Temposonics
AN AMPHENOL COMPANY

Protocol Manual

MH-Series with CANopen Safety

Magnetostrictive Linear Position Sensors

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1. Introduction

The intention of this document is not to introduce the CANopen communication protocol or its DS304 extension for Functional Safety.

It will not even give an exhaustive list of which commands the MH CAN SIL sensor is capable to responding to, as through updates, the product will be kept current with the developments of the CANopen protocol.

Instead, explained is that part of the communication that is specific to the product. Either, in that commands are using application specific codes, or in that data needs to be interpreted in ways that are not laid out by the standard.

2. Initiation of data stream

After power up, the sensor will not automatically begin to transmit position information. Instead, only a single boot message is sent.

Because of the protocol being geared towards safety relevant applications, there is a requirement to first verify the validity of the configuration. Any 'Node Start' command that is sent prior to performing this validation will be ignored.

Thus, the entire startup sequence would look like this:

COB-ID	RX/TX	DLC	D0
0x700+NI	TX	1	0x00

This is the boot message, NI stands for node ID.

COB-ID	RX/TX	DLC	D0	D1	D2	D3	D4	D5	D6	D7
0x600+NI	RX	8	0x22	0xFE	0x13	0x00	0xA5	0x00	0x00	0x00
0x580+NI	TX	8	0x60	0xFE	0x13	0x00	0x00	0x00	0x00	0x00

These two messages are the call for the configuration valid check and sensor's response ("00 00 00 00" = "configuration valid').

COB-ID	RX/TX	DLC	D0	D1
0x000	RX	2	0x01	0x00

This is the command to start all nodes.

COB-ID	RX/TX	DLC	D0	D1	D2	D3	D4	D5	D6	D7
0x0FF + 2xNI	TX	8	0x21	0x03	0x00	0x00	0x00	0x00	0x00	0x00
0x100 + 2xNI	TX	8	0xDE	0xFC	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF
0x0FF + 2xNI	TX	8	0x21	0x03	0x00	0x00	0x00	0x00	0x00	0x01
0x100 + 2xNI	TX	8	0xDE	0xFC	0xFF	0xFF	0xFF	0xFF	0xFF	0xFE
0x0FF + 2xNI	TX	8	0x21	0x03	0x00	0x00	0x00	0x00	0x00	0x02
0x100 + 2xNI	TX	8	0xDE	0xFC	0xFF	0xFF	0xFF	0xFF	0xFF	0xFD

This block shows the beginning of the process data stream. The meaning of the bytes is explained in the chapter "Structure of the SRDO, position and velocity in the process data".
For more details on starting and stopping nodes see the CANopen standard.

3. Structure of the SRDO, position and velocity in the process data

The safety relevant function of the sensor with “S02” protocol is providing the position of the target magnet along the measuring axis.
Parallel to measuring and transmitting the position, diagnosis processes continuously check for component failures or environmental conditions interfering with the measurements. If the accuracy of the position management is not guaranteed, the position data is set to “00 00 00 00”.
Depending on the sensor style, different sensors apply different position offsets. However, they are always such, that “00 00 00 00” is not part of the active output range.
Thus, the entire safety function can be established by only evaluating the position bytes in the process data.

The position information can be found in the first four bytes:

COB-ID	RX/TX	DLC	D0	D1	D2	D3	D4	D5	D6	D7
0x0FF + 2xNI	TX	8	Position (little endian)				velocity		Status	Counter

The resolution of the position is 0.1mm by default but can be altered through an SDO (see "Measuring Step Position" in section 7.3: Trim Settings).

The resolution of the velocity is 1mm/s. Thus 1m/s would read as 1000 (0x3E8).

The Sensor Status gives coded information about the findings of the diagnostics processes. For more details on the Sensor Status refer to the Safety Manual for the MH CAN SIL sensors.

The counter is part of the measures to increase the safety. Failure modes where the CAN port of the controller just repeats one message over and over can be discerned.

The function of the second message (COB-ID = 0x100 + 2x node ID) also serves to minimize chances transmission errors. It contains the bitwise inverted information of the first message. For details how to counter and inverted message see the DS304 extension of the CANopen protocol.

4. The Emergency Object, entering and leaving states of malfunction

CANopen protocol uses Emergency Objects to inform that the sensor has entered a state of error, or that a state of error has ended.
Any Error state will also be visible in the SRDO through Status byte and the position data being set to zero. The Emergency Objects enable timely reactions especially in cases where the SRDOs are generated with a slow update rate or are suspended altogether.

