Endrich ALE 12V7 Series

User's Guide

End User Documentation

Rev. 2.2

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乾坤富實業有限公司

ENDRICH Co.,Ltd.

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Revision Control

Rev.	Date	Notes
1	2020/03/24	Initial Design Release
2	2021/05/25	Modify the product name to ALE12V7 Series include ALE12V7s and ALE12V7h. Modify the capacity to 5Ah.
2.1	201/06/08	Modify table7 charge rate vs. temperature
2.2	2021/06/24	Modify table 3 12V7h minimum to 9.2V, page 25 Over Current Protection description, Table 10 parameter

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Preface

About this Document

This Endrich ALE 12V7 Series User's Guide provides detailed specifications for the ALE 12V7 Series batteries. It also provides guidance on safely and effectively configuring, and operating ALE 12V7 Series batteries as building blocks in various applications.

Intended Users

This Endrich ALE 12V7 Series User's Guide is intended for all personnel involved in designing, configuring and installing ALE 12V7 Series batteries.

Conventions Used in this Guide

Notes, Caution, Warning, and Danger Notices

NOTE

A NOTE notice presents information that is important, but not hazard-related

REMARK

A REMARK notice presents important information but not related to dangerous situations.

CAUTION

A CAUTION notice identifies conditions or practices that could result in minor or moderate injury, or damage to the equipment.

ATTENTION

An ATTENTION notice contains information essential to avoid damage to the system or equipment. The warning could apply to hardware or software.

WARNING

A WARNING notice contains information essential to avoid a hazard that can cause severe personal injury, death, or substantial property damage if you ignore the message.

DANGER

A DANGER notice contains information essential to avoid a hazard that will cause severe personal injury, death, or substantial property damage if you ignore the message.

Chapter 1

Introducing the ALE 12V7 Series Battery

Overview

Endrich' ALE 12V7 Series Lithium ion batteries are designed as drop-in replacements for 12-volt, 7-Ah, lead-acid battery(Figure 1). It provides improved performance with higher power, increased safety and exceptional calendar and cycle life compared to12-volt, 7-Ah, lead-acid batteries. They typically serve as a standby power source in many high-availability and service-critical applications.

The ALE 12V7 Series batteries are identical in size to common 12-volt, 7Ah, lead-acid batteries and designed to be compatible with most lead-acid chargers. This combination reduces product integration costs, minimizes OEM customer's time to market and aftermarket customer replacement hurdles.

ALE 12V7 Series Battery Protection Scheme

Each ALE 12V7 Series battery has integrated protection and balancing circuitry (Figure 2) that safeguar the battery from over-voltage, under-voltage, short-circuit and over-temperature conditions. At the core of the ALE 12V7 Series are eight Lithiumwerks ANR26650 cells in a four-series, two-parallel (4S2P) configuration.

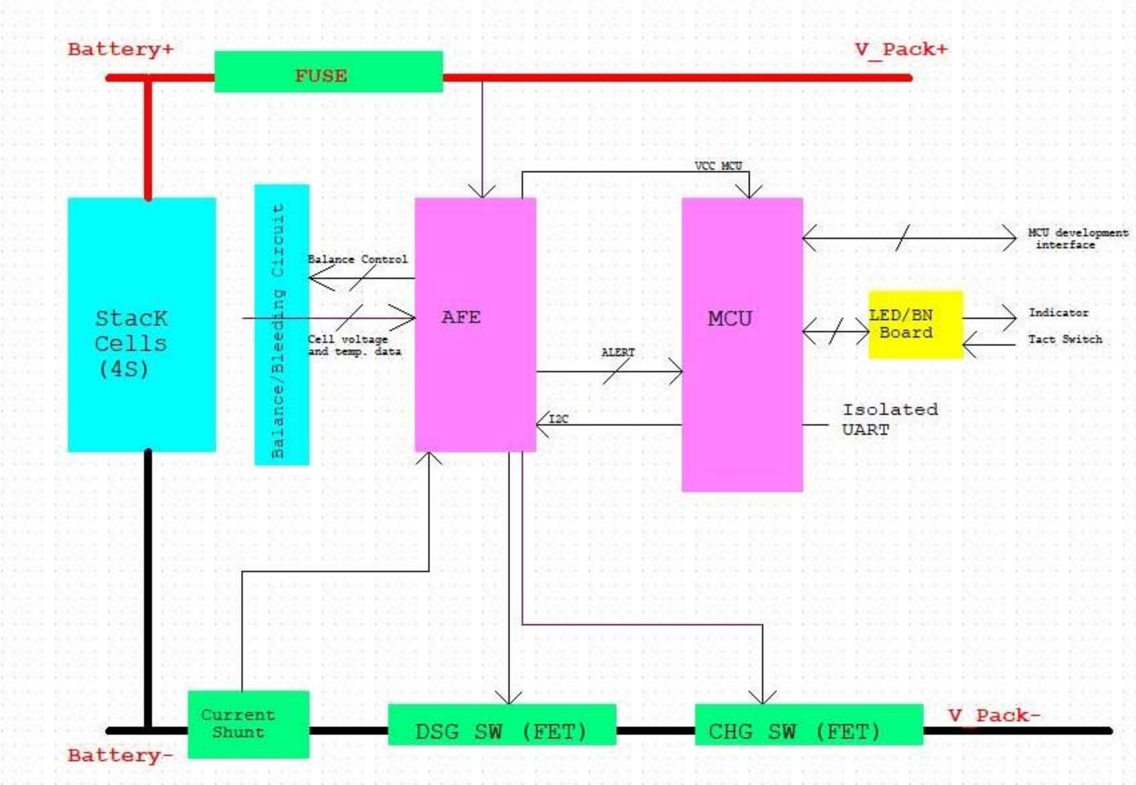


Figure 2 ALE 12V7 Series Battery Block Diagram

Chapter 2

Regulatory Compliance

Overview

ALE 12V7 Series batteries will be compliant with, or tested to, the following regulatory standards:

- UL 1973 Recognized – Batteries for use in Light Electric Rail (LER) Applications and Stationary Applications.
- cUL Recognized to CAN/CSA C22.2 # 60950-1 – Information Technology Equipment Safety - Part 1: General Requirements.
- IEC61000-6-1 (Generic standards – Immunity for residential, commercial and light-industrial environments).
- IEC61000-6-2 (Generic standards – Immunity for industrial environments).
- IEC61000-6-3 (Generic standards – Emission standard for residential, commercial and light-industrial environments).
- IEC61000-6-4 (Generic standards – Emission standard for industrial environments).
- IEC 62133 – Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications – tested and certified.
- CE – Recognized to EU consumer safety, health and environmental regulations. Signifies conformity with EMC directive (2004/108/EC).
- FCC Part 15 Subpart B Class B – Standards regulating unintentional emissions of radio frequencies from a digital device. This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:
- This device may not cause harmful interference.
- This device must accept any interference received, including interference that may cause undesired operation.
- UN 38.3 – Meets section 38.3 of the UN Recommendations on the Transport of Dangerous Goods – Manual of Test Criteria.

