American Battery Solutions

ALLIANCE®

INTELLIGENT BATTERY SERIES

User's Guide

MODELS: ALLIANCE E-SERIES (E48-20, E24-20)

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CONGRATULATIONS

on your purchase from American Battery Solutions, manufacturer of the world's most trusted Lithium Ion batteries. The battery you purchased was engineered by ABS to deliver superior energy, run-time, durability, and reliability for use in a broad range of demanding applications. Our goal is to lead the quest for clean transportation through the development of creative and robust battery solutions delivered with passion, expertise, teamwork, and relentless focus on customer satisfaction.

OUR ENERGY IS ELECTRIC!

Contents

Preface

The preface contains information about the intended audience for this document, battery documentation set, and typographic conventions used in American Battery Solutions documentation:

About This Guide

This User's Guide was created by ABS engineers and contains vital information regarding proper care and maintenance of your new battery. Please read through this User's Guide carefully and completely before using your battery. It will help you achieve optimum performance and long life from your new investment. If you have any questions concerning safety precautions or for any assistance in installing or using the battery in your system, contact American Battery Solutions customer support engineers at one of the following numbers; 248-462-6364 in North America, +1 248-462-6364 outside of North America, or send us an email at support@americanbatterysolutions.com.

This Guide provides detailed specifications for the Alliance Intelligent Battery Series™ batteries as well as guidance on the safe and effective use and operation of Alliance Intelligent Battery Series™ batteries as building blocks in various applications.

Audience

This User's Guide is intended for all personnel involved in designing, configuring, and installing Alliance Intelligent Battery Series™ batteries.

Conventions

Several graphic and typographic elements have special meanings in this manual. Most important are the Danger, Warning, and Caution notices presented here:

Danger, Warning, and Caution Notices

DANGER

DANGER NOTICES
A red DANGER notice contains information about a hazard that will cause sever personal injury, death, or substantial property damage if you ignore the information.

WARNING

WARNING NOTICES
An orange WARNING notice contains information about a hazard that can cause severe personal injury, death, or substantial property damage if you ignore the information.

CAUTION

CAUTION NOTICES
A yellow and black CAUTION notice identifies conditions or practices that could result in injury or damage to the equipment.

Typography

In this manual:

Blue text identifies cross references to other topics or external hyperlinks

Notes
A note represents information that is related to the subject but that is not related to safety.

Support

Please contact American Battery Solutions Customer Support at 248-462-6364 in North America, +1 248-462-6364 outside of North America, or e-mail service@americanbatterysolutions.com.com

Related Documents & Resources

- Link to International Civil Aviation Organization (ICAO) Technical Instructions: http://www.icao.int/safety/DangerousGoods/Pages/default.aspx
- Link to International Air Transport Association (IATA) Dangerous Goods Regulations: http://www.iata.org/whatwedo/cargo/dgr/Pages/lithium-batteries.aspx
- Link to International Maritime Dangerous Goods (IMDG) Code: http://www.imo.org/Publications/IMDGCode/Pages/Default.aspx
- Link to Lithium Battery Regulations on United Parcel Service web site: http://www.ups.com/media/news/en/intl_lithium_battery_regulations.pdf
- Link to the CANbus interface specifications on the CiA web site: http://www.can-cia.org/index.php?id=specifications&no_cache=1/s
- UN Recommendations on the Transport of Dangerous Goods - Manual of Test Criteria: http://www.unece.org/trans/danger/publi/manual/rev7/manrev7-files_e.html
- UN Recommendations on the Transport of Dangerous Goods Model Regulations: http://www.unece.org/trans/danger/publi/unrec/rev19/19files_e.html
- U.S. Department of Transportation (DOT), Office of Pipeline and Hazardous Materials Safety Administration (PHMSA): Title 49 CFR Sections 100-185 of the U.S. Hazardous Materials Regulations (HMR): https://www.fmcsa.dot.gov/regulations/hazardous-materials/how-comply-federal-hazardous-materials-regulations

Introducing the Alliance Intelligent Battery Series™

Alliance Intelligent Battery Series™ Product Line

American Battery Solutions' Alliance Intelligent Battery Series™ product line is a family of lithium-ion batteries designed to provide exceptional energy, run-time, and cycle life in a variety of applications*. The line currently consists of one model: the E48-20: 48V Nominal, 2kWh.

They are designed to replace lead-acid batteries. The Alliance Intelligent Battery Series™ batteries provide improved performance with more energy, lighter weight, maintenance-free and exceptional cycle life compared to lead-acid batteries.

Alliance Intelligent Battery Series™ batteries are smaller in size than equivalent capacity lead acid or iron phosphate and are designed to be compatible with most lead-acid chargers. This combination reduces product integration costs, minimizes OEM customers' time-to-market, and aftermarket customer replacement hurdles.

* Temperature, load, state of charge, and battery age can affect battery performance and capacity

E48V-2.0

Figure 1: Alliance Intelligent Battery Series™ Products

At the core of the Alliance Intelligent Battery Series™ are 21700-type cylindrical cells in a 14S8P configuration for the E48-2.0 model. To effectively utilize the batteries, and to keep them operating in a safe manner, each Alliance Intelligent Battery Series™

battery has integrated protection and balancing circuitry (see Figure 2) that safeguard the battery from over-current, over-voltage, under-voltage, short circuit, and over-temperature conditions.

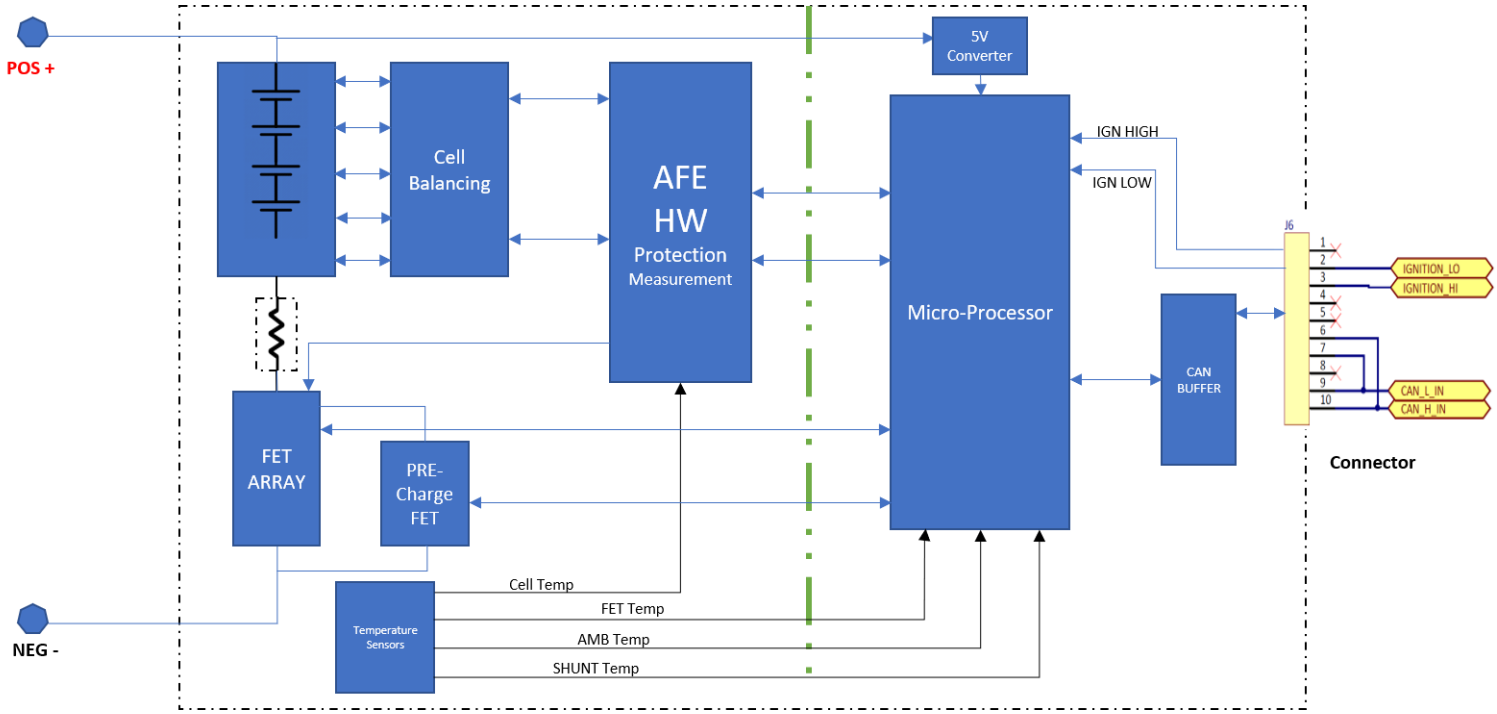


Figure 2: Alliance Intelligent Battery Series™ Battery Block Diagram

Regulatory Compliance

All Alliance Intelligent Battery Series™ models are compliant with, or tested to, these standards:

Table 1: Regulatory Standards for Alliance Products

Standard	Description
UL 2271 Compliant	Batteries for Use in Light Electric Vehicles
IEC60529	Meets IP67 Environmental Enclosure rating.
IEC61000-6-1	Generic standards – Immunity for residential, commercial, and light-industrial environments)
IEC61000-6-2	Generic standards – Immunity for industrial environments.
IEC61000-6-3	Generic standards – Emission standard for residential, commercial, and light-industrial environments.
IEC61000-6-4	Generic standards – Emission standard for industrial environments.
UL1642	UL Standard for Safety for Lithium Batteries
CE	Recognized to EU consumer safety, health, and environmental regulations. Signifies conformity with EMC directive (2004/108/EC.
FCC Part 15 Subpart B Class B	Standards regulating unintentional emissions of radio frequencies from a digital device. This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: This device may not cause harmful interference. This device must accept any interference received, including interference that may cause undesired operation.
UN 38.3	Meets section 38.3 of the UN Recommendations on the Transport of Dangerous Goods - Manual of Test Criteria

Environmental Compliance

The battery is compliant with these environmental directives and regulations.

- EU Directive 2011/65/EC on the Restriction of the use of certain Hazardous Substances (RoHS) in electrical and electronic equipment (recast)
- EU Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators
- EU Directive 1907/2006 on the Registration Evaluation Authorization and Restriction of Chemicals (REACH)
- Management Methods for Controlling Pollution Caused by Electronic Information Products Regulation (RoHS)

Transporting Lithium-Ion Batteries

The material presented in this guide is not all-inclusive of the regulations required to ship a product but is meant to inform you of the complexity involved in doing so. The information contained herein is for informational purposes only and is not legal advice or a substitute for legal counsel.

Anyone involved in the integration of lithium-ion batteries into a host product must review and meet the regulations cited in this guide. Additionally, the regulations discussed in this guide apply to lithium-ion cells and batteries.

Once an Alliance Intelligent Battery Series™ is integrated into a host product, the host product may be subject to additional transportation regulations that require additional certification testing. Since American Battery Solutions cannot anticipate every possible configuration and application of the Alliance Intelligent Battery Series™, the integrator must verify that the Alliance Intelligent Battery Series™ powered host product is compliant with all applicable regulations. Refer to Table 3 for a list of proper shipping names and UN numbers required for shipping lithium batteries.

