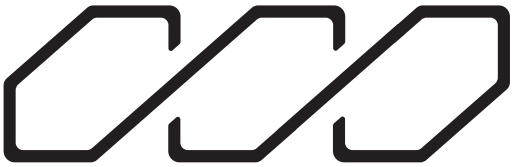


PODIUM

ADVANCED TECHNOLOGIES

BATTERY MANAGEMENT SYSTEM USER MANUAL

Contents

1 Change history

ae46a1c7369c2ff806992a8cd48d229d4b5c3e50

Author Luca Zamboni, *luca.zamboni@podium-tech.com*
Date 2019-02-19
Comment **User manual update** The balancing current has been added in the tech specs. The CAL ADDR is one-based, but the calibration protocol uses the zero-based ADDR. The charging procedure is usually done with the CU powered off. The diagnosis FSM has been added, the diagnosis line FSM has been edited. The current and power limits descriptions have been reworded. The CANIDs now appear in the user manual.

07484c2a0f583dcd48c3295ed59192f78a2312be

Author Luca Zamboni, *luca.zamboni@podium-tech.com*
Date 2018-11-27
Comment **User manual: adds detailed description of BMS diagnosis**

e70a37d3fdf711732fbc9bc48872462dbc561b47

Author Luca Zamboni, *luca.zamboni@podium-tech.com*
Date 2018-11-01
Comment **Adds calibration script w/ config, updates calibration.json generator Better doxygen comments on calibration variables for the user manual. Adds SFTY node, description of each node and BMS signals. Uses pipe as CSV separator when extracting CAL variables Modular BMS user manual with almost anything fetched from source. Lowers the max supply voltage to 36V due to IMD limit Specifies SAE J1850 as CRC8 standard, inserts possible CAL in sig descr.**

316193dc5993006b68e3b5bc81be0229a355635e

Author Luca Zamboni, *luca.zamboni@podium-tech.com*
Date 2018-09-18
Comment **User manual release for P034 (ogeco)**

b60bab99c3f9bd617ca293d03491c82968223fce

Author	Luca Zamboni, *luca.zamboni@podium-tech.com*
Date	2018-09-18
Comment	**Fixes CAN timings in user manual**

4a0aa1b5191cdb89e238ba8b378a4ae6fc92acfa

Author	Luca Zamboni, *luca.zamboni@podium-tech.com*
Date	2018-09-18
Comment	**Simplifies history generator script**

c465dfdd3bf70e4936795df5a825b7b44b6c9481

Author	Luca Zamboni, *luca.zamboni@podium-tech.com*
Date	2018-09-18
Comment	**Updates DBC, adds balancing descr. for hybrids** J1850 crc8 and tx counter added to Cmd and Diag messages Customer requested balancing procedure description in user manual Min/max for each signal HV system graph fixed

c387d13c1ff4f4910c5a5a3729dfb839d3c4ce74

Author	Luca Zamboni, *luca.zamboni@podiumengineering.com*
Date	2018-02-13
Comment	**Updates user manual, backports changes from release** Adds disch. time calibration, current and power sign meaning, cells monitor fsm, supported chargers and charging procedure

51f44da194f24d8c46bbe732987a3c07be004be3

Author	Luca Zamboni, *luca.zamboni@podiumengineering.com*
Date	2018-01-31
Comment	**Adds new 'quick start' procedures, refines behavioural FSMs**

4cc9711165f18f87d070bbaa35403b50e5f28011

Author	Luca Zamboni, *luca.zamboni@podiumengineering.com*
Date	2018-01-30
Comment	**Adds subsys FSMs, startup/shutdown procedures, bFltPresent and bChrgSts flags** Fixes T213

c2eca728ac759305b77cf427ba6fa568e47ff32e

Author	Luca Zamboni, *luca.zamboni@podiumengineering.com*
Date	2018-01-08
Comment	**BMS user manual updated**

c4a1d15f9249348419704e6065dd21aeb9a8d16c

Author	Luca Zamboni, *luca.zamboni@podiumengineering.com*
Date	2018-01-04
Comment	**HVIL check changed from false to true. SFTY updated CANIDs. User manual.**

2 BMS firmware revision

Send the RTR CAN message *INFO_00_SwVer* described in section 9 to get the BMS firmware revision in the response message.

This manual is applicable **only** to this BMS revision:

`11BC6D2D`

3 Technical data

3.1 Operating limits

	MIN	TYP	MAX	Units
Supply				
Voltage	8	12	36	V
Current, contactors open	–	0.1	–	A
Current, contactors closed	–	0.7	–	A
Temperatures				
Working	-40	–	105	℃
Junction	-40	–	125	℃
Storage	-65	–	150	℃
Times				
Startup time	–	10	–	ms
Shutdown time	–	20	–	ms
Error detection time	–	1	10	ms
Fault reaction time	0	250	500	ms
Measuring period	30	100	–	ms
CAN speed	–	1000	–	kbps
Managed battery pack				
Voltage	24	–	59.4	V
Power	–	44.4	59.4	kW
Monitoring chain				
Active current consumption	4	5	8	mA
Standby current consumption	–	22	50	μA
Balancing resistance	–	20	–	Ω
Balancing current	–	25	–	mA

4 Quick start

The procedures detailed here are the most common ones. Their descriptions assume that no faults are detected before, during or after the execution.

If a fault is detected by the BMS:

1. the flag *bFltPresent* will be set;
2. the signal *Fault* will be set;
3. the contactors will be kept open, or opened after a delay of 500ms.

Monitor the message *BMS_06_Diag01* to know which fault has been detected.

Every power demand should be reduced to zero as soon as the flag *bFltPresent* is set to prevent potentially dangerous events on the HV system.

4.1 Emergency disconnect

A separate power supply for the contactors is provided for external safety mechanisms to do an emergency disconnect of the battery pack. This power supply is assumed to be normally connected to the vehicle's power supply.

When the contactors are opened abruptly during energy exchange, their operating life is greatly reduced. The BMS keeps track of the remaining operating life and sets an error when the contactors are too worn out to guarantee a successful emergency opening.

4.2 Battery connection

In order to enable the energy transfer to/from the battery pack, the following actions have to be undertaken:

1. set the hardware *enable* signal high;
2. precharge the DC bus to the battery pack voltage;
3. set the CAN signal *bCtorEn* to 1;
4. wait for the CAN signal *eCtorSts* to reach the state *CLOSED*.

4.3 Energy transfer

After having connected the battery these conditions must be maintained:

- keep the hardware *enable* signal high;
- keep the CAN signal *bCtorEn* set;
- the current (power) limits reported with the CAN message *BMS_09_Lim01* (*BMS_10_Lim02*) must be respected.

4.4 Battery disconnection

The procedure to disconnect the battery from the DC bus is the following:

1. keep the hardware *enable* signal high;
2. turn off every HV component;
3. clear the CAN signal *bCtorEn*;
4. wait for the CAN signal *eCtorSts* to reach the state *OPEN*.

4.5 Pack balancing

The BMS will always check that balancing will not put the battery outside its safe operating area, and do at least one measure between one balancing cycle and the other.

The BMS allows the CU to request the pack balancing, even when the battery is connected to the DC bus, in this way:

1. keep the hardware *enable* signal high;
2. keep the current lower than 10% of the nominal pack current;
3. check that the CAN signal *eSysSts* equals *MONITOR* or *DRIVE*;
4. set the CAN signal *bBlncEn*;
5. wait for the cells to be balanced by checking:
    - their voltages in the CAN message *BMS_01_CellV*;
    - their states of charge in the CAN message *BMS_07_Pack02*;
6. clear the CAN signal *bBlncEn* to stop balancing.

