Diesel Engine Control, CAN Kingdom and J1939

Lars-Berno Fredriksson Kvaser AB
Michael Templin Scania AB
960324

1. Background

At the last CANHUG meeting a discussion about diesel engine control was brought up. Current work among engine producers is clearly focused on J1939 and thus directed toward truck engine control. However, for mobile hydraulics and marine applications J1939 might not be what we would like to see. Compared with the truck industry most CANHUG members represent a small market, so the engine industry may not look into CAN Kingdom unless it can be shown that J1939 could be easily mapped on CAN Kingdom. Thus, the main question is:

> Can J1939 really be mapped on CAN Kingdom offering better performance for non J1939 applications?

I would say the answer to this question is YES! J1939 is a very "stiff" protocol as the CAN identifiers are to a certain extent predefined. The updating times and data formats are predefined as well. However, the engine system controller might not be limited to any of these pre definitions but could support flexible updating times and other data formats.

A first attempt to map J1939 on CAN Kingdom would be by using the data formats defined by J1939. If this works, we can later make the protocol even more efficient by introducing King's Page 17 to let the system designer create more suitable data formats and may be also King's Page 18 to compress the data formats even more. Introducing King's Page 5, "Action Page - Reaction Page," would make further enhancements possible. In CAN Kingdom mode, fragmented messages would be handled much more reliably and faster than in J1939 mode. However, it is essential that a CAN Kingdom module would work exactly according to J1939 when set up as J1939.

A missing piece in J1939 is Network Management. There is a Draft J1939/81 but to my knowledge this is generally not implemented but each vendor has got his own, often very simple, solution. A standard CAN Kingdom implementation would meet most requirements for a vendor specific Network Management. J1939 users, not yet interested in network management, would have a good solution "free of charge" if they base their J1939 design on CAN Kingdom.

2. J1939 requirements

2.1 King's Pages required

To make a J1939 mapping an ECU we will need to support the following CAN Kingdom King's Pages:

King's Page 0	Start/Stop, Modes, CAN Kingdom compulsory.
Kings Page 1	Module initiating in a system, CAN Kingdom compulsory.
King's Page 2	Assigning CAN ID:s, CAN Kingdom compulsory.
King's Page 12	Repetition Rate and Open Window Setup Page.

The following pages should be considered, although not really needed to map J1939, as they would make modules much more versatile for CAN Kingdom users:

King's Page 3	Assigning to Groups. Most CAN Kingdom implementations have this feature.
King's Page 4	Removing from Groups. (Needed if Page 3 is implemented.)
King's Page 8	CC register settings. This feature is not mentioned in J1939 but needed in any advanced system.
King's Page 9	Change of physical address.
King's Page 10	Minimum time elapsing between two consecutive transmissions of the same Envelope. Facilitates bus management. (Needed to make event triggered systems time predictable.)
King's Page 11	Circular Time Base Setup Page.

An implementation of CAN Kingdom as above would require about 3 k ROM and 100 byte RAM.

2.2 J1939 parameters required

To make a simple engine control the following J 1939 messages would be sufficient:

From the system controller:

TSC1 (J1939/71 3.3.1)

From the engine EDC:

EEC2 (J1939/71 3.3.6)
EEC1 (J1939/71 3.3.7)
Engine Configuration (J1939/71 3.3.17) plus a subset of Transport Protocol (J1939/21 3.10)
Engine Temperature (J1939/71 3.3.28)
Engine Fluid Level/Pressure (J1939/71 3.3. 29)

The outline of these messages according to J1939:

Data content	Repetition rate	Data length, bytes	Data page	PDU format	PDU specific	Default priority	Parameter Group Number
TSC1	when active 10ms	8	0	0	Destination address	3	0 (000000_{16})
EEC2	50 ms	8	0	240	3	3	61,443 ($00F003_{16}$)
EEC1	Engine speed dependent or 20 ms	8	0	240	4	3	61,444 ($00F004_{16}$)
Engine configuration	On change of torque/speed points of more than 10% since last transmission, or every 5 sec	28	0	254	227	6	65,251 ($00FEE3_{16}$)
Broadcast Announce Message	Not scheduled	8	0	236	Destination address	6	60,416 ($00EC00_{16}$)
Engine Temperature	1s	8	0	254	238	6	65,262 ($00FEEE_{16}$)
Engine Fluid Level/Pressure	.5 s	8	0	254	239	6	65,263 ($00FEEF_{16}$)

