Research Report

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Deliverable D 4.4

Validation of comprehensive energy management system based on cloud-sourced information

DOCUMENT INFORMATION

D4.4 Validation of comprehensive energy management system	
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Acronyms and abbreviations

HMI	Human Machine Interface
BMS	Battery management system
MGU	Motor generator unit
CAN	Controlled area network
NEDC	New European driving cycle
COG	Centre of gravity

1 Introduction

The main purpose is to build an application that would allow testing communication between OIKOS board (based on the AURIX™) and the dissemination module (represented by Skoda vehicle demonstrator) over the serial port RS232, see Fig. 2.

The main idea is: sending the GPS coordinates to the OIKOS and receive recommended speed profile for the given track (while receiving the GPS coordinates, AURIX chip sends back 4 messages where 3 of them predict possible speed of the vehicle for the next 5 seconds).

Another aim is to check possibilities of other connections, such as Wi-Fi, Bluetooth, Ethernet.The OIKOS board does not provide Wi-Fi and Bluetooth and thus it is not mentioned in the document[1].

[1] The Infineon OIKOS board was existing already when project started Therefore Infineon provided it to the partners at that time for getting started. Initially the tests were planned for the iCEM CCU which was developed and is based on a new AURIX prototype and offers more communication connections such as Bluetooth. However, the iCEM CCU was not available yet when the tests had to be carried out at Skoda.

Figure 1. Automotive OIKOS board integrated in the vehicle demonstrator Skoda Rapid

1.1 Communication architecture

OIKOS board is equipped with four different ports (interfaces) - three of them are used for communication with other devices and the last one is for power supply, Fig. 3.

Interfaces used for I/O communication are USB interface, RS232 interface and Ethernet interface. As the GPS device was used u-blox 6 GPS Engine with communication by interface RS232 connected to dissemination module.

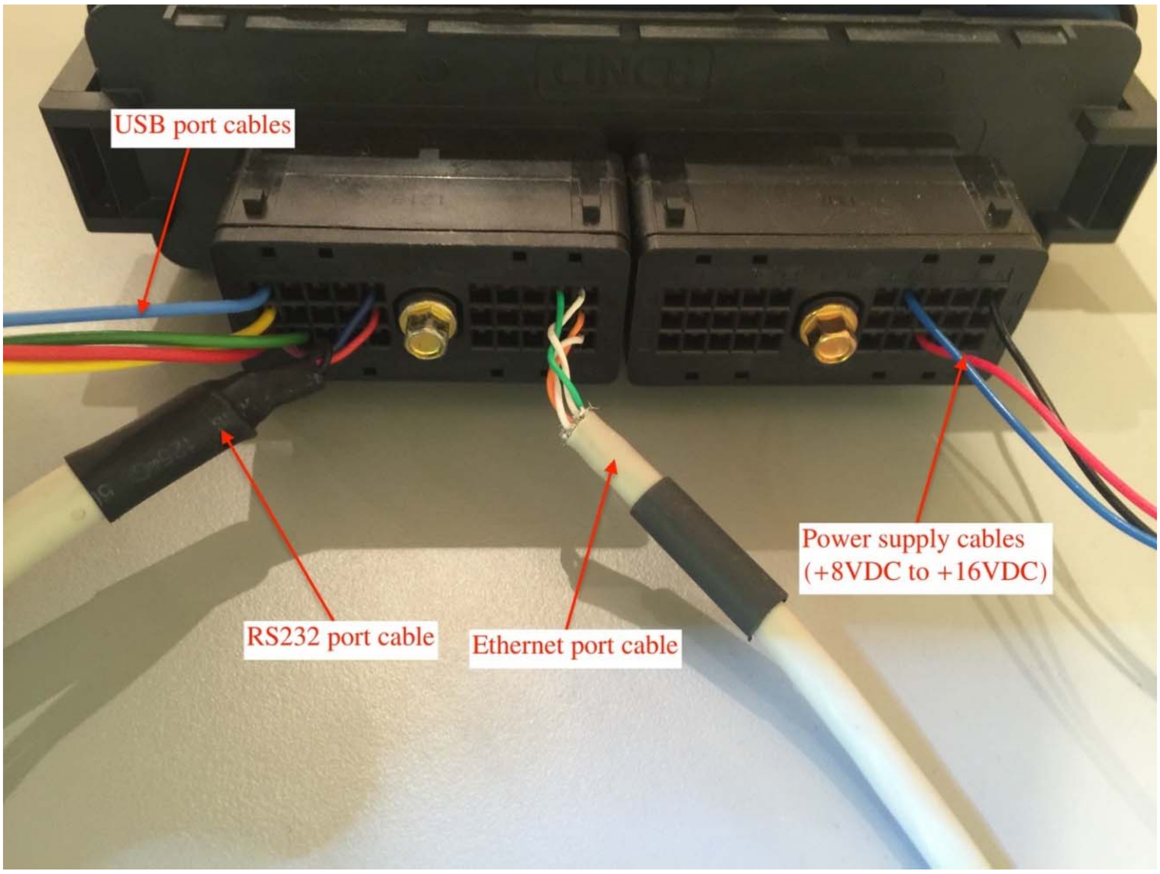


Figure 2. Photo of the OIKOS board with available ports

1.2 Data transfer diagram

There are proposed two ways how to connect OIKOS board to Dissemination Module – Ethernet and RS232. Each of them is used for the different purpose.

Ethernet

Ethernet allows HTTP based web server to run. The default Home Page address is http://192.168.100.1/. After opening the Home Page in the web browser, user can see basic information about the tasks running and the real-time data transfer.

RS232

Communication over the RS232 port is used to send CAN messages between OIKOS board and the Dissemination Module. Once the RS232 port is open, data transfer immediately begins. The main idea is that AURIX chip sends back speed profile to the dissemination module, while receiving SBD_ECAN_LOG_GPS1_POS messages including the GPS coordinates of the given track.

