LC Single or Parallel Pack CAN Bus Guide Rev 1.11

EnerDel

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Revision History

1.0	DCH	04/01/2014	Configuration differences from Generic Parallel Pack.
1.1	DCH	05/09/2014	Updated with new configurable CAN protocol
1.2	DCH	11/21/2014	Various corrections
1.3	RHJ	03/14/2016	Add Highest_Err_Cat to BMS_Startup message.
1.4	RHJ	09/20/2017	Add Frequently Asked Questions section. Add Contactors_Opening to EDL_Data06 message. Add Fuse Blown fault and Precharge Contactor Stuck On and Stuck Open faults. Rename Main Contactor Open Timeout fault to Main Contactor Open Under Load fault. Delete PTC Heater fault.
1.5	RHJ	2/19/2018	Add note about Contactor_Opening logic and timing of EDL_Data06. Update note on EDL_Data05 message. Add the BMS_Startup message to the expansion pack messages. Remove 'N/A' from No CAN Contactor Request condition code.
1.6	RHJ	6/11/2018	Add Current Fault Limits CAN message. Add Send Current Fault Limits flag in Heartbeat CAN message. Add System Config Disable Contactor condition code and error reason.
1.7	RHJ	1/22/2019	Update Contactor Conditions Codes and Highest Error Reasons.
1.8	RHJ	2/26/2019	Add Contactor Conditions Code Precharge Wait Voltage Not In Range.
		3/18/2019	Correct description of Ext_ISO_Enable in PCU Contactor Request message.
1.9	RHJ	4/15/2019	Renamed IN_12V faults to SUPPLY_V (undervolt fault and warning).
1.10	RHJ	8/6/2019	Revise text to reflect that expansion packs can be engaged without the executive pack being engaged. Add note that contactors must be engaged in order to allow the CAN Fan Request.

1.11	RHJ	9/16/2019	Add I_AM_EXEC indicator to Exec_Status byte.

Overview

EnerDel battery pack systems contain both an onboard microprocessor system and contactors that connect the battery to external loads/sources. These components, which make up the battery management system (BMS), provide control, safety, and monitoring functions through a user provided control system using a CAN based network. This document, along with a standard CANdb database file (dbc), is intended to provide the user with the information necessary to successfully control and monitor the EnerDel battery pack.

The 'LC' designation for the BMS application code stands for "Loadable Configurable". This is the most recent code set, which uses a separate configuration file stored in flash memory. This file contains several parameters which allow the application code to be tailored to a number of different operating configurations.

The CAN communications protocol provided by this BMS is based on CAN and is configured at the factory for one of two different Baud rates and one of two different ID sizes (11-bit and 29-bit).

The communications protocol consumes two ID ranges. The first (or application) range of CAN IDs is made available to the user for control and monitoring of the EnerDel battery pack. The second (or tool) range of CAN IDs is reserved for use by EnerDel for service/factory control. The user application must NOT utilize the second CAN ID range for other communications or battery pack damage (which may compromise system safety) may occur. The number of CAN IDs consumed depends on the number of parallel packs in the system. These IDs are defined in the table below.

Certain values and limits are configurable and downloaded at the factory. Descriptions below provide default values and an indication if the value is configurable. If your application required values different from default, please refer to the appropriate order information.

Protocol "Application" Message Set 1 (29-bit CAN IDs)

Message	**ID**	**Message**	**ID**
PCU_Connector_Req	0x18FF0203	No Response	
PCU_Heartbeat	0x18FF0213		
		Exec Request	0x1CFF3F60
Pack Monitor Data (Sent every 200mS)		*Volt/Temp Data*	0x1CFF**z**360
		SOC Data	0x1CFF**z**460
		Charge Data	0x1CFF**z**560
		Power Data	0x1CFF**z**660
		Contactor Data	0x1CFF**z**760
		Extended Contactor Data	0x1CFF**z**A60
		System Data	0x1CFF**z**B60
		System Data 2	
Pack Version and Fault Data (Sent every 1000mS)		*Version*	0x1CFF**z**260
		Active Fault Data	0x1CFF**z**160
		Latched Fault Data	0x1CFF**z**960
		History Fault Data	0x1CFF**z**860

Protocol "Factory" Message Set 1(29-Bit CAN IDs)

Message	ID	Message	ID
ALDLCommand	0x1CFF**x**061	*ALDL Response*	0x1CFF**y**060

Where:

1. Pack ID 0 is assigned to Executive pack at factory. Expansion packs are addressed consecutively from Pack ID 1 to Pack ID 2
2. 'x' = 2000h + (1000h * Pack ID): tool -> pack
3. 'y' = 3000h + (1000h * Pack ID): pack -> tool
4. 'z' = 3000h + (1000h * Pack ID): pack broadcast
5. Extended contactor Data only sent from executive if more than 7 expansion packs configured
6. Factory control messages that effect operation are protected with seed and key security

Protocol "Application" Message Set 2 (11-bit CAN IDs)

Message	ID	Message	ID
PCU_Connector_Req	0x310	No Response	
PCU_Heartbeat	0x311		
		Exec Request	0x72F
Pack Monitor Data (Sent every 200mS)		*Volt/Temp Data*	0x6**x**0
		SOC Data	0x6**x**1
		Charge Data	0x6**x**2
		Power Data	0x6**x**3
		Contactor Data	0x6**x**4
		Extended Contactor Data	0x6**x**A
		System Data	0x6**x**5
		System Data 2	0x6**x**6
Pack Version and Fault Data (Sent every 1000mS)		*Version ('Startup' Msg)*	0x7**y**4
		Active Fault Data	0x7**y**1
		Latched Fault Data	0x7**y**2
		History Fault Data	0x7**y**3