Many CANHUG systems have different systems architecture than J1939. J1939 supposes flat architecture but most CAN Kingdom systems presume one node to be a System Controller, designed by the system designer himself, although CAN Kingdom allows for flat systems design as well. Here we assume, to make it simple for CAN Kingdom users, that there is a System Controller node and it will take control over the engine. This is not a CAN Kingdom requirement. Other nodes, e.g., an ASR/Traction Control and an automatic gearbox could be connected to the net and share the engine control function in a J1939 network.

In the System Controller City (and other modules that would have to control the engine) we need, besides the two compulsory Folders (containing King's Document and Mayor's Document), one or two Transmit Folders (depending how the two destination addresses are implemented) and five Receive Folders to set up messages as above with CAN Kingdom. The Engine Controller City would then require five transmit Folders and one or two receive Folders. EEC2 contains information about the Accelerator Pedal (AP) position and J1939 assumes that this is measured by the Engine Controller. In some systems however, the AP position is measured by another module and a message with the same data format is transmitted to the Engine Controller as a global message. If such a message is sent from the System Controller, then one Receive Folder has to be set as Transmit there and another Transmit Folder is required in the Engine Controller City.

2.3 **J1939 CAN ID:s**

The CAN ID:s of J1939 is organized as below:

<table>
<tr><td></td><td></td><td></td><td>0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Priority</td><td>R</td><td>D
P</td><td colspan="8">PF</td><td colspan="8">PS</td><td colspan="8">SA</td></tr>
</table>

Priority	Selectable. Two default levels, high = 3 and low = 6		
R	Reserved = 0		
DP	Data Page	Currently = 0	
PF	PDU (Protocol Data Unit) Format.		
PS	PDU Specific	0 - 239	Single destination address
		240 - 255	Group Extension. Global address = 255
SA	Source Address		

For the details, please refer to the J1939/213.2. For the time being we need only to fill in the bits in the CAN Kingdom Envelope according to the J1939 standard to make a default Envelope for J1939 users. CAN Kingdom designers will certainly chose a more efficient scheme for assigning proper Envelopes.

3. CAN Kingdom Letters set up as J1939 messages.

3.1 **TSC1**

TSC1 is intended for modules taking control of the engine. The fixed updating rate is 10ms and the engine will obey TSC1 commands until
either the controlling module gives up controlling by setting the Override Control Mode bits to
00 in a broadcast message
or a message with higher Override Control Mode Priority is received
or TSC1 messages have ceased to appear on the CAN bus for two update periods.

3.1.1 TSC1 Page Form.

A CAN Kingdom Page Form for a TSC1 message is presented below. For the very details of the data, please consult J1939/71 3.3.1.

Document name:	TSC1 Document
Document List:	
Document Number:	
Document type:	

Page description.

Number of Lines: 8

Data description: Torque/Speed Control (J1939 update time 10 ms)

Line description.

Line 0:	11ppssmm		Control bits.		
			pp	Override control mode priority	
				00	Highest priority
				01	High priority
				10	Medium priority
				11	Low priority
			ss	Requested speed conditions	
				00	Transient Optimized, driveline disengaged
				01	Stability Optimized, driveline disengaged
				10	Stability Optimized, driveline condition 1
				11	Stability Optimized, driveline condition 2
			mm	Override control modes	
				00	Override disabled
				01	Speed control
				10	Torque control
				11	Speed/Torque limit control
Line 1:	SSSSSSSS	LSB	Requested speed		
Line 2:	SSSSSSSS	MSB	Resolution: .125 rpm/bit gain, 0 rpm offset (upper byte resolution = 32 rpm/bit)		
				Data range: 0 to 8031.875 rpm	
Line 3:	t t t t t t t t		Requested Torque		
				Resolution 1% gain, -125% offset	
				Data range: -125 to 125%	
				Operating range: 0 - 125%	
Line 4:	11111111		Not defined		
Line 5:	11111111				
Line 6:	11111111				
Line 7:	11111111				