Environmental Regulations

ALE 12V7 Series batteries are compliant with the following applicable environmental regulations.

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

Transporting Lithium-Ion Batteries

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

Anyone involved in the integration of lithium-ion battery packs into a host product must review and meet the regulations cited in this guide. Additionally, the regulations discussed in this guide apply to lithium-ion cells and batteries. Once an ALE 12V7 Series battery is integrated into a host product, the host product may be subject to additional transportation regulations that require additional certification testing. Since Endrich Co., Ltd. can't anticipate every possible configuration and application of an ALE 12V7 Series battery, the integrator must verify that the ALE 12V7 Series powered host product is compliant with all applicable regulations. Refer to

Table 2 on page 14 for a list of proper names and UN numbers required for shipping lithium-ion batteries.

Regulations Overview

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

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

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

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

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

Regulations by Cell/Battery Size

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

Following International and U.S. DOT Regulations

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

Table 1 outlines an example process to help ensure that batteries are shipped per the required regulations.

Table 1 Example of Steps to Obtain or Ensure Regulatory Compliance

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

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

NOTE

Table 2 shows the proper shipping names and UN numbers required for shipping lithium-ion batteries.

Table 2 Proper Shipping Names and UN Numbers

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

Chapter 3

Handling, Storage and Installation

Safety and Handling

ALE 12V7 Series batteries are more abuse tolerant than other lithium-ion batteries; however, correct handling and system integration of ALE 12V7 Series batteries are still important to ensure safe operation.

WARNING

Failure to follow these warnings may result in personal injury or damage to the equipment.

- Do not expose the ALE 12V7 Series battery to heat in excess of 60°C during operation or in storage; do not incinerate or expose to open flames.
- Do not connect ALE 12V7 Series battery to battery of other chemistries or ALE batteries of different capacities. For example, do not connect an ALE 12V7 Series battery to any lead-acid battery.

CAUTION

Do not charge or discharge an ALE 12V7 Series battery outside of its stated operating temperature range. Reduce charging limits for lower operating temperatures for longer life of the batteries.

The advanced design of the ALE 12V7 Series batteries are intended to provide protection against operation under many unsafe conditions such as over voltage, under voltage, over temperature and short circuit. Proper use within the limits stated in Chapter 4, ALE 12V7 Series Specifications, starting on page 21, is required to ensure operator and equipment safety as well as battery life.

Mounting

The ALE 12V7 Series batteries may be installed in any orientation.

The ALE 12V7 Series battery case, including its top cover is capable of sustaining a mounting force of up to 200 Newtons spread over a one-inch-wide (2.5 cm-wide) bar or holding bracket across the center of the unit. Exertions beyond this level may result in deforming of the plastic.

Battery Configuration Options

ALE 12V7 Series batteries may be arranged in series and/or in parallel configurations to achieve higher operating voltages and capacities to meet the requirements of the intended application, up to a maximum of 48 volts (four in series) and 46 Ah (ten in parallel).

Wiring Connections

To connect ALE 12V7 Series batteries, use appropriate sized AWG wire and connectors that are rated for the maximum current and temperature expected. Table 11, on page 31, provides guidance on the conditions under which the battery may encounter internal thermal or external terminal touch temperature limits.

The battery can accommodate a maximum inductance of 5 μH. For reference, 5 μH is equivalent to 3 meters (10 feet) of individual standalone cable. In a battery system, cable length inductance includes all terminal-to-terminal connections as well as cabling to charge sources and load for both the positive and negative conductors added together. It is possible to reduce a battery system's total cable inductance by orienting positive and negative conductors to cancel each other's electromagnetic induction, thus allowing for longer total cable length. Contact Endrich Co., Ltd. for assistance in determining appropriate wiring and bus bar configurations to address current sharing and stray inductance requirements.

CAUTION

- Exceeding the maximum inductance limit of 5 µH during operation could cause voltage spikes or current surges resulting in possible damage to the ALE 12V7 Series battery's circuitry.
- Do not connect the ALE 12V7 Series to an inductive load such as a DC motor without the use of a motor controller. An "on-off" switch does not constitute a motor controller. Using the batteries directly with DC motors can permanently damage the battery. Contact Endrich Co., Ltd. for further assistance.

Terminal Specifications

ALE 12V7 Series batteries use copper terminals with tin plating. The terminals have a maximum operating temperature rating of 90 °C. They are intended to mate with standard female 0.25 inch (6,35 cm) "quick connect" terminals (TE Connectivity FASTON or equivalent). Attach cable by inserting connector fully until the round locking detent has engaged the center hole.

Configuring Batteries in Series Strings

To achieve higher operating voltages, arrange the ALE 12V7 Series batteries in series strings by connecting the positive terminal of one battery to the negative terminal of the next battery, as shown in Figure 3.

NOTE

The following battery string wiring examples provide general configuration information. Actual wire configurations must be evaluated for their particular application.

The array voltage can be calculated as follows:

- Two batteries in series: 2 x 13.2 V = 26.4 V (nominal) for 24 V applications
- Three batteries in series: 3 x 13.2 V = 39.6 V (nominal) for 36 V applications
- Four batteries in series: 4 x 13.2 V = 52.8 V (nominal) for 48 V applications

The maximum number of ALE 12VE battery that may be connected in series is four.

Figure 3 illustrates three ALE 12V7 Series batteries connected in a three-series, one- parallel (3S1P) configuration.

