Communication

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CAN Protocol Communication System with MRS Developers Studio in ATV Electric Vehicles Using SAE.J1939 Standard

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Communication

CAN Protocol Communication System with MRS Developers Studio in ATV Electric Vehicles Using SAE.J1939 Standard

Natthapon Donjaroennon [1], Suphatchakan Nuchkum [2], Wattana Nambunlue [3] and Uthen Leeton *

Abstract: The advancement of technology has led to a shift in the automotive industry from gasoline vehicles to electric vehicles. One of the key factors in modern vehicles is the communication between control devices and commands. This thesis presents a prototype of communication in the form of CAN BUS Protocol with CAN STANDARD SAE.J1939 for All-Terrain Vehicle (ATV) using MRS Developers Studio software to control the CAN Bus system. This thesis discusses the operation of communication from the assembly of the ATV, the packing of a 72 V 25Ah battery as a power source for the vehicle, the layout of the wiring system for receiving/sending communication signals for the 3 CAN Bus control boxes, and programming with MRS Developers Studio software used in communication. The communication of the vehicle in the ATV consists of receiving/sending signals of switches, headlights, left turn signal, right turn signal, brake light, emergency light, horn, forward-reverse gear, and accelerator. The results of the operation of the CAN Bus Protocol found that the CAN Bus control box has only 6 input and output pins, making the communication that has both receiving and sending signals insufficient. Therefore, starting from the CAN Bus1 control box acts as a receiver of signals from the forward-reverse gear switch sent to the output of the CAN Bus3 control box, the CAN Bus1 control box acts as a receiver of all light signals sent to the output of the CAN Bus2 control box. The signal transmission between devices will send signals through the CAN HUB line to ensure stability and minimal interference. In addition, the communication between devices from testing the operation of various switches on and off up to 1000 times found that this communication does not cause errors, making this communication reliable and stable.

Keywords: CAN bus protocol; MRS developers studio; communication in electric vehicles

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1. Introduction

The CAN Bus Protocol or Controller Area Network (CAN) is a communication protocol that supports real-time communication under high security. The CAN bus communicates using two wires, referred to as CAN High and CAN Low. When both are in idle state, they have a voltage of 2.5V. However, when data bits need to be transmitted, the voltage of CAN High increases to 3.75V, while CAN Low decreases to 1.25V, resulting in a voltage difference of 2.5V show in Figure 1. This method results in the CAN Bus Protocol being minimally disturbed by magnetic fields or any other interference, making it stable and commonly used for transmitting data to various de-vices. Therefore, it is popularly used in the communication network between Micro Controller Units (MCU).

Figure 1 shows the ISO 11898-2 standard and ISO 11898-3 standard. This thesis uses ISO 11898-2 for this standard specifies the high-speed physical media attachment of the Controller Area Network (CAN), which is a serial communication protocol that supports real-time, distributed and multiplexed control for use in road vehicles. The difference in standards is the speed of data signal transmission.

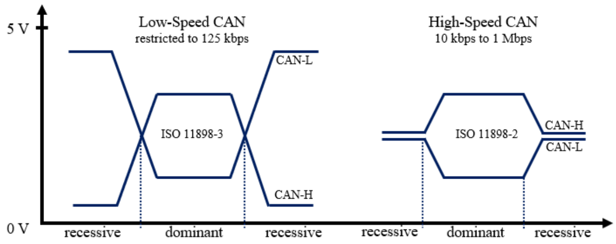

Figure 1. Low-speed signal transmission ISO 11898-3 standard High-speed signal transmission ISO 11898-2 standard (1 is recessive and 0 is dominant).

The main difference between CAN 2.0A and CAN 2.0B is indeed the identifier length. CAN 2.0A, also known as Standard CAN, uses an 11-bit identifier, while CAN 2.0B, or Extended CAN, supports both 11-bit (standard) and 29-bit (extended) identifiers. When both standard and extended frames exist on the same bus and have numerically equivalent identifiers, the standard frame will have the higher priority. This is due to the way CAN bus arbitration works: it's based on the identifier, and the lower the binary value, the higher the priority. In the case of numerically equivalent identifiers, the standard identifier is seen as having a lower binary value because the extended identifier is effectively 'padded' with additional bits. This feature allows for flexibility and complexity in device communication, making CAN bus a robust and versatile protocol for automotive and industrial applications. The standard CAN Bus 2.0B protocol shows the data storage format as shown in Figure 2.

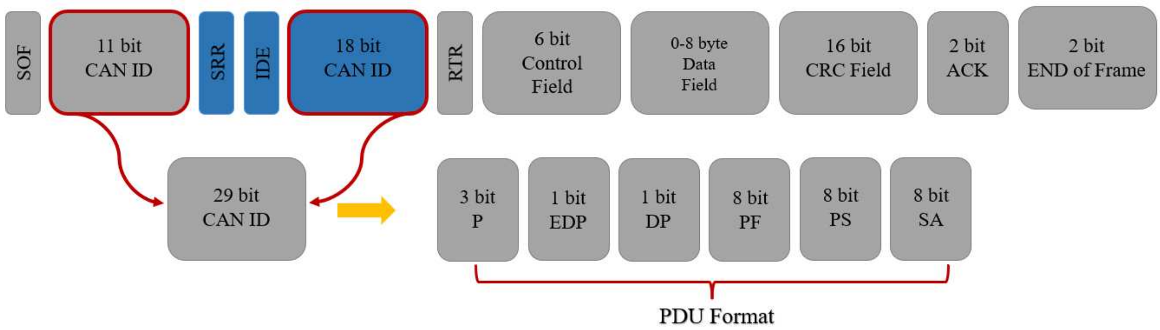

Figure 2. The standard CAN Bus 2.0B protocol.

