Modular CAN-Bus-System for small vehicles

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Abstract

One of the expensive parts in a 2- or 3-wheeler vehicle is the cable tree for the electric equipment including modern information displays. Actors and sensors have to be placed in different locations within the vehicle. Until now, the use of modern communication hardware was not useful in small vehicles due to the high costs. This paper will show that the use of a CAN-Bus-System leads under certain circumstances also in small vehicles to a cost reduction in the production and for maintenance.

Keywords: Communication, control system, environment, EV, ZEV.

1 Concept of a Modular CAN-Bus-System

The implementation of a cable tree into small vehicles can be more complex than into a normal car. Small vehicles have less space but an increasing amount of electric actors and sensors. The employment of fast communication lines (e.g. CAN-Bus) seemed to be not cost-effective up to now due to the expensive hardware. But the use of the CAN-Bus for small vehicles has the same advantages as for a normal car:
Advantages of a CAN-Bus environment are:

- extremely free of electromagnetical interference (because of differential signals) and automatic failure protocols,
- very high flexibility for the control electronics and for further modifications,
- high speed applications (up to 1MBit/s),
- possible cost and weight reductions because of non-complex cable tree and connectors (2 cables for CAN-Bus signals, 2 cables for the power supply),
- higher service comfort and less maintenance costs due to the module structure,

The higher costs of a Modular CAN-Bus-System depend on the necessary development of new hardware components. By the utilization of all advantages of the Modular CAN-Bus-System it will be possible to get a higher quality of the performance of small vehicles and at the same time get a reduction / compensation of the increase of costs.

1.1 General structure of a small vehicle

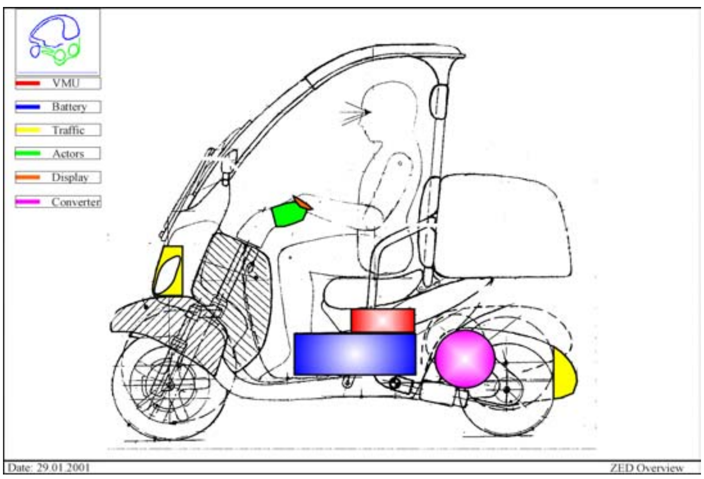

Figure 1: Overview small vehicle modules

For the project „Zero Emission Downtown“-vehicle (ZED) which was sponsored by the European Union a CAN-Bus based modular control system for a small EV was developed. Figure 1 gives an overview of the different modules of the vehicle: The vehicle has a battery (blue), a Battery Management System (BMS) and a Power Management Unit for the control of the drivetrain (PMU); in addition there are Switching Boxes Front and Rear (yellow), the Human-Machine-Interface (HMI) with the User Switches and the Display in the dashboard (green/orange). The superior Vehicle

Management Unit (VMU) coordinates all modules via the CAN-Bus and optimates the vehicle behaviour (integrated in the green module).

It can be seen also, that many components of a normal vehicle can be combined into a function group because of their close locations to each other (e.g. Traffic Lights Front/Rear, HMI).

