Dispersed Remote Vehicle Diagnostic System

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ABSTRACT

There are a large number of devices that conduct diagnosis for abnormality of vehicle in the market. However, those devices support only C-CAN signal among the vehicle signals; therefore, it is not possible to diagnose parts that use B-CAN signal. A majority of vehicle parts generate analog signal in order to operate sensor and actuator. On that account, it is essential to collect electric signal for an accurate diagnosis. However, it is required to connect a number of individual devices in order to diagnose by using the existing equipment; thus, the level of reliability of collected data will be reduced. Moreover, it is also required for an user to undergo data extraction process manually in order to extract valid data from the collected data. As a result, it takes a lot of time and the efficiency of overall inspection and verification will be reduced.

Those conventional vehicle diagnostic devices are used when a vehicle is not running. However, the frequency of abnormal signal of an actual vehicle is high while a vehicle is running. The time of occurrence is not uniform either. In general, the critical part is to monitor multiple vehicles simultaneously and finding abnormality of vehicle in this situation in terms of improving the quality of vehicle substantially.

This paper developed the dispersed remote vehicle diagnostic system that would collect and analyze C-CAN, B-CAN and analog signal. Also, this study secured the reliability of vehicle data with the differentiated performance from the conventional equipment through the synchronization with CAN communication and analog signal. The developed diagnostic system is able to diagnose abnormality of parts and search the cause hereof through the linked analyzed of synchronized AI signal and the segmented diagnosis. It is also able to reduce the unit cost of a purchaser by integrating a large number of individual diagnostic devices. Moreover, it is installed in an actually running vehicle as a system allowing for a small-scale long-hour test. As a result, it is possible to identify the cause in a daily life. It is also believed that it can contribute to the development of vehicle and improvement in research reliability since it facilitates a remote test on vehicle status for a long time.

KEYWORDS

Vehicle, Diagnostic, Disperse, Remote, CAN

1 Introduction

Recently, primary parts manufacturers have been a variety of safety related issues due to abnormal signals in a vehicle. These abnormal signals are mainly caused by an increase in the amount of data in the network for vehicles with an increase in the number of electronic devices in a vehicle.

Table 1. Classification for each type of communication

Chassis CAN	Body CAN	Analog Signal
CAN-communication to transmit and receive driving information	CAN-communication transmitted/received by the module used in vehicle body	Basic input and output signal of all electrical equipment of vehicle

The following information shows the essential signals for reading the abnormal signals in a vehicle.

1.1 C-CAN (Chassis-CAN)

It is possible to acquire C-CAN data through the equipment called vehicle diagnostic equipment or vehicle diagnostic device. One can conduct self-diagnosis of a vehicle through connecting this equipment to OBD (On Board Diagnosis) port of a vehicle. Some of the prominent domestic devices thereof include 'Carmanscan' of Nextech and 'G-Scan' of GIT. C-CAN is able to measure airbag control module, parking guide module, vehicle diagnostic module, electronic parking brake module, tire pressure monitoring module, lane departure detection module, smart cruise control module, ABS control module, etc[1].

1.2 B-CAN (Body-CAN)

B-CAN data cannot be used as a vehicle diagnostic device due to rate difference. Thus, a separately manufactured device based on individual CAN data collection devices has been used so far. Some of these individual CAN data collection devices include ‘VN Series’ of Vector and ‘NI-CAN 8473’ of National Instruments. The modules to be measured by B-CAN are driving seat door module, passenger seat door module, power trunk module, steering tilt/telescopic module, smart key control module, etc[1].

1.3 AI (Analog Signal)

It is collected by using an oscilloscope or DAQ (data acquisition) equipment. As for vehicle parts, C-CAN, B-CAN and analog signals are generated simultaneously when they are running. However, it is difficult to conduct accurate analysis with the conventional method since it measures C-CAN, B-CAN and analog signals separately. That is to say, no proper data synchronization is established with the conventional method.

