valence

advanced energy systems

U-CHARGE® XP
REV 2 USER MANUAL

Document Version 4.8 November 2011

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1. Contact Information

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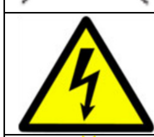
2. Before You Start - Safety Information

Read all the safety information provided in this document prior to installing and/or operating the equipment. If you believe that in the course of using the U-Charge® XP power system, you will conflict with any of the following listed conditions or any other safety precautions listed in this manual, please **DO NOT** proceed any further. Contact Valence Customer Support immediately for a free consultation, if you have any questions about the handling, operation and safe use of the battery.

The following symbols may be found in the XP Power System documentation and/or on the product labels:

Table 1: Symbol Definitions

Symbol	Definition
	Important safety information will follow.
	DO NOT dispose of battery in a fire.
	RECYCLE! Battery may require recycling in accordance with local laws. Regardless recycling is encouraged. Contact local regulatory authorities for more information. DO NOT include battery with lead acid battery recycling.
	DO NOT dispose of battery in the trash.
	Shock Hazard - Labels may be located on or inside the equipment to alert people that dangerous voltage may be present.
	Burn Hazard - Labels may be located on or inside the equipment to alert people that surface temperatures may be dangerous.

2.1. What Not to Do

CAUTION: Performing any of the following actions <u>will immediately void your warranty</u> on the product and could lead to a potentially dangerous situation.

- Breaking the lid and exposing the circuit boards and battery assemblies.
- Puncturing or otherwise physically damaging the battery casing, circuit boards, battery cells or any other part of the battery mechanism
- Operating the battery in an environment where the temperature is outside the normal operation range, -10°C (14°F) to 50°C (122°F) Discharging, 0°C (32°F) to 45°C (113°F) Charging
- Operating the battery with a charge or discharge profile in excess of the peak current and duration specified in the U-Charge® XP data sheets
- NEVER charge or discharge the battery without a properly configured U-BMS and charge protection circuitry and equipment approved by Valence Technology

2.2. Precautions

The U-Charge® XP modules must be used in conjunction with a Valence U-BMS, a properly sized fuse and an external non latching contactor or non latching relay. Ensure that all equipment is operated in accordance with the manufacturer's specifications. When used properly and in accordance with these instructions, the battery/power system is a safe, reliable and convenient energy storage solution.

CAUTION: Misuse or abuse of the U-Charge® XP power system may result in personal injury or fire. Remove all jewellery or other metallic objects during the installation of the battery.

- Individual modules are supplied in 12, 18 and 36 volt configurations. When installed in series, packs may produce a high voltage under normal operating conditions. These voltages can be lethal and require appropriate care and safety procedures.
- Only suitably qualified/trained persons should work with Valence XP Power Systems
- DO NOT use a module with any sign of damage
- Burn hazard exists if batteries are incorrectly wired or underrated power cabling is used.
- Abusive operations of the battery e.g., overcharge, over discharge, crush, puncture, excessive heat or moisture, may produce smoke. In such an event, ventilate the area.
- DO NOT disassemble, crush, puncture, or incinerate
- DO NOT short circuit external contacts
- Exercise care in handling any charged battery, particularly when placing it inside a container with metal objects
- DO NOT use with other types of batteries connected in series or parallel with the U-Charge® XP power systems
- New modules are delivered already charged so should not be assembled into large packs without first verifying that system connections are isolated or equal potential to prevent excessive current flow.

- DO NOT mix different types of modules within the same system
- DO NOT wear jewelry, watches etc. when working with electrical systems
- DO USE insulated tools appropriate for the job – guard against shorting between terminals/connections at different potentials
- Only use recommended chemicals when cleaning or lubricating the battery cases. See Section 10.6 Solvents and Lubrication for more details.
- Also refer to Valence's product Material Safety Data Sheet available on request.

3. U-Charge Revision 2 Changes and Updates

3.1. U-Charge Rev 2

U-Charge Battery Modules:

- Communication cable connectors are now Amp Superseal automotive grade connectors
- Electrical and software backwards compatibility
- Communication cables and electronics are now field replaceable.
- Event logging capability has been added to the Battery electronics
- Balance current has been increased, reducing balancing time
- The handle on the U27, U24, and UEV models is now replaceable and removable
- The indicator LED is now moved to be more accessible when hold down features are used in a system
- Module serial numbers are reported to the BMS
- Tamper proof features on the enclosure

Battery Management System (BMS):

- Fully sealed case to protect connections
- All low voltage communication, signal, and control lines are made through Amp Superseal automotive grade connectors
- Tamper proof features on the enclosure

Accessories:

- Over molded bus termination connectors available
- Inter-battery bus supply voltage booster for large strings, available
- Communication connector adaptor for backwards compatibility to Rev 1

4. GENERAL OVERVIEW

This document provides the reader an understanding of the U-Charge® XP Power System to help the user choose the correct set-up options before ordering the U-BMS for a system. The document also describes how to correctly install and operate the modules and U-BMS. Specific guidance is included for charging and discharging for optimum lifecycle performance.

4.1. Definitions

Cell - A single battery cell representing 3.2 V.

Cell Block - A group of cells configured in parallel with permanent metal plate bused connections.

XP Module/ Battery - A single U-Charge XP is made up of 4 to 12 cell blocks in series. These circuits are paralleled for to give the required capacity. The U1-12XP, U24-12XP and U27-12XP have 4 cell blocks in series with a nominal voltage of 12.8VDC The UEV-18XP has 6 series cell blocks with a nominal voltage of 19.2VDC, and the U27-36XP has 12 series cell blocks with a nominal voltage of 38.4VDC.

Rev 1

Rev 2

Battery Pack - A group of XP modules/ batteries attached in series or in parallel.

XP Power System – Battery packs & Valence U-Charge® Battery Management System (U-BMS) plus any associated accessories, e.g. contactors, fuses, manual disconnect switches, etc.

4.2. U-Charge® XP Modules

The U-Charge® XP Modules are a family of 12V, 18V, 36V battery modules (U1-12XP, U24-12XP, U27-12XP, UEV-18XP, U27-36XP) with accessories in standard BCI lead-acid battery sizes.

- The system offers scalability of voltage and capacity and flexible management systems to suit many different applications.
- The modules have two times the run-time and nearly half the weight of similar sized lead-acid batteries.
- They are built with Valence Lithium Iron Magnesium Phosphate Technology providing outstanding intrinsic safety and excellent float and cycle life resulting in low cost of ownership.
- The XP Monitoring and XP Diagnostic kits enable performance data recording and detail module status. This gives the user powerful development and diagnostic tools simplifying system integration.
- Each module has an LED indicator to display status and basic alarm conditions.
- The enclosures have rugged mechanical design – dust and water resistant to IP56 and flame retardant plastics
- Lift straps are provided on U24, U27 and UEV modules to aid installation.
- The system is maintenance free and provides thousands of cycles.

4.3. U-Charge Battery Management System (U-BMS)

The U-Charge Battery Management System (U-BMS) provides a simple off the shelf method for monitoring and protecting the range of XP battery modules.

While the U-BMS protects from serious abuse and sudden failure of the battery system, it is essential that charging and discharging currents and duty cycles are within the normal operating range of the XP modules.

The features of the U-BMS include:

- Monitoring capability, over an RS485 communications link,.
- Parameters monitored include temperature, voltage, current, state-of-charge (SOC) and multi-level alarms.
- CANbus communications for integration with OEM equipment.
- Digital and analog I/O including
  - Control of up to 4 independent contactor control circuits
  - Drive train pre-charge control
- Two main modes of operation
  - Standalone mode where only a hardwired ‘Key On’ signal is required
  - Slave mode where an application controller sets the U-BMS operational state
- Battery-to-battery balance control
- System ground isolation verification
- Low power sleep mode when ‘Key On’ signal is OFF
- Optional CANbus Data Monitoring and Logging kit available

Full details of the U-BMS functionality are explained in Section 6.

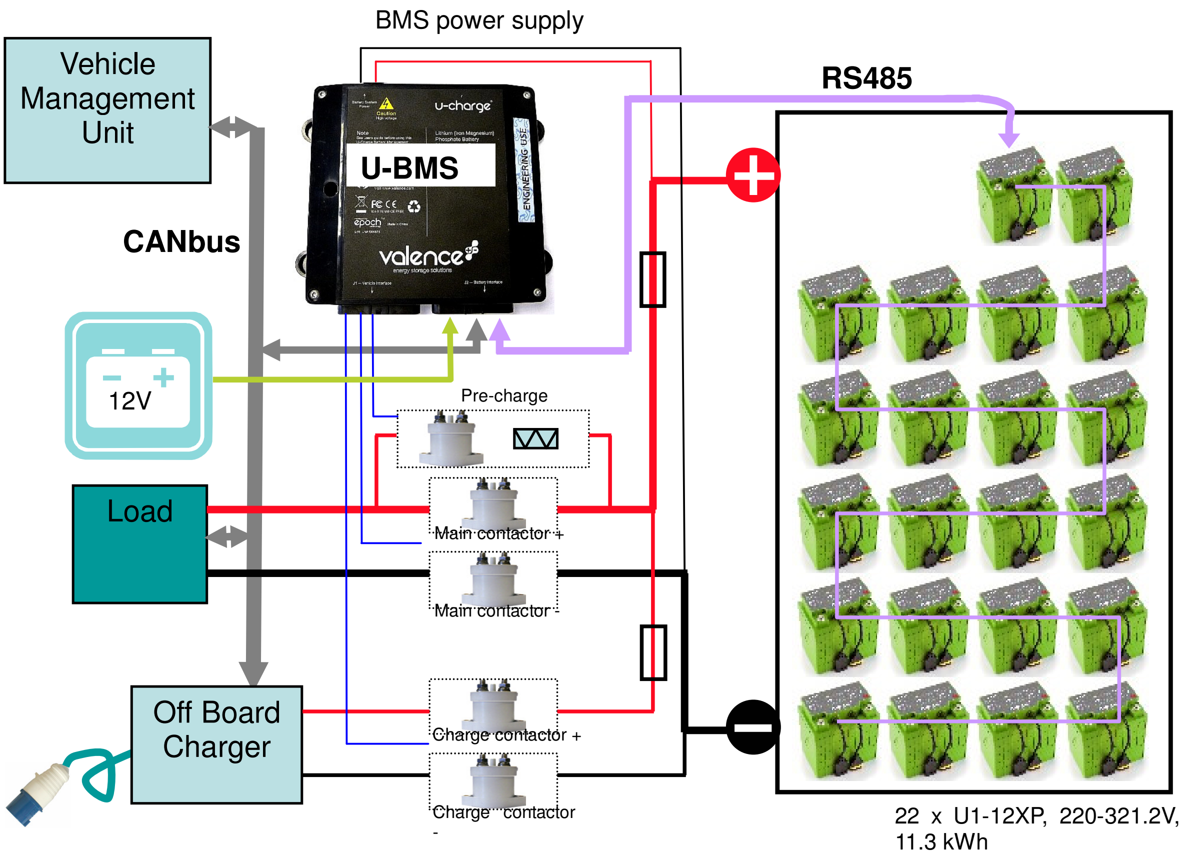
4.4. XP Power System Overview

The key components for an XP energy storage system include:

- XP Modules
- U-BMS to manage the system
- Contactors or relays to cut-off or disconnect the battery pack (controlled by the U-BMS)
- Over current protection devices, e.g. fuses
- Power cabling to interconnect the batteries
- Voltage & Current controllable battery charger to charge the system
- XP Monitoring & XP Diagnostic kits to check system status, performance and module parameters.

The battery system must have one or more external cut-off devices in order to disconnect the battery pack and provide protection. It is possible for the VMU or host controller to control the cut-off devices based on the information transmitted to the CANbus by the U-BMS. It is preferred that the cut-off device(s) are controlled by the U-BMS.

Figure 1 Example of U-Charge XP Power System.



5. XP MODULE CONFIGURATION AND FUNCTIONALITY

One of the attributes of the XP series of battery modules is its scalability. Systems can be configured from 12 VDC up to 700 VDC* and capacities from 40 Ah to over 10,000 Ah.

Your Valence representative will be happy to work with you to determine the best configuration for your application. The following sections outline how modules might be configured.

5.1. Choosing your XP Module

Several factors may influence the type of XP module chosen for an application, e.g.

- Runtime or range requirement, i.e. capacity
- Voltage limits required for the drive-train or load
- Space available

5.2. Number of XP Modules in Series

The number of XP modules in series is determined by the voltage requirements of the system. The following table shows the minimum, nominal and maximum voltages of each XP module.

Table 2: XP Module Voltages

Module Type	Minimum Voltage (VDC)	Nominal Voltage (VDC)	Maximum Voltage (VDC)
U1-12XP	10	12.8	14.6
U24-12XP	10	12.8	14.6
U27-12XP	10	12.8	14.6
UEV-18XP	15	19.2	21.9
U27-36XP	30	38.4	43.8

As an example, 24 U1-12XP modules in series would give the following system voltages:

System voltage minimum = 24 x 10.0 = 240.0 VDC
System voltage nominal = 24 x 12.8 = 307.2 VDC
System voltage maximum = 24 x 14.6 = 350.4 VDC

Note that the maximum system voltage is the same as the charge voltage set-point. This voltage should also be considered the maximum regeneration voltage for motive applications.

5.3. Number of XP Modules in Parallel

The number of XP modules in parallel will be determined by the capacity requirement for the application.
It is common to see capacities quoted as Ampere hours (amp hours or Ah), and also Watt hours (Wh). Note that Watt hours is a more useful measure as it takes into account the voltage of the module as well as the Ampere hours. The relationship between Watt hours and Ampere hours is:

Watt hours (Wh) = Amp hours (Ah) x Voltage (V)

The following table shows the capacities of each of the available XP modules

Table 3: XP Module Capacities

Module Type	Capacity
U1-12XP	512 Wh
U24-12XP	1408 Wh
U27-12XP	1766 Wh
UEV-12XP	1325 Wh
U27-36XP	1774 Wh

Continuing with the example from Section 5, the 24 U1-12XP modules would sometimes be referred to as a configuration of 24S1P, i.e. 24 modules in series and just one string in parallel.

A configuration of 24S2P is 2 series strings of 24 modules connected in parallel, i.e. a total of 48 modules.

The 24S1P configuration of U1-12XP's has a capacity of (512 x 24) Wh, or 12.3 kWh. The 24S2P configuration of U1-12XP's has a capacity of (512 x 48) Wh, or 24.6 kWh.

These values are nominal capacities at room temperature and a C/5 discharge rate. Lower temperatures and/or higher discharge rates will, as with all battery chemistries, reduce the available capacity.

5.4. XP Module Identification Number

All XP modules in a system must have a unique identification number (ID). This number is set in the XP module firmware. It may be preprogrammed at the factory, or it can easily be set by the customer using the Diagnostic Kit (see Section 9). More details are supplied in the installation section of this manual.

