

smartIO MI01

Technical data and description

The **smartIO MI01** (aka DoSto) is the first module with different inputs and outputs in one module:

- 3 potential free relay contacts (NO - NC)
- 5 analog inputs voltage ± 160 V, 1 M Ω
Can be used as digital inputs via switching threshold
- 1 analog input RTD

at approx. 100 Hz sampling rate.

The voltage measurement inputs are designed with high impedance, so that the measured voltage is only slightly loaded. A wide common mode range of up to 60 V also allows measurement on battery packs in series connection. The analog inputs are isolated from CAN and supply. An adjustable switching threshold allows



The RTD measuring input is designed for 3-wire connection, whereby a fourth, internally not connected input can accommodate the 4th connection, if present.

Each module in the RAIL version is individually tested with regard to dielectric strength and insulation. With the stable aluminum housing and nano-coating of the board, the requirements for use on rail vehicles are also met.

In the version for smartRAIL, the connectors for power supply and communication are designed as M12 connectors.

(Figure similar)

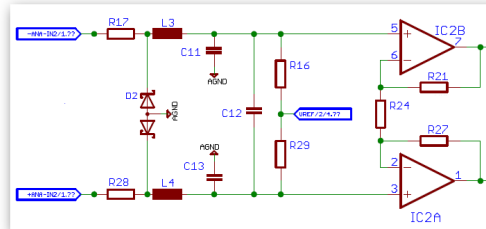
Measurement functions

The measuring module acquires analog voltages with a sampling rate of 100 Hz, due to analog aliasing filters the bandwidth is limited to 48 Hz. The raw data are directly available on the CAN bus via CAN messages.

The relay outputs are controlled via a CAN message that must be sent periodically and received by the measuring system. If the message is not received over a longer period of time, the relays fall back into the basic state.

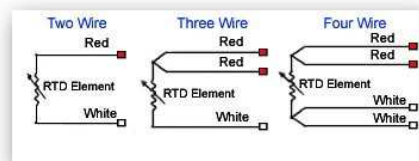
Voltage measurement

Each voltage measurement input is designed as a differential measurement input, with the circuit design allowing a wide common mode range up to 60 V DC between the measured input voltages.



Resistance measurement with line compensation

The resistance changes of an RTD for small temperature changes are in the same order of magnitude as the resistances of the connecting leads themselves¹. Since these also change their value with the ambient temperature, in practice not only 2 leads but 3 or 4 leads are used to connect the RTD sensor. Three different strategies are followed:



1. Separation of supply current and measuring voltage

The voltage dropped at the sensor is fed to the high-impedance measuring system via a separate pair of lines (sense), so that no current flows in these lines and the measuring signal thus arrives at the input of the measuring system unaltered

=> 4-wire (Wire) connection

2. Measuring the voltage drop on the line and taking it into account in the measurement result.

The voltage drop across the supply line is measured via a single line (sense) and subtracted from the voltage drop measured across the same line via resistor and return line. Here very small voltage levels must be processed, the circuit becomes correspondingly complex.

=> 3-wire (Wire) connection

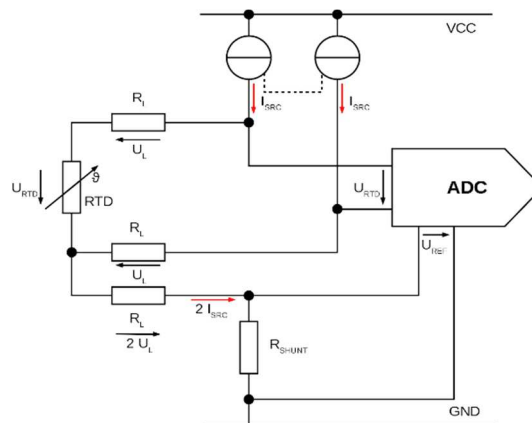
3. Compensation of voltage drops by double power supply

Instead of one current source for sensor supply, 2 are used and the supply currents are fed to the sensor via a pair of lines (white/red). The return current is fed via the third line (red). The voltage difference applied to the supply lines corresponds to that applied to the sensor resistor, since the same voltage drops across both lines in the same direction. The accuracy of the current sources does not matter if the supply current is measured in total. The noise immunity is higher, because all lines are "low impedance" terminated by the current sources.

=> 3-wire (Wire) connection

¹ For 100 m Cu conductor, 0.22 mm², this results in a line resistance of 7.8 Ω.

