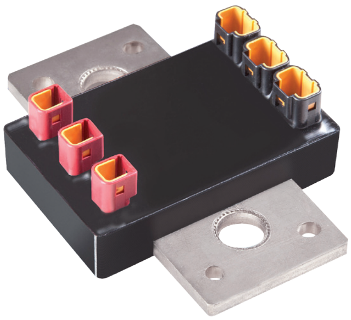
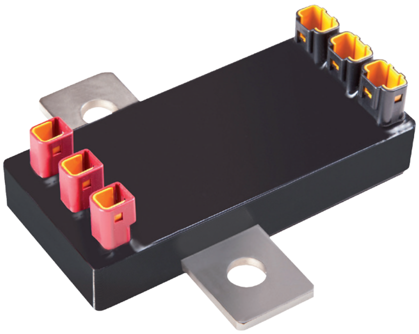
IVT-MODULAR CAN

PRELIMINARY DATA SHEET





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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 of ±2,500 A and the voltage channels include a range of ±800 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. All used components are automotive qualified. The communication is based on a CAN bus interface. A CAN description file (CAN-dbc) is available and supports a 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	Basic sensor 3
Power supply	12 V 24 V	12 V	5 V
Interface	CAN (with termination) CAN (without termination)		SPI
Isolation	✓	–	✓
Automotive/industrial grade	Automotive		Industrial
Current measurement range	±100 A; 300 A; 500 A, 1 kA; 2.5 kA		
Voltage measurement range	800 V (0 - 3 channels)		
I/O	Trigger (input) OCS (output)[1]		
Connector	JST (JWPF)		MOLEX (MLX55487)

[1] Overcurrent signal

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	Ah/As
Energy counter	Wh

NOTE: Power measurement is always based on Voltage 1.

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2. Application

Every application for DC current, voltage, energy and power measurement is possible. For example:

_ Hybrid and full electric drives
_ UPS systems
_ Stationary energy storage systems
_ Fuel cells
_ All 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 a 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 optionally an 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 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).

3.3 Diagnosis

The following data are stored continuously into the EEPROM:

_ Maximum measured current value
_ Minimum measured current value
_ Maximum measured voltage value
_ Minimum measured voltage value
_ Maximum measured temperature value
_ Minimum measured temperature value
_ Seconds in temperature range 1 (normal operation)
_ Seconds in temperature range 2 (out of range)
_ Operating hours
_ Count of restarts by command
_ Count of ASIC Watchdog events
_ Electric meter (Ah)
_ Energy meter (Wh)

After restart of the sensor the “alive” message is sent over the CAN interface.

3.4 Firmware update

To update the firmware, the IVT has an implemented bootloader.
For updating the sensor, Isabellenhütte software must be used.
The IVT must be disconnected from the bus network.

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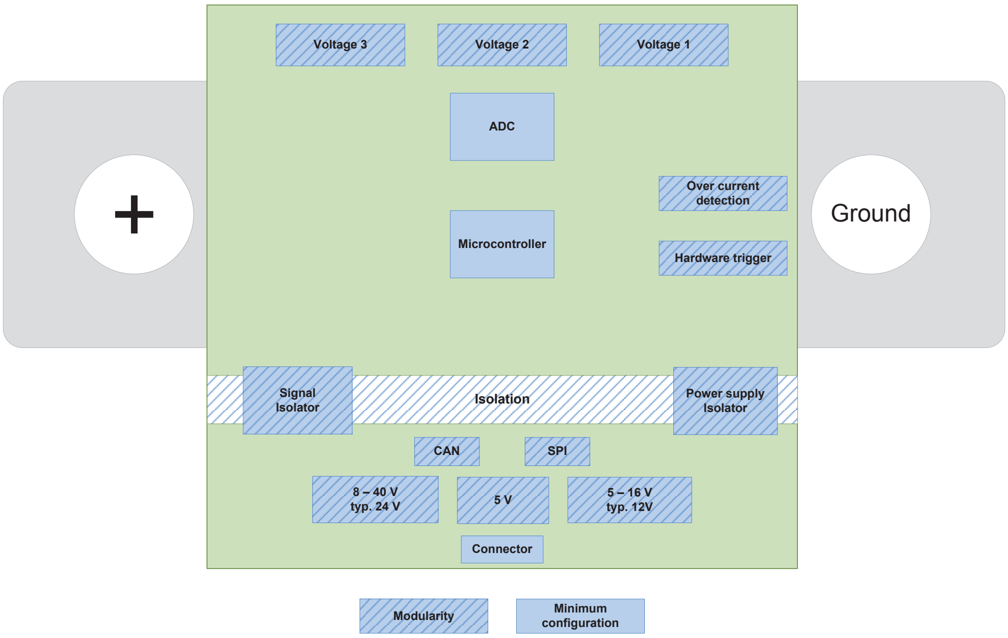
4. Functionality description