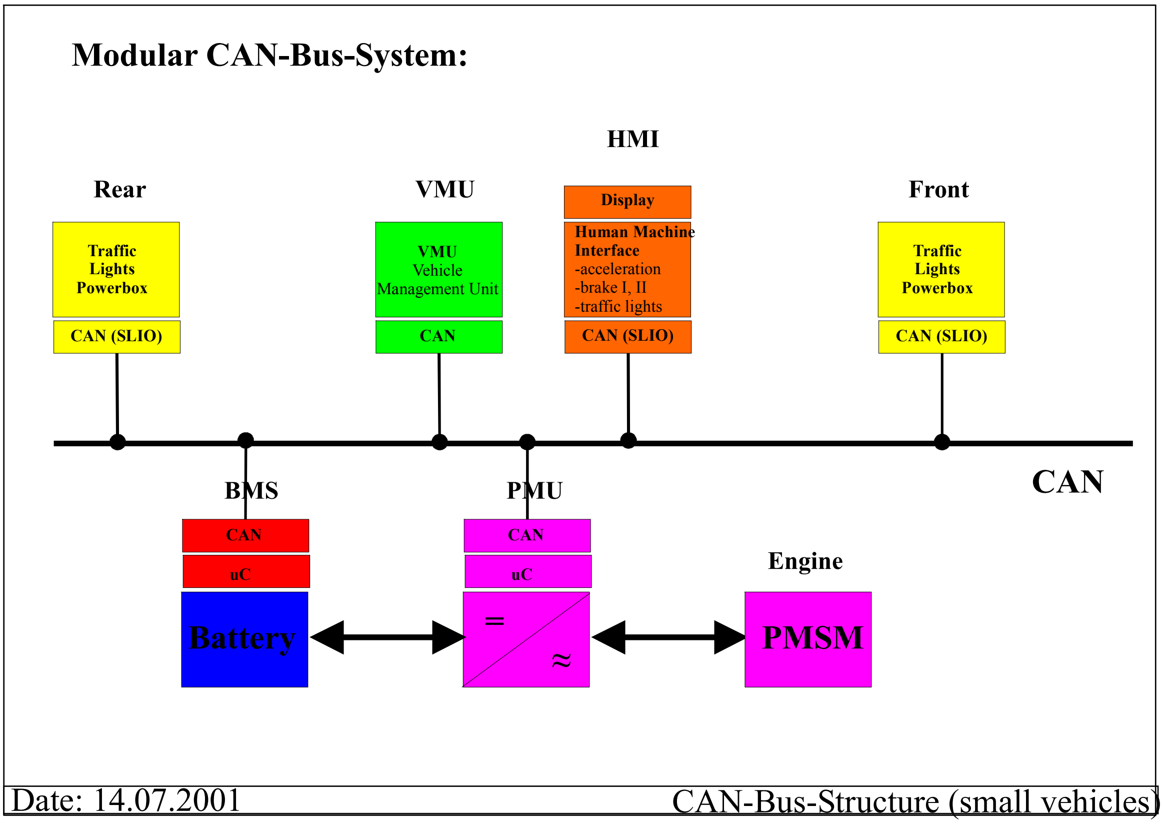

Figure 2: Structure of the Modular CAN-Bus-System

Depending on these function groups a modular design can be developed as shown in Figure 2: most of the components of a normal car are integrated into modules, which can easily be manufactured or changed (in the case of modifications or maintenance) and which can also be parts of the vehicle body. For the Modular CAN-Bus-System these modules get a standardised interface. This interface includes only 2 cables for the CAN-Bus line and 2 cables for the power supply. All additional cables of the cable tree for actors like indicators, high and low beam, brake light, horn, wiper, etc. are not required anymore. The simple structure of this Modular CAN-Bus-System will be explained in the following sections.

1.2 The modules

Two of the six modules shown in Figure 2, the BMS and the PMU, belong to the equipment of a normal vehicle and are necessary for the management of a modern traction battery (BMS) and for the drivetrain control (PMU). In a modern vehicle these modules have already a CAN-Bus interface for the communication between the modules and the VMU. These modules are not included in the Modular CAN-Bus-System but for the sake of completeness they are shown in Figure 2.

To realize the concept of the Modular CAN-Bus-System it is necessary to implement the power switches for the traffic lights and the other actors of a normal vehicle (e.g. wiper motor, -pump, heater, heater radiator, etc.) from their different locations (e.g. relay box) in the vehicle into one of the modules (like Traffic Box Front/Rear, HMI). Figure 3 gives an overview about the internal structure of these 4 new modules.

The HMI includes all for the control of the vehicle necessary switches and a possibility to visualize all vehicle informations (Display). A modern Display with a touch screen control for example needs an separate microcontroller. The User Switches can be connected to the CAN-Bus directly by using the CAN-Basic-Modul explained below. Another possibility for a connection of User Switches to the CAN-Bus-System is by the use of the microcontroller in the Display.

