



SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Vehicle Application Layer

RATIONALE

This document has been reorganized for clarification and better understanding. This revision has various corrections and references for ASCII and text file usage to current standards, and a new statement of usage for “Signal” and “Parameter” was added to enhance consistency going forward when adding new PGN and SPN definitions.

FOREWORD

The SAE J1939 communications network is defined using a collection of individual SAE J1939 documents based upon the layers of the Open System Interconnect (OSI) model for computer communications architecture. The SAE J1939-71 document defines the majority of the OSI application layer data parameters (SPs) and messages (PGs) that are relevant to most SAE J1939 applications. This document also defines the conventions and notations for data encoding and parameter placement in PG data.

The SAE J1939 communications network is a high-speed ISO 11898-1 CAN-based communications network that supports real-time closed loop control functions, simple information exchanges, and diagnostic data exchanges between electronic control units (ECUs) physically distributed throughout the vehicle.

The physical layer aspects of SAE J1939 reflect its design goal for use in heavy-duty environments. Horizontally integrated vehicles involve the integration of different combinations of loose package components, such as engines and transmissions that are sourced from many different component suppliers. The SAE J1939 common communication architecture strives to offer an open interconnect system that allows the ECUs associated with different component manufacturers to communicate with each other.

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Documents

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1. SCOPE

The SAE J1939 communications network is developed for use in heavy-duty environments and is suitable for horizontally integrated vehicle industries. The SAE J1939 communications network is applicable for light-duty, medium-duty, and heavy-duty vehicles used on-road or off-road, and for appropriate stationary applications which use vehicle-derived components (e.g., generator sets). Vehicles of interest include, but are not limited to, on-highway and off-highway trucks and their trailers, construction equipment, and agricultural equipment and implements.

SAE J1939-71 is the SAE J1939 reference document describing SAE J1939 parameter (SP) and message (PG) definitions, SLOT (standard data encoding) definitions, conventions and notations used to specify the parameter (SP) placement in PG data, conventions for text data parameters, and conventions for PG transmission rates. This document previously contained the majority of the SAE J1939 OSI application layer data parameters and messages for information exchange between the ECU applications connected to the SAE J1939 communications network. It also contained reference figures and reference information. The data parameters (SPs), messages (PGs), reference figures, and information previously published within this document are now published in SAE J1939DA.

There are several SAE J1939-7X documents that collectively define all of the SAE J1939 application layer data parameters and messages. Diagnostic services and some industry-specific data parameters and messages are documented within other SAE J1939-7X application layer documents. An ECU may simultaneously use and support data parameters and messages from multiple SAE J1939-7X application layer documents.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J824	Engine Rotation and Cylinder Numbering
SAE J1939	Serial Control and Communications Heavy-Duty Vehicle Network - Top-Level Document
SAE J1939-21	Data Link Layer
SAE J1939-22	CAN FD Data Link Layer
SAE J1939-73	Application Layer - Diagnostics
SAE J1939-81	Network Management
SAE J1939DA	J1939 Digital Annex

2.1.2 ISO Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ISO 6429	Information technology - Control functions for coded character sets
ISO 8859-1	Information processing - 8-bit single-byte coded graphic character sets - Part 1: Latin alphabet No. 1
ISO 11898-1	Road vehicles - Controller area network (CAN) - Part 1: Data link layer and physical coding sublayer

3. DEFINITIONS

Refer to SAE J1939 (top-level document) for terms and definitions that are not defined in this document.

3.1 BYTE ARRAY

A sequence of one or more whole bytes of binary data treated as an array of bytes. See 5.3.4.5.

3.2 FLOOR

Mathematical operation that returns the nearest integer rounded toward zero, i.e., the whole part with the decimal part truncated.

4. ABBREVIATIONS

Refer to SAE J1939 (top-level document) for additional abbreviations that are used in this document.

>> Bitwise logical right shift operator

% Mathematical modulo operator

5. TECHNICAL REQUIREMENTS

The application layer provides a means for application processes to access the OSI environment. This layer contains management functions and generally useful mechanisms to support applications.

