Temposonics
AN AMPHENOL COMPANY

Protocol Manual

MH-Series with J1939 Safety

Magnetostrictive Linear Position Sensors

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1. Introduction

The intent of this document “Temposonics MH CAN J1939 SIL Safety sensor manual” is to provide the user information required to implement the MH position sensor using the J1939-76 extension for Functional Safety.
It is not the intent of this document to provide a full reckoning of the SAE CANbus protocol. It is the responsibility of the user to adhere to the SAE J1939 specification and to properly integrate the sensor protocol into the Safety System.
The sensor electronics and functionality will remain current to the development of the SAE J1939 standard.
More details on the safety aspects of the sensors can be found in the MH-Series with CAN Safety Manual (Document 552177).

2. Address Claim Message

The Temposonics sensor sends an address claim message at several events.
It most importantly happens after sensor bootup.
The address claim message can also be requested, and there are prescribed behaviors when the designated node address cannot be claimed.
Detail on the J1939 CANbus address claim process is defined in the J1939-81 standard.
Example of format of the Address Claimed Message:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18EEFFSA	8	0xB1	0x7F	0x39	0x21	0x00	0x8E	0x06	0x30

The “SA” of the identifier denotes the address the sensor has just successfully claimed.
The abbreviation TSN stands for Truncated Serial Number. The J1939 standard reserves 21 bits for a unique identification entry, and Temposonics serial numbers are 27 bits wide. Therefore, the sensors serial number is reduced to its lower 21 bits.
For Example, the serial number “87654321” is equal to “05 39 7F B1” in hexadecimal.
This truncated to the lowest 21 bits is “0x19 0x7F 0xB1”.
As indicated in the table above, the TSN does not inhabit all of the byte D2. The top three bits of D2 have a different function (see J1939-81 for details). Merging the 0x20 from that function with the “19 7F B1” the entire Address Claimed Message data string would be: “B1 7F 39 21 00 8E 06 30”.

In J1939, this string is referred to as the device “Name”. The Name is also used in the process for assigning a source address, explained in the next section.

3. Safety Data Message

The Temposonics sensor output data includes the position of a single target magnet along the sensor's stroke axis. Included in the Safety Data Message is the 8-bit position transmitted as an 8 byte hexadecimal data message in little-endian format (smallest least significant byte (LSB) first). The position data is accompanied by status and diagnostic indicators as shown in figure 1.
The J1939 protocol defines the network communication as a peer-to-peer network, meaning that every device on the network communicates to every other device on the network. The network traffic is managed with what is defined as a 29-bit message ID. Included in the ID is the data that defines which device the message is produced by, and the intended consumer. Every node on the network will read the ID and decide if the data is intended for it or ignored.

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
Data Priority PGN Node ID	8	POS LSB	POS MSB	0x00	0x00	STATUS CODE	ERROR CODE	LIMIT CODE	0xFF

Fig. 1: SAE J1939 DATA FRAME

3.1 SAE J1939 29bit Identifier

J1939 29-bit extended CAN frame identifier
Example 0x18FFFFFD
SAE PGN Proprietary B - PDU 2 Format

Description		Numbers	Default Values
Data Priority		3	6
J1939 Parameter Group Number (PGN)	Reserved	1	0
	Data Page	1	0
	PDU Format	8	0xFF
	PDU Specific	8	0xFF
Source Address (Node ID)		8	0xFD

Example ID = 0x18FFFFFD

Priority Data			J1939 Parameter Group Number (PGN)																	Source Address (Node ID)							
28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1

J1939 Parameter Group Number (PGN)																	
Reserved	Data Page	PDU Format								PDU Specific							
25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8
0	0	0xFF								0xFF							

3.2 SDM Position

This first two data Bytes are the hexadecimal position data values in reversed format. These values are combined to transmit the data count for the linear displacement of the target magnet.

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18FFFFFD	8	**0x2C**	**0x01**	0x00	0x00	STATUS CODE	ERROR CODE	LIMIT CODE	0xFF

For Example: 0x2C 0x01 = 0x12C = 300 counts.
The position value represents a linear position, in counts, from the sensor flange.

