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Design of CAN bus for research applications purpose hybrid electric vehicle using ARM microcontroller

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Abstract

Research Centre for Electrical Power and Mechatronics, Indonesian Institute of Sciences has built test vehicle which able to monitored several parameters. The monitored data were communicated with serial protocols (RS232 and RS485) both protocols need master control like computer or microcontroller. There are several disadvantages using centralize control which are dependencies to master control and complicate wiring. To solve this problem need to design bus protocol, which able to multi master protocol. CAN is a multicast-based communication protocol (multi master) characterized by the deterministic resolution of the contention, low cost and simple implementation. This paper will purpose CAN bus multi master design protocol for research applications purpose hybrid electric vehicle using Nuvoton™ arm microcontroller.

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Keywords: CAN bus; hybrid electric vehicle; ARM microcontroller

1. Introduction

Hybrid-electric vehicles (HEVs) combine the benefits of gasoline engines and electric motors and can be configured to obtain different objectives, such as improved fuel economy, increased power, or additional auxiliary power for electronic devices and power tools [1]. Research Centre for Electrical Power and Mechatronics, Indonesian Institute of Sciences has built test vehicle (the vehicle which contain several sensors and data storage),

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that vehicle able to monitored several parameters like voltage, current, velocity, temperature and SOC [2]. The monitored data were communicated with serial RS232 protocols and RS485 protocols. Disadvantage of RS232 protocol is point-to-point communication, while RS485 able to multi point communication but both protocols need master control like computer or microcontroller [3]. The disadvantages of master control are need more cable, because every electronic part must connected to master control and if master control have some problem then whole system might mall function, in vehicle system mall function could be worst (fatal accident). To solve this problem needs to design bus protocol that able to multi master protocol.

Kehai on [4] has described controller area network (also referred to as CANBUS or CAN bus) is a vehicle bus standard designed to allow microcontrollers and devices to communicate with each other within a vehicle without a host computer. CAN is a message-based protocol, designed specifically for automotive applications but now also used in other areas such as industrial automation and medical equipment. Development of the CAN-bus started originally in 1983 at Robert Bosch GmbH. The protocol was officially released in 1986 at the Society of Automotive Engineers (SAE) congress in Detroit, Michigan [5]. The first CAN controller chips, produced by Intel and Philips, came on the market in 1987. Bosch published the CAN 2.0 specification in 1991. What is CAN and what features [6]:

- Serial communication with multi-master protocol,
- Compact & cost effective (twisted pair bus line only),
- Up to 1 Megabit per second,
- Robust in noisy environments,
- Priority signal setting.

The design in this paper includes software and hardware CAN bus for research applications purpose hybrid electric vehicle. Figure 1 show topology serial RS232 protocols and RS485 protocols at test vehicle, where each component has controller which can communication with master control (RS232 or RS485), for velocity using RS485 while current, temperature speed control, RPM, SOC and voltage using RS232 [2]. Table 1 show standard usage CAN bus at electric vehicle (auxiliary, accessories and main load) [7].

For research purpose, several electronic controls were eliminated, such heating elements, air conditioning system, car audio system (CD/tape/radio player and speakers), rear defogger and combination meters, electric windows, windscreen wipers, central locking door, radio aerial winder, side mirrors, ABS and car alarm. The generic design CAN bus control for hybrid electric vehicle shown at Figure 2. The purpose topology with CAN bus system shows at Figure 3.

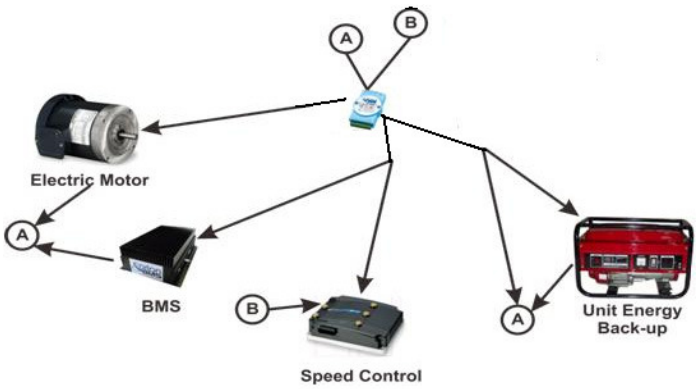

Fig. 1. Topology serial RS232 protocols and RS485 protocols at test vehicle.

Table 1. Standard usage CAN bus at electric vehicle (auxiliary, accessories and main load).