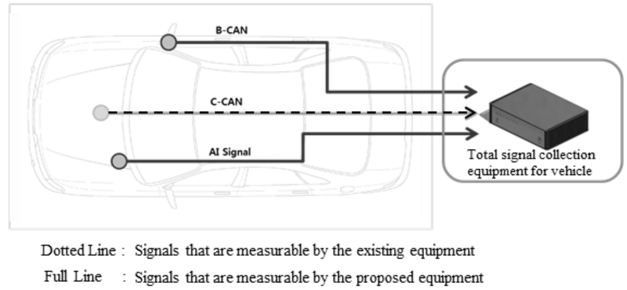

Figure 1. Example of Measurement Signal of Equipment for Vehicle.

Those conventional vehicle diagnostic devices are used when a vehicle is not moving. However, there is actually a high occurrence rate of abnormal signals when a vehicle is moving. Thus, it is required to conduct a study on diagnosing problems of a vehicle accurately and determine presence of abnormality.

The vehicle diagnostic method only based on the existing C-CAN information allowed for only one-directional diagnosis. However, the method proposed in this thesis makes it possible to diagnose abnormality of parts and search the cause hereof through the linkage analysis of synchronized AI signal and the segmented diagnosis. It also allows us to integrate those individual diagnostic devices. As a result, it will likely allow buyers to reduce unit cost. In addition, it is the system that allows for a small-scale long-hour test. Thus, it can be installed in an actually running vehicle in order to identify the causes in everyday life. That is to say, it makes it easier to conduct a remote test of vehicle status for a long time; thus, it is expected to contribute to developing a vehicle and improving research reliability.

2 Trend of Vehicle Analysis Device

CAN, which can be regarded as vehicle network standard, was first proposed by Robert Bosch of Germany in SAE (Society of Automotive Engineers) in 1986[2][3]. In 1988, Bosch and Intel produced the vehicle network system. In 1991, CAN protocol 2.0 was developed. In 1992, Mercedes Benz released the car that employed CAN. ISO11898, the ISO international standard specification, was revealed in 1993[4]. However, it was not still possible to conduct analysis perfectly using only CAN. Thus, those signal measuring instrument used for the repair work of electronic units installed in a vehicle generally leverage an oscilloscope. Also, it is possible to analyze the waveform of detected signals easily through the screen. In contrast, it is not appropriate to analyze a large number of signals since the number of channels is fixed at 2 or 4.

As for the signal detector having a different shape compared to an oscilloscope, light bulb tester is leveraged for the maintenance work of a vehicle. This light bulb tester detects whether the voltage of measurement point is on or off. As a result, it allows us to verify signal status by naked eyes. Nonetheless, the number of channels is fixed at one. Also, it is unstable to operate a vehicle due to a distortion of sensor signal when detecting sensor signal directly from the operating mode of a vehicle. Moreover, it makes it hard to measure those high speed pulse signals. The diagnostic devices have been improved to such an extent as to release OBD-II. As a result, it is now possible to measure CAN signals generated from a vehicle.

The number of electronic devices for vehicle has increased substantially in recent years. Therefore, there is a large quantity of data in a network for vehicle. Also, there is a high degree of demand for stability and reliability. On that account, even those arbitrarily established methods have emerged. Some of them are EOBD and KOBD. The United States in which OBD was first proposed made CAN compulsory with the communication method of OBD-II in all vehicles produced since 2008. In South Korea, Hyundai Motors has supported only CAN method in all vehicles produced since 2008. Even though there exist the five methods of OBD-II communication, the connectors have been unified to J1962[5][6][7].

3 Controller Area Network(CAN) Communication

3.1 Features CAN Communication

CAN communication is the serial network communication method designed for communication between micro controllers.

Thus, it is an economic and reliable communication method through which multiple CAN devices can communicate with each other.

However, it controls multiple ECUs with a single CAN interface; thus, it is able to reduce the overall cost and weight of a vehicle and improve the system control rate and reliability.

Moreover, each device has CAN controller chip; thus, it is able to control each system efficiently. CAN is the standard protocol for both ISO (International Standards Organization) and SAE (Society Automotive Engineers).

It conducts multi master communication. All of CAN controllers perform the role of a master; thus, they can be utilized when desired. Since only two lines are used, the length of wire to be used is short since there is almost no addition of line even though many controllers share bus. Moreover, it provides plug and play so that CAN controllers can be connected to and disconnected from bus. It has priority and it makes it convenient to apply distributed control of ECU. Also, it can selectively receive only those set IDs and it can conduct communication in distance of about 1km[8].

