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advanced energy storage solutions

U-Charge® XP User Guide

Version 2.3

Lithium Iron Magnesium Phosphate

Safety and Performance Redefined

www.valence.com

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Contact Information

Mailing Address:
Valence Technology, Inc.
1807 West Braker Lane, Suite 500
Austin, Texas 78758

Mailing Address:
Unit 63 Mallusk Enterprise Park
Mallusk Drive,
Mallusk, Newtownabbey
County Antrim,
Northern Ireland, BT36 4GN

Americas Sales & Support:
512-527-2900
8 AM to 5 PM CST
Fax: (512) 527-2910

Rest of World Sales & Support:
+44 (0)28 9084 5400
9 AM to 5 PM GMT

Website:
www.valence.com

Contact:
www.valence.com/contact

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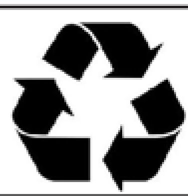
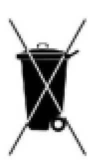
1. Safety Information

Read all 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 if you have any questions about the handling, operation, and safe use of the equipment.

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

Table 1-1: Safety Symbols

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. 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

The XP Modules have several safety features:

- Inherently safe Valence phosphate technology
- Cell voltage, current, and temperature monitoring
- Cell balancing
- LED status indication

CAUTION: Performing any of the following actions could lead to a potentially dangerous situation:

- Breaking the lid or removing side or top cover to expose the circuit boards and module assemblies
- Puncturing or otherwise physically damaging the module casing, circuit boards, battery cells, or any other part of the battery
- Operating or storing the module in an environment Where the temperature is outside the specified ranges:
    - Discharge temperature: -10°C (14°F) to 50°C (122°F)
    - Charge temperature: 0°C (32°F) to 45°C (113°F)
    - Storage temperature: -40°C (-40°F) to 50°C (122°F)
- Operating or storing the module in an environment that is not within the recommended humidity range:
    - 5% to 95%, non-condensing
- Installing the module Where water or road spray can reach the module
- Operating the module with a charge or discharge profile in excess of the peak current and duration specified in Appendix A
- Charging or discharging the module without a properly configured U-BMS along with contactor and fuse protection

The XP Power System must be used in accordance with Valence's specifications and guidelines. When used properly, and in accordance with these instructions, the XP Module is a safe, reliable, and convenient energy storage solution.

CAUTION: Misuse or abuse of the XP Power System may result in injury or fire.

1.1 First Aid Measures

This product is safe under normal use. The battery should not be opened or burned. Exposure to the ingredients contained within and/or their combustion products could be harmful. In the event that exposure does occur, please seek immediate medical attention. In addition, please review the following instructions specific to the route of exposure:

- **Inhalation:** Inhalation of material from a sealed battery is not an expected route of exposure. Vapors or mists from a compromised battery may cause respiratory irritation. If contents of an opened battery are inhaled, remove source of contamination and move victim to fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration and obtain medical attention.

- **Eye Contact:** Contact with the contents of an opened battery can cause severe irritation or burns to the eye. If eye contact with contents of an open battery occurs, immediately flush the contaminated eye(s) with copious amounts of water (or normal saline) for at least 15 minutes. Assure adequate flushing of the eyes by separating the eyelids with finger and thumb. If irritation or pain persists, seek medical attention.

- **Skin Contact:** Contact between the skin and battery will not cause harm. Contact with the contents of an opened battery, mainly the electrolyte solution, can cause severe irritation or burns to the skin. Immediately flush thoroughly with soap or mild detergent and copious amounts of water until no evidence of substance remains (typically 15-20 minutes). Remove and wash contaminated clothing promptly. If irritation or pain persists, seek medical attention.

- **Ingestion:** Swallowing of a sealed battery is not an expected route of exposure. In the event that swallowing of materials from a compromised battery occurs, serious chemical burns of the mouth, esophagus, and gastrointestinal tract can occur. If swallowed, wash out mouth with water provided person is conscious. Quickly transport victim to an emergency care facility.

1.2 Use in Life Support Applications

The XP Power System SHALL NOT be used in, or in conjunction with, any Life Support Application without the express written consent of Valence Technology, Inc. Life Support Applications include, without limitation: (i) a device to be implanted in a human body; or (ii) a system or device, which supports or monitors a human life, such that its failure could cause serious injury or death.

2. General Overview

This document provides information to assist you in configuring, installing, storing, and operating the XP Power System.

The key components for an XP Power System include:

- One or more XP Modules
- Battery Management System (U-BMS)
- A suitable charger
- Miscellaneous hardware
  - Cabling
  - Fuses and/or circuit breakers
  - Contactors
  - Pre-charge resistor(s), if needed
- XP Module Diagnostic Kit
- CANbus Monitoring Kit

An XP power system must include only a single module type, such as the U24-12XP, UEV-18XP or U27-36XP. Do not mix module types in the same system, and do not include batteries from other manufacturers. Several factors may influence the particular XP Module chosen for an application. For example:

- Runtime, range, capacity, or energy requirement
- Voltage limits required for the drive-train or load
- Space available
- Current or power requirement

The following figure is an example of a complete XP Power System in a 4S1P (four modules in one series string) configuration:

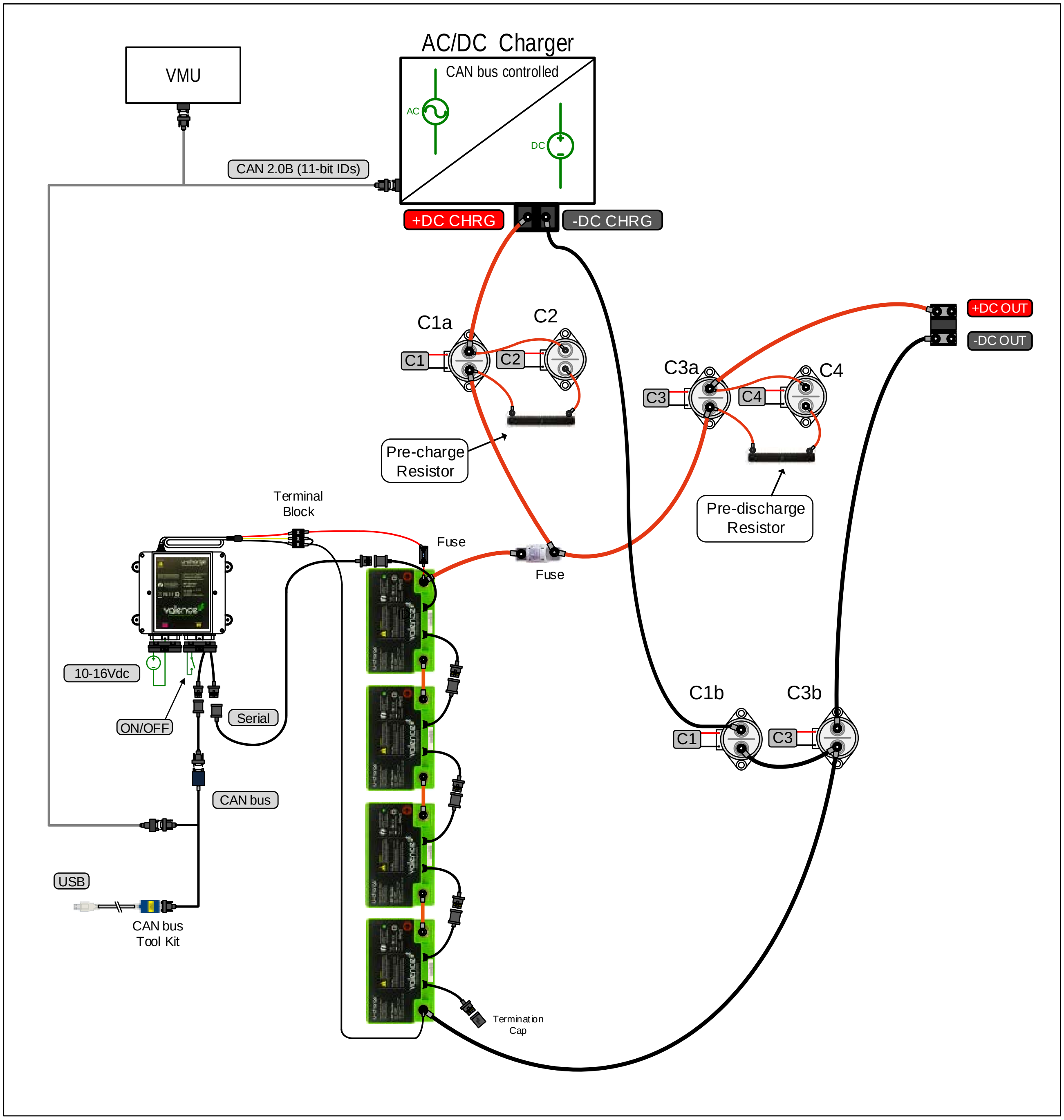


Figure 2-1: Example of an XP System

2.1 XP Modules

The XP series is a family of battery modules, including the U1-12XP, U24-12XP, U27-12XP, UEV-18XP, U27-36XP, U24-24XP and the U27-24XP. The module cases conform to standard BCI lead-acid battery case sizes (except for the UEV-18XP). Valence's modules use a kind of Lithium Ion chemistry called Lithium Iron Magnesium Phosphate ($LiFeMgPO_4$). $LiFeMgPO_4$ batteries are much less likely to experience thermal runaway than other Lithium chemistries. $LiFeMgP0_4$ batteries do not exhibit a "memory" effect – it is not necessary to fully discharge them completely before recharging. It is also not necessary to fully charge them every cycle.

Figure 2-2: XP Series Modules (straps not shown)

The modules' features include:

- Much lighter than an equivalent lead-acid battery
- Inherently safe chemistry
- Long life cycle
- Exceptional voltage stability
- Standard system voltage range from 12 V to 870 V (1000 V without insulation measurement)
- Maintenance-free
- Module and Cell Bank balancing

- Compatible with most standard lead-acid chargers
- Communication of monitored data via Battery Management System (U-BMS)
- Rugged mechanical design
- Flame retardant enclosure
- LED battery status indicator
- Carrying straps (U24, U27, UEV)

Each XP Module contains a printed circuit board assembly (PCBA) and associated components which carry out the following functions:

- Cell Bank Voltage measurement
- Current measurement
- Cell Bank temperature measurement
- State of Charge calculation
- Serial communications with the U-BMS
- LED indication of basic status of the module (see Section 3).
- Cell Bank balancing
- Event logging capability

2.2 Cells and Cell Banks

All XP Modules are made up of battery cells grouped into Cell Banks. The nominal discharge voltage of individual cells is 3.2V and the nominal discharge capacity is 1.4Ah (18650 size) and 3.15Ah (26650 size).

Figure 2-3: $LiFeMgPO_4$ Cells

To make up a module a number of cells are welded together in parallel to form a “Cell Bank”. One Cell Bank still develops 3.2 V, but the amp-hour capacity of the bank varies with the number of cells in it. Then a number of Cell Banks are wired in series to get the desired module voltage. For instance the 12 V modules (U1-12XP, U24-12XP, and the U27-12XP) consist of four Cell Banks in series, while the UEV-18XP has six in series, the U24-24XP and the U27-24XP have eight and the U27-36XP has twelve.

In operation, the BMS monitors the voltage across each Cell Bank in each module, as well as the temperature in several locations inside each module and other important parameters.

2.3 Battery Management System (U-BMS)

Never charge nor discharge any XP Module without a U-BMS and contactor(s) connected to it. Failure to do this creates a safety hazard, violates the warranty, and also could permanently damage the module.

The U-Charge® Battery Management System (U-BMS) monitors and protects XP Modules in a system. Every XP system must have a U-BMS to prevent the modules from being irreparably damaged. Refer to the U-BMS User Guide for details.

Figure 2-4: U-BMS

The features of the U-BMS include:

- Comprehensive warning and alarm monitoring
- Contactor control for protection and safety
- Independent CAN bus control
- Smart charger control
- Module balancing control
- System and battery module data logging (with CAN bus monitoring kit)
- Digital and analog I/O
- Battery-chassis isolation resistance measurement alarm
- Low-power sleep mode

Some systems have more than one U-BMS for redundancy or other reasons. Contact Valence Technical Support for details.

2.4 Charging XP Modules

NEVER CHARGE A MODULE WITHOUT A U-BMS

The U-BMS will protect the module from over charging and overheating. Charging without a U-BMS and an associated relay or contactor will void the warranty and damage the module.

2.4.1 Charge Cycle

Valence modules do not have a “memory”. It is not necessary to always fully discharge a module before recharging it. This figure illustrates the charging process for a system made up of 28 U27-12XP modules in series.

