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Framework of CANopen Protocol for a Hybrid Electric Vehicle

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Abstract—**This paper discusses the profile framework of CANopen protocol for a Hybrid electric Vehicle (HEV). Based on the analysis of the CANopen protocol and the HEV system structure, a preliminary version of CANopen profiles for the HEV is firstly drafted out. Then the Object Dictionary for each HEV module and communication mechanism of the vehicle network is described in detail. Finally the CANopen profile's fault diagnostic modes of HEV based on OBD-II and SAE J1939 are set up. Finally the attempt to implement the profile in slave node of electromotor in HEV based on the DSP of TMS320F2812.**

I. INTRODUCTION

HYbrid Electric Vehicle(HEV) has two kinds of driving source. It usually consists of a gas engine as used in modern cars, named auxiliary power unit (APU), an electric driving unit and an energy storage device. Compared to the conventional internal-combustion engine, as the efficiency energy storing devices can provide appropriate energy for the driving unit in short time, the HIV's gas engine can be smaller in size. This is favorable to improve the combustion rate and reduce the exhaust emission [1]. Of course the HEV has many good merits contrasted to the pure electric automobile, as shown in the following.

1. The HEV can fully exert the advantages of the internal-combustion engine and the pure electric automobile.
2. The suitable APU can lead to the increase of the car mileage and the improvement of the power performance, and sometimes up to the level of internal-combustion engine.
3. In HEV, the internal-combustion engine always runs near the optimum working point, so it reduces the emission, especially in low or idling speed, for only provide the energy to the store device and need not the adjustment of working point. The movement energy in braking status can be recollected to recharge the battery.

In some area with strict emission limit, such as shopping centre, tourist attraction and residential area, HEV can shut down its APU and runs in pure electric mode, so there is no any emission. As for industrialization, HEVs need not to change the industry structure, the system of energy and the driving habit of people [2].

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II. WHOLE STRUCTURE OF SYSTEM

2.1 Drive system of HEV

There are three varieties of arrangement according to the mode of drive, namely series, parallel and mixed drive system. The parallel drive in which the internal-combustion engine and electromotor all can drive alone the wheel, make full use of the energy and has good economical usage for fuel, but this mode must use automatic transmission and power combination unit and the internal-combustion engine's working point is always adjust to make the automobile run on different road surface. Mixed drive in which the internal-combustion engine and electromotor all can work alone or at the same time drive the wheel, has a CPU to control the internal-combustion engine and electromotor working state in order to run on the different road surface by the dispatch strategy. Obviously this model needs complex technique and effective control arithmetic.

For the series model, the drive system in automobile is the electromotor as the only drive source, and the auxiliary power unit (APU) consisted of two parts, the internal-combustion engine and alternator for producing alternating current. The following sketch diagram shows this kind of drive model [2], as shown in Figure 1.

From the sketch map, we can see the internal-combustion engine drives the alternator, and the alternator produces the alternating current for the electromotor, so that the electromotor can drive the wheel alone. Here the redundant energy that converts mechanical energy into electrical energy can be stored into storage battery. In this drive model the gas engine only acts as a device for generating the electrical energy for electromotor, so the working point of gas engine need not always be adjusted to the road surface state and reduce greatly the automobile emission for the full burning fuel. The storage battery is a very important device, which acts as the energy buffer in the system. A rechargeable and dischargeable storage battery can remove the difference, namely the redundant output energy can be absorbed by battery, and the supplement energy for electromotor can be afforded by battery. No more difference between this kind of HEV and conventional automobile in drive for people.

Series model has two obvious advantages. The first, the

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small type gas engine can always run at reasonable working point or full load state, so the full combustion of fuel leads to the least polluted emission. The second, the APU operates effectively and continuously, and the combination of small power gas engine, alternator, and storage battery could increase obviously the passage range.