5.1 Parameter Group (PG)

An SAE J1939 Parameter Group, or SAE J1939 message, is a standardized data object (PG Data) that contains data for a predefined group of zero or more data parameters. All data and information communicated over SAE J1939 is done using SAE J1939 PGs. The SAE J1939 Parameter Group Number (PGN) is the unique numeric identifier assigned to each SAE J1939 Parameter Group. The technical definition for an SAE J1939 PG specifies its identity characteristics (PGN, PG Name, Acronym), its PG data definition (data content, PG data length variability), and its transmit characteristics (transmission rate, addressing capability); see 5.1.1 through 5.1.12.

This document only describes the properties of PGs with a PGN value on PGN Page 0 and PGN Page 1.

Most SAE J1939 PGs are fully specified in SAE J1939DA or one of the other SAE J1939 documents. Some SAE J1939 PGs are assigned to other industry standards, and the definitions for those SAE J1939 Parameter Groups are maintained within the respective industry standard documents.

Within SAE J1939 documents, a reference to a specific PG is commonly done using either the PG Name or the PG Acronym, followed by the PGN in parenthesis. For example, Diagnostic Message 1 PG (PGN 65225) or DM1 (PGN 65225).

All transmitted SAE J1939 PGs on an SAE J1939 network shall only be standardized SAE J1939 PG and shall conform to the SAE J1939 specified characteristics including, but not limited to, transmission rate, data content, data placement, and data encoding. The PG data for each transmitted SAE J1939 PG shall only contain data for the parameters specified for that SAE J1939 PG and encoded as specified for each parameter. The only exception is the data communicated using SAE J1939 PG defined as proprietary messages, i.e., PropA, PropA1, PropB, and PropB1 PGs, where the parameter data and its placement in the PG data is defined by the transmitter of the proprietary messages.

An SAE J1939 PG describes a PDU above the data link layer; therefore, the length of the PG data for a PG can be longer than the maximum length of the data field of a single CAN data frame, e.g., 8 bytes for a CEFF data frame or 64 bytes for an FEFF data frame. When the PG data for a PG cannot be sent in its entirety in the data field of a single SAE J1939 data frame, then an SAE J1939 transport protocol is used to transfer the PG data using a series of SAE J1939 data frames, as described in SAE J1939-21 and SAE J1939-22 (SAE J1939 data link layers).

5.1.1 Parameter Group Number (PGN)

The Parameter Group Number (PGN) is an 18-bit numeric value that uniquely identifies an SAE J1939 PG. The PGN is most commonly used in SAE J1939 communications to identify the PG associated to the PG data being communicated. The PGN can be communicated as part of the PG Data to identify or reference a specific PG. The PGN can be cited in documentation, specifications, and dialog to refer to a specific PG. Due to the SAE J1939 standard for PGNs assigned to PDU1 type PGs, there are only 8672 valid PGNs out of the 131072 possible PGNs on PGN Page 0 and PGN Page 1.

For PGN Page 0 and PGN Page 1 PGNs, there are four individual component values derived from the numeric value: Extended Data Page (EDP), Data Page (DP), PDU Format (PF), and PDU Specific (PS). The relationship between the PGN value and these four component values is according to the equation in Figure 1 for PGNs on PGN Page 0 and PGN Page 1.

$$\text{PGN} = (\text{EDP} * 2^{17}) + (\text{DP} * 2^{16}) + (\text{PF} * 2^8) + \text{PS}$$

Figure 1 - Relationship of PGN to EDP, DP, PF, and PS

5.1.1.1 PGN Page

The 262144 possible PGN values are partitioned into four ranges of 65536 values, known as PGN pages. Each PGN Page is enumerated according to the 2-bit numerical value comprised of the most significant 2 bits of the 18-bit PGN value, specifically the EDP and DP values. A Page 0 PGN has an EDP value of 0 and a DP value of 0. A Page 1 PGN has an EDP value of 0 and a DP value of 1.