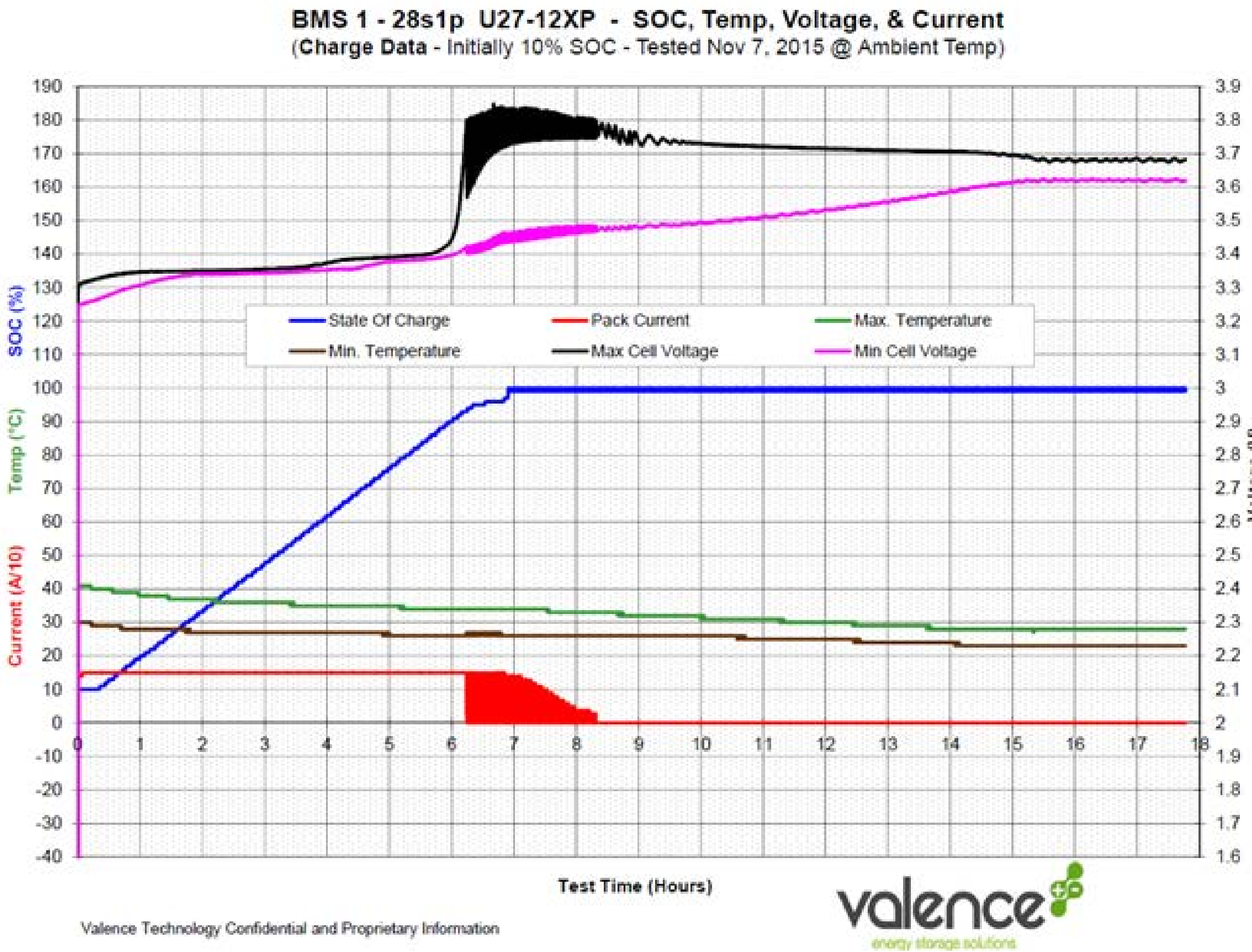


Figure 2-5: Charging

2.4.2 Main Charging

Charging a Valence module involves charging at a constant current until the charging voltage is reached, and then continuing to charge at that voltage as the charge current drops to nearly zero. Finally, a balancing stage maximizes the energy stored in the module.

The recommended charging rate for Valence modules is half the module's capacity in amps or "C/2" in battery industry C-rate terminology. The table below shows the C/2 rate for each module in the XP family. The recommended voltage for each module is shown also.

Charging at C/2 will take about two hours. More time will be required for balancing. Modules can be charged at lower rates, but doing so will take longer. Charging can be done at 1C or higher rates, but care must be taken that the modules do not overheat.

Table 2-1: Module Capacities and Charging Information

Module	Capacity	C/2 Charge Rate	Charging Voltage
U1-12XP	40 Ah	20 A	14.6 V
U24-12XP	110 Ah	55 A	14.6 V
U27-12XP	138 Ah	69 A	14.6 V
UEV-18XP	69 Ah	35 A	21.9 V
U24-24XP	56 Ah	28 A	29.2 V
U27-24XP	69 Ah	35 A	29.2 V
U27-36XP	46 Ah	23 A	43.8 V

During the main charge the voltage across the cells banks will not change much as the module charges. When the cell banks are nearly fully charged the cell bank voltages will increase quickly. At this point the charge current should reduce exponentially as the module reaches 100% state of charge. At this point the Cell Bank voltages will diverge from each other. The process of bringing them back together is called “balancing”.

2.4.3 Balancing

Maximizing the energy stored in a module requires that the Cell Banks be balanced at the end of charging. The Cell Banks in a module will have slightly different capacities due to unavoidable variations in the manufacturing process. Because of this, the lower capacity Cell Banks will charge faster than the higher capacity banks.

The cause of unequal Cell Bank voltages and module voltages includes the distribution of capacity and self-discharge of the individual cells. The Cell Bank voltage difference is most pronounced at the end of charge and the end of discharge, even more so as the module current increases. The remedy is the combination of two types of balancing, intra-module (Cell Bank to Cell Bank) and inter-module (module to module). Both types of balancing can be active at the same time. Each module is responsible for maintaining its own Cell Bank voltage balance. In some instances modules within the same system can have perfectly balanced Cell Bank voltages yet have different voltages across the Positive and Negative terminals. The module voltage balance is maintained by the BMS. When the voltage difference between Cell Banks increases to 40 mV, intra-module balancing occurs until the difference falls to 20 mV. The prerequisites for intra-module balancing is the module must be awake, the discharge current is less than 2 A, and all Cell Banks are 3.360 V or more. The module is awake when there is activity on the RS485 bus within the last two minutes. When the voltage difference between modules exceeds 100 mV, the BMS controls inter-module balancing until the difference falls below 100 mV. The prerequisites are all Cell Banks in the system are above 3.280 V.

2.4.4 Charger Selection

There are several criteria that go in to selecting a charger for a specific application. The first, of course, is that the charger must be able to produce the proper charging voltage as shown in Table 2-1. Some “intelligent” chargers have internal controllers that can be set for $LiFeMgP0_4$ modules. The best chargers have CAN bus interfaces or some other way for the BMS to set the charging current and voltage. Others have remote control inputs that the BMS can use to temporarily turn the charger off and then on again.

Some chargers designed for lead-acid batteries can be used to charge Valence modules as long as the current and voltage do not exceed the values in the table. Typical lead-acid chargers charge at a constant current until the charging voltage is reached, and then at the constant voltage for a predetermined time, after which the charge voltage is reduced. This may result in incompletely charging a Valence module. Valence modules do not need to be kept on a float charge, but can do so without any harm.

DO NOT “EQUALIZE” ANY VALENCE MODULE! Some lead-acid battery chargers have a setting called “equalization”. On this setting the charger puts out a higher voltage in order to remove sulfate crystals or equalize the acid concentration between the top and the bottom of the cells. $LiFeMgPO_4$ batteries do not suffer from these problems. Overcharging or charging at a higher than recommended voltage **WILL** damage the cells. A properly connected and configured BMS should open the charge circuit contactors if the charger is delivering too high a voltage.

As mentioned before, lead-acid state of charge indicators will not work properly with Valence modules. At best they will overestimate the charge remaining in the module.

2.4.5 Charger Control

It is best for the BMS to have some way to control the charger to maximize the energy stored. There are several ways that this may be implemented:

1. The BMS can directly control the charger over the CAN bus. Some chargers can accept voltage and current set points directly from the BMS over the CAN bus.
2. The BMS can send current and voltage set points to a vehicle management unit or system manager via the CAN bus, which in turn controls the charger.
3. The BMS can interrupt the current from the charger by opening a charge control contactor in series with the charger. Note: many chargers will sense a safety issue and shut down if this happens. Consult the manual for your charger to see if it will do this.
4. Some chargers have remote control inputs that can be connected to the charge control contactor.

2.4.6 State of Charge Realignment

The controller board executes a complex calculation to estimate the current State of Charge (SOC). The SOC estimate is reported to the BMS over the serial bus. This estimate may drift over time. Realigning it requires recharging the module until the module asserts “Charge Complete”. (See Table 2-2). This operation should be done fairly often, perhaps once per week depending on usage.

2.4.7 Charge Complete

XP Modules report “charge complete” to the BMS when certain conditions are met. If all the Cell Banks in a module are above a certain voltage and below 3.8 V, and the charging current has fallen below a certain level for 60 seconds, “charge complete” is set. If the Cell Banks are above a higher voltage the limit current can be higher. The conditions are different for each module type.

Table 2-2: Charge Complete Criteria

Module Type	If all the Cell Banks are above…	And the charge current remains below…for 60 seconds
U1-12XP	3.400 V	0.300 A
	3.650 V	2.190 A
U24-12XP	3.400 V	0.790 A
	3.650 V	5.767 A
U27-12XP	3.400 V	0.990 A
	3.650 V	7.227 A
UEV-18XP	3.400 V	0.500 A
	3.650 V	3.650 A
U24-24XP	3.400 V	0.440 A
	3.500 V	1.375 A
	3.650 V	2.750 A
U27-24XP	3.400 V	0.440 A
	3.500 V	1.375 A
	3.650 V	2.750 A
U27-36XP	3.400 V	0.333 A
	3.650 V	2.409 A

2.4.8 Recalibrating Module Capacity

The total energy storage capacity of an XP Module will decrease over time. Subjecting the cells to high temperatures can accelerate this decline. Valence recommends that the capacity should be periodically recalibrated, perhaps every six months or so. To recalibrate the capacity estimate first realign the SOC as described above, then discharge the module to less than 20% SOC. Finally, either turn off the BMS for 30 seconds, or recharge the module to charge complete. This will give the module controller an accurate value for module capacity.

2.5 Miscellaneous Hardware

The XP Power System requires certain accessories and equipment. The following sections contain some general guidelines about these items.

2.5.1 Power Cables

The size of the power cable to be used depends on the current to be used. Contact the cable manufacturer for the diameter cable needed to carry the desired current. Solid bus bars will work for applications where the modules are not subject to significant shock or vibration. Use stranded cable for all other applications, especially in any sort of vehicle.

2.5.2 Fuses and Breakers

Fuses and breakers are used to protect against sustained high currents such as short circuits that could cause a fire. They need to be sized to match the current handling capability of the power cables and contactors in the system.

Figure 2-6: Fuse

There should be at least one fuse or breaker per series string of XP Modules. They can be placed at any location in-line within the series string.

2.5.3 Contactors and Relays

Contactors and relays are used to safely connect and disconnect the system to and from the load and charger.

Figure 2-7: A Typical Contactor

They must be sized to carry the continuous current of the application and still be capable of breaking the maximum current at the highest possible system terminal voltage.

2.6 XP Diagnostic Kit

The XP Diagnostic Kit includes software and a USB-to-serial bus adapter cable. This allows the user to connect directly to the modules and get diagnostic information from them.

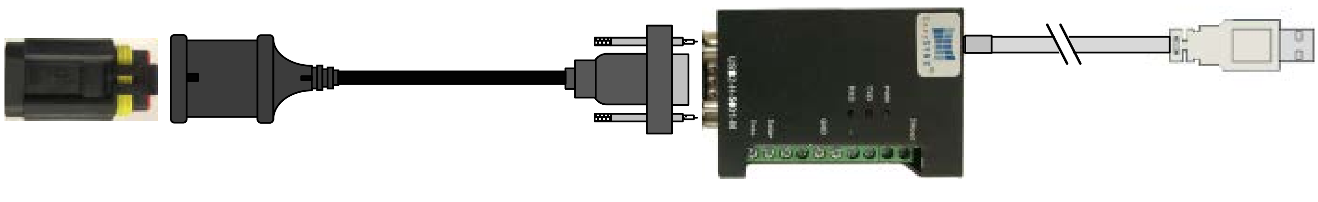


Figure 2-8: USB-to-Serial Bus Adapter

The Line Break Adapter included in the kit must be used it the diagnostic kit is connected at the same time as a BMS. It should not be used if the kit is only connected to modules.

