

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.

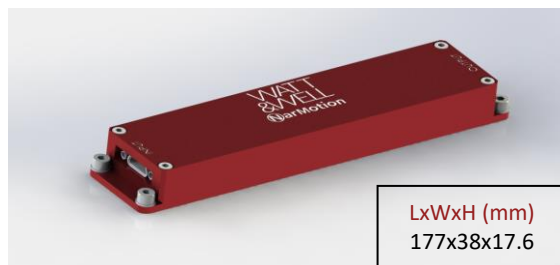
Typical applications are Downhole Tools for Oil&Gas and Geothermal markets.

#### FEATURES

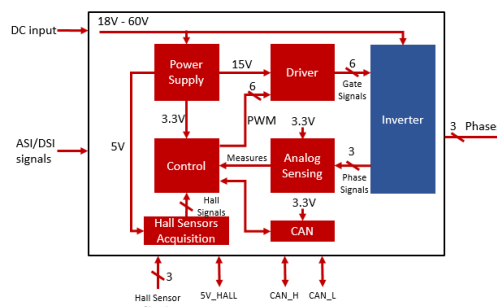
- Dimension (LxWxH): 177 x 38 x 17.6 mm (6.96 x 1.49 x 0.69 inches)
- Capability to drive DC brushless motor with sensorless speed control
- Hall Effect Sensor compatibility
- Nominal DC input voltage: **18V to 60V**
- Phase Current up to 4 A RMS
- 150 W Typical Output power
- Maximum operating temp: 175 °C (347 °F)
- CAN bus Communication

#### VERSIONS

	Rotor position sensor
NM-38-60-4-SLES-S	Sensorless Short Footprint
NM-38-60-4-HALL-S	Hall Effect Short Footprint
NM-38-60-4-SLES-L	Sensorless Legacy Footprint
NM-38-60-4-HALL-L	Hall Effect Legacy Footprint



#### BLOCK DIAGRAM



#### 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.

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## 1. Absolute maximum ratings

Parameter	Condition	Min	Max	Units
DC Input Voltage (motor driver supply)	$V_{DC}-V_{GND}$	18	60	V
DC Input Voltage common mode	$V_{GND}-V_{chassis}$	-2	+2	V
DC Input Current			4	A
DC Input Power			180	W
DSI Input voltage		0	5.6	V
ASI Input voltage		0	3.6	V
Phase Current			6	A <sub>peak</sub>
Operating Temperature <sup>1</sup>		5	175	°C
Long term storage Temperature		5	85	°C
Temperature change rate			4	°C/min

**Table 1: Absolute maximum ratings**

<sup>1</sup> 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	
<b>General</b>					
Motor Type	PMSM or BLDC				
Driver Efficiency		-	95	-	%
Phase continuous output current	T = 175 °C	-	-	4	Arms
Phase instantaneous output current	During $t_p \leq 10\text{ms}$	-	-	6	Apeak
Nominal speed Range	With 4-pole-pair motor	200	-	3000	rpm
	With 2-pole-pair motor	400	-	6000	
Switching frequency		-	10	-	kHz
Frequency control accuracy		-	1	-	%
Thermal Shutdown <sup>2</sup>	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
<b>DC input</b>					
Input voltage		18	-	60	V
Quiescent current: Standby mode	$V_{DC}=60V$ T= [ 25°C; 175°C]	-	9.4	-	mA
Quiescent current: Standby mode	$V_{DC}=18V$ T= [25°C ; 175°C]	-	44	-	mA
Quiescent current: Drive mode	$V_{DC}=60V$ T= [25°C ; 175°C]	-	11	-	mA
Quiescent current: Drive mode	$V_{DC}=18V$ T= [25°C ; 175°C]	-	47	-	mA
Under Voltage Shutdown		16	18	20	V
<b>Digital Input</b>					
High-level input voltage $V_{IH}$			2.9		V
Low-level input voltage $V_{IL}$			1.7		V
<b>Analog Input</b>					
Voltage range		0	-	3.6	V
Equivalent Resistance			High-Z		

**Table 2: Electrical characteristics**

<sup>2</sup> Optional Thermal shutdown requires internal temperature sensors and is software programmable.