5.5. Functionality

The XP module is an intelligent battery. Each XP module has a printed circuit board assembly (PCBA) and associated components which carry out the following functions:

- Cell block voltage measurement
- Current shunt voltage measurement, i.e. each module keeps track of its current flow
- Temperature sensor monitoring; each module has 1 temperature sensor per cell bank and at least 1 on PCBA (thermistor type)
- SOC calculation for the module
- RS485 communications with the U-BMS; the following data is sent to the U-BMS
  - Cell block voltages
  - Current
  - SOC
  - Cell block balance on/off
  - PCBA temperature
  - Cell block temperatures
  - Model and Serial numbers (Rev 2 Only)
  - Firmware Revision (Rev 2 Only)
  - Balance Status
  - Error Codes
  - Event log with 23 event categories (Rev 2 Only)
- LED indicator for basic status of the module (see Section 7.)
- Cell block to cell block balancing, also known as *intra* module balancing. This compensates for slight capacity imbalances between the different cell blocks within the module. Each cell block has a

shunt resistor which can be switched in or out of circuit. begins when the cell block voltage is >minimum threshold value **and** > 40mV higher than the lowest cell block voltage in the module.
(see later section 8. for details of balancing technique)

- Non Volatile Memory with event logging capability and stored lifetime Watt Hour counter. (Rev 2 Only)

6. U-BMS Configuration and Functionality

6.1. U-BMS Configuration Fundamentals

The U-BMS is available in 3 hardware versions depending on the system voltage:

- U-BMS-LV, i.e. low voltage version for systems between 10 VDC -150 VDC
- U-BMS-HV, i.e. a high voltage version for systems between 100 VDC – 450 VDC
- U-BMS-SHV i.e. a super high voltage for systems between 450 VDC – 700 VDC.

Higher system voltages up to 1000 VDC are possible - please consult with your Valence representative with regards to these higher voltage systems.

The U-BMS firmware provided for your XP Power system must be configured in firmware by Valence Technology to match your system application. This means the U-BMS cannot be interchanged with other U-BMS in different applications, without re-configuring..

Your Valence representative will work with you to determine the best configuration options for your application. These options include:

- XP module type and series parallel/configuration (See section 5 for details)
- BMS mode of operation, i.e. 'standalone' mode or 'slave' mode
- Charger control method
- Contactor control functionality
- Isolation monitoring
- CANbus speed

These options are described in detail below.

6.2. Interfacing with the U-BMS

The U-BMS CANbus output allows for communication to external devices. The CANbus communications can be used as a means of monitoring the U-BMS and battery system operating status, or optionally for controlling the operating state of the U-BMS. A copy of the U-BMS CANbus Message Specification is available from your local Valence representative and explanations of the various operating modes are given later on in this section.

The U-BMS can also be controlled by using the built in analog and digital inputs and outputs. These inputs and outputs are described below and in the installation section of this manual.

Some of the parameters available on the CANbus include:

- Battery System State of Charge (SOC)
- U-BMS Mode (standby, charge, or discharge)
- Charge State (main, equalize, or float)
- Charge Balancing (occurring or no activity)
- Lost Communication with Module
- Over Temperature Warning / Alarm
- Low Capacity / Early Warning
- Critically Discharged Warning / Alarm
- Over Voltage Warning / Alarm
- Temp Sensor Failure
- Volt Sensor Failure
- Current Sensor Failure

- Sanity Error
- Over Voltage Protection Unavailable.
- SOC Mismatch Between Modules (alarm not active)
- Over Voltage Shut Down
- Critically Discharged Shut Down
- Pre-charge Contactor Failure to Close
- Battery System Voltage
- Battery System Current
- Open Contactor Request
- Main Contactor and Charge Contactor State
- Insulation Measurement State
- End of Charge
- Battery Max Temperature
- Battery Min Temperature
- Cell Block Min and Max Voltages
- Temperature of PCBA in each Module
- Cell Block Voltages, Current, SOC, and Balancing States for all Modules

The U-BMS also has RS485 communications; this is only for communicating with the U-Charge modules in the battery pack OR changing the U-BMS firmware.

6.3. XP Module Type and Series/Parallel Configuration

The U-BMS is configured for the type of battery module and for the exact number of battery modules being used in series and in parallel. Each modules will have a unique identification number (ID) programmed into the module firmware. These ID's always start at 1 and increment to coincide with the number of modules in the system. For example, if a system has 6 modules in series and 2 strings in parallel (6S2P), 12 modules, the ID's will go from 1 to 12; modules 1-6 in the first string, and 7-12 in the second.

The U-BMS is expecting to see the correct number of modules. If the U-BMS does not see all of the expected modules then it will issue a 'Module Lost' alarm – see Section 7 for more details. If the U-BMS is configured for 6S2P but the system is actually a 7S2P, the U-BMS will not monitor the extra modules, potentially leading to a situation where the 2 additional modules are over/over charged or over discharged.

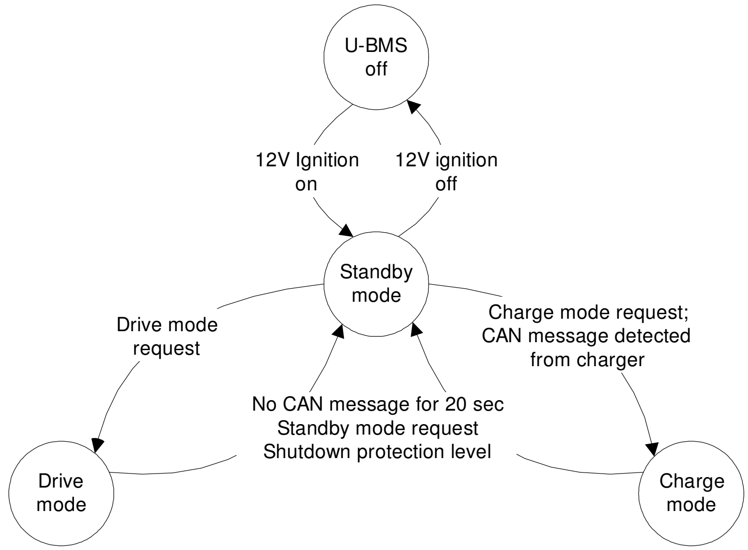
6.4. BMS Modes of Operation

The U-BMS can be configured with two main modes of operation, i.e. 'slave' mode or 'standalone' mode.

6.4.1. Slave Mode

For this method of operation the U-BMS interacts with a Vehicle Management Unit (VMU) or central controller via a CANbus communications link. The VMU sets the battery system working state, either standby or drive or charge, by sending state commands via the CANbus to the U-BMS. *Note that when the BMS is in standby all contactors controlled by the BMS are opened.* The state diagram for Slave mode is shown in figure 2 below.

Figure 2: Slave Mode State Transition Diagram



6.4.1.1. Standby Mode

The U-BMS will go into the Standby state when 12V is applied to the 12V_Ignition input (or the alternate key on input AUX1). The U-BMS is now ready for instruction from the VMU. In Standby **all** U-BMS contactor control outputs will be de-energized.

6.4.1.2. Drive Mode

The U-BMS will enter the Drive state when the drive request is sent from the VMU over the CAN bus **AND** if the BMS is communicating with one or more modules. In the drive state, the U-BMS will monitor and protect the battery system.

6.4.1.3. Charge Mode

The U-BMS will enter the charge state when under the following circumstances:

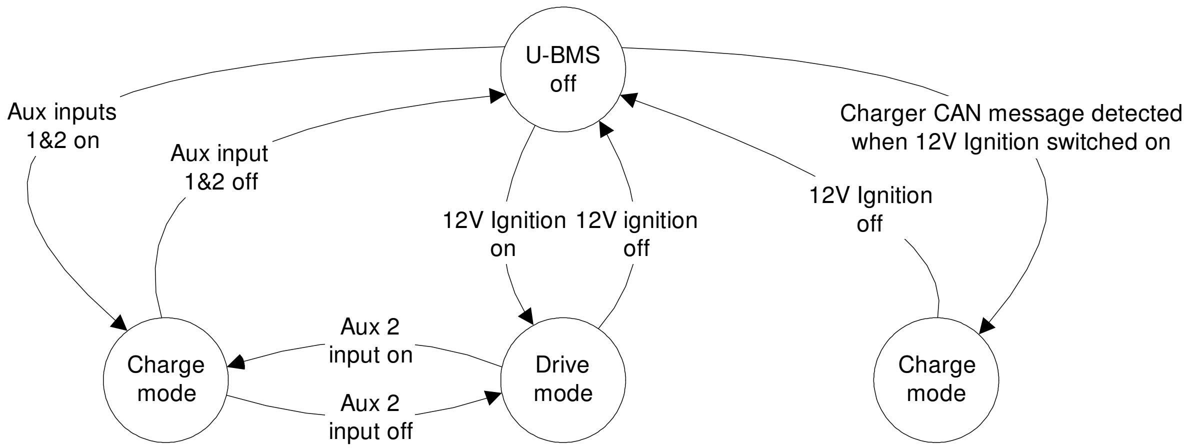
- The VMU sends a charge mode request **AND** the U-BMS is communicating with one or more modules.
- The U-BMS is configured to communicate directly with a charger over CANbus and the charger is powered on before the ‘12V Ignition’ input is energized, i.e. the charger is sending CAN messages when the U-BMS is powered on; the U-BMS recognizes the charger and goes into the charge state **PROVIDED** the U-BMS is communicating with one or more modules.

6.4.2. Stand-alone (Master) Mode

This mode is also known as VMU silent mode or VMU “Listen only”. For this method of operation the U-BMS sets the battery system working state itself. A VMU or other device is not required; however any appropriate device can act as a spy on the CANbus to monitor operational data which is still sent out on the CANbus.

Effectively, the BMS operates as a standalone device and does not require control inputs from any external device except for a hardwired 12V ignition on signal and optionally, a hardwired 12V charge enable signal (if a separate contactor is used for the charge path). The state diagram for Stand-alone mode is shown in Figure 3.

Figure 3: Stand-alone Mode State Transition Diagram



6.4.2.1. Drive State

The U-BMS will go into the Drive state when 12V is applied to the 12V_Ignition input (or the alternate key on input AUX1).
Note: BMS power connections must already be supplied (Batt + Batt-) & (12V sys, 12V Sys GND)

6.4.2.2. Charge State

The U-BMS will enter the charge state under the following circumstances:

- 12V is applied to AUX2 (Charge Enable) and AUX1 (secondary '12V Ignition') inputs
- 12V is applied to AUX2 input if '12V Ignition' input is already energized
- The U-BMS is configured to communicate directly with a charger over CANbus and the charger is powered on before the '12V Ignition' input is energized, i.e. the charger is sending CAN messages when the U-BMS is powered on; the U-BMS recognizes the charger and goes into the charge state

6.5. Charge Control Options

The U-BMS monitors the battery system during the charge state to prevent over-charge.
There are 2 layers of protection:

- U-BMS controls the charger and will set the charge current to zero to prevent
- If the charger malfunctions, the U-BMS can control contactors that will open circuit the DC bus.

The charge control options available for both the Slave and the Stand-alone operating modes are listed below. Note that full explanations and examples of the available charge options are given in Section 8

6.5.3. Charge Control Methods in Slave Mode

The following options are available for charge control in Slave mode:

- Voltage and current set points sent to the VMU via CAN; the VMU then controls the charger
- Voltage and current set points sent directly to the charger via CAN.
- Using the analog/digital outputs of the BMS
  - 0-5V analog output representing 0-100% of maximum current, OR
  - charge enable/disable digital output
- No control, i.e. pre-configured charger with no feedback from the BMS. This should only be considered for low voltage systems, i.e. up to 48V. This is not a recommended solution as it does not make best use of cell/module balancing algorithms.

Details of charge control are given in Section 8.

6.5.4. Charge Control Methods in Stand-alone mode

The following options are available for charge control in Stand-alone mode:

- Voltage and current set points sent directly to the charger via CAN.
- Using the analog/digital outputs of the BMS
  - 0-5V analog output representing 0-100% of maximum current, OR
  - charge enable/disable contactor output C2 ON/OFF
- No control i.e. pre-configured charger with no feedback from the BMS. This should only be considered for low voltage systems, i.e. up to 48V. This is not a recommended solution as it does not make best use of cell/module balancing algorithms.

Details of charge control are given in Section 8.

6.6. Contactor Control Options

The U-BMS **MUST** control one or more external cut-off devices (contactors) to be able disconnect the load or charger from the battery pack in order to provide protection of the pack.

There are 4 U-BMS outputs available for driving contactors/relays; see Section 11 for details. The state of these outputs is set depending on:

- '12V_Ignition' input (or the secondary key-on input, AUX1)
- ‘Charge_Enable’ (AUX2) input
- The mode of the U-BMS (off, standby, drive, charge)
- Alarm or shutdown situations (see Section 7)
- Charge stage (see Section 6)
- Pre-charge requirement
- ‘Vehicle Fault’

The outputs are generally referred to as:

- C1 – Charge contactor control
- C2 – Pre-charge control (charger) OR on/off charge control
- C3 – Main contactor control
- C4 – Pre-charge control (load)

6.6.5. Common Configurations

Table 4: Standard Contactor Control Options

Configuration	Outputs used	Description
1	C3	• Discharge/regeneration and charging through a single contactor • No separate charge path • No pre-charge of load or charger • No on/off charge control
2	C3, C1	• Discharge/regeneration through C3 • Charging through C1, i.e. separate charge and discharge paths • No pre-charge of load or charger • No on/off charge control
3	C3, C4	• Discharge/regeneration and charging through a single contactor • No separate charge path • Pre-charge using C4 • No on/off charge control
4	C3, C2	• Discharge/regeneration and charging through single contactor

		• No separate charge path • No pre-charge of load or charger • On/off control of charger using C2
5	C3, C1, C4	• Discharge/regeneration through C3 • Charging through C1, i.e. separate charge and discharge paths • Pre-charge of load using C4 • No pre-charge of charger • No on/off charge control
6	C3, C1, C2	• Discharge/regeneration through C3 • Charging through C1, i.e. separate charge and discharge paths • No pre-charge of load or charger • On/off control of charger using C2
7	C3, C1, C2	• Discharge/regeneration through C3 • Charging through C1, i.e. separate charge and discharge paths • No pre-charge of load • Pre-charge control of charger using C2 • No on/off charge control
8	C3, C1, C4, C2	• Discharge/regeneration through C3 • Charging through C1, i.e. separate charge and discharge paths • Pre-charge control of load using C4 • No pre-charge control of charger • On/off control of charger using C2
9	C3, C1, C4, C2	• Discharge/regeneration through C3 • Charging through C1, i.e. separate charge and discharge paths • Pre-charge control of load using C4 • Pre-charge control of charger using C2 • No on/off control of charger

Notes:

- There should always be at least a 'MAIN' line contactor (C3), i.e. where there is a single path for charging and discharging.
- A separate charge path requires an additional contactor/relay (C1)
- Contactor control C4 can be used for pre-charge of the load
- Contactor control C2 can be used for EITHER pre-charge of the charger OR on/off charge control (see Section 8)
- For each contactor control output there is an optional input to monitor an auxiliary contact on the contactor/relay. This allows the BMS to ensure the contactor state matches the U-BMS output signal state.

6.6.6. Pre-Charge Example

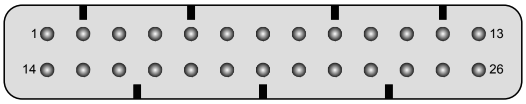
Most drive systems and some chargers use large capacitors. Connecting these devices directly to a DC source may lead to exceptionally high instantaneous currents being pulled by the load, i.e. the capacitors. This may lead to damage of the devices, or blown fuses.