Data transfer between OIKOS board (AURIX chip) and the DM is possible to see on Figure 4.

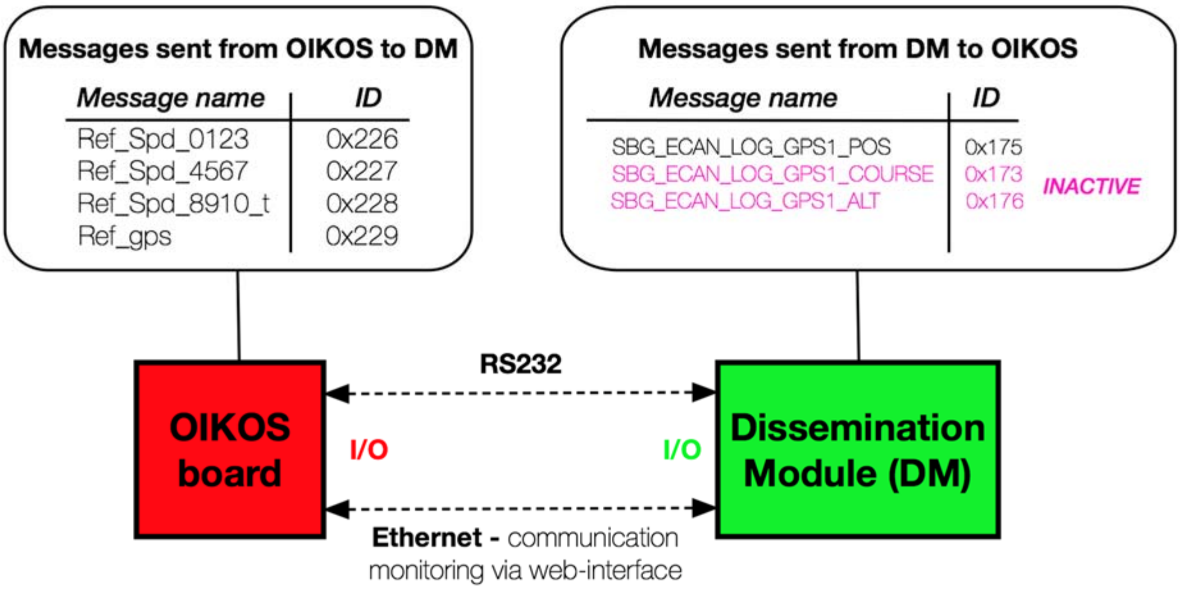


Figure 3. Data transfer diagram

1.3 Test application

For the purposes simulation, a test application have been developed for the Dissemination Module. The overall structure of the test application was written in C++. Final executable version is the GUI-based application compiled for 32-bit Windows-based operating system (supporting both 32 and 64-bit version of Windows OS).

The main features of the application are:

- Decoding CAN messages received from AURIX chip in respect to 8-byte data ID sequence.
- Decoding received data and real time visualisation.
- Written received data to the text file to allow graphical interpretation.
- Recommendation for speed profile up to 5 seconds generated by AURIX chip is displayed through the GUI and used to propose speed profile of the whole track in the real time.
- Sending messages including GPS data of the current position in the required format. (Application converts GPS Degrees-Minutes format to Degrees format and decimal format to hexadecimal).
- Loading GPS data from the text file.
- Sending GPS data to the OIKOS board with the period of 100 ms (this period can be set according to the current request).
- Since OIKOS doesn’t accept valid RS232 CRC sum and accept “every” single incoming message, there is no CRC control.

1.4 GUI

The main goal has been to create a simple GUI, which would enable to provide all required information concerning present tasks to visualise on the both devices.

Once the RS232 port is open (the user selects available serial COM port), the application gives following information:

- Total amount of received bytes.
- Received messages from OIKOS board with speed prediction up to 5 seconds (t_0 – t_{10} with the step of 0,5 sec.) and the message with GPS location.
- Each received message has its own counter.
- Rotary stack: displays received message in the real time with its correct ID.
- Data sent from the Dissemination Module with the GPS position and its decoding into hexadecimal format.
- Graph of the coming speed profile for semi-autonomous driving, Fig. 5.

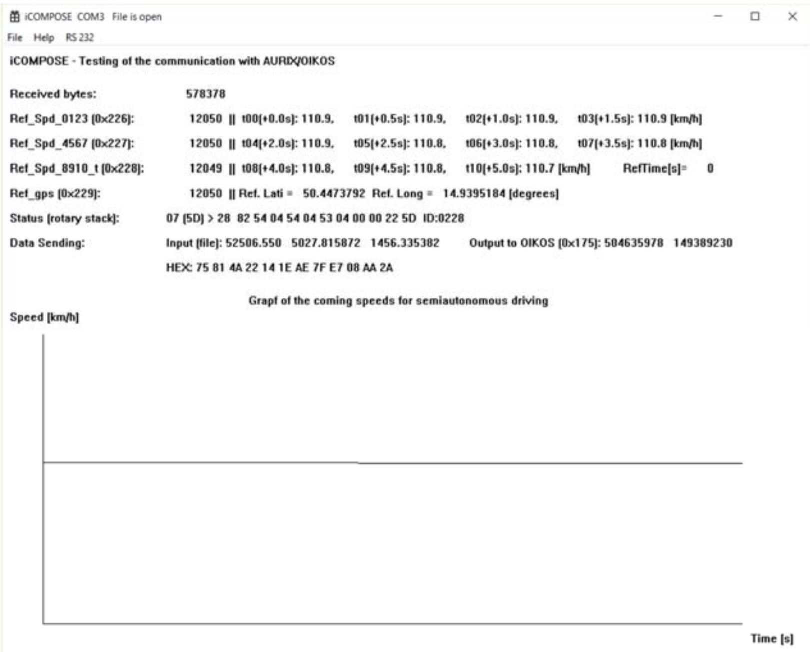


Figure 4: Running application example

Fig. 6 gives a screenshot of the running application with different speed values and a short description of each value.

