CHALMERS

Automatic verification of controller unit functions

A practical approach

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Abstract

When verifying car controller unit software, each software function is often verified individually. The verification is a very important part before the controller unit can be used in production. Invalid controller units can cause big damage to the cars vital parts, engine or gearbox. Or even worse, the car can become highly dangerous in traffic situations.

Until today the controller units has been verified manually. This thesis prepares a new method for automatic verification of controller unit functions. The automatic verification programs are written in the scripting language Python and implemented in a simulator environment called HIL (Hardware In the Loop). The aim is to develop and supply a totally automatic simulator; where controller unit functions can be tested under different kinds of predetermined driving and environment circumstances.

The automatic simulator tests generate in the end log-files for manual study. The only works for the user, with correct configured simulator and verification settings, is just to start-up the process and afterwards study the result-logs, which contain all required test information.

The results after tests with a series of controller unit functions indicate great time profits. But also many pitfalls and demand high user competence and a good knowledge of the underlying algorithms to interpret the result-logs in a correct way.

Nomenclature

Term	Description
Controller Area Network (CAN)	Network protocol and bus standard that allow controllers and devices to communicate with each other and without a host computer.
Engine Controller Module (ECM)	CAN node designated for steering of engines.
Transmission Controller Module (TCM)	CAN node designated for steering of automatic transmissions

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1. Introduction

The car industries of today have to develop, test and introduce new models in rapid speed. It's not just to keep up the pace but also increase it all the time. The company that has least delay between the drawing board and the customer has a great advantage. To provide the market with cars, whose design not being outmoded for as long time as possible, are really invaluable. The customer does not only demand a nice design though, they also ask for good functionality, low price, environmentally friendly, low fuel consumption and a bunch of other things. To fulfill the customer demand all instances of the company not only have to do their best, but also use the sharpest tools possible.

The verification of product functionalities is a very important link in the development chain, and faster verification methods leads of course to a more in depth verification analysis and/or a shorter time plan. A more in depth verification out sources less functional testing on the customer and saves both resources for calling back products for updates and the customers temper and trusting. The worst case scenario is when a car has to be called back for serious safety problems, which also have happened for many car companies more than once.

Let's now be a bit more specific and focus on software verification. There are always a number of things that have to be analyzed when releasing new software. Both the functionality and the interaction with other softwares have to be analyzed. As an example; it does not matter if the functionality for the cars light system follow specification if it disturbs the immobilizer and make it dysfunction.

The old school method and often the standard way to verify a certain implementation is to analyze it in a real car. This method is excellent for some types of analyzes, for example drivability and acceleration tests. On the other hand verification tests like turning the start key from ignition on to ignition off a couple off hundred times are not ideal to do in a real vehicle. Therefore Volvo and other car companies for a couple of years ago started to use simulation systems, which purpose is to mimic all from specific components to whole vehicles, for test and verification. Volvos simulation system is called HIL (Hardware In the Loop) and is delivered from the German company dSpace. The name comes from the possibility to add hardware like gear sticks and control boxes in the simulation loop. To do a test in the HIL system requires up to date simulation models and relevant simulator configuration. Sadly there are often very time consuming both to create and compile new simulation models and tune the simulator. Therefore it's only motivated to run simulation tests when the time efforts are big enough to cover for the model development and simulator configuration.

1.2. Background

Volvo Car Company have asked for more efficient, but still reliable, methods for car software verification, with the aim to test as much as possible in simulator environment in the future. Previous work has been done at VCC. This thesis will complement their work.

1.3. Purpose and aims

Along with the electronic networks in cars increases both in size and complexity, the demanded work for verification of new electronic solutions increases as well. To meet the requirement of a continuously increased workload without increasing the human resources, new and more time efficient methods must be developed. Verification of CAN-functionality is an area where automatic test processes can be implemented with, in this connection, quite small effort.

The thesis will result in a collection of tools for analysis and verification of CAN-logs. The aim is to develop software tools with high precision, reliability and flexibility.

1.4. Outline of thesis

This report will focus on verification of three different controller unit functionalities;

- CAN Interface
- Network Management
- State machines (in general)

1.4.1 CAN Interface

Every node connected to any of the vehicles controller area networks (CAN bus) have a CAN interface. The interface handles all data traffic between the nodes and CAN bus. Sometimes the node requires another data representation than what is used on the bus, and vice versa. Therefore mathematical operations like scaling (multiplication) and offset (addition/subtraction) are implemented in the CAN Interface.

1.4.2 Network Management

Network management is a way to control that a node always are in correct operation mode according to the network status. Key out, Operation and After run are examples of network statuses. Network management takes the network status as input and supervises the node operation mode.

1.4.3 State Machines

Network management is an example of a quite complicated state machine. A car node can contain a lot of different state machines, with purpose to supervise that one or more functions is in correct operation mode.

2 Python programming language

Python is a dynamic scripting language for Rapid Application Development (RAD). The background and basics for Python, and also why it is used in VOLVO simulators is discussed in this chapter.

2.1 Introduction

Python is a high-level dynamic programming language formally made by Guido Van Rossum in 1991. Python was from the start decided to be an open source product, it means the source code is free and available, and also possible to further develop, for everyone. Python has grown fast and a big group of voluntaries are involved in the development.

As many other modern languages it's a high level object oriented language and very similar to, for example, Perl and Ruby in respect to the fully dynamic system approach and autonomy memory management. The python language aren't focused on something special but trying to be comprehensive without delimitations. A high level language means that it contains structures which allow the programmer to execute advanced operations without detail knowledge what's lying behind. A single command can open a data stream or show a picture. That implies big advanced functions can be developed in rapid speed. The price the programmer has to pay for not using a low level language is the loss of total control in every implemented instance. As mentioned above things like memory allocation are automatically handled by Python which are very comfortable in most cases, but still is a trade off where the opportunity for total control lose.

Python is an interpreting language. The Python code is interpreted to machine code first when the program is running, line by line. The opposite is a compiling language as C and Pascal which code must be translated to machine code before the program can be executed. The advance with an interpreting language is better flexibility and faster development. With better flexibility means for example dynamic object typing, the type can change while the program is running. The down slope is slower executing comparing to a compiled language. The problem (if it's a problem!) can partly be circumvent by developing C, or other low level language, code for the time critical application and link it, via an cross language interface, to Python.

The aims for the Python development and rule of thumbs for a Python programmer are summed up by Tim Peters in the following way;

```
The Zen of Python

Beautiful is better than ugly.
Explicit is better than implicit.
Simple is better than complex.
Complex is better than complicated.
Flat is better than nested.
Sparse is better than dense.
Readability counts.
Special cases aren't special enough to break the rules.
Although practicality beats purity.
Errors should never pass silently.
Unless explicitly silenced.
In the face of ambiguity, refuse the temptation to guess.
There should be one-- and preferably only one --obvious way to do it.
Although that way may not be obvious at first unless you're Dutch.
Now is better than never.
```

```
Although never is often better than *right* now.
If the implementation is hard to explain, it's a bad idea.
If the implementation is easy to explain, it may be a good idea.
```

2.2 Why Python? - In general

Python can handle most kinds of programming issues fairly well and isn't restricted for some special kinds of development. Within every project where rapid development, scalability and flexibility are of importance Python is a good choice.

2.2.1 Mathematics

Python is an excellent tool for mathematical processing since it supports NumPy, an extension which provides interfaces to many mathematics libraries. The NumPy extension is written in C and as a result, the operating speed is higher than the built-in math support in Python. The language also supports unlimited mathematical precision. For example two very large numbers can be added without using a third party language.

2.2.2 Text processing

Text processing is easy handled in Python. Any data can be split, separated, summarized and reported. There are built-in modules to read log-files line by line, summarize the information and then write it all out again. Python actually comes with SGML-, HTML-, and XML-parsing modules for reading, writing and translating. With the support of many other languages text-processing engines and flexible object handling, Python becomes a good choice for Text processing.

2.2.3 Rapid application development

The high level and fully dynamic language architecture combined with the *less is more* syntax approach it goes very quickly to develop applications in Python. In addition the extensive module libraries that comes with Python provides interfaces to many common protocols and tools.

Another aspect of rapid development in Python is the ability of fast program evaluation. The code doesn't have to be linked and compiled but run as it is through the interpreter. Also the debugging is easily handled in the same shell and environment as the programming.

2.2.4 Cross-platform development

Python is available for all major operating systems; Windows, Linux/Unix, Mac, Amiga, among others, and supporting them in a completely neutral format. Python is therefore a good choice when the need of platform independency is big. The python code will neither have to be rewritten to implement it on another platform than it originally was supposed to run on.

2.2.5 Internet developing
The combination of Pythons high-level module support and RAD (Rapid Application Development) power results in an enormous easy accessible toolkit, and makes it ideal for web applications where often speedy development is of crucial importance. Python support, among others, libraries for parsing and handle XML, HTML and CGI scripts. Also protocols like POP3, IMAP and others are supported.

2.2.6 Database programming
Python is glancing with good support and module libraries also for database programming. Python have interfaces for all of the commonly used databases such as mySQL, Apache and Oracle. The good text processing tools in Python often makes it to a better summary and report tool than the database built-in interface.

2.3 Why Python? – In automatic testing at VOLVO

2.3.1 PowerTrain test automation (PTTA)
A system for automatic verification of control unit functions is under development at Volvo Car Company called PTTA and is written in Python. The system is connected with the HIL (Hardware In the Loop) simulation environment. The HIL-system can simulate the dynamics of a whole vehicle or just chosen parts. Through PTTA the user can start the HIL-simulation with different initial settings, depending on the test. The automatic test system also configures and starts the CAN-logger Inca. The last part in the automatic test chain is verification of the produced Inca-log, which is the main focus for this report.

2.3.2 Reasons for using Python for PTTA
There are several reasons why the automatic test system, PTTA, is written in Python. The main causes are;

- The HIL-system is delivered with a Python API for controlling the simulator.
- Developing in a scripted language takes often less time than in compiling dittos. Python is the most common script language.
- The range of Python libraries is huge. In addition, all existing C libraries can be compiled to Python libraries. And the range of C libraries is almost infinite.
- Program modules that require great performance or control can be developed in C and compiled as Python modules.

3. Scripts for automatic verification and result presentation

In this chapter theories for three different kinds of automated verifications are introduced, namely verification of State Machines, CAN Interfaces and Network Management.

3.1 State machine verification – Theory

3.1.1 Introduction

The controller units of a car contain several types of state machines, and are used to track and announce the state of a whole controller unit, a single function or something else. It's important that the state machines work in a correct way regardless external conditions. A dysfunctional state machine can, in worst case, lock down a function, node or even the whole car. Careful and comprehensive verifications are therefore needed to ensure the functionality.

3.1.2 Theoretical overview

The state machines in a car network are used for track and announce the states of whole controller units, a single function or something else, as described in 1.1. The state machine contains of a countable number of states (usually 5-25 states). Only one state can be active at the same time. The transitions between different states are controlled by transition criterions. The transition criterions between two states are often one or more logical conditions. Fig. 3.1 displays an example of a state machine. Table 3.1 contain the corresponding transition criterions for state machine in Fig. 3.1.

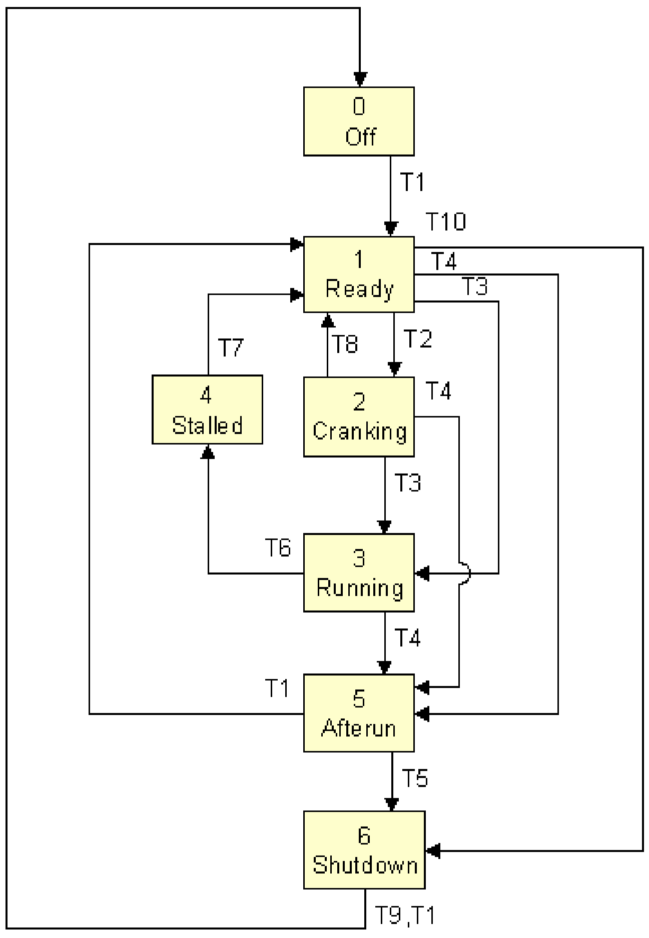


Fig. 3.1. Example of a state machine.

Table 3.1. Transition conditions for the state machine in Fig. 3.1.

Transition	**Name**	**Condition**
T1	ECM initialized	P1X: [WakeUp/KL15)] (HW) P2X, EUCD: [WakeUp] (HW) or [Kl15] (HW)
T2	Start cranking	Manual Cranking: [StartCrankManuel](INT) i.e [KL 50] (HW) and not [Startblocking](INT) Automatic Cranking: [StartCrankAutomatic] (INT) i.e when cranking conditions are fullfilled, see ref **Error! Reference source not found.**
T3	Started	a) (n > n_start and t > t_start_time) b) (T > T_start_torque) Condition a or a+b is Engine and Supplier dependent. This condition may not be the same condition as when cranking is stopped,i.e. it is possible to crank when engine is running.

T4	Normal stopped	not [KL 15] (HW) and (n < n_stopped)
T5	Afterrun finished	Time, FanReady, Diagnosis Ready, MemStore Condition is engine and supplier dependent.
T6	Stalled	n < n_stalled and then set [StalledRecoverReady](INT) (sets for next cycle)
T7	ECM reinitialized	[StalledRecoverReady](INT)
T8	Cranking Deactivated	Manual Cranking: (not [KL 50] (HW) and n=<n_start_crankstoped) or [Startblocking] (INT)) Automatic Cranking : not [Cranking](INT) and n<n__start_crankstoped This condition may not be the same condition as when cranking is stopped,i.e. it is possible to send engine state cranking when the starter motor has stoped cranking and the engine is not fully running.
T9	Shutdown	[Afterrun finished](INT)
T10	Shutdown	Not [WakeUp] (HW) and not Started (INT)

In line with Fig. 3.1, a state machine not contains conditions for all possible kinds of transition. The states not connected with a line are handled as not allowed transitions, under all circumstances.

3.1.3 Program configuration

The program settings will be done through a Microsoft Excel file (*.xls*). The Excel file must at least contain the basic state machine information, i.e. states, allowed transitions and transition criterions. But the file can also provide classes that run more specific analyzes with configuration input. Since the program will be constructed in a way that provides good support and possibilities for future extensions a flexible configuration method is necessary.

3.1.3.1 Basic Analyze configuration

The basic configuration will be a 2-dimensional matrix with the first column and also the first row containing the state names according to the states of the state machine. It will work as a *jump matrix* and covers all possible state transitions. The cells of the matrix constitute either of a X, which means not allowed transitions under all circumstances, or a T directly followed by a number (i.e. T2), which means that it follows the transtion condition specified below the transition matrix as T2 (transition condition 2).

The basic configuration sheet will also contain a table with all transiton conditions, very likely table 3.1.

In fact the basic configuration is just another representation for a fully configurationally state machine, like the one in Fig. 3.1.

3.1.3.2 Time Analyze configuration

The program will, as stated above, be provided with the possibility to extend the analyze. However, it will come with a plug-in module allready with thr program release, namely a module for analyzing the time in each state. It will be possible to set min-and max time for each state through a new Excel sheet in the configuration file.

3.1.3.3 Signal configuration
In addition to the basic analyze configuration, the Excel file must also contain what parameters to extract from the log-file, especially how the state parameter corresponds to the state names in the configuration file.

3.1.4 Verification methods
The verification process will check if the intern state parameter follows the user specifications in the configuration file. The verification algorithms will cover following sources of error;

- Not allowed transition
- Transition criterions not fullfilled
- To short time in state
- To limit in state exceeded

In other words, the python program verifies that the state machine implementation works as it was intended, but not that the implementation itself is correctly specified.

3.2 CAN Interface verification – Theory

3.2.1 Introduction
When connecting nodes, for example different types of control units, with a CAN bus it is of biggest importance that the node-to-bus interfaces works appropriate. The intern node parameter must under all conditions have the right coupling to the corresponding extern (CAN bus) parameter. That means the set of intern parameters must be compared with the corresponding CAN bus parameters during several types of operation conditions. A mismatch can cause many types of problems, everything from wrong outdoor temperature in the display window to a dysfunctional fuel injection.

3.2.2 Theoretical overview
The CAN interface is routing data between the controller unit and Controller Area Network. The verification strategy is to sample internal controller unit parameter and responding parameter on the CAN bus, and compare them.

3.2.4 Signal processing

Sometimes two parameters with the same behaviour but different gain and/or offset have to be verified with each other. Therefore functions for scaling and offset have to be implemented.
In some special cases a parameter need to be remapped to fit and be compared by another parameter. For example, some parameter vectors contain letters that must be remapped to number values to be processed. A mapping table will be used for that issue.

3.2.5 Verification methods

The main purpose with the can interface will, as mention above, be to compare internal node parameters with the extern CAN dittos. Therefore some fast, due to the possibility of big amounts of samples and/or signals, and reliable algorithms for comparing digital vectors is required.

3.2.5.1 Difference verification

The difference verification just subtracts the two signal vectors element vice. If the difference in any sample point is to big the verification will fail. How big the difference can be before the verification fails will be tuneable by the user and also individual for every pair of vectors. This method is very fast, intuitive and easy to understand, it will hopefully also be good enough for most signals. Some signal differences may have problems with spikes due to lag between intern and extern parameters, signal interpolation etcetera, and will therefore be hard to handle with an algorithm without any type of low pass filtering.

The algorithm contains three, by the user, configurable parameters;

- Maximal difference when signal derivative is low
- Breakpoint between low and high derivative.
- Maximal difference when signal derivative is high

Signal parts with big derivative sometimes require a higher tolerance for differences, due to badly synchronised signals, and therefore two configuration parameters for signal differences are needed.

3.2.5.2 Integrated difference verification

The integrated difference verification integrates the difference of the vectors in intervals of one second each. The maximum allowed value for the integration difference error over a one second interval will be tuneable by the user and individually for each pair of vectors. This verification method is more forgivable for short difference spikes than the method described in 1.5.3.1, but will maybe fail if the difference has a small, but acceptable level, all the time. In other words; the standard difference verification are searching for peaks and bigger differences, while the integrated difference verification are searching for small but steady signal deviations.

The algorithm contains three, by the user, configurable parameters;

- Maximal integrated difference when signal derivative is low
- Breakpoint between low and high derivative.

- Maximal integrated difference when signal derivative is high

Signal parts with big derivative sometimes require a higher tolerance for integrated differences, due to badly synchronised signals, and therefore two configuration parameters for integrated signal differences are needed.

3.2.5.3 Min/Max verification

Controlling minimum- and maximum values is another verification that has to be done. The verification will be done after signal processing and therefore only one minimum- respectively one maximum value are required for each pair of signal vectors.

3.2.6 Program configuration

The program configuration will be done in a Microsoft Excel file (*.xls*). It will contain possibilities to define what parameters that should be tested, but also the opportunity to adjust and tune the verification tolerances individually for each pair of parameters.

3.3 Network Management verification – Theory

3.3.1 Introduction

The network management specifies how a CAN node should interrogate and behave during all possible types of running conditions. A dysfunctional network management can cause serious problem and it's of great importance to cover all kind of running conditions during the verification process. For example the node must limp home and use safety settings when the environment does not work as intended, or enter appropriate after-run states when turned off. Unfortunately it takes time to run network management test and analyze test logs. To cut the time for test log analyzing a module for automated network management verification has been developed

3.3.2 Theoretical Overview

The network management specifies in what modes a node can be running. But also how, and when, transitions between different modes, or states, are allowed to be done. According to *CAN NETWORK MANAGEMENT 31812308* specification, the states in Table 3.2 can be used when creating the network management. Remark that the network management implementation must not contain all states.

Table 3.2. Network management states according to *CAN NETWORK MANAGEMENT 31812308*

State	***State numbering***
Reserved	0x00
Off	0x01
Start-up	0x02
Communication Software init	0x03
Operation	0x04
Buss Off	0x05
Transmission Disconnected	0x06
Silent	0x07

Wake-up Network	0x08
Wake- up pending	0x09
Expulsion	0x0A
Isolated	0x0B
Expulsion Silent	0x0C
Expulsion Diagnose	0x0D
Bus Off Wait / After-run	0x0E
CAN controller Init / Initialization	0x0F
Operation After-run	0x10
Expulsion After-run	0x11
Reserved	0x12
Reserved	0x13
Stopped	0x14

3.3.3 Required states and modes (base flow)

CAN NETWORK MANAGEMENT 31812308 also specify a base flow with required states and transitions, see Fig. 3.2. The dotted lines are optional transitions. However, remark that the automated NM verification program will not demand network management based on the flowing chart in Fig. 3.2 On the other hand it can not contain any other states than in Table 3.2.

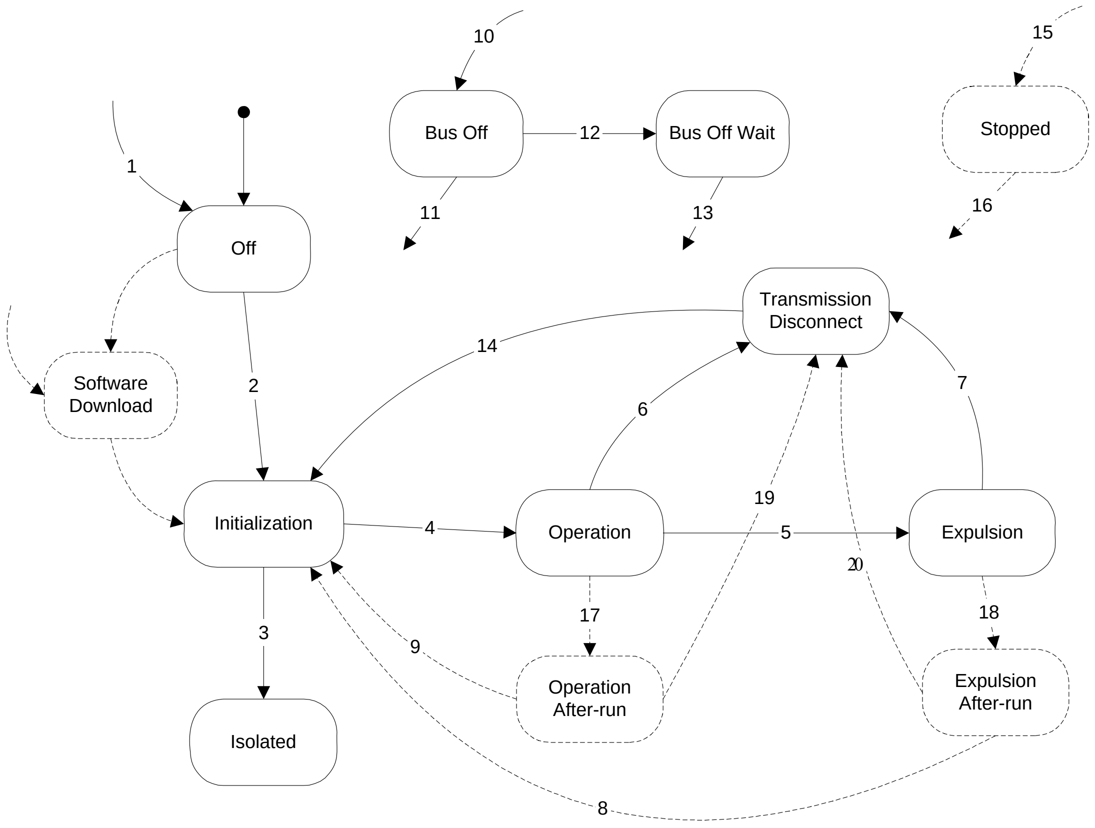


Fig. 3.2. Network management base flow according to *CAN NETWORK MANAGEMENT 31812308*.

3.3.4 Program configuration

The program settings will be done in a Microsoft Excel file (*.xls*) divided into three sheets, *NMtranistions*, *powerMode* and *Signals*. The Excel file will be configurable by the user but with the restriction to follow a template, more information about program configuration can be found in Appendix B.

3.3.4.1 Main configuration file

The main configuration files will be a 2-dimensional matrix with the first column and also the first row containing the state names according to specification *CAN NETWORK MANAGEMENT 31812308*. It will work as a *jump matrix* and covers all possible state transitions. The cells of the matrix constitute of lists with requirements for the state transition, and will be;

- If the jump is allowed to happen.
- Other states that have to be entered before the transition are allowed to take place.
- Maximum time in state before transition takes place.

In fact the main configuration file's is just another representation for a fully configurationally flowing chart, like the one in Fig. 3.2 in section 1.5.2, but with additional state transition criterions.

3.3.4.2 Power mode configuration

The power mode configuration sheet constitutes of lists with allowed power modes for each state. Power mode can very briefly be described as the electrical status of the car.

3.3.4.3 Signal configuration

The program needs three CAN parameters as input;

- Network management state status
- Power mode status
- Time status

The parameter input configuration sheet provides the python program with names of the above parameters in the current CAN-log. This feature can't be hard coded since different nodes use different parameter names.

3.3.5 Verification methods

The verification process will check if the network management CAN parameter follows the user specifications in the main configuration file. The verification algorithms will cover following sources of error;

- Not allowed transition.
- Time limit exceeded before state transition.
- Not allowed state transition due to not have entered other state or states first.

The verification points above are quite straight on, but maybe the last point needs an explanation. For example if more than one network management state has to be entered during the node initialization, the transition criterion for entering the operation mode will be that all initialization states has been passed through.

4. Program

This chapter is partly about what general program parts are needed for the automated testing, and partly about purposes, aims and delimitations for each of the different verifications.

The program modules (State machine-, CAN Interface-. and Network Management verification)) will be created in Python 2.2, and its standard libraries. It will be implemented in the Power Train Test Automation (PTTA) tool and there constitute the last chain in the test and verification process. In addition a stand alone user interface will be created for the opportunity to do verification outside the PTTA environment. With a stand alone GUI it will be much easier to distribute test versions for debugging and evaluation.
Also Interfaces to flexible generic tools, like Inca, are needed for gathering sufficient program input.

4.1 General program parts

Some parts of the program is used in all verifications and will therefore be introduced here and not together with rest of the program description.

4.1.1 Inca as CAN logger

The program Inca, developed by the German company ETAS, will be used for logging the Controller Area network. Inca can be connected to the CAN-bus or directly to a node through several different interfaces, depending on sample rate requirements and available contactors. However the log-file will have the same appearance (disregard sample rates) independent of the logging method, which of course is an advantage and will make this project easier to handle. What internal node- respectively external CAN-parameters to log can be individually configured in Inca. A rule of thumb when creating Inca log files for automatic verification is *less is more*, since a smaller log file will be faster to process. The log-file will by default be saved in *.dat* format. When recreating the measurement in MDA, which is ETAS signal analyzing tool, the *.dat*-file is interpreted by a database. In this way the log-file becomes quite small, but for our purpose it's better to export the *.dat*-file to an ASCII-file (*.txt*), since Python contains powerful tools for processing text files.

The log file generated by Inca need some processing before it can be used in the verification algorithms. First of all Inca samples the time vector faster than the measurements are sampled, the measurement vectors contains therefore a lot of empty sample points that have to be handled before any mathematical processing can be done. The best, and simplest, way is to interpolate the missing sample points. For this project a first order hold algorithm (linear interpolation) will probably be the best compromise between precision and calculation capacity. The empty sample points before the first measurement will be deleted.

4.1.2 Program configuration

The program serttings will be done in a Microsoft Excel file. The configuration file will not have the same appearance for every verifiaction method. The configuration file is the only program flexibility there is. The file is parsed into the program through Microsoft Windows COM Interface.

4.1.3 Result presentation

A result file is created after a successful verification process. The file is in ".xls" format and created through Microsoft Windows COM Interface. First of all the file contains the verification result, but also useful additional information for allocating errors and bugs. The result presentation are not equal for the different kinds of verification methods.

4.2 State Machine program

4.2.1 Background

The state machines are today verified by manually change and manipulate (inject errors etc.) the environment, and either in real time or via a log file assess if the states are correct in respect to the current environment. Both the real time view and logging functionality is managed by a program called Inca. It's possible to log both node (intern) parameters and CAN-bus parameters. An Inca log-file can be saved in either a '.dat' format for process and analyze in MDA (an analyze tool for Inca log-files) or in ASCII format for analyze in a text editor.

The setup for a state machine verification can be either a development car or a computer based simulation environment, with possibility to read node parameters.

4.2.2 Purpose and aims

The manually state machine verification takes time, and the demanded time for verification will incease along with upscaling of the cars electronic network. Verification of growing electronic networks can be handled in at least three different ways;

* Recruite more people in the same speed as the working load increase.
* Cut down the time for each verification process to handle the increased working load.
* Evolve and make the verification processes more efficient.

The aim is to create a reliable automatic state machine verification tool with purpose to considerale decrease the time demanded for state machine verification. The task will be done by developing a log-file processing tool in the language python. The final goal is a proper and well working implementation of the verification tool in the simulation environment used on VCC.

4.2.3 Delimitations

The aim is to build a very dynamic and adaptable Python class library. But there will of course be delimitations that the user most have knowledge about. The most important delimitations are shown above.