This third measuring method is implemented in the **smartIO 4RTD**. A constant current of approx. 100 μA is applied to the outgoing and one return line. The two currents flow back through the third conductor into the measuring system and are measured here as a sum. The current sources are designed to be permanently short-circuit proof for each sensor input. Due to the current direction in the same direction, the same voltage drop occurs across each feeding sensor cable and the voltage drop at the RTD sensor can thus be measured without distortion.

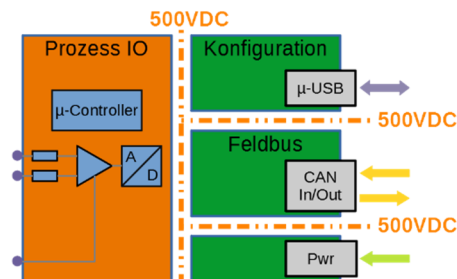


The 16-bit AD converter used directly measures the ratio between the voltage at the sensor and the supply current, i.e. the actual resistance value. A switchable gain factor allows optimized adaptation to Pt100 or Pt1000 sensors.

The small supply current of 100 μA results in a power output of 1 μW at the sensor and is thus negligible for most applications.

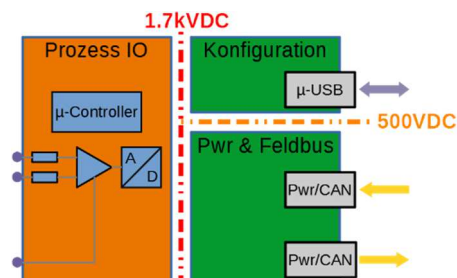
Isolation of the terminal groups

In the standard version, the supply voltage, CAN and process inputs are isolated from each other. This means that the CAN bus in this variant is potential-free. In addition to CAN-H and CAN-L, the CAN-GND must also be connected in the system for a secure data connection.



In the RAIL version, the CAN bus and the power supply are routed in the same cable. Here, the ground potential of the power supply is identical to that of the CAN bus. The isolation to the process IO is designed for 1.7 kV DC.

Process inputs among each other are, depending on the design of the module, connected with high impedance against the internal analog reference point and thus, if this is not specified, also among each other. This GND is available as "*opt GND*" at the terminal strip and can be connected to an external process ground, if *any* influence of the inputs among each other shall be avoided. Normally this is not necessary.

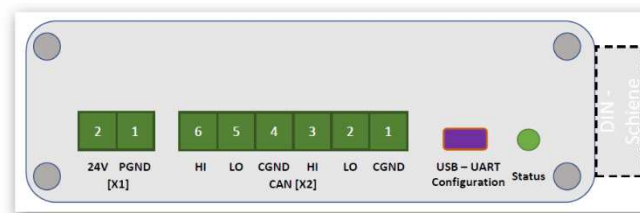


Interfaces of the module

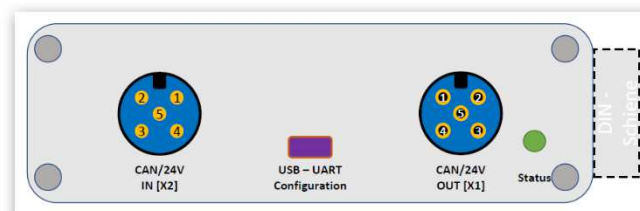
Power supply and CAN bus

The measuring module is equipped with reverse polarity protection and has a self-healing fuse against overload of the internal electronics.

Power supply and communication line to the higher-level device of the smart family (smartMINI, smartRAIL, etc.) are implemented in the basic version with Phoenix terminals with 3.5mm pitch. The isolated CAN bus is looped through the device, so that a simple cascading of several measuring modules is also possible with the terminals. The reference potential CGND is isolated from the supply voltage PGND.



In the RAIL version, power supply and CAN are available on two M12 connectors according to the Device-Net assignment. The 24 V power supply and the CAN bus connection are looped through from the plug to the socket. This allows several different smartIO modules to be connected in series. If no further smartIO module follows, the CAN bus must be terminated using a connector with integrated terminating resistor (120 Ω) or directly at the Phoenix terminal. CAN-GND is identical to the supply ground.



Pin	Signal	Description
1	CAN Shield	
2	+24V	Voltage supply +24V (wide range see technical data)
3	GND	Reference ground for voltage supply and CAN bus
4	CAN_H	CAN bus: CAN high
5	CAN_L	CAN bus: CAN-LOW

Commercially available Device-Net cables that lead from socket to plug can be used. In the case of assembled cables, twisted pair cable bundles must be selected for connection pairs 2 and 3 as well as 4 and 5.