Regulations Overview

Rechargeable lithium-ion cells and batteries are considered Dangerous Goods. The regulations that govern their transport are based on the UN Recommendations on the Transport of Dangerous Goods Model Regulations. Transport of dangerous goods is regulated internationally by:

- International Civil Aviation Organization (ICAO) Technical Instructions
- International Air Transport Association (IATA) Dangerous Goods Regulations
- International Maritime Dangerous Goods (IMDG) Code

In the United States, transportation of hazardous material (Dangerous Goods) is regulated by Title (part) 49 of the Code of Federal Regulations or CFR's.
Title 49 CFR Sections 100-185 of the U.S. Hazardous Materials Regulations (HMR) contains the requirements for transporting cells and batteries. Refer to the following sections within 49 CFR for specific information.

- Section 173.185 – Shipping requirements for lithium cells and batteries
- Section 172.102 – Special Provisions
- Sections 172.101, 178 – Further information and specifications on packaging

The Office of Pipeline and Hazardous Materials Safety Administration (PHMSA), which is within the U.S. Department of Transportation (DOT), is responsible for drafting and writing the U.S. regulations that govern the transportation of hazardous materials (also known as dangerous goods) by air, ground, and ocean.

Regulations by Cell/Battery Size

Lithium-ion batteries and cells are considered Class 9, which is one of nine classes of hazardous materials or dangerous goods defined in the regulations. As a Class 9 material, cells and batteries must meet UN testing and packaging requirements as well as shipping regulations.

Following International and U.S. DOT Regulations

Failure to comply with International and U.S. DOT regulations while transporting Class 9 Hazardous Materials (Dangerous Goods) may result in substantial civil and criminal penalties.

The USDOT requires training for anyone who handles hazardous materials including individuals who ship or receive hazardous materials, prepare hazardous materials for transportation, mark and label containers, complete shipping documents, select packaging and load or unload hazardous materials.

Table 2 outlines an example process to help ensure that batteries are shipped per the required regulations.

Table 2: Example of Steps to Obtain or Ensure Regulatory Compliance

Step Number	Process Step	Comment
1	Design the battery.	Design the battery to ensure it will pass UN Manual of Tests and Criteria.
2A	Ship the battery to a UN 38.3 test house if using an outside test laboratory.	Use the "Prototype" shipping special provisions provided in the regulations.
2B	Test the battery.	Perform UN testing T1-T5, & T7 for batteries.
3	Obtain UN compliant packaging.	All Class 9 Dangerous Goods (DG) must be shipped in UN compliant packaging.[a]
4	Package the cell or battery.	Pack per regulations and per packaging manufacturer's instructions.[a]
5	Mark and label the package.	Ensure packaging container has all the required labeling. Table 4 lists proper shipping names and descriptions for lithium-ion batteries.[a]
6	Fill out the shipping documentation.	Complete shipper's declaration for dangerous goods, airway bill, etc.[a]
7	Ship the package.	Ensure that shipping company can ship dangerous goods and that a Safety Data Sheet (or equivalent document) and any Competent Authority Approval accompanies the package.[a]

a. U.S. and international regulations require that anyone involved in the packaging, documentation, and labeling of Dangerous Goods for transportation must be trained to do so.

Table 3 shows the proper shipping names and UN numbers required for shipping lithium-ion batteries.

Table 3: Proper Shipping Names and UN Numbers

Proper Shipping Name	Description
Lithium ion batteries	UN 3480
Lithium ion batteries packed with equipment	UN 3481
Lithium ion batteries contained in equipment	UN 3481

Handling, Storage, and Installation

Safety and Handling

The Alliance Intelligent Battery Series™ battery is abuse tolerant, however correct handling and system integration of the battery are still important to ensure safe operation.

WARNING

FAILURE TO FOLLOW THESE WARNINGS MAY RESULT IN PERSONAL INJURY OR DAMAGE TO THE EQUIPMENT

Do not expose the Alliance Intelligent Battery Series™ battery to heat in excess of 60°C during operation or in storage. Do not incinerate or expose to open flame.

Do not connect Alliance batteries to batteries of other chemistries or lithium ion batteries of different capacities. For example, do not connect an Alliance Intelligent Battery Series™ to any lead-acid battery or to any other Alliance Intelligent Battery Series™ model.

Do not charge or discharge an Alliance Intelligent Battery Series™ battery outside of its stated operating temperature range. Reduce charging limits for lower operating temperatures for longer life of the batteries.

The advanced design of the Alliance Intelligent Battery Series™ is intended to provide protection against operation under many unsafe conditions such as over-voltage, under-voltage, over-temperature, and short-circuit. Proper use within the limits stated in the sections labeled "**Handling, Storage, and Installation**", "**Alliance Intelligent Battery Series™ Specifications**", and "**Operation and System Design**" is required to ensure operator and equipment safety as well as battery life.

Table 4: Proper Handling and Usage Guidelines

ALWAYS	NEVER
Always wear proper personal protective equipment (eye protection and gloves)	Never wear jewelry or other metal objects when working on or around batteries
Always use insulated tools when working on batteries	Never place objects on top of batteries
Always check connections for proper torque	Never charge a battery when the temperature is below 32°F (-0°C)
Always keep sparks and flames away from batteries. This includes sources of static electricity	Never charge a battery when the temperature is above 140°F (60°C)
Always use short cables of appropriate size to minimize voltage drop	Never store batteries below 30% State-of-Charge
Always make sure charger is set as recommended	Never exceed maximum charging currents for the battery's temperature
Always read the accompanying SDS (Safety Data Sheets) for other important safety, health, and regulatory information	Never dispose of batteries as household waste. Use recycling channels in accordance with local, state, and federal regulations
Always make sure chargers are off or disconnected while working on batteries	Never connect or disconnect terminals from batteries without first disconnecting loads
Always charge batteries before installing	Never attempt to open the battery case
	Never use pressure-washers to clean the battery or immerse the battery in water
	Never short-circuit the battery terminals
	Never physically damage the battery (this includes, without limitation: puncturing, dropping, crushing, burning, penetrating, shaking, hammering, and misconnecting terminals)
	Never over-charge the battery
	Never over-discharge the battery
	Never incinerate the battery
	Never deliberately expose the battery to fire or flame

Note
The most effective Fire Extinguisher types for Alliance Intelligent Battery Series™ batteries are copious amounts of water, CO_2, Dry Chemical (Type ABC), or Foam.

WARNING

RISK OF FIRE, EXPLOSION, OR BURNS

Do not disassemble, heat above 140°F (60°C), expose to fire or flame, or incinerate.

Mounting and Installation

Alliance Intelligent Battery Series™ batteries may be installed in the following orientations:

- Terminals up-right
- Terminals on the side

Batteries need hold-downs or restraints to prevent the battery from moving, excessive shock and vibration.

WARNING

ALLIANCE INTELLIGENT BATTERY SERIES™ CASE AND TOP COVER

The Alliance Intelligent Battery Series™ case including the top cover, is capable of sustaining a mounting force of up to 25lbs, spread over a one-inch-wide bar or holding bracket across the center of the unit. Exertions beyond this level may result in deformation or damage to the plastic.

Note

Lithium-ion batteries, including Alliance Intelligent Battery Series™, weigh substantially less than lead-acid batteries of comparable capacity. Many types of equipment are designed to utilize the weight of lead-acid batteries to achieve the manufacturer's intended weight distribution. If Alliance Intelligent Battery Series™, are installed as replacement batteries in equipment designed to use lead-acid batteries as ballast, the weight distribution of the equipment could be impacted. The system installer must understand the consequences of modified weight distribution and ensure that stability remains within a safe range for the intended use. The proper installation of Alliance Intelligent Battery Series™, may require additional ballast weights or other adjustments or equipment modifications to ensure stability and safe weight distribution. The improper installation of Alliance Intelligent Battery Series™ could compromise the weight balance and physical stability of the equipment leading to unsafe conditions. The system installer assumes all responsibility and liability for any damages, injuries, or accidents that may occur due to degraded stability resulting from an improper Alliance Intelligent Battery Series™, installation.

Battery Configuration Options

WARNING

ALLIANCE INTELLIGENT BATTERY SERIES™ PARALLEL AND SERIES CONNECTIONS

The Alliance Intelligent Battery Series™ batteries may be arranged in parallel configurations to achieve higher capacities up to a maximum of 400Ah (up to 10 batteries in parallel). The batteries are NOT designed to be connected in series.

Wiring Connections

To connect Alliance Intelligent Battery Series™ batteries, use appropriately sized wire, cables, and lugs that are rated for the maximum current and temperature expected. See table 6 for Environmental operation conditions.

The battery can accommodate a maximum inductance of 10 µH. For reference, 10 µH is equivalent to 6 meters (20 feet) of individual standalone cable. In a battery system, cable length inductance includes all terminal-to-terminal connections as well as cabling to charge sources and load for both the positive and negative conductors added together. It is possible to reduce a battery system's total cable inductance by orienting positive and negative conductors to cancel each other's electromagnetic induction, thus allowing for longer total cable length. Contact American Battery Solutions Technical Support for assistance in determining appropriate wiring and bus bar configurations to address current sharing and stray inductance requirements.

WARNING

EXCEEDING THE MAXIMUM INDUCTANCE LIMIT

Exceeding the maximum Inductance limit of 10µH during operation could cause voltage spikes or current surges resulting in possible damage to the Alliance Intelligent Battery Series™ battery's circuitry.

WARNING

INDUCTIVE LOADS

DO NOT connect the Alliance Intelligent Battery Series™ battery to inductive loads.

DO NOT connect the Alliance Intelligent Battery Series™ battery to an inductive load such as a DC motor without the use of a motor controller.

An "On-Off" switch does not constitute a motor controller. Using the batteries directly with DC motors can permanently damage the battery.

Contact American Battery Solutions Technical Support for further assistance.

Terminal Specifications

Alliance Intelligent Battery Series™ batteries use brass terminals. The terminals have a maximum operating temperature rating of 90 °C. The Terminals are tin-plated copper, with M8x1.25 thread, and should be torqued to no more than 9Nm.

When wiring lugs:

1. Connect a wiring lug directly to the surface of each battery terminal. Do not place a washer between the terminal base and the lug.
2. Next, place a flat washer on top of the lug, followed by a split washer, and finally by the bolt or nut.

Configuring Batteries in a Parallel Group (up to 1S10P)

To achieve higher capacity, arrange the batteries in a single series (1S) parallel group by connecting all like-polarity wires on adjacent batteries to an appropriately sized terminal block for your application. To ensure even loading, make two star-type connections: one for the positive battery terminals and one for the negative battery terminals. The cable lengths in each star group should be of approximately equal measure as permitted by the physical layout. From each star connection, use a twisted pair of cables to the load.

Reference local electrical codes and/or relevant standards for terminal block specifications. Bus bar connections are recommended for current exceeding 400 amps.

The nominal capacity for the parallel group can be calculated by multiplying the number of batteries in the group by nominal Ah capacity of the battery. For example, three batteries in parallel provides:

3 x 40 Ah = 120 Ah.

The maximum number of Alliance Intelligent Battery Series™ batteries that may be connected in parallel is 10 (ten).

Note
To get to higher Voltage, please contact the American Battery Solutions sales team.

