ELECTRIC VEHICLE CONTROL UNITS COMMUNICATION

David SLIVKA[1], *Petr PALACKY*[1], *Petr VACULIK*[1], *Ales HAVEL*[1]

[1]Department of Electronics, Faculty of Electrical Engineering and Computer Science, VSB-Technical University of Ostrava, 17.listopadu 15, 708 33 Ostrava Poruba, Czech Republic

david.slivka@vsb.cz, petr.palacky@vsb.cz, petr.vaculik@vsb.cz, ales.havel@vsb.cz

Abstract. *Article handles with control units cooperation, which is usable in drive control application especially in electric vehicle. Control unit with Freescale Digital Signal Controller 56F8037 is used as main subject of this research. CAN bus was selected for control units communication. This bus demonstrates the performance of selected controller. At the end of this article measurement was performed to prove usability in electric vehicle. DSC debugging is possible with Freemaster software through JTAG interface.*

Keywords

CAN bus, communication, control unit, digital signal controller, electric vehicle.

1. Introduction

Communication between control units becomes dominant when two or more units are integrated in one system. Needs of this communication has a basis in creating of systems similar to classic combustion engines vehicles systems.

There are many types of bus which serves for only short distances and few participants. On the other hand for example in application of Electric Vehicle (EV) it is important to use communication bus with high transfer speed, physical simplicity and possibility of connection any part of EV on it. These assumptions are satisfied with CAN bus. Digital Signal Controller (DSC) 56F8037 comes with implementation of the CAN module with Version 2.0 A/B protocol. This article examines using possibility of CAN module of this DSC.

At the end of the article experimental measurement was performed where communication process was captured with the bus analyzing software on oscilloscope.

2. Conception of Electric Vehicle

Electric vehicle (EV) is based on two induction motors (IM), where each has own inverter and control unit (CU). Each motor is 6 poles induction motor with rated power of 5,5 kW and maximum power of 16,5 kW. Rated torque is 55 Nm at speed of 950 rpm.

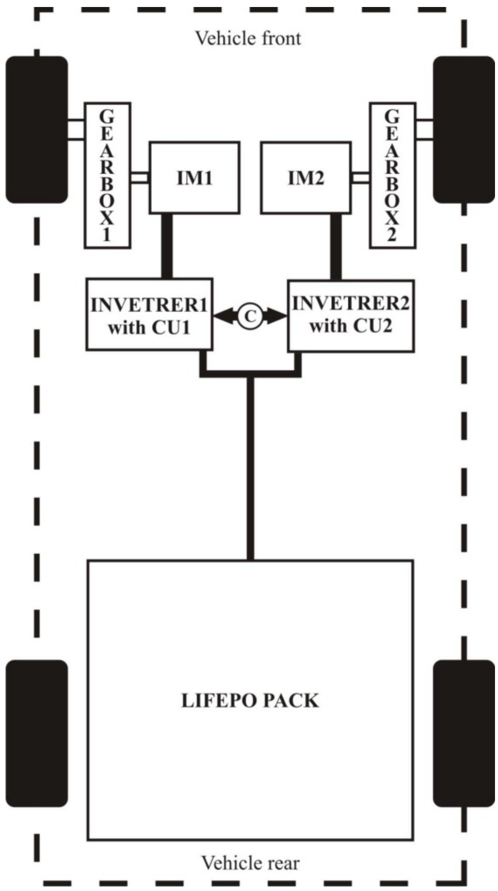

Fig. 1: EV conception.

The battery pack in the first phase of research is created by LiFePo4 batteries which total voltage amount is about 336 V. Arrangement of this EV can be seen on Fig. 1.

3. Control Unit with DSC 56F8037

This research was done on CU developed at our department. This unit is prepared to be integrates directly into vehicle drive so it contains necessary output and inputs for connecting to power inverter [1], [2]. Block scheme of this board can be seen on Fig. 2.

