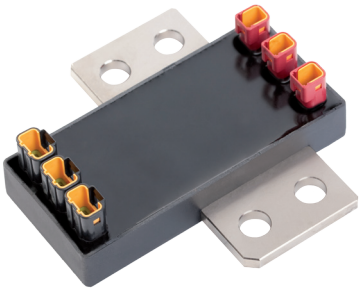
IVT-MODULAR CAN



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1. Introduction

The IVT-MOD is a high precision current and voltage measurement system, designed for DC applications. The product is based on a modular design and provides flexibility for fast adaptations to meet customer requirements in the automotive and the industrial area. The continuous current measurement has a range up to ±2,500 A and the voltage channels include a range of ±600 V, and it is approved for continuous operation. At higher currents (i. e. peaks) the measurement range will extend automatically.

The shunt-based measurement method uses a 16-bit analog-digital converter to transform the voltage drop into a digital signal. The communication is based on a CAN bus interface. A CAN description file (CAN-dbc) is available and supports fast system integration.

The modularity includes the following functionalities

- Isolation against high voltage potential
- Overcurrent detection
- Hardware trigger (for start of measurement)
- Five ranges of current measurement (according to shunt value)
- Up to three voltage measurement channels
- Digital communication (CAN with and without termination)
- Three ranges of power supply

See the description of the modularity in chapter 4.

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Due to the large number of modular combinations three basic modules were defined to cover most applications.
Every basic sensor can be adapted to customer specific requirements.

Modularity	Basic sensor 1	Basic sensor 2
Power supply	12 V 24 V	12 V
Interface	CAN (with and without internal bus termination)	
Isolation	✓	–
Automotive / Industrial	Automotive	
Current measurement range	±100 A; ±300 A; ±500 A, ±1 kA; ±2.5 kA	
Voltage measurement range	±600 V (0 - 3 channels)	
I/O	Hardware Trigger (input) Hardware OCS (output), Overcurrent signal	
Connector	JST (JWPF)	

The IVT is more than current and voltage sensing

The IVT-MOD has a total number of eight measurement signals.
The signals are individually configurable.

Table 1: List of output signals

Channel	Unit
Current	A
Voltage 1	V
Voltage 2	V
Voltage 3	V
Temperature	°C
Power	W
Current counter	As
Energy counter	Wh

NOTE: Power measurement is always based on Voltage 1.

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2. Application

The IVT-MOD is designed for a wide range of DC applications.
For example:

- Hybrid and full electric drives
- UPS systems
- Stationary energy storage systems
- Fuel cells
- Battery and storage based applications

3. Additional features

The IVT-MOD has a high number of features. The following features are available for all modular combinations.

3.1 Measurement modes

- Disable
- Trigger
- Cycle running

It is possible to configure each channel individually.

Disable mode
The measurement channel is disabled. The channel does not react to a software command or hardware trigger.

Trigger mode
The module sends a measurement result message in response to a received trigger command. This command can be either a software message or a hardware trigger line signal. In case of a detected hardware trigger signal, the module starts one single measurement cycle. The hardware trigger input is built as a high-active input (rising edge). For more information see chapter 4.

Cycle running mode
The module sends a measurement result message after a configured cycle time.
Example: current channel cycle time: 10 ms.
Every 10 ms a measurement result message for the current channel is generated and transmitted over CAN.

3.2 Internal safety

The sensor status is internally monitored by the microcontroller. In case of a sensor failure a status bit is set and the overcurrent signal (OCS) is generated (low-active signal output). (See OCS chapter 4). During the start-up phase the OCS is also active.

To verify the current measurement of the first channel, a second virtually independent ADC channel is used. The system compares the signal of both channels to determinate malfunctions in the ADC. Furthermore the ADC´s reference voltage is monitored. Therefore the IVT-MOD can detect a non-valid measurement condition on the current channel (chapter 5.1).

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3.3 Log data

The log data are continually stored, with an interval of 15 minutes. In case of a sensor reset, the last stored logdata will be recovered. It is possible to reset all logdata, as well as individual logdata. The following Logdata are available as 6-Byte values:

No.	Item	Unit	Min	Max
1	Ampere hour counter overall (only if counter is activated)	As	-72,000,000,000,000	+72,000,000,000,000
2	Ampere hour counter charging (only if counter is activated)	As	0	+144,000,000,000,000
3	Ampere hour counter discharging (only if counter is activated)	As	0	+144,000,000,000,000
4	Energy counter overall (only if counter is activated)	Wh	-72,000,000,000,000	+72,000,000,000,000
5	Energy counter charging (only if counter is activated)	Wh	0	+144,000,000,000,000
6	Energy counter discharging (only if counter is activated)	Wh	0	+ 144,000,000,000,000
7	Runtime overall	s	0	+3,000,000,000
8	Runtime current measurement within specified limits	s	0	+3,000,000,000
9	Runtime current measurement outside specified limits	s	0	+3,000,000,000
10	Runtime voltage 1 measurement within specified limits	s	0	+3,000,000,000
11	Runtime voltage 1 measurement outside specified limits	s	0	+3,000,000,000
12	Runtime voltage 2 measurement within specified limits	s	0	+3,000,000,000
13	Runtime voltage 2 measurement outside specified limits	s	0	+3,000,000,000
14	Runtime voltage 3 measurement within specified limits	s	0	+3,000,000,000
15	Runtime voltage 3 measurement outside specified limits	s	0	+3,000,000,000
16	Runtime temperature measurement within specified limits	s	0	+3,000,000,000
17	Runtime temperature measurement outside specified limits	s	0	+3,000,000,000
18	Runtime oc positive activated	s	0	+3,000,000,000
19	Runtime oc negative activated	s	0	+3,000,000,000
20	Current measurement maximum	A	-32,000	+32,000
21	Current measurement minimum	A	-32,000	+32,000
22	U1 measurement maximum	V	-32,000	+32,000
23	U1 measurement minimum	V	-32,000	+32,000
24	U2 measurement maximum	V	-32,000	+32,000
25	U2 measurement minimum	V	-32,000	+32,000
26	U3 measurement maximum	V	-32,000	+32,000
27	U3 measurement minimum	V	-32,000	+32,000
28	Temperature measurement maximum	1/10 °C	-500	+2,000
29	Temperature measurement minimum	1/10 °C	-500	+2,000

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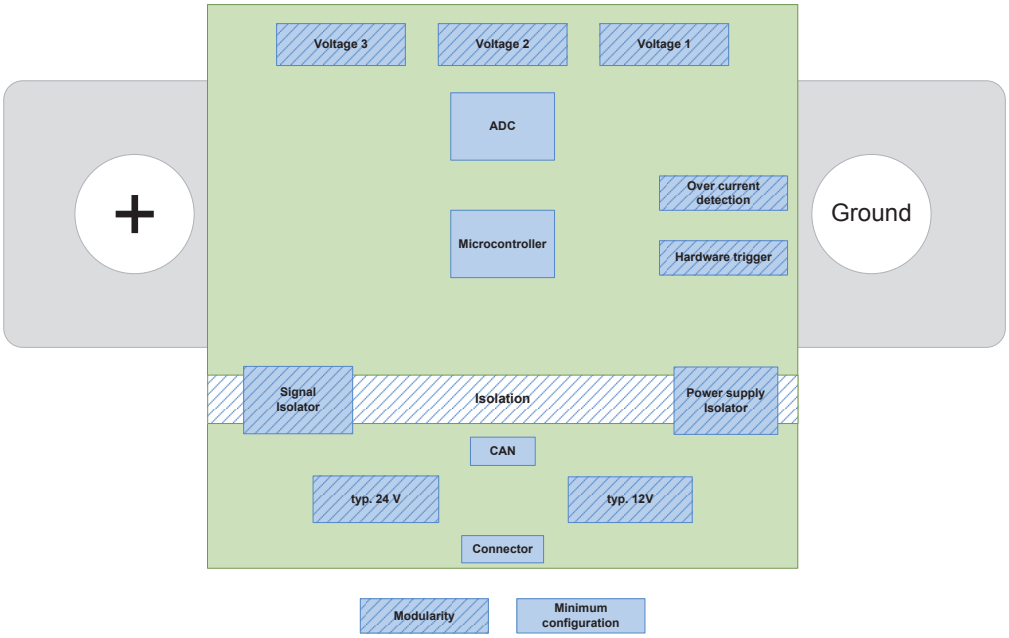
3.4 Firmware update

To update the firmware, the IVT has an implemented bootloader.
Firmware update can only be done by Isabellenhuette.

4. Functionality description

Module overview



4.1 Isolation

This functionality is designed for high voltage applications.
With the isolation module the sensor can be used with different potential levels on power supply (low voltage side) and shunt (high voltage side).

Table 2: Isolation voltage for DIN EN 60664-1:2008-01
Declarations are valid at the following condition: Sea level under 2,000 m

Maximum working isolation voltage	400 V RMS CATI-II 300 V RMS CATI-III 150 V RMS CATI-IV
Basis isolation DC voltage	560 V peak
Reinforced isolation DC voltage	350 V peak
Highest allowed transient overvoltage	4,000 V (for 10s)
Minimum External Clearance distance	>40 mm
Minimum External Creepage distance	>50 mm
Minimum Internal Clearance	5.5 mm
Material Group housing	IIIa
Material Group potting	II
Material Group connectors	II

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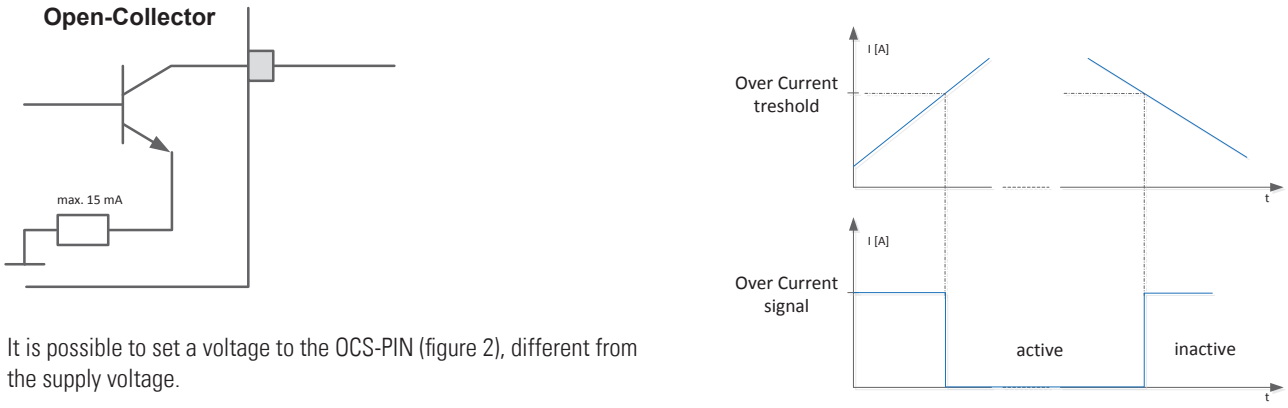
4.2 Overcurrent signal (OCS)

This functionality implements an overcurrent detection for positive and negative current directions. As soon as the overcurrent is detected the alarm line OCS is activated, which indicates an overcurrent condition to the external circuit. The OCS is a software feature, so it is possible to set the overcurrent threshold for set OCS and reset OCS, separately for positive and negative current directions. Therefore the hysteresis can be easily defined by the set and reset threshold (see figure 3). The configured threshold value is compared with the measurement value. After exceeding the threshold the open-collector output is active-low (figure 1). The OCS-Pin is designed for a maximum current of 15 mA with a min. pull-up resistor of 4 KOhm. The maximal input voltage depends on temperature and current (see figure 4). The OCS is deactivated when the measured value is below the reset threshold value (figure 3).

Figure 1: open-collector output for overcurrent signal



It is possible to set a voltage to the OCS-PIN (figure 2), different from the supply voltage.

