EM1401 CAN Protocol Guide

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Topic Page

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1 Introduction

The CAN standard specifies the data link layer between nodes. This document will specify the higher level protocol used for communication between applications running on the nodes. The CAN bus is a peer-to-peer/Broadcast communication link where all nodes have a requester/responder relationship (That is, there is not a master/slave relationship although one can be implemented at the Application layer.). *This protocol is a subset of, and is compatible with, SAE J1939.*

This document covers the protocol used on the CAN bus connecting BMS boards.

This document is to be used by anyone required to understand the intercommunication between an active cell balancing system comprised of two or more EM1401EVM BMS boards. It is assumed the user is familiar with the basic characteristics of the Bosch CAN 2.0B standard.

2 Protocol Description

2.1 CAN Message Frame Support

The EM1401EVM Higher Level Protocol (HLP) is based on utilizing messages with a 29 bit Message-Identifier/Arbitration field. An 11 bit Message-Identifier/Arbitration field can co-exist on this same CAN bus but the ID field must follow a specific format (specified later in this document). Although the standard supports Data, Remote, Error, and Overload frames, the CHLP will only support Data and Error frame messages.

2.2 Message Priority

The system is an event driven multiprocessing architecture. As per the CAN specification, the Message-Identifier/Arbitration field represents both message identifier and message priority.

2.3 Error Detection and Fault Containment

Error Detection is as per the CAN specification. Rather than providing a message confirmation, which in turn would increase the bus load, CAN goes the more aggressive route of assuming all messages transmit to their destination error free. EM1401EVM hardware implements a fault containment mechanism to remove a node if it produces a constant stream of errors.

2.4 Characteristics

- Baud rates of 250/500/1000KHz (length dependent, max length 40meters)
- 253 max active nodes (two addresses are reserved: 254 is the default self-enumeration address and 255 is the broadcast address)
- Network Management
- Predefined, low latency, Parameter Group Numbers (PGNs) via Message-Identifier
- Broadcast or Peer-to-Peer communication
- Transaction lengths up to 1,785 bytes (multi-packet transfers or Transport)

2.5 Communication Methods

- Destination specific communications
- Each receiving node must determine whether the incoming destination address matches its own address and if so, it must process the message and respond accordingly.
- Broadcast communications
- Each receiving node must determine individually whether or not the message is relevant. If it is a request, each node must process the message and respond if the requested data is available.
- Sending a message from a single or multiple sources to a single destination.
- Sending a message from a single or multiple sources to multiple destinations.

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3 Protocol Functions

3.1 Protocol Design Objectives

This protocol aims to provide the following basic functions:

- Command
- Request
- Broadcast/Response
- Acknowledgment
- Transport protocol (multi-packet transfers)
- Predefined, low latency, Message Data (parameterized)
- In addition to providing the above basic functions, CAN message ID's must be structured to address the priority of messages.

3.2 Messages

The basic mechanism for implementing this protocol is the Message-Identifier, which is part of a single CAN message. The structure of the Message-Identifier is important as it determines the message priority **and** the message type (command, request, and so forth).

3.2.1 Message Identifier Structure

3.2.1.1 Standard CAN Identifier

Below is a comparison between CAN data frames with an 11 bit identifier and a 29 bit identifier.

Table 1. CAN 11bit ID

S O F	11 Bit CAN ID	R T R	6 Bit Control Field	0 ... 8 Byte Data Field	16 Bit CRC Field	2 Bit ACK	7 Bit End of Frame

Table 2. CAN 29bit ID

S O F	11 Bit CAN ID	S R R	I D E	18 Bit CAN ID	R T R	6 Bit Control Field	0 ... 8 Byte Data Field	C R C	A C K	E O F

SOF	(Start of Frame) - Marks the beginning of data and remote Frames
SRR	Substitute Remote Request bit (Extended Format bit) is transmitted in the position of the RTR bit of a standard frame to allow for compatibility between the two formats. Allows for collisions to be resolved in favor of Standard frames over Extended frames.
IDE	Used to distinguish between 11bit and 29bit frames. Low is 11bit frame.
Arbitration Field	Includes the message ID and RTR (Remote Transmission Request) bit, which distinguishes data and remote frames
Control Field	Used to determine data size (8 bytes max) and message ID length
Data Field	The actual data (applies only to a data frame, not a remote frame)
CRC Field	Checksum
EOF	(End of Frame) – Marks the end of data and remote frames

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Both data frames (11 and 29 bit variants) may co-exist on the CAN bus and they are supported by this HLP protocol also. In case an application needs to use both data formats, it is recommended to assign a specific priority to all 11-bit ID messages, and to not use this priority level for any 29-bit ID messages. This will prevent any 11-bit messages from overriding a 29-bit message, which in turn eliminates any potential for transmission failures due to conflicts between 11-bit and 29-bit message transmission.

3.2.1.2 Higher Level Protocol (CHLP) Message Format

The protocol is based on the standard 29 bit message-identifier. Figure 1 shows how the HLP extends the 29-bit identifier beyond the standard.

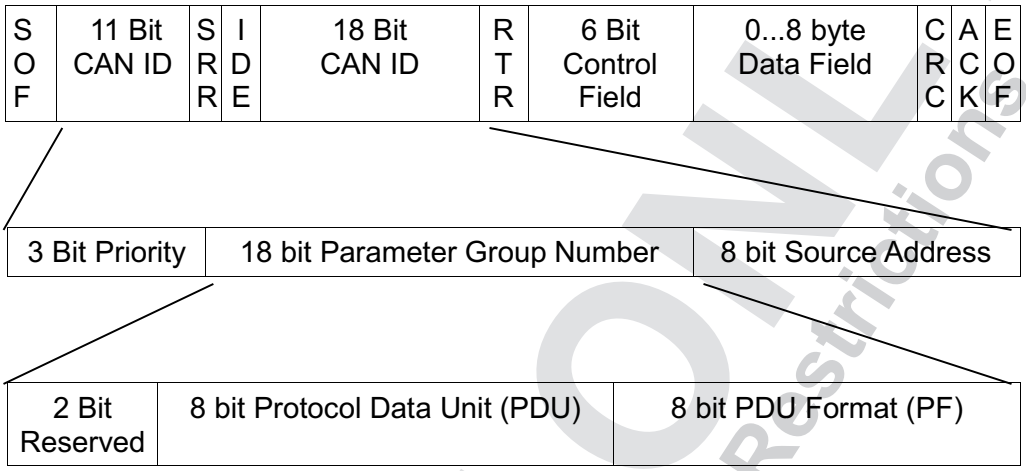

Figure 1. EM1401EVM CAN Message Format

The SRR and IDE fields are CAN bus specific and are deleted from the 18 bit Parameter Group Number (they still exist, they just are not carried forward to simplify the nomenclature).

The 29-bit CAN identifier is split into a priority field, a Parameter Group Number (PGN) to identify the content of the data field, and the source address. The 2-bit Reserved field is for future use and now must be set to zero. A message priority '0' indicates highest priority and a message priority of '7' indicates lowest priority. High priorities are usually assigned to time critical data. The last 8 bits of the 29-bit message identifier always contains the source address (i.e. the address of the transmitting node). There are no exceptions to this rule. There is a total of 254 addresses available and every address must be unique within the network (i.e. nodes cannot share addresses). PGNs, however, are independent of the source address, meaning every node is allowed to transmit any message.