- All node parameters that are used by the state machine most be able to log.
- The program scripts can only verify logical expressions of parameters with same time stamp, i.e. logical expressions with not synchronized parameters can't be handled.

However, it's in most cases possible to handle this types of limitations by expand the basic class library with a new class, tailor made for the current task.

4.3 CAN interface program

4.3.1 Background

The can interface is verified today by manual studying of the parameter behavior during different types of operations and condition settings, either in real time or via a log file. Volvo car Corporation uses Inca among others for logging the CAN and node activities. The program provides the user with possibilities to choose what signals to analyze, sample rate, scaling, offset etcetera. The log file can be saved either in ETAS own format '.dat' or in a common ASCII ('.txt') representation.

4.3.2 Purpose and aims

Manually analyzing the CAN interface is very time demanding today, and will be even worse in the future along with more complex CAN network layouts. The aim will be to create a reliable automatic verification model with the purpose to considerable decrease the time demanded for CAN interface verification. The task will be done by implementing a new function library in the scripting language Python, which are able to handle and analyze ASCII log files from Inca. Another aim is, after a successful development, use the CAN interface library in a simulation environment which automatically will generate an Inca log file for the chosen simulator settings.

4.3.3 Delimitations

It will hopefully be few delimitations when the function library are finished. The Python scripts will be close, but never able to cover every possible kind of CAN parameter verification. One of the main reason is to hold down the complexity of the, from user, demanded configurations and settings. Another problem that may occur is slow performance and allocation of all available RAM when using big log files (e.g. many samples and/or parameters) in combination with many parameters for verification.

4.4 Network Management program

4.4.1 Background

The network management is verified today by manually studying the behavior during different types of operations and condition settings, either in real time or via a log file. Volvo Car Corporation uses Inca among others for logging the CAN and node activities. The program provides the user with possibilities to choose what signals to analyze, sample rate, scaling and offset. The log file can be saved either in Inca's own format '.dat' or in a common ASCII ('.txt') representation.

4.4.2 Purpose and aims

As mention in the introduction part the time effort for testing network management manually are in many cases huge. The aim will be to create a reliable automatic verification model with the purpose to considerable decrease the time demanded for the verification process. The task will be done by implementing a new function library, in the scripting language Python, which is able to handle and analyze ASCII log files from Inca. Another aim is, after a successful development, use the network management library in a simulation environment which automatically will generate an Inca log file for the chosen simulator settings.

4.4.3 Delimitations

The program will hopefully be quite flexible, but with at least one big restriction. The node must under all circumstances follow the specifications in *CAN NETWORK MANAGEMENT 31812308*. It is the official specification for network management in, among others, the *Engine Controller Module* and *Transmission Controller Module*.

Another problem that may occur is slow performance when using large log files (e.g. many samples and/or parameters).

5. Result

The finished verification programs are described, how it is constructed both in an overview perspective but also on detail level, in this chapter. There are also examples of verification results.

5.1 Result, State Machine Verification

5.1.1 Result overview

The state machine verification program contains following parts;

- Python module *OMM_LIB.py*.
- Template for configuration file
- Result presentation in form of automatically generated Excel files.

Fig. 5.1 is an overview of the program structure represented as an UML class chart. According to the class chart, the program contains classes for handling of input, result and analyzes. But also a control class that instantiate the other classes and execute class functions. It is possible to pick and choose what type of analyze classes to use for the verification. It is also possible to create own analyze classes for inceased flexibility. Fig. 5.2 is a simplified overview of the program execution order, represented in UML format.

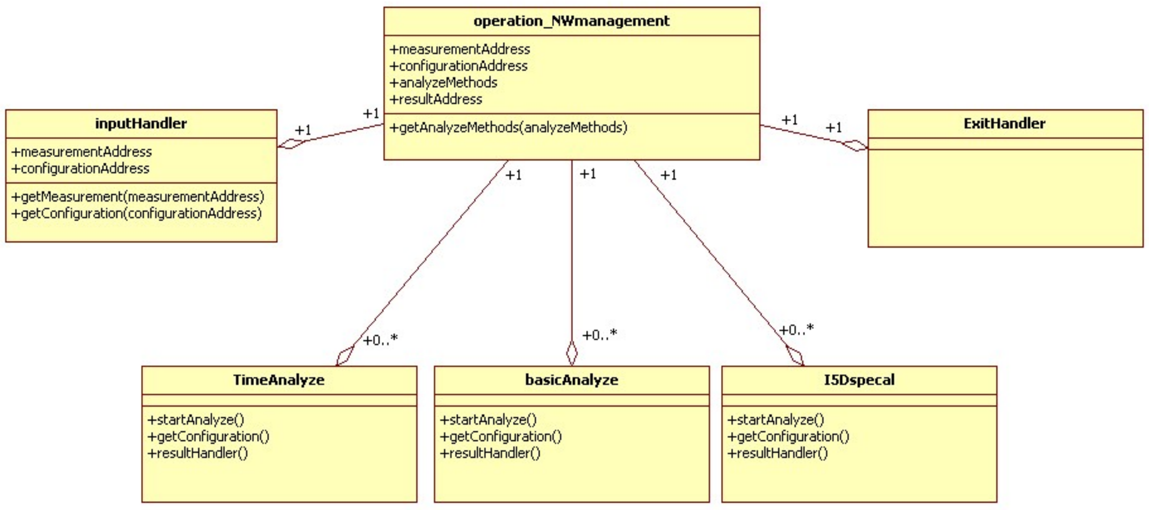


Fig. 5.1. UML class chart diagram for state machine verification program.

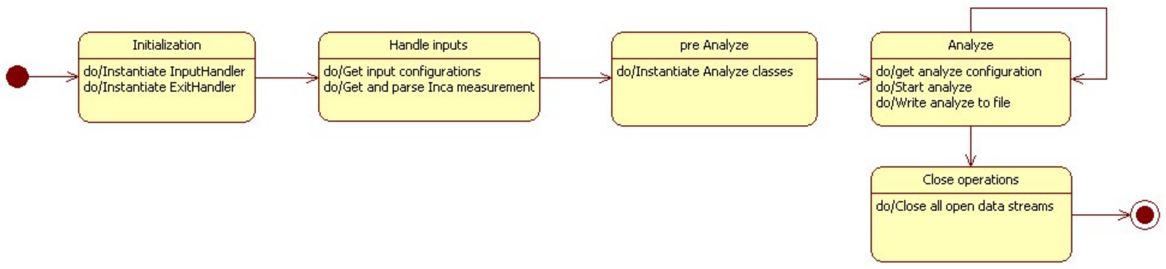

Initialization
do/Instantiate InputHandler
do/Instantiate ExitHandler
Handle inputs
do/Get input configurations
do/Get and parse Inca measurement
pre Analyze
do/Instantiate Analyze classes
Analyze
do/get analyze configuration
do/Start analyze
do/Write analyze to file
Close operations
do/Close all open data streams

Fig. 5.2. State flow for state machine verification program.

5.1.2 Program module OMM_LIB.py

The program module *OMM_LIB.py* contain all code for verification of state machines. The code is splitted into four categories;

- Input handling
- Exit handling
- Controller
- Analyze/verification handling

See Fig. 5.1 for the UML description.

5.1.2.1 Class InputHandler

The class InputHandler contain functionality to process and extract data from an Inca log-file. Table 5.1 describes the functions of InputHandler.

Table 5.1. Function declaration for class InputHandler.

Function	***Description***
getMeasurement	Extracts the information from an Inca log-file and save the raw data in a local variable.
getSignalsMatrix	Process the raw data (interpolate empty samples etc.) and extracts parameter vectors according to the configuration file, and save it as a 2-dimensional matrix.
openConfigWorkbook	Sets up all connections with the Excel application and open the configuration file.

5.1.2.2 Class ExitHandler

The class ExitHandler saves the result and closes the used applications, i.e Microsoft Excel. Does not contain any callable functions, everything is done when the class is instantiated.

5.1.2.3 Class OMManalyzer

The class OMManalyzer is the program controller. It instantiate the other classes and handles the function calls. OMManalyzer doesn't contain any functions itself, which means the verification process starts when the class is initialized and in the end produce a result file without any other lines of code. The OMManalyzer needs 4 arguments.

- Address to the Inca log-file.
- Address to the Excel configuration file.

- Address to the result destination.
- A list of names on what types of analyzes to instantiate and run.

OMManalyzer will automatically instantiate InputHandler, ExitHandler and the chosen analyzes. It also does the necessary function calls for each initialized class.

5.1.2.4 Analyze classes

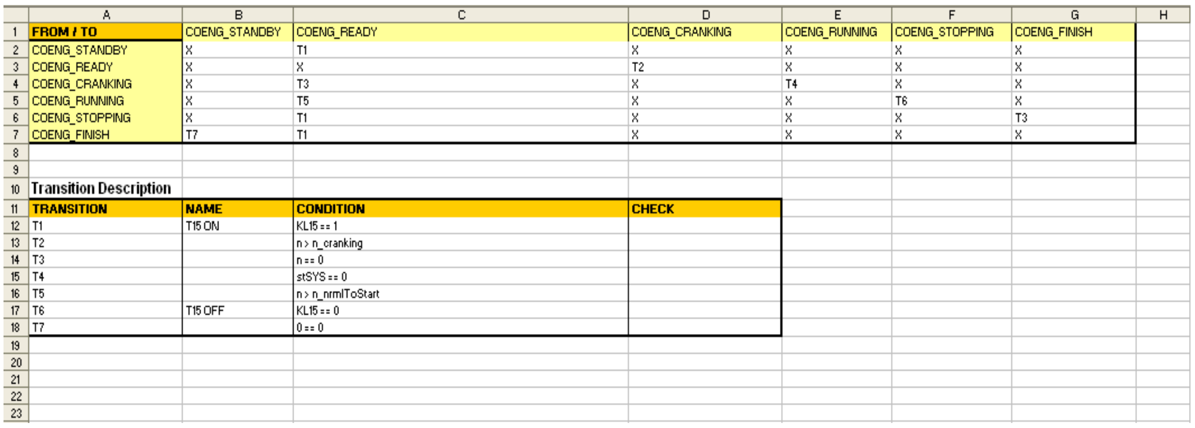
The analyze classes are responsible for verification result. In other words is the choice of analyze classes, for a certain analyze, that decides the verification focus. For example, if the time in each state is the only thing of interest for a certain verification, just instantiate the time analyze class and skip the other analyze types then. There are also good possibilities to extend the class library with new types of analyzes. The existing analyze types are created after a generic implementation method, and as long as the new analyze class follow this method it will be recognized and handled in a correct way by the OMManalyzer class. A analyze class <u>must</u> contain the functions described in Table 5.2.

Table 5.2. Function declaration for the Analyze classes.

Function	***Description***
getConfiguration	Gets the necessary information from the configuration file.
startAnalyze	Starts the analyze of the chosen parameter vectors extracted from the Inca log-file.
resultHandler	Organizes the result from the analyze and writes it to a new excel sheet.

5.1.2.5 Configuration file

The Excel configuration file must at least contain two sheets, one with information what signals to extract and process from the log-file and another with the state machine architecture. Fig. 5.3 and Fig. 5.4 display how the above mentioned Excel sheets can look like.

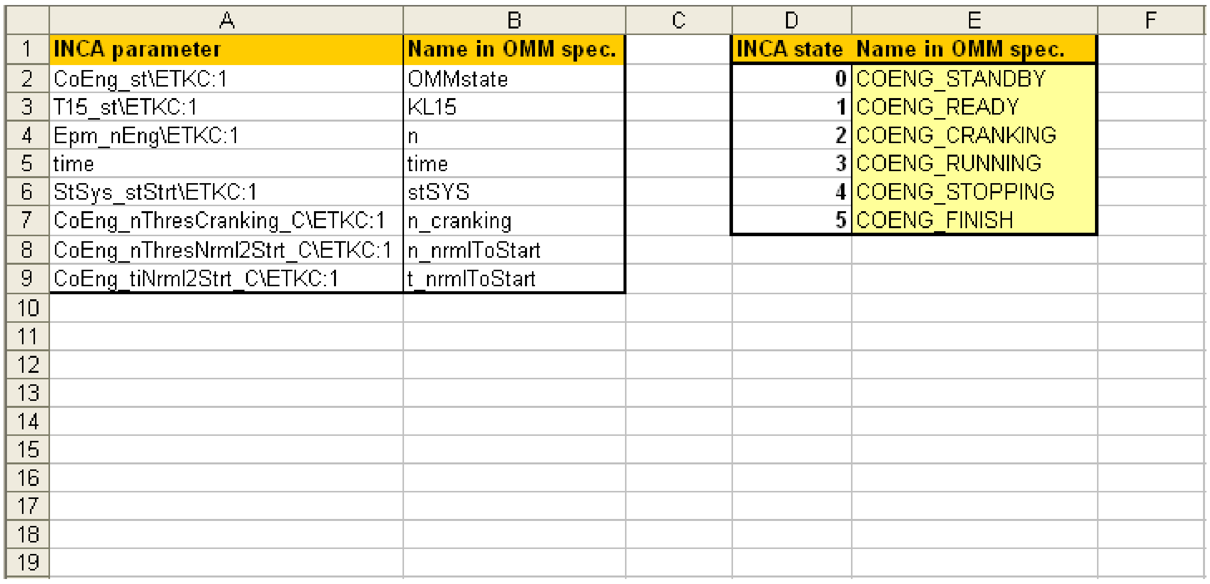


FROM / TO	COENG_STANDBY	COENG_READY	COENG_CRANKING	COENG_RUNNING	COENG_STOPPING	COENG_FINISH
COENG_STANDBY	X	T1	X	X	X	X
COENG_READY	X	X	T2	X	X	X
COENG_CRANKING	X	T3	X	T4	X	X
COENG_RUNNING	X	T5	X	X	T6	X
COENG_STOPPING	X	T1	X	X	X	T3
COENG_FINISH	T7	T1	X	X	X	X

Transition Description

TRANSITION	NAME	CONDITION	CHECK
T1	T15 ON	KL15 == 1	
T2		n > n_cranking	
T3		n == 0	
T4		stSYS == 0	
T5		n > n_nrmlToStart	
T6	T15 OFF	KL15 == 0	
T7		0 == 0	

Fig. 5.3. Example of how the state machine architecture is constructed in the configuration file.



INCA parameter	Name in OMM spec.
CoEng_st\ETKC:1	OMMstate
T15_st\ETKC:1	KL15
Epm_nEng\ETKC:1	n
time	time
StSys_stStrt\ETKC:1	stSYS
CoEng_nThresCranking_C\ETKC:1	n_cranking
CoEng_nThresNrml2Strt_C\ETKC:1	n_nrmlToStart
CoEng_tiNrml2Strt_C\ETKC:1	t_nrmlToStart

INCA state	Name in OMM spec.
0	COENG_STANDBY
1	COENG_READY
2	COENG_CRANKING
3	COENG_RUNNING
4	COENG_STOPPING
5	COENG_FINISH

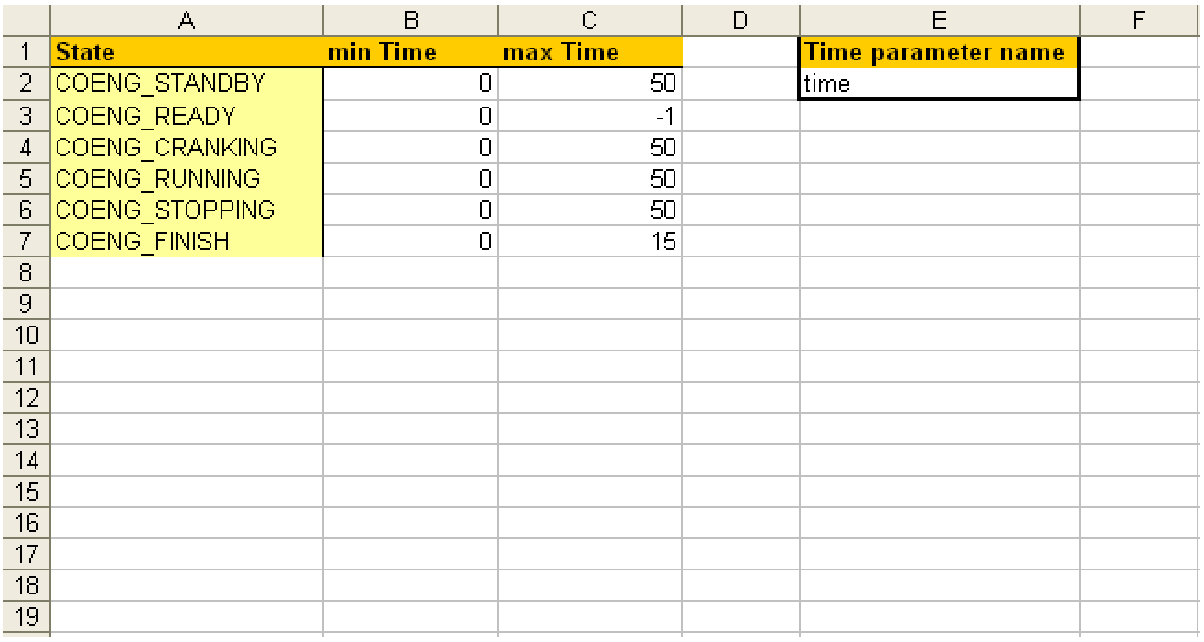
Fig. 5.4. Example of signal configuration to the left. How the state parameter will be parsed is configured on the right hand side.

Note that the logical transition conditions in Fig. 5.3 follows python (and most other programming languages as well) notation. For example implies the sign "=" assignment and "==" equal to. The following operators can be used;

- ==
- <
- >
- <=
- >=
- and
- or
- not

Also remark that the parameters fetched from the Inca log-file is renamed to shorters and more intuitive names (for example names used in the specification from the controller system supplier).

In addition to the two sheets mentioned above, the configuration file can include more sheets with configurations for other analyzes. Fig. 5.5 displays how the configurations for the time analyze can look like. The times in each states are specified in seconds (-1 means no limitations).

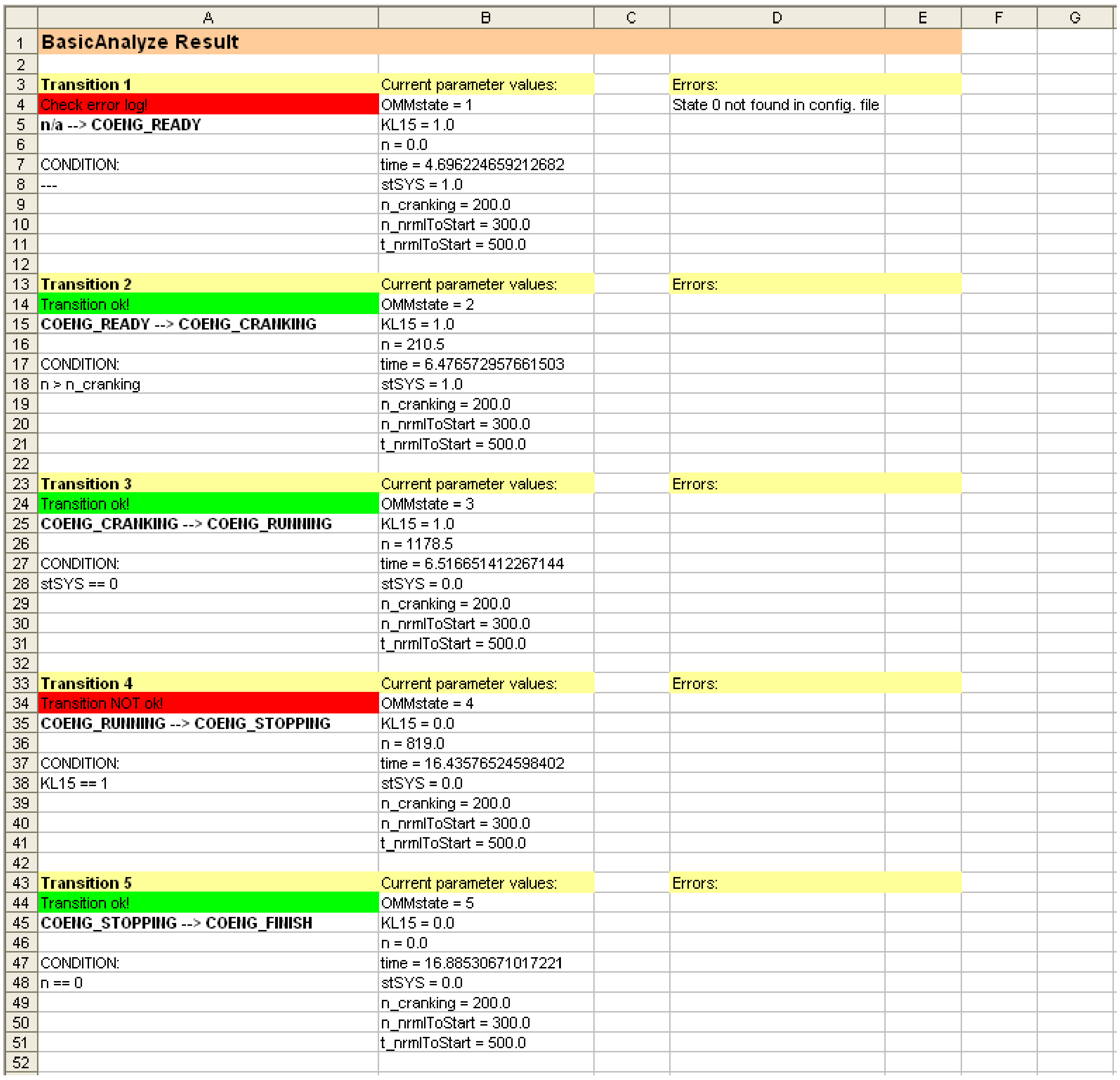


	A	B	C	D	E	F
1	State	min Time	max Time		Time parameter name	
2	COENG_STANDBY	0	50		time	
3	COENG_READY	0	-1			
4	COENG_CRANKING	0	50			
5	COENG_RUNNING	0	50			
6	COENG_STOPPING	0	50			
7	COENG_FINISH	0	15			
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						

Fig. 5.5. Example of a time analyze configuration.

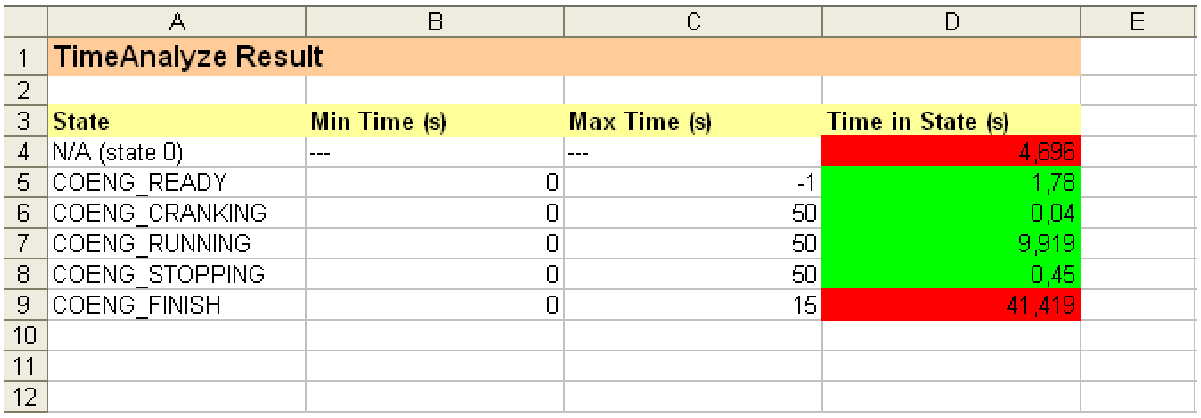
5.1.3 Result presentation

A successful State machine analyze generates an Excel result log. All state transition and belonging information is notated in the result log. The number of sheets varies and depends on which and how many analyzes was processed. The following figures, Fig. 5.6 and Fig. 5.7, are examples of the result log.



	A	B	C	D	E	F	G
1	**BasicAnalyze Result**						
2							
3	**Transition 1**	Current parameter values:		Errors:			
4	🟥 Check error log!	OMMstate = 1		State 0 not found in config. file			
5	**n/a --> COENG_READY**	KL15 = 1.0					
6		n = 0.0					
7	CONDITION:	time = 4.696224659212682					
8	---	stSYS = 1.0					
9		n_cranking = 200.0					
10		n_nrmlToStart = 300.0					
11		t_nrmlToStart = 500.0					
12							
13	**Transition 2**	Current parameter values:		Errors:			
14	🟩 Transition ok!	OMMstate = 2					
15	**COENG_READY --> COENG_CRANKING**	KL15 = 1.0					
16		n = 210.5					
17	CONDITION:	time = 6.476572957661503					
18	n > n_cranking	stSYS = 1.0					
19		n_cranking = 200.0					
20		n_nrmlToStart = 300.0					
21		t_nrmlToStart = 500.0					
22							
23	**Transition 3**	Current parameter values:		Errors:			
24	🟩 Transition ok!	OMMstate = 3					
25	**COENG_CRANKING --> COENG_RUNNING**	KL15 = 1.0					
26		n = 1178.5					
27	CONDITION:	time = 6.516651412267144					
28	stSYS == 0	stSYS = 0.0					
29		n_cranking = 200.0					
30		n_nrmlToStart = 300.0					
31		t_nrmlToStart = 500.0					
32							
33	**Transition 4**	Current parameter values:		Errors:			
34	🟥 Transition NOT ok!	OMMstate = 4					
35	**COENG_RUNNING --> COENG_STOPPING**	KL15 = 0.0					
36		n = 819.0					
37	CONDITION:	time = 16.43576524598402					
38	KL15 == 1	stSYS = 0.0					
39		n_cranking = 200.0					
40		n_nrmlToStart = 300.0					
41		t_nrmlToStart = 500.0					
42							
43	**Transition 5**	Current parameter values:		Errors:			
44	🟩 Transition ok!	OMMstate = 5					
45	**COENG_STOPPING --> COENG_FINISH**	KL15 = 0.0					
46		n = 0.0					
47	CONDITION:	time = 16.88530671017221					
48	n == 0	stSYS = 0.0					
49		n_cranking = 200.0					
50		n_nrmlToStart = 300.0					
51		t_nrmlToStart = 500.0					
52							

Fig. 5.6. Basic Analyze result log.

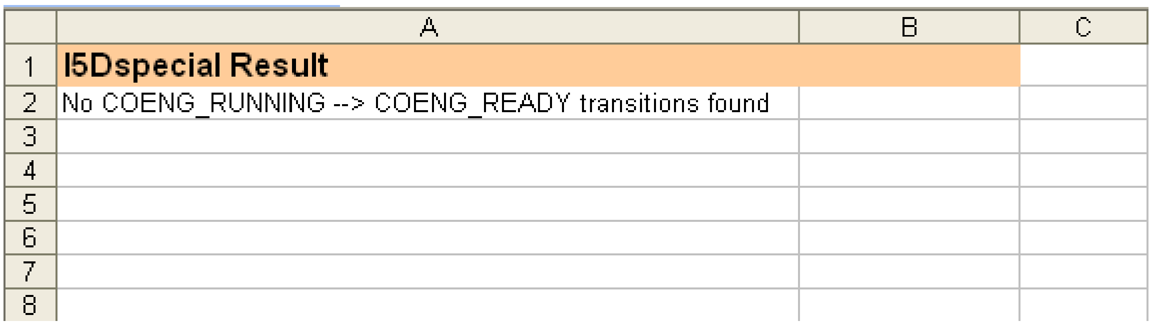


	A	B	C	D	E
1	**TimeAnalyze Result**				
2					
3	**State**	**Min Time (s)**	**Max Time (s)**	**Time in State (s)**	
4	N/A (state 0)	---	---	🟥 4,696	
5	COENG_READY	0	-1	🟩 1,78	
6	COENG_CRANKING	0	50	🟩 0,04	
7	COENG_RUNNING	0	50	🟩 9,919	
8	COENG_STOPPING	0	50	🟩 0,45	
9	COENG_FINISH	0	15	🟥 41,419	
10					
11					
12					

Fig. 5.7. Time Analyze result log.

The analyze results are colour coded, where green implies that everything is ok, red colour implies that something is wrong. Fig. 6 contain two red marked transition, transition 1 and transition 4. Transition 1 fails because the configuration file (sheet signal configuration) not contains information of how to parse the state parameter value "0". Transition 4 fails because unfulfilled transition condition. The transition condition is "KL 15 == 1", but as seen in Fig. 5.6 the current value for "KL 15" is "0.0". Both this are deliberately injected errors, the configuration file in 1.6.3 would not give such error. The red marked fields in the time analyze result log (Fig. 5.7) either mean that the state wasn't found in the time analyze configuration or the time in state is below the min time or exceeds the max time.

Some project requires tailor made analyzes for one single purpose. Fig. 5.8 displays the result log of such tailor made analyze for I5D engineState (state machine in the engine controller system of a Volvo diesel). The only purpose for this analyze class is searching for the transition "COENG_RUNNING → COENG_READY" and verify the transition condition if found. The transition condition includes time requirements for some parameters and is therefore too complicated for the basic analyze to handle.



	A	B	C
1	**I5Dspecial Result**		
2	No COENG_RUNNING --> COENG_READY transitions found		
3			
4			
5			
6			
7			
8			

Fig. 5.8. Result log for I5D engineState tailor made analyze.

5.1.4 Discussion

5.1.4.1 Program functionality

The program works, as far at it has been tested, as intended. And the implementation runs in the way it was specified. The class library that exists today will probably not cover all types of future state machine verifications, but the program controller is well prepared for implementation of new analyze-classes.

It takes some time to be familiar with the program user interface, but is anyway probably constructed in simplest possible way. A flexible program with big configuration possibility always demand some time effort of the user before it become a strong and time saving tool.