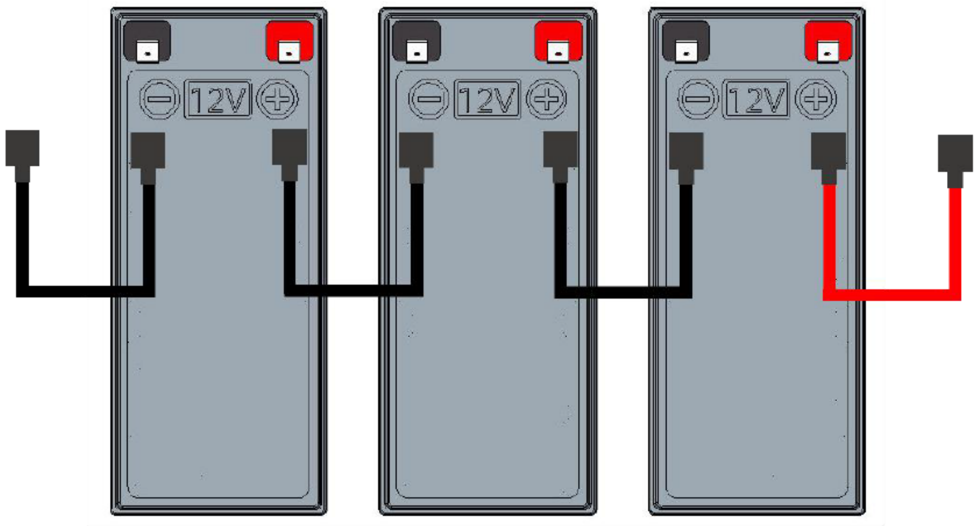


Figure 3 Three ALE 12V7 Series Batteries Connected in Series Creating a 3S

Configuring Batteries in a Parallel Group (1S2P up to 4S10P)

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

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

The nominal capacity for the parallel group can be calculated by multiplying the number of batteries in the group by 4.6 Ah. For example, three batteries in parallel provides:

3 x 4.6 Ah = 13.8 Ah.

The maximum number of ALE 12V7 Series batteries that may be connected in parallel is ten.

Series and Parallel Battery Configuration Warnings and Notices

WARNING

When configuring the ALE 12V7 Series batteries in series or in parallel, adhere to the following Warning notices:

- Do not connect more than four batteries in series. Connecting more than four batteries in series may damage the battery's circuitry, leaving the battery without critical safety features such as over-voltage and over-temperature protection.
- Do not connect more than ten batteries in parallel.
- Configuring more than one series string of batteries in parallel is allowed under certain circumstances. The maximum supported array is 4S10P. When designing and constructing any series-parallel battery combinations, contact Endrich Co., Ltd. for assistance in determining appropriate wiring and bus bar configurations to address current sharing and stray inductance requirements.
- Consider inductance during system design. An ALE 12V7 Series battery can accommodate a maximum inductance of 5 μH. Exceeding this limit during operation will cause voltage or current spikes, resulting in possible damage to the battery's circuitry.
- Consider capacitance during system design. When a battery or battery group is connected to a heavy duty charger, external capacitance may need to be added to the circuity to address the output inductance of the charger. The CV2 of theattached capacitor should be larger than the LI2 of the charger. The charger inductance is the sum of the internal and external inductances.

Transportation and Storage

When storing or transporting the ALE 12V7 Series batteries, Endrich Co., Ltd. recommends the following:

- The ALE 12V7 Series batteries can be stored in an environment with average temperatures between -40 °C and +35 °C, between 5% and 95% relative humidity, noncondensing at altitudes up to 25,000ft (7600m). Storing the ALE12V7 Series in temperatures above +35°C can significantly reduce the battery's state of charge as further described in Shelf Life on page 42.
- The ALE 12V7 Series batteries can be transported for up to two weeks in an environment with temperatures above 35 °C up to 80 °C and at altitudes up to 50,000 feet (15,240 meters).

Operating Environment

The ALE 12V7 Series batteries can be operated in an environment with temperatures between -40 °C and +60 °C, between 5% and 95% relative humidity, non-condensing, at altitudes up to 15,000 feet (4572 meters). Refer to Table 4, on page 24 for environmental specifications.

Disposal

Do not incinerate or dispose of any ALE 12V7 Series batteries. Return end-of-life or defective batteries to your nearest recycling center per the appropriate local regulations.

Chapter 4

ALE 12V7 Series Specifications

Electrical and Environmental Specifications

Table 3 ALE 12V7 Series Electrical Specifications

SPECIFICATION	12V7s	12V7h
Maximum Continuous Discharge Current at 25 °C	30 A	54 A
Maximum Pulse Discharge Current at 25 °C	38A, < 1.28s	66A, < 1.28s
Nominal Operational Voltage	13.2 V	13.2 V
Minimum Voltage	8V	9.2V
Maximum Voltage	16V [a]	16V [a]
Nominal Capacity	5 Ah	5 Ah
Standard Charge Voltage	14.4 V	14.4 V
Minimum Charge Voltage	13.8V	13.8V
Float Charge Voltage	14.0 V	14.0 V
Standard Charge Current at 25 °C	3 A	3 A
Maximum Continuous Charge Current at 25 °C	10 A	10 A

[a]. Don’t Recommend charge the ALE12V7 battery to 16V

Table 4 ALE 12V7 Series Environmental Specifications

Environmental Specification	Description
Ambient Operating Temperature Range	-20°C to +60 °C -4°F to +140 °F
Maximum Operational Altitude	15,000 ft [a]
Operating Relative Humidity (non-condensing)	5% to 95%
Environmental Rating for Battery Enclosure	Meets IEC60529 – IP65 Environmental Rating for Battery Enclosure
Recommended Storage Environment Conditions	Temperature: -40 °C to +35 °C [b] Relative Humidity (noncondensing): 5% to 95% Altitude: Up to 25,000 ft (7600 m)
Transportation Environment Conditions for up to two weeks [c]	Temperature: -40 °C to +80 °C Relative Humidity (noncondensing): 5% to 95% Altitude: Up to 50,000 ft (15,240 m)

a. The maximum operating temperature decreases by a factor of 1.1 °C per 1,000 ft of elevation above 7,500 ft.
b. Storing ALE 12V7 Series batteries in temperatures above +35°C can significantly reduce the storage time. See Shelf Life on page 42.

Physical Specifications

Table 5 and Figure 4 on page 23 provide details of the mechanical dimensions and weight of the ALE 12V7 Series batteries.