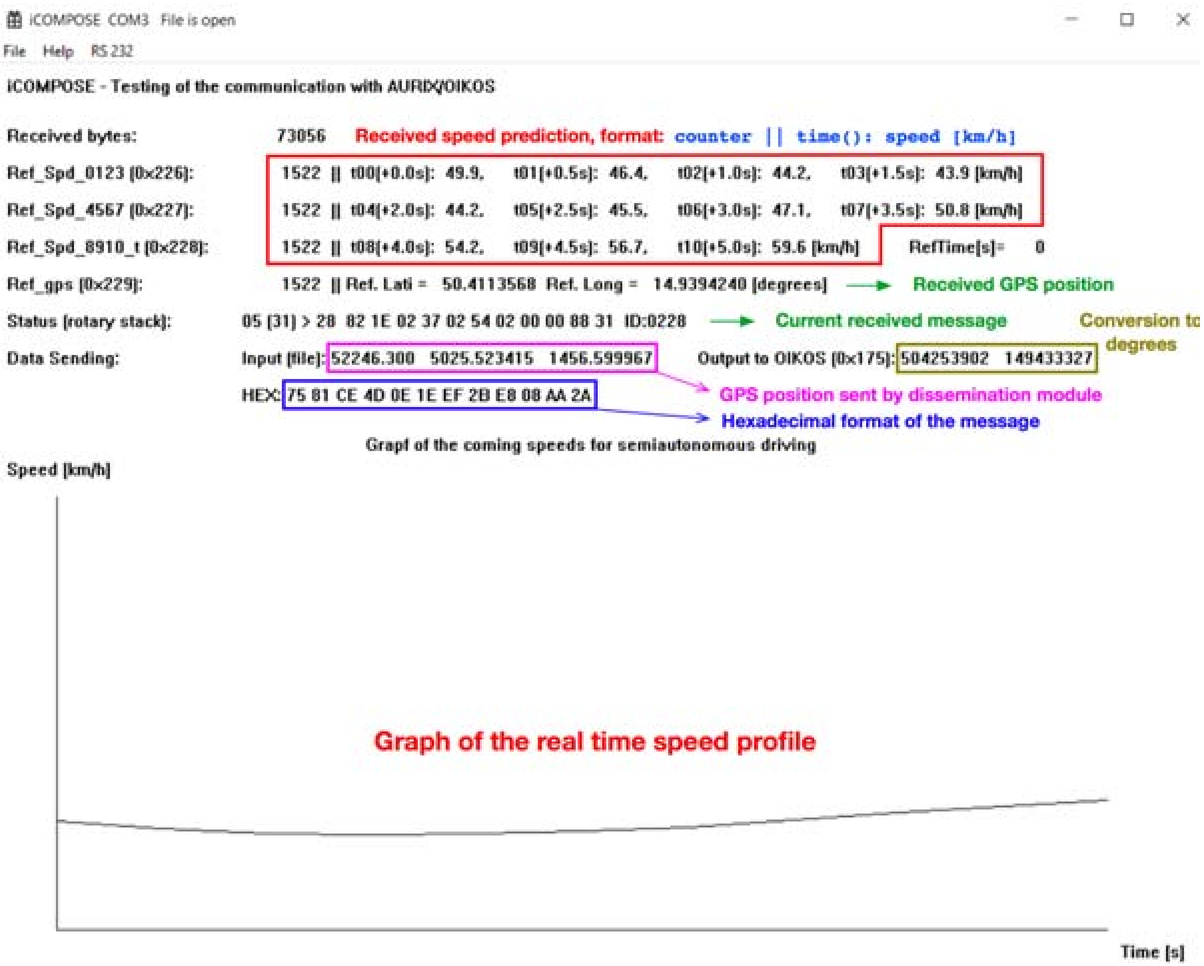


Figure 5: Debugging application

1.5 Test track

For evaluation technical features of AURIX unit was used the part of the track in the proximity Mlada Boleslav of range few kilometres.

Track starts at the GPS coordinates of: 50.4092850167, 14.942494633. This coordinates take place in Mlada Boleslav near Jicinska Street, Fig. 7.

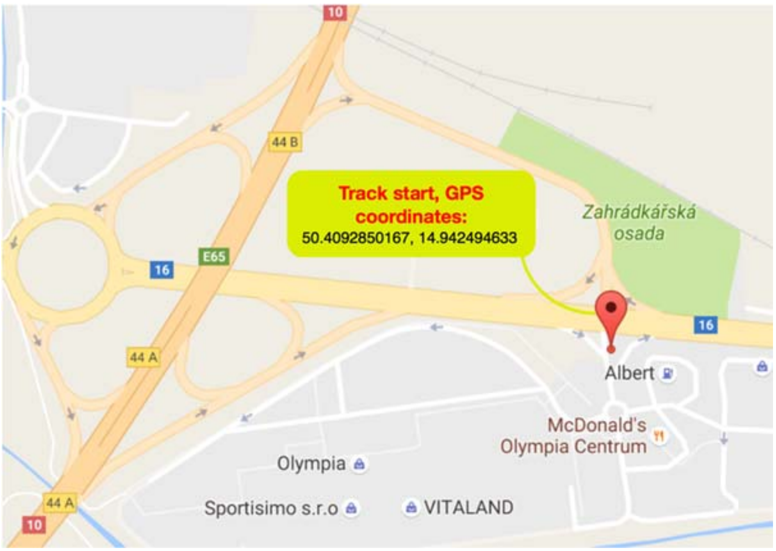


Figure 6: The beginning of the test track

The end is at the GPS coordinates of: 50.51668675, 14.989781883, that is at the D10 highway exit in Mnichovo Hradiste, Fig. 8.

Figure 7: End of the test track

The whole track is 13,5-kilometre-long and takes place mainly on the D10 highway with one speed limitation of 100 km/h, Fig. 9.

