smartIO BATMON

Technical data and description

The **smartIO BATMON** integrates the following components in a compact smartIO module

- Insulating, railway-grade, fanless **power supply** with
  - Input 24 … 110 V DC (nom.),
  - Output 24 V DC, 50 W
- **Undervoltage protection circuit** and continuous monitoring of the battery voltage at the input terminals
- Wake-up **timer** programmable depending on operating situation
  - Continuous operation
  - Control signal "KL-15[1]"
  - Timed
  - Energy saving mode
  - Undervoltage shutdown after alarm message

- **Current limiting and soft start on** the primary side, power supply can be operated without circuit breaker
- **Pt100 temperature measuring input**, e.g. for battery temperature
- CAN bus for control and diagnostic information
- **Quiescent current consumption** < 1mA

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. optiMEAS has applied for a patent for the smartIO BATMON concept.

Power supply

The core of the smartIO BATMON module is a DC/DC switched-mode power supply from intreXis that is suitable for railroad applications. It is characterized by a wide input range of nominally 24 - 110 V DC (operating range 16.8 - 154 V DC), high efficiency with a small installation space requirement and the possibility of operating it without a circuit breaker on the vehicle battery.

[1] In automotive engineering, terminal 15 (KL-15, ignition plus) designates the circuit from the ignition lock that becomes live when the ignition is switched on.

The power supply unit is sufficiently dimensioned to supply an optiMEAS ECO system consisting of smartRAIL[2] and smartIO[3] modules and, if necessary, a few sensors with power.

Use Case

If an IIoT edge device, such as the smartRAIL, is to be operated in a train even when the vehicle is disengaged, the system must be supplied by a tap upstream of the battery main switch. The non-negligible power requirements of the systems that transmit data and information via mobile communications can lead to significant battery discharge when the vehicle is stationary for long periods or in adverse weather conditions. It is also possible that other consumers are not disconnected from the battery.

Commercially available voltage monitors that switch off in the event of undervoltage usually require additional components, such as power relays and an adaptation to wide input voltage ranges. They do not allow either a time-controlled restart or a continuous, recording monitoring of the battery voltage.

smartIO BATMON uses a **switch controlled by a microcontroller on the primary side to** switch the IIoT edge device off and on as needed while minimizing quiescent current requirements < 1 mA. The microcontroller monitors the voltage curve of the battery, the switch-on process of the power supply and its own temperature.

With its intelligent functions and integrated power supply, the smartIO replaces BATMON with significantly more functionality in a single module

- Circuit breaker
- Shunting terminals
- Undervoltage protection, such as Siemens 3UG46331AL30
- Semiconductor relay with wide range voltage supply and control input
- DC/DC power supply

Measurement functions

The following measuring functions are available in the smartIO BATMON:

Description	Primary side		Secondary side smartIO
	Switched on	*Stand-By*	*Switched on*
Battery voltage	10 Hz	1 measurement / min	10 Hz
Supply current edge device	10 Hz	-	10 Hz
Temperature circuit breaker	10 Hz	1 measurement / min	10 Hz
Temperature Pt100 external	-	-	10 Hz
Table of measured values		100 records	

[2] Power consumption smartRAIL typical 6 ... 9 W

[3] Power consumption smartIO typical 1 W

Voltage measurement

The voltage measurement is performed on the primary side directly for the supply voltage. Due to the large input voltage range of 15 V to 160V to be covered, special challenges arise, especially since the Controller itself is localized in the positive signal path of the battery voltage.

The measured values acquired by the primary side controller are stored in an internal table in standby mode and can be read out by the IIoT edge device during operation. During operation, all measurements are performed at a higher sampling rate and transferred internally to the smartIO page.

Current limitation and measurement

The primary side controller is responsible for switching the power supply on and off. For this purpose, it operates a power MOSFET via a control signal, which with a switch-on resistance < 0.2 Ω produces hardly any power loss during operation. When switching on, the capacitors of the switching power supply must be charged, which usually leads to large inrush current peaks[4]. However, a fast analog current limitation is implemented via a measurement shunt before the MOSFET, which limits the operating current to < 3 A during switch-on and operation. The controller measures and monitors the current to the power supply unit and can switch off directly in the event of a short circuit on the primary side. A short circuit or overload on the secondary side is handled unchanged by the integrated power supply unit.