### 3. Hardware specification

#### 3.1. Theory of operation

NM-38-60-4-xxxx-x board consists of a power stage with three phase legs and a control stage with the following blocks:

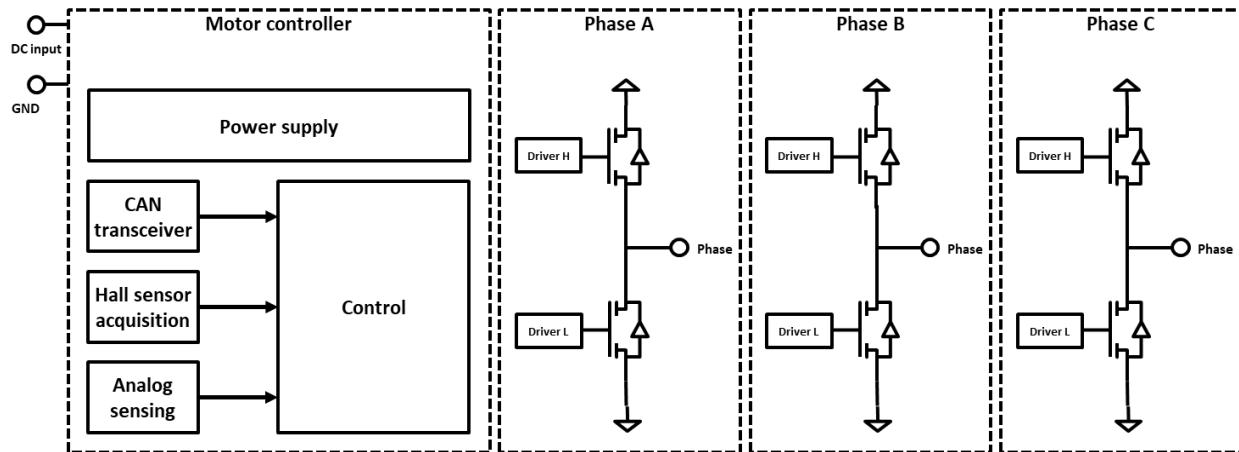


Figure 1 Block diagram

#### 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 sensor 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 **Erreur ! Source du renvoi introuvable.**) Accessible through CAN with optional features on demand. Its acquisition stage is described in the simplified diagram below

