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Technical Specification		1630B_TLS	9	07.08.24
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1630B 'Raptor'	VR420A	Various		1 / 33

VR420A

TECHNICAL SPECIFICATION

Document Status

RELEASED

Document Approval

Stage	Position	Name	Initials	Date
Author	Technical Marketing Manager	N. Oliver	NRO	7.8.24
Reviewed	Senior Mechanical Engineer	D. Bryant	DB	7/8/24
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4 REVISIONS

Revisions to this document are recorded in Table 1. Most recent changes are shown at the top of the table.

Version	AN Ref.	Detail	Date (DMY)	Initial
9	24-E049	In §10.1, Table 2, '-20°C to +60°C' changed to '-10°C to +60°C'.	07.08.24	NRO
8	24-E038	In §9.2 Figure 1, Image updated to reflect updated label artwork (LB0269 Rev2). In §10.1, Table 2, 'Minimum Capacity' row removed, and 'Typical Capacity' changed to 'Rated Capacity'. '6500mAh' changed to '6.5Ah'. In §11.1.4, 'the battery -ve inside the host' changed to 'BATT-'. In §11.3.4.2, Table 12: (i) TR2 range changed from '0°C < TEMP <+15°C' to '0°C < TEMP <+10°C', (ii) TR2A range changed from '+15°C < TEMP <+25°C' to '+10°C < TEMP <+40°C', (iii) TR3 range changed from '+25°C < TEMP <+40°C' to '+40°C < TEMP <+45°C', (iv) TR4 range changed from '+40°C < TEMP <+45°C' to '+45°C < TEMP <+53°C' and (v) TR5 range changed from '+45°C < TEMP' to '+53°C < TEMP'. Charging Mode for TR4 changed from 'High Temp Charge' to 'High Temp Charge (or Charge Inhibit)'. Charge Current for TR4 changed from '3000mA' to '1500mA (0mA)'. Charge Voltage for TR4 changed from '4.20V/Cell' to '4.15V/Cell (0mV)'. In §12.2, '470g' changed to '495g'. In 12.3.1, Figure 6, label artwork updated from LB0269 Rev to Rev 2. In §11.4, Table 15, XDFETF and XCFETF current changed from '30mA' to '40mA'. In §14.1, 'ST/SG/AC.10.11/Rev.7/Amend.1' changed to 'ST/SG/AC.10.11/Rev.8'. In §16.3, '0°C to +55°C' changed to '0°C to 45°C'.	25.07.24	NRO
7.0	24-026	In §11.3.4.1, §11.3.4.3 and 11.4 Table 15, SOT for charge and discharge changed from "+85°C" to "+80°C". In §11.3.4.2, Table 12, TR2 charge current changed from "1340mA" to "3000mA". In §14.1, "ST/SG/AC10.11/Rev.7" changed to "ST/SG/AC10.11/Rev.7/Amend.1". In §14.3, "IEC 62133-2:2017" changed to "IEC 62133-2:2017+AMD1:2021". In §14.4 "The battery meets the requirements of Directive 2006/66/EC of the European Parliament & of the Council of 6 of September 2006 on batteries & accumulators & waste batteries & accumulators & repealing Directive 91/157/EEC (equivalent to The Waste Batteries & Accumulators Regulations 2009 in the UK). Directive 2006/66/EC is more commonly referred to as "The Battery Directive". Also see the sections relating to "RoHS", "WEEE" & "REACH" in this document." changed	23.05.24	NRO

		to "The battery meets the requirements of Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC.".		
6.0	-	In §11.3.4.2, TR2 changed from '0°C < TEMP <+10°C' to '0°C < TEMP <+15°C' and '3000mA' changed to '1340mA'. TR2A changed from '+10°C < TEMP <+40°C' to ''+15°C < TEMP <+25°C'	23/11/23	NRO
5.0	23-E063	In, 12.3.1 Fig 6, product label updated to change IEC designation from ICR to INR.	05.09.23	NRO
4.0	23-E032	Updates applicable to the change from 6.2Ah to 6.5Ah. Refer to AN for full details.	08.06.23	NRO
3.0	22-E030	VR420B removed from document. In §14.3, IEC 62133:2012 changed to IEC 62133-2:2017 and CB certificate reference updated. In §15.1.1 and §15.1.2, ISO standard dates updates. Name of certifying body and certificate numbers removed.	30.08.22	NRO
2.0	16-E062	Specification updated to 2016 format. References to Intelligent Power Vault removed. In section 11.3.3: 2.5V was 2.4V and 'blow the logic fuse' removed from sentence. Discharge Short Circuit Current (Level 3) (AFE) increased from 15A / 427us to 47.5A / 915us for both models. In Table 20: XSUV removed. IEC62133 reference, Web address and telephone number on label updated. In section 12.3, text version of label artwork removed and label artwork graphics update to latest version. In section 14.3: IEC62133:2012 was IEC62133:2002. Certificate numbers updated for cells and battery. Dynamic label detail clarified. Product dimensions updated and mechanical drawing updated for clarity. Storage section updated with additional detail. In table 11, Fully Charged clear changed from 2% to 5%. Project Manager removed from document approval table.	25.04.17	NRO
1.0	-	Initial release	21.01.14	PI

Table 1 - Document Revisions

5 PROJECT & DOCUMENT

Customer name: Various

Accutronics project reference: 1630B

Document ID: 1630B_TLS

Accutronics project name: 'Raptor'

6 DEFINITIONS

°C	Degrees Celsius
A	Ampere
ADC	Analogue to Digital Convertor
AFE	Analogue Front End
Ah	Ampere Hour
C	Capacity
CC	Constant Current
CV	Constant Voltage
EMC	Electro-Magnetic Compatibility
ESD	Electro Static Discharge
IEC	International Electrotechnical Commission
LED	Light Emitting Diode
mAh	milli-Ampere Hour
mV	milli-Volts
OEM	Original Equipment Manufacturer
PEC	Packet Error Correction
POR	Power On Reset
RSoC	Relative State of Charge
SBD	Smart Bus Data
SBDS	Smart Battery Data Specification
SMBus	System Management Bus
SoC	State of Charge

7 REFERENCES

[REF1] System Management Bus Specification, Version 2.0, August 3, 2000

[REF2] Smart Battery Data Specification, Revision 1.1, December 11, 1998

[REF3] Smart Battery Charger Specification, Revision 1.1, December 11, 1998

8 TRADEMARKS

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9 INTRODUCTION

9.1 Scope

This specification describes the physical, functional & electrical characteristics of a rechargeable Lithium-Ion smart battery supplied by Accutronics Limited. This specification is the interface document between Accutronics & its customers.

9.2 Battery Overview

Each VR420A battery consists of eight Lithium-Ion rechargeable cells connected in an electrical configuration of four series by two parallel (4S2P). Batteries are rated at 14.4V & 6.5Ah (93.6Wh) at 0.2C discharge rate.

Operating voltage, capacity & energy depend on state of charge, applied load, temperature, & the age of the battery. Please refer to the detail of this specification to determine application suitability.

