# Watt & Well
CONVERTING POWER INTO CONFIDENCE

## NAR MOTION SERIES

## High-Temp – Low Power
## Nar Motion S

HIGH TEMPERATURE | OIL & GAS APPLICATION

## OVERVIEW

**Nar Motion S is the cost-effective version for low to medium power application**, even without sensor. It is part of the Nar motion series.

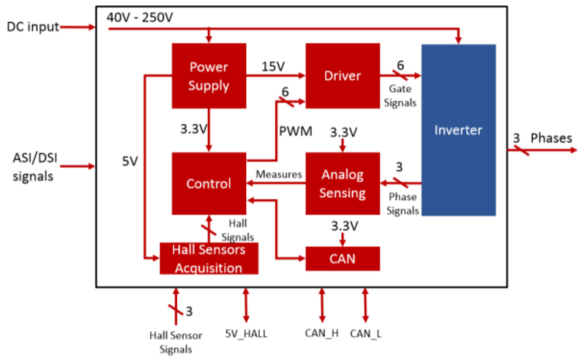
Nar Motion is our innovative high-temperature motor controller series, providing optimal operation **and high-reliability in harsh environment**.

Typical applications are Downhole Tools for Oil&Gas and Geothermal markets.


## FEATURES

- Dimension (LxWxH): 177 x 38 x 17.6 mm ( 6.96 x 1.49 x 0.69 inches)
- Capability to drive DC brushless motor with sensorless speed control
- Hall Effect Sensor compatibility
- New nominal DC input voltage: **42 V to 250 V**
- Phase Current up to 2 A RMS
- 300 W Typical Output power
- Maximum operating temp: 175 °C (347 °F)
- CAN bus Communication

## BLOCK DIAGRAM




## VERSIONS

| Part Number | Rotor position sensor |
|---|---|
| **NM-38-250-2-SLES-S** | Sensorless<br>Short Footprint |
| **NM-38-250-2-HALL-S** | Hall Effect<br>Short Footprint |
| **NM-38-250-2-SLES-L** | Sensorless<br>Legacy Footprint |
| **NM-38-250-2-HALL-L** | Hall Effect<br>Legacy Footprint |

## APPLICATION

- Drilling
- Wireline

## CUSTOMIZATION OPTIONS

- On demand

**WARNING**

This equipment operates at voltages and currents that can result in electrical shock, fire hazard and/or personal injury if not properly handled or applied. Equipment must be used with necessary caution and appropriate safeguards employed to avoid personal injury or property damage.

This board must be used only by qualified engineers and technicians' familiar with risks associated with handling high voltage electrical and mechanical components, systems and subsystems.

**TABLE OF CONTENTS**

# 1. Absolute maximum ratings

| Parameter | Condition | Min | Max | Units |
|---|---|---|---|---|
| DC Input Voltage (motor driver supply) | $V_{DC}$-$V_{GND}$ | 42 | 250 | V |
| DC Input Voltage common mode | $V_{GND}$-$V_{chassis}$ | -2 | +2 | V |
| DC Input Current | | | 4 | A |
| DC Input Power | | | 400 | W |
| DSI Input voltage | | 0 | 5.6 | V |
| ASI Input voltage | | 0 | 3.6 | V |
| Phase Current | | | 4 | Apeak |
| Operating Temperature[1] | | 5 | 175 | °C |
| Long term storage Temperature | | 5 | 85 | °C |
| Temperature change rate | | | 4 | °C/min |

**Table 1: Absolute maximum ratings**

[1] Temperature provided is the chassis temperature.

# 2. Electrical Characteristics

All specifications are given for the full temperature range [5 deg C – 175 deg C] unless otherwise noted

| Parameter | Condition | Value | | | Units |
|---|---|---|---|---|---|
| | | Min | Typ | Max | |
| **General** | | | | | |
| Motor Type | PMSM or BLDC | | | | |
| Driver Efficiency | | - | 95 | - | % |
| Phase continuous output current | T = 175 °C | - | - | 2 | Arms |
| Phase instantaneous output current | During tp≤10ms | - | - | 4 | Apeak |
| Nominal speed Range | With 4-pole-pair motor<br>With 2-pole-pair motor | 200<br>400 | - | 3000<br>6000 | rpm |
| Switching frequency | | - | 10 | - | kHz |
| Frequency control accuracy | | - | 1 | - | % |
| Thermal Shutdown[2] | | Software Programmable | | | |
| Hall effect sense or voltage supply | Max 20 mA | 4.5 | 5 | 5.5 | V |
| CAN baudrate | | - | 500 | - | kbauds |
| CAN differential output (dominant) | $CAN_H - CAN_L$ | 3.3V compatible | | | |
| CAN common mode range | $(CAN_H + CAN_L)/2 - V_{LV\_RTN}$ | -2 | - | +3 | V |
| CAN differential input voltage | (compatible with external transceivers from 3.3 to 5V) | -5 | - | +5 | V |
| **DC input** | | | | | |
| Input voltage | | 42 | - | 250 | V |
| Quiescent current: Standby mode | $V_{DC}$ = 250V, T= [ 25°C; 175°C] | - | 4.5 | - | mA |
| Quiescent current: Standby mode | $V_{DC}$ = 42V, T= [ 25°C; 175°C] | - | 21 | - | mA |
| Quiescent current: Drive mode | $V_{DC}$ = 250V, T= [25°C ; 175°C] | - | 5 | - | mA |
| Quiescent current: Drive mode | $V_{DC}$ = 42V, T= [25°C ; 175°C] | - | 23 | - | mA |
| Under Voltage Shutdown | | 37 | - | 42 | V |
| **Digital Signal Input** | | | | | |
| High-level input voltage $V_{IH}$ | | | 2.9 | | V |
| Low-level input voltage $V_{IL}$ | | | 1.7 | | V |
| **Analog Input** | | | | | |
| Voltage range | | 0 | - | 3.6 | V |
| Equivalent Resistance | | | High-Z | | |

**Table 2: Electrical characteristics**

[2] Optional Thermal shutdown requires internal temperature sensors and is software programmable.

# 3. System operation

## 3.1. System control modes

NM-38-250-2-xxxx-x board is able to control the motor in the following modes:

- Open-loop mode (scalar control):
    - The motor driver increases the phases' voltage frequency and amplitude by respecting a fixed ratio between them.
    - The speed setpoint is set thru CAN communication.
- Sensored (Hall) closed-loop mode (this mode is not included in NM-38-250-2-SLES-S):
    - The motor driver controls the motor speed using the measured position provided by the Hall effect sensors.
    - The speed setpoint is set thru CAN communication.
- Sensorless closed-loop mode.
    - The motor driver controls the motor speed without a use of any sensor, this mode is based on a sensorless algorithm.
    - The speed setpoint is set thru CAN communication.