The **Protocol Data Unit** (PDU) basically defines the function of the **PDU Format** (PF). PDU Format (PF) means that its content is interpreted according to the information in the Protocol Data Unit (PDU). A PDU value between 0 and 239 indicates a destination address is contained in the PF field (peer-to-peer communication). A PDU value between 240 and 255 inclusive (broadcast message) indicates an extension of the PDU Format (PF).

Table 3. PDU Value(1)

	Protocol Data Unit (PDU)	PDU Format (PF)	Communications Mode
Type Peer to Peer	0 – 239 0x00 - 0xEF	Destination Address(1)	Peer-to-Peer
Type Broadcast	240-255 0xF0 - 0xFF	PDU Extension	Broadcast

(1) Note: While the destination address is defined to address a specific node in the network, it can also be used to address all nodes at the same time. A destination address (DA) of 255 is called a Global Destination Address and it requires all nodes to listen and, if required, to respond. A destination address of 254 is reserved as the Default Self-Enumeration Address.

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3.2.1.3 EM1401EVM Specific Message Identifier Implementation.

Most messages are Broadcast and such messages cannot be transmitted to a specific destination. For the EM1401EVM implementation the Message type will be restricted to the following PDU ranges: (see Table 4)

Table 4. Specific Message Address PDU Value

	Protocol Data Unit (PDU)	PDU Format (PF)	Communications Mode
Type Peer to Peer	239 0xEF	Destination Address[1] 0x00 - 0xFD[2]	Peer-to-Peer
Type Broadcast	255 0xFF	PDU Extension 0x00 - 0xFF	Broadcast

(1) Note: While the destination address is defined to address a specific node in the network, it can also be used to address all nodes at the same time. A destination address (DA) of 255 is called a **Global Destination Address** and it requires all nodes to listen and, if required, to respond. A destination address of 254 is reserved as the **Default Self-Enumeration Address**.

(2) The Default Self-Enumeration Address is a special network reserved code. A node with this address requires special handling until it claims a permanent destination address.

3.2.1.4 EM1401EVM Specific Message Identifier Nomenclature.

To ease working with the protocol's Message Identifier for documentation purposes, the 18 bit Parameter Group Number (PGN) field of the Message ID is extended to 24 bits by adding 6 zero's to the most significant bits. Remember, the SRR and IDE fields are CAN bus specific and are deleted from the 18-bit Parameter Group Number to make things less complicated. So when referring to EM1401EVM Peer-to-Peer Parameter Group Numbers the nomenclature should look like 0x00EFXX and for EM1401EVM Broadcast Parameter Group Numbers: 0x00FFXX where XX is a destination address for peer-to-peer and a PDU Extension for Broadcast. This should ease translation from PGN specifications to “code” without error.

3.2.1.5 Parameter Group Number (PGN) Template (Nomenclature)

Below is a sample template to define the format for the numerous PGNs that will define the specific format of a message transaction. PGNs contain information on parameter assignments within the 8 byte CAN data field of each message as well as repetition rate and priority.

Parameter Group Number Name	AFE Bottom Stack Voltage
Parameter Group Number	0x00EF05
Definition	Peer-to-Peer communication
Transmission Rate	10 ms (0 = once)
Data Length	16 bytes: 2 packets (multi-packet)
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	239 (0xEF)
PDU Specific	8-bit Destination Address (0x05 in this particular example)
Default Priority	6
Data Description	AFE Channel Voltage (channels 0 ... 6)

Byte	**Value**
1	**packet sequence number**
2	**channel 0 LSByte**
3	**channel 0 MSByte**
4	**channel 1 LSByte**
5	**channel 1 MSByte**
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The PGN uniquely identifies the Protocol Data Unit (PDU) being transmitted as part of the message. Each PF (a grouping of specific parameters) has a definition that includes the assignment of each parameter within the 8-byte data field (size in bytes, location of LSB), and the transmission rate and priority of the message.

3.2.2 Protocol Data Units

There are a total of five message types. The Request, Acknowledgment and Group Function message types are assigned specific PGNs. Command and Broadcast/Response message types may be associated with any PGN not assigned by the other message types.

3.2.2.1 Command

A message interpreted as a command. It could be issued to a specific destination node (peer-to-peer) or to many nodes (broadcast). The Command message type is nothing else but an ordinary PGN.

3.2.2.2 Request

As the name implies, the Request message type is being used to request data globally or from a specific destination. The Request message type supports only Peer-to-Peer communication. Global Requests can be made if the destination address is set to the Global Address Destination Address (255, 0xFF). A node receiving a request, is required to respond either with the requested data or with a Negative Acknowledgment (NACK) when the requested PGN does not exist.

The Request message type is associated with a specific PGN as described below.

Parameter Group Number Name	Request
Parameter Group Number	0x00EAxx (where xx is the destination address)
Definition	Requests a Parameter Group from a single device or all devices in the network.
Transmission Rate	User defined (no more than 2 to 3 times a second is recommended)
Data Length	3 bytes (CAN DLC = 3)
Reserved Bit 0	0
Data Page	0
PDU Format	234 (0xEA)
PDU Specific	Destination Address (Global or Specific)
Default Priority	6
Data Description	Bytes 1,2, and 3 = Requested Parameter Group Number

3.2.2.3 Broadcast/Response

The definition of a Broadcast/Response message type serves only the purpose of having a description of a PGN interpreted as a data message. It may be an unsolicited broadcast of data or it can be a response to a Command or Request. **Note: A Response differs from a Broadcast in that a destination address is specified.**

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3.2.2.4 Acknowledgment

As its name implies, an Acknowledgment is a response to a command or a request. Supports only peer to peer communication. The Acknowledgment message type is associated with a specific PGN as described below.

Parameter Group Number Name	Acknowledgment
Parameter Group Number	0x00E8xx (where xx is the destination address)
Definition	Provides handshake between transmitting and responding nodes. Peer-to-Peer Communication
Transmission Rate	Upon reception of a command or request.
Data Length	8 bytes (As described in the following)
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	232 (0xE8)
PDU Specific	Destination Address (Global = 255). Using global makes it possible to filter one CAN ID for all ACK messages.
Default Priority	6
Data Description	Bytes 1...8 = Positive Acknowledgment, Negative Acknowledgment, Access Denied or Cannot Respond (See following description).

Positive Acknowledgment (ACK)

Byte	**Value**
1	Control byte = 0
2	PDU Value (if applicable)
3-4	Reserved: should be filled with 0xFF
5	Address Acknowledged
6	PGN of requested data -- LSB
7	PGN of requested data
8	PGN of requested data -- MSB

Negative Acknowledgment (NACK)

Byte	**Value**
1	Control byte = 1
2	PDU Value (if applicable)
3-4	Reserved: should be filled with 0xFF
5	Address NACK
6-8	PGN of requested data

Access Denied (PGN Supported, but Security Denied Access)

Byte	**Value**
1	Control Byte = 2
2	PDU Value (if applicable)
3-4	Reserved: should be filled with 0xFF
5	Address Access Denied
6-8	PGN of requested data

Can Not Respond (PGN is supported, node can't respond, try later)

Byte	**Value**
1	Control Byte = 3
2	PDU Value (if applicable)
3-4	Reserved: should be filled with 0xFF
5	Address Busy
6-8	PGN of requested data

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3.2.2.5 PGN Group Functions

PGN Group functions use this mechanism to report data. This is also used for multi-packet transport functions.