Protocol "Factory" Message Set 2 (11-Bit CAN IDs)

Message	ID	Message	ID
ALDLCommand	0x6**x**E	*ALDL Response*	0x6**x**F

Where:

1. Pack ID 0 is assigned to Executive pack at factory. Expansion packs are addressed consecutively from Pack ID 1 to Pack ID 2
2. 'x' = (10h * Pack ID): tool -> pack
3. 'y' = (20h * Pack ID): pack -> tool
4. Extended contactor Data only sent from executive if more than 7 expansion packs configured
5. Factory control messages that effect operation are protected with seed and key security

The (application) messages are single frame messages which are typically passed between the user provided power control unit (PCU) and the first EnerDel battery pack (which is designated the Executive). If additional parallel (expansion) battery packs are present in the system, they will communicate with the Executive battery pack using the same CAN communications channel as the PCU. The network loading with 7 Enerdel battery packs along with a PCU is approximately **15%**.

The PCU controls the EnerDel battery packs though two broadcast messages (received by all the EnerDel battery packs on the same network). The EnerDel battery packs also broadcast status information in a number of packets. The EnerDel battery pack that is designated as the Executive (one with lowest Pack ID) transmits system status information as an accumulation of its own data along with expansion battery pack data. Therefore, the PCU generally only needs to monitor the Executive battery pack broadcast communications.

Pack Control Functions

Pack operation requires the PCU to continuously send two CAN messages that provide both heartbeat and contactor closure functionality. The heartbeat function actually requires the PCU to broadcast both CAN messages: PCU_Contactor_Req and PCU_Heartbeat at recommended rate of every 200 ms (+/- 50 ms). If both messages are NOT continually sent within the specified time, contactor closure is prevented <or> if already closed, contactors will be opened and a fault recorded.

Contactor closure (EnerDel battery pack engagement to the power bus) requires specific signals (bits) to be set in the PCU_Contactor_Req CAN request. A closure signal (bit) is actually provided for each parallel battery pack in the system to allow for flexibility. Typically, all bits are activated by the PCU at the same time. However, customized control stategies may be implemented by the vehicle controller (PCU) as necessary.

Signal positions and additional notes are provided in the message definitions below.

Pack Monitor Functions

Data that requires monitoring by the PCU is provided in several CAN messages from the Executive pack. Two of the most important signals are the Max_Chg_Current and Max_DChg_Current (EDL_Data02). These parameters provide the maximum charge (sink) and maximum discharge (source) current that may be safely passed through the battery system at any given time. If the PCU allows more than the specified current for a specific time, the battery pack contactors will open and a fault will be recorded. Alternatively, the signals Max_Chg_Power and Max_DChg_Power (EDL_Data03) may be used if kW is preferred over Amps.

SOC data is provided to give the end user the State Of Charge of the battery pack. This value gives an indication of how much charge is left in the pack at any particular time based on a percentage.

Fault and contactor code data is provided to give the end user an indication of why contactors are not closing in the system.

Additional signals, signal positions, and additional notes are provided in the message definitions below.

Pack Operational Modes (Drive / Charge)

Before contactors are closed (and BMS system is enabled), the battery pack must be placed in one of two modes: Drive or Charge. Drive mode is enabled through the Key Run (hardware) input while Charge mode is enabled through the Charge Wake (hardware) input. Drive mode is fully capable of allowing either pack charging or discharging depending entirely on whether the external system is supplying or drawing current. Charge mode is optional and with this release, the only difference between the modes is that Charge mode minimizes cell balancing action and records pack history information in a separate category.

Note that the Hardware EPO (Emergency Power Off) input must also be present to close contactors. This input is normally high and goes low when active (power off).

When both Key Run and Charge Wake inputs are removed, the BMS system remains powered long enough for history values to be stored to EEPROM. Thereafter, the system shuts down with minimal draw on the battery pack and auxiliary power.

Sequence of Operation Notes

- On the rising edge of the Key Run (wakeup) signal, the BMS will power up and go through hardware initialization.

- After initialization, battery packs start broadcasting status information including an indication of BMS_Init_Successful. On reception of status information, the PCU should also validate that no faults exist (i.e. Cell UnderVoltage Fault, etc.).

- The PCU should then start sending PCU_Contactor_Req and PCU_Heartbeat CAN messages.

  After initialization, the BMS will wait up to 4 seconds to receive PCU_Contactor_Req and PCU_Heartbeat CAN messages. If the BMS does not receive those CAN messages within this time, the BMS will set the BMS_Contactor_Conditions_Code signal (Msg EDL_Data00) to “No PCU Data Received” (decimal 11) and leave the contactors de-energized until these messages are received.

- Once these CAN messages are received and the PCU_Contactor_Req data is calling for contact closure, the BMS starts the following contact closure sequence:

  1. **Contactors self-test** - A series of internal contactor closures and measurements. During this time a complete battery pack current path is NOT completed to the external bus. If the self-test fails, the contactor sequence is aborted and the proper fault information provided.
  2. **Internal isolation test (optional)** - If configured, this Internal test typically takes approximately 10 seconds to check for leakage to chassis ground. During this period a complete battery pack

current path is NOT completed to the external bus. If isolation resistance is below a preset limit, the contactor sequence is aborted and the proper fault information is provided.