Hybrid core of this DSC combines the Microcontroller unit (MCU) and the Digital Signal Processing unit (DSP). MCU offers many peripherals which can be used in wide range of application. DSP ensures high computing. Both are based on 16 bits architecture. Internal relaxation oscillator makes possible to use frequency of 32 MHz, therefore computing power is 32 Million Instruction per Second (MIPS) in fixed point arithmetic [3].

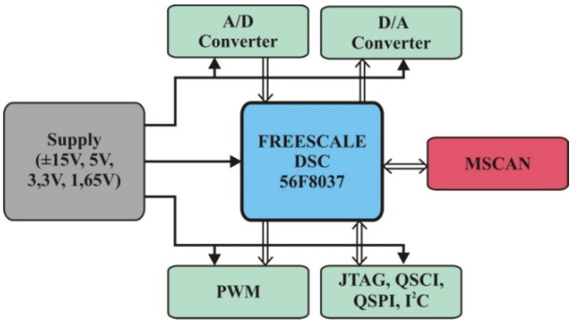

Fig. 2: Block scheme of created board.

Real board of Control Unit (CU) can be seen on following figure.

Fig. 3: Control unit board with 56F8037.

CU parameters:

- 4 x 2 channels of ADC (analogue input ±10 V),
- 6 + 2 PWM,
- 2 channels of DAC (analogue output ±10 V),
- USB (RS232 to USB), SPI, IIC, JTAG,
- CAN module.

DSC 56F8037 has implemented MSCAN which offers following [3]:

- CAN protocol–Version 2.0 A/B,
- programmable bit rate up to 1 Mbps,
- standard and extended data frames,
- 0-to-8 bytes data length.

3.1. Control Algorithms

Vector control of IM is used as control algorithm. Classic conception is used, where the vector of stator current is decomposed into two perpendicular components in oriented coordinates (Fig. 4) [4].

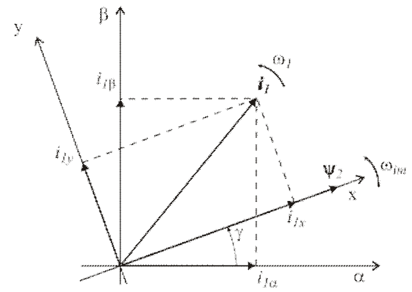

Fig. 4: Vector of stator current decomposition in oriented coordinates.

There are stator system coordinates [α,β] and [x, y] are oriented system coordinates which real component is toward the rotor vector flux linkage ψ_2. Oriented system rotates with radial speed ω_{im}. Components i_{1x} represent magnetization of IM and i_{1y} represent torque of the machine [4], [5], [6].

Very important is communication of CUs, because it is needed to interchange actual values of important variables due to possibility of creating function which is similar for example to mechanical differential. This communication can serve for following data exchange:

- speed of rotor shaft,
- torque current component of IM,
- error states of IM,
- error states of inverter.

Communication algorithm is based on Master-Slave configuration of control units. Where slave periodically sends data to master, then master do necessary computation with these data and sends computed data back to slave. Typically application of this arrangement can be used in:

- control units in Electric Vehicles,
- control units in Smart Grids.

Control algorithm has been developed in CodeWarrior development studio with implemented QuickStart graphical configuration tool. Freemaster software is used for real-time DSC debugging. This software uses JTAG interface for interchanging data between DSC and itself.

Communication is created with CAN bus. CAN description can be found in next chapter.

4. CAN

Standard of CAN protocol comes from Robert BOSCH GmbH. This research works with CAN bus specification 2.0. CAN protocol specifications [7]:

- wide configuration possibilities,
- multimaster & Multicast,
- messages priority,
- guarantee of Latency times,
- detecting and signaling of errors,
- automatic retransmission.

Typical application is in complex systems or in vehicles, where all important parts of the system are connected to this bus.

4.1. CAN Protocol

Communication with CAN bus is realized with using various type of communication frames of programmable length [6]. It is multimaster bus type with arbitration, so when is bus free any unit can start transmitting. It also supports error detection.