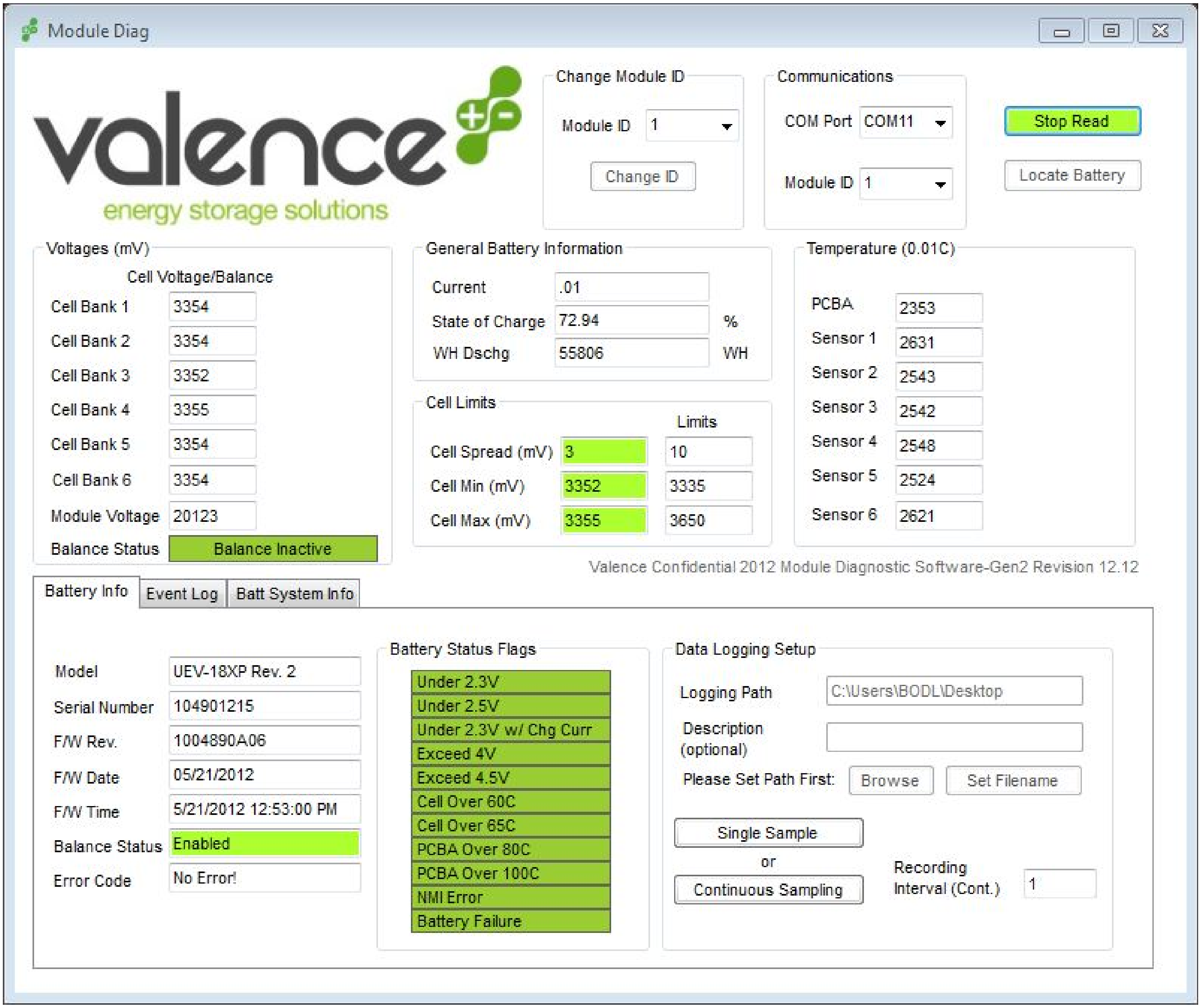


Figure 2-9: Example Screenshot of the Module Diagnostics Software (your screen may differ)

Once connected, the user can do the following:

- View module data
- Update the module's firmware

- Re-program the identification number (only necessary if the module has been ordered as a replacement)

The XP Diagnostic Kit cannot be used while the module is connected to the BMS unless a line break adapter is used.

Below is a partial list of data that can be viewed with an XP Diagnostic Kit:

- Module ID
- Cell Bank voltages
- Cell temperatures
- Module SOC
- Module current
- Module serial number
- Module model number
- Firmware revision, date, and time
- Module balance status
- Error codes
- Event log

Contact Valence Technical Support to obtain the latest version and user guide for the software used with the diagnostic kit and your module.

2.7 Design Considerations

One of the attributes of the XP series of battery modules is its scalability. Systems can be configured from 12.8 V nominal up to 614 V nominal if the isolation measurement is used, up to 870 V nominal if the isolation measurement is not used[1], and from 40 Ah up to 1000's of Ah. Several factors may influence the XP Modules chosen for an application. For example:

- Runtime, range, capacity, or energy requirement
- Voltage limits required for the drive-train or load
- Space available
- Current or power requirement

The following sections provide examples and information to help you determine how many modules may be required in series and parallel to meet your voltage and capacity requirements.

2.7.1 Voltage

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 2-3: XP Module Voltages

Module Type	Minimum Voltage (V)	Nominal Voltage (V)	Maximum Voltage (V)
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
U24-24XP	20	25.6	29.2
U27-24XP	20	25.6	29.2
U27-36XP	30	38.4	43.8

[1] The maximum voltage allowed is 700 V using the isolation measurement and 1000 V if it is not used. These are the maximum charging voltages for configurations whose nominal voltages are 614 and 870 V nominal.

For example, 24 of the U1-12XP modules in series gives the following system voltages:

System minimum voltage = 24 modules x 10.0 V = 240.0 V

System nominal voltage = 24 modules x 12.8 V = 307.2 V

System maximum voltage = 24 modules x 14.6 V= 350.4 V

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

2.7.2 Capacity

The number of XP Modules in parallel will be determined by the capacity requirement for the application. Capacity can be stated in units of charge as Ampere-hours (amp hours or Ah), or in units of energy as Watt-hours (Wh).

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

Table 2-4: XP Module Nominal Capacities

Module Type	Capacity (Ah)	Energy (Wh)
U1-12XP	40	512
U24-12XP	110	1408
U27-12XP	138	1766
UEV-18XP	69	1325
U24-24XP	56	1434
U27-24XP	69	1766
U27-36XP	46	1766

The system capacity scales with the number of series strings in parallel. The maximum number of strings depends on the system configuration. Contact Valence Technical Support for details.

Continuing the U1-12XP example in Section 2.7.1, a 24S1P system consists of one series string of 24 modules, with a system capacity of 40 Ah or 12.3 kWh (512 Wh x 24 modules). A 24S2P system consists of two series strings of 24 modules, with a system capacity of 80 Ah or 24.6 KWh (512 Wh x 48 modules).

2.8 Sizing Examples

The following table displays the voltage, capacity, and energy for various U1-12XP configurations. Other modules have higher voltages and/or higher capacities:

Table 2-5: U1-12XP Sizing Example

		Series Strings in Parallel			
		1	2	3	4
Modules in Series	1	12.8 V, 40 Ah 512 Wh	12.8 V, 80 Ah 1024 Wh	12.8 V, 120 Ah 1536 Wh	12.8 V, 160 Ah 2048 Wh
	2	25.6 V, 40 Ah 1024 Wh	25.6 V, 80 Ah 2048 Wh	25.6 V, 120 Ah 3072 Wh	25.6 V, 160 Ah 4096 Wh
	3	38.4 V, 40 Ah 1536 Wh	38.4 V, 80 Ah 3072 Wh	38.4 V, 120 Ah 4608 Wh	38.4 V, 160 Ah 6144 Wh
	4	51.2 V, 40 Ah 2048 Wh	51.2 V, 80 Ah 4096 Wh	51.2 V, 120 Ah 6144 Wh	51.2 V, 160 Ah 8192 Wh
	5	64 V, 40 Ah 2560 Wh	64 V, 80 Ah 5120 Wh	64 V, 120 Ah 7680 Wh	64 V, 160 Ah 10240 Wh
	6	76.8 V, 40 Ah 3072 Wh	76.8 V, 80 Ah 6144 Wh	76.8 V, 120 Ah 9216 Wh	76.8 V, 160 Ah 12288 Wh
	7	89.6 V, 40 Ah 3584 Wh	89.6 V, 80 Ah 7168 Wh	89.6 V, 120 Ah 10752 Wh	89.6 V, 160 Ah 14336 Wh
	8	102.4 V, 40 Ah 4096 Wh	102.4 V, 80 Ah 8192 Wh	102.4 V, 120 Ah 12288 Wh	102.4 V, 160 Ah 16384 Wh
	9	115.2 V, 40 Ah 4608 Wh	115.2 V, 80 Ah 9216 Wh	115.2 V, 120 Ah 13824 Wh	115.2 V, 160 Ah 18432 Wh
	10	128 V, 40 Ah 5120 Wh	128 V, 80 Ah 10240 Wh	128 V, 120 Ah 15360 Wh	128 V, 160 Ah 20480 Wh
	11	140.8 V, 40 Ah 5632 Wh	140.8 V, 80 Ah 11264 Wh	140.8 V, 120 Ah 16896 Wh	140.8 V, 160 Ah 22528 Wh
	12	153.6 V, 40 Ah 6144 Wh	153.6 V, 80 Ah 12288 Wh	153.6 V, 120 Ah 18432 Wh	153.6 V, 160 Ah 24576 Wh

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

3. LED Status Indicator

3.1 Overview

Each module in the XP series has an LED that indicates the module status. This LED allows information about the module to be conveyed to a user without using the Configuration, Diagnostic and Monitoring software (CMD) or the Module Diag software. The module also sends its error status to the BMS, which may be configured to act on certain errors or ignore them. The LED can be red, yellow, or green, and flashes at different rates depending on the module status. The module controller measures parameters such as the voltage across each Cell Bank, the temperature at several places inside the module, the current through the module, and temperatures at various other locations inside the module. The controller compares each parameter to a fixed set of limits. If all the parameters are inside the limits, the LED is green. If a limit is exceeded, the LED is yellow or red.

If the module is communicating with a U-BMS, it is said to be in active mode. If no U-BMS is connected, the module controller goes to sleep mode to conserve energy.

3.2 LED States

There are four possible states: normal, warning, alarm and shutdown. These are the same terms used in the U-BMS, but the limits in the U-BMS are set by the configuration file and can be changed by a Valence applications engineer. The limits in the modules are built into the firmware and cannot be changed.

Warnings and alarms are resettable, they are cleared if the condition that caused them returns to normal. Shutdowns are not resettable, they indicate that the module may have been permanently damaged.

3.3 Parameters Monitored

The parameters that are monitored include:

- The voltage across each Cell Bank. The voltage may be too high, an Over Voltage (OV) condition or too low, an Under Voltage (UV) condition.
- The temperature inside each Cell Bank, as well as temperatures in other places inside the module. The temperature may be too high, an Over Temperature (OT) condition or too low, and Under Temperature (UT) condition. Note: The U27-24XP and the U24-24XP measure the temperature at more places than the other XP Modules, for instance, the temperature of each terminal is measured.
- The current flowing through the module. It may be too high, an Over Current (OC) condition.

The controller also watches for other errors:

- Temperature or voltage measurement errors – these errors are raised if the temperature or voltage is off the scale of the measuring circuit.

- Cell reversal – if the voltage of a particular Cell Bank drops too much it may actually turn negative. This would damage the Cell Bank.
- Flash memory error: the controller monitors its non-volatile memory for errors
- Program Checksum error: this error indicates that the controller firmware has been corrupted.
- Oscillator error: this error indicates that some oscillators on the control board have drifted away from their design frequency.
- Sanity error: can be raised if:
    - The sum of the voltages across the Cell Banks differs from the voltage across the entire module by more than 150 mV.
    - The current measurement was off the high end of the scale, even for a short time.
- Event log overflow: the internal event log has overflowed.
- Unexpected Interrupt: an internal fault has caused an unexpected interrupt to occur.

valence

3.4 LED Displays

Table 3-1: LEDs for the 12XP and 36XP Modules

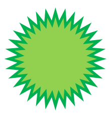
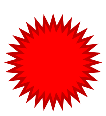
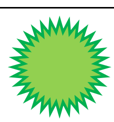
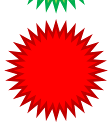
<table>
<tr><th>LED Status</th><th>Indication</th><th>LED Behavior</th><th>Module Status/Mode</th><th>Resolution</th></tr>
<tr><td rowspan="2">Flashing Green</td><td rowspan="2">Normal Operation</td><td>Flashes every 20 seconds</td><td>Power saving, not communicating with U-BMS</td><td rowspan="2">N/A</td></tr>
<tr><td>Flashes every 5 seconds</td><td>Active, communicating with U-BMS</td></tr>
<tr><td rowspan="4">Flashing Yellow</td><td rowspan="4">Temporary Warning</td><td rowspan="4">Flashes every 20 seconds (green once voltage or temperature normalizes)</td><td>At least one Cell Bank under voltage
(Use CMD or Module Diag to confirm)</td><td>Charge</td></tr>
<tr><td>At least one Cell Bank over voltage
(Use CMD or Module Diag to confirm)</td><td>Discharge</td></tr>
<tr><td>Cell temp = 60 - 65°C
(Use CMD or Module Diag to confirm)</td><td rowspan="2">Allow module to cool</td></tr>
<tr><td>PCBA temp = 80 - 100°C
(Use CMD or Module Diag to confirm)</td></tr>
<tr><td rowspan="5">Flashing Red</td><td rowspan="5">Fault</td><td>Flashes every 5 seconds (green once voltage is above 3.3 V)</td><td>Cell voltage < 2.3 V
(Use CMD or Module Diag to confirm)</td><td>Charge</td></tr>
<tr><td rowspan="4">Flashes every 5 seconds (remains red when cause for alarm no longer exists)</td><td>Cell voltage < 2.3 V with charge current > 0.5 A for 1 min</td><td rowspan="4">Contact Valence</td></tr>
<tr><td>Cell voltage > 4.5 V</td></tr>
<tr><td>Cell temp > 65°C</td></tr>
<tr><td>PCBA temp > 100°C</td></tr>
<tr><td>Red & Green flashing alternately</td><td>Electronics Fault</td><td>Red and green flash alternately</td><td>Issue with onboard electronics</td><td>Contact Valence</td></tr>
</table>

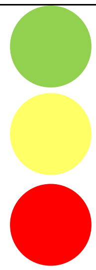
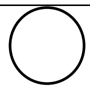
	Any color remains on	Electronics Fault	Any LED color remains on	Issue with onboard electronics	**Contact Valence**
	Permanently off	Electronics Fault	No LED output	Non-recoverable	**Contact Valence**

3.5 24XP LED Display

The U24-24XP and the U27-24XP have a slightly different LED display than the 12XP and 36XP Modules.