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

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
Minimum External Clearance distance	> 40 mm
Minimum External Creepage distance	> 50 mm
Minimum Internal Clearance	5.5 mm
CTI housing	Material Group IIIa
CTI potting	Material Group II
CTI connectors	Material Group II
Sea level (a.s.l.) <30 khz	2,000 m

The power consumption depends on the isolation module.
(See technical data chapter 6).

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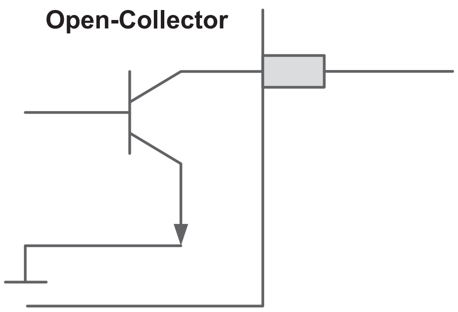
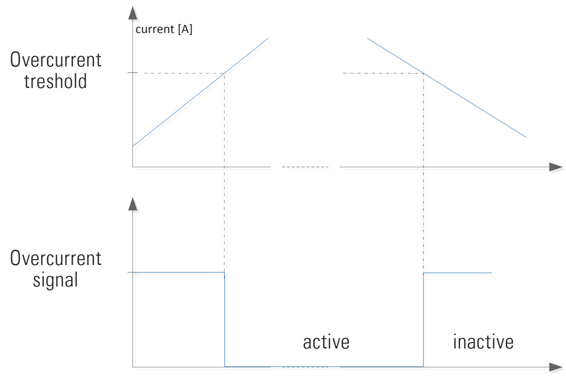
4.2 Overcurrent signal (OCS)

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 short-circuit-proof with a maximum current of 15 mA with a min. pull-up resistor of 4K Ohm. 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

