Self-Diagnostic Signal Monitoring System of KWP2000 Vehicle ECU using Bluetooth

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Abstract: On-Board Diagnostic(OBD) systems are in most cars and light trucks on the load today. During the 1970's and early 1980's manufacturers started using electronic means to control engine functions and diagnose engine problems. The CARB's diagnostic requirements to meet EPA emission standards have been designated as OBD with a goal of monitoring all of the emissions-related components, as well as the chassis, body, accessory devices and the diagnostic control network of the vehicle for proper operation.

In this paper, we present a remote measurement system for the wireless monitoring of diagnosis signal and sensors output signals of ECU adopted KWP2000, united the OBD communication protocol, on OBD-compliant vehicle using the wirless communication technique of Bluetooth. In order to measure the ECU signals, the interface circuit is designed to communicate ECU and designed terminal wirelessly according to the ISO, SAE regulation of communication protocol standard. A microprocessor S3C3410X is used for communicating ECU signals. The embedded system's software is programmed to measure the ECU signals using the ARM compiler and ANCI C based on MicroC/OS kernel to communicate between bluetooth modules using bluetooth stack. The diagnostic system is developed using Visual C++ MFC and protocol stack of bluetooth for Windows environment. The self-diagnosis and sensor output signals of ECU is able to monitor using PC with bluetooth board connected in serial port of PC. The algorithms for measuring the ECU sensor output and self-diagnostic signals are verified to monitor ECU state. At the same time, the information to fix the vehicle's problem can be shown on the developed monitoring software. The possibility for remote measurement of self-diagnosis and sensor signals of ECU adopted KWP2000 in embedded system verified through the developed systems and algorithms.

Keywords: Electronic Control Unit, KWP2000, Bluetooth Module, Wireless communication, Remote measurement

1. INTRODUCTION

Telematics, a compound of Telecommunication and Informatics, is the service for vehicle to offer information that the vehicle, wireless communication, displayer, internet, contents and applications is integrated. It has offered the new opportunity to the wide industries combined the growing IT industry rapidly with the vehicle industry. The vehicle's ECU(Electronic Control Unit) improve the fuel-efficient, the driving sensibility and the stability of the vehicle using a variety of the sensor's information during drive the vehicle. In addition to restraint the emission of an air-pollution matter and to detect easily the vehicle's defaults with the OBD(On Board Diagnostics) offering much useful information like the diagnostic trouble codes of the vehicle.[1-5] Up to now, the tester which is used as the vehicle diagnostic equipment has offered information of the sensor output signal and diagnostic trouble codes. This system usually used the communication method by cable. The system of the cable communication has the advantage of the stability, but it has a lot of disadvantages that is expensive for individual use, restrictive in usable environment and inconvenient for using and equipping.[6-9]

Therefore in this paper, we developed the remote measurement signal using the bluetooth module, the short -range wireless communication device which is suggested to compose the network between the inner devices of the vehicle such as one of the telematics technologies. The protocol of communication to diagnose the vehicle's ECU is the KWP2000 and the embedded system with a build-in RTOS(Real Time Operating System) make that is able to measure the ECU's information through the bluetooth in PC. By comparing the diagnostic trouble code and sensor's output signal such as the experimental results with the common scanner, we could certify the usefulness of the developed system.

2. BASIC CONSTRUCTION OF REMOTE MEASUREMENT SYSTEM

The basic construction of this study have the ECU applied the KWP2000 protocol on vehicle and the embedded system composed of the S3C3410X(ARM7TDMI core) micro-processor, the bluetooth module and the microC/OS-II. The interface part for the communication between the ECU and the embedded system is satisfied with the condition of the ISO 14230 standard. The bluetooth module in the embedded system send to another bluetooth module connected with the PC the ECU's self-diagnostic signals and sensor signals. The PC program software is developed using visual C++ MFC tool which application can control the bluetooth module for requesting the services to ECU and receiving the data from ECU. Also, the user easily is able to analyze the received data and monitor the defect codes and the sensor signals of vehicle.