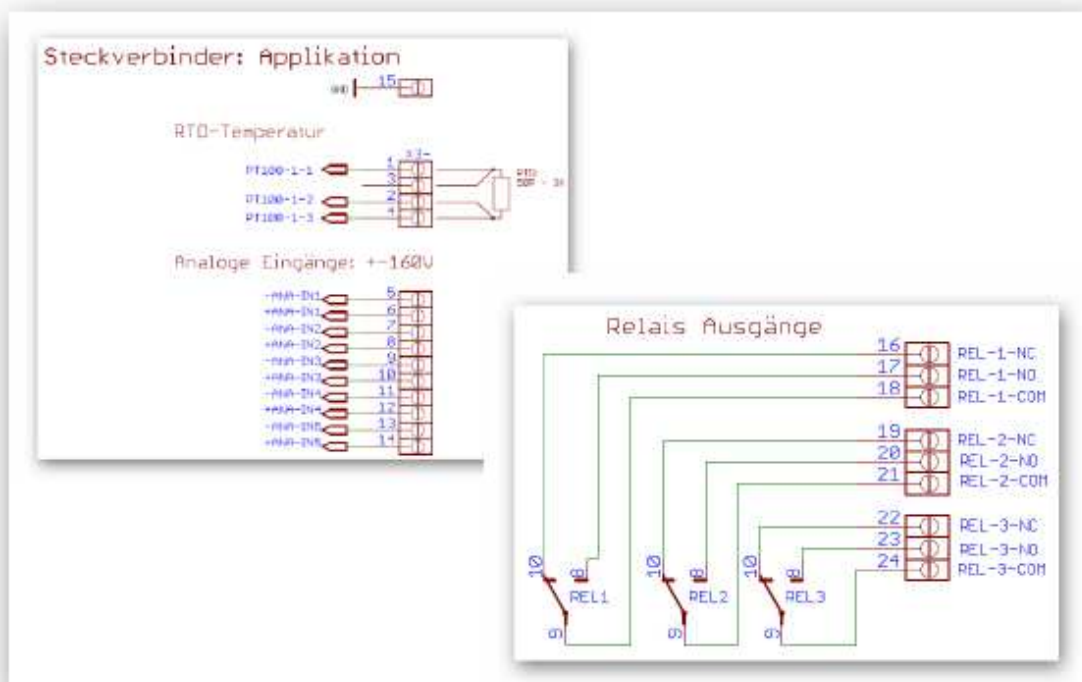
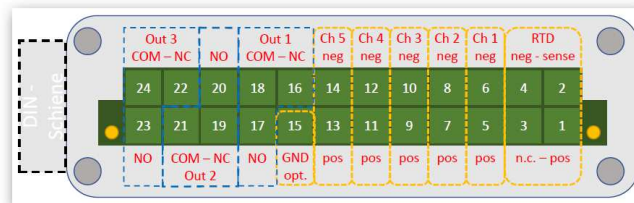
Configuration

Behind the USB-UART configuration interface there is a USB-Serial converter (CP2102N), which is mapped as Virtual COM port under Windows. For the configuration of the module the ASCII based SCPI protocol is used. A description of the commands is available on request.

For the configuration of the smartIO modules the optiCONTROL software from optiMEAS is recommended, which implements this protocol and provides a graphical user interface with appropriately prepared dialogs.






Measurement input

For the measuring inputs, double-row Phoenix terminals with 3.5 mm pitch are used in both versions. Due to the coding of the connectors, a pre-assembly of the plugs and a confusion-proof connection is possible.



Special approvals and declarations

For the *smartRAIL version*, in addition to the CE declaration of conformity, the following certifications to EN50155 are also carried out:

EC Declaration of Conformity		<p>The CE mark indicates compliance with the</p> <ul style="list-style-type: none"> • EMC Directive, • RoHS 2011/65/EU (08.06.2011) and the • Low Voltage Directive an.
<p>Railroad applications -</p> <p>Electronic devices on</p> <p>Rail vehicles.</p> <p>EN 50155:2008</p>	   	<p>The systems meet the standard for the following properties:</p> <ul style="list-style-type: none"> • <i>Environmental conditions:</i> <ul style="list-style-type: none"> ○ AX (2000m) EN50125-1 §4.2.1 ○ TXEN50155 §4.1.2 • <i>Climate</i>² <ul style="list-style-type: none"> ○ RefrigerationEN50155 §13.4.5.2 ○ Dry heatEN50155 §13.4.5.3 ○ Humid heatEN50155 §13.4.5.7cyclic • <i>Swing</i>IEC61373 §8 + 9 • <i>Shock</i>IEC61373 §10 • <i>EMC, insulation</i>EN50121-3-2 EN 61000-3-2/3 EN 55016-2-1/2 • <i>Fire protection</i>EN45545-2 <p><i>routine tests according to</i> EN50155 §12.2</p> <ul style="list-style-type: none"> • <i>Visual inspection</i> EN50155 §12.2.1 • <i>Insulation</i> EN50155 §12.2.9.1 • <i>Withstand voltage</i> EN50155 §12.2.9.2

