A New CAN Bus Communication Based Automotive Power Distribution Module Application : ‘eaPDM’

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Abstract—**Power distribution module is a multi-layer control and diagnostic component which is used especially in automotive applications. It consists an input/output connection junction, a multi layered power distribution module and transceiver communication layer which is used for message sending/receiving. By courtesy of the module, the power stored in vehicle accumulator would be distributed to electrical components via electronic control unit and diagnosis would be performed for each component on power line. In this study, as distinct from similar applications current cut-off ranges of module outputs, communication speed parameters, node definition parameters and output/input types of power distribution module would be controlled via computer interface. It has been aimed to create an innovative and stable design of power distribution module with these features. One prototype of the module has been produced and its calibration and control interface has been developed for desktop usage. Its prototype also has been tested for some reliability cases. In the study, the module structure and some examples on the market have been examined.**

Keywords:

Keywords— electronic control units, can bus, power electronics, power distribution

I. Introduction

During the design of a vehicle, several thousand signals between up to 70 ECUs have to be considered [8]. Especially in recent years, electronic systems usage trend in automotive industry has been dramatically increased. In a sense, it would be said that, the future of automotive sector is depended on innovations reached in electronics. Nowadays, the electronic systems and functions which are used in modern vehicles are increasing continuously. The factors which forces this motion would be listed as; more security necessities, lower fuel consumption, more warning indications for driver, comfort requirements and infotainment expectations. [1]

Today, "automotive electronics" refers to forming a complex network, advanced sensors, control units, power electronics and actuators and includes mechanical motion systems integrated with them.

Data communication in modern automobiles is done by a network. [2] In modern automobiles reliable and robust signal transferring has been a critical point and special data communications such as CAN Bus, Ethernet, LIN Bus etc. have been started to use in automotive industry. Based on the given requirements, the network designer has to setup a compound of automotive bus systems [9].

In summary, thanks to advancing electric-electronic technologies, lighter and more environmentally friendly vehicles are developed, can be obtained higher reliability and superior control value in automotive technology. Automotive technology can be broadly examined in five parts:

- Information Systems (Infotainment)
- Power and Transmission Systems (Power train)
- Body Comfort and Convenience Systems
- Security and Protection Systems
- Electrical and Electronics Power Systems

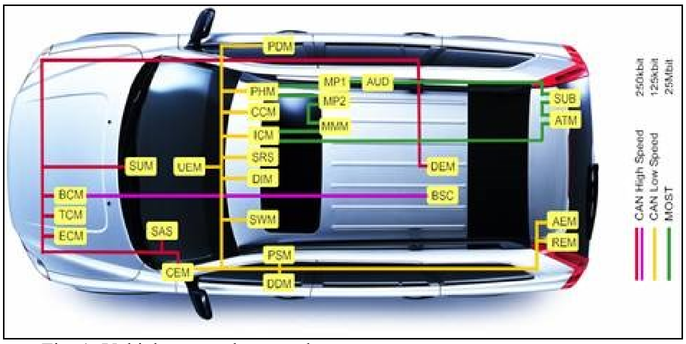

Fig. 1. Vehicle network example

In this study, it has been introduced a new CAN BUS communication based power distribution module production phases which is located under the category ‘Electrical and Electronics Power Systems’. By 2035 predictive models says that electric vehicles will have 35% market share on market and smart power distribution modules will have to have more capabilities day by day. Configurable, flexibly changeable hardware necessity will rise up.

The most important motivation to put forward to idea of creating this electronic control unit was creating a flexible and modular power distribution module which would be easy to use and configure. In the study, a user friendly calibration and control software demo interface for the eaPDM module has been developed and tested on system. Reliability tests on the module have been scheduled for future arrangements.

II. GENERAL INFORMATION

A. Power Distribution Modules

As a result of increased comfort and safety requirements, the electrical energy used in vehicles has been increased. Therefore, the importance of efficiency power distributed to the components in the structure of the vehicle has increased and there is a need for using smart units for these purposes. Figure 2 shows some loads on a vehicle.