In the modern automotive industry, the CAN Bus system is a network of electronic devices that communicate with each other using a common protocol called Controller Area Network (CAN). This system is widely used in modern cars. The CAN Bus system allows efficient communication between various electronic devices using only two bus lines, CAN-High and CAN-Low, to transmit data between modules in the car. Each module has a unique identifier and can send and receive messages on the network. In addition, the CAN Bus system provides real-time data transmission and uses a priority-based scheduling format to ensure that important messages are sent first, ensuring that all devices can access the same data at the same time. Data is transmit-ted using different electrical voltages between the two lines for receiving and transmitting data. At both ends of the line, a 120Ω resistor (called terminating resistor) is connected to reduce resistance for high drive lines and reduce noise signals. The CAN Bus system also helps reduce the complexity of wiring with fewer wires, making it easier to install and maintain the system. The CAN Bus also reduces the weight of the car and increases space for other equipment.

From the Figure 2. The dominating CAN-based higher-layer protocol for cars, trucks and busses, defined by SAE. J1939 is divided into several parts describing the physical layer, data link layer, network management, and a large number of predefined messages. SAE.J1939 or The Society of Automotive Engineers (SAE) J1939 describes a standard vehicle bus for diagnostics and communications in cars, trucks and other heavy-duty vehicles. J1939 was first released in 1994, while CAN Bus was included in 2000. With data rates up to 250 kbps. The SAE J1939 standard communication is defined in the form of PDU Format for communication in electric vehicles. The format for receiving and sending data is shown in Figure 3.

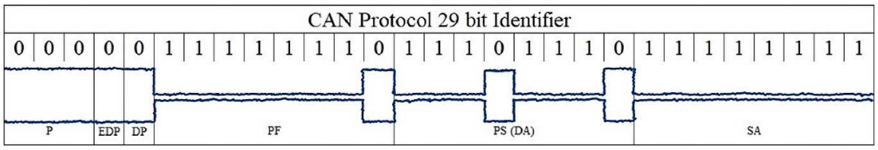

Figure 3. The SAE.J1939 standard communication is defined in the form of PDU Format.

All J1939 standards have 8 bytes of data and a standard header which has an index called Parameter Group Number (PGN) embedded in the 29 bits identifier of the message. The PGN specifies the function of the message and the associated data. J1939 attempts to define standard PGNs to cover objectives in automotive, agriculture, marine, and diverse road applications. The range of PGNs (00FF00 to 00FFFF) is reserved for proprietary use. The PGN defines data composed of a number of variables of the component Suspect Parameter Number (SPN) specified for non-repetitive data.

This thesis consists of 5 sections: Section 1 discusses the standards and importance of data transmission in the CAN Bus system. Section 2 talks about the creation of a CAN Bus 2.0B communication system in All-Terrain Vehicle (ATV) using the SAE.J1939 standard, which includes signals for turn signals, emergency lights, headlights, and a forward-backward gear control unit. Section 3 is the research methodology for the thesis, starting with the use of the SAE.J1939 standard in conjunction with the MRS Developer Studio software for controlling the ATV to operate as desired. Section 4 presents the results obtained from using the SAE.J1939 standard in conjunction with the software. After uploading the program into the CAN Bus Controller, performance tests are conducted to serve as a prototype for communication in electric vehicles (EV). This leads to the conclusion of the experiment in Section 5.

2. Elements and Communication in ATV

This section discusses the components related to the communication of ATV vehicles, the packaging of batteries for load distribution, the use of CAN Bus Controller equipment, communication between more than 2 CAN Bus Controllers, and the basics of using MRS Developer Studio software.

2.1. The overview of communication in the SAE.J1939 standard in conjunction with ATV vehicles.

The advancement of technology today has led to various forms of communication in electric vehicles, one of which is the CAN Bus protocol. This thesis focuses on the communication of an electric ATV vehicle using the SAE.J1939 standard, with the MRS Developer Studio software serving as a medium for writing and uploading programs into the CAN Bus Controller. The overview of communication in conjunction with the software is shown in Figure 4. Due to the limitation of only 6 pins of Analog and digital inputs and outputs of the control box, it is not possible to use a single control box. Therefore, additional control boxes are necessary. In addition, the writing of various standards will be shown in Table 1 in the form of PGN Group (PGN Group is the PDU Format in the path of controlling and commanding various systems in electric vehicles). For the ATV vehicle that studies the reception and transmission of data, includes Switches, Headlights, Left Turn Signal, Right Turn Signal, Brake light, Emergency light, Horn, Forward-Reverse gear and Accelerator only. Because some types of communication are copyrighted and permission must be obtained before use. Therefore, this ATV vehicle is one prototype of communication in electric vehicles.

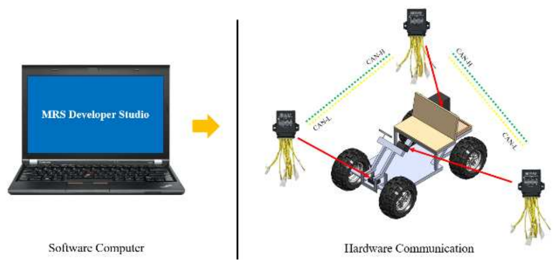

Figure 4. Overview of Communication software and hardware.

Table 1. SAE.J1939 standard for communication in electric ATV vehicles.

CAN BUS Communication	PGN	SPN	CAN ID
Switches	57344	1656	0x00E000
Headlights	65088	2350	0x00FE40
Left Turn Signal	65088	2368	0x00FE40
Right Turn Signal	65088	2370	0x00FE40
Brake light	65089	2375	0x00FE41
Emergency light	65088	2386	0x00FE40
Horn	65088	2392	0x00FE40
Forward-Reverse gear	61445	524	0x00F005
Accelerator	65247	515	0x00FEDF

*CAN ID will use in MRS Developer Studio software.

The usage table of the SAE.J1939 standard, the use of PGN, SPN, CAN ID data will be shown in Appendix.

2.2. The general structure of ATV electric vehicle.

- ATV Electric Vehicle

This thesis discusses the design of a standard SAE.J1939 communication system in a small electric ATV vehicle. The structure of the electric ATV vehicle is assembled using Solid Work software for modeling. The materials and equipment used in the assembly are shown in Table 2.

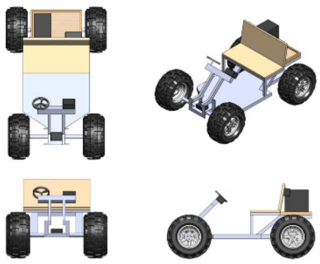

Figure 5. General structure of the Electric vehicle.