² Already according to EN 50155:2017
 Errors and omissions excepted.
 www.optimeas.de

Technical data

Supply voltage / ambient conditions

Symbol	Parameter	Comment	Min	Type	Max	Unit
V _{CC}	Supply voltage	with reverse polarity protection	7		36	V DC
	Overvoltage protection		no			
	ESD protection	TVS diode			40	V
I _{CC}	Current consumption	@ 24V		40	100	mA
	Connector (standard)		Phoenix, pitch 3.5mm			
	Connector (smartRAIL)	together with CAN bus	M12 in / M12 out			
T _{operating}	Operating temperature	EN 50155 / Range TX	-40		85	°C
	Relative humidity	Nano coating, 50°C	5		95	%
	Housing		Aluminum			
L	Dimensions: Length	without plug / feet / clip		104		mm
B	Wide			85		mm
H	Height			35		mm
m	Weight			250		g
	Screw connection	Front panels against carcass	M3, stainless steel VA2, lock washers			
	Mounting (standard)	Option mounting feet or				
	Mounting (RAIL)	mounting rail (EN 50022)	TS 35			
	Cooling		passive			
	Protection class	(ISO 20653 - 2013)	IP54			
	Insulation resistance RAIL	@500V	10			GΩ
	Withstand voltage test, 60s RAIL	To measurement input		1.7		kV

Analog inputs

Symbol	Parameter	Comment	Min	Type	Max	Unit
N _{AIInU}	Type / Quantity	Voltage, differential		5		
U _{Mess}	Measuring range	U _{IN+} - U _{IN-}	-160		160	V
U _{CM}	Common mode voltage	(U _{IN+} + U _{IN-}) / 2	-60		60	V
ΔU	Resolution ADC			80		mV
U _{AIInMax}	Permissible input voltage	short term, < 1min			250	V
R _{AIIn}	Input resistance			1		MΩ
	Converter	Sigma Delta		12		bit
f _{AIIn}	Sampling rate	128x oversampling		100		Hz
f _{-3dB}	Bandwidth			48		Hz
	Accuracy	On measuring range		1,5		%

Symbol	Parameter	Comment	Min	Type	Max	Unit
N _{AIInR}	Type / Quantity	Resistance		1		
R _{Mess}	Measuring range	for Pt100	18,5	100	375	Ω
			-200	0	800	°C
		for Pt1000	185	1000	3750	Ω
			-200	0	800	°C
I _{SENSOR}	Feed current		90	100	110	μA
ΔR	Resolution ADC	for Pt100 @ 20 °C			0,1	°C
		for Pt1000 @ 20 °C			0,1	°C
R _{Ain}	Input resistance			30		kΩ
	Converter	Sigma Delta		16		bit
f _{Ain}	Sampling rate	128x oversampling		10		Hz
f _{-3dB}	Bandwidth			4		Hz
	Accuracy	On measuring range		0,5		%

Digital outputs

Symbol	Parameter	Comment	Min	Type	Max	Unit
N _{DO}	Type / Quantity	Relay		3		
	Circuit diagram		NC-COM-NO			
P _{CONT}	Switching capacity	DC			60	W
		AC			125	VA
U _{CONT}	Switching voltage	DC	0.01		220	V DC
		AC			250	V AC
I _{CONT}	Switching current	DC / AC	10 μ		2	A
	Continuous current	DC / AC			2	A
R _{INIT}	Switch-on resistor			75		mΩ
T _{SW}	Switching time	Sigma Delta	1		2	ms
R _{ISOL}	Insulation resistance	Open contact @ 500V		1		GΩ

CPU

Symbol	Parameter	Comment	Min	Type	Max	Unit
	Processor		SAMC21E			
	Family		ARM Cortex-M0+			
	Clock			48		MHz
	ROM	FLASH		256		kByte
	RAM	SRAM		32		kByte
	Data bus width			32		bit