Table 5 ALE 12V7 Series Physical and Mechanical Specifications

Specification	Description
Dimensions (excluding terminals)	151 x 64.5 x 92 mm (5.9 x 2.5 x 3.6 in)
Weight (approximate)	980 g (1.874 lb)
Case Material	PC+ABS Plastic, UL 94 V0 Flame Rating

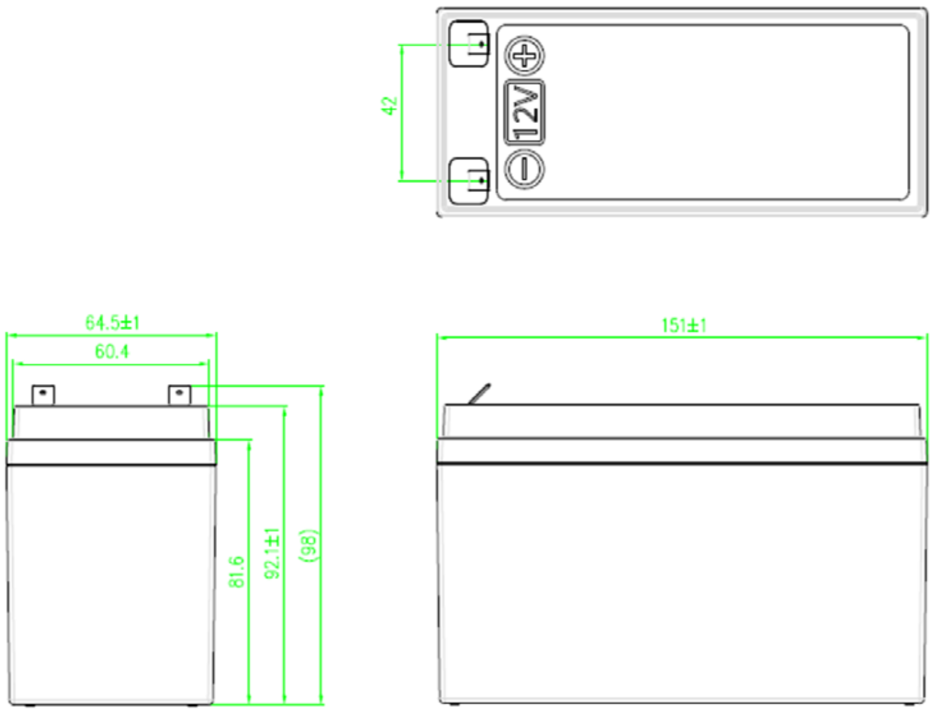


Figure 4 ALE 12V7 Series Mechanical Dimensions

Chapter 5

Operation and System Design Considerations

Integrated AFE and MCU Battery Protection

The ALE 12V7 Series technology includes integrated protection circuitry to prevent the battery from certain damaging use conditions. The battery's circuitry interrupts either charging or discharging current if the battery is in danger of exceeding upper or lower limits to voltage, current, and temperature.

Transient Energy Limit

The ALE 12V7 Series design protects the battery from transients containing excess energy of up to 46 Joules. Inductance inherent in the cabling used to connect to the battery can store this transient energy and release it to the battery's protection devices as the battery's protection mechanism engages, which introduces an open circuit. When this occurs, active sources like power supplies and battery chargers can create large transient spikes. While the product has been designed to handle a maximum inductance of 5 µH and tolerate connections to most power supplies, the user is responsible for ensuring that the battery does not experience over voltage surge energy in excess of 46 Joules when conduction is interrupted. External energy absorption devices like capacitors or clamps can reduce the overshoot or stress on the battery and may be required based on the application.

Over Current Protection

The ALE 12V7 Series batteries apply a time-based current limit that allows higher level current pulses for short durations. Table6 on page 29 shows the maximum current limits and time intervals. The maximum current limit of 260 A and 100uS for 12V7h and 234A and ??uS for 12V7s.

NOTE

Charge sources exceeding the continuous current will charge the battery at a duty-cycle inversely proportional to the charger's current. Exceeding the 160 A peak current will result in NO charge.

Table 6 Over Current Protection Parameter

Model	Max Current	Time Interval
12V7s	234A	
	38A	1.28A
12V7h	260A	100uS
	66A	1.28S

Over Discharge Protection Under Voltage Protection (UVP)

As the ALE 12V7 Series battery nears 0% State of Charge (SOC), the terminal voltage begins to drop rapidly. The battery is considered fully discharged when one of its internal cell voltages falls to 2.0 volts or the battery's terminal voltage is in the range of 8.0 volts to 11 volts.

The ALE 12V7 Series is designed to enter an Under Voltage Protection (UVP) state if any cell drops below 2 volts. In the UVP state, the ALE 12V7 Series battery will disconnect its terminals causing the output voltage to drop to 0 volts. Slight differences in the cells' state of charges lead to differences between the cell voltages, especially at low states of charge. In such a case, one cell may activate the UVP protection before the others do. When this happens the voltage measured at the battery terminals will be higher than 8 volts. Table 10 on page 30, shows the voltage at which a battery could enter UVP and open the terminals. UVP is disabled and the terminals are closed once the battery is connected to an active charge source and/or the lowest cell voltage returns to 2.3 volts or higher.

Table 7 End of Discharge – Effective ALE 12V7 Series Terminal Cut-Off Voltages in Different Series Configurations

ALE Configuration	Typical Observed ALE Terminal Cut-Off Voltage (V)	Average Voltage per Cell (V)	Absolute Minimum ALE Terminal Cut-Off Voltage (V)
1S - (12 V)	8.8	2.2	8.00
2S - (24 V)	17.5	2.2	16.00
3S - (36 V)	26.4	2.2	24.00
4S - (48 V)	35.2	2.2	32.00

NOTE

Under voltage protection creates an open circuit, removing voltage from the terminals. With a lead-acid battery, finding no voltage at the terminals often indicates the battery is no longer usable. With the ALE 12V7 Series battery, no voltage at the terminals typically means the cell protection circuitry has interrupted current to protect the battery. Simply connect the battery to a charge source to restore voltage to the terminals.

Over Charge Protection

Similar, but opposite to the case at low States of Charge, the ALE 12V7 Series battery's terminal voltage begins to rise rapidly at high States of Charge. The ALE 12V7 Series is considered at 100% SOC when the cells are balanced and terminal voltage measures 13.8 volts or above. At this point, the average cell voltage is the terminal voltage divided by 4. The ALE12V7 Series batteries are designed to enter an Over Voltage Protection (OVP) state if any cell rises above 4.0 volts. In the OVP state, the ALE 12V7 Series will be disconnect its terminals and not accept further charge current. To exit the OVP state, apply a load to discharge to the battery. The battery will then return to Normal State once the cell voltages fall below 4.0 volts. For further details, refer to Balancing, on page 41.

Over Temperature Protection

The ALE 12V7 Series circuitry continuously monitors the battery's temperature. The battery will open its terminals when the temperature is too high for safe operation. Do not operate the battery outside of the operational temperature range specified in Table 4 on page 23.

High Temperature Operation

Both charge and discharge functions increase battery temperatures. High rate battery usage causes the largest temperature increase. The ALE 12V7 Series battery's over temperature protection (OTP) circuitry removes voltage from the terminals if the battery exceeds the temperature limits. During high rate battery usage, the user must ensure that ambient operating temperature combined with the charge or discharge rate does not exceed the operational temperature limits. Table 11 shows how the ALE 12V7 Series usage rate and ambient temperature relate to measured delta SOC before entering OTP state.