Table 2. Materials and Equipment for Communication in ATV Vehicle.

Materials and Equipment	Units
Push Button Start	1
Electric car headlights	1
Klaxon (Horn)	1
Front turn signal	2
Back turn signal	2
CAN connector line	2
CAN Controller Box	3
DC to DC Step down (72V to 12V)	1
Battery Pack 72 V (Li-ion: NMC)	1
Motor DC 1500W 60V	1

- Battery Packs

In the communication of electric ATV vehicles, it is necessary to have a power source for propulsion. The ATV uses a 60V motor for propulsion, so the energy suitable for powering the system should be greater than the electrical power of the motor. This thesis chooses to use a 72V25Ah battery as shown in Figure 6. The process of packing a battery to have a voltage of 72 V 25 Ah starts with using a lithium-ion (NMC) battery that has a voltage of 3.7 V 25 Ah. From the calculation, NMC needs 20 cells (follow in equation 1) connected in series to achieve approximately 72 V. Before packing, each cell should be balanced to have the same voltage.

Then, pack them in a container to prevent cell dispersion and short circuits. Once the battery pack is ready, connect a BMS to each cell to maintain the voltage level and prevent cell damage.

Figure 6. Battery pack and balance with BMS.

Battery Pack Shown in equation 1

$$n = \frac{V_{72V}}{V_{3.7V}} \tag{1}$$

When n is Number of battery cells
V72V is Battery Packing
V3.7V is Li-Ion (NMC) 1 Cell

- Energy control system in electric vehicles

Given that the battery pack has a voltage of 72 V, it cannot supply power to the load of devices such as light bulbs, electric accelerators, and power supply boards for controllers, etc. Therefore, a device is needed to reduce the voltage to a suitable level that does not exceed 12 V for operation. Following in Figure 7.

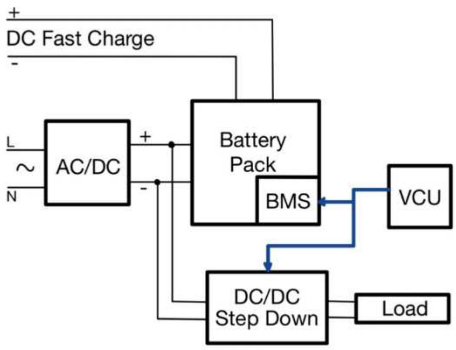

Figure 7. Energy control system.

The control unit of an electric vehicle consists of 4 parts: 1. Vehicle Control Unit (VCU), which controls the operation of the electric vehicle, similar to the ECU in an internal combustion engine vehicle, 2. Motor Control Unit (MCU), which controls the operation of the motor as commanded by the VCU, including the Inverter, 3. DC/DC Converter, which converts direct current voltage for driving the motor, charging the battery, and supplying the 12 V electrical system in the vehicle, 4. Battery Management System (BMS), which monitors and controls battery charging, discharging, temperature checking, charging status, and high-voltage battery energy usage. It also transmits important data to other systems and most importantly adjusts the electrical system of the battery to function as specified.

- CAN Bus Controller

The device used for communication is the CAN I/O model PLC 1.033.30B.00 from MRS (MRS Developers Studio). It can receive and send data through software programming. The signal is transmitted via a high-speed or low-speed connection, depending on the usage. This control system requires a 24 V power supply to operate.

From the Figure 4. This thesis will use 3 CAN Bus Controllers due to the limitation of inputs and outputs, which have only 6 pins of Analog and 8 pins of Digital shown in Figure 8. This results in a need for communication to be categorized. Specifically, the CAN Bus Control Box 1 is responsible for receiving signals composed of headlights, front turn signals, horn sounds, and electric throttle to process and send to the CAN Bus Control Box 2. At the same time, the CAN Bus Control Box 2 will receive signals composed of taillights to process and send to the CAN Bus Control Box 3. The circuit connection is shown in Figure 9.

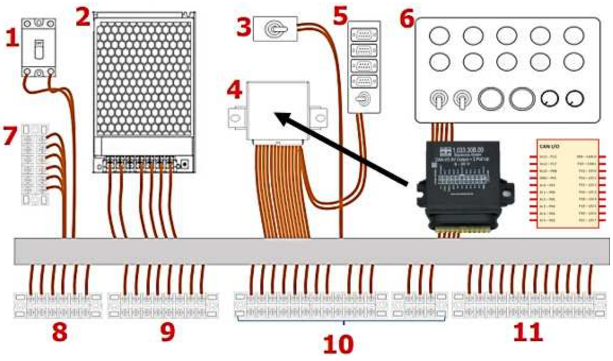

Figure 8. CAN Bus Controller.

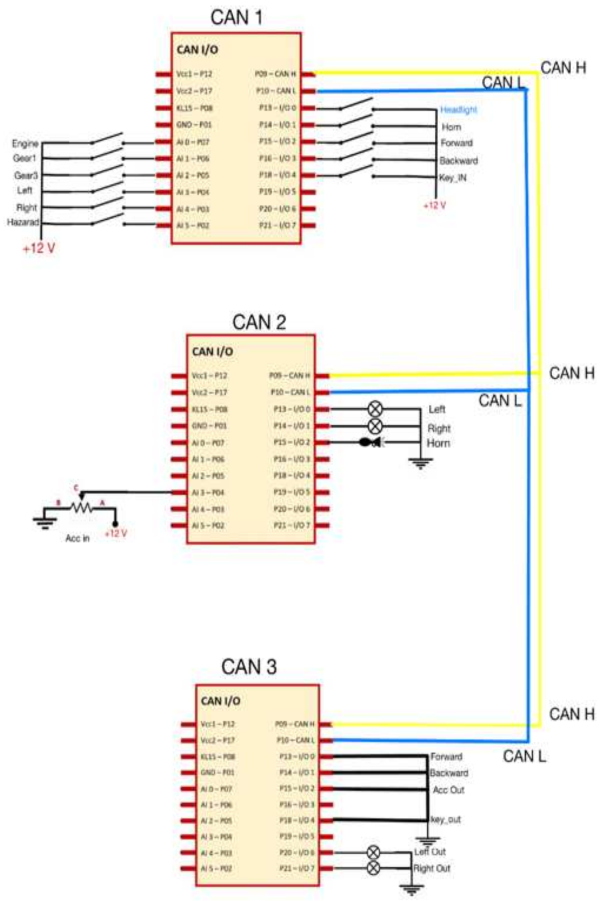

Figure 9. Communication of CAN Bus Controller. .