To limit the inrush current into a drive systems capacitors or charger capacitors an external pre-charge resistor may be used. As an example, configuration 5 from the above table is shown in figure 4a and figure 4b below.

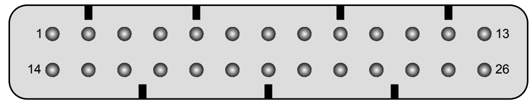
When the U-BMS enters drive mode the contactor control C4 will be energized first of all to provide a path for current flow through the pre-charge resistor. The pre-charge resistor limits the current to the discharge load capacitors for 2 seconds allowing the capacitors to charge up to close to the stack voltage. After the 2 seconds the main discharge contactor control C3 energizes and shortly thereafter C4 de-energizes so that the current flows only through the main discharge contactor, C3, to the load.

Figure 4: BMS Connection Pin-Out

Connector A Vehicle Interface



Connector B Battery Interface



Connector A VEHICLE INTERFACE		
Pin	**Description**	
1	Positive	Contactor 1
2	Negative	
3	Sense	
4	Sense GND	
5	Positive	Contactor 2
6	Negative	
7	Sense	
8	Sense GND	
9	Positive	Contactor 3
10	Negative	
11	Sense	
12	Sense GND	
13	Positive	Contactor 4
14	+12V DC for System	
15		
16		
17	12V System Ground	
18		
19		
20		
21	RS485 - A2	**Reserved.** Do not use.
22	RS485 + B2	
23	RS485_VCC2	
24	Sense GND	Contactor 4
25	Sense	
26	Negative	

Connector B BATTERY INTERFACE			
Pin	**Description**		
1	AUX3 (Chg Cur Con)	O/p	Analog/ Digital Interface
2	SOC	O/p	
3	12V Ignition	I/p	
4	AUX1 (wake up)	I/p	
5	Vehicle Fault	I/p	
6	AUX4 (chg Req)	O/p	
7	BMS Fault	O/p	
8	12V System Ground		
9			
10			
11	CAN_H		CAN Interface
12	CAN_L		
13	+5v, CAN Vcc**		
14	+12v DC for System		
15			
16			
17	Disable Regen	O/p	Analog/ Digital Interface
18	AUX2 (Chg Enable)	I/p	
19	Early Warning	O/p	
20	12V System Ground		
21			
22			
23			
24	RS485 + B1		Module RS485 Interface
25	RS485 - A1		
26	RS485_VCC1		

Figure 4a: Pre-Charge Example – U-BMS Connections

Connector A

Pin	Description
1	Contactor 1 Positive
2	Contactor 1 Negative
9	Contactor 3 Positive
10	Contactor 3 Negative
13	Contactor 4 Positive
26	Contactor 4 Negative

Connector B

Pin	Description
2	State of Charge
3	12V Ignition
4	AUX1
8,9,10 (any)	12V System Ground
14,15,16 (any)	12V Sys

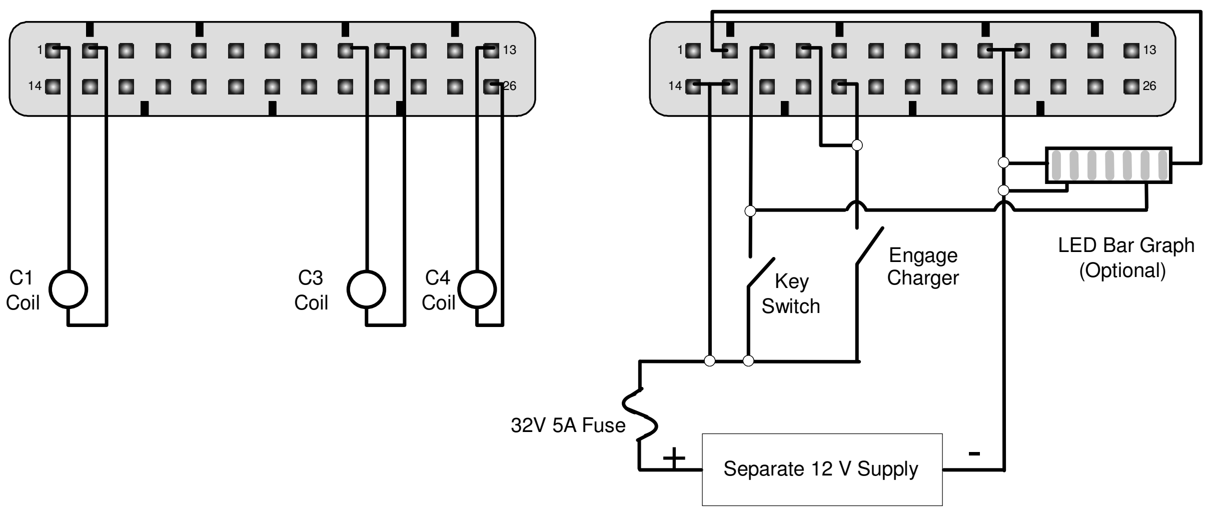
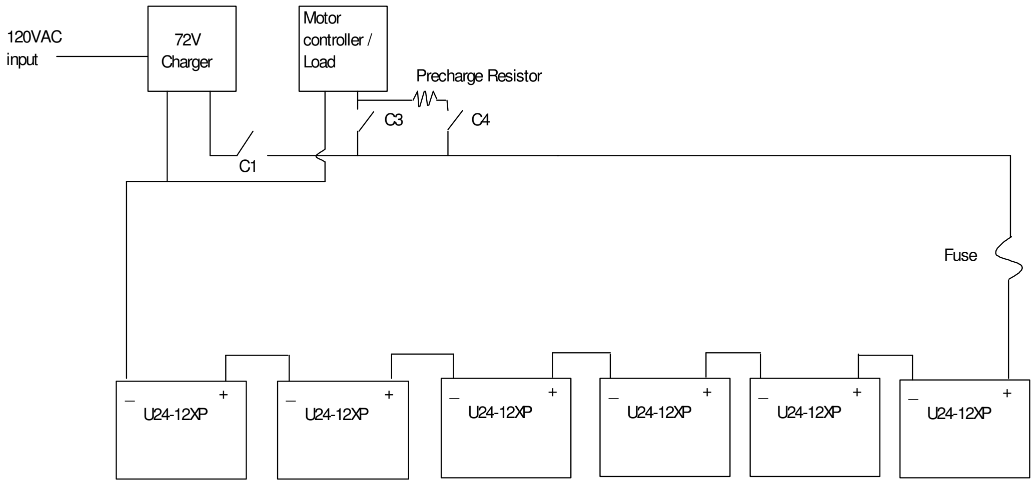


Figure 4b: Pre-Charge Example – Power Wiring



6.7. Isolation Measurement Option

The isolation measurement function monitors the resistance between the 12V system ground ('12V_SYS_Gnd') and the battery pack positive and negative terminals ('Batt Pos+' and 'Batt Neg -' stack connections).

If the isolation measurement option is enabled, the U-BMS will measure the isolation resistance, when '12V_Ignition' is energized *after* energizing any contactor controls. The isolation measurement will then be carried out again about every 15 minutes thereafter.

IMPORTANT: The U-BMS isolation measurement does not guarantee isolation fault protection or safety. The de-activation of the contactors by the U-BMS in response to a failed isolation measurement is an option that has to be specifically requested during U-BMS configuration.

The monitoring feature is selected in U-BMS configuration and can be disabled if required (particularly on low Voltage applications).

6.8. Cell Block Balancing

Cell block balancing is required to maintain the maximum available capacity of the battery system. Balancing is carried out in 2 ways: *inter* and *intra* module balancing. Intra-module balancing is controlled internally in each XP module. Inter-module balancing is controlled by the U-BMS. This compensates for slight capacity imbalances between different battery modules. The balancing is achieved by switching a shunt resistor in or out of the circuit across the module (inter) or cell block (intra). This allows the higher voltage modules or cell blocks to be discharged (or charged less) compared to those without the balance resistor active.   Further details of the balancing function are given in Section 8.

6.9. State of Charge (SOC)

Each XP module tracks its own SOC. This is communicated to the U-BMS over the RS485 communications link. The system SOC reported by the U-BMS is the lowest module SOC. The SOC is calculated using both coulomb counting and also voltage models based on charge/discharge rate and temperature.

The system SOC is available on CANbus as well as via a 0 to 5V analog output. The SOC of each individual module is available on CANbus.

6.10. Maximum Recommended Discharge and Regeneration Current

A U-BMS will continuously calculate the recommended maximum peak discharge and peak regeneration current for its particular module configuration using SOC and temperature. These parameters apply to the peak (30second duration) and are only available over the CANbus.

7. BATTERY SYSTEM PROTECTION

One of the critical functions of the U-BMS is to protect the battery system from being damaged. It does this by monitoring the state of the battery and de-energising the DC bus contactors under its control. The protection of the battery system works differently depending on whether or not the U-BMS is operating in 'Slave' mode or 'Stand-alone' mode (see Section 6. for details of these modes).

Note that the state of all of the warning, alarm and shutdown functions described in the following sub-sections are available on the CANbus in both the 'Slave' and 'Stand-alone' modes. The CAN message details can be found in the Valence U-BMS CANbus Specification.

7.1. Protection in Stand-Alone Mode

There are 2 levels of protection in 'Stand-alone' mode, i.e. warning and alarm.

Warnings
Warnings are for information only.

Alarms
If an alarm situation occurs, the BMS will immediately open all contactors under its control to prevent damage to the battery system.

7.2. Protection in Slave Mode

There are up to 3 levels of protection in 'slave' mode, i.e. warning, alarm and shutdown.

IMPORTANT: Most systems in Slave Mode operate with 2 levels of protections; i.e. the VMU or host controller will take action on contactors at an ALARM level before SHUTDOWN is reached, at which time the U_BMS will attempt to take action. The third level is optional depending on specific configuration request.

Warnings
Warnings are for information only and valid only when the condition is present. Typically the Vehicle Management Unit (VMU) or host controller might reduce the power capability of the system, when a warning is received, to prevent the system from reaching an alarm condition.

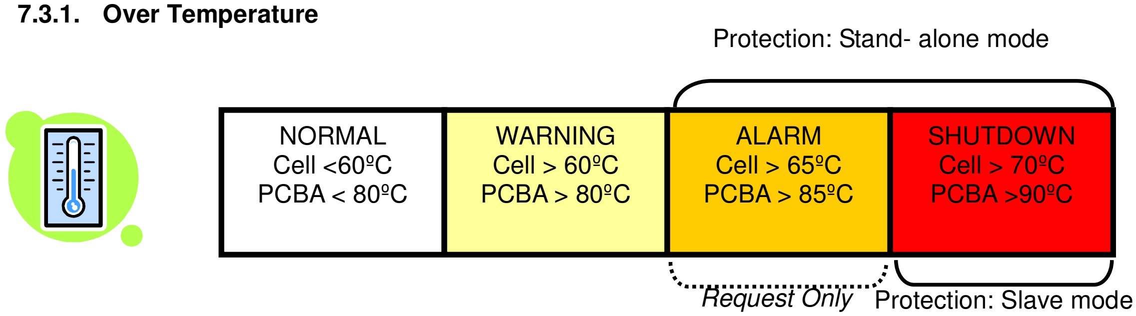
Alarms
When any alarm becomes active an 'Open Contactor Request' will be sent onto the CANbus. An alarm condition is latching and stays valid until system checked and BMS 12v power is reset. The VMU will command the U-BMS to go into standby mode shortly after any alarm indication is received. In standby mode, the energy storage system is disconnected from the load and charger. It is possible to have a delay between the BMS issuing the alarm signal over CANbus, and the VMU sending out the standby mode command. This gives the VMU the opportunity to carry out a controlled shutdown of other components applications. It is recommended that the delay from receiving the alarm until the standby command is issued should be less than 60 seconds.

Shutdown
If the VMU does not respond appropriately to an alarm and a shutdown level is reached, the U-BMS will act independently of the VMU state commands and go to standby opening all of its contactors.

NOTICE: The U-BMS is in communication with all of the batteries during drive, charge and standby modes. If there is a loss of communication to any of the batteries, the U-BMS will open both the discharge and charge contactor after 15 seconds and return to Standby Mode.

7.3. Voltage and Temperature Limits for Warning, Alarm and Shutdown Levels

7.3.1. Over Temperature

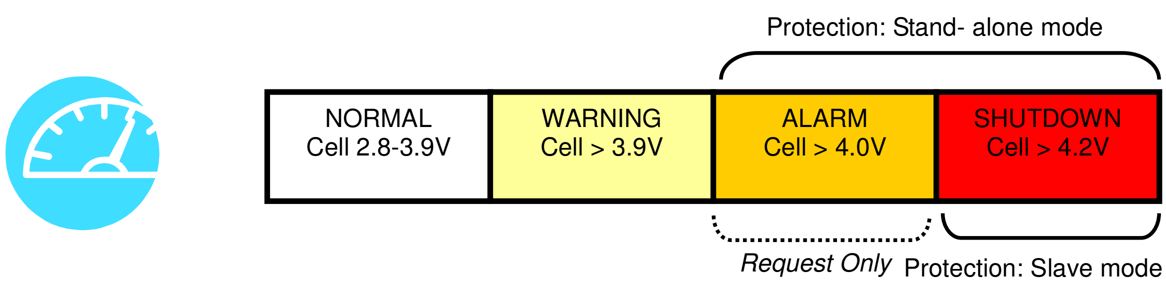


Over temperature Warning
A warning is annunciates when the cell temperature reaches at 60ºC or the PCBA temperature is greater then 80ºC. 'Over temperature warning' flag transmitted over CANbus

Over Temperature Alarm
An alarm is annunciated when the cell temperature is above 65ºC, or PCBA temperature is above 85ºC
Slave Mode - An 'Open Contactor Request' and 'Over temperature Alarm' flag is transmitted over the CANbus.
Stand-Alone Mode – The contactor output's (C1-C4) are switched off.

Over Temperature Shut Down
This occurs at a cell temperature of 70ºC or a PCBA temperature of 90ºC., and is only applicable in Slave mode. If the VMU does not respond to the over temperature alarm by putting the BMS into standby effectively opening all contactors, then at shutdown temperature the BMS will immediately open the contactors without permission from the VMU. An 'Over Temperature Shut Down' flag is transmitted over the CANbus

7.3.2. Over Voltage

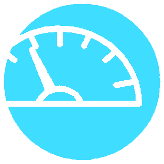


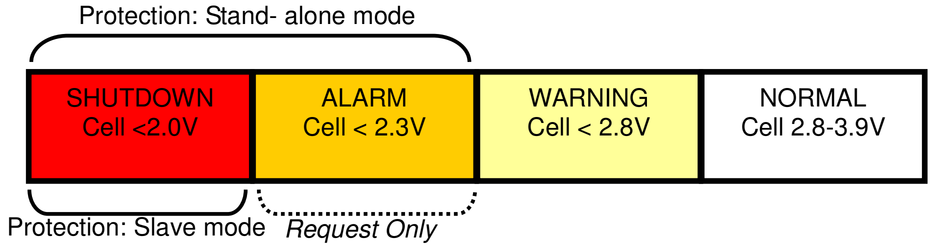
Over Volt Warning
This is a warning only when maximum cell block voltage > 3.9V.

