Watt & Well

CONVERTING POWER INTO CONFIDENCE

ENERGY

NAR MOTION SERIES

High-Temp – Low Power
Nar Motion X

HIGH TEMPERATURE | OIL & GAS

OVERVIEW

NarMotion X is the cost-effective version for low power application, even without sensor. It is part of the Nar-motion series.

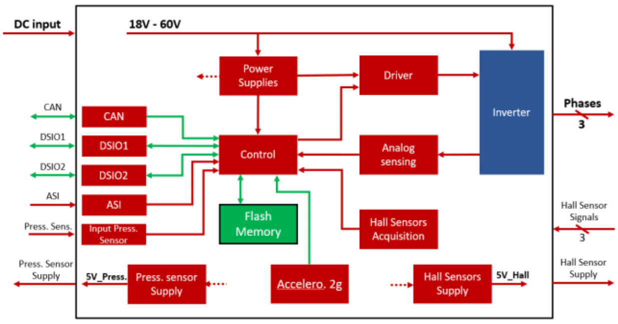
Nar-Motion X is our innovative high-temperature motor controller series, providing optimal operation **and high-reliability in harsh environment**.

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

FEATURES

- Dimension (LxWxH): 228*38*18 mm (8.98x 1.49 x 0.71 inches).
- Capability to drive BLDC motor with Sensorless open and closed loop.
- Hall Effect Sensor closed loop compatibility (5V up to 20mA supply, open-collector compatibility).
- Nominal DC input voltage: 18V to 60V.
- Phase Current up to 12 A_{RMS}.
- 150 W Typical Output power.
- 300 W Maximum Output power.
- Maximum operating temp: 190 °C (374 °F).
- Integrated Capacitor bank, 100µF up to 190°C
- Very low Quiescent current in standby mode for battery application purpose (<20mA on full input voltage scale).
- CAN bus Communication.
- Accelerometer ±2g on 3-Axis.
- Data logging on Flash-Memory (256MB).
- Input for an external Pressure sensor, millivolt output type (with a 5V supply up to 1 mA supply).
- 2 Digital Signal Input/Output.
- Analog Signal Input.

BLOCK DIAGRAM



APPLICATION

- Drilling
- Wireline
- Slickline
- MWD

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
V_{DC} Input Voltage		0	60	V
DC Input Current			7	A
Output Power	V_{DC}<48V		150	W
	V_{DC}>48V		300	W
Phase Current - peak			12	A
Operating Temperature		25	190	°C
Long term storage Temperature		5	85	°C
Temperature change rate			3	°C/min
Quiescent current (Hall sensor off, drive off) Temperature = 25°C			10	mA
Quiescent current (Hall sensor off, drive off) Temperature = 190°C			20	mA

Table 1: Absolute maximum ratings

2. Electrical Characteristics

All specifications are given for the full temperature range unless otherwise noted

Parameter	Condition	Value			Units
		Min	Typ	Max	
General					
Motor Type	Three phase BLDC motor				
Driver Efficiency		-	90	-	%
Phase continuous output current	T = 175 °C	-	-	6	Arms
Phase instantaneous output current	T = 175 °C	-	-	12	Apeak
Absolute nominal speed Range	With 4-pole-pair motor	500	-	4000	rpm
Switching frequency		-	10	-	kHz
Thermal Shutdown[1]		Software Programmable			
CAN baud rate		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 output (dominant)	CAN transceiver powered with 3.3V	1.1	-	-	V
CAN differential input voltage	(compatible with external transceivers from 3.3 to 5V)	-5	-	+5	V
LV input					
Input voltage		18	48	60	V
Input current	T = 175 °C – input voltage =48V	-		7	A
Under Voltage Shutdown	T = 25 °C T = 175 °C		16		V
Over Voltage Shutdown	T = 25 °C T = 175 °C		60	62	V
Input / Output					
Hall effect supply output	Max 20mA	4.875	5	5.125	V
Hall effect senses input	Open drain sensors	0	-	5	V
Pressure voltage supply output (Pout_P - Pout_N)	Max 1 mA	4.875	5	5.125	V
Pressure sensor input common mode		-	2.5	-	V
Pressure sensor input differential mode		0	-	55	mV
Pressure sensor Gain		-	56	-	-
ASI	Typical impedance 20kΩ	0	-	3.3	V
DSIO	Input mode	0	-	3.3	V
DSIO Low-level input voltage (V_{IL})	Input mode	0	-	1.2	V
DSIO High-level input voltage (V_{IH})	Input mode	1.3	-	3.3	V

Table 2: Electrical characteristics

[1] Optional Thermal shutdown requires internal or external temperature sensors and is software programmable. External sensor (e.g. motor temperature) is not included

3. Theory of operation

The NarMotion-X module board consists of a power stage with three phase legs and a control stage with the following blocks:

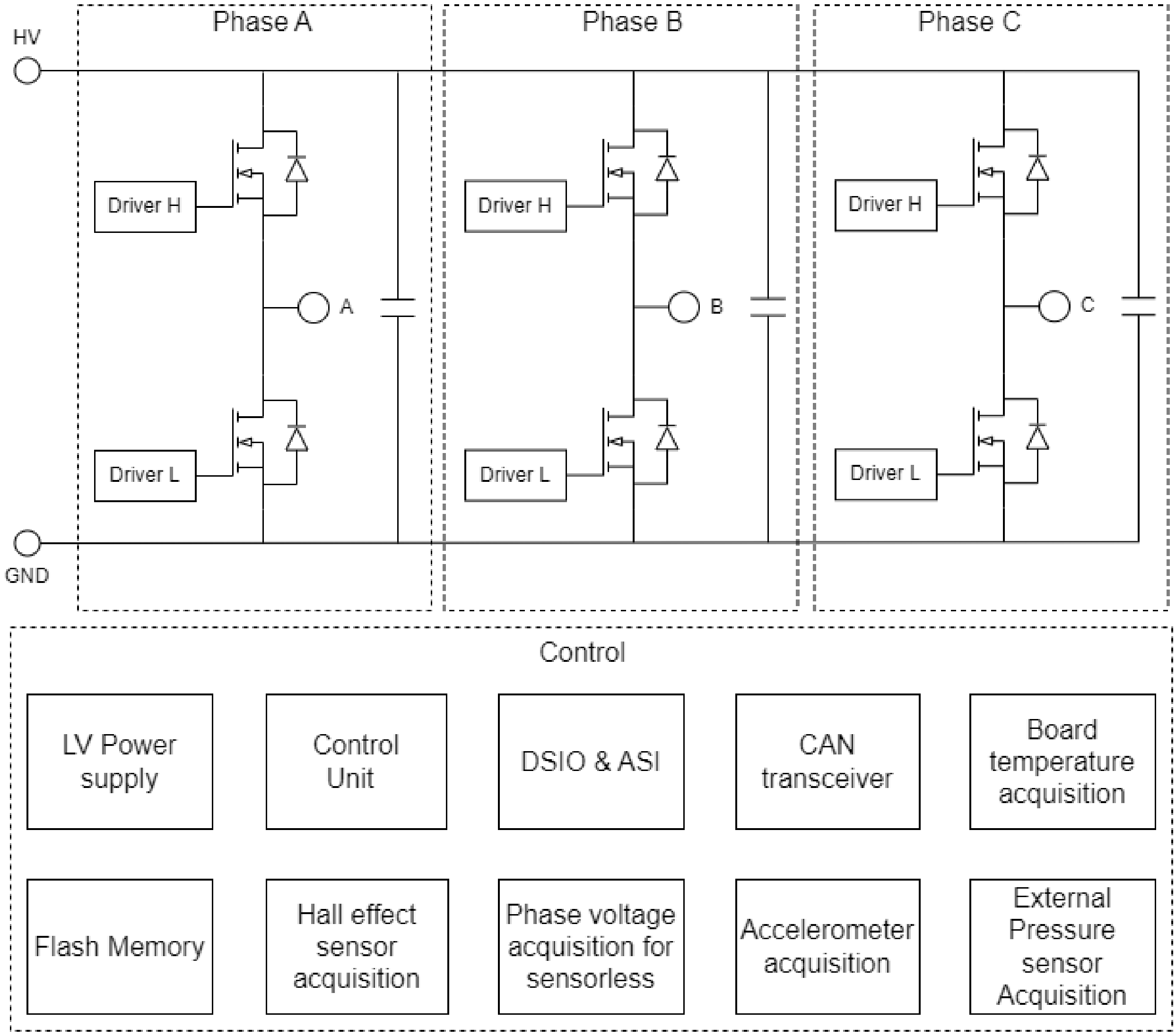


Figure 1: NarMotion-X block diagram

3.1. CAN Transceiver

Non-isolated CAN transceiver to communicate through a high speed CAN. The driver itself is powered at 3.3V (CMOS levels) but it accepts inputs from CAN transceiver powered at 5V (TTL or CMOS levels).
CAN bus is expected to be terminated at both ends with a resistance matching the intrinsic impedance of the twisted pair used (typically 120 Ω). By default, NarMotion-X has a 120 Ω resistor internally connected.