3.1.2 TSC1 CAN ID

The outline of the CAN ID of TSC1 according to J1939 looks as below:

<table>
<tr><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0
1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td colspan="3">priority
3</td><td>R</td><td>D
P</td><td colspan="8">PF</td><td colspan="8">PS
Destination address
Engine # 1 = 0
Engine # 2 = 1</td><td colspan="8">SA
Source address, here as an example "Management Computer" = 39</td></tr>
</table>

For systems with one or two engines this would work but for systems with more engines, e.g., train or ship systems, another ID has to be defined anyhow. For multi-engine systems having a group address for all of them might also be attractive. This is not possible in J1939 but no problem in CAN Kingdom.

Let us assume that this Document is placed in a fixed Folder 3. Setting up this (or these) Envelope(s) in CAN Kingdom would be done by a King's Page 2:

Document name:	King's Document
Document List:	T1 Capital / 0 City
Document Number:	0 Capital / 0 City
Document type:	Transmit (Capital) Receive (City)

Page description.

Page number:	2
Number of Lines:	8
Data description:	The King's Page 2. Assigning an Envelope to or expelling an Envelope from a Folder forming Letters and restraining the use of an Envelope.

Line description.

Line 0: City or Group address

Line 1:	00000010	(Page 2)	
Line 2:	00100111	Envelope Number, LSB	(SA = 39, Management Computer)
Line 3:	00000000	Envelope Number	(PS, DA = 0, Engine #1)
Line 4:	00000000	Envelope Number	(PF = 0)
Line 5:	10001100	Envelope Number, MSB	(Priority = 3, R = 0, DP = 0)
	ECr	r = 0	Reserved
		C = 1/0	Compressed Envelope yes/<u>no</u>.
		E = 1/0	<u>Extended</u> / Std. format.
Line 6:	00000011	Folder Number 3	
Line 7:	rrrrrAAE	E = 1/0	Enable/Disable the use of this Envelope. (Folder Number is ignored.)
		AA = 00	Keep current assignment. (Folder Number is ignored.)
		AA = 01	Assign this Envelope to the Folder on Line 6. If another Envelope is already assigned to this Folder, the previous assignment will be kept in parallel. The use of this Envelope is enabled or disabled according to the value of E.
		AA = 11	Transfer the current assignment of this Envelope to the Folder on Line 6. The old assignment is canceled. The use of this Envelope is enabled or disabled according to the value of E.
		AAE = 100	Expel this Envelope from any assignment. (Folder Number is ignored.)
		rrrrr = 00000	Reserved All other combinations are reserved.

3.1.3 Repetition rate

Let us assume that we have made a fixed implementation of Circular Time Base Setup as follows:

A grain fixed to 2 µs
Number of grains per segment fixed to 250
Number of segments per revolution fixed to 200
Number of revolutions for maximum time fixed to 200.

Such a circular time setup would give a resolution of 2µs, .5 ms per segment, 100 ms per revolution and a maximum time of 20 s.

The required repetition rate of 10 ms for TSC1 would then be set up by King's Page 12:

Document name:	King's Document	
Document List:	T1 Capital / 0 City	
Document Number:	0 Capital / 0 City	
Document type:	Transmit (Capital) Receive (City)	
Page description.		
Page number:	12	
Number of Lines:	8	
Data description:	The King's Page 12. Repetition rate and open window setting.	
Line description.		
Line 0:	City or Group address	
Line 1:	00001100	(Page 12)
Line 2:	00000011	Folder Number 3.
Line 3:	00000000	Start Segment offset.
Line 4:	00000000	Start Revolution offset.
Line 5:	00000000	Open window. Number of segments. Window always open.
Line 6:	00010100	Repetition increment (within a revolution), number of segments. (In this example a segment is 2*250 µs. 20 segments will make 10 ms.)
Line 7:	00000001	Repetition increment, number of revolutions. 1 will recommence repetition at every revolution.

3.2 **EEC2**

3.2.1 EEC2 data format

The EEC2 Data Content is "Accelerator pedal position / Percent Load at Current speed." A corresponding CAN Kingdom Page Form would look as below:

Document name:	EEC2 Document
Document List:	
Document Number:	
Document type:	

Page description.