Table 3-2: LED Displays for the 24XP Series Modules

LED Status	Flashing Rate	Indication	Resolution
	20 seconds	Module operating normally in sleep mode (Module is not communicating with a U-BMS)	N/A
	5 seconds	Module operating normally in active mode (Module is communicating with a U-BMS)	N/A
	10 seconds	Module is in sleep mode and warning or alarm condition(s) exist. Warnings: OT, UT, OV, UV, OC, PCBA OT, terminal OT. Alarms: OT, UT, OV, UV, OC, PCBA OT, terminal OT	See Section 3.6
	8 seconds	Module is in active mode and warning condition(s) exist: OT, UT, OV, UV, OC, PCBA OT, event log overflow, and/or terminal OT	See Section 3.6
	5 seconds	Module is in active mode and alarm condition(s) exist: OT, UT, OV, UV, OC, PCBA OT, and/or terminal OT	See Section 3.6
	2 seconds	Module is in calibration mode	Contact Valence
	20 seconds	Under voltage shutdown	Contact Valence
	5 seconds	Module is sleep mode and a shutdown condition exists: OV, UV, OC, PCBA OT, terminal OT, flash error, temp measurement error, voltage measurement error, oscillator error, program checksum error, sanity error, and/or cell reversal error	Contact Valence
	3 seconds	Module is in active mode and a shutdown condition exists: OV, UV, OC, PCBA OT, terminal OT, flash error, temp measurement error, voltage measurement error, oscillator error, program checksum error, sanity error, and/or cell reversal error	Contact Valence
 	Red and green flashing alternately	Electronics fault	Contact Valence

	Any color remains on	Electronics fault	Contact Valence
	LED is not illuminated	Electronics fault	Contact Valence

3.6 Dealing with Error Conditions with the U24-24XP and the U27-24XP

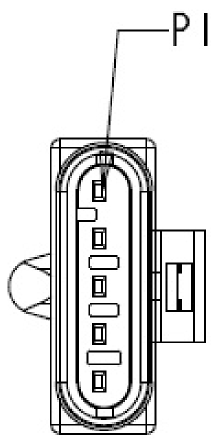
As mentioned above, warnings and alarms (yellow LED) are resettable. Shutdowns and errors (red LED) are not. The table shows that several different warnings or alarms can cause the LED to turn yellow. To determine exactly which condition is active requires connecting the module to a PC running the Module Diag software, or to a BMS and to a PC running the Configuration, Monitoring and Diagnostic software (CMD). The following table describes how to reset warnings or alarms:

Table 3-3: Remediating Errors with the U24-24XP and the U27-24XP

Condition	Action
Over temperature	Reduce the current flow and allow the module to cool
Under temperature	Warm the module
Over voltage	Discharge the module using a BMS to monitor the process
Under voltage	Charge the module using a BMS to monitor the process
Over current warning	Reduce the current flow
PCBA over temperature	Reduce the current flow and allow the module to cool
Terminal over temperature	Check for a loose connection, or reduce the current flow and allow the module to cool

4. Communications

Each XP Module has one male and one female AMP SUPERSEAL® connector for serial communications. This allows daisy-chain communication among modules. The final module added to the serial link will have an unused connector. Connect a 120 Ω termination plug, Valence part # 1005187 (male).



Pin	Signal Name	Pin Type	Description
1	SHIELD	Power	Shield
2	GROUND	Power	Ground for serial communication
3	B (+)	Signal	B signal for serial communication
4	A (-)	Signal	A signal for serial communication
5	VCC (+5)	Power	Power supply for serial communication

Figure 4-1: AMP SUPERSEAL® Pinout

Valence can provide extension cables that are 0.5, 1 and 2 meters long. In the event that making a custom cable is necessary, it should comply with the following requirements:

- **Connectors:**
  - Receptacle (Female): TE Connectivity / AMP SUPERSEAL® 1.5 Series P/N: 282089-1
  - Tab (Male): TE Connectivity / AMP SUPERSEAL® 1.5 Series P/N: 282107-1
- **Bulk Cable:**
  - Multi-conductor, 24 AWG (7/32) tinned copper, suitable for data communication
  - 2 twisted pairs (pins 2&5 and pins 3&4) with overall foil or braid shield (pin 1)
  - 120 Ω characteristic impedance
  - Low capacitance
  - UL safety rated

- Length under 100 ft. (30.5 m)
- Examples include Alpha Wire 6413, Automation Direct L19954, Belden 9842, and General Cable C0842A

For proper performance, the shield signal should be passed through all the cable connections, but tied to ground at a single point (preferably at the BMS).

5. Installation

CAUTION: When multiple modules are connected in series, a lethal DC voltage may be present.

When working with XP Power System components, please follow standard electrical safety practices. In addition, please consider the following safety information:

- Workers must be qualified for electrical work
- Wear eye protection
- Remove any possible metallic shorting risk
    - Rings, jewelry, watches, pens, metal bars, and frames
- All tools must be insulated

Important! Be sure to turn off power to the load and charger prior to installation.

5.1 Mounting Hardware and Recommended Torque

The following table details the bolt sizes, required wrench size, and recommended torque for each module:

Important: Do not apply thread locker, corrosion inhibitor, or lubricant to the bolts as this may damage parts of the module and/or alter the torque required to tighten bolts.

Table 5-1: Hardware and Recommended Torque

Module Type	Mounting Hardware	Quantity	Wrench	Torque
U1-12XP	M6 x 1.0 thread/ terminal washer/ spring washer	2 each	10 mm	12.4 Nm (110 in-lbs.)
U24-12XP, U27-12XP, UEV-18XP, U27-36XP	M8 x 1.25-12/ terminal washer/ spring washer	2 each	13 mm	16 Nm (141.6 in-lbs.)
U24-24XP and U27-24XP (See also Appendices D and E)	M8 x 1.25-12 terminal washer	4 each	13 mm	25 Nm (222 in-lbs.)

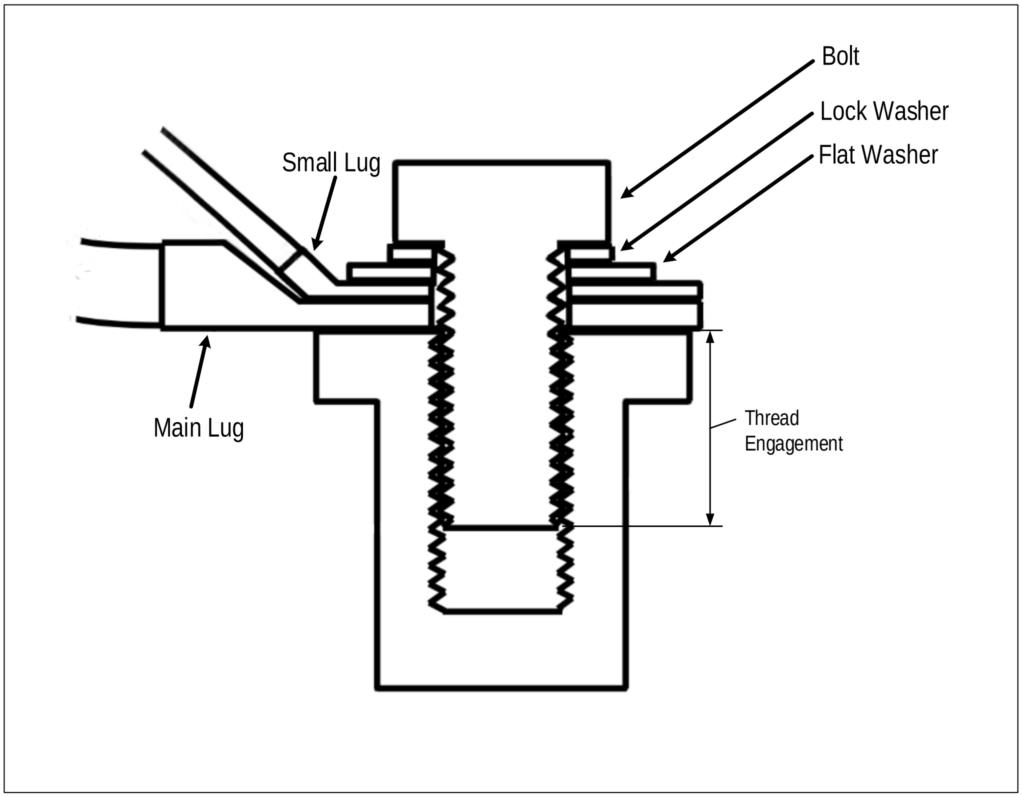


Figure 5-1: Cross-section of terminal and bolt

The ideal bolt will allow a good physical connection, and not bottom out. The bolt should be sized to achieve a recommended thread engagement of 8 to 12 mm.

5.2 Module Identification Number

Each module comes with an Identification number assigned by Valence. It is located on the sticker on the top of the module, as seen below (sticker location may vary slightly):

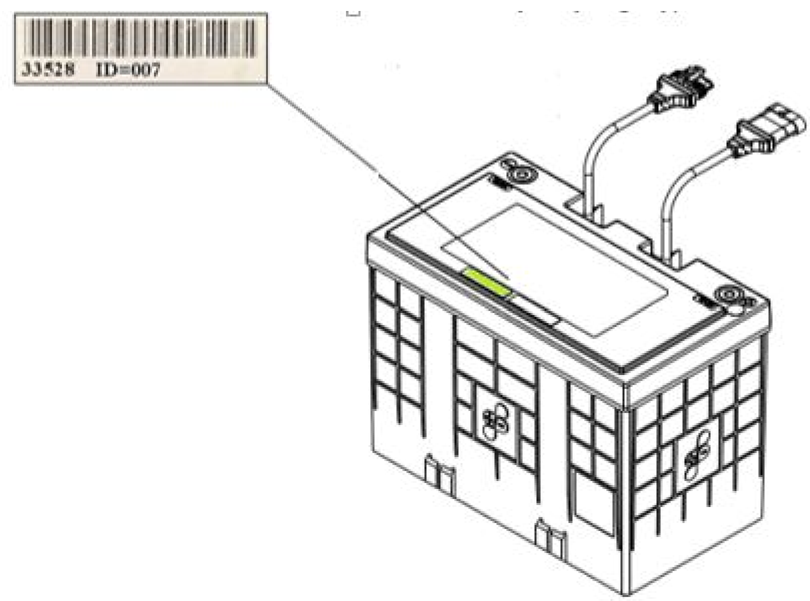


Figure 5-2: Module ID Sticker

Make sure all XP Modules in the system have a different identification number (ID) listed in a sequential order from 1 to *n* (*n*=total number of modules). If a set of modules is ordered together for a particular configuration, Valence will preconfigure the IDs as 1, 2, 3...n

If it becomes necessary to change a module ID use the Diagnostic Kit and the relevant module software (see Section 2.6).

When hooking serial strings in parallel, each string needs to have IDs in sequential order, (i.e. in a 4S2P system, String 1 uses 1-4, String 2 uses 5-8), refer to Figure 5-3 as an example. The exact physical ordering does not matter (i.e. module 4 can be between modules 3 and 2). It is recommended to keep a diagram of where each module is in the battery pack for diagnostic purposes.