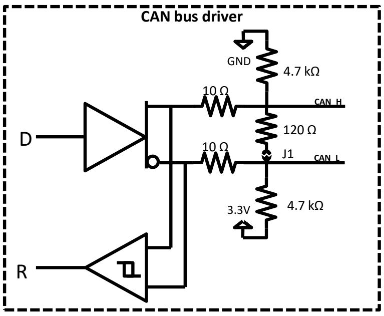


Figure 2: CAN transceiver simplified diagram

3.2. Hall Sensor Acquisition

NarMotion X product provides power to the hall sensors (5V, 20mA) and acquires each sensor state. This block is compatible with Open Drain/Open Collector output. Typical pull-up resistor used is 100kΩ. A 100pF capacitor is also included. For noise immunity, proper wiring and shielding is strongly advised for best results.

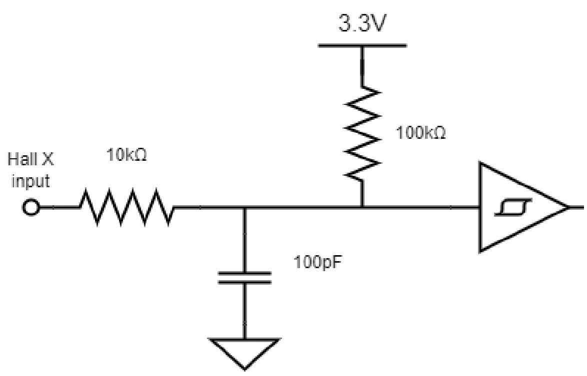


Figure 3: Hall Effect sensor interface simplified diagram

3.3. Digital Signal Input / Output (DSIO0 and DSIO1)

Two digital signal input/output are accessible from P1 connector and configurable through the DSP. Both digital input/output are buffered.

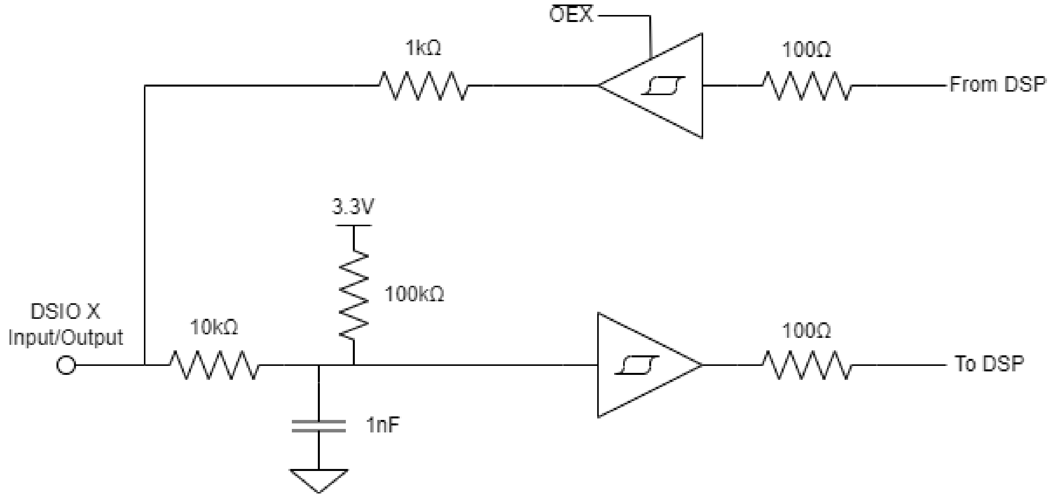


Figure 4: DSIO sensor interface simplified diagram

3.4. Ambient Temperature Sensor

A temperature sensor is located on the power board.

3.5. External Pressure Sensor

One acquisition circuit is located on the board to precisely measure a strain gauge sensor, with a minimum sensor impedance of 1 kΩ.
NarMotion X product provides a power supply to the pressure sensor (5V, 0.8mA).

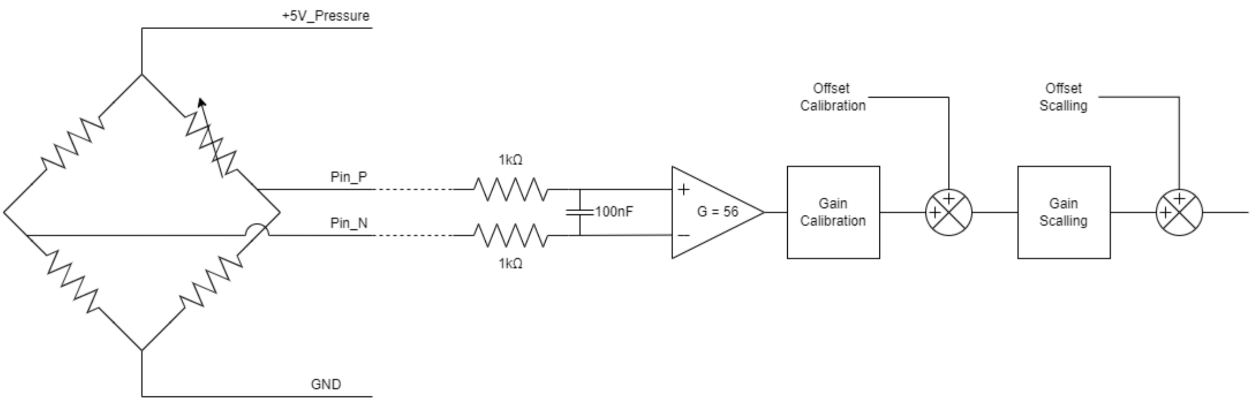


Figure 5: Acquisition circuit for External Pressure Sensor

4. Mechanical specifications

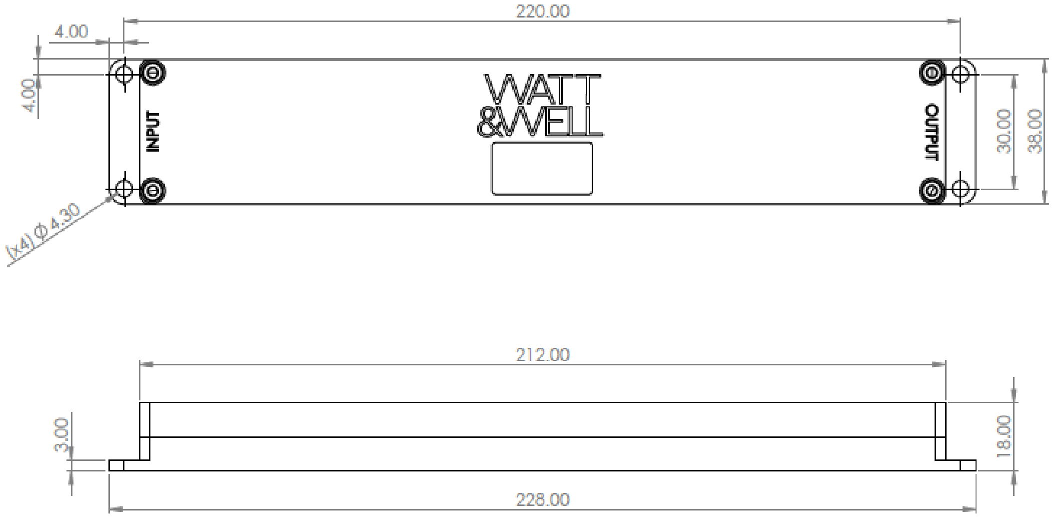


Figure 6: Mechanical specifications

All dimensions in mm
General tolerances: ISO 2768 mK

5. Wiring connections

5.1. Low power signals

The connectors described in this section are used for low voltage power interface.

