DOMEL, d.o.o. Otoki 21
4228 Železniki, Slovenia

T: +386 (0)4 51 17 100
F: +386 (0)4 51 17 106
E: info@domel.com
www.domel.com

EC – Controller
Invento S Drives

Operating and installation instructions

Contents

1. GENERAL SAFETY

This Installation guide contains the information necessary for safety. Installation and basic running of the EC – Controller.

Danger!

Electric voltage on the device

EC-Drive must only be connected, installed, modified or repaired by a qualified personnel! Incorrect mounting can cause material damage and fatal injury from electric shock! Domel is not responsible for any damage caused by incorrect or bad circuit connection or by non-professional installation!

Use fuses for power lines. Install all earth wires. Before operating check the wires for short circuits. Use only cables that meet the specified installation requirements for voltage, current, insulation material, load etc.

Warning!

Electric voltage!

Never open EC-Controller or parts of them when the main supply is connected. It can be extremely dangerous and could cause fatal injury from electric shock!

When it is necessary to touch high voltages lines, disconnect the main power supply and wait at least 5 minutes before servicing the drive.

Note!

It is the responsibility of the user or installer to ensure correct grounding and protection in accordance with national and local standards.

1.1. Personal Safety

The ***[Start / Stop]*** input on the user interface panel of the EC drive does not disconnect the drive from the AC line. Do not use it as a safety switch.

Do not remove the terminal lines from the motor and AC line supply while the EC drive is connected to the active AC line. Ensure that the AC line supply has been disconnected and wait 5 minutes before removing motor and AC lines.

The motor can be started by means of digital commands, bus commands, references or local start command whenever the drive is connected to the AC line. Therefore, an unintended start may occur anytime power is applied (fire mode, Start/Stop switch is on, etc.). Never service the drive or equipment when power is applied to the drive.

Before installing and operating EC-controller please read this instruction carefully!

1.2. Approvals, standards and certifications

General electromagnetic compatibility: EN-61800-3
Domel declares that the products are manufactured in accordance with Council Directive 92/31/EEC on electromagnetic compatibility (and subsequent amendments).

Domel guarantees that the controller will be operating within specifications, if all directions and recommendations are taken into consideration. Domel does not accept any responsibility for failures resulting from improper of use.

2. INVENTO-S DRIVE OVERVIEW

2.1. Operating and ambient condition

Protection level:..... IP55
Vibration max:..... 0.7 g
Relative humidity:.....5% - 90%
Operating temperature max:.....+45°C without air flow
Operating temperature min: .....-10°C

Storage & transport:
Temperature max:.....+70°C
Temperature min:.....-25°C
Relative humidity max.....90%

SPECIFICATIONS, FUNCTIONS AND PROTECTIONS

2.2. Mechanical and electrical specification

- Dimensions.....332,3 x 309,7 x 122 mm
- Weight.....6,9 kg
- Protection level.....IP55
- Power Supply: .....400V (+-10%) / 50-60 Hz

- Efficiency .....up to 95%
- Power Factor (PF): ..... >0,9
- RPM min: .....10% of Nominal
- RPM max: .....5.000 RPM (depending on motor)

	Drive Type	Output Power
Invento S Drives	**Invento S15**	**1,5 kW**
	Invento S22	**2,2 kW**
	Invento S30	**3,0 kW**
	Invento S40	**4,0 kW**
	Invento S55	**5,5 kW**

Table 1: Invento S drive family by power

2.3. Functions

Relay Error function: Controller is equipped with isolated Relay error function via relay 250VAC/3A, NO(17), COM(18) and NC(19).
Relay error function is always activated when error occurs.

Reset of processor is usually necessary after fixing the cause of error (depending on error type – see error table – chapter 6. Troubleshooting)

AN1: Analog input 1 (terminals 9,10)– Input voltage from 0-10VDC. Electronics controls speed linear from RPM min to RPM max. Maximal or minimal speed (inverted) is defined as input voltage 9,5V ± 3%.
To start the motor via AN1 analog input, connect Start/Stop terminal pins (3 and 4) and FIRE mode terminal pins (1 and 2) together. Make sure you are in mode 0 (speed) or mode 1 (torque).
For additional information see chapter 5. (INVENTO-S controller parameters)

Electrical parameters: Vin_{max}=12V, Zin=10kΩ, Resolution 10-bit, tolerance AN1±5%
Important: Wrong polarity at input AN1 could cause serious damage on the controller.

AN2: Analog input 2 (terminals 12, 13). Input Voltage from 0 – 10VDC. This input is used as output signal from sensor (usually temperature or pressure). Terminals 14 and 13 can be used as power supply for the sensor and terminal 12 is used as measuring/process signal from sensor.
For additional information see chapter 5. (INVENTO-S controller parameters)

Set RPM via potentiometer: Controller is be controlled by external potentiometer (4k7 to 47kΩ) connected to terminals (9 = GND), (10 = input) and (11 = +10V). If the direction of rotary potentiometer is incorrect, change the wires on terminal (9) and (11).

Electrical parameters: Three-wire, R_{pot}=4k7 - 47kΩ, Zin = 10kΩ

Power supply 10V_{DC}/10mA: Controller is equipped with 10V_{DC}/10mA for power supply to an external potentiometer. Power supplying other loads is not allowed. The 10 V_{DC} supply is galvanically isolated from the supply voltage, but has the same potential as the analogue and digital inputs and outputs.

Electrical parameters: 10V_{DC} +/- 5% (regulated); 10mA; Terminal number: 10.

Power supply 24V_{DC}/40mA: Controller is equipped with 24V_{DC}/40mA power supply for external sensor connected to AN2, or for small external fan for cooling controller. The 24 V_{DC} supply is galvanically isolated from the supply voltage, but has the same potential as the analogue and digital inputs and outputs.

Electrical parameters: 24V_{DC} +/- 10% (not regulated); 50mA; Terminal number: 1, 4, 14.

Speed output: Controller is equipped with an Open Collector speed output signal for speed monitoring, and offers some additional choices for process control.
For additional information see chapter 5. (INVENTO-S controller parameters)

Fire mode function: Controller is equipped with Fire mode function. In this case electronics runs as emergency controlled unit, (for example: extract the smoke from a burning building), with disabled protections and functions. Fire mode is activated by opening terminals 1 and 2 and enabling it via settable parameter.

In Fire mode all errors are disabled, but power derating function is still active.
Electrical parameters: Operating voltage = 24V, Zin=10kΩ

Note!
Fire mode function is used only for protection in case of a burning building, to extract the smoke from it. In normal conditions, fire mode function is not used. In this case Domel is not responsible for damage to the controller caused by improper use.

Star/Stop function: Controller is equipped with Start/Stop switch. If the controller has all conditions for running, the motor starts when the terminal pins (3) and (4) are connected together (switch ON). Reference is red from AN1 analog input. This function is enabled in mode 0 (AN1 value = scaled speed reference), mode 1 (AN1 value = scaled torque reference) and mode 4.

Electrical parameters: Operating voltage = 24V, Zin=10kΩ

LED indicators: LEDs are currently used to indicate code running on PIC processor and SPI communication between processor in following manner:

- RED LED blinking slow: Indicates code running on PIC processor
- GREEN LED blinking fast: Indicates SPI communication between processors

This is normal state during controller operation and should be always present.

When controller is reset, green led stops blinking and only red led is active. This happens as the PIC processor starts operating quickly after reset (red led blinking), but the SPI communication between processor is not yet active (green led not blinking-either lit or not). As soon as the communication between processors is established, green led starts blinking too, usually after a few seconds after reset.

Modbus RTU 485 serial communication: Controller is equipped with Modbus RTU 485 communication. To connect controllers into chain use only shielded cables.