Series and Parallel Battery Configuration Warning and Notices

WARNING

WHEN CONFIGURING BATTERIES IN PARALLEL ADHERE TO THESE WARNING NOTICES:

DO NOT connect any battery in series with any Alliance Battery. These batteries are meant to be connected in parallel only. Connecting one or more batteries in series may damage the battery's circuitry, leaving the battery without critical safety features, such as over-voltage and over-temperature protection.

DO NOT connect more than 10 Alliance Intelligent Battery Series™ batteries in parallel.

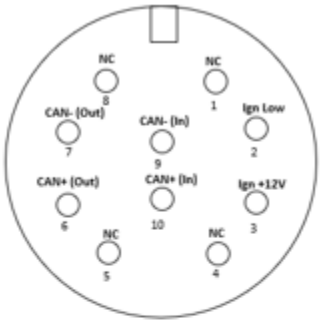
When designing and constructing any parallel battery combination contact American Battery Solutions Technical Support for assistance in determining appropriate wiring and bus bar configurations to address current sharing and stray inductance requirements.

Consider Inductance during system design. The Alliance Intelligent Battery Series™ battery can accommodate a maximum inductance of 10µH. Exceeding this limit during operation will cause voltage or current spikes that may damage the battery's circuitry.

Consider capacitance during system design. When a battery or battery group is connected to a heavy-duty charger, external capacitance may need to be added to the circuitry to address the output inductance of the charger. Contact American Battery Solutions Technical Support for assistance in determining appropriate capacitance for your system and charger.

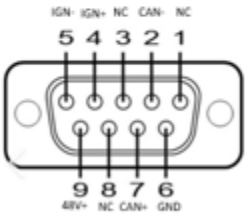
Connecting Alliance Intelligent Battery Series™ Communication Cables

The Alliance Intelligent Battery Series™ intelligent battery has a special 10-pin communication connector. American Battery Solutions can provide harnesses for connecting modules to industry standard D-sub 9 connectors or open wires for connecting to system or vehicle wire harnesses for industry standard CAN bus communications as shown in Figure 3. Only one of the two bus interfaces is enabled depending on the ordered configuration. The connectors mate together (one male, one female) so that one battery's bus output cable can be connected to the next battery's bus input cable in any order.



Female

Pin	Name	Color	Function
1	N/C	Brown	No Connect
2	Ign Low	Blue	Ignition Active when switched to ground (should be N/C if not used)
3	Ign +12V	White	Ignition Active when 12V high (should be N/C if not used)
4	N/C	Green	No Connect
5	N/C	Yellow	No Connect
6	CAN+ (Out)	Grey	CAN High Bus Line (Twisted pair with CAN- Out)
7	CAN- (Out)	Purple	CAN High Bus Line (Twisted pair with CAN+ Out)
8	NC	Red	No Connect
9	CAN- (in)	Black	CAN High Bus Line (Twisted pair with CAN+ In)
10	CAN+ (in)	Orange	CAN High Bus Line (Twisted pair with CAN- In)



Female

Pin	Name	Color	Function
1	N/C		No Connect
2	CAN- (in)	Blue	CAN High Bus Line (Twisted pair with CAN+ In)
3	N/C		No Connect
4	Ign +12V	Brn	Ignition Active when 12V high (should be N/C if not used)
5	Ign Low	Brn/wht	Ignition Active when switched to ground
6	Batt Gnd	Green	Battery Ground (if equipped with external harness)
7	CAN+ (in)	Blue/wht	CAN High Bus Line (Twisted pair with CAN- In)
8	N/C		No Connect
9	48V	Grn/Wht	B+ (if equipped with external harness)

Figure 3: 9-Pin D-Sub Communication Cable Connector Pin-Out Descriptions

Transportation and Storage

When storing or transporting the Alliance Intelligent Battery Series™ batteries, American Battery Solutions recommends the following:

- Batteries can be **stored** in an environment with average temperatures between -40 °C and +35 °C, between 5% and 95% relative humidity, noncondensing, and at altitudes up to 25,000 feet (7600 m). Storing the batteries in temperatures above +35 °C can significantly reduce the battery's state of charge and storage time and life time as further described in , in Table 7.
- Batteries can be **transported** for up to two weeks in an environment with temperatures above 35 °C up to 60°C and at altitudes up to 50,000 feet (15,240 m).
- Batteries have been tested to 11.6 kPa (50,000 feet) at 20 °C ±5 °C.
- When storing or warehousing batteries, always consult your local fire marshal for specific rules related to your jurisdiction.
- Consult your insurance carrier for specific requirements they may have.

Operating Environment

Alliance Intelligent Battery Series™ batteries are engineered to disconnect from the host system under a variety of conditions in order to avoid internal damage. When this occurs in equipment with Alliance batteries, all power will be lost. In certain types of equipment, an abrupt interruption of power can cause undesirable and unexpected equipment behavior, such as braking loss or sudden braking. The system installer must understand the consequences of this behavior and ensure that proper system features are in place to avoid potentially harmful changes in equipment behavior without properly notifying the operator. The system installer assumes all responsibility and liability for any damages that may occur if these features are not properly implemented.

Recycling/Disposal

Do not incinerate or dispose of the battery. Return end-of-life or defective batteries to your nearest recycling center per the appropriate local regulations.

Alliance Intelligent Battery Series™ Specifications

Electrical and Environmental Specifications

Table 5: Alliance Intelligent Battery Series™ Electrical Specifications

Specification	Description
Maximum Continuous Discharge Current to 100% DOD at 25 °C [a]	40A[a]
Maximum Continuous Charge Current to 100% capacity at 25 °C [a]	12A[a]
Maximum Pulse Discharge Current	150A for 2sec[b] 120A for 10sec[b] 104A for 30sec[b] 80A for 120sec[b]
Maximum Pulse Charge Current	65A for 2sec[c] 50A for 10sec[c] 12A for 30sec[c]
Nominal Operational Voltage	50.8 V
Minimum Operational Voltage	28 V
Maximum Charge Voltage (CC or CV)	57.4 V
Nominal Capacity	40 Ah
Minimum Capacity at BOL	38 Ah

a. Continuous current (charge or discharge) is defined as occurring over a single full-charge or full-discharge cycle.

b. Current that exceeds this value will be interrupted by the battery's protection circuitry.

c. Charge sources exceeding the continuous current will charge the battery at a duty-cycle inversely proportional to the charger's current.

d. Although high ripple current at low frequencies (60Hz/120Hz) is not recommended, the Alliance Intelligent Battery Series™ battery will support average ripple current with peaks up to 240 amps without any adverse effects. As a comparative example, the maximum ripple current for a typical AGM (absorbent glass mat) 12 volt 35 Ah VRLA battery (@ 20hr rate) would be 35 Ah/20 hr or 1.75 amps.

Table 6: Alliance Intelligent Battery Series™ Environmental Specifications

Specification	Description
Ambient Operating Temperature Range[a]	Charge -0 °C to +50 °C Discharge -30 °C to + 60°C
Maximum Operating Altitude	15,000 ft above Sea Level
Operating Relative Humidity (noncondensing)	5% to 95%
Environmental Rating for Battery Enclosure	Meets IEC60529 – IP67 Environmental Rating for Battery Enclosure
Recommended Storage Environment Conditions	Temperature: -40 °C to +35 °C [b] Relative Humidity (noncondensing): 5% to 95% Altitude: Up to 25,000 ft (7600 m)
Transportation Environment Conditions for up to two weeks c	Temperature: -40 °C to +60 °C Relative Humidity (noncondensing): 5% to 95% Altitude: Up to 50,000 ft (15,240 m)

a. The maximum operating temperature decreases by a factor of 1.1 °C per 1,000 ft of elevation above 7,500 ft.

b. Storing Alliance Intelligent Battery Series™ batteries in temperatures above +35 °C can significantly reduce the storage time. See section "Transportation and Storage".

Physical Specifications

Table 7 and Figure 4 provide details of the mechanical dimensions and weight of the Alliance Intelligent Battery Series™ battery.

Table 7: Alliance Intelligent Battery Series™ Physical and Mechanical Specifications

Specification	Description
Dimensions (excluding terminals)	373 x 233 x 99 mm (14.7 x 9.17 x 3.9 in)
Weight (approximate)	10.2 kg (22.5 lbs.)
Case Material	ABS Plastic, UL 94 V0 Flame Rating
Terminal Bolt Requirements	Tin Plated Copper, M8 x 1.25mm torque up to 9Nm (79.7in-lbs)
Maximum Terminal Temperature (before damage)	90 °C
Communications Connectors (if equipped)	10-pin female connector

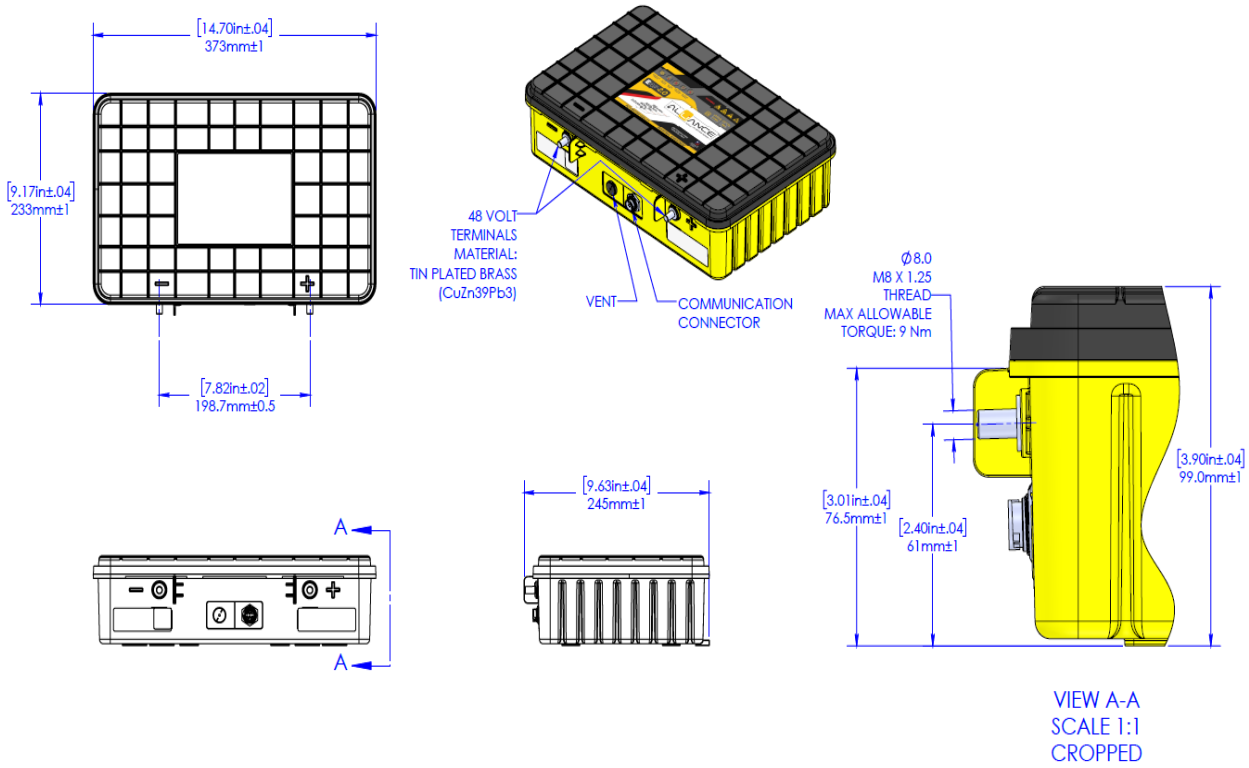


Figure 4: Alliance Intelligent Battery Series™ Mechanical Dimensions

Operation and System Design

General Battery Optimization

The Alliance Intelligent Battery Series™ battery technology incorporated an intelligent Battery Management System (BMS) which ensures safe Battery Operation. The BMS shall operate mainly in 2 Modes: Drive and Charge.

