

Diagnostic System for Power Products Using Automatic Recognition Technology for Multi-protocols

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ABSTRACT

Honda has adopted serial communication, CAN communication and K-Line communication as communication protocols for its power products equipped with ECUs. Capabilities for automatic recognition of these multi-protocols were examined, using the difference in communication voltages and the difference in the ECUs' product ID data. An interface unit (I/F unit) conducts analog-to-digital conversion of the input communication voltages, transfers the data to the CPU, and determines the communication protocols. A technology has been developed to automatically and precisely recognize the protocols by checking the threshold voltages and recheck for return values of the acquisition command for product ID data.

A diagnostic system with this technology has been developed to check the operation data and malfunction data of power products. The PC application software used in the system provides functions to assist in conducting precise diagnosis. The screen display is easy to use for a wide range of operators, regardless of whether it is used indoors or outdoors. Data for new power products can also be easily built in to the system.

1. Introduction

Honda power products include products that are equipped with ECUs, such as general-purpose engines⁽¹⁾, snow throwers⁽²⁾, outboard motors⁽³⁾, electrical generators, and 4-wheel scooters⁽⁴⁾. On the other hand, many power products without ECUs are also sold. At service shops that handle power products without ECUs, in many cases the service operations that are performed depend on the skills of the operators. At service shops where power products with ECUs are also handled, there is a limit to the service operations that can be performed with human skills alone.

The use of ECU diagnostic systems has become normal practice at automobile service worksites. The ECU diagnostic system for power products was first introduced in 2003 as a special system for outboard motors, to coincide with the start of sales for the BF225⁽⁵⁾ outboard motor. However, dealers that handled products other than outboard motors also wanted a diagnostic system that could properly visualize operation data and malfunction data.

Different communication protocol types are used for different power products that are equipped with ECUs. For example, general-purpose engines and snow throwers use a half duplex asynchronous communication type of serial communication, which is a unique format. Outboard motors use K-Line communication, which primarily has been used for automobile communication. Four-wheel scooters use CAN communication as a Drive by Wire (DBW) system. An ECU diagnostic system was examined that has a function for automatically recognizing multiple communication protocols in power products equipped with ECUs.

This document describes the technology in an I/F unit that has a function for automatically recognizing multiple communication protocols, and a diagnostic system that can be used at outdoor service worksites.

2. Multi-Protocol Automatic Recognition System

In previous diagnostic systems, a special I/F unit was

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used for each communication protocol. For example, a special diagnostic system was used for outboard motors, and rewriting software⁽⁶⁾ was used for general-purpose engines, with ECU diagnostics performed separately for each product.

To enhance usability, a system was developed with a common I/F unit that could connect with all these communication protocols.

2.1. Communication Protocol Automatic Recognition

Table 1 shows three different communication protocol specifications: serial communication, CAN communication, and K-Line communication. Figure 1 shows a system block diagram of an I/F unit with a function for automatically recognizing these communication protocols.

During communication protocol recognition, the CPU conducts analog-to-digital conversion of the communication voltages that are input to the I/F unit. It then compares these converted values to the thresholds to determine the communication protocols. In Fig. 1, the voltage on the side sending (T_x) to the ECU is set as V_{Tx} , and the voltage on the side receiving (R_x) from the ECU is set as V_{Rx} . The sampled values in a 1 ms cycle are set as V_{Tx_i} and V_{Rx_i} , respectively, and the feedback values for determining the communication protocols are shown in Eqs. (1) and (2), and are set as V_{Txave} and V_{Rxave} , respectively.

$$V_{Txave} = \frac{\sum_{i=1}^n V_{Tx_i}}{n} \quad (1)$$

$$V_{Rxave} = \frac{\sum_{i=1}^n V_{Rx_i}}{n} \quad (2)$$

Table 2 shows the threshold for determining each communication voltage. The system compares the

Table 1 Communication protocols

Protocol	Signal voltage level (V)	Communication speed (kbps)
Serial	$0 \leq V \leq 5.0$	9.6
CAN	$1.5 \leq V \leq 3.5$	500.0
K-Line	$0 \leq V \leq \text{Battery voltage}$	10.4

Table 2 Threshold level of communication voltage

Signal	Pin name		Communication voltage level (V)
No device	Tx	0	$V \leq 0.7$
	Rx	0	$V \leq 0.7$
Serial	Tx	$0 \leq V \leq 5.0$	$V \leq 0.7$
			$4.0 \leq V \leq 5.2$
	Rx	$0 \leq V \leq 5.0$	$V \leq 0.7$
			$4.0 \leq V \leq 5.2$
CAN	CAN_L	$1.5 \leq V \leq 3.5$	$1.4 \leq V \leq 3.6$
	CAN_H	$1.5 \leq V \leq 3.5$	$1.4 \leq V \leq 3.6$
K-Line	K-Line	$8.0 \leq V \leq 16.0$	$6.0 \leq V \leq 16.0$
	SCS	$0 \leq V \leq 5.0$	$4.0 \leq V \leq 5.2$
Error	Tx	$17.0 \leq V$	$17.0 \leq V$
	Rx	$17.0 \leq V$	$17.0 \leq V$

feedback values of the communication voltage to these thresholds to determine the communication protocol.