5.1.4.2 Known problems and bugs

No bugs or problems detected. But new types of state machines will most likely require additional, new developed, analyze classes. But it's more a limitation rather than a problem. The program needs a better evaluation before confirming that it is free from bugs.

5.1.5 Conclusion

The state machine verification program works very well. It is fast, flexible and in this connection easy to use. A lot of responsibility is given to the user. A configuration miss can

cause verification errors, or even worse; not detecting state machine bugs and errors. But that's the price to pay for flexible solutions.
Developing of new analyze classes will probably be required for a total verification future state machines.

5.1.6 Future work

- Developing new analyze classes to meet up with the verification requirements of upcoming state machines.

- Create configuration files for more state machines.

- Improve GUI to simplify for the user.

5.2 Result, CAN Interface Verification

5.2.1 Result overview

The finished CAN interface verification program contains following parts;

- Python library *CANinterface_LIB.py*.
- Configuration file, for example *CANconfiguration.xls*.
- Mapping tables, for example *mapping1 sheet in CANconfiguration.xls*.
- Stand alone user interface *GUI.py*.
- Result file, for example *result.xls*.

The program starts with reading the CAN log and configuration file. It will then start to fetch pairs of parameter names to compare from the configuration file. The parameters corresponding measurement vectors are fetched from the CAN log, and the signal- and verification processes starts. The result is stored in a program variable. This procedure repeats until all parameters are fetched from the configuration file, and the result is written to the result log. See Fig. 5.9 for an overview of the program execution order.

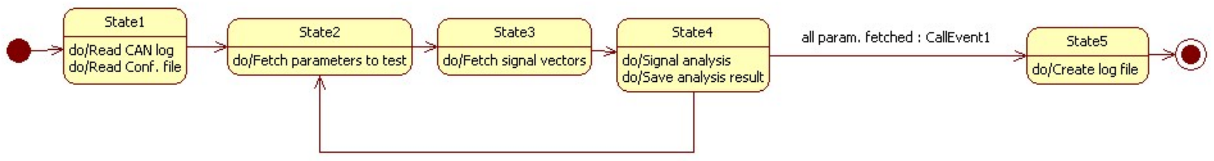


Fig 5.9. UML state chart diagram of the verification program.

5.2.2 Program module

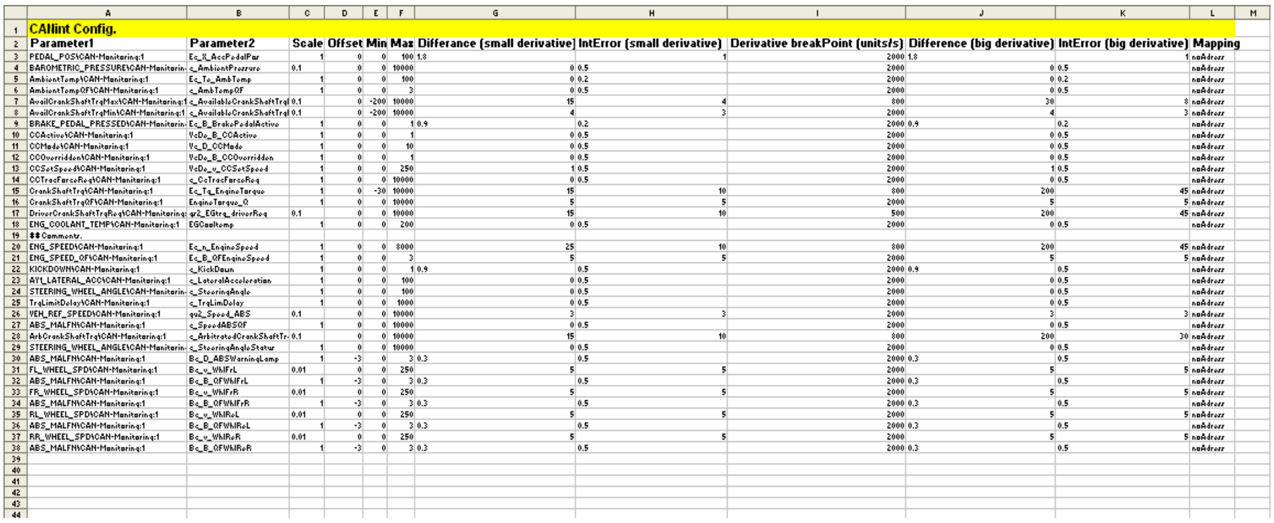
The program library *CANinterface_LIB.py* contains all functions that are callable through PTTA or the stand alone GUI. A functions declaration can be found in Table 5.3.

Table 5.3. Function declaration for CANinterface_LIB.py.

Function	***Description***
readFromFile	Reads the CAN file
readSettingsFromExcel	Reads the excel configuration file.
findCanColumn	Finds the right CAN file column due to the required parameters in the configuration file
getColumnLin	Extract a column in the CAN file due to the parameters in the configuration file. Uses a first order hold algorithm to interpolate empty samples.
syncParam	Sync two measurement vectors.
uTest	Contains the CAN interface testing algorithm
executeConfig	Executes the CAN interface verification
resultToExcelWriter	Write the CAN interface verification result to a Microsoft Excel file (.*xls*) through the COM interface

5.2.2 Configuration file

The appearance of the configuration file is more or most hard coded and very few deviations will be accepted. For an example of a correct configuration file, see Fig. 5.10. Note that comments only can be done in the first column and must be proceeding by double number signs (##). Also remark that links to mapping files can't contain single backslashes due to Python notation. All single backslashes must therefore be replaced by either a single frontslash or double backslashes.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	CANint Config.												
2	Parameter1	Parameter2	Scale	Offset	Min	Max	Differance (small derivative)	IntError (small derivative)	Derivative breakPoint (units/s)	Difference (big derivative)	IntError (big derivative)	Mapping	
3	PEDAL_POS\CAN-Monitoring:1	Ec_X_AccPedalPar	1	0	0	100	1.8	1	2000	1.8	1	noAdress	
4	BAROMETRIC_PRESSURE\CAN-Monitorin	c_AmbientPressure	0.1	0	0	10000	0	0.5	2000	0	0.5	noAdress	
5	AmbientTemp\CAN-Monitoring:1	Ec_Te_AmbTemp	1	0	0	100	0	0.2	2000	0	0.2	noAdress	
6	AmbientTempQF\CAN-Monitoring:1	c_AmbTempQF	1	0	0	3	0	0.5	2000	0	0.5	noAdress	
7	AvailCrankShaftTrqMax\CAN-Monitoring:1	c_AvailableCrankShaftTrql	0.1	0	-200	10000	15	4	800	30	8	noAdress	
8	AvailCrankShaftTrqMin\CAN-Monitoring:1	c_AvailableCrankShaftTrql	0.1	0	-200	10000	4	3	2000	4	3	noAdress	
9	BRAKE_PEDAL_PRESSED\CAN-Monitorin	Ec_B_BrakePedalActive	1	0	0	1	0.9	0.2	2000	0.9	0.2	noAdress	
10	CCActive\CAN-Monitoring:1	VcDe_B_CCActive	1	0	0	1	0	0.5	2000	0	0.5	noAdress	
11	CCMode\CAN-Monitoring:1	Vc_D_CCMode	1	0	0	10	0	0.5	2000	0	0.5	noAdress	
12	CCOverridden\CAN-Monitoring:1	VcDe_B_CCOverridden	1	0	0	1	0	0.5	2000	0	0.5	noAdress	
13	CCSetSpeed\CAN-Monitoring:1	VcDe_v_CCSetSpeed	1	0	0	250	1	0.5	2000	1	0.5	noAdress	
14	CCTracForceReq\CAN-Monitoring:1	c_CcTracForceReq	1	0	0	10000	0	0.5	2000	0	0.5	noAdress	
15	CrankShaftTrq\CAN-Monitoring:1	Ec_Tq_EngineTorque	1	0	-30	10000	15	10	800	200	45	noAdress	
16	CrankShaftTrqQF\CAN-Monitoring:1	EngineTorque_Q	1	0	0	10000	5	5	2000	5	5	noAdress	
17	DriverCrankShaftTrqReq\CAN-Monitoring:	qr2_EGtrq_driverReq	0.1	0	0	10000	15	10	500	200	45	noAdress	
18	ENG_COOLANT_TEMP\CAN-Monitoring:1	EGCooltemp	1	0	0	200	0	0.5	2000	0	0.5	noAdress	
19	## Comments.												
20	ENG_SPEED\CAN-Monitoring:1	Ec_n_EngineSpeed	1	0	0	8000	25	10	800	200	45	noAdress	
21	ENG_SPEED_QF\CAN-Monitoring:1	Ec_B_QFEngineSpeed	1	0	0	3	5	5	2000	5	5	noAdress	
22	KICKDOWN\CAN-Monitoring:1	c_KickDown	1	0	0	1	0.9	0.5	2000	0.9	0.5	noAdress	
23	AY1_LATERAL_ACC\CAN-Monitoring:1	c_LateralAcceleration	1	0	0	100	0	0.5	2000	0	0.5	noAdress	
24	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngle	1	0	0	100	0	0.5	2000	0	0.5	noAdress	
25	TrqLimitDelay\CAN-Monitoring:1	c_TrqLimDelay	1	0	0	1000	0	0.5	2000	0	0.5	noAdress	
26	VEH_REF_SPEED\CAN-Monitoring:1	qu2_Speed_ABS	0.1	0	0	10000	3	3	2000	3	3	noAdress	
27	ABS_MALFN\CAN-Monitoring:1	c_SpeedABSQF	1	0	0	10000	0	0.5	2000	0	0.5	noAdress	
28	ArbCrankShaftTrq\CAN-Monitoring:1	c_ArbitratedCrankShaftTr	0.1	0	0	10000	15	10	800	200	30	noAdress	
29	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngleStatus	1	0	0	10000	0	0.5	2000	0	0.5	noAdress	
30	ABS_MALFN\CAN-Monitoring:1	Bc_D_ABSWarningLamp	1	-3	0	3	0.3	0.5	2000	0.3	0.5	noAdress	
31	FL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrL	0.01	0	0	250	5	5	2000	5	5	noAdress	
32	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrL	1	-3	0	3	0.3	0.5	2000	0.3	0.5	noAdress	
33	FR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrR	0.01	0	0	250	5	5	2000	5	5	noAdress	
34	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrR	1	-3	0	3	0.3	0.5	2000	0.3	0.5	noAdress	
35	RL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReL	0.01	0	0	250	5	5	2000	5	5	noAdress	
36	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReL	1	-3	0	3	0.3	0.5	2000	0.3	0.5	noAdress	
37	RR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReR	0.01	0	0	250	5	5	2000	5	5	noAdress	
38	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReR	1	-3	0	3	0.3	0.5	2000	0.3	0.5	noAdress	
39													
40													
41													
42													
43													
44													

Fig. 5.10. Example of a correct CAN interface configuration file.

3.2.6.4 Mapping tables

The mapping tables constitutes of a simple Excel-sheet. The mapping tables are used for mapping one or more values to other values. For example, this functionality is needed if the internal parameter who sample the gear selector use the values [p, r, n, d] and the CAN dito uses the numbers [0, 1, 2, 3] instead. Fig. 5.11 and 5.12 are examples of how a mapping table looks like.

Mapping1

From	To
2.0	150
3.0	2700
4.0	3000

Fig. 5.11. Mapping table Example.

Mapping2

From	To
p	0
r	1
n	2
d	3

Fig. 5.12. Another mapping table example.

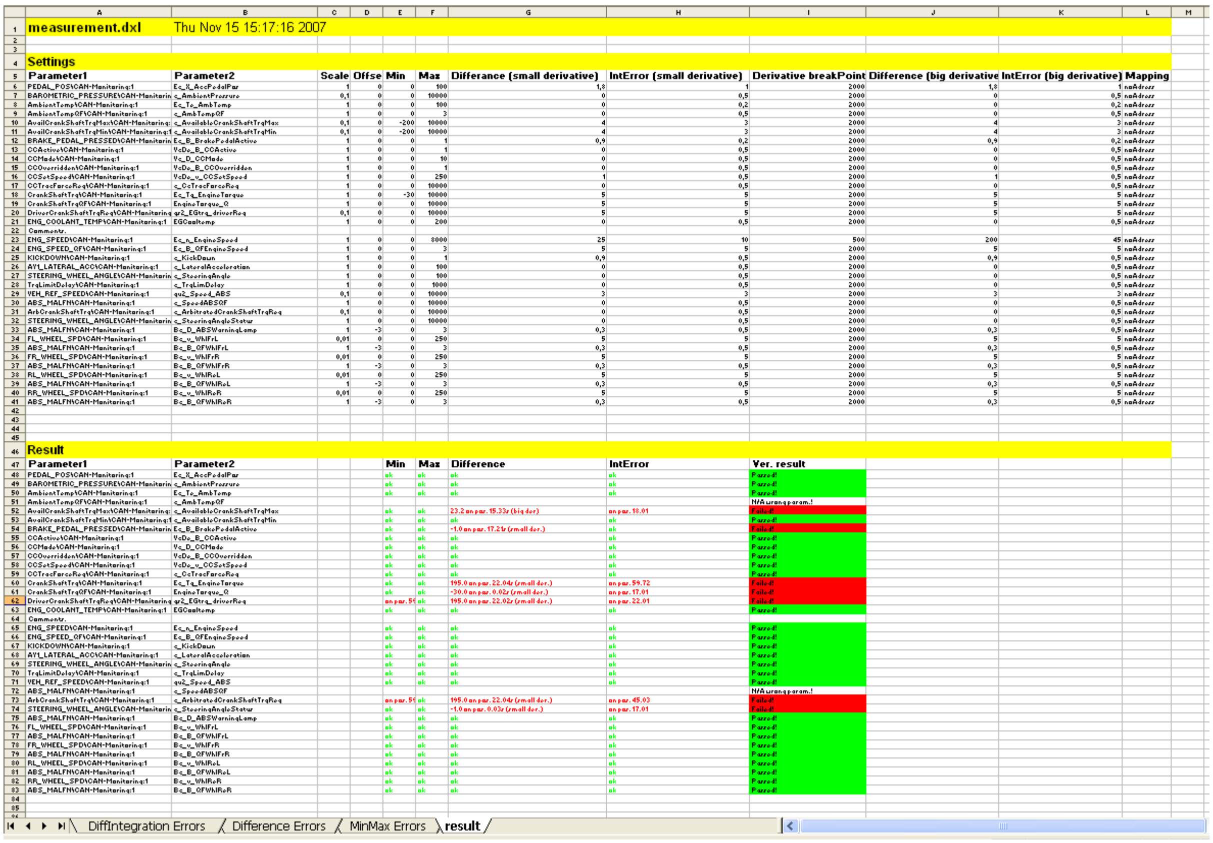
5.2.3 Stand alone user interface

See Appendix A for a brief description of the simple stand alone user interface.

5.2.4 Logging result

5.2.4.1 Result file

A successful CAN interface analysis generates a result log. The result file contains information of both the settings and result. The first table is a copy of the configuration file and the second table contains the verification results.


measurement.dxl Thu Nov 15 15:17:16 2007

Settings

	Parameter1	Parameter2	Scale	Offse	Min	Max	Differance (small derivative)	IntError (small derivative)	Derivative breakPoint	Difference (big derivative	IntError (big derivative)	Mapping
6	PEDAL_POS\CAN-Monitoring:1	Ec_X_AccPedalPar	1	0	0	100	1,8	1	2000	1,8	1	noAdress
7	BAROMETRIC_PRESSURE\CAN-Monitorin	c_AmbientPressure	0,1	0	0	10000	0	0,5	2000	0	0,5	noAdress
8	AmbientTemp\CAN-Monitoring:1	Ec_Te_AmbTemp	1	0	0	100	0	0,2	2000	0	0,2	noAdress
9	AmbientTempQF\CAN-Monitoring:1	c_AmbTempQF	1	0	0	3	0	0,5	2000	0	0,5	noAdress
10	AvailCrankShaftTrqMax\CAN-Monitoring:	c_AvailableCrankShaftTrqMax	0,1	0	-200	10000	4	3	2000	4	3	noAdress
11	AvailCrankShaftTrqMin\CAN-Monitoring:1	c_AvailableCrankShaftTrqMin	0,1	0	-200	10000	4	3	2000	4	3	noAdress
12	BRAKE_PEDAL_PRESSED\CAN-Monitorin	Ec_B_BrakePedalActive	1	0	0	1	0,9	0,2	2000	0,9	0,2	noAdress
13	CCActive\CAN-Monitoring:1	VcDe_B_CCActive	1	0	0	1	0	0,5	2000	0	0,5	noAdress
14	CCMode\CAN-Monitoring:1	Vc_D_CCMode	1	0	0	10	0	0,5	2000	0	0,5	noAdress
15	CCOverridden\CAN-Monitoring:1	VcDe_B_CCOverridden	1	0	0	1	0	0,5	2000	0	0,5	noAdress
16	CCSetSpeed\CAN-Monitoring:1	VcDe_v_CCSetSpeed	1	0	0	250	1	0,5	2000	1	0,5	noAdress
17	CCTracForceReq\CAN-Monitoring:1	c_CcTracForceReq	1	0	0	10000	0	0,5	2000	0	0,5	noAdress
18	CrankShaftTrq\CAN-Monitoring:1	Ec_Tq_EngineTorque	1	0	-30	10000	5	5	2000	5	5	noAdress
19	CrankShaftTrqQF\CAN-Monitoring:1	EngineTorque_Q	1	0	0	10000	5	5	2000	5	5	noAdress
20	DriverCrankShaftTrqReq\CAN-Monitoring	qr2_EGtrq_driverReq	0,1	0	0	10000	5	5	2000	5	5	noAdress
21	ENG_COOLANT_TEMP\CAN-Monitoring:1	EGCooltemp	1	0	0	200	0	0,5	2000	0	0,5	noAdress
22	Comments.											
23	ENG_SPEED\CAN-Monitoring:1	Ec_n_EngineSpeed	1	0	0	8000	25	10	500	200	45	noAdress
24	ENG_SPEED_QF\CAN-Monitoring:1	Ec_B_QFEngineSpeed	1	0	0	3	5	5	2000	5	5	noAdress
25	KICKDOWN\CAN-Monitoring:1	c_KickDown	1	0	0	1	0,9	0,5	2000	0,9	0,5	noAdress
26	AY1_LATERAL_ACC\CAN-Monitoring:1	c_LateralAcceleration	1	0	0	100	0	0,5	2000	0	0,5	noAdress
27	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngle	1	0	0	100	0	0,5	2000	0	0,5	noAdress
28	TrqLimitDelay\CAN-Monitoring:1	c_TrqLimDelay	1	0	0	1000	0	0,5	2000	0	0,5	noAdress
29	VEH_REF_SPEED\CAN-Monitoring:1	qu2_Speed_ABS	0,1	0	0	10000	3	3	2000	3	3	noAdress
30	ABS_MALFN\CAN-Monitoring:1	c_SpeedABSQF	1	0	0	10000	0	0,5	2000	0	0,5	noAdress
31	ArbCrankShaftTrq\CAN-Monitoring:1	c_ArbitratedCrankShaftTrqReq	0,1	0	0	10000	0	0,5	2000	0	0,5	noAdress
32	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngleStatus	1	0	0	10000	0	0,5	2000	0	0,5	noAdress
33	ABS_MALFN\CAN-Monitoring:1	Bc_D_ABSWarningLamp	1	-3	0	3	0,3	0,5	2000	0,3	0,5	noAdress
34	FL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrL	0,01	0	0	250	5	5	2000	5	5	noAdress
35	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrL	1	-3	0	3	0,3	0,5	2000	0,3	0,5	noAdress
36	FR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrR	0,01	0	0	250	5	5	2000	5	5	noAdress
37	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrR	1	-3	0	3	0,3	0,5	2000	0,3	0,5	noAdress
38	RL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReL	0,01	0	0	250	5	5	2000	5	5	noAdress
39	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReL	1	-3	0	3	0,3	0,5	2000	0,3	0,5	noAdress
40	RR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReR	0,01	0	0	250	5	5	2000	5	5	noAdress
41	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReR	1	-3	0	3	0,3	0,5	2000	0,3	0,5	noAdress

Result

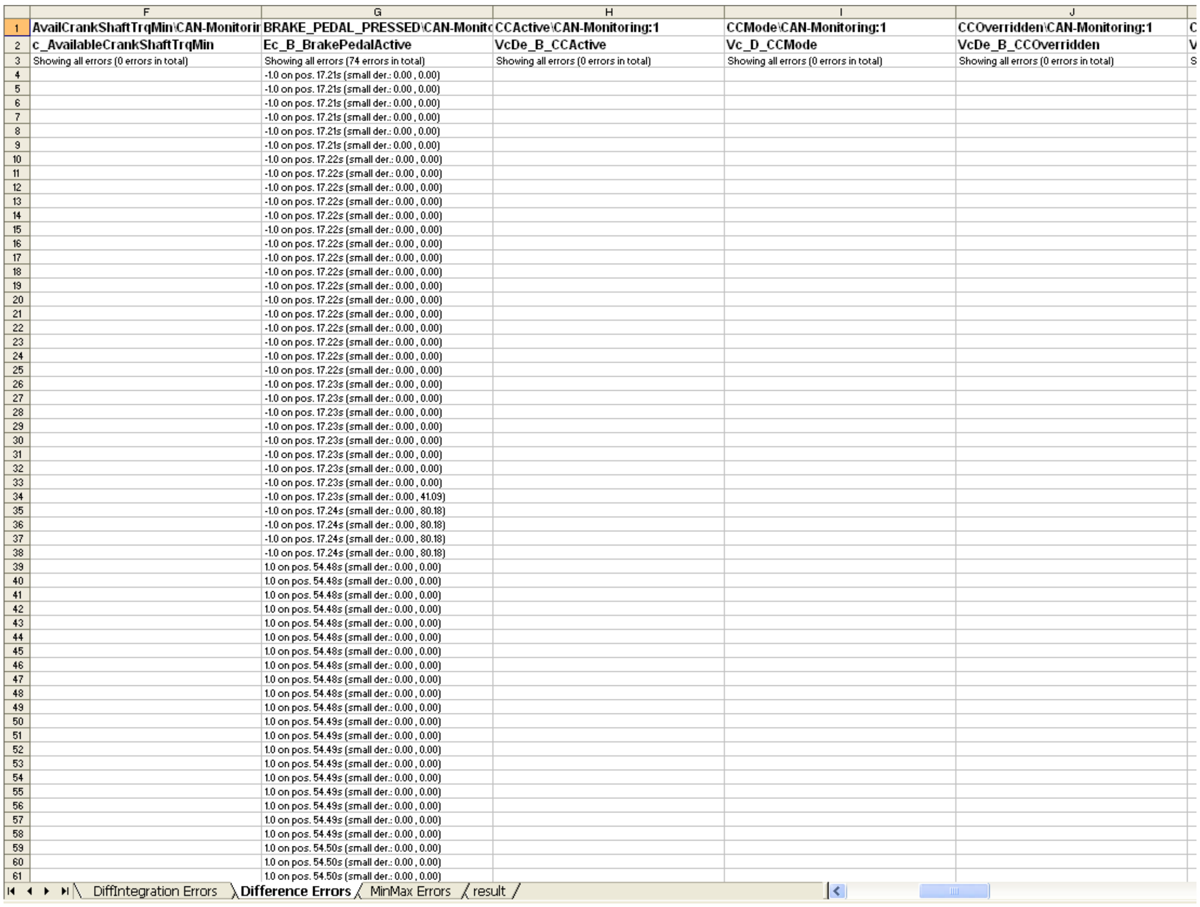
	Parameter1	Parameter2	Min	Max	Difference	IntError	Ver. result
48	PEDAL_POS\CAN-Monitoring:1	Ec_X_AccPedalPar	ok	ok	ok	ok	Passed!
49	BAROMETRIC_PRESSURE\CAN-Monitorin	c_AmbientPressure	ok	ok	ok	ok	Passed!
50	AmbientTemp\CAN-Monitoring:1	Ec_Te_AmbTemp	ok	ok	ok	ok	Passed!
51	AmbientTempQF\CAN-Monitoring:1	c_AmbTempQF					N/A wrong param.!
52	AvailCrankShaftTrqMax\CAN-Monitoring:	c_AvailableCrankShaftTrqMax	ok	ok	23.2 on par. 15.33s (big der)	on par. 18.01	Failed!
53	AvailCrankShaftTrqMin\CAN-Monitoring:1	c_AvailableCrankShaftTrqMin	ok	ok	ok	ok	Passed!
54	BRAKE_PEDAL_PRESSED\CAN-Monitorin	Ec_B_BrakePedalActive	ok	ok	-1.0 on par. 17.21s (small der.)	ok	Failed!
55	CCActive\CAN-Monitoring:1	VcDe_B_CCActive	ok	ok	ok	ok	Passed!
56	CCMode\CAN-Monitoring:1	Vc_D_CCMode	ok	ok	ok	ok	Passed!
57	CCOverridden\CAN-Monitoring:1	VcDe_B_CCOverridden	ok	ok	ok	ok	Passed!
58	CCSetSpeed\CAN-Monitoring:1	VcDe_v_CCSetSpeed	ok	ok	ok	ok	Passed!
59	CCTracForceReq\CAN-Monitoring:1	c_CcTracForceReq	ok	ok	ok	ok	Passed!
60	CrankShaftTrq\CAN-Monitoring:1	Ec_Tq_EngineTorque	ok	ok	195.0 on par. 22.04s (small der.)	on par. 59.72	Failed!
61	CrankShaftTrqQF\CAN-Monitoring:1	EngineTorque_Q	ok	ok	-30.0 on par. 0.02s (small der.)	on par. 17.01	Failed!
62	DriverCrankShaftTrqReq\CAN-Monitoring	qr2_EGtrq_driverReq	on par. 5	ok	195.0 on par. 22.02s (small der.)	on par. 22.01	Failed!
63	ENG_COOLANT_TEMP\CAN-Monitoring:1	EGCooltemp	ok	ok	ok	ok	Passed!
64	Comments.						
65	ENG_SPEED\CAN-Monitoring:1	Ec_n_EngineSpeed	ok	ok	ok	ok	Passed!
66	ENG_SPEED_QF\CAN-Monitoring:1	Ec_B_QFEngineSpeed	ok	ok	ok	ok	Passed!
67	KICKDOWN\CAN-Monitoring:1	c_KickDown	ok	ok	ok	ok	Passed!
68	AY1_LATERAL_ACC\CAN-Monitoring:1	c_LateralAcceleration	ok	ok	ok	ok	Passed!
69	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngle	ok	ok	ok	ok	Passed!
70	TrqLimitDelay\CAN-Monitoring:1	c_TrqLimDelay	ok	ok	ok	ok	Passed!
71	VEH_REF_SPEED\CAN-Monitoring:1	qu2_Speed_ABS	ok	ok	ok	ok	Passed!
72	ABS_MALFN\CAN-Monitoring:1	c_SpeedABSQF					N/A wrong param.!
73	ArbCrankShaftTrq\CAN-Monitoring:1	c_ArbitratedCrankShaftTrqReq	on par. 5	ok	195.0 on par. 22.04s (small der.)	on par. 45.03	Failed!
74	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngleStatus	ok	ok	-1.0 on par. 0.03s (small der.)	on par. 17.01	Failed!
75	ABS_MALFN\CAN-Monitoring:1	Bc_D_ABSWarningLamp	ok	ok	ok	ok	Passed!
76	FL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrL	ok	ok	ok	ok	Passed!
77	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrL	ok	ok	ok	ok	Passed!
78	FR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrR	ok	ok	ok	ok	Passed!
79	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrR	ok	ok	ok	ok	Passed!
80	RL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReL	ok	ok	ok	ok	Passed!
81	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReL	ok	ok	ok	ok	Passed!
82	RR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReR	ok	ok	ok	ok	Passed!
83	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReR	ok	ok	ok	ok	Passed!

Fig. 5.13. CAN interface verification results for a Jaguar car.

The result file contains three more sheets in addition to the *result* sheet;

- Integrated difference (diffintegration) errors.
- Difference errors.
- MinMax errors.

The additional sheets contain detailed verification logs. Fig. 5.14 shows an example of a *difference errors* log.



	F	G	H	I	J	
1	AvailCrankShaftTrqMin\CAN-Monitorir	BRAKE_PEDAL_PRESSED\CAN-Monitc	CCActive\CAN-Monitoring:1	CCMode\CAN-Monitoring:1	CCOverridden\CAN-Monitoring:1	C
2	c_AvailableCrankShaftTrqMin	Ec_B_BrakePedalActive	VcDe_B_CCActive	Vc_D_CCMode	VcDe_B_CCOverridden	V
3	Showing all errors (0 errors in total)	Showing all errors (74 errors in total)	Showing all errors (0 errors in total)	Showing all errors (0 errors in total)	Showing all errors (0 errors in total)	S
4		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
5		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
6		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
7		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
8		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
9		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
10		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
11		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
12		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
13		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
14		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
15		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
16		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
17		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
18		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
19		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
20		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
21		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
22		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
23		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
24		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
25		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
26		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
27		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
28		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
29		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
30		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
31		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
32		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
33		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
34		-1.0 on pos. 17.23s (small der.: 0.00 , 41.09)				
35		-1.0 on pos. 17.24s (small der.: 0.00 , 80.18)				
36		-1.0 on pos. 17.24s (small der.: 0.00 , 80.18)				
37		-1.0 on pos. 17.24s (small der.: 0.00 , 80.18)				
38		-1.0 on pos. 17.24s (small der.: 0.00 , 80.18)				
39		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
40		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
41		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
42		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
43		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
44		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
45		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
46		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
47		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
48		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
49		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
50		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
51		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
52		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
53		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
54		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
55		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
56		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
57		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
58		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
59		1.0 on pos. 54.50s (small der.: 0.00 , 0.00)				
60		1.0 on pos. 54.50s (small der.: 0.00 , 0.00)				
61		1.0 on pos. 54.50s (small der.: 0.00 , 0.00)				

Fig. 5.14. Part of a *difference errors* log.