- A 15 pin connector (MDAL15SCBPPT1 from AXON CABLE) is used to interface the system through Low Voltage Input, CAN Communication, two Digital Signal Input/Output (DSIO), analog signal input (ASI), Pressure sensor supply and differential inputs on the left side of the equipment.
  Its recommended matting micro-sub D connector is MDAL15PCWxxxxx from AXON CABLE.
- A 9 pin connector(MDAL09SCBPPT1 from AXON CABLE) is used to interface the motor phases and Hall effect sensor, on the right side of the equipment.
  Its recommended matting micro-sub D connector is MDAL09PCWxxxxx from AXON CABLE.

Pin-outs are shown in Table 3 and Table 4.

Pin	Signal Name	Details	Harness - MIL-STD-681 Wire Color
1	+5V_PRESSURE	Pressure sensor supply (5V – 1mA)	Black
2	PIN_P	Pressure sensor differential positive input	Brown
3	DSIO2	Digital Signal Input/Output n°2	Red
4	CAN_L	Can Bus Low	Orange
5	CAN_H	Can Bus High	Yellow
6	GND	Ground (recommended for Power supply)	Green
7	GND	Ground (recommended for Power supply)	Blue
8	HV	Voltage Input (recommended for Power supply)	Purple
9	GND	Ground (for CAN/ASI/DSIO/Pressure sensor)	Grey
10	PIN_N	Pressure sensor differential negative input	White
11	ASI	Analog Signal Input	Black
12	DSIO1	Digital Signal Input/Output n°1	Brown
13	GND	Ground (recommended for Power supply)	Red
14	HV	Voltage Input (recommended for Power supply)	Orange
15	HV	Voltage Input (recommended for Power supply)	Yellow

Table 3: P1 pinout (External interface)

Pin	Signal Name	Details	Harness - MIL-STD-681 Wire Color
1	GND	Ground	Black
2	Hall_B	Hall effect sensor phase B	Brown
3	Phase_B	Output Phase B	Red
4	GND	Ground	Orange
5	+5V_Hall	Hall effect sensor supply (5V – 20mA)	Yellow
6	Phase_C	Output Phase C	Green
7	Hall_C	Hall effect sensor phase C	Blue
8	Hall_A	Hall effect sensor phase A	Purple
9	Phase_A	Output Phase A	Grey

Table 4: P2 pinout (motor interface)

5.2. Recommended connection for CAN bus

CAN bus signals can be connected to a 9 pin Sub-D socket connector (also known as female DB9) for easy interface with commercial CAN transceivers (such as Kvaser which features a DB9 header connector). The pin-out of such connector is as follow :

Signal Name	Pin in P1	Pin in DB9 (female)
CAN_H	5	7
CAN_L	4	2
CAN_Ref	9	3
CAN_Shield	9	5

Table 5: CAN pinout on external connector

CAN bus shield
Although ISO-11898-2 does not specify the wires type or the need for a shield, a shielded cable is recommended for electronically harsh environments. It is recommended to ground the shield at a single point on one of the dedicated CAN_Shield pins of the NarMotion boards to avoid ground loops.

5.3. Grounding recommendation

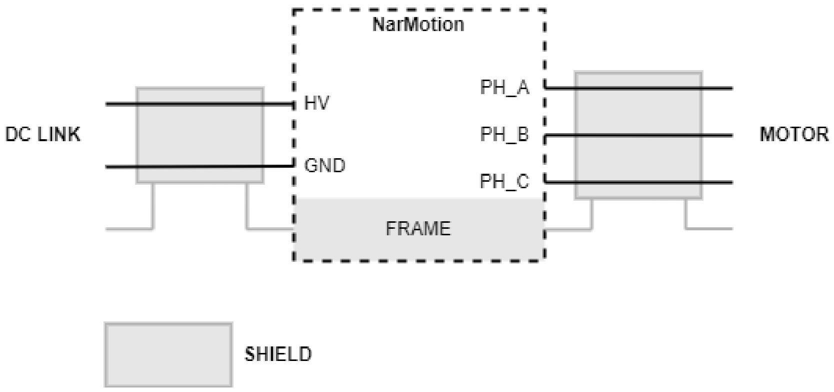


Figure 7: Grounding recommendation

6. NarX Control Modes

The advantage of NarX is that there are three implemented control strategies available for the user: Open-Loop, Closed-Loop Sensorless and Closed-Loop Hall Effect Sensors.

The selection of the system control modes is managed from the main system state machine. One dedicated parameter per mode is used for enabling/disabling. These three parameters are adjustable by the user via the CAN communication.

The control mode can be described on the following truth table:

Control	Hall Effect mode	Sensorless mode	Open-Loop
StandBy	0	0	0
Open-Loop	0	0	1
Sensorless Closed-Loop	0	1	X
Hall effect Closed-Loop	1	X	X

Table 6: List of control modes

If the three parameters dedicated to enable the control modes are null, then the system will remain in Standby mode.

It should be noted that there is a priority given to the Hall effect Closed-Loop. It means that if three control modes are activated, the system goes to hall effect Closed-Loop mode. Furthermore, the Sensorless Closed-Loop mode includes an open-loop phase in order to reach the closed-loop one.

7. System State Machine

The system state machine is described in the following diagram:

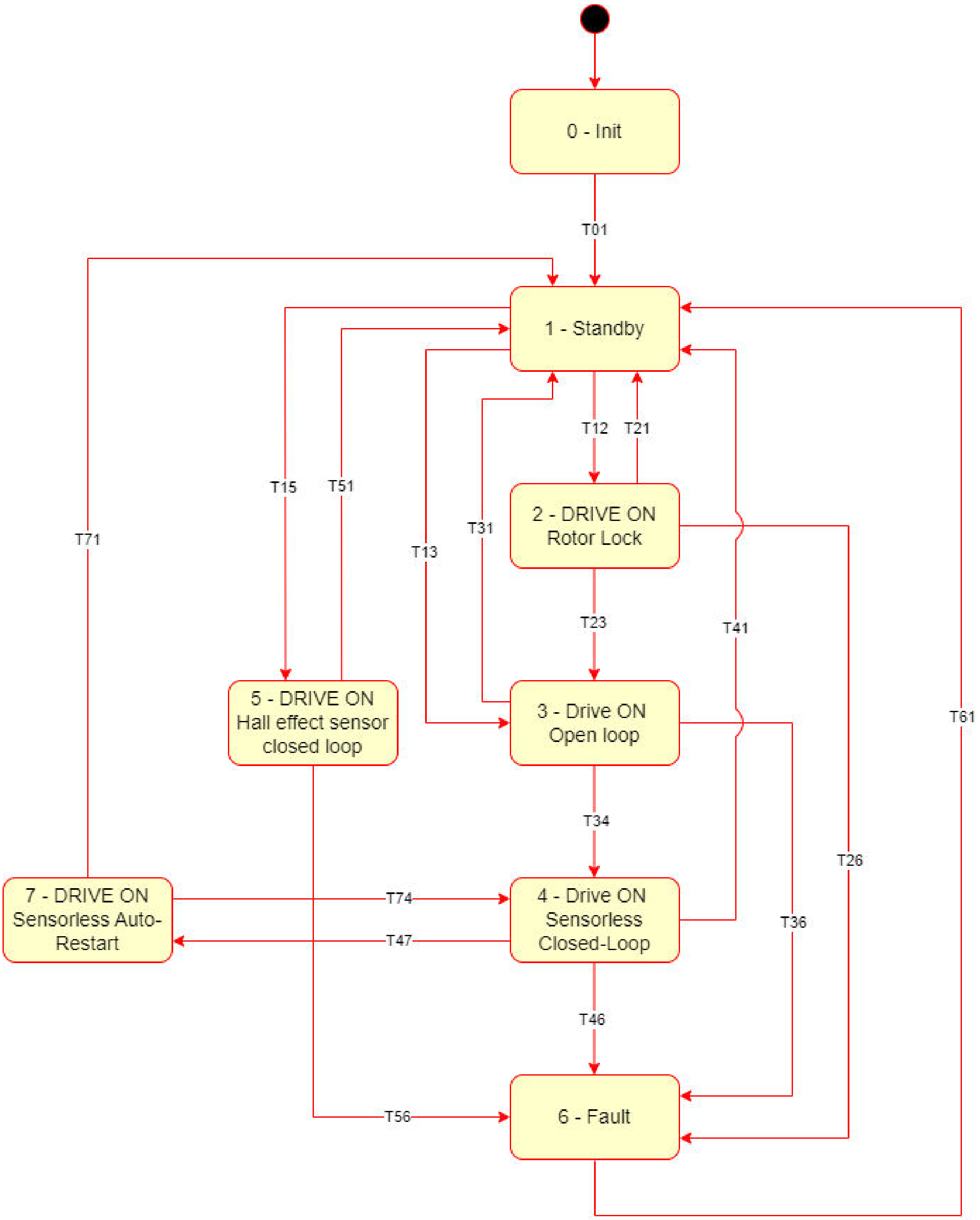


Figure 8: State machine of NarX

The transitions are described in the following table:

Transitions	Description
T01	After Boot-up time (0.5 s)
T12	If (parameter CL_SL_enable=1) && (parameter CL_HES_enable=0) && (Control Request= DRIVE_MODE)
T13	If (parameter OL_enable = 1) && (parameter CL_HES_enable = 0) && (parameter CL_SL_enable = 0) && (Control Request=DRIVE_MODE)
T15	If (parameter CL_HES_enable = 1) && (Control Request=DRIVE_MODE)
T21	If (Control Request=Standby)
T23	After Rotor Lock Duration (0.15 s) && (Control Request= DRIVE_MODE)
T26	Fault detection
T31	If (Control Request=Standby)
T34	After Open-loop Duration (0.5 s) && If (parameter CL_SL_enable=1) && If (parameter CL_HES_enable=0)
T36	Fault detection
T41	If (Control Request=Standby)
T46	Fault detection
T47	If (speed_estimated=0)
T51	If (Control Request=Standby)
T56	Fault detection
T61	If (Control Request=Standby)
T71	After auto-restart time (2 s) && (speed_estimated=0) OR (Control Request=Standby)
T74	After auto-restart time (2 s) && (speed_estimated>0)

Table 7: List of transitions of state machine

The system states are:

State	Description
0 - Initialization	• Motor control is off • PWMs are off
1 - Standby	• Drive the motor to a predefined electrical position in order to start the open-loop phase from a known position. • PWMs are on
2 - Rotor lock	• Drive the motor to a predefined electrical position in order to start the open-loop phase from a known position. • PWMs are on
3 - Open-loop	• Drive the motor in open-loop mode, this phase is essential to boot-up the Sensorless algorithm. • PWMs are on
4 - Sensorless Closed-loop	• Drive the motor in Sensorless mode, the speed is controlled using the estimated one based on Back-EMF Zero Crossing Detection. • PWMs are on
5 - Closed-loop Hall Effect Sensors	• Drive the motor in Hall Effect Sensors mode, the speed is controlled using the estimated one based on the output of Hall Effect Sensors. • PWMs are on
6 - Fault	• Motor control is off • PWMs are off • This state is enabled when a fault has been occurred; the system is maintained in this state until the fault is acknowledged.
7 – Sensorless Auto-Restart	• Drive the motor in Sensorless mode, if the estimated speed is still zero after an auto-restart time then the system should go to standby state. • PWMs are on

8. Firmware specifications

8.1. CAN bus communication

The motor driver NarX can be operated by a CAN bus communication.
The NarMotion CAN protocol is a simple protocol designed for **real time efficiency** (low CPU overhead) and **simplicity** (no communication stack required).

When using this protocol, NarMotion boards includes several functionalities:

- High level monitoring of motor control driver
- Real time scope

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.

8.2. Non-volatile memory

The NarX board is able to store FW high-level parameters configuration (i.e. calibration, motor settings, control) in a non-volatile memory, for storing motor parameters. Furthermore, this external flash memory is used for the logging feature implemented in the NarX software to provide to the user the possibility to log specific data (min, max, mean, live measurements…).

8.3. CAN programing capability

The firmware embeds a bootloader to be able to program the board on the fly via the CAN communication. This feature is very useful when it needs to upgrade the FW.

8.4. Graphical User Interface (GUI)

The GUI is a software tool that allows an easy real-time system configuration (faults sensitivity, faults thresholds, control loops parameters …), system control (command the states of the system, setpoints …) and system monitoring (get system control feedback, measurements …).

The following tools are needed for GUI utilization:
• Windows operating system
• Compatible with NI CAN series 2 and Kvaser Leaf Light series USB to CAN transceivers
• USB to CAN transceivers drivers.
Note that the interface is intended to communicate with one board at a time.

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

- Basic Operation: enable start /stop the drive, select the control mode, set the speed, and get main measurements from the NarMotion board.
- Virtual Scope: enable to trigger and download measurements (voltages, currents, position, …) and internal signals at the control rate (10kHz).
- Parameters update: enable to tune the whole board parameters, including controllers’ loops constants, limitations, calibrations, etc...
- Logging: enable to set parameters of data logging and download the data logs.
- CAN programing.

8.4.1. CAN configuration

This window allows to configure the CAN communication between the GUI and the motor controller.

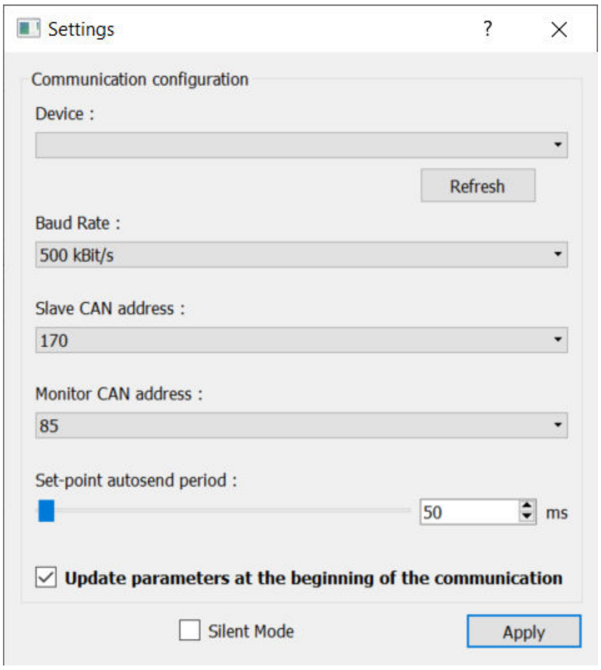


Figure 9: CAN bus configuration

The parameters of the CAN setting are:

- Communication Device: the USB to CAN transceiver device.
- Baud rate: CAN communication baud rate is 500kBit/s.
- Slave CAN address: CAN ID of the motor driver. Default value is 170.
- Monitor CAN address: CAN ID of the Monitor. Default value is 85.
- Set-point auto-send period: sending period of the CAN frame containing the set-points by the monitor.

8.4.2. Main window

The main panel contains all the main feedback information of the motor driver.