Over Volt Alarm
Occurs when maximum cell block voltage >4.0V
Slave Mode - 'Open Contactor Request' is sent to the VMU
Stand-Alone Mode - Contactor output's (C1-C4) are switched OFF.

Over Voltage Shutdown
Occurs when maximum cell block voltage >4.2V
Only Applicable in Slave Mode - If the VMU does not respond to the over voltage alarm by putting the BMS into standby and effectively opening all of the contactors, then at over volt shutdown, the BMS will immediately open the contactors, without permission from the VMU.

7.3.3. Under Voltage





Critically Discharged Warning (Early Warning)
This is a warning only, when minimum cell block voltage < 2.8V**.**

Critically Discharged Alarm
Occurs when the minimum cell block voltage <2.3V
Slave Mode – 'Open Contactor Request' is sent to the VMU
Stand-Alone Mode - Contactor output's (C1-C4) are switched OFF.

Critically Discharged Shut Down
Occurs when minimum cell block voltage <2.0V
Only Applicable in Slave Mode - If the VMU does not respond to the critically discharged alarm by putting the BMS into standby and effectively opening all contactors, then at critically discharged shutdown the BMS will immediately open the contactors, without permission from the VMU.

Note: A Critically discharged recovery process has been designed into the BMS which can be used to recover from a permanent critically discharged condition, please contact Valence Technical Support for details.

7.4. Other Warnings and Alarms

7.4.4. Module Lost

If the BMS cannot communicate with all of the modules, a 'Module Lost' alarm is activated. 15 seconds after the communication is lost, the 'Module Lost' flag is set on the CANbus and 'open contactor request' is sent to the VMU. Contactor controls C1-C4 are switched off. The number of modules in communication with the U-BMS is available on the CANbus.

7.4.5. Sanity Error

This is an indication of invalid data received by the U-BMS over the RS485 communications link from the modules. It is generally an indication of noise or poor connections on the RS485 bus affecting the U-BMS data processing. Contactors controls C1-C4 are switched off at the same time a sanity error is detected. (Note: the Detection time is up to 60 seconds. If severely disrupted conditions occur the contactors may open immediately). All RS485 data cabling should be verified for pin continuity/integrity and possible shielding issues.

7.4.6. Low Capacity

This is an indication that the SOC is <20%. No action is taken with regards to contactor control switching.

7.4.7. Temperature Sensor Failure

This is set, if a sensor reading indicates a temperature outside of -30 °C to +127 °C range. Generally this indicates an open or short circuit in the sensor wiring; this is a warning only and no action is taken The reading from the failed sensor is ignored. The warning is reset, when the sensor reading returns to the normal range.

7.4.8. Voltage Sensor Failure

The warning is given if a cell voltage reading changes by more than 1 V within a 300ms second period. This is a warning only and no action is taken. A flag can only be reset by cycling the BMS power.

7.4.9. Current Sensor Failure

This is set, if the current reported from any one module is different by 10% from the average current of the modules in the system. (excluding min. and max.). This is a warning only and no action is taken. The warning resets when the current is within range.

7.4.10. SOC Mismatch

This is set, if the difference in SOC between any 2 modules is >30%. This is a warning only and no action is taken, with regards to contactor control switching.

7.5. BMS Fault Output

This output is provided to energize a low power circuit to drive an indicator or low power relay and is activated in the event that an 'open contactor' request is generated, i.e. any of the following events occur:

- Under Voltage Alarm
- Over Voltage Alarm
- Over Temperature Alarm
- Module Lost
- Vehicle Fault Input = 12V
- Sanity error (serial communication fault)

This output is latched and is only cleared when the fault condition has been cleared and 12V input power is cycled. The maximum output load is ~10µA at 11.5VDC

7.6. Resetting the U-BMS after an alarm/shutdown

Once a U-BMS goes into an alarm or shutdown situation, the alarm or shutdown can only be reset by cycling the 12V input power (or AUX 1 input) of the U-BMS.

7.7. XP Module LED status Indicator

This is an additional feature to aid with the module level diagnostics. The U-BMS will be the primary monitoring and control device and will provide all the necessary status, warnings and alarms via CANbus interface or analog output.

GREEN FLASHING = Normal Operation

The LED will blink every 20 seconds, when in sleep mode, and every 5 seconds, when it is awake, active, and communicating with the U-BMS. A module will go into sleep mode, if it does not receive any communications from the U-BMS for 120 seconds.

YELLOW FLASHING = Temporary Warning Indication

If the LED indicator blinks YELLOW, one of the following is occurring:

- Over temperature warning i.e. the cell temperature is between 60 and 65 °C, or the internal electronics' temperature is between 85 and 100 °C
    - Allow the battery system to immediately cool.
- Over Discharge warning i.e. the cell voltage is between 2.3 and 2.5 volts.
    - Reduce discharge immediately.

RED BLINKING = Fault Indication

A red blinking LED indicates that the recommended limits for normal operation have been exceeded.

If the LED indicator blinks RED, one of the following has occurred:

- Over temperature alarm i.e. cell temperature is > 65°C or Internal electronics temperature > 100°C
- Overcharge alarm i.e. Cell voltage is >4.0V.
- Over discharge alarm i.e. Cell voltage is < 2.3V and will not rise above 2.3V after charge current > 0.5Amp for 1 minute.

For the overcharge and over-temperature alarms, the red light will remain latched, even when the condition for the alarm no longer exists. For the over discharged alarm the LED will be reset, i.e. go to green, if all the module cell voltages are charged back above 3.3V.

Should a module exhibit a red flashing LED, please contact Valence Technical Support Staff immediately for help to determine if the battery is recoverable. Do not attempt to charge or discharge!

Alternate RED - GREEN BLINKING = Electronics Fault Indication

The module onboard electronics is attempting to recover from an unexpected serious error and is likely to have been damaged. Should a module exhibit this behavior, please contact Valence Technical Support Staff immediately for help to determine battery is recoverable. Do not attempt to charge or discharge!

or or **Permanently ON = Electronics Fault Indication**

This indicates that the module onboard electronics is not functioning, and the processor has stopped. If a module exhibits this behavior,, please contact Valence Technical Support Staff immediately to determine battery recoverable. Do not attempt to charge or discharge!

Permanently OFF (NO LED output) = Fault Indication or Seriously Over Discharged

Generally, no LED indicates that either the module has been over discharged to such an extent that the voltage is not high enough to drive the onboard electronics, or that the processor has entered an illegal state.

Should a module exhibit this behavior please contact Valence Technical Support Staff immediately to determine battery recoverable. Do not attempt to charge or discharge!

8. Charging Profile & Methods

8.1. General Guidelines

Charging
It is vital that on first installation the battery pack is fully charged, charge complete. This allows all cells to balance and the modules' SOC indication to align and reset to 100%. When sizing a charger for an application it is vital to choose a charger that can be controlled by the BMS and at a rate that allows for a charge complete cycle on a periodic basis. For further information please contact Valence technical support.

SOC Alignment
SOC Alignment occurs at charge complete, after all cell blocks have balanced. To optimize the performance of the battery pack this should be done as often as possible. The minimum recommended is at least once a month.

Capacity Learning
Valence modules continuously learn their own capacity. A periodic discharge to 20% SOC followed by charge complete cycle will optimize this process

The U-Charge® XP modules must be charged under the control of the Valence U-BMS .

- An external, series connected, non latching protection contactor or relay controlled by the U-BMS is essential to prevent any overcharging.
- Do not connect batteries of different models in series. The system capacity is limited to the smallest battery in the string. .
- It is recommended that the charging circuit and cables are protected by an over-current fuse.
- In systems with high voltage, many local safety regulations require that fail safe interlocks are used. Please verify local regulations before installing any equipment.

8.1.1. U-BMS Charge control options and protection.

The U-BMS monitors the battery system during charge to prevent a possible over-charge event. There are two layers of protection. The U-BMS controls the charger and will inhibit current flow to prevent an overcharge. If the charger should malfunction, the U-BMS can control contactors that will open circuit the DC bus.

The following options are available for charge control:

Voltage and current set points sent to the VMU via CANbus
  - The VMU then controls the charger (Slave Mode)
- Voltage and current set points are sent directly to the charger via CANbus.
- Using the analog/digital outputs of the BMS
  - 0-5V analog output represents 0-100% of maximum current, OR
  - Charge enable/disable digital output
- No control i.e. pre-configured charger with no feedback from the BMS. This should only be considered for low voltage systems. This is not a recommended solution, as it does not make best use of cell/module balancing algorithms.

8.1.2. Charging Profile and Charge Times

The charging process brings the individual internal cell blocks up to an equal and fully charged stage. The characteristic flat voltage profile and sudden voltage rise near end of charge is shown in the example 8.1.3 It is critical to control the voltage and current in the final charging stages. This control is automatically provided by the U-BMS. The charging can be considered in two main phases as follows:

Bulk charging Phase
The modules should be charged at a constant current (CC) rate up to 90-99% SOC. The recommended maximum current rates are given in Section 8.2. For example, the U1-12XP Module has 40Ah capacity. The C/2 constant rate is 20 Amps. This is merely a recommendation, and the current may be increased up to C rate, without adverse effects to the battery. Please consult Valence if a higher C rate is required.

Caution: Inappropriate fast charging may lead to excessive temperature rise, premature ageing of the battery and void the product warranty.

Equalizing/ balancing phase
Towards the end of the charging process, 95% up 100% SOC, the U-BMS will detect that one or more cell blocks are fully charged, and the charger will switch CC to constant voltage (CV). The U-BMS will begin control of the charger current and the module balance circuits, until the charge level is equal across the full system.

Balancing Technique
Cell block balancing is required to maintain the maximum available capacity of the battery system. This is performed by "passive balancing" and is carried out in 2 ways:

- Intra module balancing is controlled internally in each XP module.
This is active on cells above 3.360V and > 40mV above the lowest cell.

- Inter module balancing is controlled by the U-BMS to compensate between different XP battery modules.
This is active on modules with minimum cell block above 3.28V and >100mV above the module terminal voltage. This means in a system of N modules the maximum number possible with interbalance active is N-1 and this decreases as balancing continues.

The balancing is achieved by switching a shunt resistor in or out of circuit across the module (inter) or cell block (intra), this allows the higher voltage modules or cell blocks to be discharged (or charged less) compared to those without the balance resistor active.

There are thermal limits on the PCBA and shunt resistor circuits so balancing can also be de-activated in the event of PCBA temperature > 80deg.C and re-activated <78deg.C (specific to U27-36XP module)
(note: older firmware revisions of Rev1 & Rev2 modules operated balancing at higher threshold of 3.4V.
For any specific firmware functionality details contact Valence Customer Support Team)

After the battery modules are fully charged and “charge complete” is indicated, they are ready for use. The battery can be left connected to the charger at the recommended voltage or a reduced voltage or “float” charge. This will not damage the battery and will finely balance the cell voltages.

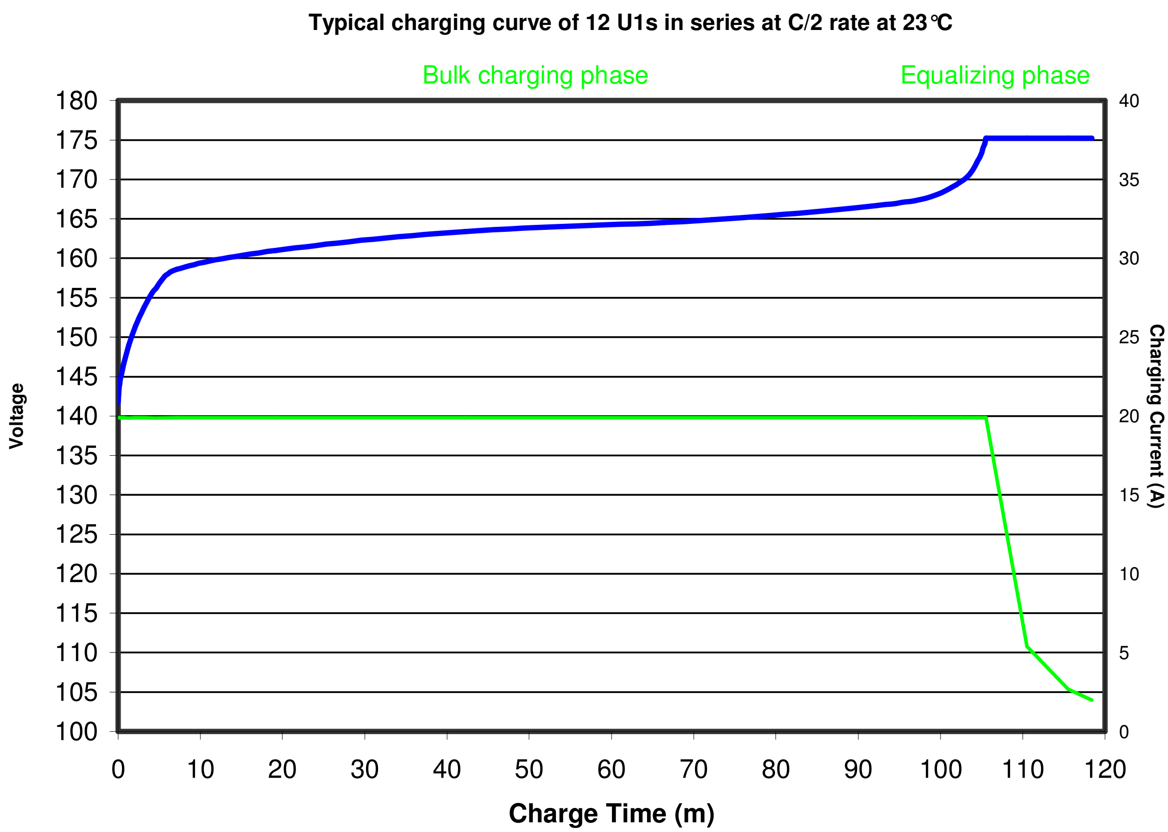
Estimated charge times to fully charge the XP modules
The charge time is dependant on the constant current rate and temperature during charging and amount of cell ‘unbalance’ since the last full charge.

- Using C/2 rate with modules well balanced = 2 hours + approx. 30 minutes equalizing.
- Using C rate and with modules well balance = 1 hour + approx. 30 minutes equalizing.

Operating temperature recommendations
Ideally, the ambient temperature should be between 0 and 45℃ (32 and 113℉). Charging outside of this temperature range is not recommended and may reduce the useful life of the battery system.

8.1.3. Example of Charging 12 U-Charge® Batteries:

Figure 5: Charge Curve Example of 12 U1 Modules in Series



KEY: Voltage = (blue line)
Current = (green line)

- Charge with constant current up to 175.2V = (14.6V x 12 batteries in series)
- When voltage first reaches 175.2V, the battery is 90-99% charged.
- Hold the voltage constant at 175.2V, the current is controlled during this equalizing, until 100%SOC.
- Continue to float charge between (13.8V -14.6 V x 12 batteries in series) i.e. 165.6V – 175.2V

![valence logo]

8.2. Charge Voltage and Current Recommendations

The following values are recommendations only. If you wish to charge at higher rates, please contact Valence.