Temperature measurements

The smartIO BATMON can record two temperatures. One is recorded as the internal temperature (of the power MOSFET) and can also be logged in stand-by mode as the module temperature at longer time intervals. The second is sensed by the smartIO side of the BATMON and is designed for connection of an external 3-wire Pt100 sensor. The circuitry is the same as that of the smartIO 4RTD except for the adjustable measuring range.

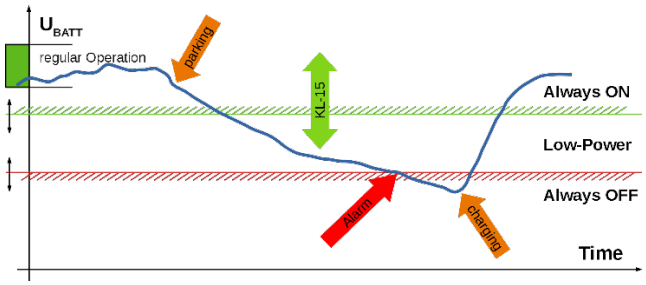
[4] This is the reason why such a power supply cannot be operated directly by a system-typical undervoltage switching device. The switching outputs may only be loaded with a few 100 mA and always require a downstream power relay for higher powers.

Function depending on battery voltage, KL-15

Two absolute voltage limits can be set in the smartIO BATMON, which perform the following function:

- **UAlwaysOn**
  If the measured battery voltage is above this limit, the power supply is initially always switched on and thus the edge device is always in operation.
  Independently of this, the edge device can send
  a shutdown command to the smartIO BATMON to actively switch off the system for a certain period of time. The system can also be switched off via the KL-15 control input by removing the control voltage and switching to time-controlled operation.
- **UAlwaysOff**
  If the battery voltage drops below the lower limit, the edge device is switched on a "last time" to be able to send an alarm message, and then switched off until the battery voltage rises above the limit again.
  During this time, a controller monitors the input voltage on the primary side at longer time intervals in order to be able to detect the switch-on time. The intervals are configurable.

The diagram shows a typical voltage curve of a vehicle battery over time, which is continuously discharged after an operating phase by shutting down the vehicle. The set limit values **UAlwaysOn** and **UAlwaysOff** are passed one after the other. In the low-power range, the BATMON switches to a power-saving mode.
The edge device receives a shutdown command that must be followed - as with a UPS[5] - before the supply voltage is actually switched off a short time later. At adjustable time intervals, the edge device is switched on again to record and transmit current measured values before the switch-off cycle starts again. The edge device can also generate the switch-off command itself, in which case the switch-off duration is sent to the smartIO BATMON with the control command and can thus be extended or shortened depending on the situation.



Similar to the ignition in a car, the control input KL-15 can be used to switch the smartIO BATMON on and off with an external signal. Only the edges on the signal are taken into account.

- Switching on via KL-15 switches the Edge device on permanently.
- A shutdown via KL-15 activates the time-controlled operation as well as a shutdown command sent by the edge device.

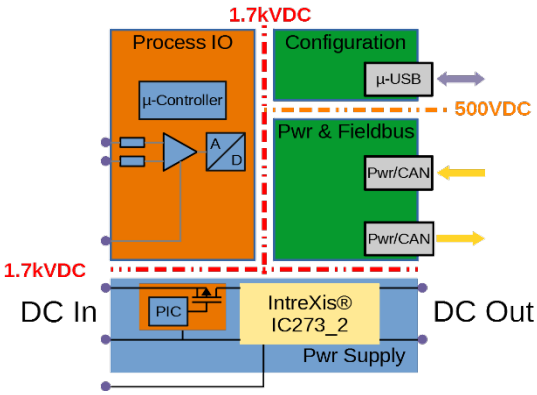
[5] Uninterruptible power supply before the switch-off point of the buffer battery

As soon as the BATMON has been started once with the KL-15 signal, the state change between Always-ON and Low-Power is only controlled by the KL-15. The function of the Always-OFF threshold is retained. In an installation situation without KL-15 or after the battery voltage is applied to the module input again, only both voltage thresholds are activated.

In energy-saving mode, the BATMON records up to 100 time-stamped values of battery voltage and module temperature every minute (adjustable). These measured values can be queried by the edge device after startup and, supplemented by other life measured values of the overall system, can be transmitted to the data cloud.