Number of Lines:	8
Data description:	Accelerator pedal position / percent load at actual speed (J1939/71 3.3.6, repetition rate 50 ms)

Line description.

Line 0:	1111kkll	Status_EEC2	
		kk	AP kick down switch
		00	Kick down passive
		01	Kick down active
		ll	AP low idle switch
		00	AP not in low idle condition
		01	AP in low idle position
Line 1:	pppppppp	AP position	
			Resolution: .4%bit gain, 0% offset
			Data Range: 0% to 100%
Line 2:	LLLLLLLL	Percent load at current speed	
			Resolution 1% gain, 0% offset
			Data range: 0% to 125 %
			Operating range: 0 - 125%
Line 3:	11111111	Not defined	
Line 4:	11111111		
Line 5:	11111111		
Line 6:	11111111		
Line 7:	11111111		

3.2.2 EEC2 CAN ID

The CAN identifier for EEC2 messages is defined as below in J1939:

<table>
<tr><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0
1</td></tr>
<tr><td colspan="3">priority
3</td><td>R</td><td>D
P</td><td colspan="8">PF
240</td><td colspan="8">PS
3</td><td colspan="8">SA
Engine #1 = 0
Engine #2 = 1</td></tr>
</table>

In a simple CAN Kingdom implementation the EEC2 Document would be placed in a fixed Folder, e.g., Folder 3. To this Folder an Envelope with the ID above is assigned by a King's Page 2:

Document name:	King's Document
Document List:	T1 Capital / 0 City
Document Number:	0 Capital / 0 City
Document type:	Transmit (Capital) Receive (City)

Page description.

Page number:	2
Number of Lines:	8
Data description:	The King's Page 2. Assigning an Envelope to or expelling an Envelope from a Folder forming Letters and restraining the use of an Envelope.

Line description.

Line 0: City or Group address

Line 1:	00000010	(Page 2)	
Line 2:	00000000	Envelope Number, LSB	(SA = 0, Engine 1)
Line 3:	00100111	Envelope Number	(PS, DA = 39, Management Computer)
Line 4:	00000000	Envelope Number	(PF = 0)
Line 5:	10001100	Envelope Number, MSB	(Priority = 3, R = 0, DP = 0)
	ECr	r = 0	Reserved
		C = 1/0	Compressed Envelope yes/no.
		E = 1/0	Extended / Std. format.
Line 6:	00000011	Folder Number 3	
Line 7:	rrrrrAAE	E = 1/0	Enable/Disable the use of this Envelope. (Folder Number is ignored.)
		AA = 00	Keep current assignment. (Folder Number is ignored.)
		AA = 01	Assign this Envelope to the Folder on Line 6. If another Envelope is already assigned to this Folder, the previous assignment will be kept in parallel. The use of this Envelope is enabled or disabled according to the value of E.
		AA = 11	Transfer the current assignment of this Envelope to the Folder on Line 6. The old assignment is canceled. The use of this Envelope is enabled or disabled according to the value of E.
		AAE = 100	Expel this Envelope from any assignment. (Folder Number is ignored.)
		rrrrr = 00000	Reserved All other combinations are reserved.

Here we have assumed that the AP position is sent from the Engine 1. If it would be sent from the Management Computer, Line 2 and 3 would have been switched and line 2 and 3 in the

EEC2 Document would have been padded with 1:s indicating Not Available (as that information source is definitely the engine).

3.2.3 EEC2 Repetition rate

Let us assume that we have made a fixed implementation of Circular Time Base Setup like for TSC1. The required repetition rate of 50 ms for EEC2 would then be set up by King's Page 12:

Document name:	King's Document	
Document List:	T1 Capital / 0 City	
Document Number:	0 Capital / 0 City	
Document type:	Transmit (Capital) Receive (City)	
Page description.		
Page number:	12	
Number of Lines:	8	
Data description:	The King's Page 12. Repetition rate and open window setting.	
Line description.		
Line 0:	City or Group address	
Line 1:	00001100	(Page 12)
Line 2:	00000011	Folder Number 3.
Line 3:	00000000	Start Segment offset.
Line 4:	00000000	Start Revolution offset.
Line 5:	00000000	Open window. Number of segments. Window always open.
Line 6:	0010100	Repetition increment (within a revolution), number of segments. (In this example a segment is 2*250 µs. 100 segments will make 50 ms.)
Line 7:	00000001	Repetition increment, number of revolutions. 1 will recommence repetition at every revolution.