Bulk Charge; Use the following constant current rates for each series string.

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
C/2 Rate	20 A	55 A	70 A	35 A	23 A

Equalizing / Balancing; Use the following constant voltage with limited current. (3.65V per cell).

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge Voltage	14.6 VDC	14.6 VDC	14.6 VDC	21.9 VDC	43.8 VDC

Fully Charged & "Charge complete status"; When the cell voltages are all between 3.8V & 3.4V and the charge current drops below following levels for 1 minute, the battery is considered 100% charged.

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge Current	0.3 A	0.79 A	0.99 A	0.5 A	.33 A

A second criteria will independently trigger "Charge Complete". The condition is: Minimum cell voltage > 3.65V and charge current drops below:

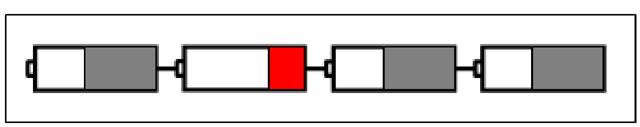
MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge Current	2.19 A	5.77 A	7.23 A	4.95 A	2.41 A

The modules can stay connected to the charger after charging has completed.

Float Voltage; Use the following constant voltage (minimum 3.45V per cell).

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Float Voltage	13.8 VDC	13.8 VDC	13.8 VDC	20.7 VDC	41.4 VDC

Balancing/ Equalizing Recommendations:



Balancing should be performed as often as possible to keep the overall capacity optimum and ensure that all batteries are contributing equally to the total output. Ideally the battery system should stay connected to the charger at floating level to allow optimum balancing. The period between periodic balancing can be extended depending on the application. The result will be that available capacity may be reduced. When balancing is finally performed, it will take much longer to bring all cell blocks to same charge level.

8.3. Selecting a Battery Charger

When choosing a charger, please discuss with Valence Technical Support as some types are unsuitable. In the absence of CANbus control or variable current control, the charger must be able to be cycled repeatedly either by an enable/disable input or by switching the DC output or AC input.

Many types of existing lead acid chargers are compatible with the U-BMS.

Charger Voltage: The charger maximum voltage output should match the maximum charge voltage of the battery system. The required maximum voltage is calculated by multiplying the number of U-Charge® modules that are connected in series with the maximum voltage of each module.

Charger Current: The recommend charge current is C/2 rate. The XP modules may be charged at higher C rates. Please contact Valence Technical Support for guidance as inappropriate charging may lead to premature ageing of the battery and void the warranty.

Important Advice:
Many advanced multistage chargers, if used without U-BMS control, will have state transitions based on system terminal voltage or thermal measurements. These may provide a charge profile acceptable for use initially on several charge cycles but not allow high enough voltage or sufficient time to balance charge the battery. This drift in charge balance is particularly noticeable with higher voltage systems as the total number of cell blocks will be increased, and the relative voltage unbalance is less significant compared to overall system voltage. An unbalanced battery pack will be limited in capacity by the cell block with the lowest charge.

8.4. U-BMS Charger Control Techniques in Detail:

The charger can be controlled by the U-BMS in 3 ways:

- CANbus interface for some programmable automotive types.
- Analog/digital interface
    - Contactor C2 ON/OFF control required for equalizing/balancing.
    - Analog charge control output representing 0-100% of maximum recommended current

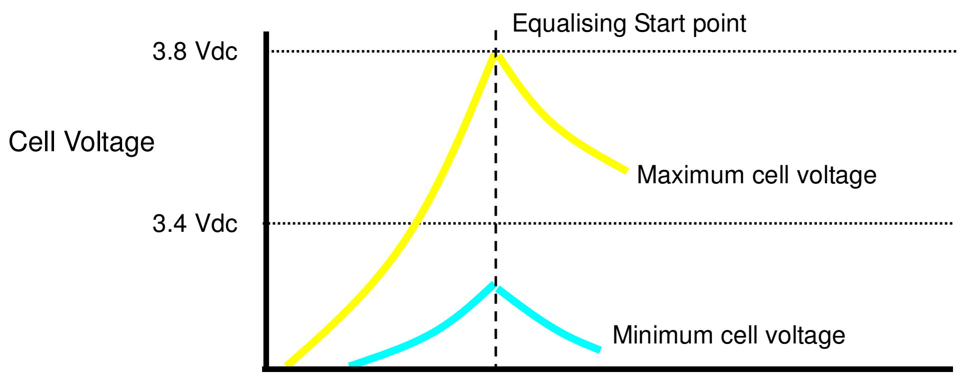
8.4.1. CAN Interface Charge Control.

The U-BMS will provide a recommended charge voltage and current “setpoint” via CANbus messaging. The charger must be capable of a charge voltage, of 3.65 VDC per cell.

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge Voltage	14.6 VDC	14.6 VDC	14.6 VDC	21.9 VDC	43.8 VDC

- **Bulk Charge Stage:** The current setpoint is normally less than C/2 (typical 12A, however C/2 is the recommended limit) until the SOC = 95% approx.
  The CAN message will send a “Main Charge” signal during this stage.

- **Balancing Equalizing Stage:** When the maximum cell block reaches 3.8 VDC, the current setpoint is automatically reduced to lower level (typically 4A) and voltage will decay temporarily before rising again.



Well balanced: If the module is initially well balanced, it is likely that the maximum cell voltage will not reach 3.8 VDC. If the minimum voltage is above 3.4 VDC, the current will decay exponentially, until fully charged. The charge state will continue to be signaled by CAN message as "Main Charge"

Out of Balance: If the module is not finely balanced, this stage continues with the setpoint current alternating between 0 and 4A and cycling the charger,(maximum cell block voltage 3.75 VDC = ON to 3.8 VDC OFF). This will allow the lower voltage cells to charge and protect the higher charge cells from reaching 3.9 VDC. The CANbus message during this process is "Equalizing".

* If the maximum cell voltage reaches 3.8 VDC and the minimum voltage is 3.4 VDC (with the current less than the fully charged threshold) the U-BMS will start equalization immediately followed by floating charge.

- **Fully Charged**: The U-BMS will signal "Charge complete" & SOC=100% via CAN message when all cells are in the range of 3.4 VDC to 3.8 VDC, and the charge current is below threshold for 1 minute.

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge Current	0.3 A	0.79 A	0.99 A	0.5 A	.33A

For small systems, it is possible to achieve a fully charged state, while a higher current is flowing under the following conditions: When the cell voltages are all between 3.8V & 3.65V and charge current drops below following levels for 1 minute, the battery is considered 100% charged.

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge Current	2.19 A	5.767 A	7.227 A	4.95 A	2.41 A

- **Float Charge Stage**: Once fully charged the charge state is signaled by the CAN message "Float Charge" and Setpoint current remains at 0A. The charger can be turned off or allowed to float charge which will help further to finely balance the cell voltages. The minimum float levels are given below:

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Float Voltage	13.8 VDC	13.8 VDC	13.8 VDC	20.7 VDC	41.4 VDC

- **IMPORTANT: Many CANbus controllable chargers will turn off, once fully charged., If the charger turns OFF, the cell voltages will relax normally to below 3.4 VDC. The "Charge Complete" message will disappear, and SOC will adjust to 98-99%.**

8.4.2. Contactor C2 ON/OFF Equalizing Control

If a CANbus charger is not available, the U-BMS can be configured to use a C2 contactor to turn ON/OFF the charger output to help balance the battery pack. (The CAN messages will be transmitted by a CAN interface similar to the previous CAN control method but are not used by VMU/ charger. The CAN messages will be visible to the user via XP Monitoring Software if connected).

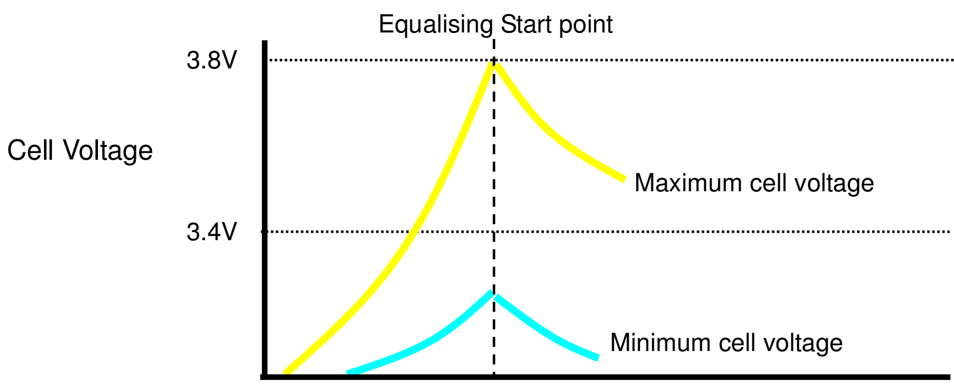
The charger should be capable of a 3.65 VDC/cell charge voltage.

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge Voltage	14.6 VDC	14.6 VDC	14.6 VDC	21.9 VDC	43.8 VDC

- **Bulk Charge Stage:** The recommended maximum current from the charger should be C/2.

Balancing Equalizing Stage: When the maximum cell block is above 3.8 VDC, the C2 contactor will open.

(Unlike the CANbus interface control method, the C2 control does not indicate charge mode as "equalizing stage" but continues in main charge.)



Well balanced: If the module is initially well balanced with the charger maintaining a constant voltage, it is likely that the maximum cell voltage will not reach 3.8 VDC. If the minimum voltage above 3.4, VDC, the current will decay, exponentially, until fully charged.

Out of Balance: If the module is not finely balanced, this stage continues with C2 contactor output to switch ON/ OFF charge, (maximum cell block voltage is 3.75 VDC = ON to 3.8 VDC OFF). This will allow the lower voltage cells to charge in the period the current is ON, until fully charged.

* If the maximum cell voltage reaches 3.8 VDC (with the current less than fully charged), the BMS will start equalization.

- **Fully Charged**: The BMS will signal "Charge Complete," and the SOC is 100%, when all cells are between 3.4 VDC to 3.8 VDC and the charge current is below threshold for 1 minute.

(NOTE: The AUX 3 output signal can be used as an optional latching 5V signal to indicate charge complete)

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge current	0.3 A	0.79 A	0.99 A	0.5 A	.33 A

It is possible to achieve Fully Charged, while a higher current is flowing under the following conditions: When the cell voltages are all between 3.8V & 3.65V and charge current drops below following levels for 1 minute, the battery is considered 100% charged.

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge current	2.19 A	5.767 A	7.227 A	4.95 A	2.41A

- **Float Charge Stage**: Once fully charged, the charge state is signaled by the CANbus message “Floating Charge”. Contactor C2 will continue to maintain the voltage between 3.8 VDC and 3.75 VDC..
- The minimum float levels are given below: (3.45 VDC per cell)

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Float voltage	13.8 VDC	13.8 VDC	13.8 VDC	20.7 VDC	41.4VDC

- **IMPORTANT:**
    - There is no analog signal from the U-BMS to signal the charger to change from CV equalizing to a float charge stage. The charger remains ON at the previous voltage level, and the cell balancing circuits equalize the cell voltages between 3.45 VDC & 3.8VDC. The C2 Contactor will stay on, while the cell blocks reach a fine balance condition.
    - If the charger is turned off the cell voltages decrease normally to below 3.4 VDC. The CANbus message “Charge Complete” will clear, and the SOC will adjust to 98-99%.
    - The AUX 3 Output signal can be used as a latching 5V signal to indicate that charge complete has been achieved.

8.4.3. Analog Charge Control Output AUX 3 Representing 0-100% of Recommended Current.

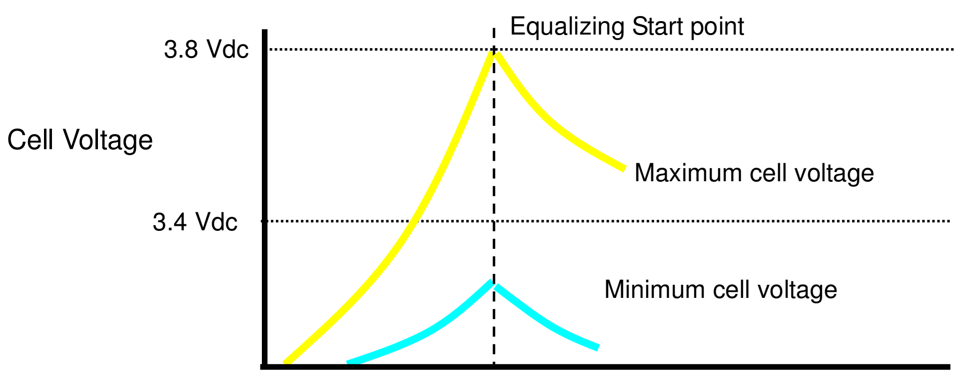
If a charger with a CANbus interface is not available, the U-BMS can be configured to use the AUX 3 charge control (0-5 VDC) output to vary the charge current from 0-100%. The CANbus messages are visible via the XP Monitoring Software.

The charger should be capable of the recommended charge voltage, 3.65 VDC per cell.

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge Voltage	14.6 VDC	14.6 VDC	14.6 VDC	21.9 VDC	43.8 VDC

- **Bulk Charge Stage:** The recommended current from the charger is C/2.
- **Balancing Equalizing Stage:** When the maximum cell block reaches 3.8 VDC, the charge control output will reduce to 0 VDC

(This charge control method indicates this stage as main charge.)



Well balanced: If the module is initially well balanced with the charger maintaining a constant voltage, it is likely that maximum cell voltage will not reach 3.8 VDC.I If the minimum is above 3.4 VDC, the current will decay exponentially, until fully charged.

Out of Balance: If the module is not finely balanced, this stage continues with a charge control output varying between 0 VDC and 5 VDC

* When the maximum cell voltage reaches 3.8 VDC and the current is less than fully charged the U-BMS will start equalization, when thresholds indicated below are reached.

- **Fully Charged**: The BMS will signal "Charge complete" & SOC equals 100% via CAN messages, when all cells are in the range of 3.4V to 3.8V, and the charge current is below a threshold for 1 minute.

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge current	0.3 A	0.79 A	0.99 A	0.5 A	.33A

It is possible to achieve a fully charged state, while a higher current is flowing, under the following conditions: When the cell voltages are all between 3.8V & 3.65V and charge current drops below the following levels for 1 minute, the battery is considered 100% charged.

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Charge current	2.19 A	5.767 A	7.227 A	4.95 A	2.41A

- **Float charge Stage**: Once fully charged the charge state is signaled by the CAN message "Floating Charge". The charge control output will continue to indicate the percent of current requested, 0V=0%, 5V = 100%. The charger can be turned off or allowed to float charge, If float charging occurs, the charger will finely balance the cell voltages. The minimum float levels are given below: (3.45V per cell)

MODULE	U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U27-36XP
Float voltage	13.8 VDC	13.8 VDC	13.8 VDC	20.7 VDC	41.4 VDC

- **IMPORTANT:**
  - If the charger remains ON, the balancing circuit will equalize the cell blocks to a voltage between 3.45 & 3.8 VDC
  - If the charger is turned OFF, the Cell Voltages now relax to below 3.4 VDC. The "Charge Complete" message will disappear, and the SOC will adjust to 98-99%.