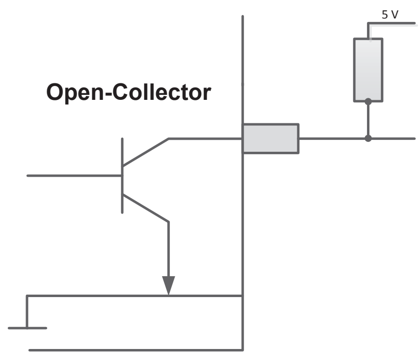


Figure 3: set threshold and reset threshold

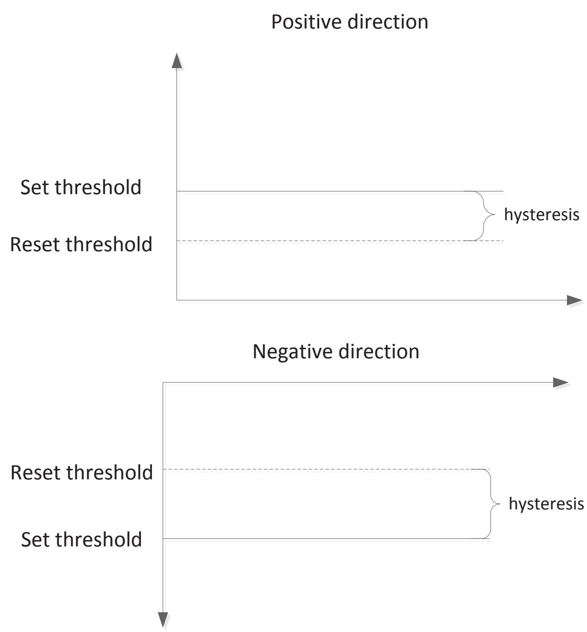
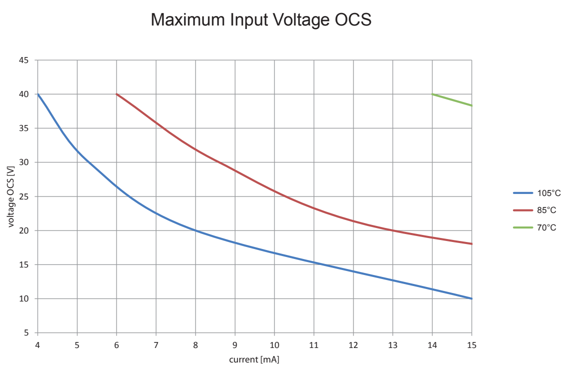


Figure 4: chart for the pull-up resistor



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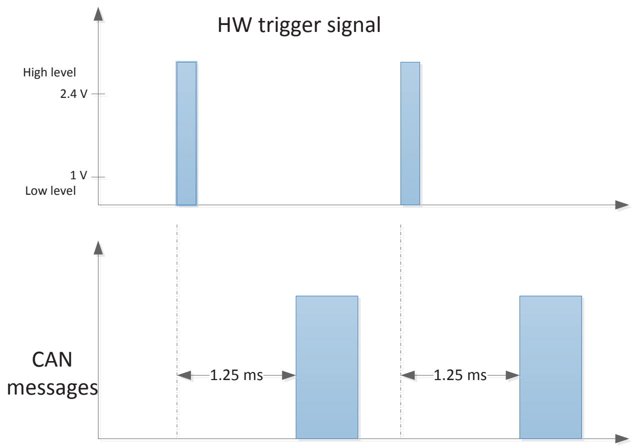
4.3 Hardware trigger

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.a and PIN3.c. 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 the leading edge of the trigger signal within 0…250 µs, depending on the current sample interval. As the minimum sample interval a minimum time of 1.25 ms is required before triggering the next measurement. A trigger interval of less than 1.25 ms will not be considered as valid trigger command.

Figure 5: a channel in "trigger mode"



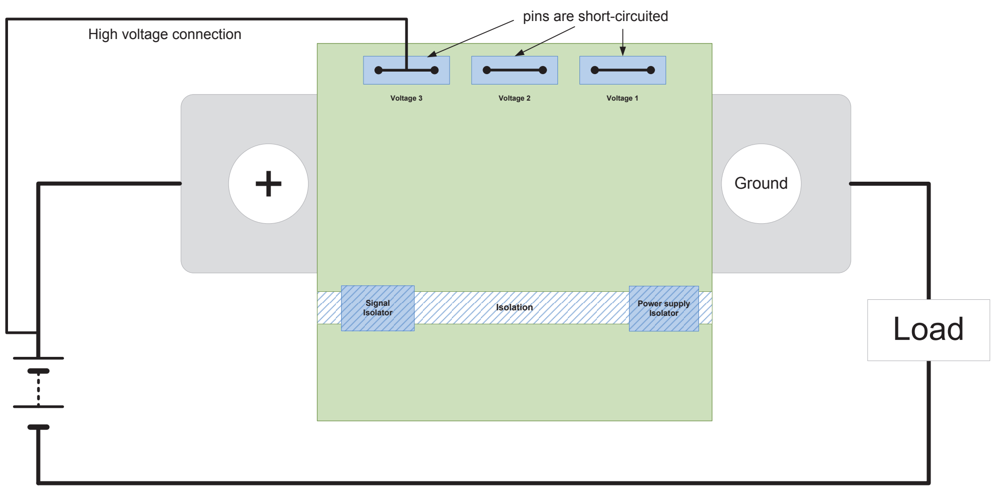
4.4 Ranges

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). There, the resolution depending on the shunt is listed. 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.