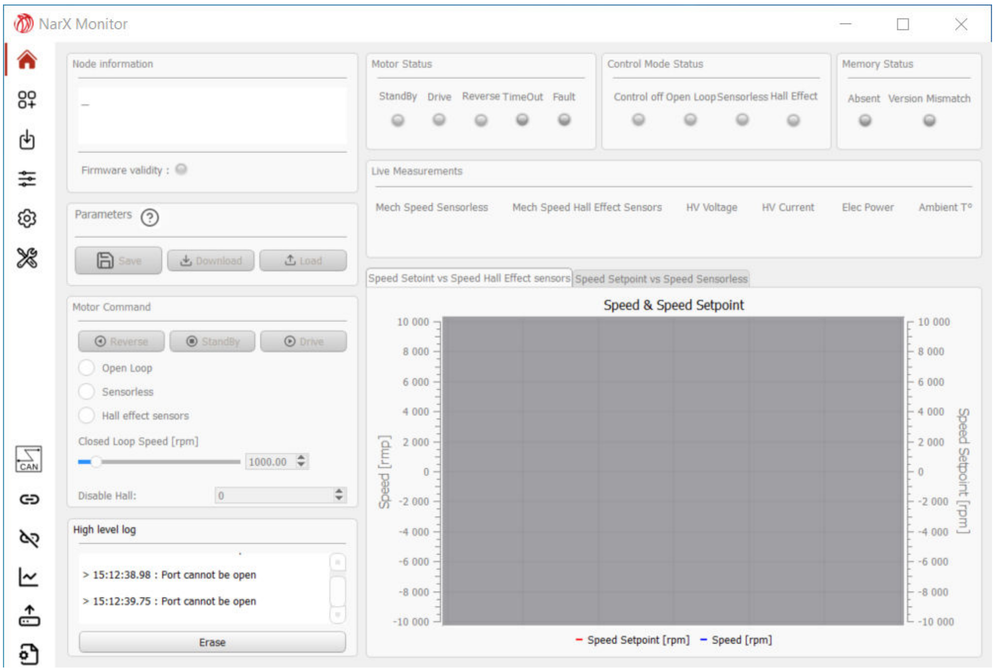


Figure 10: GUI Main panel

The live measurements are sent periodically by the motor controller through the CAN communication.

In addition, the GUI includes a real-time plot that shows the evolution of the motor mechanical speed and its setpoint.

Besides that, there is a panel specified for some live measurements as well as for the calibration process. It should be noted that an auto-calibration process has been implemented based on the power supply voltage.

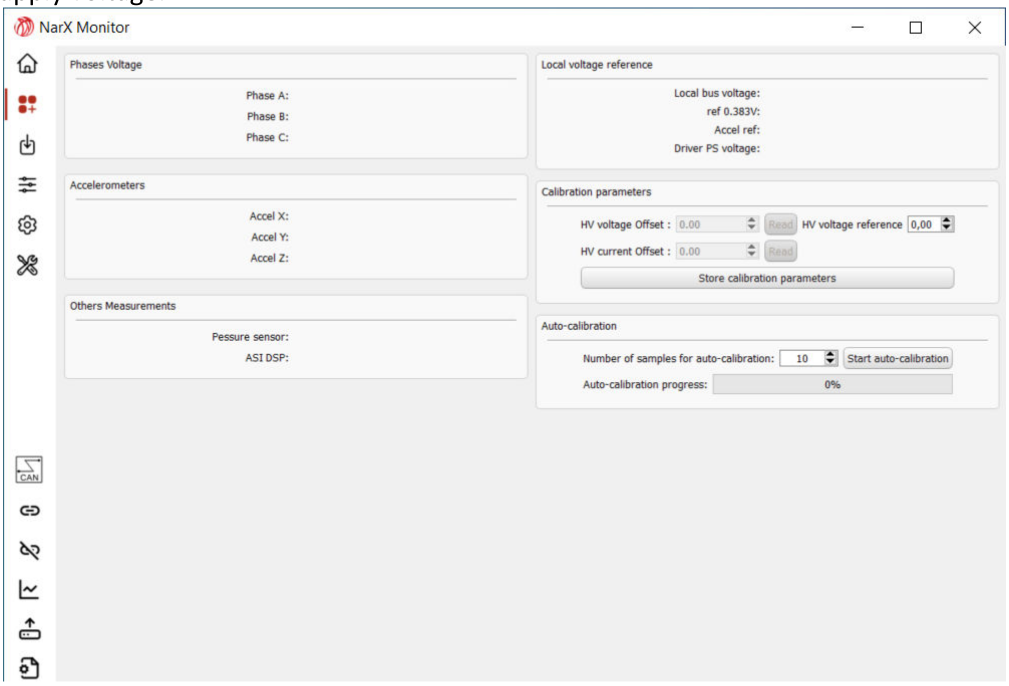
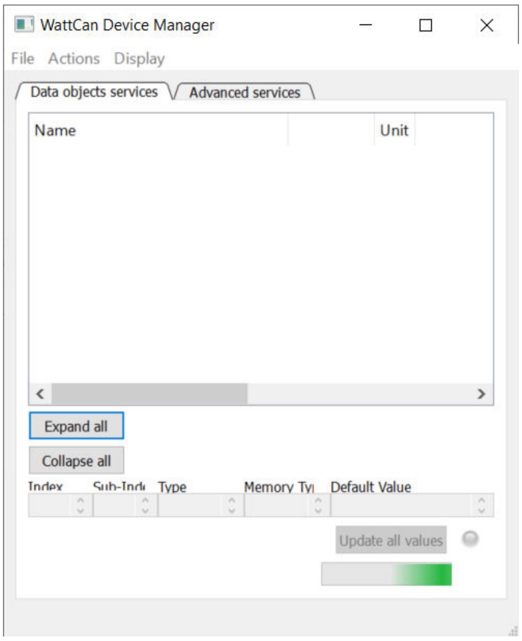
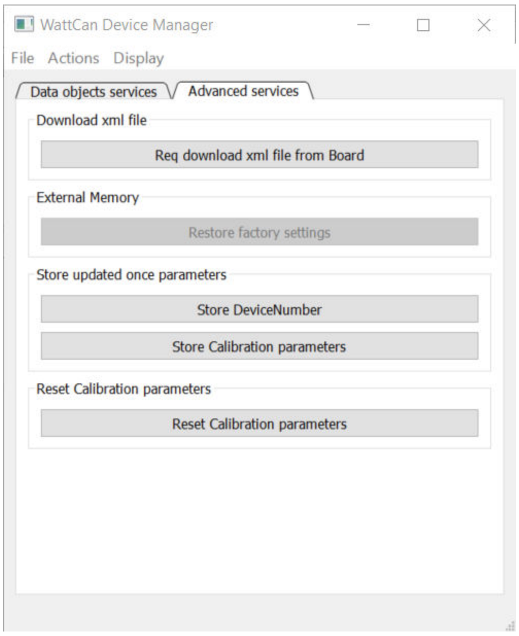


Figure 11: Live measurements and calibration panel

8.4.3. Device Manager

The Device Manager window allows access to all the motor driver's parameters.





It's composed by 2 panels: "Data objects services" and "Advanced services". In "data objects services", it is possible to have access to all the high-level FW parameters. The "advanced services" panel includes:

- Download xml file: the "Req download xml file from board" button requests to download from the board the xml file that presents the data objects' structure.
- External memory: the "Restore factory settings" button requests to reset the parameters stored in the NVM by their factory default values.
- Store updated once parameters: to store the device number and calibration parameters in the NVM.
- Reset calibration parameters: to reset the calibration parameters

8.4.4. Virtual scope

The Virtual Scope is a feature that allows plotting real-time data and save them to an excel file if needed. It’s a powerful feature to diagnose the motor driver system.