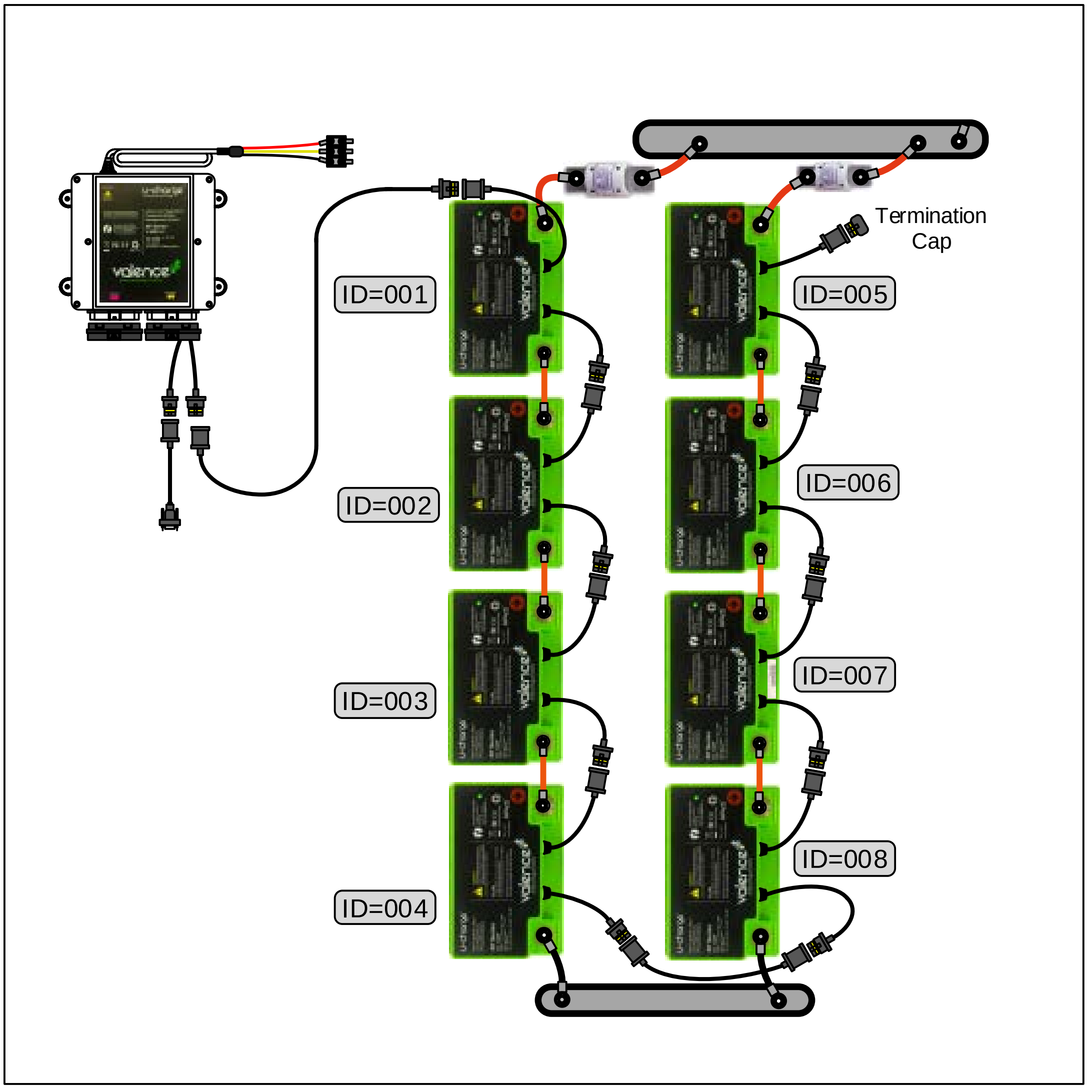


Figure 5-3: Module IDs in Sequence

5.3 Location and Orientation

When choosing the installation location for your XP Modules, please follow the guidelines below:

- Do not install near heat generating equipment.
- Do not install 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 where vibration is not an issue.
- 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 modules.
- Valence recommends that modules be installed so that the terminals are facing up. If necessary, a module can be installed on its side with the terminals facing out, however please ensure that it will not come into contact with water or metal, such as a cabinet door, in this orientation. The module can be installed with the terminals facing down, but balancing may take longer since more heat may build up on the controller board inside the module.

For further details please contact Valence Technical Support.

6. System Configurations

The following sections provide detail on installation of the XP Power System in various configurations. Please see Section 2 above for assistance in determining the appropriate configuration for your application.

IMPORTANT: Modules wired together should be at the same state of charge and voltage.

6.1 Single Module

Single XP Modules provide nominal voltages of 12.8 V, 19.2 V, 25.6 V or 38.4 V. A single module configuration is known as 1S1P, shown below in Figure 6-1 . If higher voltage and/or increased capacity is needed, refer to Section 2.7 for examples.

1. Ensure that the battery module has the ID number set to 1. If the module was purchased from Valence it should come already configured with ID number set to 1. If not, use the Module Diagnostics software to change the ID to 1.
2. Fasten the battery module securely in position so it cannot move.
3. Ensure that the device/equipment is turned off prior to connecting the power cables. Some equipment may have banks of capacitors that are connected directly to the output which can cause a sudden current spike and weld contactors when energized. Refer to the installation instructions for the specific equipment before connecting the battery system to determine if a pre-charge contactor and pre-charge resistor are recommended.
4. A minimum of one contactor controlled by the BMS and an in-line fuse are required for protection of the battery. Some systems may require more than one contactor for separate control of charge and discharge paths, and/or if pre-charge is needed. Refer to the BMS User Guide for more details.
5. Install a properly sized in-line fuse as shown in Figure 6-1. Use flexible insulated copper cables of the appropriate gauge for connections to the battery. The same gauge cable should be used for all power connections.
6. Before making connections to the contactor, use a meter to ensure the contacts are open. Attach an interconnect cable from one side of the contactor to +DC Out, then connect the positive cable from the device/equipment to other side of the contactor as shown in Figure 6-1.
7. Attach the negative cable from the device/equipment to the negative battery terminal, -DC Out as shown in Figure 6-1.

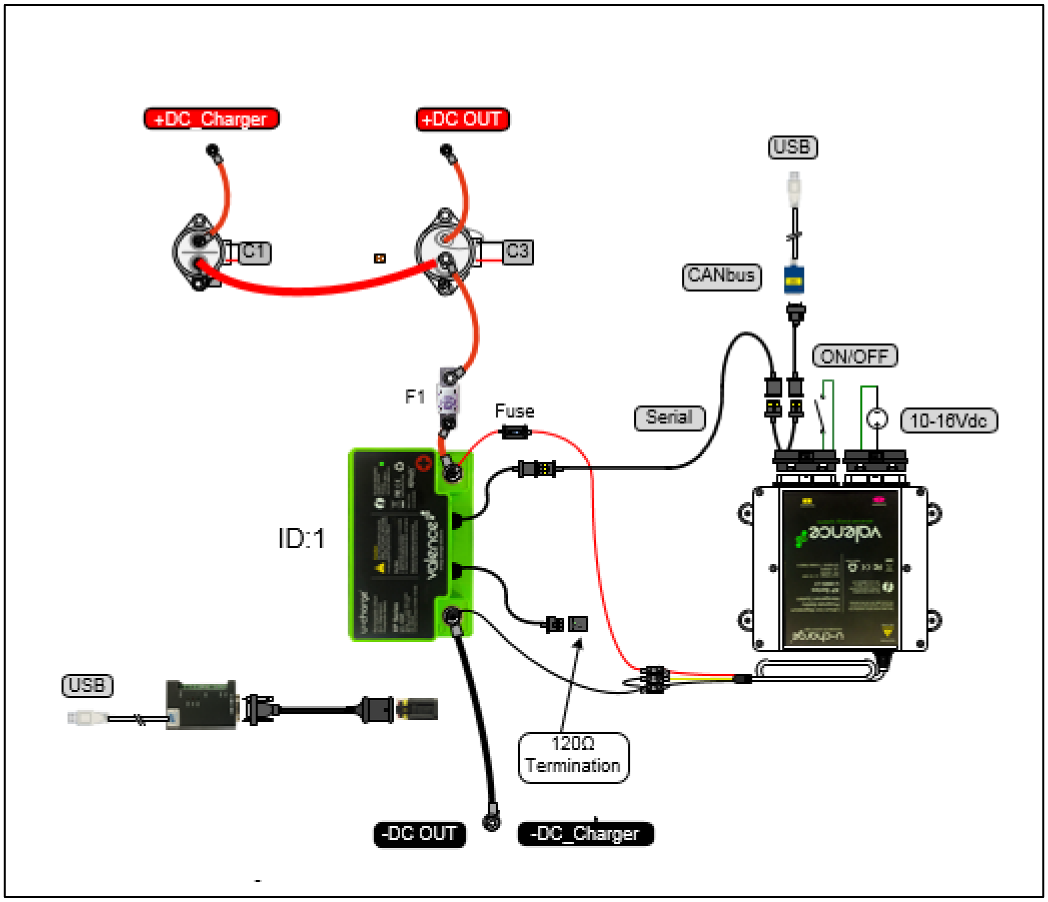


Figure 6-1: Single Module

6.2 Series

Series configurations allow a higher voltage while the capacity remains the same. The configuration in this example is known as 4S1P, shown below in Figure 6-2.

1. Each battery module should have a different ID number, as described in Section 5.2. When installing the modules into position, make note of the location of each ID# for future reference.
2. Fasten all battery modules securely in position so they cannot move.
3. Ensure that the device/equipment is turned off prior to connecting the power cables. Some equipment may have banks of capacitors that are connected directly to the output which can cause a sudden current spike and weld contactors when energized. Before connecting the battery system refer to the installation instructions for the specific equipment to determine if a pre-charge contactor and pre-charge resistor are recommended.
4. Confirm that the voltages across each module are close to the same. If they are not it will be difficult for the BMS to balance all of the modules. If some modules are lower than the others, consider charging the lower modules on a single module charger. Contact Valence Technical Support for suggestions.
5. A minimum of one contactor controlled by the BMS and an in-line fuse are required for protection of the batteries. Some systems may require more than one contactor, for separate control of charge and discharge paths, to open both the positive and negative ends of the string, and/or if pre-charge is needed. Refer to the BMS User Guide wiring section for more details.
6. Install a properly sized in-line fuse in the center or at the end of the series string as shown in Figure 6-2. Install flexible insulated copper interconnect cables of the appropriate gauge for all connections to the battery modules. The same gauge cable should be used for all of the series string connections. Depending on the physical layout of the battery string, it may be better to make the final power connection at the mid-pack connection, at the end of step 7 below.
7. Before making connections to the contactors, use a meter to ensure the contacts are open. Attach an interconnect cable from one side of the contactor +DC Out, then connect the positive cable from the device/equipment to other side of the contactor as shown in Figure 6-2.
8. Attach the negative cable from the device/equipment to the negative terminal of the lowest potential battery module, -DC Out as shown in Figure 6-2.

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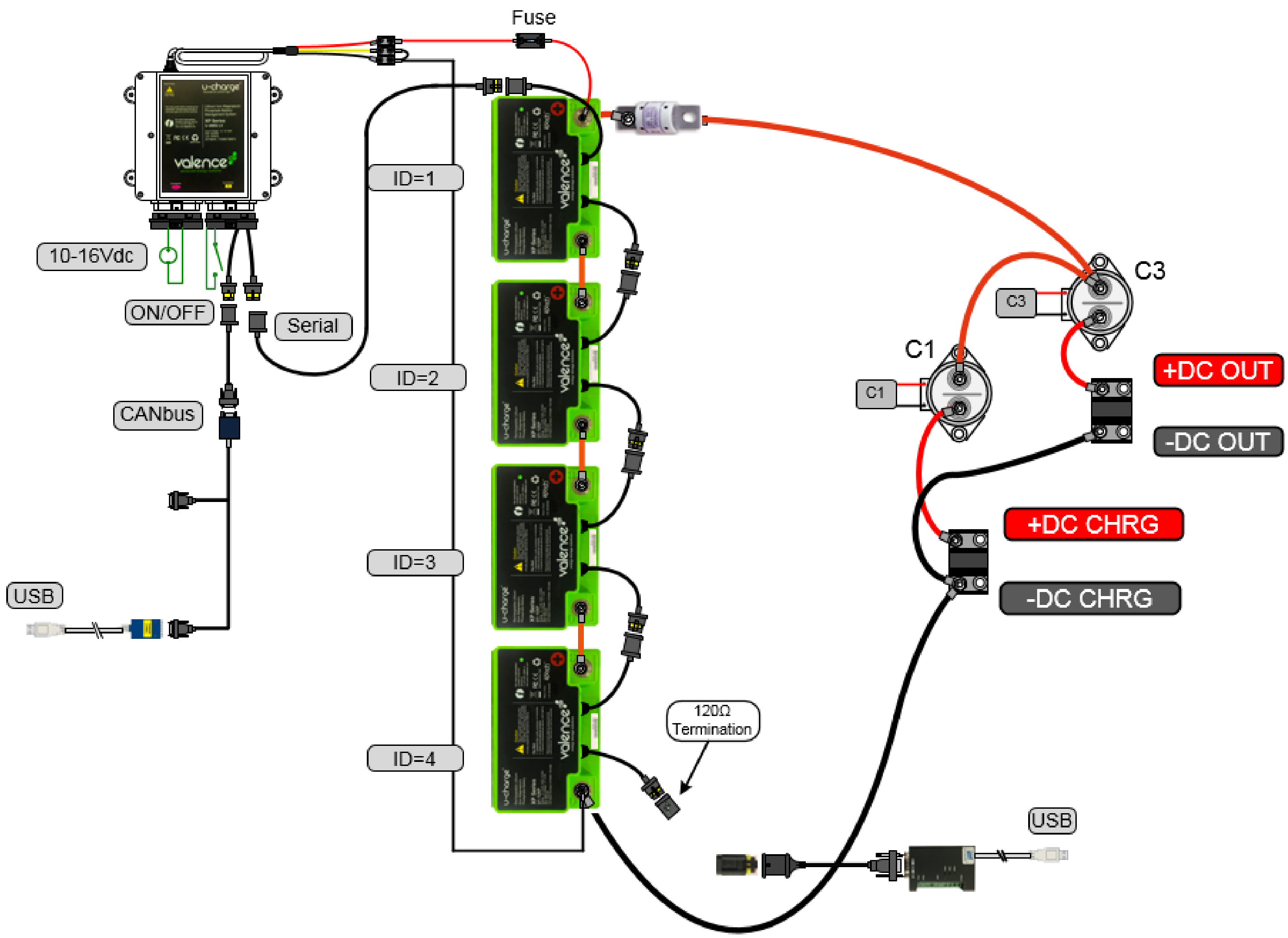


Figure 6-2: Series Configuration

6.3 Parallel

Parallel configurations allow the capacity to increase, while the voltage remains the same. The configuration in this example is known as 1S4P, that is, 4 strings of 1 module each in parallel.