- CAN Hub transmission line

CAN Hub is a central device that connects more than two CAN Bus control boxes together. In the CAN network system, the CAN Hub is a device used to connect the signals of network devices together. For controllers to recognize each other or to send data to each other, they must go through this device. Currently, the CAN Hub is compared to a Switch but has higher capabilities and is considered a standard device for connecting signals in a network system. Whenever a computer within the network wants to send data, the hub will copy the data and send it to various devices within the network. This is not just for computers, but also for other devices, meaning it sends data to all. And if this data belongs to any device, that device will automatically receive it. A downside of the hub that should be noted is that when any device sends data in the network via the hub, other devices must wait for the transmission to complete. This can be compared to a One-Way road where data cannot be sent in opposite directions.

Figure 10. Can Hub transmission line.

3. Research and Communication with MRS

The procedure begins with communication between the device and the software in the CAN Bus test board in Figure 8 before it is installed on the ATV. The test involves communication of Switches, Headlights, Left Turn Signal, Right Turn Signal, Brake light, Emergency light, Horn, Forward-Reverse gear, Accelerator. In addition to communication, wiring and electric vehicle frame formation are also crucial for the results.

- MRS Developers Studio

The communication system of electric vehicles for the CAN I/O control device starts with opening the MRS Developers Studio software and creating a new project, following in Figure 11. Should input the address according to the CAN I/O box, which is modelled PLC 1.033.30B.00, select Revision as type E, and name the project as desired. If the information does not match with the CAN I/O box, it will prevent the electric vehicle from communicating.

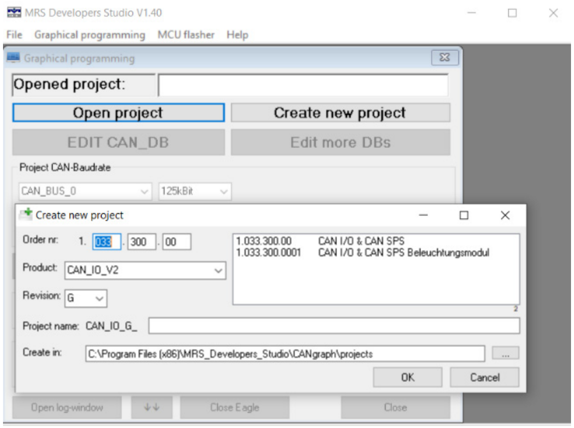

Figure 11. MRS Developer Studio Software.

When opening a project, set the numbers in the order shown in Figure 12, starting from number 1. Use it to update when writing logic in the software, number 2 is used to save the work file, numbers 3-4 are used to set up data transmission between the CAN Bus test box, number 5 is used to determine the response speed for data transmission, number 6 is used to write the control of the electric vehicle operation, number 7 shows the usage of Analog and Digital pins for write the control system, and numbers 8-9 are used to open control in programming.

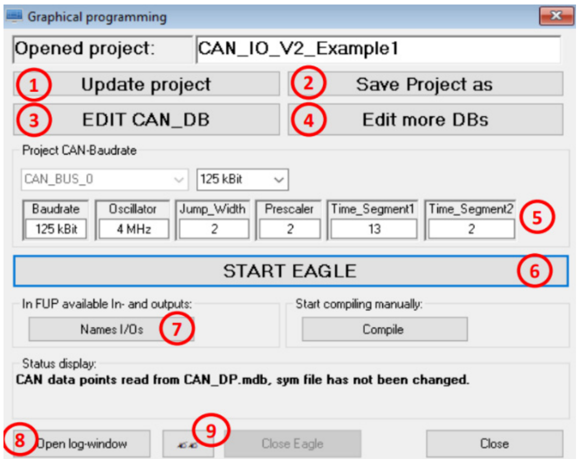

Figure 12. Graphical programming.

In the window Graphical programming click on button "EDIT CAN_DB" (Number 3 from Figure. 9) to show the definitions of CAN block and CAN data points, EDIT CAN_DB is shown in Figure 13.

CAN-block is a CAN frame which is defined by a 11 or 29 (extended) identifier, by a name and by a data content from 0 to 8 bytes. CAN-data point is a variable inside a CAN-block, which is defined by a number of bits within the 8 Bytes array. It is possible to have multiple CAN-data points within the same CAN-block as long as it has bits to be attributed.