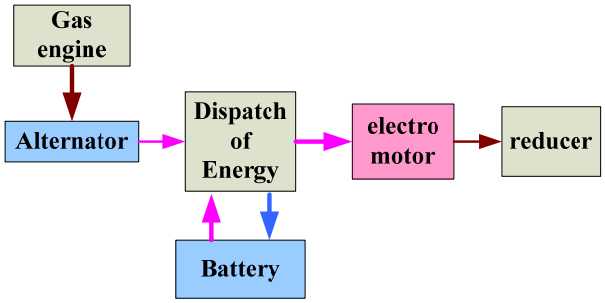

Figure 1. Structure of the drive system in series mode

2.2 *HIV's System Structure*

In our research, the HIV's drive system is based on the series model, and the whole system structure consists of a number of modules, as shown in Figure 2. In this system, the alternator produces the current to afford to the electromotor (the three-phase alternating current asynchronous motors) for driving the wheels, and converts mechanical energy into electrical energy, and redundant electrical energy could recharge the battery or super capacitor. No clutch or transmission is required in this drive system.

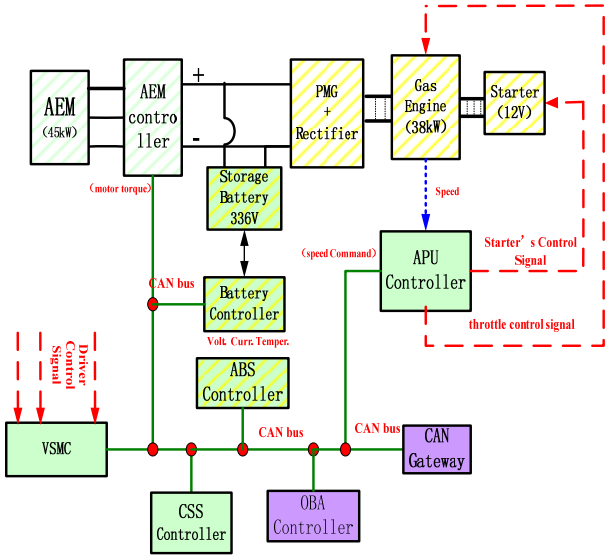

Figure 2. The frame of the HEV system.

Aem: Asynchronism electromotor. Aemc: Aem Controller. VMSC: The Vehicle Management System Controller. PMG: Permanent magnetic generator. CSS: Central Surveillance System. OBA: On-board Air- condition. ABS: anti-lock brake system. APU: auxiliary power unit.

III. CANOPEN PROTOCOL FRAMEWORK

In HEV system, it is obvious for every part's importance, such as electromotor, gas engine, central surveillance system, battery and so on, all those should cooperate with each other. These modules always change their working model, so a real time local controller area network is indispensable. The Controller Area Network or CAN provides the driver with many powerful features including multi-master functionality, the ability to broadcast/multicast telegrams, high data reliability and short reaction times, especially good error-tolerance property for HEV system [3].

3.1 *Characteristic of CANopen Protocol*

CANopen is a higher layer protocol based on the CAN bus system and provides a mechanism whereby devices of different types and makes can be integrated together and communicate in a standard form, therefore making different CAN devices interoperable with one another. CANopen is used in most applications as an internal bus system in embedded network applications. In Europe, CAN has been implemented on many medical equipments. Now in public transportation, off-road vehicles, maritime electronics, and building automation and some large-scale machines, the CANopen protocol has acquired wide applications [4]. Based on the CAN Bus communication protocol, SAE J1939 is the only protocol so far that supports all classes of automotive communication defined by the Society of Automotive Engineers (SAE), and is formed with CAN-Bus 29 bits identifier[5][6]. Compared to J1939, CANopen has many advantages and some shortcomings.

The CANopen protocol is open and users need not pay for the protocol, on the contrary the J1939 is required. Then the CANopen can easy expand to other application fields, and the protocol can offer the base frame to manage the network. CANopen can offer the master/slave mode telegrams. Based on 11 bits identifier, the message in CANopen can transfer faster. Of course, through many years improvement, the SAE J1939 can perfectly support many classes of automotive communication, but for the HEV, CANopen could be expanded easy or at least a approach for solving the HEV communication by adopting some useful mechanism in J1939[7].