Parameter Group Number Name	PGN Example A
Parameter Group Number	0x00EFxx, where xx is the destination address.
Definition	Report data registers x,y,z. **Peer-to-Peer** communication.
Transmission Rate	Upon reception
Data Length	0 to 1,785 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	239 (0xEF)
PDU Specific	8-bit Destination Address
Default Priority	6
Data Description	Example A Specific
Parameter Group Number Name	**PGN Example B**
Parameter Group Number	0x00FF00 – 0x00FFFF
Definition	Report data registers A to B inclusive. **Broadcast** communication.
Transmission Rate	Upon reception.
Data Length	0 – 1,785 bytes (multi-packet supported)
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	255 (0xFF)
PDU Specific	8-bit Destnation Address
Default Priority	6
Data Description	Example B specific

3.2.3 Transport Protocol Functions

Certain PGNs may require more than the 8 data bytes supported by the CAN standard. This protocol supports the transfer of messages up to 1,785 bytes in length. This section describes how message transactions beyond the 8 byte limit of a CAN message (multi-packet) are accomplished. The major parts of the TP Functions are:

- Message Packaging & Reassembly
- Connection Management
- Flow control and handshaking features for destination specific transmissions

3.2.3.1 Message Packaging & Reassembly

In order to package CAN messages into a sequence of up to 1,785 messages (as well as to re-assemble the CAN frames into one data package) the Transport Protocol defines the following:

- Each multi-packet message is being transmitted by using a dedicated Data Transfer PGN (0x00EB00, TP.DT = Transfer Protocol Data Transfer), i.e. all message packets will have the same ID.
- The flow control is managed by another dedicated PGN (0x00EAF2, TP.CM = Transfer Protocol Communication Management).
- The CAN message length must always be 8 bytes (DLC = 8).
- The first byte in the data field contains a sequence number that ranges from 1 to 255.
- The remaining 7 bytes are filled with the data of the original long (> 8 bytes) message.

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- All unused data bytes in the last packet are being set to 0xFF.
- The actual total message length is defined by the corresponding PGN (see multi-packet broadcast below). The data packages are re-assembled in the order of their sequence number and the final data packet can then be passed to the application layer.

3.2.3.2 Connection Management

Connection Management is defined for peer-to-peer multi-packet messages. Broadcast is support through the use of the Global Destination Address (0xFF).

3.2.3.2.1 Multi-Packet Broadcast and BAM

Messages are broadcast to all nodes in the network by using the global destination address (0xFF).

To broadcast a multi-packet message a node must first send a Broadcast Announce Message (BAM). A BAM message contains the following components:

- PGN of the multi-packet message
- Size of the multi-packet message in bytes
- Number of packets

The BAM message allows all receiving nodes (i.e. all nodes interested in the message) to prepare for the reception by allocating the appropriate amount of resources (memory).

The Broadcast Announce Message (BAM) is embedded in the Transport Protocol Connection Management (TP.CM) PGN 0x00EC00 and the actual data transfer is handled by using the Data Transfer PGN 0x00EB00.

PGN Name	**Transport Protocol -- Connection Management (TP.CM)**
Parameter Group Number	0x00EC00
Definition	Used for Communication Management Flow-Control (for example, Request to Send, Clear to Send, Broadcast Announce Message, and so forth).
Transmission Rate	According to the Parameter Group Number to be transferred
Data Length	8 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	236 (0xEC)
PDU Specific	Destination Address (255 [0xFF] for broadcast)
Default Priority	7
Data Description	(for broadcast announce message only)
Data Description	
Byte	**Value**
1	Control Byte = 32
2,3	Message Size (Number of Bytes)
4	Total Number of Packages
5	Reserved (should be filled with 0xFF)
6-8	Parameter Group Number of the multi-packet message Byte 6 = LSB Byte 8 = MSB

The transport of Multi-Packet Broadcast messages is not regulated by any flow-control functions and thus it is necessary to define timing requirements between the sending of a Broadcast Announce Message (BAM) and the PGN. The PGN must specify:

- a minimum packet interval (i.e. 50 to 200 ms)
- a timeout (i.e. 750 ms).

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A timeout will occur when a time of greater than 750 ms elapsed between two message packets when more packets were expected. Timeouts will cause a connection closure.

A connection is considered closed when:

- The sender of a data message sends the last Data Transfer package.
- A timeout occurs.

Multi-Packet Peer-to-Peer

The communication of destination specific (peer-to-peer) multi-packet message is subject to flow-control. The three basic components of flow control are:

- **Connection Initialization** – The sender of a message transmits a **Request to Send** message. The receiving node responds with either a **Clear to Send** message or a **Connection Abort** message in case it decides not to establish the connection. A **Connection Abort** as a response to a **Request to Send** message is preferred over a timeout by the connection initiator. The **Clear to Send** message contains the number of packets the receiver is expecting plus the expected sequence number.
- **Data Transfer** – The sender transmits the Data Transfer PGN after receiving the **Clear to Send** message. Data transfer can be interrupted/stopped by a **Connection Abort** message.
- **Connection Closure** – The receiver of the message, upon reception of the last message packet, sends an **End of Message ACK** (Acknowledgment) message, provided there were no errors during the transmission. Any node, sender or receiver, can send a **Connection Abort** message. The reason of aborting a connnection can be a timeout.

A reliable flow-control will must also include timeouts in order to assure proper network function. A number of timeouts as listed below and their application is explained in Table 5:

Table 5. Flow Control

Tr = 200 ms	Response Time
Th = 500 ms	Holding Time
T1 = 750 ms	
T2 = 1250 ms	
T3 = 1250 ms	
T4 = 1050 ms	

Scenarios for timeout control are:

- A node (regardless whether the node is the receiver or sender of the data message) does not respond within 200 ms (Tr) to a data or flow control message.
- If a receiving node needs (for any reason) to delay the transmission of data it can send a Clear to Send message where the number of packages is set to zero. In cases where the flow must be delayed for a certain time the receiver of a message must repeat the transmission of the Clear to Send message every 0.5 seconds (Th) to maintain an open connection with the sender of the message. As soon as the receiver is ready to receive the message it must send a regular Clear to Send message.
- A time of greater than T1 elapsed between two message packets when more packets were expected.
- A time greater than T2 elapsed after a Clear to Send message without receiving data from the sender of the data.
- A time greater than T3 elapsed after the last transmitted data packet without receiving a Clear to Send or End of Message Acknowledgment (ACK) message.
- A time greater than T4 elapsed after sending a Clear to Send message to delay data transmission without sending another Clear to Send message

Any timeout condition will consequently cause a **connection closure.**

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Other reasons for **connection closure** are:

- The sender of a data message sends the last Data Transfer package.
- The receiver of a data message receives the last Data Transfer package and a T1 timeout occurs.
- The sender of a data message receives an End of Message ACK message.
- Reception of Connection Abort message.