Figure 2: 5 V application

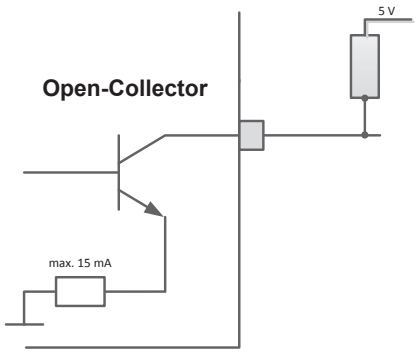


Figure 4: chart for the pull-up resistor

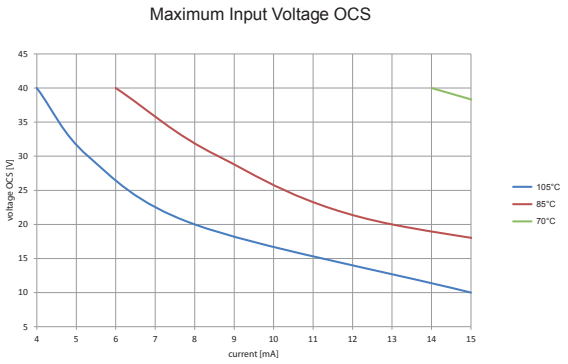
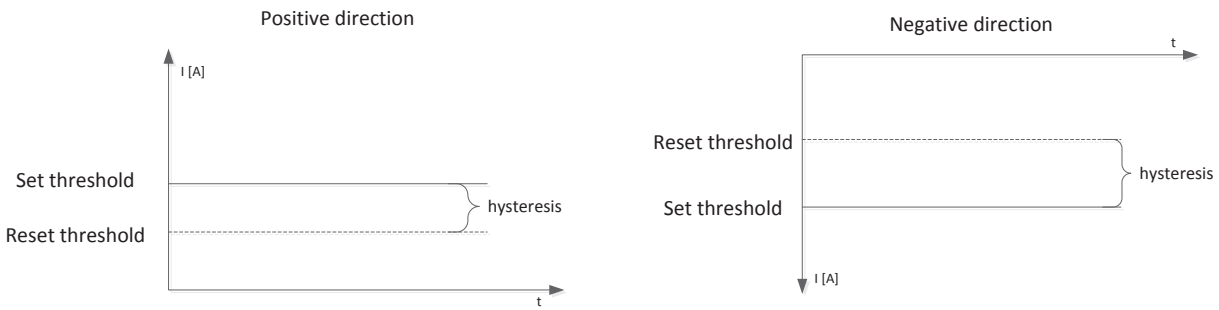


Figure 3: set threshold and reset threshold



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4.3 Hardware trigger

The IVT-MOD optionally provides a hardware trigger input. The trigger signal could be used to synchronise the measurement between the IVT-MOD and external systems.

Every channel that is configured to "trigger mode" or "cyclic mode" reacts to a rising edge on PIN 3.b and PIN3.d. The channels will reset to their initial condition and start measuring by using the configured interval. Figure 5 shows a channel that reacts to a trigger signal. After detecting trigger signal the measurement starts within 0…250 µs. As the minimum trigger interval a time of 2 ms + configured trigger interval is required before triggering the next measurement. A trigger interval of less than 50% of the configured trigger interval will cause a retrigger.
A pulse width of at least 200 µs has to be complied (see Figure 6).

Electrical properties see chapter 6.5.

Figure 5: a channel in "trigger mode"

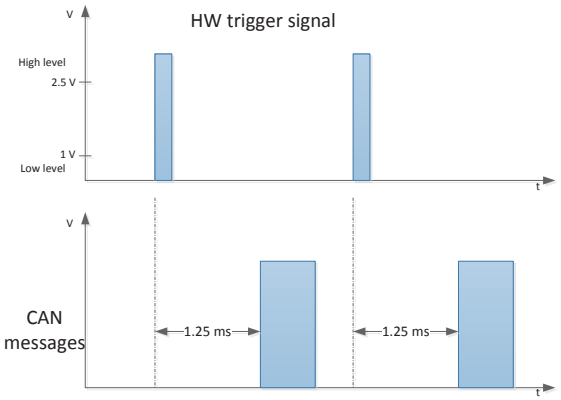
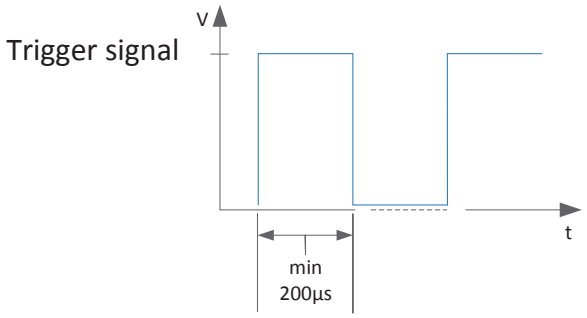


Figure 6: limit value of "trigger pulse"



4.4 Ranges

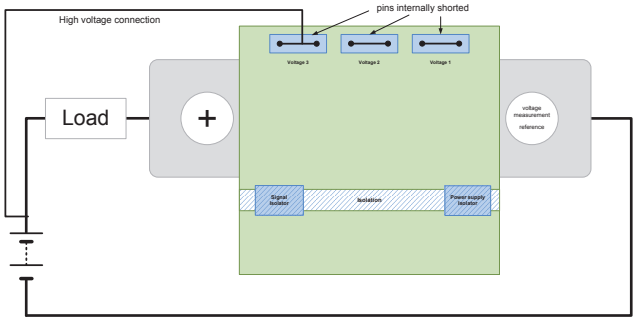
The IVT-MOD product family offers five different, customer selectable current measurement ranges. The selection of a required measurement range determines the shunt resistance. Every shunt value has unique characteristics (see technical data, chapter 6).
One limitation characteristic is the maximum load of the shunt resistor. The limitation is based on the internal thermal resistance and a maximum tolerable heating of 20 Kelvin. To ensure that the limits are not exceeded a good heat dissipation over the bus bar and the environmental temperature must be provided.

Note:
To ensure that the measurement limits are in the specified range, care has to be taken to the thermal connection between shunt and busbar. In case of an inadequate shunt to busbar connection the sensor can possibly overheat due to the internal power dissipation.

4.5 Voltage measurement

For an optimized adaption to the application, there is the possibility to order the sensor with one, two or three voltage channels. Each channel is individually configurable and voltage levels are measured with reference to sensor ground.
In every case, the first channel is used for the power measurement and has highest priority. Channel two and three are configured with a maximum output rate of 3 ms.

Figure 7: example for voltage measurement



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4.6 Communication interface

The IVT-MOD uses the standard CAN 2.0 protocol. It is possible to order the sensor with CAN termination (figure 8) or without CAN termination (figure 9), depending on the bus topology.

Examples for CAN topology

Figure 8: star topology

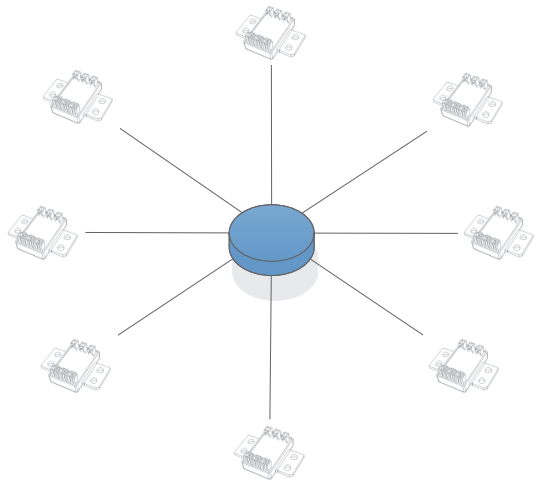
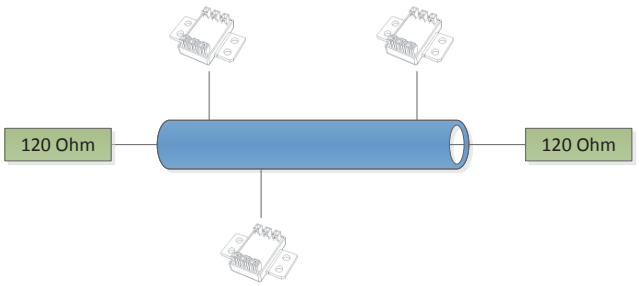


Figure 9: bus topology



The complete protocol description is listed in chapter 7.

4.7 Power supply

There are three options to operate the IVT.

Power supply	Application	Isolated version	Non-isolated version
12 V	standard 12 V automotive application	available	available
24 V	standard 24 V automotive application	available	not available

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5. Measurement description

Depending on the selected functionality there are up to eight measurement output signals (table 1: list of output signals). Every signal can be configured individually (output transfer rate and value). Based on these variations a high number of applications are possible, i. e. a fast current measuring as well as a complete filtered measuring of all signals.

5.1 Sampling rates

Current measurement characteristics:
One ADC channel is only used for the current measurement, with a provided maximum output rate of 1 ms.

Based on the configured measuring interval, the measurement result provides an average value of all single measurements within the interval (figure 11). The use of higher sample intervals increases the accuracy of the measurement.

Figure 10: CAN bus

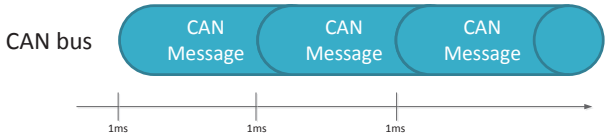


Figure 11: averaging over 5 ms

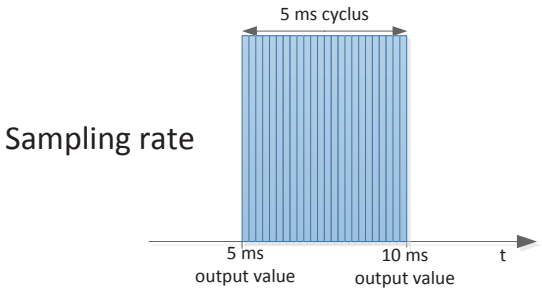
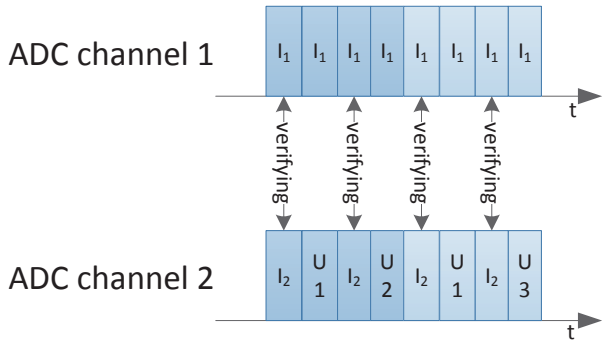


Figure 12: behaviour of ADC channel 1 and 2



After every channel sampling, the current channel is additionally sampled for internal use (verifying current measurement for internal safety, see chapter 3.2).

Voltage measurement characteristics:
The second ADC (ADC2) channel is used for voltage measurement. This channel is used for different signals, which are multiplexed.