The system mode selection is controlled thru CAN communication using a dedicated CAN frame (refer to CAN protocol dictionary).

The sensorless closed-loop mode is the default mode.

### 3.2. Main system state-machine

NM-38-250-2-xxxx-x board control system states are controlled by a finite state-machine as presented below:

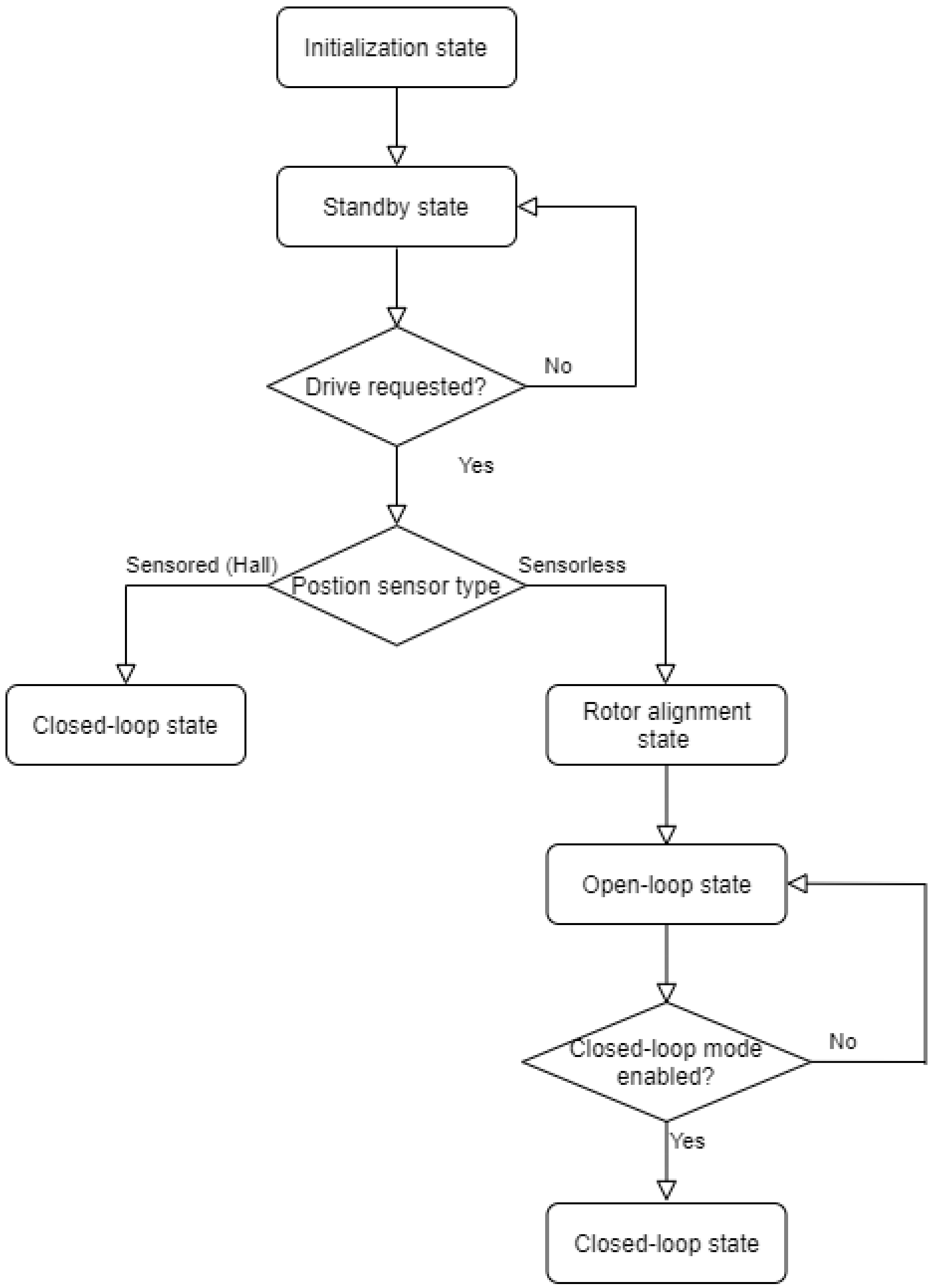



**Figure 1: System state-machine**

The system states are:

- Initialization state: the boot-up phase state.
- Stand by state: Motor control is off
- Rotor alignment state (forward and reverse directions): Drive the motor's rotor to a predefined position in order to start the open-loop phase from a known position.
- Open-loop state (forward and reverse directions): Drive the motor in open-loop mode, this phase is critical to boot-up the sensorless algorithm.
- Closed-loop state (forward and reverse directions): Drive the motor in sensorless mode, the speed is controlled using speed feedback (sensored or estimated).
- Fault state: Motor control is off and report error thru CAN communication.

The system state is controlled thru CAN communication using a dedicated CAN frame (refer to CAN protocol dictionary).

Based on the selected system mode and on the requested state, the system will enable the appropriate state, for example if open-loop mode is selected and Drive (or Reverse) the motor is requested => the system will target to go to "open-loop state" and it will be handled in that state until "Stand-by" will be requested or a protection fault will occur.

### 3.3. System configuration

NM-38-250-2-xxxx-x board addresses a wide range of PMSM motor types thanks to the board's control non-volatile parameters. The motor driver saves the parameters configuration that optimize the system operation to address a specific application need (operation point, motor …). This configuration will be loaded at each boot-up phase. These parameters are configurable using the CAN protocol, they can be written and read. It is preferred to not change the parameters value while driving the motor.

The motor controller receives the speed setpoint and the commands to drive/stop the motor using a dedicated CAN protocol frames. The figure below presents the block diagram of the CAN protocol that allows system configuration:

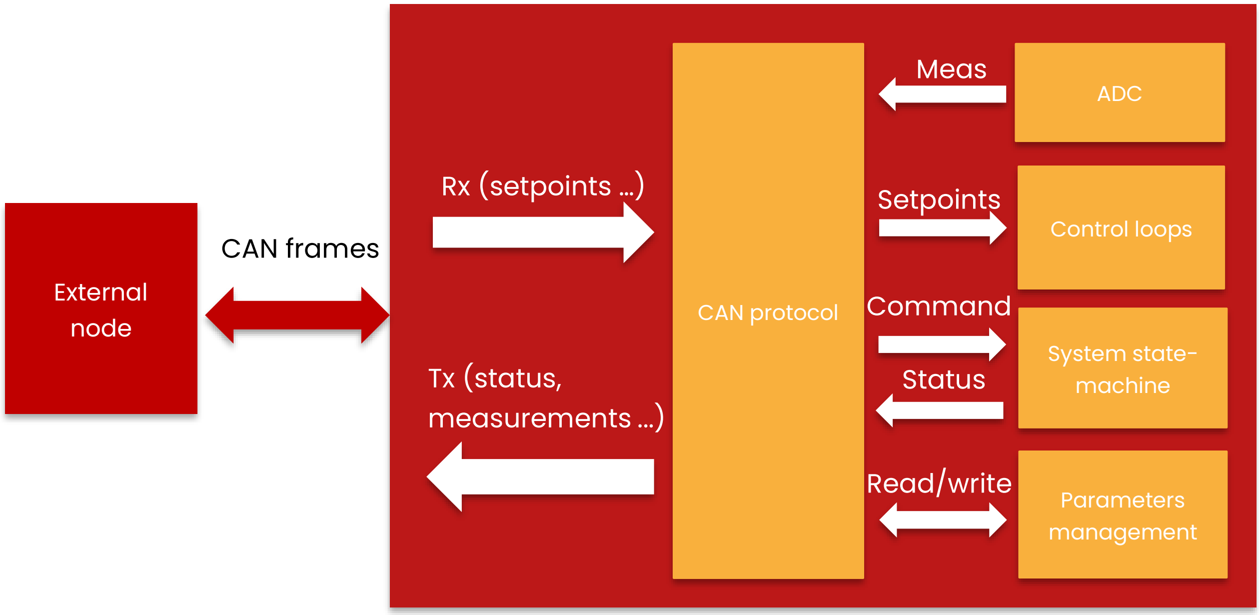



**Figure 2: System configuration thru CAN protocol**

The board can be easily integrated to a complex system that needs variable speed motor controller unit. Multiple motor controller units can share the same CAN bus where each unit will have a dedicated CAN address, they can receive setpoints and commands and send feedbacks without any confusion.

### 3.4. Sensorless control algorithm

The implemented sensorless control algorithm is based on the BEMF ZCD. The algorithm tracks the floating phase where a BEMF is present. When a zero-crossing is detected, positive or negative based on the current rotor position sector, the algorithm switches to the appropriate next sector.

The sensorless control has a start-up sequence before reaching the closed-loop phase:

- Step 1: rotor lock phase where the motor rotor is brought to a known position
- Step 2: Open-loop phase where the motor is controlled in scalar mode where the time, speed and duty-cycle are parameters that can be tuned depending on the motor characteristics.
- Step 3: Closed-loop mode is enabled using the estimated position and speed.

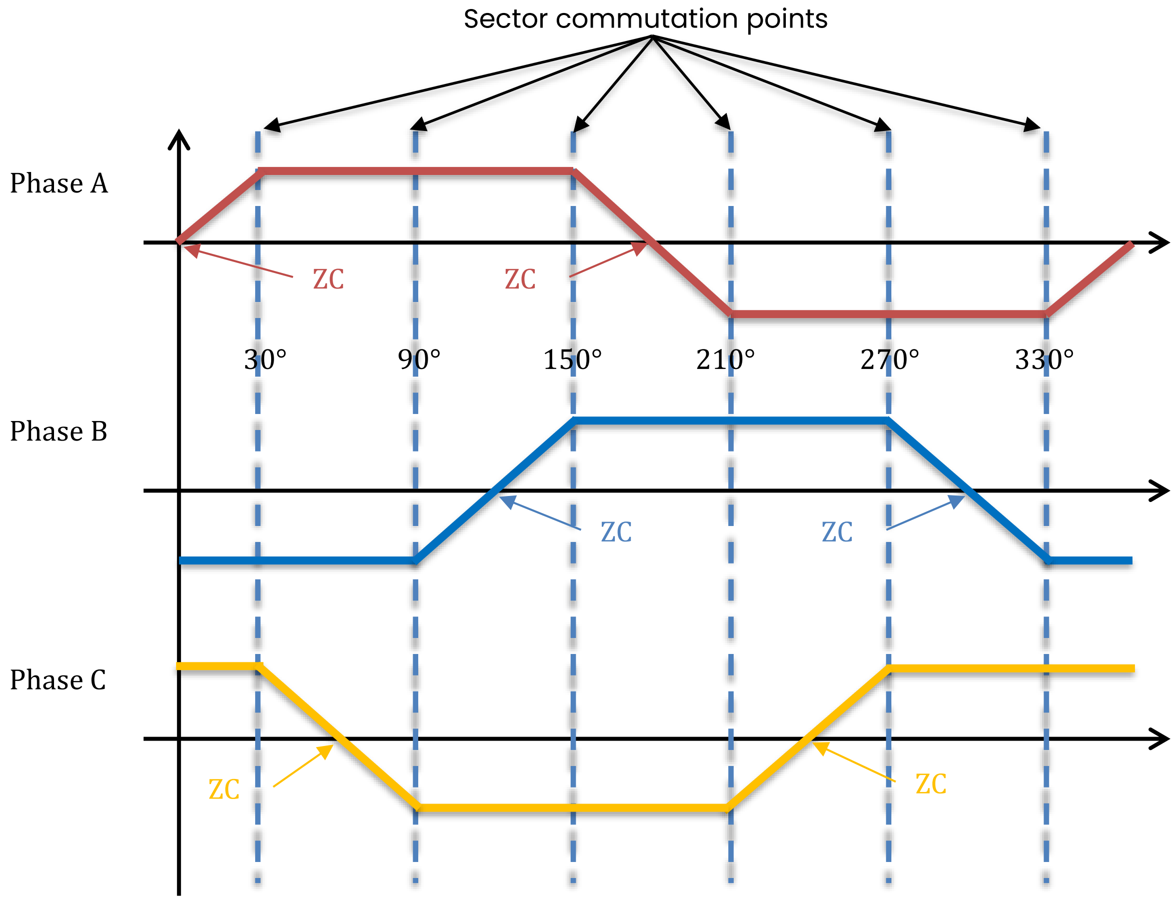



**Figure 3: Sensorless control back-emf detection**

# 4. Hardware specification

## 4.1. Theory of operation

NM-38-250-2-xxxx-x board consists of a power stage with three phase legs and a control stage with the following blocks:

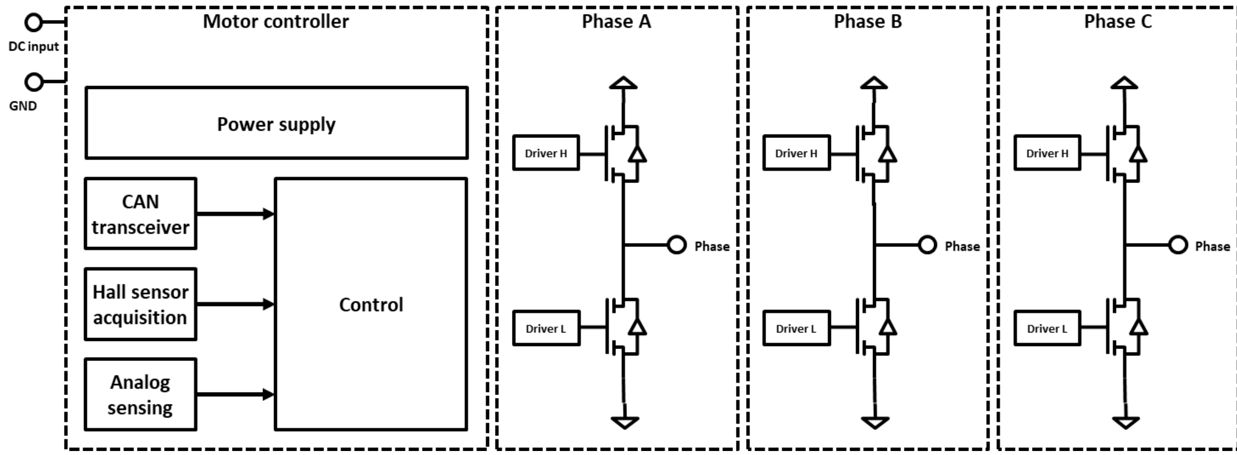



**Figure 4 Block diagram**

## Control

The control unit is based on a low power consumption microcontroller.
Two control modes can be performed:

- Sensorless: It starts the motor rotation in an open loop control mode and estimates the motor speed on the basis of back EMF sensing. Once the speed is correctly estimated, the controller switches to a closed loop control.
- Hall effect Sensor: Need Hall sensors to estimate the rotor position.

## Power supply

The low voltage power supply is composed of a flyback converter to convert DC input voltage to 15 V used to power the gate driver. Local voltages (e.g. 3.3V, 5V …) are derived from 15 V voltage.

## Analog sensing

The analog sensing block is used to measure phases back EMF, HV input current and voltage and board temperature.

### Digital signal Input (DSI-IN)

One digital signal input is available from connector P1 (see Table 4). Accessible through CAN with optional features on demand. Its acquisition stage is described in the simplified diagram below.

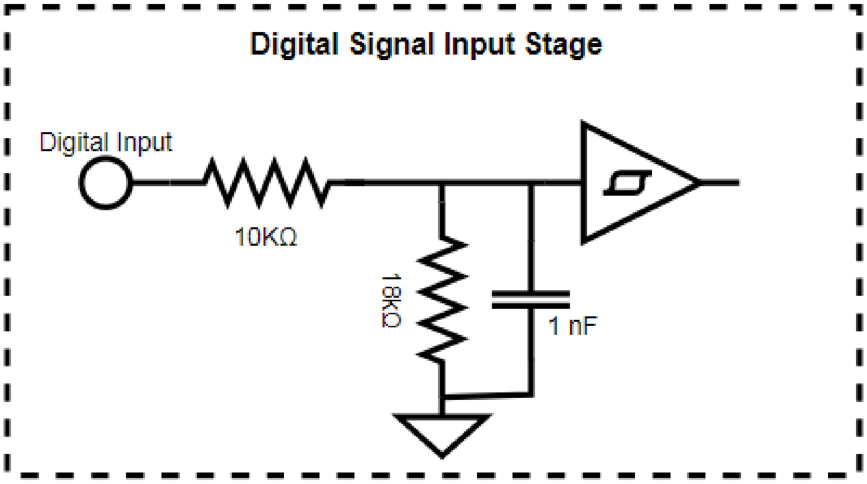



**Figure 5 Digital signal input stage simplified diagram**

#### ANALOG SIGNAL INPUT (ASI-IN)

One analog signal input is available from connector P1 (see Table 4). Accessible through CAN with optional features on demand. Its acquisition stage is described in the simplified diagram below

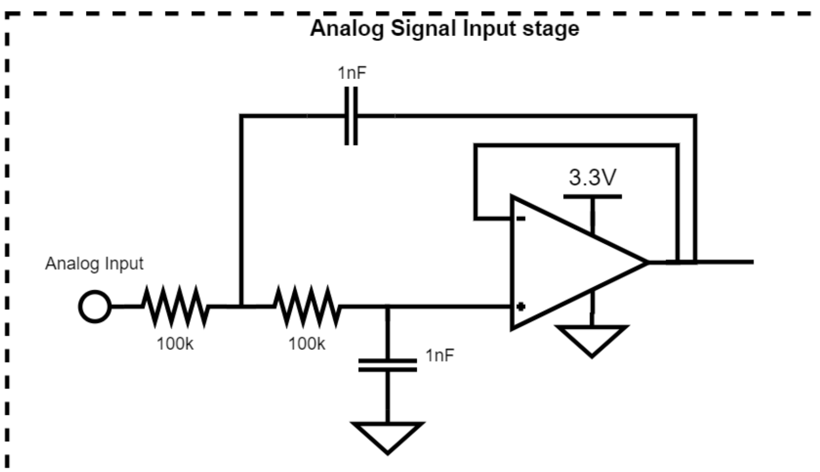



**Figure 6 : Analog signal input stage simplified diagram**

#### CAN TRANSCEIVER

Non-isolated CAN transceiver is implemented to allow communication through a high-speed CAN protocol.

CAN bus is expected to be terminated at each bus end with a 120 Ω resistance. Wiring should be selected to have an intrinsic impedance of the twisted that match this 120 Ω.

By default, NM-38-250-2 does not include any 120 Ω resistor to avoid overloading the bus.

External 120 Ω bus termination could be needed to ensure proper functionality.

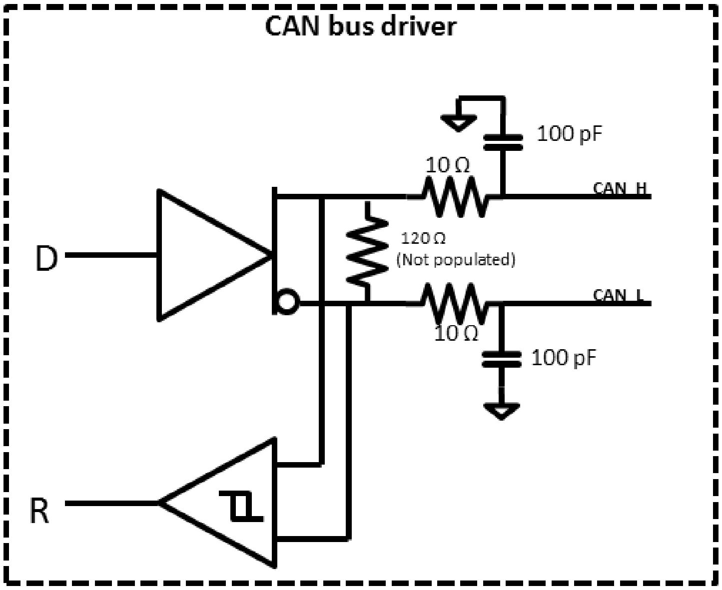



**Figure 7: CAN transceiver simplified diagram**

## RS485

RS485 hardware is implemented to allow communication through a high-speed half duplex protocol:

- RS485_A/Y: RS485 non-inverting receiver input and non-inverting driver output.
- RS485_B/Z: RS485 inverting receiver input and inverting driver output.

