J1939 for stage-V engines

This year the new EU exhaust regulation for industrial diesel engines stage V becomes active. The demands on engine management that result from these regulations can no longer be satisfied by mechanically governed engines.

(Source: AdobeStock)

Modern electronically governed diesel engines are the upcoming technology in industrial machinery from 2019 on. Such engines come with whole new set of options that offer a new level of comfort for the end user. They no longer rely on mechanical or electrical signals only - they can be controlled by digital commands and also send information about their current status. Commands and status information are no longer transmitted via analog connections but via a digital bus – the CAN network. The fact that most manufacturers are forced to switch from mechanical to electrical engines means that many of them come into contact with the CAN network for the first time.

The de facto standard is CAN with the SAE J1939 protocol which is well proven from the automotive industry. The standard defines a set of messages and the data that is transmitted with each message. At maximum 254 nodes can be connected to a CAN network. These are either master or slave and generally have a pre-defined, fixed, and unique address. They communicate at a fixed global bus speed of 125 Kbit/s, 250 Kbit/s, or 500 Kbit/s and information is packed into messages.

The majority of J1939 messages are expected to be broadcasted. This means that any device connected to the bus can read this data. An advantage of this technique is that less request messages are needed which saves bandwidth for other data. Nevertheless messages can be sent to specific addresses. CAN messages have a 29-bit identifier and an 8-byte data frame. The identifier has the 3-bit priority field, the 18-bit PGN (parameter group number), and the 8-bit source address.

The priority can be 0 to 7 where 0 is the highest priority. If a node tries to send a message and reads a message from a different node with higher priority it stops its own transmission. That means that in theory nodes with high priority can block the bus communication if they send lots of messages. PGNs are furthermore broken into four fields: 1 bit is reserved, the data page has also 1 bit, 8 bit PDU format, and also 8 bit PDU specific.

CAN data types are identified by unique so called SPNs (suspect parameter number). These SPNs have a different length depending on the data they contain. Engine speed (SPN 190) e.g. has a length of 2 bytes where engine starter mode (SPN 1675) only needs 4 bit. These are not long enough to fill the whole 8-byte data frame. For an efficient bus communication multiple SPNs are thus combined to PGNs. The ▷

kW	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
0-7									Stage V	
8-18									Stage V	
19-36	Stage IIIA								Stage V	
37-55	Stage IIIA			Stage IIIB					Stage V	
56-74	Stage IIIA	StageIIIB		Stage IV						Stage V
75-129	Stage IIIA	StageIIIB		Stage IV						Stage V
130-560	Stage IIIB			Stage IV					Stage V	
>560									Stage V	

Figure 1: Road map EU exhaust regulation (Source: EHB Electronics)

driver's demand engine % torque (SPN 512), actual engine % torque (SPN 513), engine speed (SPN 190), SA of controlling device for engine control (SPN 1483), engine starter mode (SPN 1675), and engine demand % torque (2432) in its data frame.

Table 1: CAN messages have a 29 bit identifier and an 8 byte data frame (Source: EHB Electronics)

29 bit Identifier	8 byte Data Frame

Unfortunately different engine manufacturers also interpret the standard differently. That means that for certain functions each engine type needs a different implementation. The TSC1 message e.g. contains information about requested speed and torque. It also contains certain control bits and bit positions that are not defined. These bits are used differently and messages are sent in different repetition rates.

Table 2: The identifier has a 3-bit priority field, an 18-bit so called PGN and an 8-bit source address (Source: EHB Electronics)

3 bit priority	18 bit PGN	8 bit source address

But that is not everything yet. Engine manufacturers use two techniques or a combination of both to tackle the problem of diesel engine emissions - selective catalytic reduction (SCR) and diesel particulate filter (DPF). Some new functions and CAN messages are needed to manage these and engine manufacturers don't stick to a single standard here either. Therefore a lot of knowledge is needed to realize the control mechanisms for certain types of engines.

For SCR a controller that communicates with the engine control unit (ECR) needs to display the catalyst level and certain repeated warning messages that inform about an abnormal status.

DPF functions for the controller are a bit more complex. A DPF can clog up with ash and soot. A commonly used counter action is to regenerate it by a high exhaust temperature that burns soot remains. In the automotive domain this happens automatically when cars drive at a certain speed but industrial machines are often run at a fix engine rotations per minute. That means regeneration is much less intuitive in this field. Different levels of regeneration can be used but not all of them are used by all engine manufacturers. When the ECU detects that a regeneration is necessary, it sends a status update of the corresponding level via DPFC1 message over the CAN network. The controller then has to take different actions and send the regeneration command via CM1 message.

The lowest level is the passive regeneration. This means that the engine can be regenerated during operation if a certain engine load is set. A controller needs to inform the end user to keep or increase the current load until regeneration is finished.

Active regeneration is the next higher level where the machine has to be brought to a defined regeneration state that doesn't allow normal operation any more. Some engine types require that a park break status is sent inside the CCVS message. Otherwise regeneration won't start.

These regeneration requests can be inhibited (intentionally ignored). This can lead to a totally clogged up filter that doesn't fulfill any exhaust regulation. The engine ECU then either stops the engine or limits its rotation per minute to a level that doesn't allow normal operation. This is when the highest level of regeneration comes into action. It usually requires an engine technician who can start a very specific regeneration procedure only with a dedicated service tool.

A controller that is stage V ready also needs to display information about the current regeneration status, soot level, ash level, and warnings about high exhaust temperatures that occur during regeneration and can harm people or gear near the exhaust pipe. A final difficulty that comes with CAN messages is that they are usually encoded in HEX format and thus hard to interpret by humans. That is why end users profit from an HMI that translates these messages into clear text.

EHB offers such a HMI for engines with CAN – the CANarmatur. It allows users to start and stop an engine, displays engine data in a human readable format, allows users to change the engine rotations per minute and can be parameterized by the user. It is prepared for stage V engines from manufacturers like Yanmar, Kubota, Lombardini, and many more.

In addition to the CANarmatur, there is a broad portfolio of CAN-based products to implement holistic complete control solutions. These include further display solutions, I/O modules, controllers, etc. With EHB Electronics, equally efficient powerpack solutions are interesting. Programming and assembly times are significantly reduced and intuitive plug and play solutions are available. ◀

Figure 2: The CANarmatur by EHB (Source: EHB Electronics)

Author

Matthias Hanke
EHB Electronics
info@ehb-electronics.de
www.ehb-electronics.de

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