# Installation

1(1)

Electrical Interface Specification Marine engines D9, D13, D16 EMS

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### **General Information**

This document describes how Volvo Penta marine engines equipped with the EMS 2.0 and EMS 2.2 control system are controlled using the OEM CAN bus interface.

The intention is to provide vehicle and control module manufacturers with the information necessary for compatibility with the EMS and properly implement data-link-based vehicle functions.

#### **OEM control system**

OEM designed control systems must apply SAE J1939 standards with additional Volvo Penta proprietary messages.

#### **IMPORTANT!**

If non-Volvo Penta equipment is connected to the communication busses, there is always a risk that the safety of the system is jeopardized.

#### **Related Documents**

- SAE J1939 International automotive guidelines
- ISO 15765 Diagnostics on Controller Area Networks

#### Abbreviations

- BB1 = CAN J1939 Backbone 1 250 kbit
- DM1 = Diagnostic Message
- DTC = Diagnostic Trouble Code
- EMS = Engine Management System
- FMI = Failure Mode Identifier
- MID = Message Identifier Description
- N/A = Not Available
- NC = Normally Closed
- NO = Normally Open
- NVM = Non Volatile Memory
- OEM = Original Equipment Manufacturer
- PGN = Parameter Group Number
- PM = Power Module
- Rx = Receive
- SA = Source Address
- SPN = Suspect Parameter Number
- Tx = Transmit
- VP = Volvo Proprietary

## **Engine control interface**

### CAN bus interface



#### **OEM control system**

Volvo Penta marine engines are controlled via a CAN bus interface using SAE J1939.

OEM designed control systems must apply to SAE J1939 standards with additional Volvo proprietary messages using Data bus links SAE J1708 / J1587.

- 1 Control system
- 2 8-pin engine connector
- 3 6-pin diagnostic connector
- 4 Aftermarket tools
- 5 EMS
- 6 Power module



CAN communication overview solutions.

### **OEM** interface

#### **Electrical interface**

#### **Connector A**

| Engine 8-pin Deutsch connector |                   |  |  |
|--------------------------------|-------------------|--|--|
| Pin                            | Description       |  |  |
| 1                              | BB1 CAN H / J1939 |  |  |
| 2                              | BB1 CAN L / J1939 |  |  |
| 3                              | Battery –         |  |  |
| 4                              | Battery +         |  |  |
| 5                              | Ignition          |  |  |
| 6                              | N/A               |  |  |
| 7                              | J1708 A / J1587   |  |  |
| 8                              | J1708 B / J1587   |  |  |



OEM machine harness female pin connector  ${\bf A}$  and  ${\bf B}.$ 

#### **Connector B**

Safety system interface (Optional)

| Engine 8-pin Deutsch connector |                                |  |  |
|--------------------------------|--------------------------------|--|--|
| Pin                            | Description                    |  |  |
| 1                              | Overspeed sensor –             |  |  |
| 2                              | Overspeed sensor +             |  |  |
| 3                              | Common 0V, battery –           |  |  |
| 4                              | + 24V supply                   |  |  |
| 5                              | Shutdown activation relay coil |  |  |
| 6                              | Coolant temperature switch     |  |  |
| 7                              | Gear oil pressure switch       |  |  |
| 8                              | Oil pressure switch            |  |  |



Secondary battery interface female pin connector



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External stop interface female pin connector

#### **Connection for secondary battery**

| Engine 2-pin Deutsch connector |                       |  |  |  |
|--------------------------------|-----------------------|--|--|--|
| Pin Description                |                       |  |  |  |
| 1                              | Battery + (fused 16A) |  |  |  |
| 2                              | Battery –             |  |  |  |

#### **External stop interface (Optional)**

Engine 2-pin Deutsch connector

**D9** and **D16** engines: NO (normally open). **D13** can be ordered NO or NC (normally closed).

**NO**: External stop is triggered by the pins closure.

NC: External stop is triggered by opening of the circuit.



### D9 engine connectors

- 1 Connector B
- 2 Connector A
- 3 External stop switch
- 4 Secondary battery
- 5 Diagnosis (VODIA connections)



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D9





- 1 Connector B
- 2 Connector A
- 3 External stop switch
- 4 Secondary battery
- 5 Diagnosis (VODIA connections)





### D16 engine connectors

- 1 Connector B
- 2 Connector A
- 3 External stop switch
- 4 Secondary battery
- 5 Diagnosis (VODIA connections)



D16

### **CAN** bus termination



CAN bus termination

- A EMS
- B CAN device (No termination)
- C OEM CAN device

#### **Requirement for BB1**

To avoid signal reflection interference on the CAN bus,  $120\Omega$  resistors must be provided at each end of the network. Termination should be done at the nodes farthest away.