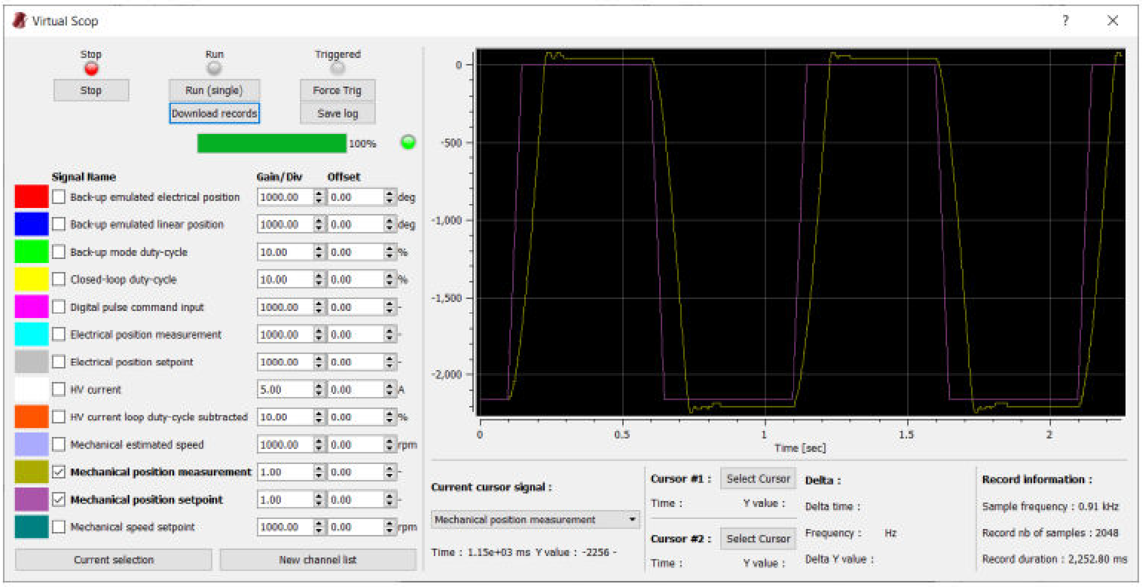


Figure 12: Virtual scope window

The virtual scope is only available after downloading the data definition file from the board, which configures all its parameters like the available signals to monitor, the sampling rate …
The steps to use the virtual scope are:

- Select the signals to plot by checking the appropriate checkbox.
- Press the “Run (single)” button to enable real-time data saving on the motor driver.
- Press the “Force Trig” button to start real-time data saving on the motor driver.
- Wait for the “Stop” led to be red before downloading data, the recording time is linked to the sampling frequency.
- Press the “Download records” button to download, from the motor driver, the saved data and plot them.

8.4.5. Logging

95% of the 256Mb flash memory is dedicated to data logging.
The logging feature is integrated to the parameter module which has access to the flash memory low-level drive to erase/write/read the external flash memory through the SPI communication.
The logging module is integrated in the code generation project, it requires 2 group of parameters (see NarX parameters description section):

- Logging data (structure of the parameters to log)
- Logging control (log control parameters)

The logging module have two actions:

- Download Logs: send log data through the CAN communication.
- Erase Log: erase the whole log memory data.

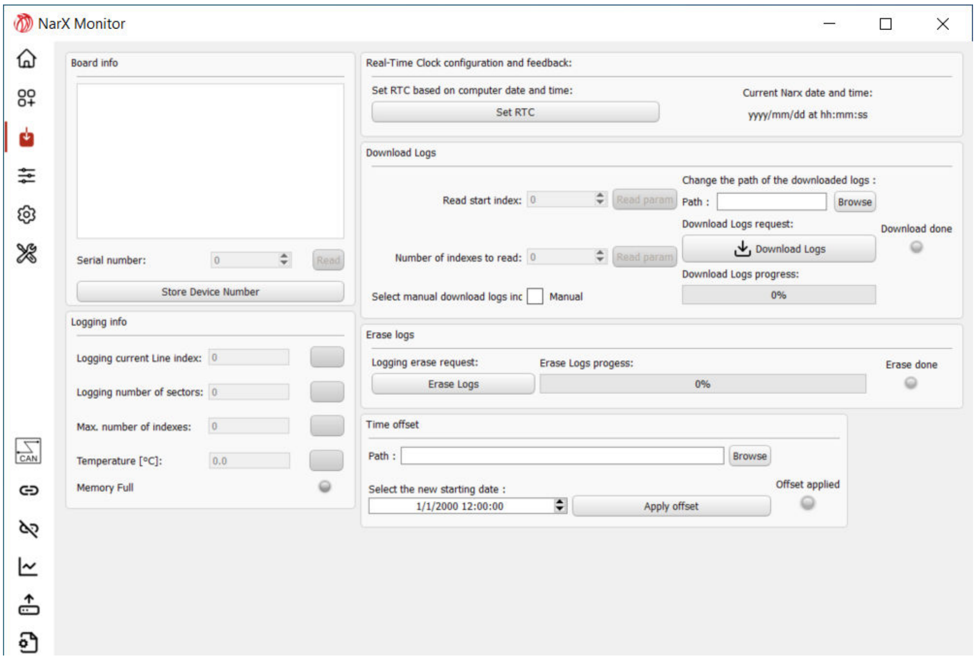


Figure 13: Logging panel

9. Safety instruction

9.1. 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.

9.2. 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 1 of this document.

9.3. 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.

10. Installation

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

10.1. Mechanical installation

Refer to chapter 4 for the dimensions of the product.

10.2. 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.

10.3. 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.

11. Ordering information

PART NUMBER	ROTOR POSITION SENSOR
SYS-NARXWTC-V1.0	Hall effect sensor
	Sensorless

contact@wattandwell.com

Engineering Center: 129 avenue de Paris - Massy (91300) France
Production Facilities: 121 rue Louis Lumière - Pertuis (84120) France
USA Subsidiary: Watt & Well USA, Inc. 3500 Washington Ave, Suite 100 HOUSTON, TX 77007 USA

Annex A - NarMotion X CAN protocol

The communication protocol is the W&W CAN protocol, based on CAN communication.
NarMotion protocol does not conform to a predefined standard, but it is fully documented, and the protocol can be reused on other projects without restrictions.

1. Message Identifier Format

Each CAN 2.0B frame has a 29 bit identifier and up to 64 bits of data. NarMotion 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 messages 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.

2. NarX CAN messages dictionary

With the 29 bits CAN ID defined above, each node can build a message dictionary using the 9-bits Opcode.
The NarX CAN messages are presented in the following table:

3. NarX CAN messages dictionary

With the 29 bits CAN ID defined above, each node can build a message dictionary using the 9-bits Opcode.
The NarX CAN messages are presented in the following table:

Computed MsgID (29 bits)	Priority (2bits)	Src Address (8 bits)	Dst address (8 bits)	Msg Type (2bits)	OpCode value (9 bits)	OpCode Name	Data Size	Format	Word 0	Word 1	Word 2	Word 3
0x1552A800	2	AA	55	0	0	BUILD_INFO	4*16b	Uint16/ Uin32 / Uint16	BuildNb	SrcModified	BuildDate	
0xAAD5400	1	55	AA	2	0	BUILD_INFO	4*16b	Uint16	(0x0000)	(0x0000)	(0x0000)	(0x0000)
0x1552A801	2	AA	55	0	1	DEVICE_INFO	4*16b	Uint16	HwRelease	SwRelease	DeviceNumber	CanAddress
0xAAD5401	1	55	AA	2	1	DEVICE_INFO	4*16b	Uint16	(0x0000)	(0x0000)	(0x0000)	(0x0000)
0xAAD5202	1	55	AA	1	2	REQUEST_WORD	4*16b	Bit-Wise	RequestWord		(0x0000)	(0x0000)
0x1552A803	2	AA	55	0	3	STATUS_WORD	4*16b	Bit-Wise	StatusWord		(0x0000)	(0x0000)
0x1552A804	2	AA	55	0	4	FAULT_WORD	4*16b	Bit-Wise	FaultWord		(0x0000)	(0x0000)
0x1552A805	2	AA	55	0	5	CRITICAL_FAULT	4*16b	Bit-Wise	Critical FaultWord		Extended Fault Code	(0x0000)
0x1552A865	2	AA	55	0	101	REBOOT	4*16b	Uint16	Ack(0x0001)	(0x0000)	(0x0000)	(0x0000)
0x1552A866	2	AA	55	0	102	MOTOR_CMD	4*16b	Uint16	SpeedCmd	(0x0000)	(0x0000)	(0x0000)
0xAAD5266	1	55	AA	1	102	MOTOR_CMD	4*16b	Uint16	SpeedCmd	(0x0000)	(0x0000)	(0x0000)
0xAAD5267	1	55	AA	1	103	DSIO_DATA_CMD	4*16b	Uint16	DSIO1 Output Enable	DSO1 Value	DSIO2 Output Enable	DSO2 Value
0xAAD5268	1	55	AA	1	104	Disable_Hall_PS	4*16b	Uint16	Disable Hall PS	(0x0000)	(0x0000)	(0x0000)
0x1552A86E	2	AA	55	0	110	PARAMETER	4*16b	Uint16/int32	Uint16/int32	Param Read Value	Param Read Value	(0x0000)
0xAAD526E	1	55	AA	1	110	PARAMETER	4*16b	Uint16/int32	Param Number	Param New Value	Param New Value	(0x0000)
0xAAD546E	1	55	AA	2	110	PARAMETER	4*16b	Uint16	Param Number	(0x0000)	(0x0000)	(0x0000)