The battery includes a microprocessor-based battery management module that provides fuel gauging & active protection. The module can communicate with host or the charger through the System Management Bus (SMBus). The battery is fully SMBus & SBDS Revision 1.1 compliant & can provide a wide range of information about the battery status. Active protection is provided for over-charge, over-discharge, & short circuit. A second, redundant protection IC provides additional protection against over-charge. Passive safety devices are included in the pack to protect against over-current. The battery includes a visual state of charge indicator in the form of a 5 bar LED display which is activated by a push button. The battery is terminated using a 6-way connector which is shrouded to prevent accidental short circuit.

The cells & electronics are housed in a two-piece injection moulded case which is unitized using internal mechanical clips & RTV adhesive. See Figure 1 for a CAD render of the battery.

Figure 1 - VR420A Battery Exterior

10 DESIGN SPECIFICATION

10.1 High Level Battery specification

Parameter	Value	Notes
Technology	Rechargeable Lithium Ion	
Configuration	4 cells in series, 2 in parallel (4S2P)	
Nominal Voltage	14.4V	Based on charging at CC-CV 3A, 16.8V until the battery broadcasts a Terminate Charge Alarm, followed by a 0.2C discharge to Terminate Discharge Alarm (at +23°C)
Rated Capacity	6.5Ah	
Charge Temperature	0°C to +45°C	Refer to section 11.3.4.2
Discharge Temperature	-10°C to +60°C	Performance is dependent on initial state of charge, discharge current, temperature, & age. Empirical testing is required to determine performance
Maximum Discharge Current	6.2A	
Storage Temperature	-20°C to +60°C	See section 10.5

Table 2 - Battery Specification Summary

10.2 Connector Specification

The battery is fitted with a Samtec UPS-06-07.0-01-L-V, 6-way Connector (pin-out as defined in Table 3). For information, the mating part used on the Intelligent Power Vault is a Samtec UPT-06-03.0-01-L-V-LC-TR (vertical mount connector). A right angle version, UPT-06-01-01-L-RA part is also available.

Terminal	Legend	Description
1	(-)	Negative Side of Battery
2	(T)	300Ω ± 5% resistor connected between (T) & (-)
3	(P)	Battery Present – see section 11.1.4
4	(D)	SMBus Data. Internally a 1MΩ resistor is connected between (D) & (-)
5	(C)	SMBus Clock. Internally a 1MΩ resistor is connected between (C) & (-)
6	(+)	Positive side of battery

Table 3 - Connector Pin-out

The SMBus Clock & data lines require pull-ups to system logic voltage in the customer equipment, NOT the battery voltage. Typically, a 15KΩ pull-up resistor is used, but please refer to the SMBus Specification [REF1] for additional information.

10.3 Charging

When used with a compatible smart charger, the battery will request appropriate charging voltage, and charging current & this will be supplied if adequate power is available. Charge should be halted if the OVER_TEMP_ALARM or TERMINATE_CHARGE_ALARM alarm is broadcast see Table 8 for more details.

The battery conforms to JEITA guidelines where charging voltage & current which are modified depending on the internal temperature of the battery. Refer to section 11.3.4.2 for more information.

10.4 Discharging

During discharge, the host device should respond to alarms broadcast by the battery to prevent unforeseen shutdown. It is advised that REMAINING_TIME_ALARM or REMAINING_CAPACITY_ALARM be used to prompt the user to reconnect an external supply before the battery power is exhausted. Discharge should be halted when TERMINATE_DISCHARGE_ALARM is broadcast by the battery. Discharge should be halted when OVER_TEMP_ALARM is broadcast, see Table 8.

10.5 Storage & Transport

The battery pack is capable of being safely stored & transported over a temperature range of -20°C to +60°C. The battery pack should ideally be stored open circuit, in an environment with low humidity free from corrosive gas within a temperature range of -20°C to +30°C. Batteries stored between +30°C & +60°C risk a deterioration of battery performance, although this is still within the commercial storage tolerance set by the cell manufacturer. Storage of fully charged batteries &/or at high temperatures is not recommended as this can permanently degrade their performance.

Batteries are shipped from Accutronics at <30% state of charge, & with the fuel gauge set to 'shutdown mode' which minimizes quiescent current drain from the fuel gauge. Batteries shipped in this status can be stored for a minimum of twelve months storage at less than +30°C without the need for maintenance by the customer. Storage that exceeds this time may result in the batteries discharging to a level where the active cell protection will remove the cells from circuit to reduce discharge rate & reduce the risk of permanent cell damage. It should be noted that Accutronics ship the batteries in a shutdown mode to minimize discharge on the battery; any form of charging, discharging or communication will remove the battery from shutdown mode & it will subsequently only revert to 'sleep mode' which has a higher quiescent current drain (see section 11.1.2).

If customers need to store batteries for a long period of time (> 12 months), cannot put batteries into shutdown mode & have no requirement to ship them by air then storage at between 40% & 60% SoC is recommended.

10.5.1 Shutdown Mode

Batteries are shipped from Accutronics in 'Shutdown mode' (also known as 'storage mode' or 'ship-mode'). Shutdown mode puts the battery fuel gauge electronics into a very low power state to maximise storage performance. When the battery is in shutdown mode its charge & discharge protection MOSFETS are turned off & the LED bar graph function is disabled. Battery output will remain at 0V even if the Battery Present terminal is connected to the Battery Negative terminal.

To remove the battery from shutdown mode the battery requires a wake-up charge. If the battery is connected to a compliant smart charger, it will detect the presence of the battery (via the 'T' Terminal) & apply a wake up charge of up to 100mA. If no smart charger is available then a charge of 16.8V, limited to 100mA can be applied which will also wake the battery.

Note that once the battery is removed from shutdown mode it cannot be put back into this state. If disconnected from a charger or device the battery will enter 'sleep' mode which is also a low power state. LED function is not disabled when the battery is in sleep mode.

10.6 Warranty

Each battery is warranted against defects in design, workmanship, material & construction. The warranty period is 12 months from the date of shipment from Accutronics Limited (indicated by date code on the battery label).

10.7 Life Expectancy

Each battery will deliver a minimum of 80% of its minimum rated capacity after 300 cycles where the charge phase is CC-CV 3A, 16.8V until the battery broadcasts a TERMINATE_CHARGE_ALARM & the discharge phase is 0.5C until the battery broadcasts a TERMINATE_DISCHARGE_ALARM.

11 SMART ELECTRONICS MODULE

11.1 Fuel-Gauge Electronics

11.1.1 Overview of Operation

The battery can communicate with host or the charger through the System Management Bus (SMBus).

The fuel gauge & protection system is implemented using a Texas Instruments BQ20z65-R1. The BQ20z65-R1 SBS-compliant fuel gauge & protection IC is a single IC solution. The BQ20z65-R1 measures & maintains an accurate record of available charge in the battery using its integrated high performance analogue peripherals. It monitors capacity change, battery impedance, open circuit voltage, & other critical parameters of the battery pack & reports the information to the system host controller over a serial-communication bus. Together with the integrated analogue front end (AFE) short circuit & overload protection, the BQ20z65-R1 maximises functionality & safety while minimising external component count.

The implemented impedance track fuel gauging technology continuously analyses the battery impedance which results in superior gas-gauging accuracy. This enables remaining capacity to be calculated with discharge rate, temperature & cell aging all accounted for during each stage of every cycle with high accuracy.

A 5-bar LED display shows the remaining capacity in 20% increments. The display is activated by pressing a button under the main product label.