4.6 Power off

To shut down the BMS, it is sufficient to:

1. turn off every HV component;
2. clear the hardware *Enable* signal.

The BMS will, from every state:

1. open the contactors, if they were closed;

2. stop the monitoring chain;
3. save the persistent data;
4. shut down.

5 Detailed description

5.1 Target HV system

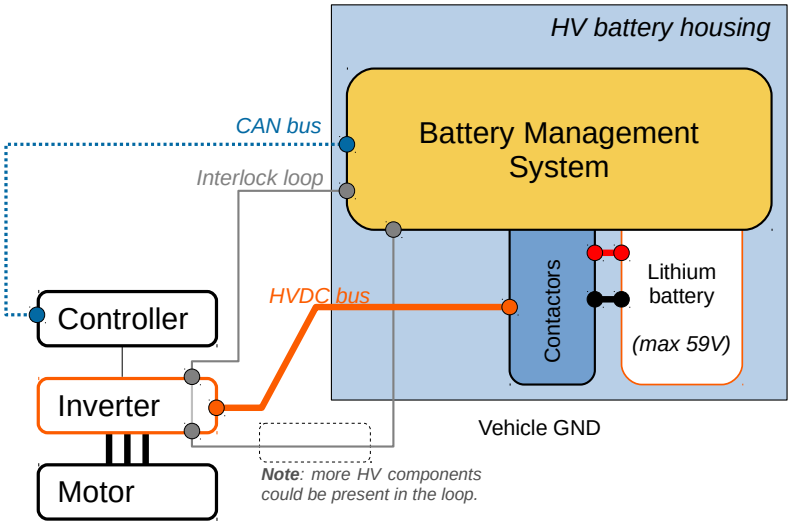


Figure 1: Target HV system

The **Podium battery management system** (BMS) is designed to be put inside the high voltage battery housing, together with the lithium battery. The BMS uses a CAN bus communication to accept commands from the hybrid/electric powertrain controller.

The **lithium battery pack** is made of cells arranged in series of equal dimensions parallel strings. The BMS can monitor packs from 6 to 12 strings (from 24V up to 59.4V). Any lithium chemistry is supported.

The **contactors** connect and disconnect the battery poles to the high voltage DC bus powering the high voltage systems. The BMS drives the contactors.

These components inside the battery housing are not represented in figure 1:

current sensor(s) placed before the contactors;
high voltage sensors placed before and after the contactors;
high current fuse with a threshold slightly higher than the maximum pack current;
temperature sensor measuring the temperature inside the housing;
water leakage sensor if the pack is equipped with a cooling system.

5.2 System manager

The system manager reads the BMS HW and CAN inputs, chooses the operating state (*MONITOR*, *DRIVE*) and enables or disables these subsystems:

Monitoring chain reads the cell strings voltages and temperatures, computes the state of charge (SoC), state of health (SoH), power limits and charging/discharging times;

Contactors drives the positive and negative contactors, the precharge and discharge circuits, computes contactors state of health and diagnoses welded contactors;

Its behaviour is described by the FSM in figure 2:

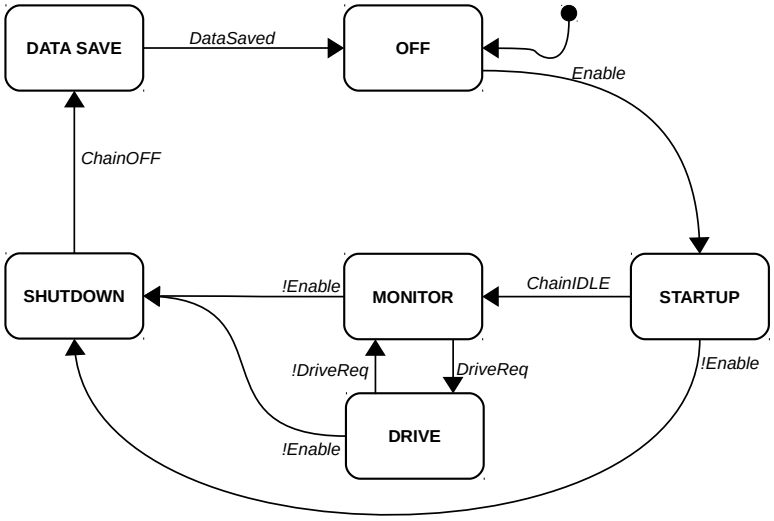


Figure 2: System manager

5.2.1 Signals

Enable true when the hardware *enable* is high, false otherwise;
ChainIDLE true when the device chain is powered up and ready for operation, false otherwise;
ChainOFF true when the device chain is powered down, false otherwise;
DriveReq true when the CAN signal *bCtorEn* is set, false otherwise;
DataSaved triggers when the persistent data have been saved.

5.2.2 States and transitions

OFF the BMS is powered down. It may transition to:
STARTUP if *Enable* is set.

STARTUP the pack is disconnected from the DC bus, the BMS is waiting for the device chain to be powered up and configured:

- monitors the HV voltages,temperature and water leakage sensors;
- accepts commands with *BMS_00_Cmd* and checks if a charger is connected.

It may transition to:
SHUTDOWN if *Enable* is cleared;
MONITOR if *ChainON* is set.

MONITOR the pack is disconnected from the DC bus, the BMS:

- monitors the HV voltages,temperature and water leakage sensors;
- accepts commands with *BMS_00_Cmd*;
- computes the pack SOCand power limits, performs cell balancing if bBlncEn is set;

It may transition to:
SHUTDOWN if *Enable* is cleared;
DRIVE if *DriveReq* is set.

DRIVE the BMS enables the contactors operation, and:

- monitors the HV voltages,temperature and water leakage sensors;
- accepts commands with *BMS_00_Cmd*;
- computes the pack SOCand power limits, performs cell balancing if bBlncEn is set;
- drives the contactors according to *bCtorEn*.

It may transition to:
SHUTDOWN if *Enable* is cleared;
MONITOR if *DriveReq* is cleared.

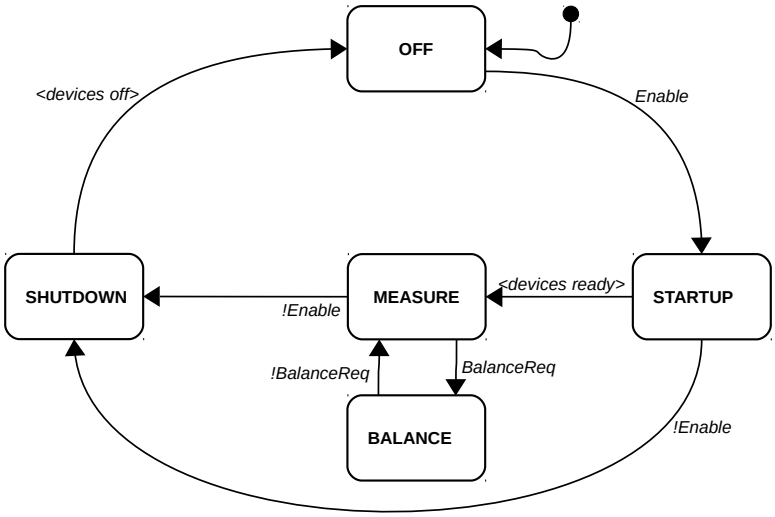
SHUTDOWN the pack is disconnected from the DC bus, the BMS is waiting for the monitoring chain to be powered down:

- monitors the HV voltages, temperature and water leakage sensors;
- only sends on the CAN bus, ignoring every message received.