5.1.1.2 Extended Data Page (EDP)

The Extended Data Page is a 1-bit value of the four component values that comprise the SAE J1939 PGN and one of two component values that identify the Page of the PGN. The EDP value is the result of the PGN value bit shifted right by 17, as shown by the equations in Figure 2.

$$\text{EDP} = \text{PGN} \gg 17$$

$$\text{EDP} = \text{floor}(\text{PGN} / 131072)$$

Figure 2 - Equations for calculating EDP from PGN

5.1.1.3 Data Page (DP)

The Data Page is a 1-bit value of the four component values that comprise the SAE J1939 PGN and one of two component values that identify the Page of the PGN. The DP value is the least significant bit of the result of the PGN value bit shifted right by 16, as shown by the equations in Figure 3.

$$\text{DP} = (\text{PGN} \gg 16) \% 2$$

$$\text{DP} = (\text{floor}(\text{PGN} / 65536)) \text{ modulo } 2$$

Figure 3 - Equations for calculating DP from PGN

5.1.1.4 PDU Format (PF)

The PDU Format is an 8-bit value of the four component values that comprise the SAE J1939 PGN. There is a correlation between the PF value of the PGN and the PDU Type of the PG. A PDU1 Type PG shall have a PGN with a PF value from 0 to 239, inclusively, and a PDU2 Type PG shall have a PGN with a PF value from 240 to 255, inclusively. The PF value is the least significant byte of the result of the PGN value bit shifted right by 8, as shown by the equations in Figure 4.

$$PF = (PGN \gg 8) \% 256$$

$$PF = (\text{floor}(PGN / 256)) \text{ modulo } 256$$

Figure 4 - Equations for calculating PF from PGN

5.1.1.5 PDU Specific (PS)

The PDU Specific is an 8-bit value of the four component values that comprise the SAE J1939 PGN. The PS value for the PGN of a PDU1 Type PG shall always be 0, and the PS value for a PDU2 Type PG PGN shall be from 0 to 255, inclusively. The PS value is the least significant byte of the PGN value, as shown by the equations in Figure 5.

$$PS = PGN \% 256$$

$$PS = PGN \text{ modulo } 256$$

Figure 5 - Equations for calculating PS from PGN

5.1.2 PG Label (PG Name) and Acronym

A unique PG Name and unique Acronym are assigned to each Parameter Group to aid in referring to the PG in documentation, specifications, and dialog. The PG Name is a title meant only to provide a general description of the parameter data content, e.g., Transmission Control 1, or the function of the PG, e.g., Request. The Acronym for a PG is generally derived from the PG Name, e.g., TC1 for the Transmission Control 1.

5.1.3 PG PDU Type

The PDU Type property describes the destination addressing capability of the PG. There are two PDU types assigned to SAE J1939 PGs: PDU1 or PDU2.

A PDU1 type PG is commonly referred to as a destination specific PG. Each instance of a PDU1 type PG can be addressed (sent) to a different controller application (CA) (e.g., network device). A PDU1 type PG can be addressed to a single CA or globally to all CAs (using the Global Destination Address). PDU1 type is best suited for a PG with control or command information in its PG data, where it can be necessary to send the PG with different parameter data values to different CAs. For example, sending actuator position commands to different actuators. Some PDU1 type PGs have special destination address requirements. For example, the Address Claimed PG and the Acknowledgement PG, both PDU1 type PGs, each require using the global address (255) as the destination address.

A PDU2 type PG is commonly referred to as a broadcast PG and does not support destination addressing. A PDU2 type PG can only be sent globally to all devices on the network. A PDU2 type PG cannot be directed only to a specific receiver. A PDU2 type is best suited for a PG with measured or status data, such as engine speed or oil temperature, where the reported PG data values are the same regardless of the receiver.

There is a correlation between the PDU Type of the PG and the PDU Format (PF) value of the assigned PGN. The PDU Format value for a PDU1 PG is from 0 to 239, inclusively, and the PDU Format value for a PDU2 PG is from 240 to 255, inclusively.

5.1.4 Default Priority

The Default Priority for a PG specifies the recommended data link layer (D_PDU) priority to use when transmitting an instance of the PG. Refer to SAE J1939-21 and SAE J1939-22 for more details.