Low Temperature Operation

At low temperatures, the maximum available discharge current decreases due to increased internal impedance at lower temperatures. Refer to Figure 9 on page 40 and Charge Limits and Temperatures, on page 34 for more details.

NOTE

Do not operate the battery outside of the operational temperature range specified in Table 4 on page 22.

Charging Single Batteries

The ALE 12V7 Series batteries are compatible with most common 12V lead-acid battery chargers. A single ALE 12V7 Series battery can accept up to 10 A charge current maximum. Higher current for short durations is allowed. However, in some situations, internal component temperatures may be exceeded causing performance to be curtailed by the battery's protection circuitry. For more information on hardware protection limits, refer to Appendix A, Operational Protection Hardware Circuitry on page 46. Additional charge limit information is also described in Charge Limits and Temperatures, on page 34.

NOTE

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

Constant Current (CC), Float Voltage Chargers

For ALE 12V7 Series batteries operating under normal conditions during a charge, a charger applies a constant current (CC) until the terminal voltage reaches its end of charge voltage (maximum), as shown in Figure 5 on page 34. This process is followed by a float voltage, where the charge current decays to near zero. As the battery approaches 100% State of Charge (SOC), the balancing circuitry performs cell balancing. This process charges the ALE 12V7 Series battery to 100% State of Charge (SOC).

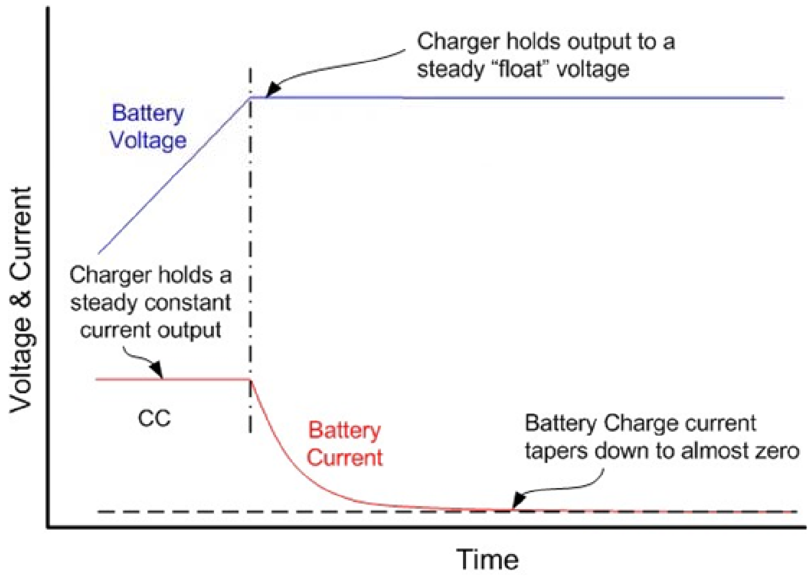


Figure 5 Battery Voltage and Current During Recharge

If the ALE12V7 Series battery has entered an Under Voltage Protection (UVP) state, the battery disconnects from the load. Connecting a charger to the battery resumes normal operation based on replenished energy.

NOTE

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

Charge Limits and Temperatures

At room temperature and above, ALE 12V7 Series batteries can accept full rated charge. As with all battery technologies, charge acceptance is limited at low temperatures. A permanent loss of capacity over time may be observed if charge rates are not reduced at low cell temperatures. As the cells' temperature rises during the charging process, they can gradually accept higher currents. Table 7 on page 29 show charging guidelines to maximize battery life.

Table 8 Charge Rate by Temperature a.

Temperature (°C)	Current (A)	Temperature (°C)	Current (A)
60	10	20	10
50	10	10	10
40	10	0	5
30	10	-10	2.5
25	10	-20[b]	1

[a] For charge acceptance, do not exceed the limits specified. For the higher temperatures (and charging rates), exceeding these rates may result in engaging the ALE 12V7 Series protection circuitry. For lower temperatures, exceeding these rates will result in a shorter battery life.

[b] Now, sample stage could only charge higher than -10°C. MP stage will adjust to -20°C.

Charging Multiple Batteries

When charging multiple batteries, maximum charge current should not exceed 10A for arrays of ALE12V7 Series batteries connected in parallel and/or series configurations. The end-of-charge voltage will depend on the system's series and parallel configuration.

Charging Batteries in Series

series, multiply the number of batteries connected in series by the maximum charge voltage of a single battery (14.4 V), as shown in Equation 1.

Eq. 1 (Number of Series Connected ALE 12V7 Series Batteries) x (14.4V) = Max Charge Voltage, Battery System.

Table 8 shows Recommended Float and Maximum Charge voltages. Charger voltages exceeding the Maximum up to 60.0 volts will not damage an ALE 12V7 Series battery, but the battery may not operate due to over voltage protection. When the battery is in the normal state, the charger voltage should be less than or equal to the Maximum Charge Voltage.

WARNING

Applying charger voltages in excess of 60.0 V could damage the charge and discharge control circuitry, creating a safety hazard, and will void the warranty.

Table 9 Supported Float and Maximum Charge Voltages

Series Configuration	Recommended Float Charge Voltage (V)	Maximum Charge Voltage (V)
1s	13.6 to 14.4	14.4
2s	27.2 to 28.8	28.8
3s	40.8 to 43.2	43.2
4s	54.5 to 57.6	57.6

Charging Batteries in Parallel

The maximum charge current for any parallel array of batteries is 10 A.

Discharge Performance

The typical 25 °C constant current discharge behavior of the ALE 12V7 Series at different discharge rates is shown in Figure 6. Compared to lead-acid batteries, the output voltage of the ALE 12V7 Series remains relatively constant across its capacity range at any given discharge rate.

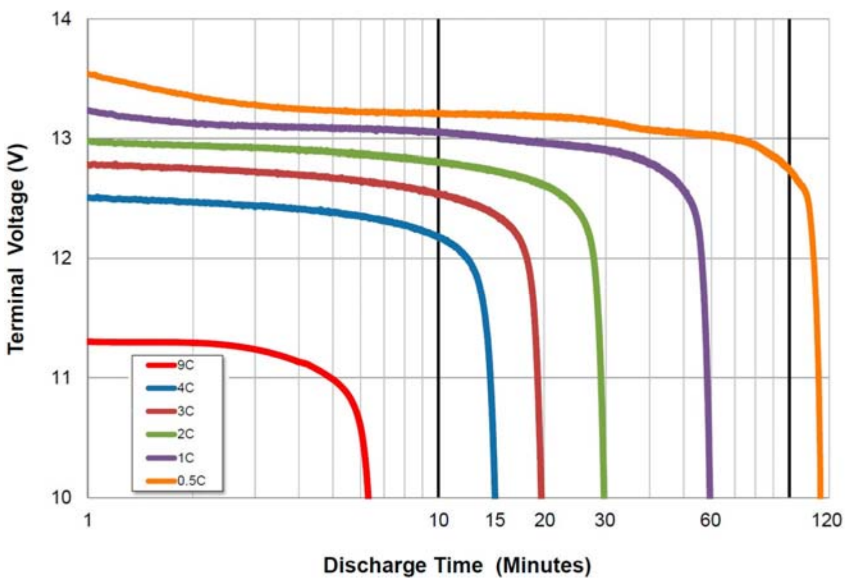


Figure 6 ALE 12V7 Series Typical Constant Current Discharge Behavior at 25 °C

As the ALE 12V7 Series discharges, this moderate voltage drop translates into superior (I x V) power delivery capability as shown in Figure 7. Additionally, the ALE 12V7 Series delivered capacity is nearly independent of discharge rate.