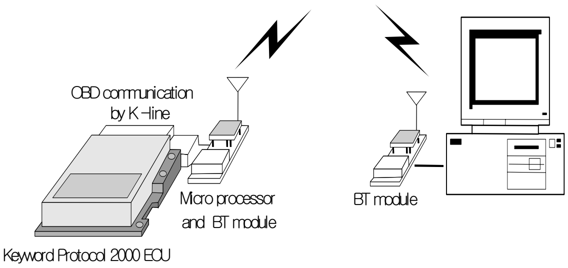


Fig. 1 Configuration of self-diagnostic system using bluetooth module

Fig.1 show the overall configuration of this paper. The ECU is separated from the vehicle to make an experiment and connected the equivalent circuit composed of the 12V power supply, fuse, power relays etc. to be able to operate normally.

2.1 Bluetooth

Bluetooth is a low cost, low power, short-range radio technology, originally developed as a cable replacement to connect devices such as mobile phone handsets, headsets, and portable computers. The bluetooth specification version 1.0 came out in 1999, but Bluetooth started in 1994 when Ericsson Mobile Communication began a study to examine alternatives to the cables. Bluetooth device operate at 2.4GHz in the globally available, licence-free ISM(Industrial, Scientific, and Medical) band.

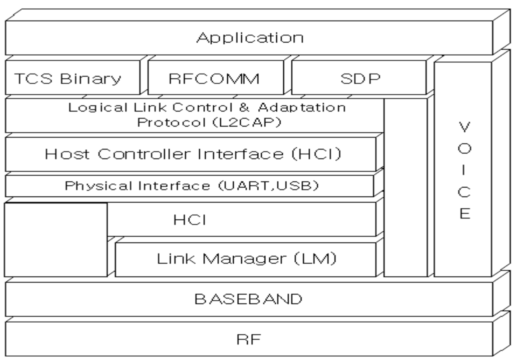


Fig. 2 Protocol stack structure of the bluetooth

The operating band is divided into 1MHz-spaced channels. Both devices retune their radio to a different frequency after each packet(FHSS, Frequency hopping spread spectrum). The radio power is defined three different power classes, which provide operation ranges of 10m, 20m, and 100m. Bluetooth allows both time critical data communication such as the voice or audio. To carry such data, two different types of links are defined between any two devices that are SCO(Synchronous Connection Oriented) links for voice communication and ACL(Asynchronous Connectionless) links for data communication.[10-11]

Fig.2 show a possible protocol stack with a device and security manager that can handle establishment and configuration of the link. The device manager interfaces to the HCI layer, SDP, RFCOMM, L2CAP, and to applications.

2.2 Keyword Protocol 2000(KWP2000)

OBD systems are in most cars and light trucks on the load today. Manufacturers started using electric means to control engine functions and diagnose engine problems. The CARB's diagnostic requirements to meet EPA emission standards have been designated as OBD with a goal of monitoring all of the emissions-related components, as well as the chassis, body, accessory devices and the diagnostic control network of the vehicle for proper operation.

OBD-II defined a data protocol and a standard vehicle connector which enables a scan-tool to query the ECU and ask it if the vehicle is polluting. OBD-II lowed three different electrical interfaces to be used; J1850 PWM(Pulse Width Modulated), J1850 VPW(Variable Pulse Width), and ISO-9141-2.

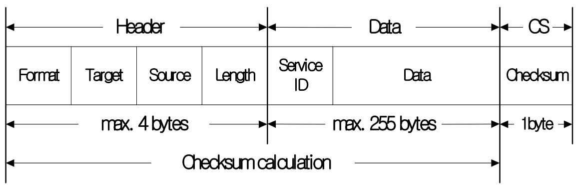


Fig. 3 Message structure between ECU and scanner

The keyword protocol 2000, also called ISO 14230 or KWP2000, is a newer version of the ISO-9141 protocol. The physical implementation is identical, but it uses a different data format, as well as an optional "fast" initialization sequence.