8.5. Common Charging Problems:

- Once the charge cycle completes and the charger turns off, there is a period where the module voltages relax. During this process, there should be no discharge from the battery pack such as auxiliary loads. If such loads are unavoidable the charger must be controlled to give a zero current, when the current set point is 0A.

- With multi-stage programmable chargers, it is possible that the stage transitions are automatically controlled by the charger based on system voltage, time constants or temperature measurements. These may not always be suitable for charging Valence XP modules.

8.6. State Of Charge (SOC) Measurement

U-BMS SOC accuracy is dependant on many factors including; the number of modules in the system, temperature, current and period, since last maintenance charge.

Each module will monitor its own cell voltages, current and temperature to calculate its individual state-of-charge (SOC). The SOC value is then communicated to the U-BMS, which calculates the system level SOC based on the lowest module in the system. The SOC remains accurate with regular charge and discharge cycles. The accuracy will benefit from maintenance charging/reaching calibration points <20% on discharge and 100% on recharge.

During discharge, profiles which have very fast dynamic currents > 1C, the SOC value will track accurately until the SOC is< 50%. Below this level fluctuation may be observed; This is normal and is caused by the statistical variations in the current measurements and larger influence of the cell voltage at lower states of charge.

The state-of-charge is automatically adjusted for normal self-discharge of the battery, when the unit is in storage and updates when the module is communicating with the U-BMS.

During the life time of the battery, the capacity is continually re-learned by the algorithm. The 100% charge corresponds to the remaining capacity of re-learned value not the initial rated capacity. The optimum calibration of this re-learned capacity value is achieved by making a full discharge <20% and full recharge to 100% at constant current < C/2.

Note: Lead acid state-of-charge meters should not be used with the Valence U-Charge® power systems. At best, they will underestimate the remaining capacity, however, if the XP modules are used with an incorrect charging profile, the battery could reach fully discharged before the lead acid state-of-charge meter gives a warning.

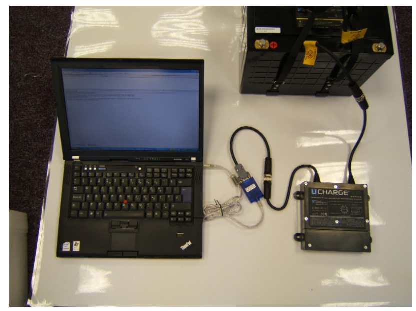
9. XP CANBUS MONITORING KIT AND XP DIAGNOSTIC KIT

The XP Monitoring and Diagnostic Kits are powerful development and support tools. They are essential to view system status, record the performance, and diagnose system faults. The Valence software programs associated with these kits are called "Configuration & Monitoring" and "Module Diag"

9.1. XP CANbus Monitoring kit

This comprises the necessary CANbus to USB hardware allowing the user to connect the computer USB port to the BMS CANbus interface and display/record system performance.
Contact Valence technical support to obtain the latest software for your PC and the separate user guide.
The data displayed includes:

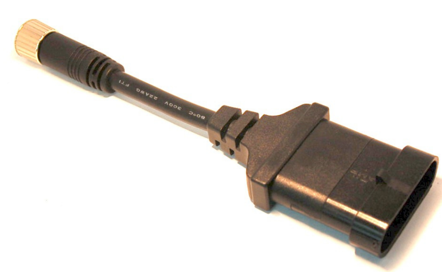
- Cell Voltages
- Cell Temperatures
- Modules SOC
- Modules Current
- Warnings and Alarm
- Contactor Status
- Balancing Status



9.2. XP Diagnostic Kit

This kit comprises a RS485 to USB cable and hardware. This allows the user to connect a computer directly to the XP modules, and enables the user to view information directly from the module. The XP Diagnostic Kit is needed to upload new configurations to the U-BMS and battery and to re-program the identification number of the module.
Contact Valence technical support to obtain the latest software "Config and monitoring" and "Module Diag" and the separate user guides for each.
Below is a partial list of data that can be viewed with a Diagnostic Tool Kit

- Module ID
- Cell Bank voltages
- Cell temperatures
- Each modules SOC
- Each modules current
- Module Serial Number
- Module Model Number
- Firmware Rev, Date, & Time
- Module Balance Status
- Error codes
- Event Log



A key feature of this kit is that it enables the user to re-program the identification number of the module. This is only necessary if the module has been ordered as a replacement or the user wishes to change the original identification number.

Additionally the XP Diagnostic Kit may be used to upload new firmware onto the U-BMS or XP module.

10. XP Module Installation

10.1. Before You Start

It is extremely important to understand that:

- When multiple XP modules are connected in series, a lethal DC voltage may be present..
- Shorting an XP module(s) may result in a short circuit current in excess of 2000 amps.

To work with XP Power System components:

- You must be qualified for electrical work
- You must wear eye protection
- Remove any possible metallic shorting risk
    - Jewelry, Watches, Pens. Metal bars and frames
- All tools must be insulated

IMPORTANT
Turn off power to the device prior to installation of the U-Charge® power system. Remove all other batteries prior to replacing them with U-Charge® batteries.

10.2. Tools Required

The following table details the sizes of the bolts supplied, the wrench size required and the recommended torque for each module.

Table 5: Terminal Hardware and Torque Information

Model	Mounting Hardware	Quantity	Wrench	Torque
U1-12XP	M6 x 1.0 thread/ terminal washer/ spring washer	2 each	12 mm	12.4 Nm (110 in-lbs)
U24-12XP	M8* 1.25-12/ terminal washer/ spring washer	2 each	13 mm	16 Nm (141.6 in-lbs)
U27-12XP	M8* 1.25-12/ terminal washer/ spring washer	2 each	13 mm	16 Nm (141.6 in-lbs)
UEV-18XP	M8* 1.25-12/ terminal washer/ spring washer	2 each	13 mm	16 Nm (141.6 in-lbs)
U27-36XP	M8* 1.25-12/ terminal washer/ spring washer	2 each	13 mm	16 Nm (141.6 in-lbs)

10.3. Installation Locations and Orientation

It is recommended that the general guidelines are followed, when choosing the installation location for your XP modules.

FOR DETAILS PLEASE REFER TO THE SEPARATE INSTALLATION & TROUBLE SHOOTING GUIDE.

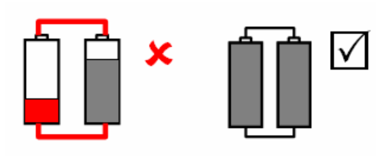
- Do not install U-Charge® XP power systems near heat generating equipment.
- Do not install U-Charge® XP power systems in a location where water or road spray can reach any surface of the module.
- In applications where vibration and shock is likely, use flexible insulated copper cables. Solid bus bars should only be used for stationary applications.
- Secure the XP Modules on all sides to prevent movement.
- XP modules are not load bearing and not designed to sit directly on top of one another; A load bearing frame or tray should be used when stacking XP Modules.
- Since these batteries are sealed and have no free electrolyte, they can be mounted in almost any orientation, although terminals up are recommended.

If the battery must be mounted on its side, Valence recommends that the terminals is positioned towards the top of the battery.

10.4. Installation Steps for a Battery Pack

- Attach negative cable from the vehicle/device to the negative terminal on the first battery.
- Attach a jumper cable between the positive terminal in the first battery pack and the negative terminal on the second battery pack. (Note: the jumper cable must be the same gauge cable as the positive and negative terminal cables).
- Add additional jumpers to complete the series string.
- Please contact Valence support, if the system includes more than 30 batteries.
- Attach the positive cable from the LINE (discharge) contactor to the positive terminal of the final battery.

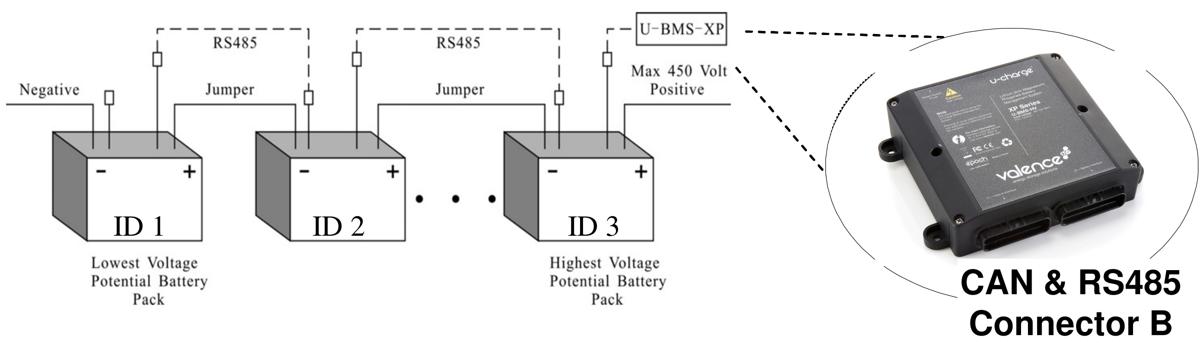
Batteries should be the same state of charge, when wiring them in parallel.



10.4.1. Series Installation

Batteries are configured in a series, when increased voltage is needed. As shown below, three batteries are connected with jumpers. Assume these are 12V batteries. Connecting them in this configuration, results in nominal voltage of 36V, but the amp hour capacity stays the same.

Figure 6: Installation of U-Charge® XP Power Systems in Series



10.4.2. Parallel Installation

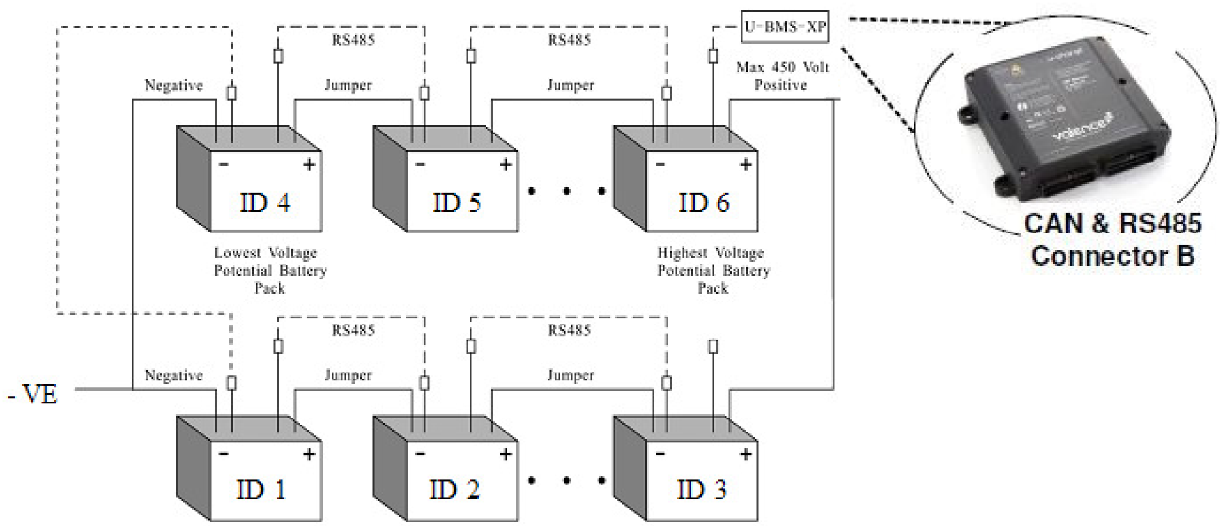
Parallel configurations allow the capacity to increase, while voltage remains the same.

10.4.3. Parallel & Series Installation

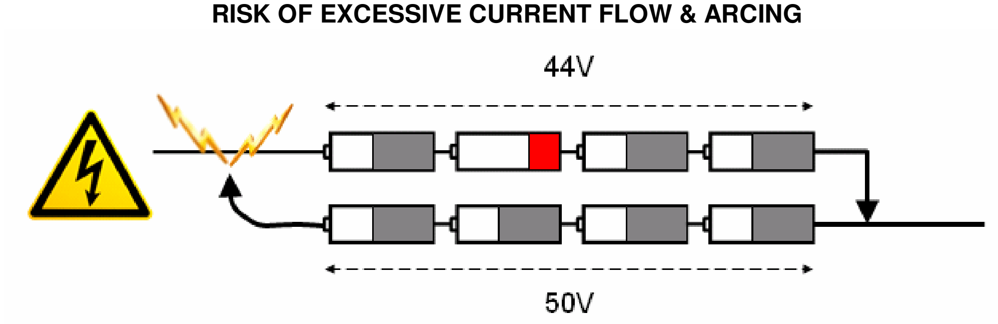
As shown in Figure 7, a combination of the parallel and series batteries allows for increased capacity and voltage resulting in longer run time. For example, if each battery shown below is a 12V battery, the combined parallel and series installation will result in 36V and twice the capacity. (This is known as 3S2P configuration.)

SPECIAL NOTE: The internal resistance of the modules is very low in comparison with other battery technologies. Special care is required to ensure identical cable resistance is installed on all the series strings. The system connections to the pack are deliberately offset and an equal length of cable is used on –VE and +VE interconnects.

Figure 7: Installation of U-Charge ® XP Power Systems in Parallel and in Series



RISK OF EXCESSIVE CURRENT FLOW & ARCING



Ensure that the voltages in each string are the same prior to connecting the batteries in parallel. A voltage differential can cause arcing and large current surges. This sudden energy transfer can be extremely dangerous, and the resulting circulating current, from the higher voltage string into the lower voltage cells (in red), may over-charge the higher voltage cells in the lower voltage string.

10.5. Module to U-BMS Communications

An RS-485 type serial bus provides the communications module to module and module to BMS. Each XP module has one male and one female SuperSeal connector, which allows for daisy-chained communication. Figure 8 and Table 6 describe the pin-out of the two connectors. The final module in the string will have an unused RS485 connector. A 120Ohm termination resistor/cap across Pin 3 & 4 should be installed on the cable.