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 2 ms.

Figure 6: 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 7) or without CAN termination (figure 8), depending on the bus topology.

Examples for CAN topology

Figure 7: star topology

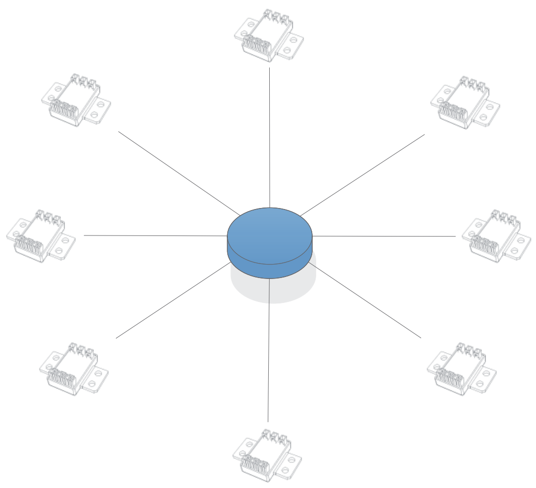
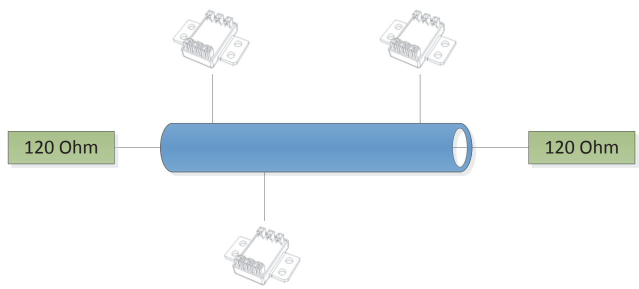


Figure 8: bus topology



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
5 V	a stable supply voltage is required	not available	available
12 V	standard 12 V automotive application	available	available
24 V	standard 24 V automotive application	available	not available

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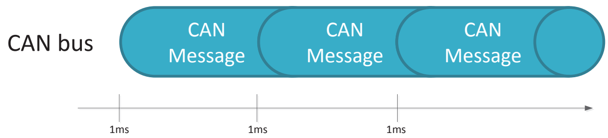
5. Measurement description

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.

Figure 9: CAN bus

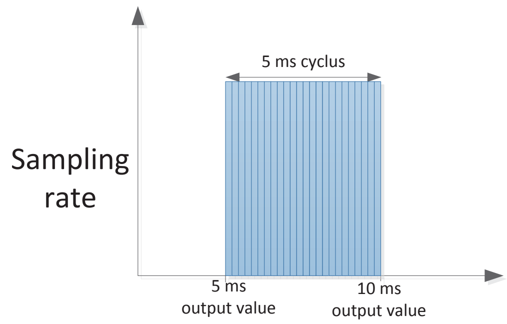


5.1 Sampling rates

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 10). The use of higher sample intervals increases the accuracy of the measurement.

Figure 10: averaging over 5 ms

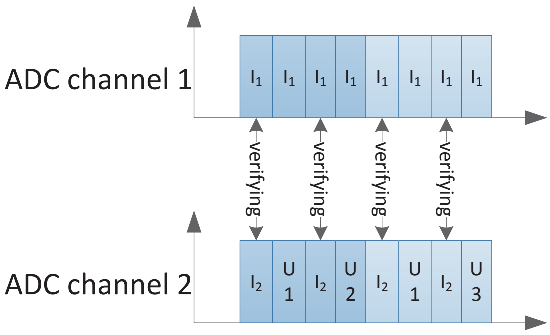


Voltage measurement characteristics:
The second ADC channel is used for voltage measurement.
This channel is used for different signals, which are multiplexed.