3.2 *CANopen Protocol [4] [8]*

CANopen Protocol sets are based on the "communication sets", namely communication profile which establishes the base communication mechanism and characteristics. The communication profile provides the means to configure devices and communication data and defines how data is communicated between devices, and Device profiles describing the device functionality will add device-specific behavior for devices, e.g. digital I/O, analog I/O, motion controllers, encoders, etc. Different devices supporting CANopen profiles from different manufacturers can be configured by the same mechanism. The most important part of a CANopen device is the object dictionary (OD). The

object dictionary is essentially a grouping of objects accessible via the network in an ordered pre-defined form. Each object within the dictionary is addressed using a 16-bit index and an 8-bit sub-index. The application object can be visited in network by this addressed entry include index and sub-index, and the object in OD could be the input or output signal, device function and network variables. This communication model defines four types of messages: Administrative message, Service Data Object (SDO), Process Data Object (PDO) and Predefined or Special Objects include Synchronization (SYNC), Time Stamp, Emergency and so on. For reducing configuration effort in simple networks, a mandatory default CAN-identifier allocation scheme is defined, may be modified by means of dynamic distribution. The allocation scheme is based on the division of the 11-bit CAN-identifier into a 4-bit function code part and a 7-bit node-identifier (Node-ID) part as shown in Figure 3.

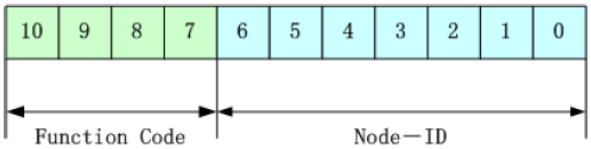

Figure 3. Structure of the 11-bit CAN-identifier in the CANopen Predefined Master /Slave Connection Set.

3.3 CANopen Protocol for HEV -- HEV Profiles

In hybrid electric vehicle each module can run by the microprocessor's control and management, and all module can communicate with each other and exchange data by the CAN bus. As shown in figure 2, each microprocessor becomes one node in communication CANopen network and the network must choose one to act as master station for network management and maintenance. The Vehicle Management System Control (VMS) or Central Surveillance System (CSS) can be the master. Our research chooses the CSS to act as the master node, other nodes act as the slave node. The Node-ID arrangement is as shown in Figure 4.

Master	Slave Node-ID (Hex)							
0x01	02	03	04	05	06	07	08	…
CSS	Aemc	vmsc	APU	Battery	OBA	ABS	Gateway	…

Figure 4. The Node-ID (7-bits) of all controllers in HEV

Each node in network can receive or transmit message by CAN-bus, for example the electromotor (Node-ID=0x02) demands the message about the command parameter from the VMS control (Node-ID=0x03), and requires to send periodically message about its really state data. The electromotor needs the command parameters, such as the range of drive speed, the rated motor voltage and some parameters about the torque and rotate speed characteristic for describing the big variable range load , such as low invariable speed power (Pmr),the rated motor rotate speed (nmr) and the max motor rotate speed (nm max.). The real state parameters need be seed for the VSM node, such as the motor voltage, motor temperature, real rotate speed, real torque, the radiator, the state of fan and so on. Every node needs to exchange data with other node in network. The device supporting the CANopen protocol in the application layer has two parts: the base communication profiles and the device profile.

6000 - 6FFF	Data Area of electromotor
7000 - 78FF	Data Area of gas engine
7900 - 7FFF	Data Area of VMSC
8000 - 84FF	Data Area of Storage Battery
8500 - 88FF	ABS, Emergency and Safety
8900 - 89FF	On-board Air-condition Area
8A00 - 8BFF	Central Surveillance System Area
8C00 - 8FFF	Reserved
9000 - 8FFF	Reserved
9800 - 9FFF	Gateway and Network Area
A000 -AFFF	OBD-II CODE
B000 -FFFF	Reserved

Figure 5. General CANopen Object Dictionary structure for HEV profile (Index is in hexadecimal notation).

The OD is the most important part of a CANopen device, and the relevant range of a node's OD lies between 1000h and 9FFFh, where the front part from 1000h to 5FFFh must be defined in communication profile and the rear part from 6000h to 9FFFh must be defined in device profiles. So the OD's arrangement must be implemented according to the HEV profile, as shown in Figure 5.