One bit is made from 3 parts, each of these is consisted from Time Quantum (TQ) and these are base parts of whole communication [7]:

- synchronization – one TQ in beginning of each bit,
- time segment 1 – 4-16 TQ for compensation of edge phase errors,
- time segment 2 – 2-8 TQ for compensation of edge phase errors.

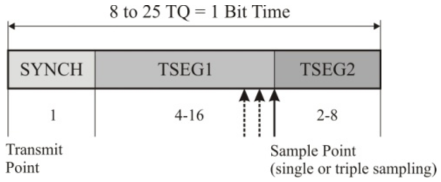

Fig. 5: One bit on CAN bus.

As you can see there is possibility of using single or triple sampling method. Triple sampling offer higher reliability, because value of the bit is read tree times at the end of TSEG1.

Bit rate of CAN bus can be computed with using (1).

$$Bit\ \ Rate = \frac{f_{TQ}}{Number\ of\ TQ}[Bd]. \tag{1}$$

Frame types are shown on the following figures.

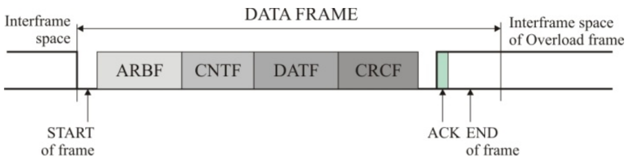

Fig. 6: Data frame.

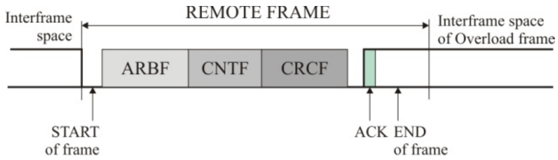

Fig. 7: Remote frame.

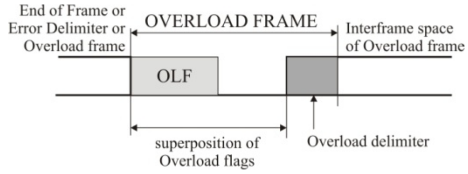

Fig. 8: Overload frame.

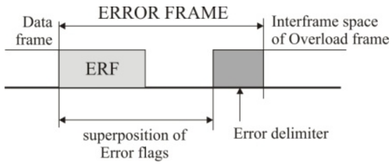

Fig. 9: Error frame.

There are 5 error types:

- bit error,
- stuff error,
- CRC error,
- form error,
- acknowledgement error.

The most important is Data Frame so each part of this one is shown bellow [7].

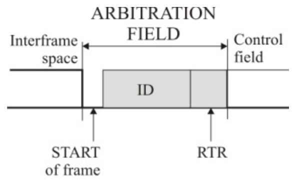

Fig. 10: Arbitration field of data frame.

ID stands for Identification, length can be set to standard (11 bits) of extended (29 bits).

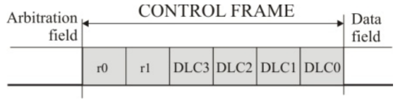

Fig. 11: Control filed of data frame.

The first two bits are reserved bits and DLC3 to DLC0 identify number of data bytes. Maximum count of data bytes is 8 bytes per one data frame. After this Data Field section is following.

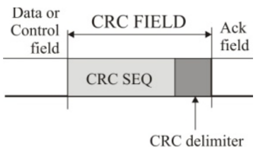

Fig. 12: Control filed of data frame.

5. Laboratory Model Configuration

Laboratory model is consisted from two CUs. Only these two units have been connected to testing bus, so it was necessary to connect termination resistors on them. Following configuration was used.

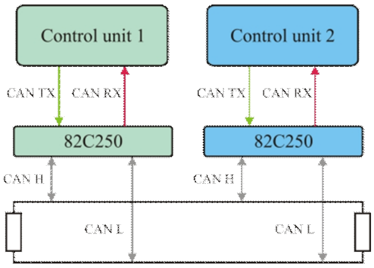

Fig. 13: Laboratory model.

CAN module was set to these parameters:

- TSEG1 = 4, TSEG2 = 3, SJW = 1 (8 TQ per bit),
- single and triple sampling method,
- data length 8 bytes,
- transfer speed is 1 MBaud.