It may transition to:
DATA SAVE if *ChainOFF* is set.

DATA SAVE the BMS is saving its persistent data; everything else is disabled. It may transition to:
OFF when *DataSaved* is set.

5.2.3 Monitoring chain subsystem



Signals

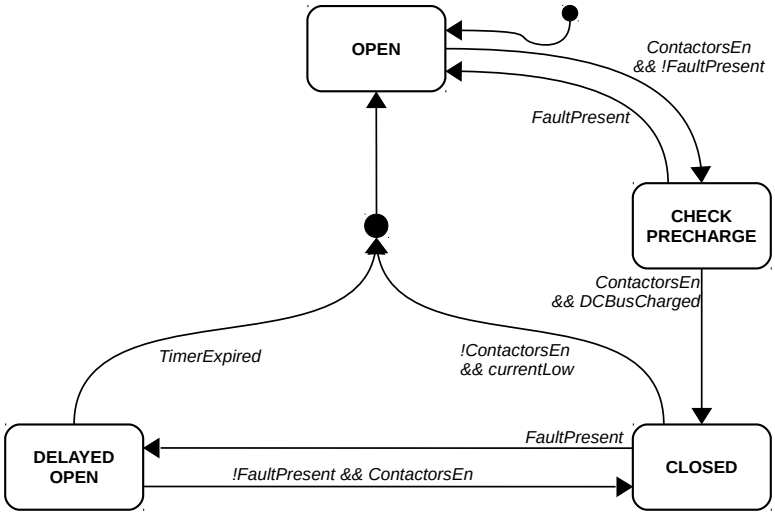
Enable true when the hardware *enable* is high, false otherwise.
BalanceReq true if a balancing request is active (commanded with *bBlncEn* in *MONITOR* and *DRIVE* modes) and the balancing conditions are satisfied, false when the balancing period expires and a new measure has not been done yet.

States

OFF the device chain is powered off.
STARTUP the BMS is powering up and configuring the device chain.

MEASURE voltages and temperatures are periodically measured, the BMS computes the state of chargeand power limits after each measure.
BALANCE the balancing resistors are active.
SHUTDOWN the BMS is powering down the device chain.

5.2.4 Contactors subsystem



Signals

ContactorsEn true when the system is requesting to close the contactors, false otherwise.
CurrentLow true if the measured current is low enough to open the contactors without damaging them, false otherwise.
TimerExpired the fault reaction timeout (500ms) has expired.
DCBusCharged true when the difference between the battery voltage and the DC bus voltage is low enough to close the contactors without damaging them, false otherwise.
FaultPresent the BMS is reporting a fault (see the CAN message *BMS_06_Diag01*).

States

OPEN negative and positive contactors driven open.
CHECK PRECHARGE the negative contactor is closed.
CLOSED both contactors are closed.
DELAYED OPEN both contactors are closed,a 500ms timer is started. **The motorcontrollers shall reduce the current to zero before the timer expires.**

6 Diagnosis and recovery

6.1 FSM

Each monitored condition is assigned to a diagnosis line *F*, having:

- a state (INACTIVE, ACTIVE or CONFIRMED), driving a warning flag *F.flag* and a request to open the contactors *F.reqCtorOpen*;

- a fault counter *F.cnt*, reset to zero at each powerup;
- a calibratable counter threshold *F.thr*;
- a fault type *F.type* specifying if the diagnosis can go in state CONFIRMED (F.type == FAULT) or not (F.type == WARNING); this attribute depends on the BMS operating state.

The diagnosis line state machine is described in figure 3.

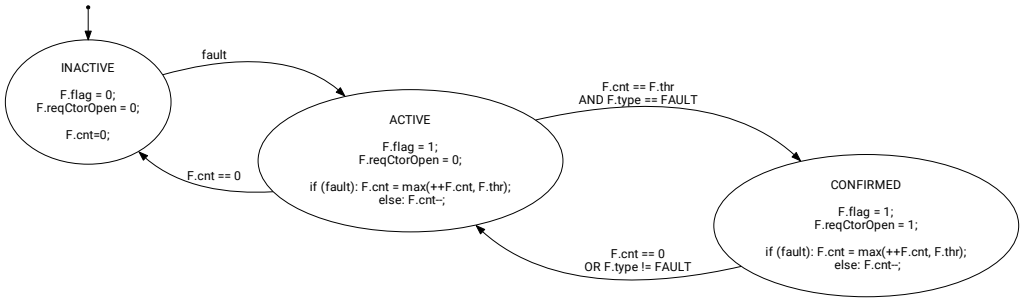


Figure 3: Diagnosis line FSM

When at least one diagnosis line enters CONFIRMED state:

- the CAN signal *bFltPresent* will be set;
- the HW signal *Fault* will be set;
- a 500ms timer is started.

If the BMS is configured to not be able to recover from faults (CFG.stickyFault set), the fault signals will not be cleared until the BMS is powered down. Otherwise the BMS clears the fault signals and enables the contactors operation if all the diagnosis lines become inactive.

The diagnosis state machine is described in figure 3.

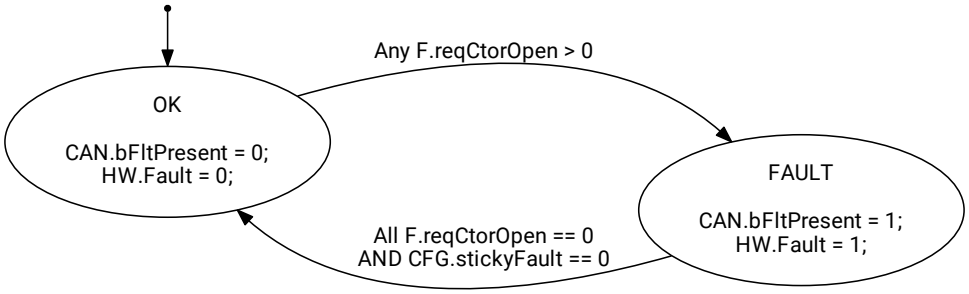


Figure 4: Diagnosis FSM

6.2 List of implemented diagnoses

Name	Description
AnIgNC	Analog sensors power failure.
BrdOT	Ambient temperature too high.
BrdUT	Ambient temperature too low.

BusOV	DC bus voltage too high.
CANCmd	Communication with CU went into timeout.
CANNC	The CAN cable is disconnected or the CAN communication is malfunctioning.
CellOT	One or more cells are in overtemperature.
CellOV	One or more cells are in overvoltage.
CellUT	One or more cells are in undertemperature.
CellUV	One or more cells are in undervoltage.
CtorDmg	The contactors are worn out or damaged.
CtorNClsd	The contactor on the negative battery pole is stuck closed.
CtorNOpen	The contactor on the negative battery pole is stuck open.
CtorPClsd	The contactor on the positive battery pole or the precharge relay is stuck closed.
CtorPOpen	The contactor on the positive battery pole is stuck open.
Curr1NC	The current sensor 1 is not connected.
Curr2NC	The current sensor 2 is not connected.
DevBaud	The measurement chain cannot communicate using the calibrated baudrate.
DevCom	The measurement chain communication failed.
DevHW	The measurement chain has an internal hardware fault.
DevNC	The measurement chain is not connected.
Eeprom	The internal eeprom memory is faulty and its contents have been reset to zero.
Flash	The internal flash memory is faulty and its contents have been reset to zero.
HVShrt	DC bus linked to battery due to safety coprocessor misbehaving.
PackOC	The measured pack current is too high.
PackOV	The measured pack voltage is too high.
PackUV	The measured pack voltage is too low or the MSD is open.
WtrLk	The waterleak sensor signals the presence of water inside the pack.
WtrLkNC	The waterleak sensor is not connected.