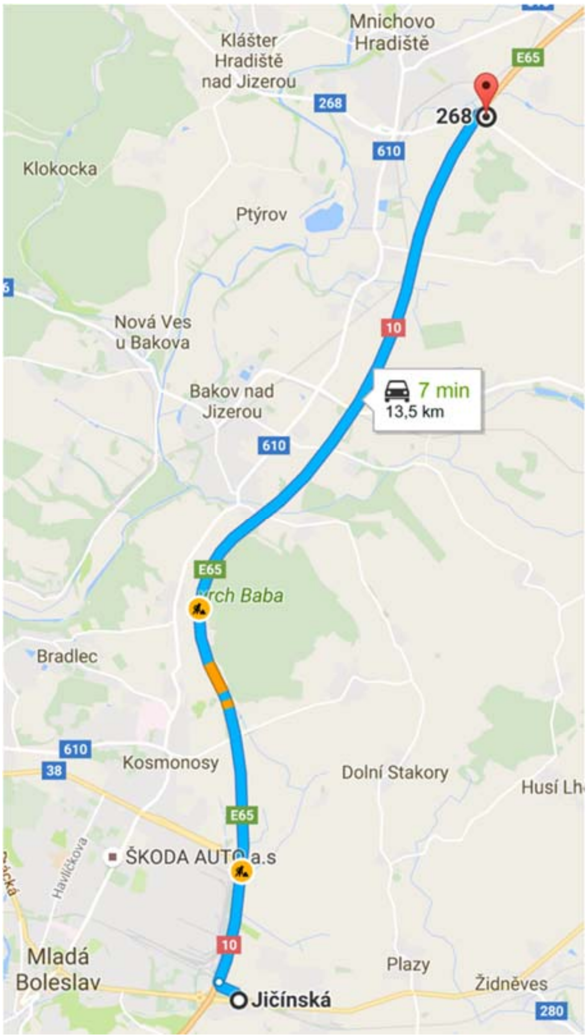


Figure 8: Test track

1.6 Ethernet communication

As above mentioned, the most important feature of the Ethernet Port is the HTTP based web server.

To set up OIKOS board, the following steps should be made:

- *IP-ADDRESS:* xxx.168.100.2
- *SUBNET MASK:* xxx.255.255.0

The web server listens on TCP Port 80 for HTTP-request and may be accessed by all common web browsers [1].

1.6.1 Testing

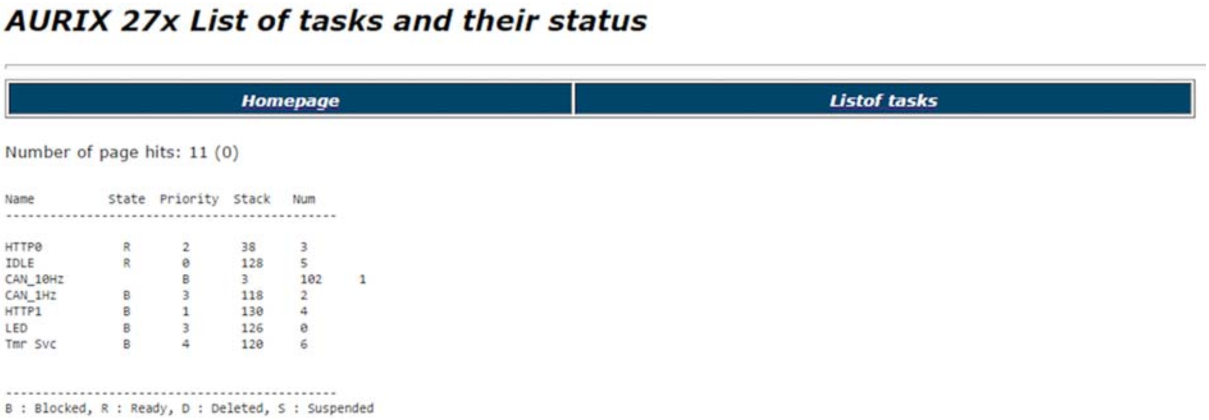
All setup has been tested on both operating systems - Windows 10, MAC OS X 10.11.

The OIKOS board has acted as descripted in the previous chapter and the Home Page for was available in the web browser at the address: http://xxx.168.100.1/. (Used web browsers: IE, Google Chrome, Apple Safari), Fig. 10.

When the web page is loaded, there are basically two options. First of them is the home page site, where you can see some general information about AURIX family of chips which is a part of OIKOS board architecture and some information about the operating system FreeRTOS.

Figure 9: Google Chrome: the default AURIX web page

The other option is to open "List of tasks" table. This table shows the running tasks (their status with priorities) between dissemination module and OIKOS board, Fig. 11.



Name	State	Priority	Stack	Num	
HTTP0	R	2	38	3	
IDLE	R	0	128	5	
CAN_10Hz		B	3	102	1
CAN_1Hz	B	3	118	2	
HTTP1	B	1	130	4	
LED	B	3	126	0	
Tmr Svc	B	4	120	6	

B : Blocked, R : Ready, D : Deleted, S : Suspended

Figure 10: List of tasks and their status

1.7 RS232 communication

Data communication between OIKOS board and the Dissemination Module takes place through serial interface RS232. The basic setting is:

- Data length: 8 bit.
- Baud Rate: 230400 bd.

- Start/Stop bits: 1/1.
- No parity checking.
- No hardware handshaking / Flow Control (RTS/CTS/DTR/DSR disables/unused) [1].

Setting of the other parameters is similar to the recommended values stated in “Skoda Demonstrator – Communication Interface” document.

1.7.1 Testing RS232 communication

OIKOS board begins to send messages in the order of 0x229, 0x226, 0x227 and 0x228 immediately after the device is turned-on. The messages frequency is constant and its value is 100 ms.

The message with the ID 0x229 contains the GPS position. The rest of the messages (0x226, 0x227, 0x228) contains the speed prediction for the next few seconds.