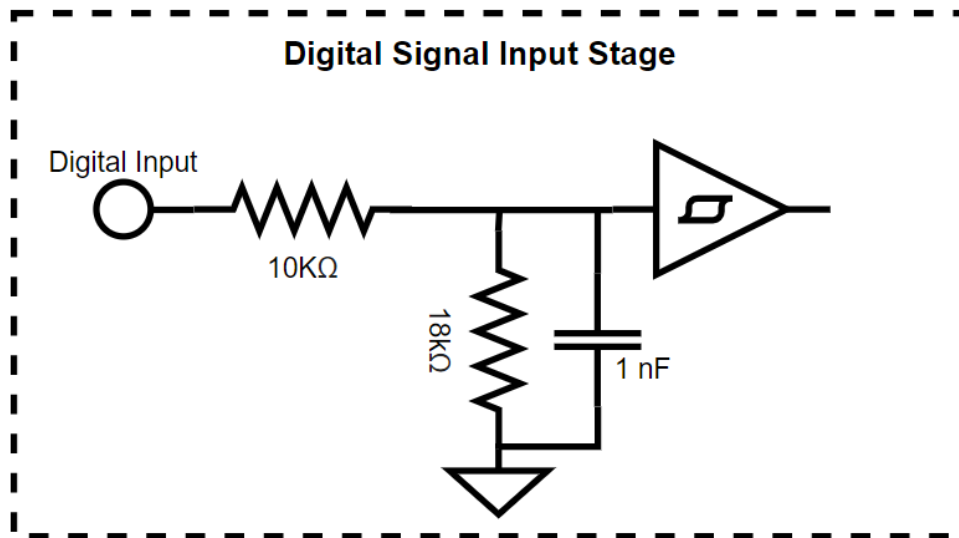


Figure 2 Digital signal input stage simplified diagram

### ANALOG SIGNAL INPUT (ASI-IN)

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

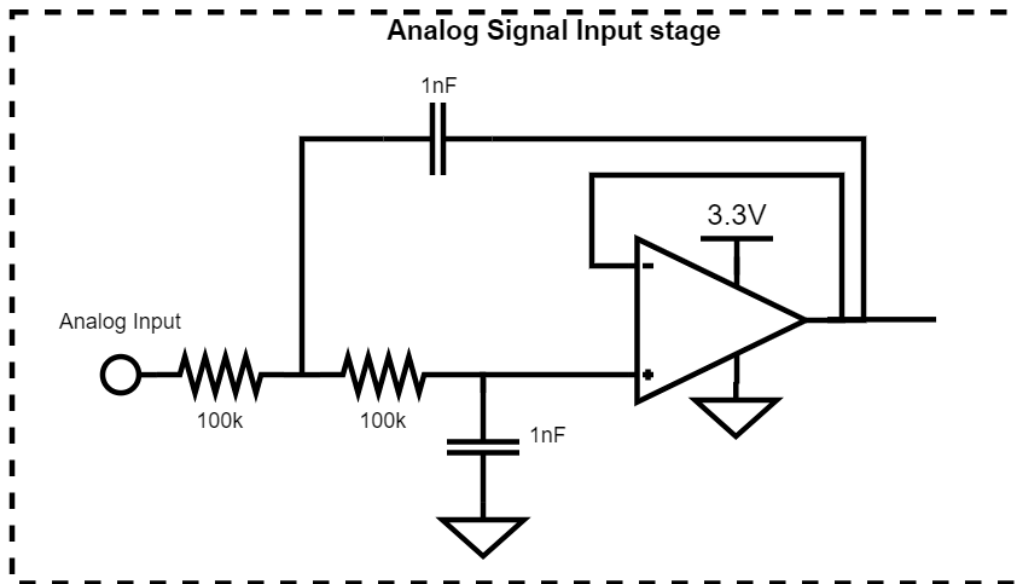


Figure 3 : Analog signal input stage simplified diagram

### 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-38-60-4 **does not include** any 120 Ω resistor to avoid overloading the bus.