All the diagnosis lines have a flag that is reported in the CAN message *BMS_06_Diag01* with the prefix *BMS_bFlt*.

All the diagnosis counter threshold can be calibrated, and are listed in section 8.1 with the prefix *DIAG_thr*.

7 Vehicle interface

7.1 Hardware connections

The BMS has the following hardware interface with the vehicle:

	Voltage (V)	**Current** (A)	**Comment**
+12V	12	2	Always-on supply voltage (usually KL30)
GND	0	2	Ground reference
contactors +12V	12	4	Contactors supply voltage
contactors GND	0	4	Ground reference for contactors supply
Enable	12	2	BMS enabling input (usually KL15)
Fault	12	1	Fault detected, request to stop energy transfer
CANH	5	0.05	CAN bus digital communication
CANL	5	0.05	CAN bus digital communication
HV DC bus +	59.4	0.05	Positive HV DC bus cable
HV DC bus −	59.4	0.05	Negative HV DC bus cable

8 Calibration

8.1 Calibration variables

The calibration cannot be applied to the safety coprocessor. Only the variables in the main processor can be calibrated.

The calibration messages are ignored when the contactors are closed. It's a safety measure.

All variables are unsigned 16-bit. The complete list is:

Variable	ADDR+1	Description
password	1	Hex password requested to edit calibration values. Default: 0xabcd.
BMS_canBusSpeedSel	2	CAN bus speed selector: 0:1000, 1:500, 2:250, 3:125, 4:100, 5:75, 6:50, 7:10 [kbps] If the safety is sending CAN messages, then the bus speed cannot actually be changed.
BMS_canBusTermSel	3	CAN terminator selector. 0: not terminated, 1: terminated. It is advisable to place the appropriate terminations on the CAN line instead of relying on this calibration, because the termination is not present when the BMS is inactive.
BMS_ctlCanId	4	CAN ID of the controlling message BMS_00_Cmd.
BMS_sysCanId	5	CAN ID of the system status message BMS_05_Sys01.
BMS_diagCanId	6	CAN ID of the diagnostic message BMS_06_Diag01.
BMS_cellVCanId	7	CAN ID of the cell voltage message BMS_01_CellV.
BMS_cellTCanId	8	CAN ID of the cell temperatures message BMS_02_CellT, sent only if there are some thermistors placed on the cell boy.
BMS_tabTCanId	9	CAN ID of the tab temperatures message BMS_03_TabT, sent only if there are some thermistors placed on the cell connecting tabs.
BMS_HVCanId	10	CAN ID of the high voltage measures message BMS_04_Pack01. The measures of VPackSns and VBusSns are very slow and coarse. It is advisable to use VPackCalc instead.
BMS_packCanId	11	CAN ID of the battery pack Pack02 message BMS_07_Pack02. The pack SOC is actually the lowest charged cell SOC. To determine if the pack is balanced, a comparison with the SOCHigh signal should be done.
BMS_currLimCanId	12	CAN ID of the current limits message BMS_09_Lim01.
BMS_powerLimCanId	13	CAN ID of the power limits message BMS_10_Lim02.
BMS_rangeCanId	14	CAN ID of the range message BMS_08_Pack03. Time ranges are the seconds before reaching the OV or UV condition with the actual/mean current.
BMS_singleCellVCanId	15	CAN ID of the multiplexed single cell voltage message INFO_01_DbgV. The transmission of this message is enabled by sending the BMS_00_Cmd message with the BMS_bAllVTEn signal set.
BMS_singleTempCanId	16	CAN ID of the single cell temperature message INFO_01_DbgT. The transmission of this message is enabled by sending the BMS_00_Cmd message with the BMS_bAllVTEn signal set.
BMS_chainCanId	17	Not implemented. This message is enabled only in the debug environment and is never seen on released firmwares.

BMS_dbgHvCanId	18	Not implemented. This message is enabled only in the debug environment and is never seen on released firmwares.
BMS_swInfoCanId	19	CAN ID of the software version message INFO_00_SwVer. Send it as an 8-byte RTR message to get the firmware version hash. This information is required when submitting a bug report.
MEM_ctlCanId	20	CAN ID of the calibration request message MEM_00_Rq. This message is sent from the calibration tool to the BMS. The calibration protocol is described in the user manual.
MEM_stsCanId	21	CAN ID of the calibration response message MEM_01_Fb. This message is sent by the BMS in response to a calibration request. The calibration protocol is described in the user manual.
EXTIO_cmdCanId	22	Reserved, do not write
EXTIO_stsCanId	23	Reserved, do not write
NLG5_ctlCanId	24	Reserved, do not write
NLG5_stsCanId	25	Reserved, do not write
NLG5_actIlCanId	26	Reserved, do not write
EDN_tst1CanId	27	Reserved, do not write
NLG6_demLimCanId	28	Reserved, do not write
NLG6_actLimCanId	29	Reserved, do not write
EVSE_EVCtl1CanId	30	Reserved, do not write
EVSE_EVCtl2CanId	31	Reserved, do not write
EVSE_EVCtl3CanId	32	Reserved, do not write
EVSE_EVCtl4CanId	33	Reserved, do not write
EVSE_VIM2CanId	34	Reserved, do not write
EVSE_VIM3CanId	35	Reserved, do not write
EVSE_VIM6CanId	36	Reserved, do not write
CHG_maxIDC	37	Reserved, do not write
align	38	Reserved, do not write
DIAG_thr_ImdKo	39	Reserved, do not write
DIAG_thr_ImdNC	40	Reserved, do not write
DIAG_thr_ImdLoR	41	Reserved, do not write
DIAG_thr_Imd	42	Reserved, do not write
DIAG_thr_ImdGnd	43	Reserved, do not write
DIAG_thr_rsvd01	44	Reserved, do not write
DIAG_thr_rsvd02	45	Reserved, do not write
DIAG_thr_rsvd03	46	Reserved, do not write
DIAG_thr_HVIL	47	Reserved, do not write
DIAG_thr_WtrlkNC	48	Counter threshold of the diagnosis: WtrlkNC
DIAG_thr_Wtrlk	49	Counter threshold of the diagnosis: Wtrlk
DIAG_thr_BrdOT	50	Counter threshold of the diagnosis: BrdOT
DIAG_thr_BrdUT	51	Counter threshold of the diagnosis: BrdUT
DIAG_thr_AnlgNC	52	Counter threshold of the diagnosis: AnlgNC
DIAG_thr_Curr1NC	53	Counter threshold of the diagnosis: Curr1NC
DIAG_thr_Curr2NC	54	Counter threshold of the diagnosis: Curr2NC
DIAG_thr_DevNC	55	Counter threshold of the diagnosis: DevNC
DIAG_thr_DevCom	56	Counter threshold of the diagnosis: DevCom
DIAG_thr_DevBaud	57	Counter threshold of the diagnosis: DevBaud
DIAG_thr_DevHW	58	Counter threshold of the diagnosis: DevHW
DIAG_thr_CellOV	59	Counter threshold of the diagnosis: CellOV
DIAG_thr_CellUV	60	Counter threshold of the diagnosis: CellUV
DIAG_thr_CellOT	61	Counter threshold of the diagnosis: CellOT
DIAG_thr_CellUT	62	Counter threshold of the diagnosis: CellUT
DIAG_thr_HVShrt	63	Counter threshold of the diagnosis: HVShrt
DIAG_thr_PackOC	64	Counter threshold of the diagnosis: PackOC