Isolation of the terminal groups

As a module of the RAIL series, 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. The isolation between smartIO and the controlled power supply is also provided with 1.7 kV.



Note: The smartRAIL V2.0, smartRAIL-S V2.0 or smartRAIL V2.0 with additional modules (MVB, etc.) is supplied via the CAN_1 connection of the smartRAIL. For this purpose, the smartIO BATMON RAIL is equipped with an internal bridge between the DC Out of the switching power supply and the 24V at the Pwr/CAN connections. This minimizes external wiring work. If the BATMON is to be used in an installation situation in which the isolation between DC Out and the 24V at the Pwr/CAN connections is required, this must be specified as an order option. In this case, the power supply of a smartRAIL V2.0 would have to be provided by an external power supply at the terminating bus termination.

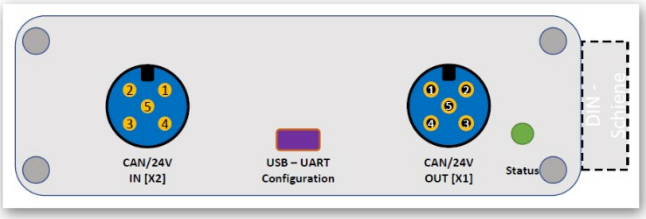
Note: In order to switch higher powers than 24V 50W, a power relay can be connected to the output of the power supply unit, via which further independent circuits can be connected. Since the voltage output of the module is designed potential-free, connected ground potentials can be built up as required.

Interfaces of the module

Power supply and CAN bus [smartIO]

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

As a RAIL version, the switched, stabilized 24V supply of the power supply unit and CAN are available on two M12 connectors according to the Device-Net assignment. To supply the smartRAIL V2.0 and other smartIO modules, an internal bridge in the BATMON module connects the 24V of the switched-mode power supply to both M12 connectors. The CAN bus connection is looped through from the plug to the socket. This allows several different smartIO modules and a smartRAIL V2.0 to be connected in series. If no other smartIO module follows, the CAN bus must be terminated with a plug with integrated terminating resistor (120 Ω). CAN-GND is identical to the supply ground.



Pin	Signal	Description
1	CAN Shield	
2	+24V	**Voltage supply +24V,** identical to V(+) Switched
3	GND	**Voltage supply GND,** identical to V(-) Switched 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.

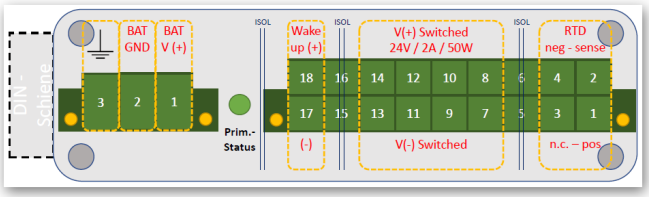
Measurement input

For the measuring input, the connection of the control terminal (KL-15) and the output of the power supply unit, 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.

Inputs and outputs of the power supply unit

The internally switched input of the power supply unit is connected to the battery voltage via a 3-pin Phoenix plug. Since both the power supply unit and the control circuit on the primary side are protected by their own fuses (non-resetting) in the event of an accident, the use of an additional circuit breaker is not necessary.

The potential-free output of the power supply unit is connected several times to the 2-row Phoenix connector, so that distribution of the power supply is possible on a small scale without shunting terminals.

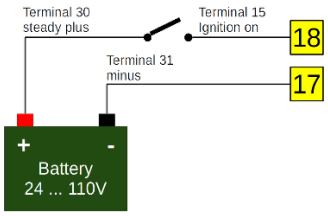


Note: As RAIL version, the switched 24V output is also connected to the M12 connectors next to the CAN bus in order to supply smartRAIL V2.0 and smartIO without further wiring effort. If this is not desired or the isolation of the voltage levels is required, the BATMON can also be produced and delivered without this bridge.