The IVT retrieves a new voltage sample every millisecond. This leads to the following behaviour:

- The min. sample interval of Voltage channel 1 is 1 ms if no additional Voltage channel is configured.
- The min. sample interval of Voltage channel 1 is 2 ms if Voltage channel 2 or Voltage channel 3 is configured.
- The min. sample interval of Voltage channel 1 is 3 ms if Voltage channel 2 and Voltage channel 3 is configured.
- The min. sample interval of Voltage channel 2 and channel 3 is the same as Voltage 1.

Figure 11: 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).

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Example 1:

Figure 12: configuration: 1 current channel, 3 voltage channel, 3 ms measurement interval

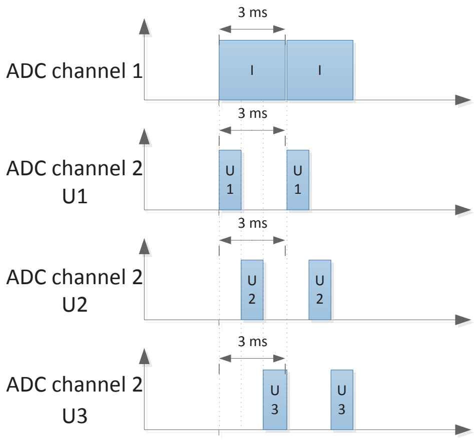


Figure 12 shows an example with 4 signals. All signals are configured with a measurement interval of 3 ms. The current measurement extends over 3 ms. The voltage measurement is multiplexed (U1, U2, U3).

Example 2:

Figure 13: configuration: 1 current channel, 2 voltage channel

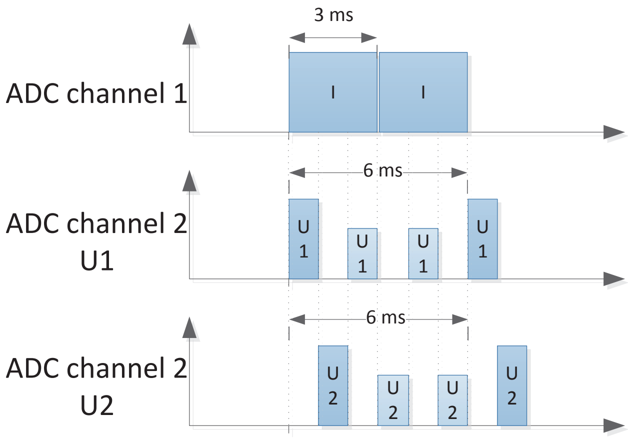
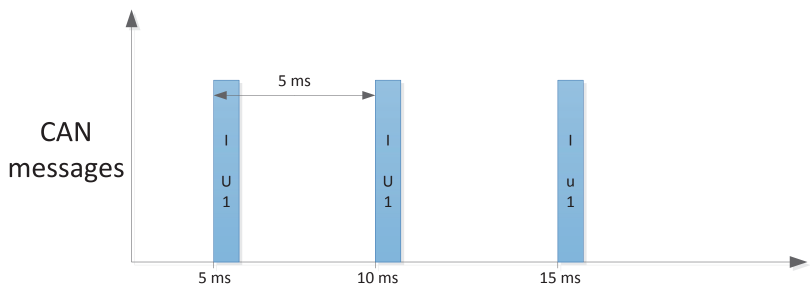


Figure 13 shows an example with 3 signals. The current measurement interval is 3 ms. The voltage measurement interval is 6 ms.
The current measurement extends over 3 ms.
The voltage measurement multiplexes every 2 ms (U1, U2).
After 6 ms the measured value is averaged over 3 values.