This leads to the following behaviour:

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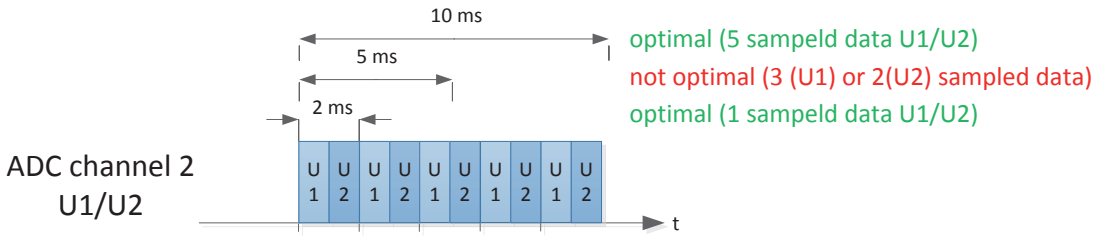
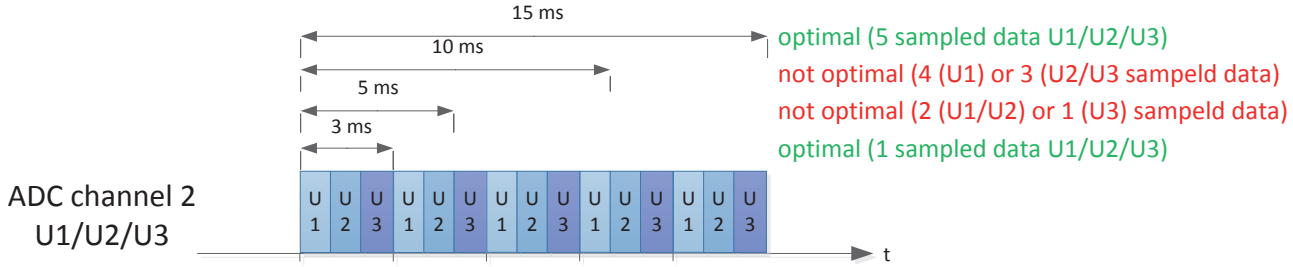
Figure 13: example with two channel on ADC2



If two voltage channels are set, it is recommended to choose an output rate of a factor of 2. As can be seen in the Figure 13, one value is determined at an output rate of 2 ms. With an output rate of 10 ms, the output value is averaged over 5 values. If an output rate is not a multiple of the selected channels, according to time frame 3 values (U1) or a 2 value (U2) can be processed.
An output rate under 2 ms is not possible here.

Figure 14: example with three channel on ADC2



If three voltage channels are set, it is recommended to choose an output rate of factor three. As can be seen in the Figure 14 (3 ms), one value is determined at an output rate of 3 ms. With an output rate of 15 ms, the output value is averaged over 5 values.
If an output rate is not a multiple of the selected channels (e.g. 10 ms), according to time frame 4 values (U1) or a 3 value (U2/U3) can be processed. An output rate under 3 ms is not possible here.

Example 1:

Figure 15: configuration: 1 current channel, 3 voltage channel, 3 ms measurement interval

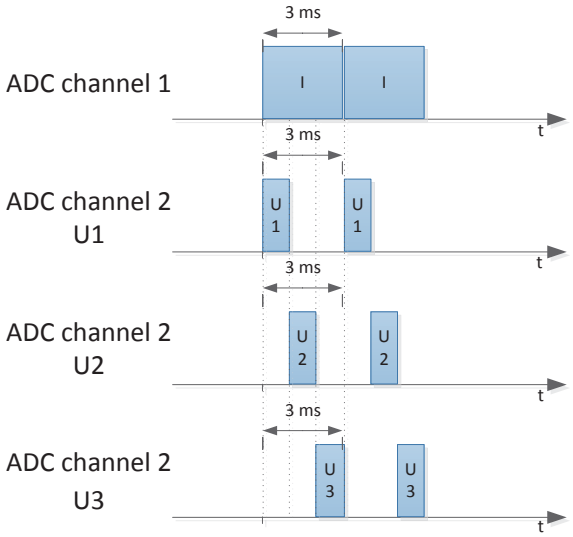


Figure 15 shows an example with 4 signals. All signals are con-figured with a measurement interval of 3 ms. The current measurement extends over 3 ms. The voltage measurement is multiplexed (U1, U2, U3).

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Example 2:

Figure 16: configuration: 1 current channel, 2 voltage channel

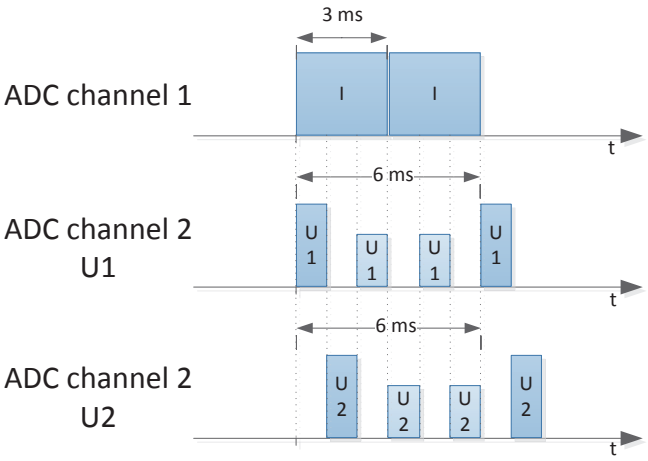
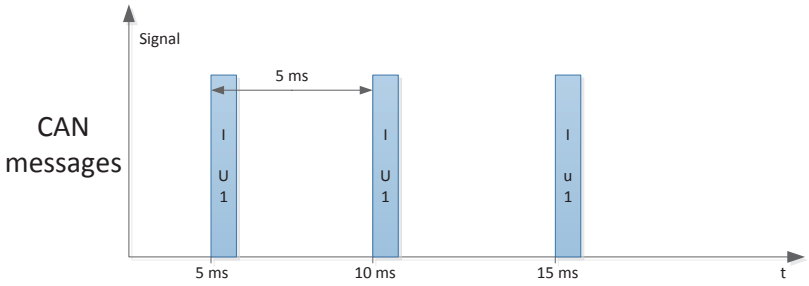


Figure 16 shows an example with 3 signals. The current measurement interval is 3 ms. The voltage measurement interval is 6 ms.
The current measurement extends over 3 ms.
The voltage measurement multiplexes every 2 ms (U1, U2).
After 6 ms the measured value is averaged over 3 values.

After evaluation of the configured measurement signals, the result messages of every signal will be generated and provide via CAN bus.

Example 3:

Figure 17: two channels; 5 ms output rate



Configuration condition (figure 17):
Two channels are configured, both with a measurement interval of 5 ms.
In this case the sensor sends the current and voltage result every 5 ms.

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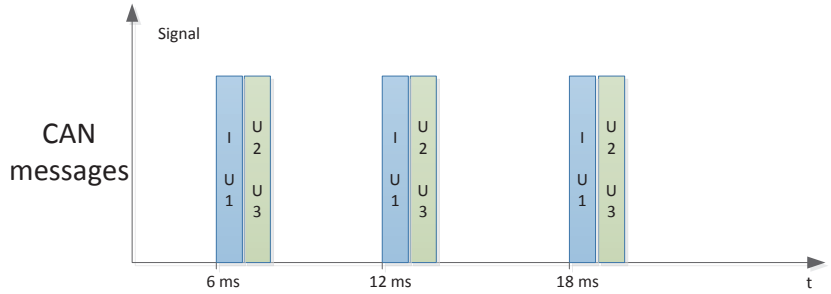
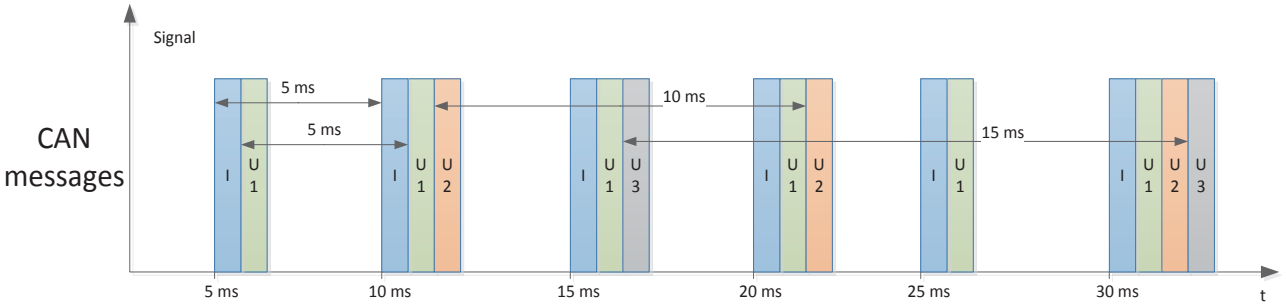
Figure 18: four channels; 6 ms output rate



Configuration condition (figure 18):
Four channels are configured; all with a measurement interval of 6 ms. In this case the sensor sends a current result every 6 ms, and the voltage result U1, U2 and U3 every 6 ms, as well.

Figure 19: Four channels; different measurement interval



Configuration condition (figure 19):
Four channels are configured: Current channel (5 ms interval), Voltage channel 1 with a measurement interval of 5 ms, Voltage channel 2 with a measurement interval of 10 ms and Voltage channel 3 with a measurement interval of 15 ms. In this case the sensor sends the current result every 5 ms and the Voltage 1 result every 5 ms as well, every 10 ms Voltage 2 result and every 15 ms Voltage 3 result.

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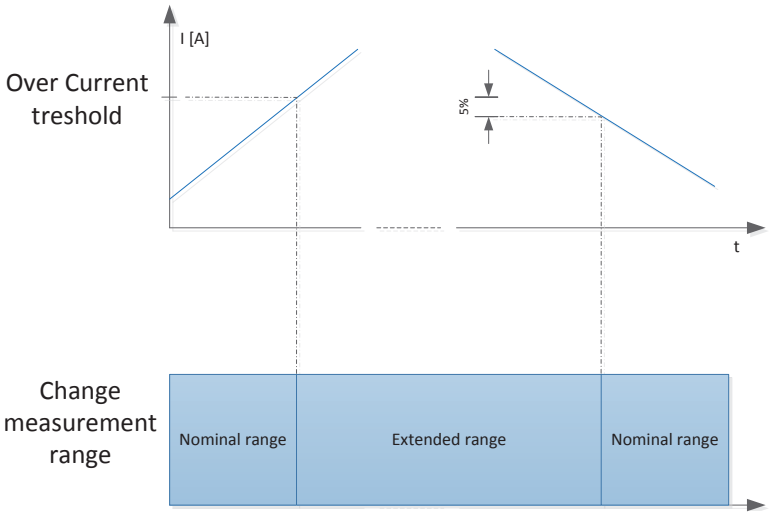
5.2 Overcurrent measurement

For overcurrent conditions the extended measurement range is used. As soon as the measured value exceeds the nominal range, the system switches over to the extended measurement range. The resolution decreases by factor 8. Switching back from the extended measurement range to the nominal range takes place when the lowest value in this measurement range is lower than 5 % of the nominal range. The extended measurement range is wider than the nominal measurement range by factor 8.

Figure 20: change measurement range



5.3 Temperature calibration

Each measurement result can be influenced by shifting temperature. For this reason, the IVT-MOD includes an internal temperature compensation to provide an optimized result in the complete defined temperature range.

5.4 Plausibility check (functional safety)

Since there are two independent ADC channels, the measured value from the first ADC channel is compared with the measured value from the second ADC channel. Both channels are also compared with the same bandgap (U_{ref}). Therefore a measurement drift between both channels, as well as a drift in the bandgap, can be detected. This plausibility check of the ADC provides a high reliability of the system over time and temperature. If there is a drift detected, a status byte within the result message is set to the corresponding issue.