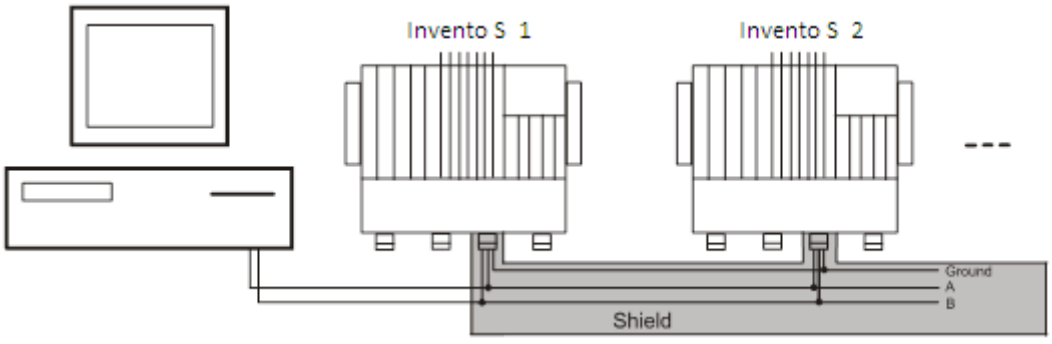


Fig.1:Shielded cable for ground connection between controllers is necessary

2.4. Protections

Thermal protection: Function that limits thermodynamic stresses on electronics by limiting power. This function is a temperature limiter which reduces the output power, when temperature on the controller reaches 95°C (is settable via Modbus as pderate_Tlow). The power is decreased until it reaches a settable minimum value of torque.

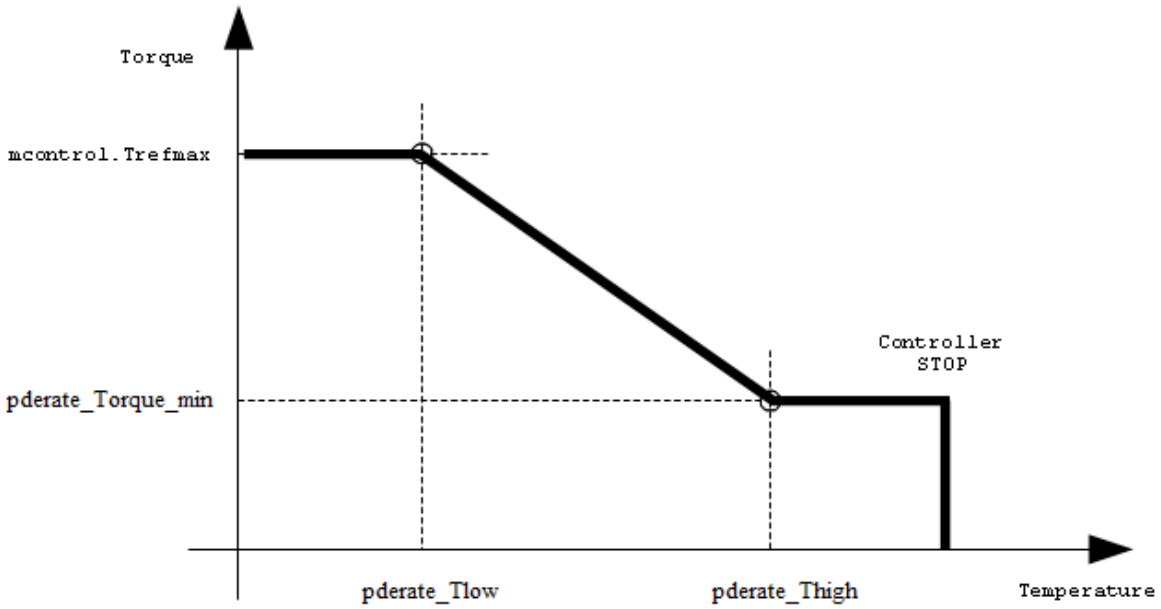


Fig.2: Power derating with associated parameters

In the event that the temperature of controller is still rising the controller stops the motor. When the temperature of controller falls below pderate_Tlow, controller automatically restarts. **Power derating function is enabled, but the overheating error is disabled in Fire mode.**

Under and over voltage: Controller is equipped with under and over voltage protection. Electronics shuts down when the main voltage is not in the required range.

Motor phase loss: Controller is equipped with power supply phase loss detection. In this case controller stops the motor**.** Error is usually triggered at relatively high RPM, when the algorithm can reliably detect 100Hz component in DC link.

Overcurrent protection: Controller is equipped with software and hardware phase overcurrent protection. Software overcurrent error triggers when current exceeds fixed limit (cannot be changed via modbus) and hardware overcurrent error triggers when current exceeds limit, set by resistors on current measuring chipset .

Ground current fault: This protection triggers an error, when the sum of the motor currents is more than 3A. Check the motor if it is damaged (cables, winding, etc.).

Parameters CRC: CRC check routine reports an error if reading/writing of parameters into EEPROM is corrupted.

Drivers fault: This protection triggers an error, if high and low side of the motor phase transistors are open at the same time.

ADC offset fault: Error in ADC reading on current measurements or DC link voltages. Reset of electronics is necessary.

SPI comm fault: Triggered when communication between processors is lost.

System error: Error in software(state machine error). Reset of the electronics is necessary.

Invento S Drive will not run if errors (non-autorestart) are present (see chapter 5). Usually processor or Drive reset is required . Processor reset can be made via Modbus (address 1 in coils tab) or by disconnecting and reconnecting the main power supply (hard reset). As you disconnect the controller from power supply wait until LED indicators stop flashing before reconnecting.

Note!

Heating the controller over the maximal temperature is not allowed.
Above 105°C (adjustable) controller stops the motor, and restarts it again when the temperature of controller falls below 95°C (adjustable). However, if the controller is overheating and motor was shutdown, disconnect power supply (safety switch) and wait at least 20 minutes before you service them. In case of controller overheating, it`s housing and components might still be very hot and could cause serious damage to your skin.
If controller starts overheating over lower adjustable temperature limit during running, it will limit the output power. In this case add small 24V/40mA fan on controller or ensure air flow through the ribs. Fan can be supplied by power from controller (page 15 – wiring diagram). Overheating problem appears in the case of installation of the controller in the space without air flow. Avoid installing controller on direct sunlight.

3. INSTALLATION AND CONNECTION OF INVENTO-S DRIVE

Use shield / armoured motor cable to comply with EMC emission specifications, and connect this cable to both the decoupling plate and the motor metal.

Use only hard wire or fibre copper wire with ferrule (Fig 1).

Keep motor cables as short as possible to reduce the noise level and leakage currents. To reduce the operating problems, use a shielded cable. Max length of cables is shown in the table below.

Invento S	Length max [m]
Power supply	-
Relay Fault	-
Set RPM via voltage	-
Set RPM via potentiometer	20
Speed Output	-
Fire mode	40
Start/Stop	40
Modbus	40
Motor	5