MSCAN module configuration in QuickStart can be seen on Fig. 14.

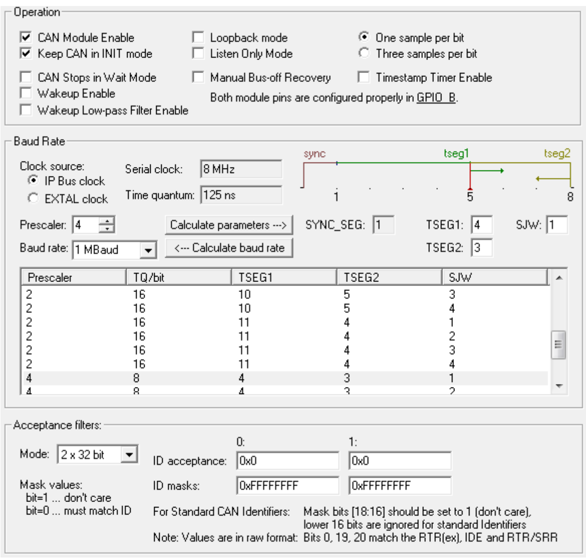

Fig. 14: CAN module properties in QuickStart.

5.1. Experimental Results

This chapter presents results which have been captured on laboratory model with using oscilloscope with bus analyzing software.

Fig. 15 shows data frame sending by slave to the master unit with identifier of 0x33. The first channel shows whole data frame, on the second channel it can be seen start of the frame. The third represent only data part and the last channel stands for end of data frame. How you can see DSC work very well on this speed so transmitted data was sent without any transfer error.

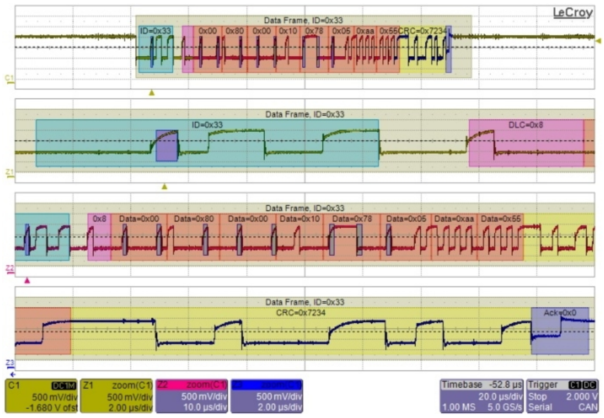

Fig. 15: Data sent by Slave with triple sampling and transfer speed of 1 Mbaud.

Answer of the master is depicted on Fig. 16. Identifier is set to 0x66 and data are sends back to the slave. On the second channel can be seen end of data frame with slave acknowledge.

This answer of the master serves for new regulation values in vector algorithm of a drive.

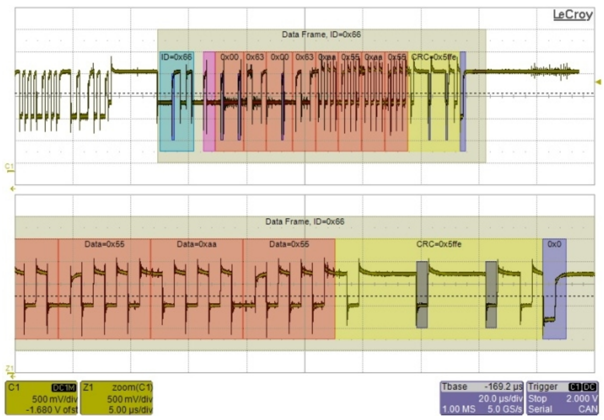

Fig. 16: Data sent by master with triple sampling and transfer speed of 1 MBaud.