The EMS has built-in terminations.

### Source addresses

#### Applies to PEA2 electrical architecture

Refer to table below for used source addresses:

|                     | BB1 |      |  |
|---------------------|-----|------|--|
|                     | dec | hex  |  |
| EMS (Engine)        | 0   | 00 h |  |
| TECU (Transmission) | 3   | 03 h |  |
| OEM controller      | 17  | 11 h |  |
| ВВМ                 | 230 | E6 h |  |

### **Power-up sequence**

To power up the EMS, the ignition pin in the engine connector must be connected to battery + (system voltage). The EMS will then activate the Power Module, acting as a main relay, and hold the power until the power-down sequence is finished.

The engine management system will power up within one second of ignition being switched on.

#### **Bus interface**

Associated input:

OEM interface connector pin 5 – ignition.

### Start

A start request is addressed by the 'Start request' signal on CAN. The engine will then start to crank and continue to do so until one of the following conditions become true:

- The engine speed exceeds a stated limit.
- The start signal goes inactive.
- A stop request is simultaneously active.
- The engine does not start.
- Starter motor overheat protection goes active.
- Low battery charge level.

#### **Bus interface**

Associated signals:

BB1: Rx: VP70 'Start request' Tx: EEC1 'Engine starter mode'

### Stop

There are two different ways to request engine stop:

#### 1. Stop request on CAN

The 'Stop request' signal is sent on CAN in the VP70 message and results in instant engine stop. This is the standard method to initiate engine stop.

#### 2. External stop interface

For D9 and D16 engines, Normally Open are default: External stop is triggered by the pins closure.

On D13 this can be set as Normally Open or Normally Closed using the aftermarket tool (VODIA).

#### **Bus interface**

Associated signals:

BB1: Rx: VP70 'Stop request'

### **Power-down sequence**

In the standard configuration, where 'Ignition off stops engine' is set to FALSE, the engine must be stopped before Ignition off will start the power-down sequence. If the 'Ignition off stops engine' option is selected, and the ignition is turned off, the engine will be stopped and then the system will initiate power down.

#### **EMS** power down

The EMS has a main relay self-hold function to ensure that data is stored correctly in the memory before it powers down.

The duration of the EMS power-down sequence is up to 10 seconds. Do not switch off the battery until this sequence is done.

#### **Bus interface**

Associated input: OEM interface connector pin 5 – ignition.

Associated signals: BB1: Rx: VP71 'Engine power down ack'

### **Speed control**

There are two ways of controlling the engine speed:

- 1 'Accelerator pedal position' in the CAN message VP70.
- 2 Speed control mode in TSC1.

#### Source selector

On Variable speed engines, 'Idle speed select' can be used as 'limp home' in the event of faulty pedal.



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Schematic overview of speed control selection.

- 1 Pedal evaluation
- 2 TSC1 evaluation speed control
- 3 Pedal target engine speed
- 4 Target engine speed/torque
- 5 Source selector

#### **Pedal evaluation**

Pedal evaluation is primarily through Volvo Proprietary message VP70 received on the BB1 CAN link.

If no valid VP70 messages are received, engine speed will be set to idle speed.

Pedal evaluation considers one signal in the VP70 message: 'Accelerator pedal position'

#### Variable speed

The 'Accelerator pedal position' signal is interpreted as a 0-100% request where 0% means idle speed and 100% equals maximum engine speed. In the case of a pedal signal fault the engine will go to idle speed. When all pedal signal requirements are fulfilled again, the pedal signal will be considered valid only after a valid zero (0%) pedal demand.

The VP70 pedal request will also be overridden if an external request is received in a TSC1 CAN message.

#### Genset

On Genset applications there is a specific engine speed controller in order to synchronize and perform load sharing. A 50% 'Accelerator pedal counter' demand corresponds to a rated nominal speed of 1500 or 1800 rpm.

When controlling the engine using the VP70 message, it is possible to adjust the speed  $\pm 90$  rpm by accelerator position 0-100%.

Faulty accelerator pedal signals will result in a frozen pedal demand value. Whatever value the accelerator pedal position signal had prior to the pedal signals becoming faulty, will be the pedal demand input to the engine.