The battery pack block diagram is shown in Figure 2.

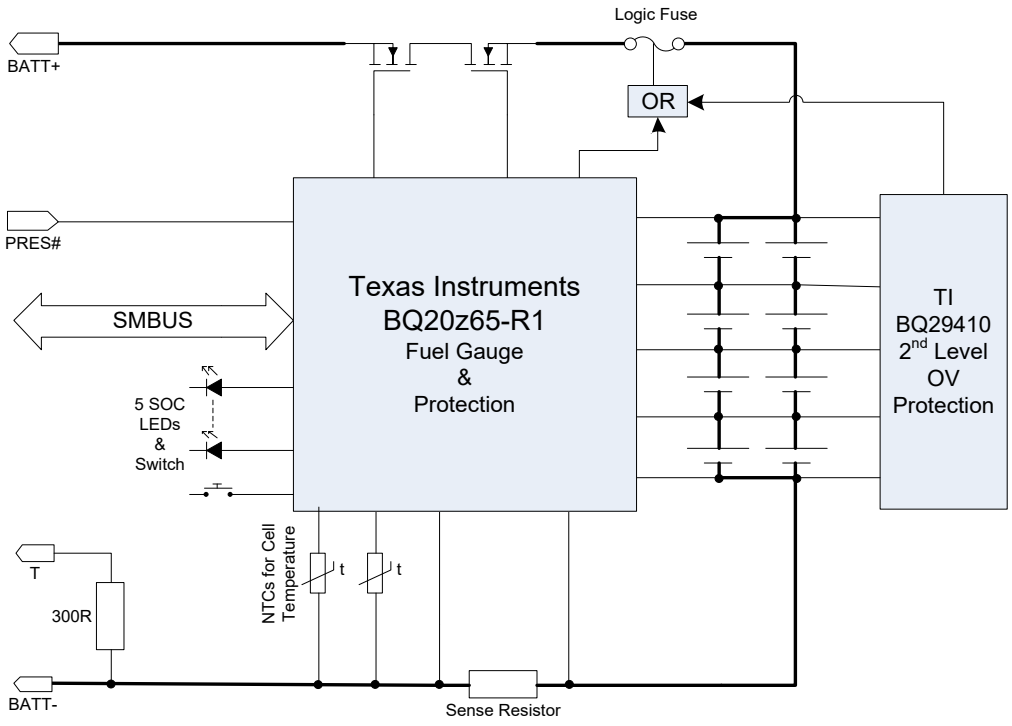

Figure 2 - Battery Pack Electronics Block Diagram

11.1.2 DC Specifications

Parameter	Typical value
Normal mode current consumption	550uA
Sleep mode current consumption	100uA
Shutdown mode current consumption	1uA

Table 4 – DC Specifications

11.1.3 Measurement of Voltage, Current & Temperature

The BQ20z65-R1 uses an integrating delta-sigma analogue-to-digital converter (ADC) for current measurement, & a second delta-sigma ADC for individual cell & battery voltage, & temperature measurement.

- Voltage - the voltage measurements have a resolution of 1mV.
- Temperature - the internal pack temperature is measured by two NTC thermistors attached to the cell stack. The temperature reading has a resolution of 0.1°K.
- Current - the current measurements have a resolution of 1mA.

The temperature measurement occurs in two locations on the battery for a more accurate pack temperature measurement & enhanced temperature protection.

11.1.4 System Present Pin (PRES#)

The battery includes a system present input on the connector (PRES#); this signal is used by the fuel gauge to indicate when it has been inserted into a system. This pin needs to be connected to BATT-. The fuel gauge samples the PRES# input once every second. When the battery is removed from the system the PRES# pin will go high & the fuel gauge will switch off the charge & discharge MOSFETs & enter sleep mode.

11.2 SMBus & SBD Parameters

11.2.1 Overview of Operations

The battery SMBus shall be compliant with the System Management Bus Specification [REF1]. The battery parameters shall be compliant with the Smart Battery Data Specification [REF2]. The battery shall be compliant with the necessary requirements of the Smart Battery Charger Specification [REF3].

11.2.2 Communication Protocol

The battery pack SMBus Interface complies with SBS Specification Version 1.1. A host processor uses the interface to access various battery pack registers. The interface uses a command-based protocol, where the host processor sends the battery address command byte to the battery pack. The command directs the battery pack to either store the next data received to a register specified command byte or output the data specified by the command byte. The Bus Host communicates with the battery pack using one of three protocols:

- Write Word
- Read Word
- Read Block

Refer to the SMBus specification [REF1] for further protocol details.

11.2.3 Host to Battery Message (Slave Mode)

The Host acting in the role of a bus master uses the read word, write word, & read block protocols to communicate with the battery, operating in slave mode.

Function	Cmd Code	Description	Unit	Access	Default (POR)
ManufacturerAccess()	0x00			r/w	-
RemainingCapacityAlarm()	0x01	Remaining Capacity Alarm Threshold	mAh or 10mWh	r/w	650mAh
RemainingTimeAlarm()	0x02	Remaining Time Alarm Threshold	minutes	r/w	10
BatteryMode()	0x03	Battery Operational Modes	bit flags	r/w	0x0081
AtRate()	0x04	This function is the first half of a two-function call-set used to set the AtRate value used in calculations made by the AtRateTimeToFull(), AtRateTimeToEmpty(), & AtRateOK() functions	mAh	r/w	0
AtRateTimeToFull()	0x05	Returns the predicted remaining time to fully charge the battery at the AtRate() value	minutes	r	65535
AtRateTimeToEmpty()	0x06	Returns the predicted remaining operating time if the battery is discharged at the AtRate() value.	minutes	R	65535
AtRateOK()	0x07	Returns a Boolean value that indicates whether or not the battery can deliver the AtRate() value of additional energy for 10 seconds. If the AtRate() value is zero or positive, the AtRateOK() function will always return true	Boolean	r	1
Temperature()	0x08	Returns the internal temperature of the battery	0.1°K	r	-
Voltage()	0x09	Returns the voltage of the battery	mV	r	-
Current()	0x0a	Returns the current being supplied (or accepted) through the battery terminals	mA	r	-
AverageCurrent()	0x0b	Returns a one minute rolling average of the current flowing into or out of the battery	mA	r	-
MaxError()	0x0c	Returns the expected margin of error	percent	r	See § 11.2.7
RelativeStateofCharge()	0x0d	Returns the predicted remaining battery capacity expressed as a percentage of FullChargeCapacity()	percent	r	-
AbsoluteStateOfCharge	0x0e	Returns the predicted remaining battery capacity expressed as a percentage of DesignCapacity()	percent	r	-
RemainingCapacity()	0x0f	Returns the predicted remaining battery capacity	mAh	r	-