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6. Technical Data

6.1 Operation conditions

Parameter	Min.	Typ.	Max. (max. rating)	Unit
Operating temperature	-40		+85 (+105)	°C
Storage temperature	-40		+125	°C
Supply voltage	5,5	12	16 (+28)	V
	9	24	40 (+60)	V
Current consumption [1]	20	<40	60	mA
Current consumption [2]	40	<60	95	mA
Re-/Startup time [3]		350	400	ms
Waiting time power on/off	2			ms
Isolation	According to chapter 4.1			

6.2 Current measurement

Parameter						Unit
Nominal measurement range (depends on the shunt)	±100	±300	±500	±1,000	±2,500	A
Power loss	<3	<9	<9	<20	<32	W
Overcurrent measurement range	±800	±2,500	±6,900	±12,200	±48,000	A
Extended load (max. time)						
5 min	±120	±320	±730	±1,100	±2,700	A
30 s	±200	±430	±860	±1,400	±3,200	A
10 s	±300	±600	±1,000	±2,000	±4,300	A
1 s	±900	±1,600	±2,700	±5,500	±11,300	A
200 ms	±2,000	±3,600	±6,000	±12,000	±24,000	A
Initial accuracy [5, 6]			±0.1			% rdg [4]
Total accuracy [5, 6]			±0.4			% rdg [4]
Offset	8	25	75	125	500	mA
Linearity [6]			0.01			% of range
Noise [7]	5	15	40	70	280	mA (rms)
Resolution	3	10	27	47	186	mA
Accuracy overcurrent range			± 3			%rdg [4]
Offset overcurrent range	60	200	540	940	3,720	mA
Linearity overcurrent range			0.1			% of range
Noise overcurrent range	40	120	320	560	2,240	mA (rms)
Resolution overcurrent range	24	80	216	376	1,488	mA

[1] without isolation
[2] with isolation
[3] depends on the modularity
[4] failure of reading
[5] with temperature calibration
[6] in nominal measurement range
[7] without averaging

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6.3 HV voltage measurement

Parameter	Min.	Typ.	Max.	Unit
Nominal measurement range		±600		V
Extended range (non linear)		±800		V
Initial accuracy [6, 9]		0.1		% rdg [5]
Total accuracy [6, 9]		0.6		% rdg [5]
Offset [9]		100		mV
Linearity [9]		0.01		% of range
Noise [7]		60		mV (rms)
Resolution		30		mV

[5] failure of reading, [6] with temperature calibration, [7] without averaging, [9] in nominal measurement range

6.4 Communication

Interface	Specification	Speed	Termination	Max. number of Unit
CAN	2.0 a	250kbit/s; 500kbits/s; 1Mbit/s	120R	6

Direction			Min.	Max.	Unit
V_{CC}	Supply voltage for CAN		4.75	5.25	V
V_I or V_{IC}	Voltage at any bus terminal (separately or common mode)		-12	12	V
V_{max}	Voltage at any bus terminal (max. rating)		-26	26	V
V_{IH}	High-level input voltage	TXD,S	2	5.25	V
V_{IL}	Low-level input voltage	TXD,S	0	0.8	V
V_{ID}	Differential input voltage		-6	6	V
I_{OH}	High-level output current	Driver		-70	mA
		Receiver		2	mA
I_{OL}	Low-level output current	Driver		+70	mA
		Receiver		2	mA

6.5. OCS and Trigger level

Type	Direction	Signal	Low level	High level	Max. output current
OCS	output	low active	<1 V	>2.5 V	15 mA (max. 4 kOhm; VCC)
Trigger	input	rising edge	<1 V	>2.5 V	

Description		Min.	Max.	Unit
Trigger ratings	Input voltage	0	28	V
	Trigger pulse width	200		µs
Regular trigger	The minimum time between two trigger signals to reliably detect a trigger. Depending on configured trigger interval Ti [ms]	Ti+2		ms
Re-trigger	The maximum time within an active trigger interval to reliably detect a retrigger. Depending on configured trigger interval Ti [ms]	0	Ti*0.5	ms
Overcurrent-Signal	Response delay on overcurrent	0	3	ms

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6.6. Connector

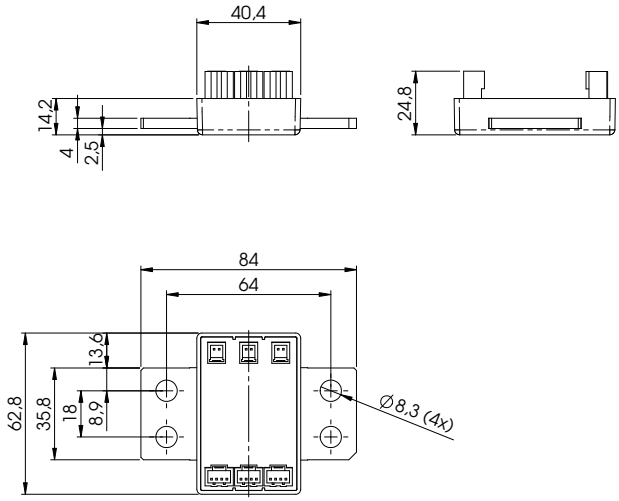
	Manufacturer	Type	No. of pins	Colour	Man. part no.
Modul connector	JST	JWPF	2	red	B02B-JWPF-RK-R (LF)(SN)
			4	black	B04B-JWPF-KK-R (LF)(SN)
Wire connector	JST	JWPF	2	red	02R-JWPF-VRLE-S
			4	black	04R-JWPF-VKLE-S
Crimp contact	JST		–	–	SWPR-001T-P025
CAN termination connector	ISA	JWPF	4	black	–

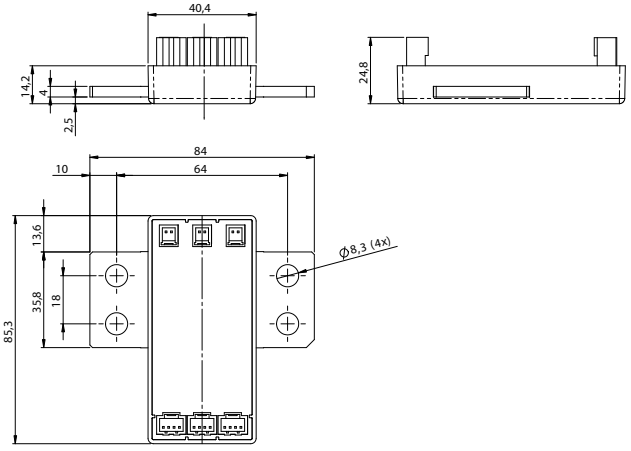
6.7 Mechanical dimension

IVT-MOD non-isolated

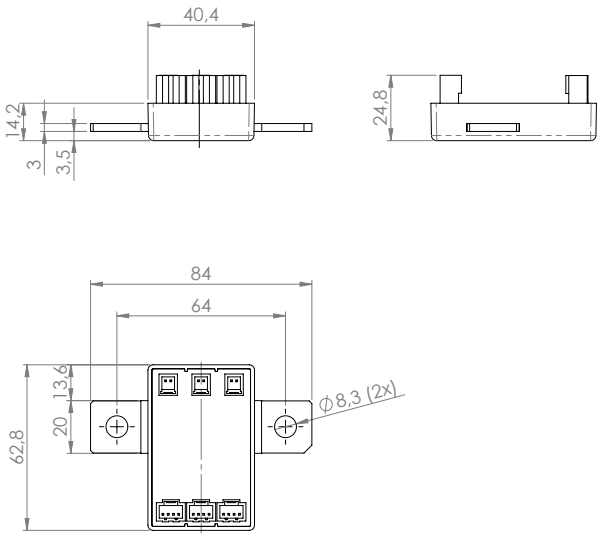
IVT-MOD isolated

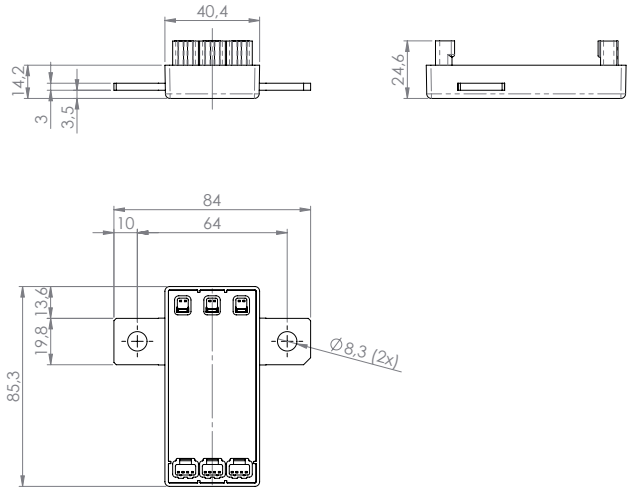
1,000 / 2,500 A





100 / 300 / 500 A





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6.8 Bus bar connection

The accuracy and repeatability of current measurement depends from the quality of the connection between customer's bus bar and the shunt bus bar. To ensure a good and useful connection between customer's bus bar and the shunt consider the following instructions:

- Mounting the IVT-MOD on a bus bar is highly recommended (instead of mounting a cable onto the shunt)
- Screwing the IVT-MOD on a bus bar by using all mounting holes, never use less than the available hole for screwing
- Always use screws with an outer diameter of 8 mm (M8), using smaller screws (e. g. M6 or M5) is NOT recommended
- Never use flat washers between the bus bar and the shunt!
- All screws using for mounting must be tightened with a torque as equal as possible!
- The recommended torque is 15 - 20 Nm
- Shunt and bus bar must be clean and free of grease

Figure 21: correct mounting 20 mm overlap

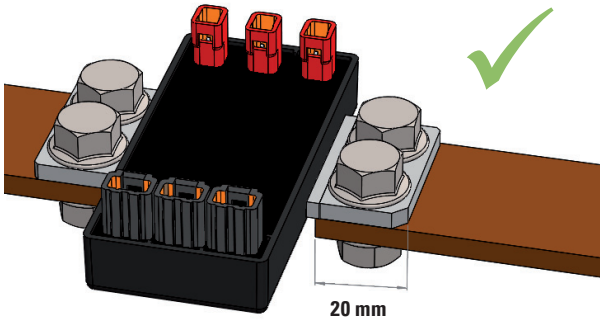


Figure 22: Incorrect mounting 15 mm overlap

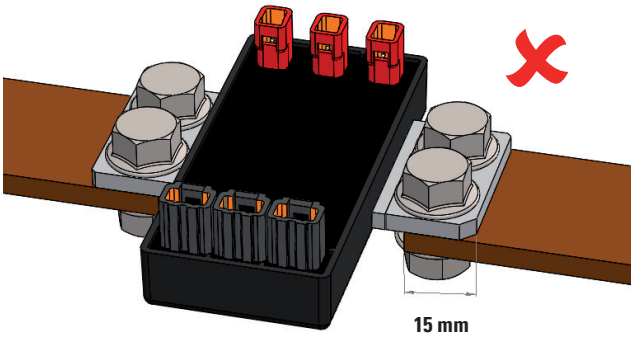


Figure 23: correct mounting 20 mm overlap

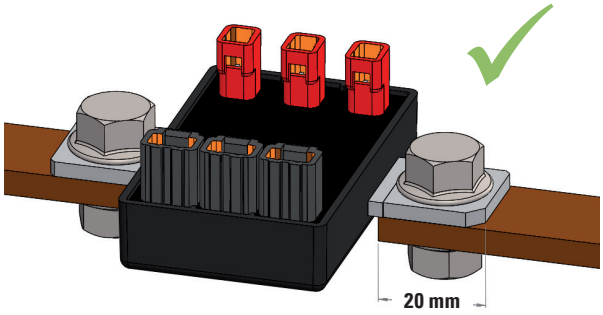
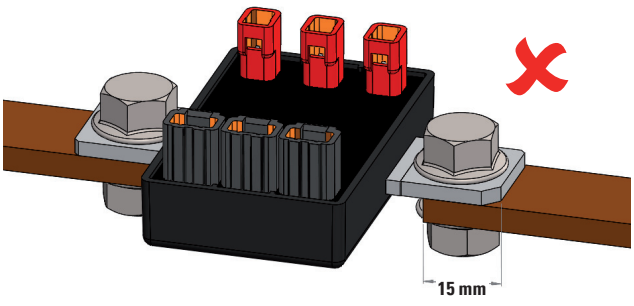


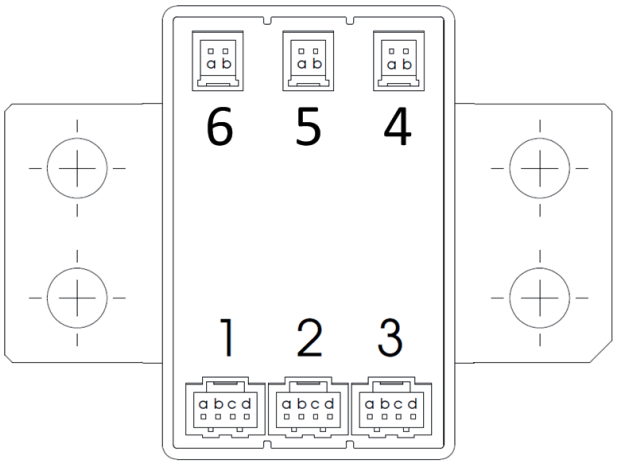
Figure 24: Incorrect mounting 15 mm overlap



IVT-MODULAR

6.9 Pin configuration (full modularity)

Figure 25: Pin configuration



PIN	Description	Remark (module or basic)
1 [9]	Power IN / CAN IN	Basic
a	VCC	
b	GND	
c	CAN L	
d	CAN H	
2 [9]	Power OUT / CAN OUT	Only for non internal CAN termination variation
a	VCC	Max. current on Power OUT < 500 mA
b	GND	
c	CAN L	
d	CAN H	
3	Trigger and OCS	Module
a	OCS	
b	Trigger	
c	OCS	c, d only present in case of non internal CAN termination
d	Trigger	
4 [10]		
a, b	Voltage measurement 1	U1 module (both pins internally shorted)
5 [10]		
a, b	Voltage measurement 2	U2 module (both pins internally shorted)
6 [10]		
a, b	Voltage measurement 3	U3 module (both pins internally shorted)

[9] There is no short-circuited protection between Connector 1 and Connector 2.
[10] High voltage Pin (reference to module ground (see module overview chapter 4))

Note:
There is no short circuit protection of the GND Line.
In case of wrong wiring the sensor can possibly be destroyed!