The CANopen network of the Hybrid electric Vehicle can be designed according to the base communication profile --- CiA 301 and the HEV profile. By the communication object PDO with high priority in CAN bus, every control can exchange data in peer-to-peer or one-to-multiple or broadcast communication mode. The communication object SDO is used for large, low-priority data transfer between devices, typically used for configuring the devices on a CANopen network by visiting the CANopen Object Dictionary to read or write the device parameters.

IV. SYSTEM DIAGNOSIS

With the development of automobile electronic technology, the automobile's framework becomes more complex, and the difficulty of its diagnostic and servicing technology is increasing. The automobile diagnostic technology has been developing rapidly, and on-board diagnostic has combined with the off-board diagnostic. Some special automobile scan tools can finish the complex diagnosis for automobiles.

4.1 The Diagnosis in OBD-II and SAE J1939

The automobiles and trucks made in United States after 1 January in 1996 year must have the On-Board Diagnosis II (OBD-II) [9]. As follows is the advantage of OBD-II:

- Unifying the communication protocol for automobile.
- Standardization of diagnostic connecter.
- Uniform diagnostic trouble code.
- Enlarging the range of the diagnostic parts.
- Adding the system diagnostic requirements.

The basic structure of OBD-II message package based on SAE J1979 has several parts as follows: the first three bytes of all diagnostic messages are the header bytes, the first header byte is dependant on the bit rate of the data link and the type of message, the second header byte is target address, the third header byte is source address. Then the data bytes are limited to seven bytes. The final part is error checkout byte. The message format is described in Figure 6.

Head(3B)	Data Area (7B)	CRC
Byte1 - 3	Byte1 - 7	Checkout Code

Figure 6. The basic structure of OBD-II message package.

This is a basic structure of OBD-II message package that is demanded by SAE J1979. It does not include the extra bytes required by control interfaces. Most message packages will send a control byte before sending OBD-II message package. At the same time, there will be an extra byte (indicates frame number) after OBD-II message package. Whether request or not response message, these extra bytes are different according to the different protocols used. Detailed information of these bytes is introduced in SAE J1979. Fault-diagnostic code in OBD-II consists of a letter and 4 numerals, the letter indicates electronic system code(I), other 4 numerals indicate differently coding corporation code(II), system trouble code (III) and (IV), and specific trouble code(V)[10], as shown in Figure 7.

BYTE1			BYTE2	
B7-B6	B5-B4	B3-B0	B7-B4	B3-B0
I	II	III	IV	V

Figure 7. Structure of OBD-II Data

J1939 is a network protocol that supports high-speed communication between several microprocessors. It is mainly used in truck and passenger car and is based on CAN 2.0B. J1939 uses only 3 layers of OSI 7-layer model. Its message format compliant with the CAN 2.0B, however J1939 redefines CAN identifier and only uses CAN extended frame format for standardized communication, the standard frame format is used for user-defined communication message frame. In order to avoid many nodes using the same CAN identifier, J1939 regulates one code must has one or several exclusive addresses. RTR in CAN bus has not been used.

In the J1939 protocols, the J1939-73 defines diagnostic message (DM) [11] which is used to complete diagnostic service. J1939-73 defines 21 DMs. The data field of DM consists of two parts, malfunction indicator lamp (MIL) and diagnostic trouble code (DTC). MIL indicates the indicators' information. DTC consists of 4 separate fields, which is Suspect parameter number (SPN), Failure mode identifier (FMI), occurrence count (OC) and SPN conversion method (CM).

4.2 The HEV protocol diagnostic criterion

On-board diagnostic system has been an important part of automobile, which improves vehicle's stability and security, especially HEV has two different power systems, so its' diagnostic is rather important. HEV diagnostic protocol includes system diagnostic protocol and some regulations for scan tool, which is based on J1939-73.