When the communication protocol satisfies Eqs. (3) and (4), it is determined to be CAN communication.

$$V_{Txave} \geq 1.4 \wedge V_{Txave} \leq 3.6 \quad (3)$$

$$V_{Rxave} \geq 1.4 \wedge V_{Rxave} \leq 3.6 \quad (4)$$

When it satisfies Eqs. (5) and (6), it is determined to be K-Line communication.

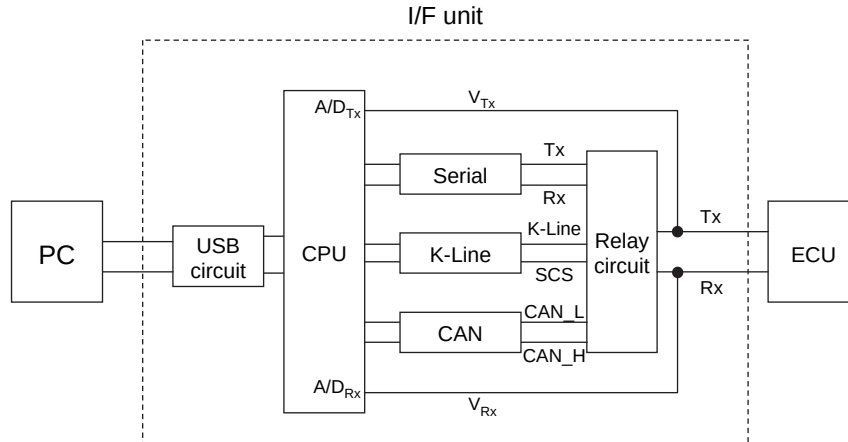


Fig. 1 I/F unit system block diagram

Table 3 Average voltage of each communication protocol

Signal	Test result voltage level (V)		Threshold voltage level (V)
Serial	V_{Txave}	0	$V \leq 0.7$
		4.8	$4.0 \leq V \leq 5.2$
	V_{Rxave}	0	$V \leq 0.7$
		4.8	$4.0 \leq V \leq 5.2$
CAN	V_{Txave}	2.5	$1.4 \leq V \leq 3.6$
	V_{Rxave}	2.5	$1.4 \leq V \leq 3.6$
K-Line	V_{Txave}	11.8	$6.0 \leq V \leq 16.0$
	V_{Rxave}	4.9	$4.0 \leq V \leq 5.2$

$$V_{Txave} \geq 6.0 \wedge V_{Txave} \leq 16.0 \quad (5)$$

$$V_{Rxave} \geq 6.0 \wedge V_{Rxave} \leq 16.0 \quad (6)$$

In serial communication, because the initial communication voltage is indefinite, the system cannot determine whether it is connected or not. If the condition in Eq. (7) is satisfied, the I/F unit provisionally determines the protocol to be serial communication and performs provisional communication. At this time, the I/F unit sends a product ID acquisition command to the ECU. If there is a response from the ECU within 5 seconds, including the retransmission, the system determines the communication protocol to be serial communication. If there is no response from the ECU within 5 seconds, the system determines that it is not connected.

$$V_{Txave} \leq 0.7 \wedge V_{Rxave} \leq 0.7 \quad (7)$$

If Eq. (8) is satisfied at this time, the system determines that there is an error in the communication voltage, and sends a voltage error generation alert to the diagnostic application software.

$$V_{Txave} \geq 17.0 \vee V_{Rxave} \geq 17.0 \quad (8)$$

After the communication protocol is determined in the CPU, the relay circuit is activated to open the communication line and establish communication with the I/F unit. After communication is established, the common product ID acquisition command for all the communication protocols is sent to the ECU from the diagnostic application software, and the ECU product ID data is acquired. This enables a recheck of whether the diagnostic application software and I/F unit have correctly recognized the communication protocol. This communication protocol automatic recognition function also continuously monitors the communication voltage during communication. The CPU determines if there are interruptions in the ECU communication line or communication voltage errors, and immediately switches to a non-connection condition.

Table 4 Pin assignment of connector

Pin No.	Serial	K-Line	CAN
1	GND	GND	GND
2	Tx	K-Line	CAN_L
3	Rx	SCS	CAN_H
4	—	12 V	—

2.2. Test Results

Table 3 shows examples of V_{Txave} and V_{Rxave} based on measured values for Eqs. (1) and (2) during the recognition for each communication protocol. It can be seen that V_{Txave} and V_{Rxave} are within the minimum and maximum thresholds. Based on these results, it was proven that when determining the communication protocol, no duplicate judgments are made for different protocols.

3. Power Products Diagnostic System

Figure 2 shows a diagram of the power products diagnostic system. The following issues were addressed when constructing this power products diagnostic system.

- (1) Integration of communication connectors
- (2) Development of diagnostic application software
- (3) Addition of new power product data

3.1. Communication Connector

A common communication connector to connect the communication unit and the power products was needed to enhance connection convenience and reduce costs. As a result, the communication connector that was installed on power products was integrated with the connector for the outboard motor ECU diagnostic system. Table 4 shows the pin layout for function assignment in each communication protocol.