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

Example 3:

Figure 14: two channels; 5 ms output rate



Configuration condition (figure 14):
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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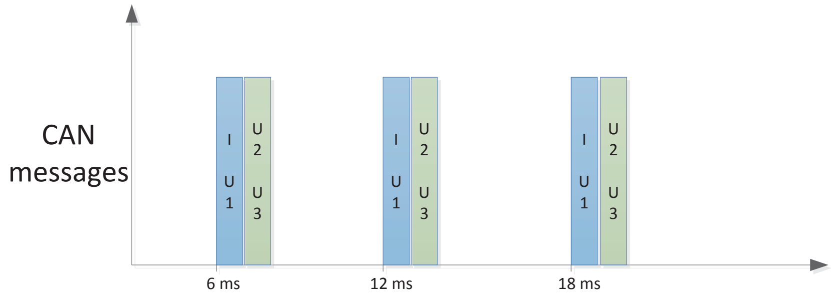
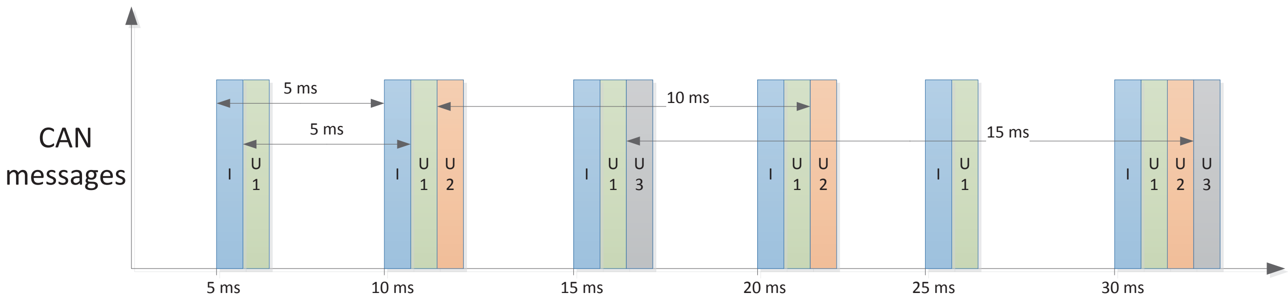
Figure 15: four channels; 6 ms output rate



Configuration condition (figure 15):
Four channels are configured; all with a measurement interval of 6 ms. In this case the sensor sends an current result every 6 ms, and the voltage result U1, U2 and U3 every 6 ms, as well.

Figure 16: Four channels; different measurement interval



Configuration condition (figure 16):
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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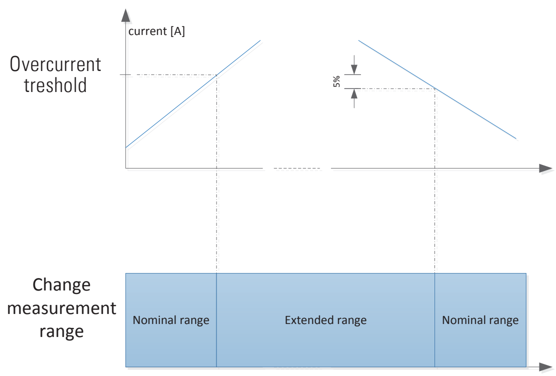
5.2 Overcurrent measurement

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 17: 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 measured system of 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.	Unit
Operating temperature	-40		+85	°C
Storage temperature	-40		+125	°C
	4.85	5	5.15	V
Supply voltage	5	12	16	V
	9	24	40	V
Current consumption [2]	20	<40	40	mA
Current consumption [3]	40	<60	80	mA
Startup time [4]	100		200	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
Overcurrent measurement range	± 800	± 2,500	± 6,900	± 12,200	± 48,000	A
Power loss	<3	<9	<9	<20	<32	W
Extended load (depends on the shunt)						
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 [6] nominal range			±0.1			% rdg [5]
Total accuracy [6] nominal range			±0.6			% rdg [5]
Error overcurrent range			±3			% rdg [5]
Offset	7	21	60	100	400	mA [7]
Linearity [8]			0.01			% rdg
Noise	5	15	40	70	280	mA (rms)
Resolution	3	10	27	47	186	mA