In the version of Figure 3 the User Switches and the Display are separated. This allows a greater flexibility in the arrangement of these components.

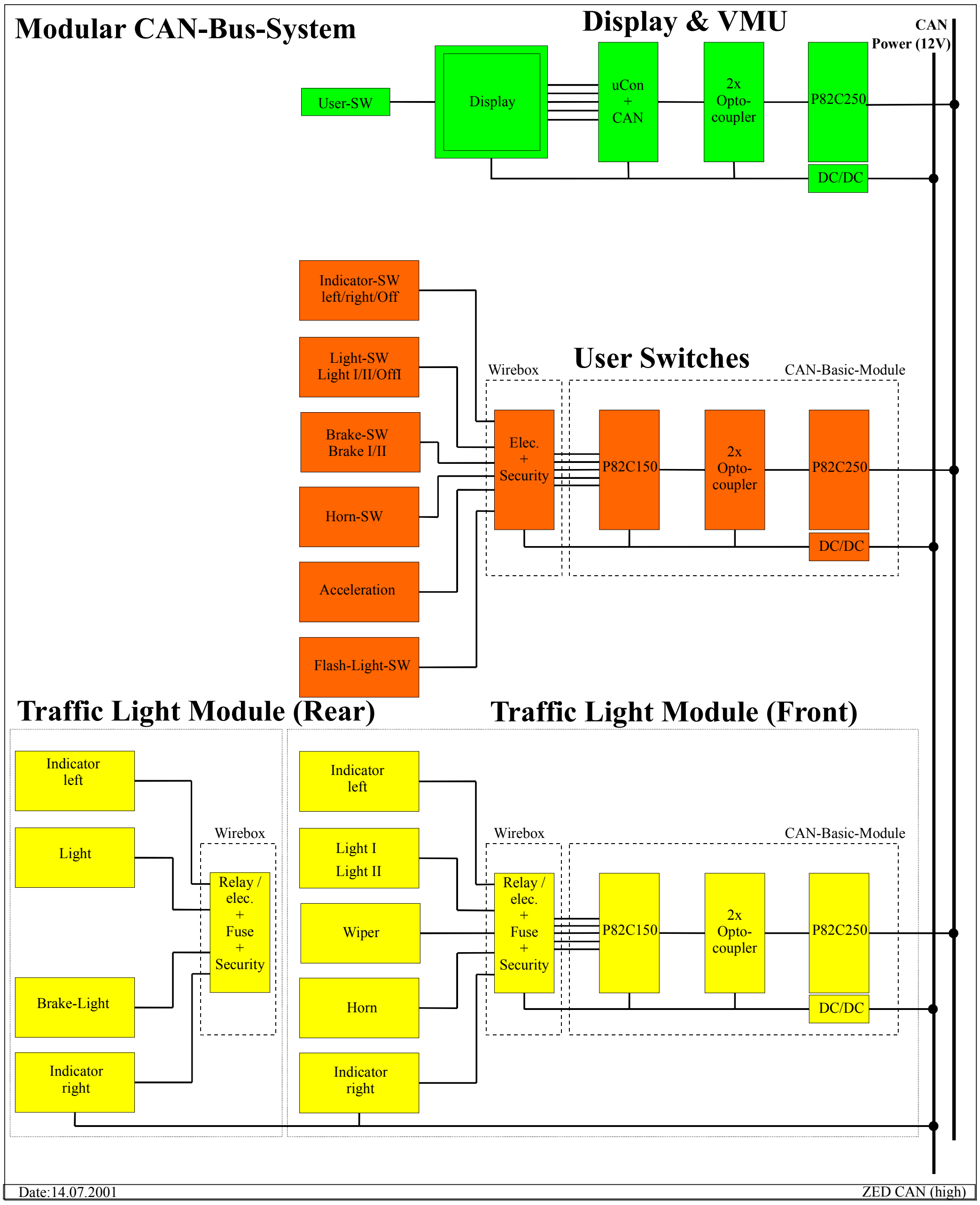

Figure 3: New hardware modules

For the consumer loads of the modules Traffic Lights Front/Rear the power switches have to move from an outside relay box into the Traffic Lights Modules Front resp. Rear itself. This results in a reduction of the control power and includes an increase of the interference resistance and lifetime if modern semiconductors (Mosfet) are used. Figure 3 shows additionally the possibility of reducing the costs by defining a CAN-Basic-Module which can be used in different modules simultaneously (HMI and Traffic Light Modules).