Table 1: Length of cables

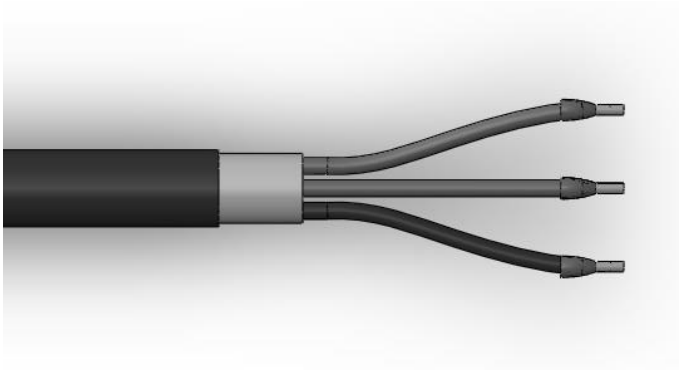


Fig.3: Wire with ferrule

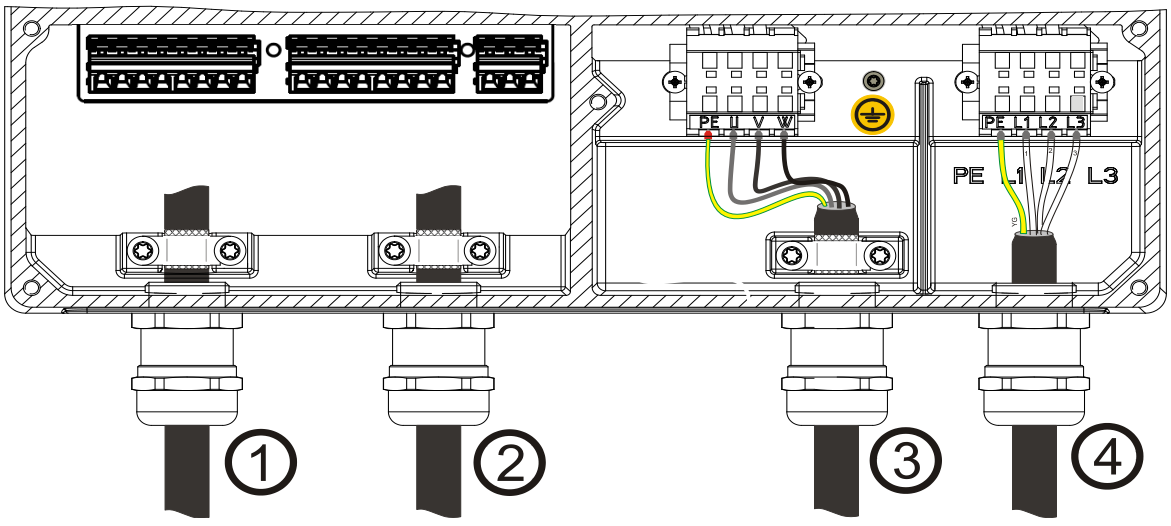


Fig.4**:** Proper wire connection to the motor and mains terminals.

3.1. General installation

Correct and precise mounting of the controller is required to provide reliable and carefree operation. The assembly should only be carried out by qualified personnel, because proper mounting, cooling and sealing of controller is required. Mounting is permitted only at prescribed places. All positions are allowed if conditions for solid attachment and adequate cooling are fulfilled (to prevent overheating of electronic).

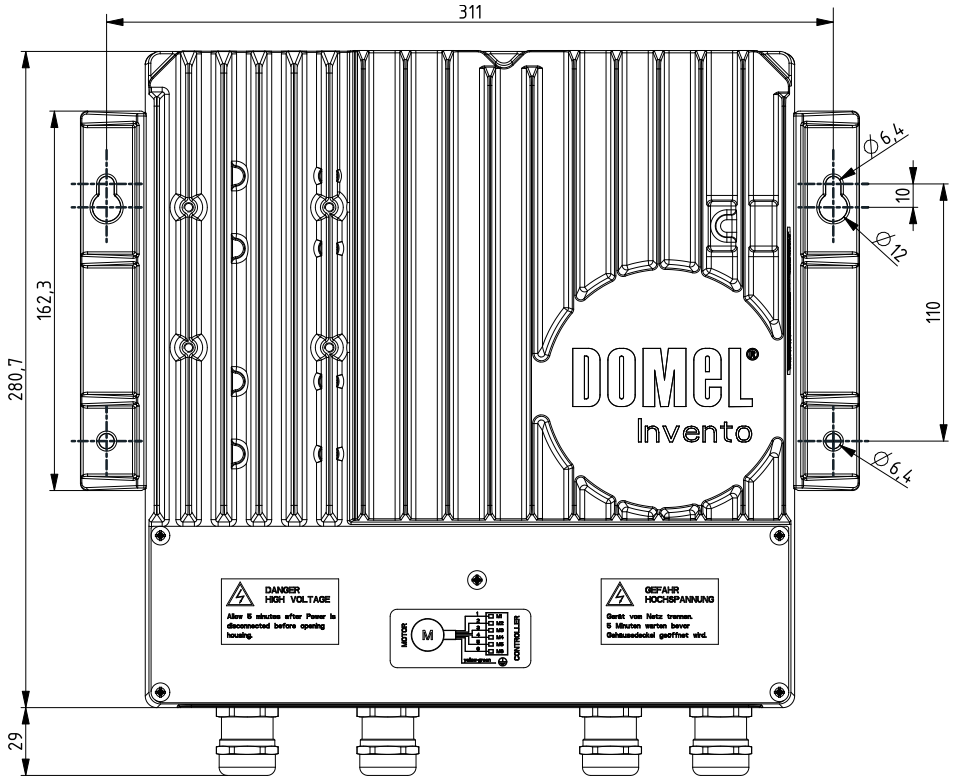
3.1.1. Mounting and sealing

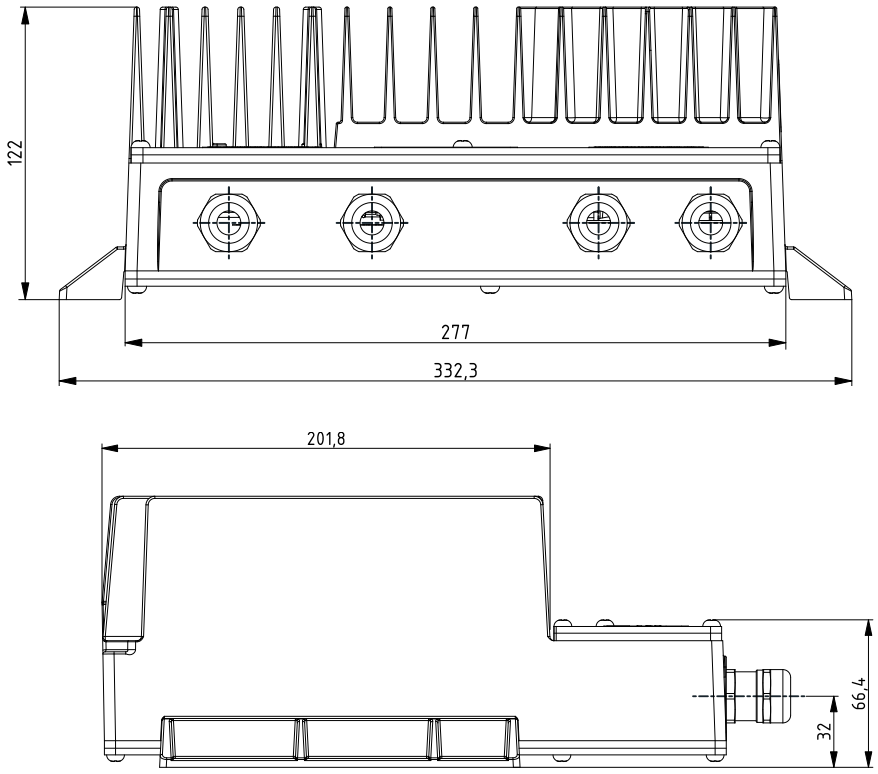
We recommend horizontal (on table) or vertical (on wall, with cable glands pointing down) attachment of the electronics. In horizontal installation we also recommend mounting on 2°-5° angle with glands pointing down, for easier drainage of surface liquids. Suitable sealing for top cover and all glands should be provided at mounting (whether there are cables or not). Space between other objects and controller must be at least 20 mm (from the closest corner of the electronics). When attaching to metal surfaces, the M5x15 screw (according to DIN912) with spring washers is recommended. When attaching to non-metal materials the M5x70 screw for walls is recommend.

3.1.2. Cooling

For smooth operation it is necessary to provide the required thermal conditions. We recommend force cooling, with speed 1.5 m/s of fresh cooling air, through the cooling ribs, although is possible to have cooling only with natural convection[1]. By cooling with natural convection, the user should ensure at least 1 m of space over the highest cooling rib and also controller may not be located in an enclosed place or placed under direct sunlight.

Note: Cooling exclusively with natural convection decreases lifetime of electronics.





3.2. Connection instructions

a) Remove the Top cover of the terminal strips and unscrew the cable glands No3 (Fig.2). Insert the motor cable through and mount the shield and connect the motor wires (U, V, W) to the corresponding terminal. Motor PE wire (yellow-green wire) can be connected to the terminal or screwed directly to the housing (Fig.2).

b) Fig.3 shows how to properly connect wire to the motor and mains terminals

c) Remove the sealing insert for sealing cable gland No1 and insert the communication cable. Mount the cable and carefully (fig. 4) connect desired user interface terminals. Screw the cable gland for optimum IP protection.

d) If Fault Relay function is needed then unscrew the cable glands No2. Connect the wires for Relay Fault to the corresponding terminals. Tighten the cable gland for optimum IP protection. Do not use the same cable gland for Relay Fault as for communication cable. It could cause operating problems and unstable control signals due to noise.

e) Connect mains supply wires to the corresponding terminals in the following sequence:

(1) PE ; (2) L1 ; (3) L2; (4) L3 ;

f) If there is some blank cable gland, fill it with sealing inserts.

g) Check all connections again.

h) Carefully replace the Top cover back and connect the Power supply voltage.