RS485 software is not implemented by default.

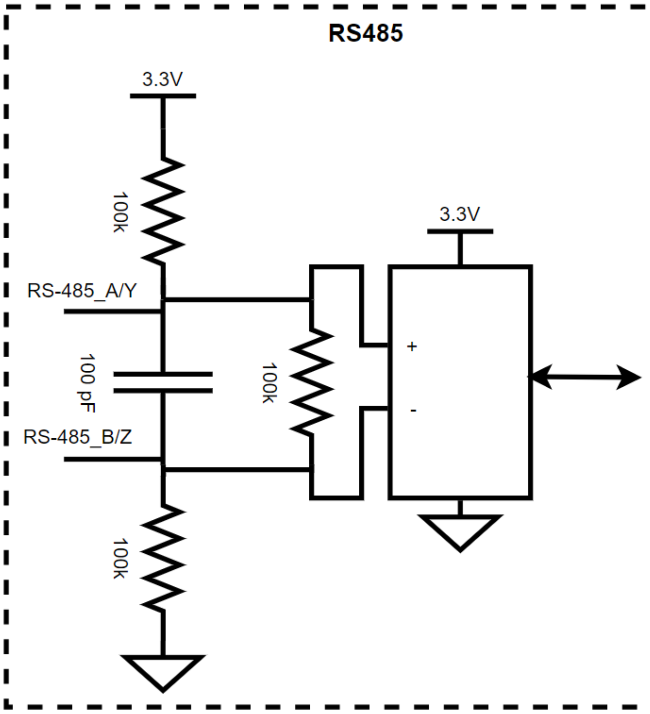



**Figure 8: RS485 simplified diagram**

**HALL SENSOR ACQUISITION** (NM-38-250-2-HALL version only)**:**

It provides a dedicated hardware block to power the hall sensors (5V, 20mA) and acquires each sensor state. 3 inputs are compatible with Open Drain/Open Collector output. Internal pull-up resistor is 10kΩ. A 100nF capacitor is also included for noise immunity but proper wiring and shielding is strongly advised for best results.

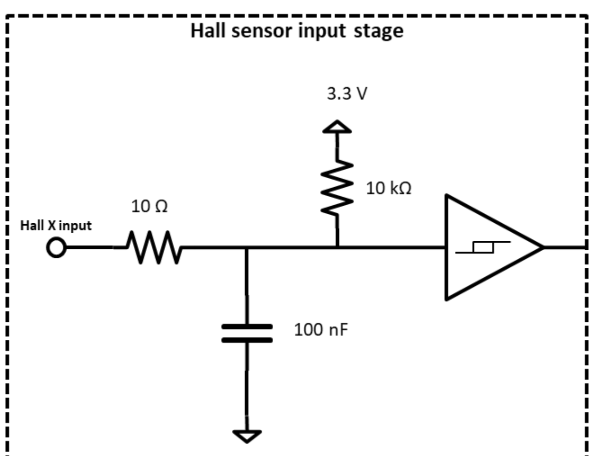



**Figure 9 Hall Effect sensor interface simplified diagram**

## 4.2. Interfaces

The connectors described in this section are placed on each side of the product. P1 (15 pins) is the connector on the power supply side and P2 (9 pins) is the connector on the motor side.

Recommended matting micro-sub D connectors are a MDAL15PCW100M (or any MDAL15P series) from Axon on the Input side (P1) and MDAL9PCW100M (or any MDAL9P series) on the Output side (P2). Pin-outs are shown in Table 4 and
Table 5.

| | Connector reference | Mating connector reference |
|---|---|---|
| **P1 (Input side)** | MDAL15SCBPPT1 | MDAL15PCW100M |
| **P2 (Output side)** | MDAL9SCBPPT1 | MDAL9PCW100M |

**Table 3 Connector and Harness references**

### SUPPLY SIDE CONNECTOR

| Pin | Signal Name | Details | Harness MIL-STD-681 Wire Color |
|---|---|---|---|
| 1 | RS485_A/Y | RS485 A/Y bus line | Black |
| 2 | RS485_B/Z | RS485 B/Z bus line | Brown |
| 3 | GND | GND | Red |
| 4 | CAN_L | Low level CAN bus line | Orange |
| 5 | CAN_H | High level CAN bus line | Yellow |
| 6 | GND | GND | Green |
| 7 | GND | GND | Blue |
| 8 | DC | Input DC supply voltage | Purple |
| 9 | +5V_HALL | +5V HALL | Grey |
| 10 | GND | GND | White |
| 11 | ASI_IN | Analog input | White/Black |
| 12 | DSI_IN | Digital Input | White/Brown |
| 13 | GND | GND | White/Red |
| 14 | DC | Input DC supply voltage | White/Orange |
| 15 | DC | Input DC supply voltage | White/Yellow |

**Table 4 P1 pinout (Input side)**

### MOTOR SIDE CONNECTOR

| Pin | Signal Name | Details | Harness MIL-STD-681 Wire Color |
|---|---|---|---|
| 1 | GND | GND | Black |

| | | | |
|---|---|---|---|
| 2 | HALL_B | Hall Sensors B | Brown |
| 3 | PHASE_B | Phase B | Red |
| 4 | GND | GND | Orange |
| 5 | +5V_HALL | 5V Hall | Yellow |
| 6 | PHASE_C | Phase C | Green |
| 7 | HALL_C | Hall sensor C | Blue |
| 8 | HALL_A | Hall sensor A | Purple |
| 9 | PHASE_A | Phase A | Grey |

**Table 5 P2 pinout (output side)**

# 5. Mechanical specifications

## 5.1. Short Footprint

NM-38-250-2-XXXX-S is packaged in aluminum housing with the following dimensions:

| Parameter | Value | | | Units |
|---|---|---|---|---|
| | Min | Typ | Max | |
| Length | - | 177 | - | mm |
| Width | - | 38 | - | mm |
| Height | - | 17.6 | - | mm |