5.1.5 PG Data Length Specification

PG Data Length is a specification of the length of the PG data for the PG. The PG data for a PG can be defined as having a fixed (non-variable) length or having a variable length. For a PG defined with fixed length PG data, the length of the PG data is the specified byte length for every instance of that PG. For a PG defined with variable length PG Data, the length of the PG data can vary between instances for that PG. A PG is defined with variable length PG data when its PG data definition contains parameters with variable length data, contains repeating groups of parameters, and/or its PG data definition can be modified and extended to accommodate additional parameters.

SAE J1939 uses numerous methods for specifying the length of the PG data. In SAE J1939 and some SAE J1939 documents, the length characteristic of the PG data is defined using only the “PG Data Length” property. In SAE J1939DA and other SAE J1939 documents, the length characteristic of the PG data is defined by the combination of “PG Data Length Class,” “PG Data Minimum Length,” and “PG Data Length Constraint” properties.

5.1.5.1 PG Data Length

The PG Data Length property specifies the length characteristic of the PG data. When the PG Data Length specifies a single numeric value, the length of the PG data for all instances of the PG should be that specified length. If the PG Data Length specifies “variable” or a range of numeric values, then the length of the PG data can vary for the PG.

SAE J1939 is transitioning from using the PG Data Length property to using the combination of “PG Data Length Class,” “PG Data Minimum Length,” and “PG Data Length Constraint” properties for specifying the length characteristics of the PG data. The transition allows SAE J1939 to better distinguish when a PG has fixed length PG Data that shall never change, and a PG has fixed length PG Data for all instances by an originator, but the length of the PD Data can change over time as new SPs are added to the PG data definition.

5.1.5.2 PG Data Length Class

PG Data Length Class property describes the variability in the length of PG Data per PG data definition. It also describes the ability for the PG data definition to be lengthened to add more data parameters. Each of Data Length classes are described in Table 1. The PG Data Length Class property is used together with the PG Data Minimum Length and PG Data Length Constraint properties.

Table 1 - PG data length class descriptions

Classification	Description
Fixed	PG Data length shall always be <i>PG Data Minimum Length</i> for all instances of PG. The PG data definition shall not be extended longer than <i>PG Data Minimum Length</i> . The PG data definition only has single instances of fixed length parameters (SPs).
Fixed Extendable	PG Data length can be as short as <i>PG Data Minimum Length</i> , can vary between instances from different senders, and should be constant between instances from same sender. The PG data definition can be extended (by the SAE J1939 Committee) with new bytes beyond last defined byte to accommodate new parameters (SPs). The PG data definition only has single instances of fixed length parameters (SPs).
Variable	PG Data length can be as short as <i>PG Data Minimum Length</i> and can vary between all instances of the PG. The PG data definition can be extended (by the SAE J1939 Committee) with new bytes beyond last defined byte to accommodate new parameters (SPs). The PG data definition contains variable length SPs and/or repeated groups of SPs.

5.1.5.3 PG Data Minimum Length

PG Data Minimum Length property specifies the shortest permissible length of the PG Data for any instance of the PG. This does not mandate nor require support of the parameters whose data is positioned in the bytes within the specified minimum length. The value of this property is established at PG assignment and is never changed. Bytes associated with unassigned data bits and unsupported parameters are encoded as specified in 5.1.10 and 5.1.11.

For one example, consider a Fixed Extendable PG specified with a PG Data Minimum Length of 15 bytes where a transmitter of the PG supports SPs whose data occupy PG data through byte 11. In this situation, the transmitter shall append 4 bytes of FFh following the 11 bytes spanning the supported SPs so the transmitter sends the PG with PG data that is at least 15 bytes long, i.e., the specified PG Data Minimum Length for the PG.

For another example, consider a Fixed Extendable PG specified with a PG Data Minimum Length of 15 bytes and defined with SPs whose data occupy PG data through byte 22. In this example, a transmitter of the PG supports SPs whose data occupy PG data through byte 18. In this situation, the transmitter is not required to append any bytes of FFh following the 18 bytes spanning the supported SPs since the length of the PG data is equal to or greater than the specified PG Data Minimum Length for the PG. The transmitter in this example is permitted to send the PG with PG data that is 18 bytes long.

5.1.5.4 PG Data Length Constraint

PG Data Length Constraint property describes any special constraint on the length of PG Data. Most commonly used when there is a need to limit the maximum length of the PG data.