3. **Precharge cycle/test** - Internal contact closure connects battery pack to external bus through a precharge resistor to reduce reactive currents and provide either a short circuit or excessive bus voltage difference test. If the external bus voltage is below 20 volts before precharge cycle and does not increase at least 50 volts (configurable) with-in 200 mS (configurable) after the precharge cycle starts, the contactor sequence is aborted and a shorted bus fault indication is provided. Additionally, if the bus voltage does not reach within 5% (configurable) of the battery pack voltage with 1.0 sec (configurable) the precharge cycle will fail. After a 2 sec delay, the pack will attempt a **single** retry. Failure results depend on which battery pack fails:

   Executive pack - contactor sequence is aborted and the proper fault is information is provided. Since executive contact closure is aborted, all expansion pack contactor closure is also aborted.

   Expansion pack - battery pack is disconnected from external bus. However, it remains in a stall condition waiting for the external bus voltage to fall within 5% of battery pack voltage.

4. **Contactors Closed** - If the above steps complete successfully, the precharge resistor is switched out and the battery pack is connected directly to the external bus until commanded to disconnect or a fault occurs.
5. **External Isolation Test (optional)** - After contactor closure, the executive pack continues to perform external isolation resistance to chassis ground test every 30 sec (configurable) or as commanded by the PCU (Ext_ISO_Enable). If the resistance falls below a preset value (configurable), a fault is recorded and contactors are opened. Note that enabling this test will present a very high impedance path to chassis ground which may interfere with external isolation detection devices. If an isolation fault is detected during operation, the contactors will remain closed for 60 seconds (configurable) to allow safe discontinuation of operation.

- When expansion packs are present in the system, the following consideration should be followed with respect to the PCU_Contactor_Req contactor request data:

  1. Typical operation is to activate all packs concurrently.
  2. The PCU may effectively remove a malfunctioning battery pack by no longer setting the associated contactor request bit.
  3. The individual battery pack contactor status can be determined from the contactor status information in CAN message EDL_Data04.

- Once battery pack contactors are closed (attached to external bus) the PCU may enable external loading or sourcing of current. A component of the battery pack status information is the real-time Max_DChg_Current and the Max_Chg_Current signals. The PCU MUST prevent the external loading or sourcing of current from exceeding these values. If the system current exceeds these current limits by a certain margin (configurable) for 10.0 Seconds (configurable), a fault is recorded and contactors will open. Overcurrent limits are set based on the characteristics of the application.

  Max_DChg/Chg_Current signals are determined from the number of expansion packs actually connected to the bus.

- The BMS system also records a fault and opens contacts on an absolute over-current condition. This fault is activated if the system current exceeds a certain maximum limit (configurable) for 2.0 Seconds (configurable). Overcurrent limits are set based on the characteristics of the application.

- Additional Fault Considerations:

    1. When the BMS detects a fault for which it is necessary to open the contactors, it will first zero out the reported Max_DChg/Chg_Current and the Max_DChg/Chg_Power signals in Msg EDL_Data02 and EDL_Data03. Then the BMS will wait up to **3 seconds** for current to stop before opening contactors. If the 3 second period is exceeded and system current is still present, the BMS proceeds to open the contactors. It is preferred that the PCU adhere to the values in the max current limit variables, so that contactors are not opened under load.
    2. During operation and after PCU communications has been established, if messages PCU_Contactor_Req and PCU_Heartbeat are lost for **1 second**, the BMS records the fault and opens the contactors.
    3. Signal BMS_Contactor_Conditions_Code gives additional information in the case where the contactors cannot be engaged or must be dropped out. This signal can be found in CAN message EDL_Data00 for the Executive pack and in Exp<n>_Data00 for the Expansion packs. The data descriptions for CAN message EDL_Data00 also detail which of these faults are Key Cycle Category Faults and which are Service Category faults.
    4. A Key Cycle Category fault will hold the contactors off (even after the fault condition is resolved) until the Key Run input is cycled off and back on. Which faults are defined as Key Run faults are listed under the EDL_Data00 definition below.
    5. A Service Category fault will hold the contactors off until the Service Category faults are manually cleared with a service tool (see CAN Msg 1CFF2061). Which faults are defined as Service Category faults are listed under the EDL_Data00 definition below.
    6. Should a pack experience an excessive shelf life and/or allowed to discharge below allowable cell voltage limits, contactors will be prevented from closure. Factory service may be required to restore the battery pack to normal operation.

Frequently Asked Questions

- How do I determine if it is OK to draw current from the battery pack or charge the pack?

  Before drawing current, check that Max_DChg_Current in message EDL_Data02 is non-zero. Do not exceed this specified limit.

  Before charging the pack, check that Max_Chg_Current in message EDL_Data02 is non-zero. Do not exceed this specified limit.

- How do I determine if there are any conditions in the pack which will prevent the contactors from engaging or cause the contactors to disengage?

  Check if BMS_Contactor_Conditions_Code in message EDL_Data00 is non-zero. If non-zero, the contactors will not engage. The meaning of the code values can be found in the description of the EDL_Data00 message below.

- How do I determine if the Battery Management System (BMS) has detected any abnormal conditions (Faults) in the pack?