Figure 8: Female Type Amp SuperSeal Connector

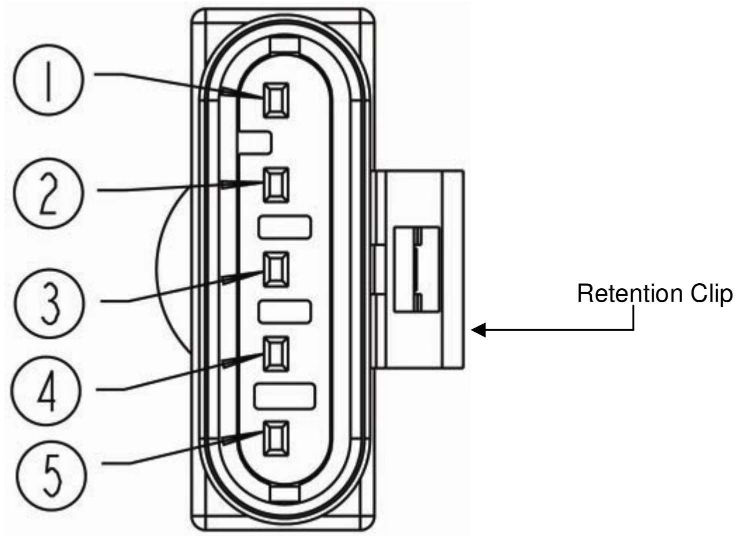


Table 6: Pin-out of the RS-485 Connectors in U-Charge® XP Power System

Pin	Signal Name	Wire Color	Pin Type	Description
1	N/A	Black	N/A	Shield
2	GROUND	Black	Power	Ground for the RS-485 transceiver
3	B (+)	White	Signal	B signal from the RS-485 transceiver
4	A (-)	Green	Signal	A signal from the RS-485 transceiver
5	VCC (+5)	Red	Power	Power supply for the RS-485 transceiver

10.6. Solvents and Lubrication

The battery modules are constructed of Cycoloy Resins C6600. This resin is flame retardant and impact resistance. Care must be taken when using cleaning solvents and/or lubricants, as not to compromise the chemical make up of the case. Below is a list of chemicals and the impact they have when coming in contact with Cycoloy resin. Valance recommends only using chemicals that are highlighted with green. For further information visit www.sabic-ip.com

Chemical Category	Chemical Name	Strain Level	Exposure Time	Temp. °C	Retention of TE @ Break C6600	Retention of TS @ Yield C6600
Adhesives	Adhesive Remover (1613-N)	0.0%	3 days	23		
		0.5%	3 days	23		
		1.0%	3 days	23		
Automotive Fluids, Non-Fuel	Motor Oil - 10W30	0.0%	3 days	23		
		0.5%	3 days	23		
		1.0%	3 days	23		
Cleaners/ Detergents	Bleach, 5500 PPM	0.0%	60 Hrs	23		
	Salmiak	0.5%	7 days	23		
		1.0%	7 days	23		
Disinfectants / Cleaners	Amphyl	0.0%	7 days	23		
		0.5%	7 days	23		
	Brial	0.5%	7 days	23		
		1.0%	7 days	23		
	Cavicide	0.0%	7 days	23		
		0.5%	7 days	23		
	Cidex	0.5%	3 days	23		
			7 days	23		
		1.0%	7 days	23		
	Citriguard II	0.0%	7 days	23		
		0.5%	7 days	23		
	Dismozon	0.0%	7 days	23		
		0.5%	7 days	23		
		1.0%	7 days	23		
	Household Bleach in Water	0.5%	3 days	23		
			7 days	23		
		1.0%	7 days	23		
	Klorax	0.5%	7 days	23		
		1.0%	7 days	23		
	Matar	0.0%	60 Hrs	23		
	Methyl Ethyl	0.5%	7 days	23		
		1.0%	7 days	23		
	Perform	0.0%	7 days	23		
		0.5%	7 days	23		
		1.0%	7 days	23		
	Sanicloth	0.5%	3 days	23		
	Sanicloth HB	0.5%	3 days	23		
			7 days	23		
	Sekusept	0.0%	7 days	23		
		0.5%	7 days	23		
		1.0%	7 days	23		
	TBQ Aqueous Germicidal	0.5%	14 days	23		
	Virex	0.5%	3 days	23		
			7 days	23		
		1.0%	7 days	23		

Chemical Category	Chemical Name	Strain Level	Exposure Time	Temp. °C	Retention of TE @ Break C6600	Retention of TS @ Yield C6600
Lubricants (Oils and Greases)	Alvania-General Purpose	0.0%	3 days	23	Green	
		0.5%	3 days	23	Green	
		1.0%	3 days	23	Green	
	Antirust P-2300	0.0%	3 days	23	Green	
		0.5%	3 days	23	Green	
		1.0%	3 days	23	Green	
	Antirust P-3600	0.0%	3 days	23	Green	
		0.5%	3 days	23	Yellow	
		1.0%	3 days	23	Red	
	C3421A	0.0%	3 days	23	Green	
		0.5%	3 days	23	Green	
		1.0%	3 days	23	Green	
	Castrol ILOCUT 201 AM	0.5%	7 days	23	Red	
		1.0%	7 days	23	Red	
		1.5%	7 days	23	Red	Green
	Dow Corning	0.5%	7 days	23		Green
		1.0%	7 days	23		Green
	Fumio Grease	0.0%	7 days	23		Green
		0.5%	7 days	23		Green
		1.0%	7 days	23		
	Grease Lithium H/C	0.0%	3 days	23	Green	
		0.5%	3 days	23	Green	
		1.0%	3 days	23	Green	
		2.0%	3 days	23	Yellow	
	Multemp PS No2 - Grease	0.0%	3 days	23	Yellow	
		0.5%	3 days	23	Red	
		1.0%	3 days	23	Red	
	MULTEMP SB-M	0.0%	3 days	23	Green	
		0.5%	3 days	23	Green	
		1.0%	3 days	23	Red	
	Multemp SRL Grease	0.0%	3 days	23	Red	
		0.5%	3 days	23	Red	
		1.0%	3 days	23	Red	Green
	RPM Grease	0.5%	7 days	23		Green
		1.0%	7 days	23		
	Rustcoat 600	0.0%	3 days	23	Green	
		0.5%	3 days	23	Green	
		1.0%	3 days	23	Red	
	Shell Alvania Grease S2	0.0%	3 days	23	Green	
		0.5%	3 days	23	Green	
		1.0%	3 days	23	Yellow	

Recommended	Green
Use with Caution	Red
Do Not use	Yellow

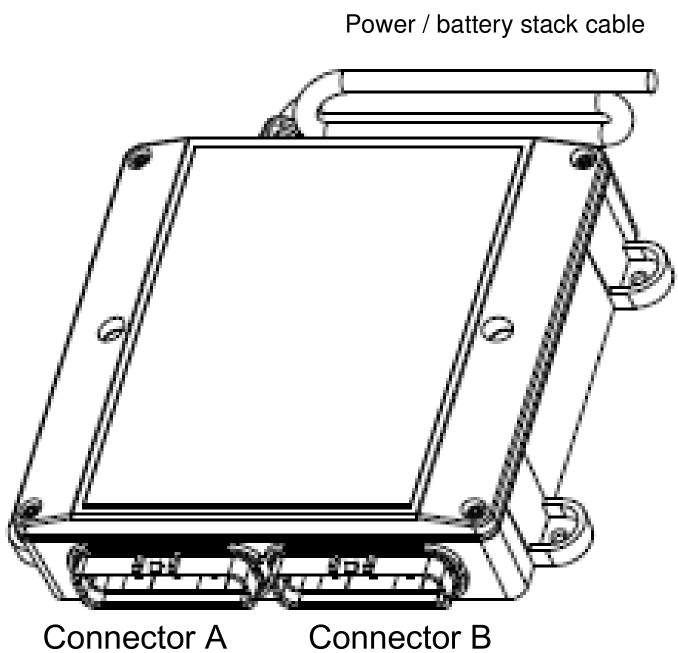
11. BMS INSTALLATION

Verify all U-Charge XP batteries, power and communication connections. Check the stack voltage to ensure it is within the U-BMS operational range (10V-150V DC for LV model or 100V~450V DC for HV model or 400V~700V DC for SHV)..

Fixture Location: Mount the U-BMS in an area that is easy to access, yet protected from the elements. The unit can be mounted in any orientation.
Temperature Range: The U-BMS functional operating range is -40 to + 85ºC.

Figure 9 shows the location of the two 26-pin connectors and the power cable. Each of these connectors is described in detail in the following sections.

Figure 9: U-BMS Illustration



Connector A and B are 26-pin Amp SuperSeal connectors.
Connector A is illustrated in Figure 10. The pin-out is available in Table 7.

Figure 10: Male Type 26-pin Amp SuperSeal Connector

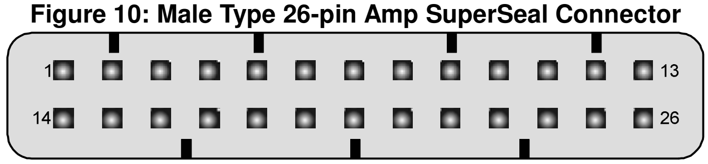


Table 7: Pin-out of Connector A

Connector A						
Pin	**Signal**	**Description**		**Nominal Voltage**	**Voltage Range**	**Nominal Current**
1	M1_POS	Positive	Contactor 1 Control	12 VDC		5A cont. 7A peak
2	M1_NEG	Negative				
3	M1_STATE	Sense				
4	M1_GND	Sense GND				
5	A1_POS	Positive	Contactor 2 Control			5A cont. 7A peak
6	A1_NEG	Negative		12VDC		
7	A1_STATE	Sense				
8	A1_GND	Sense GND				
9	M2_POS	Positive	Contactor 3 Control	12 VDC		5A cont. 7A peak
10	M2_NEG	Negative				
11	M2_STATE	Sense				
12	M2_GND	Sense GND				
13	A2_POS	Positive	Contactor 4 Control	12 VDC		5A,7A pk
14	12V_SYS	+12V DC BMS System Power		12 VDC	10-16 VDC	
15	12V_SYS					5A cont. 7A peak
16	12V_SYS					
17	GND	12V System BMS Ground				
18	GND					
19	GND					
20	GND					
21	RS485_B2+	Reserved				
22	RS485_A2-					
23	RS485_VCC2					
24	A2_GND	Sense GND	Contactor 4 Control			
25	A2_STATE	Sense				
26	A2_NEG	Negative		12 VDC		

Table 8: Pin-out of Connector B

Connector B						
Pin	**Signal**	**Description**	**Sub System**	**Nominal Voltage**	**Voltage Range**	**Nominal Current**
1	CHGCUR_CON	AUX3	Analog/ Digital Interface	N/A	0-5	~10mA
2	SOC_CON	SOC		0-5	0-5	~10mA
3	12V_IGNITION_CON	12V Ignition		12	10-16	<90μA
4	WAKEUP_CON	AUX1		12	4.5-16	<90μA
5	VEHICLE_FAULT_CON	Vehicle Fault		12	0, 12.5-16	<120μA
6	CHGREQ_CON	AUX4				
7	FAULT_CON	BMS Fault		12	0, 12	~10μA
8	GND	12V System Ground	BMS System Power			
9	GND					
10	GND					
11	CAN_H	CAN Interface	CANbus Comm Port			
12	CAN_L					
13	CAN_VCC					
14	12V_SYS	12V DC for System	BMS System Power		10-16	
15	12V_SYS					
16	12V_SYS			12		
17	DISABLE_REGEN_CON	Disable Regen	Analog/ Digital Interface	12	0, 12	~10μA
18	CHG_ENABLE_CON	AUX2		12	12.5 - 16	<120μA
19	EARLY_WARNING_CON	Early Warning		12	0, 12	~200mA
20	GND	12V System Ground	BMS System Power			
21	GND					
22	GND					
23	GND					
24	RS485_B1+	RS485 Interface to modules	Battery Comm Bus			
25	RS485_A1-					
26	RS485_VCC1					

The Power Cable is a 3 conductor cable that is used for connecting the stack voltage or other supply voltage to the BMS to power its circuitry. The connections are described in Table 9.

Table 9: Power Cable Connections

Connector Signal	Description	Wire Color	Nominal Rating
Stack -	Negative side of the battery stack	Black	0 VDC
Stack +	Positive side of the battery stack	Red	10 – 150 VDC for LV BMS
			100 – 450 VDC for HV BMS
			400 – 700 VDC for SHV BMS
Contactor Status	Not currently implemented	Yellow	Same as Stack +

BMS starter KIT includes a pre-wired 4-way CANbus connector cable

Figure 11: Female Type 4 Way Amp SuperSeal Connector

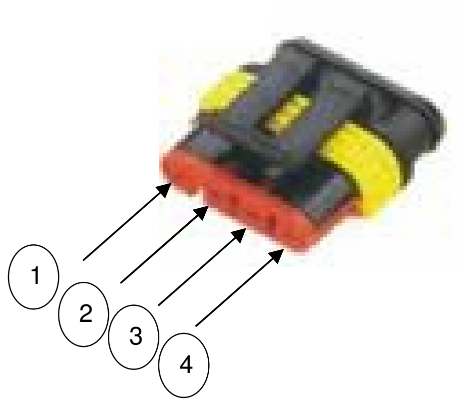


Table 10: CANbus Cable Connections

Pin	Signal Name	Wire Color	Pin Type	Description
1	N/A	Black	N/A	Shield
2	GROUND	Black	Power	Ground for the CAN transceiver
3	CAN H	White	Signal	CAN Hi signal
4	CAN L	Green	Signal	CAN Lo signal

12. SHIPPING, STORAGE, MAINTENANCE AND DISPOSAL.

12.1. Shipping

International law requires that the batteries are shipped under UN 3480 Class 9 Regulations for hazardous materials/dangerous goods.

IMPORTANT: The US Department of Transport currently (April 2010) has a specific exclusion for ground transport of lithium phosphate batteries. Valence advises that you verify current regulations with your specific carrier. The battery boxes and associated packing material are specifically designed and marked for compliant transportation. It is advisable to retain all material for any onward transport.

Please contact local authorities for regulations relating to transport of any battery.

Visual Inspection:
Upon receipt of product, please inspect all material. Report any damage to Valence Technology immediately.

12.2. Battery Storage

- When a battery is disconnected from other modules and the U-BMS, it will automatically go into sleep mode. The monitoring circuitry shuts down to maximize shelf life in sleep mode; a fully charged battery can be stored safely for up to a year, without the need for recharge. (It is advisable to check the condition, module voltage and top charge periodically..)
- Store in a well ventilated, clean, dry area, between -40℃ and 50℃, Ideally < 30℃ for maximum life.
- Do not expose the battery to extremes of temperature over 60℃ (140℉).
- Do not expose the battery to direct sunlight or moisture and/or precipitation
- Handle each battery carefully to avoid sharp impacts or extreme pressure on the case.

12.3. Storage Checks and Maintenance Charging

While being stored, the voltage of the battery should be measured and batteries inspected <u>every 6 months</u> to assess the health of the battery. The U1-12XP interval is every 3 months. If long storage periods are regularly planned, a maintenance charge routine should be established, at these intervals. Contact Valence technical support for help with maintenance charging.

If you find any single battery's voltage is less than 10V (15V for UEV) at room temperature, the battery has been over-discharged or is self-discharging due to some defect/parasitic load.

- The LED should flash green every 20 seconds (or 5 seconds when communicating to U-BMS).
  If these checks fail, you must discontinue use and contact Valence Technical Support immediately.

12.4. Disposal

The battery modules must not be disposed in a fire or in normal waste; it should be recycled in accordance with local laws and statutes.