1.3 The module Human-Machine-Interface (HMI)

Additionally to the automatic indication of changed switch signals the possibility of handling switch failures like shortcircuits during startups etc. The separation of the modules HMI und Display allows the arrangement of the user switches close to the driver in vehicles like CITY-EL (City-Com GmbH) or TWIKE (TWIKE SA). In the vehicle of the project ZED the driver will sit like in a motorbike. Due to this reason a combination of the modules HMI and Display was more sensible and more cost effective, too.

1.4 The Switching Box Front/Rear

In the Switching Box Front resp. Rear the consumer loads of the areas in the front and in the rear of the vehicle body are handled: low and high beam, park light, brake light, indicators, horn, wiper, wiperpump, heater, heater radiator, etc. The expected maximum switching power depends on the consumer loads and has been calculated by the simultaneously operation of the highest consumer load (high beam + 2 indicators + 1 small load). The power is restricted up to 144 W (12 A). The Switching Boxes and the HMI have besides the CAN-Bus-Interface only one connector for the power supply line (2 cables). The power supply line should provide the necessary power for all Switching Boxes.

For cost reasons the already mentioned CAN-Basic-Modul received a kind of wirebox which includes the power switches for the consumer loads. Both modules are combined to the Switching Box. This Box has maximal 9 channels for consumer loads (Figure 4).

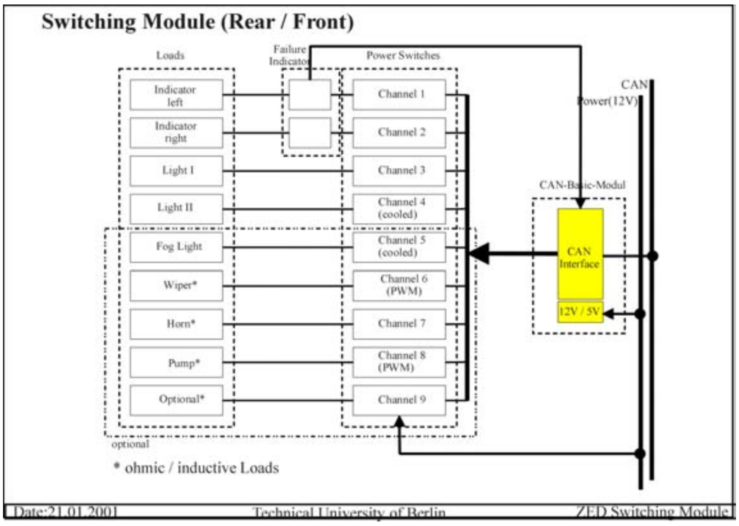

Figure 4: Structure of the Switching Box

All 9 channels can handle ohmic loads up to 19 A (peak current). This value can be increased by changing the Mosfet type. 2 ohmic channels have an error detection of the loads, which are used for verifying the indicator lamps. 4 channels are able to handle ohmic/inductive loads by using free wheeling diodes. 2 of these ohmic/inductive channels can also produce PWM power signals for analog loads (e.g. wiper motor with variable speed).

The CAN-Interface is based on the Serial-Link-Input-Output-IC 82C150 (SLIO) from PHILIPPS. Up to 16 of this small CAN-Bus-IC can be connected to one CAN-Bus line. The IC has Input, Output and PWM features (used for the Switching Box and the HMI) and additionally the possibility to handle up to 6 channels for Analog-to-Digital-Converter operations.

Figure 5 shows one completely equiped Switching Box. The size is half a Eurocard board with 30mm height. The aluminium chassis will additional be used for the cooling of the power switches. By changing the package (e.g. direct integration into the vehicle body) the cooling must be warranted.