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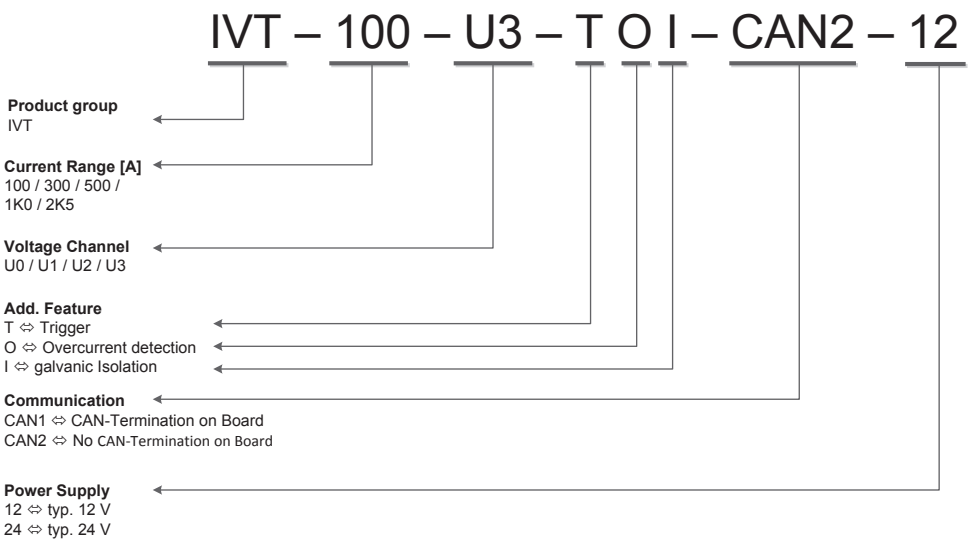
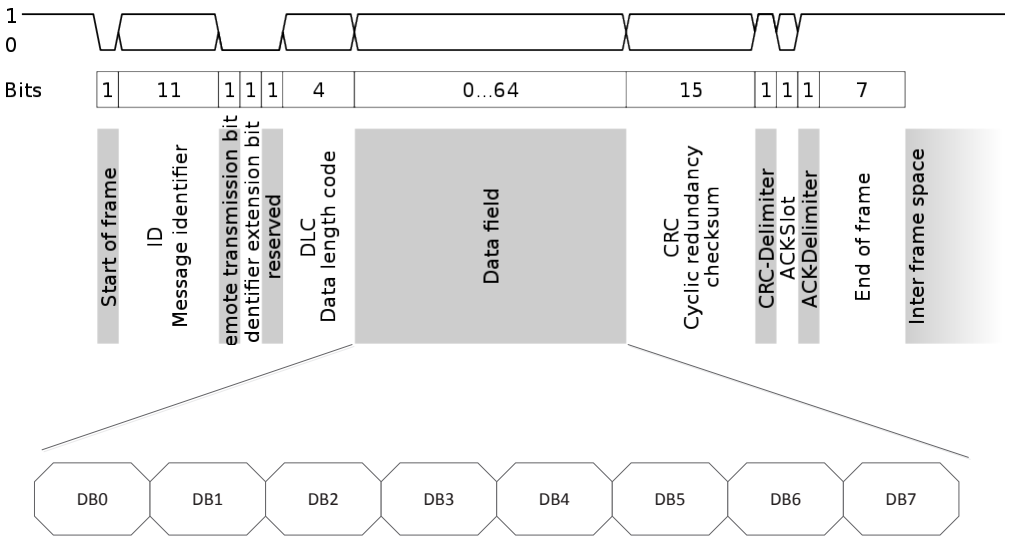
6.10 Part description



7. CAN-Protocol



Selectable bitrate

- 1,000,000 bit/s
- 500,000 bit/s
- 250,000 bit/s

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Default parameters
CAN bitrate = 500,000 bit/s

Signals	Mode	Time [ms]
Current	Cyclic	20
U1	Cyclic	60
U2	Cyclic	60
U3	Cyclic	60
T	Disable	100
W	Disable	30
As	Disable	30
Wh	Disable	30

Messages Overview

Description	Default CAN-ID	Length DLC	Remark
IVT_Msg_Command	0x411	8	Function commands, SET and GET commands. A command-ID-byte is included for identification.
IVT_Msg_Debug	0x510	8	Message only for internal use
IVT_Msg_Response	0x511	8	Response to SET and GET command messages. A response-ID-byte is included for identification.
IVT_Msg_Result_I	0x521	6	Current
IVT_Msg_Result_U1	0x522	6	Voltage 1
IVT_Msg_Result_U2	0x523	6	Voltage 2
IVT_Msg_Result_U3	0x524	6	Voltage 3
IVT_Msg_Result_T	0x525	6	Temperature
IVT_Msg_Result_W	0x526	6	Power (referring to current and voltage U1)
IVT_Msg_Result_As	0x527	6	Current counter
IVT_Msg_Result_Wh	0x528	6	Energy counter (referring to current and voltage U1)

- Not used bytes in response messages are undefined and reported as 0x00.
- Not used / undefined bytes in command messages must be set to 0x00.
- Each defined command will report its response message even if there was no change done or is currently not allowed (e.g. set configuration during run mode). This is done to give acknowledge to the sender.
- Consecutive commands must be sent not faster than 2 ms, or you can wait until the related response is sent.
- Response messages must be available on the bus (free bus) at least +500 ms after the related command, if not otherwise specified.
- If not otherwise mentioned byte orders are Big Endian.

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Multiplexable messages
All messages sent by the IVT will be uniquely identifiable by the first databyte sent as muxbyte.

DB0 (Muxbyte)	Remark
0x0n	Results (measured or calculated)
0x1n	Set CAN ID
0x2n	Set config result
0x3n	Set commands
0x4n	Get error/log data
0x5n	Get CAN ID
0x6n	Get config result
0x7n	Get commands
0x8n	Response on error/log data
0x9n	Responses on CAN ID
0xAn	Responses on Config Result
0xBn	Responses on Set and Get Commands
0xCn	--
0xDn	--
0xEn	--
0xF0 ::: 0xFE	--
0xFF	Response on not allowed message

7.1 Result messages

DB	Signal	Value	Description
0	MuxID	0x00 ... 0x07	Multiplexer, n = channel number
1 Low nibble	IVT_MsgCount	0x0 ... 0xF	Cyclic counter individually for each channel
1 High nibble	IVT_Resulte_state	0b0000 ... 0b1111	bit 0: set if OCS is true bit 1: set if - this result is out of (spec-) range - this result has reduced precision - this result has a measurement-error bit 2: set if - any result has a measurement-error bit 3: set if - system-error, sensor functionality is not ensured!
2 ... 5	IVT_<Resultname>		All results as signed long, see configuration

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MuxID DESCRIPTION FOR IVT_MSG_RESULT

MuxID	Resultname	Unit
0x00	IVT_Msg_Result_I	1 mA
0x01	IVT_Msg_Result_U1	1 mV
0x02	IVT_Msg_Result_U2	1 mV
0x03	IVT_Msg_Result_U3	1 mV
0x04	IVT_Msg_Result_T	0.1 °C
0x05	IVT_Msg_Result_W	1 W
0x06	IVT_Msg_Result_As	1 As
0x07	IVT_Msg_Result_Wh	1 Wh

Examples:
Default configured as "big Endian" (see Config Result)

Example for results:

DB 0	DB 1	DB 2	DB 3	DB 4	DB 5
0x01	0x05	0x00	0x00	0x88	0xb8

Decode the message:

Byte(s)	Value	Information
DB 0	0x01	IVT_Msg_Result_U1
DB 1 – High byte	0x0	state bits = 0
DB 1 – Low byte	0x5	Message number 5
DB 2 to DB 5	0x000088b8	35,000 mV

Optionally configured as "little Endian" (see Config Result)

Example for results:

DB 0	DB 1	DB 2	DB 3	DB 4	DB 5
0x01	0x05	0xb8	0x88	0x00	0x00

Decode the message:

Byte(s)	Value	Information
DB 0	0x01	IVT_Msg_Result_U1
DB 1 – High byte	0x0	state bits = 0
DB 1 – Low byte	0x5	Message number 5
DB 2 to DB 5	0xb8880000	35,000 mV

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7.2 Set CAN ID

Command "Set CAN ID"

DB	Value	Remark
0		Indicates which message type is being changed:
	0x10	IVT_Msg_Result_I
	0x11	IVT_Msg_Result_U1
	0x12	IVT_Msg_Result_U2
	0x13	IVT_Msg_Result_U3
	0x14	IVT_Msg_Result_T
	0x15	IVT_Msg_Result_W
	0x16	IVT_Msg_Result_As
	0x17	IVT_Msg_Result_Wh
	0x1D	IVT_Msg_Command
	0x1F	IVT_Msg_Response
1	0 … 0x07	High byte of desired 11 bit CAN ID
2	0 … 0xFF	Low byte of desired 11 bit CAN ID
3	0x00 … 0xFF	High byte of 32-bit serial number
4	0x00 … 0xFF	Mid-high byte of 32-bit serial number
5	0x00 … 0xFF	Mid-low byte of 32-bit serial number
6	0x00 … 0xFF	Low byte of 32-bit serial number

Configuration only in Stop-Mode

7.3 Config result

Set config result

DB	Value	Remark
0	0x2n	Set configuration of measurement. "n" represents the according result (e. g. 3 = IVT_Msg_Result_U3).
1 Low nibble		Trigger mode:
	0x0	Disabled
	0x1	Triggered
	0x2	Cyclic running
1 High nibble		Config result flags in high byte
	0bnnn1	Bit 4: for future use
	0bnn1n	Bit 5: for future use
	0bn1nn	Bit 6: endianess, 0: Big Endian (default), 1: Little Endian
	0b1nnn	Bit 7: sign unchanged (default), 1=sign is changed (+ <-> -)
2 - 3	0xnnnn	Output-cycle-time / Measurement-interval / Trigger delay [ms] (+/- 10%) - 0x0000 is ignored. // Trigger delay begins at 1ms

Configuration only in Stop-Mode

IVT-MODULAR

Output and measurement configuration details:

DB 0 (n)	Signals	Default MODE	Default TIME [ms]	Min TIME [ms]	Description
0	Current	Cyclic	20	1	output-cycle-time = Measurement-interval
1	U1	Cyclic	60	3	output-cycle-time = Measurement-interval (depending on configuration of U1 ... U3)
2	U2	Cyclic	60	3	output-cycle-time = Measurement-interval (depending on configuration of U1 ... U3)
3	U3	Cyclic	60	3	output-cycle-time = Measurement-interval (depending on configuration of U1 ... U3)
4	T	Disable	100	1	Output-cycle-time, Measurement-interval = **100 ms**
5	W_{U1}	Disable	30	1	Output-cycle-time, Measurement-interval = **30 ms**
6	As	Disable	30	1	Output-cycle-time, Measurement-interval = **30 ms**
7	Wh_{U1}	Disable	30	1	Output-cycle-time, Measurement-interval = **30 ms**