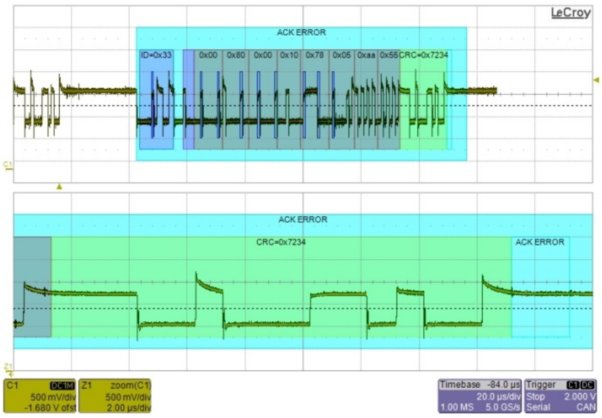

Fig. 17: Acknowledge error on CAN bus caused by not acknowledging by Master (disconnected cable).

Fig. 17 shows data frame sent by slave which hasn't been acknowledged by master (cable was disconnected).

6. Conclusion

CAN module works perfectly on selected DSC. Transfer speed of 1 MBaud was reached without any communication error. For this DSC is not problem to compute vector control algorithm and communicate at speed up to 1 MBaud through CAN bus.

Main purpose of this article is to show that this DSC could be used in cooperation of more units in complex system for example of Electric Vehicle. In addition this DSC offers many peripheries and modules, which can be usable in wide range of systems.

In next research the created Control Unit in Pure Electric Vehicle, will serve for additional control and communication with other parts of the vehicle. So this will lead to simulate mechanical differential in EV.

Acknowledgements

This article was supported by SGS project SP2011/103.

References

[1] MADI, A., M. EHSANI and J. MILLER. *Vehicular Electric Power Systems: Land, Sea, Air and Space Vehicles*. New York, USA: Marcel Dekker. ISBN 0-8247-4751-8.

[2] BRANDSTETTER, P., J. VANEK, J. PUMR and J. MICHALIK. Microcomputer Control System for Industrial Electronics Applications. In: *International Conference on Applied Electronics*. Pilsen, 2009. p. 57-60. ISBN 978-80-7043-781-0.

[3] Freescale [online]. 2007. *56F802x and 56F803x Peripheral Reference Manual*. Texas. Available at: http://www.freescale.com.

[4] BRANDSTETTER, Pavel. *Regulated drives*. Ostrava: VSB-TU of Ostrava. 1999, 181 p. ISBN 80-7078-668-X.

[5] CHMELIK, Karel. *Asynchronous and synchronous electric drives*. Ostrava: VSB-TU Ostrava, 2002. ISBN 80-248-0025-X.

[6] NOVOTNY, D. and T. LIPO. *Vector control and dynamics of AC drives*. New York: Oxford University Press, 1996, 440 p. ISBN 01-985-6439-2.

[7] GmbH, R. B. [online], *CAN specification version 2.0*. Stuttgart. 1991. Available at: http://www.bosch-semiconductors.de.

About Authors

David SLIVKA was born in Frydek in 1985. He received his Master's degree in field of drive control in 2009. He is currently pursuing Ph.D. study at Department of Electronics at VSB-Technical University of Ostrava on Faculty of Electrical Engineering and Computer Science. His research includes drives control and control systems in electric vehicles.

Petr PALACKY was born in Novy Jicin in 1970. He obtained his Ph.D. degree in field of AC drives control and parameters identification. He was appointed as Associate Professor at Faculty of Electrical Engineering and Computer Science of VSB-Technical University of Ostrava in 2005. His research includes modern control algorithms of electric drives with digital signal processors and applied electronics.

Petr VACULIK was born in Zlin in 1983. He received his Master's degree in field of Power Electronics Systems in 2007. He obtained his Ph.D. degree in Power converters and simulation of electric vehicles. Currently he acts at Department of Electronics at VSB-Technical University of Ostrava on Faculty of Electrical Engineering and Computer Science.

Ales HAVEL was born in Celadna in 1984. He obtained his Master's degree in field of power electronics systems and electric machines design in 2009. He is currently pursuing Ph.D. study at Department of Electronics at VSB-Technical University of Ostrava on Faculty of Electrical Engineering and Computer Science. His research includes power systems, design and modeling of electric machines.