3.2 CAN Hardware Structure

CAN is not interfered by electromagnetic wave. However, when electromagnetism collides directly with bus, bus lines on both sides will be affected and there will be EMI (Electro Magnetic Interference). For impedance matching for preventing it, resistance treatment of 120R shall be conducted at the end node when configuring the node.

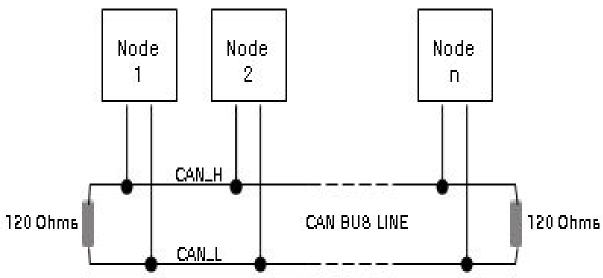

Figure 2. CAN BUS

3.3 Classification of CAN Communication

H-CAN uses voltage of 2.5V to 3.5V and it conducts high-speed communication of more than 200Kbit/sec. L-CAN uses voltage of 1.5V t 2.5V and it is used with the speed between 33.33Kbit/sec and 125Kbit/sec.

Table 2. Rate of CAN Communication

Communication Method	Voltage Level	Communication Rate
H-CAN	2.5V~3.5V	Higher than 200Kbit/Sec
L-CAN	1.5V~2.5V	33.33Kbit/Sec ~125Kbit/Sec

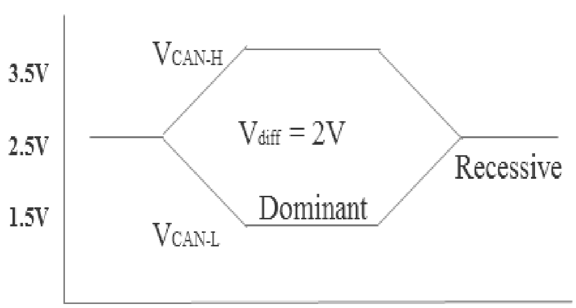

Figure 3. H-CAN, L-CAN Voltage level comparison

There are a variety of factors behind an occurrence of failure in CAN system. Of those, some of the most prominent factors include wiring of components, accurate endpoint of bus and compliance with the maximum bus length. Wiring should have no electrical connection between lines.

Also, it should be within the values allowed by line resistance and line impedance. Lastly, line opening/closing and ground resistance must be in compliance with the pre-determined range. Furthermore, it is imperative to eliminate other failure causes separately from wiring due to the phase of CAN and arbitration mechanism. To prevent signal reflection, CAN bus should be terminated with one 120-Ohm resistance on both ends. In addition, the maximum bus length should not be exceeded.

As mentioned before, it is required to eliminate additional causes of failure that would affect the operation and reliability of system through review when setting it. Of those, such cases as clear failure and confusion of signal lines, etc. cause communication problem. Moreover, the entire common-mode voltage and signal level, which were transmitted, are measured; therefore, it is also imperative to secure an sufficient level of quality of transmitted signals[9]. First, signals shall be placed within the range of 1.5V to 3V in accordance with the standard (ISO 11898-2, high speed), and VCAN_L shall be higher than -2V and VCAN_H shall be less than 7V as common-mode voltage. In particular, any failure caused by signal quality often cause serious problems that would result in a significant amount of cost to solve the causes hereof.

4 Proposed Vehicle Diagnostic System

4.1 Classification of CAN Communication

Previously, a majority of measurement and data transmission works have been conducted only by using C-CAN. However, B-CAN is not equipped with a vehicle diagnostic module; thus, B-CAN communication module cannot easily conduct failure diagnosis just like C-CAN module.