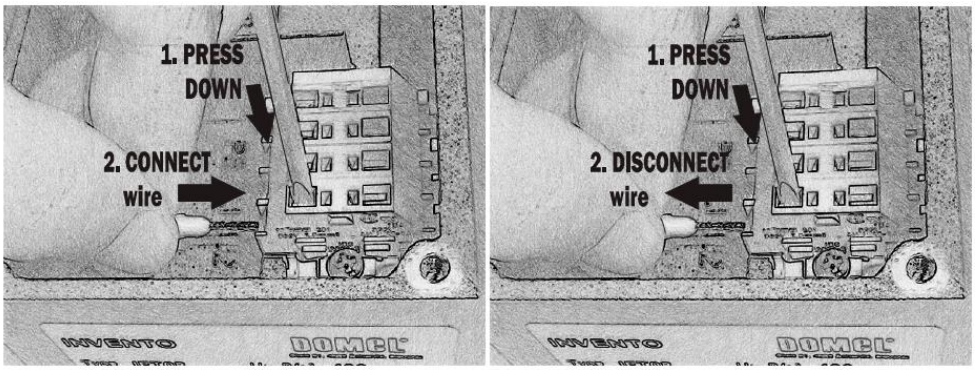


Fig.5: How to Connect / Disconnect wire

Warning!

Use cable with minimal 7mm thickness. All unused glands must be closed. Use appropriate sealing insert or appropriate stopper if cable is not used. Top cover must be screwed with 1Nm of torque and all screws must be used. These actions must be done to avoid exceesive humidity and possible fluid leaks inside the controller.

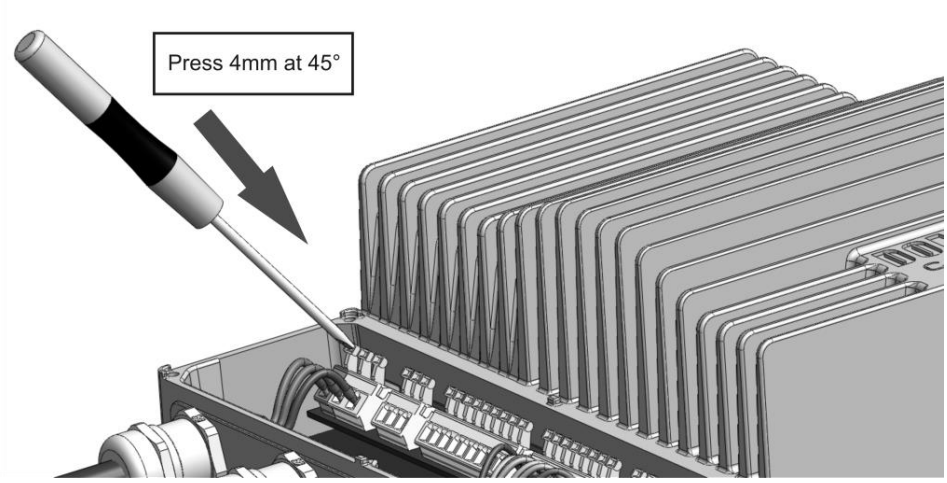


Fig.6**:** How to operate correctly with terminal strips

Warning!

Press only 0,5kg max, 4mm deep at angle 45° with 3mm slot screwdriver. Damaged terminal strips can cause serious damage on the Controller and fatal injury from electric shock.

Note!
It is the responsibility of the user or installer to ensure correct grounding and protection in accordance with national and local standards.

3.3. Grounding

Comply with the following at installation:

- **Safety grounding:** The drive has a high leakage current and must be grounded properly for safety. Follow all local safety regulations.
- **High frequency grounding:** Keep grounding cables as short as possible.

Connect all grounds to ensure the lowest possible conductor impedance. The lowest possible conductor impedance is achieved by keeping the conductor as short as possible and by grounding with the greatest possible surface area.

3.4. Installation to minimize EMI / RFI

To minimize conducted and radiated high frequency emissions :

- **Use only shielded/armoured motor cables and shielded/armoured control cables.**
- **Connect the shield to ground at both ends.**
- **Use attached cable clamps for installation to provide shielding at high frequencies.**

Correct grounding

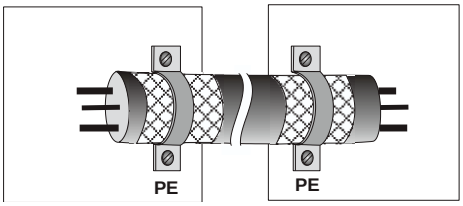


Fig.7a: Correct grounding

Incorrect grounding

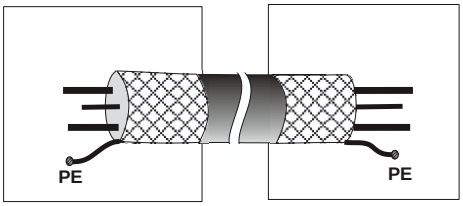


Fig.7b: Incorrect grounding

Correct grounding to minimize EMI/RFI emissions: Fig.7a

Control cables and cables for serial communication must be attached with cable clamps at both ends to ensure maximum possible electrical contact.

Incorrect grounding: Fig.7b

Do not use screen ends that are twisted together – that will increase screen impendence at higher frequencies.

3.5. Connecting the electrical system

Check whether the data on the type plate matches with the connection data.

Before connecting the device, ensure that supply voltage matches operating voltage of the device.

Only use cables that are configured for the current according to the specification on the type plate.

3.5.1. Mains supply connection and fuse protection

Invento S	Drive Type	Nominal voltage	Nominal output power	Input current at max load	Safety fuse (max)	Cable cross - section	
						mm^2	AWG
Power Supply	**Invento S15**	**400 V**	**1,5 kW**	**3,1 A**	**16 A**	**2,5**	**13**
	Invento S22		**2,2 kW**	**5,0 A**	**16 A**		
	Invento S30		**3,0 kW**	**6,3 A**	**16 A**		
	Invento S40		**4,0 kW**	**8,4 A**	**16 A**	**4**	**11**
	Invento S55		**5,5 kW**	**11,5 A**	**16 A**		
User control						**0,5 - 2,5**	**20 - 13**

Table 2: Invento S drive family electrical specifications

Install fast response gG fuses to protect the controller from damage if short circuit occur. If UL should be complied with, use UL fuses like Bussmann type RK1 / KTS – R(x), Bussmann type J / JKS – (x), SIBA type RK1, Ferraz – Shawmut type CC or RK1,...

Connect the device only to the circuits that can be switched off using an all-pole disconnecting switch.

Do not try to run motor unloaded (no wheel on motor shaft) if it was preset for a certain fan with specific moment of inertia.

		Terminal number	Description
Control	**+24V**	1,4,14	+24 V_{DC} ± 10% / Imax 40 mA
	Fire	2	Digital input; FIRE mode: Enabling function – open pin; Disabling Bridge to +24 V
	Start/Stop	3	Digital input; Start/Stop mode: Disabling function – open pin; Enabling Bridge to +24 V
	A	5, 7	Bus connection RS485 – A; MODBUS RTU
	B	6, 8	Bus connection RS485 – B; MODBUS RTU
	GND	9, 13, 15	I/O ground
	AN1	10	Analogue Input 1; Set value 0-10 V or 10-0 V; R ≥ 1 kΩ
	+10V	11	+10 V ± 5 % / 10 mA for potentiometer
	AN2	12	Analogue Input 2; Sensor signal (0-10 V)
	Speed	16	Digital output; NPN open collector output
Relay Fault	**NC**	17	Normally close
	COM	18	Common connection; Contact rating 250V / 5A
	NO	19	Normally open
Motor	**PE**	Motor connection	
	U		
	V		
	W		
Mains supply	**PE**	PE connection	
	L1	Supply voltage	
	L2		
	L3		