0x1552A870	2	AA	55	0	112	LOG VIRTUAL SCOPE	4*16b	Uint16/Q3.12	Log first word address	Log data word 1	Log data word 2	Log data word 3
0xAAD5270	1	55	AA	1	112	LOG VIRTUAL SCOPE	4*16b	Uint16	Log trigger req (0x0000)	(0x0000)	(0x0000)	(0x0000)
0xAAD5470	1	55	AA	2	112	LOG VIRTUAL SCOPE	4*16b	Uint16	Log download req (0x0000)	(0x0000)	(0x0000)	(0x0000)
0xAAD5271	1	55	AA	1	113	RESTORE_FACTORY_SETTING	4*16b	Uint16	s/n of the board	(0x0000)	(0x0000)	(0x0000)
0xAAD5482	1	55	AA	2	130	XML_DOWNLOAD_REQUEST	4*16b	Uint16	cmd (req or start downloading)	(0x0000)	(0x0000)	(0x0000)
0x1552A882	2	AA	55	0	130	XML_DOWNLOAD_ANSWER	4*16b	Uint16	Xml file length in words	(0x0000)	(0x0000)	(0x0000)
0x1552A883	2	AA	55	0	131	XML_DOWNLOAD_DATA	4*16b	Uint16	Xml data first word address	Xml data word 1	Xml data word 2	Xml data word 3
0x1552A88C	2	AA	55	0	140	EXT_MEM_LOG_READ_DATA	4*16b	Uint16	Log memory metadata	Log memory data word 1	Log memory data word 2	Log memory data word 3
0x1552A8C8	2	AA	55	0	200	MEASUREMENT_0	4*16b	Fixed-point	Accel X	Accel Y	Accel Z	DSI1_DSP
0x1552A8C9	2	AA	55	0	201	MEASUREMENT_1	4*16b	Fixed-point	Mechanical estimated speed SL	Mechanical position		Electrical input Power
0x1552A8CA	2	AA	55	0	202	MEASUREMENT_2	4*16b	Fixed-point	HV Voltage	HV Current	+6V_MEAS	Driver 14V Voltage
0x1552A8CB	2	AA	55	0	203	MEASUREMENT_3	4*16b	Fixed-point	Ambient Temperature	Vref Accel (+1.8V)	+0.383VREF	ASI_DSP
0x1552A8CC	2	AA	55	0	204	MEASUREMENT_4	4*16b	Fixed-point	VoltagePhaseA	VoltagePhaseB	VoltagePhaseC	PIN_MEAS
0x1552A8CD	2	AA	55	0	205	MEASUREMENT_5	4*16b	Fixed-point	Mechanical estimated speed HES	DSI2_DSP	(0x0000)	(0x0000)
0x1552A8CF	2	AA	55	0	207	MEASUREMENT_7 (reserved)	4*16b	Fixed-point	(0x0000)	(0x0000)	(0x0000)	(0x0000)
0x1552A8D0	2	AA	55	0	208	MEASUREMENT_8 (reserved)	4*16b	Fixed-point	(0x0000)	(0x0000)	(0x0000)	(0x0000)

Figure 14: CAN messages dictionary

4. NarX CAN frames description

4.1. Request word, status word and fault word messages

These three words are defined bit wise, that is, each bit inside the word has a particular definition:

- Request Word: used to configure the behavior of the system. Table 4 (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.

The details of request word and status word are shown in the following table:

Bit	Request Word	Status Word	Description
0:3		Motor Mode Status	Set/acknowledge the motor mode state 0 - Standby 1 - Drive ON 2 - Reverse mode 3 – Fault mode: PWM off because of a critical fault. System status should be set to Standby to clear the fault
4:7		Reserved	
8:11		Control Mode Status	Set/acknowledge the control mode state 0 - Control OFF 1 – Open-loop mode 2 – Sensorless Closed-loop mode 3 – Hall effect sensor Closed-loop mode
12:15		Reserved	
16:20		Logging_status	Set/acknowledge the system logging state 0 – LOG_BOOT_UP 1 – LOG_INIT 2 – LOG_WRITE_WAIT_PER 3 – LOG_WRITE 4 – LOG_READ_REQ_INIT 5 – LOG_SEND_READ_REQ 7 – LOG_WAIT_READ_RESULT 8 – LOG_READ_SEND_CAN_FRAMES 9 – LOG_EREASE_ONGOING 10 – LOG_EREASE_END 11 – LOG_READ_END
21	Reserved	Logging_memory_full	Logging_memory_full
22	Reserved	Logging_memory_erased	Logging_memory_erased
23	Reserved	Logging_read_enable	Logging_read_enable
24	Reserved	Logging_erase_enable	Logging_erase_enable
25:31		Reserved	

Table 8: Request Word/Status Word Bit definition

The details of the fault word are shown as well in the following table:

Bit	Description
0	Warning ambient temperature
1	Shutdown ambient temperature fault (Over Temperature fault)
2	Over-voltage HV fault
3	Under-voltage HV fault
4	Over-current HV fault
5	Legs driver fault
6	Hall sensors fault
7	~~Unused~~ Pin trig fault
8	Unused
9	Unused
10	Unused
11	Unused
12	Unused
13	Unused
14	Unused
15	Unused
16	Unused
17	Unused
18	Unused
19	Unused
20	Unused
21	Unused
22	Unused
23	Unused
24	Unused
25	Unused
26	ParamExtMemoryMappingMismatch
27	Emergency_Shutdown
28	External_Shutdown
29	DeviceTimeOut
30	Non-volatile memory absent
31	Non-volatile memory FW version mismatch

Table 9: Fault word bit wise definition

5. Endianness

Endianness and data format within a CAN frame is application dependent (not part of the CAN specification). The NarMotion protocol uses Big Endian (also known as Network Order).
The resulting byte order for NarMotion 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 Word	High Word		Low Word		High Word		Low Word	
32-bits Word	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 Word**	**32-bits Word**
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		

Annex B - NarX Parameters Description

This section details data contained in the list of parameters sent by the DSP to the GUI of NarX.

A list of parameters has been implemented to deeply configure the system.
The list is indexed so each parameter can be set/read using Can Bus.

This list of parameters is recorded in two places:

- Internal memory of controller which contains initial factory values.
- External memory where parameters values can be modified by user (via Can Bus).

At any moment, the factory values of parameters can be loaded using 'RESTORE_FACTORY_SETTING' button. The changes are effective after a 'Reboot'.