FullChargeCapacity()	0x10	Returns the predicted battery capacity when fully charged	mAh	r	-
RunTimeToEmpty()	0x11	Returns the predicted remaining battery run time at the present rate of discharge	minutes	r	-
AverageTimeToEmpty()	0x12	Returns a rolling average of the predicted remaining battery run time	minutes	r	-
AverageTimeToFull()	0x13	Returns a rolling average of the predicted remaining time until the battery is fully charged	minutes	r	-
ChargingCurrent()	0x14	Returns the battery's desired charging current	mA	r	See § 11.3.4.1
ChargingVoltage()	0x15	Returns the battery's desired charging voltage	mV	r	See § 11.3.4.1
BatteryStatus()	0x16	Returns the battery status word	Bit flags	r	-
CycleCount()	0x17	Returns the number of charge / discharge cycles the battery has experienced	cycles	r	-
DesignCapacity()	0x18	Returns the theoretical capacity of the new battery	mAh	r	6500mAh
DesignVoltage()	0x19	Returns the theoretical voltage of a new battery	mV	r	14400
Specification()	0x1a	Returns the version number of the SBDS the battery pack supports, as well as voltage & current scaling information (v1.1 with PEC)	Formatted Word	r	0x0031
ManufacturerDate()	0x1b	Returns the date the battery was manufactured	Formatted Word	r	-
SerialNumber()	0x1c	Returns the serial number of the battery	number	r	-
Reserved	0x1d – 0x1f				
ManufacturerName()	0x20	Returns the name of the manufacturer	string	r	ACCUTRONICS
Device Name()	0x21	Returns the model of the battery	string	R	VR420A
Device Chemistry()	0x22	Returns the chemistry of the battery	string	r	LION
ManufacturerData()	0x23	Returns data specific to the manufacturer		r	-
Authenticate	0x2f	SHA-1 authentication	string	r/w	-
VCELL4 to VCELL1	0x3c – 0x3f	These functions return the calculated individual cell voltage in mV	Formatted Word	r	-

Table 5 - Host to Battery Messages

11.2.4 Battery to Charger Messages (Master Mode)

The battery, acting in the role of a bus master, uses the write word protocol to communicate with the charger, operating in slave mode. If the CHARGER_MODE bit in BatteryMode() is clear, the battery will broadcast charger request information at 10-second intervals.

Function	Command Code	Description	Unit	Access
ChargingCurrent()	0x14	Send the desired charging current to the battery charger	mA	W
ChargingVoltage()	0x15	Send the desired charging voltage to the battery charger	mV	W

Table 6 - Battery to Charger Messages

11.2.5 Critical Messages (Master Mode)

Whenever the battery detects a critical condition, it takes the role of a bus master & sends an AlarmWarning() message to the host &/or charger. The battery broadcasts the AlarmWarning() message at 10 second intervals until the critical condition(s) have been corrected.

Function	Command Code	Description	Unit	Access
BatteryStatus()	0x16	This message is to the host &/or charger to notify them that one or more alarms exist	Formatted word	W

Table 7 - Battery Critical Messages

Bit	Battery Status	Status	Definition
15	OVER_CHARGED_ALARM	ON	Battery is being charged beyond the maximum overcharge limit
		OFF	There is 2mAh of continuous discharge
14	TERMINATE_CHARGE_ALARM	ON	Battery is requesting 0 ChargingCurrent() & the charger continues to supply current
		OFF	When either condition is removed
13	*Reserved*		
12	OVER_TEMP_ALARM	ON	See section 11.3.4.4
		OFF	See section 11.3.4.4
11	TERMINATE_DISCHARGE_ALARM	ON	During discharge when the battery voltage drops <2.75V/cell for 5s or when RSOC = 0%
		OFF	When RSOC rises above 5% or 3.2V/cell
10	*Reserved*		
9	REMAINING_CAPACITY_ALARM (User settable)	ON	Battery detects that it's RemainingCapacity() is less than that set by the RemainingCapacityAlarm().
		OFF	Either the value set by the RemainingCapacityAlarm() is lower than the RemainingCapacity() OR when the RemainingCapacity() in increases by charging the battery.

8	REMAINING_TIME_ALARM	ON	Battery detects that the estimated remaining time at the present discharge rate is less than that set by the RemainingTimeAlarm().
		OFF	Either the value set by the RemainingTimeAlarm() is lower than the AverageTimeToEmpty() OR when the AverageTimeToEmpty() in increases by charging the battery.

Table 8 - Alarm Bit Definitions

Bit	Battery Status	Status	Definition
7	INITIALIZED	ON	Always
		OFF	
6	DISCHARGING	ON	Battery "Current()" is not positive
		OFF	Battery "Current()" is positive
5	FULLY_CHARGED	ON	When the battery is being charged & "Current()" declines ≤100mA for >80s & "Voltage()" ≥ (ChargingVoltage() - 0.3V)
		OFF	When the SOC of the battery declines 5% from the "FULLY_CHARGED" detection point.
4	FULLY_DISCHARGED	ON	Battery RSOC = 0% OR ≤2.75V/cell for 5s
		OFF	Battery RSOC ≥5% OR ≥3.2V/cell.

Table 9 - Status Bit Definitions

11.2.6 FullChargeCapacity & RelativeStateOfCharge Updates

The BQ20z65-R1 acquires & updates the battery-impedance profile during normal battery usage. It uses this profile, along with state-of-charge & the Qmax values, to determine FullChargeCapacity & RelativeStateOfCharge specifically for the present load & temperature.

See the Texas Instruments Theory & Implementation of Impedance Track Battery Fuel-Gauging Algorithm in bq20zxx Product Family application report (SLUA364B) for further details.

11.2.7 Max Error

This read-word function returns an unsigned integer value of the expected margin of error, in %, in the state-of-charge calculation, with a range of 1% to 100%.

Max error is incremented internally by 0.05% for every increment of CycleCount after the last QMAX update.

Event	MaxError Setting
Full Reset	Set to 100%
Qmax & Ra table update	Set to 1%
QMAX update	Set to 3%
RA table update	Set to 5%

Table 10 - Max Error Events

11.3 Protection Electronics

11.3.1 Overview of Operation

The 1st level of protection is provided by the BQ20z65-R1 which constantly monitors cell voltage, current & temperature to check they are within defined limits, if the limits are exceeded one or two MOSFETs are used to interrupt the charge or discharge current.

A 2nd level of protection is provided by an independent circuit that monitors the cell voltages & then controls the charge MOSFET to interrupt charge current.

11.3.2 Over-Charge Protection

The protection circuit will prevent the battery from charging until the clear condition is met.

Description	Protection Type	Set Voltage	Clear Voltage
1st Level – BQ20z65-R1	MOSFET	4.25V	3.95V
2nd Level – BQ20z65-R1	Logic Fuse	4.30V	-
3rd Level – BQ29410	Logic Fuse	4.35V	-

Table 11 - Over-Voltage Protection

11.3.3 Over-Discharge Protection

The protection circuit will prevent the battery from being further discharged once any cell voltage reaches 2.5V or less per parallel-cell-group. Then, once the battery voltage has risen by to more than 3.0V by charging, it will allow the battery to discharge again. If any cell voltages fall below 2.0V for 5s the fuel gauge will permanently disable the battery.

11.3.4 Temperature Protection

11.3.4.1 Charging

The protection circuit provides over-temperature protection that will prevent the battery from charging if the temperature is equal to or more than +53°C ± 2°C for 2 seconds. Charge is inhibited by turning off the charge FET & broadcasting the OVER_TEMP_ALARM message. Normal operation is allowed when the temperature drops to +40°C ± 2°C.