3.2.4 EEC1

The EEC1 message would be set up in the same way as the other two messages above. According to J1939 the repetition rate is engine speed dependent. The reason for this is that two methods of measuring-transmission are allowed: Crank Angle or Time-Based Update Rates. Then at maximum and minimum time delay between sampling and transmission is specified for different speeds. This part of the J1939 spec. does not seem very relevant. As measuring and CAN transmissions are two independent tasks, any repetition rate could be allowed and J1939/71 3.1.6.2, 2."Normal" update rates, shows that a fixed transmission rate of 20 ms would be sufficient for a standard J1939 module.

3.2.5 EEC1 Document

The EEC1 Document would look as below and be placed in a fixed Folder, e.g., Folder 4.

Document name: EEC1 Document
Document List:
Document Number:
Document type:

Page description.

Number of Lines: 8

Data description: Torque/Speed Control (J1939/71 3.3.7 repetition rate engine speed dependent)

Line description.

Line 0:	1111mmmm		Status_EEC1
		mmmm	Engine torque mode (3.2.2.1)
Line 1:	dddddddd		Driver's demand engine - percent torque Resolution: 1%bit gain, -125% offset (00 = -125%, 125 = 0%, 250 = 125%) Data Range: -125% to 125% Operating Range: 0 to 125%
Line 2:	SSSSSSSS		Actual engine - percent torque Resolution 1% gain, -125% offset Data range: -125 to 125 % Operating range: 0 - 125%
Line 3:	SSSSSSSS	LSB	Engine speed
Line 4:	SSSSSSSS	MSB	Resolution: .125 rpm/bit gain, 0 rpm offset (upper byte resolution = 32 rpm/bit) Data range: 0 to 8031.875 rpm
Line 5:	11111111		Not defined
Line 6:	11111111		
Line 7:	11111111		

3.2.6 EEC1 CAN ID

The EEC1 CAN ID looks as below and would be setup by a King's Page 2 as earlier messages.

<table>
<tr><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0
1</td></tr>
<tr><td colspan="3">priority
3</td><td>R</td><td>D
P</td><td colspan="8">PF
240</td><td colspan="8">PS
4</td><td colspan="8">SA</td></tr>
</table>

3.2.7 EEC1 repetition rate

EEC1 would be set up for a 20 ms repetition rate in the same way as earlier messages.

3.3 **Engine Configuration**

The Engine Configuration parameter contains 28 bytes and will be sent according to the J1939 transport protocol. In CAN Kingdom Engine Configuration would be a multi-page Document and by putting the Page Number on Line 0 we would get the same format as the J1939 transport protocol. For non-J1939 users the Engine Configuration does not seem very efficient. The Reference Engine Torque is transmitted in byte 20 and 21 although it never changes. This would rather be a parameter of its own. The MSB and LSB of engine speed at point 3 will be transmitted in two different messages as well as the speed and torque of point 5.

Although using the same scheme for creating a CAN ID for the Engine Configuration messages would be possible as for the other messages, J1939 has a different way to handle fragmented messages. Fragmented messages are handled according to J1939/21 3.10.3 "Transport Protocol - Connection Management Messages." Non-J1939 users would probably not consider using this as a direct use of a Paginated Engine Configuration Document would be simpler, faster and safer.

The J1939 Transport Protocol can be implemented in different ways, all possible to map with CAN Kingdom. Here we will only discuss the simplest way, by a Broadcast Data Transfer Sequence according to FIGURE C3 in SAE J1939/21. Then we have to start the transmission of Engine Configuration by a TP.CM_BAM message followed by four messages with data, each within a 50 to 200 ms period, and we have not to deal with any acknowledgment or error handling procedure.

3.3.1 Connection Management (TP.CM) for Engine Control

In CAN Kingdom a Connection Management Document Form the Engine Control parameter would look as below:

Document name:	Connection Managent Document (TP.CM)
Document List:	
Document Number:	
Document type:	

Page description.