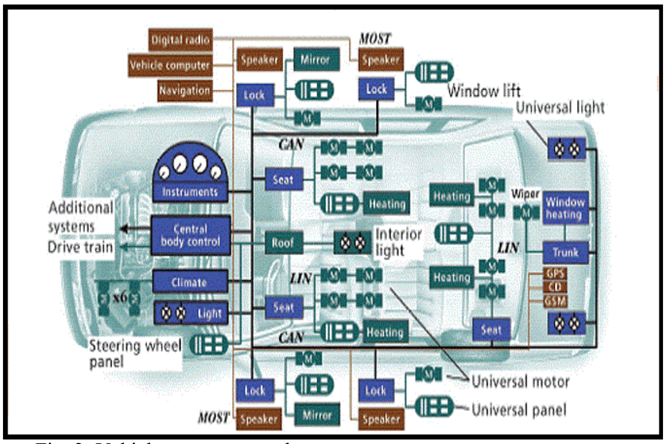

Fig. 2. Vehicle power network

A strong example of a ‘smart’ power distribution module could be body computer modules in automotive industry. Body computer modules have fast response control capability of input and output control. They have application-specific integrated circuits and surface mounted reliable circuit board design and they could fit in small spaces. Beside integrating this functions, a single module can control a big part of safety components and appropriate body functions. As well as having outputs for door / luggage lock function, internal / external lighting group control, motor and relay outputs, they can control tools such as odometer. At the same time, they can also provide inputs and outputs for peripherals / check can be made related to heat / fan / air conditioning (HVAC) systems and burglar alarm functions.

In power distribution module structure a network interface is located on the module to communicate external network. This makes it easy to exchange data in digital form via transreceiver interface. Generally, CAN bus or LIN bus are used to communicate via the communication protocols on these architectures. The received power from a main bus/connection is transferred to the switching elements and peripherals and via control algorithm loaded in the microprocessor activates / de-activates some different functions.

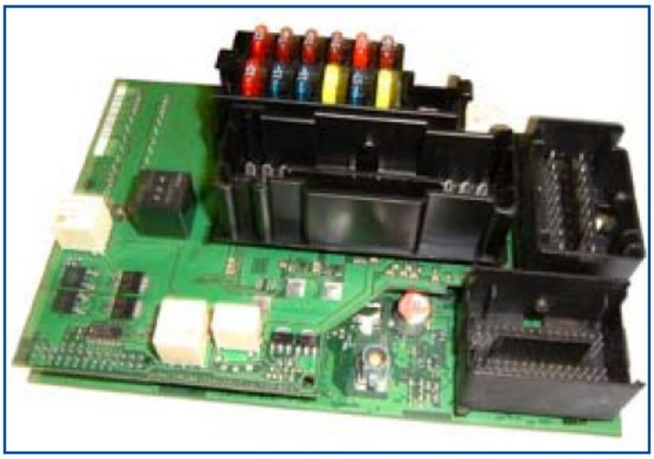
Fig. 3. Body computer module

B. Controller Area Network (CAN)

Control Area Network protocol has been designed in order to create a series of powerful data transmission in automotive applications by the German company Robert Bosch in 1986. [3] In 1993, it has been accepted as an international standard by the ISO. [4]

Message transfer in a control area network is controlled by four types of message frame. These are; data frame, remote frame, error frame, frame overload. Data frame in a CAN message is the frame which carries data from the transmitter to the receiver and handles CRC, including synchronization information consists of changing loads. Standards that are supported by CAN controllers are standard data frame (CAN 2.0A standard with 11 bit identifier) and Extended Data Frame (CAN 2.0B standard with 29 bit identifier). [5]