When all pedal signal requirements are fulfilled again, a new pedal demand value can be considered by the engine.

The VP70 pedal request will also be overridden if an external request is received in a TSC1 CAN message.

#### Idle speed select

#### Variable speed

If the pedal signals become faulty, the engine will go to idle. By releasing the pedal, the 'Idle speed select' will go from zero to one.

When the 'Idle speed select' signal goes from one to zero, the engine speed request will slowly ramp up to 70% of the maximum engine speed.

By releasing the pedal and setting the 'Idle speed select' signal to one, idle speed is instantly requested.

#### Genset

If the pedal signals become faulty, the engine speed request value will be frozen. If the 'Idle speed select' signal goes from zero to one and engine load is low, idle speed is requested.

### **TSC1** control

The TSC1 message can be used to request speed/ torque instead of the VP70 message. It is also possible to limit the permissible engine speed/ torque when shifting gear etc. by overriding the demanded speed/torque request.

TSC1 messages can be received from the following source addresses:

|                     | BB1<br>dec hex |      |  |
|---------------------|----------------|------|--|
|                     |                |      |  |
| TECU (transmission) | 3              | 03 h |  |
| OEM (controller)    | 17             | 11 h |  |

#### Transmission rate and TSC1 timeout

The expected Tx rate for 'Transmission rate' is 10ms.

#### **Bus interface**

Associated signals:

- BB1: Rx: VP70 'Accelerator pedal position' VP70 'Idle speed select'
  - VF70 lule speed select
  - TSC1 'Engine override control mode' TSC1 'Override control mode priority'

  - TSC1 'Engine requested speed/speed limit'
  - TSC1 'Engine requested torque/torque limit'
  - TSC1 'Control purpose'

### Governor mode select

When several engines are used together, divergences in engine performance may result in an uneven load share.

If the engine is running in 'Engine speed mode', a small offset from demanded engine speed will over time result in a large change in engine output torque.

When the 'Governor mode select' is changed from 'Engine speed mode' to 'Torque mode', the target engine speed will be automatically changed for all engines individually, to achieve an equal load share.

Depending on Variable speed or Genset configuration, 'Torque mode' has different effects on the target engine speed.

For single engine control or when the 'Governor mode select' signal is not used, it must be set to 'Not available'.

#### Variable speed

In Variable speed engines, 'Torque mode' will add a negative offset to the target speed when increasing the torque.

n<sub>target</sub> = n<sub>dem</sub> - n<sub>delta</sub>

n<sub>delta</sub> = Trq <sub>output</sub> [Nm] / GovGradient [Nm/rpm]

GovGradient is a fixed value that can be set using an aftermarket tool.

Example: If the GovGradient is set to 100, every 100 Nm torque increase will result in a 1 rpm decrease in target speed in the engine speed controller.

When the engine torque output is very high, the average engine speed will drop slightly, and the demanded speed may need to be adjusted.



Example: GovGradient for Variable speed engines.

- A Engine speed (rpm)
- B Torque output
- C Engine torque (Nm)

#### Genset

In case of Genset engines, it is important that engine speed does not drop below nominal speed. The 'droop' will add an offset to nominal engine speed.

 $n_{target} = n_{droop} - n_{delta} (1)$ 

 $n_{droop} = n_{nominal} + n_{nominal} * droop (2)$ 

The amount of droop is set as a percentage of nominal speed. Increased nominal speed will affect droop speed.

n<sub>delta</sub> = Trq<sub>output</sub> [Nm] / GovGradient [Nm/rpm] (3)

GovGradient = 'Rated engine torque' / (n<sub>nominal</sub> \* droop/100)

(2), (3) in (1) => n<sub>target</sub> = n<sub>nominal</sub> + n<sub>nominal</sub> \* droop ( 1 - Trq<sub>output</sub> / Trq<sub>rated</sub> )

If the engines run at very low load, the target engine speed will increase towards the droop speed. When the load increases towards rated torque, target speed will approach rated engine speed.

When several Gensets are used together, a low torque output will thus increase the target speed and the engine will have a larger share of the load.



Droop for Genset engines

- A Engine speed (rpm)
- B Torque output
- C Engine torque (Nm)
- D Torque output Rated

#### **Bus interface**

Associated message:

BB1: Rx: VP70 'Governor mode select'

### **Restored operation**

The 'Engine restored operation' signal is available to allow the operator to handle critical situations without any power loss for short periods of time.

The restored operation is active as long as the request remains active and for a further predefined period when released, but subject to an upper limit.