A 2nd level of protection is provided by the fuel gauge that will blow the logic fuse to permanently disable the battery if the temperature is equal to or more than +80°C ± 2°C for 5 seconds

The BQ20z65-R1 follows the JEITA guidelines which specify that charging voltage & charging current depend on the temperature. Temperature ranges are used for specifying the values for the charging voltage & the charging current. This is implemented as shown in Table 12.

11.3.4.2 Charge Characteristics

Flag	Temperature Range	Charging Mode	Charge Current	Charge Voltage
TR1	<0°C	Charge Suspend or Charge Inhibit	0mA	0mV
TR2	0°C < TEMP <+10°C	Low Temp Charge	3000mA	4.20V/Cell
TR2A	+10°C < TEMP <+40°C	Std Temp Charge 1	3000mA	4.20V/Cell
TR3	+40°C < TEMP <+45°C	Std Temp Charge 2	3000mA	4.20V/Cell
TR4	+45°C < TEMP <+53°C	High Temp Charge (or Charge inhibit)	1500mA (0mA)	4.20V/Cell (0mV)
TR5	+53°C < TEMP	Charge Suspend or Charge Inhibit	0mA	0mV

Table 12 - Charge Characteristics Over Temperature

A hysteresis of 1°C is implemented between ranges.

11.3.4.3 Discharging

The protection circuit provides over-temperature protection that will prevent the battery from discharging if the temperature is equal to or more than +72 ± 2°C for 2 seconds. Discharge is inhibited by turning off the discharge FET & broadcasting the OVER_TEMP_ALARM message. Normal operation is allowed when the temperature drops to +55°C ± 2°C.

A 2nd level of protection is provided by the fuel gauge that will blow the logic fuse to permanently disable the battery if the temperature is equal to or more than +80°C ± 2°C for 5 seconds.

11.3.4.4 Over Temperature Alarm (OTA)

The OTA is set when:

- Charging & the "Temperature()" >= +53°C for 2 seconds
- Discharging & the "Temperature()" >= +72°C for 2 seconds

The OTA is reset when:

- Charging & the "Temperature()" drops below +40°C
- Discharging & the "Temperature()" drops below +55°C

11.3.5 Over-Current Protection

There are two levels of active over-current protection provided:

- Short Circuit
- Overload

Condition	Current	Trip Delay	Recovery Condition
Charge Over Current Level 1-Tier 1	3.2A	3s	PRES# pin toggle
Charge Over Current Level 1-Tier 2	3.52A	2s	PRES# pin toggle
Charge Safety Over Current Level 2	5A	4s	N/A
Charge Short Circuit Current Level 3 (AFE)	10A	915us	PRES# pin toggle

Table 13 - Over-Current in Charge Protection Values

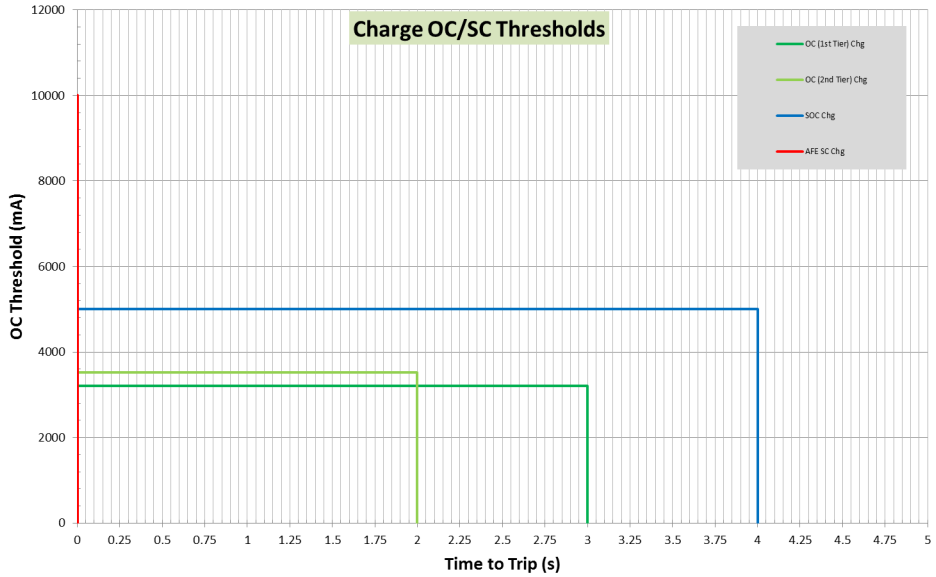

Figure 3 - Charge OC/SC Thresholds

Condition	Current	Trip Delay	Recovery Condition
Discharge Over Current (Level 1 - Tier 1)	6.4A	3s	PRES# pin toggle
Discharge Over Current (Level 1 - Tier 2)	7.04A	2s	PRES# pin toggle
Discharge Safety Over Current (Level 2)	11A	4s	N/A
Discharge Over Current (Level 3 – Tier 3) (AFE)	14A	31ms	PRES# pin toggle
Discharge Short Circuit Current (Level 3) (AFE)	47.5A	915us	PRES# pin toggle

Table 14 - Over-Current in Discharge Protection Values

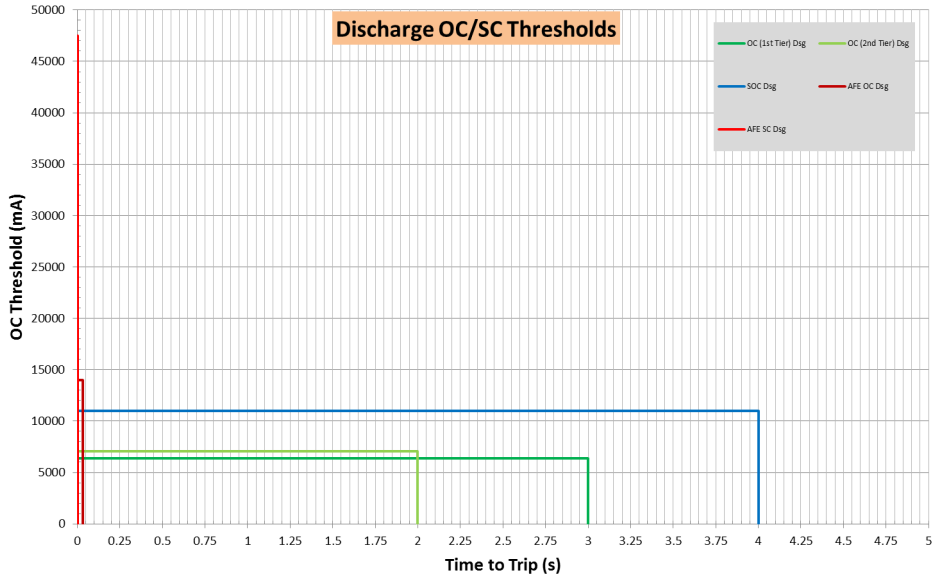

Figure 4 - Discharge OC/SC Protection Values

11.4 Logic Fuse

If the active protection system fails, the battery is fitted with a 15A logic fuse which will blow if the battery is subjected to excessive charge or discharge current. The fuse can also be blown by the active protection system or the secondary over voltage protection system (see section 11.3.2).