The flow control messages, such as Request to Send, Clear to Send, and so forth, are embedded in the Transport Protocol – Connection Management (TP.CM) PGN 0x00EC00 and the actual data transfer is handled by using the Data Transfer PGN 0x00EB00.

PGN Name	**Transport Protocol – Connection Management (TP.CM)**
Parameter Group Number	(0x00EC00)
Definition	Used for Communication Management flow-control (for example, Request to Send, Clear to Send, Broadcast Announce Message and so forth).
Transmission Rate	According to the Parameter Group Number to be transferred
Data Length	8 bytes (multi-packet supported)
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	236 (0xEC)
PDU Specific	Destination Address (= 255 for broadcast)
Default Priority	7
Data Description	Depending on content of Control Byte – See following description.
TP.CM_RTS	Connection Mode Request to Send
Byte	**Value**
1	Control Byte = 16
2,3	Message Size (Number of bytes)
4	Total number of packets
5	Max. number of packets in response to CTS.
	0xFF No limit when filled with 0xFF.
6 to 8	Parameter Group Number of the multi-packet message
	Byte 6 LSB
	Byte 8 MSB
TP.CM_CTS	Connection Mode Clear to Send
Byte	**Value**
1	Control Byte = 17
2	Total number of packets Value should not exceed byte 5 provided in RTS
3	Next packet number
4 to 5	Reserved (should be filled with 0xFF)
6 to 8	Parameter Group Number of the multi-packet message
	Byte 6 LSB
	Byte 8 MSB
TP.CM_EndOfMsgACK	End of Message Acknowledgment
Byte	**Value**
1	Control Byte = 19
2 to 3	Message Size (Number of bytes)
4	Total number of packages
5	Reserved (should be filled with 0xFF)
6 to 8	Parameter Group Number of the multi-packet message
	Byte 6 LSB
	Byte 8 MSB

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TP.Conn_Abort	Connection Abort	
Byte	**Value**	
1	Control Byte = 255 (0xFF)	
2	Connection Abort Reason (See following description)	
3 to 5	Reserved (should be filled with 0xFF)	
6 to 8	Parameter Group Number of the multi-packet message	
	Byte 6	LSB
	Byte 8	MSB

Control Byte = 32 is reserved for Broadcast Announce Message. Control Bytes 0-15, 18, 20-31, 33-254 are reserved.

The Connection Abort Reasons can be:

1 – Node is already engaged in another session and cannot maintain another connection.

2 – Node is lacking the necessary resources.

3 – A timeout occurred.

4...255 - Reserved.

If a receiving node needs (for any reason) to delay the transmission of data it can send a Clear to Send message where the number of packages is set to zero. In cases where the flow must be delayed for a certain time the receiver of a message must repeat the transmission of the Clear to Send message every 0.5 seconds (Th) to maintain an open connection with the sender of the message. As soon as the receiver is ready to receive the message it must send a regular Clear to Send message. The Clear to Send message can be sent by the receiver of the data message at any time, either immediately after the reception of a Request to Send message or after reception of a data packet, meaning any time during the data transfer.

The data transfer is handled by using the Data Transfer PGN.

Table 6.

PGN Name	**Transport Protocol – Data Transfer (TP.DT)**
Parameter Group Number	(0x00EB00)
Definition	Data Transfer of Multi-Packet Messages
Transmission Rate	According to the Parameter Group Number to be transferred
Data Length	8 bytes (multi-packet supported)
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	235 (0xEB)
PDU Specific	Destination Address
Default Priority	7
Data Description	
Byte	**Value**
1	Sequence Number (1 to 255)
2 to 8	Data

The last packet of a multi-packet PGN may require less than eight data bytes. All unused data bytes in the last package are being set to 0xFF.

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4 System Interfaces

4.1 GUI Description

A Graphical User Interface is available for the PC to allow the user to interface to the EM1401EVM BMS boards. Details of the GUI and its operation are provided in a separate document.

4.2 Third Party CAN Network Analysis Tools

Users can interface to the CAN bus on the EM1401EVM from their own custom hardware, or users may elect to communicate to the EM1401EVM boards using the GUI or other third party tools running on and connected to a PC. Several third party network tool vendors provide tools for this purpose. An example of one such tool is the USB-CAN tool from VSCom (http://www.vscom.de/1_1_05_2.htm), but other tools are available. Chosen tools should support the CAN 2.0B standard (not only the CAN 1.1 standard).

4.3 Physical Connectors

CAN bus communication between EM1401EVM boards is accomplished by connecting standard shielded twisted pair wiring (CAT-5 equivalent) between adjacent printed circuit boards. A stacked, single piece connector is provided on each EM1401EVM board to accept two cables, one from each of two adjacent boards. The last board in the connection will have only a single cable connected to either of the two available ports in the stacked connector.

4.4 CAN Bus Isolation

5kV RMS Isolation of the CAN bus is accomplished via an isolation IC on the EM1401EVM printed circuit board.

4.5 CAN Bus Power

CAN bus power is typically supplied by the host. The host is either the PC running the BMS GUI or some network analysis software over third party serial to CAN converters, or the host is a custom PCB running custom control software. There is an option to have CAN bus power supplied by the EM1401EVM, but this is atypical operation, as it requires careful consideration and only a single bus source should be activated (meaning only one of likely many interconnected EM1401EVMs would be different than all other EM1401EVMs in the communications string).

5 EM1401EVM Specific PGNs

5.1 Purpose

This section describes the specific PGNs for the EM1401EVM system. Section 3.2 is a prerequisite for understanding the following material.

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5.1.1 PGN Reset Module Command/Request (0x00D1xx)

Table 7.

PGN Name	**Reset Request**	
Parameter Group Number	0x00D1xx, where xx is the destination address	
Definition	Perform a EM1401EVM Module software reset. Peer-to-Peer communication. No response if a Command, respond if a Request.	
Transmission Rate	Once	
Data Length	1 (command)	
Reserved Bit 0	0	
Reserved Bit 1	0	
PDU Format	209 (0xD1)	
PDU Specific	8 bit Destination Address.	
Default Priority	6	
Data Description	**(Payload for command)**	
Byte	**Value**	
1	Reset Type	
	0x00	Soft reset (preferred)
	0x01	Core reset
	0x02..0xFF	Reserved (Other codes TBD)

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5.1.2 PGN Module Status Command/Request (0x00D2xx)

Table 8.

PGN Name	**Module Status Command/Request**	
Parameter Group Number	0x00D2xx, where xx is the destination address	
Definition	Report Status. Peer-to-Peer communication	
Transmission Rate	Once	
Data Length	8	
Reserved Bit 0	0	
Reserved Bit 1	0	
PDU Format	210 (0xD2)	
PDU Specific	8 bit Destination Address	
Default Priority	6	
Data Description		
Byte	**Value**	
1	Module Status	
	0x00	Reserved (Meaning TBD)
	0x01	POST from last reset was good
	0x02..0xFF	Reserved (Meaning TBD)
2	Firmware Version (Customer release version)	
3	Firmware Revision (Intermediate build version)	
4	Hardware Version	
5	Rework Level	
6	Physical (stack) location (0xff if unassigned)	
7	Number of cells in Module (0x0e by default)	
8	**Device Type**	
	0x00	Reserved
	0x01	EM1401EVM
	0x02	GUI
	0x03	Cougar
	0x04	Puma
	0x05..0xff	Reserved

NOTES:

1. Firmware Version will be set to 0x01 upon first customer release, and increment for each subsequent release. Firmware Build is the sub-version and is incremented for intermediate code updates between customer release code versions.
2. The Hardware Version field will be broken into two 4-bit fields. The upper four bits represent the “letter” version, and the lower four bits represent the “number” version. For example, an “A4” is broken down to “A” (yields 1) and “4” (yields 4), so “A4” is encoded as 0b00010100 (0x14).
3. Rework Level is simply the level of rework encoded as a count (stored in flash at board initialization).