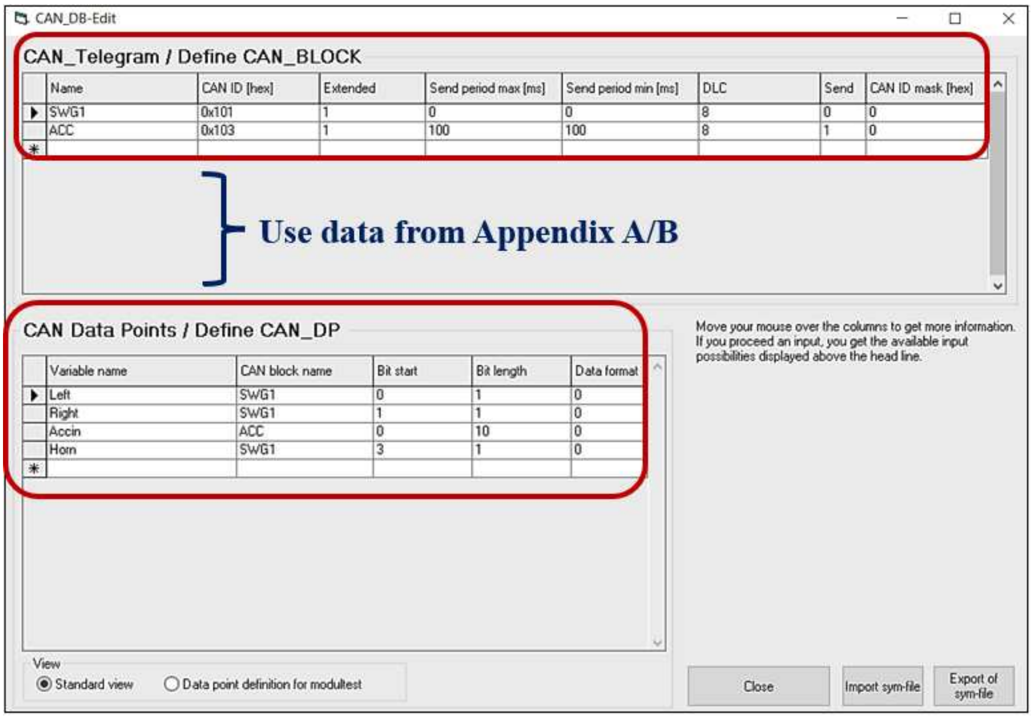

Figure 13. Setting up communication in ATV devices (Information from Appendix A/B).

From Figure 13, that is indicated that variables need to be set for the transmission of data between devices. The method for setting various parameters is shown in Table 3, CAN-block definition and Table 4. CAN-data definition.

Table 3. CAN-block definition.

Header	Description
Name	Name of the CAN-Block
CAN ID [hex]	CAN-Identifier from CAN-Block in [hex]
Extended	0 is 11 bits identifier, 1 is 29 bits identifier

Send period max	Time of send period max
Send period min	Time of send period min
Data length	Length of the CAN frame data in byte
Send	0 is CAN-Block received the CAN bus 1 is CAN-Block send to the CAN bus
CAN ID mask	When you want to listen to variable CAN ID information. (EX: 0x10F, 0x100)

*Data can use from Appendix A and Appendix B.

Table 4. CAN-data definition.

Header	**Description**
Variable name	Name of the data point
CAN block name	Definition of linked CAN-block (Write down in which CAN-block the variable is to be found)
Bit start	0 to 63, start position of the data into the CAN frame data area
Bit length	Length of the information in bits

*Data can use from Appendix A-B.

From Figure 12. “Graphical programming” by clicking "Edit more DBs" a new window is opened to specify the settings of all I/O of the module. You can set the digital I/O, analog inputs, PWM outputs and the lists for EEPROM index and user variable index shown in Figure 14. (*use A&D variables in the control design as defined by the program only).

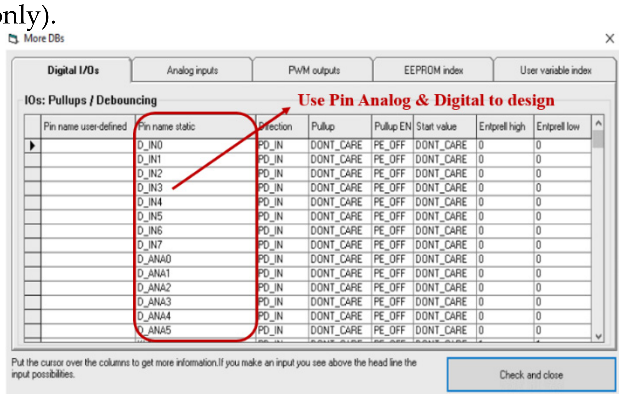

Figure 14. Variables used to assist in writing A&D pins.

When you have set the variables as needed, for this thesis, we will write a diagram related to controlling the switches, headlights, left turn signal, right turn signal, brake light, emergency light, horn, forward-reverse gear, and accelerator. The entire system is shown in Figures 15–17.

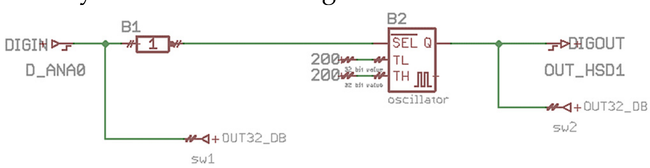

Figure 15. Writing a program for signal lights.

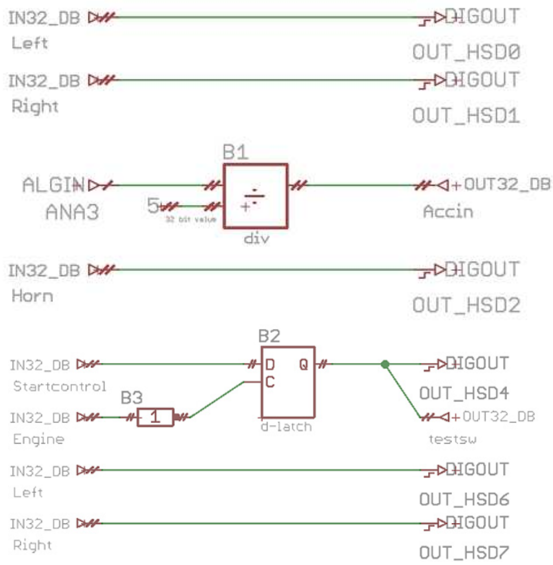

Figure 16. Writing a program for horn, engine start, other light.

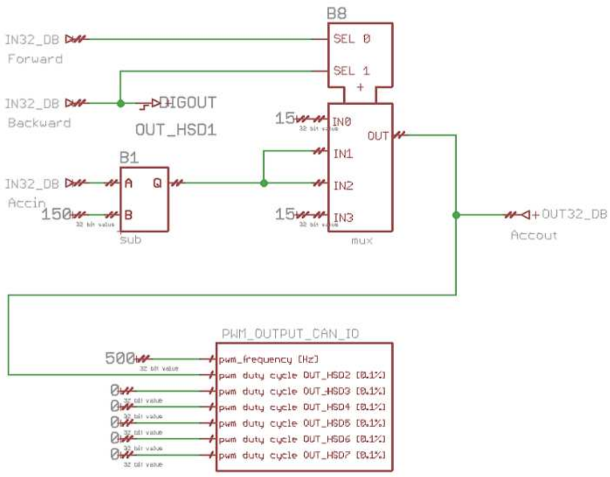

Figure 17. Writing a program for forward-reverse gear and accelerator.