  The detected fault codes are transmitted in three CAN messages: EDL_Active_Fault_Data, EDL_Latched_Fault_Data, and EDL_History_Fault_Data (see detail below).
  The Active Fault message lists faults which are present at this time.
  The Latched Fault message lists faults which have been present during this ignition cycle.
  The History Fault message lists faults which have occurred since faults were manually cleared.
  Note that some faults will affect contactor operation and some will not. See the list of BMS_Contactor_Conditions_Codes detailed under message EDL_Data00 to determine which faults and conditions will affect contactor operation.

- Is there any way to determine if the BMS is about to open contactors, besides checking if the current limits are zero?

  Yes, the signal Contactors_Opening in message EDL_Data06 will become TRUE if the BMS needs to open contactors and is waiting for current to fall below an acceptable level before opening the contactors. Also, while this signal is TRUE, the periodic rate of message EDL_Data06 is increased to 25 ms to facilitate rapid communication of this signal.

- Is there a way to turn on the pack fan?

  Yes, if the pack is equipped with a fan, signal Force_Fan_On in received message PCU_Contactor_Req will cause the fan to turn on when the signal is set to TRUE. The contactors must be engaged in the pack in order for the fan to operate. Note that if the BMS commands the fan to be on, the fan will be on regardless of the state of the Force_Fan_On signal.

BMS CAN Messages

An overview of the messages contained in the dbc file follows. A brief description is added for any signal in the message that is critical for operation or is considered noteworthy for any other reason. (Any signals defined in the dbc file but not presently used in the system are excluded from these lists.)

Messages Received by the BMS

PCU Contactor Req

Received by BMS (* Required for operation)
Periodic Rate: 200 ms
Signals:

Byte	Bit	Signal	Notes
0	bCAN_Contactor_Req (MSB)		
	0	Contactor_Request_Pack_8	This represents a request from the PCU, however, expansion packs will NOT engage contactors unless the corresponding message from the EXEC indicates OK to engage Actual number of requests dependent on number of expansion packs configured for system.
	1	Contactor_Request_Pack_9	
	2	Contactor_Request_Pack_10	
	3	Contactor_Request_Pack_11	
	4	Contactor_Request_Pack_12	
	5	(reserved)	
	6	(reserved)	
	7	(reserved)	
1	bCAN_Contactor_Req (LSB)		
	0	Contactor_Request_Pack_0 (Executive)	
	1	Contactor_Request_Pack_1	
	2	Contactor_Request_Pack_2	
	3	Contactor_Request_Pack_3	
	4	Contactor_Request_Pack_4	
	5	Contactor_Request_Pack_5	
	6	Contactor_Request_Pack_6	
	7	Contactor_Request_Pack_7	
2	PCU Commands		
	0	PCU_Fault	Open pack contactors (normal delay)
	1	(reserved)	
	2	(reserved)	
	3	(reserved)	
	4	PCU_Critical_Fault	Open pack contactors (no delay)
	5	Exec send local data only	Does not include aggregation of expansion pack data (generally limited to testing only)
	6	Ext_ISO_Enable	Commands the Executive pack to perform an external isolation test. This command is active only if the External ISO Mode is configured to one of these modes: Switched Requested Mode, Non-switched Requested Mode, Switched Continuous Mode, or Non-switched Continuous Mode.
	7	Force Fan On	Fan override - If fan operation configured, contactors closed, no isolation fault, and a minimum number of valid temp readings present
3	(reserved)		
4	(reserved)		

5	(reserved)	
6	(reserved)	
7	(reserved)	

Suggested transmit values (hex):

ID	Data 0	Data1	Data 2	
18FF0203	00	01	00	(Data shown for Pack 0 contactor request)

Note:

If the PCU commands immediate contactor opening as a result of an emergency condition, signal PCU_Critical_Fault must remain set until contactors open to guarantee fast open operation.

PCU Heartbeat

Received by BMS (* Required for operation)

Periodic Rate: 200 ms

Signals:

Byte	Bit	Signal	Notes
0	Byte 0		
	0	(reserved)	Byte 0 Bit 7 controls whether the Current Fault Limits CAN message is transmitted.
	1	(reserved)	
	2	(reserved)	
	3	(reserved)	
	4	(reserved)	
	5	(reserved)	
	6	(reserved)	
	7	Send Current Fault Limits	
1	Byte 1		
	0	(reserved)	
	1	(reserved)	
	2	(reserved)	
	3	(reserved)	
	4	(reserved)	
	5	(reserved)	
	6	(reserved)	
	7	(reserved)	

Suggested transmit values (hex):

ID	Data 0	Data1
18FF0213	00	00

Messages Transmitted by the BMS

The following data packets are broadcast by both Executive and Expansion battery packs. The difference in data is that the Executive battery pack presents the system (or accumulated) data from all the battery packs that are currently engaged. The only exception to this is the Current Fault Limits message, which transmits values calculated by each individual pack, for diagnostic purposes.