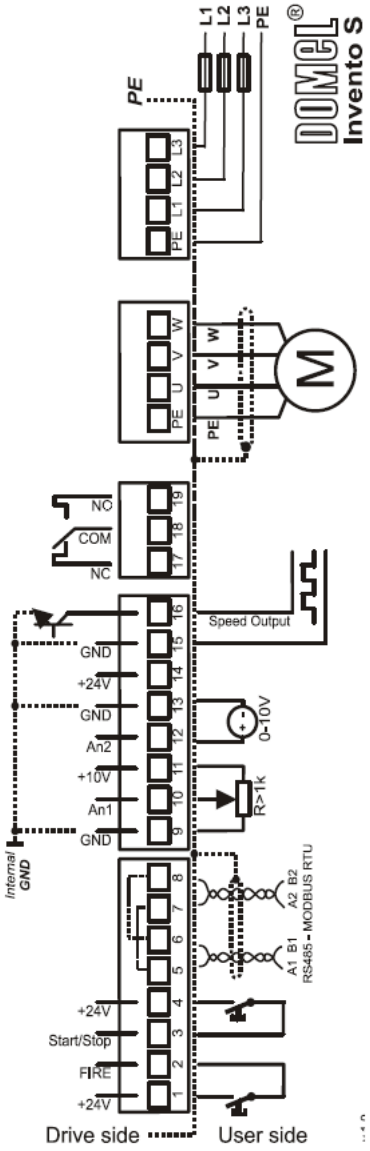


Table 3: Terminal/Pin description

4. MODBUS RTU

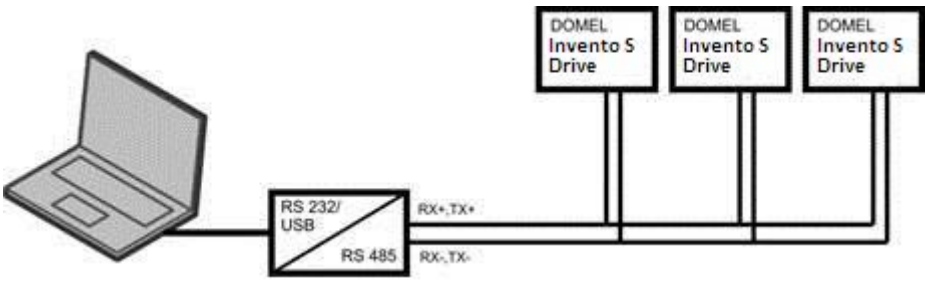
4.1. MODBUS overview

The MODBUS RTU protocol is based on the built-in RS-485 (EIA-485) interface. RS-485 is a two-wire bus-interface that allows multi-drop network topology i.e. nodes can be connected as a bus (daisy chain), or via drop cables from a common trunk line.

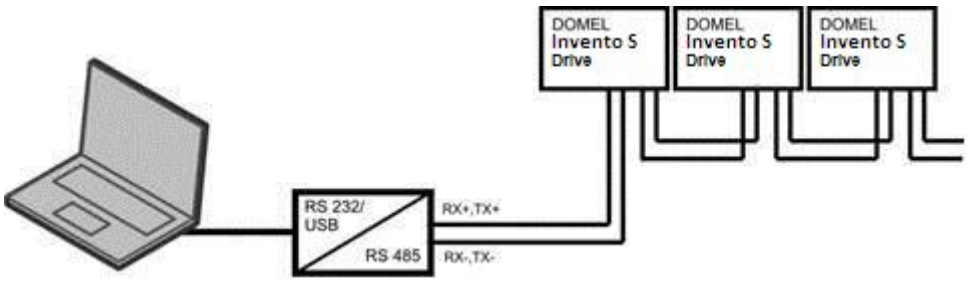
Domel's Invento S drives uses the two-wire system where the communication between master and slave is half-duplex, i.e. it cannot transmit and receive at the same time. Each signal uses one twisted-pair line — two wires twisted around themselves. The signal on one wire is ideally the exact opposite of the signal on the second wire. Since RS-485 is a multipoint communication system, all devices are connected to the single twisted-pair cable.

The Modbus RTU uses master/slave architecture, where each slave device has its unique address and responds only to packets addressed to this device. The packets are generated by the master (Controller), which periodically polls all connected slave devices. Data travels over the single line in both directions.

One or more EC drives can be connected to a control (or master) using the RS-485 standardized interface. Maximal number of IFT EC Drives connected to the network is 32. If more than one frequency converter is connected to a master, use parallel connections. Modbus user interface uses terminals (5) (6) in parallel connection with (7) (8) (see page 17).



Parallel connections



"Daisy chain" connection

Default Configuration (set by Domel):

- MODBUS address: **80**
- Baud Rate: **19200**
- START Bit: **1**
- STOP Bit: **1**
- Parity: **NONE**

Supported MODBUS commands:

- 0x01: Read Coils
- 0x02: Read Input
- 0x03: Read Holding Registers
- 0x04: Read Input Register
- 0x05: Write Single Coil
- 0x06: Write Single Holding Register

To connect PC and DOMEL Invento S Drive over serial line (MODBUS) RS-232/USB to RS-485 Converter is needed. We recommend ADAM-4561 converter.
The ADAM-4561 device driver can be used in combination with Windows 2000/XP/Vista/7 (32 & 64-bit).

4.2. MODBUS parameters

1. Configuration
MODBUS RTU: 19200-8-N-1
Slave addr: 0x50 (HEX) or 80 (DEC) (default settable by MB_ADR:009)

Coils			
Address	**Function**	**Range**	**Description**
0	Motor ON/OFF	0-1	Indication, 1=ON, 0=OFF
1	Reset Controller	0-1	1=Reset controller
2	Fire active	0-1	1=Fire mode active

Discrete status bits (inputs)			
Address	**Function**	**Range**	**Description**
0	Under Voltage	0-1	1=Voltage too low to run
1	Over Voltage	0-1	1=Voltage too high to run
2	Over Current SW	0-1	1=Software IGBT current protection
3	Over Temperature	0-1	1=Controller too hot to operate
4	Phase Loss	0-1	1=Main power supply phase loss
5	Ground Current Fault	0-1	1=Asymmetrical Load (sum of all currents >3 A)
6	Parameters CRC	0-1	1=Parameter checksum failed (TBD)
7	Drivers Fault	0-1	1=Failed transistor driver initialization
8	ADC Fault	0-1	1=ADC conversion error
9	SPI Comm Fault	0-1	1=No communication between processors
10	Power Derate Active	0-1	1=Controller entered power derating
11	Power Derate Shut Down	0-1	1=Controller reached end temperature (motor stop)
12	Over Current HW	0-1	1=Hardware IGBT current protection
13	FLW Active	0-1	1=Field weakening active
14	System error	0-1	1=State machine fail

Input Registers			
Address	**Function**	**Resolution**	**Unit**
0	Speed	1	RPM
1	Stator current RMS	0.01	A
2	Power	1	W
3	Torque	0.01	Nm
4	IGBT Temperature	0.01	°C
5	uC Temperature	0.01	°C
6	DC Bus Voltage	0.1	V
7	5V supply	0.001	V
8	15V supply	0.001	V
9	Analog Input 1	0.01	V
10	Analog Input 2	0.01	V
11	Speed output voltage	0.01	V
12	Speed output current	0.01	mA
13	AN2 reference	0.01	V
14	AN2 sensor signal	0.01	V
15	current ramp value	1	-
16	max ramp value	1	-
17	Torque reference	0.01	Nm
18	ErrorCode	1	-
19	Fire Minutes	1	min
20	Fire Days	1	day
21	Fire Cycles	1	-
22	Operation Minutes	1	min
23	Operation Days	1	day
24	AccessCount	1	-
25	OpDaysTotal	1	day
26	Controller version	1	-
27	Firmware version	1	-
28	Speed reference	1	RPM

Holding registers						
Address	Description	min	max	units	access level	Factory value
0	SETPOINT	0	10000	0.01%	1	10000

Sets the reference point for modes 2(SPEED), 3(TORQUE) and AN2 input.