- The Construction of Mechanical Structures

After initial software testing, the next step is to shape the mechanical structure of the electric vehicle. This article will assemble the CAN I/O test suite of all three devices onto the electric vehicle and upload various operational diagrams to complete it. The simple structure of an electric vehicle is shown in Figure 18.

Figure 18. Mechanical Structures of electric vehicle.

4. Results

The results from the CAN Bus communication with the SAE.J1939 standard in the ATV electric vehicles were put into the CAN Bus Test Box, which includes switches, headlights, left turn signal, right turn signal, brake light, emergency light, horn, forward- reverse gear and accelerator. CAN Bus Test Box found that the communication was responsive and stable. This is because the researchers used high-speed communication with a resistance value of 120Ω in parallel with the CANH-CANL signal line as shown in Figure 19. In addition, when it was found that the communication results were satisfactory, they were uploaded to the electric ATV. The components of various structures are shown in Figure 19. It was tested for performance and lifespan in operation by testing the opening and closing of the said equipment up to 1000 times as shown in the test results table 5. This is to be a prototype of one communication standard for EV in the future. In addition to the results of the tests on the CAN Bus Test Box, the researchers also uploaded the communication to the ATV electric vehicle as shown in Table 6.

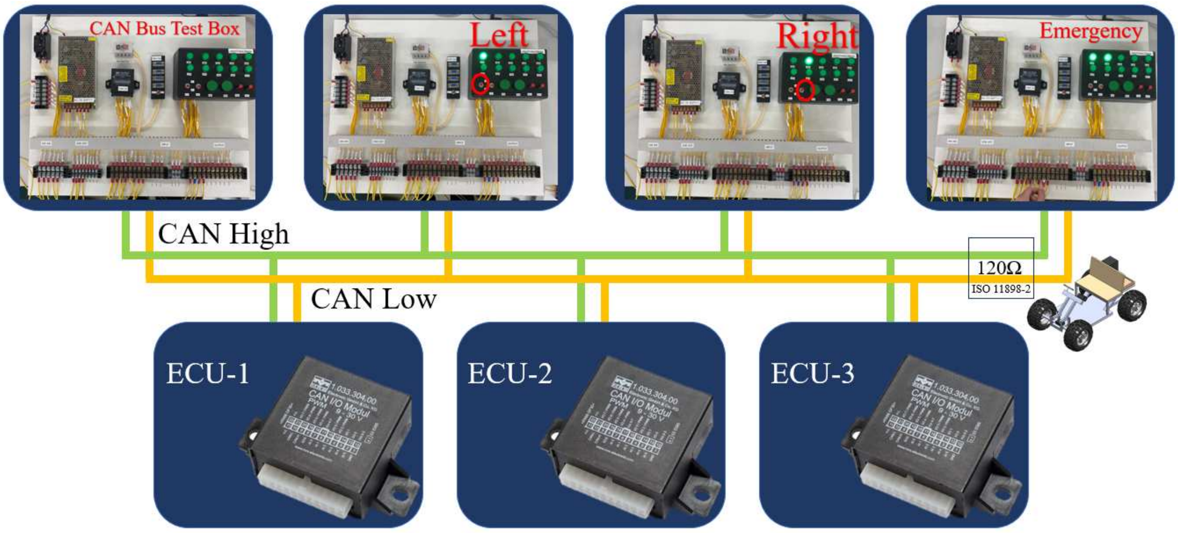

Figure 19. Can Bus communication in ATV electric vehicle.

Table 5. Testing communication of the CAN Bus system.

Testing CAN Bus communication	Testing (Counts)		
	1	100	1000
Switches	✓	✓	✓
Headlights	✓	✓	✓
Turn signal	✓	✓	✓
Brake light	✓	✓	✓
Emergency light	✓	✓	✓
Horn	✓	✓	✓
Forward-Reverse gear	✓	✓	✓
Electric Accelerator	✓	✓	✓

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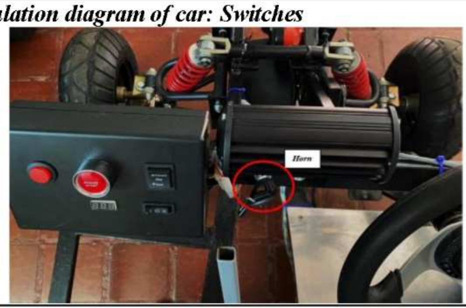
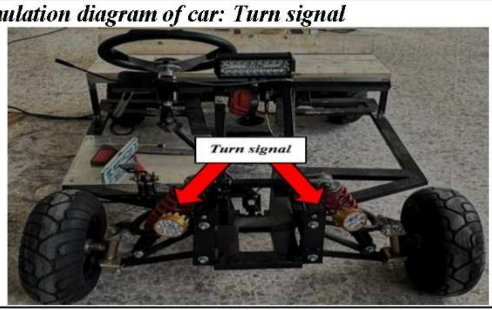
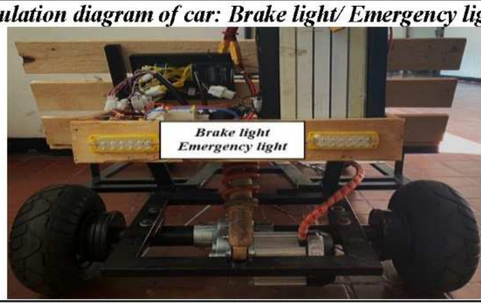
Table 6. Testing communication in ATV.

- Simulation diagram of car: Horn 	***- Simulation diagram of car: Electric Accelerator*** 
- Simulation diagram of car: Forward-Reverse gear 	***- Controller Box/wiring*** 
- Simulation diagram of car: Switches 	***- Simulation diagram of car: Turn signal*** 
- Simulation diagram of car: Headlights 	***- Simulation diagram of car: Brake light/ Emergency light*** 

Cost of electricity per battery charge

-The electrical energy of the battery can be found from equation (2)

$$Wh = V \times Ah \tag{2}$$

-The unit of electrical energy usage can be found from equation (3)

$$Unit = \frac{Wh}{1000} \tag{3}$$

-Calculating the cost of electricity in Thailand can be found from equation (4)

$$price = Unit \times 3.99 \frac{THB}{Unit} \tag{4}$$

From the above equation, calculating the cost for charging a 72 V 25 Ah battery, substituting the given parameters, find that the energy used to charge the battery 100% is 1800 Wh, equivalent to 1.8 units. Therefore, the cost of electricity for charging is 7.182 baht per charge.