The restored operation includes 'Engine protection override'.

**NOTICE!** If used, warranty may be voided.

#### **Bus interface**

Associated signals:

BB1: Rx: VP70 'Engine restored operation' Tx: VP71 'Restored operation'

### Communication

### J1939 Backbone 1 (BB1) - EMS

**NOTICE!** All unused signals must be set to 'Not available'. All unused bits in the messages used must be set to 1.

| ldentifier | PGN   | SPN  | Frame Name / Signal name  | Update<br>period<br>Tx = transmit<br>Rx = receive |  |
|------------|-------|------|---|---|--|
| 0x18FECA00 |       |      | <b>DM1 - Active Diagnostic trouble codes</b><br>Description: The message contains the first active diagnostic<br>trouble code, but requires the multipacket transport TP. CM<br>when more than one active DTC exists. | Tx 1000ms   |  |
| 0x18FEE300 | 65251 |      | EC1 - Engine configuration  | Tx 5000ms<br>or on request                        |  |
|            |       | 188  | Engine speed at idle P1   |   |  |
|            |       | 539  | Engine percent torque at idle P1  |   |  |
|            |       | 528  | Engine speed at P2  |   |  |
|            |       | 540  | Engine percent torque at P2   |   |  |
|            |       | 529  | Engine speed at P3  |   |  |
|            |       | 541  | Engine percent torque at P3   |   |  |
|            |       | 530  | Engine speed at P4  |   |  |
|            |       | 542  | Engine percent torque at P4   |   |  |
|            |       | 531  | Engine speed at P5  |   |  |
|            |       | 543  | Engine percent torque at P5   |   |  |
|            |       | 532  | Engine speed at high idle P6  |   |  |
|            |       | 544  | Engine reference torque   |   |  |
|            |       | 533  | Engine maximum momentary override speed P7  |   |  |
|            |       | 534  | Engine maximum momentary override time limit  |   |  |
| 0x0CF00400 | 61444 |      | EEC1 - Electronic engine controller 1   | Tx 20ms   |  |
|            |       | 512  | Drivers demand engine - percent torque  |   |  |
|            |       | 513  | Actual engine - percent torque  |   |  |
|            |       | 190  | Engine speed  |   |  |
|            |       | 1675 | Engine starter mode   |   |  |
| 0x0CF00300 | 61443 |      | EEC2 - Electronic engine controller 2   | Tx 50ms   |  |
|            |       | 91   | Accelerator pedal position 1  |   |  |
|            |       | 92   | Engine percent load at current speed  |   |  |
| 0x18FEDF00 | 65247 |      | EEC3 - Electronic engine controller 3   | Tx 250ms  |  |
|            |       | 514  | Nominal friction - percent torque   |   |  |
|            |       | 27   | Engine exhaust gas recirculation 1 valve position   |   |  |
|            |       | 94   | Engine fuel delivery pressure   |   |  |
|            |       | 100  | Engine oil pressure   |   |  |
|            |       | 109  | Engine coolant pressure <sup>(1)</sup>  |   |  |
|            |       | 111  | Engine coolant level  |   |  |
| 0x18FEEE00 | 65262 |      | ET1 - Engine temperature 1  | Tx 1000ms   |  |
|            |       | 110  | Engine coolant temperature  |   |  |
|            |       | 175  | Engine oil temperature 1  |   |  |