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5.1.3 PGN Configure Read/Write to Module External Device (0x00D3xx)

Table 9.

PGN Name	**Configure Read/Write to Module External Device**
Parameter Group Number	0x00D3xx, where xx is the destination CAN address
Definition	Data Transfer Configuration. Set up the target device for the data, the type of operation (read or write), the starting address of the data and the number of data bytes to transfer. This PGN is used in conjunction with the D4 PGN. Peer to Peer.
Transmission Rate	Upon Transmission
Data Length	6 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	211 (0xD3)
PDU Specific	Destination Address
Default Priority	6
Data Description	
Byte	**Value**
1	Data Direction and Target Device/Data Byte High bit: 0 = Write, 1 = Read Bits 6..0: Target Device ID 0x00: Flash/EEPROM or Shadow Flash/EEPROM 0x01: Reserved 0x02: Liger Top (not implemented) 0x03: Liger Bottom (not implemented) 0x04: AFE associated ADC (not implemented) 0x05: Temp Sense ADC (not implemented) 0x06: Microprocessor I/O 0x07..0x54: Reserved 0x55: Flash Commit 0x56: Restore from Manufacturer's Default Configuration 0x57: Flash/EEPROM directly 0x58..0x7D: Reserved 0x7E: Enable Write of Manufacturer's Area 0x7F: Reserved
2 to 4	Target Starting Address (LSB = Byte2)
5 to 6	Number of Bytes to Transfer (LSB of size = Byte5)

NOTES:

1. A reliable flow-control will must also include timeouts in order to assure proper network function. A number of timeouts as listed below and their application is explained in the following.

2. This PGN sets up the transfer conditions used by the data transfer carried out by PGN D4.

3. For target 0x06/0x86 (IO Port), the data length should always be 0x0001. The address fields should contain the desired port address in the form Px.y, where x is in the range {“A”..”E”} (0x41..0x45), and y is the range {0x00..0x0f). Port “letter” is lowest address byte, port “bit number” is middle address byte and upper address byte is always 0x00. The D4 portion should contain the data to be written, or the D4 response PGN will contain the data read. Data will be in the range {0x00..0x01}. DLC for the D3 portion of the D3/D4 PGN pair should be 6; DLC for the D4 portion of the D3/D4 pair should be 8.

4. Target 0x55 (Flash Commit) will copy the content in the Shadow Flash to the external flash/EEPROM. If the starting address is 0x000000 and the length is 0xffff, then the entire shadow flash area will be committed to the external flash/EEPROM, otherwise the user must supply a starting address and data length in bytes. The copy process will first invalidate the flash/EEPROM, then copy the data, then validate the flash/EEPROM. (The state of the flash/EEPROM validation is indicated by the FlashValid flag. Please refer to the Flash Map documentation for the appropriate memory address of the FlashValid flag.)

5. Target 0x56 (Restore from Manufacturer's Defaults) will copy the data in the manufacturer's default configuration area to the working area of the flash/EEPROM (but not directly into the shadow flash). The microprocessor will reset at the completion of the data copy, causing the new data values to be copied into the shadow flash. The address and length fields in the D3 PGN will be ignored, but it is recommended to use 0x000000 and 0x0800 for address and length respectively.

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(continued)

NOTES:

6. Target 0x57/0xD7 (Write/Read Flash/EEPROM Directly) allows reads directly from the external flash/EEPROM, ignoring the data in the shadow flash (i.e. copy in microprocessor's RAM). Writes will write to the shadow flash then immediately commit the written data to the external flash/EEPROM. This is equivalent to writing to target 0x00 followed by a 0x55 (commit to flash).

7. Target 0x7E (Enable Write to Manufacturer's Area) requires special codes (ADDR_EN_CODE and LEN_EN_CODE) to enable writes and special codes (ADDR_COPY_CODE and LEN_COPY_CODE) to allow the area to be written with data in shadow flash. These codes are valid only for use by Texas Instruments. Writing to the manufacturer's area is a four step process: (1) write to target 0x7e with ADDR_EN_CODE and LEN_EN_CODE, (2) write desired data to shadow flash using target 0x00, (3) write to target 0x7e with ADDR_COPY_CODE and LEN_COPY_CODE, (4) reset board or write to target 0x7e with any address and length other than the above special codes (this will disable writes to the manufacturer's area).

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5.1.4 PGN Read/Write to Module External Device (0x00D4xx)

Table 10.

PGN Name	**Read/Write to Module External Device**
Parameter Group Number	0x00D4xx, where xx is the destination address
Definition	Data Transfer to external device on module. This PGN is used in conjunction with the D3 PGN. Peer to Peer.
Transmission Rate	Upon Transmission.
Data Length	1..8 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	212 (0xD4)
PDU Specific	Destination Address
Default Priority	6
Data Description	
Byte	**Value**
1 to 8	Data (LSB in Byte1 will be stored at starting address provided by PGN D3, Byte2 will be stored at starting address +1, and so forth)

5.1.5 PGN Auto Cell Balance (0x00D5xx)

Table 11.

PGN Name	**Start/Stop Auto Cell Balance**
Parameter Group Number	0x00D5xx, where xx is the destination address
Definition	Data Transfer Peer to Peer
Transmission Rate	Function of charging duration.
Data Length	8 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	213 (0xD5)
PDU Specific	Destination Address
Default Priority	6
Data Description	**(Payload for command)**
Byte	**Value**
1	Command Byte 0 = Stop Cell Charge Balance Operation 1 = Start Auto Cell Balance Operation
2	Max Cell Balance Current (tenths of Amps)
3	Hysteretic Threshold(mV) LSB
4	Hysteretic Threshold (mV) MSB
5	Cell Balance Threshold (mV) LSB
6	Cell Balance Threshold (mV) MSB
7	Charge Duration (ms) LSB
8	Charge Duration (ms) MSB

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5.1.6 PGN Module Cell[3:0] Status (0x00D6xx)

Table 12.

PGN Name	**Report Cell Voltages for Cells[3:0]**
Parameter Group Number	0x00D6xx, where xx is the destination address
Definition	Data Transfer Peer to Peer/Broadcast
Transmission Rate	Upon Transmission, or periodic as set up by another PGN.
Data Length	8 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	214 (0xD6)
PDU Specific	Destination Address
Default Priority	6
Data Description	(Payload in response to request)
Byte	Value
1	Cell 0 LSB
2	Cell 0 MSB
3	Cell 1 LSB
4	Cell 1 MSB
5	Cell 2 LSB
6	Cell 2 MSB
7	Cell 3 LSB
8	Cell 3 MSB

NOTES:

Cell voltage reported is only lower 14-bits of 16-bit data reported. The upper 2 bits indicate:

- MSB bit 15 = 1 cell is being charged
- MSB bit 15 = 0 cell is not being charged
- MSB bit 14 = 1 cell is being discharged
- MSB bit 14 = 0 cell is not being discharged
- Once the top 2 bits have been removed from the measurement value, the cell measurement in volts can be calculated by multiplying the value by 0.0003052.