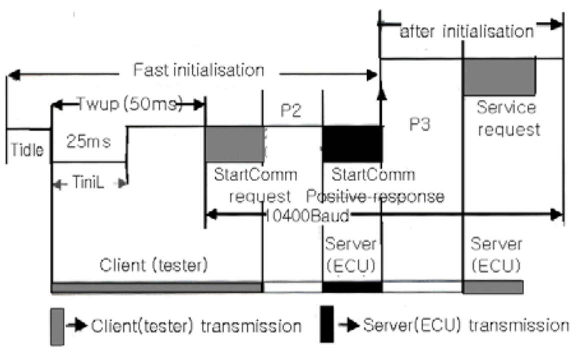


Fig. 4 Fast initialization and start communication of ECU

The K-line of ECU is a bi-directional data bus to transfer a command from the scanner to ECU and a data from ECU to the scanner. Fig.3 show the message structure which is communicated between ECU and scanner. The message structure consists of three parts; header, data, and checksum. The header consists of a maximum of 4 bytes; format byte, target byte, source byte, and length byte. The first byte of the data parts always begins with the Service Identification. The checksum byte is the sum series of all bytes in the message.[12-15]

Fig. 4 show the "fast initialization", "Start Communication Request" and "Start Communication Positive Response". the "fast initialization" is achieved by sending a 25millisecond pulse, then sending an initialization request at the normal 10.4K baud-rate.

3. REMOTE MEASUREMENT SYSTEM

3.1 Hardware Construction of System

Fig.5 shows the construction of remote measurement system to monitor self-diagnostic signals and sensor output signals from vehicle ECU applied KWP2000. The remote measurement system consists of embedded system having the RTOS, interface circuit, and bluetooth module. In this system, the bluetooth module made use of the product manufactured in Samsung electric-mechanics and allowed the power class of maximum 100m and the microprocessor each communicates with the bluetooth module and ECU through the USART (Universal Synchronous Asynchronous Receiver Transmitter). Table 1 shows the detailed specification of embedded system.

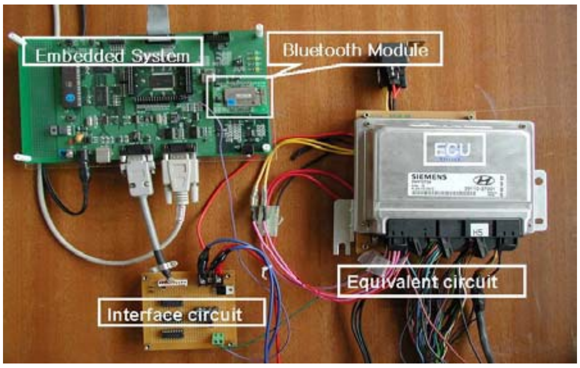


Fig. 5 Configuration of embedded system with experimental ECU and interface circuit

The ECU used in the experiment has the KWP2000 and was manufactured in the SIEMENS Inc.. This ECU was furnished to the NEW EF-SONATA model was manufactured in HYUNDAI MOTOR COMPANY of Korea. A ECU has outside a DLC(Data Link Connector) for the vehicle's diagnosis. This connector has the K-line which can communicate with the tester. To experiment the ECU in a room, we constructed the equivalent circuit which consists of the rated-fuse, power relay and 12V power supply for operating normally the ECU.

Fig.6 show the block diagram of the interface circuit between ECU and embedded system.

Table 1 Specification of the development board used as embedded system.

Part	Specification
Processor	S3C3410X (ARM7TDMI core)
Flash Memory	8Mbit (512kbx16)
SDRAM	64Mbit
EEPROM	4Mbit(256kbx16)
RS-232 Transceivers	1Mbps data rate
Dual UART	Two UART channels, 50bps to 4M bps data rate
USB Interface Device	Spec. v2.0, 2Mbyte/s
Audio Codec	13-bit linear PCM filter
Bluetooth Module	Spec. v1.1

A car is usually 12V power system, but the embedded system is 3.3V power system. And also, The K-line is a bi-directional data bus-line to be able to transmit and to receive the datum by one line, but the UART port of embedded system has both the transmitter (TX-line) and receiver (RX-line). To work out the problems, we need to design the interface circuit to be able to transform to the suitable signal-level between the vehicle ECU and a embedded system.