From Figure 6, evident that the battery pack, which includes a JIKONG BMS model, allows the user to check the voltage, resistance values of each cell, and the battery pack's charging current through an

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application. In addition to this, it also enables the user to monitor the temperature status. The different statuses are displayed as shown in Figure 20.

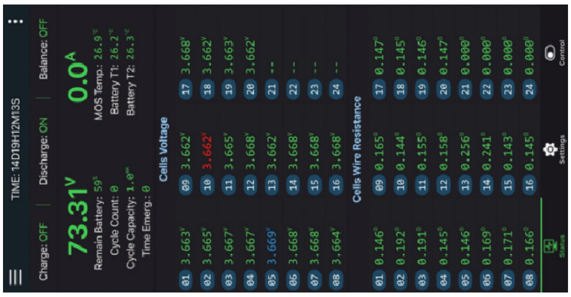

Figure 20. Parameter of Battery Pack.

5. Conclusion

The results from the communication of the thesis "CAN Protocol Communication System with MRS Developers Studio in ATV Electric Vehicles" using the SAE.J1939 standard found that the communication testing of switches, headlights, left turn signal, right turn signal, brake light, emergency light, horn, forward-reverse gear, and accelerator can receive and send signals through the CAN Bus Controller in real-time. Therefore, the SAE.J1939 standard is suitable and is one of the standards for electric vehicles that the examiner can modify the MRS Developer Studio program command set when there is a communication error between devices. This is because the SAE.J1939 standard has defined the format of the protocol. The researcher must choose to use according to the standard set. In addition, the communication between devices from testing the operation of various switches on and off up to 1000 times found that this communication does not cause errors, making this communication reliable and stable. However, the disadvantage of this standard is that it requires permission to use the standard because the use of this communication is copyrighted. However, if anyone wants to study this communication standard, they can contact the researcher or the university to use it as a guideline for one form of communication in the future.

Acknowledgment: The simulation thesis for CAN Protocol Communication System with MRS Developers would like to thank the Suranaree University of Technology, Faculty of Engineering for their assistance in terms of budget and equipment for the thesis, as well as advice and close monitoring of thesis.

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Appendix A

Parameter Group Number (PGN)

SAE J1939-71 - Revised MAR2011 - 925 -

(R) PGN 57344 Cab Message 1 ***CM1***

Message containing parameters originating from the vehicle cab.

Transmission Repetition Rate:	1 s
Data Length:	8
Extended Data Page:	0
Data Page:	0
PDU Format:	224
PDU Specific:	DA PGN Supporting Information:
Default Priority:	6
Parameter Group Number:	57344 (0x00E000)

Start Position	Length	Parameter Name	SPN
1	1 byte	Requested Percent Fan Speed	986
2-3	2 bytes	Cab Interior Temperature Command	1691
4.1	2 bits	Auxiliary Heater Coolant Pump Request	1684
4.3	2 bits	Battery Main Switch Hold Request	1682
4.5	2 bits	Operator Seat Direction Switch	1714
4.7	2 bits	Seat Belt Switch	1856
5.1	2 bits	Park Brake Command	5630
5.3	2 bits	Vehicle Limiting Speed Governor Decrement Switch	1655
5.5	2 bits	Vehicle Limiting Speed Governor Increment Switch	1654
5.7	2 bits	Vehicle Limiting Speed Governor Enable Switch	1653
6.1	2 bits	Diesel Particulate Filter Regeneration Inhibit Switch	3695
6.3	2 bits	Diesel Particulate Filter Regeneration Force Switch	3696
6.5	2 bits	Automatic Gear Shifting Enable Switch	1666
6.7	2 bits	Engine Automatic Start Enable Switch	1656
7.1	4 bits	Auxiliary Heater Mode Request	1683
7.5	2 bits	Request Engine Zone Heating	1685
7.7	2 bits	Request Cab Zone Heating	1686
8	1 byte	Selected Maximum Vehicle Speed Limit	2596

Figure A1. Example of SAE.J1939 PGN 65098 Electroic Transmission Controller 7 standard.

SAE J1939-71 - Revised MAR2011 - 1062 -

PGN 65088 Lighting Data ***LD***

This lighting message is a response to the request for lighting data in the lighting command message. Each lighting controller on the tractor and attached implements must transmit this message to the Tractor ECU when requested. The tractor will use this information to determine which lighting systems are functioning. Lighting controllers that have lamp sensing capability will also report failed light bulbs. This is a legal requirement in many areas.

See PGN 65089 for the lighting command message.

Transmission Repetition Rate:	As requested.
Data Length:	8
Extended Data Page:	0
Data Page:	0
PDU Format:	254
PDU Specific:	64 PGN Supporting Information:
Default Priority:	6
Parameter Group Number:	65088 (0x00FE40)

Start Position	Length	Parameter Name	SPN
1.1	2 bits	Running Light	2404
1.3	2 bits	Alternate Beam Head Light Data	2352
1.5	2 bits	Low Beam Head Light Data	2350
1.7	2 bits	High Beam Head Light Data	2348
2.1	2 bits	Tractor Front Fog Lights	2388
2.3	2 bits	Rotating Beacon Light	2386
2.5	2 bits	Right Turn Signal Lights	2370
2.7	2 bits	Left Turn Signal Lights	2368
3.1	2 bits	Back Up Light and Alarm Horn	2392
3.3	2 bits	Center Stop Light	2376
3.5	2 bits	Right Stop Light	2374
3.7	2 bits	Left Stop Light	2372
4.1	2 bits	Implement Clearance Light	2384
4.3	2 bits	Tractor Clearance Light	2382
4.5	2 bits	Implement Marker Light	2380

Figure A2. Example of SAE.J1939 PGN 65088 Lighting Data standard.