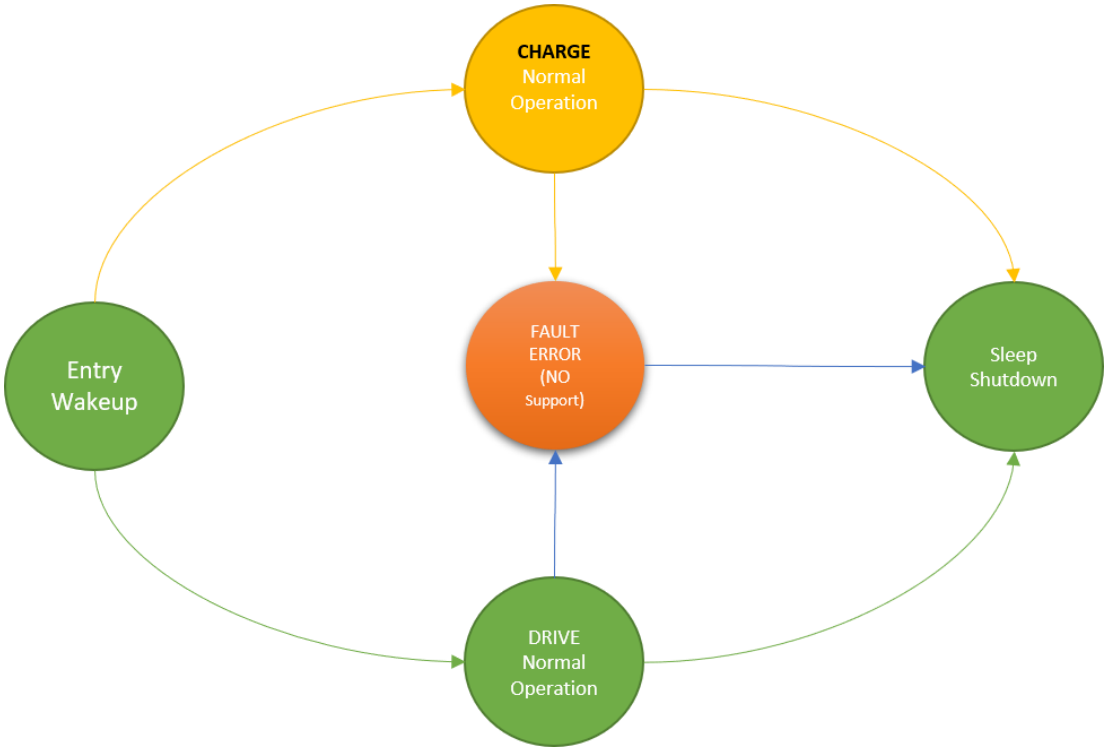


Figure 5: Battery State Diagram

Drive mode is initiated via CAN or IGN Low; this is the normal mode of operation and allows for both discharging and charging of the battery. The Charge mode will optimize the battery charge cycle when used with a compatible smart charger such as the DeltaQ Intelligent battery chargers.

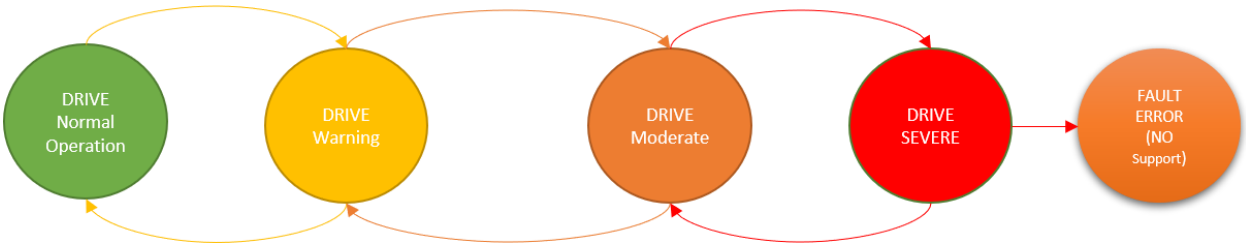


Figure 6: Fault State Transition Diagram

The BMS shall enter Fault Error Mode based on any of the Protection Features as mentioned in further sections. The BMS has escalating fault states for many of the failure conditions with (Warning, Moderate and Sever) with elevating effects to the condition. All fault states are broadcast on CAN in the Batt_Eventmatrix_A/B messages.

Table 8: Alliance Intelligent Battery Series™ Fault State Reactions

Fault State	*Reaction*
Normal Operation	100% Power Delivery, Circuit Breaker will be Closed (Normal Operation) Recovery Allowed
Warning	100% Power Delivery, Circuit Breaker will be Closed (Normal Operation) Recovery Allowed
Moderate	Potentially Reduced Power Delivery, Circuit Breaker will be Closed Recovery Allowed
Severe	No Power Delivery, Circuit Breaker will Open Recovery Allowed
Severe- Permanent	No Power Delivery, Circuit Breaker will Open No Recovery Allowed

Battery Management System (BMS) Initialization and Wakeup

The Alliance Intelligent Battery Series™ has two wake-up configurations:

a. Wake on CAN
   The Alliance Intelligent Battery Series™ is equipped with a Wake on CAN transceiver which will wake the BMS out of sleep mode any time there are messages on the CAN bus. To enable the battery terminals, the appropriate HOST_stateRequest signal (Drive = 1 or Charge = 2) in the HOST_BatteryRequest Message (0x502) must be sent at a rate of 1 Hz.

b. IGN-Based Wakeup
The Alliance Intelligent Battery Series™ can be woken by connecting the Ign Low (Pin 2 of the low voltage connector) to the negative terminal of the battery or connecting the Ign +12V to an external 12V source. (It is assumed that connection to the negative terminal of the battery is through chassis ground or the application wiring harness.) When either Ing pin is activated (Switching Ign Low to ground or applying 12V to Ign +12V) will enter Drive mode (assuming no failures are present), at which point Discharge and Charge functions are available. The BMS will enter sleep mode within 5 seconds of removing the Ignition signal.

Pins on the Alliance Intelligent Battery Series™ low voltage connector that are not used should be left not connected (NC).

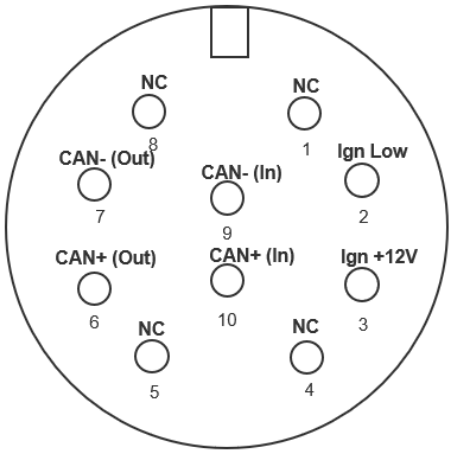


Figure 7: CAN Connector Pin-out

Battery Management System (BMS) Modes of Operation

The Alliance Intelligent Battery Series™ has 5 Major states of Operation:

1. Standby Not Ready (fault condition present)
2. Standby
3. Drive
4. Charge
5. Sleep

For CAN based systems, the states can be commanded through the HOST_stateRequest Signal in the HOST_batteryRequest Message (0x502). The Drive and Charge states allow current to flow in and out of the battery. The Standby and Standby Not Ready states indicate that the BMS is awake but not delivering power, either by the None command or because there is a fault in the system preventing the power to/from the battery. The Sleep state is a low power state the BMS will enter when given the sleep command or when CAN communication has ceased for approximately 5 seconds. (Note: if the Sleep command is initiated, CAN communication must be terminated immediately afterward, otherwise the system will wake due to CAN traffic).

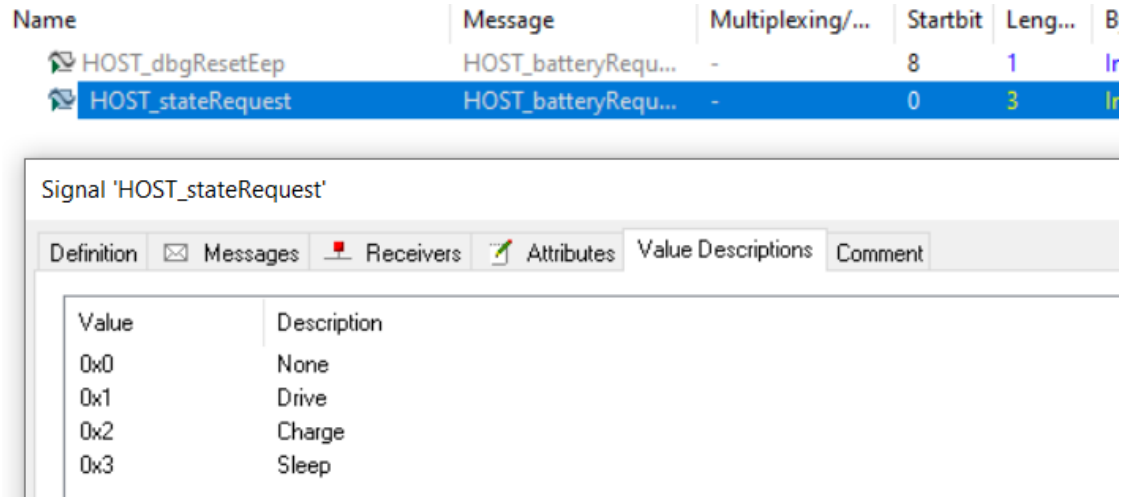


Figure 8: State Request List

Table 9: Alliance Intelligent Battery Series™ Operation State Actions

Host Request	*Reaction*
None	No Power Delivery, FET (Circuit Breaker will be Open)
Drive	Power Delivery, Circuit Breaker will be Close (Normal Operation)
Charge	Power Delivery, Circuit Breaker will be Close (Mainly for Charger)
Sleep	No Power Delivery, Circuit Breaker will Open (shutdown the BMS)

In IGN-based Wakeup operation, the BMS will default to the Drive state if there are no faults present, and power will be allowed to flow through the terminals. If a fault is present the BMS will stay in the Standby Not Ready state until the fault condition has cleared. The BMS will enter sleep state within 5 seconds of the Ing Low signal being removed.