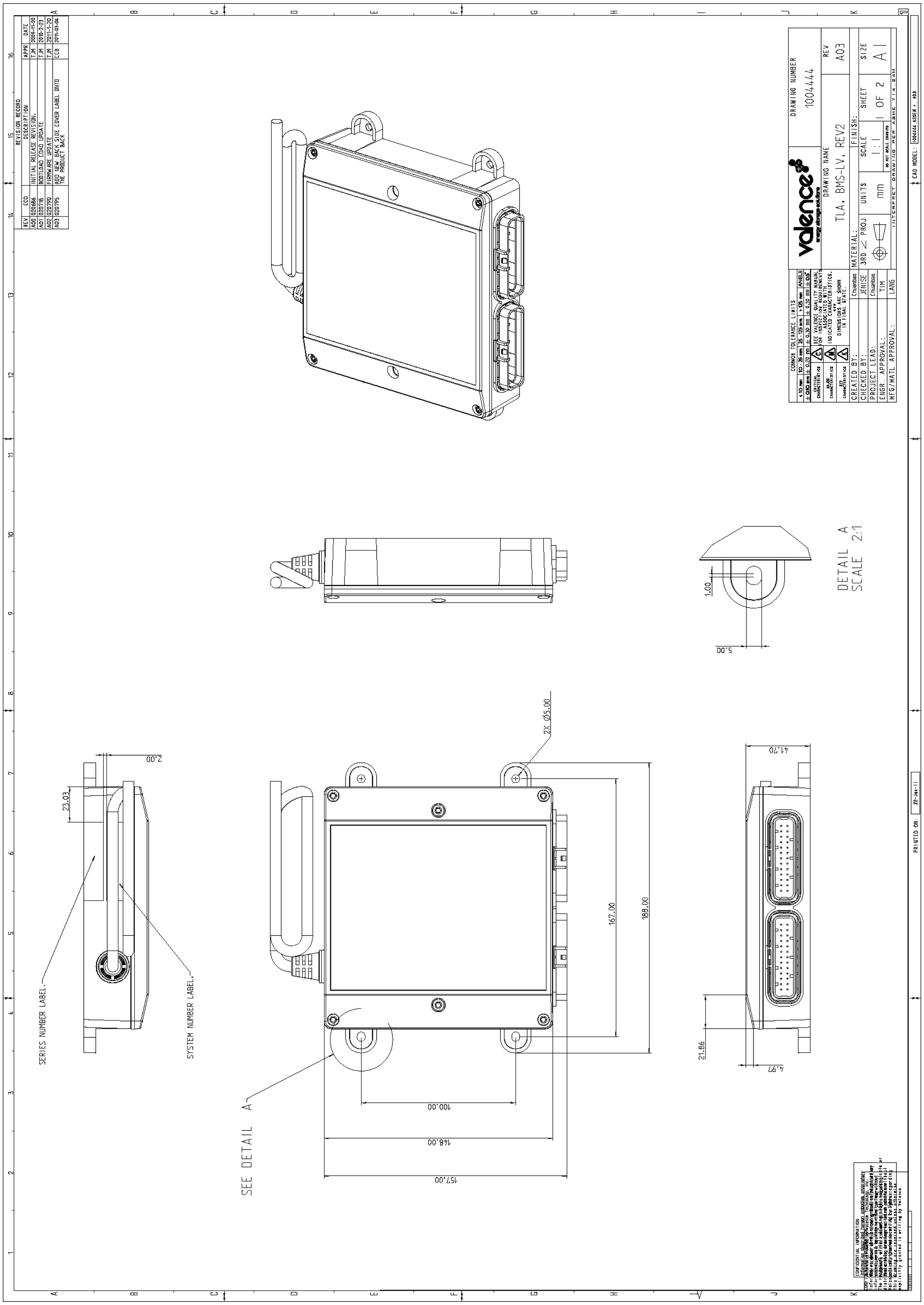
(Note: the disposal procedure may require the user to totally discharge the battery to a level which is below the lowest normal operating condition of the module. If you require advice on methods of achieving this, please contact Valence Technology.)

Disclaimer: Valence Technology cannot advise on disposal/recycling methods applicable in every user region. The product’s user/importer has the responsibility to confirm that disposal/recycling methods are compliant with local legislation.

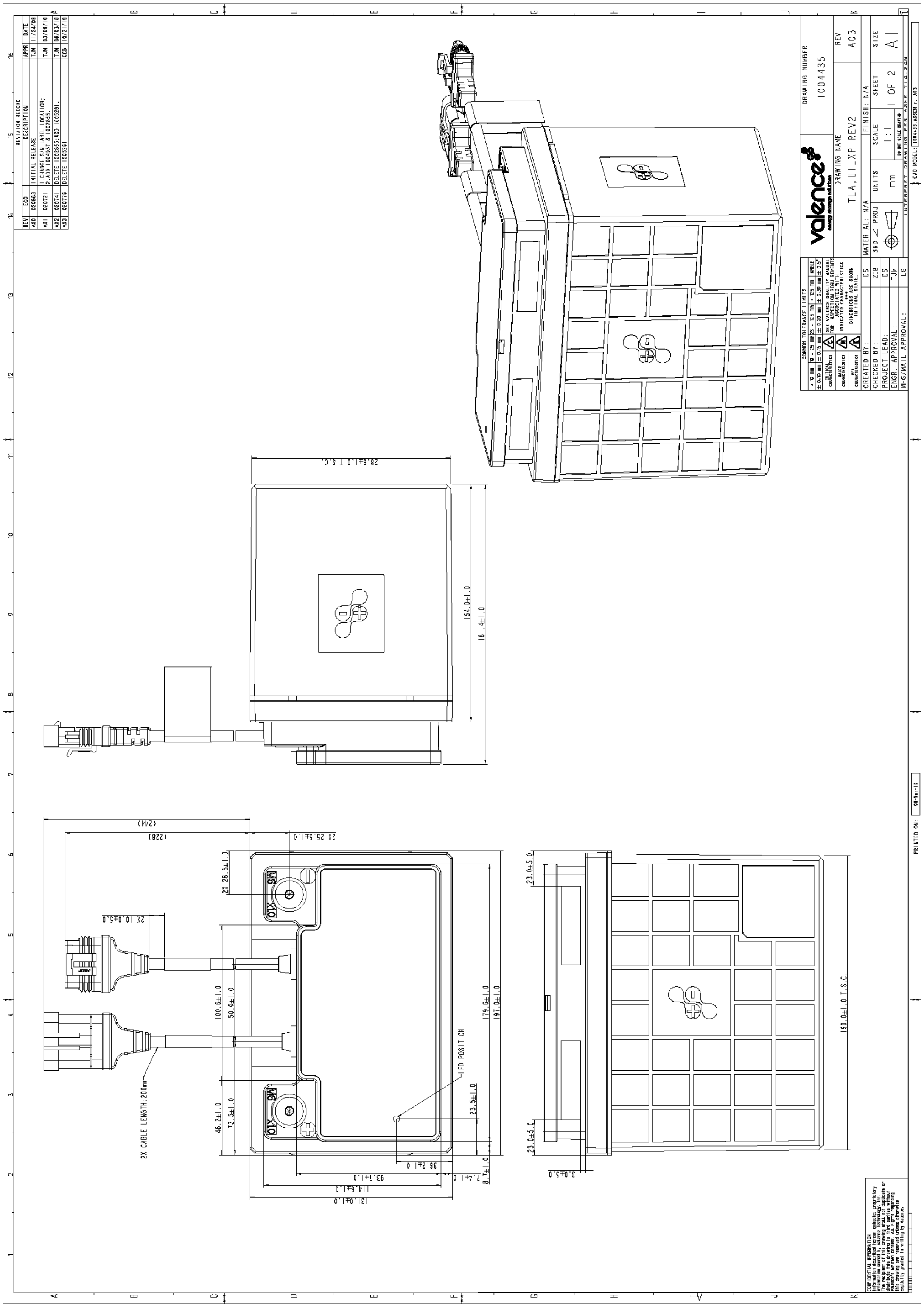
GLOSSARY

CANbus	Controller Area Network bus is a standard communication link used for automotive systems.
PCBA	Printed Circuit Board Assembly
RS 485	Standard type of serial communication interface.
SOC	State of Charge
U-Charge®	Brand name for range of products for Valence energy storage systems
U-BMS	Valence Battery Management System for U-Charge®
VMU	Vehicle Management Unit

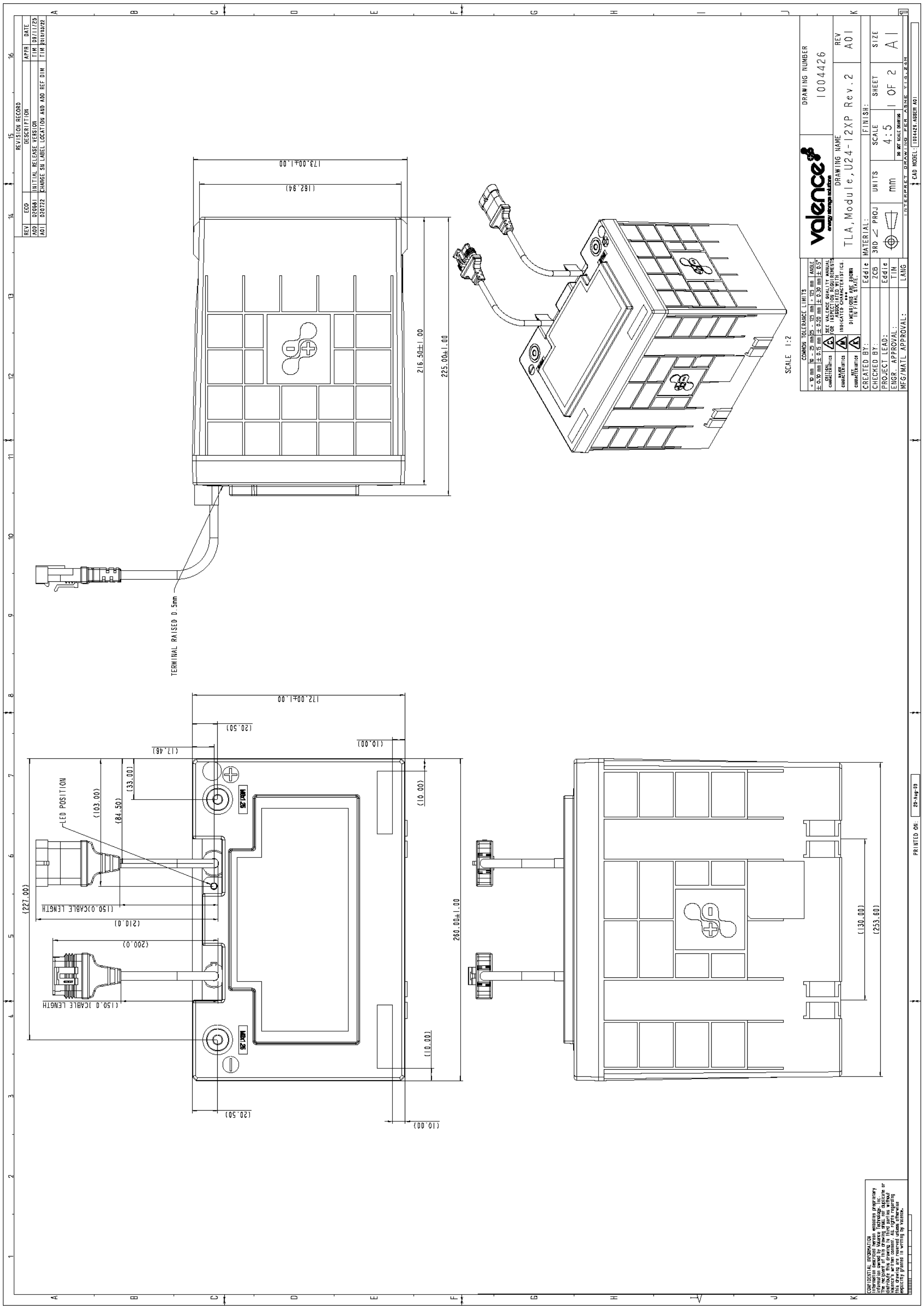
Appendix 1 U-BMS Mechanical Dimensions



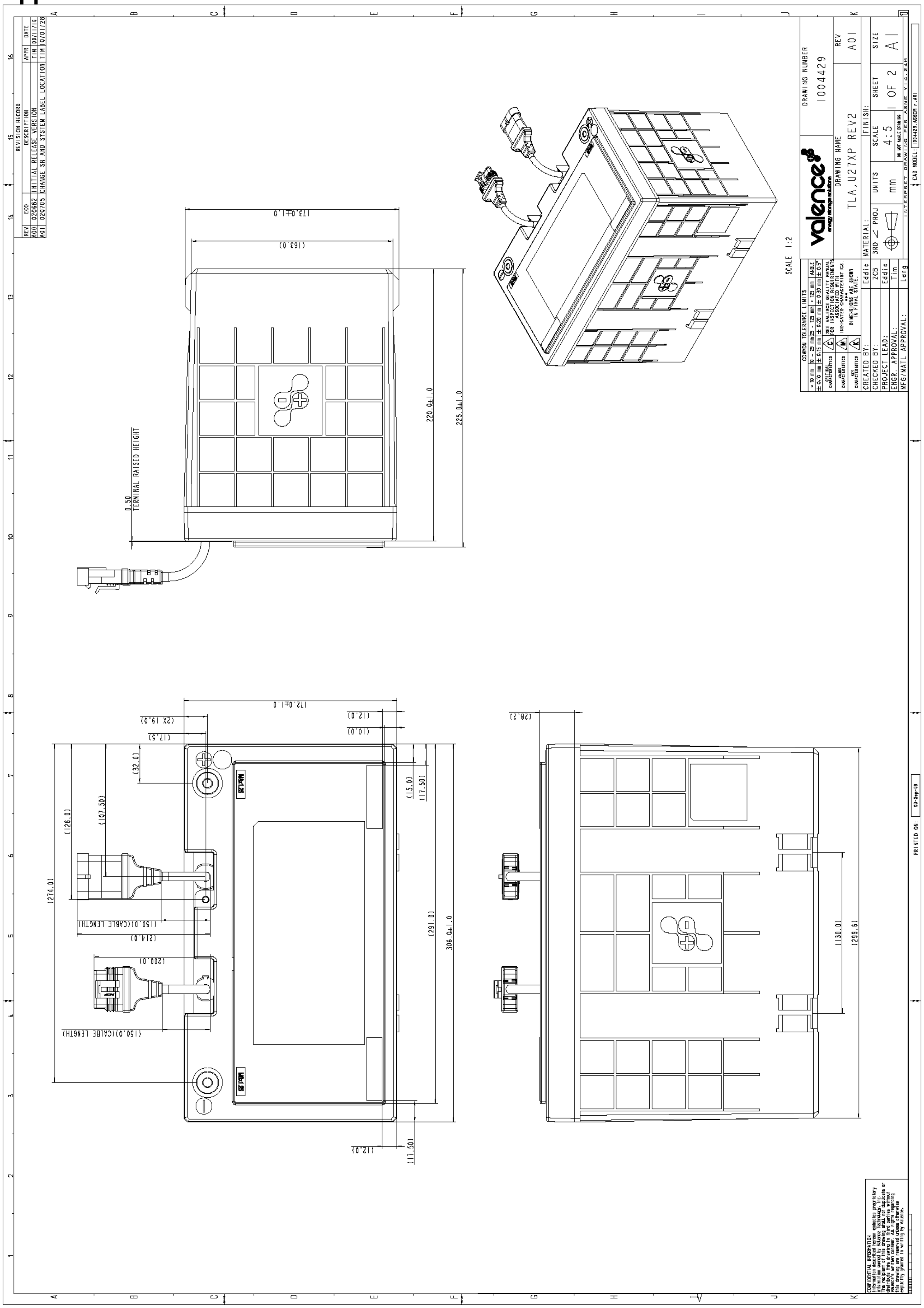
Appendix 2: U1-12XP Mechanical Dimensions



Appendix 3: U24-12XP Mechanical Dimensions



Appendix 4: U27-12XP & U27-36XP Mechanical Dimensions



Appendix 5: UEV-18XP Mechanical Dimensions