SAE J1939-71 - Revised MAR2011 - 929 -

PGN 61445 Electronic Transmission Controller 2 ETC2

Transmission Repetition Rate:	100 ms
Data Length:	8
Extended Data Page:	0
Data Page:	0
PDU Format:	240
PDU Specific:	5 PGN Supporting Information:
Default Priority:	6
Parameter Group Number:	61445 (0x00F005)

Start Position	Length	Parameter Name	SPN
1	1 byte	Transmission Selected Gear	524
2-3	2 bytes	Transmission Actual Gear Ratio	526
4	1 byte	Transmission Current Gear	523
5-6	2 bytes	Transmission Requested Range	162
7-8	2 bytes	Transmission Current Range	163

Figure A3. Example of SAE.J1939 PGN 61445 Electronic Transmission Controller 2 standard.

SAE J1939-71 - Revised MAR2011 - 1111 -

PGN 65247 Electronic Engine Controller 3 EEC3

Transmission Repetition Rate:	250 msec (preferred) or Engine Speed Dependent (if required by application)
Data Length:	8
Extended Data Page:	0
Data Page:	0
PDU Format:	254
PDU Specific:	223 PGN Supporting Information:
Default Priority:	6
Parameter Group Number:	65247 (0x00FEDF)

Start Position	Length	Parameter Name	SPN
1	1 byte	Nominal Friction - Percent Torque	514
2-3	2 bytes	Engine's Desired Operating Speed	515
4	1 byte	Engine's Desired Operating Speed Asymmetry Adjustment	519
5	1 byte	Estimated Engine Parasitic Losses - Percent Torque	2978
6-7	2 bytes	Aftertreatment 1 Exhaust Gas Mass Flow	3236
8.1	2 bits	Aftertreatment 1 Intake Dew Point	3237
8.3	2 bits	Aftertreatment 1 Exhaust Dew Point	3238
8.5	2 bits	Aftertreatment 2 Intake Dew Point	3239
8.7	2 bits	Aftertreatment 2 Exhaust Dew Point	3240

Figure A4. Example of SAE.J1939 PGN 61445 Electronic Transmission Controller 2 standard.

Appendix B

SPN Data Communication and Control

SPN 1656 Engine Automatic Start Enable Switch

Switch signal which enables the idle management system to be enabled. When this system is enabled with the engine in an idle mode and safe operating conditions existing, then the engine may be started or stopped automatically.

00 - Switch in the off state
01 - Switch in the on state
10 - Error
11 - Not available

Data Length:	2 bits	
Resolution:	4 states/2 bit, 0 offset	
Data Range:	0 to 3	Operational Range: same as data range
Type:	Measured	
Supporting Information:		
PGN reference:	57344	

Figure A5. Engine Automatic Start Enable Switch.

SPN 2350 Low Beam Head Light Data

This parameter provides measured data from the tractor low beam head light lamps.

00 De-activated
01 Activated
10 Fault Detected
11 Not Available

Data Length:	2 bits	
Resolution:	4 states/2 bit, 0 offset	
Data Range:	0 to 3	Operational Range: same as data range
Type:	Measured	
Supporting Information:		
PGN reference:	65088	

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Figure A6. Low Beam Head Light Data.

SPN 2350 ***Low Beam Head Light Data***

This parameter provides measured data from the tractor low beam head light lamps.

00 De-activated
01 Activated
10 Fault Detected
11 Not Available

Data Length:	2 bits	
Resolution:	4 states/2 bit, 0 offset	
Data Range:	0 to 3	Operational Range: same as data range
Type:	Measured	
Supporting Information:		
PGN reference:	65088	

Figure A7. Left Turn Signal Lights.

SPN 2370 ***Right Turn Signal Lights***

This parameter provides measured data from the tractor and attached implement right turn signal lights.

00 De-activated
01 Activated
10 Fault Detected
11 Not Available

Data Length:	2 bits	
Resolution:	4 states/2 bit, 0 offset	
Data Range:	0 to 3	Operational Range: same as data range
Type:	Measured	
Supporting Information:		
PGN reference:	65088	

Figure A8. Right Turn Signal Lights.

SPN 2375 ***Center Stop Light Command***

Command to activate or de-activate the tractor and implement center stop light

00 De-activate
01 Activate
10 Reserved
11 Don't Care

Data Length:	2 bits	
Resolution:	4 states/2 bit, 0 offset	
Data Range:	0 to 3	Operational Range: same as data range
Type:	Status	
Supporting Information:		
PGN reference:	65089	

Figure A9. Center Stop Light Command.

SPN 2386 ***Rotating Beacon Light***

This parameter provides measured data from the beacon light on tractor or attached implements.

00 De-activated
01 Activated
10 Fault Detected
11 Not Available

Data Length:	2 bits	
Resolution:	4 states/2 bit, 0 offset	
Data Range:	0 to 3	Operational Range: same as data range
Type:	Measured	
Supporting Information:		
PGN reference:	65088	

Figure A10. Rotating Beacon Light.

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SPN 2392 ***Back Up Light and Alarm Horn***

This parameter provides measured data from the back up lights and/ or associated alarm.

00 De-activated
01 Activated
10 Fault Detected
11 Not Available

Data Length:	2 bits	
Resolution:	4 states/2 bit, 0 offset	
Data Range:	0 to 3	Operational Range: same as data range
Type:	Measured	
Supporting Information:		
PGN reference:	65088	

Figure A11. Back Up Light and Alarm Horn.

SPN 515 ***Engine's Desired Operating Speed***

An indication by the engine of the optimal operating speed of the engine for the current existing conditions. These conditions may include the torque generated to accommodate powertrain demands from the operator (via the accelerator pedal), cruise control, road speed limit governors, or ASR. Dynamic commands from functions such as smoke control or shift control are excluded from this calculation.

Data Length:	2 bytes	
Resolution:	0.125 rpm/bit, 0 offset	
Data Range:	0 to 8,031.875 rpm	Operational Range: (upper byte resolution = 32 rpm/bit)
Type:	Status	
Supporting Information:		
PGN reference:	65247	

Figure A12. Engine’s Desired Operating Speed.

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