As for B-CAN module, a vehicle maintenance technician should conduct dissemble work for failure diagnosis. Also, it is required to diagnose a failure with those individually manufactured failure diagnosis for each B-CAN communication module or check analog signals generated by each B-CAN module by using such an analog signal test equipment as multi-meter or oscilloscope. It is required to extract valid data or signal manually out of the collected data or signals when a vehicle maintenance technician diagnoses a failure of B-CAN communication module by using an individually manufactured failure diagnostic equipment or analog signal test equipment. On that account, it has a lot of time consumption and it is inefficient. Also, the efficiency and reliability of overall inspection and verification work will be lowered. Moreover, such CAN communication modules as C-CAN module and B-CAN module are not able to generate analog signal through their own actuator (or sensor) when they are broken down. As a result, the corresponding actuator that could not receive the above-mentioned analog signal could not be operated even though it is in normal mode.

In this case, the corresponding actuator might be unnecessarily repaired or replaced if a vehicle maintenance technician misjudges it as a failure. To solve the aforementioned problem, it will be required to analyze a failure after synchronizing analog signal and CAN signal. However, the current system stores CAN signal and analog signal separately for analysis.

Thus, it has a difficulty of determining presence of abnormality for signals in the same time slot.

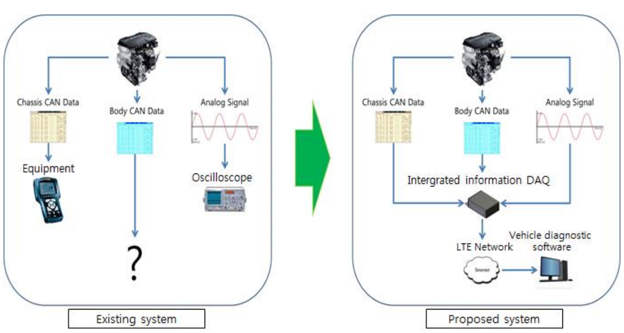

Figure 4. Holistic configuration diagram of dispersed remote vehicle diagnostic system

4.2 Program design for detection of abnormal signal of vehicle

Fig. 5 is the graph displaying the result of failure diagnosis. If CAN communication module outputting CAN signal and analog signal is normal, then analog signal is changed simultaneously as CAN signal is changed as shown in Fig. 5 (a) during the synchronization collection period, in other words, the pre-determined time interval (t). Also, analog signal can be changed a certain time delay after CAN signal is changed as shown in Fig. 5 (b).

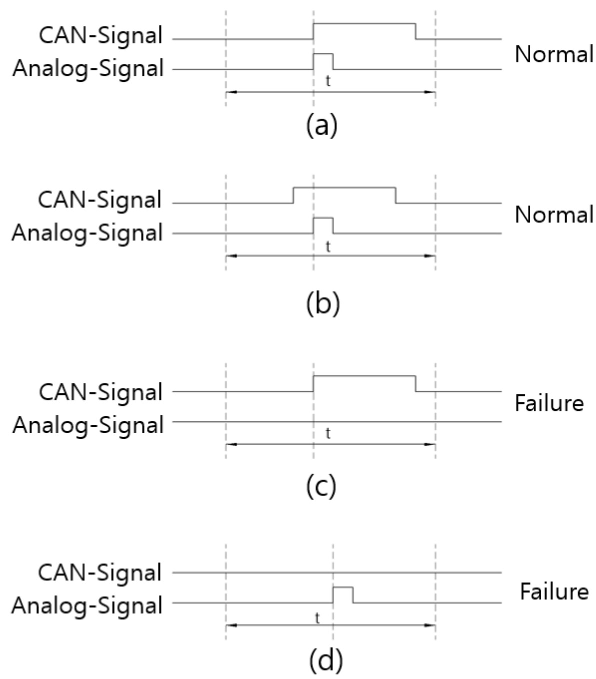

Figure 5. Result of Failure diagnosis

On the other hand, analog signal will not be changed even though CAN signal is changed as shown in Fig. 5(c) during the synchronization collection period, in other words, the pre-determined time interval (t) when CAN communication module that generates CAN signal and analog signal is failed. Also, CAN signal is not changed even though analog signal is changed as shown in Fig. 5(d). As can be seen above, it is not necessary to use the conventional type of portable vehicle diagnostic device that was mentioned in the previous technologies, the failure diagnostic device produced separately for each communication module or such analog signal test devices as multi-meter and oscilloscope.