The internal resistance of the modules is very low in comparison with other battery technologies. Special care is required to ensure that interconnect cables of identical resistance, the same gauge and length are installed. The system connections to the pack (+DC Out and –DC Out) are deliberately offset as shown in

Figure 6-4 below. When installing battery modules in parallel, ensure that they are at the same voltage and state of charge prior to installation.

1. Each battery module should have a different ID number as described in Section 5.2. When installing the modules into position, make note of the location of each ID number for future reference.
2. Fasten all battery modules securely in position so they cannot move.
3. Ensure that the device/equipment is turned off prior to connecting the power cables. Some equipment may have banks of capacitors that are connected directly to the output which can cause a sudden current spike and weld contactors when energized. Before connecting the battery system refer to the installation instructions for the specific equipment to determine if a pre-charge contactor and pre-charge resistor are recommended.

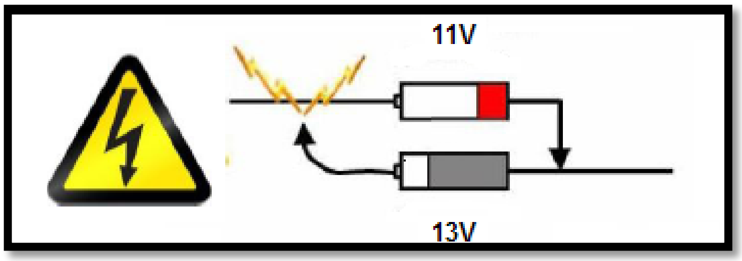


Figure 6-3: Risk of Excessive Current Flow and Arcing

4. Ensure that the voltages of each battery module are the same prior to connecting the batteries in parallel. A voltage differential can cause arcing and a large surge of current. This sudden energy transfer can be extremely dangerous and the resulting circulating current into the lower voltage battery may over-charge any cells in a battery module which are close to fully charged, as shown in Figure 6-3 above.
5. Install a properly sized in-line fuse to each battery as shown in Figure 6-4. Install flexible insulated copper interconnect cables of the appropriate gauge for all connections to the battery. Use the same gauge and length cable for all series string connections. Use the same gauge and length cable for joining the strings in parallel. A main in-line fuse can also be used, but the series string fuses are still required.
6. A minimum of one contactor controlled by the BMS is required for protection of the batteries. Some systems may require more than one contactor, for separate control of charge and discharge paths, to open both the positive and negative ends of the string, and/or if pre-charge is needed. Refer to the BMS User Guide for more details.
7. Before making connections to the contactors, use a meter to ensure the contacts are open. Attach an interconnect cable from one side of the contactor to +DC Out, then connect the positive cable from the device/equipment to other side of the contactor as shown in Figure 6-4.
8. Attach the negative cable from the device/equipment to –DC Out as shown in Figure 6-4.

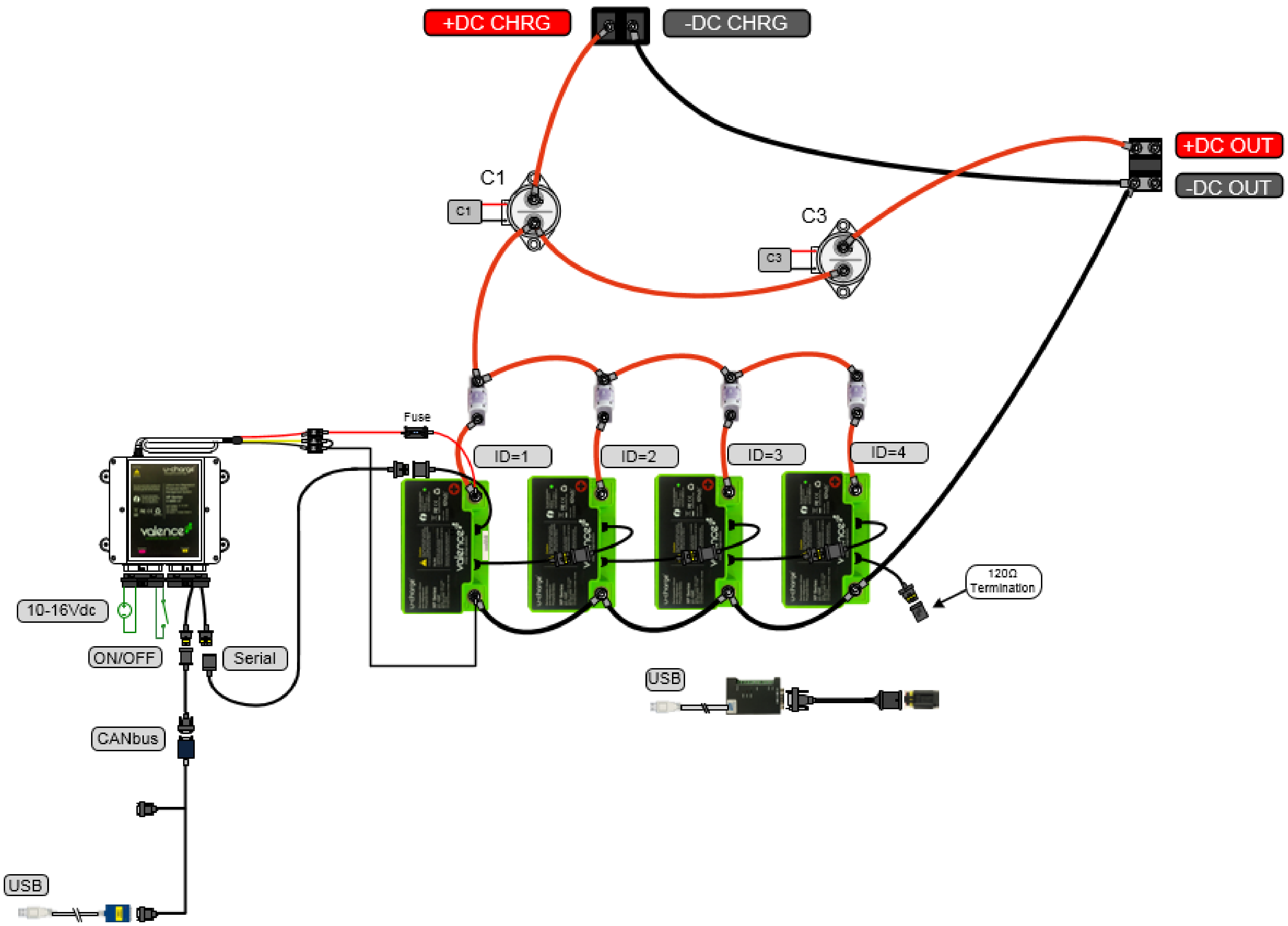


Figure 6-4: Parallel Configuration

6.4 Parallel & Series

Series parallel configurations allow both the voltage and capacity to increase. The configuration in this example is known as 4S2P, shown below in Figure 6-6.

The internal resistance of the modules is very low in comparison with other battery technologies. Special care is required to ensure that interconnect cables of identical resistance, the same gauge and length are installed. The system connections to the pack (+DC Out and –DC Out) are deliberately offset as shown in Figure 6-6 below.

When installing battery modules in series and parallel, ensure that they are at the same voltage and state of charge prior to installation. This will enable the maximum capacity to be realized from your pack quickly without the need for excessively long initial charge and balance time.

1. Each battery module should have a different ID number as described in Section 5.2. When installing the modules into position, make note of the location of each ID number for future reference.
2. Fasten all battery modules securely in position so they cannot move.
3. Ensure that the device/equipment is turned off prior to connecting the power cables. Some equipment may have banks of capacitors that are connected directly to the output which can cause a sudden current spike and weld contactors when energized. Before connecting the battery system refer to the installation instructions for the specific equipment to determine if a pre-charge contactor and pre-charge resistor are recommended.

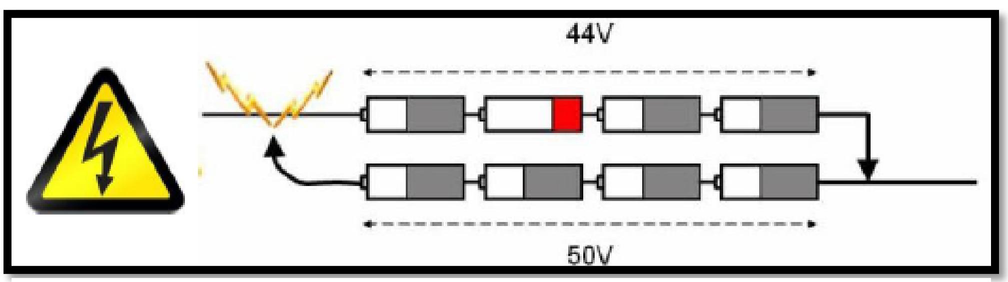


Figure 6-5: Risk of Excessive Current Flow and Arcing

4. Ensure that the voltages of each string are the same prior to connecting the strings in parallel. A voltage differential can cause arcing and a large surge of current. This sudden energy transfer can be extremely dangerous and the resulting circulating current into the lower voltage string may over-charge any cells in a battery module which are close to fully charged, as shown in figure 6-5.
5. Install a properly sized in-line fuse in the center or at the end of each series string as shown in Figure 6-6. Install flexible insulated copper interconnect cables of the appropriate gauge for all

connections to the battery modules. Install the series string cables first, use the same gauge and length cable for all series string connections. Install the parallel cables using the same gauge and length cable for joining the strings in parallel. A main in-line fuse can also be used, but the series string fuses are still required.

Note: Do not join the strings in parallel at any of the mid series string connections.

6. A minimum of one contactor controlled by the BMS is required for protection of the batteries. Some systems may require more than one contactor, for separate control of charge and discharge paths, to open both the positive and negative ends of the string, and/or if pre-charge is needed. Refer to the BMS User Guide for more details.
7. Before making connections to the contactors, use a meter to ensure the contacts are open. Attach an interconnect cable from one side of the contactor to +DC Out, then connect the positive cable from the device/equipment to other side of the contactor.
8. Attach the negative cable from the device/equipment to –DC Out.

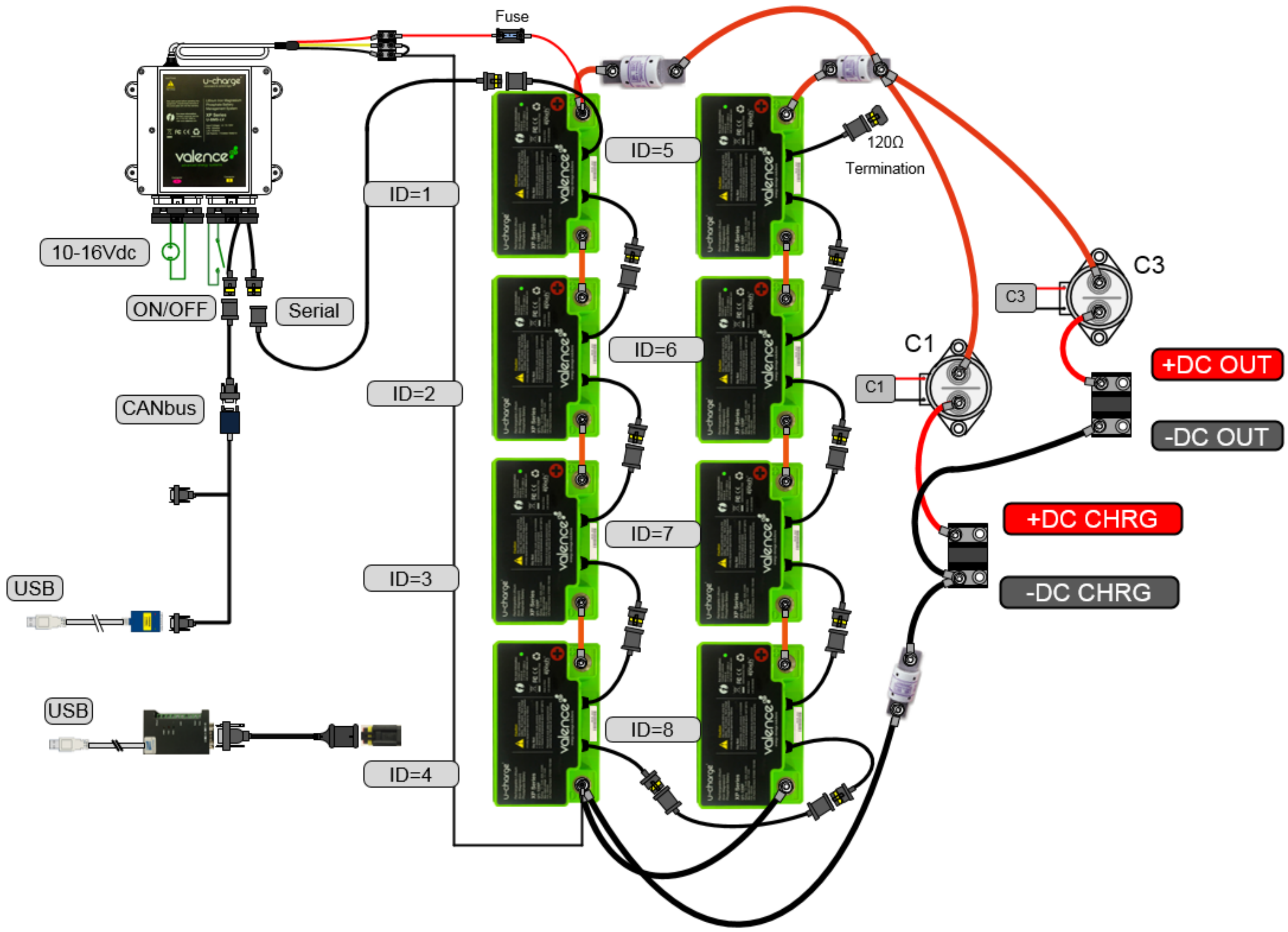


Figure 6-6: Parallel and Series Connection

7. Shipping, Storage, Maintenance and Disposal

7.1 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 Transportation currently has a specific exclusion for ground transport which requires UN 3480 Class 9. Valence advises that you verify current regulations with your specific carrier. The battery cartons and associated packing material are specifically designed and marked for compliant transportation. It is advisable to retain all material for any onward transport.