Battery Configuration

The Alliance Intelligent Battery Series™ can be configured to operate as a single module or with multiple modules in parallel if additional power or energy required. (Series configuration of the Alliance Intelligent Battery Series™ is not supported and will result in permanent damage to the BMS if configured as such).

a. Single Module Setup
   The battery pack can work in a standalone fashion with little or no modification to the wiring. The Power cables to the Positive and Negative terminals need to be connected and then the system state needs to be commanded to Drive or Charge, as described above.

b. Multi-Module Setup
   For proper operation in a multi-module setup, the Alliance Intelligent Battery Series™, batteries need to know the state of the other batteries in the system. This is accomplished through inter-module CAN communication, with the wiring as shown below. Additionally, the terminals of the batteries must also be connected to each other for operation. Failure to do this will result in the batteries entering a faulted condition and the batteries will be in a **Standby Not Ready** condition. The number of modules that can be connected in parallel is limited to 10.

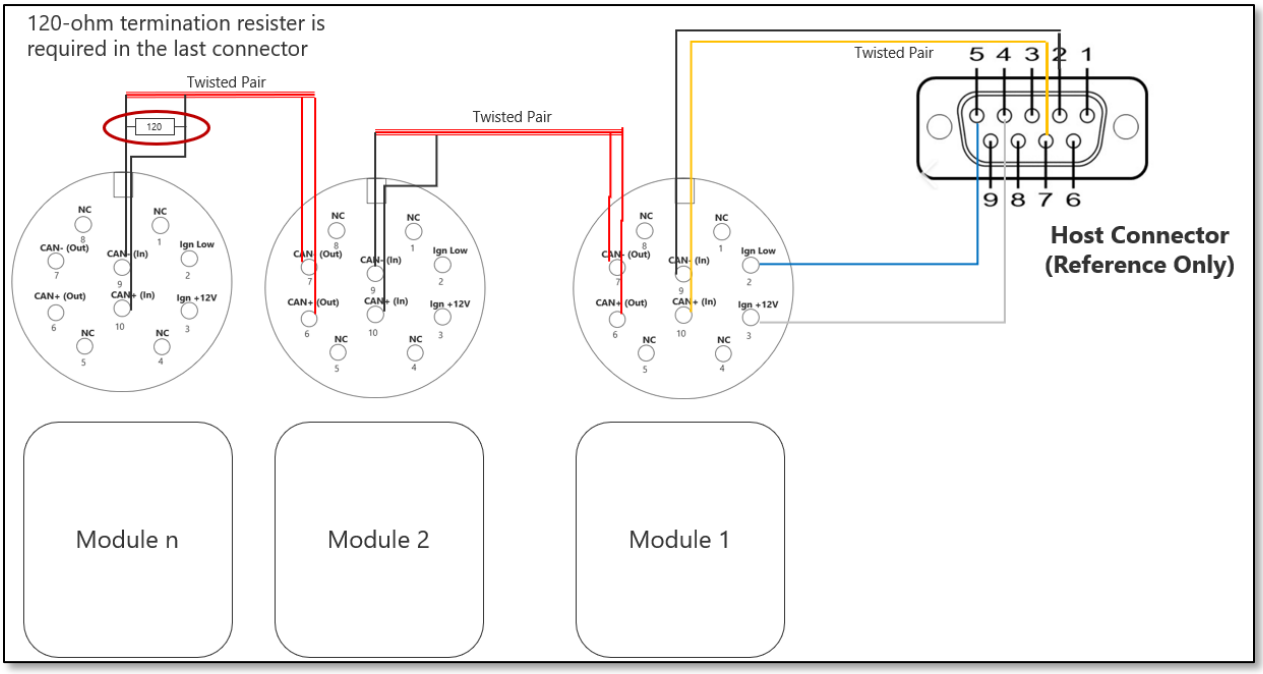


Figure 9: Multi-Module CAN Connection

Table 10: Alliance Intelligent Battery Series™ Multi-Module Faults

Event	Condition
Module Select Disagreement	Inter-module pre-charge ID mismatch
Module Connect Fault	One or more permitted modules failed to pre-charge or join bus
Module MIA	One or more inter-module critical messages missing (see inter-module data section)
Module Imbalance	Difference in voltage too great to join bus

Integrated Battery Protection

The Alliance Intelligent Battery Series™ battery technology includes integrated protection circuitry to prevent the battery from certain damaging use conditions. The battery's circuitry interrupts either charging or discharging current if the battery is in danger of exceeding limits to voltage, current, temperature or internal failure of the BMS.

Transient Energy Limit

The battery is designed to protect itself from transient voltage spikes which contain excess energy of up to 2.5 Joules. Inductance, inherent in the cabling used to connect to the battery and the system, stores energy which can be released suddenly when the battery protection circuit opens. When this occurs, the passive energy stored in the wiring and active sources like power supplies and battery chargers can create large transient spikes, that if exceed 2.5 Joules, can permanently damage the BMS.

While the product has been designed to handle a maximum inductance of 10 µH and tolerate connections to most power supplies, the user is responsible for ensuring that the battery does not experience over-voltage surge energy in excess of 2.5 Joules when conduction is interrupted. External energy absorption devices like capacitors or clamps can reduce the overshoot or stress on the battery and may be required based on the application. Please contact American Battery Solutions if you have any concerns or questions regarding Transient Energy and your specific application and connection.

Over-Current Protection

The Alliance Intelligent Battery Series™ calculates current limits based upon current direction (Discharge/Charge), State of Charge (SOC), temperature, current value and amount of time at the current value.

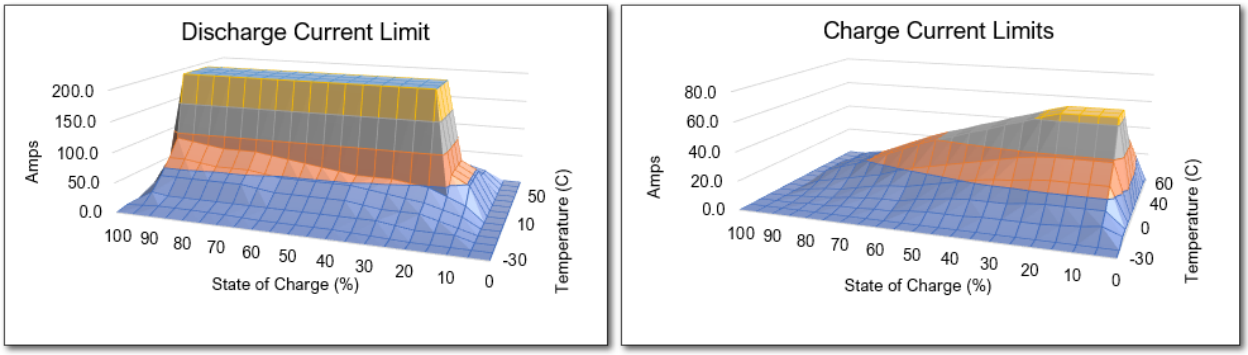


Figure 10: BMS Current Control Limits

The Alliance Intelligent Battery Series™ battery supports 2 level of over current protection.

1. **Overcurrent Protection** – will trigger if the sensed current exceeds the allowed current limits for a time. In the event of exceeding the current limits the BMS FETs will open interrupting current to the system and will remain open for up to 60 seconds.

2. **Hardware Overcurrent** – Exceeding the Hardware Overcurrent threshold (250 A) will cause the BMS FETs to open, interrupting current to the system and will remain open for up to 60 seconds. The Hardware Overcurrent protection is designed to protect the battery and operator from external short circuits.

Over-Discharge Protection (Under-Voltage Protection)

As the battery nears 0% State of Charge (SOC), the terminal voltage begins to drop rapidly. The Alliance Intelligent Battery Series™ is considered fully discharged when any one of its internal cell voltages falls to 3.0 volts or the battery's terminal voltage is approximately 42 volts.

The Alliance Intelligent Battery Series™ is designed to enter an Under-Voltage Protection (UVP) state if any cell drops below 2.75 volts. In the UVP state, the Alliance Intelligent Battery Series™ will disconnect its terminals causing the output voltage to

drop to 0 volts. Terminals will be allowed to reconnect once the voltage has increased above 2.78 volts for 20 seconds.

Slight differences in the cells' capacity lead to differences between the cell voltages, especially at low states of charge. In such a case, one cell may trip the UVP protection before the others do. When this happens, the voltage measured at the battery terminals may be higher than 42 volts.

The Alliance Intelligent Battery Series™ battery supports 3 level of under-Voltage protection.

1. **Undervoltage Warning** – Undervoltage Warning sets a warning flag if any of the Battery cell voltage goes below Minimum Discharge Voltage. This notifies the user to take appropriate actions and use the battery efficiently without opening the FETs.

2. **Undervoltage Moderate** - Undervoltage Moderate flag is set if any of the Battery cell voltage goes further below Minimum Discharge Voltage. This fault put the pack is low power mode. This helps the user the take appropriate actions and use the battery efficiently without opening the FETs.

3. **Undervoltage Severe**– Undervoltage Severe protections is set if any of the Battery cell voltage goes below Discharge Under Voltage Protection limit. Setting this fault opens the FETs. This helps battery from protecting itself from deep discharge conditions. For further details, refer to Table 15: Alliance Intelligent Battery Series™ **Event Matrix.**

Note
Under-Voltage Protection creates an open circuit, removing voltage from the terminals.
With a lead-acid battery finding no voltage at the terminals often indicates the battery is no longer usable. With the Alliance Intelligent Battery SeriesTM battery, no voltage at the terminals typically means the cell protection circuitry has interrupted current to protect the battery. Simply connect the battery to a charge source to restore voltage to the terminals.

Smart Charger Support

Smart charger technologies require the presence of a terminal voltage before supplying a charge current. To support smart chargers when in a protection state (i.e. Under Voltage Protection (UVP) the Alliance Intelligent Battery Series™ will present a current limited terminal voltage. When there is no charger or load connected, there is no current flowing, so the circuit allows the terminals to show the actual battery voltage. This terminal voltage can be measured with a multi-meter or other high impedance

voltage measurement device.

Over-Charge Protection (Over-Voltage Protection)

Similar, but opposite to the case at low states of charge, the Alliance Intelligent Battery Series™ terminal voltage begins to rise rapidly at high states of charge. The Alliance Intelligent Battery Series™ is considered at 100% SOC when the cells are balanced and terminal voltage measures 57.4 volts or above. At this point, the average cell voltage is the terminal voltage divided by 14, or 4.1 volts. The Alliance Intelligent Battery Series™ is designed to enter an Over Voltage Protection (OVP) state if any cell rises above 4.1 volts. In the OVP state, the Alliance Intelligent Battery Series™ will disconnect its terminals and not accept further charge current. To exit the OVP state, apply a load to discharge the Alliance Intelligent Battery Series™. The battery's internal balancing circuitry will also cause an automatic exit of this state, but it may take longer. The Alliance Intelligent Battery Series™ will return to Normal State once the cell voltages fall below 4.08 volts. For further details, refer to the section: "Balancing".

The Alliance Intelligent Battery Series™ battery supports 3 level of Over Voltage protection.

1. **Overvoltage Warning** – Overvoltage Warning sets a warning flag if any of the Battery cell voltage goes above Maximum Charge Voltage. This notifies the user to take appropriate actions and will not allow entry into charging without opening the FETs.

2. **Overvoltage Moderate** - Overvoltage Moderate flag is set if any of the Battery cell voltage goes further above Maximum Charge Voltage. This fault will exit the charge state to stop further charging of the battery without opening the FETs.