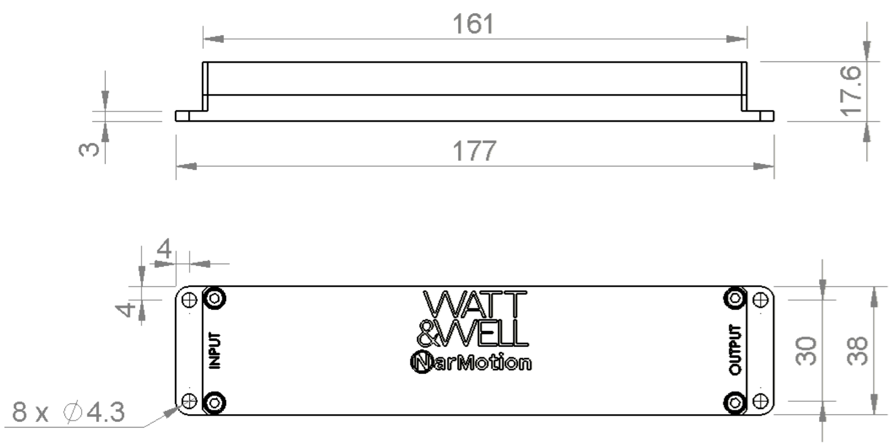



**Figure 10 - NM-38-250-2-XXXX-S Mechanical Dimension**

## 5.2. Legacy Footprint

NM-38-250-2-XXXX-L is packaged in aluminum housing with the following dimensions:

| Parameter | Value | | | Units |
|---|---|---|---|---|
| | Min | Typ | Max | |
| Length | - | 228 | - | mm |
| Width | - | 38 | - | mm |
| Height | - | 17.6 | - | mm |

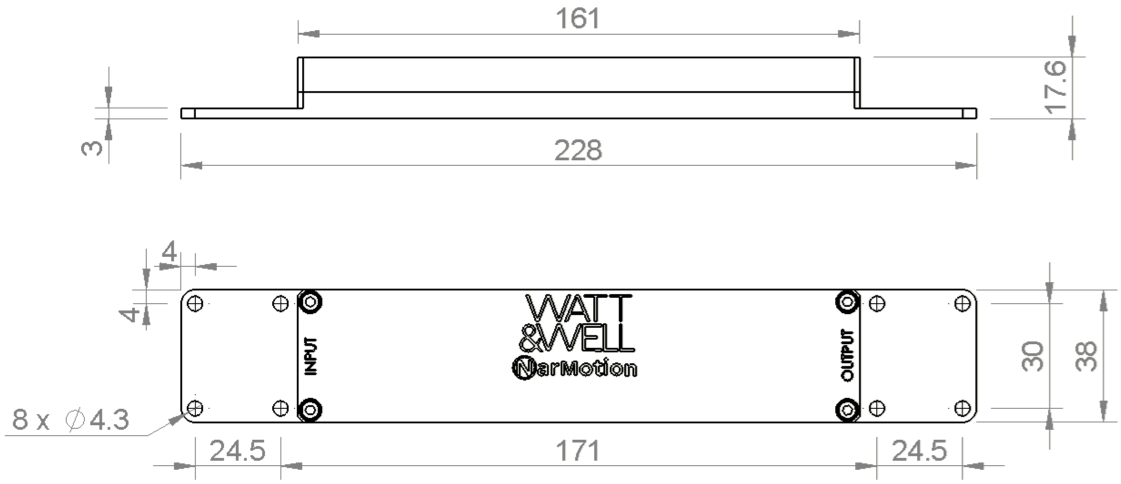



**Figure 11: NM-38-250-2-XXXX-L Mechanical Dimension**

# 6. Firmware specifications

## 6.1. CAN protocol

The motor driver can be operated by a CAN bus communication.

Then from the motor point of view, in addition to the power supply and its load, the electrical speed and electrical power consumption of the motor can also be limited by the Nar Motion CAN protocol.

The Nar Motion CAN protocol is a simple protocol designed for **real time efficiency** (low CPU overhead) and **simplicity** (no communication stack required). It is fully documented and the protocol can be reused on other projects without licensing restrictions.

When using this protocol, Nar Motion boards include high level monitoring of motor control driver.

## 6.2. Digital bus configuration

Each motor controller features a CAN transceiver to communicate with a bus master. In this Master/Slave scheme, each motor controller is considered as a slave, while the master can be either a Graphical User Interface in a PC or another electronic board.

CAN bus is configured to respect the standard 2.0B (29-bit message identifier) at a default baud rate of **500 kbps** with sampling point at **80**%. For best result, it is advised that all CAN nodes use the same sampling point configuration.

## 6.3. Graphical User Interface

The product is provided with a graphical user interface that contains a large variety of functionalities:

- Basic Operation: enable start /stop the drive, set the electrical speed and power setpoints, and get the main measurements from the Nar Motion board.
- Parameters update: enable to tune the whole board parameters, including controllers' loops constants, limitations, calibrations, etc.

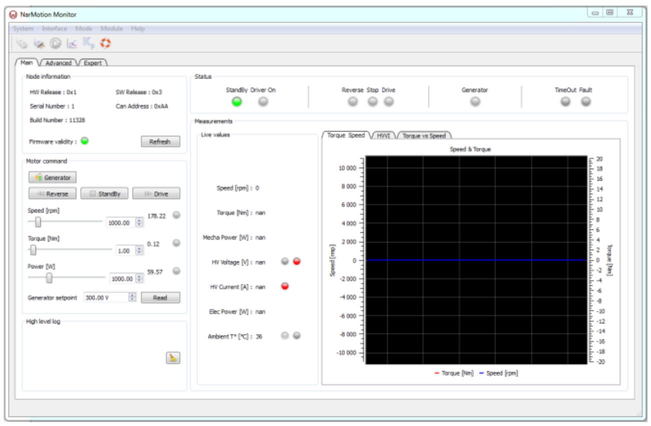
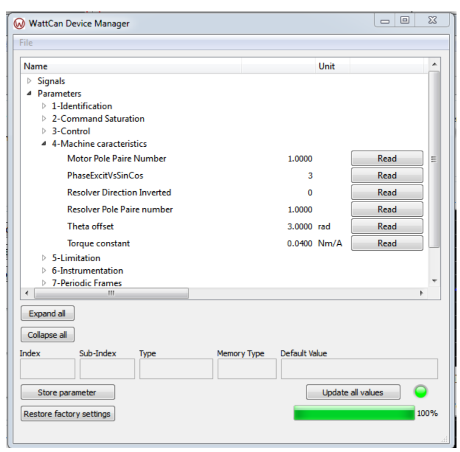


**Figure 12: GUI Main panel**

**Figure 13 : Parameters panel**



# 7. Safety instruction

## 7.1. Caution

The following safety instruction must be observed during all phases of operation, service and repair of this equipment. Failure to comply with the safety precautions or warnings in this documentation violates safety standards of design, manufacture and intended use of this equipment and may impair the built-in protections within. WATT & WELL shall not be liable for users to comply with these requirements.

