter must be described and their ranges must be controlled in the simulation model (cp. Chapter 3.2 and 4.1).

Interface implementation requirements:

Interface / Pins / Parameters	**Example**	**Requirements**
Power Supply	GND, V_{CC}, V_{bat}, V_{io}, V_{33}, …	– analogue interface implementation – voltages, currents – validity of model behaviour according to the data sheet
Bus Interface, Bus Termination	CAN-high, CAN-low, LIN Bus Lines, RTH, RTL, SPLIT, …	– analogue interface implementation – correct currents, power, impedances (also at VCC = 0 V) – representation of correct impedance for completely un-powered (GND = Vcc) Transceiver – correct short circuit behaviour, signal integrity, symmetry, slew rate, delays, filter, thresholds, internal termination – validity in all operation modes of the transceiver – parameterisation (cp. chapter 3.5)

Data In- / Output	TxD_CAN, RxD_CAN,
	TxD_LIN, RxD_LIN, …
		– digital interface implementation for LEVEL 1 models
		  o correct delays
		– analogue interface implementation for LEVEL 2 models
		  o correct currents, impedances, delays, filter, thresholds, signal integrity, slew rate
		– parameterisation (cp. chapter 3.5)

Digital Mode Control Digital Inputs	Standby, Enable, Read Only Mode, …	– digital interface implementation – controls as described in the datasheet
Digital Outputs	ERR, Reset, Switches, Interrupt, …	– digital interface implementation – functionality as described in the datasheet, according to required functionality in chapter 3.3
Analogue Inputs	Wake up	– analogue interface implementation – filters, threshold voltages, impedances – controls as described in the datasheet
Analogue Outputs	INH, V_{ref}, Voltage Regulator Outputs, …	– analogue interface implementation – functionality as described in the datasheet, according to required functionality in chapter 3.3
Parameters	switching of the parameter set: “high_temp“, “low_temp“, “typical	– parameter cp. chapter 3.5 – description for the high/low effects

Requirements for all existing pins (excepting V_{CC}):

- Validity of model behaviour according to the voltage ranges denoted in the data sheet,
- Signal- and parameter monitoring (valid range), error and warning reports have to be implemented e.g. if passing operational limits (Ch. 3.2, 4.1).

Requirements for V_{CC} pin:

- V_{CC} fixed to nominal voltage or 0V,
- Validity of model behaviour according to typical and unpowered condition denoted in the data sheet,
- Global parameters (High / Low Temp) to force the model into the worst case corners including the V_{CC} influence. (cp. 3.5)

3.5 Model Parameterisation

A transceiver simulation model shall support three different operating areas selected by the model parameters "Typical", "High_Temp" , "Low_Temp" including the V_{CC} influence.

- In the operating area "Typical", the typical transceiver behaviour at room temperature shall be provided, similar to the typical data defined in the product data sheet.
- In the operating area "High_Temp", the corner case behaviour of a worst-case transceiver corresponding to a high environmental temperature condition shall be provided. This corner case shall reflect the corresponding worst-case transceiver parameters reflected by the min/max definitions in the product data sheet, which are reached at high temperatures like e.g. the highest loop delay or weakest driver strength (direction of temperature influence depends on implementation and technology).
- In the operating area "Low_Temp", the corner case behaviour of a worst-case transceiver corresponding to a low environmental temperature condition shall be provided. This corner case shall reflect the corresponding worst-case transceiver parameters reflected by the min/max definition in the product data sheet, which are reached at low temperatures like e.g. the shortest loop delay or highest driver strength (direction of influence depends on implementation and technology).

Goal of the corner case models is allowing to simulate a worst-case system, which might exist in a vehicle combining multiple transceivers including all silicon production spread and temperature influences.

Within these parameter sets not only parameters based on technology:

- resistance load,
- capacitance load

have to be considered but also the influences of operation parameters:

- specified supply voltage limitations,
- specified limitations of temperature.

In this context, the following transceiver properties have to be implemented in such a way that they can be parameterized within the range of valid transceiver values:

- rise time and fall time of the bus signals (e.g. CAN_{High}, CAN_{Low}),
- Propagation delay (e.g. TxD → CAN_{High}/CAN_{Low}, CAN_{High}/CAN_{Low}, → RxD),
- Properties of the transmitter (e.g. R_{on}, signal symmetry, current drive capability),
- Properties of the receiver (e.g. R_{CM}, receiver thresholds, hysteresis).

3.5.1 Implementation

Due to the physical dependencies, it is possibly unrealistic to vary the above mentioned parameters separately or directly. Therefore the quantities, that have any influences on these parameters, may be parameterized instead (e.g. temperature operating mode, Vcc operating mode: see 3.4 and 3.5).

Accordingly, additional pins or parameters are to be used, which allow the variation of the models. In this way the above mentioned transceiver properties (e.g. propagation delay, impedances) are indirectly variable. The aim is to obtain a realistic transceiver behaviour, in order to simulate the influence of these variances in the network. Within the model, the parameters shall be tested for their range of valid values and the adjustable range. The para-meter dependency shall be documented (see Ch. 4.1).

To handle different models from different manufacturers in one topology correctly, these have to be optimised for only one simulation algorithm (Newton-Raphson) and a fixed time stepping to avoid or at least limit the different model and simulation behaviour at different simulator tools and thus, increase the reproducability of the model test.

Remark: The Newton algorithm was selected to ensure exchangeability of models in a mixed simulation.

4 Support Requirements

With the creation and delivery of transceiver models, the following chapters define support services that are expected from the semiconductor manufacturer.

4.1 Model Documentation

A detailed description of the following items has to be provided:

- the implemented transceiver functionalities and properties
- the functions and the simplifications that are not implemented
- parameters and interfaces (functions, behaviour, default value, type):
  e.g. pin name, pin type, signal name, signal type, parameter name, parameter type, quantity name, quantity type
- important internal values of the model (e.g. internal states)
- important physical values that are modelled and observable
- range of validity (of signals, pins, quantities, parameters)
- the model parameterization of the desired variable properties and their effect according to Ch. 3.5 / 3.5.1, documentation of possible parameter settings and their consequence in a spreadsheet
- implementation of error and warning reports
- integration of the model into test bench
- supported analysis types
- recommended simulator settings / initial values (for iteration / convergence)
- test report of the entire model
- known deviations of the model to the real transceiver

4.2 Model Application

- Generation and description of a symbol suitable to the model
- Pin names of the model shall match to the datasheet specifications
- Preparation of example simulation project(s)
- If necessary, support on model application / model integration
- Initial verification of the models with the transceiver and documentation of relevant deviations within a defined test bench
- Determination of the simulation speed of the transceiver models using a defined test bench

4.2.1 Test Bench

Test bench will be defined in a separate document. The signals shall be simulated in the test bench using the different parameter sets and shall be measured in a real test bench setup. The simulated curve progressions represents the limits for the measured curves.

4.3 Model Maintenance

– Modification of the model due to model errors

– model update including the documentation in the case of product changes

– description of version and model differences

– contact for model maintenance and use

4.4 Delivery Dates

– The delivery date will be coordinated with the GIFT Consortium (e.g. transceiver model delivery together with delivery of transceiver samples)

– Coordination with the GIFT Consortium about a possible step-wise implementation of the models

5 Contacts

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