No	Component	Remarks
1	Headlights	Resistive two filaments inside each headlight for high beam and low beam. Controlled by front board panel control
2	External Lights	Resistive Include red taillights (park and brake), fog lights , reverse lights and hazard (indicator) lights, turn light (rear and front)
3	Internal Lights	Resistive Include door lights, reading lights and boot light.
4	Power Steering	Inductive Include a motor for hydraulic pressure, control pressure based on vehicle velocity/movement
5	Other Electronics	Resistive Heating elements Fan Heater.
		Inductive Include air conditioning system (not working) and fans.
		Resistive Include car audio system (CD/Tape/Radio player and speakers), rear defogger and combination meters.
		Inductive Include electric windows, windscreen wipers, central Locking, radio aerial winder, side mirrors and horn.
6	BMS	Battery management system, include give information about SOC
7	Motor Control	Controlling electric motor speed, also give information about current, voltage and temperature displayed at dashboard (optional).
8	ABS	Electronic Antilock Braking System
9	Car Alarm	Triggered from input from alarm sensor and output to speaker or horn. Give input to master control to block whole control till acknowledge from owner (advance)
10	Suspension	Electronic control suspension
11	Transmission	Electric transmission give input to main control for displayed at dashboard (optional)

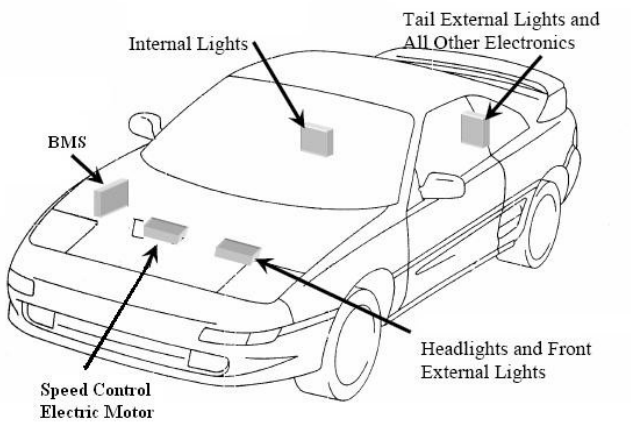

Fig. 2. The generic design CAN bus control for electric vehicle.

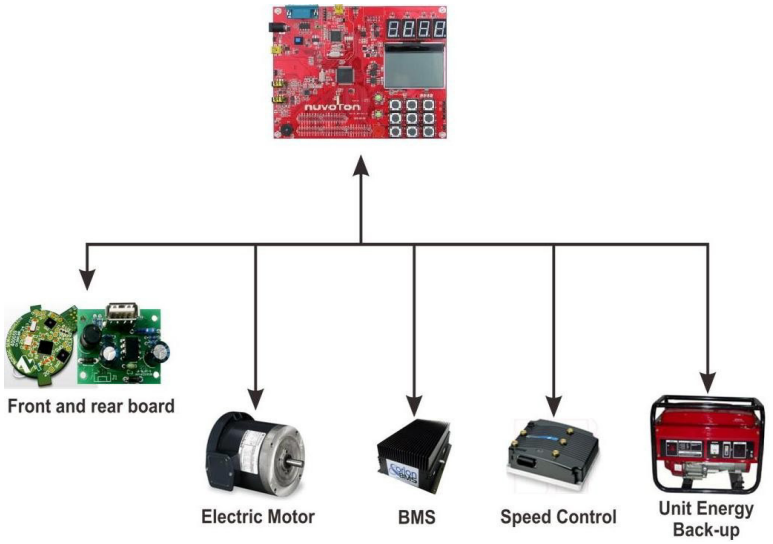

Fig. 3. Purpose topology with CAN.

2. Methodology

Hybrid electric vehicle contain several component, mostly that component came from different vendor and has different type for communication data. Design methodology in this paper divided by three parts which is:

- Make component which already has CAN bus enable feature to synchronize with CAN bus design
- Make converter CAN bus for component that has communication data feature but has not CAN bus enable yet.
- Built from scratch for component that has not communications data feature yet.

2.1. Synchronize CAN bus

The BMS features are: two CAN bus 2.0B interfaces, allowing custom messages to be transmitted at regular intervals. This provides powerful integration capabilities with other CAN bus enabled devices. Virtually everything about the messages can be customized: Identifier (standard or extended), Frequency (speed of broadcast), Message length, Message contents (byte values), Message order (Endianness), Byte order (LSB, MSB), Broadcast on CAN1 or CAN2, Multiple baud-rates supported (125 Kbps, 250 Kbps, 500 Kbps, 1 Mbps), CAN1 and CAN2 are isolated from each other and may use different baud rates, Mathematical operations can be performed on CANBUS message contents, can be configured to communicate with devices other CAN, Standards configurable using the BMS utility[8].