5.2.4.2 Plots

In addition to the result log, plots are also automatically generated for signals that didn't pass the verification processes. Plots are a very good complementary to the result file when it's hard to decide if the verification shall pass or fail. See Fig. 5.15 for an example.

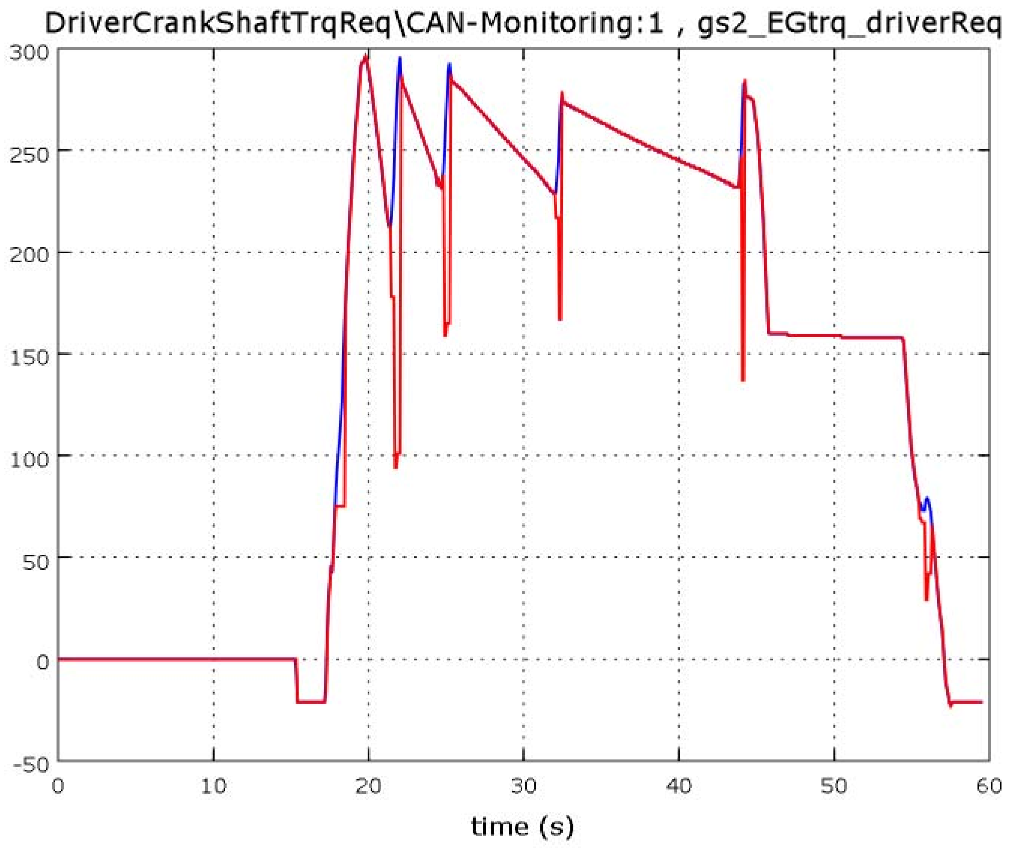


Fig. 5.15. Example of two signals that didn't pass the verification processes. It's not hard to understand why it failed.

5.2.5 Discussion

5.2.5.1 Program functionality

The program works, as far at it has been tested, as intended. The implementation runs in the way it was specified. It takes some time to be comfortable with the program and its mechanics, the demanded user inputs are quite big. The main focus during development was flexibility rather then user simplicity. The program will exclusively be used by an analyze and verification group at Volvo car company, who required a program for handling more or most all the CAN interface verification. The need of a *simple to use* program for everyone was therefore non-existent.

5.2.5.2 Known problems and bugs

There are, at least, two major problems with automated CAN interface verification;

- Handling big Inca measurement logs in combination with many verification parameters may allocate all RAM.
- Verify pair of parameters which are asynchronous in time and contain big variations with rapid changing.

Big measurement logs (≈100Mb and above) in combination with many verification parameters mean a lot of sample points to read and process, which takes time for the Python interpreter to process. It can also result in allocation of all free RAM, which will decrease the system performance a lot. Unfortunately the automated, and in most cases very comfortable, memory allocation in Python doesn't handle this problem in the best of ways. Python is fast for being an interpreting language, but not comparable with compiled languages such as C. In addition, in C all memory allocation is controlled by the programmer. Maybe the Python code can be optimized due to execution time in some points, but will then be much harder-to-grasp and edited.

Comparing two parameters with bad time synchronisation and rapid changing will lead to big difference errors and even sometimes a fair difference integration error. It means the user must be aware of the approximate look and behaviour of the tested parameters when tuning the allowed error levels. A more sophisticated signal processing would probably partly handle this problem, but on the other side lead to a longer execution time. This is over all a minor problem, and a very few parameters are affected, compared to increase the execution time further.

The program is designed to run on a windows platform with office 2003 installed. It seems like the interface to win32 COM in office 2007 slightly differs from the 2003 version in some points. Hopefully (and as far It's tested) it' will work as intended also on a platform with office 2007.

5.2.6 Conclusion

More or most all types of CAN interface parameters can be verified with this program module. But the user must be aware of how to configure it for every single parameter pair to get a useful result. That will however presumably not be a problem; it will exclusively be configured and used by experienced CAN verifiers.

The functionality and performance will be best when using moderately big log files (≈5-50 Mb), and the crashing risk will be minimal.

5.2.7 Future work

- Writing big parts of the module in a compiling language, preferable C, will speed up the execution time a bit. However the program runs today sufficiently fast for the most applications.
- Extend the program flexibility and possibility to cover even more, or maybe future, types of CAN parameters. The seamy side with extended flexibility will be a more unwieldy configuration file.
- Refine and optimize the code for faster execution and readability. Not a big need, but refining can always be done until end of days though.

5.3 Result, Network Management

5.3.1 Result overview

The finished Network Management verification program contains following parts;

- Python module *NM_LIB.py*.
- NMtransition configuration, as sheet in for example *NMconfiguration.xls*.
- Signals configuration, as sheet in for example *NMconfiguration.xls*.
- Power mode settings, as sheet in for example *NMconfiguration.xls*.
- Stand alone user interface *GUI.py*.
- Result file, for example *result.xls*.

Fig. 5.16 is a shortly description of the program functionality represented in an UML state chart diagram. According to state chart diagram the program starts with reading the Network management log and configuration file. It will then fetch the needed parameter (or signal) vectors from the CAN-log.

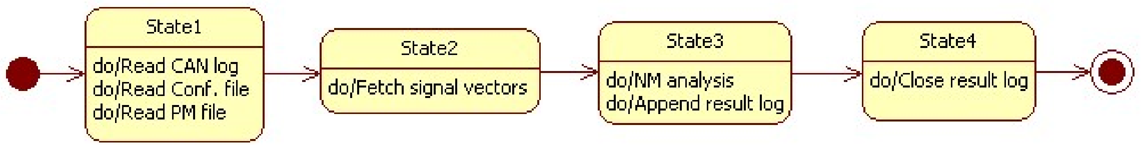


Fig. 5.16. UML state chart diagram of the Network Management verification program.

5.3.2 Program module

The program module *NM_LIB.py* contains all functions that are callable through PTTA or the stand alone GUI. The function declaration can be found in Table 5.4.

Table 5.4. Function declaration for *NM_LIB.py*.

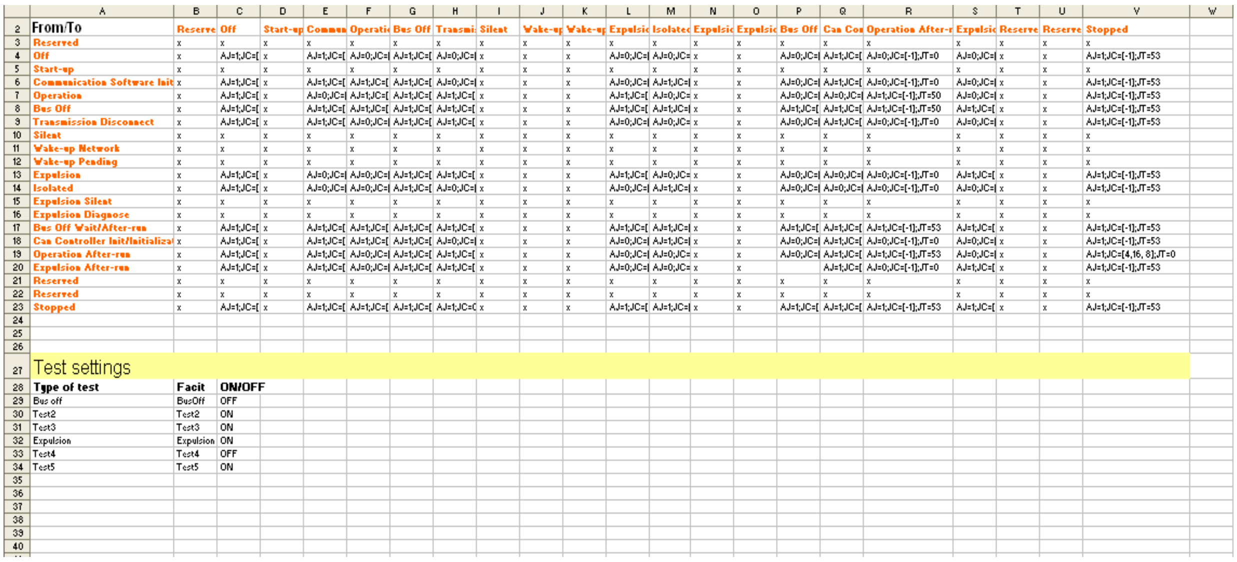
Function	***Description***
CanFileReader	Reads the CAN file
allInOneMatrixReader	Reads the first (*NMtransition*) sheet in the configuration file
conditionMatrixReader	Reads the *Signal* sheet in configuration file
pmReader	Reads the *power mode* sheet in configuration file
findCanColumn	Finds the right CAN file column due to the required parameters in the parameter file.
getPointedCanVector	Extract a column in the CAN file due to the parameters in the parameter file. Uses a zero order hold algorithm to interpolate empty samples.
getPointedCanMatrix	Merges the extracted columns from *getPointedCanVector*.
pCanMatrixVerification	Verifying the network management
getStateInTime	Extract the network management state for a given
getLastValue	Extract the last network management state in the Can log
appendLog	Adds a text string to the result file

5.3.3 Configurations

5.3.3.1 Main configuration sheet

The NMtransition sheet is, as mentioned in 1.5.4.1, a documentation of criterions for all possible transitions. The left most column contains the *from* states, while the first row contains the *to* state. See Fig. 5.17 for an example. Note that the cells are unexpanded.

In addition to the transition matrix it also contains a table for activation or deactivation of tests. A *test* is searching for a specific combination of transitions, specified in the configuration file in the sheet with the same name as the test. For example; configurations for the test *Bus off* can be found in the sheet named *Bus off*.

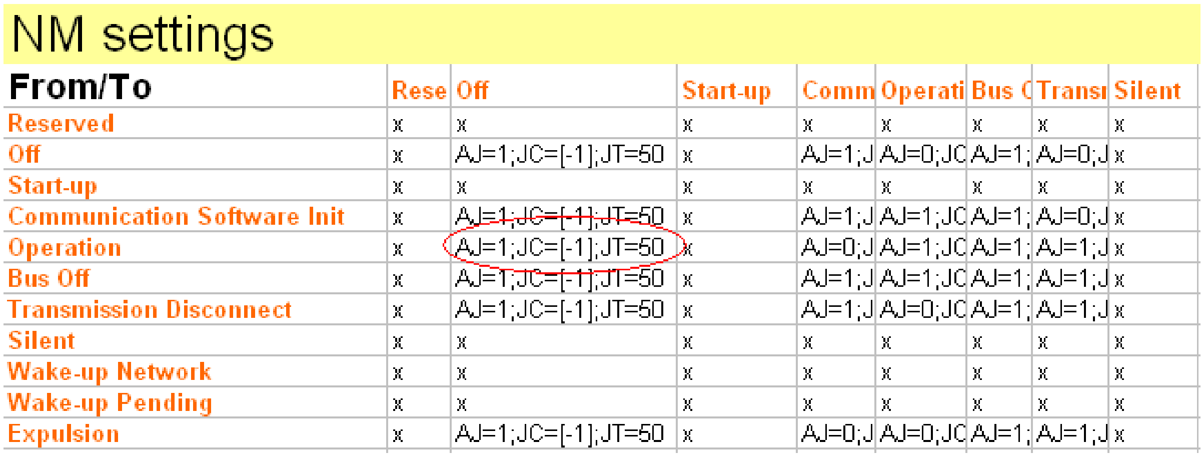


From/To	Reserve	Off	Start-up	Commun	Operati	Bus Off	Transmi	Silent	Wake-up	Wake-up	Expulsic	Isolatec	Expulsic	Expulsic	Bus Off	Can Co	Operation After-r	Expulsic	Reserve	Reserve	Stopped
Reserved	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Off	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[	x	x	x	AJ=0;JC=[	AJ=0;JC=	x	x	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[-1];JT=0	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53
Start-up	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Communication Software Init	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=0;JC=[	x	x	x	AJ=0;JC=[	AJ=1;JC=[	x	x	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[-1];JT=0	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53
Operation	x	AJ=1;JC=[	x	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=1;JC=[	AJ=0;JC=	x	x	AJ=0;JC=[	AJ=0;JC=[	AJ=1;JC=[-1];JT=50	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53
Bus Off	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=1;JC=[	AJ=1;JC=[	x	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[-1];JT=50	AJ=1;JC=[	x	x	AJ=1;JC=[-1];JT=53
Transmission Disconnect	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=0;JC=[	AJ=0;JC=	x	x	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[-1];JT=0	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53
Silent	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Wake-up Network	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Wake-up Pending	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Expulsion	x	AJ=1;JC=[	x	AJ=0;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=1;JC=[	AJ=0;JC=	x	x	AJ=0;JC=[	AJ=0;JC=[	AJ=0;JC=[-1];JT=0	AJ=1;JC=[	x	x	AJ=1;JC=[-1];JT=53
Isolated	x	AJ=1;JC=[	x	AJ=0;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[	x	x	x	AJ=0;JC=[	AJ=1;JC=[	x	x	AJ=0;JC=[	AJ=0;JC=[	AJ=0;JC=[-1];JT=0	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53
Expulsion Silent	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Expulsion Diagnose	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Bus Off Wait/After-run	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=1;JC=[	AJ=1;JC=[	x	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[-1];JT=53	AJ=1;JC=[	x	x	AJ=1;JC=[-1];JT=53
Can Controller Init/Initializat	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=0;JC=[	x	x	x	AJ=0;JC=[	AJ=1;JC=[	x	x	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[-1];JT=0	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53
Operation After-run	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=0;JC=[	AJ=0;JC=	x	x	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[-1];JT=53	AJ=0;JC=[	x	x	AJ=1;JC=[4,16, 8];JT=0
Expulsion After-run	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=0;JC=[	AJ=0;JC=	x	x		AJ=1;JC=[	AJ=0;JC=[-1];JT=0	AJ=1;JC=[	x	x	AJ=1;JC=[-1];JT=53
Reserved	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Reserved	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Stopped	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=C	x	x	x	AJ=1;JC=[	AJ=1;JC=[	x	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[-1];JT=53	AJ=1;JC=[	x	x	AJ=1;JC=[-1];JT=53

Test settings

Type of test	Facit	ON/OFF
Bus off	BusOff	OFF
Test2	Test2	ON
Test3	Test3	ON
Expulsion	Expulsion	ON
Test4	Test4	OFF
Test5	Test5	ON

Fig. 5.17. Network management main configuration sheet.



NM settings

From/To	Rese	Off	Start-up	Comm	Operati	Bus (	Transı	Silent
Reserved	x	x	x	x	x	x	x	x
Off	x	AJ=1;JC=[-1];JT=50	x	AJ=1;J	AJ=0;JC	AJ=1;	AJ=0;J	x
Start-up	x	x	x	x	x	x	x	x
Communication Software Init	x	AJ=1;JC=[-1];JT=50	x	AJ=1;J	AJ=1;JC	AJ=1;	AJ=0;J	x
Operation	x	AJ=1;JC=[-1];JT=50	x	AJ=0;J	AJ=1;JC	AJ=1;	AJ=1;J	x
Bus Off	x	AJ=1;JC=[-1];JT=50	x	AJ=1;J	AJ=1;JC	AJ=1;	AJ=1;J	x
Transmission Disconnect	x	AJ=1;JC=[-1];JT=50	x	AJ=1;J	AJ=0;JC	AJ=1;	AJ=1;J	x
Silent	x	x	x	x	x	x	x	x
Wake-up Network	x	x	x	x	x	x	x	x
Wake-up Pending	x	x	x	x	x	x	x	x
Expulsion	x	AJ=1;JC=[-1];JT=50	x	AJ=0;J	AJ=0;JC	AJ=1;	AJ=1;J	x

Fig. 5.18. Part of NM configuration file. NM state transition criterions from *Operation* to *Off* are red marked.

The state transition criterion can either contain the character *x* or a string of the same type as in Fig. 5.18. If the transition criterion between two states is *x* marked means the transition can't be done. It can for example be from or to a non used state in a specific implementation. In Fig. 5.17 the transition from or to the Start-up state are marked with an *x* because that NM state isn't used in the example implementation, the same goes for *Reserved* and a number of other NM states.

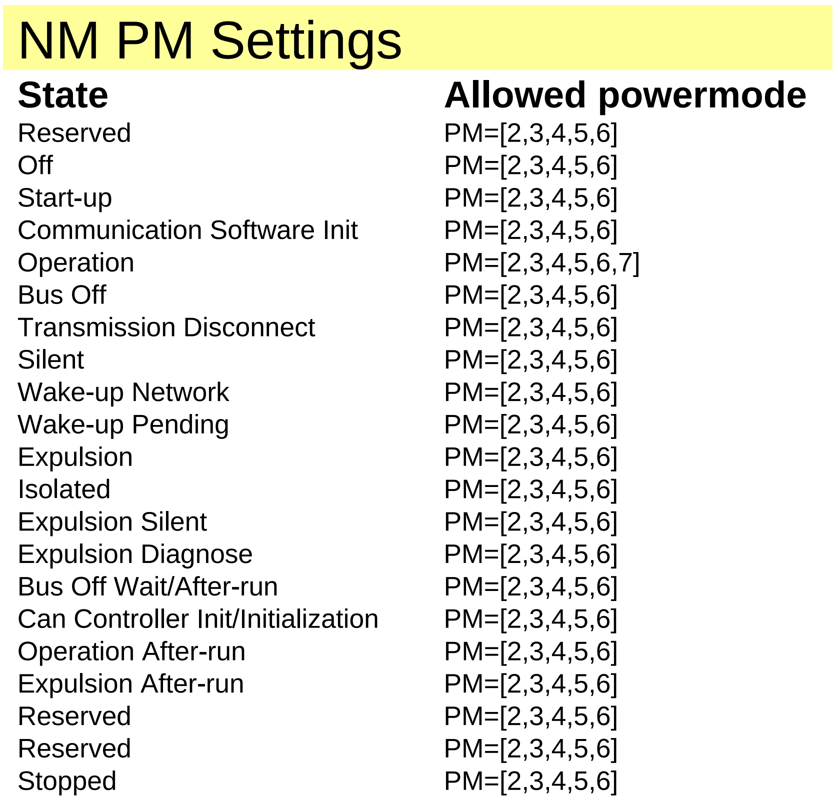
If the transition criterion contains a text string, like the red marked one in Fig. 5.18, the analysis will use that string as input. The text string contents with descriptions are listed in Table 5.5. In fact the text strings follows the Python notation and are therefore ideally as program input.

Table 5.5. NM state transition criterions

Variabel name	***Description***
AJ	Stands for *Allowed Jump*. Equal to *1* means *allowed* transition Equal to *0* means *not allowed* transition
JC	Stands for *Jump Criterions*. Contains a list with states which must have been entered before transition. If no criterions, the list will only contain the single value -1.
JT	Stands for *Jump Time*. Contains the maximum time for the transition to be done

5.3.3.2 Power mode settings

The power mode settings are done in the *PoweMode* sheet of the configuration file. It contains the allowed power modes for each network management state. Fig. 5.19 is an example for how the setting file should look like.



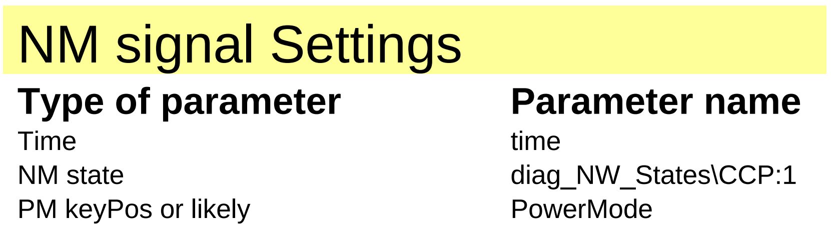
NM PM Settings

State	**Allowed powermode**
Reserved	PM=[2,3,4,5,6]
Off	PM=[2,3,4,5,6]
Start-up	PM=[2,3,4,5,6]
Communication Software Init	PM=[2,3,4,5,6]
Operation	PM=[2,3,4,5,6,7]
Bus Off	PM=[2,3,4,5,6]
Transmission Disconnect	PM=[2,3,4,5,6]
Silent	PM=[2,3,4,5,6]
Wake-up Network	PM=[2,3,4,5,6]
Wake-up Pending	PM=[2,3,4,5,6]
Expulsion	PM=[2,3,4,5,6]
Isolated	PM=[2,3,4,5,6]
Expulsion Silent	PM=[2,3,4,5,6]
Expulsion Diagnose	PM=[2,3,4,5,6]
Bus Off Wait/After-run	PM=[2,3,4,5,6]
Can Controller Init/Initialization	PM=[2,3,4,5,6]
Operation After-run	PM=[2,3,4,5,6]
Expulsion After-run	PM=[2,3,4,5,6]
Reserved	PM=[2,3,4,5,6]
Reserved	PM=[2,3,4,5,6]
Stopped	PM=[2,3,4,5,6]

Fig. 5.19. Example of a Power mode settings file.

5.3.3.3 Signal settings

Also the parameter settings are configured via the Excel Sheet *Sginals*. The left column contain the python program parameter name, while the right column contains the respective CAN-log address. See Fig. 5.20 for an example.



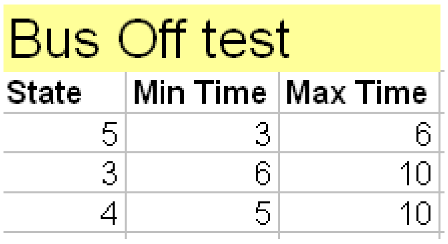
NM signal Settings

Type of parameter	Parameter name
Time	time
NM state	diag_NW_States\CCP:1
PM keyPos or likely	PowerMode

Fig. 5.20. Example of a signal settings file.

5.3.3.4 Settings for special tests

As mentioned in 1.6.3.1, there are a number of special tests. Each of these tests has its own configuration sheet, see Fig. 5.21 for an example. The special test configurations contain a three column table. The first column specifies what combination of states to search for. The other two columns specifies min- and max-time in each state.



Bus Off test

State	Min Time	Max Time
5	3	6
3	6	10
4	5	10

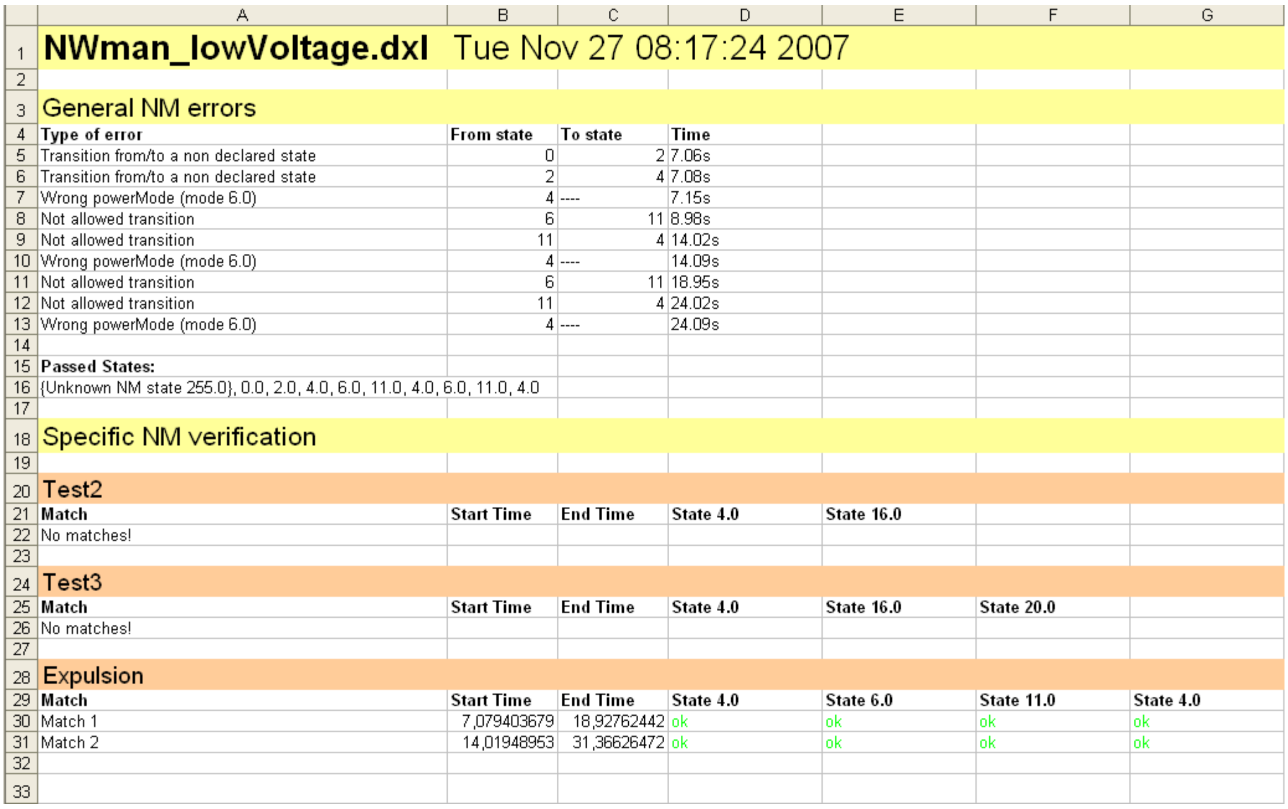
Fig. 5.21. *Bus off test* configurations.

5.3.3.5 Stand alone user interface

See Appendix B for a brief description of the simple stand alone user interface.

5.3.4 Result File

A successful Network Management analysis generates a Microsoft Excel result file. All upcoming network management errors during the verification are presented in the result file. In addition, the last part of the log contains results for the activated special tests. See Fig. 5.22 for an example log.



	A	B	C	D	E	F	G
1	**NWman_lowVoltage.dxl**	Tue Nov 27 08:17:24 2007					
2							
3	General NM errors						
4	**Type of error**	**From state**	**To state**	**Time**			
5	Transition from/to a non declared state	0	2	7.06s			
6	Transition from/to a non declared state	2	4	7.08s			
7	Wrong powerMode (mode 6.0)	4	----	7.15s			
8	Not allowed transition	6	11	8.98s			
9	Not allowed transition	11	4	14.02s			
10	Wrong powerMode (mode 6.0)	4	----	14.09s			
11	Not allowed transition	6	11	18.95s			
12	Not allowed transition	11	4	24.02s			
13	Wrong powerMode (mode 6.0)	4	----	24.09s			
14							
15	**Passed States:**						
16	{Unknown NM state 255.0}, 0.0, 2.0, 4.0, 6.0, 11.0, 4.0, 6.0, 11.0, 4.0						
17							
18	Specific NM verification						
19							
20	Test2						
21	**Match**	**Start Time**	**End Time**	**State 4.0**	**State 16.0**		
22	No matches!						
23							
24	Test3						
25	**Match**	**Start Time**	**End Time**	**State 4.0**	**State 16.0**	**State 20.0**	
26	No matches!						
27							
28	Expulsion						
29	**Match**	**Start Time**	**End Time**	**State 4.0**	**State 6.0**	**State 11.0**	**State 4.0**
30	Match 1	7,079403679	18,92762442	ok	ok	ok	ok
31	Match 2	14,01948953	31,36626472	ok	ok	ok	ok
32							
33							

Fig. 5.22. Example of a Network Management result file.

5.3.4.1 General NM errors

The first part of the result file presents all general Network Management errors. It can be all from an illicit transition to wrong powermode or unidentified states. In addition, all passed states are presented in the order they were activated.

5.3.4.2 Specific NM verification

The log file's second and last part contains the result of the special tests. Each match of the specified state series is presented. Whole or part of the series can either be marked as *ok* in green colour, or as *failed* in red colour. *Failed* means time in state whether is below the minimum time limit or exceeds the maximum time limit.

5.3.5 Discussion

5.3.5.1 Program functionality

The program works as intended, as far at it has been tested. The implementation runs in the way it was specified. The by far biggest risk when using the program is wrong configurations (set by the user) according to specification. But the program will exclusively be used by an analyze and verification group at Volvo car company and flexibility was therefore prioritized, instead of use ability.

It takes some time to be comfortable with the program and its mechanics, the demanded user inputs are quite big. The main focus during development was flexibility rather then user simplicity, and a program that can handle more or most all the Network Management verification. The need of a *simple to use* program that everyone can use for verifying the Network Management was therefore non-existent.

5.3.5.2 Known problems and bugs

There are no recognized bugs, as far as tested.

5.3.6 Conclusion

The program can be used for verifying the Network Management in most cases. The seamy side is an ungainly configuration file. The configuration file design can be improved in a plural ways. Not much job is done there though, because the state machine verification algorithms can in most cases be used also for verifying the Network Management state machine.