- **SPEED** reference is calculated as: (current reference value can be seen in input register tab at address 28)

$$SpeedReference[RPM] = \frac{SetPoint[0-10000] \cdot maxRPM[RPM]}{10000}$$

$$SpeedReference < minRPM \;;\; SpeedReference = minRPM$$
$$SpeedReference > maxRPM \;;\; SpeedReference = maxRPM$$

- **TORQUE** reference is calculated as: (current reference value can be seen in input register tab at address 17

$$Tmax\,[Nm] = 3 \cdot p \cdot \Psi \cdot I_n$$

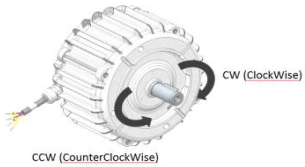
- **AN2** : Sets reference for AN2 feedback sensor signal. Reference value can be seen in input register tab at address 13

1	DIRECTION	0	1	*	3	0

Sets the direction of rotation of the motor shaft.

0: (CCW) CounterClockWise direction

1: (CW) Clockwise direction



Direction cannot be changed during motor run.

2	Minimal RPM	0	5000	RPM	2 & 3	motor dep.

Sets the minimal setable RPM reference. Parameter uses value on level 3 as minimum value for level 2. Controller uses level 2 value for operation. (level 3 minRPM = 200 => level 2 minRPM = 200+)

3	Maximal RPM	0	5000	RPM	2 & 3	motor dep.

Sets the maximal setable RPM reference. Parameter uses value on level 3 as maximum value for level 2. Controller uses level 2 value for operation.

RPM reference can be set between minimal RPM and maximal RPM limits defined in level 2. Level 3 values are just for limiting level 2 values.

4	Speed Variation	1	50	RPM	2	30

Sets maximum diference between actual and reference (ramp) value.

5	Ramp gain value	1	1000	*	2	350

This parameter affects motor acceleration, by affecting ramp value in relation to difference between the actual speed and reference. Motor accelerates faster if gap between actual and reference speed is bigger.

6	Speed Variation AN2	1	50	RPM	2	20

Sets maximum diference between actual and reference (ramp) value, when AN2 input is active.

7	Ramp gain value AN2	1	1000	*	2	100

This parameter is used for ramp calculation when AN2 sensor signal is used. It directly regulates AN2 input without any PID controllers. User sets this value depending on application. Higher values are for fast processess (pressure) and lower for slow processess (thermodynamics)

8	Password	0	32767	*	1	*

This parameter is used for setting access levels, restoring to factory settings, reading/writing to EEPROM.

0: Enter level 1, most parameters are locked

1: Enter level 2, user can change parameters requiring level 2 and level 1 access

31114: Enter level 3, user can change most of the parameters

10000: store values to EEPROM at current level

10001: restore values from EEPROM (last saved values)

10002: restore default values from one level above current

10011: restore level 3 parameters from factory settings

10020: set previous value as password (will not be accepted if password matches 10000.11000 or access level is<1)

6+6666: restore all parameters from factory settings

9	Modbus Address	2	147	*	2	80

Sets modbus address.

10	Operation Mode	0	32767	*	1	0

Selects current controller operation mode. Available modes are:

0: AN1 Speed mode: Speed reference is set as:

$$Speed_{reference} = RPM_{Min} + \frac{\mathbf{AN1} - AN1_{Min}}{AN1_{Max} - AN1_{Min}} \cdot (RPM_{Max} - RPM_{Min})$$

RPM_{Min} ... $minimum\ RPM\ (Address\ 2 - holding\ registers)$

RPM_{Max} ... $maximum\ RPM\ (Address\ 3 - holding\ registers)$

$AN1_{Min}$ ... $minimum\ AN1\ threshold\ (Address\ 20 - holding\ registers)$

$AN1_{Max}$ ... $maximum\ AN1\ threshold\ (Address\ 21 - holding\ registers)$

$AN1$ ... $current/actual\ AN1\ value$

Holding registers						
Address	Description	min	max	units	access level	Factory value
	2: Modbus Speed mode: Speed reference is calculated based on value in SETPOINT register. Controller starts if Modbus start ON/OFF register is set to 1. **4:** ON/OFF mode: Speed reference is set to maximal RPM. Controller starts when terminals 3 and 4 are shorted. **-1:** Fire mode: Activated automatically if fire mode register is enabled AND either terminals 1 and 2 are opened OR a value of 32767 is entered into this register.					
11	SO (Speed Output) Mode	0	11	*	2	0
	Sets speed output mode, which is used for RPM monitoring, cascade linking of multiple controllers and AN2 input toggle. **0:** Disabled: Speed output disabled. **1:** Frequency output (25 mA): Square signal is generated with frequency in linear relation with motor speed (5kHz at 50% maxRPM,) and 50% duty cycle (13 mA at 500Ω resistor) **2:** Frequency output (10 V, 1 mA): Square signal with peak to peak voltage of 10 V is generated with frequency in linear relation with motor speed (5kHz at 50% maxRPM,) and 50% duty cycle. **3:** PWM (25 mA): Square signal is generated with 1 kHz frequency and Duty cycle in linear relation with motor speed (50% duty cycle at 50% maxRPM) ((13 mA at 500Ω resistor)) **4:** PWM (10 V, 1 mA): Square signal with peak to peak voltage of 10 V is generated with 1 kHz frequency and Duty cycle in linear relation with motor speed (50% duty cycle at 50% maxRPM). **5:** Current speed RPM output (0…20 mA): DC current is generated and forced through resistor in linear relation to motor speed (10 mA at 50 %maxRPM) **6:** Voltage speed RPM output (0…10 V): DC voltage in linear relation to motor speed (5V at 50% maxRPM) **7:** Current speed RPM output (4…20 mA): DC current is generated and forced through resistor in linear relation to motor speed (12 mA at 50% maxRPM) **8:** Voltage speed RPM output (2…10 V): DC voltage in linear relation to motor speed (6V at 50% maxRPM) **9:** AN1 style RPM output: DC voltage is generated, with amplitude calculated by the following equation: $\{Speed\ Ouput = AN1Min + \frac{(RPM - RPMMin) * (AN1Max - AN1Min)}{RPMMax - RPMMin}\}\ [x\ 0.01V]$ **10:** Direct/Mirrored AN1 output: DC voltage is generated,with amplitude calculated by the following equation: $\{Speed\ Ouput = AN1\}\ [x\ 0.01V]$ Speed Output modes 9 and 10 can be used for cascade operation of multiple controllers, using only one AN1 input signal for first one, which is then multiplied/copied for all controllers in cascade. Speed output on the last controller in chain can be used for monitoring. **11:** AN2 ON/OFF input: In this mode speed output function is used as input, enabling user to change register AN2 ON without using MODBUS communication. AN2 ON register (address 12) is 0 or 1 depending on voltage on terminals 15 and 16 as: $AN2\ ON = \begin{cases} 1\ ; Speed\ Output > 5V \\ 0\ ; Speed\ Output \leq 5V \end{cases}$ One of voltage potentials available on controller (terminals 1,4,11 or 14) can be used, either 10V or 24V. Simply connect terminal 16 with one of the terminals providing either 10V or 24V. Switch can be used between these two terminals if AN2 input is not to be used permanently. *Note* : When changing AN2 ON from 1 to 0, time delay will be larger when using 24V rather than 10V potential, as it takes more time for voltage to fall from 24V below 5V. *Note* : This Speed output mode also works in mode 2 (MODBUS speed reference).					
12	AN2 ON/OFF	0	1	*	2	0
	This parameter sets AN2 input. If the value is 1, AN2 input is active, if the value is 0, AN2 input is deactivated. AN2 input is available only in mode 0 and 2. Parameter can also be changed by changing SO register to 11 and applying 10V or 24V to					