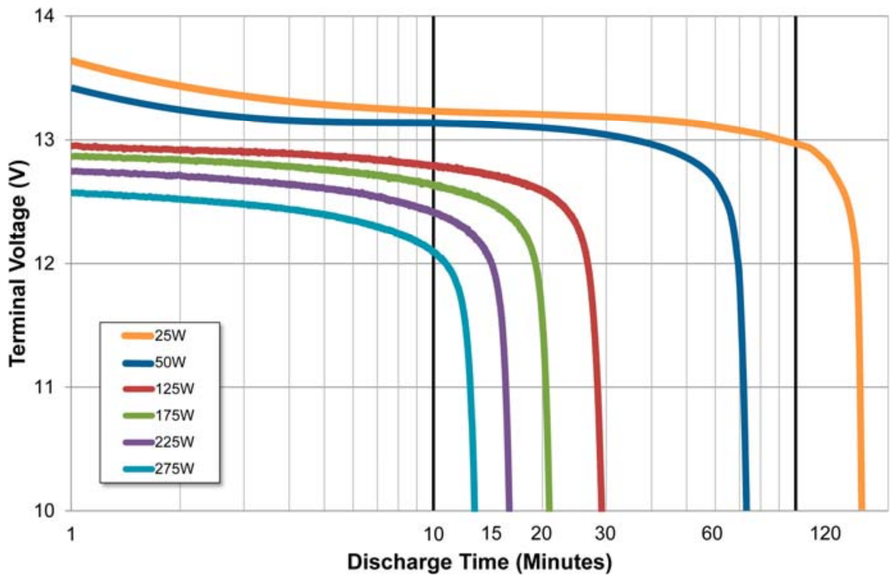


Figure 7 ALE12V7 Series Typical Constant Power Discharge Behavior at 25 °C

Voltage drop in the ALE 12V7 Series is an inverse function of the ALE 12V7 Series battery's internal temperature. As the internal temperature of the ALE 12V7 Series drops, the impedance rises leading to an increased voltage drop. It is important to consider the resulting performance impacts when designing a product for cold conditions. Figure 8 shows impacts of temperature on 50W constant power discharge.

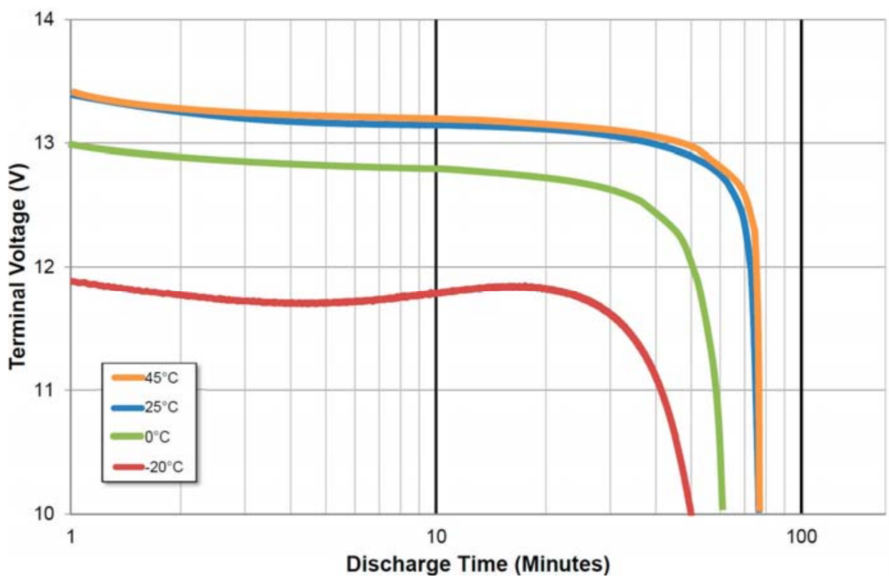


Figure 8 ALE 12V7 Series Typical 50W Constant Power Discharge Behavior

The ALE 12V7 Series battery's End of Discharge (EOD) terminal voltage is a function of the core cells, any cell-to-cell variations and series impedance of the internal power pathway.

These elements are impacted by discharge rate and temperature. The battery's protection circuitry will stop discharge when any cell voltage drops below 2.0 volts.

Cell-to-cell variation has the largest impact on the expected EOD terminal voltage. Cells vary in performance in a variety of ways based on normal manufacturing.

Applications that use a low battery voltage threshold value (LVCO, LVLD, LVBD, etc.) to initiate actions such as disconnecting the load or initiating a charge cycle should adhere to the battery terminal voltages shown in the discharge performance curves in Figure 7, Figure 8, and Figure 9. Depending on the discharge rate, temperature, and other factors in the application, a different voltage trigger value based on the appropriate discharge curve may be needed, compared to lead-acid or other battery chemistries. Otherwise, undesired behavior of the battery application may occur such as the unexpected loss of voltage if the ALE 12V7 Series battery enters UVP state, or taking action too soon such as disconnecting the load while significant energy still remains in the battery.

If the intent of the application is to maximize the amount of energy available from the ALE 12V7 Series battery before charging, it may be advantageous to disable external cutoff mechanisms based on the terminal voltage and instead use the battery's internal protection circuitry to determine when to interrupt the discharge cycle. The battery protects itself from unsafe conditions and typically disconnects due to low voltage when only 5-10% of full charge capacity remains.