## 7.2. Input rating

Do not use power supplies which exceeds the input voltage rating of this instrument. The electrical rating of this instrument is given into the chapter 2 of this document.

## 7.3. Live circuits

Operating personnel are not allowed to open the housing of this equipment.
Internal adjustment or component replacement is not allowed by non WATT & WELL qualified personnel. Never replace components with cable connected to this instrument. To avoid injuries, always disconnect power and remove external voltage sources before touching components.

# 8. Installation

Do not use or install product in case of visible physical damage.

## 8.1. Mechanical installation

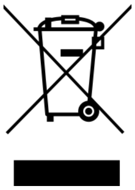
Refer to chapter 4 for the dimensions of the product.

## 8.2. Electrical installation

Never invert polarity of the connectors. Never force to place a connector. Use only approved manufacturer parts for electrical or mechanical connection.
It is strongly recommended to fix the cables to avoid any stress on connection. All high-power connectors must be screwed to avoid any disconnection.
Be careful if other devices are connected, risk of electrical charge transfer.

Wait two minutes before touching the device after complete suppression of input voltage. Check for lack of voltage, on all access, with the correct equipment.

## 8.3. Disposal



Do not dispose of electronic tools tighter with household waste material. In accordance with WEEE European Directive (2012/19/UE), Electric material that have reach the end of their life must be collected separately and return to an environmentally compatible recycling facility. Please contact WATT & WELL for any questions about WEEE.

## 8.4. Thermal and lifetime in operation

The lifetime in operation depends on the operation temperature.
It is limited to:

1500 Hours of operation at 150 deg C[3]
450 hours of operation at 175 deg C[4]
As defined in the maximum absolute rating, the board must not be used above 175 deg C[5].

## 8.5. Humidity

The NarMotionS device shall be stored, as provided by Watt&Well, with sealed ESD bag with moisture indicator cards and desiccant bag.
Maximum relative humidity in operation: 30% at 20°C (under red limit below), to avoid condensation and icing.

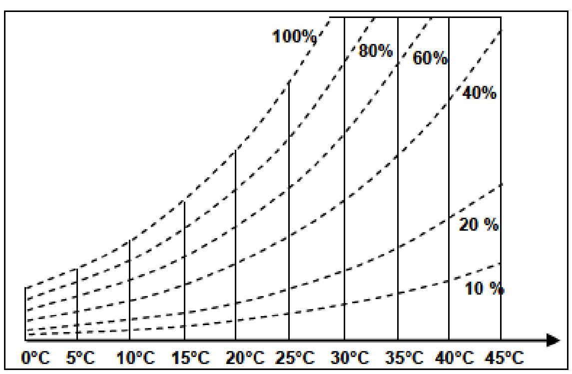



**Figure 14 – Hygrothermal diagram**

## 8.6. Vibrations

[3] Temperature provided is the stiffener temperature where the power Mosfet are located.
[4] Temperature provided is the stiffener temperature where the power Mosfet are located.
[5] Temperature provided is the stiffener temperature where the power Mosfet are located.

The NarMotionS device is compliant with vibrations, up to: 20g RMS on 3 axes

# 9. Ordering information

| | ROTOR POSITION SENSOR | FOOTPRINT |
|---|---|---|
| **NM-38-250-2-SLES-S** | Sensorless | Short Footprint |
| **NM-38-250-2-HALL-S** | Hall Effect | Short Footprint |
| **NM-38-250-2- SLES -L** | Sensorless | Legacy Footprint |
| **NM-38-250-2-HALL-L** | Hall Effect | Legacy Footprint |

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# 10. Product revision history

| PRODUCT REVISION | APPLICABLE DATASHEET |
|---|---|
| SYS-NARSWTC-V1.1.X | NM-38-250-2 AA |
| | |
| | |

# Appendix A - Nar Motion CAN protocol

## 1. Message Identifier format

Each CAN 2.0B frame has a 29-bit identifier and up to 64 bits of data. Nar Motion CAN protocol uses this message ID for node addressing and message description (opcodes):

| **Bit** | **28-27** | **26-19** | **18-11** | **10-9** | **8 -0** |
|---|---|---|---|---|---|
| **Field** | Priority Bits (2bits) | SRC Address (8bits) | DST Address (8bits) | MSG Type (2bits) | Opcode (9bits) |

- Priority bits: priority level of the message. Priority bits can be used to optimize message delivery but should be ignored by each node when decoding the message.
  - 00 : highest priority
  - 01: high priority
  - 10: low priority
  - 11 : lowest priority
- SRC Address: source address.
- DST Address: destination address.
- MSG type: 3 types of message are defined:
  - Type 0 or « Slave Tx »: Message sent from slave to master
  - Type 1 or « Data Set »: Message sent from master to the slave to set a value on the slave memory.
  - Type 2 or « Data Request » Message sent from master to slave to request data from slave. Each data request will trigger Type 0 (Slave Tx) from the slave.
- OpCode: Identifier of message used to describe signification of message.

By default, the setting is the following:

| | **Address** | **Priority** |
|---|---|---|
| **Master (Monitor)** | 0xAA | 1 |
| **Slave (Nar Motion)** | 0x55 | 1 |

**Table 6: Default CAN settings**

## 2. CAN messages dictionnary

With the 29 bits CAN ID defined above, each node can build a message dictionary using the 9-bits Opcode.

| OpCode Name | OpCode value | Msg type | Format | Word 0 | Word 1 | Word 2 | Word 3 | Comment |
|---|---|---|---|---|---|---|---|---|
| **BUILD_INFO** | **0** | **0** | Uint16/ Uin32 / Uint16 | BuildNb | SrcModified | BuildDate | | Answer |
| **BUILD_INFO** | **0** | **2** | Uint16 | (0x0000) | (0x0000) | (0x0000) | (0x0000) | Request |
| **DEVICE_INFO** | **1** | **0** | Uint16 | HwRelease | SwRelease | DeviceNumber | CanAddress | Answer |
| **DEVICE_INFO** | **1** | **2** | Uint16 | (0x0000) | (0x0000) | (0x0000) | (0x0000) | Request |
| **REQUEST_WORD** | **2** | **1** | Bit-Wise | RequestWord | | (0x0000) | (0x0000) | State request |
| **STATUS_WORD** | **3** | **0** | Bit-Wise | StatusWord | | (0x0000) | (0x0000) | State feedback - Sent periodically by the slave |
| **REBOOT** | **101** | **0** | Uint16 | Ack(0x0001) | (0x0000) | (0x0000) | (0x0000) | |
| **MOTOR_CMD** | **102** | **0** | Fixed-point | SpeedCmd | (0x0000) | (0x0000) | (0x0000) | Setpoint write |
| **MOTOR_CMD** | **102** | **1** | Fixed-point | SpeedCmd | (0x0000) | (0x0000) | (0x0000) | Setpoint feedback |
| **MEASUREMENT_0** | **200** | **0** | Fixed-point | VoltagePhaseA | VoltagePhaseB | VoltagePhaseC | (0x0000) | Sent periodically by the slave |
| **MEASUREMENT_1** | **201** | **0** | Fixed-point | SpeedEstimated | (0x0000) | (0x0000) | PowerElec | Sent periodically by the slave |
| **MEASUREMENT_2** | **202** | **0** | Fixed-point | HV_Voltage_raw | HV_Current | 15V_Voltage | (0x0000) | Sent periodically by the slave |
| **MEASUREMENT_3** | **204** | **0** | Fixed-point | Temp_Ambient | BEMF_V0p2_reference | Vref 1.5V | ASI | Sent periodically by the slave |