| Identifier  | PGN       | SPN      | Frame Name / Signal name  | Update<br>period<br>Tx = transmit<br>Rx = receive |
|---|-----------|----------|---|---|
| 0x18FEE500  | 65253     |          | HOURS - Engine hours, revolutions<br>NOTICE! Deviation from SAE J1939 standards (Tx on<br>request).                                     | Tx 10000ms  |
|   |           | 247      | Engine total hours of operation   |   |
| 0x18FEF600  | 65270     |          | IC1 - Intake/exhaust conditions 1   | Tx 500ms  |
|   |           | 102      | Engine intake manifold 1 pressure   |   |
|   |           | 106      | Engine air intake pressure  |   |
|   |           | 105      | Engine intake manifold 1 temperature  |   |
|   |           | 173      | Engine exhaust gas temperature  |   |
| 0x18FEE900  | 64777     |          | LFC - Fuel consumption (liquid)   | Tx 100ms  |
|   |           | 182      | Engine trip fuel  |   |
|   |           | 250      | Engine total fuel used  |   |
| 0x18FEF200  | 65266     |          | LFE - Fuel economy (liquid)   | Tx 100ms  |
|   |           | 183      | Engine fuel rate  |   |
| 0x18EA0003,<br>0x18EA0011,<br>0x18EA00E6 or<br>0x18EA00EA |           |          | Request PGN   |   |
| 0xC000003,<br>0xC000011,<br>0xC0000E6 or<br>0xC0000EA     | 0         |          | TSC1 - Torque/speed control 1 (EMS)   | Rx rate<br>defined in<br>SPN 3349                 |
|   |           | 695      | Engine override control mode  |   |
|   |           | 897      | Override control mode priority  |   |
|   |           | 898      | Engine requested speed/speed limit  |   |
|   |           | 518      | Engine requested torque/torque limit  |   |
|   |           | 3350     | Control purpose   |   |
| 0x18ECFF00  |           |          | <b>TP.CM (EMS)</b><br>Transport protocol connection management from EMS.  | Transmitted at change.                            |
| 0x18EBFF00  |           |          | <b>TP.DT (EMS)</b><br>Address claim prevents different nodes from using the same<br>SA and sending potentially conflicting information. | Transmitted at change.                            |
| 0x18FEF700  | 65271     |          | VEP1 - Vehicle electrical power 1   | Tx 1000ms   |
|   |           | 158      | Keyswitch battery potential   |   |
| <sup>1)</sup> Not available in                            | all confi | iguratic | DNS   |   |

| Identifier | PGN   | PDU format<br>(dec) | PDU spe-<br>cific (dec) | Data length | Priority | Description                 | <b>Update</b><br><b>period</b><br>Tx = transmit<br>Rx = receive |
|------------|-------|---------------------|-------------------------|-------------|----------|-----------------------------|---|
| 0x0CFF4611 | 65350 | 255                 | 70                      | 8 bytes     | 3        | Engine control sta-<br>tus. | Rx 20ms   |

#### **VP70 - VP Status**

**NOTICE!** All unused signals must be set to 'Not available'. All unused bits in the messages used must be set to 1.

| Frame Name / Signal name  |  |  |  |  |
|---|--|--|--|--|
| Start request   |  |  |  |  |
| Start position: 1.1<br>Length: 2 bits<br>Factor: 1<br>Offset: 0 | 0 = Inactive<br>1 = Active<br>2 = Error indication<br>3 = Not available  |  |  |  |
| Stop request  |  |  |  |  |
| Start position: 1.3<br>Length: 2 bits<br>Factor: 1<br>Offset: 0 | 0 = Inactive<br>1 = Active<br>2 = Error indication<br>3 = Not available  |  |  |  |
| Governor mode select  |  |  |  |  |
| Start position: 1.5<br>Length: 2 bits<br>Factor: 1<br>Offset: 0 | 0 = Engine speed mode request<br>1 = Torque mode request<br>2 = Error indication<br>3 = Not available  |  |  |  |
| Idle speed select   |  |  |  |  |
| Start position: 1.7<br>Length: 2 bits<br>Factor: 1<br>Offset: 0 | 0 = Normal running speed request<br>1 = Idle speed request<br>2 = Error indication<br>3 = Not available  |  |  |  |
| Frequency select  |  |  |  |  |
| Start position: 2.1<br>Length: 2 bits<br>Factor: 1<br>Offset: 0 | <ul> <li>0 = Primary engine speed request (1500rpm)</li> <li>1 = Secondary engine speed request (1800rpm)</li> <li>2 = Error indication</li> <li>3 = Not available</li> <li>Note: Only used on dual speed Genset engines.</li> </ul> |  |  |  |
| Preheat request   |  |  |  |  |
| Start position: 2.5<br>Length: 2 bits<br>Factor: 1<br>Offset: 0 | 0 = Inactive<br>1 = Active<br>2 = Error indication<br>3 = Not available  |  |  |  |
| Engine restored operation                                       |  |  |  |  |
| Start position: 2.7<br>Length: 2 bits<br>Factor: 1<br>Offset: 0 | 0 = Inactive<br>1 = Active<br>2 = Error indication<br>3 = Not available  |  |  |  |

| Accelerator pedal position   |  |
|--|--|
| Start position: 3.1<br>Length: 2 bits<br>Factor: 0.097752<br>(100/1023)%/bit | 0x0000-0x03FF = 0-100%<br>0x0400-0xFDFF = Not valid range<br>0xFE00-0x0FFE = Error indication<br>0xFFFF = Not available  |
| Offset: 0  |  |
| Disable fuel   |  |
| Start position: 5.1<br>Length: 2 bits<br>Factor: 1<br>Offset: 0              | 0 = Inactive<br>1 = Active<br>2 = Error indication<br>3 = Not available<br><b>NOTICE!</b> Only used on dual speed Genset |