The message structure is as follows:

COB-ID	RX/TX	DLC	D0	D1	D2	D3	D4	D5	D6	D7
0x80+NI	TX	8	Emergency Error Code		Error Register	Status	0x00	0x00	0x00	0x00

Note that the COB-ID being "0x80 + NI" is just the default setting. If needed, it can be altered

The Emergency Error Code can contain the following signatures:

Emergency Error Code	Meaning
0x0000	Error cleared message or no error
0x1000	Magnet signal is deformed or too few / too many magnets detected
0x3000	Check of internal voltages failed
0x4200	Internal temperature left allowed range
0x5000	Internal hardware check failed
0x6300	Parameter integrity check failed
0xFFA0	Minimum Position
0xFFA1	Working Area Low
0xFFA2	Maximum Position
0xFFA3	Working Area High

The Error Register can show multiple errors by setting corresponding bits to one:

Error Register Bits	Meaning
Bit 0	Generic Error
Bit 1	Current
Bit 2	Voltage
Bit 3	Temperature
Bit 4	Communication Error
Bit 5	Profile Specific
Bit 6	Reserved
Bit 7	Manufacturer Specific

The Sensor Status gives coded information about the findings of the diagnostics processes. For more details on the Sensor Status refer to the Safety Manual for the MH CAN SIL sensors.

5. Changing Node ID and Baud Rate through LSS

The Layer setting services (LSS) allow manipulations of certain settings. For the product at hand these are the node ID and the baud rate.

The first step is to enter the LSS state. This is done by sending a sequence of four messages. Each message contains a 7 byte long hexadecimal number, narrowing down the selection until only one unit is responding.

COB-ID	RX/TX	DLC	D0	D1	D2	D3	D4	D5	D6	D7
0x7E5	RX	8	0x40	Vendor - ID						
0x7E5	RX	8	0x41	Product Code						
0x7E5	RX	8	0x42	Revision Number						
0x7E5	RX	8	0x43	Sensor Serial Number						

The first three numbers (Vendor – ID / Product Code / Revision Number) are fixed for all Temposonics sensors, so they will always look like in the example below:

COB-ID	RX/TX	DLC	D0	D1	D2	D3	D4	D5	D6	D7
0x7E5	RX	8	0x40	0x40	0x00	0x00	0x00	0x00	0x00	0x00
0x7E5	RX	8	0x41	0x00	0x78	0x78	0x53	0x00	0x00	0x00
0x7E5	RX	8	0x42	0x31	0x30	0x2E	0x31	0x00	0x00	0x00
0x7E5	RX	8	0x43	0x34	0x12	0x50	0x09	0x00	0x00	0x00
0x7E5	TX	8	0x044	0x00	0x00	0x00	0x00	0x00	0x00	0x00

The fourth line shows how the sensor serial number is interpreted as if it were in hexadecimal format: “9501234” is sent as 0x9501234.
The final row displays the response from the sensor, acknowledging to have entered the LSS mode.
To learn more about the LSS, like for example the global command to enter the LSS state, refer to the DS304 extension of the CANopen protocol.

6. Summary of SDOs

Index	SDO name	Access	For details see
0x1000	Device Type	constant	7.1
0x1001	Error Register	read only	7.2
0x1002	Manufacturer status register	read only	7.2
0x1008	Manufacturer device name	constant	7.1
0x1009	Manufacturer hardware version	constant	7.1
0x100A	Manufacturer software version	constant	7.1
0x1010	Store parameters Save all parameters	read / write	7.6
0x1011	Restore parameters to default values	read / write	7.6
0x1014	COB-ID EMCY message	read / write	7.5
0x1017	Producer Heartbeat Time	read / write	7.5
0x1018	Identity Object Entries	constants	7.1
0x1200	SDO server parameters COB-ID client → server	constants	7.1
0x1301	SRDO communication parameters	read / write	7.4
0x1381	SRDO mapping parameters	constants	7.4
0x13FE	Configuration valid	read / write	7.4
0x13FF	Safety configuration signature SRDO1 signature	read / write	7.4
0x1800	Transmit PDO Communication Parameters	read / write	7.5
0x1A00	Transmit PDO Mapping Parameters	constants	7.5
0x6005	Measuring Step Position / Velocity	read / write	7.3
0x6010	Position Offset Position Offset	read only	7.3
0x6020	Position	read only	7.2
0x6030	Velocity	read only	7.2
0x6200	Transmission Rate	read / write	7.5
0x6501	Measuring Step Position	constant	7.3