Holding registers						
Address	Description	min	max	units	access level	Factory value
terminal 16 and ground potential to 15.						
13	Modbus ON/OFF	0	1	*	2	0
This parameter activates controller when using Modbus modes (2 and 3). If the value is 1, controller starts the motor, if the value is 0, controller stops the motor.						
14	Modbus DC timeout	0	1	*	2	1
This parameter enables/disables error activation when Modbus connection is lost. If the value is 1, Modbus disconnection is ignored, if the value is 0, error is triggered (controller stops) after 4 seconds, when Modbus disconnection occurs. When Modbus connection is restored, controller automatically starts.						
15	Fire Mode RPM	2/3 max RPM	max RPM	RPM	2	max RPM
Fire mode RPM can be set freely in interval set by maxRPM as: $\frac{2}{3} maxRPM \leq Fire\ mode\ RPM \leq maxRPM$ If fire mode is not to be used, user can disable it by either shorting terminals 1 and 2 or by changing Fire mode active register (address 63) to 0.						
16-19	Resonance Avoidance function	0	5000	RPM	2	0
Allows user to set 3 independent values for RPM with respected interval for controller to avoid during operation. Resonance 1 (address 16): First value for resonance Resonance 2 (address 17): Second value for resonance Resonance 3 (address 18): Third value for resonance Resonance width (address 19): The width in % around every individual resonance (Resonance 1 = 500, width = 10%, Resonance Avoidance interval = 450 to 550 RPM)						
20-22	AN1 input control parameters	0	1000	0.01V	2	0,935,0
This function sets analogue AN1 input working areas by seting values of 3 following registers: AN1 MIN (address 20): Sets the minimum value for AN1 input when controller starts or stays at minRPM. AN1 MAX (address 21):Sets the maximum value for AN1 input when controller reaches maxRPM. AN1 STOP (address 22): Sets the threshold when controller sets reference value for speed to 0. *Note* : If AN1 MAX is set lower than AN1 MIN, function is inverted.						
23	Nominal Current	0	4000	0.01A	3	motor dep.
Sets maximal current, controller uses during operation. It should not be set to more than nominal motor current.						
24	NZS Speed Threshold	0	5000	RPM	3	motor dep.
Sets threshold when controller leaves open loop ("Near Zero Speed") control and enters sensorless control. This setting depends on motor BEMF.						
25	NZS Ramp Speed	1	1000	RPM	3	motor dep.
Sets Ramp speed, when controller is in open loop.						
26	Fire mode active	0	1	*	3	1
Toggles between actived or deactivated fire mode function. **0:** Deactivated **1:** Activated *Note* :If this register is se to 0, fire mode can not be activated ,either by opening terminals 1 and 2 or via Modbus.						
27	Inverted regulation	0	1	*	3	0
Toggles between normal regulation or inverted. Normal regulation is usually used, when using pressure sensor feedback signal or with hot air. Inverted regulation can be used when cool air is used as a medium. **0:** Normal regulation **1:** Inverted regulation						
30	PD Torque	0	8533	0.01 Nm	3	motor dep.
Sets minimum torque, when power derating function is active.						

5. INVENTO-S CONTROLLER SETTINGS

5.1 Factory settings

Most of the time drives will be preset for the desired motor with parameters in Table 4 – holding registers.
CHANGING PARAMETERS IN LEVEL 1,2 and 3

Level 1 parameters are accessible to user on level 1 (**user access level-password = 0**) access and can be changed (password register = 0). When changing parameters, make sure to save them to EEPROM by typing 10000 in Password register (address 8). Check if the save was successful by reseting the controller. **These are the only parameters that can be changed during motor run.**

Level 2 parameters (**customer access level**) can be accessed by entering 1 value in password register. User is now in level 2 and can change level 2 parameters freely. To save parameters in level 2, one simply writes 10000 in password register. Check if the save was successful by reseting the controller.

Level 3 parameters (**installer access level**) can be accessed by entering 31114 value in password register. User is now in level 3 and can change parameters freely. To save parameters in level 2, one simply writes 10000 in password register. User can now enter value 10000 to save parameters in level 3. Check if the save was successful by reseting the controller.

Example of saving parameters in level 3:
Password register (address 8) value:

- 31114 (enter level 3)
- 10000 (saving to EEPROM – same as for level 1)

5.2 Additional parameter explanation

5 minRPM, maxRPM

These two parameters use two layers (level 2 and level 3).

Level 3: Used in level 3 or as minimum or maximum limit for level 2 parameters.
Level 2: Allowed value written in level 2 is always in interval between minRPM and maxRPM written in level 3.
Example:

Level 3 minRPM = 200
Level 3 maxRPM = 1200

Level 2 minRPM = settable in range 200 - 1200 RPM
Level 2 maxRPM = settable in range 200 - 1200 RPM

6 SPEED VARIATION/AN2, MAXIMUM RAMP VALUE/AN2

SPEED (SPEED VARIATION, MAXIMUM RAMP VALUE) (address 4,5)

Speed variation register sets the difference between actual value and reference ramp value (not the same as reference value). Maximum ramp value register, acts as “ramp value attenuation” factor. These 2 parameters are used to calculate current ramp value, as the value is changed regarding the difference between actual and reference value. The larger the difference between them, the larger is the ramp value. This speeds up the responsiveness when necessary and maintains accuracy and stability. This method can also regulate AN2 input efficientlly ,that is why this controller does not have PID regulator for AN2.

Current ramp value can be seen at input register tab at address 15, and current maximum ramp value can be seen at address 16.

If you find the response to slow, try increasing Maximum ramp value parameter. Maximum acceleration is limited by motor nominal current.

If you find response unstable/oscillating/overshooting, try reducing Speed variation and/or Maximum ramp value parameter accordingly (falling to 1 while acceleration).

AN2 (SPEED VARIATION AN2, MAXIMUM RAMP VALUE AN2) (address 6,7)

When AN2 ON parameter is set to 1, speed variation AN2 and maximum ramp value AN2 parameters are used for ramp calculation. This is used because oscillations are more prominent when AN2 signal is used and these two parameters are set lower, specially maximum ramp value. Value of maximum ramp value parameter is dependent on system response (mostly ventilator size, hose length between pressure transmitter and measuring point) and should be set experimentally on an actual application. Usually on systems with faster response (smaller ventilators, shorter measuring connections) maximum ramp value can be set higher without overshoot or unstable response. Another thing to consider is allowed response for the user (If an overshoot is not allowed to happen, maximum ramp value should be set lower until system response is appropriate – system response will be slower but more stable).

7 SPEED OUTPUT MODE (address 11)

USING CURRENT SPEED OUTPUT MODES (1, 3, 5, 7)

Current loops are very robust sensor signaling standard. Fig. 8 shows a schematic of a simple current loop:

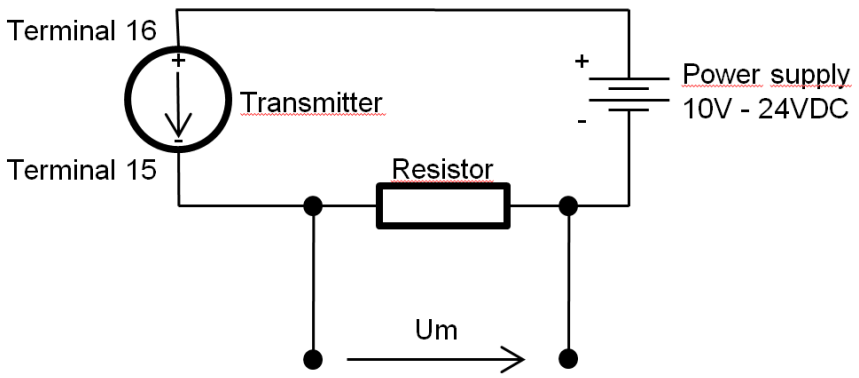


Fig.8:Typical connection for measurements using current loop

There are 4 components:

- A DC power supply
- A 2-wire transmitter
- A receiver resistor that converts current into voltage
- Wire that interconnects it all

In Figure 8, current supplied from the power supply flows through the wire to the transmitter and the transmitter regulates the current flow within the loop. The current allowed by the transmitter is called the loop current and it is proportional to the parameter that is being measured, making this method immune to different wire lengths, wire resistances,…The loop current flows back to the controller through the wire, and then flows through the resistor to ground and returns to the power supply. The current flowing through resistor produces a voltage drop Um (Figure 8) that is easily measured.
For a 250 Ω resistor, the voltage will be 1 VDC at 4 mA and 5 VDC at 20 mA.
WARNING: When using current loops, only use Speed Output modes 0,1,3,5 or 7 (current modes)! Controller does not work as intended, if other Speed Output modes are used and Speed Output terminals are connected according to Figure 8!