Note that position data will immediately read **"0x00 0x00"** for any error code trigger. This trigger covers all failure modes and does not require the evaluation of Byte 5 Status, Byte 6 Error, or Byte 7 Limit.
Errors can safely be detected by recognizing Byte 1 and 2 data as "0x00 0x00".

3.3 SDM Status Code

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18FFFFFD	8	POS LSB	POS MSB	0x00	0x00	**STATUS CODE**	ERROR CODE	LIMIT CODE	0xFF

Included in the 8 Byte data frame is Byte #5 Status Code. The status code provides several diagnostic codes including:

Code	Status
0x00	Normal
0x82	Temperature Error
0xA8	Missing Magnet
0xA9	Extra Magnet

These Status Codes can be used to help troubleshoot the fault mode.

3.4 SDM Error Code

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18FFFFFD	8	POS LSB	POS MSB	0x00	0x00	STATUS CODE	**ERROR CODE**	LIMIT CODE	0xFF

Included in the 8 Byte data frame is Byte #6 Error Code.
The error code provides the following codes including internal memory and controller errors, range error, temperature error, no magnet detected, and multiple magnets detected.

Each error adds a bit value to the resulting error code:

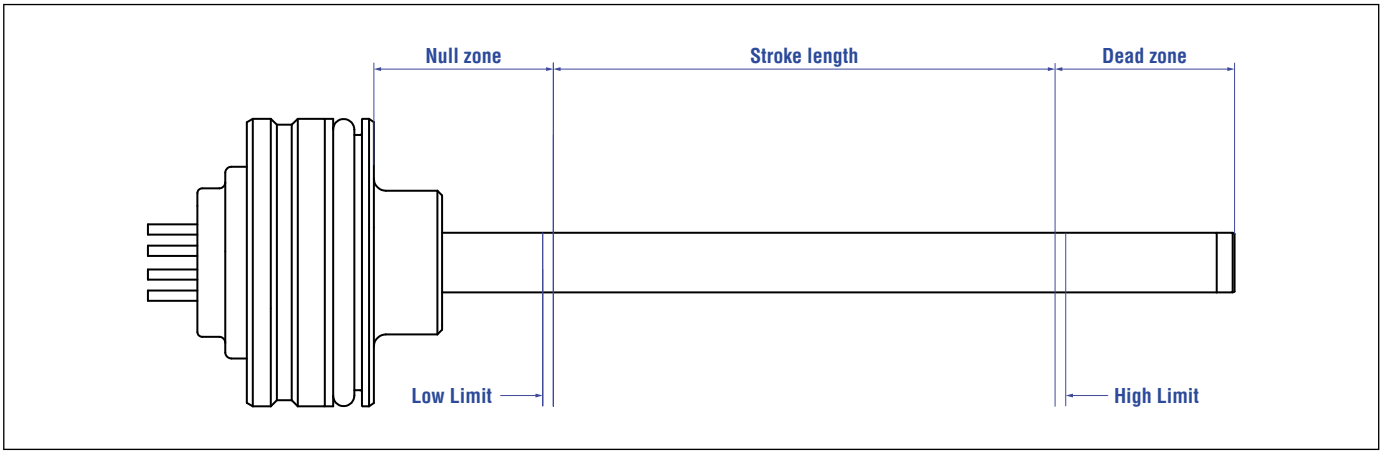
Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
Memory Error	Controller Error	Range Error	Temperature Error	No magnet error	Multiple magnet error	Always 0	Always 0

Bit 1 and Bit 2
Memory and Controller Error – Internal error indicating a problem with the sensor microcontroller. If this error is found, the sensor should be replaced and returned to Temposonics for evaluation.
Bit 3
Range Error – the position magnet is not inside the active stroke range.
Bit 4
Temperature Error – the temperature is outside of the specified range (–40…+105 °C).
Bit 5
No Magnet Error – The electronics does not see the magnet response pulse.
Bit 6
Multiple Magnet Error – The electronics sees multiple magnet response pulses.