3.2. Diagnostic Application Software

In ECU diagnostics, in addition to the I/F unit, diagnostic application software is needed to perform power products diagnostics using a computer. This section describes the functions of this diagnostic application software.

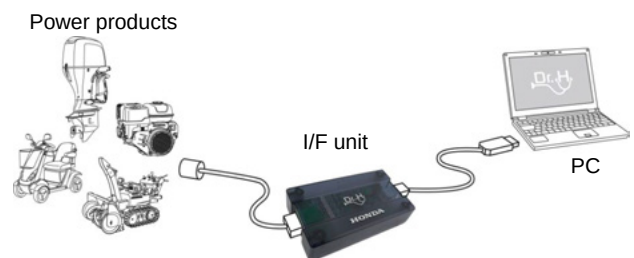


Fig. 2 Diagnostic system diagram

Table 5 Functions of application software

Screen	Detail
Data list	Checks data in real time
DTC (Data trouble code)	Checks operational errors, warnings and failures
All history	Checks history of past errors
Initial setting	Checks ECU setting information
Simple diagnostic	Chooses data and checks data automatically
Function test	Function test of single device
Graph mode	Graph and storage function
Service manual linkage	Service manual linkage
Service report function	Outputs service report

3.2.1. Diagnostic functions

The following issues needed to be addressed for the diagnostic application software to be able to retrieve ECU information and perform precise diagnostics.

- (1) Able to perform accurate diagnostic assistance
- (2) Able to quickly locate the malfunctioning location

Table 5 shows these functions and their characteristics.

“Data list”, “DTC”, “All history”, and “Initial setting” in Table 5 are functions that check the operation status and history status. “Function test” is a function that tests whether a single device that is connected to the ECU, such as a throttle motor or fuel injector, operates correctly. As shown in Fig. 3, “Graph mode” is a function that displays and saves the waveforms of data stored in the ECU. This can be used to check the instant at which the malfunction occurred.

3.2.2. Graphical User Interface (GUI) design

Different service operations for power products have different work environments, such as maintenance that is

performed outdoors. A wide range of age groups are also likely to perform the operations, so the computer screen needed to be easy to read and use.

Careful consideration was given to the coloration and brightness balance of the background and text to help achieve good visibility in sunlight and in darker environments. A friendlier GUI design was developed by creating color-coordination with good visibility over all parts of the screen, allowing use under all kinds of light conditions.

Also, to open up the tool to as many people as possible, efforts were made to create friendlier screens by carefully designing operation buttons and display text, and by representing the power products on the screen with illustrations (Fig. 4). In this way, it was hoped that operators would feel a connection with the system, which might otherwise be seen as a cold and mechanical tool.

3.3. Function for Adding New Power Product Data

Previously, whenever a power product underwent a model change or minor change, it often took a long time to develop additions to the diagnostic application software. Excel data called an “ECU data appropriation list” is used in the diagnostic application software. In this ECU data



Fig. 4 Top screen of diagnostic system



Fig. 3 Graph mode screen

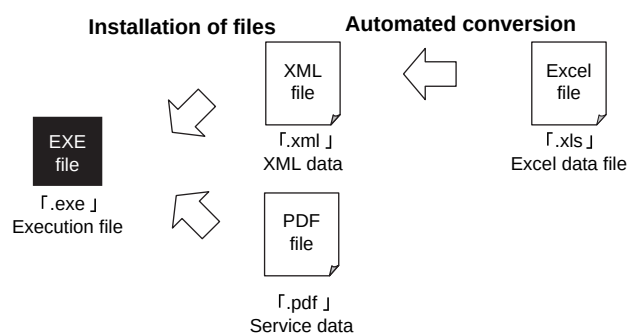


Fig. 5 File generation

appropriation list, information such as data names, physical value conversion formulas, and units are input into specific address cells. In this development, file conversion software was created that automatically converts the ECU data appropriation list from Excel data into Extensible Markup Language (XML) data.

This file conversion software enables product data to be easily added for power products undergoing a model change or minor change. Figure 5 shows the flow for adding new power products. All these flows can be performed just by a file conversion. They allow low-cost and short time-period development, even when adding new power product data.

Based on the concept of performing diagnostics for all power products, this power products diagnostic system was named “Dr. H” (symbolic of a Honda service operator who performs product diagnostics).

4. Conclusion

The following benefits will result from introducing the new power products diagnostic system that is proposed.

- (1) Enables the automatic recognition of communication protocols using the difference in communication voltages and in the ECUs’ product ID data.
- (2) A power products diagnostic system was constructed that can be connected to power products that are equipped with ECUs.
 - The communication connectors were integrated to enhance convenience when connecting to the power products diagnostic system.
 - File conversion software enables the addition of new power product data in a shorter period of time.
 - The GUI design was created by taking into account visibility, operability, and user-friendliness, to enhance its use as a work tool anywhere, by anyone.

5. References

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