BMS with feature that mention above, there several customized should be done which is: Using standard identifier, Using 500 Kbps baud-rates, only using CAN1 and hardware connected through BMS port as shown in Figure 4.

2.2. Converter CAN bus

Hybrid electric vehicle using speed control which already has communication data feature like revolution per minute (RPM) of electric motor, power electronic speed control component temperature, state of charge (SOC) batteries, batteries voltage, and current load but hasn't CAN bus enable yet. From Figure 5, the communication data is still in RS232 format so converter RS232 to CAN bus is required.

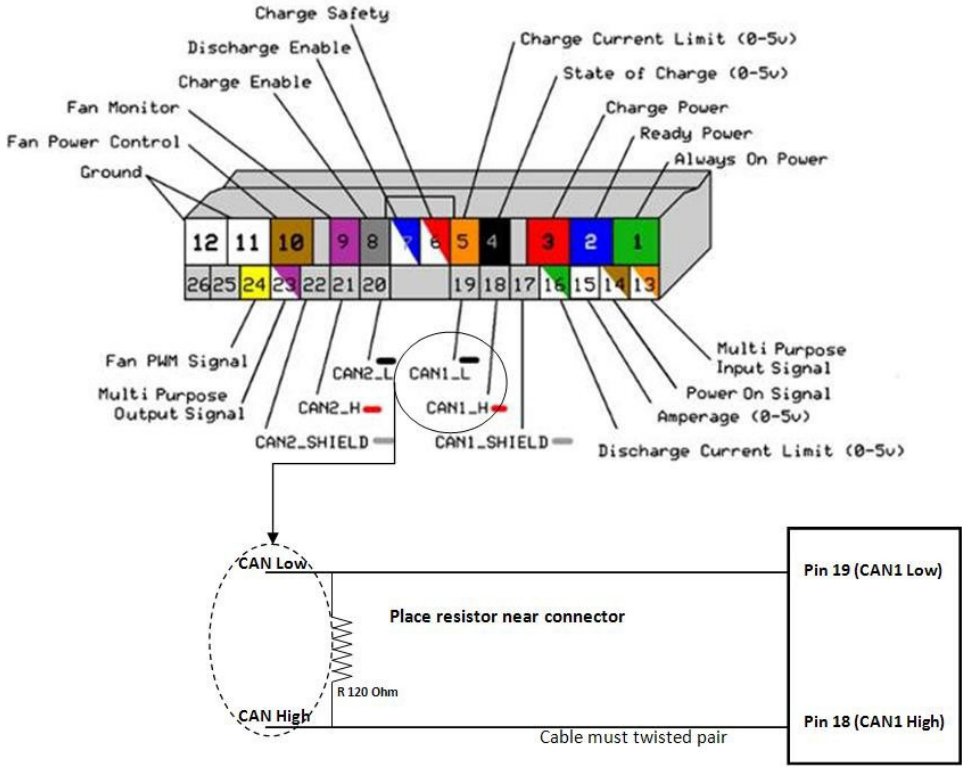

Fig. 4. BMS port connected to system.

The converter comprises of a microcontroller and signal line driver such as RS232 driver/receiver and CAN bus transceiver which functions are control the data flow and modify the signal voltage respectively. In order to conduct data transmission microcontroller should be able to be configured to accommodate two communication bus, CAN and UART bus. Choosing microcontroller with CAN bus feature is not difficult because many kind microcontroller has this feature lately and almost every microcontroller has UART bus feature, but for research purpose learning board with many auxiliary feature could become consideration. NU-LB-NUC140 evaluation board from Nuvoton™ is used in this paper, The NUC140 series are ARM® Cortex™-M0 core embedded microcontroller with 32 bit performance and the board is CAN bus system enables device communication in harsh environments, found in automotive applications. As a multi-master system, each device (node) can obtain bus access through its unique priority code (address) and broadcasts messages to all bus participants simultaneously. Also the chips had offered the robustness of the CAN architecture which is licensed from Bosch [9].

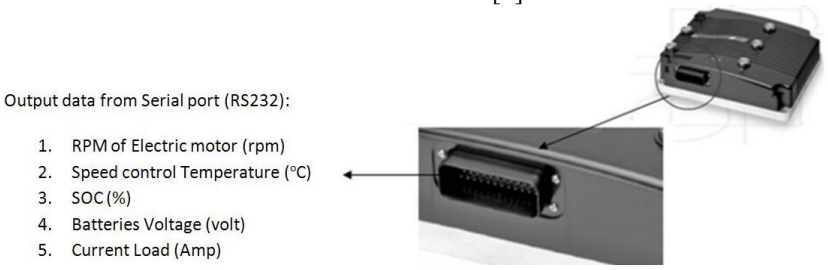

Fig. 5. Serial port speed control.