5.1.6 PG Data and PG Data Definition

PG Data refers to the data object containing the data communicated by the PG. The data content and structure of the PG Data for a PG is specified by its PG Data Definition and PG Data length properties.

PG Data Definition refers to the specification of each parameter whose data is communicated in the PG Data and the position of the parameter's data within that structured data object. For each data parameter (SP) communicated within the PG data, the PG data definition references the data parameter (SP) by its assigned SPN and specifies the position of the parameter's encoded data in the PG data structure. The SP definition specifies the technical details such as parameter name, data size, and data encoding, as discussed in 5.2. The PG data position for the data for a parameter is specified as either an absolute position (e.g., bytes 4 to 5) or a relative position (subsequent placement following data for another parameter), as discussed in 5.1.8.

The PG data for some PGs can contain multiple instances of data for a single SP, multiple instances of data for a group of SPs, or both. When a PG can contain multiple instances of SPs in the PG Data, the SP or group of SPs are specified in the PG data definition and a description of the repeated data is described in the PG Description. Some examples are Engine Maximum Net Torque Map PG (PGN 64248) and Active Diagnostic Trouble Codes (DM1) PG (PGN 65226).

SAE J1939 specifies a technique for encoding PG data bits for unassigned (undefined) bits and bits for unsupported data parameters, as discussed in 5.1.10 and 5.1.11. This technique permits unassigned bits to be assigned to parameter data in the future without causing incompatibilities.

Parsing parameter data from PG data requires knowing the position of parameters per the PG data definition for that PG and knowing the data parameter's (SP) data definition for the data size and its encoding. For data parameters with relative position, parsing the parameter data can require evaluating or parsing other data parameters.

5.1.7 PG Data Bit Numbering

SAE J1939 uses a one-based index numbering when specifying byte and bit positions in the PG data. Using a Big-endian model, byte 1 is the leftmost byte, byte 2 follows to the right, and so on. Bit 1 is the lowest order bit in a byte, and bit 8 is the highest order bit in a byte. Parameter position notations are described in detail in 5.5.

5.1.8 SP Position (SP Position in PG)

The SP Position specifies the placement of the data for the SP in the PG data. See 5.5 for details on conventions for specifying SP Position in PG and the placement of the SP data.

The following guidelines provide the basis for the parameter data placement conventions. These guidelines and the conventional parameter placement methods should be applied when defining the placement of parameters in PGs.

- a. Parameters with less than 8 bits should reside within a byte boundary.
- b. Parameters with more than 8 bits should either start or stop on a whole byte boundary.
- c. Only parameters with more than 8 bits should span a byte boundary.
- d. Text data parameters, variable length parameters, and parameters with repeating data should start and stop on whole byte boundaries.
- e. Byte ordering rules are specified in 5.1.9.

5.1.9 Parameter Data Byte Ordering

This section specifies the byte ordering of parameter data in the PG data. This applies to all parameters with more than 1 byte of data. Data bits within a byte boundary are always placed (ordered) so the most significant bit of the data is placed in the highest order bit occupied by the parameter data and the least significant bit of the data is placed in the lowest order bit occupied by the parameter data.

Further description of bit placement within PG data is described in 5.5.

5.1.9.1 Default Data Ordering

Parameters with more than 1 byte of data, other than text or byte array data, shall be placed (ordered) least significant byte first in the PG data. Least significant byte (LSB) first for data with integral number of bytes means the least significant byte of the encoded data is positioned in the lowest ordered byte of the PG data bytes occupied by the parameter data, and the most significant byte of the encoded data is positioned in the highest ordered byte of the PG data bytes occupied by the parameter data.

5.1.9.2 Text Data Ordering

Parameter data with text data encoding (see 5.3.4.2), formerly referred to as ASCII, shall be placed (ordered) most significant byte first in the PG data. Most significant byte (MSB) first for text data means the individual characters are positioned in the PG data in left-to-right reading order of the text string. The leftmost character of the text string shall be positioned in the lowest ordered byte of the PG data bytes occupied by the parameter data, and the rightmost character of the text string shall be positioned in the highest ordered byte of the PG data bytes occupied by the parameter data. For example, if the text string is "The quick brown fox jumped over the lazy dog" and the PG definition indicates the parameter data is to start at byte 1 in the PG data, then the text character "T" shall be positioned in byte 1 of the PG data and the text character "g" shall be positioned in byte 44 of the PG data.