8 Resonance 1,2,3 (address 16,17,18) ; Resonance width (address 19)

Invento-S controller allows user to enter 3 Resonance intervals in RPM units, which are used by controller to avoid setting speed reference in these intervals.
Example:
Resonance 1 = 300 RPM
Resonanec 2 = 800 RPM
Resonance 3 = 1100 RPM
Resonance width = 10%

If these parameters are set, controller will avoid setting speed reference in the following intervals/bands:

Resonance 1 band = 270 – 330 RPM
Resonance 2 band = 720 – 880 RPM
Resonance 3 band = 990 – 1210 RPM

Resonance avoidance only works in modes 0, 2 and 4 (speed regulation). It does not work if AN2 input is active.

9 AN1.min, AN1.max, AN1.stop (address 20,21,22)

These 3 parameters are used to set the “working area” when using AN1 analogue input. AN1.Min parameter can be set to the desired minimum threshold. AN1,Max parameter can be set to the desired maximum threshold. AN1.Min and AN1.Max can be set from 0 to 1000 (0V to 10V). If AN1.Max is smaller than AN1.Min function is inverted (10V to 0V). Stop threshold voltage is set by AN1.stop. If AN1.stop is 0, threshold voltage is disabled and motor will run with minimal settable RPM, even if AN1 = 0. By setting AN1.stop higher than 0 motor will start, when AN1>AN1.stop and AN1>AN1.min. Speed reference is set by the following equation:

$$Speed_{reference} = RPM_{Min} + \frac{\mathbf{AN1} - AN1_{Min}}{AN1_{Max} - AN1_{Max}} \cdot (RPM_{Max} - RPM_{Min})$$

Where:

RPM_{Min} …$minimum\ \ RPM\ (Address\ 2 - holding\ registers)$
RPM_{Max} …$maximum\ RPM\ (Address\ 3 - holding\ registers)$

$AN1_{Min}$ ...$minimum\ AN1\ threshold\ (Address\ 20 - holding\ registers)$
$AN1_{Max}$ ...$maximum\ AN1\ threshold\ (Address\ 21 - holding\ registers)$
$AN1$ ...$current/actual\ AN1\ value$

Example:

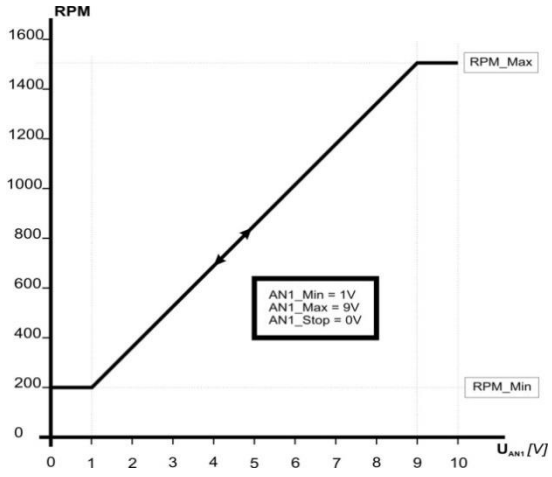


Fig.9

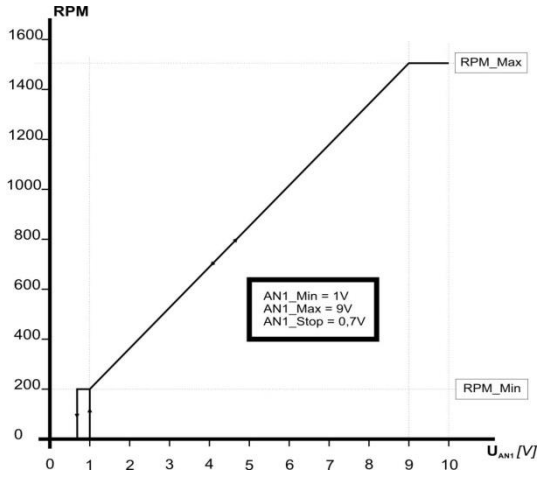


Fig.10

AN1.min is set to 1V and AN1.max is set to 9V. In the figures above, controller works from 200 RPM to 1500 RPM. AN1 operates from 1V to 9V (AN1.max > AN1.min). AN1.stop is set to 0V in figure 9, this means that AN1.stop is disabled and motor will run with minimal RPM also in case if AN1 is 0V. In figure 10 AN1.stop is set to 0,7V. This means that threshold voltage is 0,7V and motor will not run if AN1 is below 0,7V.

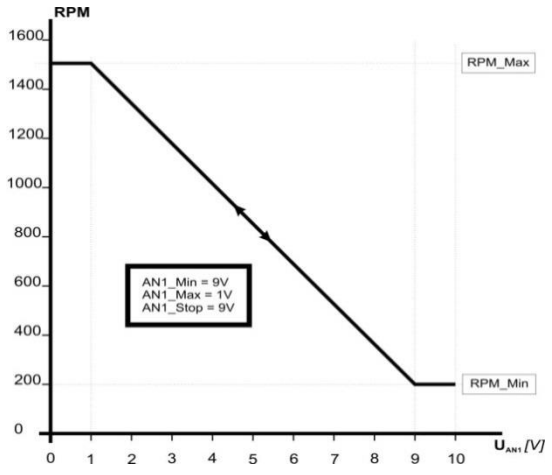


Fig.11

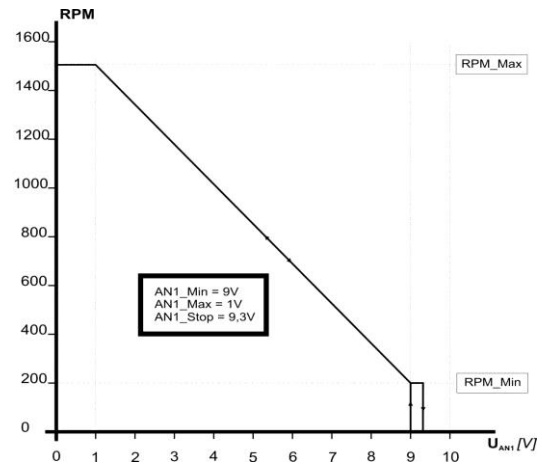


Fig.12

AN1.min is set to 9V and AN1.max is set to 1V. In the pictures above, controller works from 200 RPM to 1500 RPM and AN1 operates inverted from 9V to 1V (AN1.max < AN1.min). AN1.stop is set to 10V in figure 10, this means that AN1stop is disabled and motor will run with minimal RPM also in case if AN1 is 10V. In figure 12 AN1.stop is set to 9,3V. This means that threshold voltage is 9,3V and motor will not run if AN1 is higher than 9,3V.

AN1.max should be set little lower that the maximum possible AN1 value (example: AN1max=9.5V, AN1.max is set to 945 (9,45V)). This guaranties maximum reference will be set close to maximum value of AN1 and not before.

6. ERROR STRATEGY TABLE

Bellow is a table providing information about errors that are triggered by various operating faults. Table may change with other software versions.

Error	Normal mode	# retries	Fire mode	# retries
undervoltage	waits for condition fullfilment **	x	waits for condition fullfilment **	x
overvoltage	waits for condition fullfilment **	x	Ignore	x
over current SW	"blind" start after 20 sec	2	Ignore	x
Over temperature	waits for condition fullfilment **	x	Ignore	x
Phase loss	"blind" start after 20 sec	infinite	Ignore	x
Ground Current Fault	Asymetric load, check load /manual restart *	0	Ignore	x
Parameters CRC	EEPROM CRC check fault /manual restart *	0	Ignore	x
Drivers Fault	Driver initialization unsucessful / manual restart *	0	Ignore	x
ADC offset Fault	ADC fault /manual restart *	0	Ignore	x
SPI Comm fault	automatically tries to restore connection **	x	Ignore	x
Power derate active	indicator	x	Ignore	x
Power derate shutdown	waits for condition fullfilment **	x	Ignore	x
Over Current HW	"blind" start after 20 sec	2	"blind" start after 20 sec	infinite
FLW active	indicator	x	Ignore	x
System error	manual restart *	0	Ignore	x
rotor blocked/fault start	"blind" start after 20 sec	4	"blind" start after 20 sec	infinite

Table 5: Error table

* Disconnect controller from Power distribution network for 5 min.
** Automatic restart, when conditions for normal functioning are restored