3. **Overvoltage Severe–** Overvoltage Severe protections is set if any of the Battery cell voltage goes above the Charge Over Voltage Protection limit. Setting this fault opens the FETs. This helps battery from protecting itself from over Charge conditions.

Over-Temperature Protection

The Alliance Intelligent Battery Series™ battery's circuitry continuously monitors the battery's temperature. The battery will open its terminals before the temperature is too high for safe operation. Do not operate the battery outside of the operational temperature range specified in Table 6.

Both charge and discharge functions increase battery temperatures. High rate battery usage causes the largest temperature increase. The Alliance Intelligent Battery Series™ over temperature protection (OTP) circuitry disconnects the terminals if the battery exceeds the temperature limits. During high rate battery usage, the user must ensure that ambient operating temperature combined with the charge or discharge rate does not exceed the operational temperature limits.

Under certain conditions, the Alliance Intelligent Battery Series™ terminals will exceed the 70 °C touch temperature limit as described in UL 1973. For operation beyond those touch temperature limits, not to exceed 90 °C, the Alliance Intelligent Battery Series™ will require the placement of guards to prevent accidental contact. American Battery Solutions recommends that additional testing be conducted under specific use cases. The gauge of wire may be changed depending on final temperature requirements and application.

1. **Over Temperature Warning** - Over Temperature Warning sets a warning flag if any of the Battery cell Temperature goes above Maximum operating temperature. This notifies the user the take appropriate actions and use the battery efficiently without opening the FETs.

2. **Over Temperature Moderate** - Over Temperature Moderate flag is set if any of the Battery cell Temperature goes above Charge Over Temperature Protection Limit. This fault restricts the user from operating the battery pack in charging mode by opening the FETs in Charge Mode. This helps the battery from protecting itself from charging at above the rated temperature to maintain the life of the Battery.

3. **Over Temperature Severe -** Over Temperature Severe flag is set if any of the Battery cell Temperature goes above Discharge Over Temperature Protection. This fault restricts the user from operating the battery pack during Driving mode by opening the FETs in Drive Mode. This helps the battery from protecting itself from discharging at above the rated temperature to maintain the life of the Battery.

Note
Cell life will be limited by exposure to high temperatures.

Low Temperature Operation

At low temperatures, the maximum available discharge power decreases due to increased internal impedance at lower temperatures.

1. **Under Temperature Warning** – Under Temperature Warning sets a warning flag if any of the Battery cell Temperatures go below minimum operating temperature. This notifies the user the to take appropriate actions and use the battery efficiently without opening the FETs.

2. **Under Temperature Moderate** - Under Temperature Moderate flag is set if any of the Battery cell Temperatures go below Charge under Temperature Protection Limit. This fault restricts the user from operating the battery pack during charging mode by opening the FETs in Charge Mode. This helps the battery protect itself from charging at below the rated temperature to maintain the life of the Battery.

3. **Under Temperature Severe**– Under Temperature Severe flag is set if any of the Battery cell Temperature goes below Discharge under Temperature Protection. This fault restricts the user from operating the battery pack during Driving mode by opening the FETs in Drive Mode. This helps the battery protect itself from discharging at below the rated temperature to maintain the life of the Battery.

Note
Do not operate the battery outside of the operational temperature range specified in table 7, on page 23.

Charging a Single Battery Module

The Alliance Intelligent Battery Series™ is compatible with most common 48-volt, lithium-ion battery chargers. A single Alliance Intelligent Battery Series™ can accept continuous charge current up to 20 amps for 48V module and 40 amps for 24V module at certain temperature and SOC range. Higher current for short durations is allowed. However, in some situations, internal component temperatures may be exceeded causing performance to be curtailed by the battery's protection circuitry.

Note
Use of chargers with a temperature compensation feature, typically required for lithium-ion batteries may result in an incomplete charge, or possibly no charge at elevated temperatures, but will not damage the battery. It is recommended that such temperature compensation features be disabled.

Constant Current (CC), Float Voltage Chargers

For Alliance Intelligent Battery Series™ batteries operating under normal conditions during a charge, a charger applies Constant Current (CC) until the terminal voltage reaches its End of Charge (EOC) voltage (maximum), as shown in Figure 11. This process is followed by a float voltage, where the charge current decays to near zero. During the charging, the balancing circuitry performs cell balancing. This process charges the Alliance Intelligent Battery Series™ battery to 100% SOC. Please refer to "Over Charge Protection (Over Voltage Protection)" for the battery voltage limit in CV stage and refer to "Charge limits and Temperatures" for battery current limit in CC stage.

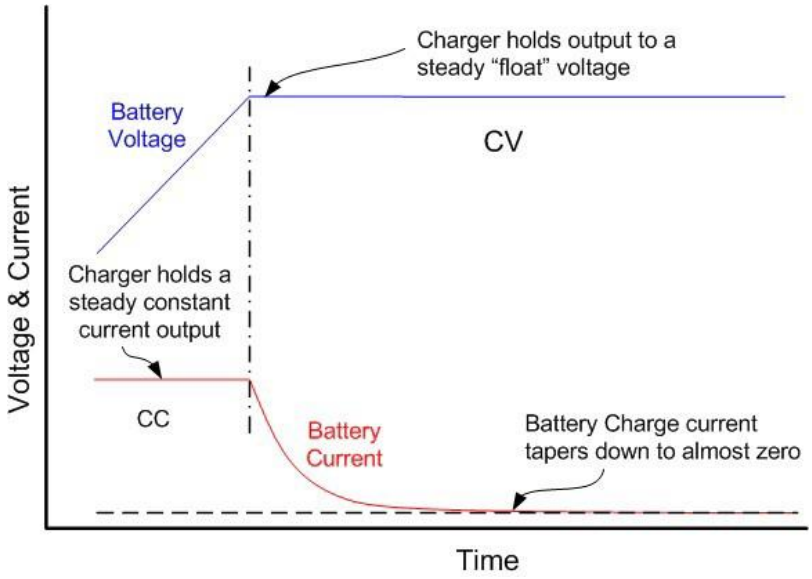


Figure 11: Battery Voltage and Current During Normal Charge

Note
New batteries may be used as received. However, to ensure that all cells are balanced and fully charged before their first use, individual batteries should be charged for 4 to 24 hours with a float charge. Charging is particularly necessary prior to performing capacity tests. After initially balancing the batteries, normal use should maintain the cells in a proper state.

Charger Recommendation

Delta-Q IC-series CANOpen chargers are recommended for Alliance Intelligent Battery Series™ modules.

Charge Limits and Temperatures

At room temperature and above, the Alliance Intelligent Battery Series™ battery can accept full rated charge. As with all battery technologies, charge acceptance is limited at low and high temperatures. A permanent loss of capacity may be observed if charge rates are not reduced at limited range of cell temperatures. As the cells' temperature falls into optimal temperature range during the charging process, they can gradually accept higher currents. The Alliance Intelligent Battery Series™ batteries can be charged with current limits shown in Table 11.

Table 11: Max charge continuous current limits for single module

Temperature (°C)	E48-2.0 model (Amps)
< 0	0
0	5.6
10	8.0
25	12.0
33	12.0
40	20.0
45	20.0
50	12.0
> 50	0

Charging Multiple Battery Modules in Parallel

Alliance Intelligent Battery Series™ battery modules can be connected in parallel. The following is an example of connecting 3 modules to the charger.

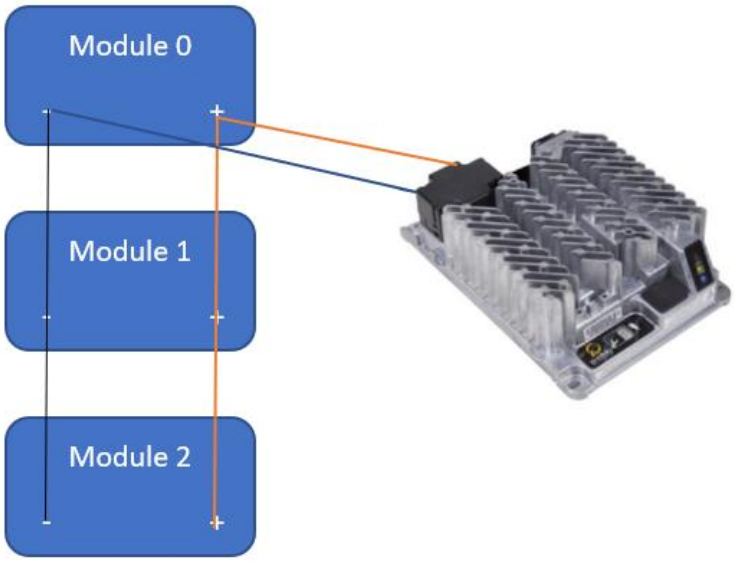


Figure 12: Connecting multiple modules in parallel to a charger

When charging multiple batteries, maximum charge current should not exceed the number of modules multiplied by the single module current limit for the number of Alliance Intelligent Battery Series™ battery modules connected in any parallel configuration. Alliance Intelligent Battery Series™ battery modules are only allowed to connect in parallel and are not designed to connect in series.

Table 12: Max charge continuous current limits for multiple modules in parallel

Temperature (°C)	E48-2.0 model (Amps)
< 0	0
0	5.6 * # of modules
10	8.0 * # of modules
25	12.0 * # of modules
33	12.0* # of modules
40	20.0 * # of modules
45	20.0 * # of modules
50	12.0 * # of modules
> 50	0

Discharge Performance

Compared to lead-acid batteries, the output voltage of the Alliance Intelligent Battery Series™ remains relatively constant across its capacity range at any given discharge rate. As the Alliance Intelligent Battery Series™ battery discharges, limited voltage drop translates into superior (I x V) power delivery capability. Additionally, Alliance Intelligent Battery Series™ battery delivered capacity is nearly independent of discharge rate. Voltage drop in the Alliance Intelligent Battery Series™ is an inverse function of the battery internal temperature. As the internal temperature of the Alliance Intelligent Battery Series™ drops, the impedance rises leading to an increased voltage drop. It is important to consider the resulting performance impacts when designing a product for cold conditions. Please contact American Battery Solutions Technical Support to understand rate and temperature performance of Alliance Intelligent Battery Series™ batteries in your application.

The Alliance Intelligent Battery Series™ battery End of Discharge (EOD) terminal voltage is a function of the core cells, any cell-to-cell variations, and series impedance of the internal power pathway. These elements are impacted by discharge rate and temperature. The battery's protection circuitry will stop discharge when any cell voltage drops below 2.0 volts.

Cell-to-cell variation has the largest impact on the expected EOD terminal voltage. Cells vary in performance in a variety of ways based on normal manufacturing. Depending on the discharge rate, temperature, and other factors in the application, a different voltage trigger value based on the appropriate discharge curve may be needed compared to lead-acid or other battery chemistries. Otherwise, undesired behavior of the battery may occur such as the unexpected loss of voltage if the Alliance Intelligent Battery Series™ enters UVP state, or taking action too soon such as disconnecting the load while significant energy still remains in the battery.

If the intent of the application is to maximize the amount of energy available from the Alliance Intelligent Battery Series™ battery before charging, it may be advantageous to disable external cutoff mechanisms based on the terminal voltage and instead use the battery's internal protection circuitry to determine when to interrupt the discharge cycle. The battery protects itself from unsafe conditions and typically disconnects due to low voltage when only 5-10% of full charge capacity remains.