According to OBD-II communication format described in Figure 8, the header in J1939 is a 29-bit identifier, but CANopen is 11 bits, it seems hard to implement. However in CANopen network DTC is usually sent to the master station or monitor device, so the source address in header of OBD-II is unnecessary. Emergency message in CANopen protocol can implement diagnostic, but very simple and high priority emergency message could not happen usually. The second method is to use two functional codes that haven't been used in CANopen to complete diagnostic message. Of course, the third method combined above two methods, in which the important trouble message is sent through Emergency message, and the light uses the second method, could be considered. These three methods have their own character-ristics. Our research introduces the second method, as shown in figure 8.

COB-ID (Hex)	Object	Function
000h	**NMT**	0000
080h	**SYNC**	0001
080h+Node_ID	**Emergency**	0001
100h	**Time stamp**	0010
180h+Node-ID	PDO1(Tx)	0011
200h+Node-ID	PDO1(Tx)	0100
……	…….	…….
580h+Node-ID	SDO(Tx/Ser)	1011
600h+Node-ID	SDO(Rx/Cli)	1100
680h+Node-ID	**FDO(Tx)**	**1101**
701h+Node-ID	NMT Error Control	1110
780h+Node-ID	**FDO(Rx)**	**1111**

Figure 8. Assignment of Identifiers in CANopen Predefined Master/Slave Connection Set.

In this Figure, 680h+Node-ID denotes the transmitted Fault- Code Object (FDO), which is used by slave codes to send diagnostic message.780h+Node-ID denotes the received FDO (Rx), which is used to receive the previously active diagnostic trouble codes. Note that the node ID cannot be 127. The data in Figure 8 can be defined according to J1939-73. The first two bytes indicate the state of malfunction indicator

lamp (MIL), as shown in Figure 9.

BYTE1				BYTE2			
B7-6	B5-4	B3-2	B1-0	B7-6	B5-4	B3-2	B1-0
A	B	C	D	SPN1	F	G	E

Figure 9. Malfunction indicator lamp status of HEV profile.

In this figure, A: malfunction indicator lamp status. B: Red stopping lamp status C: Amber warning lamp status. D: protective lamp status. E, F, and G: Reserved. And SPN1:

The first part of DTC, an English letter, used for diagnostic trouble code. The DTC representation in CANopen data frame can be defined as in figure 10.

BYTE3			BYTE4		BYTE5		BYTE6	
7-4	3-1	0	7-4	3-0	7-6	5-0	7	6-0
SPN3	SPN2	SPN1	SPN4	SPN5	Res.	FMI	CM	OC

Figure 10. The basic structure of OBD-II message package.

In figure 10, SPN2, SPN3, SPN4, and SPN5 indicate the 4 hexadecimal numerals. Compared to SAE J1979, the HEV profile extends the bits of SPN1 and SPN2 used to deal with electromotor and other device in HEV. The rear part of data consists of two bytes; the Byte5 and Byte6 are similar to the definition in J1939-73. FMI in Byte5 indicates failure mode indicator, and CM that may be reserved indicates Conversion Method in J1939 and OC is the count of DTC. Diagnostic trouble codes can be stored in Object Dictionary (OD), the indexes of A000h-AFFFh in OD are for Diagnostic Trouble Code and the explanation of the DTC or other information.

4.3 Application Example of FDO Message

Supposing that there is a malfunction in power system, Diagnostic Trouble Code (DTC) is P0100, which denotes Mass or Volume Air Flow Circuit Malfunction. It's data as follows:

The DTC for P0100 means that Malfunction indicator lamp status:01(2 bits),Red stopping lamp status:00(2 bits),Amber warning lamp status:00(2bits),FMI:0000(4bits),OC:0000010(7 bits).

The first letter in OBD-II diagnosis trouble code (DTC) can be P, B, C and U. The P represents the power system. The B is for Bodywork system, the C represents the car's Chassis, and U is the Communication Network System. In FDO message of HEV system the distribution of data as shown in Figure 11.The P: 000 (3bits), B: 001(3bits), C: 010(3bits), U: 010(3bits).

FDO message: Producer->consumer

COB-ID	0	1	2	3	4	5
680+NodeID	40	00	10	00	00	02

Figure11. The FDO Message

This FDO message is sent based on the definition of FDO in figure 9 and figure 10.