Pin	Signal	Description	
1	RTD-Pos	Sensor supply,	positive (EN 60751: white)
2	RTD-Sense	Sensor feedback,	negative (EN 60751: red)
3	RTD-n.c.	Not connected (parking position)	positive (EN 60751: white)
4	RTD-Neg	Sensor supply,	negative (EN 60751: red)
7,9,11,13	GND	Isolated, switched 24 V supply, earth	
8,10,12,14	24V	Isolated, switched 24 V supply, 24V	
17	Wake-Up (-)	Voltage signal for switching on, negative connection	
18	Wake-Up (+)	Voltage signal for switching on, positive connection	

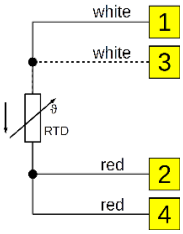
Wake-up connection (KL15)

A switched voltage can be used as a control signal to switch on the BATMON and the supplied modules. In automotive engineering, this connection is known as terminal 15, ignition on. If these connections are used, the BATMON immediately switches to KL15-controlled operation. The connections for the wake-up signal are potential-free.



RTD connection (Pt 100)

According to EN 60751, Pt100 sensors should use the cable colors red and white in the supply line, whereby the conductors of the same color are interchangeable. However, there are also manufacturers who use other cable colors. Which of the colors then belong together according to the following connection diagram can be found in the corresponding sensor data sheet. Even if the smartIO BATMON only evaluates the sensor and its lead resistors in the three-wire circuit, a fourth connection can be parked on pin 3 (n.c.).



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		The CE mark indicates compliance with the • EMC Directive, • RoHS 2011/65/EU (08.06.2011) and the • Low Voltage Directive an.
Railroad applications - Electronic devices on Rail vehicles. EN 50155:2008		The systems meet the standard for the following properties: • *Environmental conditions*: ○ AX (2000m) EN50125-1 §4.2.1 ○ TXEN50155 §4.1.2 • *Climate*[6] ○ Refrigeration EN50155 §13.4.5.2 ○ Dry heat EN50155 §13.4.5.3 ○ Humid heat cyclic EN50155 §13.4.5.7 • *Swing* IEC61373 §8 + 9 • *Shock* IEC61373 §10 • *EMC, insulation* EN50121-3-2 EN 61000-3-2/3 EN 55016-2-1/2 • *Fire protection* EN45545-2 *routine tests according to* EN50155 §12.2 • *Visual inspection* EN50155 §12.2.1 • *Insulation* EN50155 §12.2.9.1 • *Withstand voltage* EN50155 §12.2.9.2

[6] Already according to EN 50155:2017

Technical data

Supply voltage / ambient conditions [smartIO]

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 (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		124		mm
B	Wide			85		mm
H	Height			45		mm
m	Weight			480		g
	Screw connection	Front panels against carcass	M3, stainless steel VA2, lock washers			
	Mounting (standard)	Option mounting feet or mounting rail (EN 50022)				
	Mounting (RAIL)		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_{AInR}	Type / Quantity	**Resistance**		1		
R_{Mess}	Measuring range	for Pt100	18,5	100	375	Ω
			-200	0	800	°C
I_{SENSOR}	Feed current		90	100	110	µA
ΔR	Resolution ADC	for Pt100 @ 20 °C			0,1	°C
R_{Ain}	Input resistance			30		kΩ
	Converter	Sigma Delta		16		bit
f_{Ain}	Sampling rate			10		Hz
f_{-3dB}	Bandwidth			4		Hz
	Accuracy	On measuring range		0,5		%

Primary side power switching group

Symbol	Parameter	Comment	Min	Type	Max	Unit
U_{IN}	Input voltage		17,5		154	V
	Reverse polarity protection	permanent		yes	-154	V
I_{MAX}	Current limitation	dynamic			3	A
R_{IN}	Input series resistance			0,45	0,5	Ω
I_{STDBY}	Quiescent current, standby	Depart. from UIN		500	1000	µA
I_{CTRL}	Input current control	Depart. from UIN			5	mA
	Control	Microcontroller		PIC16F		
I_{FUSE}	Fuse	Fuse 250V		5		A T
U_{KL15}	Control voltage	"Clamp-15"	10		150	VDC
I_{KL15}	Control current	"Terminal-15", type @ 24V		5	30	mA

Power supply unit, intreXis IC273_2

Only the most important key data of the integrated power supply is listed here. For a complete description, please refer to the manufacturer's data sheet. Information without guarantee.