ALSO IMPORTANT: Shipping Valence modules by air involves following some very specific restrictions. Contact Valence Technology for help.

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

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

7.2 Module Storage

- When a module 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 module can be stored safely for up to a year, without the need for recharge. (It is advisable to check the condition, module voltage, and charge the module periodically with the BMS attached.)
- Store in a well-ventilated, clean, and dry area with a temperature between -40 °C and 50 °C. For maximum life, the ideal storage temperature is < 30 °C.
- Do not expose the module to extremes of temperature over 60 °C (140 °F).
- Do not expose the module to direct sunlight or moisture and/or precipitation.
- Handle each module carefully to avoid sharp impacts or extreme pressure on the case.

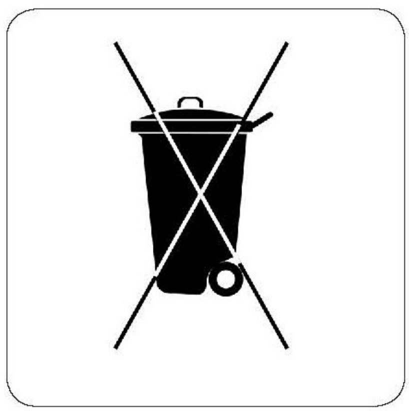
7.3 Storage Checks and Maintenance Charging

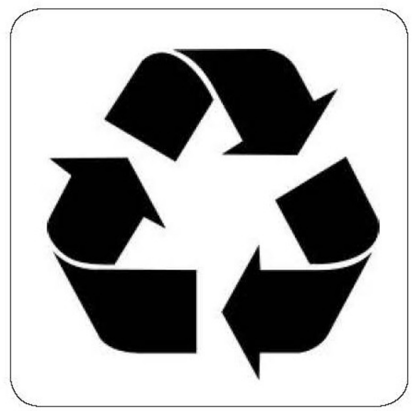
While being stored, the voltage of each module should be measured and the modules inspected every 6 months to assess their health.

If long storage periods are regularly planned, a maintenance charge routine should be established. Contact Valence Technical Support for help with determining the maintenance charging routine.

If you find that the voltage across a single -12XP module is less than 10 V (15 V for UEV-18XP, 20 V for the U27-24XP or the U24-24XP, or 30 V for the U27-36XP) at room temperature, the module has been over-discharged or is self-discharging due to some defect/parasitic load. If no LED is flashing, contact Valence Technical Support.

7.4 Disposal





A battery module must not be disposed of in a fire or with ordinary waste; it should be recycled in accordance with local laws and statutes.

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 to achieve this, please contact Valence Technical Support.

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

8. Glossary

Ah: Ampere (amp) hours, a unit of electric charge, equal to the charge transferred by a steady current of one ampere flowing for one hour

Battery Pack: A group of modules attached in series and/or in parallel

BCI: Battery Council International

CAN bus: Controller Area Network bus, a standard communication link used for automotive systems

Cell: A single battery cell representing 3.2 V nominal

Cell Bank: A group of cells configured in parallel with permanent welded metal plate connections

PCBA: Printed Circuit Board Assembly

SOC: State of Charge

U-Charge®: Brand name for a range of Valence energy storage system products

U-BMS: Valence Battery Management System for U-Charge®

XP Module: A single U-Charge® XP is made up of 4 to 12 Cell Banks in series. These circuits are paralleled to give the required capacity. The U1-12XP, U24-12XP and U27-12XP have 4 Cell Banks in series with a nominal voltage of 12.8 V. The UEV-18XP has 6 series Cell Banks with a nominal voltage of 19.2 V. The U27-24XP has 8 series Cell Banks with a nominal voltage of 25.6 V. Finally, the U27-36XP has 12 series Cell Banks with a nominal voltage of 38.4 V.

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.

Wh: One watt for one hour. This is simply Ah multiplied by the voltage.

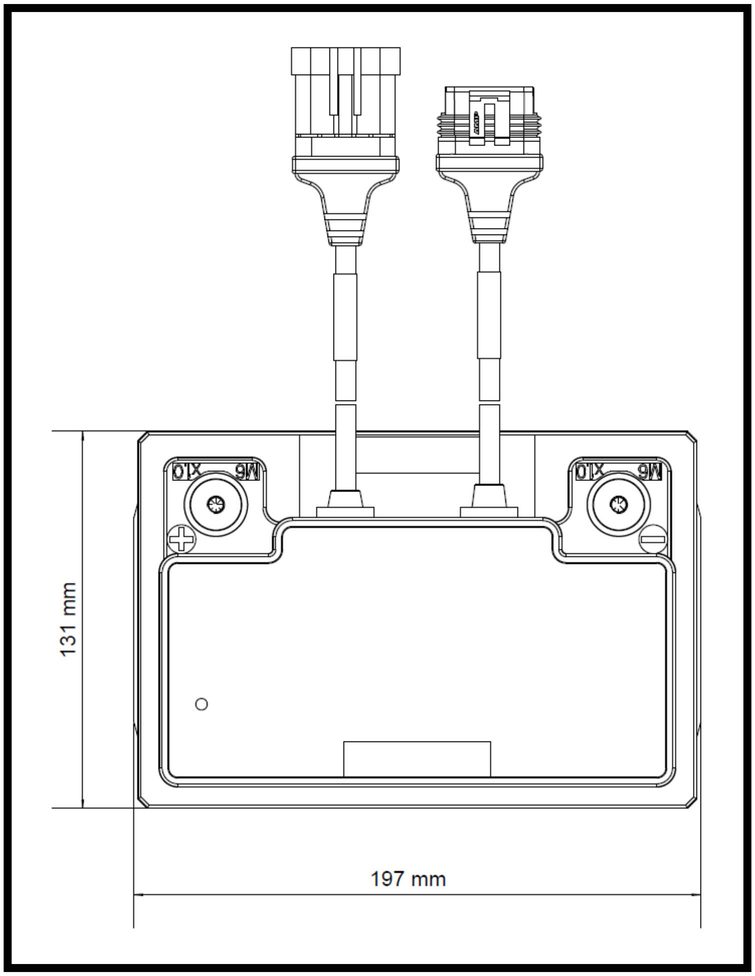
(x)S(y)P: This is an abbreviation used for module configuration in series and parallel. In this example, x would indicate the number of modules in series, and y would indicate the number of parallel strings.

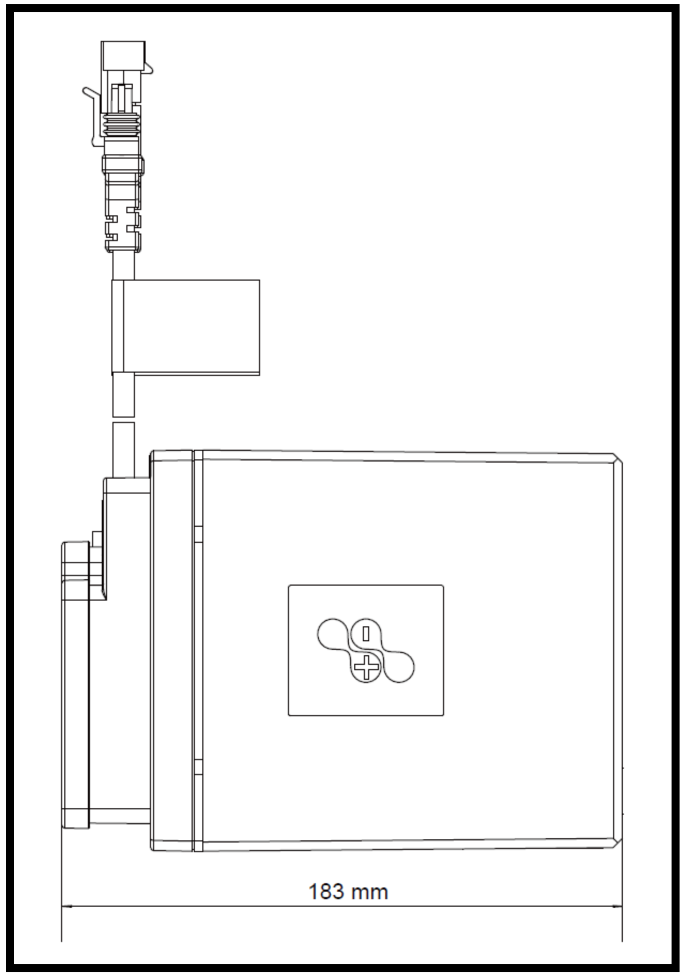
Appendix A. Data Sheet Information

Specifications		U1-12XP	U24-12XP	U27-12XP	UEV-18XP	U24-24XP	U27-24XP	U27-36XP
Nominal Module Voltage		12.8 V	12.8 V	12.8 V	19.2 V	25.6 V	25.6 V	38.4 V
Nominal Capacity (C/5, 23°C)		40 Ah	110 Ah	138 Ah	69 Ah	56 Ah	69 Ah	46 Ah
Weight (approximate) kg		6.5 kg	15.8 kg	19.5 kg	14.9 kg	15.8 kg	18.6 kg	19.6 kg
Weight (approximate) lbs		14.3 lbs	34.8 lbs	42.9 lbs	32.8 lbs	34.8 lbs	42.9 lbs	43.1 lbs
Dimension incl. Terminals LxWxH (mm) Dimension incl. Terminals LxWxH (inches)		197 x 131 x 182 7.8 x 5.1 x 7.2	260 x 172 x 225 10.2 x 6.8 x 8.9	306 x 172 x 225 12.0 x 6.8 x 8.9	269 x 148 x 245 10.6 x 5.8 x 9.7	260 x 172 x 225 10.2 x 6.8 x 8.9	306 x 172 x 225 12.0 x 6.8 x 8.9	306 x 172 x 225 12.0 x 6.8 x 8.9
BCI Group Number		U1R	Group 24	Group 27	N/A	Group 24	Group 27	Group 27
Terminals, Female-Threaded		M6 x 1.0	M8 x 1.25	M8 x 1.25	M8 x 1.25	M8 x 1.25	M8 x 1.25	M8 x 1.25
Specific Energy		79 Wh/kg	89 Wh/kg	91 Wh/kg	89 Wh/kg	91 Wh/Kg	95 Wh/kg	91 Wh/kg
Energy Density		110 Wh/l	139 Wh/l	148 Wh/l	136 Wh/l	142 Wh/l	148 Wh/l	148 Wh/l
Standard Discharging @ 25°C	Max. Cont. Load Current Peak Load Current (30 sec) Cut-off Voltage	80 A 120 A 10 V	150 A 300 A 10 V	150 A 300 A 10 V	120 A 200 A 15 V	112A 168 A 20 V	138 A 207 A 20 V	90 A 135 A 30 V
Standard Charging	Charge Voltage Recommended Current C/2 Charge Time C/2 *	14.6 V 20A 2.5 hrs	14.6 V 55A 2.5 hrs	14.6 V 70A 2.5 hrs	21.9 V 35A 2.5 hrs	29.2 V 28 A 2.5 hrs	29.2 V 35A 2.5 hrs	43.8 V 23A 2.5 hrs
DC internal resistance (max)		15 mΩ	6 mΩ	5 mΩ	10 mΩ	18 mΩ	15 mΩ	25 mΩ
Part Number		1004434	1004425	1004428	1004431	1007735	1007520	1005199