4.4 Slave node for Asynchronous Electromotor

As we known, the driver source in HEV system is very important part, and the technique of controlling the alternat -ing current asynchronous electromotor to drive the wheels is very complex. The electromotor can be run at different mode. When the message from master node include speed set-value can be reached with the torque set value, then speed-control is achieved, and when the message include speed set-value is set to a value that cannot be reached with the torque set value, then the torque controlled is achieved. The following figure 12 shows the need data for electromotor running.

Msg	B7--B6	B5--B4	B3	B 2	B1--B 0		Cyc.	ID
Es1	Actual speed	Actual torque	Statu s	Err or	Battery Voltage		20hz	182
Es2	Heatsink temp.	Motor temp.	Max. current		Res.		20hz	282
Cmd	Speed -set	neg. torque	Pos. Torque set		Rs.	Sta rt	10hz	202

Figure12. The CANopen Message of slave node of electromotor

The three messages are activated by timer mechanism in different frequency and the node-ID is two. In our research the slave stack of CANopen for electromotor has been implemented based on the Digital Signal Processor (DSP, TMS320F2812). This DSP chip has obviously advantage in industry control area, especially with the eCAN module [12].

The eCAN module has the following features: 1. fully compliant with CAN protocol, version 2.0B. 2. Supports data rates up to 1 Mbps. 3.Thirty-two mailboxes, each with the following properties:4.Configurable as receive or transmit, standard or extended identifier, a programmable acceptance filter mask, supports data and remote frame, supports 0 to 8 bytes of data. 5. Uses a 32-bit time stamp on received and transmitted message, protects against reception of new message, allows dynamically programmable priority of transmit message, employs a programmable interrupt scheme with two interrupt levels, automatic reply to a remote request message. 6. 32-bit time-stamp counter synchronized by a specific message (communication in conjunction with mailbox 16), operates in a loop back mode receiving its own message. A "dummy" acknowledge is provided, thereby

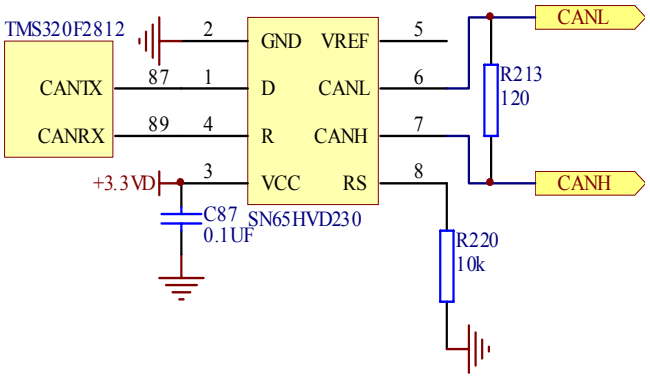

Figure 13. The design of the eCAN bus interchange circuit.

eliminating the need for another node to provide the acknowledge bit. Code migration in Ti DSP2812 platform is a relatively easy task, more so with code written in C language. The referenced hardware design of eCAN module interface as shown in figure 13.

In circuit the transceiver is the chip of SN65HVD230[13], of course the 82c250 produced by Philips can also be used, but the 82c250's reference voltage is 5V, so between the DSP(3.3V) and transceiver need the voltage transform, for example the chip of 74lvc4245.

The whole frame of CANopen slave stack code based the hardware as shown in upper figure can be include two parts according to the data flow, as shown in figure 14.