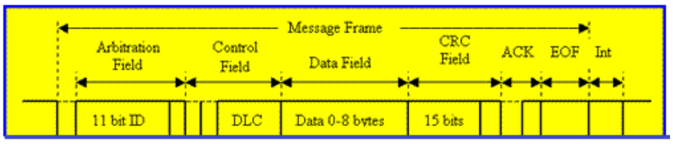

Fig. 4. Controller area network standart data frame

III. COMPONENTS INSIDE MODULE STRUCTURE

Created modular components forming the control board can be classified under subheadings as; power interface and control and communication interface. For fast prototype one actuator control interface and 2 channel current measurement have been adapted to module. All other input/outputs have been delivered to external pins for extension. 1 CAN Bus channel has been soldered out for connection calibrations. Robust prototyping and packaging of extended module have been scheduled for next step. Herein, it has been described that the baselines of architecture created and general perspective of selected components inside the module.

A. *Power Interface*

1) *Actuator Control-Mosfet Interface*

Ground input of the mosfets (Metal Oxide Semiconductor Field Effect Transistor) are totally isolated from the semiconductor body. Therefore, the input impedance of the MOSFETs is very high. High bandwidth and operating frequency mosfets are widely used in the construction of integrated systems and in the manufacture of sensitive electronic circuits.

Mosfets used in project can operate between 0-35 volts and has a maximum driving current of 50 Ampers.

Fig. 5. Actuator control interface

2) *Voltage Regulator*

The LM2596 is used to provide the supply voltage of the control circuit microcontroller and communication interface.LM2596 is a buck (lowering) type voltage regulator. It has monolithic structure and capable of working in an integrated output current capacity of 3 Amps and 150 kHz. Suitable for automotive applications with a stable structure and is an inexpensive component that can be easily found.

Another reason for using LM2596 as a regulator in the project is in an emergency it can be switched off from outside by a microcontroller or another switching component and most importantly, it has 80 µ of stand-by mode current consumption characteristic.

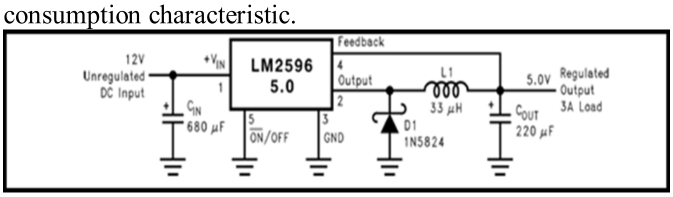

Fig. 6. LM2596 Application on module

3) *Current Measurement*

ACS712 Fully integrated hall effect-based linear current sensor IC has been used for current measurement feedbacks. The device consists of a precise, low-offset, linear hall circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which the hall IC converts into a proportional voltage. The thickness of the copper conductor allows survival of the device at up to 5× overcurrent conditions.

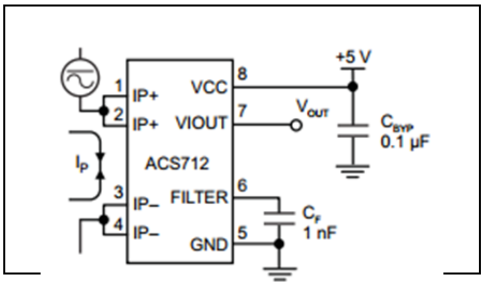

Fig. 7. Typical application

a) *Linearity Calculations*

The degree of the voltage output from the IC varies in direct proportion to the primary current through its full-scale amplitude. Nonlinearity in the output can be attributed to the saturation of the flux concentrator approaching the full-scale current. The following equation is used to derive the linearity:

$$100\left\{1-\left[\frac{\Delta\text{ gain}\times\%\text{ sat}\,(V_{\text{IOUT\_full-scale amperes}}-V_{\text{IOUT(Q)}})}{2\,(V_{\text{IOUT\_half-scale amperes}}-V_{\text{IOUT(Q)}})}\right]\right\}$$

b) *Ratiometry Calculations*

The ratiometric feature means that its 0 A output, VIOUT(Q), (nominally equal to VCC/2) and sensitivity are proportional to its supply voltage, VCC . The following formula is used to derive the ratiometric change in 0 A output voltage, □VIOUT(Q)RAT (%).

$$100\left(\frac{V_{\text{IOUT(Q)VCC}}\,/\,V_{\text{IOUT(Q)5V}}}{V_{\text{CC}}\,/\,5\text{ V}}\right)$$

B. *Control and Communication Interface*

1) *Microcontroller with CAN Bus Interface*

In module, it has been used the PIC18F4580 product of Microchip company, which has CAN Bus communication protocol internally run.