The fuel gauge will activate the logic fuse if any of the conditions occur:

PF Cfg Ref	Failure Mode	Condition
XSOPT1	Open Thermistor Permanent Failure On TS1	N/A
XSOCD	Discharge Safety Over Current Permanent Failure	11A for 4 seconds
XSOCC	Charge Safety Overcurrent	5A for 4 seconds
XDFETF	DSG FET Permanent Failure	40mA for 5 seconds
XCFETF	CHG FET Permanent Failure	40mA for 5 seconds
XSOT1D	Safety Over Temperature On TS1 During Discharge	+80°C ± 2°C for 5 seconds
XSOT1C	Safety Over Temperature On TS1 During Charge	+80°C ± 2°C for 5 seconds
XSOV	Safety Overvoltage Permanent Failure	4300mV for 5 seconds
XSOPT2	Open Thermistor Permanent Failure On TS2	N/A
XSOT2D	Safety Over Temperature On TS2 During Discharge	+80°C ± 2°C for 5 seconds
XSOT2C	Safety Over Temperature On TS2 During Charge	+80°C ± 2°C for 5 seconds

Table 15 - Fuel Gauge Logic Fuse Activation Conditions

12 MECHANICAL SPECIFICATIONS

12.1 Case

The cells & electronics are housed in an injection moulded plastic case. The casing material meets the flammability requirements of UL 94V-0 at the minimum wall thickness. The case colour is black. The overall nominal dimensions of the battery are 152.0mm x 87.9mm x 22.8mm.

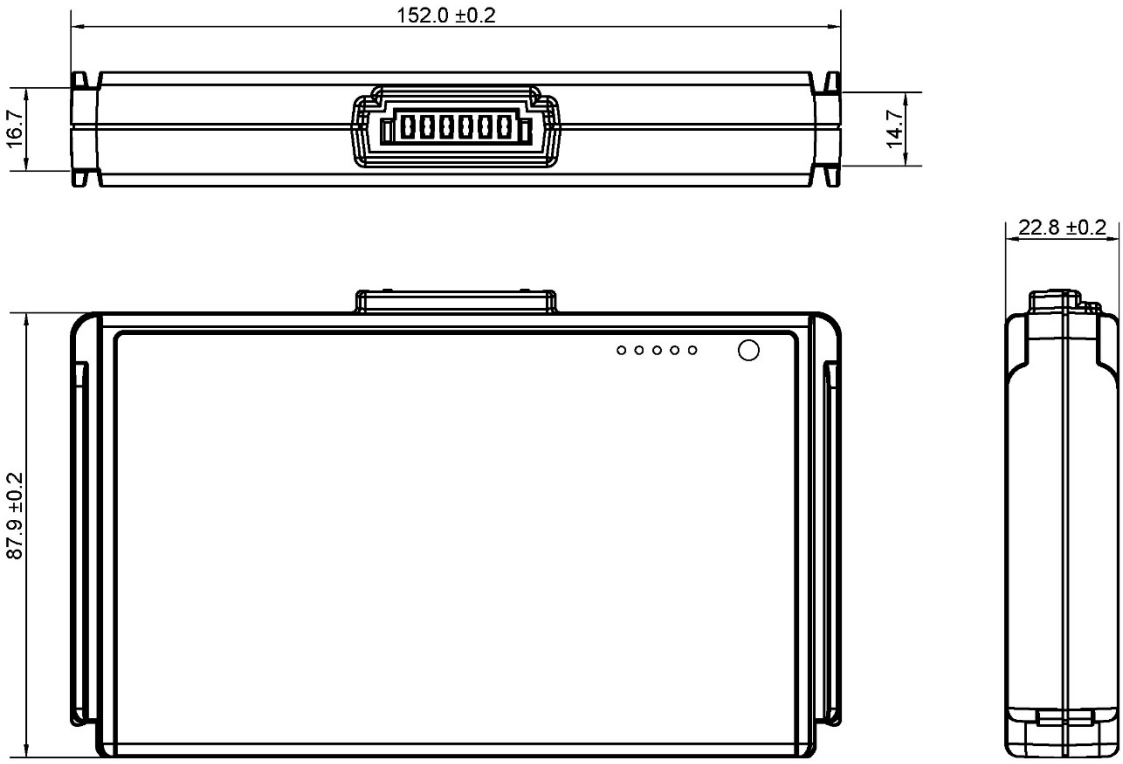

Figure 5 - Mechanical Drawing

12.2 Weight

The typical battery pack weight is 495g.

12.3 Label Details

12.3.1 Static Label

The static information label is flooded black. Text & logos (including Entellion Logo) are white. The VR420A label is shown in Figure 6.