When a message with the ID 0x175 containing the GPS positions in proximity Mlada Boleslav is sent from the dissemination module, the OIKOS board starts to send back messages with the nearest GPS position and the most relevant speed plan with 11 values.

For the purposes of testing, OIKOS board received GPS positions of the whole track on the D10 highway from Mlada Boleslav to Mnichovo Hradiste in sequence with range of 10 minutes (= 600 sec).

The output generated by OIKOS is visualised on the graph, Fig. 12.

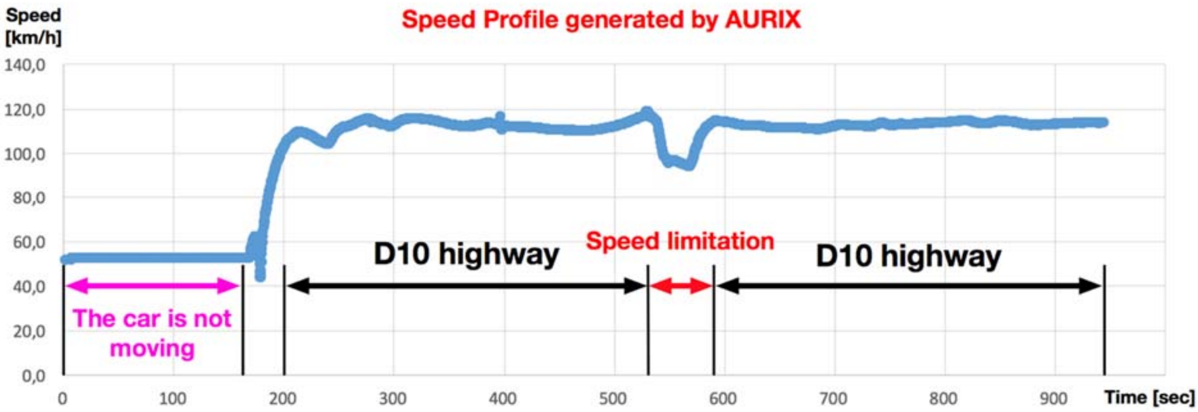


Figure 11: D10 highway speed profile

As you can see on the graph, the speed profile does not show any extreme values and so this speed progression can be considered as matching the expected values. One of the proofs may be the speed limitation to 100 km/h on the D10 highway in the middle of the track, Fig. 13.

Figure 12: D10 highway speed limitation

When resending the same GPS positions of the given track, the device always recognizes these positions and send back the similar speed profile, Fig. 14.

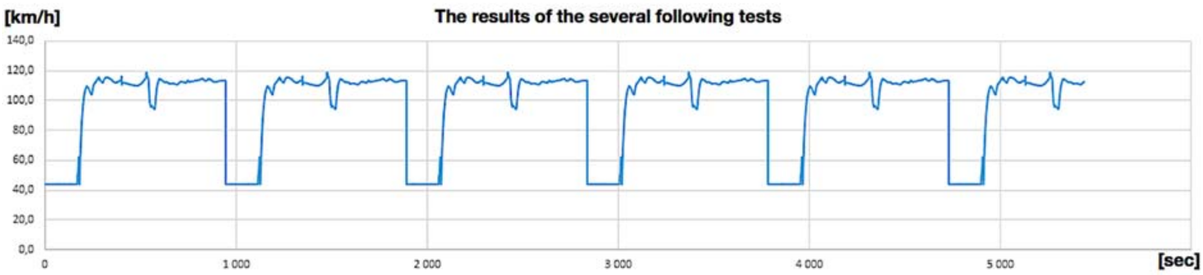


Figure 13: The results of the several following tests

Sending messages with the ID 0x175 with the different frequency than 100 ms, doesn't affect the frequency of the messages sent by OIKOS board, which always keeps the frequency constant at 10 Hz.

1.7.2 Alternative testing of OIKOS board

For the purposes of the next experiment, all tracks are used. The track starts at the GPS coordinates of: 50.41172502, 14.93894002. After reaching the D10 highway exit (end of the first experiment), vehicle continued off the highway and returned to the starting point up the road 268 and 16, Fig. 15.

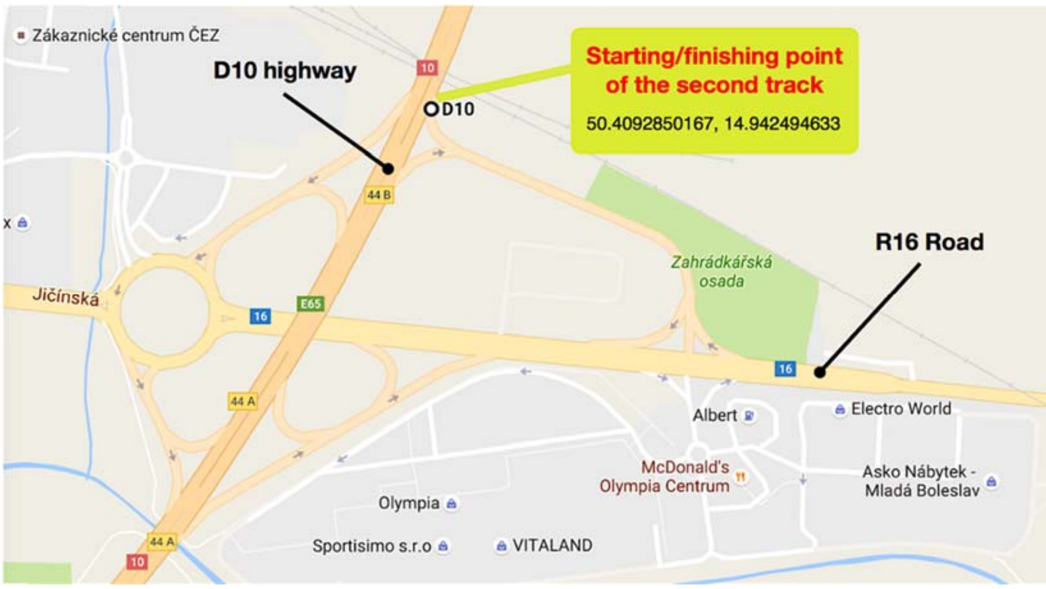


Figure 14: Start/End point of the second testing

The whole track is over 30-kilometre-long and takes about 30 minutes. As mentioned previously, there are two types of roads: D10 highway – speed is limited up to 130 km/h and two roads with the limitation of 90 km/h (there are also few sections where speed is limited up to 50 km/h).