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5.1.7 PGN Module Cell[7:4] Status (0x00D7xx)

Table 13.

PGN Name	**Report Cell Voltages for Cells[7:4]**
Parameter Group Number	0x00D7xx, where xx is the destination address
Definition	Data Transfer Peer to Peer/Broadcast
Transmission Rate	Upon Transmission, or periodic as set up by another PGN.
Data Length	8 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	215 (0xD7)
PDU Specific	Destination Address
Default Priority	6
Data Description	**(Payload in response to request)**
Byte	**Value**
1	Cell 4 LSB
2	Cell 4 MSB
3	Cell 5 LSB
4	Cell 5 MSB
5	Cell 6 LSB
6	Cell 6 MSB
7	Cell 7 LSB
8	Cell 7 MSB

NOTES:

Cell voltage reported as 0xFF is cell is not present. PGN may be deleted if 0x00D6xx becomes a multi-packet message PGN.

Cell voltage reported is only lower 14-bits of 16-bit data reported. The upper 2 bits indicate:

- MSB bit 15 = 1 cell is being charged
- MSB bit 15 = 0 cell is not being charged
- MSB bit 14 = 1 cell is being discharged
- MSB bit 14 = 0 cell is not being discharged

Once the top 2 bits have been removed from the measurement value, the cell measurement in volts can be calculated by multiplying the value by 0.0003052.

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5.1.8 PGN Module Cell[11:8] Status (0x00D8xx)

Table 14.

PGN Name	**Report Cell Voltages for Cells[11:8]**
Parameter Group Number	0x00D8xx, where xx is the destination address
Definition	Data Transfer Peer to Peer/Broadcast
Transmission Rate	Upon Transmission, or periodic as setup by another PGN.
Data Length	8 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	216 (0xD8)
PDU Specific	Destination Address
Default Priority	6
Data Description	(Payload in response to request)
Byte	Value
1	Cell 8 LSB
2	Cell 8 MSB
3	Cell 9 LSB
4	Cell 9 MSB
5	Cell 10 LSB
6	Cell 10 MSB
7	Cell 11 LSB
8	Cell 11 MSB

NOTES:

Cell voltage reported as 0xFF is cell is not present. PGN may be deleted if 0x00D6xx becomes a multi-packet message PGN.

Cell voltage reported is only lower 14-bits of 16-bit data reported. The upper 2 bits indicate:

- MSB bit 15 = 1 cell is being charged
- MSB bit 15 = 0 cell is not being charged
- MSB bit 14 = 1 cell is being discharged
- MSB bit 14 = 0 cell is not being discharged
- Once the top 2 bits have been removed from the measurement value, the cell measurement in volts can be calculated by multiplying the value by 0.0003052.

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5.1.9 PGN Module Cell[13:12] Status (0x00D9xx)

Table 15.

PGN Name	**Report Cell Voltages for Cells[13:12]**
Parameter Group Number	0x00D9xx, where xx is the destination address
Definition	Data Transfer Peer to Peer/Broadcast
Transmission Rate	Upon Transmission, or periodic as set up by another PGN.
Data Length	8 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	217 (0xD9)
PDU Specific	Destination Address
Default Priority	6
Data Description	(Payload in response to request)
Byte	**Value**
1	Cell 12 LSB
2	Cell 12 MSB
3	Cell 13 LSB
4	Cell 13 MSB
5	Reserved (0xFF)
6	Reserved (0xFF)

NOTES:

Cell voltage reported as 0xFF is cell is not present. PGN may be deleted if PGN 0x00D6xx becomes a multi-packet message PGN.

Cell voltage reported is only lower 14-bits of 16-bit data reported. The upper 2 bits indicate:

- MSB bit 15 = 1 cell is being charged
- MSB bit 15 = 0 cell is not being charged
- MSB bit 14 = 1 cell is being discharged
- MSB bit 14 = 0 cell is not being discharged

Once the top 2 bits have been removed from the measurement value, the cell measurement in volts can be calculated by multiplying the value by 0.0003052.

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5.1.10 PGN Module Temperature Status (0x00DAxx) Command

Table 16.

PGN Name	**Report Module Temperatures Command (legacy use only – use 0x00DDxx)**
Parameter Group Number	0x00DAxx, where xx is the destination address
Definition	Data Transfer of Multi-Packet Messages, Peer to Peer/Broadcast
Transmission Rate	Upon Transmission, or periodic as setup by another PGN.
Data Length	8bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	218 (0xDA)
PDU Specific	Destination Address
Default Priority	6
Data Description	**(Payload for command)**
Byte	**Value**
1	Command Byte 1 = Stop continuous sample operation 2 = Start continuous sample operation 3 = Single sample
2	Reserved: 0xFF
3	Thermistor Beta value LSB
4	Thermistor Beta value MSB
5	Resistor value LSB
6	Resistor value
7	Resistor value
8	Resistor value MSB

NOTES:

1. Beta values are taken from the data sheet of the implemented thermistor. A typical value is in the range 2000 to 6000.
2. A typical thermistor value is in the range 10000 Ω to Ω.
3. Both Beta and thermistor values are stored in hexadecimal. Example: values for a 54.9K thermistor with a Beta of 4150, are stored as 0xd674 and 0x1036 respectively
4. The above command sent to an EM1401EVM will garner one or more (typically four) responses from the EM1401EVM in the format described on the following page. Each response contains data for two consecutive channels as defined by the PGN response description on the following page.

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5.1.11 PGN Module Temperature Status (0x00DAxx) Response

Table 17.

PGN Name	**Report Module Temperatures Response**
Parameter Group Number	0x00DAxx, where xx is the destination address
Definition	Data Transfer of Multi-Packet Messages, Peer to Peer/Broadcast
Transmission Rate	Upon Transmission, or periodic as setup by another PGN.
Data Length	6 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	218 (0xDA)
PDU Specific	Destination Address
Default Priority	6
Data Description	(Payload for response)
Byte	**Value**
1	Temp channel number n
2	Temp channel n Temp (decimal, 2 places)
3	Temp channel n Temp (integer)
4	Temp channel number n+1
5	Temp channel n+1 (decimal, 2 places)
6	Temp channel n+1 (integer)

NOTES:

1. Temperatures are reported in consecutive channel pairs. Channels are numbered from 1 to 8. The first channel of the pair is always an odd channel.
2. To allow temperatures in excess of 99 ° to be reported, the integer and decimal portions of a temperature are converted to hexadecimal for storage. For example, 20.32 °C is encoded as 0x14 0x20. Full example of a report for Ch1=20.36 °C, Ch2=18.48 deg C: 18DAttss 6 01 24 14 02 30 12.
3. An errata exists which does not allow negative temperatures to be reported. Currently minimum temperature is 00.00 °C, maximum is 255.99 °C. When errata is fixed, high bit of temperature will indicate, when set, if temperature report is reporting a negative temperature. The range will then be –127.99 °C to 127.99 °C.
4. The 00DA00 response PGN may be changed to another PGN. This is because the 00DA00 PGN sent as a command has a completely different payload length and structure than the 00DA00 response. A new PGN has not been assigned.