Balancing

Over time, the Alliance Intelligent Battery Series™ cells diverge in both capacity and SOC. All Alliance Intelligent Battery Series™ batteries perform cell balancing at high SOC values, based on balancing-enable conditions, to maximize the available capacity of the battery. The balancing circuit's purpose is to drive all cells to a balanced state.

Alliance Intelligent Battery Series™ batteries are shipped at 30% SOC. Fully charging the Alliance Intelligent Battery Series™ at float voltage for 4-24 hours prior to first use will ensure optimal balance and maximize the first discharge delivered capacity.

Cycle Life

Cycle life is dependent upon many application-specific factors including operating temperature, charge/discharge rates, state of charge swing, and calendar time. Please contact American Battery Solutions to understand the performance of Alliance Intelligent Battery Series™ batteries in your specific application, given your duty/drive cycles.

Shelf Life

Alliance Intelligent Battery Series™ batteries ship from the factory at approximately 30% State of Charge (SOC) and slowly discharge primarily due to the small parasitic load of the battery management system. Although batteries can remain above 10% SOC for up to 18 months of storage where temperatures do not exceed 25 °C, storage at higher temperatures accelerates the rate of discharge. Therefore, batteries that are stored for extended periods of time should be charged every 12 months to ensure the batteries do not discharge themselves into an unrecoverable under voltage lockout state (UVLO).

Alliance Intelligent Battery Series™ batteries being shipped by Air must comply with ICAO regulations, which requires that the batteries be at or below a 30% SOC. These batteries shipped by Air can remain functional for 16 months of shelf life where temperatures do not exceed 25 °C.

Storage temperatures above 25 °C accelerate the rate of self-discharge and reduce the shelf life.

Control Area Network (CAN) Interface

CAN is a standardized, low-cost, multi-master, broadcast network that is well suited for smart battery applications. The Alliance Intelligent Battery Series™ battery CAN interface provides access to battery status and configuration information. Through the CAN interface the end-user can monitor battery performance, be notified of alarm or warning conditions, and configure the CAN communications parameters and battery's behavior. CAN has error detection, fault containment and nondestructive arbitration

built into the hardware layer, making for a robust network that can operate reliably in electrically noisy environments. The Alliance Intelligent Battery Series™ network interface is compatible with CAN-to-USB adapters that provide galvanic isolation only. The Vector CAN Case and PCAN have been evaluated by American Battery Solutions and are known to work. Other CAN-to-USB adapters that provide galvanic isolation may work, but compatibility cannot be guaranteed. All CAN bus configurations require 60 ohm impedance, accomplished by having a 120 ohm terminations in parallel at each end of the CAN bus. If the alliance battery is placed at the end of the CAN communication bus, 120ohm resister is required to be installed across pins 6 and 7 of the last module physically connected to the CAN bus. Additionally, the termination that had previously been at the end of the CAN bus needs to be removed from the circuit.

The Alliance Intelligent Battery Series™ is based upon the CAN 2.0A/B protocol. All messaging from the "pack" (1 – 10 modules in parallel) to the host application and charger is accomplished using CAN 2.0A protocol (11 bit message identifiers). One module will speak to the host application and convey limits and status of the "pack." All Inter-module communication that conveys information about specific modules within the pack is accomplished using CAN 2.0B (29 bit message identifiers). Using this scheme, it is easy for the host application to only pay attention to signals that are relevant to it and ignore the non-relevant module information. If desired the host can see the module information and can be decoded from the CAN database file (DBC), Please contact American Battery Solutions for the DBC file your application.

In addition to the Standard CAN messaging the Alliance Intelligent Battery Series™ also supports a limited number of CANOpen protocols. Please contact American Battery Solutions for details or custom application software.

CAN Network Configuration

To establish CAN communications between 1 or more Alliance Intelligent Battery Series™ connect CAN In+/CAN In- to the vehicle host or charger CAN+/CAN- wires. To connect multiple modules together, connect the CAN Out+/CAN Out- to the adjacent modules CAN In+/CAN In-, as shown in figure 13. To ensure proper communication it is important that the CAN bus is appropriately terminated. If the batteries are at the physical end of the CAN bus, a 120-ohm termination resister needs to be placed between CAN+ and CAN-. This can be done as shown below, or between pins 6 and 7 (CAN Out+/CAN Out-). A CAN bus should have 60 ohms of impedance when properly balanced. American Battery Solutions offers several different options for connecting multiple batteries. Please contact American Battery Solutions for more details.

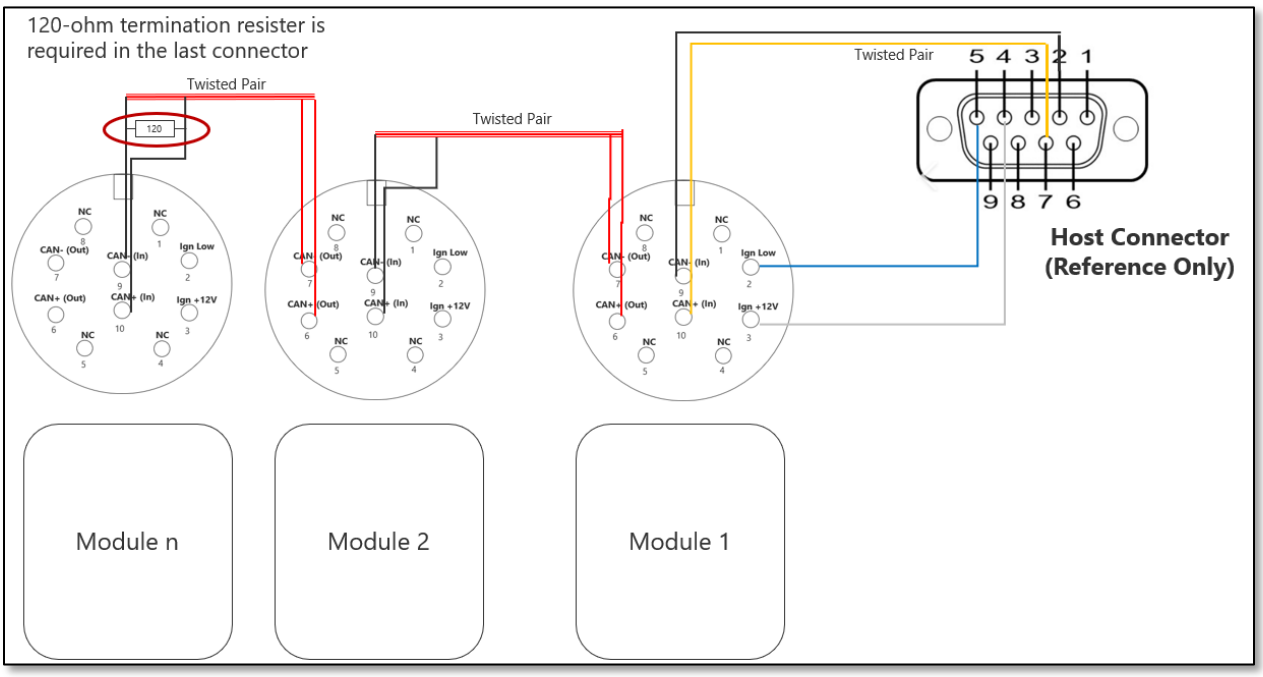


Figure 13: CAN Bus Interface

CAN Bus Settings

The default CAN bit rate is 500 kbit/s with the sample point set to 75% and a synchronization jump width of 2 bits. To support any other Baud rate, please contact American Battery Solutions technical support to give proper solutions.

CAN Message Mapping

The most common CAN Signals and messages are listed below. Please contact American Battery Solutions for a complete CAN database (DBC) file.

Table 13: Alliance Intelligent Battery Series™ messages and signals on the CAN interface

SIGNAL NAME	MESSAGE	MESSAGE ID	UNIT	COMMENT
BATT_USERMODE	BATT_userInputs	0x100		0 - Request to be reduced Range...
BATT_USERSOC	BATT_userDisplay	0x101	%	State of Charge for the battery pack
BATT_PACKFULLCAPACITY_AH	BATT_packStatus	0x103	Ah	Estimated full charge capacity
BATT_PACKNUMMODSCONFIGURED	BATT_packStatus	0x103		Number of parallel modules configured for the pack
BATT_PACKNUMMODSONHVBUS	BATT_packStatus	0x103		Number of modules on the HV bus
BATT_PACKNUMMODSONNETWORK	BATT_packStatus	0x103		Number of modules on the network
BATT_PACKREMAININGCAP_AH	BATT_packStatus	0x103	Ah	Remaining charge
BATT_PACKSOC	BATT_packStatus	0x103	%	State of Charge for the battery pack
BATT_PACKSTATE	BATT_packStatus	0x103		Reports the current state of the battery
CHRG_CHARGERENABLED	CHRG_chargingControl	0x111		0 - Charger is disabled...
CHRG_CHARGINGCURRENT	CHRG_chargingControl	0x111	A	Output current from charger
CHRG_CHARGINGVOLTAGE	CHRG_chargingControl	0x111	V	Output voltage from charger
BATT_IPACKCHGLIMITCONT	BATT_packChgContLimits	0x112	A	Current recharge limit in A
BATT_IPACKDCHLIMITCONT	BATT_packDchContLimits	0x113	A	Current discharge limit in A
INV_CURRENT	INV_power	0x115	A	Current measured by motor
INV_VOLTAGE	INV_power	0x115	V	Voltage measured by motor
BATT_IPACK	BATT_packHvStatus	0x124		Pack current - combined current of all modules
BATT_VPACK	BATT_packHvStatus	0x124	V	Voltage of the pack
BATT_VPACKLOAD	BATT_packHvStatus	0x124	V	Voltage measured across load
BATT_TPACKMODULEMAX	BATT_packMinMax	0x125	deg C	Maximum Battery temperature
BATT_TPACKMODULEMAXID	BATT_packMinMax	0x125		ID of maximum Battery temperature
BATT_TPACKMODULEMIN	BATT_packMinMax	0x125	deg C	Minimum Battery temperature
BATT_TPACKMODULEMINID	BATT_packMinMax	0x125		ID of minimum Battery temperature
BATT_VPACKBRICKMAX	BATT_packMinMax	0x125	V	Maximum brick voltage
BATT_VPACKBRICKMIN	BATT_packMinMax	0x125	V	Minimum brick voltage
BATT_VPACKMODULEMAXID	BATT_packMinMax	0x125		ID of maximum brick voltage
BATT_VPACKMODULEMINID	BATT_packMinMax	0x125		ID of minimum brick voltage
HOST_DBGRESETEEP	HOST_batteryRequest	0x502		Debug reset EEPROM (1 = reset)
HOST_STATEREQUEST	HOST_batteryRequest	0x502		State to be requested from battery by host

Operational Protection Alarms and Settings

Table 14 lists the Alliance Intelligent Battery Series™ Operational Protection matrix covering warnings, alarms and hardware circuitry for voltage and temperature.