(See DBC file for more information on byte positions and scaling)

BMS_Startup (Version Information)

Transmitted by BMS
Periodic Rate: 1 sec
Signals:

Byte	Bit	Item	Notes
0	SW_Major_Ver		Software version information
1	SW_Minor_Ver		
2	SW_Build		
3	SW_Program_Target		Software program information
4			
5	BMS_HW_Ver		Hardware version information
6	BMS_Init_Successful		True if system initialized properly
7	Highest_Err_Cat		Highest error category 0 - 4

Highest Error Category:

0 No error
1 Reserved
2 Continue operation, possible reduced power
3 Delayed switch off, till timeout or Key Off
4 Immediate switch off, with current ramp-down if possible

EDL_Data00

Transmitted by BMS
Periodic Rate: 200 ms
Signals:

Byte	Bit	Item	Notes
0	Max_CV (Max Cell Voltage)		0.0024414 V/bit (Exec: MAX of all packs)
1			
2	Min_CV (Min Cell Voltage)		0.0024414 V/bit (Exec: MIN of all packs)
3			
4	Max_Pack_Temp (Max Cell Voltage)		1 degC/bit (Exec: summary of all packs)
5	Min_Pack_Temp (Min Cell Voltage)		
6	BMS_Contactor_Conditions_Code		Failure if not zero (see conditions below)
7	0-6	BMS_Highest_Error_Reason	Failure if not zero (see highest err below)
	7	Remote_Comm_Fault	If internal RLEC communications fault

BMS Contactor Conditions Code:

Decimal value, Present Status, Designators (S) = Service Category Fault
(K) = Key Cycle Category Fault

0 Conditions OK
1 Emergency Power Off Not Present (K)
2 All Internal Slave Data Not Received
3 Cell Over Voltage (K)
4 Cell Under-Voltage (K)
5 Pack Over Current (K)
6 Pack Over Temperature (K)
7 Pack Under-Temperature (K)

8	Circuit Board Over Temperature	(K)
9	PreCharge Retry Fault	(K)
10	PreCharge Short Circuit Fault	(K)
11	No PCU Data Received (Battery & Heartbeat)	(K)
12	(Reserved)	(K)
13	(Reserved)	(K)
14	PCU Fault (Battery command bit)	
15	Isolation Fault with Contactors On	(K)
16	Isolation Fault with Contactors Off	(K)
17	Low Voltage Pack Recover Mode	
18	Key Cycle Category Fault	(Contactors locked out til next key cycle)
19	Service Category Fault	(Contactors locked out til service faults codes cleared)
20	Circuit Board Under-Temperature	(K)
21	Powerup Self Test Fail	(K)
22	No CAN Contactor Request	
23	Secondary ContA or FuseA Fault	(K)
24	Contactor 1 Stuck On Fault	(S)
25	Contactor 2 Stuck On Fault	(S)
26	(Reserved)	(N/A)
27	Secondary Contactor Stuck On Fault	(K)
28	(Reserved)	(N/A)
29	Contactor 1 Dropout Fault	(K)
30	(Reserved)	(N/A)
31	Contactor 2 Dropout Fault	(K)
32	Contactor 1 Stuck Open Fault	(K)
33	Contactor 2 Stuck Open Fault	(K)
34	Secondary ContB Or FuseB Fault	(K)
35	Pack Over-current Regulation Fault	(K)
36	Aux Batt Undervoltage Fault	
37	Discharge during Charge Fault	(K)
38	Cell Voltage Connection Fault	(S)
39	Extreme Cell Undervoltage Fault	(S)
40	Current Sensor AD Fault	(K)
41	Low Current Correlation Fault	(K)
42	High Current Correlation Fault	(K)
43	Fuse Blown Fault	(K)
44	CellV Compare Fault	(K)
45	ModuleV To CellV Compare Fault	(K)
46	Module Voltage Outlier Fault	(K)
47	High Contactor Current Fault	(K)
48	Invalid System Configuration Loaded	
49	Precharge Contactor Stuck On	
50	Precharge Contactor Stuck Open	
51	OBD Comm Disabled	
52	System Config Disable Contactor	
53	Contactor Pull In Reset Fault	
54	Internal Comm Fault	
55	Precharge Wait Voltage Not In Range	

BMS Highest Err Reason

Decimal value, Highest detected error, Designators (S) = Service Category Fault

0	No Error	
1	PCU Fault	
2	No Charge Current	
3	Circuit Board Temperature Warning	
4	Current Limit On Low Temperature	
5	Current Limit On High Temperature	
6	External Isolation Fault	
7	Internal Isolation Fault	
8	(Reserved)	
9	(Reserved)	
10	No PCU Data Received (Contactor Req / Heartbeat)	
11	PreCharge Short Circuit Fault	
12	PreCharge Retry Fault	
13	Circuit Board Over-Temperature Fault	
14	Pack Under-Temperature Fault	
15	Pack Over-Temperature Fault	
16	Pack Over-Current Fault	
17	Cell Under-Voltage Fault	
18	Cell Over-Voltage Fault	
19	Contactor 2 Stuck On Fault	(S)
20	Secondary Contactor Open Fault	
21	Emergency Power Off Active	
22	Circuit Board Under-Temperature Fault	
23	Contactor 1 Stuck On Fault	(S)
24	Slave Data Not Received Fault	
25	Powerup Self Test Fault	
26	Secondary Contactor Stuck On Fault	
27	Contactor Dropout Fault	
28	Fan Current High Fault	
29	Fan Current Low Fault	
30	Aux Batt Under-Volt Fault	
31	Contactor 1 Stuck Open Fault	
32	Contactor 2 Stuck Open Fault	
33	Discharge during Charge Fault	
34	Key Cycle Category Fault	
35	Service Category Fault	
36	High Contactor Coil Current Fault	
37	Cell Voltage Connection Fault	(S)
38	Extreme Undervoltage Fault	(S)
39	One Current Sensor Fault	
40	Both Current Sensors Fault	
41	Low Current Correlation Fault	
42	High Current Correlation Fault	
43	Pack Voltage Sensor Fault	
44	String Voltage Mismatch Fault	