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5.1.12 PGN Module Error (0x00DBxx)

Table 18.

PGN Name	**Report Module Errors**
Parameter Group Number	0x00DBxx, where xx is the destination address
Definition	Data Transfer Peer to Peer/Broadcast
Transmission Rate	Upon Transmission
Data Length	8 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	219 (0xDB)
PDU Specific	Destination Address
Default Priority	6
Data Description	
Byte	**Value**
1	bits 0:3 – BCD value below indicates Message Level 1 = Debug 2 = Inform 3 = Warn 4 = Critical 5 = Fatal Bits 4:7 1 = Legacy 2 = Fixed 3 = Debug
2	Fixed Notification Code (See Section 6)
3	Task State – any bit below can be set indicating that task is running 0 = AFE 1 = Bottom ACB Converter 2 = Top ACB Converter 3 = Module Balance (Reserved on EM1401EVM) 4 = Temp Sense 5 = Manual Cell Transfer
4	Power Status 0 = 5V5 1 = 5VD 2 = 5V1 3 = 5V2 (Reserved on EM1401EVM) 4 = -5V 5 = 12V 6 = 3V3
5	BCD Value below indicates the Power Mode that is currently activated 0 = Reserved 1 = IDLE_NO_AFE 2 = IDLE 3 = RUN 4 = TESTMODE
6	Reserved (0xFF)
7	Firmware build minor (0.xx)
8	Firmware build major (x.00)

5.1.13 PGN Module Cell Configuration (0x00DCxx)

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Table 19.

PGN Name	**Configure Module Cells**
Parameter Group Number	0x00DCxx, where xx is the destination address
Definition	Data Transfer Peer to Peer/Broadcast
Transmission Rate	Upon Transmission, or periodic as setup by another PGN.
Data Length	8 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	220 (0xDC)
PDU Specific	Destination Address
Default Priority	6
Data Description	
Byte	**Value**
1	Number of Cells
2	Manufacturer Code LSB
3	Manufacturer Code MSB
4	Chemistry Code LSB
5	Chemistry Code MSB
6	Max Charge Current (Tenths of Amps)
7	Max Voltage (Tenths of volts)
8	Min Voltage (Tenths of volts)

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5.1.14 PGN Configure Temperature Reporting (0x00DDxx)

Table 20.

PGN Name	**Report Module Temperatures Command**
Parameter Group Number	0x00DDxx, where xx is the destination address
Definition	Data Transfer of Multi-Packet Messages, Peer to Peer/Broadcast
Transmission Rate	Upon Transmission, or periodic as setup by another PGN.
Data Length	8bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	221 (0xDD)
PDU Specific	Destination Address
Default Priority	6
Data Description	**(Payload for command)**
Byte	**Value**
1	Module/Cell Temperature Report Rate LSB (milliseconds) 0 = Turn off reporting 1 = Single sample 2 - 255 Valid time (LSB)
2	Module/Cell Temperature Report Rate MSB (milliseconds) 0 = Turn off reporting 0 = Single sample 1 - 255 Valid time (MSB)
3	Thermistor Beta value LSB
4	Thermistor Beta value MSB
5	Resistor value LSB
6	Resistor value
7	Resistor value
8	Resistor value MSB

NOTES:

1. Beta values are taken from the data sheet of the implemented thermistor. A typical value is in the range 2000 to 6000.
2. A typical thermistor value is in the range 10000 Ω to 100000 Ω.
3. Both Beta and thermistor values are stored in hexadecimal. Example: values for a 100K thermistor with a Beta of 4150, are stored as 0x0186A0 and 0x1036 respectively.

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5.1.15 PGN Set Transmission Rates (0x00DExx)

Table 21.

PGN Name	**Set Transmission Rates**
Parameter Group Number	0x00DExx, where xx is the destination address
Definition	Data Transfer Peer to Peer/Broadcast
Transmission Rate	Upon Transmission
Data Length	8 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	222 (0xDE)
PDU Specific	Destination Address
Default Priority	6
Data Description	**(Payload for command)**

Optional. Change transmission rate of data to other than default. A value of 0xFF will not reset the present, default, value. Reserved values should be programmed to 0xff.

Byte	Value
1	Cell Voltage Report Rate LSB (milliseconds)
2	Cell Voltage Report Rate MSB
3	Module/Cell Temperature Report Rate LSB (milliseconds)
4	Module/Cell Temperature Report Rate MSB
5	Cell voltage Over-samples Per Report (default 32)
6	Reserved (0xFF)
7	Reserved (0xFF)
8	Reserved (0xFF)

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5.1.16 PGN Manual Cell Charge Transfer (0x00DFxx)

Table 22.

PGN Name	**Start/Stop Manual Cell Charge Transfer**
Parameter Group Number	0x00DFxx, where xx is the destination address
Definition	Data Transfer Peer to Peer
Transmission Rate	Function of charging duration
Data Length	8 bytes
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	223 (0xDF)
PDU Specific	Destination Address
Default Priority	6
Data Description	**(Payload for command)**
Byte	**Value**
1	Command Byte
	0 = Stop Charge operation
	1 = Start Charge operation
2	Current Setpoint. (tenths of Amps)
3	Charge Direction
	0 = Charge
	1 = Discharge
4	Cell to charge/discharge (1 is lowest cell in stack)
5	Charge Transfer Duration (Seconds) LSB
6	Charge Transfer Duration (Seconds) MSB
7	Reserved (0xFF): potential relaxation time LSB
8	Reserved (0xFF): potential relaxation time MSB

NOTES:

1. Current Setpoint range is {10..50}: 1 to 5 Amps
2. Cell number range is {1..14}: Cells 1 (lowest) to 14 (highest)
3. Charge Transfer Duration range is {1..65535}: 1 Second to 18.2 Hours (65535 Seconds)

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5.1.17 Time Synchronization (0x00C0xx)

Table 23.

PGN Name	**Time Synchronization**
Parameter Group Number	0x00C0xx, where xx is the destination address
Definition	Data Transfer Peer to Peer/Broadcast
Transmission Rate	Every two seconds when enabled
Data Length	4 byte
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	192 (0xC0)
PDU Specific	Destination Address
Default Priority	1
Data Description	**(Payload for command)**
Byte	**Value**
1	Tick Count Least Significant Byte (milliseconds)
2	Tick Count
3	Tick Count
4	Tick Count Most Significant Byte

NOTE:

Time Synchronization packets should be sent only by a single EM1401EVM in a network, or the time sync may be provided by an external controller. If a single EM1401EVM supplies the time synchronization packet, it is called the master.

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5.1.18 PGN Power Mode Select (0x00C1xx)

Table 24.