DIAG_thr_PackOV	65	Counter threshold of the diagnosis: PackOV
DIAG_thr_PackUV	66	Counter threshold of the diagnosis: PackUV
DIAG_thr_BusOV	67	Counter threshold of the diagnosis: BusOV
DIAG_thr_rsvd04	68	Reserved, do not write
DIAG_thr_rsvd05	69	Reserved, do not write
DIAG_thr_rsvd06	70	Reserved, do not write
DIAG_thr_rsvd07	71	Reserved, do not write
DIAG_thr_rsvd08	72	Reserved, do not write
DIAG_thr_rsvd09	73	Reserved, do not write
DIAG_thr_rsvd10	74	Reserved, do not write
DIAG_thr_rsvd11	75	Reserved, do not write
DIAG_thr_rsvd12	76	Reserved, do not write
DIAG_thr_rsvd13	77	Reserved, do not write
DIAG_thr_rsvd14	78	Reserved, do not write
DIAG_thr_PlugLockOpen	79	Reserved, do not write
DIAG_thr_PlugLockClsd	80	Reserved, do not write
DIAG_thr_Eeprom	81	Counter threshold of the diagnosis: Eeprom
DIAG_thr_Flash	82	Counter threshold of the diagnosis: Flash
DIAG_thr_rsvd15	83	Reserved, do not write
DIAG_thr_rsvd16	84	Reserved, do not write
DIAG_thr_rsvd17	85	Reserved, do not write
DIAG_thr_rsvd18	86	Reserved, do not write
DIAG_thr_CANCmd	87	Counter threshold of the diagnosis: CANCmd
DIAG_thr_CANChrg	88	Reserved, do not write
DIAG_thr_CANNC	89	Counter threshold of the diagnosis: CANNC
DIAG_thr_CANCnt	90	Reserved, do not write
DIAG_thr_CANCRC	91	Reserved, do not write
DIAG_thr_rsvd19	92	Reserved, do not write
DIAG_thr_rsvd20	93	Reserved, do not write
DIAG_thr_rsvd21	94	Reserved, do not write
DIAG_thr_CtorNOpen	95	Counter threshold of the diagnosis: CtorNOpen
DIAG_thr_CtorNClsd	96	Counter threshold of the diagnosis: CtorNClsd
DIAG_thr_CtprPOpen	97	Counter threshold of the diagnosis: CtprPOpen
DIAG_thr_CtorPClsd	98	Counter threshold of the diagnosis: CtorPClsd
DIAG_thr_CtorPrOpen	99	Reserved, do not write
DIAG_thr_CtorDsOpen	100	Reserved, do not write
DIAG_thr_CtorDmg	101	Counter threshold of the diagnosis: CtorDmg
DIAG_thr_CtorRLoad	102	Reserved, do not write
DIAG_faultMasks_23	103	Diagnosis types bitfield related to SNS errors (bytes 2 and 3 of the DIAG message). The bits are: [F]Curr2NC [E]Curr1NC [D]AnlgNC [C]BrdUT [B]BrdOT [A]Wtrlk [9]WtrlkNC [8]unused [7]unused [6]unused [5]unused [4]unused [3]unused [2]unused [1]unused [0]unused. Setting the bit enables the corresponding fault. Shall be 0x7E00
DIAG_faultMasks_01	104	Diagnosis types bitfield related to HV and CHAIN errors (bytes 0 and 1 of the DIAG message). The bits are: [F]unused [E]unused [D]unused [C]BusOV [B]PackUV [A]PackOV [9]PackOC [8]HVShrt [7]CellUT [6]CellOT [5]CellUV [4]CellOV [3]DevHw [2]DevBaud [1]DevCom [0]DevNC. Setting the bit enables the corresponding fault. Shall be 0x1FFF

DIAG_faultMasks_67	105	Diagnosis types bitfield related to CPU and PLUGLOCK errors (bytes 6 and 7 of the DIAG message). The bits are: [F]unused [E]unused [D]unused [C]unused [B]Flash [A]Eeprom [9]unused [8]unused [7]unused [6]unused [5]unused [4]unused [3]unused [2]unused [1]unused [0]unused. Setting the bit enables the corresponding fault. Shall be 0x0C00
DIAG_faultMasks_45	106	Diagnosis types bitfield related to CTORS and CAN errors (bytes 6 and 7 of the DIAG message). The bits are: [F]unused [E]CtorDmg [D]unused [C]CtorPrOpen [B]CtorPClsd [A]CtorPOpen [9]CtorNClsd [8]CtorNOpen [7]unused [6]unused [5]unused [4]unused [3]unused [2]CANNC [1]unused [0]CANCmd. Setting the bit enables the corresponding fault. Shall be 0x5F05

8.2 Calibration protocol

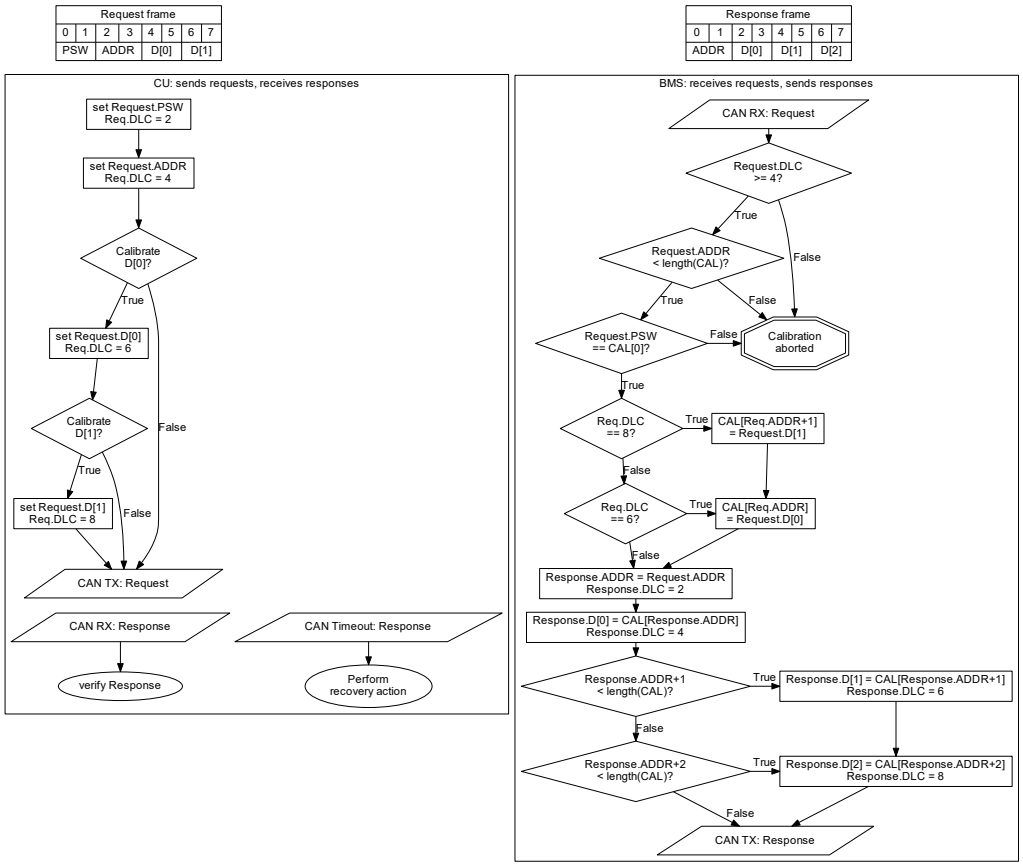


Figure 5: BMS calibration protocol

Calibration is done via the dedicated CAN messages (*Request* and *Response*).