45 Aux Batt Under-Volt Warning
46 Main Contactor Open Under Load Fault
47 Fuse Blown Fault
48 CellV Compare Fault
49 ModuleV To CellV Compare Fault
50 Module Voltage Outlier Fault
51 No CAN Contactor Request
52 (Reserved)
53 First PreCharge Fail Fault
54 Analog Input Invalid Calibration
55 Invalid System Configuration Loaded
56 Precharge Contactor Stuck On
57 Precharge Contactor Stuck Open
58 OBD Disable Comm
59 Sys Config Disable Comm
60 Contactor Pull In Reset Fault
61 Internal Comm Fault

EDL_Data01

Transmitted by BMS
Periodic Rate: 200 ms
Signals:

Byte	Bit	Item	Notes
0	Avg_CV (Average Cell voltage)		0.0024414 V/bit (Exec: AVG of packs)
1			
2	Delta_CV (diff between min and max CV)		0.0024414 V/bit (Exec: MAX of packs)
3			
4	Sys_Total_Ratio		0.00156 %/bit SOC compensated for imbalance and pack capacity
5			
6	Sys_SOUE (State Of Usable Energy)		(Exec: calculation of all packs)
7	Sys_SOC (State Of Charge)		(Exec: calculation of all packs)

EDL_Data02

Transmitted by BMS
Periodic Rate: 200 ms
Signals:

Byte	Bit	Item	Notes
0	Max_Chg_Current		0.1A/bit
1			
2	Max_DChg_Current		0.1A/bit
3			
4	System_Current		0.1A/bit - Pos = charge / Neg = discharge) (Exec: Sum of all packs)
5			
6	String_1_Voltage		0.1 V/bit
7			

EDL_Data03

Transmitted by BMS
Periodic Rate: 200 ms
Signals:

Byte	Bit	Item	Notes
0	Max_Chg_Power		0. 1 KW/bit
1			
2	Max_DChg_Power		0. 1 KW/bit
3			
4	Total_DChg_Energy		0.1 KWH/bit
5			
6			
7			

EDL_Data04

Transmitted by BMS
Periodic Rate: 200 ms
Signals:

Byte	Bit	Item	Notes
0	Exec_Contactor_Status		
	0	Stuck Check in Progress	
	1	ISO Check in Progress	
	2	Current Limit Active	
	3	Precharge Status	Current contactor status
	4	Cont A Status (String 1 Mid-pack)	
	5	Cont B Status (String 2 Mid-pack)	
	6	Cont 1 Status	
	7	Cont 2 Status	
1	Exp_1_Contactor_Status		Exec Only - should be zero for exp packs (same bit pattern as byte 0)
2	Exp_2_Contactor_Status		
3	Exp_3_Contactor_Status		
4	Exp_4_Contactor_Status		
5	Exp_5_Contactor_Status		
6	Exp_6_Contactor_Status		
7	Exp_7_Contactor_Status		

EDL_Data04B

Transmitted by BMS
Periodic Rate: 200 ms
Signals:

Exp_8_Contactor_Status - Exp_11_Contactor_Status
(Present only if system supports more than 7 expansion packs)

EDL_Data05

Transmitted by BMS
Periodic Rate: 200 ms
Signals:

Byte	Bit	Item	Notes
0	Bus_Voltage[1]		0.1V/bit
1			
2	Pack_Voltage		0.1V/bit
3			
4	Iso_Res (Int/Ext Isolation Resistance)		1 KOhm/bit
5			
6	String_Voltage[2]		0.1 V/bit
7			

Notes:

1. Series executive pack transmits summed series Bus Voltage (Exec + Exp1), otherwise local Bus Voltage is transmitted.
2. Executive pack: Minimum system-level string voltage.
   Expansion packs: String 2 voltage (or 0 if not present).
   Series packs: Summed series Bus Voltage (Exp 2 + Exp 3).

EDL_Data06

Transmitted by BMS

Periodic Rate: 200 ms (25 ms when contactors are about to open)

Signals:

Byte	Bit	Item	Notes
0	Max_Chg_Voltage		0.1V/bit
1			
2	Min_DChg_Voltage		0.1V/bit
3			
4	Max_SOC		0.4 %/bit
5	Min_SOC		
6	Avg_Pack_Temp		1 DegC/bit (signed)
7	System_Status[1]		
	4	I Am Executive	
	5	Exec sending local data	
	6	Contactors_Opening	
	7	Fan Active	

Notes:

1. Present in Executive message only

Note, the signal Contactors_Opening in message EDL_Data06 will become TRUE if the BMS needs to open contactors and is waiting for current to fall below an acceptable level before opening the contactors. Also, while this signal is TRUE, the periodic rate of message EDL_Data06 is increased to 25 ms to facilitate rapid communication of this signal.

Current_Fault_Limits

Transmitted by BMS

Periodic Rate: On new current limit calculation (typically once per second)
Transmitted if enabled by Send Current Fault Limits flag in Heartbeat message.