Selected microcontroller has 5 ports (A, B, C, D, E ports) including a total of 36 input-output terminals. From these terminals; MCL (reset terminal), CLK and CLKO (external oscillator), and CANTX/CANRX communication terminals are used as in fixed structure and except these terminals microcontroller have 31 inputs-outputs more for using in peripheral controls.

Microcontroller has the capability to run in 3 different power control modes; Run mode, Idle (idle running) and Sleep (sleep mode). Stored data in the EEPROM can be hold more than 40 years. This feature is preferable in terms of reliability in the automotive industry about a microcontroller. External interrupt requests of the microcontroller could be programmable in priority order and these speciality can be used for event-driven interrupt signal based automotive peripherals control.

Microcontroller guarantees operation under a wide voltage range between 2.0 Volts to 5.5 Volts and by courtesy of this feature, it is minimally affected by sudden voltage drops on the power line.

Runs at high input-output current (25mA), this current characteristic is enough to drive directly from its output any active power components. It has 3 physical external interrupt inputs. It has the ability to compare the difference of signal levels with its sampling feature. Active actuator controllers and other environmental elements are designed to be able to control by PWM output. Closing time may adjustable. This feature is an essential feature in the automotive sector in order to fulfill the critical tasks of the ECUs on CAN bus lines in automotive after switching off the ignition.

Also supports communication protocols such as LIN 1.3, Master Synchronous Serial Port (MSSP), 3-wire SPI, I2C, USART, RS-485 and RS-232. By sending the start bit of the protocol in use, the microcontroller in sleep mode can be automatically awakened.

Processor has 10-bit resolution, up to 11 channel analog - digital converter (A / D) for usage and its analog inputs can make the comparison process also.

When we look at the CAN interface, CAN bus communication has the capability up to 1 Mbps (High Speed CAN Bus) with no property. Supports CAN Bus 2.0B specification (extended CAN protocol). Has 3 priority ordered data sending buffer and 2 receive data buffer internally. Apart from this, microprocessor has programmable 6 can send and 6 receive buffers, 3 buffers with extended CAN identifier that can receive all messages (29bit CAN ID) and 16 message filter masks which can be defined with extended CAN identifier.

When all these features in mind, when we think about maximum acceptable defective components in automotive industry (3-4 pieces in a million) microcontroller of the microchip company seemed as a good option to use in the module.

IV. FAST PROTOTYPING STEP

Fast prototype of power distribution module had been applied on phenolic perforated prototype board. The proposed design has a core module including microcontroller, CAN Bus interface and main regulating and passive components.

Functional tests, CAN Bus communication connectivity tests and some general hardware requirement tests applied on the prototype and basic principles of power distribution have been validated. [7]

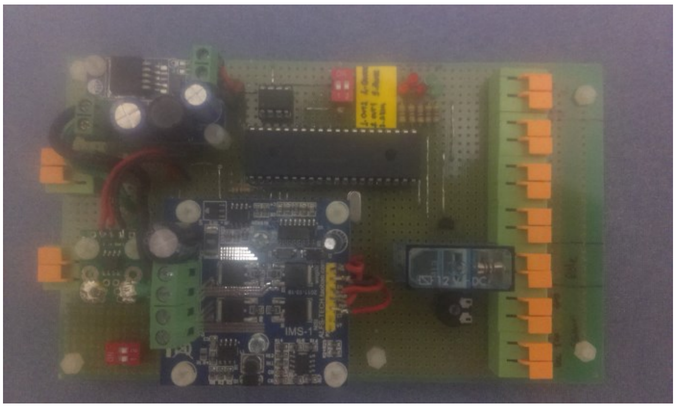

Fig. 8. Prototype of eaPDM

A. *Calibrating and Control Interface*

According to set CANBUS baudrate settings, the message IDs that eaPDM will broadcast, generating general or channel specific diagnosis log files, input and ouput definition and current output limitation settings there has been created a calibration and control interface for desktop usage. (See fig.9)