Symbol	Parameter	Comment	Min	Type	Max	Unit
U_{IN}	Input voltage	permanent	16,8		154	VDC
U_{IN1s}	Temporary according toEN 50155, 5.1.1.3	< 1 s	14.4		154	VDC
	Reverse polarity protection	permanent		yes	-154	VDC
$I_{IN,IR}$	Input / starting current	limited by BATMON			3	A
U_{OUT}	Output voltage			24		VDC
	Regulation	entire load range			0,2	%
		Influence input voltage			0,1	%
P_{OUT}	Output power		0		50	W
I_{OUT}	Output current		0		2,1	ADC
	Limitation (short circuit)	permanent	2,19		2,63	A
η	Efficiency	Dep. of UIN and load	88	90	93	%
U_{ISOL}	Internal isolation	Input -> Output, 60s	2,5		3,3	kVrms
		Input -> Housing, 60s		1,5		kVrms
		Output -> Housing, 60s		1,0		kVrms

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	including supply voltage		M12 in / M12 out		
	Terminating resistor			no		
	Isolation RAIL	to measurement input		1.7 kV		
	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 messages[7] 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)

[7] 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_ 2147499698 Module_Info: 8 Vector__XXX
 SG_ u32_TypSerial : 8|32@1+ (1,0) [0|4.29497e+009] "" 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_ 2147499898 Module_Status: 8 Vector__XXX
 SG_ u8_PIC_Software_Version : 16|16@1+ (1,0) [0|65535] "" Vector__XXX
 SG_ u16_Modulsttaus : 48|16@1+ (1,0) [0|65535] "" Vector__XXX
 SG_ u8_RTD_Rollercounter : 0|8@1+ (1,0) [0|255] "" Vector__XXX
```

Raw data

Raw data and status information about the BATMON function are transmitted in four messages.

DBC Description:

```
BO_ 120 Values_1_2_3_4: 8 Vector__XXX
 SG_ i16_Temperature_Mosfet : 32|16@1- (0.1,0) [-3276.8|3276.7] "°C" Vector__XXX
 SG_ u16_Power_Supply_Current : 16|16@1+ (0.001,0) [0|65.535] "A" Vector__XXX
 SG_ u16_Power_Supply_Voltage : 0|16@1+ (0.01,0) [0|655.35] "V" Vector__XXX

BO_ 121 Values_5_6_7_8: 8 Vector__XXX
 SG_ i16_Temperature : 48|16@1- (0.1,0) [-3276.8|3276.7] "°C" Vector__XXX

BO_ 125 Batmon_Status: 8 Vector__XXX
 SG_ m_u16_Boot_Counter : 48|16@1+ (1,0) [0|65535] "sec" Vector__XXX
 SG_ Dummy : 40|8@1+ (1,0) [0|255] "" Vector__XXX
 SG_ u8_Shutdown_Counter : 32|8@1+ (1,0) [0|255] "sec" Vector__XXX
 SG_ eBusinessMode : 24|8@1+ (1,0) [0|255] "" Vector__XXX
 SG_ ePowerMode : 16|8@1+ (1,0) [0|255] "" Vector__XXX
 SG_ eShutdown_Event : 8|8@1+ (1,0) [0|255] "" Vector__XXX
 SG_ eWakeup_Event : 0|8@1+ (1,0) [0|255] "" Vector__XXX

BO_ 130 Batmon_Parameter: 8 Vector__XXX
 SG_ u16_V_Threshold : 48|16@1+ (0.01,0) [0|655.35] "V" Vector__XXX
 SG_ u16_Boot_Time : 32|16@1+ (1,0) [0|65535] "sec" Vector__XXX
 SG_ u16_Wakeup_Time : 16|16@1+ (1,0) [0|65535] "sec" Vector__XXX
 SG_ u16_Shutdown_Time : 0|16@1+ (1,0) [0|65535] "sec" Vector__XXX
```

Control

With the following messages on the one hand time stamps for the integrated data storage as well as the shutdown command with corresponding parameters are sent. The protocol for the command interface is available on request.

DBC Description:

```
BO_ 126 RTC: 8 Vector__XXX
 SG_ u64_Milliseconds_since_1970 : 0|64@1+ (1,0) [0|1.84467e+019] "" Vector__XXX

BO_ 127 Batmon_Shutdown: 1 Vector__XXX
```

BO_ 128 Batmon_Com_Rxd: 0 Vector__XXX

BO_ 129 Batmon_Com_Txd: 0 Vector__XXX

Contact

optiMEAS Measurement and Automation Systems GmbH

Am Houiller Platz

464381 Friedrichsdorf

+49 (6172) 997712-0

info@optimeas.de