2.3. Built from scratch

Auxiliary load and accessories component hybrid electric vehicle has not communication data feature yet, mostly auxiliary load and accessories using hardwire direct connect control, so each auxiliary load and accessories need wire (more load more cable). Built from scratch for component which has not communication data feature is required. First step is choosing microcontroller (hardware design), the microcontroller must have CAN bus communication feature. Second step is identified Auxiliary load and accessories component which have to built became CAN bus enable. Third step is design software.

The auxiliary load and accessories are identified at Table 2 (point 1 to 3), switch and display is place at dashboard. Headlights board will place near dashboard and using general-purpose input out (GPIO) feature to receive input from switch at dashboard while tail external lights board and internal lights board will place near the load, both of them only using CAN bus feature to receive command from bus. Topology design for auxiliary load and accessories component with CAN bus using NU-LB-NUC140 evaluation board from Nuvoton™ shown at Figure 6.

Table 2. The generic component list using CAN bus control for hybrid electric vehicle.

No	Component	Remarks	
1	Headlights	CAN bus board for triggering relay for Head light, Also for front external lights (turn light without flasher, fog light and hazard light)	Switch/ display at dashboard
2	Tail External Lights	CAN bus board for controlling red taillights (park and brake), reverse lights and rear hazard (indicator) lights, rear turn light	
3	Internal Lights	CAN bus board for controlling door lights, reading lights and boot light.	
4	BMS	Battery management system, already include information about SOC in CAN format	
5	Motor Control	Controlling electric motor speed, also give information about load current, batteries voltage and power electronics temperature	

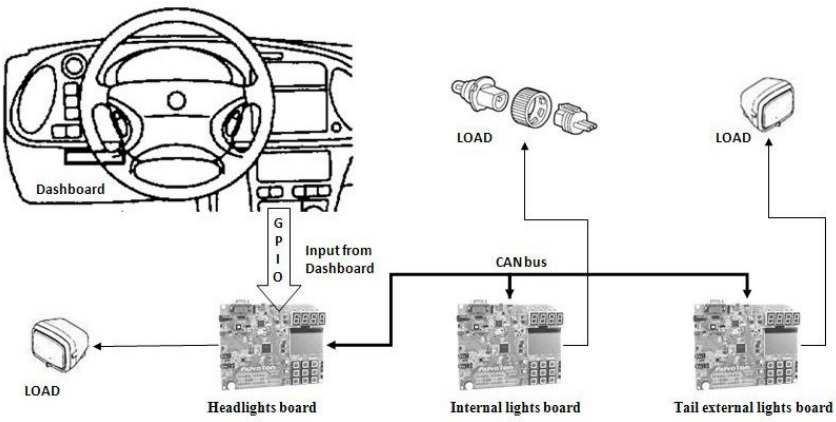

Fig. 6. Topology auxiliary load and accessories with CAN bus.

3. Result and discussion

Synchronize CAN bus is done by align the message Identifier from BMS, the message ID can be found from CAN adapter and connected to computer first. The GUI CAN adapter shown at Figure 7. Data flow from speed control through UART bus to microcontroller to be processed to fit CAN message format that comprises the data itself, Identifier and message ID, the two least mentioned are predefined and are constant in this paper.

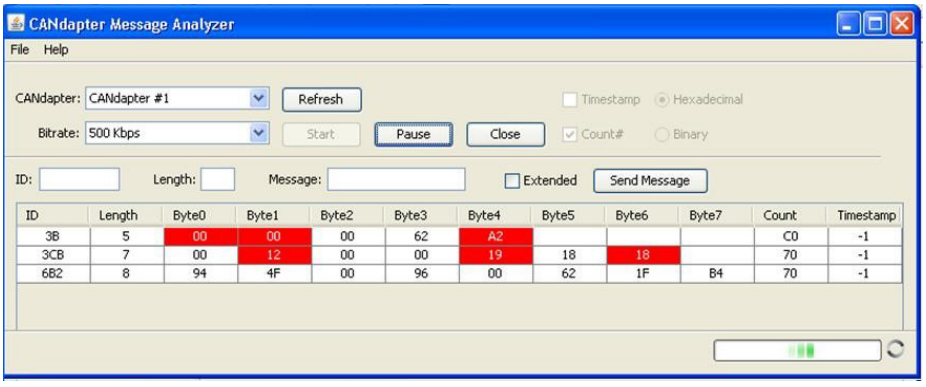

Fig. 7. GUI CAN adapter.