1.8 Results

The testing method of OIKOS board was similar to that used in the previous track. Once the GPS coordinates conversion was done and the text file (with these coordinates) made, dissemination module has sent the whole track to OIKOS board several times.

The main difference with the previous evaluation is that speed prediction from OIKOS unit has been compared with the real speed profile measured during driving. In this case we have considered real speed profile to be the default value. However, there are factors, such as traffic behaviour or possible delays that make influence on these values.

The graph on the next page shows comparison of real speed profile and predicted speed profile from OIKOS unit for one drive.

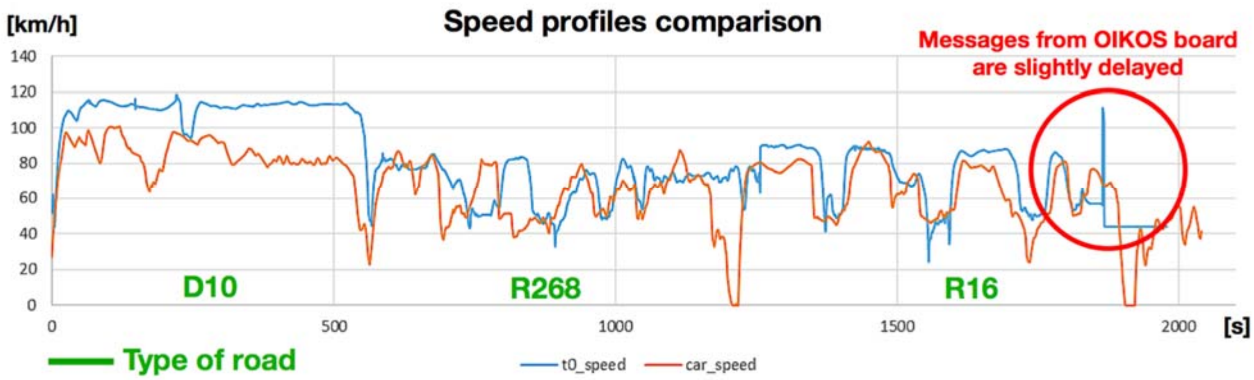


Figure 15: Speed profiles comparison

As you can see on the Fig. 16 variable *car_speed* represents the speed of a vehicle and variable *t0_speed* represents predicted speed profile where t0 refers to the only real-time value send by OIKOS, the speed profile from OIKOS represents an "ideal" model of driving without any traffic limits. This was not so obvious in the first testing, because there was no comparable data available. The lower average speed of the vehicle on the D10 highway was most probably caused by increased traffic and the driver himself.

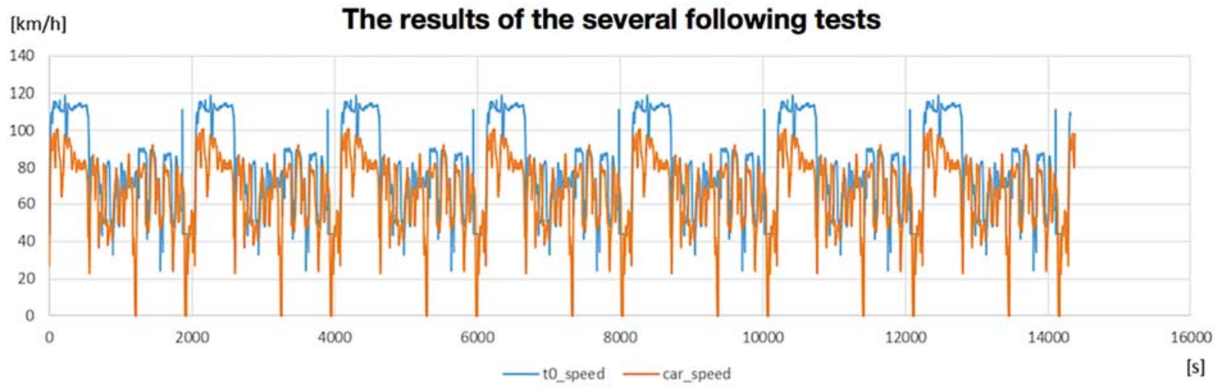


Figure 16: The results of the successive tests

After sending the same GPS coordinates, we have again obtained similar speed profile which indicates no unstable behaviour, Fig. 17.

Fig. 18 shows the same speed comparison as inFigure 16, but in this case axis X represents the distance in metres from the starting point.

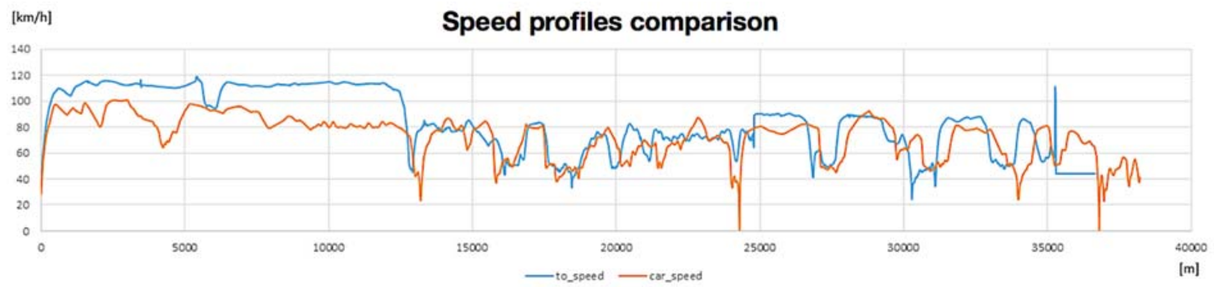


Figure 17: Speed profile comparison

According to both testing, we have observed following issues:

- Speed profile mostly matches the characteristics of the track (speed limitations, traffic regulations).
- Recommended speeds are always delayed. Delay seems to be constant and not varying (the data has no extreme values). This may be caused by OIKOS signal delay.
- The signal coming out of the OIKOS board is unstable around starting point (D10 highway entrance). It looks like the device is unable to find the correct GPS position.
- When the input signal towards the OIKOS is missing messages are still being send to the dissemination module at the frequency of 10Hz. However, these messages contain only constant data. The same situation was observed while the GPS coordinates show a position off the road. When the position is off the track, there should be some type of a warning and the data transfer should be suspended.
- OIKOS board responds very fast (in a range of milliseconds).

2 Energy consumption verification

The aim of this task was to evaluate the real time parameters of the AURIX platform in automotive conditions and positive influence to the energy consumption. A developed model of vehicle speed profile has been integrated to the AURIX unit and evaluated by the vehicle simulator Skoda. This model has been developed to find optimal driving profiles for a car driving along a known path from point A to point B with a certain gain function. This function can take various forms and in our case it provides weighted optimisation of two contradicting criteria: time consumption and power consumption. The goal is to provide an optimal leading speed and acceleration/deceleration signals to maximise the gain (i.e. minimise the loss in terms of spent time and energy consumption).

The model was learned to be able to work with a different drive type (electric) and the use of the neutral gear was heavily revised. Herein is present the overview of the current status with circuit around Mlada Boleslav , consists of highway, primary roads and local roads.

The theoretical approach to achieve the above stated goal lies in the use of Bayesian Networks in the form of decision graphs. We profit from the decomposability property of this type of graph and Bellman’s principle leading to the possibility of local solutions. The path is traversed backwards obtaining optimal profiles leading to the next point in each step. When the algorithm reaches the start of the track, the forward pass constructs the optimal solution profile.

The testing circuit was measured repeatedly, after verification and regularisation of metrics, correlations of the road surface parameters and dynamic features were assessed from the vehicle demonstrator Skoda FEV.

This verification of energy consumption was done for priority alpha = 0.7, 0.6 and 0.5 with coasting algorithm. The results are shown on figures 19-20 and in Tab. 2-1.

The average speed of AURIX profile is lower than theoretical profile. In this case AURIX profile should have lower energy consumption, see Fig. 6. Average speed of both profiles is very close: AURIX 72.66 [km/h] and theoretical 75.62 [km/h]. The difference between energy consumption is only 0.3651 [kWh] per one track which is approx. 1 [kWh/100km]. The result is that the total consumed energy on this track is almost equal. For continuous recording data CAN and RS232 was used Skoda data logger.

The comparable energy consumption is for AURIX profile and theoretical profile for alpha = 0.7 (Fig. 21). Difference is only 0.0709 [kWh] per track which is approx. 0.2 [kWh/100km] with advantage of AURIX and with difference of average speed 8.6 [km/h].

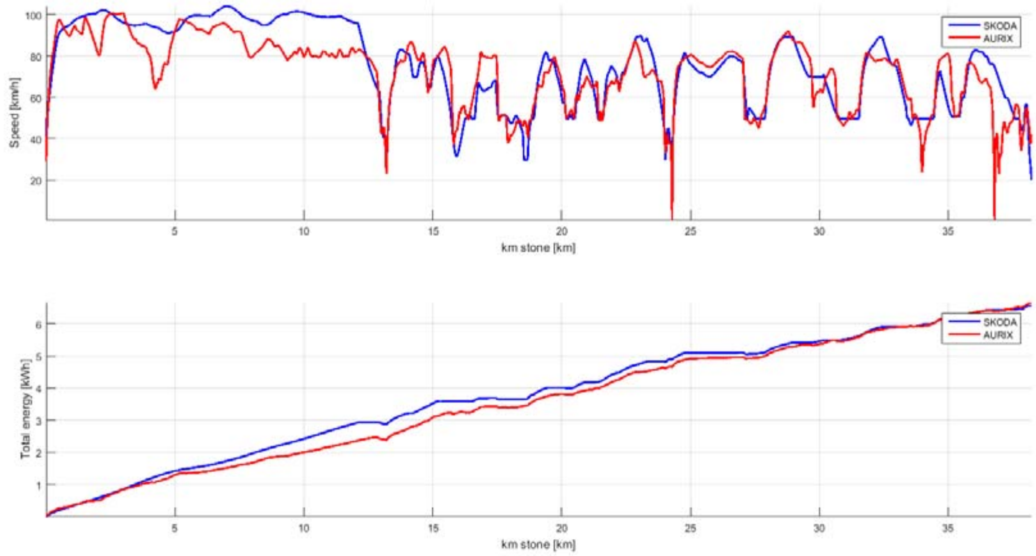


Figure 18: Simulation of energy consumption for AURIX and theoretical profile (alpha = 0.5) speed profile