Inside the 'Can settings' section of the interface program, it is possible to select CANBUS communication baudrate from pre-defined parameters in list (mostly used baudrates in industry such as : 20 Kbps, 50 Kbps, 125 Kbps,250 Kbps, 500 Kbps, 1 Mbps).

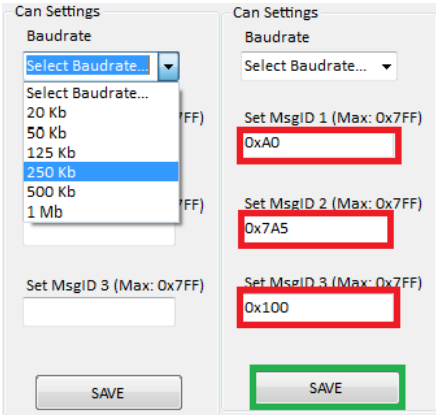

Fig. 9. eaPDM CAN settings section

It is also possible to define spesific Message Identification numbers (MsgIDs) for the messages which are broadcasting by eaPDM power distribution module. In order to save the selected settings there has been created a 'SAVE' button inside the section. After clicking save button, program interface will send the calibration parameters to eaPDM microcontroller via a usb-to-canbus converter which is connected to the computer and microcontroller inside the power distribution module will capture this data and save in its EEPROM. Demo program has been created compliant with standart CAN BUS protocol (CAN 2.0A). In this protocol CAN message packets uses 11 bit identifiers (which shall be maximum 0x7FF in hexadecimal format), so user is restricted to fill the message ID inputs between 0x000 – 0x7FF in hexadecimal. [6] Otherwise, calibration message will not be send to eaPDM unit and there will be indicated a warning message on screen.

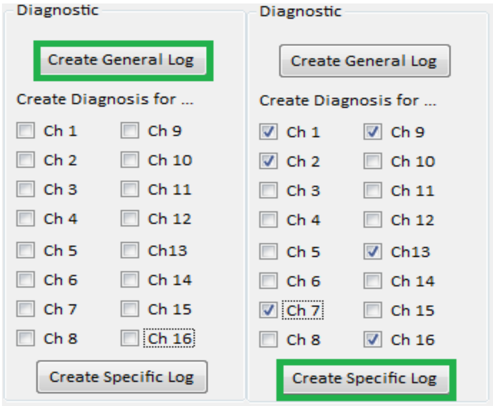

Fig. 10. eaPDM Diagnostic settings/log section

There are 31 usable inputs-outputs in selected microcontroller structure. For prototyping, 16 channels have been soldered out. By courtesy of eaPDM calibration and control interface, it is possible to select these 16 channels as input or output also.

Mostly, ECUs have fixed packages of inputs/ouputs and do not have flexibility. For most special project developments, having a CANBUS communication ECU with changeable message IDs and changeable input/output definition would be very advantageous and time effective. Peripheral control interfaces (transistor based controlling interfaces, filters, direct current drivers) would be added such a power distribution module externally afterwards.

After selecting the input/output type, save button sends the calibration data as can message to eaPDM module and module save the configuration in its EEPROM. After a power down reset new configuration will be valid. An information message will be displayed on screen after successful calibration process.