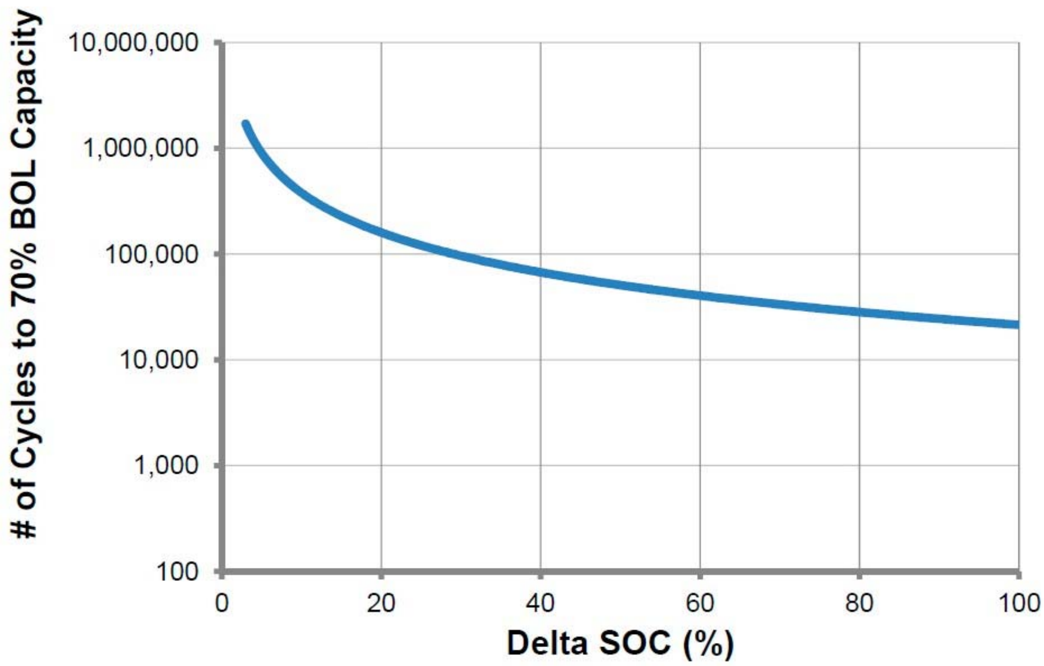
Balancing

Over time, the ALE 12V7 Series cells diverge in both capacity and SOC. All ALE 12V7 Series batteries perform cell voltage balancing at high SOC values based on cell voltage to maximize the available capacity of the battery. The balancing circuit's purpose is to drive all cells to the same voltage. Cell balancing continues on a per-cell basis as long as the cell voltage exceeds 3.385 volts.

ALE 12V7 Series batteries are shipped at 100% SOC. However, fully charging the ALE and holding the ALE at float voltage for 4-24 hours prior to first use will ensure optimal balance and maximize the first discharge delivered capacity.

Cycle Life

Cycle life is dependent upon charge and discharge rates, operating temperature, calendar time and state of charge swing or delta SOC. Figure 9 projects cycle life expectations as a function of delta SOC where reducing delta SOC results in greatly enhanced cycle life.



Number of cycles is dependent upon average SOC, charge/discharge rates, temperature and calendar time. Actual results will depend on specific use cases.

Figure 9 Cycle Life versus Delta SOC Behavior of Nanophosphate® Lithium-Ion Cell

After 6 years of continuous testing, original A123 Systems ANR26650M1A cells still retain 65% of their initial capacity after 20,000 full depth of discharge (100% DOD), +1C/-1C cycles at 23 °C. The ALE 12V7 Series batteries use the next generation ANR26650M1B cells.

Through testing under the same conditions, cells of this model are demonstrating further improved cycle life behavior over their predecessors, as shown in Figure 10.

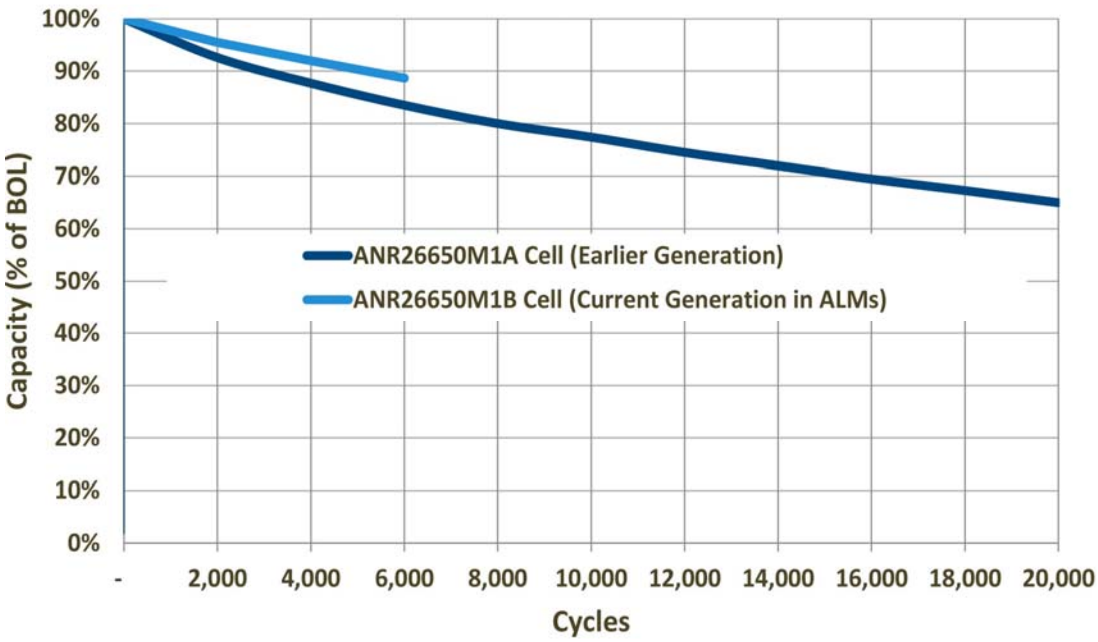


Figure 10 Cycle Life Test Results +1C/-1C, 23 °C, 100% DOD

NOTE

The number of cycles, as shown in Figure 10 and Figure 11, are dependent upon average SOC, charge/discharge rates, temperature and calendar time. Actual results will depend on specific use case. Contact Endrich Co., Ltd. for more detail.

NOTE

Overall system life is a function of Shelf Life (Time at temperature) and Cycle Life (charge discharge rates and watt-hour throughput).

Troubleshooting

Overview

The ALE 12V7 Series are extremely reliable batteries that provide greater useful life than comparable 12V7 lead-acid batteries. Despite the high reliability of the ALE 12V7 Series batteries, you may encounter situations where the battery does not operate as expected. This chapter details potential issues with the ALE 12V7 Series batteries and the appropriate troubleshooting procedures.