5.3.7 Future work

- Cleaner code and user interface are needed, specially the configuration interface needs an update.

- Update the state machine verification code to fully include also network management. This software will then be replaced with the state machine verification tool, which is much more flexible.

6. Discussion and Conclusion

Profits and disadvantages for automated verification in general are discussed in this chapter. Especially time profits and useability for automated verification methods are highlighted.

6.1. Program functionality and useability

The overall program functionality, and particularly the usability, for PowerTrain Test Automation (PTTA) is now, with the log-file verification and result presenting implemented, improved. And the step from development- to commercial software has significantly decreased.

The PTTA system itself is a very flexible tool with big opportunities. The program parts developed, scripted and tested in this thesis are developed in the same spirit, and will hopefully be flexible enough to analyze and verify also future State machines, Network management and CAN interface architectures. But software tools with high flexibility, as everything else, also has a seamy side; the demand of competence and experienced manpower for handling the program configuration. To learn and master PTTA is sadly not the only obstacle. It also requires adaptation of a whole test environment, namely the car, to a simulated ditto. That requires of course great efforts from the developers of the simulator and its surrounding environment to get things work in a proper way, but also from the users. They have to change, or in many cases try new, ways of working.

This thesis has only been about verification of three different types of controller unit functions, and it maybe seems like verify these collection of functions in a manual or automatic way doesn't matter. But that's wrong, at least from two very important perspectives. First; these three are somewhat the absolutely most time consuming functions to verify, especially the CAN-interface. And the verification has to, or at least should, be done with every new software update. Second; hopefully this thesis in combination with the other parts of PTTA works as a good example and guidance for future work.

6.2. Time profits

The time savings for using automatic verification methods instead of manual must be managed as the very most important parameter during the whole development process. It's, without question, the heaviest argument when convincing the possible user to change working methods. Other important parameters are of course reliability, storage functions, flexibility etc, but not nearly as important, for the user, as the time profits.

The configuration and first run for a whole new controller unit, independent of it's verification of CAN-interface, network management or the engine state machine, will take about the same time as to test it manually. In other words; it will take 4 hours or more, dependent of software, type of function for verification, coverage etc. The big time profits are instead received when iterating the verification process, for example when a new software update is released. Usually a controller unit last for 3-6 years. That implies plenty of software updates; in general 40-50 updates a year. With that basis just a single hour time profit when using automatic verification methods is a huge time save.

6.3. Problems and pitfalls

There are of course, apart from the benefits, also several problems and pitfalls with using automated verifications. The biggest source of error for manual verification is without doubt the human factor. But I will say the same goes for automatic verification if the algorithms itself is verified in a proper way. It can be everything from incorrect configuration to wrong result interpretation. But of course, the tester must be aware of program flaws, even if it's well tested. One of the most important qualities for the tester to possess is the capacity for estimate the reliability of the result, just because it's so easy to inject an error in the configuration.

6.4. The importance of satisfying specifications

A prerequisite for automatic verification of controller unit functions is good and exhaustive specifications. Of course good function specifications are also required if the verification is done manually, but it doesn't have to be crystal clear in every single way. A manual test is allways, and will allways be, much more flexible than automatic tests. If something are not clear or not mentioned in the specification of the function the manual tester, in many cases, can decide if the function is ok just by using his/her logical mind and experience. The function will of course not follow the specification to hundred percent, but it's at least working. That flexibility will never be reached by using automatic tests. An automatic verification algorithm contains as much intelligence, neither more or less, as required for verifying that the implementation follows specification. In the very most cases a bad function specification leads to bad or useless automatic test results.

7. Future Work

The future work in the automated software verification area is endless. This thesis, combined with the PTTA development, is just a first step in the right direction and guidance for future strategies. But if we just focus on future work strongly connected to this thesis, the following points are important to handle in the near future;

- Extend the library of configuration files for verification of more types of controller unit software. The automated test system is designed to work with all available TCM and ECM software, but it's only tested with a few ones because the lack of configuration files.
- Education of the testers in the new way of work. Automated testing requires in many cases both different kind of competence and work approach than manual testing.

8. Bibliography

[1] M. Lutz, *Programming Python*, O'Reilly Media, Inc, 1996

[2] *CAN specification version 2.0,* Robert Bosch GmbH, 1991

[3] Steve Corrigan, *Introduction to the Controller Area Network (CAN)*, Texas Instruments Incorporated, 2003

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[5] Niklas Smith, Personal Communication, September-December 2008.

Appendix 1

1. State machine verification – user manual

1.1 Introduction

The program is written in the interpreting language Python and is used for verification of state machines. See Fig.1 for an example of a state machine. The intention is to change from manually state machine verification to scripted algorithms and analysis tools. The program requires an Inca measurement log-file as input. Remark that the file must be saved in ASCII (.dxl) format. The verification program contain following parts;

- Python module *OMM_LIB.py*.
- Template for configuration file
- Result presentation in form of automatically generated Excel files.

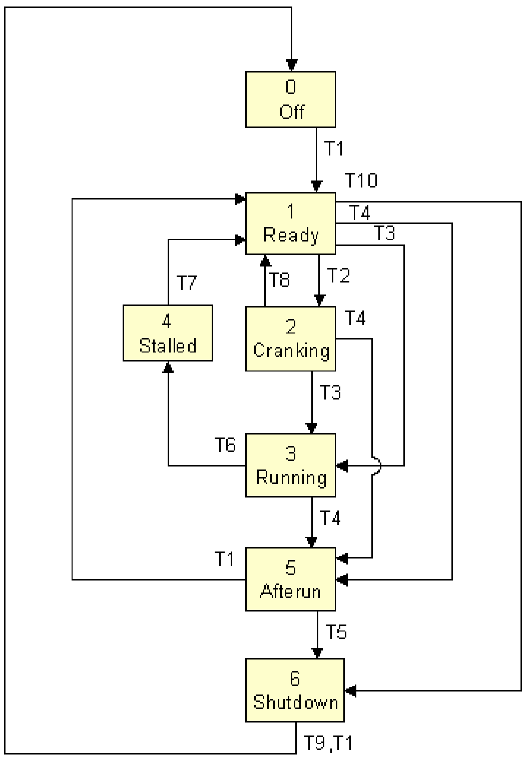


Fig.1. Example of a state machine.

1.2 Program module OMM_LIB.py

1.2.1 Overview

The library, *OMM_LIB.py,* contains classes for input/output-handling, signal processing and verification. See Fig. 2 for an overview of the program execution order. It is possible to choose what types and how many analyzes to use for the current state machine verification. It is also possible to connect new analyze classes to the verification tool, if the existing ones doesn't fit the current purpose.

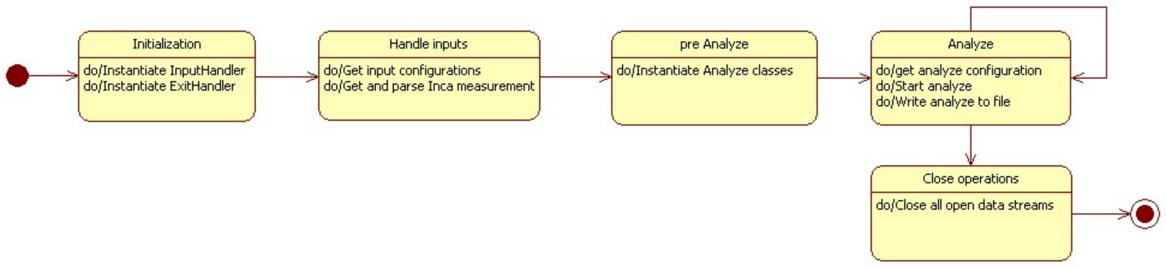

Initialization
do/Instantiate InputHandler
do/Instantiate ExitHandler
Handle inputs
do/Get input configurations
do/Get and parse Inca measurement
pre Analyze
do/Instantiate Analyze classes
Analyze
do/get analyze configuration
do/Start analyze
do/Write analyze to file
Close operations
do/Close all open data streams

Fig. 2. State flow for state machine verification program.

1.3 Analyze classes

The analyze classes are responsible for verification result. In other words is the choice of analyze classes, for a certain analyze, that decides the focus of the verification. For example, if the time in each state is the only thing of interest for a certain verification, just instantiate the time analyze class and skip the other analyze types then. There are also good possibilities to extend the class library with new types of analyzes. The existing analyze types are created after a generic implementation method, and as long as the new analyze class follow this method it will be recognized and handled in a correct way by the verification tool. A analyze class <u>must</u> contain the functions described in Table 3.

Table 1. Function declaration for the Analyze classes.

Function	***Description***
getConfiguration	Gets the necessary information from the configuration file.
startAnalyze	Starts the analyze of the chosen parameter vectors extracted from the Inca log-file.
resultHandler	Organizes the result from the analyze and writes it to a new excel sheet.

Currently there are three created analyze classes;

- Basic Analyze
- Time Analyze
- Special Analyze for I5D-engineState.

The basic and- time analyze classes are general algorithms for state machine verification, while the special analyze is tailor made for I5D-engineState verification.

1.3.1 Basic Analyze

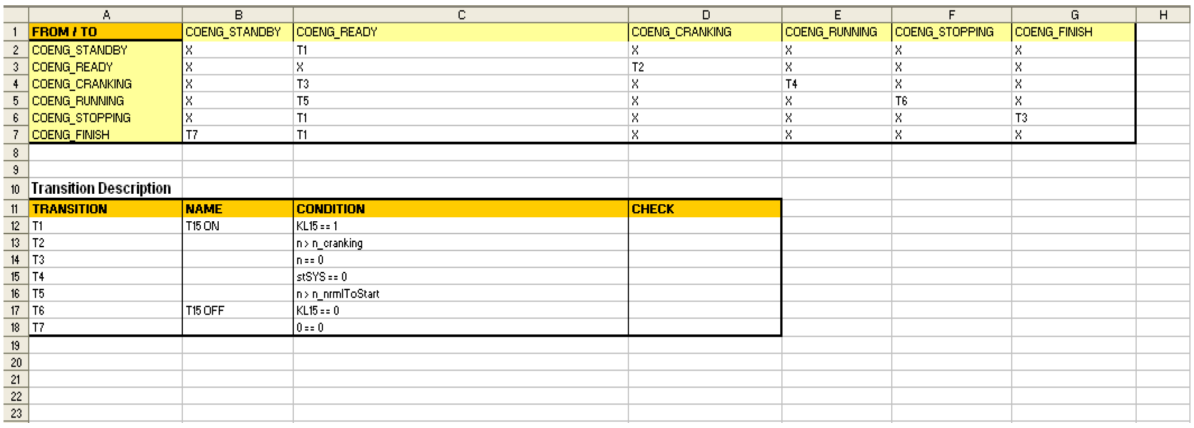
The basic analyze search for eligible state transitions in the log-file, in respect to transition conditions. Many state transitions are never allowed (i.e. the one not connected with an arrow in Fig. 1). Errors will be presented in the result file.

1.3.2 Time Analyze

Calculates and verifies the time in each state. Errors will be presented in the result file.

1.4 Configuration file

The Excel configuration file must at least contain two sheets, one with information what signals to extract and process from the log-file and another with the state machine architecture. Fig. 3 and Fig. 4 display how the mentioned Excel sheets can look like.

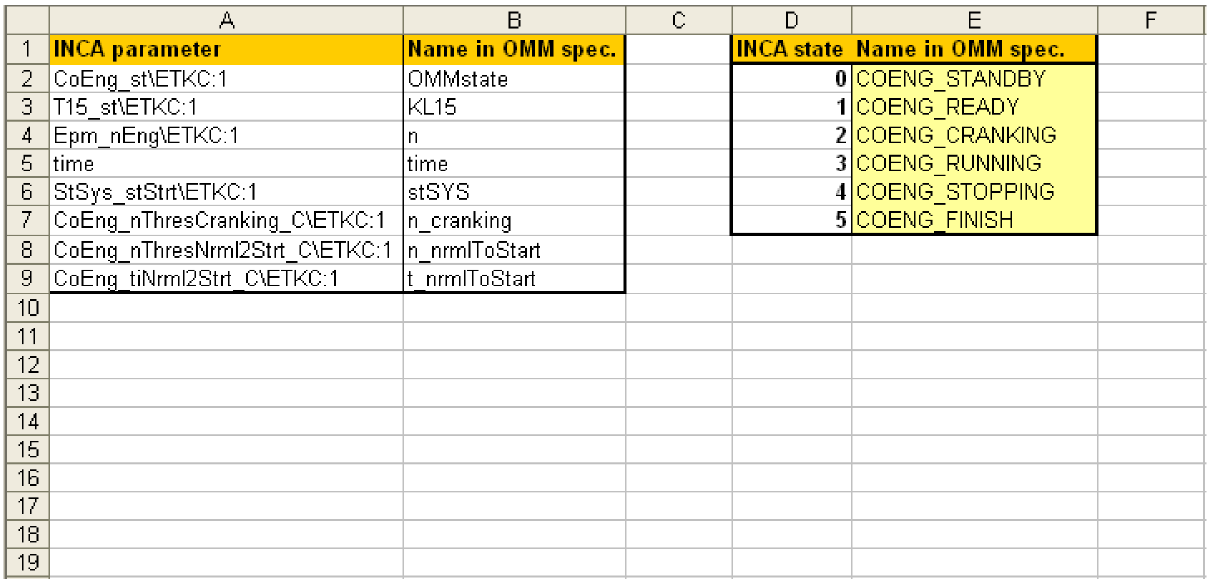


FROM / TO	COENG_STANDBY	COENG_READY	COENG_CRANKING	COENG_RUNNING	COENG_STOPPING	COENG_FINISH
COENG_STANDBY	X	T1	X	X	X	X
COENG_READY	X	X	T2	X	X	X
COENG_CRANKING	X	T3	X	T4	X	X
COENG_RUNNING	X	T5	X	X	T6	X
COENG_STOPPING	X	T1	X	X	X	T3
COENG_FINISH	T7	T1	X	X	X	X

Transition Description

TRANSITION	NAME	CONDITION	CHECK
T1	T15 ON	KL15 == 1	
T2		n > n_cranking	
T3		n == 0	
T4		stSYS == 0	
T5		n > n_nrmlToStart	
T6	T15 OFF	KL15 == 0	
T7		0 == 0	

Fig. 3. Example of how the state machine architecture is constructed in the configuration file.



INCA parameter	Name in OMM spec.
CoEng_st\ETKC:1	OMMstate
T15_st\ETKC:1	KL15
Epm_nEng\ETKC:1	n
time	time
StSys_stStrt\ETKC:1	stSYS
CoEng_nThresCranking_C\ETKC:1	n_cranking
CoEng_nThresNrml2Strt_C\ETKC:1	n_nrmlToStart
CoEng_tiNrml2Strt_C\ETKC:1	t_nrmlToStart

INCA state	Name in OMM spec.
0	COENG_STANDBY
1	COENG_READY
2	COENG_CRANKING
3	COENG_RUNNING
4	COENG_STOPPING
5	COENG_FINISH

Fig. 4. Example of signal configuration to the left. How the state parameter will be parsed is configured on the right hand side.

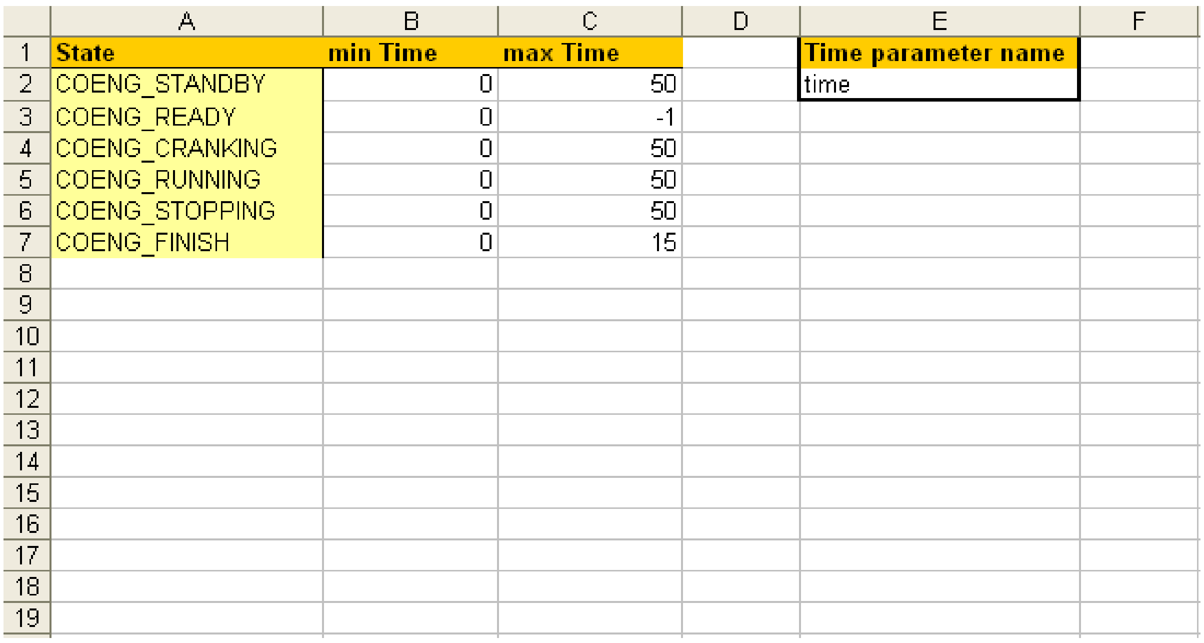
Note that the logical transition conditions in Fig.3 follows python (and most other programming languages as well) notation. For example implies the sign "=" assignment and "==" equal to. The following operators can be used;

- ==
- <
- >
- <=
- >=
- !=

- and
- or
- not

Also remark that the parameters fetched from the Inca log-file is renamed to shorter and more intuitive names (for example names used in the specification from the controller system supplier).

In addition to the two sheets mentioned above, the configuration file can include more sheets with configurations for other analyzes. Fig. 5 displays how the configurations for the time analyze can look like.

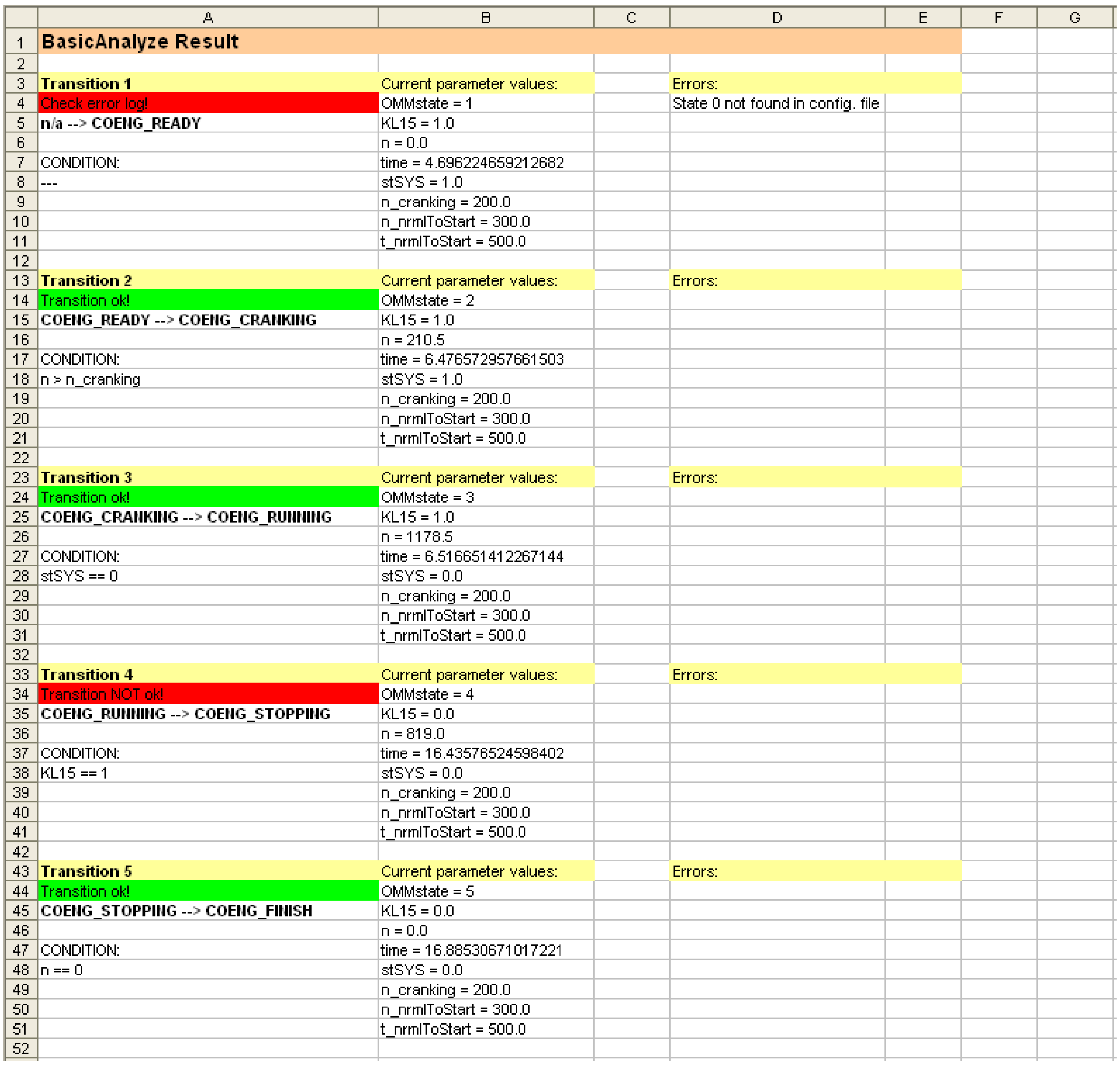


	A	B	C	D	E	F
1	**State**	**min Time**	**max Time**		**Time parameter name**	
2	COENG_STANDBY	0	50		time	
3	COENG_READY	0	-1			
4	COENG_CRANKING	0	50			
5	COENG_RUNNING	0	50			
6	COENG_STOPPING	0	50			
7	COENG_FINISH	0	15			
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						

Fig. 5. Example of a time analyze configuration.

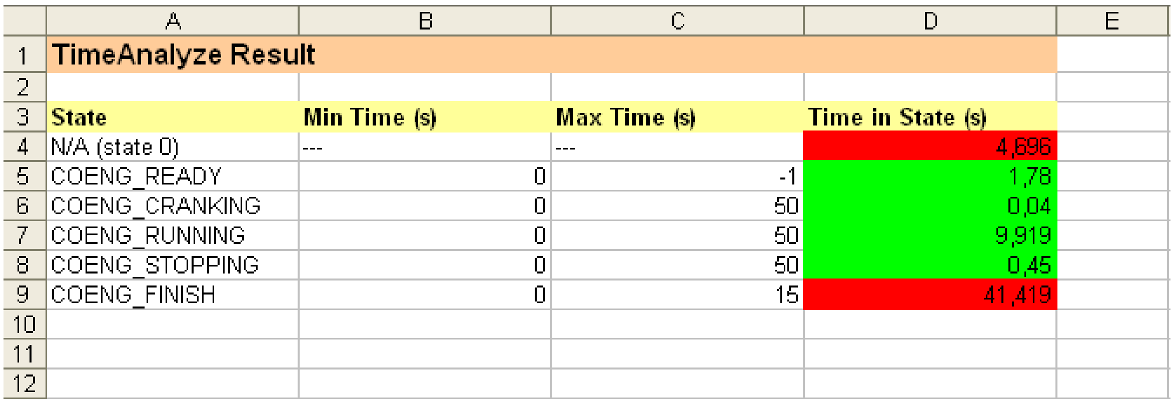
1.5 Result presentation

A successful State machine analyze generates an Excel result log. All state transition and belonging information is notated in the result log. The number of sheets varies and depends on which and how many analyzes was processed. The following figures, Fig. 6 and Fig. 7, are examples of the result log.



	A	B	C	D	E	F	G
1	**BasicAnalyze Result**						
2							
3	**Transition 1**	Current parameter values:		Errors:			
4	Check error log!	OMMstate = 1		State 0 not found in config. file			
5	**n/a --> COENG_READY**	KL15 = 1.0					
6		n = 0.0					
7	CONDITION:	time = 4.696224659212682					
8	---	stSYS = 1.0					
9		n_cranking = 200.0					
10		n_nrmlToStart = 300.0					
11		t_nrmlToStart = 500.0					
12							
13	**Transition 2**	Current parameter values:		Errors:			
14	Transition ok!	OMMstate = 2					
15	**COENG_READY --> COENG_CRANKING**	KL15 = 1.0					
16		n = 210.5					
17	CONDITION:	time = 6.476572957661503					
18	n > n_cranking	stSYS = 1.0					
19		n_cranking = 200.0					
20		n_nrmlToStart = 300.0					
21		t_nrmlToStart = 500.0					
22							
23	**Transition 3**	Current parameter values:		Errors:			
24	Transition ok!	OMMstate = 3					
25	**COENG_CRANKING --> COENG_RUNNING**	KL15 = 1.0					
26		n = 1178.5					
27	CONDITION:	time = 6.516651412267144					
28	stSYS == 0	stSYS = 0.0					
29		n_cranking = 200.0					
30		n_nrmlToStart = 300.0					
31		t_nrmlToStart = 500.0					
32							
33	**Transition 4**	Current parameter values:		Errors:			
34	Transition NOT ok!	OMMstate = 4					
35	**COENG_RUNNING --> COENG_STOPPING**	KL15 = 0.0					
36		n = 819.0					
37	CONDITION:	time = 16.43576524598402					
38	KL15 == 1	stSYS = 0.0					
39		n_cranking = 200.0					
40		n_nrmlToStart = 300.0					
41		t_nrmlToStart = 500.0					
42							
43	**Transition 5**	Current parameter values:		Errors:			
44	Transition ok!	OMMstate = 5					
45	**COENG_STOPPING --> COENG_FINISH**	KL15 = 0.0					
46		n = 0.0					
47	CONDITION:	time = 16.88530671017221					
48	n == 0	stSYS = 0.0					
49		n_cranking = 200.0					
50		n_nrmlToStart = 300.0					
51		t_nrmlToStart = 500.0					
52							

Fig. 6. Basic Analyze result log.



	A	B	C	D	E
1	**TimeAnalyze Result**				
2					
3	**State**	**Min Time (s)**	**Max Time (s)**	**Time in State (s)**	
4	N/A (state 0)	---	---	4,696	
5	COENG_READY	0	-1	1,78	
6	COENG_CRANKING	0	50	0,04	
7	COENG_RUNNING	0	50	9,919	
8	COENG_STOPPING	0	50	0,45	
9	COENG_FINISH	0	15	41,419	
10					
11					
12					

Fig. 7. Time Analyze result log.

The analyze results are colour coded, where green implies that everything is ok, red colour implies that something is wrong. Fig. 6 contain two red marked transition, transition 1 and transition 4. Transition 1 fails because the configuration file (sheet signal configuration) not contains information of how to parse the state parameter value "0". Transition 4 fails because unfulfilled transition condition. The transition condition is "KL 15 == 1", but as seen in Fig.6

the current value for "KL 15" is "0.0". Both this are deliberately injected errors, the configuration file in 1.6.3 would not give such error. The red marked fields in the time analyze result log (Fig.7) either mean that the state wasn't found in the time analyze configuration or the time in state is below the min time or exceeds the max time.

1.6 User Interface

This verification tool will be implemented in the power train test automation (PTTA) program and its graphical user interface. PTTA is a tool for automatically generate and verify log-files for different operation conditions, decided by the user. In other words; it takes care of the whole chain, from simulator configuration to log generation and verification.

2. CAN interface verification – user manual

2.1 Program overview

The program is written in the interpreting language Python and used for CAN interface verification. The intention is to change from manually CAN interface verification to scripted algorithms and analysis tools. The program needs an Inca measurement log as input. Remark that the file must be saved in ASCII (.dxl) format. This analysis tool can be used for both TCM and ECM CAN interface verification. Fig.1 is a brief overview of the program's execution order. The program itself contains the following parts:

- Python module *CANinterface_LIB.py*
- Configuration file, for example *CANconfiguration.txt*
- Mapping tables, for example *mapping1 sheet*
- Stand alone user interface *GUI.py*.
- Result file, for example *result.xls*

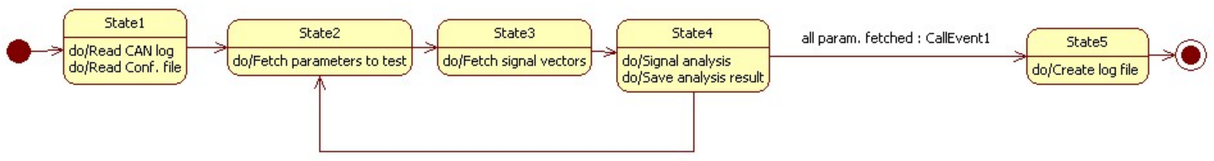


Fig 1. UML flowing chart for the CAN interface verification algorithm.

2.2 Delimitations

It will hopefully be few delimitations, but there will always be test settings of non standard type the program can't handle. The main reason not cover every possible test case is to hold down the complexity in the, from user, demanded configurations and settings. It will neither be time sufficient implement everything. Another problem that may occur is slow performance and allocation of all available RAM when using big log files (e.g. many samples and/or parameters) in combination with many verification parameters.