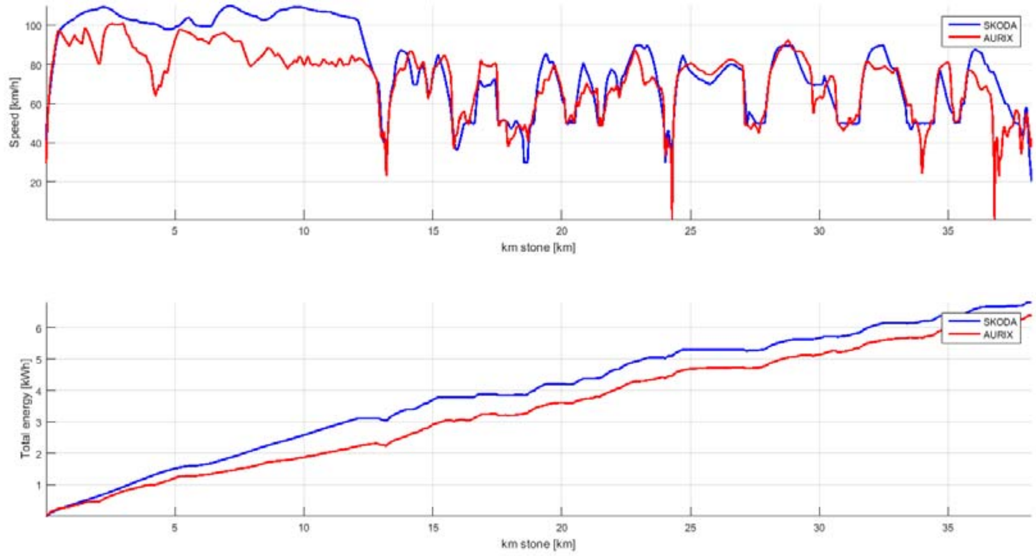


Figure 19: Simulation of energy consumption for AURIX and theoretical profile (alpha = 0.6) speed profile

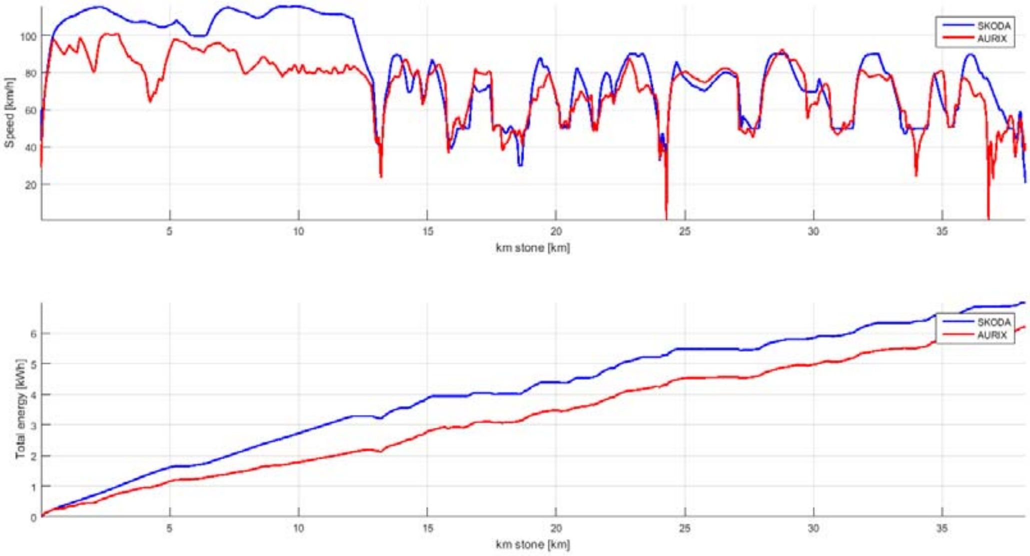


Figure 20: Simulation of energy consumption for AURIX and theoretical profile (alpha = 0.7) speed profile

Simulated energy consumption for different speed profiles					
Speed profile	Average speed [km/h]	Energy [kWh]			Energy consumption [kWh/100km]
		Consumed	Regenerated	Total	
AURIX	72,66	7,5976	0,6731	6,9245	18,12
Theoret. profile 0.5	75,62	6,7529	0,1935	6,5594	17,16
Theoret. profile 0.6	78,74	7,0588	0,2561	6,8026	17,80
Theoret. profile 0.7	81,26	7,2786	0,2833	6,9954	18,30

Table 2-1: Simulation of energy consumption for AURIX speed profile and three theoretical profiles generated for alpha = 0.5, 0.6 and 0.7 with coasting algorithm

Example of testing without the free wheel mode for different alpha coefficients, shown in Fig. 22. Theoretical average speed and power consumption for the three speed profiles are given in Tab. 2-2.

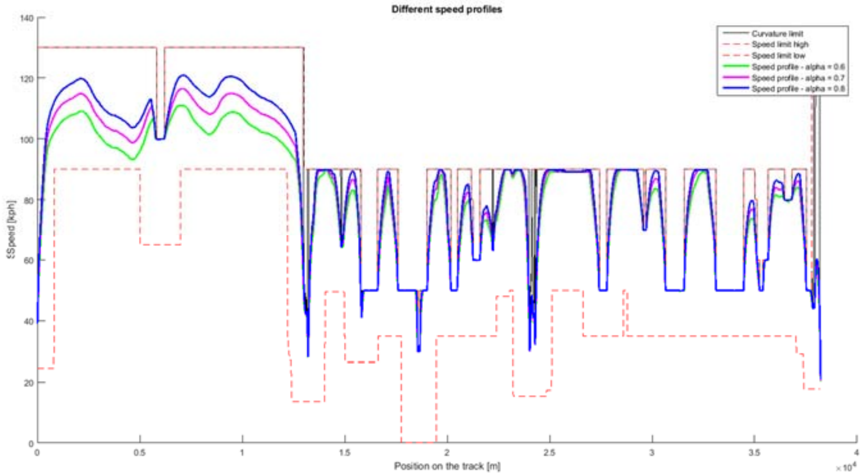


Figure 21: Model outputs for different coefficients alpha = 0.6, 0.7, 0.8

Alpha	Energy per track [kWh]			Average speed [kph]
	Consumed	Regenerated	Total	
0,6	8,3964	0,4434	7,953	80,6228
0,7	8,6789	0,5088	8,1702	83,1274
0,8	8,9555	0,5765	8,3789	85,294

Table 2-2: Theoretical power consumption/regeneration and average speed of designed profiles