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

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6.3 HV voltage measurement

Parameter	Min.	Typ.	Max.	Unit
Nominal measurement range		800		V
Initial accuracy		0.1		% rdg [5]
Total accuracy		0.6		% rdg [5]
Offset		100		mV
Noise		45		mV (rms)
Resolution		30		mV

[5] failure of reading

6.4 Communication

Interface	Specification	Speed	Termination
CAN	2.0 a/(b) [1]	250kbit/s; 500kbits/s; 1Mbit/s	120R

[1] CAN 2.0b implementation is planned, not available yet

6.5 Functionality

Type	Direction	Signal
OCS	output	low active
Trigger	input	high active

Manufacturer	Type	No. of Pins	For interface type	IP Protection	For voltage measure
JST	JWPF	2 / 4	CAN	IP67	✓
Molex	MLX55487	2 / 4 / 14	CAN	-	✓

Type	Potting	Size	Technology
Housing	✓	62.8 mm x 40.4 mm	housing filled with potting
Housing	✓	85.3 mm x 40.4 mm	housing filled with potting

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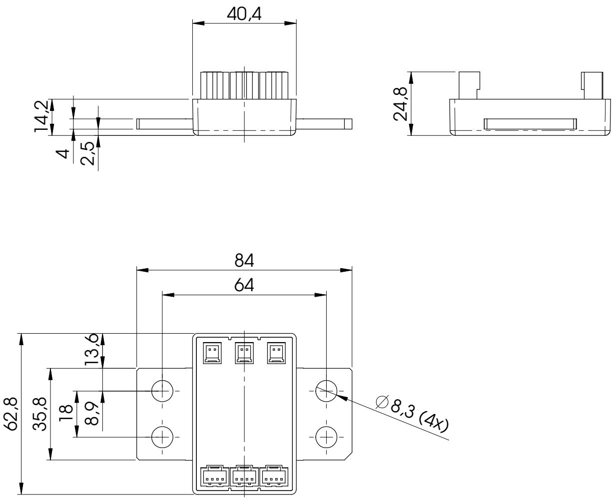
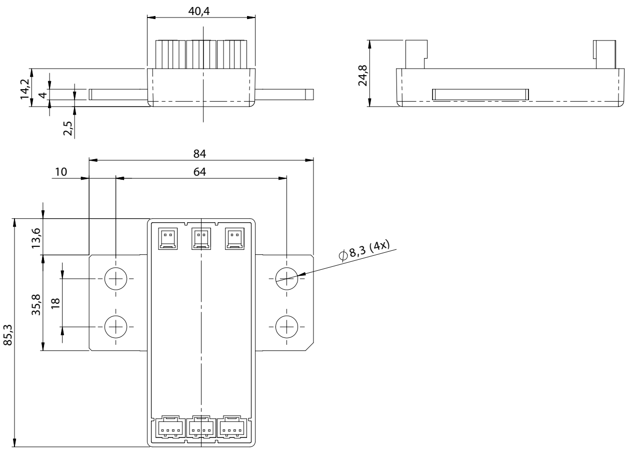
6.6 Mechanical dimension