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



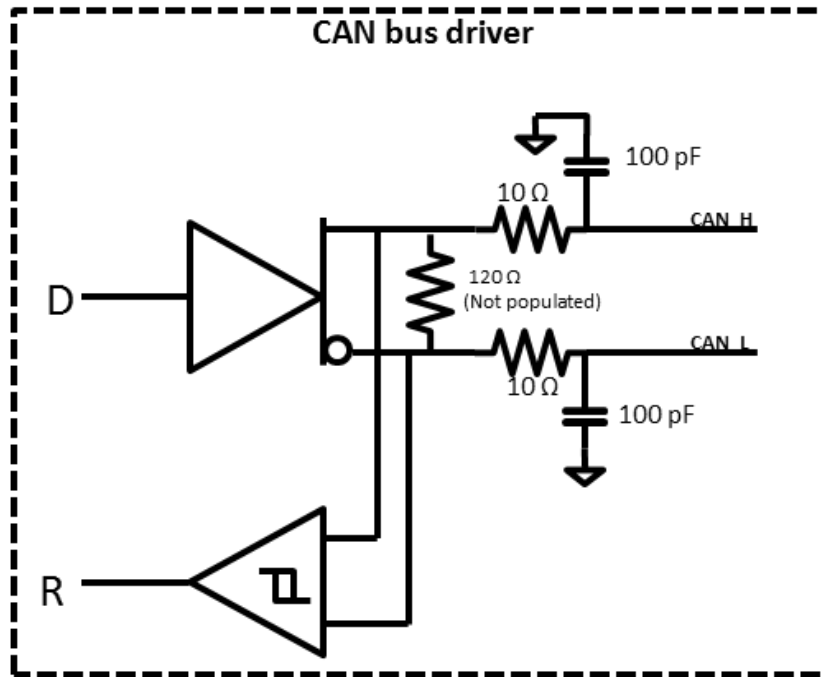


Figure 4: CAN transceiver simplified diagram

**RS485**

RS485 hardware is implemented to allow communication through a high-speed half duplex protocol:  
 -RS485\_A/Y: RS485 noninverting receiver input and non-inverting driver output.  
 -RS485\_B/Z: RS485 inverting receiver input and inverting driver output.

RS485 is not software implemented.