Appendix B. U1-12XP Mechanical Dimensions

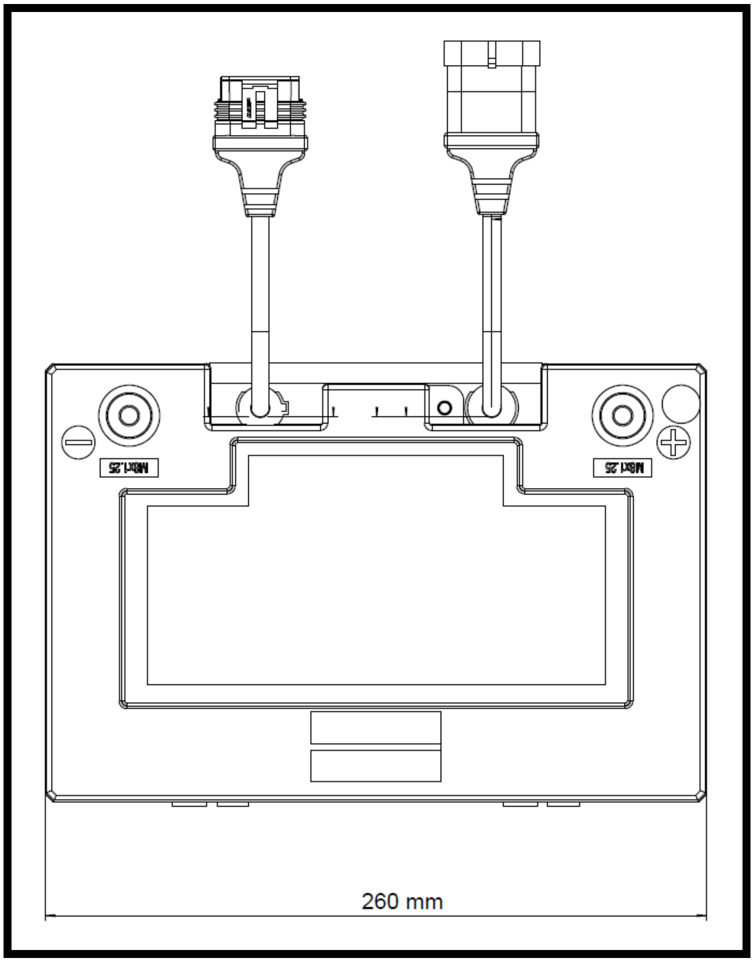
U1-12XP Module Mechanical Dimensions

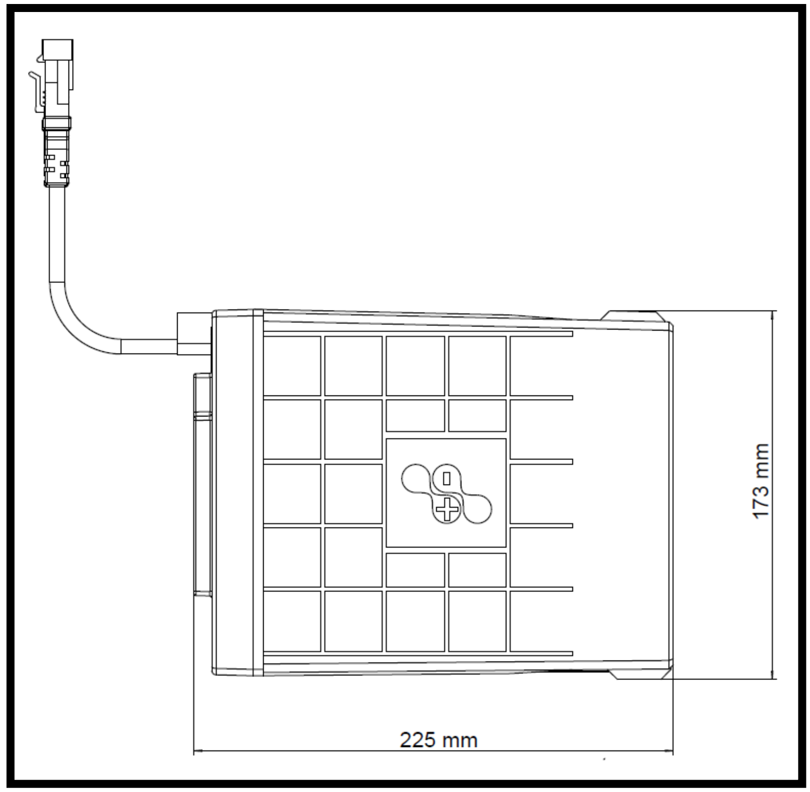




Note: The height dimension does not include bolts or cables that are attached to the terminal. 3D model available upon request.

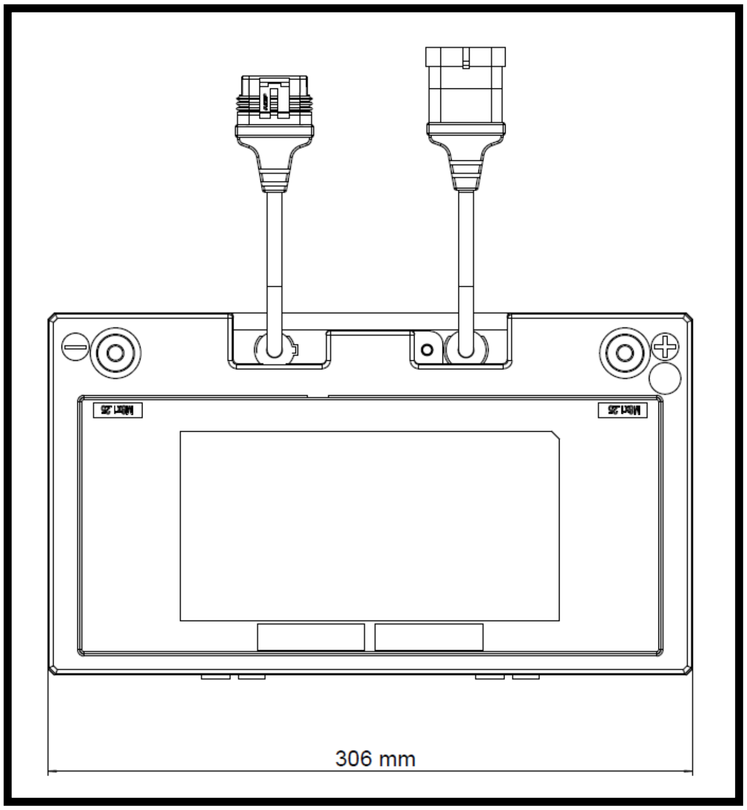
Appendix C. U24-12XP / U24-24XP Module Mechanical Dimensions

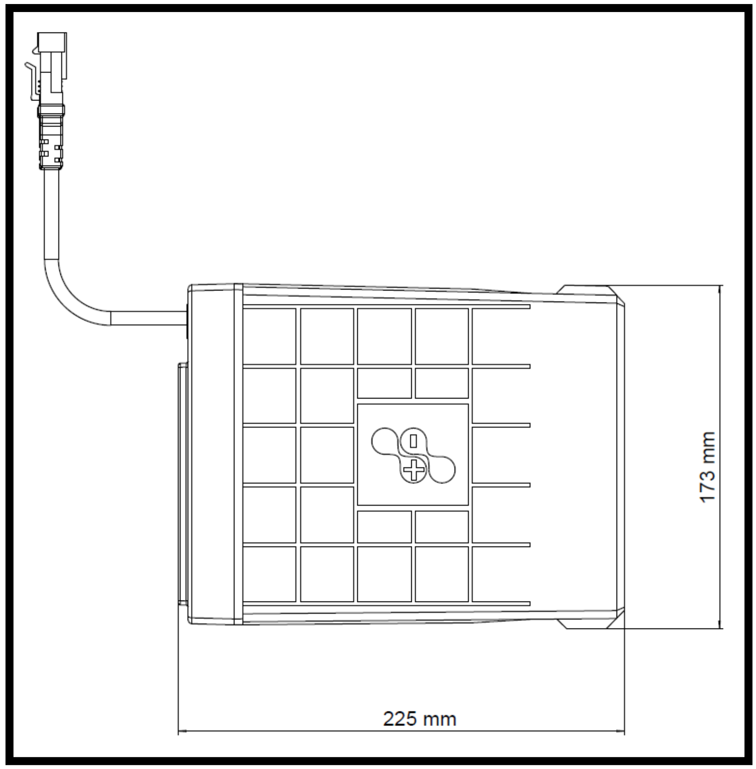




Note: The height dimension does not include bolts or cables that are attached to the terminal. 3D model available upon request.

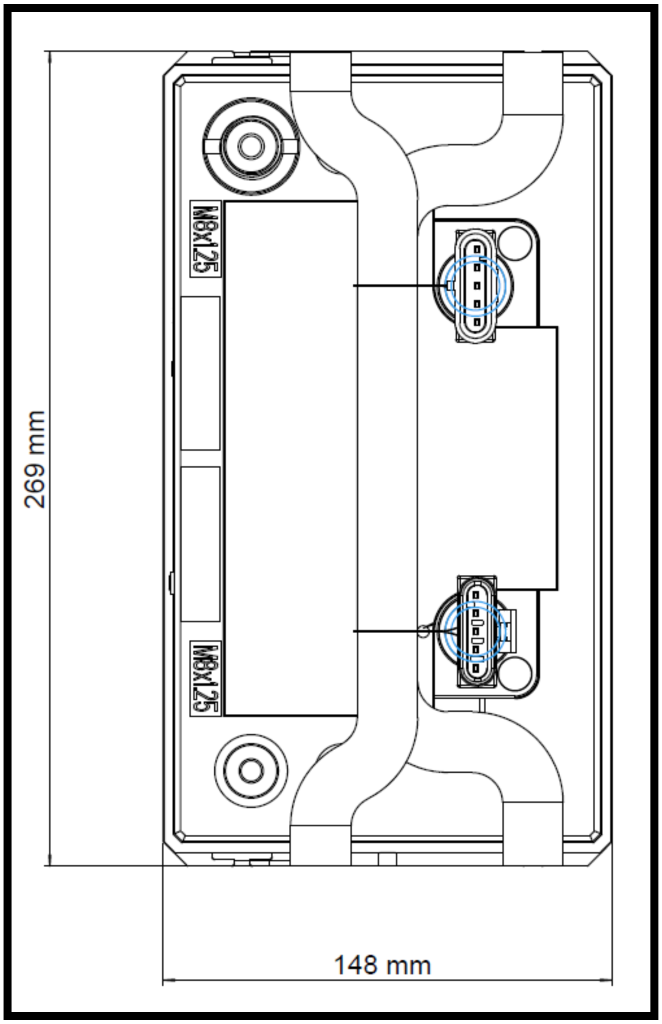
Appendix D. U27-12XP / U27-24XP / U27-36XP Module Mechanical Dimensions

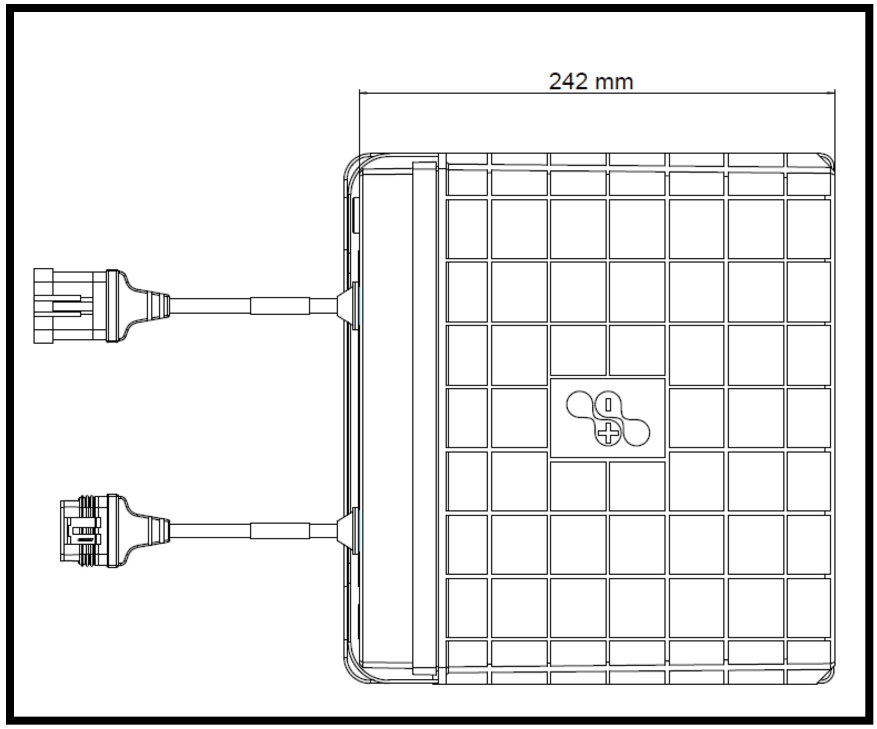




Note: The height dimension does not include bolts or cables that are attached to the terminal. 3D models available upon request.

Appendix E. UEV-18XP Module Mechanical Dimensions





Note: The height dimension does not include bolts or cables that are attached to the terminal. 3D models available upon request.

Appendix F. 24XP Power Terminals

The power terminals on the U24-24XP and the U27-24XP are different from the terminals on the other modules in the series. The module's terminals look like this:

Each terminal has two bolts instead of the single bolt used on the other modules. The holes are 1.0 inch center to center. The matching bolts are M8 x 1.25 inches. The recommended torque is 222 in-lbs. or 25 N-m.

The bolt holes are tapped using locking thread technology, designed to grip the bolt tighter than traditional tapped holes do. This special thread may eliminate the need for a lock washer to keep the bolt tight. Valence still recommends that a flat washer be used to maximize the surface area of the electrical connection.

These dual bolt terminals can be used in several ways.

- Longer than usual cable lugs are available that have two bolt holes in them. These lugs offer more surface area to improve the electrical connection.
- When connecting modules in parallel, the traditional single bolt design requires that two lugs be stacked on top of each other. This results in a less-than-ideal electrical connection. With two bolts, one cable can be attached to the one bolt and the second cable attached to the other.

Corporate Headquarters
North America Sales

1807 West Braker Lane, Suite 500
Austin, Texas 78758
USA

Tel: +1 (512) 527-2900
Fax: +1 (512) 527-2910
Email: www.valence.com/contact

EMEA

Sales

Unit 63 Mallusk Enterprise Park
Mallusk Drive
Mallusk Newtownabbey
County Antrim
Northern Ireland
BT36 4GN

Tel: +44(0) 28 9084 5400
Fax: +44(0) 28 9083 8912
Email: www.valence.com/contact

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