The calibration protocol is represented in figure 5.

The new calibration variables are saved back to nonvolatile memory only after setting the *Enable* input low. If the power (KL30/KL31) is interrupted before clearing the *Enable* signal, the newly calibrated

variables will **not** be saved.

9 CAN messages

The CAN IDs and the presence of the CAN termination resistance can be calibrated into the BMS. The safety coprocessor CAN IDs and CAN speed cannot be calibrated.

The full CAN database in Vector (*.dbc) format is provided together with the BMS. All signals are big endian.

The following tables list the CAN nodes, messages and signals in the BMS DBC; the database being the authoritative source in case of a discrepancy.

9.1 Nodes

Name	Description
BMS	The Battery Management System is controlling the battery connection and the DC bus insulation, monitoring the cell voltages and temperatures, and reporting the battery limits.
VCU	The Control Unit managing the HV powertrain, requesting the BMS to connect the battery and receiving from the BMS the diagnoses related to the HV battery and the HV DC bus status.
CAL	The calibration and debug tool developed according to the provided BMS calibration protocol. Other than the calibration it can be used to read the BMS firmware revision and to read the single cell voltages and temperatures the BMS is measuring.
SFTY	The BMS safety coprocessor. It is a redundant processor monitoring the thresholds of all BMS signals, and cannot be calibrated.

9.2 BMS to VCU

BMS_01_CellV Highest and lowest cell voltages, and their cell ID. Sent only if the monitoring chain is active. **Send type**: cyclic **Cycle time**: 100 ms **Default frame ID**: 0x111

Name	Properties	Scaling	Unit	Description
BMS_VCellAvg	unsigned	0.001	V	Average cell voltage.
BMS_VCellHi	unsigned	0.001	V	Highest cell voltage.
BMS_VCellHiId	unsigned	1	–	Cell ID reporting the highest voltage.
BMS_VCellLo	unsigned	0.001	V	Lowest cell voltage.
BMS_VCellLoId	unsigned	1	–	Cell ID reporting the lowest voltage.

BMS_02_CellT Highest and lowest temperatures measured on the cell body, and the thermistor ID. Sent only if the monitoring chain is active and some thermistors are configured as cell body thermistors. **Send type**: cyclic **Cycle time**: 100 ms **Default frame ID**: 0x112

Name	Properties	Scaling	Unit	Description
BMS_TCellAvg	unsigned	0.01	degC	Average temperature of the cell bodies.
BMS_TCellHi	unsigned	0.01	degC	Highest measured cell body temperature.
BMS_TCellHiId	unsigned	1	–	Thermistor ID reporting the highest cell body temperature.
BMS_TCellLo	unsigned	0.01	degC	Lowest measured cell body temperature.

BMS_TCellLoId	unsigned	1	–	Thermistor ID reporting the lowest cell body temperature.

BMS_04_Pack01 Measured pack voltages, current and power. **Send type**: cyclic **Cycle time**: 10 ms **Default frame ID**: 0x114

Name	Properties	Scaling	Unit	Description
BMS_iPackSns	signed	0.1	A	Pack current.
BMS_PPackSns	signed	0.1	kW	Pack power.
BMS_VBusSns	unsigned	0.1	V	Measured voltage on the DC bus.
BMS_VPackSns	unsigned	0.1	V	Measured battery voltage.

BMS_05_Sys01 BMS system and subsystems statuses. **Send type**: cyclic **Cycle time**: 100 ms **Default frame ID**: 0x115

Name	Properties	Scaling	Unit	Description
BMS_eChrgSts	unsigned	1	–	Charger subsystem status.
BMS_eCtorSts	unsigned	1	–	Battery contactor status.
BMS_eDevSts	unsigned	1	–	Device chain status.
BMS_eImdSts	unsigned	1	–	IMD status.
BMS_eInvSts	unsigned	1	–	Inverter subsystem status.
BMS_eSysSts	unsigned	1	–	System status.
BMS_RImdSns	unsigned	1	kOhm	Grounds insulation resistance.
BMS_TBrd	unsigned	0.01	degC	BMS ambient temperature.

BMS_06_Diag01 BMS diagnostic flags. **Send type**: cyclicAndTriggered **Cycle time**: 500 ms **Default frame ID**: 0x116

Name	Properties	Scaling	Unit	Description
BMS_bFltAnlgNC	unsigned	1	–	Analog sensors power failure.
BMS_bFltBrdOT	unsigned	1	–	Ambient temperature too high.
BMS_bFltBrdUT	unsigned	1	–	Ambient temperature too low.
BMS_bFltBusOV	unsigned	1	–	DC bus voltage too high.
BMS_bFltCANChrg	unsigned	1	–	CAN communication went into timeout.
BMS_bFltCANCmd	unsigned	1	–	CAN communication went into timeout.
BMS_bFltCANCnt	unsigned	1	–	Fault detected on transmission counter.
BMS_bFltCANCRC	unsigned	1	–	Fault detected on wrong received CRC.
BMS_bFltCANNC	unsigned	1	–	The CAN cable is disconnected or the CAN communication is malfunctioning.
BMS_bFltCellOT	unsigned	1	–	One or more cells are in overtemperature.
BMS_bFltCellOV	unsigned	1	–	One or more cells are in overvoltage.
BMS_bFltCellUT	unsigned	1	–	One or more cells are in undertemperature.
BMS_bFltCellUV	unsigned	1	–	One or more cells are in undervoltage.
BMS_bFltCtorDmg	unsigned	1	–	The contactors are damaged.
BMS_bFltCtorDsOpen	unsigned	1	–	The discharge relay is not working, discharge not possible.
BMS_bFltCtorNClsd	unsigned	1	–	The contactor on the negative battery pole is stuck closed.