- *Min Time for three configured voltage result messages*
- *The configuration has to ensure that the maximum output rate of all messages shall not exceed 1,000 messages per second. Otherwise the data calculation for As, Wh and Log data can be influenced.*

7.4 Set commands

Set commands without restart

Command "Reset Error- and Logdata"

DB	Value	Remark
0	0x30	Reset Error- and Logdata
1	0x00	Reset "Measurement Error"
	0x01	Reset "System Error"
	0x02	Reset "Logdata Since Reset"
2	0x00	All Counters reset
	0x01 ... 0xFF	DB1 of corresponding Error or Logdata value to be cleared
3 - 6	0xnnnnnnnn	Serial-number

- *Command only in Stop-Mode*
- *Response message at least +1,200 ms after command*

Set commands without restart

Command "TRIGGER"

DB	Value	Remark
0	0x31	Triggers a measurement cycle
1 - 2	0xnnnn	Bit field for channel to trigger, 0-unselected 1-selected
	0b0000 0000 xxxx xxx1	IVT_Msg_Result_I
	0b0000 0000 xxxx xx1x	IVT_Msg_Result_U1
	0b0000 0000 xxxx x1xx	IVT_Msg_Result_U2
	0b0000 0000 xxxx 1xxx	IVT_Msg_Result_U3
	0b0000 0000 xxx1 xxxx	IVT_Msg_Result_T
	0b0000 0000 xx1x xxxx	IVT_Msg_Result_W
	0b0000 0000 x1xx xxxx	IVT_Msg_Result_As
	0b0000 0000 1xxx xxxx	IVT_Msg_Result_Wh

- *Command available only in Run-Mode*

IVT-MODULAR

Command "STORE"

DB	Value	Remark
0	0x32	All configured items are stored to nonvolatile memory. -Measurement configurations -Overcurrent thresholds -Startup Mode -Can-IDs -Baud rate

- *The storing process is only completed if the related response message is sent by module, up to +1,000 ms depending on amount of data to store.*
- *No further commands are allowed if storing is in progress.*
- *Remark: The storing command is only available during Module is in stop mode*

Command "START_OC_TEST"

DB	Value	Remark
0	0x33	Test the OC signal
1+2	0 ... 65535	Duration of the OC signal in ms

- *Command only in Stop-Mode*

Command "SET_MODE"

Mode means the whole sensor (config means the result message)

DB	Value	Remark
0	0x34	Set operation mode
1		Actual Mode (valid until next reset)
	0x00	Stop
	0x01	Run
2		Startup operation mode (STORE command required before reset)
	0x00	Stop
	0x01	Run
3+4		Code for level of access for future use
	0x0000	User
	0xnnnn	Expert (nnnn = access key) for further use only
	0xyyyy	OEM customer (yyyy = access key) for further use only

- *Retrievable in STOP- and RUN-mode*

Command "SET_THRESHOLD_POS"

DB	Value	Remark
0	0x35	Set overcurrent thresholds positive current direction
1+2	-32,768 … +32,767	Overcurrent set threshold in 1A-steps 0 means off (default)
3+4	-32,768 … +32,767	Overcurrent reset threshold in 1A-steps 0 means off

- *Command only in Stop-Mode*

IVT-MODULAR

Command "SET_THRESHOLD_NEG"

DB	Value	Remark
0	0x36	Set overcurrent thresholds negative current direction
1+2	-32,768 … +32,767	Overcurrent set threshold in 1A-steps 0 means off (default)
3+4	-32,768 … +32,767	Overcurrent reset threshold in 1A-steps 0 means off

- *Command only in Stop-Mode*

Set commands with restart

Command "RESTART_TO_BITRATE"

DB	Value	Remark
0	0x3A	Restart to configured Bitrate
1		Bitrate acc. to pre-scaler:
	0x08	250 k
	0x04	500 k (default)
	0x02	1,000 k

- *Bitrate is automatically stored before reboot. This may take additional time (up to 1 s) which must be added to the following startup time.*
- *Command only in Stop-Mode*

Command "RESTART_TO_DEFAULT"

DB	Value	Remark
0	0x3D	Restart_to_default

- *Command only in Stop-Mode*

Command "RESTART"

DB	Value	Remark
0	0x3F	Restart

- *Retrievable in STOP- and RUN-mode*

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7.5 Get error logdata

Get measurement errors

DB	Value	Remark
0	0x40	Get measurement errors
1	0x00	Get bitmask of occurred measurement errors (specific counter != 0)
		Get specific Error Counter (Positive edge of error state cause up counting):
	0x01	Error ADC interrupt
	0x02	Error Overflow ADC channel 1
	0x03	Error Underflow ADC channel 1
	0x04	Error Overflow ADC channel 2
	0x05	Error Underflow ADC channel 2
	0x06	Error V_{ref}
	0x07	Error current measurement implausible I1 – I2 (check in nominal range)
	0x08	Error thermal EMF correction
	0x09	Error current measurement I1 open circuit
	0x0a	Error voltage measurement U1 open circuit
	0x0b	Error voltage measurement U2 open circuit
	0x0c	Error voltage measurement U3 open circuit
	0x0d	Error ntc-h open circuit
	0x0e	Error ntc-l open circuit
	0x0f	Error calibration data (offset-, gain error to high)

- *Retrievable in STOP- and RUN-mode*

Get system errors

DB	Value	Remark
0	0x41	Get system errors
1	0x00	Get bitmask of occurred measurement errors (specific counter != 0)
		Get specific Error Counter (Positive edge of error state cause up counting):
	0x01	Error Code CRC
	0x02	Error Parameter CRC
	0x03	Error CAN bus receive data
	0x04	Error CAN bus transmit data
	0x05	Error overtemp
	0x06	Error undertemp
	0x07	Error power failure
	0x08	Error system clock
	0x09	Error system init
	0x0a	Error configuration
	0x0b	Error overcurrent detection
	0x0c	Error eeprom r/w
	0x0d	Error ADC Clock
	0x0e	Error Reset illegal opcode
	0x0f	Error Reset Watchdog
	0x10	Error Reset EMC

- *Retrievable in STOP- and RUN-mode*

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7.6 Get Overall Logdata (reset only by ISA)

DB	Value	Remark
0	0x42	Get Overall Logdata
	–	Get details of Logdata:
	0x01	Ampere hour counter overall (As)
	0x02	Ampere hour counter charging (As)
	0x03	Ampere hour counter discharging (As)
	0x04	Energy counter overall (Wh)
	0x05	Energy counter charging (Wh)
	0x06	Energy counter discharging (Wh)
	0x10	Runtime overall (s)
	0x11	Runtime current within specified limits (s)
	0x12	Runtime current outside specified limits (s)
	0x13	Runtime voltage 1 within specified limits (s)
	0x14	Runtime voltage 1 outside specified limits (s)
	0x15	Runtime voltage 2 within specified limits (s)
	0x16	Runtime voltage 2 outside specified limits (s)
	0x17	Runtime voltage 3 within specified limits (s)
1	0x18	Runtime voltage 3 outside specified limits (s)
	0x19	Runtime temperature within specified limits (s)
	0x1A	Runtime temperature outside specified limits (s)
	0x1B	Runtime overcurrent positive activated (s)
	0x1C	Runtime overcurrent negative activated (s)
	0x21	Current maximum (A)
	0x22	Current minimum (A)
	0x23	U1 maximum (V)
	0x24	U1 minimum (V)
	0x25	U2 maximum (V)
	0x26	U2 minimum (V)
	0x27	U3 maximum (V)
	0x28	U3 minimum (V)
	0x29	Temperature maximum (°C)
	0x2A	Temperature minimum (°C)

- *Retrievable in STOP- and RUN-mode*

IVT-MODULAR

Get Logdata Since Reset (Reset by using command)

DB	Value	Remark
0	0x43	Get Logdata Since Reset
1	–	Get details of Logdata:
	0x01	Ampere hour counter overall (As)
	0x02	Ampere hour counter charging (As)
	0x03	Ampere hour counter discharging (As)
	0x04	Energy counter overall (Wh)
	0x05	Energy counter charging (Wh)
	0x06	Energy counter discharging (Wh)
	0x10	Runtime overall (s)
	0x11	Runtime current within specified limits (s)
	0x12	Runtime current outside specified limits (s)
	0x13	Runtime voltage 1 within specified limits (s)
	0x14	Runtime voltage 1 outside specified limits (s)
	0x15	Runtime voltage 2 within specified limits (s)
	0x16	Runtime voltage 2 outside specified limits (s)
	0x17	Runtime voltage 3 within specified limits (s)
	0x18	Runtime voltage 3 outside specified limits (s)
	0x19	Runtime temperature within specified limits (s)
	0x1A	Runtime temperature outside specified limits (s)
	0x1B	Runtime overcurrent positive activated (s)
	0x1C	Runtime overcurrent negative activated (s)
	0x21	Current maximum (A)
	0x22	Current minimum (A)
	0x23	U1 maximum (V)
	0x24	U1 minimum (V)
	0x25	U2 maximum (V)
	0x26	U2 minimum (V)
	0x27	U3 maximum (V)
	0x28	U3 minimum (V)
	0x29	Temperature maximum (°C)
	0x2A	Temperature minimum (°C)

- *Retrievable in STOP- and RUN-mode*

IVT-MODULAR

7.7 Get CAN ID

DB	Value	Remark
		Indicates which message type is requested
	0x50	IVT_Msg_Result_I
	0x51	IVT_Msg_Result_U1
	0x52	IVT_Msg_Result_U2
	0x53	IVT_Msg_Result_U3
0	0x54	IVT_Msg_Result_T
	0x55	IVT_Msg_Result_W
	0x56	IVT_Msg_Result_As
	0x57	IVT_Msg_Result_Wh
	0x5D	IVT_Msg_Command
	0x5F	IVT_Msg_Response
1	0 … 0x00	Ignored
2	0 … 0x00	Ignored
3	0x00 … 0xFF	High byte of 32-bit serial number
4	0x00 … 0xFF	Mid-high byte of 32-bit serial number
5	0x00 … 0xFF	Mid-low byte of 32-bit serial number
6	0x00 … 0xFF	Low byte of 32-bit serial number

- *Retrievable in STOP- and RUN-mode*

7.8 Get Config Result

DB	Value	Remark
		Get Config
	0x60	Result_I
	0x61	Result_U1
	0x62	Result_U2
0	0x63	Result_U3
	0x64	Result_T
	0x65	Result_W
	0x66	Result_As
	0x67	Result_Wh

- *Retrievable in STOP- and RUN-mode*

7.9 Get commands and Info's without corresponding set-commands

DB	Value	Command	Remark
	0x73	GET_OC_TESTTIME	Get the remaining OC_TESTTIME
	0x74	GET_MODE	Get the operation mode setting
	0x75	GET_THRESHOLD_POS	Get the configuration of overcurrent thresholds Pos
	0x76	GET_THRESHOLD_ NEG	Get the configuration of overcurrent thresholds Neg
0	0x79	GET_DEVICE_ID	Get the device ID
	0x7A	GET_SW_VERSION	Get the software version
	0x7B	GET_SERIAL_NUMBER	Get the serial number
	0x7C	GET_ARTICLE_NUMBER	Get the article number