2.3 CANinterface_LIB module

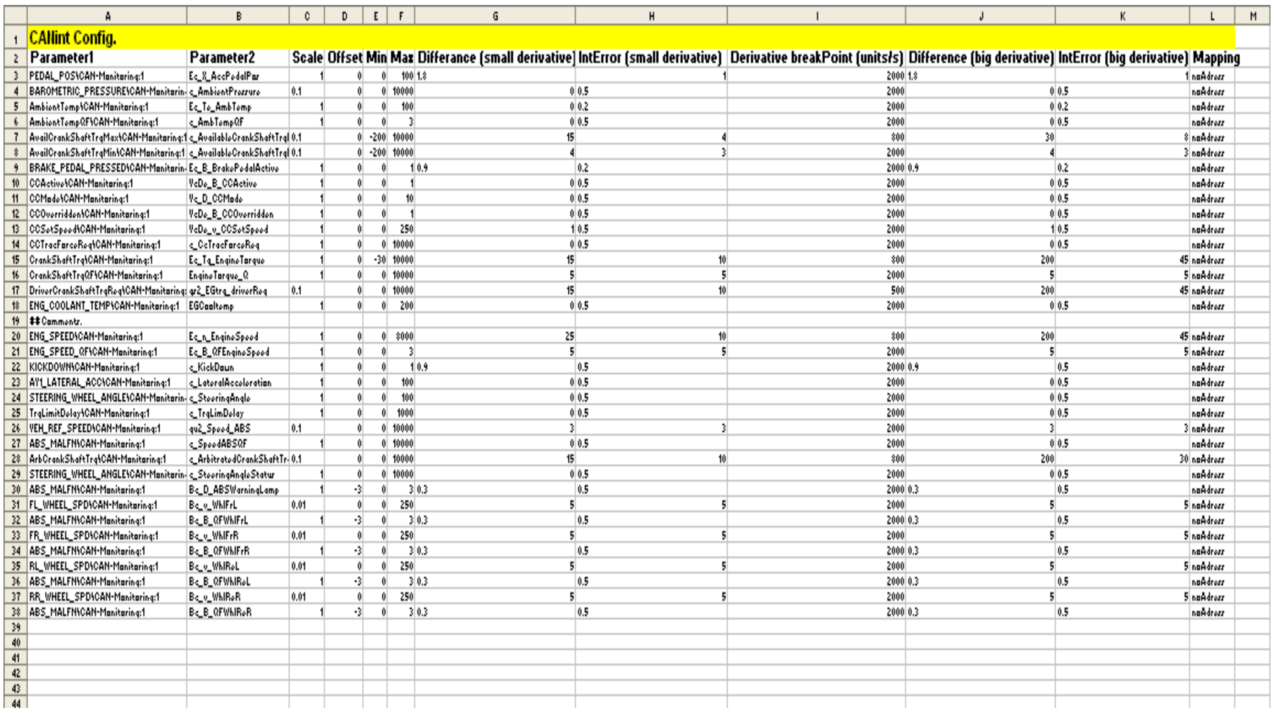
CANinterface_LIB.py is the home for all implemented functions that are callable through the user interface. Table 1 shows the containing functions.

Table 1. Function declaration for CANinterface_LIB.py.

Function	***Description***
readFromFile	Reads the CAN file
readSettingsFromExcel	Reads the configuration file through COM interface
findCanColumn	Finds the right CAN file column due to the required parameters in the configuration file
getColumnLin	Extract a column in the CAN file due to the parameters in the configuration file. Uses a first order hold algorithm to interpolate empty samples.
syncParam	Sync two measurement vectors.
uTest	Contains the CAN interface testing algorithm
executeConfig	Executes the CAN interface verification
resultToExcelWriter	Write the CAN interface verification result to a Microsoft Excel file (.*xls*) through the COM interface

2.4 Configuration file

The CAN interface configuration file must be an Excel file (.xls) and contain one or more sheets. For a configuration file example, see Fig. 2. The file provides the program with user defined test settings such as processing parameters and tolerances.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	CANint Config.												
2	Parameter1	Parameter2	Scale	Offset	Min	Max	Differance (small derivative)	IntError (small derivative)	Derivative breakPoint (units/s)	Difference (big derivative)	IntError (big derivative)	Mapping	
3	PEDAL_POS\CAN-Monitoring:1	Ec_X_AccPedalPar	1	0	0	100	1.8	1	2000	1.8	1	noAdress	
4	BAROMETRIC_PRESSURE\CAN-Monitorin	c_AmbientPressure	0.1	0	0	10000	0	0.5	2000	0	0.5	noAdress	
5	AmbientTemp\CAN-Monitoring:1	Ec_Te_AmbTemp	1	0	0	100	0	0.2	2000	0	0.2	noAdress	
6	AmbientTempQF\CAN-Monitoring:1	c_AmbTempQF	1	0	0	3	0	0.5	2000	0	0.5	noAdress	
7	AvailCrankShaftTrqMax\CAN-Monitoring:1	c_AvailableCrankShaftTrq	0.1	0	-200	10000	15	4	800	30	8	noAdress	
8	AvailCrankShaftTrqMin\CAN-Monitoring:1	c_AvailableCrankShaftTrq	0.1	0	-200	10000	4	3	2000	4	3	noAdress	
9	BRAKE_PEDAL_PRESSED\CAN-Monitorin	Ec_B_BrakePedalActive	1	0	0	1	0.9	0.2	2000	0.9	0.2	noAdress	
10	CCActive\CAN-Monitoring:1	VcDe_B_CCActive	1	0	0	1	0	0.5	2000	0	0.5	noAdress	
11	CCMode\CAN-Monitoring:1	Vc_D_CCMode	1	0	0	10	0	0.5	2000	0	0.5	noAdress	
12	CCOverridden\CAN-Monitoring:1	VcDe_B_CCOverridden	1	0	0	1	0	0.5	2000	0	0.5	noAdress	
13	CCSetSpeed\CAN-Monitoring:1	VcDe_v_CCSetSpeed	1	0	0	250	1	0.5	2000	1	0.5	noAdress	
14	CCTracForceReq\CAN-Monitoring:1	c_CcTracForceReq	1	0	0	10000	0	0.5	2000	0	0.5	noAdress	
15	CrankShaftTrq\CAN-Monitoring:1	Ec_Tq_EngineTorque	1	0	-30	10000	15	10	800	200	45	noAdress	
16	CrankShaftTrqQF\CAN-Monitoring:1	EngineTorque_Q	1	0	0	10000	5	5	2000	5	5	noAdress	
17	DriverCrankShaftTrqReq\CAN-Monitoring:	qr2_EGtrq_driverReq	0.1	0	0	10000	15	10	500	200	45	noAdress	
18	ENG_COOLANT_TEMP\CAN-Monitoring:1	EGCooltemp	1	0	0	200	0	0.5	2000	0	0.5	noAdress	
19	##Comments.												
20	ENG_SPEED\CAN-Monitoring:1	Ec_n_EngineSpeed	1	0	0	8000	25	10	800	200	45	noAdress	
21	ENG_SPEED_QF\CAN-Monitoring:1	Ec_B_QFEngineSpeed	1	0	0	3	5	5	2000	5	5	noAdress	
22	KICKDOWN\CAN-Monitoring:1	c_KickDown	1	0	0	1	0.9	0.5	2000	0.9	0.5	noAdress	
23	AY1_LATERAL_ACC\CAN-Monitoring:1	c_LateralAcceleration	1	0	0	100	0	0.5	2000	0	0.5	noAdress	
24	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngle	1	0	0	100	0	0.5	2000	0	0.5	noAdress	
25	TrqLimitDelay\CAN-Monitoring:1	c_TrqLimDelay	1	0	0	1000	0	0.5	2000	0	0.5	noAdress	
26	VEH_REF_SPEED\CAN-Monitoring:1	qu2_Speed_ABS	0.1	0	0	10000	3	3	2000	3	3	noAdress	
27	ABS_MALFN\CAN-Monitoring:1	c_SpeedABSQF	1	0	0	10000	0	0.5	2000	0	0.5	noAdress	
28	ArbCrankShaftTrq\CAN-Monitoring:1	c_ArbitratedCrankShaftTr	0.1	0	0	10000	15	10	800	200	30	noAdress	
29	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngleStatus	1	0	0	10000	0	0.5	2000	0	0.5	noAdress	
30	ABS_MALFN\CAN-Monitoring:1	Bc_D_ABSWarningLamp	1	-3	0	3	0.3	0.5	2000	0.3	0.5	noAdress	
31	FL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrL	0.01	0	0	250	5	5	2000	5	5	noAdress	
32	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrL	1	-3	0	3	0.3	0.5	2000	0.3	0.5	noAdress	
33	FR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrR	0.01	0	0	250	5	5	2000	5	5	noAdress	
34	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrR	1	-3	0	3	0.3	0.5	2000	0.3	0.5	noAdress	
35	RL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReL	0.01	0	0	250	5	5	2000	5	5	noAdress	
36	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReL	1	-3	0	3	0.3	0.5	2000	0.3	0.5	noAdress	
37	RR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReR	0.01	0	0	250	5	5	2000	5	5	noAdress	
38	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReR	1	-3	0	3	0.3	0.5	2000	0.3	0.5	noAdress	
39													
40													
41													
42													
43													
44													

Fig. 2. CAN interface configuration file.

2.4.1 Parameters

The first two columns in the CAN configuration file contain the test parameters. Parameter1 is tested against the contiguous Parameter2. It's advisable to let the parameter names in the configuration file be exactly the same as in the Inca CAN log to avoid problems. If the parameter's corresponding value vector contains literals they have to be mapped, please read section 2.2.7.

2.4.2 Scaling

The third column in the CAN configuration file contains information of how Parameter2 will be scaled. The scaling algorithm is very simple, Parameter2 is just multiplied with the scaling value. For example; if the scaling value is *3* Parameter2 will be three times as big as the original. Scaling value one means no scaling at all.

2.4.3 Offset

The forth column in the CAN configuration file contains information about the offset for Parameter2. The offset just adds to Parameter2. For Example; offset value -40 means the vector values, corresponding to Parameter2, all will be lowered with 40. Offset equal to zero means no offset.

2.4.4 Min/Max

Column 5-6 contains the minimum respectively maximum value for Parameter1 and Paramter2. The min/max evaluation for Parameter2 will be done first when the scaling has been done and the offset is added. If either or both of the parameters not fulfill the min/max criterions a notation will be done in the result file.

2.4.5 Difference

The program contains an algorithm that compares Parameter1 to Parameter2. The seventh and tenth columns in the CAN configuration file contain the maximum values (tolerances) for the difference without declare a verification error in the result file. The seventh column contains the maximum allowed difference when the signal derivative is low and the tenth column maximum value when the derivative is big. The break point between high and low derivative can be configured in column ninth, see 2.4.7

2.4.6 IntError

One of the program algorithms divides the parameter vectors in 1 second interval. And then integrates the difference between Parameter1 and Parameter2 over each of the interval. If the integrated difference exceeds the IntError in column eight or eleven a notation will be done in the result log. The eight column contains the maximum allowed IntError when the signal derivative is low, respectively the eleventh column when the signal derivative is big.

2.4.7 Derivative breaking point

The value when the derivative changes from *low* to *high* is configured in column nine.

2.4.8 Mapping

The twelfth and last column in the configuration file contains "sheet names" to mapping tables, for more information see 2.5. If Parameter2 doesn't need a mapping the corresponding mapping address cell should contain the string *NoAdress*.

2.4.9 Comments in configuration file

The configuration file in Fig 2 contains a comment string; *##comment.*. Comment strings can only be done in the first column and must be declared with double number signs *##*. Comments can for example be used to sort different kinds of parameters in different groups.

2.5 Mapping tables

Mapping lists are used for parameter remapping. The lists are linked to the parameters through the configuration file, see section 2.2.7. A mapping list contains information of how the mapping should be done, see Fig. 3 and 4 for examples. Remark if Inca logs an integer as float you have to handle it like it's done in Fig. 3.

Mapping1	
From	**To**
2.0	150
3.0	2700
4.0	3000

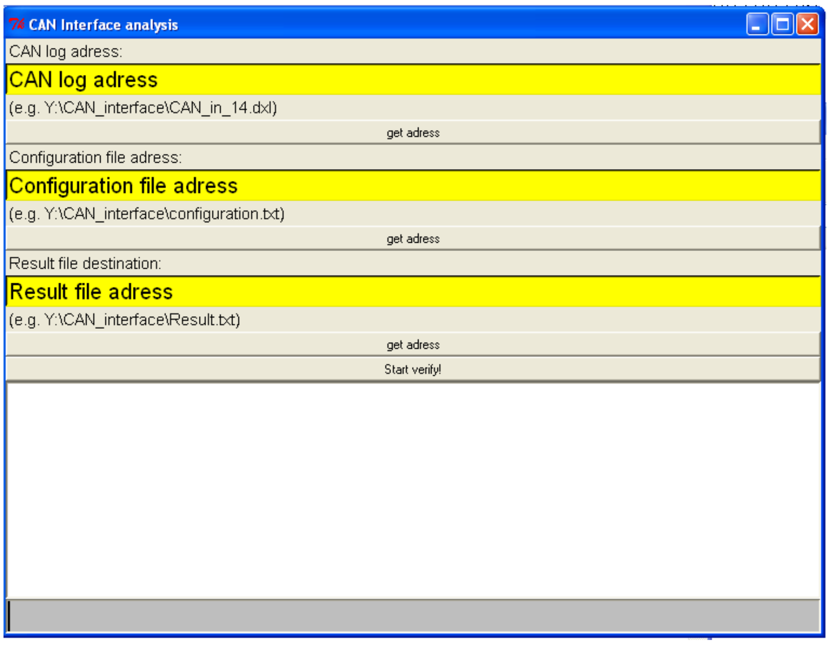
Mapping2	
From	**To**
p	0
r	1
n	2
d	3

Fig. 3. Mapping table Example.

Fig. 4. Another mapping table example.

2.6 Graphical user interface

The CANinterface*_LIB.py* is provided with a stand alone user interface *GUI.py*. Through the interface users can execute CAN interface analysis with different settings. Fig 5 shows the interface start screen.



CAN Interface analysis

CAN log adress:

CAN log adress

(e.g. Y:\CAN_interface\CAN_in_14.dxl)

get adress

Configuration file adress:

Configuration file adress

(e.g. Y:\CAN_interface\configuration.txt)

get adress

Result file destination:

Result file adress

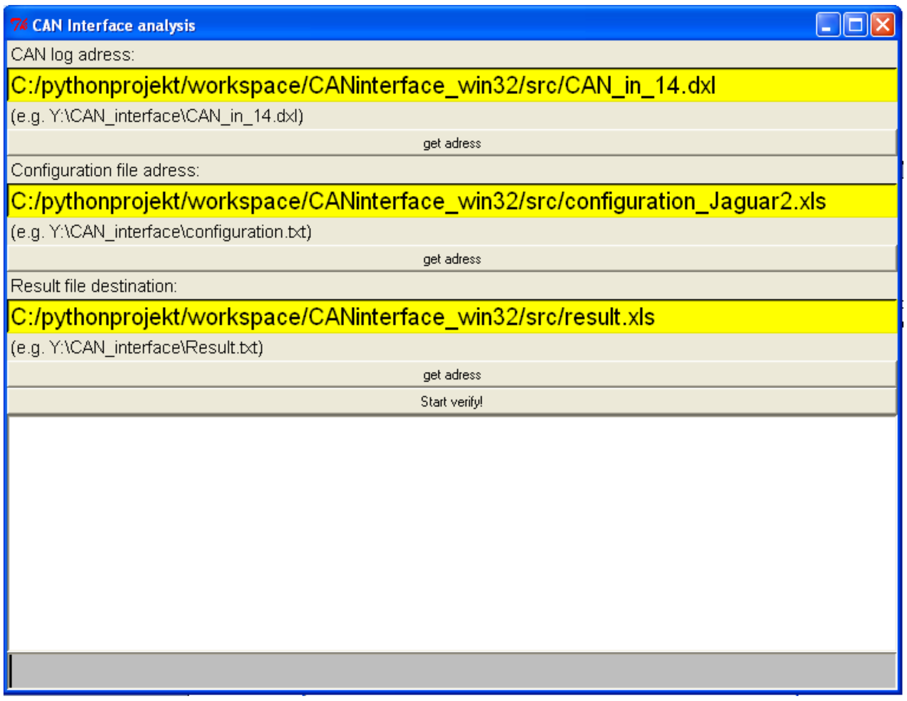
(e.g. Y:\CAN_interface\Result.txt)

get adress

Start verify!

Fig. 5. User interface start screen.

The program need some input before the analysis can be done. Fill in the right configuration file address, CAN log address etcetera. For an example of a correct configured GUI see Fig. 6.



CAN Interface analysis

CAN log adress:

C:/pythonprojekt/workspace/CANinterface_win32/src/CAN_in_14.dxl

(e.g. Y:\CAN_interface\CAN_in_14.dxl)

get adress

Configuration file adress:

C:/pythonprojekt/workspace/CANinterface_win32/src/configuration_Jaguar2.xls

(e.g. Y:\CAN_interface\configuration.txt)

get adress

Result file destination:

C:/pythonprojekt/workspace/CANinterface_win32/src/result.xls

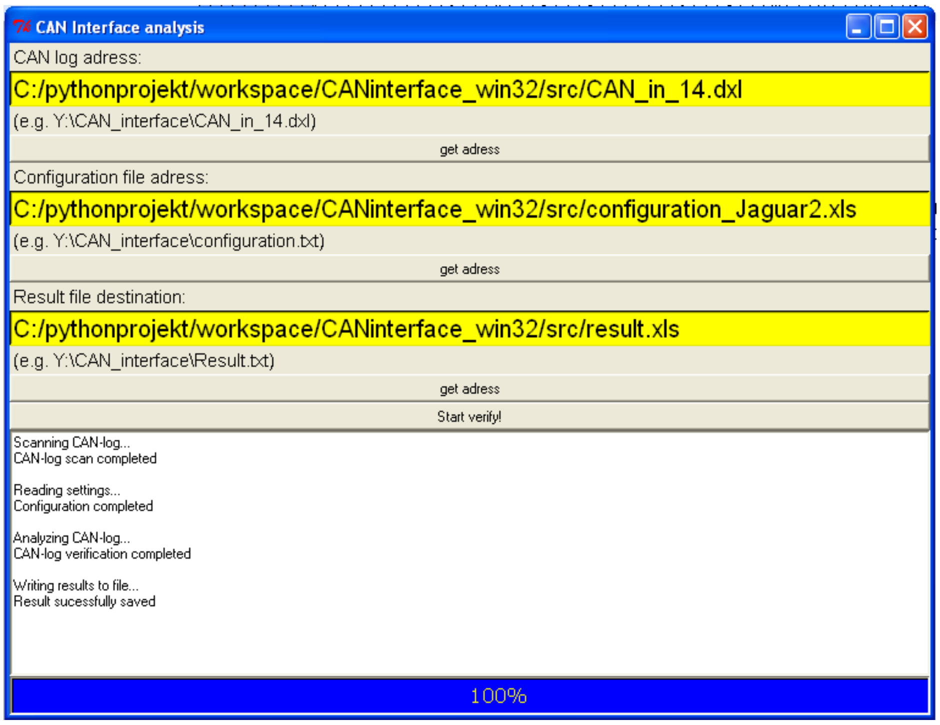
(e.g. Y:\CAN_interface\Result.txt)

get adress

Start verify!

Fig.6. Example of a correct configured GUI.

When all inputs are correct just click the *start verify!* button to start the verification. If everything went as intended the entry box in the GUI now should contain a simple text log, see Fig.7.


CAN Interface analysis
CAN log adress:
(e.g. Y:\CAN_interface\CAN_in_14.dxl)
get adress
Configuration file adress:
(e.g. Y:\CAN_interface\configuration.txt)
get adress
Result file destination:
(e.g. Y:\CAN_interface\Result.txt)
get adress
Start verify!
100%

C:/pythonprojekt/workspace/CANinterface_win32/src/CAN_in_14.dxl

C:/pythonprojekt/workspace/CANinterface_win32/src/configuration_Jaguar2.xls

C:/pythonprojekt/workspace/CANinterface_win32/src/result.xls

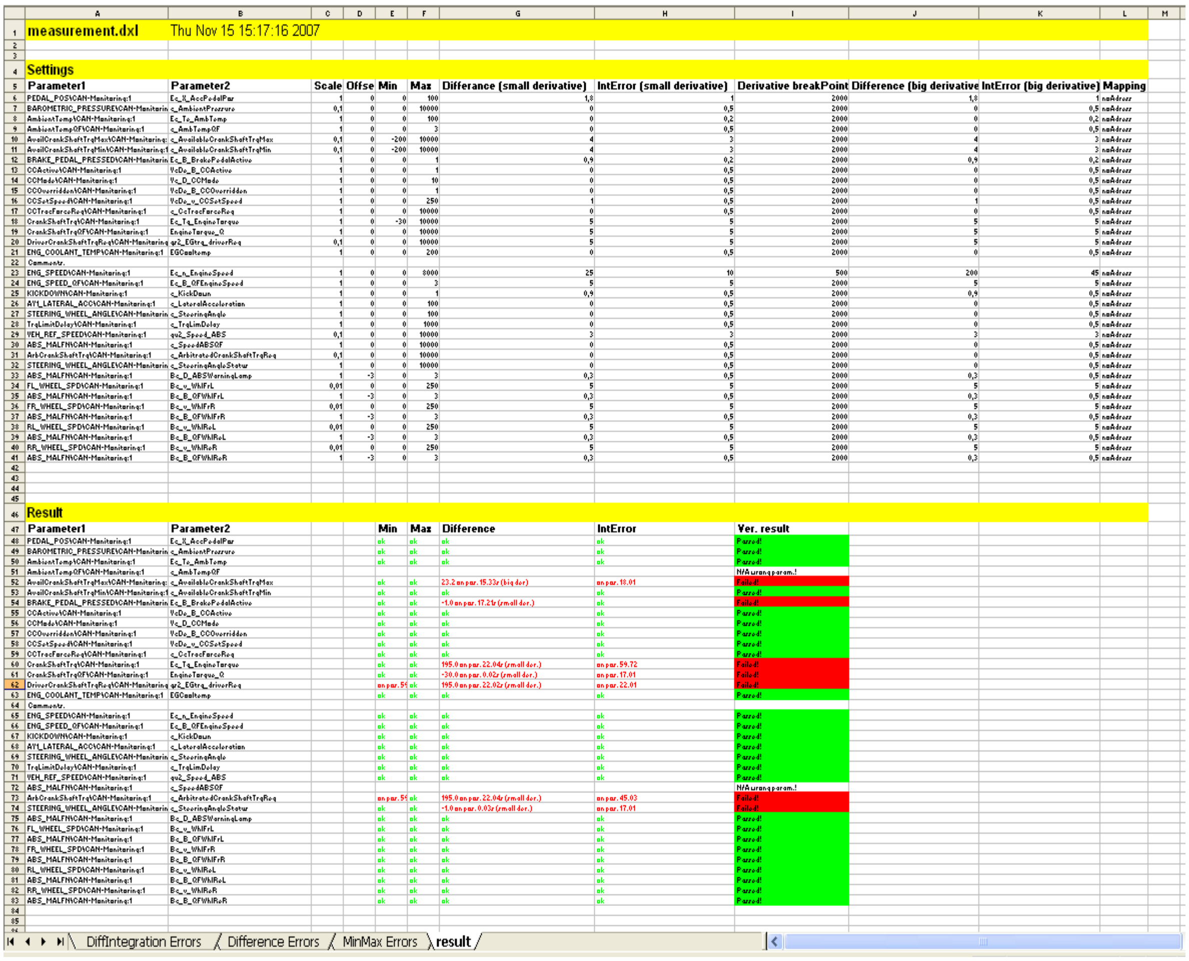
```
Scanning CAN-log...
CAN-log scan completed

Reading settings...
Configuration completed

Analyzing CAN-log...
CAN-log verification completed

Writing results to file...
Result sucessfully saved
```

Fig. 7. Example of a successful CAN interface verification.

.

2.7 Result File

A successful CAN interface analysis generates a result log saved in Microsoft Excel (.xls) format. The result log both contains used configuration and verification result. The first table, *settings*, is a copy of the configuration file. The second table, *result*, contains the verification results. The left most column declares if the verification *passed* or *failed*. The main reasons for adding the *settings* table are to store both configuration and result at the same place and the possibility to compare the configuration with the out coming result. For an example, see Fig. 8.



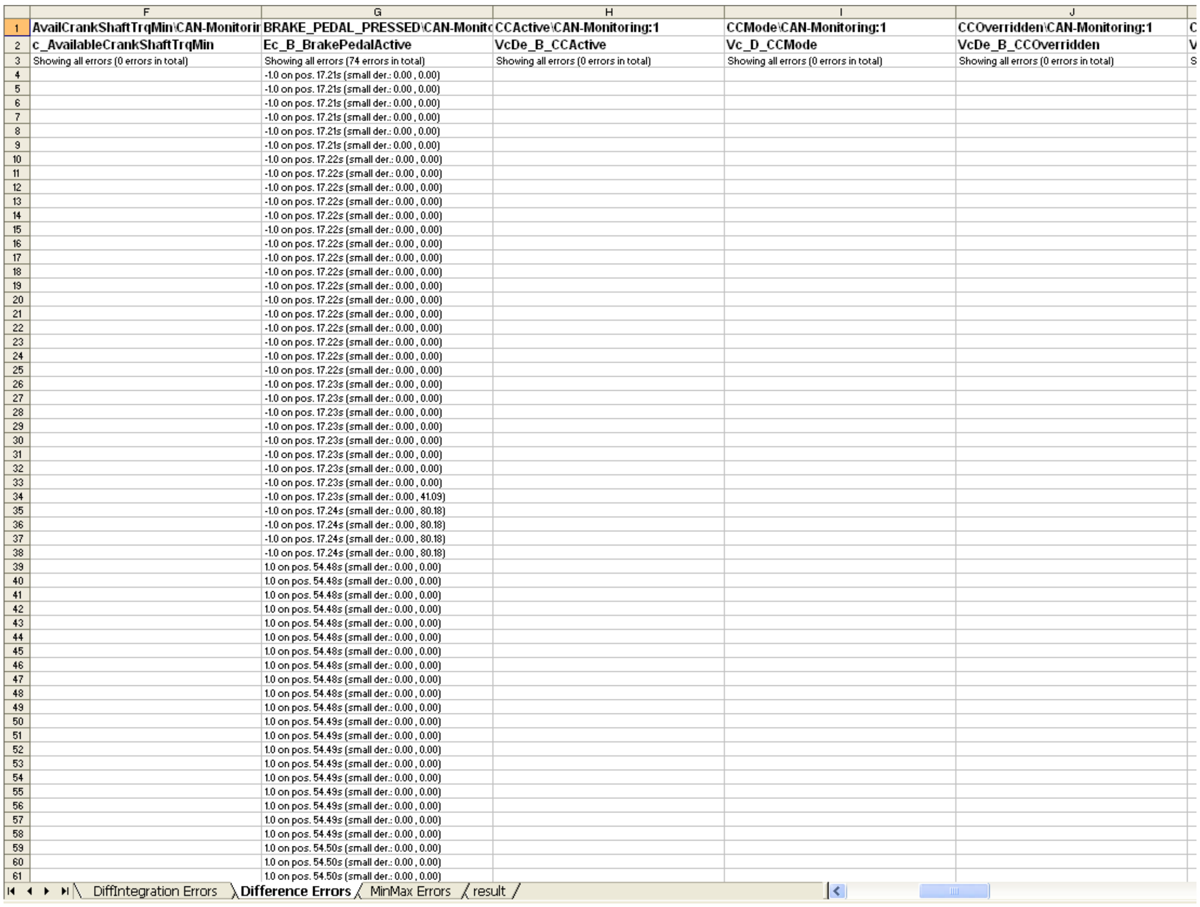
	A	B	C	D	E	F	G	H	I	J	K	L
1	**measurement.dxl**	Thu Nov 15 15:17:16 2007										
2												
3												
4	**Settings**											
5	**Parameter1**	**Parameter2**	**Scale**	**Offse**	**Min**	**Max**	**Differance (small derivative)**	**IntError (small derivative)**	**Derivative breakPoint**	**Difference (big derivative**	**IntError (big derivative)**	**Mapping**
6	PEDAL_POS\CAN-Monitoring:1	Ec_X_AccPedalPar	1	0	0	100	1,8	1	2000	1,8	1	noAdress
7	BAROMETRIC_PRESSURE\CAN-Monitorin	c_AmbientPressure	0,1	0	0	10000	0	0,5	2000	0	0,5	noAdress
8	AmbientTemp\CAN-Monitoring:1	Ec_Te_AmbTemp	1	0	0	100	0	0,2	2000	0	0,2	noAdress
9	AmbientTempQF\CAN-Monitoring:1	c_AmbTempQF	1	0	0	3	0	0,5	2000	0	0,5	noAdress
10	AvailCrankShaftTrqMax\CAN-Monitoring:	c_AvailableCrankShaftTrqMax	0,1	0	-200	10000	4	3	2000	4	3	noAdress
11	AvailCrankShaftTrqMin\CAN-Monitoring:1	c_AvailableCrankShaftTrqMin	0,1	0	-200	10000	4	3	2000	4	3	noAdress
12	BRAKE_PEDAL_PRESSED\CAN-Monitorin	Ec_B_BrakePedalActive	1	0	0	1	0,9	0,2	2000	0,9	0,2	noAdress
13	CCActive\CAN-Monitoring:1	VeDe_B_CCActive	1	0	0	1	0	0,5	2000	0	0,5	noAdress
14	CCMode\CAN-Monitoring:1	Ve_D_CCMode	1	0	0	10	0	0,5	2000	0	0,5	noAdress
15	CCOverridden\CAN-Monitoring:1	VeDe_B_CCOverridden	1	0	0	1	0	0,5	2000	0	0,5	noAdress
16	CCSetSpeed\CAN-Monitoring:1	VeDe_v_CCSetSpeed	1	0	0	250	1	0,5	2000	1	0,5	noAdress
17	CCTracForceReq\CAN-Monitoring:1	c_CcTracForceReq	1	0	0	10000	0	0,5	2000	0	0,5	noAdress
18	CrankShaftTrq\CAN-Monitoring:1	Ec_Tq_EngineTorque	1	0	-30	10000	5	5	2000	5	5	noAdress
19	CrankShaftTrqQF\CAN-Monitoring:1	EngineTorque_Q	1	0	0	10000	5	5	2000	5	5	noAdress
20	DriverCrankShaftTrqReq\CAN-Monitoring	gr2_EGtrq_driverReq	0,1	0	0	10000	5	5	2000	5	5	noAdress
21	ENG_COOLANT_TEMP\CAN-Monitoring:1	EGCooltemp	1	0	0	200	0	0,5	2000	0	0,5	noAdress
22	Comments.											
23	ENG_SPEED\CAN-Monitoring:1	Ec_n_EngineSpeed	1	0	0	8000	25	10	500	200	45	noAdress
24	ENG_SPEED_QF\CAN-Monitoring:1	Ec_B_QFEngineSpeed	1	0	0	3	5	5	2000	5	5	noAdress
25	KICKDOWN\CAN-Monitoring:1	c_KickDown	1	0	0	1	0,9	0,5	2000	0,9	0,5	noAdress
26	AY1_LATERAL_ACC\CAN-Monitoring:1	c_LateralAcceleration	1	0	0	100	0	0,5	2000	0	0,5	noAdress
27	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngle	1	0	0	100	0	0,5	2000	0	0,5	noAdress
28	TrqLimitDelay\CAN-Monitoring:1	c_TrqLimDelay	1	0	0	1000	0	0,5	2000	0	0,5	noAdress
29	VEH_REF_SPEED\CAN-Monitoring:1	qu2_Speed_ABS	0,1	0	0	10000	3	3	2000	3	3	noAdress
30	ABS_MALFN\CAN-Monitoring:1	c_SpeedABSQF	1	0	0	10000	0	0,5	2000	0	0,5	noAdress
31	ArbCrankShaftTrq\CAN-Monitoring:1	c_ArbitratedCrankShaftTrqReq	0,1	0	0	10000	0	0,5	2000	0	0,5	noAdress
32	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngleStatus	1	0	0	10000	0	0,5	2000	0	0,5	noAdress
33	ABS_MALFN\CAN-Monitoring:1	Bc_D_ABSWarningLamp	1	-3	0	3	0,3	0,5	2000	0,3	0,5	noAdress
34	FL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrL	0,01	0	0	250	5	5	2000	5	5	noAdress
35	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrL	1	-3	0	3	0,3	0,5	2000	0,3	0,5	noAdress
36	FR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrR	0,01	0	0	250	5	5	2000	5	5	noAdress
37	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrR	1	-3	0	3	0,3	0,5	2000	0,3	0,5	noAdress
38	RL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReL	0,01	0	0	250	5	5	2000	5	5	noAdress
39	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReL	1	-3	0	3	0,3	0,5	2000	0,3	0,5	noAdress
40	RR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReR	0,01	0	0	250	5	5	2000	5	5	noAdress
41	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReR	1	-3	0	3	0,3	0,5	2000	0,3	0,5	noAdress