BMS_bFltCtorNOpen	unsigned	1	–	The contactor on the negative battery pole is stuck open.
BMS_bFltCtorPClsd	unsigned	1	–	The contactor on the positive battery pole is stuck closed.
BMS_bFltCtorPOpen	unsigned	1	–	The contactor on the positive battery pole is stuck open.
BMS_bFltCtorPrOpen	unsigned	1	–	The precharge relay is not working, precharge not possible.
BMS_bFltCtorRLoad	unsigned	1	–	The preharge phase didn't complete because someone is requesting current.
BMS_bFltCurr1NC	unsigned	1	–	The current sensor is not connected.
BMS_bFltCurr2NC	unsigned	1	–	The current sensor is not connected.
BMS_bFltDevBaud	unsigned	1	–	The measurement chain cannot communicate using the calibrated baudrate.
BMS_bFltDevCom	unsigned	1	–	The measurement chain communication failed.
BMS_bFltDevHW	unsigned	1	–	The measurement chain has an internal hardware fault.
BMS_bFltDevNC	unsigned	1	–	The measurement chain is not connected.
BMS_bFltEeprom	unsigned	1	–	The internal eeprom memory is faulty and its contents have been reset to zero.
BMS_bFltFlash	unsigned	1	–	The internal flash memory is faulty and its contents have been reset to zero.
BMS_bFltHVIL	unsigned	1	–	Interlock broken.
BMS_bFltHVShrt	unsigned	1	–	DC bus linked to battery due to safety coprocessor misbehaving
BMS_bFltImd	unsigned	1	–	The IMD signals an internal fault.
BMS_bFltImdGnd	unsigned	1	–	The IMD signals a ground error.
BMS_bFltImdKo	unsigned	1	–	The IMD signals an error condition.
BMS_bFltImdLoR	unsigned	1	–	The IMD signals a low resistance.
BMS_bFltImdNC	unsigned	1	–	The IMD is not connected.
BMS_bFltPackOC	unsigned	1	–	The measured pack current is too high.
BMS_bFltPackOV	unsigned	1	–	The measured pack voltage is too high.
BMS_bFltPackUV	unsigned	1	–	The measured pack voltage is too low.
BMS_bFltPlugLockClsd	unsigned	1	–	Plug lock not opening or stuck closed.
BMS_bFltPlugLockOpen	unsigned	1	–	Plug lock not closing or stuck open.
BMS_bFltPresent	unsigned	1	–	One non-masked fault is causing the contactors to open.
BMS_bFltWtrLk	unsigned	1	–	The waterleak sensor signals the presence of water inside the pack.
BMS_bFltWtrLkNC	unsigned	1	–	The waterleak sensor is not connected.
BMS_cntDiag01	unsigned	1	–	Message transmission counter.
BMS_crc8Diag01	unsigned	1	–	SAE J1850 CRC on message.

BMS_07_Pack02 Calculated pack total voltage, state of charge and power limits. Sent only if the monitoring chain is active. **Send type**: cyclic **Cycle time**: 100 ms **Default frame ID**: 0x117

Name	Properties	Scaling	Unit	Description
BMS_rPackSOC	unsigned	0.01	%	Calculated pack state of charge.
BMS_rPackSOChigh	unsigned	0.01	%	Calculated pack state of charge.

BMS_rPackSOH	unsigned	0.01	%	Estimated pack state of health, to be used for debugging purposes only.
BMS_VPackCalc	unsigned	0.1	V	Total pack voltage (as sum of the cell voltages)

BMS_08_Pack03 Charge and discharge times. Sent only if the monitoring chain is active. **Send type**: cyclic **Cycle time**: 100 ms **Default frame ID**: 0x118

Name	Properties	Scaling	Unit	Description
BMS_tChrgTm	unsigned	1	min	Time to bulk charge the battery pack to 95% SOC with average current.
BMS_tChrgTmMn	unsigned	1	min	Time to bulk charge the battery pack to 95% SOC with the continuous current limit.
BMS_tDschrgTm	unsigned	1	min	Time to discharge the battery pack to 5% SOC with average current.
BMS_tDschrgTmMn	unsigned	1	min	Time to discharge the battery pack to 5% SOC with the continuous current limit.

BMS_09_Lim01 Current limits. Sent only if the monitoring chain is active. **Send type**: cyclic **Cycle time**: 100 ms **Default frame ID**: 0x119

Name	Properties	Scaling	Unit	Description
BMS_iPackChrgCont	unsigned	0.1	A	Charging current limit, The continuous maximum limit is declared by the cell manufacturer.
BMS_iPackChrgPeak	unsigned	0.1	A	Charging current limit, The peak maximum limit is declared by the cell manufacturer.
BMS_iPackDschrgCont	unsigned	0.1	A	Discharging current limit, The continuous maximum limit is declared by the cell manufacturer.
BMS_iPackDschrgPeak	unsigned	0.1	A	Discharging current limit, The peak maximum limit is declared by the cell manufacturer.

BMS_10_Lim02 Power limits. Sent only if the monitoring chain is active. **Send type**: cyclic **Cycle time**: 100 ms **Default frame ID**: 0x11a

Name	Properties	Scaling	Unit	Description
BMS_PPackChrgCont	unsigned	0.1	kW	Calculated charging power limit, considering the instantaneous voltage drop after actuation.
BMS_PPackChrgPeak	unsigned	0.1	kW	Calculated charging power limit, considering the instantaneous voltage drop after actuation.
BMS_PPackDschrgCont	unsigned	0.1	kW	Calculated discharging power limit, considering the instantaneous voltage drop after actuation.
BMS_PPackDschrgPeak	unsigned	0.1	kW	Calculated discharging power limit, considering the instantaneous voltage drop after actuation.

9.3 BMS to CAL

INFO_01_DbgV Single cell voltage (multiplexed). **Send type**: cyclicIfActive **Cycle time**: 5 ms **Default frame ID**: 0x120

Name	Properties	Scaling	Unit	Description
BMS_eDbgVId	unsigned	1	–	Single cell ID.
BMS_VDbgV000	unsigned	0.001	V	Cell 0 voltage.
BMS_VDbgV001	unsigned	0.001	V	Cell 1 voltage.
BMS_VDbgV002	unsigned	0.001	V	Cell 2 voltage.
BMS_VDbgV003	unsigned	0.001	V	Cell 3 voltage.
BMS_VDbgV004	unsigned	0.001	V	Cell 4 voltage.
BMS_VDbgV005	unsigned	0.001	V	Cell 5 voltage.
BMS_VDbgV006	unsigned	0.001	V	Cell 6 voltage.
BMS_VDbgV007	unsigned	0.001	V	Cell 7 voltage.
BMS_VDbgV008	unsigned	0.001	V	Cell 8 voltage.
BMS_VDbgV009	unsigned	0.001	V	Cell 9 voltage.
BMS_VDbgV010	unsigned	0.001	V	Cell 10 voltage.
BMS_VDbgV011	unsigned	0.001	V	Cell 11 voltage.
BMS_VDbgV012	unsigned	0.001	V	Cell 12 voltage.
BMS_VDbgV013	unsigned	0.001	V	Cell 13 voltage.
BMS_VDbgV014	unsigned	0.001	V	Cell 14 voltage.
BMS_VDbgV015	unsigned	0.001	V	Cell 15 voltage.
BMS_VDbgV016	unsigned	0.001	V	Cell 16 voltage.

INFO_02_DbgT Single thermistor temperature (multiplexed). **Send type**: cyclicIfActive **Cycle time**: 10 ms **Default frame ID**: 0x121

Name	Properties	Scaling	Unit	Description
BMS_eDbgTId	unsigned	1	–	Single thermistor ID.
BMS_TDbgT000	unsigned	0.01	degC	Thermistor 0 temperature.
BMS_TDbgT001	unsigned	0.01	degC	Thermistor 1 temperature.
BMS_TDbgT002	unsigned	0.01	degC	Thermistor 2 temperature.
BMS_TDbgT003	unsigned	0.01	degC	Thermistor 3 temperature.
BMS_TDbgT004	unsigned	0.01	degC	Thermistor 4 temperature.
BMS_TDbgT005	unsigned	0.01	degC	Thermistor 5 temperature.
BMS_TDbgT006	unsigned	0.01	degC	Thermistor 6 temperature.
BMS_TDbgT007	unsigned	0.01	degC	Thermistor 7 temperature.
BMS_TDbgT008	unsigned	0.01	degC	Thermistor 8 temperature.
BMS_TDbgT009	unsigned	0.01	degC	Thermistor 9 temperature.
BMS_TDbgT010	unsigned	0.01	degC	Thermistor 10 temperature.
BMS_TDbgT011	unsigned	0.01	degC	Thermistor 11 temperature.
BMS_TDbgT012	unsigned	0.01	degC	Thermistor 12 temperature.
BMS_TDbgT013	unsigned	0.01	degC	Thermistor 13 temperature.
BMS_TDbgT014	unsigned	0.01	degC	Thermistor 14 temperature.
BMS_TDbgT015	unsigned	0.01	degC	Thermistor 15 temperature.
BMS_TDbgT016	unsigned	0.01	degC	Thermistor 16 temperature.