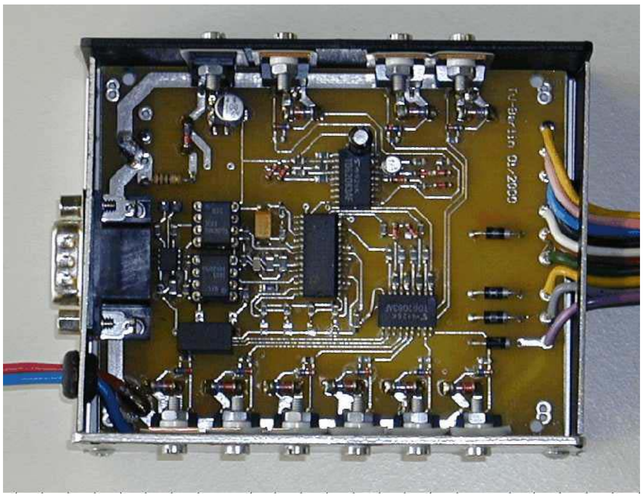

Figure 5: Switching Box

On the left side of the card the interfaces of the CAN-Bus and of the power supply line are mounted. At the right hand there are the lines of the separat consumer loads (one cable for each load + one common GND line). On the lower edge there are 6 and on the upper edge there are 3 power switches.

In the ideal case one Switching Box is integrated with all consumer loads into one Traffic Light Module (Figure 3). These modules are a part of the vehicle body like shown in Figure 6 (left the Traffic Light Module Rear, right the Traffic Light Module Front). They are easy to produce, to modify or to change (modul design).

1.5 Practical experience

For first practical experiences the electric system for a small EV has been built up in a testbench (Figure 6). At the left side the Traffic Light Module Rear (consumer load: low beam, brake light, indicator left/right) and at the right side the Traffic Light Module Front (consumer load: low and high beam, park light, indicator left /right, horn, wiper motor) are visible. In the lower edge the User Switches (separated version) and in the upper edge the Display with VMU are shown.

The main interest of the testbench was directed to the response time of the CAN-Bus-System and the temperature behaviour of the Switching Boxes.

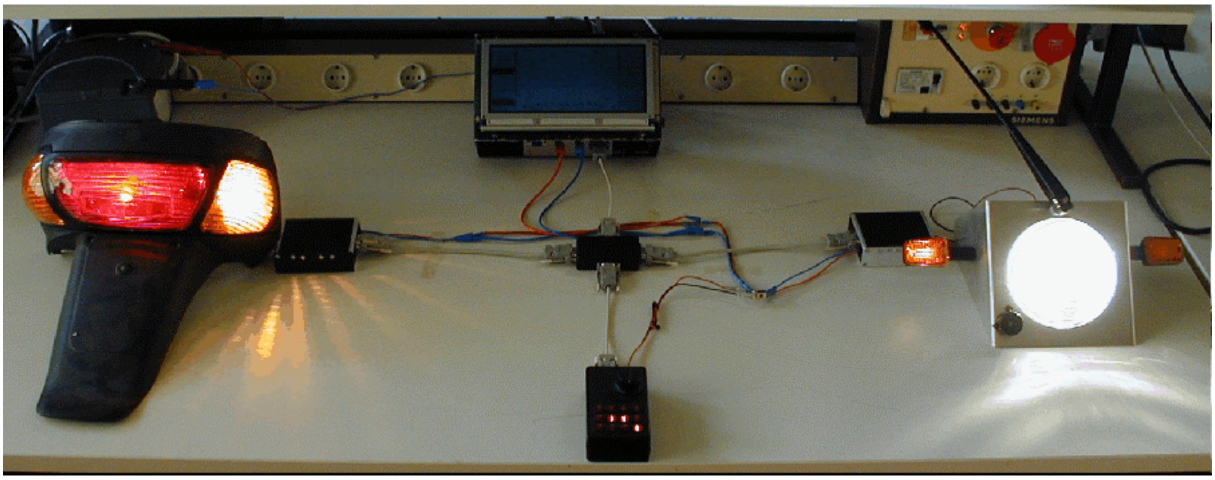

Figure 6: Testbench

After 2h endurance test (maximal operation time of small EV's) of the greatest consumer load (high beam with 6A nominal current) the package temperature was less than 41°C. The maximum temperature load receives the Switching Box by the handling of high frequency PWM channels due to the switching losses. Frequencies up to 6 kHz are not critical since the resulting package temperature is less than 41°C.