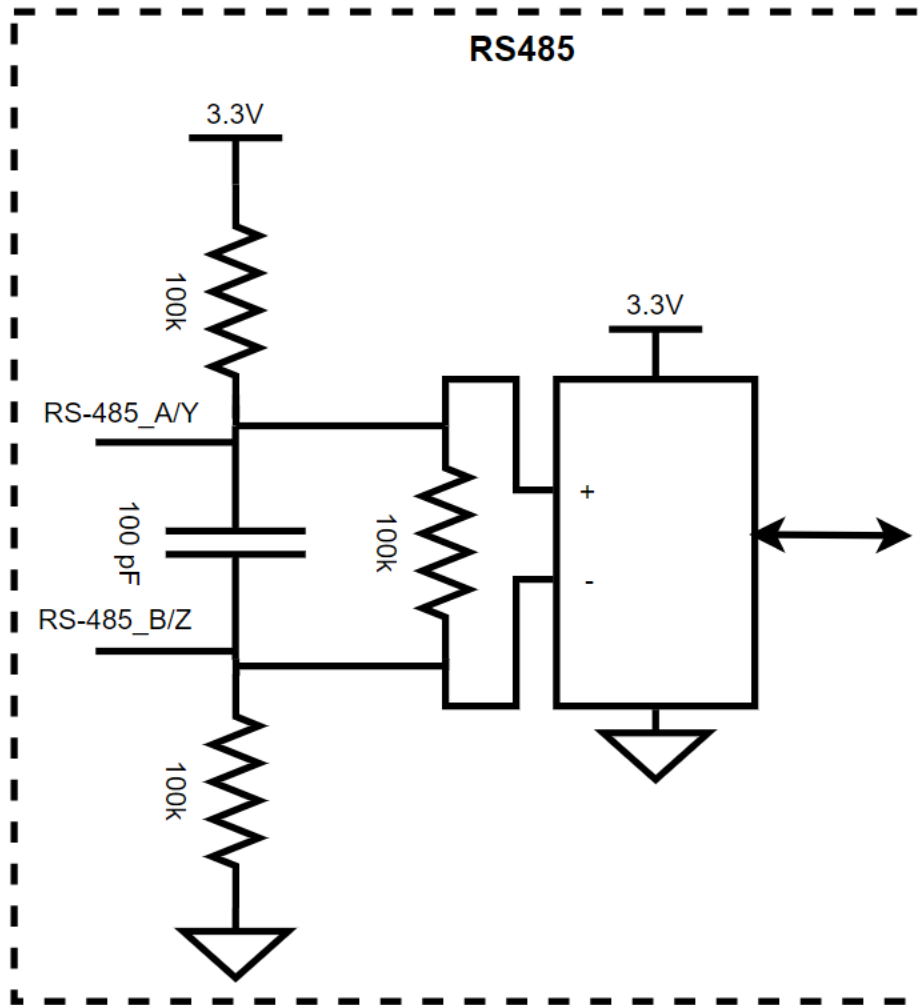


Figure 5: RS485 simplified diagram

**HALL SENSOR ACQUISITION** (NM-38-60-4-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.

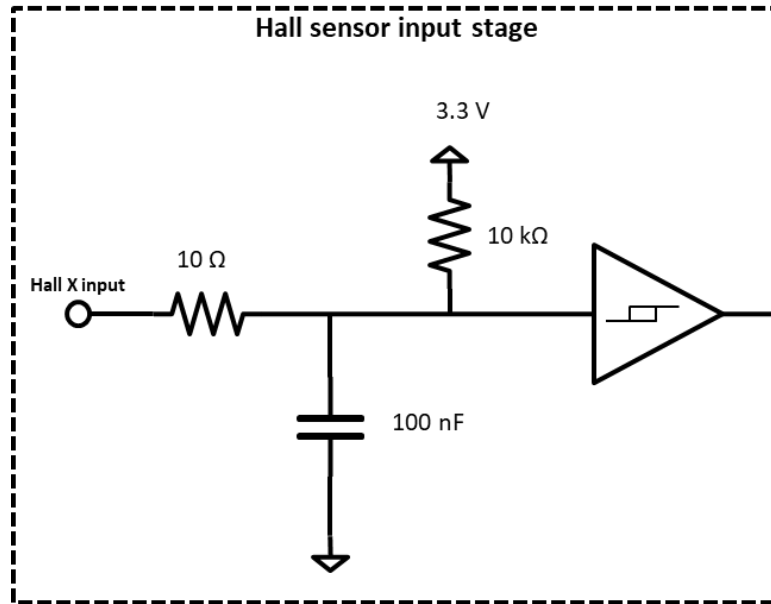


Figure 6 Hall Effect sensor interface simplified diagram

**3.2. 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
<b>P1 (Input side)</b>	MDAL15SCBPPT1	MDAL15PCW100M
<b>P2 (Output side)</b>	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)**