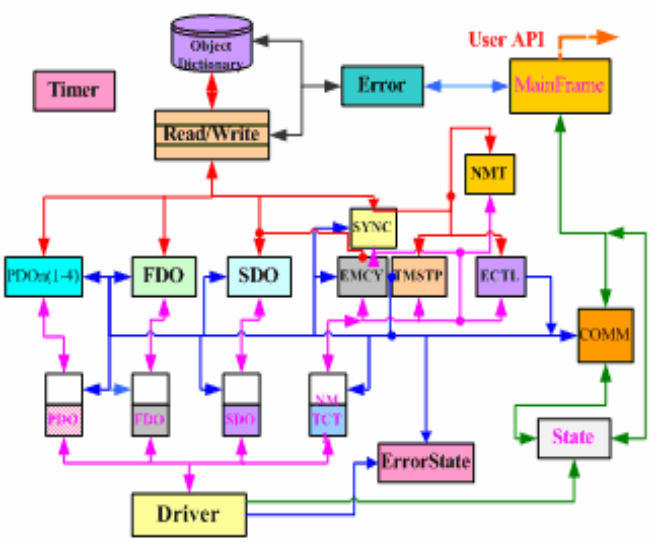

Figure 14. The frame of the CANopen Slave Stack

By means of the eCAN modules' powerful interrupt, when a receive interrupt is generated if enabled. If no match is detected, the message is not stored. When a message is received, the message controller starts looking for a matching identifier at the mailbox. If the message should be received, the message data is stored in the matching Rx-Data-Buffer and notifies the core part: COMM Module, and then exit the interrupt. If the system interrupt is generated for some error states, the error-state module receives message and notifies the COMM Module. This is the first data flow handling depended on interrupt to drive. The second is the received message data refreshes the object dictionary or the stack, and check out the ready transmitting message and fill in the Tx-Data-Buffer, at the some time the state machine of stack deals with the different type messages according to the current state. All these are drived by the event or the predefined running rule.

V. CONCLUSION

This paper introduces CANopen network frame and protocol for a Hybrid electric Vehicle. Firstly, the CANopen protocol profile for HEV was established through analyzing the structure of HEV and CANopen protocol. Then by analyzing J1939 the diagnostic system of HEV profile can be implemented. For the advantage of CANopen, the CANopen network with on-board diagnostic system in HEV has broad application foreground in automobile electronics. On-board diagnostic system will be the necessary part of HEV, and not only perfects diagnostic part of CANopen protocol but also has practical meaning for local area network in HEV.

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REFERENCES

[1] S.Plotkin, D.Santini, "Hybrid Electric Vehicle Technology Assessment: Methodology", Analytical Issuses, and Interim Results, ANL/ESD/02- 2.W.-K. Chen, Linear Networks and Systems (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.

[2] WANG Yin-hui, LIU Xing-hua, QFU Tao, "A Study on the Hybrid Electric Vehicle", Internal Combustion Engines, 2003-03.

[3] Nan Jinrui, Wang Jianqun, Sun Fengchun, Fu Liding, "The Implementation Method for CAN Communication in Electric Vehicle Control System", Proceedings of the 19th Electric Vehicle Symposium, Busan, Korea, Oct 2002.

[4] H.Boterenbrood, "CANopen, high-level protocol for CAN-bus", NIKHEF internal documentation, NIKHEF, Amsterdam Version 3.0 March 20, 2000, P2-16.

[5] SAE Stardard, "Vehicle Application Layer", SAE J1939/11. 1996.

[6] SAE Stardard, "Vehicle Application Layer", SAE J1939/81. 1997.

[7] Dickey, S.R., Xian-Yun Lu, "Control Actuation of Fully Automated Heavy-duty Vehicles Using SAE J1939", Intelligent Vehicles Symposium, 2003. Proceedings. IEEE, 9-11 June 2003.

[8] CAN-in-Automation, CANopen, CAL-based Communication Profile for Industrial Systems, CiA DS-301, Version 4.0, June 16 1999.

[9] Transportation Systems Branch Environment Canada, "On-Board Diagnostics II (OBDII) and Light-Duty Vehicle Emission Related Inspection and Maintenance (I/M) Programs", Prepared by D. Cope Enterprises, April 2004.

[10] SAE Stardard, "Vehicle Diagnostic Test Modes", SAE J1979, April 30, 2002.

[11] SAE Stardard, "Vehicle Application Layer", SAE J1939/73, 1996.

[12] TMS320F28x Enhanced Controller Area Network (eCAN) Reference Guide, Texas Instruments Incorporated, Literature Number: SPRU074A. America, June 2003.

[13] SN65HVD230 Data Sheet [Z]. Texas Instruments Incorporated, America, 2003.