The list of NarX parameters presented in the GUI are described in the following tables:

General parameters:

Category	Name	Unit	Description
0-CommonInfo	0 Memory Mapping Flag	-	Parameter in read only mode to consider that the external memory has the right mapping
0-CommonInfo	1 Device Number	-	Serial number of the board.
0-CommonInfo	2 Slave CAN address	-	CAN address of the device
0-CommonInfo	3 Master CAN address	-	CAN address of the monitor
0-CommonInfo	4 Hardware Release	-	Hardware Release version
01-Identification	Build number	-	Build number of the firmware programmed on the board. It's a unique number given by SVN tool used by Watt & Well for maintaining current and historical versions of the firmware source project.
01-Identification	Software Release	-	Software Release version
01-Identification	Source modified	-	Version control check result (0-> OK, 1-> fail)
02-Calibration	Temperature measurement source selection	-	Selection of source of temperature measurement (1 -> external, 0 -> internal)
02-Calibration	Accel use ref for scaling selection	-	Selection of the acceleration measurement offset (1 -> use the low voltage measurement 1.8 V, 0 -> use the adjustable parameter acceleration_meas_offset)
02-Calibration	Accel X calib offset	g	Accelerometer in X axis calibration offset
02-Calibration	Accel Y calib offset	g	Accelerometer in Y axis calibration offset

02-Calibration	Accel Z calib offset	g	Accelerometer in Z axis calibration offset
02-Calibration	HV current calib offset	A	HV current calibration offset
02-Calibration	HV voltage calib offset	V	HV voltage calibration offset
02-Calibration	Temperature calib offset	°C	Temperature calibration offset
02-Calibration	Mechanical position calibration value	deg	Mechanical position calibration value
02-Calibration	Set position calibration value (rising edge)	-	Use mechanical position calibration value when this parameter goes from 0 to 1
02-Calibration	Pressure calib offset	-	Pressure calibration offset
02-Calibration	Pressure calib gain	-	Pressure calibration gain
02-Calibration	Pressure meas offset	-	Pressure measurement scaling offset
02-Calibration	Pressure meas gain	-	Pressure measurement scaling gain
13-Instrumentation	Virtual Scop Channels Selection	-	Parameter that defines signals to be logged
13-Instrumentation	Virtual Scop Samples Number	samples	Number of samples of signals to be logged
13-Instrumentation	Virtual Scop Sampling Prescaler	-	Virtual scope sampling prescaler (to define time scale)
13-Instrumentation	Virtual Scop Sampling Time	s	The sampling rate of recording the values of selected signals in RAM memory
13-Instrumentation	Virtual Scop Trig phase	samples	Number of samples of trigger phase
15-Logging data	01 - Logging start index	-	First object that delimits the log data structure.
15-Logging data	02 - Logging package index	-	Index of the logged data, it increments for each write operation.
15-Logging data	40 - Logging end index	-	Last object that delimits the log data structure.
16-Logging control	Logging read start index	-	First index of the log data to read
16-Logging control	Logging read number of indexes	-	Number of log data indexes to read
16-Logging control	Logging data size bytes	-	Feedback of the log data structure based on the “Logging data” objects
16-Logging control	Logging data max index	-	Feedback of the maximum indexes for logging
16-Logging control	Logging data write index	-	Current index of the log data
16-Logging control	Logging period	ms	Period of the logging

16-Logging control	Logging data subsectors number	-	Feedback of the subsectors used by the logging
16-Logging control	Logging data ongoing subsector erase index	-	Current index of the subsector while erase operation
16-Logging control	Logging read request	-	Command to request log read, the logging module is sensitive on the rising edge which means write “0” then write “1”
16-Logging control	Logging erase request	-	Command to request log erase, the logging module is sensitive on the rising edge which means write “0” then write “1”.
16-Logging control	Logging memory full flag	-	Memory full flag

Table 10: Parameters description

Control parameters:

Category	Name	Unit	Description
03-Machine characteristics	Motor pair poles	-	Number of pole pairs of the motor
03-Machine characteristics	Select control sequence for standard motor	-	Selection of Hall effect PWM sequence(1 -> standard motor, 0 -> motor with sensors misalignment)
03-Machine characteristics	Hall effect offset angle	deg	Hall Effect Sensors offset if there is a misalignment (non-standard motor)
04-Control	Open-loop enable	-	Enable the Open-loop strategy
04-Control	Closed-loop Sensorless enable	-	Enable the Closed-loop Sensorless strategy
04-Control	Closed-loop Hall Effect Sensors enable	-	Enable the Closed-loop Hall Effect Sensors strategy
04-Control	Closed-Loop initial duty cycle	%	Initial duty cycle applied at the beginning of the closed-loop phase
04-Control	Max period between two ZC events	ticks	Max period between two Zero Crossing events
04-Control	N periods to discard after a sector change	ticks	Number of periods to discard after a sector change
04-Control	Open-Loop duty cycle	%	Duty cycle applied in Open-loop phase
04-Control	Open-loop speed setpoint	rpm	Speed setpoint applied in Open-loop phase
04-Control	Rotor lock duty cycle	%	Duty cycle applied in Rotor-lock phase
04-Control	Speed Ki coefficient SL	V/rad	Speed Ki gain for PI speed controller in closed-loop Sensorless phase
04-Control	Speed Kp coefficient SL	V.s/rad	Speed Kp gain for PI speed controller in closed-loop Sensorless phase
04-Control	Speed Ki coefficient HES	V/rpm	Speed Ki gain for PI speed controller in closed-loop hall effect phase
04-Control	Speed Kp coefficient HES	V.s/rpm	Speed Kp gain for PI speed controller in closed-loop hall effect phase
04-Control	HV current Kp coefficient	V/A	HV current Kp gain for PI HV current controller
04-Control	HV current Ki coefficient	V.s/A	HV current Ki gain for PI HV current controller
04-Control	Max HV current setpoint rate	A/s	HV current setpoint rate used in the Max HV current setpoint generation
04-Control	Hall Effect Sensors PS enable	-	Enable the power supply excitation of Hall Effect Sensors
04-Control	Max duty cycle SL	%	Max duty cycle with Sensorless strategy

04-Control	Speed setpoint rate	rpm/s	Speed setpoint rate used in the speed setpoint generation in closed-loop phase in order to apply a ramp before to attain the speed setpoint
04-Control	ZC delay compensation	ticks	Zero Crossing delay compensation of the analog comparator output
06-Command saturation	Speed setpoint max saturation SL	rpm	Max speed setpoint in Sensorless
06-Command saturation	Speed setpoint min saturation SL	rpm	Min speed setpoint in Sensorless
06-Command saturation	Speed setpoint max saturation HES	rpm	Max speed setpoint with Hall Effect Sensors
06-Command saturation	Speed setpoint min saturation HES	rpm	Min speed setpoint with Hall Effect Sensors
06-Command saturation	Max HV current limitation soft start	A	Max HV current allowed at start-up to ensure soft start
06-Command saturation	Max HV current limitation	A	Max HV current allowed
06-Command saturation	Max duty cycle	%	Max duty cycle with Hall Effect Sensors strategy
10-Timing	Open-Loop phase duration	s	The duration of the open-loop phase before reaching the closed-loop Sensorless phase
10-Timing	Open-Loop ramp rising time	s	Ramp rising time used to create a ramp while generating the open-loop speed setpoint
10-Timing	Rotor lock phase duration	s	The duration of the rotor-lock phase before reaching the open-loop phase
10-Timing	can_autosend_period	ms	Broadcasting period of CAN Tx frames
10-Timing	Fault state wait time before acknowledgement	ms	Fault state wait time before acknowledgement
09-Limitation	Electrical period measurement time-out	s	1/6 of max electrical period that corresponds to min allowed speed using hall effect
09-Limitation	Can TimeOut period	ms	Can timeout period used to enable broadcasting Tx frames
09-Limitation	Critical fault mask	-	Parameter used to mask unused faults with respect to the critical fault word
09-Limitation	Over-current HV threshold	A	Overcurrent Fault level on HV Current measurement
09-Limitation	Over-pressure threshold	V	Over-pressure Fault level on pressure measurement
09-Limitation	Over-temperature shutdown	°C	ShutdownTemperature Fault level on Temperature Ambient measurement

	threshold		
09-Limitation	Over-voltage HV threshold	V	Overvoltage Fault level on HV Voltage measurement
09-Limitation	Under-voltage HV threshold	V	Undervoltage Fault level on HV Voltage measurement
09-Limitation	Over-temperature warning threshold	°C	Warning Temp Fault level on Temperature Ambient measurement

Table 11: Control parameters