### **VP71 - VP Engine industry**

| Identifier | PGN   | PDU format<br>(dec) | PDU spe-<br>cific (dec) | Data length | Priority | Description              | Update<br>period<br>Tx = transmit<br>Rx = receive |
|------------|-------|---------------------|-------------------------|-------------|----------|--------------------------|---|
| 0x0CFF4700 | 65351 | 255                 | 71                      | 8 bytes     | 3        | Engine informa-<br>tion. | Tx 50ms   |

**NOTICE!** All unused signals must be set to 'Not available'. All unused bits in the messages used must be set to 1.

| Frame Name / Signal name   |  |  |  |
|--|--|--|--|
| Running indication   |  |  |  |
| Start position: 1.3<br>Length: 2 bits<br>Factor: 1<br>Offset: 0  | 0 = Stopped<br>1 = Running<br>2 = Reserved<br>3 = Not available                            |  |  |
| Buzzer   |  |  |  |
| Start position: 3.1<br>Length: 2 bits<br>Factor: 1<br>Offset: 0  | 0 = Inactive<br>1 = Torque mode request<br>2 = Error indication<br>3 = Not available       |  |  |
| Restored operation Description: 'Restored operation' includes 'Engine protection override'.              |  |  |  |
| Start position: 3.7<br>Length: 2 bits<br>Factor: 1<br>Offset: 0  | 0 = Inactive<br>1 = Active<br>2 = Error state<br>3 = Not available                         |  |  |
| OEM Fan Speed Request<br>Description: External fan speed request from OEM to EMS                         |  |  |  |
| Start position: 7.1<br>Length: 8bits<br>Factor: 1.4<br>Offset: 0   | 0 = Inactive<br>1 = Active<br>2 = Error state<br>3 = Not available                         |  |  |
| <b>Engine power down ack</b><br>Description: When 'Engine power down ack' =1, EMS afterrun is completed. |  |  |  |
| Start position: 8.3<br>Length: 2 bits<br>Factor: 1<br>Offset: 0  | 0 = Power off not allowed<br>1 = Power off allowed<br>2 = Error state<br>3 = Not available |  |  |

### J1587 Power Module Diagnosis

#### **Supported Power Module diagnosis**

Power Module (PM) switch two battery/power supply inputs to three outputs with different current drive capabilities.

Data bus links used are SAE J1708/J1587.

MID 158 is used when sending on J1587.

Battery # 1 input is connected to starter battery and Battery # 2 to secondary battery.

#### **Transmitted messages on PM J1587**

PPID 194, Proprietary Transmitter System Diagnostics is used to notify other components on the data link of diagnostic conditions of parameters that are not available as standard parameters in J1587 and which are not appropriate for general use.

The structure follows the general format of proprietary messages PID 254.

The data bytes are structured in the same way as the standard message 'Transmitting System Diagnostic' (PID194), except bit 6 in the DCC (Diagn Code Char) which is used for the diagnostics of P2PIDs.

1 = standard code: PPID. 0 = extended: P2PPID.

| Fault                     | Fault code J1587 |     | Active when   |  |
|---------------------------|------------------|-----|---|--|
| Fault                     | PSID             | FMI | Active when   |  |
| Battery #1 low voltage    | 1                | 4   | Below 23.6 V for 30 seconds.                              |  |
| Battery #1 high voltage   | 1                | 3   | Over 32.0 V for 30 seconds.                               |  |
| Battery #2 low voltage    | 2                | 4   | Below 23.6 V for 30 seconds.                              |  |
| Battery #2 high voltage   | 2                | 3   | Over 32.0 V for 30 seconds.                               |  |
| 30 supply high current    | 4                | 6   | Over current fuse function activated.                     |  |
| EMS supply high current   | 5                | 6   | If EMS+1 and EMS+2 do not have connection after power up. |  |
| Extra supply high current | 6                | 6   | Over current fuse function activated.                     |  |

#### **Transmitted PID messages**

| Message | Name                | According<br>to standard |
|---------|---------------------|--------------------------|
| PID 168 | Battery # 1 voltage | 1 (1)                    |
| PID 444 | Battery # 2 voltage | 1                        |

1) http://standards.sae.org/j1587\_201301/



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