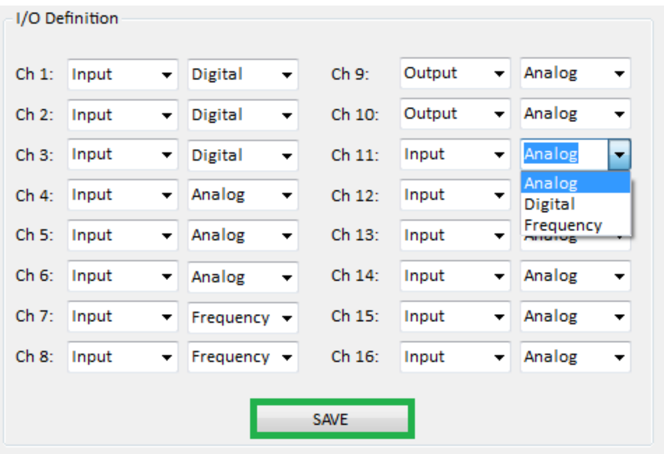

Fig. 11. eaPDM input/output definition interface

Current cut-off limitations settings for 4 outputs have been designed to calibrate(These 4 outputs are different from 16 calibrateable channels). 0...8 amperes would be set as an output current cut off limit. These 4 outputs drives mosfets and these mosfets are serially connected to a current measurement chip for getting feedback from loads.

V. RESULTS AND FUTURE ARRANGEMENTS

The most important motivation to design eaPDM was the necessity of a power distribution module highly modulable and calibratable. In that way, this module can be easily used especially in specific application and research projects. Most of the traditional power distribution modules which are used in automotive and mobility applications have fixed architecture and modification of hardware or software can be difficult considering time and cost parameters. The proposed design provides a flexible architecture so that new peripherals would be integrated to current design as a future arrangement by creating some sub-components mounted on extendable PCBs.

TRL4 (technology readiness level) fast prototype of the power distribution module prototype has been produced by adding some experimental sub-components (current measurement ICs, actuator controller mosfet interface and transistors) and input/output efficiencies have been tested. On this prototype Can Bus network message broadcastings and current cutoff, input/output definition functions validated. Designed module would be used in early phases of a project to validate some cases and to simulate the power net environment basically.

The selected components are suitable for mid-level applications, although they may some restraints for high level applications. As a future contribution, module microprocessor would be changed into a MATLAB Simulink programmable environment and peripheral interfaces would be extendable.

For a fully diagnosticable and logable solid solution prototyping has been started and surface mounted printed circuit boards prototypes will be produced (SMD Pcbs). After a solid prototype production, module packaging could be improved by a robust case to meet IP protection class requirements and to pass some environmental component tests.

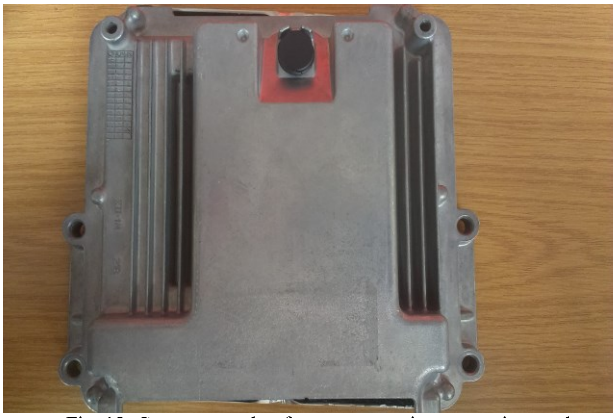
Fig. 12. Cover example of a component in automotive market

For mass production step, module circuit architecture shall be also improved and required tests shall be considered on design phase. To guarantee component reliability; General hardware requirement tests, software static tests, network management tests, diagnosis capability tests, connector and harness compatibility tests, unified diagnostic services tests (UDS), EEPROM programming necessities tests, vehicle configuration requirement tests , end of line functional capability test would be scheduled on component for validation.

Demo calibration and control software would be further improved and more functionalities would be added in the software.

As a future arrangement, application would be developed by high voltage components and proposed modular configuration would be improved to conform high voltage EMC requirements and to protect module from fly-back voltage ripples.

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