## 4. Mechanical specifications

### 4.1. Short Footprint

NM-38-60-4-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

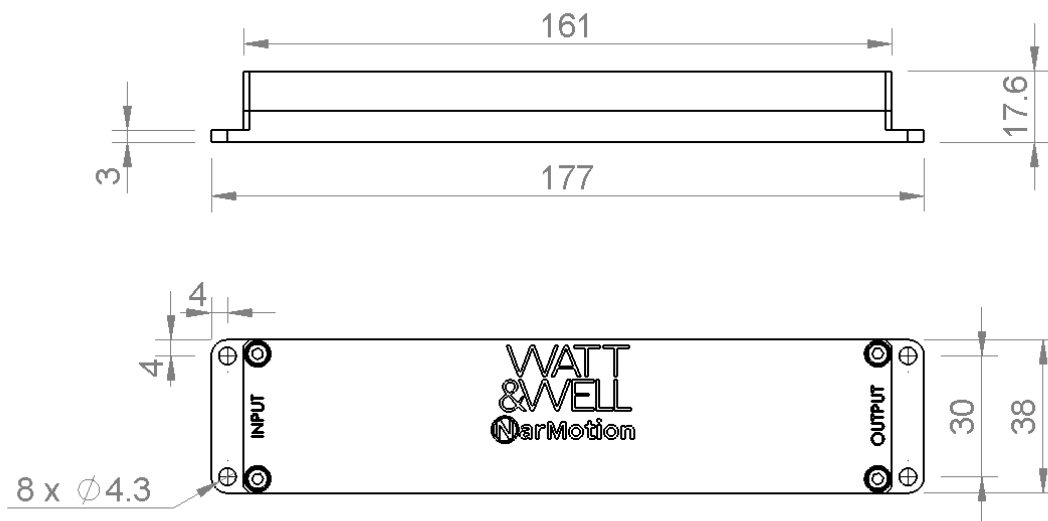


Figure 7 - NM-38-60-4-XXXX-S Mechanical Dimension

## 4.2. Legacy Footprint

NM-38-60-4-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

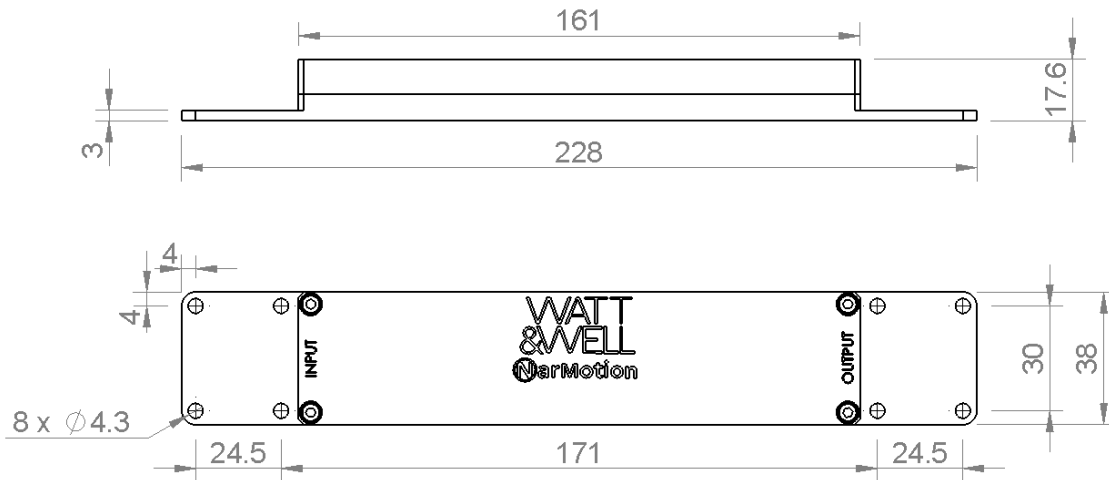


Figure 8: NM-38-60-4-XXXX-L Mechanical Dimension

## 5. Firmware specifications

### 5.1. 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). Nar Motion protocol does not conform to a predefined standard, but 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.

### 5.2. 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 baudrate of **500 kbps** with sampling point at **80%**. For best result, it is advised that all CAN nodes use the same sampling point configuration.

### 5.3. 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, ect.

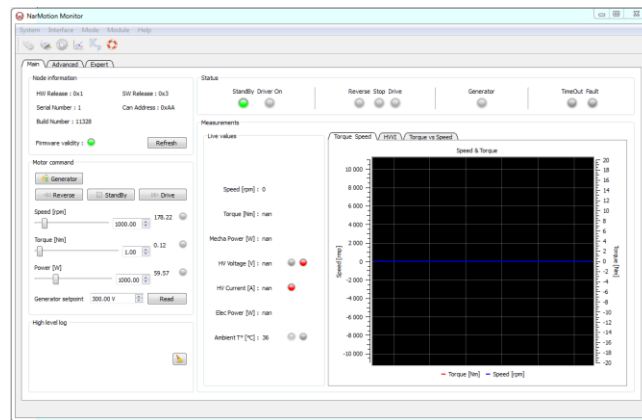


Figure 9: GUI Main panel

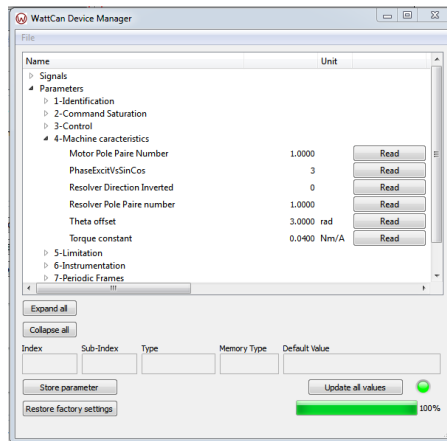


Figure 10 : Parameters panel



## 6. Safety instruction

### 6.1. 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.

### 6.2. 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.

### 6.3. Live circuits

Operating personnel are not allowed to open the case 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.

## 7. Installation

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

### 7.1. Mechanical installation

Refer to chapter 4 for the dimensions of the product.

### 7.2. 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.

### 7.3. Disposal



Do not dispose of electronic tools together 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.