**Table 7: CAN message frame dictionary**

**CAN data description** details data contained in those message frames and, where applicable, gives the normalization value (for details on how to convert these fixed-point values to physical unit see section Conversion factor and units).

| Frame | Data | Format | Normalization | Description |
|---|---|---|---|---|
| **BUILD_INFO** | BuildNb | Uint16 | - | Version control number |
| **BUILD_INFO** | SrcModified | Uint16 | - | Version control check result (0-> OK, 1-> fail) |
| **BUILD_INFO** | BuildDate | Uint16 | - | Build date (second since 1900) |
| **BUILD_INFO** | SwRelease | Uint16 | - | Software Release version |
| **BUILD_INFO** | HwRelease | Uint16 | - | Hardware Release version |
| **BUILD_INFO** | DeviceNumber | Uint16 | - | Number of the device |
| **BUILD_INFO** | CanAddress | Uint16 | - | CAN address of device |
| **REQUEST_WORD** | RequestWord | Uint32 bit wise | - | System Control Request Word |
| **STATUS_WORD** | StatusWord | Uint32 bit wise | - | System Control Status Word |
| **MOTOR_CMD** | SpeedCmd | Uint16 | - | Electrical Speed setpoint |
| **MEASUREMENT_0** | VoltagePhaseA | Signed Q9.6 | - | Phase A voltage |
| **MEASUREMENT_0** | VoltagePhaseB | Signed Q9.6 | - | Phase B voltage |
| **MEASUREMENT_0** | VoltagePhaseC | Signed Q9.6 | - | Phase C voltage |
| **MEASUREMENT_1** | SpeedEstimated | Uint16 | - | Shaft speed |
| **MEASUREMENT_1** | PowerElec | Signed Q10.5 | - | Inverter electrical power |
| **MEASUREMENT_2** | HV_Voltage_raw | Uint16 | - | Inverter input HV voltage – raw format |
| **MEASUREMENT_2** | HV_Current | Signed Q7.8 | - | Inverter input HV current |
| **MEASUREMENT_2** | 15V_Voltage | Unsigned Q6.10 | - | Low voltage power supply current |
| **MEASUREMENT_3** | Temp_Ambient | Signed Q8.7 | - | Inverter board temperature |
| **MEASUREMENT_3** | BEMF_V0p2_reference | Unsigned Q6.10 | - | Local 200mV reference |
| **MEASUREMENT_3** | Vref 1.5V | Unsigned Q6.10 | - | Local 1.5V reference voltage |
| **MEASUREMENT_3** | ASI | Unsigned Q4.12 | - | Analog signal input |

**Table 8: CAN data description**

## 2.1. Request word, status word and fault word messages

Three words are defined bit wise:

- *Request Word*: used to configure the state of the system. Table 9: Request Word/Status Word Bit definition details these words.
- *Status word*: acknowledges that status in the system. It has a similar definition to the request word but is read only. This word is sent by controller periodically.
- *Fault Word*: word containing flag errors. This word is sent by controller synchronously.

| Bit | Request Word | Status Word | Description |
|---|---|---|---|
| 0:3 | System Mode | | Set/acknowledge the system state<br>0 - System Off: PWM off (power switches in high impedance)<br>1 - Reserved<br>2 -Rotor lock<br>3 - Open-loop phase<br>4 - Drive: positive speed<br>5 - Reverse: negative speed<br>6 - Reserved<br>7 – Fault Mode: PWM off because of a critical fault. System status should be set to system off to clear the fault |
| 4 | Reserved | | |
| 5 | Reserved | | |
| 6 | Reserved | Reserved | |
| 7 | Reserved | | |
| 8 | Reserved | Reserved | |
| 9-32 | Reserved | | |

**Table 9: Request Word/Status Word Bit definition**

### 2.2. Can error code

Not implemented in this version.

# 3. Fixed-point data type

The microcontroller is fixed-point, all the data exchanged through the CAN are fixed point type.

The standard notation QX.Y uses X bits for the integer part (before the point) and Y bits for the fractional part (after the point), the type can be signed or unsigned.

For example:

The HV current measurement is “Signed Q7.8”, that means it’s a signed 16 bits words with 8 bits of fractional part.

# 4. Endianness

Endianness and data format within a CAN frame are application dependent (not part of the CAN specification). Nar Motion protocol uses Big Endian (also known as Network Order)[6]. The resulting byte order for Nar Motion communications is the following:

| Bits | 0 7 | 8 15 | 16 23 | 24 31 | 32 39 | 40 47 | 48 55 | 56 63 |
|---|---|---|---|---|---|---|---|---|
| Bytes | Byte 0 | Byte 1 | Byte 2 | Byte 3 | Byte 4 | Byte 5 | Byte 6 | Byte 7 |
| | **MSB** | **LSB** | | | | | | |
| 16-bits words: | High word | | Low word | | High word | | Low word | |
| 32-bits words | 32-bit word 0 | | | | 32-bit word 1 | | | |

For example, the 64-bit hexadecimal number « 0x0001 0203 0405 0607 » will be send in CAN bus as follows

| **Bytes** | **16-bits words** | **32-bits words** |
|---|---|---|
| Byte 0: 0x00 | High word: 0x0001 | 32-bit word: 0x00010203 |
| Byte 1: 0x01 | | |
| Byte 2: 0x02 | Low word: 0x0203 | |
| Byte 3: 0x03 | | |
| Byte 4: 0x04 | High word: 0x0405 | 32-bit word: 0x04050607 |
| Byte 5: 0x05 | | |
| Byte 6: 0x06 | Low word: 0x0607 | |
| Byte 7: 0x07 | | |

[6] Computers are usually based on the x86 architecture which is little endian for 16 and 32 bits words. 64-bit numbers (not used on NarMotion communications) in 32-bits architectures are compiler dependent.