Table 14: Alliance Intelligent Battery Series™ Operational Protection Settings

	Warning Set Value ALLIANCE INTELLIGENT BATTERY SERIES™	Moderate Set Value ALLIANCE INTELLIGENT BATTERY SERIES™	Severe Set Value ALLIANCE INTELLIGENT BATTERY SERIES™	Severe Clear Condition ALLIANCE INTELLIGENT BATTERY SERIES™	Applies to
OVP Cell	4.101V	4.11V	4.15V	5s	Any cell
UVP Cell	2.99V	2.8V	2.75V	20s	Any cell
OTP Cell	50°C	55°C	65°C	2s	Battery
UTP Cell	2°C	0°C	-20°C	2s	Battery
OTP FET	N/A	N/A	80°C	1s	Battery
OCP HW	N/A	N/A	±250A	60s	Battery
Temperature Imbalance Protection	N/A	N/A	10°C/5°C (*)	1s	Battery (Discharge/Charge)
Voltage Imbalance Protection	N/A	N/A	0.2V	10s	Battery

(*) Unique Discharge/Charge limits

Table 15: Alliance Intelligent Battery Series™ Event Matrix

Module	Event ID (Hex)	Event Name	Charge	Charge Entry	Drive	Drive Entry	Regen	Full Power
Battery	0x1106	Brick Overvoltage Severe						
Battery	0x1105	Brick Overvoltage Moderate						
Battery	0x1104	Brick Overvoltage Warning						
Battery	0x1116	Brick Undervoltage Severe						
Battery	0x1115	Brick Undervoltage Moderate						
Battery	0x1114	Brick Undervoltage Warning						
Battery	0x1506	Module Over Temp Severe						
Battery	0x1505	Module Over Temp Moderate						
Battery	0x1504	Module Over Temp Warning						
Battery	0x1516	Module Under Temp Severe						
Battery	0x1515	Module Under Temp Moderate						
Battery	0x1514	Module Under Temp Warning						
Battery	0x1305	Overcurrent Charge						
Battery	0x1315	Overcurrent Discharge						
Battery	0x1325	Overcurrent HW						
FET	0x30CF	CHG FETs Stuck Open						
FET	0x30DF	CHG FETs Welded						
FET	0x31DF	CHG FETs Welded Aux						
FET	0x30AF	DSG FETs Stuck Open						
FET	0x30BF	DSG FETs Welded						
FET	0x31BF	DSG FETs Welded Aux						
FET	0x1345	FET Over Temp						
Pre-charge	0x3105	Pre-charge Too Fast						
Pre-charge	0x3115	Pre-charge Too Slow						
Pre-charge	0x3135	Pre-charge Timeout						
Pre-charge	0x3185	Pre-charge FET Fail						
Pack	0x8045	Module Connect Fault						
Pack	0x8055	Module Imbalance						
Pack	0x8065	Module Select Disagreement						
Pack	0x4025	Module Missing Message						
Pack	0x808F	Module CHG FET Welded						
Pack	0x809F	Module DSG FET Welded						
Pack	0x8075	Module ID Fault						
Pack	0x8085	Module Exited from Bus						
Pack	0x8095	Module Expected Num Mismatch						
Battery	0x2105	Sensor Pack Voltage Error						
Battery	0x2115	Sensor Load Voltage Error						
Battery	0x2305	Sensor Current Error						
Battery	0x2905	Cell Sense Open Wire						
Battery	0x2895	Cell Sense Impedance High						
Battery	0x7015	AFE Fault						
Battery	0x7025	AFE Error						
Host	0x4035	Host Missing Message						
Battery	0x1526	Ambient Over Temp Severe						
Battery	0x1525	Ambient Over Temp Moderate						
Battery	0x1524	Ambient Over Temp Warning						

Table 15: Alliance Intelligent Battery Series™ Event Matrix cont.

Module	Event ID (Hex)	Event Name	Charge	Charge Entry	Drive	Drive Entry	Regen	Full Power
Platform	0x50C5	Abnormal Reset Reason						
Platform	0x5015	Flash App CRC Error						
Platform	0x5025	Flash Bootloader CRC Error						
Platform	0x5035	Task Lockup						
Platform	0x5045	RAM Over Utilization						
Platform	0x5075	BMS Memory Error						
Platform	0x5085	BMS Processor Failure						
Battery	0x50A5	Event Logger Full						
Battery	0x5095	Event Logger Almost Full						
Battery	0x1125	Battery Brick Overcharged						
Battery	0x1135	Battery Brick Over discharged						
Battery	0x1145	Battery Brick Voltage Imbalance						
Battery	0x1555	Battery Temperature Imbalance						
Battery	0x1905	Battery Capacity Low (SOH-C)						
Battery	0x1805	Battery Resistance High (SOH-R)						
Battery	0x1705	Battery Pack Power Insufficient						
Battery	0x181F	Battery Cell Soft Short						
Charge	0x6305	Charge Undercurrent						
Charge	0x6315	Charger Error						
Charge	0x6335	Charger Comm Error						

Allowed State for condition

Non-Allowed state for condition

FAQ

For unused inputs (Ign Low, Ign 12V) it says that momentary application will turn on ignition, but also unused inputs should be N/C.

Q: Does this imply that a momentary signal is needed?

A: The batteries can be woken with 3 different methods, Wake on CAN, Wake on Ign- Wake on Ign +12V. If wake on Ign- then there are 2 methods that can be employed:

1. momentary connection to ground like pressing ignition button on car, and then transmitting CAN messages to keep alive.
2. Maintaining a ground connection with no CAN.

In the first case, the batteries will stay alive until a shutdown command is given by the host and CAN communication stops. If the second method is employed, then the battery will shut down when the Ign- ground is released

Q: Do you mean by N/C to for Ign Low tie to GND or Ign +12V, and for Ing +12V tie to GND or vice versa?

A: All unused pins can be left non-connected; they are internally pulled up/down.

Q: What happens if it pulled to 48V, can this be done through a resistor?

A: The Ign +12V is for use with an auxiliary battery as a lot of motive types of applications do. The input is protected for 48V.

Q: Can this be wired as -48V system (+ve Ground) or are there internal connections that prevent this? What about the +12V signal, would that become -12V or is +12V still needed?

A: The internal FETs are only on the high side so everything would be isolated from the battery. The internal power supply for the BMS is still referencing the negative terminal so all switching would be relative to the negative terminal. I.e. Ign- would be switched to negative terminal and Ign+ would be voltage referenced to negative terminal.

Q: Are the CAN nodes isolated?

A: No.

Q: What is the timeout period? How frequent do CAN messages need to come?

A: Message times are defined in the DBC file. Messages from the host are expected every 1000 ms and timeout currently is after 10 seconds.

Q: If CAN is not used how does the keep alive work?

A: By grounding the Ign- pin. When released the system will commence its sleep routine.

Q: I assume the Ign inputs only work for discharge (correct?), so then CAN is required for charge?

A: CAN is not required for charge. As soon as the current or voltage limits are violated then the BMS will open FETs and protect itself. Still, you will get a better-quality charge if you follow the current and voltage limits set forth by the BMS.

Q: How does the battery behave when voltage drops during charging to below the OC voltage of the battery?

A: While charging the system voltage should be increasing. If there is a charger on the system but you are discharging at the same time beyond the capacity of the charger, then the BMS will see current draining from the battery and SOC will be determined based upon the coulombs leaving the battery.

Troubleshooting

Despite the high reliability of the Alliance Intelligent Battery Series™ batteries, you may encounter situations where the battery does not operate as expected. This chapter details potential issues with integrating the Alliance Intelligent Battery Series™ batteries and the appropriate troubleshooting procedures.

Table 16: Alliance Intelligent Battery Series™ Troubleshooting and Solutions

Problem	Possible Cause(s)	Solution(s)
The battery does not deliver the expected Ah (capacity).	• The battery is out-of-balance.	• Apply charger for 48 hours and leave battery active to ensure balancing
	• The battery has reached the end of its useful service life.	• Replace the battery.
	• The battery overheated due to ambient temperature or C-Rate.	• Reduce the ambient temperature or C-Rate.
Charge current suddenly goes to zero while connected to a source.	• The battery overheated, enabling over-temperature protection.	• Allow the battery to cool.
	• The battery is out-of-balance.	• Apply charger for 48 hours and leave battery active to ensure balancing
	• Charge current is too high, exceeding OCP protection. [a]	• Reduce charge current.
Voltage drops abruptly while in use after appearing constant.	• The battery is fully discharged.	• Perform a charge cycle.
	• OCP has engaged	• Reduce the load.
Low or zero volts across the terminal	• The battery is in UVP or UVLO.	• Perform a charge cycle.
	• The battery is in OTP.	• Allow the battery to cool.

a. High-speed OCP occurs in10 µs so it will not be visible on a digital voltmeter.

Glossary

A	Ampere.
AC	Alternating Current.
AC BUS	A common connection line for AC elements, such as the inverter's AC-side connection.
AC Resistance	With respect to a cell's resistance, the passive resistance of a cell, not including the electrochemical and ionic resistances.
Ah	Amp Hour. An Ampere hour or Amp hour is a unit of electrical charge, having the dimensions of electric current multiplied by time, equal to the charge transferred by a steady current of one Ampere flowing for one hour.
Amp	Ampere. The unit for measuring flow of electricity.
Application	A scenario or use case, in which a particular control algorithm is used to achieve objectives such as charge, discharge, regen, etc.
Balanced	A condition in which all the series cells in a battery contain the same amount of charge.
Battery	A collection of cells, wired in parallel or series to provide energy storage.
Battery cell	An elemental energy storage device.
Battery management system	The computing and monitoring system in a Battery system that manages the battery cells, operations, and communicatees with the customer via CAN.
Battery module	A collection of cells, wired in parallel or series to provide energy storage.
Battery string	One or more battery modules joined together and connected in parallel or series in an overall system.
BESS	Generic term for battery energy storage system.
BMS	See battery management system.

BOL	Beginning of Life; the state of the product at the beginning of its commissioning.
CAN	Controller Area Network: a communications protocol used for communication between battery modules, battery management systems, and customer application systems.
Cell	A single unit of electrical energy storage.
Charger	A device specifically designed to convert energy from a commonly available power supply to DC energy for charging the battery.
DC	Direct current.
Discharge capacity	The maximum amount of energy (kWh) that can be obtained from a system during discharge.
DOD	Depth of Discharge; the relative amount of SOC removed from a battery during a discharge event. For example, a discharge from 100% SOC to 30% SOC results in 70% DOD.
EMC	Electromagnetic Compatibility.
Enclosure	Battery housing.
EOL	End of Life; The point in the product's life where performance falls below required or acceptable specifications such as storable energy, deliverable power, DC resistance, output voltage, etc.
FET	Field-Effect Transistor, used for switching current.
GUI	Graphical User Interface.
INV	Inverter.
kW	Kilowatt.
LED	Light emitting diode.
LVBD	Low voltage battery disconnect.

LVCO	Low voltage Cut-off
Module	See Battery Module.
OCP	Over Current Protection.
OTP	Over Temperature Protection.
OVP	Over Voltage Protection.
P	Power.
PDO	Process Data Object.
Personal Protective Equipment	Safety gear required when working in a potentially unsafe environment, including but not limited to high voltage equipment. PPE often includes special gloves, safety glasses, face shields, and clothing that both insulate and protect from arc flash.
PPE	See Personal Protective Equipment.
SOC	State of Charge.
Thermistor	A resistor used to measure temperature.
UVP	Under-Voltage Protection.
V	Volts.
W	Watts.