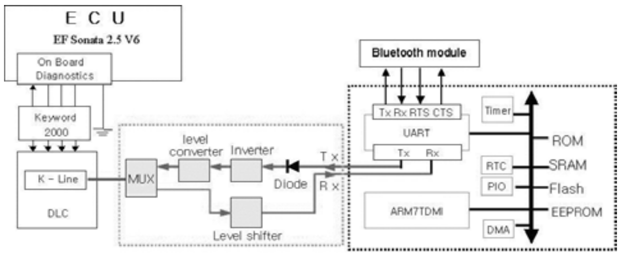


Fig. 6 Interface diagram between ECU and embedded system

3.2 Software Construction of System

The software of embedded system was based on RTOS, and consists of the bluetooth stack and the application. Fig.7 show the function of each tasks and the structure of a whole system.

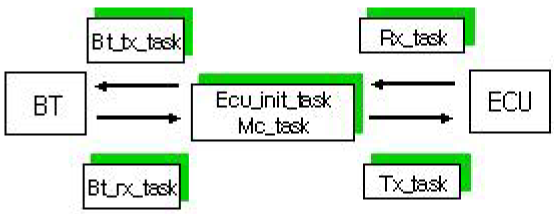


Fig. 7 The role of task in the application and structures of system

The MicroC/OS-II is the noncommercial kernel to the public as one of RTOSs, but is equivalent ability to many commercial real-time kernels that has the functions; the multitasking, the context switch, the scheduler, the reentrancy, the mutual exclusion and so on. The MicroC/OS-II kernel execute the tasks.[16-17]

First, the "*Mc_task*" create the other tasks. both "*Bt_tx_task*" and "*Bt_rx_task*" communicate with the bluetooth module based on bluetooth stack and "*Rx_task*", "*Tx_task*" and "*Ecu_init_task*" communicate with the ECU based on the KWP2000. In addition, the PC software was developed to communication with the embedded system by bluetooth.

4. SIGNAL MEASUREMENT AND EXPERIMENTAL RESULTS

The experimental ECU normally operate then supply it with the 12 voltage instead of a battery, and turn on a starting switch. The normal operating of experimental ECU can be checked through the sensor-line.

The application program of embedded system search the other bluetooth devices in all around through the inquiry after the system initialization of MicroC/OS-Ⅱ and bluetooth stack. If the bluetooth device is searched, the bluetooth devices give and take the packets as occasion demands for the connection.

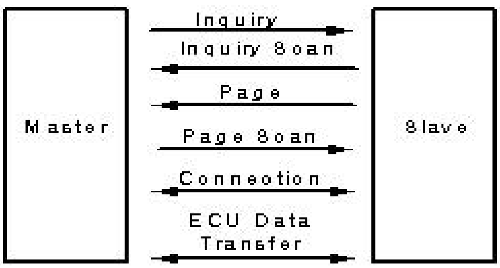


Fig. 8 Connection between master and slave

Fig. 8 shows the connected process of bluetooth devices. Bluetooth devices can operate in two modes; as a Master or as a Slave. It is the Master that sets the frequency hopping sequence. Slaves synchronize to the Master in time and frequency by following the Master's hopping sequence. Here, it is the Master that communicates with the embedded system by UART and it is the Slave that communicates with the PC system. If bluetooth devices complete successfully the ACL link, each device is able to transfer the data. Then, The slave transmit the ECU initialization message the master and the application program execute the ECU initialization after confirming the received message by bluetooth.

Fig.9 shows the "*Fast initialization*" and the "*Start Communication Service*" between the ECU and a embedded system(or Tester). The initialization of the ECU used the "*Fast initialization*" way that transmits a Wake up Patten(WnP) with the low level of the 25ms and the high level of the 25ms after the idle time with the high level of the 300ms on K-line. After ECU is initialized, the embedded system transmits the first bit of the "*StartCommunication Service*" after a time of a Wake up Pattern following the first falling edge. After that time, ECU will transmit the "*StartCommunication Positive Response*" within P2 time if it successfully was initialized. After this process, can request the other services within P3. The default value of P2 and P3, the timing parameter is each 25ms and 50ms.