Number of Lines:	8
Data description:	Broadcast Announce Message for Engine Control J1939/21 3.10.3 (FIGURE 11) (J1939/71 3.3.17 repetition rate on change of torque/speed points of more than 10% since last transmission, or every 5 sec)

Line description.

Line 0:	00100000		Control byte = 32
Line 1:	00011100	LSB	Total message size, number of bytes (28)
Line 2:	00000000	MSB	
Line 3:	00000100		Total number of packets (4)
Line 4:	r r r r r r r r	r=1	Reserved
Line 5:	11100011	LSB	Parameter Group to be transferred ($00FEE3_{16}$)
Line 6:	11111110		
Line 7:	00000000	MSB	

3.3.2 Broadcast Announce Message for Engine Control CAN ID

The TP.CM_BAM Letter will have the following CAN ID assigned to its Form:

<table>
<tr><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0
1</td></tr>
<tr><td colspan="3">priority
6</td><td>R</td><td>DP</td><td colspan="8">PF
236</td><td colspan="8">PS
255
Global</td><td colspan="8">SA
Engine #1 = 0
Engine #2 = 1</td></tr>
</table>

3.3.3 Engine Configuration Document

An Engine Configuration Document according to J1939 would look like as below. Each Page is concecutively transmitted within a 50 to 200 ms time frame.

Document name:	Engine Configuration Document
Document List:	
Document Number:	
Document type:	

Page description.

Number of Lines: 8

Data description: Engine performance map (J1939/71 3.3.17 repetition rate on change of torque/speed points of more than 10% since last transmission, or every 5 sec)

Line description.

Line 0:	00000001	Page 1	
Line 1:	s_1 s_1 s_1 s_1 s_1 s_1 s_1 s_1	LSB	Engine speed at idle, point 1
Line 2:	s_1 s_1 s_1 s_1 s_1 s_1 s_1 s_1	MSB	Resolution: .125 rpm/bit gain, 0 rpm offset Data range: 0 to 8031.875 rpm
Line 3:	t_1 t_1 t_1 t_1 t_1 t_1 t_1 t_1		Percent torque at idle, point 1 Resolution 1% gain, -125% offset Data range: -125 to 125 % Operating range: 0 - 125%
Line 4:	s_2 s_2 s_2 s_2 s_2 s_2 s_2 s_2	LSB	Engine speed at point 2
Line 5:	s_2 s_2 s_2 s_2 s_2 s_2 s_2 s_2	MSB	Resolution: .125 rpm/bit gain, 0 rpm offset Data range: 0 to 8031.875 rpm
Line 6:	t_2 t_2 t_2 t_2 t_2 t_2 t_2 t_2		Percent torque at point 2 Resolution 1% gain, -125% offset Data range: -125 to 125 % Operating range: 0 - 125%
Line 7:	s_3 s_3 s_3 s_3 s_3 s_3 s_3 s_3	LSB	Engine speed at point 3 Resolution: .125 rpm/bit gain, 0 rpm offset Data range: 0 to 8031.875 rpm

Document name:	Engine Configuration Document
Document List:	
Document Number:	
Document type:	

Page description.

Number of Lines:	8
Data description:	Engine performance map (J1939repetition rate on change of torque/speed points of more than 10% since last transmission, or every 5 sec)

Line description.

Line 0:	00000010	Page 2	
Line 1:	$s_3\ s_3\ s_3\ s_3\ s_3\ s_3\ s_3\ s_3$	MSB	Engine speed at point 3 Resolution: .125 rpm/bit gain, 0 rpm offset Data range: 0 to 8031.875 rpm
Line 2:	$t_3\ t_3\ t_3\ t_3\ t_3\ t_3\ t_3\ t_3$		Percent torque at idle, point 3 Resolution 1% gain, -125% offset Data range: -125 to 125 %
Line 3:	$s_4\ s_4\ s_4\ s_4\ s_4\ s_4\ s_4\ s_4$	LSB	Engine speed at point 4
Line 4:	$s_4\ s_4\ s_4\ s_4\ s_4\ s_4\ s_4\ s_4$	MSB	Resolution: .125 rpm/bit gain, 0 rpm offset Data range: 0 to 8031.875 rpm
Line 5:	$t_4\ t_4\ t_4\ t_4\ t_4\ t_4\ t_4\ t_4$		Percent torque at point 4 Resolution 1% gain, -125% offset Data range: -125 to 125 % Operating range: 0 - 125%
Line 6:	$s_5\ s_5\ s_5\ s_5\ s_5\ s_5\ s_5\ s_5$	LSB	Engine speed at point 5
Line 7:	$s_5\ s_5\ s_5\ s_5\ s_5\ s_5\ s_5\ s_5$	MSB	Resolution: .125 rpm/bit gain, 0 rpm offset Data range: 0 to 8031.875 rpm