5.1.9.3 Byte Array Data Ordering

Parameter data with byte array data encoding (see 5.3.4.5) shall be placed (ordered) in the PG data as follows: the data byte with array index 1 is placed first, followed by the data byte with array index 2, etc. Byte array data refers to a sequence of one or more whole bytes of binary data treated as an array of bytes.

5.1.10 Unassigned PG Data Bits

PG data definitions can have PG data bits that are not yet assigned to any parameter. SAE J1939 refers to these bits as unassigned, unspecified, or SAE J1939 reserved bits. These unassigned bits are strictly reserved for future assignment by SAE J1939 and cannot be used at the discretion of component and system designers.

The “SAE J1939 not available bit encoding” technique (described in 5.1.11) is used to encode PG data bits not yet assigned to a data parameter. This unused PG data bit encoding practice allows SAE J1939 to assign additional data parameters to the unused bits at some future date in order to maximize the data content of the PG data. This encoding technique allows a recipient of the PG data to determine if data is provided for data parameters assigned to those PG data bits even when a data parameter is assigned to those PG data bits in the future.

5.1.11 Unsupported Parameters

The transmitter of an SAE J1939 PG is not required to provide actual parameter data for every SP that is contained in the PG data. The “SAE J1939 not available bit encoding” technique is used to encode PG data bits associated with an unsupported data parameter.

SAE J1939 employs the “SAE J1939 not available bit encoding” technique for encoding PG data bits that are not supported by the transmitter or unassigned data bits. Per this data encoding practice, each PG data bit is encoded with a numerical value of one (1). This practice allows a recipient of the PG data to determine if data is provided for any data parameter assigned to those PG data bits. In cases where “Measured” and “Control” parameters use 2-bit data (11b), these are used as “not available” or “don’t care.”

5.1.12 Transmission Rate

The transmission rate specifies the required transmit behavior and timing requirements for the PG. Most SAE J1939 PGs are transmitted in either a continuous unsolicited behavior or a solicited (requested) behavior. While there are numerous transmission rate models, the most common transmission rate models are continuous unsolicited transmit (e.g., fixed interval period and fixed interval period with event-driven updates) and solicited transmit (e.g., on request). For a PG with continuous unsolicited transmit behavior, the PG is sent automatically and periodically by a transmitter (producer) of the PG. For a PG with solicited transmit behavior, the PG is only sent when requested or prompted. The Request PG (PGN 59904; refer to SAE J1939-21 or SAE J1939-22) provides the service for requesting (soliciting) another device to transmit a specific PG. The PG data for the Request PG contains the PGN of the PG being requested to be transmitted.

All Parameter Group transmission repetition rates defined in SAE J1939 are nominal rates. The actual transmission repetition rate on the network should be at this rate plus/minus the “typical” jitter which occurs in microcontroller-based systems. The average rate should be the nominal value.

5.1.12.1 Transmission Rate for Engine Speed and Crank Angle Based Update Behavior

The transmission rate specified for some PGs include the declaration “engine speed dependent.” This clause can be specified in the PG transmission rate for a PG when the PG data contains parameters that can be calculated, measured, and/or updated based on engine crank angle rather than at a fixed time interval. The primary goal with this allowance is to minimize the latency associated with sampling, calculating, and transmitting the data without overburdening the network, such as when the engine is not running or running at idle speeds. This allowance provides the producer the ability to change the interval between successive instances of the PG based on the current operating speed, keeping the intervals within an acceptable range (see Figure 6).

There are many approaches to sampling the data to be converted and sent over the network. The two preferred approaches are: (a) time-based sampling, calculating, and transmit; and (b) a hybrid of time-based and engine crank angle-based sampling, calculating, and transmit, where timing is modified based on the current operating speed in order to maintain an update rate within an acceptable range (see Figure 6). Because there are multiple ways to acquire and transmit data onto the network, the following guidelines have been defined for the engine speed and directly associated data.