	A	B	E	F	G	H	I
46	**Result**						
47	**Parameter1**	**Parameter2**	**Min**	**Max**	**Difference**	**IntError**	**Ver. result**
48	PEDAL_POS\CAN-Monitoring:1	Ec_X_AccPedalPar	ok	ok	ok	ok	Passed!
49	BAROMETRIC_PRESSURE\CAN-Monitorin	c_AmbientPressure	ok	ok	ok	ok	Passed!
50	AmbientTemp\CAN-Monitoring:1	Ec_Te_AmbTemp	ok	ok	ok	ok	Passed!
51	AmbientTempQF\CAN-Monitoring:1	c_AmbTempQF					N/A wrong param.!
52	AvailCrankShaftTrqMax\CAN-Monitoring:	c_AvailableCrankShaftTrqMax	ok	ok	23.2 on par. 15.33s (big der)	on par. 18.01	Failed!
53	AvailCrankShaftTrqMin\CAN-Monitoring:1	c_AvailableCrankShaftTrqMin	ok	ok	ok	ok	Passed!
54	BRAKE_PEDAL_PRESSED\CAN-Monitorin	Ec_B_BrakePedalActive	ok	ok	-1.0 on par. 17.21s (small der.)	ok	Failed!
55	CCActive\CAN-Monitoring:1	VeDe_B_CCActive	ok	ok	ok	ok	Passed!
56	CCMode\CAN-Monitoring:1	Ve_D_CCMode	ok	ok	ok	ok	Passed!
57	CCOverridden\CAN-Monitoring:1	VeDe_B_CCOverridden	ok	ok	ok	ok	Passed!
58	CCSetSpeed\CAN-Monitoring:1	VeDe_v_CCSetSpeed	ok	ok	ok	ok	Passed!
59	CCTracForceReq\CAN-Monitoring:1	c_CcTracForceReq	ok	ok	ok	ok	Passed!
60	CrankShaftTrq\CAN-Monitoring:1	Ec_Tq_EngineTorque	ok	ok	195.0 on par. 22.04s (small der.)	on par. 59.72	Failed!
61	CrankShaftTrqQF\CAN-Monitoring:1	EngineTorque_Q	ok	ok	-30.0 on par. 0.02s (small der.)	on par. 17.01	Failed!
62	DriverCrankShaftTrqReq\CAN-Monitoring	gr2_EGtrq_driverReq	on par. 5	ok	195.0 on par. 22.02s (small der.)	on par. 22.01	Failed!
63	ENG_COOLANT_TEMP\CAN-Monitoring:1	EGCooltemp	ok	ok	ok	ok	Passed!
64	Comments.						
65	ENG_SPEED\CAN-Monitoring:1	Ec_n_EngineSpeed	ok	ok	ok	ok	Passed!
66	ENG_SPEED_QF\CAN-Monitoring:1	Ec_B_QFEngineSpeed	ok	ok	ok	ok	Passed!
67	KICKDOWN\CAN-Monitoring:1	c_KickDown	ok	ok	ok	ok	Passed!
68	AY1_LATERAL_ACC\CAN-Monitoring:1	c_LateralAcceleration	ok	ok	ok	ok	Passed!
69	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngle	ok	ok	ok	ok	Passed!
70	TrqLimitDelay\CAN-Monitoring:1	c_TrqLimDelay	ok	ok	ok	ok	Passed!
71	VEH_REF_SPEED\CAN-Monitoring:1	qu2_Speed_ABS	ok	ok	ok	ok	Passed!
72	ABS_MALFN\CAN-Monitoring:1	c_SpeedABSQF					N/A wrong param.!
73	ArbCrankShaftTrq\CAN-Monitoring:1	c_ArbitratedCrankShaftTrqReq	on par. 5	ok	195.0 on par. 22.04s (small der.)	on par. 45.03	Failed!
74	STEERING_WHEEL_ANGLE\CAN-Monitorin	c_SteeringAngleStatus	ok	ok	-1.0 on par. 0.03s (small der.)	on par. 17.01	Failed!
75	ABS_MALFN\CAN-Monitoring:1	Bc_D_ABSWarningLamp	ok	ok	ok	ok	Passed!
76	FL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrL	ok	ok	ok	ok	Passed!
77	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrL	ok	ok	ok	ok	Passed!
78	FR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlFrR	ok	ok	ok	ok	Passed!
79	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlFrR	ok	ok	ok	ok	Passed!
80	RL_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReL	ok	ok	ok	ok	Passed!
81	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReL	ok	ok	ok	ok	Passed!
82	RR_WHEEL_SPD\CAN-Monitoring:1	Bc_v_WhlReR	ok	ok	ok	ok	Passed!
83	ABS_MALFN\CAN-Monitoring:1	Bc_B_QFWhlReR	ok	ok	ok	ok	Passed!

Fig. 8. Example of a result log file

2.7.1 Detailed analyze error logs

The result file also contain sheets with detailed analyze error logs, in addition to the main result page. The in depth error logs are very handy when analyzing what lies behind an error. See Fig. 9 for an example of a detailed error log for the difference analyze.



	F	G	H	I	J	
1	AvailCrankShaftTrqMin\CAN-Monitorir	BRAKE_PEDAL_PRESSED\CAN-Monito	CCActive\CAN-Monitoring:1	CCMode\CAN-Monitoring:1	CCOverridden\CAN-Monitoring:1	C
2	c_AvailableCrankShaftTrqMin	Ec_B_BrakePedalActive	VcDe_B_CCActive	Vc_D_CCMode	VcDe_B_CCOverridden	V
3	Showing all errors (0 errors in total)	Showing all errors (74 errors in total)	Showing all errors (0 errors in total)	Showing all errors (0 errors in total)	Showing all errors (0 errors in total)	S
4		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
5		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
6		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
7		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
8		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
9		-1.0 on pos. 17.21s (small der.: 0.00 , 0.00)				
10		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
11		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
12		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
13		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
14		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
15		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
16		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
17		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
18		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
19		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
20		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
21		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
22		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
23		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
24		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
25		-1.0 on pos. 17.22s (small der.: 0.00 , 0.00)				
26		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
27		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
28		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
29		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
30		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
31		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
32		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
33		-1.0 on pos. 17.23s (small der.: 0.00 , 0.00)				
34		-1.0 on pos. 17.23s (small der.: 0.00 , 41.09)				
35		-1.0 on pos. 17.24s (small der.: 0.00 , 80.18)				
36		-1.0 on pos. 17.24s (small der.: 0.00 , 80.18)				
37		-1.0 on pos. 17.24s (small der.: 0.00 , 80.18)				
38		-1.0 on pos. 17.24s (small der.: 0.00 , 80.18)				
39		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
40		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
41		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
42		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
43		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
44		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
45		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
46		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
47		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
48		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
49		1.0 on pos. 54.48s (small der.: 0.00 , 0.00)				
50		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
51		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
52		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
53		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
54		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
55		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
56		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
57		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
58		1.0 on pos. 54.49s (small der.: 0.00 , 0.00)				
59		1.0 on pos. 54.50s (small der.: 0.00 , 0.00)				
60		1.0 on pos. 54.50s (small der.: 0.00 , 0.00)				
61		1.0 on pos. 54.50s (small der.: 0.00 , 0.00)				

Fig. 9. Part of a *difference errors* log.

3. Network management verification – user manual

3.1 Introduction and program overview

The program is written in the interpreting language Python and is used for network management (NM) verification. The intention is to change from manually NM verification to scripted algorithms and analysis tools. The program needs an Inca measurement log file as input. Remark that the file must be saved in ASCII (.dxl) format. The analysis tools can be used for both TCM and ECM network management verification as long as it follows the *CAN NETWORK MANAGEMENT 31812308* standard. Fig. 1 is a brief overview of the program's execution order. The program itself contains following parts;

- Python module *NM_LIB.py*.
- NMtransition configuration, as sheet in for example *NMconfiguration.xls*.
- Signals configuration, as sheet in for example *NMconfiguration.xls*.
- Power mode settings, as sheet in for example *NMconfiguration.xls*.
- Stand alone user interface *GUI.py*.
- Result file, for example *result.xls*.

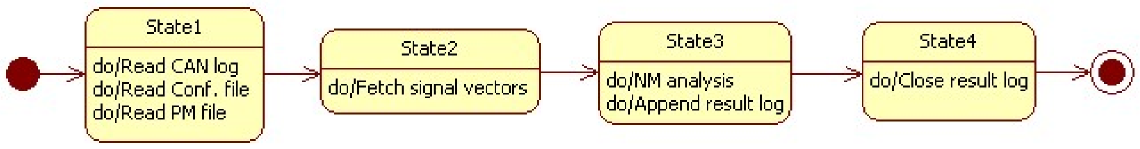


Fig. 1. UML flowing chart for the Network management verification program.

3.2 Program description

3.2.1 The module NM_LIB.py

NM_LIB.py is the home for all implemented functions that are callable through the user interface. Table 1 show all functions in *NM_LIB.py*.

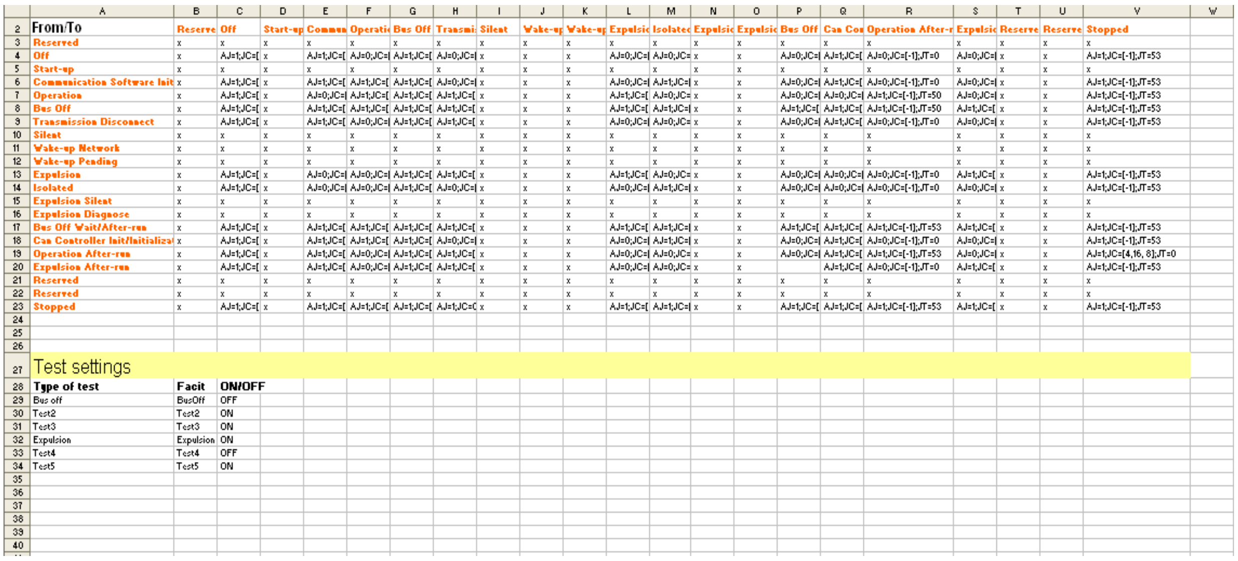
Table 1. Function overview for *NM_LIB.py*.

Function	***Description***
CanFileReader	Reads the CAN file
allInOneMatrixReader	Reads the first (*head*) sheet in the configuration file
conditionMatrixReader	Reads the *Signal* sheet in configuration file
pmReader	Reads the *power mode* sheet in configuration file
findCanColumn	Finds the right CAN file column due to the required parameters in the parameter file.
getPointedCanVector	Extract a column in the CAN file due to the parameters in the parameter file. Uses a zero order hold algorithm to interpolate empty samples.
getPointedCanMatrix	Merges the extracted columns from *getPointedCanVector*.
pCanMatrixVerification	Verifying the network management
getStateInTime	Extract the network management state for a given
getLastValue	Extract the last network management state in the Can log
appendLog	Adds a text string to the result log

3.2.2 Configuration file

3.2.2.1 Overview

The NM configuration file must be a Microsoft Excel file (.xls). The first sheet should have same appearance as in Fig.2.

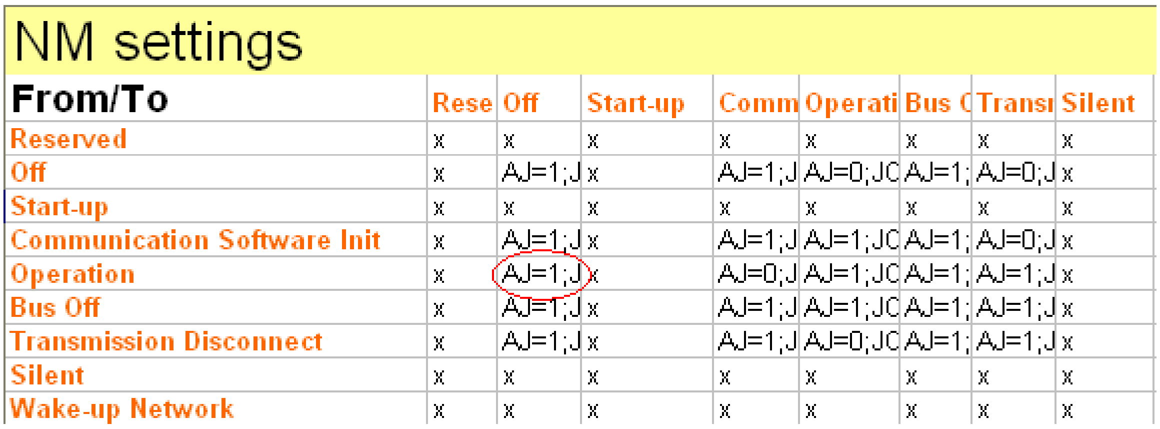


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
2	From/To	Reserve	Off	Start-up	Commun	Operati	Bus Off	Transmi	Silent	Wake-up	Wake-up	Expulsio	Isolated	Expulsio	Expulsio	Bus Off	Can Con	Operation After-r	Expulsio	Reserve	Reserve	Stopped	
3	Reserved	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
4	Off	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[	x	x	x	AJ=0;JC=[	AJ=0;JC=	x	x	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[-1];JT=0	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53	
5	Start-up	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
6	Communication Software Init	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=0;JC=[	x	x	x	AJ=0;JC=[	AJ=1;JC=[	x	x	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[-1];JT=0	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53	
7	Operation	x	AJ=1;JC=[	x	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=1;JC=[	AJ=0;JC=	x	x	AJ=0;JC=[	AJ=0;JC=[	AJ=1;JC=[-1];JT=50	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53	
8	Bus Off	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=1;JC=[	AJ=1;JC=[	x	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[-1];JT=50	AJ=1;JC=[	x	x	AJ=1;JC=[-1];JT=53	
9	Transmission Disconnect	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=0;JC=[	AJ=0;JC=	x	x	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[-1];JT=0	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53	
10	Silent	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
11	Wake-up Network	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
12	Wake-up Pending	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
13	Expulsion	x	AJ=1;JC=[	x	AJ=0;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=1;JC=[	AJ=0;JC=	x	x	AJ=0;JC=[	AJ=0;JC=[	AJ=0;JC=[-1];JT=0	AJ=1;JC=[	x	x	AJ=1;JC=[-1];JT=53	
14	Isolated	x	AJ=1;JC=[	x	AJ=0;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[	x	x	x	AJ=0;JC=[	AJ=1;JC=[	x	x	AJ=0;JC=[	AJ=0;JC=[	AJ=0;JC=[-1];JT=0	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53	
15	Expulsion Silent	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
16	Expulsion Diagnose	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
17	Bus Off Wait/After-run	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=1;JC=[	AJ=1;JC=[	x	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[-1];JT=53	AJ=1;JC=[	x	x	AJ=1;JC=[-1];JT=53	
18	Can Controller Init/Initializat	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=0;JC=[	x	x	x	AJ=0;JC=[	AJ=1;JC=[	x	x	AJ=0;JC=[	AJ=1;JC=[	AJ=0;JC=[-1];JT=0	AJ=0;JC=[	x	x	AJ=1;JC=[-1];JT=53	
19	Operation After-run	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=0;JC=[	AJ=0;JC=	x	x	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[-1];JT=53	AJ=0;JC=[	x	x	AJ=1;JC=[4,16, 8];JT=0	
20	Expulsion After-run	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=0;JC=[	AJ=1;JC=[	AJ=1;JC=[	x	x	x	AJ=0;JC=[	AJ=0;JC=	x	x		AJ=1;JC=[	AJ=0;JC=[-1];JT=0	AJ=1;JC=[	x	x	AJ=1;JC=[-1];JT=53	
21	Reserved	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
22	Reserved	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
23	Stopped	x	AJ=1;JC=[	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=0	x	x	x	AJ=1;JC=[	AJ=1;JC=[	x	x	AJ=1;JC=[	AJ=1;JC=[	AJ=1;JC=[-1];JT=53	AJ=1;JC=[	x	x	AJ=1;JC=[-1];JT=53	
24																							
25																							
26																							
27	Test settings																						
28	Type of test	Facit	ON/OFF																				
29	Bus off	BusOff	OFF																				
30	Test2	Test2	ON																				
31	Test3	Test3	ON																				
32	Expulsion	Expulsion	ON																				
33	Test4	Test4	OFF																				
34	Test5	Test5	ON																				
35																							
36																							
37																							
38																							
39																							
40																							

Fig.2. Network management configuration file.

3.2.2.2 NM state transitions

The file constitutes of a 2 dimensional matrix with the NM states on each axis. The matrix covers all possible NM state shifting; the left most column contains *from* states and the first row *to* states. As an example, Fig. 3 shows which cell that holds the NM transition criterions from *Operation* to *Off*.

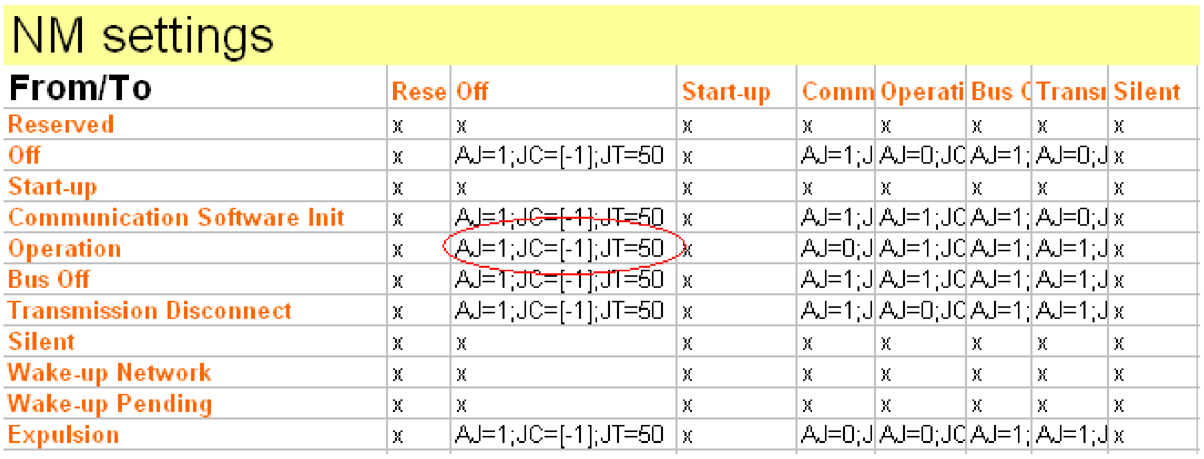


NM settings								
From/To	Rese	Off	Start-up	Comm	Operati	Bus (	Transı	Silent
Reserved	x	x	x	x	x	x	x	x
Off	x	AJ=1;J	x	AJ=1;J	AJ=0;JC	AJ=1;	AJ=0;J	x
Start-up	x	x	x	x	x	x	x	x
Communication Software Init	x	AJ=1;J	x	AJ=1;J	AJ=1;JC	AJ=1;	AJ=0;J	x
Operation	x	AJ=1;J	x	AJ=0;J	AJ=1;JC	AJ=1;	AJ=1;J	x
Bus Off	x	AJ=1;J	x	AJ=1;J	AJ=1;JC	AJ=1;	AJ=1;J	x
Transmission Disconnect	x	AJ=1;J	x	AJ=1;J	AJ=0;JC	AJ=1;	AJ=1;J	x
Silent	x	x	x	x	x	x	x	x
Wake-up Network	x	x	x	x	x	x	x	x

Fig. 3. Part of NM configuration file head sheet. NM state transition criterion from *Operation* to *Off* is red marked.

3.2.2.3 NM state transition criterions

The state transition criterion can either contain the character *x* or a string of the same type as in Fig. 4 .



NM settings

From/To	Rese	Off	Start-up	Comm	Operati	Bus (	Transı	Silent
Reserved	x	x	x	x	x	x	x	x
Off	x	AJ=1;JC=[-1];JT=50	x	AJ=1;J	AJ=0;JC	AJ=1;	AJ=0;J	x
Start-up	x	x	x	x	x	x	x	x
Communication Software Init	x	AJ=1;JC=[-1];JT=50	x	AJ=1;J	AJ=1;JC	AJ=1;	AJ=0;J	x
Operation	x	AJ=1;JC=[-1];JT=50	x	AJ=0;J	AJ=1;JC	AJ=1;	AJ=1;J	x
Bus Off	x	AJ=1;JC=[-1];JT=50	x	AJ=1;J	AJ=1;JC	AJ=1;	AJ=1;J	x
Transmission Disconnect	x	AJ=1;JC=[-1];JT=50	x	AJ=1;J	AJ=0;JC	AJ=1;	AJ=1;J	x
Silent	x	x	x	x	x	x	x	x
Wake-up Network	x	x	x	x	x	x	x	x
Wake-up Pending	x	x	x	x	x	x	x	x
Expulsion	x	AJ=1;JC=[-1];JT=50	x	AJ=0;J	AJ=0;JC	AJ=1;	AJ=1;J	x

Fig. 4. Part of NM configuration file head sheet. NM state transition criterions from *Operation* to *Off* are red marked.

If the transition criterion between two states is *x* marked means the transition can't be done. It can for example be from or to a non used state in a specific implementation. In Fig.3 the transition from or to the Start-up state are marked with an *x* because that NM state isn't used in the example implementation, the same goes for *Reserved* and a number of other NM states.

If the transition criterion contains a text string, like the red marked one in Fig.3, the analysis will use that string as input. The text string contents with descriptions are listed in Table 2. In fact the text strings follows the Python notation and are therefore ideally as program input.

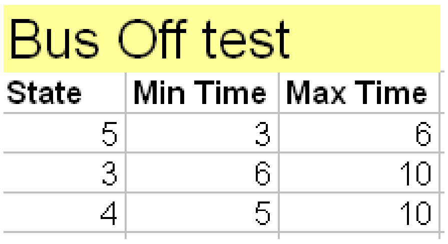
Table 2. NM state transition criterions

Variabel name	***Description***
AJ	Stands for *Allowed Jump*. Equal to *1* means *allowed* transition Equal to *0* means *not allowed* transition
JC	Stands for *Jump Criterions*. Contains a list with states which must have been entered before transition. If no criterions, the list will only contain the single value -1.
JT	Stands for *Jump Time*. Contains the maximum time for the transition to be done

3.2.2.4 Settings for special tests

In addition to the transition matrix the main sheet also contains a table for activation or deactivation of tests. A *test* is searching for a specific combination of transitions, specified in the configuration file in the sheet with the same name as the test. For example; configurations for the test *Bus off* can be found in the sheet named *Bus off*.

There are a number of special tests. Each of these tests has its own configuration sheet, see Fig. 5 for an example. The special test configurations contain a three column table. The first column specifies what combination of states to search for. The other two columns specify min- and max-time in each state. The configuration of a special test is saved on an own sheet in the configuration document. The sheet name must be the same as the name of the test.



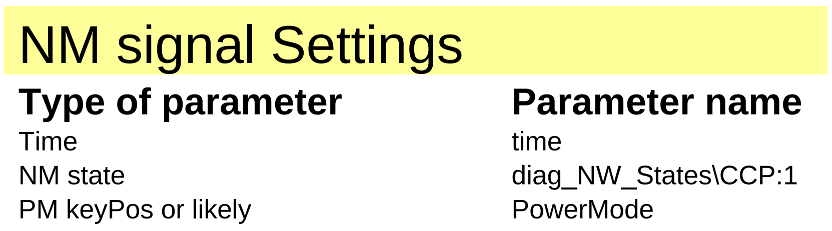
Bus Off test

State	Min Time	Max Time
5	3	6
3	6	10
4	5	10

Fig. 5. *Bus off test* configurations.

3.2.3 Signal settings file

The parameter settings file should be saved as a new sheet, with the name *Signals,* in the configuration file. It contains the parameter links between the Can log and the network management verification program. Fig. 6 shows how the parameter settings file should look like.



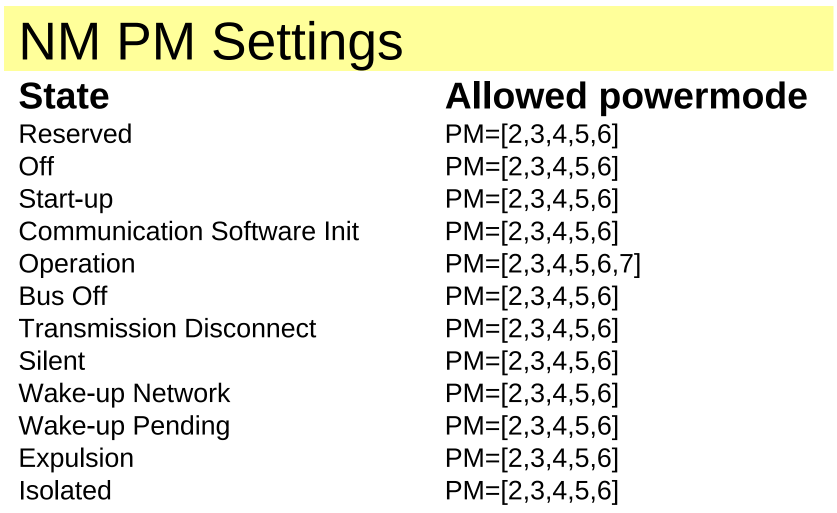
NM signal Settings

Type of parameter	Parameter name
Time	time
NM state	diag_NW_States\CCP:1
PM keyPos or likely	PowerMode

Fig. 6. Example of a parameter settings file.

3.2.4 Power Mode settings file

The power mode settings file should be saved as a new sheet, with the name PowerMode, in the configuration file. It contains the allowed power modes for each network management state. Fig. 7 shows how the power mode settings file should look like.