Document name:	Engine Configuration Document
Document List:	
Document Number:	
Document type:	

Page description.

Number of Lines: 8

Data description: Engine performance map (J1939repetition rate on change of torque/speed points of more than 10% since last transmission, or every 5 sec)

Line description.

Line 0:	00000011	Page 3	
Line 1:	$t_5\ t_5\ t_5\ t_5\ t_5\ t_5\ t_5\ t_5$		Percent torque at idle, point 5 Resolution 1% gain, -125% offset Data range: -125 to 125 %
Line 2:	$s_6\ s_6\ s_6\ s_6\ s_6\ s_6\ s_6\ s_6$	LSB	Engine speed at high idle, point 6
Line 3:	$s_6\ s_6\ s_6\ s_6\ s_6\ s_6\ s_6\ s_6$	MSB	Resolution: .125 rpm/bit gain, 0 rpm offset Data range: 0 to 8031.875 rpm
Line 4:	GGGGGGGG	LSB	Gain (KP) of endspeed governor
Line 5:	GGGGGGGG	MSB	Resolution: .0007813% engine reference torque/rpm per bit gain (normailized), 0%/rpm per bit offset Data range: 0 to 50.2%/ rpm
Line 6:	$t_r\ t_r\ t_r\ t_r\ t_r\ t_r\ t_r\ t_r$	LSB	Reference engine torque
Line 7:	$t_r\ t_r\ t_r\ t_r\ t_r\ t_r\ t_r\ t_r$	MSB	Resolution: 1 Nm/bit gain, 0 Nm offset Data range: 0 to 64 255 Nm

Document name:	Engine Configuration Document
Document List:	
Document Number:	
Document type:	

Page description.

Number of Lines: 8

Data description: Engine performance map (J1939repetition rate on change of torque/speed points of more than 10% since last transmission, or every 5 sec)

Line description.

Line 0:	00000100	Page 4	
Line 1:	m_s m_s m_s m_s m_s m_s m_s m_s	LSB	Max. momentary engine override speed, point 7
Line 2:	m_s m_s m_s m_s m_s m_s m_s m_s	MSB	Resolution: .125 rpm/bit gain, 0 rpm offset Data range: 0 to 8031.875 rpm
Line 3:	m_t m_t m_t m_t m_t m_t m_t m_t		Max. momentary engine override time limit Resolution: .1 s/bit gain, 0 s offset Data range: 0 s to 25 s 0 = no override of high idle allowed 255 = n.a. (no time restriction)
Line 4:	r_{sl} r_{sl} r_{sl} r_{sl} r_{sl} r_{sl} $r_{sl}r_{sl}$		Requested speed control range lower limit Resolution: 10 rpm/bit gain, 0 rpm offset Data range: 0 rpm to 2500 rpm
Line 5:	r_{su} r_{su} r_{su} r_{su} r_{su} r_{su} $r_{su}r_{su}$		Requested speed control range upper limit Resolution: 10 rpm/bit gain, 0 rpm offset Data range: 0 rpm to 2500 rpm
Line 6:	r_{tl} r_{tl} r_{tl} r_{tl} r_{tl} r_{tl} r_{tl} r_{tl}		Requested torque control range lower limit Resolution 1% gain, -125% offset Data range: -125 to 125 % Operating range: 0 - 125%
Line 7:	r_{tu} r_{tu} $r_{tu}r_{tu}$ r_{tu} r_{tu} $r_{tu}r_{tu}$		Requested speed control range upper limit Resolution 1% gain, -125% offset Data range: -125 to 125 % Operating range: 0 - 125%

3.3.4 Engine Configuration CAN ID

The CAN ID for Engine Configuration data (globally distributed) will be according to J1939/21 FIGURE 11:

<table>
<tr><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0
1</td></tr>
<tr><td colspan="3">priority
6</td><td>R</td><td>D
P</td><td colspan="8">PF
235</td><td colspan="8">PS
255
Global</td><td colspan="8">SA
Engine #1 = 0
Engine #2 = 1</td></tr>
</table>

3.4 Engine Temperature

Engine Temperature messges would be set up in the same way as previous single page messages.