- a. At speeds above 500 rpm, the time from sampling to message transmission shall not exceed 12 ms. Systems that acquire engine speed dependent information via period measurement inherently have less time delay at higher speeds.
- b. Above 1000 rpm, for instance, the time from sampling to message transmission shall range from 5 to 30 ms. Less time is required because the period measurement takes less time at higher speeds. How much time is saved depends on the number of crank angle degrees used to perform the period measurement.

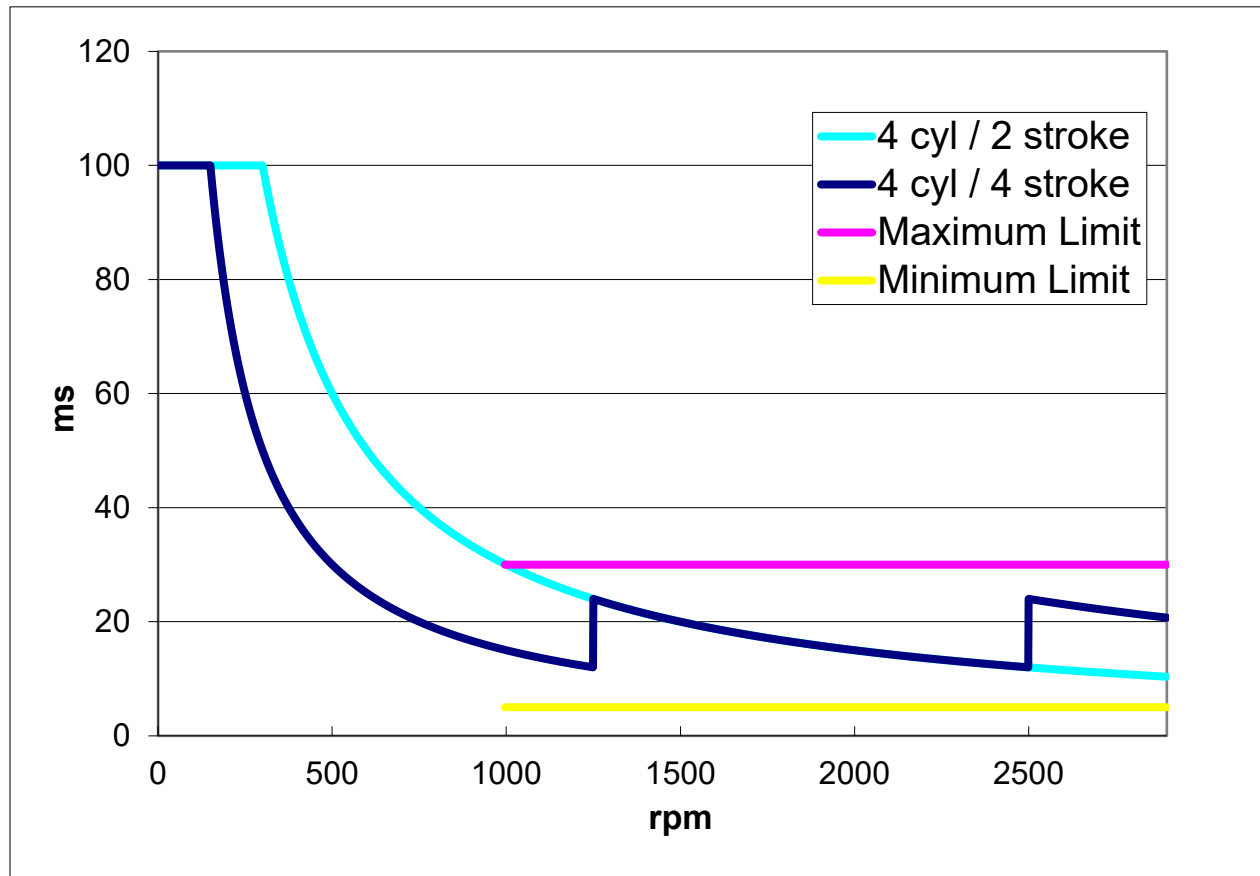


Figure 6 - Limits of hybrid update rates