MEM_01_Fb Calibration response message. **Send type**: triggered **Default frame ID**: 0x56

Name	Properties	Scaling	Unit	Description
BMS_eCalBmsAddr	unsigned	1	–	Read memory address.
BMS_eCalBmsD0	unsigned	1	–	Read memory data, first word.
BMS_eCalBmsD1	unsigned	1	–	Read memory data, second word.
BMS_eCalBmsD2	unsigned	1	–	Read memory data, third word.
BMS_eCalBmsMem	unsigned	1	–	Memory selection.

9.4 VCU to BMS

BMS_00_Cmd Command message sent to the BMS. **Send type**: cyclic **Cycle time**: 100 ms **Default frame ID**: 0x110

Name	Properties	Scaling	Unit	Description
BMS_bAllVTEn	unsigned	1	–	Enable the sending of single cell voltages and temperatures.
BMS_bBlncEn	unsigned	1	–	Enables pack balancing.
BMS_bChrgDis	unsigned	1	–	Stops charging and disables the charger.
BMS_bCtorEn	unsigned	1	–	Allows the contactors to be closed.
BMS_bDschrgEn	unsigned	1	–	Allow the DC bus to be discharged (if the contactors are open).
BMS_cntCmd	unsigned	1	–	Message transmission counter, shall be incremented at each transmission.
BMS_crc8Cmd	unsigned	1	–	SAE J1850 CRC8 (poly: 0x1D, initial value: 0xFF, final XOR: 0xFF) calculated on previous message bytes.

9.5 CAL to BMS

INFO_00_SwVer RTR message showing the BMS software version hash. **Send type**: triggered **Default frame ID**: 0x82

Name	Properties	Scaling	Unit	Description
BMS_eSwVer0	unsigned	1	–	Software version hash.
BMS_eSwVer1	unsigned	1	–	Software version hash.

MEM_00_Rq Calibration request message **Send type**: triggered **Default frame ID**: 0x55

Name	Properties	Scaling	Unit	Description
BMS_eCalExtAddr	unsigned	1	–	Write memory, address.
BMS_eCalExtD0	unsigned	1	–	Write memory, first word.
BMS_eCalExtD1	unsigned	1	–	Write memory, second word.
BMS_eCalExtMem	unsigned	1	–	Memory selection.
BMS_eCalExtPsw	unsigned	1	–	Write memory, passcode.

9.6 CAL to SFTY

SFTY_00_Reset BMS reset request **Send type**: triggered **Default frame ID**: 0x95

Name	Properties	Scaling	Unit	Description
SFTY_KV4cmdReset	unsigned	1	–	If 1, safety coprocessor command the reset to the KV4 processor
SFTY_psswByte0	unsigned	1	–	Validation Password first byte for main processor reset
SFTY_psswByte1	unsigned	1	–	Validation Password byte for main processor reset
SFTY_psswByte2	unsigned	1	–	Validation Password byte for main processor reset
SFTY_psswByte3	unsigned	1	–	Validation Password byte for main processor reset
SFTY_psswByte4	unsigned	1	–	Validation Password byte for main processor reset
SFTY_psswByte5	unsigned	1	–	Validation Password byte for main processor reset
SFTY_psswByte6	unsigned	1	–	Validation Password byte for main processor reset

9.7 SFTY to VCU

SFTY_01_Pack01 Pack status messages from safety coprocessor. **Send type**: cyclicIfActive **Cycle time**: 100 ms **Default frame ID**: 0x96

Name	Properties	Scaling	Unit	Description
SFTY_HVbat	unsigned	1	V	Measured battery voltage.
SFTY_HVbatpDCn	unsigned	1	V	Crossed measure battery + / HVdc - voltage.
SFTY_HVdc	unsigned	1	V	Measured voltage on the DC bus.
SFTY_HVDCpBatn	unsigned	1	V	Crossed measure battery - / HVdc + voltage.

SFTY_02_Diag01 Diagnostic message from safety coprocessor. **Send type**: cyclicIfActive **Cycle time**: 100 ms **Default frame ID**: 0x97

Name	Properties	Scaling	Unit	Description
SFTY_bFltDschrg	unsigned	1	–	Timeout discharge DC BUS reached. Problem on discharge process.
SFTY_bHScmd	unsigned	1	–	Coprocessor commands to the High Side: 0 OPEN, 1 CLOSE
SFTY_bKV4CTreq	unsigned	1	–	Confirmation of main processor request the High Side contactors closing.
SFTY_cntDiag01	unsigned	1	–	Counter SFTY_02_Diag01 message.
SFTY_crc8Diag01	unsigned	1	–	SAE J1850 CRC8 SFTY_02_Diag01 message
SFTY_FltAnlgNC	unsigned	1	–	Analog sensors power failure.
SFTY_FltBrdOT	unsigned	1	–	Ambient temperature too high.
SFTY_FltBrdUT	unsigned	1	–	Ambient temperature too low.
SFTY_FltBusOV	unsigned	1	–	DC bus voltage too high.
SFTY_FltCalibCRC	unsigned	1	–	The calibration EEPROM memory status check.
SFTY_FltCANtout	unsigned	1	–	CAN communication went into timeout.
SFTY_FltCurrNC	unsigned	1	–	The current sensor is not connected.
SFTY_FltDev	unsigned	1	–	The chain claims a fault.

SFTY_FltHS	unsigned	1	–	The High Side contactor driver went in a fault condition.
SFTY_FltIL	unsigned	1	–	Interlock broken.
SFTY_FltImdKO	unsigned	1	–	The IMD signals an error condition.
SFTY_FltKV4lowV	unsigned	1	–	Processor's power supply failure.
SFTY_FltPackOC	unsigned	1	–	The measured pack current is too high.
SFTY_FltPackOV	unsigned	1	–	The measured pack voltage is too high.
SFTY_FltPackUV	unsigned	1	–	The measured pack voltage is too low.
SFTY_FltWL	unsigned	1	–	The waterleak sensor signals the presence of water inside the pack.
SFTY_FltWLNC	unsigned	1	–	The waterleak sensor is not connected.

10 Acronyms

AFE Analog Front-End
BMS Battery Management System
BMU Battery Monitoring Unit
CAN Controller Area Network
EV Electric Vehicle
HEV Hybrid Electric Vehicle
HV High Voltage
HVIL High Voltage Interlock Loop
IMD Insulation Monitoring Device
LV Low Voltage
PSU Power Supply Unit
PHEV Plug-in Hybrid Electric Vehicle
SOA Safe Operating Area
SOC State of Charge
SOH State of Health
SOP State of Power/Performance

11 Disclaimer