Interfaces

Symbol	Parameter	Comment	Min	Type	Max	Unit
	Type / Quantity	CAN 2.0B		1		
	Baud rate	parameterizable		500		kBit/s
	Connector (standard)		Phoenix, pitch 3.5mm			
	Connector (RAIL)	Together with supply	M12 in / M12 out			
	Terminating resistor		no			
	Isolation RAIL	To measurement input	1.7 kV			
	Isolation standard	to measurement input / CAN	500 V			
	Type / Quantity	Serial / USB		1		
	Baud rate	Fixed		38400		Bit/s
	Connector		Micro USB			
	Chipset	Supply through USB	CP2102N			
	Isolation	To CAN/supply	isolated			

Process image

The following messages³ are transmitted via the CAN bus:

Status

Approx. 60 seconds after the start of the module, the following information is transmitted once:

- Serial number
- Firmware version

The module periodically sends messages for self-diagnosis, which can be evaluated by the higher-level system as a heartbeat. The following functions are mapped via this message:

- Status bit as the result of a verification of the set parameters against a checksum generated during configuration. In this way, an accidental change in the configuration can be detected and reported.
- Counters for the independent program loops and interrupt service routines. If the counter values change in each message, it can be assumed that all functions of the module are served.
- Further status bits, e.g. for sensor diagnostics (if available)

³ For the description of the CAN messages the DBC format of the company Vector-Informatik GmbH, developed already in 1992, is used here. This represents a de facto standard in the context of CAN bus systems.

DBC Description:

BO_ 2147499692 Module_Info_Get: 8 Vector_XXX
SG_u32_TypSerial : 8|32@1+ (1,0) [0|0] "" Vector_XXX
SG_u8_year of construction : 0|8@1+ (1,0) [0|255] "" Vector_XXX
SG_u8_FIRMWARE_MINOR : 56|8@1+ (1,0) [0|255] "" Vector_XXX
SG_u8_FIRMWARE_MIDDLE : 48|8@1+ (1,0) [0|255] "" Vector_XXX
SG_u8_FIRMWARE_MAJOR : 40|8@1+ (1,0) [0|255] "" Vector_XXX

BO_ 2147499892 Module_Status_Get: 8 Vector_XXX
SG_u8_RTD_RollingCounter : 8|8@1+ (1,0) [0|255] "" Vector_XXX
SG_u16_Module_Status : 48|16@1+ (1,0) [0|65535] "" Vector_XXX
SG_u8_Digital_Out_Watchdog_10telsec : 16|8@1+ (0,1,0) [0|25.5] "sec" Vector_XXX
SG_u8_ADC_RollingCounter : 0|8@1+ (1,0) [0|255] "" Vector_XXX

Raw data

In time with the acquisition of the raw data, the measured values are transmitted in two messages as 16-bit values.

DBC Description:

BO_ 81 ADC_5_6_7_8_Get: 8 Vector_XXX
SG_i16_Dummy : 48|16@1- (1,0) [-32768|32767] "" Vector_XXX
SG_i16_PT100_Resistance : 32|16@1- (0,1,0) [-3276.8|3276.7] "Ohm" Vector_XXX
SG_i16_Temperature_01 : 16|16@1- (0,1,0) [0|3276.7] "°C" Vector_XXX
SG_ADC_05 : 0|16@1- (0,01,0) [0|327.67] "V" Vector_XXX

BO_ 80 ADC_1_2_3_4_Get: 8 Vector_XXX
SG_ADC_04 : 48|16@1- (0,01,0) [0|327.67] "V" Vector_XXX
SG_ADC_03 : 32|16@1- (0,01,0) [0|327.67] "V" Vector_XXX
SG_ADC_02 : 16|16@1- (0,01,0) [0|327.67] "V" Vector_XXX
SG_ADC_01 : 0|16@1- (0,01,0) [0|327.67] "V" Vector_XXX

Control outputs

The digital outputs can be controlled and their status read back via the two following CAN messages.

DBC Description:

BO_ 83 Digital_Out_Set: 1 Vector_XXX
SG_b_Relay_3 : 2|1@1- (1,0) [0|1] "" Vector_XXX
SG_b_Relay_2 : 1|1@1- (1,0) [0|1] "" Vector_XXX
SG_b_Relay_1 : 0|1@1- (1,0) [0|1] "" Vector_XXX

BO_ 84 Digital_IO_Get: 2 Vector_XXX
SG_u8_Digital_OUT : 8|8@1- (1,0) [-128|127] "" Vector_XXX
SG_u8_Digital_IN : 0|8@1+ (1,0) [0|255] "" Vector_XXX

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