PGN Name	**Mode Select**
Parameter Group Number	0x00C1xx, where xx is the destination address
Definition	Data Transfer Peer to Peer/Broadcast
Transmission Rate	Once Upon Transmission
Data Length	1 byte
Reserved Bit 0	0
Reserved Bit 1	0
PDU Format	193 (0xC1)
PDU Specific	Destination Address
Default Priority	6
Data Description	(Payload for command)
Byte	Value
1	Command Byte (Power Mode) 0 = Reserved 1 = IDLE_NOAFE mode 2 = IDLE mode (AFE) 3 = RUN mode (ACB/MCT) 4 = TEST mode (all power supplies on) 5 = Reserved 6 = CALIBRATION 7 = Reserved 8 = SINGLEAFE 9 = MAXMIN 10 - 255 = Reserved

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6 Appendix A

Fixed Message Code – A fixed message (hex) for common system notifications from the BMS.

Table 25.

Hex	Dec	Name	Description
0x00	0	debugCode	Generic Debug
0x01	1	criticalError	Critical fault
0x02	2	queueOverflow	CAN callback queue overflow
0x03	3	topLigerFault	Top half-stack cell balancing fault
0x04	4	bottomLigerFault	Bottom half-stack cell balancing fault
0x05	5	cellBalancingStopped	Cell balancing stopped
0x06	6	invalidParameter	Invalid parameter
0x07	7	invalidFlashMap	Invalid Flash map version
0x08	8	invalidFlashWrite	Flash write of this value not allowed
0x09	9	overVoltageCell1	Cell 1 over recommended max voltage
0x0A	10	overVoltageCell2	Cell 2 over recommended max voltage
0x0B	11	overVoltageCell3	Cell 3 over recommended max voltage
0x0C	12	overVoltageCell4	Cell 4 over recommended max voltage
0x0D	13	overVoltageCell5	Cell 5 over recommended max voltage
0x0E	14	overVoltageCell6	Cell 6 over recommended max voltage
0x0F	15	overVoltageCell7	Cell 7 over recommended max voltage
0x10	16	overVoltageCell8	Cell 8 over recommended max voltage
0x11	17	overVoltageCell9	Cell 9 over recommended max voltage
0x12	18	overVoltageCell10	Cell 10 over recommended max voltage
0x13	19	overVoltageCell11	Cell 11 over recommended max voltage
0x14	20	overVoltageCell12	Cell 12 over recommended max voltage
0x15	21	overVoltageCell13	Cell 13 over recommended max voltage
0x16	22	overVoltageCell14	Cell 14 over recommended max voltage
0x17	23	overVoltageCell15	Cell 15 over recommended max voltage
0x18	24	overVoltageCell16	Cell 16 over recommended max voltage
0x19	25	minCellAtMaxVoltage	Min cell is at max recommended voltage
0x1A	26	underVoltageCell1	Cell 1 under recommended min voltage
0x1B	27	underVoltageCell2	Cell 2 under recommended min voltage
0x1C	28	underVoltageCell3	Cell 3 under recommended min voltage
0x1D	29	underVoltageCell4	Cell 4 under recommended min voltage
0x1E	30	underVoltageCell5	Cell 5 under recommended min voltage
0x1F	31	underVoltageCell6	Cell 6 under recommended min voltage
0x20	32	underVoltageCell7	Cell 7 under recommended min voltage
0x21	33	underVoltageCell8	Cell 8 under recommended min voltage
0x22	34	underVoltageCell9	Cell 9 under recommended min voltage
0x23	35	underVoltageCell10	Cell 10 under recommended min voltage
0x24	36	underVoltageCell11	Cell 11 under recommended min voltage
0x25	37	underVoltageCell12	Cell 12 under recommended min voltage
0x26	38	underVoltageCell13	Cell 13 under recommended min voltage
0x27	39	underVoltageCell14	Cell 14 under recommended min voltage
0x28	40	underVoltageCell15	Cell 15 under recommended min voltage
0x29	41	underVoltageCell16	Cell 16 under recommended min voltage
0x2A	42	maxCellAtMinVoltage	Max cell is at min recommended voltage
0x2B	43	overTemp1	Temp channel 1 over max recommended temp

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Table 25. (continued)

Hex	Dec	Name	Description
0x2C	44	overTemp2	Temp channel 2 over max recommended temp
0x2D	45	overTemp3	Temp channel 3 over max recommended temp
0x2E	46	overTemp4	Temp channel 4 over max recommended temp
0x2F	47	overTemp5	Temp channel 5 over max recommended temp
0x30	48	overTemp6	Temp channel 6 over max recommended temp
0x31	49	overTemp7	Temp channel 7 over max recommended temp
0x32	50	overTemp8	Temp channel 8 over max recommended temp
0x33	51	underTemp1	Temp channel 1 under min recommended temp
0x34	52	underTemp2	Temp channel 2 under min recommended temp
0x35	53	underTemp3	Temp channel 3 under min recommended temp
0x36	54	underTemp4	Temp channel 4 under min recommended temp
0x37	55	underTemp5	Temp channel 5 under min recommended temp
0x38	56	underTemp6	Temp channel 6 under min recommended temp
0x39	57	underTemp7	Temp channel 7 under min recommended temp
0x3A	58	underTemp8	Temp channel 8 under min recommended temp
0x3B	59	thermistor1NotAttached	Temp channel 1 no thermistor
0x3C	60	thermistor2NotAttached	Temp channel 2 no thermistor
0x3D	61	thermistor3NotAttached	Temp channel 3 no thermistor
0x3E	62	thermistor4NotAttached	Temp channel 4 no thermistor
0x3F	63	thermistor5NotAttached	Temp channel 5 no thermistor
0x40	64	thermistor6NotAttached	Temp channel 6 no thermistor
0x41	65	thermistor7NotAttached	Temp channel 7 no thermistor
0x42	66	thermistor8NotAttached	Temp channel 8 no thermistor
0x43	67	moduleBalanced	Module balanced
0x44	68	bottomStackBalanced	Bottom half-stack balanced
0x45	69	topStackBalanced	Top half-stack balanced
0x46	70	powerModeChangedLimp	Operating mode changed to LIMP
0x47	71	powerModeChangedIdle	Operating mode changed to IDLE
0x48	72	powerModeChangedIdleNoAFE	Operating mode changed to IDLE_NOAFE
0x49	73	powerModeChangedRun	Operating mode changed to RUN
0x4A	74	powerModeChangedShutdown	Operating mode changed to SHUTDOWN
0x4B	75	powerModeChangedLowPower	Operating mode changed to LOWPOWER
0x4C	76	powerModeChangedTest	Operating mode changed to TEST
0x4D	77	postCompleted	POST completed
0x4E	78	featureNotImplemented	This feature has not been implemented
0x4F	79	commandReadbackFailure	Command read back failed
0x50	80	bottomLigerStopped	Bottom half-stack stopped
0x51	81	topLigerStopped	Top half-stack stopped
0x52	82	extiFault	Ext Interrupt channel 5-15 not defined
0x53	83	bottomStackBalance	Bottom half-stack balancing started
0x54	84	topStackBalance	Top half-stack balancing started

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Table 25. (continued)

Hex	Dec	Name	Description
0x55	85	MMBPitcherStarted	MMB Pitcher started
0x56	86	MMBCatcherStarted	MMB Catcher started
0x57	87	MMBTransferStopped	MMB transfer stopped
0x58	88	MMBTransferComplete	MMB transfer finished

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