- *Retrievable in STOP- and RUN-mode*

IVT-MODULAR

7.10. Responses on Error- and Logdata

DB	Value	Remark
0	0x80	Response measurement errors
1	0x00	Response bitmask of occurred measurement errors (specific counter != 0)
2		Bits 0 ... 7 of measurement errors
	0b00000001	Error ADC interrupt
	0b00000010	Error Overflow ADC channel 1
	0b00000100	Error Underflow ADC channel 1
	0b00001000	Error Overflow ADC channel 2
	0b00010000	Error Underflow ADC channel 2
	0b00100000	Error V_{ref}
	0b01000000	Error current measurement implausible I1 – I2
	0b10000000	Error thermal EMF correction
3		Bits 0 ... 7 of measurement errors
	0b00000001	Error current measurement I1 open circuit
	0b00000010	Error voltage measurement U1 open circuit
	0b00000100	Error voltage measurement U2 open circuit
	0b00001000	Error voltage measurement U3 open circuit
	0b00010000	Error ntc-h open circuit
	0b00100000	Error ntc-l open circuit
	0b01000000	Error calibration data (offset-, gain error to high)

- *Retrievable in STOP- and RUN-mode, depends on get command DB1*

DB	Value	Remark
0	0x80	Response measurement errors
1		Specific Error Counter
	0x01	Error ADC interrupt
	0x02	Error Overflow ADC channel 1
	0x03	Error Underflow ADC channel 1
	0x04	Error Overflow ADC channel 2
	0x05	Error Underflow ADC channel 2
	0x06	Error V_{ref}
	0x07	Error current measurement implausible I1 – I2
	0x08	Error thermal EMF correction
	0x09	Error current measurement I1 open circuit
	0x0a	Error voltage measurement U1 open circuit
	0x0b	Error voltage measurement U2 open circuit
	0x0c	Error voltage measurement U3 open circuit
	0x0d	Error ntc-h open circuit
	0x0e	Error ntc-l open circuit
	0x0f	Error calibration data (offset-, gain error to high)
2	0xnn	Number of occurred errors (max. 256)

- *Retrievable in STOP- and RUN-mode, depends on get command DB1*

IVT-MODULAR

Response on system errors

DB	Value	Remark
0	0x81	Response system errors
1	0x00	Response bitmask of occurred measurement errors (specific counter != 0)
		Bits 0 ... 7 of measurement errors
	0b00000001	Error Code CRC
	0b00000010	Error Parameter CRC
	0b00000100	Error CAN bus receive Data
2	0b00001000	Error CAN bus transmit Data
	0b00010000	Error overtemp
	0b00100000	Error undertemp
	0b01000000	Error power failure
	0b10000000	Error system clock
		Bits 0 ... 7 of measurement errors
	0b00000001	Error system init
	0b00000010	Error configuration
	0b00000100	Error overcurrent detection
3	0b00001000	Error eeprom r/w
	0b00010000	Error ADC Clock
	0b00100000	Error Reset illegal opcode
	0b01000000	Error Reset Watchdog
	0b10000000	Error Reset EMC

- *Retrievable in STOP- and RUN-mode, depends on get command DB1*

DB	Value	Remark
0	0x81	Response system errors
		Specific Error Counter
	0x01	Error Code CRC
	0x02	Error Parameter CRC
	0x03	Error CAN bus receive Data
	0x04	Error CAN bus transmit Data
	0x05	Error overtemp
	0x06	Error undertemp
	0x07	Error power failure
1	0x08	Error system clock
	0x09	Error system init
	0x0a	Error configuration
	0x0b	Error overcurrent detection
	0x0c	Error eeprom r/w
	0x0d	Error ADC Clock
	0x0e	Error Reset illegal opcode
	0x0f	Error Reset Watchdog
	0x10	Error Reset EMC
2	0xnn	Number of occurred errors (max. 256)

- *Retrievable in STOP- and RUN-mode, depends on get command DB1*

IVT-MODULAR

Response on Overall Logdata

DB	Value	Remark
0	0x82	Response on Overall Logdata
1	–	Details of Logdata:
	0x01	Ampere hour counter overall (As)
	0x02	Ampere hour counter charging (As)
	0x03	Ampere hour counter discharging (As)
	0x04	Energy counter overall (Wh)
	0x05	Energy counter charging (Wh)
	0x06	Energy counter discharging (Wh)
	0x10	Runtime overall (s)
	0x11	Runtime current within specified limits (s)
	0x12	Runtime current outside specified limits (s)
	0x13	Runtime voltage 1 within specified limits (s)
	0x14	Runtime voltage 1 outside specified limits (s)
	0x15	Runtime voltage 2 within specified limits (s)
	0x16	Runtime voltage 2 outside specified limits (s)
	0x17	Runtime voltage 3 within specified limits (s)
	0x18	Runtime voltage 3 outside specified limits (s)
	0x19	Runtime temperature within specified limits (s)
	0x1A	Runtime temperature outside specified limits (s)
	0x1B	Runtime overcurrent positive activated (s)
	0x1C	Runtime overcurrent negative activated (s)
	0x21	Current maximum (A)
	0x22	Current minimum (A)
	0x23	U1 maximum (V)
	0x24	U1 minimum (V)
	0x25	U2 maximum (V)
	0x26	U2 minimum (V)
	0x27	U3 maximum (V)
	0x28	U3 minimum (V)
	0x29	Temperature maximum (°C)
	0x2A	Temperature minimum (°C)
2	0x00 ... 0xFF	Highest byte of Logdata value (see signal definition)
3	0x00 ... 0xFF	–
4	0x00 ... 0xFF	–
5	0x00 ... 0xFF	–
6	0x00 ... 0xFF	–
7	0x00 ... 0xFF	Lowest byte of Logdata value (see signal definition)

IVT-MODULAR

Response on Logdata Since Reset

DB	Value	Remark
0	0x83	Response on Logdata Since Reset
1	–	Details of Logdata:
	0x01	Ampere hour counter overall (As)
	0x02	Ampere hour counter charging (As)
	0x03	Ampere hour counter discharging (As)
	0x04	Energy counter overall (Wh)
	0x05	Energy counter charging (Wh)
	0x06	Energy counter discharging (Wh)
	0x10	Runtime overall (s)
	0x11	Runtime current within specified limits (s)
	0x12	Runtime current outside specified limits (s)
	0x13	Runtime voltage 1 within specified limits (s)
	0x14	Runtime voltage 1 outside specified limits (s)
	0x15	Runtime voltage 2 within specified limits (s)
	0x16	Runtime voltage 2 outside specified limits (s)
	0x17	Runtime voltage 3 within specified limits (s)
	0x18	Runtime voltage 3 outside specified limits (s)
	0x19	Runtime temperature within specified limits (s)
	0x1A	Runtime temperature outside specified limits (s)
	0x1B	Runtime overcurrent positive activated (s)
	0x1C	Runtime overcurrent negative activated (s)
	0x21	Current maximum (A)
	0x22	Current minimum (A)
	0x23	U1 maximum (V)
	0x24	U1 minimum (V)
	0x25	U2 maximum (V)
	0x26	U2 minimum (V)
	0x27	U3 maximum (V)
	0x28	U3 minimum (V)
	0x29	Temperature maximum (°C)
	0x2A	Temperature minimum (°C)
2	0x00 ... 0xFF	Highest byte of Logdata value (see signal definition)
3	0x00 ... 0xFF	–
4	0x00 ... 0xFF	–
5	0x00 ... 0xFF	–
6	0x00 ... 0xFF	–
7	0x00 ... 0xFF	Lowest byte of Logdata value (see signal definition)

IVT-MODULAR

7.11 Response "CAN_ID"

DB	Value	Remark
0		Indicates which message type is being changed:
	0x90	IVT_Msg_Result_I
	0x91	IVT_Msg_Result_U1
	0x92	IVT_Msg_Result_U2
	0x93	IVT_Msg_Result_U3
	0x94	IVT_Msg_Result_T
	0x95	IVT_Msg_Result_W
	0x96	IVT_Msg_Result_As
	0x97	IVT_Msg_Result_Wh
	0x9D	IVT_Msg_Command
	0x9F	IVT_Msg_Response
1	0 … 0x07	High byte of desired 11 bit CAN ID
2	0 … 0xFF	Low byte of desired 11 bit CAN ID
3	0x00 … 0xFF	High byte of 32-bit serial number
4	0x00 … 0xFF	Mid-high byte of 32-bit serial number
5	0x00 … 0xFF	Mid-low byte of 32-bit serial number
6	0x00 … 0xFF	Low byte of 32-bit serial number

7.12. Response "CONFIG RESULT"

DB	Value	Remark
0	0xAn	Response configuration of measurement n represents the According result (e.g. 3 = IVT_Msg_Result_U3)
1 Low byte		Trigger mode:
	0x0	Disabled
	0x1	Triggered
	0x2	Cyclic running
1 High byte		Config result
	0bnnn1	Bit 4: for future use
	0bnn1n	Bit 5: for future use
	0bn1nn	Bit 6: endianess, 0: Big Endian (default), 1: Little Endian
	0b1nnn	Bit 7: sign of result, 0: default, 1: sign is changed (+ <-> -), changes polarity (+ <-> -),
2 - 3	0xnnnn	output-cycle-time / Measurement-interval / Trigger delay [ms] (+/- 10%)

IVT-MODULAR

7.11 Response on Get and Set commands

Response messages are sent by the sensor as a response to a SET or GET command message. The response to a SET command works just like the response to a GET command.

Response "RESET ERROR- AND LOGDATA"

DB	Value	Remark
0	0xB0	Response Logdata
1	0x00	Reset "Measurement Error"
	0x01	Reset "System Error"
	0x02	Reset "Logdata Since Reset"
2	0x00	All Counters reset
	0x01 .. 0xFF	DB1 of corresponding Error or Logdata value to be cleared
3 - 6	0xnnnnnnnn	Serial number

Response "TRIGGER"

DB	Value	Remark
0	0xB1	Response Trigger
1 - 2	0b0000 0000 nnnn nnnn	Bit field for Channel to trigger, 0-unselected 1-selected, -all other bits are undefined and must be set to 0

Response "STORE"

DB	Value	Remark
0	0xB2	Response STORE (Response after successful writing to non-volatile memory)
1	0xnn	0 = OK, Error else
2	0x00 … 0xFF	High byte of 32-bit serial number
3	0x00 … 0xFF	Mid-high byte of 32-bit serial number
4	0x00 … 0xFF	Mid-low byte of 32-bit serial number
5	0x00 … 0xFF	Low byte of 32-bit-serial number

Response "OC_TEST"

DB	Value	Remark
0	0xB3	Response OC-Test
1+2	0 ... 65535	Remaining OC-Test time (ms)

Response "MODE"

Mode means the whole sensor (config means the result message)

DB	Value	Remark
0	0xB4	Response operation mode
1	0x00	Stop
	0x01	Run
2		Startup operation mode
	0x00	Stop
	0x01	Run
3+4		Code for level of access for future use
	0x0000	User
	0xnnnn	Expert (nnnn = access key)
	0xyyyy	OEM customer (yyyy = access key)

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Response "THRESHOLD_POS"

DB	Value	Remark
0	0xB5	Response overcurrent thresholds positive current direction
1+2	-32,767 … +32,767	Overcurrent set threshold in 1A-steps, 0 means off
3+4	-32,767 … +32,767	Overcurrent reset threshold in 1A-steps, 0 means off

Response "THRESHOLD_NEG"

DB	Value	Remark
0	0xB6	Response overcurrent thresholds negative current direction
1+2	-32,767 … +32,767	Overcurrent set threshold in 1A-steps, 0 means off
3+4	-32,767 … +32,767	Overcurrent reset threshold in 1A-steps, 0 means off

Response "DEVICE_ID"

DB	Value	Remark
0	0xB9	Response DEVICE_ID
1		Device-type
	0x01	1 = IVT-Mod
2		I-nominal / 16
	0x06	100 A
	0x12	300 A
	0x1F	500 A
	0x3E	1,000 A
	0x9C	2,500 A
3 High nibble		I-nominal % 16
	0x4	100 A
	0xC	300 A
	0x4	500 A
	0x8	1,000 A
	0x4	2,500 A
3 low nibble		Number of Voltage Channels
	0x0	0 channels
	0x1	1 channel
	0x2	2 channel
	0x3	3 channel
4		Trigger (T) / OCS(O) / Isolation(I) / -(none)
	0x00	–
	0x01	T
	0x02	O
	0x03	I
	0x04	TO
	0x05	TI
	0x06	OI
	0x07	TOI
5		Type of communication
	0x00	– (none)
	0x01	CAN1 (termination)
	0x02	CAN2 (no termination)
6	0xnn	nn nominal supply voltage [V]