NM PM Settings

State	Allowed powermode
Reserved	PM=[2,3,4,5,6]
Off	PM=[2,3,4,5,6]
Start-up	PM=[2,3,4,5,6]
Communication Software Init	PM=[2,3,4,5,6]
Operation	PM=[2,3,4,5,6,7]
Bus Off	PM=[2,3,4,5,6]
Transmission Disconnect	PM=[2,3,4,5,6]
Silent	PM=[2,3,4,5,6]
Wake-up Network	PM=[2,3,4,5,6]
Wake-up Pending	PM=[2,3,4,5,6]
Expulsion	PM=[2,3,4,5,6]
Isolated	PM=[2,3,4,5,6]

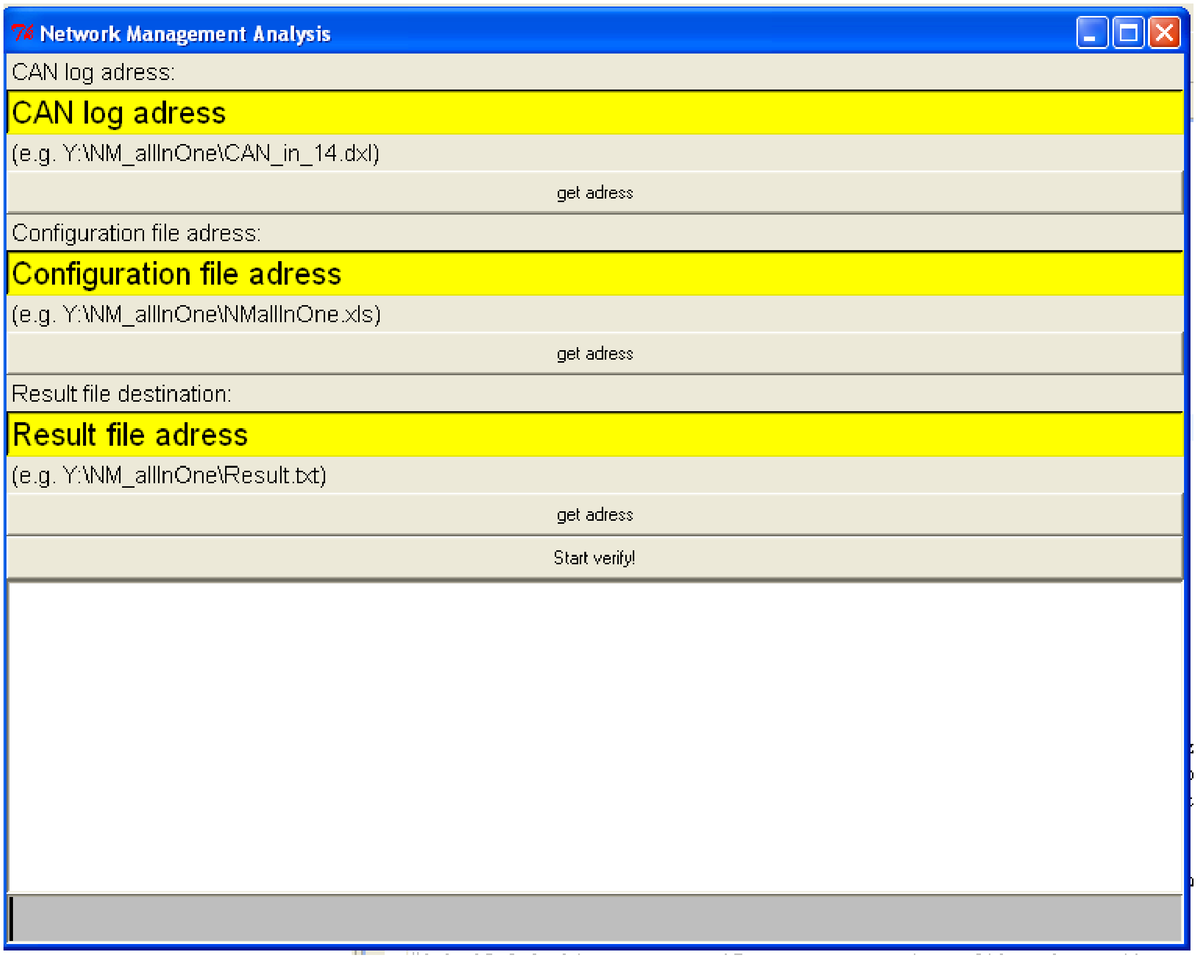
Expulsion Silent	PM=[2,3,4,5,6]
Expulsion Diagnose	PM=[2,3,4,5,6]
Bus Off Wait/After-run	PM=[2,3,4,5,6]
Can Controller Init/Initialization	PM=[2,3,4,5,6]
Operation After-run	PM=[2,3,4,5,6]
Expulsion After-run	PM=[2,3,4,5,6]
Reserved	PM=[2,3,4,5,6]
Reserved	PM=[2,3,4,5,6]
Stopped	PM=[2,3,4,5,6]

Fig. 7. Example of a power mode settings file.

The *State* column contains each NM state. The *Allowed powermode* column contains a list (follows Python notation) with allowed power modes. The list must contain at least one element.

3.2.5 Graphical user interface

The *NM_LIB.py* is provided with a stand alone user interface *GUI.py*. Through the interface users can execute network management analysis with different settings. Fig. 8 shows the interface start screen.


Network Management Analysis

CAN log adress:

CAN log adress

(e.g. Y:\NM_allInOne\CAN_in_14.dxl)

Configuration file adress:

Configuration file adress

(e.g. Y:\NM_allInOne\NMallInOne.xls)

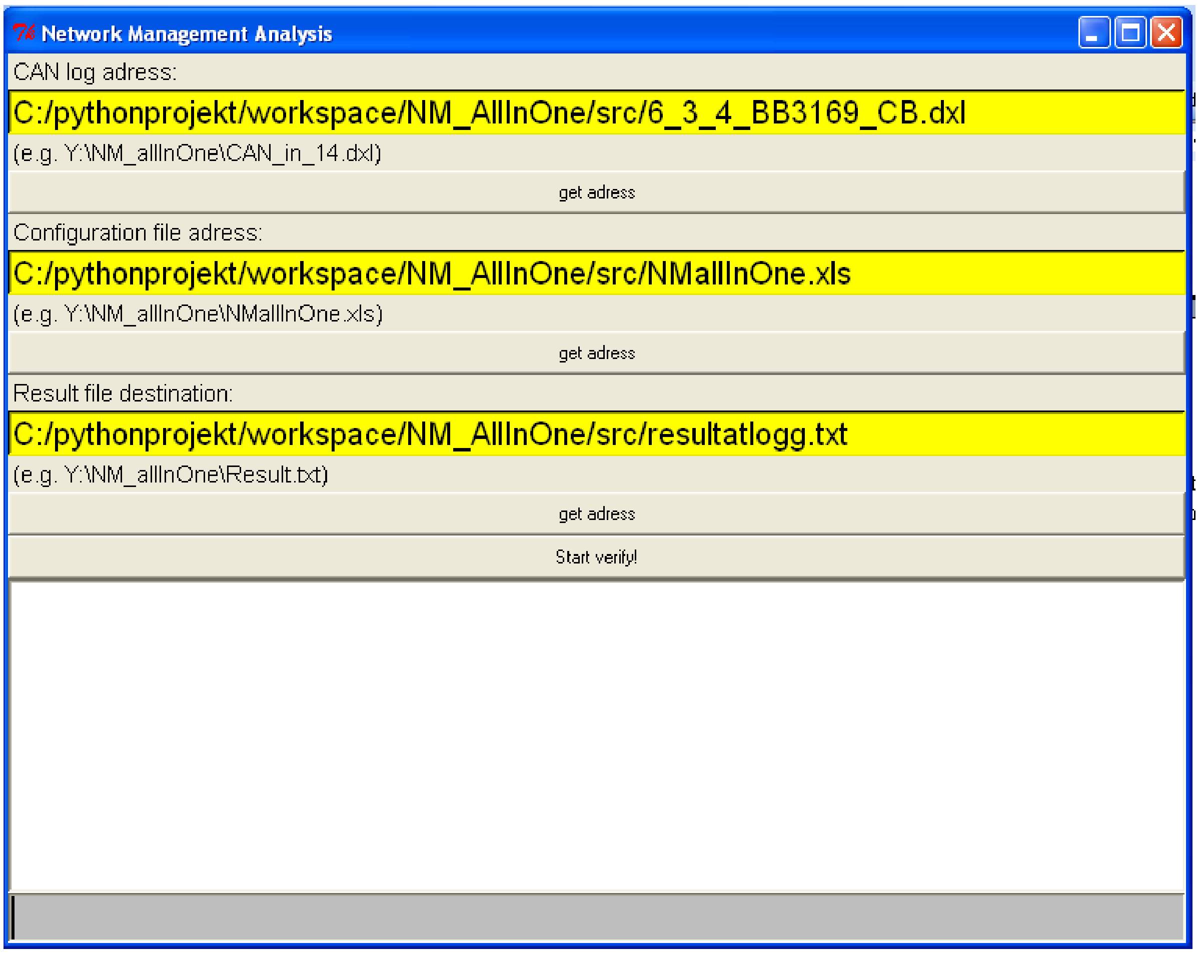
Result file destination:

Result file adress

(e.g. Y:\NM_allInOne\Result.txt)

Fig. 8. User interface start screen.

Before a Network management analysis can be done the program needs to know the addresses to the INCA log file, configuration file and result file. Fig. 9 contains an example of a correct configuration.



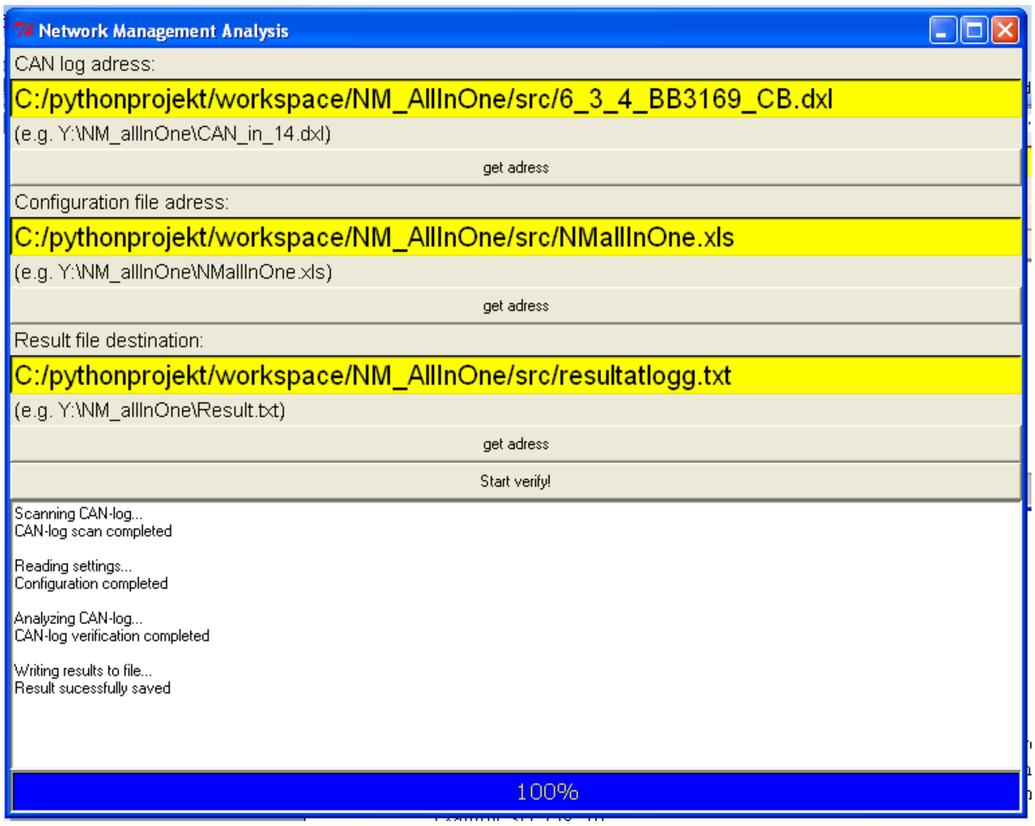
C:/pythonprojekt/workspace/NM_AllInOne/src/6_3_4_BB3169_CB.dxl
(e.g. Y:\NM_allInOne\CAN_in_14.dxl)

C:/pythonprojekt/workspace/NM_AllInOne/src/NMallInOne.xls
(e.g. Y:\NM_allInOne\NMallInOne.xls)

C:/pythonprojekt/workspace/NM_AllInOne/src/resultatlogg.txt
(e.g. Y:\NM_allInOne\Result.txt)

Fig. 9. Example of a correct configured GUI.

When all inputs have been done just click the *start verify!* button to start the verification. If everything went as intended the entry box in the GUI now should contain a simple text log, see Fig. 10.

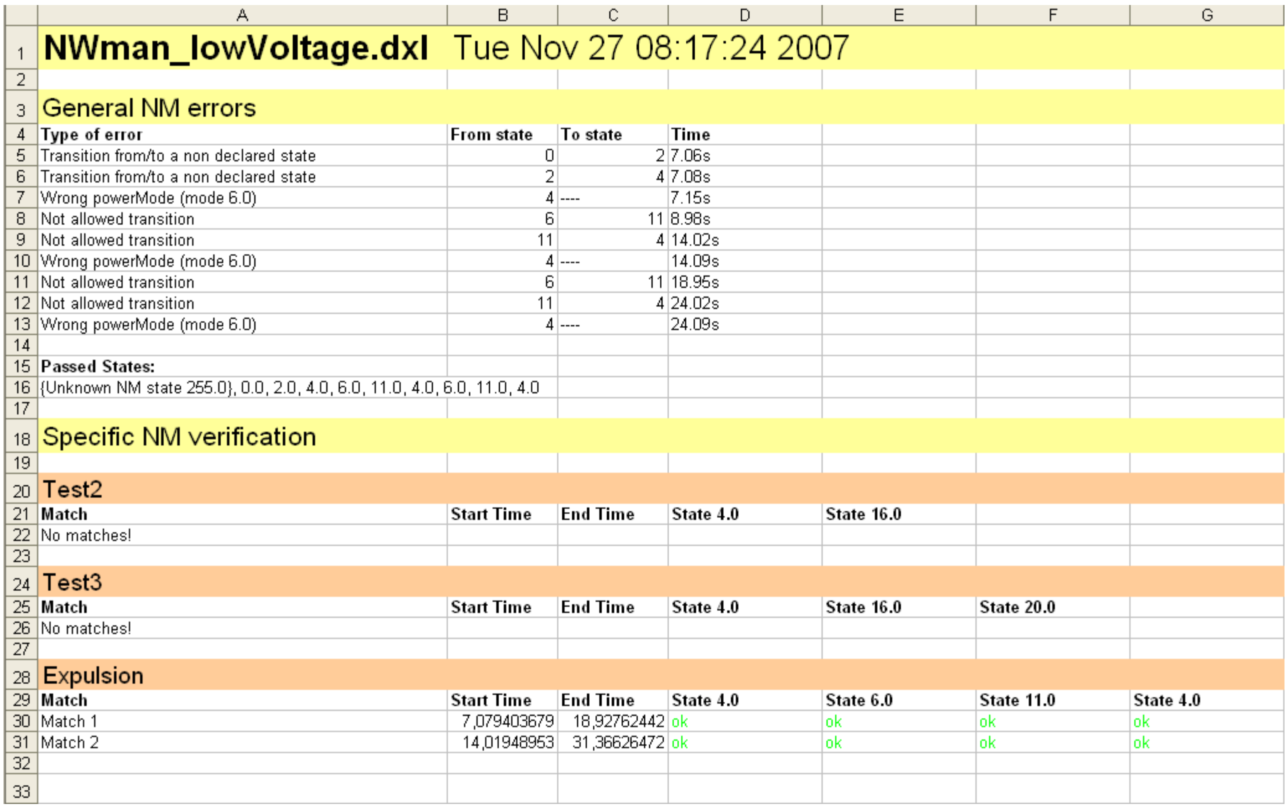

Network Management Analysis
CAN log adress:
C:/pythonprojekt/workspace/NM_AllInOne/src/6_3_4_BB3169_CB.dxl
(e.g. Y:\NM_allInOne\CAN_in_14.dxl)
get adress
Configuration file adress:
C:/pythonprojekt/workspace/NM_AllInOne/src/NMallInOne.xls
(e.g. Y:\NM_allInOne\NMallInOne.xls)
get adress
Result file destination:
C:/pythonprojekt/workspace/NM_AllInOne/src/resultatlogg.txt
(e.g. Y:\NM_allInOne\Result.txt)
get adress
Start verify!
100%

```
Scanning CAN-log...
CAN-log scan completed

Reading settings...
Configuration completed

Analyzing CAN-log...
CAN-log verification completed

Writing results to file...
Result sucessfully saved
```

Fig. 10. Example of a successful Network management verification.

3.2.6 Result File

A successful Network Management analysis generates a Microsoft Excel result file. All upcoming network management errors during the verification are presented in the result file. In addition, the last part of the log contains results for the activated special tests. See Fig. 11 for an example log.



	A	B	C	D	E	F	G
1	**NWman_lowVoltage.dxl**	Tue Nov 27 08:17:24 2007					
2							
3	General NM errors						
4	**Type of error**	**From state**	**To state**	**Time**			
5	Transition from/to a non declared state	0	2	7.06s			
6	Transition from/to a non declared state	2	4	7.08s			
7	Wrong powerMode (mode 6.0)	4	----	7.15s			
8	Not allowed transition	6	11	8.98s			
9	Not allowed transition	11	4	14.02s			
10	Wrong powerMode (mode 6.0)	4	----	14.09s			
11	Not allowed transition	6	11	18.95s			
12	Not allowed transition	11	4	24.02s			
13	Wrong powerMode (mode 6.0)	4	----	24.09s			
14							
15	**Passed States:**						
16	{Unknown NM state 255.0}, 0.0, 2.0, 4.0, 6.0, 11.0, 4.0, 6.0, 11.0, 4.0						
17							
18	Specific NM verification						
19							
20	Test2						
21	**Match**	**Start Time**	**End Time**	**State 4.0**	**State 16.0**		
22	No matches!						
23							
24	Test3						
25	**Match**	**Start Time**	**End Time**	**State 4.0**	**State 16.0**	**State 20.0**	
26	No matches!						
27							
28	Expulsion						
29	**Match**	**Start Time**	**End Time**	**State 4.0**	**State 6.0**	**State 11.0**	**State 4.0**
30	Match 1	7,079403679	18,92762442	ok	ok	ok	ok
31	Match 2	14,01948953	31,36626472	ok	ok	ok	ok
32							
33							

Fig. 11. Example of a result log-file.

3.2.6.1 General NM errors

The first part of the result file presents all general Network Management errors. It can be all from an illicit transition to wrong powermode or unidentified states. In addition, all passed states are presented in the order they were activated.

3.2.6.2 Specific NM verification

The log file's second and last part contains the result of the special tests. Each match of the specified state series is presented. Whole or part of the series can either be marked as *ok* in green colour, or as *failed* in red colour. *Failed* means time in state whether is below the minimum time limit or exceeds the maximum time limit.

4 Controller Area Network

4.1 Introduction

The Controller Area Network (CAN) was first designed for the automotive environment but is nowadays also used in other applications. The transfer protocol sends on a two wire data bus, which often are twinned for better noise reduction. It has during the years experienced three major updates, see Table 1. For maximal transfer rate the wiring can't be longer than 40 meters. A wiring of double length results in about half the transfer rate.

Table 1. The different Controller Area Network versions [3]

Nomenclature	*Standard*	*Max. signal rate*	*Identifier*
Low-speed CAN	ISO 11519	125 kbps	11-bit
CAN 2.0A	ISO 11989:1993	1 Mbps	11-bit
CAN 2.0B	ISO 11989:1995	1 Mbps	29-bit

4.2 Data transmission

The protocol does not us addresses to send a message to a specific node. A message identifier is used instead, which allows all nodes who want the information to read on bus. Every node consists of a masking system that masks the identifier all the time, if the received identifier matches the mask the transmitted data will be stored. The identifier consists of either 11 or 29 bits, depending on the CAN version.

When a node wants to transmit it has to wait until the bus is free undependable of priority. If two nodes wants to send at the same time they will both start to send it's frame, which always starts with the identifier. Both nodes sends until it has been investigated which frame has the lowest identifier. The node with the higher identifier then stop to transmit, a lower identifier has therefore priority over a higher one. For an example see Fig. 1.

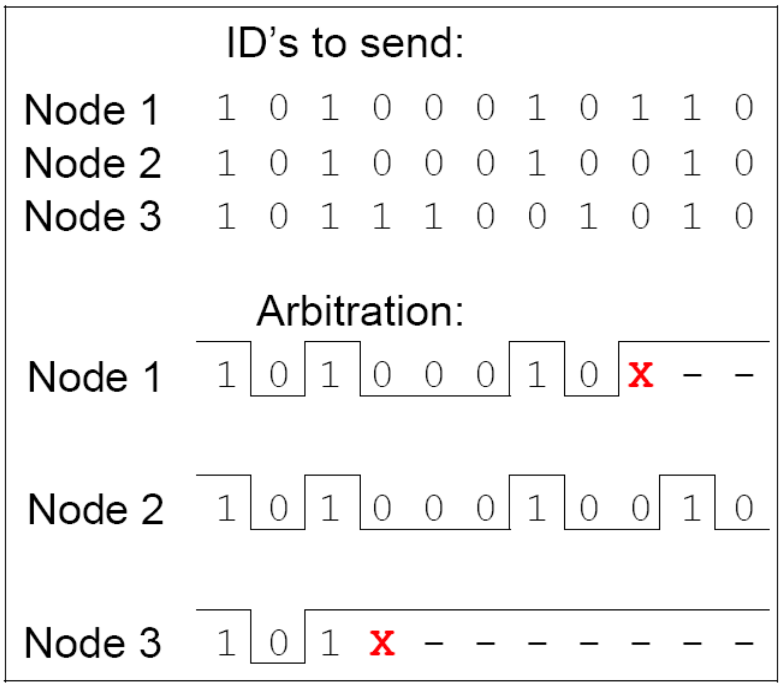

ID's to send:
Node 1 1 0 1 0 0 0 1 0 1 1 0
Node 2 1 0 1 0 0 0 1 0 0 1 0
Node 3 1 0 1 1 1 0 0 1 0 1 0
Arbitration:
Node 1 1 0 1 0 0 0 1 0 X – –
Node 2 1 0 1 0 0 0 1 0 0 1 0
Node 3 1 0 1 X – – – – – – –

Fig. 1. Arbitration, in this example Node 2 has the lowest identifier and will continue to send the remaining frame part. [2]

4.3 OSI model

The OSI model divides data communication in seven layers for a more foreseeable representation, see Fig. 2. The layers are all linked together; one level receives data from a lower level and distributes it up one level. The OSI representation for Controller Area Network follows below.

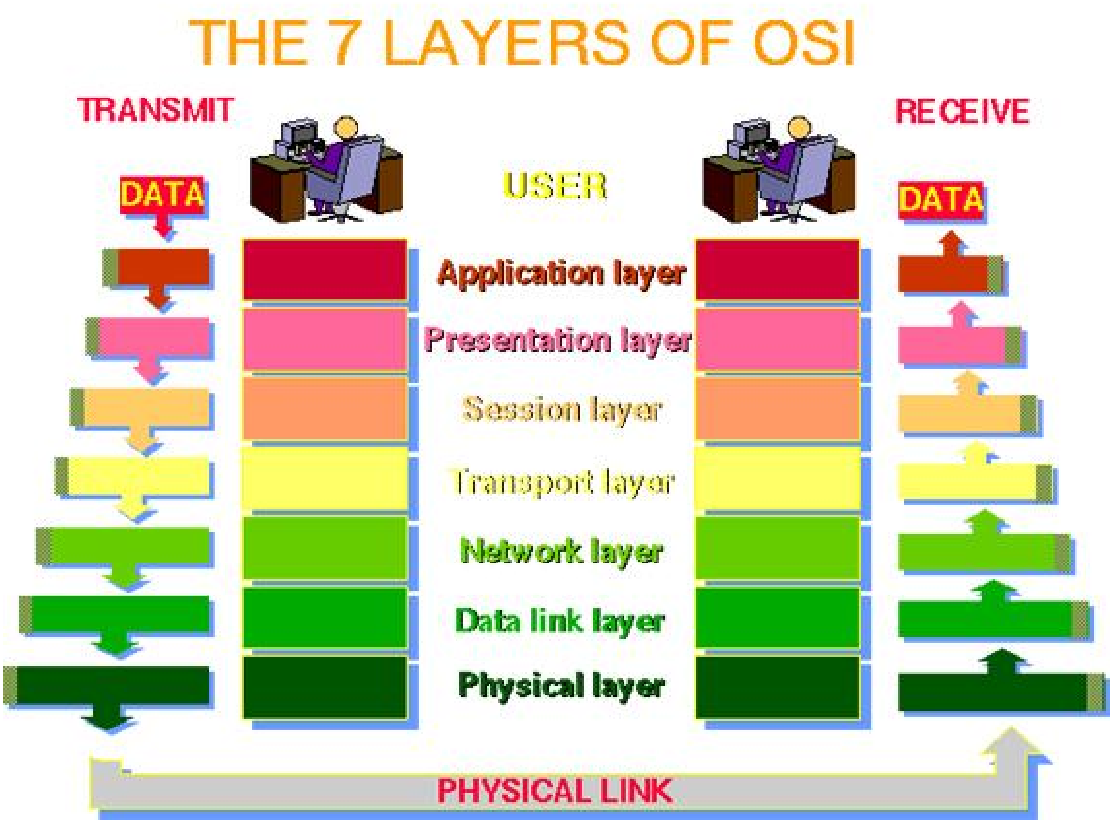


Fig. 2. OSI model.

4.3.1 Physical layer

Defines how the signals are transmitted. Handles signal levels, bit representation and transmission medium.

4.3.2 Transport layer (merged with Data Link and Network layer)

- Data Link layer takes care of error correction and handles the flow control. The layer can be divided into two sub layers, Media Access Layer (MAC) and Logical Link Control (LLC).
- The Network layer packs data together and administrates the routing.
- The Transport layer keeps track of the packages sent and retransmits those who fail.

In a Controller Area network these layers handles the following tasks.

- Fault confinement
- Error detection

- Message validation
- Acknowledgement
- Arbitration
- Message framing
- Transfer rate and timing
- Information routing

4.3.3 Session and Presentation layer

Structure the messages for the intended application. Message filtering and handling, handles the status as well.

4.3.4 Application layer

The main interface for end user.

4.4 CAN frames

The transmissions on the Controller Area Network are divided into frames, and can be configured for two different CAN formats, CAN 2.0A or CAN 2.0B. CAN 2.0A only supports a CAN base frame with a length of 11 bits for the identifier, while CAN 2.0B supports an extended base frame with a length of 29 bits for the identifier. CAN 2.0B is compatible with CAN 2.0A but not vice versa. To separate base frames from extended frames an IDE bit is used, dominant (0) for base frames and recessive (1) for extended frames. The CAN network has four different types of frames;

- **Data frame**: Containing data a node wants to transmit.
- **Remote frame**: Requests the transmission of an identifier.
- **Error frame**: Frame for detecting an error.
- **Overload frame**: Frame for add some space between other frames.

4.4.1 Data frame

The Data frame are used for data transmission between the nodes and has different designs for CAN 2.0A (11 bit identifier) and CAN 2.0B (29 bit identifier). Table 2 describes the base data frame format and Table 3 the extended data frame format.

Table 2. Base frame format. [3]

Field name	***Length (bits)***	***Purpose***
Start-of-frame	1	Denotes the start of the frame.
Identifier	11	Data identifier, used for handling the buss priority.
Remote Transmission Request (RTR)	1	Must be dominant (0). Optional.
Identifier Extension bit (IDE)	1	Must be dominant (0). Optional.
Reserved bit (r0)	1	Reserved bit.
Data Length Code (DLC)	4	Number of bytes of Data (0-8 bytes).
Data field	0-8 bytes	Data to be transmitted.
CRS	15	Cyclic Redundancy Check, a kind of checksum.
CRS delimiter	1	Must be recessive (1).
ACK slot	1	Transmitter sends recessive (1) and any receiver can assert dominant (0).
ACK delimiter	1	Must be recessive (1)
End-of-frame (EOF)	7	Must be recessive (1)

Table 3. Extended frame format. [3]

Field name	***Length (bits)***	***Purpose***
Start-of-frame	1	Denotes the start of the frame.
Identifier A	11	First part of the data identifier
Substitute Remote Request (SRR)	1	Must be recessive (1). Optional.
Identifier Extension bit (IDE)	1	Must be recessive (1)
Identifier B	18	Second part of the data identifier
Remote Transmission Request (RTR)	1	Must be dominant (0)
Reserved bits (r0, r1)	2	Reserved bits.
Data Length Code (DLC)	4	Number of bytes of Data (0-8 bytes).
Data field	0-8 bytes	Data to be transmitted.
CRS	15	Cyclic Redundancy Check, a kind of checksum.
CRS delimiter	1	Must be recessive (1).
ACK slot	1	Transmitter sends recessive (1) and any receiver can assert dominant (0).
ACK delimiter	1	Must be recessive (1)
End-of-frame (EOF)	7	Must be recessive (1)

4.4.2 Remote frame

In general there are most of the times no need for a remote frame, the nodes are transmitting new data without being requested first. Anyway sometimes it can be necessary for a node to request data from another specific node and will then use a remote frame. The remote frame has the same appearance as the data frame but with the RTR bit set to 1 (recessive) and no data field.

4.4.3 Error frame

The error frame consists of two bit fields, error flag field and error delimiter. The error flag field consists of superposition of error flags from different network stations. The error flags can be divided in active and passive flags. An active error flag is transmitted by a node detecting an error, while a passive error flag is transmitted of a node detecting an active error flag.

4.4.4 Overload frame

The overload frame contains of 2 bit fields, overload flag and overload delimiter. Transmission of the overload flag occurs if the internal conditions of a receiver require a delay before the next frame or if a dominant bit is detected during the intermission. The overload flag consists of six dominant bits, the overload delimiter of eight recessive bits and is of the same type as the error delimiter.