Fig.10 shows the measured waveform in the real circuit for this process.

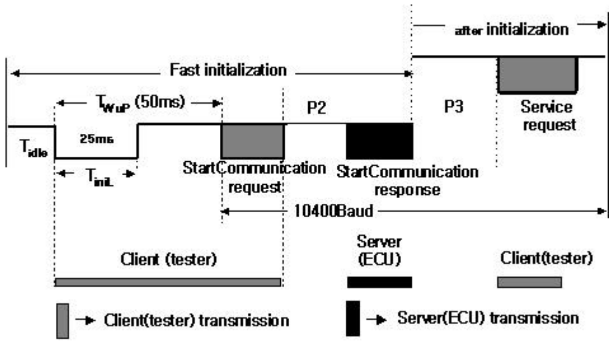


Fig. 9 Fast initialization

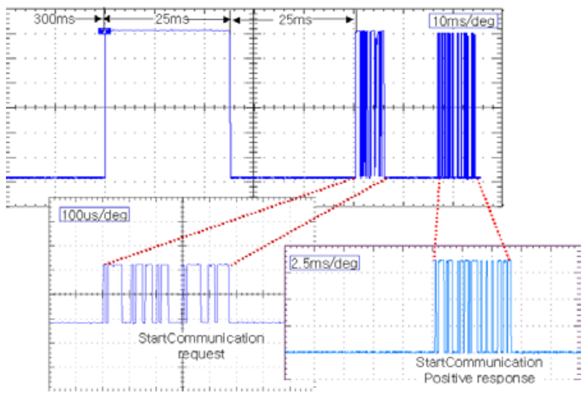
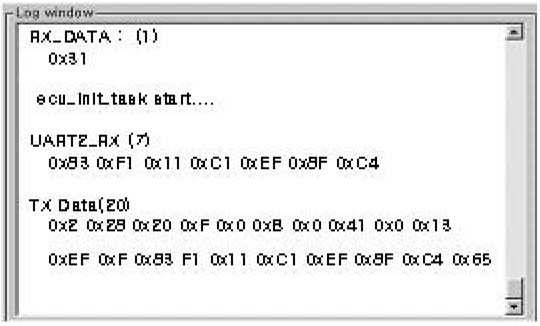


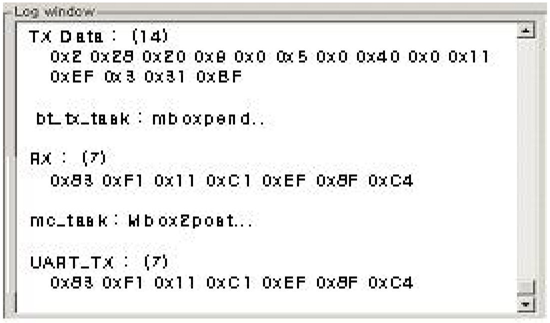
Fig.10 A waveform of the Fast initialization, the Start Communication request, and the Positive response

Fig.11 shows the log window in the PC that the packets and datum are transferred between master and slave by bluetooth. Both TX_Data and RX_Data are the packets transferred by bluetooth and Both UART_TX and UART2_RX are the data transferred between embedded system and ECU. If any service isn't executed within P3 timing parameter after the ECU is initialized, the ECU must be initialized to execute the any service again.

ECU stored the trouble codes and status in the memory when the fault was happen in the vehicle. This trouble information can obtain through the "*ReadDTCbyStatus*" service. Table 2 shows the positive response from the experimental ECU when the "*ReadDTCbyStatus*" service was requested. The 5th byte is a number of the happened troubles. The troubles to the number of 7 happened in the experimental ECU. The trouble information consists of a total 3 byte; the trouble code of 2 byte and the trouble status of 1 byte. Table 3 shows the trouble codes and status of the experimental ECU.