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Response "SW_VERSION"

DB	Value	Remark
0	0xBA	Response SW_VERSION
1		Hardware variant
	0xn000 0000 ... 0xn111 1111	0: illegal version
	0b1nnn nnnn	Bit mask: Represents a debug version if set
2	0x00 … 0xFF	VERSION_NR 0 … 255
3	0x00 … 0xFF	VERSION_REV 0 … 255
4	0x00 … 0xFF	VERSION_YY Year
5	0x00 … 0xFF	VERSION_MM Month
6	0x00 … 0xFF	VERSION_DD Day
7	0x00 … 0xFF	Internal use

Response "SERIAL_NUMBER"

DB	Value	Remark
0	0xBB	Response serial number
1	0x00 … 0xFF	High byte serial number
2	0x00 … 0xFF	Mid-high byte serial number
3	0x00 … 0xFF	Mid-low byte serial number
4	0x00 … 0xFF	Low byte serial number

Response "ARTICLE_NUMBER"

DB	Value	Remark
0	0xBC	Response article number
1	0x00 … 0xFF	High byte article number
2	0x00 … 0xFF	–
3	0x00 … 0xFF	–
4	0x00 … 0xFF	–
5	0x00 … 0xFF	–
6	0x00 … 0xFF	–
7	0x00 … 0xFF	Low byte article number

Errormessage

DB	Value	Remark
0	0xFF	Not allowed command, or not otherwise specified
1	0x00 … 0xFF	MUX ID of invalid command

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8. Startup

During Startup, the Sensor performs several internal tests to ensure the system functionality.
These are:

- CPU Register check
- RAM test
- CPU clock test
- Boot-loader Flash test CRC
- App-Flash test CRC
- Calibration Parameter test CRC
- User parameter test CRC

Startup behavior (Alive message)

DB	Value	Remark
0	0xBF	Alive message after start-up (sensor ready for communication)
1	0x00 … 0x07	Command ID (high byte)
2	0x00 … 0xFF	Command ID (low byte)
3	0x00 … 0xFF	High byte serial number
4	0x00 … 0xFF	Mid-high byte serial number
5	0x00 … 0xFF	Mid-low byte serial number
6	0x00 … 0xFF	Low byte serial number

9. Qualification

The sensor is qualified in accordance to MBM-LV124, ISO7637-2, CISPR25 and ISO 16750 (automotive grade, modified tests / scope possible). The qualification was carried out with the modular encapsulation concept, which guarantees a maximum in flexibility and modularity. In case of very rough environmental conditions it may be necessary to adapt the encapsulation of the sensor.
Depending on the special environmental conditions different encapsulation concepts are available, on customer request.

IVT-MODULAR

9.1. Qualification Summary EMC

ESD immunity

Modularity	Standard	Test description	Result
Isolated 24 V / non isolated 12 V	ISO 10605:2008	Direct discharge (contact), +/-8 kV, unpowered	Status I
Isolated 24 V / non isolated 12 V	ISO 10605:2008	Direct discharge (air), +/-15 kV, unpowered	Status I
Isolated 24 V / non isolated 12 V (1kA, 2,5kA)	ISO 10605:2008	Indirect discharge (contact), +/-8 kV, powered	Status I
non isolated 12 V (100A, 300A, 500A)	ISO 10605:2008	Indirect discharge (contact), +/-8 kV, powered	Status II
Isolated 24 V / non isolated 12 V (1kA, 2,5kA)	ISO 10605:2008	Direct discharge (air), +/-8 kV, powered	Status II
non isolated 12 V (100A, 300A, 500A)	ISO 10605:2008	Direct discharge (air), +/-8 kV, powered	Status I
Isolated 24 V, non isolated 12 V (100A, 300A, 500A)	ISO 10605:2008	Direct discharge (contact), +/-15 kV, powered	Status II
Non Isolated 12 V (1kA, 2,5kA)	ISO 10605:2008	Direct discharge (contact), +/-15 kV, powered	Status II

Immunity to radiated electromagnetic fields

Modularity	Standard	Test description	Result
Isolated 24 V / non isolated 12 V	ISO 11452-2:2004	80 MHz – 400 MHz, vertical, 50 V/m, AM	Passed
Isolated 24 V / non isolated 12 V	ISO 11452-2:2004	400 MHz – 800 MHz, vertical, 50 V/m, AM	Passed
Isolated 24 V / non isolated 12 V	ISO 11452-2:2004	400 MHz – 800 MHz, horizontal, 50 V/m, AM	Passed
Isolated 24 V / non isolated 12 V	ISO 11452-2:2004	800 MHz – 1000 MHz, vertical, 50 V/m, PM	Passed
Isolated 24 V / non isolated 12 V	ISO 11452-2:2004	800 MHz – 1000 MHz, horizontal, 50 V/m, PM	Passed
Isolated 24 V / non isolated 12 V	ISO 11452-2:2004	1000 MHz – 2700 MHz, vertical, 50 V/m, PM	Passed
Isolated 24 V / non isolated 12 V	ISO 11452-2:2004	1000 MHz – 2700 MHz, horizontal, 50 V/m, PM	Passed

Conducted transient immunity

Modularity	Standard	Test description	Result
Isolated 24 V / non isolated 12 V	ISO 7637-2:2004	Pulse 1, Level (12 V / 24 V): -100 V / -600 V, 5000 pulses	Passed
Isolated 24 V / non isolated 12 V	ISO 7637-2:2004	Pulse 2, Level (12 V / 24 V): 50 V / 50 V, 5000 pulses	Passed
Isolated 24 V / non isolated 12 V	ISO 7637-2:2004	Pulse 2b, Level (12 V / 24 V): 10 V / 20 V, 10 pulses	Passed
Isolated 24 V / non isolated 12 V	ISO 7637-2:2004	Pulse 3a, Level (12 V / 24 V): -150 V /-200 V, 60 min	Passed
Isolated 24 V / non isolated 12 V	ISO 7637-2:2004	Pulse 3b, Level (12 V / 24 V): 100 V / 200 V, 60 min	Passed
Isolated 24 V / non isolated 12 V	ISO 7637-2:2004	Pulse 4, Level (12 V / 24 V): -6 V / -12 V, 1 pulse	Passed
Isolated 24 V / non isolated 12 V	ISO 7637-2:2004	Pulse 5b, Level (12 V / 24 V): 24 V / 60 V, 1 pulse	Passed

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Conducted Emission

Modularity	Standard	Test description	Result
Non isolated 12 V	CISPR25:2008	0.15 MHz – 108 MHz	Class 4
Non isolated 12 V	CISPR25:2008	0.15 MHz – 108 MHz, probe position 50mm	Class 4
Non isolated 12 V	CISPR25:2008	0.15 MHz – 108 MHz, probe position 750mm	Class 4
Isolated 24 V	CISPR25:2008	0.15 MHz – 108 MHz	Class 1
Isolated 24 V	CISPR25:2008	0.15 MHz – 108 MHz, probe position 50mm	Class 1
Isolated 24 V	CISPR25:2008	0.15 MHz – 108 MHz, probe position 750mm	Class 4

Radiated Emission

Modularity	Standard	Test description	Result
Non isolated 12 V	CISPR25:2008	0.15 MHz – 30 MHz	Class 2
Non isolated 12 V	CISPR25:2008	30 MHz – 230 MHz, horizontal/vertical polarisation	Class 2
Non isolated 12 V	CISPR25:2008	230 MHz – 1000 MHz, horizontal/vertical polarisation	Class 2
Non isolated 12 V	CISPR25:2008	1000 MHz – 2500 MHz, horizontal/vertical polarisation	Class 2
Isolated 24 V	CISPR25:2008	0.15 MHz – 30 MHz	Class 1
Isolated 24 V	CISPR25:2008	30 MHz – 230 MHz, horizontal/vertical polarisation	Class 1
Isolated 24 V	CISPR25:2008	230 MHz – 1000 MHz, horizontal/vertical polarisation	Class 1
Isolated 24 V	CISPR25:2008	1000 MHz – 2500 MHz, horizontal/vertical polarisation	Class 1

Conducted transient Emission

Modularity	Standard	Test description	Result
Non isolated 12 V	ISO 7637-2:2004	+75 V, -100 V, supply disconnected before artificial network	Passed
Non isolated 12 V	ISO 7637-2:2004	+75 V, -100 V, supply disconnected behind artificial network	Passed
Isolated 24 V	ISO 7637-2:2004	+150 V, -450 V supply disconnected before artificial network	Passed
Isolated 24 V	ISO 7637-2:2004	+150 V, -450 V, supply disconnected behind artificial network	Passed

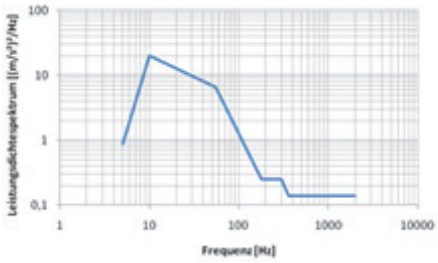
ISO 16750-2 Immunity

Modularity	Standard	Test description	Result
Isolated 24 V / non isolated 12 V	ISO 16750-2:2010	Direct current supply voltage	Passed
Isolated 24 V / non isolated 12 V	ISO 16750-2:2010	Overvoltage	Passed
Isolated 24 V / non isolated 12 V	ISO 16750-2:2010	Superimposed alternating voltage	Passed
Isolated 24 V / non isolated 12 V	ISO 16750-2:2010	Slow decrease and increase of supply voltage	Passed
Isolated 24 V / non isolated 12 V	ISO 16750-2:2010	Momentary drop in supply voltage	Passed
Isolated 24 V / non isolated 12 V	ISO 16750-2:2010	Reset behaviour at voltage drop	Passed
Isolated 24 V / non isolated 12 V	ISO 16750-2:2010	Starting profile	Passed
Isolated 24 V / non isolated 12 V	ISO 16750-2:2010	Open circuit tests	Passed
Isolated 24 V / non isolated 12 V	ISO 16750-2:2010	Reversed voltage	Passed

IVT-MODULAR

9.1. Qualification Summary EMC

Conducted transient immunity

Modularity	Standard	Test description	Result
Isolated 24 V / non isolated 12 V	MBN-LV124:2009	L-02 Life test – high-temperature endurance test, 95°C	1361 h
Isolated 24 V / non isolated 12 V	MBN-LV124:2009	L-03 Life test – temperature cycle test, -40°C … +85°C	282 cycles
Isolated 24 V	MBN-LV124:2009	M-01 Free fall	Fulfilled
Isolated 24 V / non isolated 12 V	MBN-LV124:2009	Vibration test, vibration profile 4 	
Isolated 24 V / non isolated 12 V	MBN-LV124:2009	K-05 Temperature shock, -40°C … +125°C, t_{hold}= 1h	141 cycles
Isolated 24 V / non isolated 12 V; with voltage measurement	MBN-LV124:2009	K-14 Humid heat, constant, SG2 93% rel. humidity, 65°C	100h
Isolated 24 V / non isolated 12 V; without voltage measurement	MBN-LV124:2009	K-14 Humid heat, constant, SG2 93% rel. humidity, 65°C	875h
Isolated 24 V / non isolated 12 V	-	Storage test, in accordance to MBN-LV124 L02:2009, 125°C	1700h
Isolated 24 V	ISO 60664-3:2010	Insulation resistance test, 2828 VDC, >100MΩ	fulfilled
Isolated 24 V	ISO 60664-3:2010	Withstand voltage test, I_{max}>2 mA, 2828 VAC	fulfilled
Isolated 24 V / non isolated 12 V	ISO 20653	IP protection class	IP65