As a result of detecting a change in the above CAN signal and analog signal that were collected during the synchronization collection period, in other words, the pre-determined time interval from the aforementioned signal collection device, the above diagnostic device determines that CAN communication module, which generates CAN signal and analog signal, is broken down unless a change in either of the two signals is not detected. Therefore, it is possible to diagnose promptly, accurately and easily a failure of all CAN communication modules installed in a vehicle regardless of whether it is a chassis-CAN communication module connected to a vehicle electronic control device through chassis-CAN or the above body-CAN communication module connected to a vehicle electronic control device through body-CAN regardless of the type of CAN that connects a vehicle electronic control device to CAN communication module.

5 System Design

LED indicating power status and error status is installed at the front side in order to identify the status of corresponding equipment. The back side is designed in a way that B-CAN, C-CAN and analog 24 channel can be used.

Figure 6. Dispersed remote vehicle diagnostic equipment

The proposed instrument is an embedded system with a FPGA-based Real Time OS.

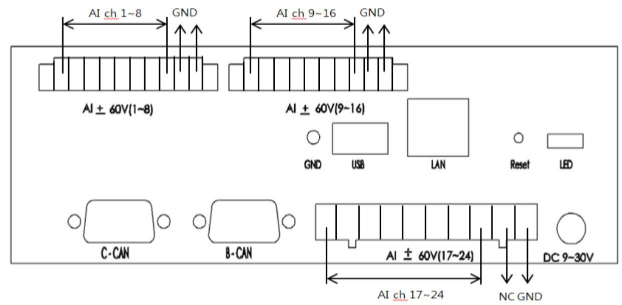

Figure 7. The front of system

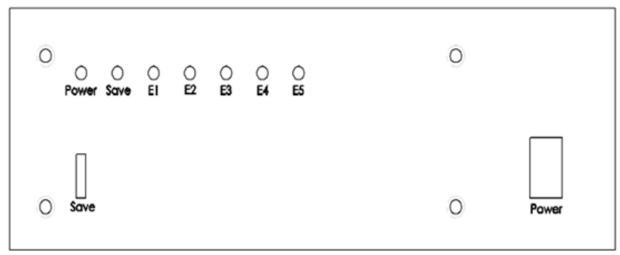

Figure 8. The back of system

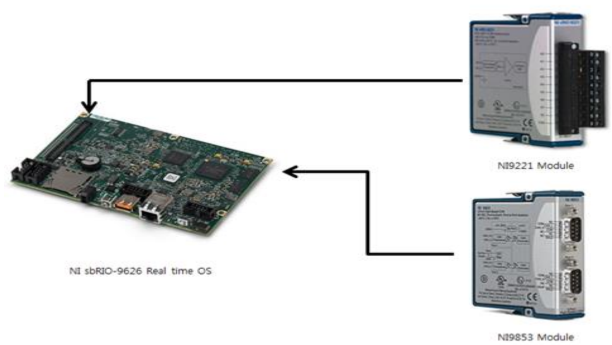

Figure 9. The inside of system

The system was used NIsbRIO, NI9853, NI9221 and LabVIEW.

Table 3. Specification of system

NI sbRIO – 9626 Chassis	NI 9853 Module	NI 9221 Module
-Real time OS -Analog Input 16ch -Analog Output 4ch -Spartan-6 LX45 FPGA -40 ~ 85	-5VDC voltage -2 CAN Port -1 Mbits/s -Sleep / Wakeup mode	-Analog Input 8ch --60v ~ 60v range -12bit sampling rate 100 KS/s/Ch

6 Conclusion

The system developed in this thesis was designed to determine the presence of abnormality in a vehicle by receiving data through LTE network in addition to identifying abnormality after collecting vehicle related data. The technical configuration and attributes of the developed system are as follows.

1) It has the function of performing the status monitoring and saving of a vehicle with voltage signal by collecting both high-rate network signal and low-rate network signal of a vehicle.

2) The technical features of the above device operates and saves with its own battery while measuring vehicle data and electrical signal in a synchronized state. Also, it has the function of transmitting data using LTE network.

3) It can be leveraged in all vehicle models. It utilizes the software based on the analysis algorithm in the data verification process. It is designed to minimize the required time in the verification process and to allow users to secure the expandability of vehicle signal (CAN signal).

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