(a) Master



(b) Slave

Fig.11 StartCommunication request message and response between master and slave

Table 2 ReadDTCbyStatus positive response for experimental ECU

Byte No.	Response (ECU→Tester)	
	Parameter	Hex value
1	Format	0x97
2	Target	0xF1
3	Source	0x11
4	Service ID	0x58
5	Number of DTC	0x07
6 ~ 26	List of DTC and Status	0x15, 0x10, 0xF4, 0x15, x11, 0xF4, 0x01, 0x20, 0xF1, x01, 0x15, 0xF1, 0x02, 0x30, xE2, 0x16, x24, 0xE2, 0x16, 0x25, 0xE2
27	Checksum	0x91

Table 3 DTC and trouble content for experimental ECU

Trouble Code	Trouble Content
P1510	Idle speed control valve circuit malfunction
P1511	Idle speed control valve circuit malfunction
P0120	Throttle position sensor malfunction
P0115	Coolant temperature sensor malfunction
P0230	Fuel pump drive circuit malfunction
P1624	Radiator fan malfunction
P1625	Air conditioner fan circuit malfunction

Fig.12 shows the display executing the "*ReadDTCbyStatus*" service by the commercial scanner. The trouble codes and status by the commercial scanner can confirm that identifying its by the developed self-diagnostic measurement system.

Fig.13 shows one example of the main panel of remote measurement system based on PC for a general driver or skilled expert. The PC software has the functions; the vehicle's register, fix recodes, self-diagnosis, and fix instruction. These functions are the advantages of the present scanner in managing the vehicle. Also, a general driver quickly can check the problem of vehicle by himself.

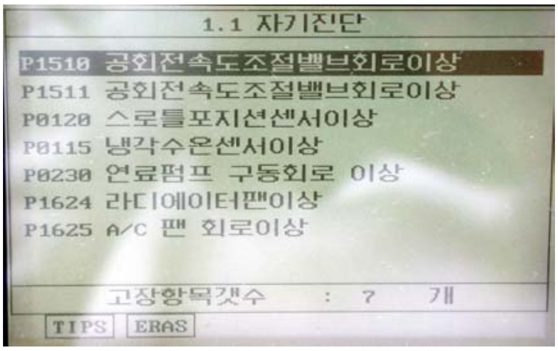


Fig. 12 Display of the self-diagnostic results on the commercial scanner

Fig. 13 One example of the main panel using bluetooth

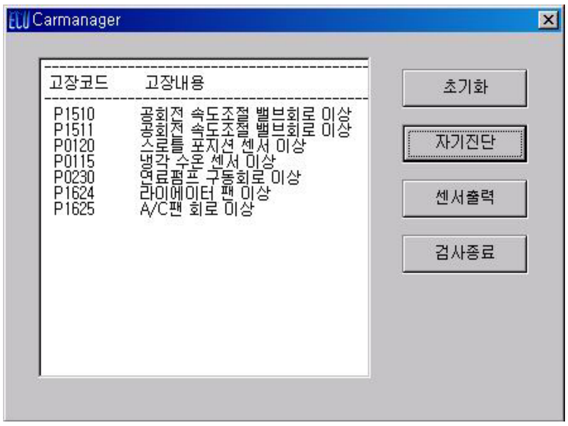


Fig. 14 One example of self-diagnostic panel using bluetooth

Fig.14 shows one example of the self-diagnostic panel of remote measurement system based on PC. The self-diagnostic codes and status identify as that in the commercial scanner tester. So, we were able to confide in the self-diagnostic system using the remote measurement by bluetooth.

5. CONCLUSIONS

In this paper, the remote measurement system using the bluetooth as one of short-range radio solutions is developed to measure the self-diagnostic signals of the vehicle's ECU. The obtained results are as follows;

1) In relation to the vehicle information in the vehicle network, the remote measurement of ECU's signals using bluetooth successfully is executed from the developed system.
2) The remote measurement system could be confided in the measured ECU's data by bluetooth as comparing with the real data of ECU through the scanner. And the possibility to develop the tester that the driver can do the self-diagnosis and the repairs by oneself.
3) If this system is set in the vehicle, the driver is able to identify the vehicle's defects and inform to a repairman or an insurance company using LAN. This will help the driver to be able to drive safely.

ACKNOWLEDGEMENT

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