## 7.4. 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<sup>3</sup>
- 450 hours of operation at 175 deg C<sup>4</sup>

As defined in the maximum absolute rating, the board must not be used above 175 deg C<sup>5</sup>.

## 7.5. Humidity

The NarMotionS device shall be stored, as provide 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.

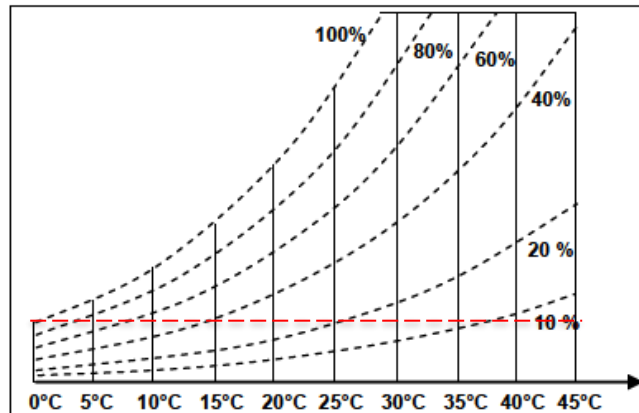


Figure 11 – Hygrothermal diagram

## 7.6. Vibrations

The NarMotionS device is compliant with vibrations, up to:

- 20g RMS on 3 axes
- Chassis temperature up to 150°C

<sup>3</sup> Temperature provided is the stiffener temperature where the power Mosfet are located.

<sup>4</sup> Temperature provided is the stiffener temperature where the power Mosfet are located.

<sup>5</sup> Temperature provided is the stiffener temperature where the power Mosfet are located.

## 8. Ordering information

	<b>ROTOR POSITION SENSOR</b>	<b>FOOTPRINT</b>
<b>NM-38-60-4-SLES-S</b>	Sensorless	Short Footprint
<b>NM-38-60-4-HALL-S</b>	Hall Effect	Short Footprint
<b>NM-38-60-4- SLES -L</b>	Sensorless	Legacy Footprint
<b>NM-38-60-4-HALL-L</b>	Hall Effect	Legacy Footprint

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## 9. Product revision history

<b>PRODUCT REVISION</b>	<b>APPLICABLE DATASHEET</b>
SYS-NARXWTC-V1.0.X	NM-38-60-4.AF

## Annexe 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
<b>Master (Monitor)</b>	0xAA	1
<b>Slave (Nar Motion)</b>	0x55	1

**Table 6: Default CAN settings**

## 2. CAN messages dictionary

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_refere nce	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 0 - System Off: PWM off (power switches in high impedance) 1 - Reserved 2 -Rotor lock 3 - Open-loop phase 4 - Drive: positive speed 5 - Reverse: negative speed 6 - Reserved 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 used microcontroller is fixed-point one, 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.

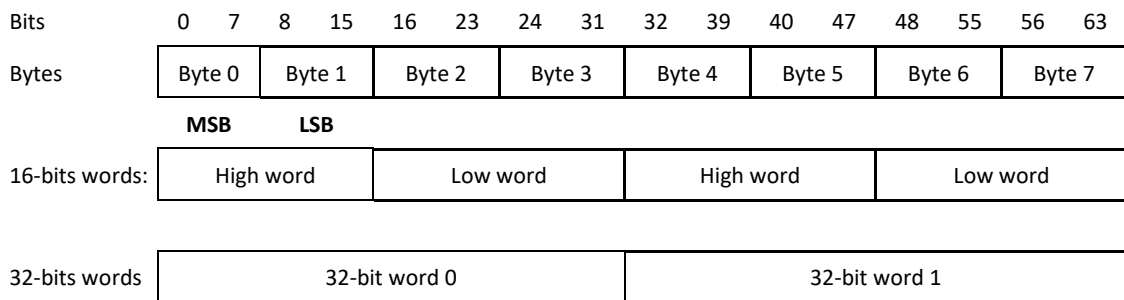
For example:

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)<sup>6</sup>.

The resulting byte order for Nar Motion communications is the following:



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		

<sup>6</sup> 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.