3.4.1 Engine Temperature Document

Document name:	Engine Temperature Document
Document List:	
Document Number:	
Document type:	

Page description.

Number of Lines:	8
Data description:	Engine temperature (J1939/71 3.3.28, repetition rate 1 sec)

Line description.

Line 0:	cccccccc		Engine coolant temperature Resolution 1ºC/bit gain, -40ºC offset Data range: -40ºC to +210ºC
Line 1:	f f f f f f f f		Fuel temperature Resolution 1ºC/bit gain, -40ºC offset Data range: -40ºC to +210ºC
Line 2:	LLLLLLLL	LSB	Engine oil temperature
Line 3:	LLLLLLLL	MSB	Resolution .03125ºC/bit gain, -273ºC offset Data range: -273ºC to +1735ºC
Line 4:	TTTTTTTT	LSB	Turbo oil temperature
Line 5:	TTTTTTTT	MSB	Resolution .03125ºC/bit gain, -273ºC offset Data range: -273ºC to +1735ºC
Line 6:	I I I I I I I I		Engine intercooler temperature Resolution 1ºC/bit gain, -40ºC offset Data range: -40ºC to +210ºC
Line 7:	11111111		Not defined

3.4.2 Engine Temperature CAN ID

1	1	0	0	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0 1
priority 6			R	D P	PF 254								PS 238								SA Engine #1 = 0 Engine #2 = 1							

3.5 **Engine Fluid Level/Pressure**

Engine Fluid Level/Pressure messges would be set up in the same way as previous single page messages.

3.5.1 Engine Fluid Document

Document name: Engine Fluid Level/Pressure Document
Document List:
Document Number:
Document type:

Page description.

Number of Lines: 8

Data description: Engine Fluid Level/Pressure (J1939/71 3.3.29, repetition rate .5 s)

Line description.

Line 0:	f f f f f f f f		Fuel delivery pressure Resolution 4 kPa/bit gain, 0 kPa offset Data range: 0 kPa to +1000 kPa
Line 1:	11111111		Not defined
Line 2:	l_o l_o l_o l_o l_o l_o l_o l_o		Engine oil level Resolution ,4 %/bit gain, 0% offset Data range: 0 % to 100 %
Line 3:	p_o p_o p_o p_o p_o p_o p_o p_o		Engine oil pressure Resolution 4 kPa/bit gain, 0 kPa offset Data range: 0 kPa to +1000 kPa
Line 4:	p_{cr} p_{cr} p_{cr} p_{cr} p_{cr} p_{cr} p_{cr} p_{cr}	LSB	Crankcase pressure
Line 5:	p_{cr} p_{cr} p_{cr} p_{cr} p_{cr} p_{cr} p_{cr} p_{cr}	MSB	Resolution 7.8125 Pa/bit gain, -250 kPa offset Data range: -250 kPa to +251.99 kPa
Line 5:	p_c p_c p_c p_c p_c p_c p_c p_c		Coolant pressure Resolution 2 kPa/bit gain, 0 kPa offset Data range: 0 kPa to +500 kPa
Line 6:	l_c l_c l_c l_c l_c l_c l_c l_c		Coolant level Resolution .4 %/bit gain, 0% offset Data range: 0 % to 100 %

3.5.2 Engine Fluid Level/PressureCAN ID

1	1	0	0	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0 1
priority 6			R	D P	PF 254								PS 239								SA Engine #1 = 0 Engine #2 = 1							

4. Conclutions

By this example it is shown that J1939 could be directly mapped on CAN Kingdom. J1939 users would not see any difference between a "genuine" J1939 module and a CAN Kingdom node set up according to the requirements of J1939. However, for CAN Kingdom users it would give a system designer much greater flexibility.