7. Description of SDOs

7.1 Constants

These SDOs have read-only access and deliver the same value for all sensors at all times:

Index:Sub-Index	Explanation	Value
0x1000:00	device profile 406 multi-sensor encoder interface	0xA0196
0x1008:00	Manufacturer Device Name	"C99"
0x1009:00	Manufacturer HW revision	"1.01"
0x100A:00	Manufacturer SW revision	"3.10"
0x1018:01	Identity Object Vendor Id	0x40
0x1018:02	Identity Object Product Code	0x53787800
0x1018:03	Identity Object Revision number	0x10001
0x1018:04	Identity Object Serial number	0x1
0x1200:01	SDO server parameter COB-ID client to server	0x67F
0x1200:02	SDO server parameter COB-ID server to client	0x5FF

To read these constants, the master sends a message to the sensor (RX) that contains the index and sub-index information with the four following bytes being "00". The sensor will respond with a very similar message (TX) that has the data filled in.

The example is for the Identity Object Product Code:

COB-ID	RX/TX	DLC	D0	D1	D2	D3	D4	D5	D6	D7
				index		s-idx	Data			
0x600+NI	RX	8	0x40	0x18	0x10	0x02	0x00	0x00	0x00	0x00
0x580+NI	TX	8	0x43	0x18	0x10	0x02	0x00	0x78	0x78	0x53

7.2 Live Read Outs

Most of the information that the sensor commutes through other means is also accessible by reading the corresponding SDO:

Index:Sub-Index	Explanation
0x1001:00	Error Register
0x1002:00	Manufacturer status register
0x6020:01	Position
0x6030:01	Velocity

The reading procedure is identical to what is described under 7.1.

7.3 Trim settings

The following trim settings are accessible through SDOs:

Index:Sub-Index	Explanation	Access
0x6005:01	Measuring Step Position	read / write
0x6005:02	Measuring Step Velocity	read only
0x6010:01	Offset in micrometers	read only
0x6501:00	Measuring Step Position	read only

The offset is set at the factory and cannot be changed by the customer.

The parameter Measuring Step Position describes the resolution for the position datum in the CAN message. Its unit is nanometers, so that the setting 100,000 yields the standard resolution of 0.1 mm.
It can be altered from a fine as 0.1 micrometer (Measuring Step = 100) to as coarse as 1 cm (10,000,000).

The parameter Measuring Step Velocity describes the resolution for the velocity datum in the CAN message. Its unit is 10µm/s, so that the setting 100 represents the standard resolution of 1mm/s.

7.4 Safety Relevant SDOs

The parameters that directly define how the safety relevant data is presented on the bus form a special group of SDO's. A checksum object exists that must match the CRC across the safety relevant SDOs to enable the sensor to enter the operational status.

Thus, if any of the safety relevant SDOs is altered, a new checksum must be programmed.

Index:S.-I.	Explanation	Access	Default
0x1301:01	SRDO communication parameter Information direction	read / write	0x1
0x1301:02	SRDO communication parameter tx : refresh-time rx : SCT	read / write	various
0x1301:03	SRDO communication parameter tx : reserved rx : SRVT	read / write	0x14
0x1301:05	SRDO communication parameter COB-ID 1	read only	various
0x1301:06	SRDO communication parameter COB-ID 2	read only	various
0x1381:00	SRDO mapping parameter Highest sub-index supported	read only	0x8
0x1381:01	SRDO mapping parameter Position	read only	0x60200120
0x1381:02	SRDO mapping parameter Position Inverted	read only	0x60200120
0x1381:03	SRDO mapping parameter Speed	read only	0x60300110
0x1381:04	SRDO mapping parameter Speed Inverted	read only	0x60300110
0x1381:05	SRDO mapping parameter Status	read only	0x30000008
0x1381:06	SRDO mapping parameter Status Inverted	read only	0x30000008
0x1381:07	SRDO mapping parameter Working Counter	read only	0x30010008
0x1381:08	SRDO mapping parameter Working Counter Inverted	read only	0x30010008

The parameters labelled with 'various' depend on the model number with which the unit was ordered. The 'refresh time SCT' is the transmission rate (20ms = 0x14), the two COB-IDs are filled in by the sensor software on power up using the unit's node ID.