Signals:

Byte	Bit	Item	Notes
0	Chg_Over_Current		0.1A/bit
1			

2 3	DChg_Over_Current	0.1A/bit
4 5	Chg_Over_Reg_Current	0.1A/bit
6 7	DChg_Over_Reg_Current	0.1 V/bit

EDL_Active_Fault_Data

Transmitted by BMS

Periodic Rate: 1 second

	Malf #	Name	Description
Byte 0			
Bit 0	0	BUS_VOLT_AD_FLT	Bus voltage A/D fault
Bit 1	1	PACK_VOLT_AD_FLT	Pack voltage A/D fault
Bit 2	2	PACK_CUR_B_HI_AD_FLT	Pack current B hi A/D fault
Bit 3	3	PACK_CUR_B_LO_AD_FLT	Pack current B lo A/D fault
Bit 4	4	PACK_CUR_A_HI_AD_FLT	Pack current A hi A/D fault
Bit 5	5	PACK_CUR_A_LO_AD_FLT	Pack current A lo A/D fault
Bit 6	6	BD_UNDER_TEMP_FLT	Circuit board under temperature fault
Bit 7	7	SEC_STUCK_ON_FLT	A secondary contactor is stuck closed
Byte 1			
Bit 0	8	INT_ISO_FLT	Internal isolation fault
Bit 1	9	EXT_ISO_FLT	External (or internal) isolation fault
Bit 2	10	SEC_CONTA_OPEN_FLT	Secondary contactor A or fuse A fault
Bit 3	11	CONT_PCHG_SHORT_FLT	Short circuit detected at precharge
Bit 4	12	CONT1_DROPOUT_2ND_FLT	Contactor 1 dropout second fault
Bit 5	13	CONT1_DROPOUT_1ST_FLT	Contactor 1 dropout first fault
Bit 6	14	CONT_PCHG_RETRY_FLT	Max number of precharge retries exceeded
Bit 7	15	CONT_PCHG_FLT	Contactor precharge timeout fault
Byte 2			
Bit 0	16	REDUNDANT_CELLV_COMPARE_FLT	Redundant cell V comparison fault
Bit 1	17	CONT2_STUCK_ON_FLT	Contactor 2 detected stuck closed
Bit 2	18	NO_CHARGE_CUR_FLT	No charge current fault
Bit 3	19	BD_OVER_TEMP_FLT	Circuit board over temperature fault
Bit 4	20	UNDER_TEMP_FLT	Pack under (low) temperature fault
Bit 5	21	OVER_TEMP_FLT	Pack over temperature fault
Bit 6	22	FAN_CUR_LO_FLT	Fan current low (open) fault
Bit 7	23	FAN_CUR_HI_FLT	Fan current high fault
Byte 3			
Bit 0	24	MODULEV_TO_CELLV_COMPARE_FLT	Module V to cell V comparison fault
Bit 1	25	CONT1_STUCK_ON_FLT	Contactor 1 detected stuck closed
Bit 2	26	UNDER_VOLT_FLT_B	Cell under voltage fault string B
Bit 3	27	UNDER_VOLT_FLT_A	Cell under voltage fault string A
Bit 4	28	OVER_VOLT_FLT_B	Cell over voltage fault string B
Bit 5	29	OVER_VOLT_FLT_A	Cell over voltage fault string A
Bit 6	30	OVER_CURRENT_FLT	Pack over current fault

	Bit 7	31	SPI_FLT	SPI transmit / receive timeout fault
Byte 4				
	Bit 0	32	CONT2_DROPOUT_2ND_FLT	Contactor 2 dropout second fault
	Bit 1	33	CONT2_DROPOUT_1ST_FLT	Contactor 2 dropout first fault
	Bit 2	34	CONT1_STUCK_OPEN_FLT	Contactor 1 detected stuck open
	Bit 3	35	CONT2_STUCK_OPEN_FLT	Contactor 2 detected stuck open
	Bit 4	36	SEC_CONTB_OPEN_FLT	Secondary contactor B or fuse B fault
	Bit 5	37	NO_PCU_DATA_FLT	No PCU data received fault
	Bit 6	38	OVER_CURRENT_REG_FLT	Pack over current regulation fault
	Bit 7	39	SUPPLY_V_UNDER_VOLT_FLT	12V / 24V input under voltage fault
Byte 5				
	Bit 0	40	LO_DCHG_DURING_CHG_FLT	Low level discharge during charge fault
	Bit 1	41	HI_DCHG_DURING_CHG_FLT	High level discharge during charge fault
	Bit 2	42	SLAVE_COMM_FLT	Internal slave data not received fault
	Bit 3	43	STRING_V_MISMATCH_FLT	String voltages have excessive disperity
	Bit 4	44	SUPPLY_V_UV_WARNING	12V / 24V input under voltage warning
	BIT5	45	HI_CONT_COIL_CUR_FLT	High contactor coil current fault
	Bit 6	46	CV_CONNECTION_FLT	Cell voltage connection fault
	Bit 7	47	EXTREME_UNDER_VOLT_FLT	Extreme cell undervoltage fault
Byte 6				
	Bit 0	48	LO_CUR_CORRELATION_FLT	Low current sensor correlation fault
	Bit 1	49	HI_CUR_CORRELATION_FLT	High current sensor correlation fault
	Bit 2	50	MAIN_CONT_OPEN_UNDER_LOAD	Main contactor open under load fault
	Bit 3	51	FUSE_BLOWN_FLT	Fuse blown fault
	Bit 4	52	PACK_TEMPERATURE_AD_FLT	Pack temperature AD fault
	Bit 5	53	MODULE_V_OUTLIER_FLT	Module voltage outlier fault
	Bit 6	54	UNREASONABLE_TEMP_FLT	Exessive unreasonable temperature fault
	Bit 7	55	HIGH_TEMP_DELTA_FLT	High temperature max / min delta fault
Byte 7				
	Bit 0	56	HIGH_CV_DELTA_FLT	High cell voltage max / min delta fault
	Bit 1	57	NO_EPO_FLT	EPO voltage not present
	Bit 2	58	INVALID_AIN_CAL	Lost analog calibration data
	Bit 3	59	INVALID _CONFIG	System configuration not loaded
	Bit 4	60	EXT_FAULT	Fault signaled externally from PCU
	Bit 5	61	CONT_PCHG_STUCK_ON_FLT	Precharge contactor stuck on fault
	Bit 6	62	CONT_PCHG_STUCK_OPEN_FLT	Precharge contactor stuck open fault
	Bit 7			(Not used)