3.5 SDM Limit Code

Included in the data frame is Byte #7 Limit Code. The Limit Code is used as a limit trigger indicator when the magnet moves out of the working stroke range of the sensor:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18FFFFFD	8	POS LSB	POS MSB	0x00	0x00	STATUS CODE	ERROR CODE	**LIMIT CODE**	0xFF



LL (Stroke Span) = 0x08
0 = Position value above low limit
1 = Position value below low limit

Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
0	0	0	0	1	0	0	0

HL (Stroke Span) = 0x02
0 = Position value below high limit
1 = Position value above high limit

Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
0	0	0	0	0	0	1	0

4. Safety Header Message

The elevated requirements for safety relevant applications requires additional data security as described in the SAE J1939-76 (Section 6.1) specification. The sensor features a second message called the Safety Header Message (SHM). The Safety Header Message (SHM), together with the Safety Data Message (SDM) make up the Safety Data Group (SDG).
The SHM must be processed together with the SDM to produce valid sensor data.
Please refer to the J1939-76 (Section 5.1.5 and 6.2.2) specification for definitions detailing the SHM message and the 32 bit CRC checksum number for authentication of the Safety Data Message.
Safety Header Message (PGN 0x0E00 = 3584), Default SA = 0xFD

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x180E00SA	8	0xSC	ISA	IPS	IPF	32 bit CRC			

The SHM includes:
- A sequence counter SC (5 bits for each SDG)
- The bit inverted Source Address ISA (Default 0xFD)
- The bit inverted PDU Specific (PS) Value IPS (Default 0xFF)
- The bit inverted PDU Format (PF) Value IPF (Default 0xFF)
- The CRC for the SDM data (32 bits)

5. Commanded Address Messages

The Commanded Address Message allows changes to the source address the sensor will assume on power up. Every device on CAN network requires a unique source address (Node ID). The commanded address messages, or "BAM" Broadcast Announce Message provides a method of changing the sensor Node ID.
When multiple sensors with the same Node ID are utilized on the same CANbus, the BAM message can be used to change the sensor address based on the sensor application.
The sequence of messages used for BAM use the sensor's "Name" string.
The controller can utilize the sensor Name Bytes to identify the sensor and determine the sensor name, or use the sensor Serial Number to identify and assign a proper Node ID.
Either of the two methods can be the best choice, depending on the circumstances.
The Commanded Address Message will need to send the "Name" string plus one byte for the desired address. Since this brings the total to 9 bytes, the command is conveyed using a multi-message BAM process.
Note that the timeout between the three messages is 250 ms, so that manually sending messages (during test bench programming) can only be done by sending of all three messages very quickly as a group. Additional detail on the BAM transport protocol can be found in the SAE J1939-21 standard.

BAM data messages used to update Source Address:

DataMessage1:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18**EC**FFFF	8	0x20	0x09	0x00	0x02	0xFF	0xD8	0xFE	0x00

DataMessage2:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18**EB**FFFF	8	**0x01**	**Name Bytes 0-6**						

DataMessage3:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18**EB**FFFF	8	**0x02**	**Name Byte 7**	**SA**	**0xFF**	**0xFF**	**0xFF**	**0xFF**	**0xFF**

In the identifier – "SA" is the source address producer, and "MA" is the master address consumer (both shown as 0xFF global address).
The "SA" in Message 3 sets the new source address for the sensor.
The new address will be stored into the sensor's nonvolatile memory. The sensor power supply must be maintained securely during the execution of the new Node ID command. If interrupted, the nonvolatile memory could be corrupted leaving the sensor unrepairable.
A checksum stored in nonvolatile memory verifies communications settings such as the protocol and baud rate. If the checksum does not match, the settings cannot be trusted and the sensor remains silent as not to become the source of a blocked CAN bus.

When the new address has been successfully stored, the sensor will assume the new address during operation and acknowledge by sending the Address Claimed Message.

6. Proprietary Configurable Message

The Temposonics Safety sensor is programmed with several proprietary PGN numbers which can be used to apply application specific settings. The abbreviations MA and SA in the identifier designate Master Address (global 0xFF) and Sensor Address (default 0xFD).