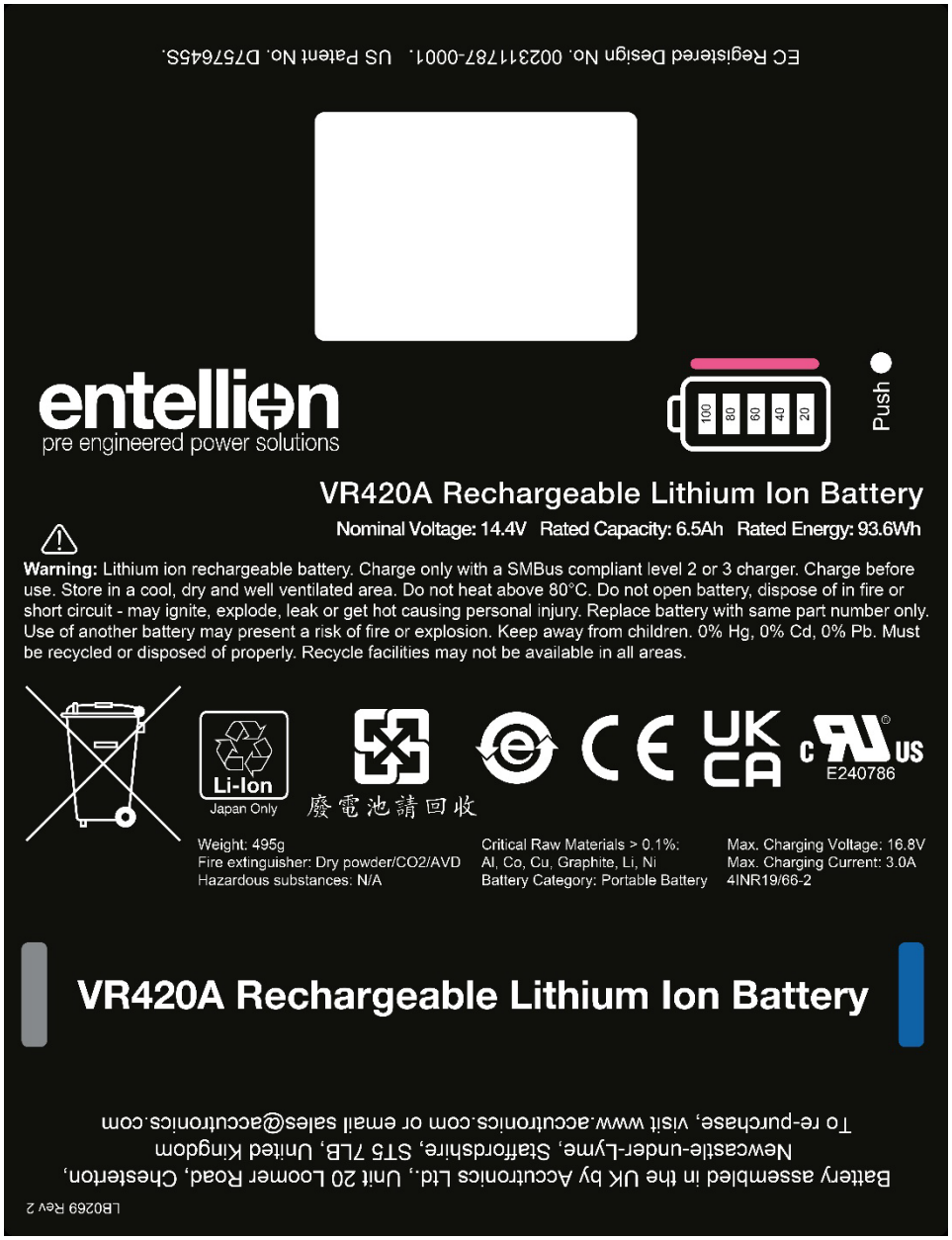

Figure 6 - Label Artwork

12.3.2 Dynamic Label

A second, smaller label carries dynamic information relating to the revision & manufacture date of the battery. It measures 14mm x 50mm & is placed in a recess on the rear of the battery. The label is manufactured from silver polyester & is suitable for printing on a thermal transfer printer. The information on the label is as follows:

(i) Text: "PART NUMBER: PPPPPPPPPPPP" where PPPPPPPPPPPP is 46A051AJ00018.

(ii) Text: "DATE OF MANUFACTURE: YYWW" (where YY is the year & WW is the ISO week number).

(iii) Text: "REVISION: SW-aaa-HW-bbb" where aaa is the Firmware Revision (if firmware revision is 1.1 then aaa = 011) & bbb is the General Assembly Drawing Revision (if drawing revision is D then bbb = 004).

(iv) Text: "SERIAL NUMBER: NNNNN". (where NNNNN is the battery electronic serial number).

The label is shown in Figure 7.

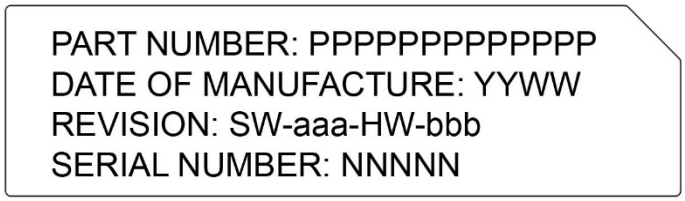

Figure 7 - Dynamic Label Artwork

13 PACKAGING

The battery is placed into an anti-static bag & then packaged in an individual white card carton. The outside of the carton is labelled with a white paper label that shows the part number, description, voltage, capacity, energy, & date of manufacture (YYWW).

14 ENVIRONMENTAL / SAFETY SPECIFICATIONS

14.1 Transportation

The battery meets the requirements of testing specified in the Recommendations on the Transport of Dangerous Goods, Manual of Tests & Criteria (ST/SG/AC.10.11/Rev.8).

14.2 UL 2054

The battery meets the requirements of UL 2054 2nd Edition. UL file numbers BBFS2.E240786 (Batteries, Household & Commercial – Component), NWGQ2.E240786 (Information Technology Equipment Including Electrical Business Equipment - Component) & NWGQ8.E240786 (Information Technology Equipment Including Electrical Business Equipment Certified for Canada - Component) apply.

14.3 IEC 62133-2:2017

The battery meets the requirements of IEC 62133-2:2017+AMD1:2021 (Secondary cells & batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, & for batteries made from them, for use in portable applications - Part 2: Lithium Systems).

14.4 Directives

The battery meets the requirements of Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC.

14.5 EMC

The battery meets the intent of the EMC Directive. Compliance has been demonstrated by conformance to the following standards which have been listed in the Official Journal of the European Communities. EMC: Emissions EN55022:1998 +A1:2000 +A2:2003, Immunity EN55024:1998 +A1:2001 +A2:2003.

14.6 EHS Regulations

14.6.1 Restriction of Hazardous Substances (RoHS)

No RoHS banned materials are used (as per the Europa Chemical Candidate List). The battery meets the requirements of the RoHS 3 Directive (2015/863/EU), the RoHS Recast (RoHS2) Directive 2011/65/EU & original RoHS Directive 2002/95/EC.

14.6.2 Waste Electrical & Electronic Equipment (WEEE)

The battery is compliant with the Waste Electronic & Electrical Equipment Regulations 2006 (UK) & meets the requirements of the Waste Electronic & Electrical Equipment Directive (2002/96/EC, Amendment 2003/108/EC & Recast 2012/19/EU).

14.6.3 REACH

The battery is compliant with the Registration, Evaluation, Authorisation & Restriction of Chemicals (REACH) - EU directive 1907/2006. No substances as per the European chemical Candidate List are present in the battery or used during its manufacture.

14.7 CE /UKCA Marking

Compliance with applicable EMC directives permit the battery to be CE & UKCA marked.

15 BATTERY PRODUCTION REQUIREMENTS

15.1 Quality Management System

15.1.1 ISO 9001

The battery has been designed & manufactured by Accutronics Ltd, operating a quality management system which complies with the requirements of ISO 9001:2015.

15.1.2 ISO 13485

The battery shall be designed & manufactured by Accutronics Ltd, operating a quality management system which complies with the requirements of ISO 13485:2016.

15.2 Battery Production Testing Requirements

15.2.1 PCBA

The PCBA within the battery is manufactured in accordance with IPC-A-610E class III. Accutronics ensure that the PCBA used within the battery has been fully functionally tested by the PCBA supplier. Test records are maintained for traceability purposes.

15.2.2 Battery

As part of the assembly process, Accutronics ensure that the electronics within the battery function correctly: (i) the fuel gauge is programmed correctly & (ii) the fuel gauge temperature, current & voltage measurements are accurate.

Once assembled, the battery is subjected to a 'burn in' test which involves a full cycle of the battery. Once cycled the accuracy of the fuel gauge & the performance of the cells during the cycle are checked. Test records are maintained for traceability purposes.

16 LITHIUM ION BATTERY GENERAL PRECAUTIONS

16.1 Danger!

Do not disassemble or modify the battery. The battery is equipped with built-in safety/protection features. Should these features be disabled, the battery can leak electrolyte, overheat, emit smoke, burst &/or ignite.

Do not connect the positive (+) & negative (-) terminals with a metal object such as wire. Do not transport or store the battery together with metal objects such as necklaces, hair pins, etc. Otherwise, short-circuiting will occur, over-current will flow, causing the battery to leak electrolyte, overheat, emit smoke, burst &/or ignite, or the metal object such as wire, necklace or hair pin can generate heat.

Do not discard the battery into fire or heat it. Otherwise, its insulation can melt down, its gas release vent or safety features will be damaged &/or its electrolyte can ignite, possibly leading to electrolyte leakage, overheating, smoke emission, bursting &/or ignition on it.

Do not use or leave the battery near a heat source such as a fire or a heater (+80°C or higher). If the resin separator should be damaged owing to overheating, internal short-circuiting may occur to the battery, possibly leading to electrolyte leakage, smoke emission, bursting &/or ignition of the battery.