IVT-MOD non-isolated

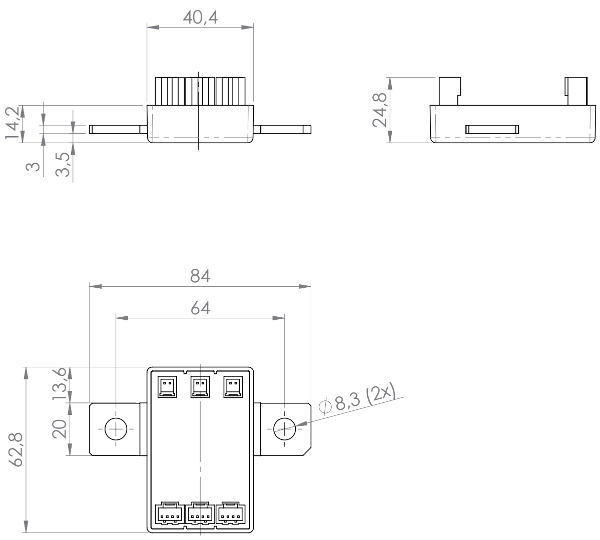
IVT-MOD isolated

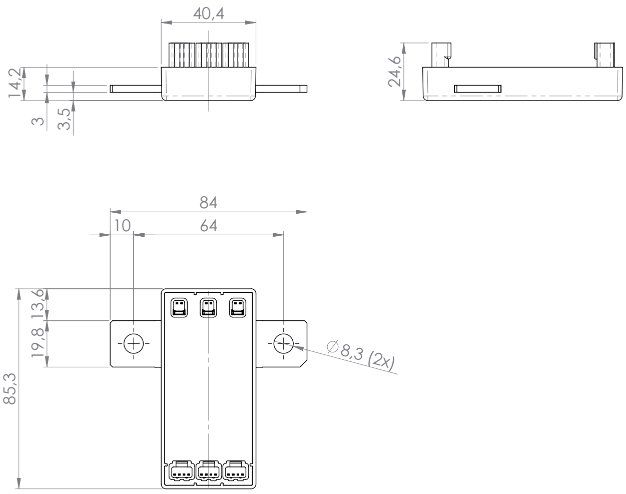
1,000 / 2,500 A





100 / 300 / 500 A





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6.7 Pin configuration (full modularity)

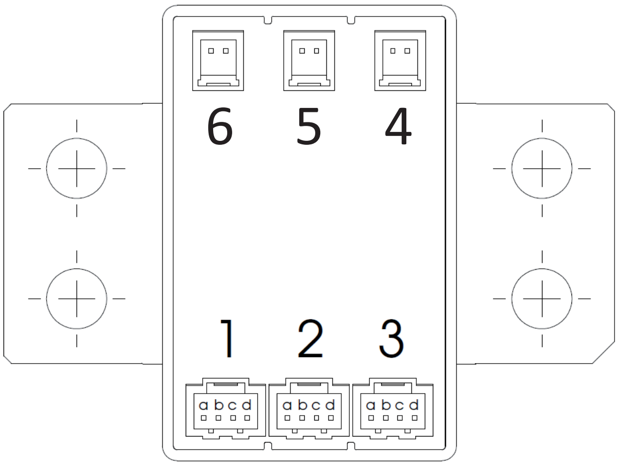

Table 3: Pin configuration

PIN	Description	Remark (module or basic)
1	Power IN / CAN IN	Basic
a	VCC	
b	GND	
c	CAN L	
d	CAN H	
2	Power OUT / CAN OUT	Only for non-CAN termination version
a	VCC	
b	GND	
c	CAN L	
d	CAN H	
3	Trigger and OCS	Module
a	Trigger	
b	OCS	
c	Trigger	c, d only present in case of non-CAN termination
d	OCS	
4 [9]	Voltage measurement 1	U1 module (both pins are short-circuited)
5 [9]	Voltage measurement 2	U2 module (both pins are short-circuited)
6 [9]	Voltage measurement 3	U3 module (both pins are short-circuited)

[9] High voltage Pin. The ground is the module ground (see module overview chapter 4).

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6.8 Part description

IVT – 100 – U3 – T O I – CAN2 – 12

Product group
IVT

Current Range [A]
100 / 300 / 500 /
1000 / 2500

Voltage Channel
U0 / U1 / U2 / U3

Add. Feature
T ⇔ Trigger
O ⇔ Overcurrent detection
I ⇔ galvanic Isolation

Communication
CAN1 ⇔ CAN-Termination on Board
CAN2 ⇔ No CAN-Termination on Board
SPI ⇔ SPI Interface

Power Supply
5 ⇔ typ. 5V
12 ⇔ typ. 12 V
24 ⇔ typ. 24 V

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