PGN (hex)	Description
0xB100	Sensor Name
0xB200	Cycle Time
0xB300	PGN
0xB400	Sensing Element ID
0xBA00	SN and SE Length

Proprietary Configurable Message #1: Configure Sensor Name allows modification of 4 Bytes of the Sensor Name Byte 4 through Byte 7

NOTE
The first four Bytes are required as a “password unlock”

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18**B1**SAMA	8	**0x54**	**0x45**	**0x4D**	**0x50**	**Name bytes 4-7**			

Proprietary Configurable Message #2: Configure Cycle Time (transmission rate) allows modification of the cycle timing rate the sensor reports position data.

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18**B2**SAMA	8	**0x54**	**0x45**	**0x4D**	**0x50**	**LSB 0x14**	**MSB 0x00**	**0x00**	**0x00**

NOTE
Units are in milliseconds. (0x14 = 20ms)

Proprietary Configurable Message #3: Allows modification of the PGN lower byte.

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18**B3**SAMA	8	**0x54**	**0x45**	**0x4D**	**0x50**	**LSB 0x??**	**0xFF**	**0x00**	**0x00**

Example - Send to sensor:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18**B3**FFFF	8	**0x54**	**0x45**	**0x4D**	**0x50**	**0xAA**	**0xFF**	**0x00**	**0x00**

Sensor Reply:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18FF**AA**FD	8	**Position LSB**	**Position MSB**	**0x00**	**0x00**	**Status Code**	**Error Code**	**Limit Code**	**0xFF**

Proprietary Configurable Message #4 – only applies to the MH FLEX Safety: Sensing Element Identification allows the read of SE Serial Number and SE Length data.

Send request to Sensor:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3
0x18**EA**SAMA	3	**0x00**	**0xBA**	**0x00**

NOTE
PGN 0xEA00 is used for general requests

Sensor Reply:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18**BA**00**SA**	8	**Serial Number**						**SE Length**	

The format for both entries is Little-Endian, and the unit for the SE length parameter is micrometer. Thus, a serial number of “87654321” (=0x05397FB1) and a meter long (0x0F4240) sensing element would lead to a response with the data string “B1 7F 39 05 40 42 0F 00”.

7. Software ID and Component Identification

The software and component Identification are described in the standard J1939-71.
This section explains how to interpret the numbers in the data strings.

7.1 Software ID

Send Request to Sensor:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3
0x18**EA**SAMA	3	**0xDA**	**0xFE**	**0x00**

Sensor Reply:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18FEDASA	8	0x02	SW Number			0x2A	SW Revision		

7.2 Component SE Identification

Send Request to Sensor:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3
0x18**EA**SAMA	3	**0xEB**	**0xFE**	**0x00**

Sensor Reply:

29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
0x18**FEEB**SA	8	0x2A	0x2A	Sensor Serial Number				0x2A	0x2A

The format for the sensor serial number is Little-Endian. Therefore, a sensor with the serial number of “87654321” (=0x05397FB1) would response with the data string “2A 2A B1 7F 39 05 2A 2A”.

8. Example: Address Claim, Safety Header Message, and Safety Data Messages

The software and component Identification are described in the standard J1939-71.
This section explains how to interpret the numbers in the data strings.

Description	29 bit ID	Data Packet Bytes	Data Byte 1	Data Byte 2	Data Byte 3	Data Byte 4	Data Byte 5	Data Byte 6	Data Byte 7	Data Byte 8
Address Claim Message	0x18EEFFFD	8	0x5E	0xCF	0x3C	0x21	0x00	0x8E	0x06	0x30
Safety Header Message	0x180E00FD	8	Sequence Counter	ISA 0x02	IPS 0x00	IPF 0x00	CRC 0x45	CRC 0xE9	CRC 0x8F	CRC 0x0E
Safety Data Message	0x18FFFFFD	8	0x0C	0xB5	0x01	0x00	0x00	0x00	0x00	0xFF

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