Table 10 ALE12V7 Series Troubleshooting and Solutions

Problem	Possible Cause(s)	Solution(s)
The battery does not deliver the expected Ah (capacity).	1. The battery is out-of-balance. 2. The battery has reached the end of its useful service life. 3. The battery overheated due to ambient temperature or C-Rate.	1. Apply a float charge for 48 hours to balance the battery cells. 2. Replace the battery. 3. Reduce the ambient temperature or C-Rate.
Charge current suddenly goes to zero while connected to a source.	1. The battery overheated, enabling over-temperature protection. 2. The battery is out-of-balance. 3. Charge current is too high, exceeding OCP protection. [a]	1. Allow the battery to cool. 2. Apply a float charge for 48 hours to balance the battery's cells. For more details on charging battery, batteries, or strings, refer to Charging Single Batteries on page 33 and Charging Multiple Batteries on page 36. 3. Reduce charge current.
Voltage drops abruptly while in use after appearing constant.	1. The battery is fully discharged. 2. OCP has engaged	1. Perform a charge cycle. 2. Reduce the load.
Low or zero volts across the terminal	1. The battery is in UVP or UVLO. 2. The battery is in OTP.	1. Perform a charge cycle. 2. Allow the battery to cool.

[a] High-speed OCP occurs in100 µs so it will not be visible on a digital volt meter.

Appendix A

Operational Protection Hardware Circuitry

Table 18 lists the ALE 12V7 Series batteries Operational Protection matrix covering hardware circuitry for voltage and temperature. The following list defines abbreviations used in Table 10:

- FETs: Field-Effect Transistors
- OTP: Over-Temperature Protection
- OVP: Over-Voltage Protection
- UVP: Under-Voltage Protection
- UVLO: Under-Voltage Lock-Out

Table11 ALE 12V7 Series Operational Protection Parameters

Parameter	Set Value ALE 12V7s	Set Value ALE 12V7s HP	Clear Value ALE 12V7s	Clear Value ALE 12V7s HP	Applies to
OVP	>4.1 V	>4.1 V	<3.6V	<3.6 V	Any cell
UVP	<2 V	<2.0 V	2.3	2.6	Any cell
UV lockout	<1.9 V @1sec	< 1.9V @2sec	Wake up by charging	Wake up by charging	Any cell
UVLO mode	6 V (No charger)	6 V (No charger)	Never	Never	Battery
OTP cell	70 °C	70 °C	65 °C	65 °C	Any cell
OTP-2 cell	80 °C	80 °C	75 °C	75 °C	Any cell
OTP FET	80 °C	80°C	70 °C	70 °C	FETs
OTP-2 FET	95 °C	95 °C	85 °C	85 °C	FETs

Appendix B

Acronyms and Terminology

The following table lists and describes acronyms and terms used in this guide.

Term/Acronym	Description
Ah	Amp-Hour is a unit of measure of charge that can be stored or delivered to/from a battery.
Battery	One or more cells which are electrically connected together by permanent means, including case, terminals and markings. Also, the ALE 12V7 Series battery.
BMS	Battery Management System – The Battery Management System refers to the collection of electronics responsible for monitoring and controlling an ESS. The ALE 12V7 Series batteries do not require an external BMS (See Battery Configuration Options on page 16).
BOL	Beginning of Life – at the time the product was first assembled at the factory.
CC	Constant Current – A method to charge or discharge a battery in which the current is held constant independent of the battery's terminal voltage.
CE	Conformité Européenne, meaning "European Conformity"- Tests and Certifies safe and compliant product operation in Europe.
Cell	The individual Lithiumwerks ANR26650M1*B* cell is the basis for the ALE 12V7 Series battery.
CFET	Charge control FET
C-Rate	An electrical current value corresponding to that which will fully charge or discharge a battery in one hour.
CV	Constant Voltage – A method to charge a battery in which the terminal voltage is held constant, and the current is determined by the power path impedance or some active current limiting.
$CV^2/2$	Formula for Energy stored in capacitance
DFET	Discharge control FET
DOD	Depth of Discharge
EMC	Electro Magnetic Compatibility

Term/Acronym	Description
EOD	End of Discharge
ESS	Energy Storage System
FCC	Federal Communications Commission. RF Emissions governing body in the United States.
FET	Field-Effect Transistor, used for switching high current levels.
HW	Hardware
SW	Software
kbit/s	kilobit per second
$LI^2/2$	Formula for Energy stored in inductance
LVBD	Low Voltage Battery Disconnect
LVCO	Low Voltage Cut-off
LVLD	Low Voltage Load Disconnect
Mbit/ s	Megabit per second
OCP	Over-Current Protection
OTP	Over-Temperature Protection
OVP	Over-Voltage Protection
OEM	Original Equipment Manufacturer – in reference to this document, the maker of the equipment into which an ESS is installed and used.
Nominal Energy	The energy value of a cell or battery determined under specified conditions and declared by the manufacturer. The nominal energy is calculated by multiplying nominal voltage by rated capacity expressed in ampere-hours. Also known as Watt-hour rating.
Nominal Voltage	The approximate value of the voltage used to designate or identify a cell or battery
Non-Volatile Memory	General term for all forms of solid state (no moving parts) memory that has the capability to hold saved data even when its power is turned off. Unlike volatile memory, it does not require periodic refreshing of its memory contents.

Term/Acronym	Description
Room Temperature	The range between 20 and 23 °C (68 and 73 °F), with an average of 21.5 °C (70.7 °F).
SOC	State of Charge
Touch Temperature	The external surface temperature of various battery components
UL	Underwriter Laboratories - Tests and Certifies safe and compliant product operation in North America & internationally
UVP	Under-Voltage Protection
UTP	Under-Temperature Protection
UVLO	Under-Voltage Lock-Out
Wh	Watt-Hour rating (see also Nominal Energy rating)

Related Documents and Resources

- Link to International Civil Aviation Organization (ICAO) Technical Instructions: http://www.icao.int/safety/DangerousGoods/Pages/default.aspx
- Link to International Air Transport Association (IATA) Dangerous Goods Regulations: http://www.iata.org/whatwedo/cargo/dgr/Pages/lithium-batteries.aspx
- Link to International Maritime Dangerous Goods (IMDG) Code: http://www.imo.org/Publications/IMDGCode/Pages/Default.aspx
- Link to Lithium Battery Regulations on United Parcel Service web site: http://www.ups.com/media/news/en/intl_lithium_battery_regulations.pdf
- UN Recommendations on the Transport of Dangerous Goods - Manual of Test Criteria
- UN Recommendations on the Transport of Dangerous Goods Model Regulations
- U.S. Department of Transportation (DOT), Office of Pipeline and Hazardous Materials Safety Administration (PHMSA): Title 49 CFR Sections 100-185 of the U.S. Hazardous Materials Regulations (HMR)

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