Typical CAN messages of SLIO's are composed of three bytes and 64 framebits, altogether 96 bits [1]. Based onto a transfer speed of 125kBits one CAN message between VMU and each CAN-Basic-Modul needs about 768 µs. For switching one consumer load (On or Off) one message has to be sent from the HMI to the VMU and another messages from the VMU to the Switching Box: the overall message time is about 1,5 ms. The signal runtime inside the IC is negligible, as well as the switching time delay of about 900 ns due to the power switches (Figure 7). For Switching-On one consumer load a overall time delay of 1,5 ms must be considered.

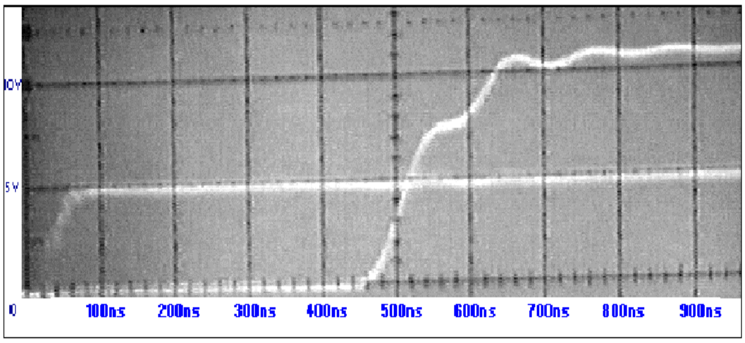

Figure 7: Switching-On of a consumer load

For Switching-Off a consumer load the Switching Box needs about 110 µs (Figure 8). If the time delay mentioned above is taken into account the overall time delay for Switching-Off a consumer load results in about 1,6 ms.

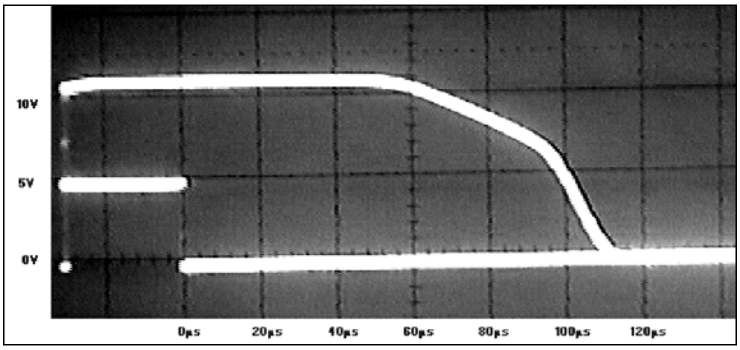

Figure 8: Switching-Off of a consumer load

2 Cost Calculation

A comparision of the number of electric components for a small vehicle with a Modular CAN-Bus-System with a normal electric system shows that the electronic effort for the Modular CAN-Bus-System is bigger. The necessary hardware (card boards, etc.) is more expensive than the additional more complex cable tree. The production efforts (Switching Boxes, HMI ⇔ cable tree) may vary only a little bit.

Table 1 shows the cost evulation of the material of the Modular CAN-Bus-System depending on the number of production units. Comparable informations about productions costs of cable trees and relay boxes have not been available but they may not vary much.

Table1: Cost calculation for the Modular CAN-Bus-System (alle prices in €)

Part	**Name**	**Quantity**	**Price (1x)**	**(10x)**	**(25x)**	**(100x)**
	CAN-Basic-Module	3	79,52	63,63	58,44	54,36
	Wirebox Traffic	2	22,00	18,00	16,40	13,80
	Wirebox Actors	1	7,50	6,00	6,50	5,00
	Cable tree	1	7,20	6,46	5,01	4,90
all			116,22	94,09	86,35	78,06

In effect the advantages of the Modular CAN-Bus-System will not be found in less production costs but in less efforts (= less costs) in case of service and maintenance and in the higher quality and reliability of the vehicle:

- By using a modern communication line the EMC of the vehicle will be increased,
- more flexibility in the equipment and for modifications is reached,
- due to the modular design the service and maintenance costs are very much reduced.

3 Conclusion

The proposed Modular CAN-Bus-System has the potential to transfer the advantages of a CAN-Bus-System to small vehicles. By simultaneous use of the modular design advantages it will possible to equalise or even reduce the costs compared to a conventional system. Especially for service and maintenance the Modular CAN-Bus-System will lead to cost reductions during the lifetime of the vehicle.

4 References

[1] Philips Semiconductors, *P82C150 - Serial Link Input/Output Interface (SLIO)*

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