The data received form speed control has unique character "**:**" as delimiter to next data to distinguish various values such as BDI, Amps (ampere), Rpm and Volts that are the main parameter for hybrid electric vehicle. CAN message that already consist of one of the parameter value then broadcasted in vehicle's CAN network. The process repeated for another vehicle parameter mentioned above. The code below show microcontroller receives and transmit values form non-CAN device to CAN network.

```
unsigned int tx_flags;
char data[8];
unsigned long msg_id = 11001;
...
CAN1SetOperationMode(_CAN_MODE_NORMAL,0xFF);
...
while (1)
{
 if (UART1_Data_Ready() == 1) // if data is received
        {
         UART1_Read_Text(output, ":", 3);   // reads text until ':' is found
         CAN1Write(msg_id, output, 1, tx_flags);
        }
  }
```

Determined data frame is first thing to do for design software or programming CAN bus at microcontroller from scratch, after that programming receive and transmit data. Each command has different messages (msg1.Data) and each board have different identifier (msg1.Id). Headlight read switch from dashboard (Scan key) then broadcast it to bus. Programming flow chart for transmit data shown at Figure 8 while programming flow chart for receiving data shown at Figure 9.

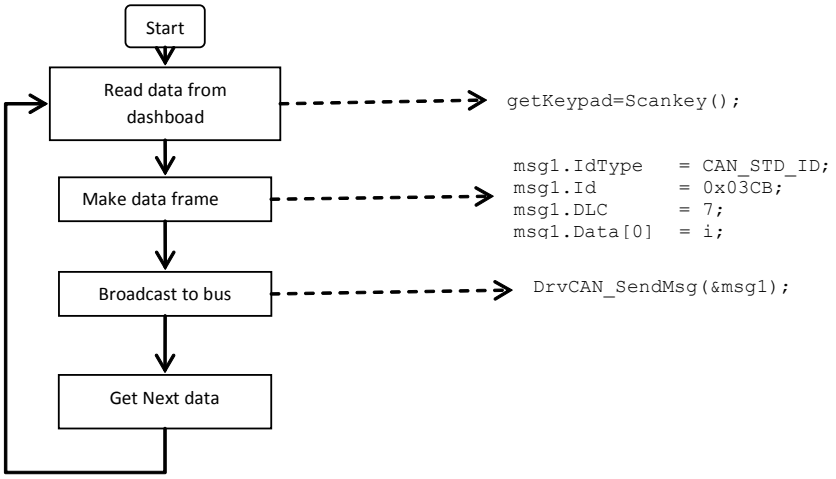

Fig. 8. Programming flow chart for transmit data.

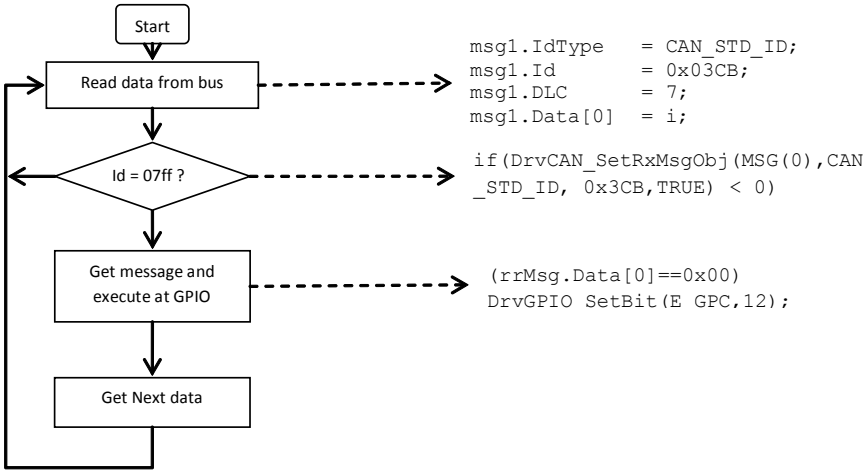

Fig. 9. Programming flow chart for receiving data.

4. Conclusion

The design of CAN bus for research applications purpose on hybrid electric vehicle using arm microcontroller has been developed. As the results of this research:

- CAN bus automatically decrease the number of line on system that connecting between sensor, module and another hardware.
- CAN bus protocol can build from serial UART and made some data synchronizing and convert the data level to CAN + and CAN – mode.
- CAN bus can applied for research applications purpose hybrid electric vehicle.

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