EDL_Latched_Fault_Data

Transmitted by BMS
Periodic Rate: 1 second

(Same bit definitions as active fault data)

EDL_History_Fault_Data

Transmitted by BMS

Periodic Rate: 1 second

(Same bit definitions as active fault data)

Tool Command

These command and response IDs are typically reserved for factory use only

ID: 1CFF2061 (Executive pack)
(Expansion pack 1: 1CFF3061, Expansion pack 2: 1CFF4061, Expansion pack 3: 1CFF5061)
(Expansion pack 4: 1CFF6061, Expansion pack 5: 1CFF7061, Expansion pack 6: 1CFF8061)

Received by BMS
Periodic Rate: non-periodic

(Example message which clears service fault codes)
To clear service fault codes, send the following message (values in hex):

ID	Data 0	Data1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7
1CFF2061	04	11	00	00	00	00	00	00

Upon successful clearing of service faults, the BMS will transmit the following message:

ID	Data 0	Data1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7
1CFF3060	04	11	AA	00	00	00	00	00

Inter-pack Communications

The following messages are used by the packs to communicate information to one another. They may be ignored by the external system controller or may be monitored for information purposes if desired.

Executive to Expansion pack (sync message)

Transmitted by BMS
Periodic Rate: 200 ms
Signals:

Byte	Bit	Item	Notes
	0	Exec engage contactor	Ok for expansion packs to engage contactor
	1	Exec clear MALFs	Global command for all packs to clear faults
	2	(reserved)	
	3	(reserved)	
	4	(reserved)	
	5	(reserved)	
	6	(reserved)	
	7	(reserved)	
1	(reserved)		
2	(reserved)		
3	(reserved)		
4	(reserved)		
5	(reserved)		
6	(reserved)		

7	(reserved)	

Exp1_BMS_Startup (Version Information)

<Same data format as EDL_Data01 except only expansion pack local data>

Transmitted by BMS
Periodic Rate: 1 sec

In this message, Expansion Packs report their version information to the Executive Pack.

Exp1_Data01 - Exp7_Data01

<Same data format as EDL_Data01 except only expansion pack local data>

Transmitted by BMS
Periodic Rate: 200 ms

In this message, Expansion Packs report their Data01 signals to the Executive Pack.

Exp1_Data02 - Exp7_Data02

<Same data format as EDL_Data02 except only expansion pack local data>

Transmitted by BMS
Periodic Rate: 200 ms

In this message, Expansion Packs report their Data02 signals to the Executive Pack.

Exp1_Data03 - Exp7_Data03

<Same data format as EDL_Data03 except only expansion pack local data>

Transmitted by BMS
Periodic Rate: 200 ms

In this message, Expansion Packs report their Data03 signals to the Executive Pack.

Exp1_Data04 - Exp7_Data04

<Same data format as EDL_Data04 except only expansion pack local data>

Transmitted by BMS
Periodic Rate: 200 ms

In this message, Expansion Packs report their Data04 signals to the Executive Pack.

Exp1_BMS_Startup - Exp7_BMS_Startup

<Same data format as BMS_Startup except only expansion pack local data>

Transmitted by BMS
Periodic Rate: 1 second

In this message, Expansion Packs report their BMS_Startup signals to the Executive Pack.

Exp1_Active_Fault_Data - Exp7_Active_Fault_Data

<Same data format as EDL_Active_Fault_Data except only expansion pack local data>

Transmitted by BMS
Periodic Rate: 1 second

In this message, Expansion Packs report their Active Fault signals to the Executive Pack.
(Same bit definitions as Executive pack active fault data)

Exp1_Latched_Fault_Data - Exp7_Latched_Fault_Data

<Same data format as EDL_Latched_Fault_Data except only expansion pack local data>

Transmitted by BMS
Periodic Rate: 1 second

In this message, Expansion Packs report their Latched Fault signals to the Executive Pack.
(Same bit definitions as Executive pack active fault data)

Exp1_History_Fault_Data - Exp7_History_Fault_Data

<Same data format as EDL_History_Fault_Data except only expansion pack local data>

Transmitted by BMS
Periodic Rate: 1 second
In this message, Expansion Packs report their History Fault signals to the Executive Pack.
(Same bit definitions as Executive pack active fault data)