For examples on how to read and write the safety relevant SDOs see 7.1 and 7.3.

Two additional objects exist to handle the checksum requirement:

Index:Sub-Index	Explanation
0x13FE:00	Configuration valid
0x13FF:01	Safety configuration signature SRDO1 signature

The SDO "Safety configuration signature SRDO1 signature" gives access to the checksum variable inside the sensor.

The example shows how SDO "Configuration valid" can be used to validate whether the checksum is correct:

COB-ID	RX/TX	DLC	D0	D1	D2	D3	D4	D5	D6	D7
				index		s-idx	Data			
0x600+NI	RX	8	0x22	0xFE	0x13	0x00	0xA5	0x00	0x00	0x00
0x580+NI	TX	8	0x60	0xFE	0x13	0x00	0x00	0x00	0x00	0x00

As shown, the master sends a 0xA5 towards that location, which the sensor acknowledges by returning 0x0. Any value other than zero means, that the checksum was not a match.

The calculation for the checksum uses the following prescription:

The generator polynomial shall be: $G(x) = X_{16}+X_{12}+X_5+1$
The order for data, which are checked by the CRC, shall be as follows:
SRDO communication parameter
a) Information direction 1 byte = $a_7 \ldots a_0$
b) Refresh time or SCT 2 byte = $b_{15} \ldots b_0$
c) SRVT 1 byte = $c_7 \ldots c_0$
d) COB-ID 1 4 byte = $d_{31} \ldots d_0$
e) COB-ID 2 4 byte = $e_{31} \ldots e_0$
SRDO mapping parameter
f) Sub-index 00h 1 byte (Number of mapped application objects in SRDO) = $f_7 \ldots f_0$
g_1) Sub-index 1 byte (SRDO mapping for the nth application object to be mapped) = $g^1{}_7 \ldots g^1{}_0$
h_1) Mapping data 4 byte (2 byte index, 1 byte sub-index, 1 byte data length) = $h^1{}_{31} \ldots h^1{}_0$
to
g_8) Sub-index 1 byte (SRDO mapping for the 8th application object to be mapped) = $g_{87} \ldots g_{80}$
h_8) Mapping data 4 byte (2 byte index, 1 byte Sub-index, 1 byte data length) = $h^8{}_{31} \ldots h^8{}_0$
$D(x) = x_n + \ldots\ldots\ldots + x_0$
$D(x) = a_7+\ldots+a_0+b_7+\ldots+b_0+b_{15}+\ldots+b_8+c_7+\ldots+c_0+d_7+\ldots+d_0+d_{15}+\ldots+d_8+d_{23}+\ldots+d_{16}+d_{31}+\ldots+d_{24}+\ldots$ etc.
The CRC shall start with the value 0x0.

7.5 Communication Parameters

Index:Sub-Index	Explanation
0x1800:01	Transmit PDO Communication Parameter COB ID
0x6200:00	Transmission Rate
0x1014:00	COB-ID EMCY message
0x1017:00	Producer Heartbeat Time

Using the first two SDOs one can adjust the node ID and the rate with which position and velocity are sent on the bus (20ms = 0x14).
The third command allows to customize the ID for emergency (error) messages. By default, 0x700 + node ID is assigned for emergency messages.
The last SDO allows launching heart beat messages. The default setting "0ms" leads to that feature being inactive.

For examples on how to read and write the communication SDOs see 7.1 and 7.3.

7.6 Nonvolatile Memory Interaction

All manipulation of parameters is don in the volatile memory of the sensor. Without initiating a parameter backup into the nonvolatile everything would revert on the next power cycle.

COB-ID	RX/TX	DLC	D0	D1	D2	D3	D4	D5	D6	D7
				index		s-idx	Data ("SAVE")			
0x600+NI	RX	8	0x23	0x10	0x10	0x01	0x73	0x61	0x76	0x65
0x580+NI	TX	8	0x60	0x10	0x10	0x01	0x00	0x00	0x00	0x00

There is also an SDO for reverting to the parameter set from the nonvolatile memory without a power down.

COB-ID	RX/TX	DLC	D0	D1	D2	D3	D4	D5	D6	D7
				index		s-idx	Data ("LOAD")			
0x600+NI	RX	8	0x22	0x11	0x10	0x00	0x6C	0x6F	0x61	0x64
0x580+NI	TX	8	0x60	0x11	0x10	0x00	0x00	0x00	0x00	0x00

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