Do not immerse the battery in water or seawater & do not allow it to get wet. Otherwise, the protective features in it can be damaged, it can be charged with extremely high current & voltage, abnormal chemical reactions may occur in it, possibly leading to electrolyte leakage, smoke emission, bursting &/or ignition.

Do not recharge the battery near fire or in extremely hot weather. Otherwise, hot temperatures can trigger its built-in protective features, inhibiting recharging, or can damage the built-in protective features, causing it to be charged with an extremely high current & voltage &, as a result, abnormal chemical reactions can occur in it, possibly leading to electrolyte leakage, overheating, smoke emission, bursting &/or ignition.

To recharge the battery use the battery charger specifically designed for the purpose & observe the recharging conditions specified by ACCUTRONICS. A recharging operation under non-conforming recharging conditions (higher temperature & larger voltage/current than specified, modified battery charger, etc.) can cause the battery to be overcharged, or charged with extremely high current, abnormal chemical reaction can occur in it, possibly leading to electrolyte leakage, overheating, smoke emission, bursting &/or ignition.

Do not pierce the battery with a nail or other sharp objects, strike it with a hammer, or step on it, otherwise, the battery will become damaged & deformed, internal short-circuiting can occur, possibly leading to electrolyte leakage, overheating, smoke emission, bursting &/or ignition.

Do not subject the battery to sudden mechanical shock. The impact might cause leakage, overheating, smoke emission, bursting &/or ignition. Also, if the protective feature in it becomes damaged, it could become charged with an extremely high current & voltage, abnormal chemical reactions can occur, which can lead to electrolyte leakage, overheating smoke emission, bursting &/or ignition.

Do not use an apparently damaged or deformed battery. Otherwise, electrolyte leakage, overheating, smoke emission, bursting &/or ignition of the battery may occur.

Do not directly solder the battery. Otherwise, heat can melt down its insulation, damage its gas release vent or safety features, possibly leading to electrolyte leakage, overheating, smoke emission, bursting &/or ignition.

Do not reverse the positive (+) & negative (-) terminals. Otherwise, during recharging, the battery will be reverse-charged, abnormal chemical reactions then may occur, or excessively high current can flow during discharging, leading to electrolyte leakage, overheating, smoke emission, bursting &/or ignition.

The positive (+) & negative (-) terminals are arranged in a particular orientation. Do not force the connection if you cannot easily connect the battery terminals to the battery charger or other equipment. Confirm that the terminals are correctly oriented. Reversing the terminals will result in reverse-charging, possibly leading to electrolyte leakage, overheating, smoke emission, bursting &/or ignition of the battery.

Do not connect the battery to an electrical outlet, vehicle cigarette lighter, etc. When subjected to large voltage, over-current can flow on the battery, possibly leading to electrolyte leakage, overheating, smoke emission, bursting &/or ignition.

Do not use the battery for a purpose other than those specified. Otherwise, its guaranteed performance will be lost &/or its service life will be shortened. Depending on the equipment in which the battery is used, excessively high current can flow through battery, possibly damaging it & leading to electrolyte leakage, overheating, smoke emission, bursting &/or ignition.

If the battery leaks & electrolyte gets into the eyes, do not rub them. Instead, rinse the eyes with clean running water & immediately seek medical attention. Otherwise, eye injury may result.

16.2 Warning!

Do not use the battery in combination with primary batteries (such as dry-cell batteries) or batteries of different capacities or brands. Otherwise, the battery can be over-discharged during use or overcharged during recharging, abnormal chemical reactions may occur, possibly leading to electrolyte leakage, overheating, smoke emission, bursting &/or ignition.

If recharging operation fails to complete even when a specified recharging time has elapsed, immediately stop further recharging. Otherwise, electrolyte leakage, overheating, smoke emission, bursting &/or ignition can occur.

Do not put the battery into a microwave oven or pressurised container. Rapid heating or disrupted sealing can lead to electrolyte leakage, overheating, smoke emission, bursting &/or ignition.

If electrolyte leaks from the battery or gives off a bad odour, remove it from any exposed flame. Otherwise, the leaking electrolyte may catch fire & the battery may emit smoke, burst or ignite.

If the battery gives off an odour, generates heat, becomes discoloured or deformed, or in any way appears abnormal during use, recharging or storage, immediately remove it from the equipment or battery charger & stop using it. Otherwise, the problematic battery can develop electrolyte leakage, overheating, smoke emission, bursting &/or ignition.

16.3 Caution!

Do not subject the battery to intense sunlight or hot temperatures, for example in a car during hot weather. Otherwise, electrolyte leakage, overheating &/or smoke emission can occur. Also, its guaranteed performance will be lost &/or its service life will be shortened.

The battery incorporates built-in safety devices. Do not use it in a location where static electricity (greater than the manufacturer's guarantee) may be present. Otherwise, the safety devices can be damaged, possibly leading to electrolyte leakage, overheating, smoke emission, bursting &/or ignition.

The guaranteed recharging temperature range is 0°C to +45°C. A recharging operation outside this temperature range can lead to electrolyte leakage &/or overheating of the battery & may cause damage to it.

If electrolyte leaking from the battery comes into contact with your skin or clothing, immediately wash it away with running water. Otherwise, skin inflammation can occur.

Store the battery in a location where children cannot reach it. Also, make sure that a child does not take the battery out of the battery charger or equipment.

Before use, study carefully these Precautions. For further information contact the nearest ACCUTRONICS distributor or representative. Retain the original product literature for future reference.

For recharging procedures, refer to the Operation Manual of your battery charger.

If you find rust, a bad odour, overheating &/or other irregularities when using the battery for the first time, return it to your supplier or vendor.

16.4 Recommendations to End Users

The following represents a typical, but not exhaustive list of good advice to be provided by the equipment manufacturer to the end-user.

Do not dismantle, open or shred secondary cells or batteries.

Do not expose cells or batteries to heat or fire. Avoid storage in direct sunlight.

Do not short-circuit a cell or a battery. Do not store cells or batteries haphazardly in a box or drawer where they may short-circuit each other or be short-circuited by other metal objects.

Do not remove a cell or battery from its original packaging until required for use.

Do not subject cells or batteries to mechanical shock.

In the event of a cell leaking, do not allow the liquid to come in contact with the skin or eyes. If contact has been made, wash the affected area with copious amounts of water & seek medical advice.

Do not use any charger other than that specifically provided for use with the equipment.

Observe the plus (+) & minus (-) marks on the cell, battery & equipment & ensure correct use.

Do not use any cell or battery which is not designed for use with the equipment.

Do not mix cells of different manufacture, capacity, size, or type within a device.

Keep cells & batteries out of the reach of children.

Seek medical advice immediately if material or content from a cell or a battery has been swallowed.

Always purchase the correct cell or battery for the equipment.

Keep cells & batteries clean & dry.

Wipe the cell or battery terminals with a clean dry cloth if they become dirty.

Secondary cells & batteries need to be charged before use. Always use the correct charger & refer to the manufacturer's instructions or equipment manual for proper charging instructions.

Do not leave a battery on prolonged charge when not in use.

After extended periods of storage, it may be necessary to charge & discharge the cells or batteries several times to obtain maximum performance.

Secondary cells & batteries give their best performance when they are operated at normal room temperature (+20°C ± 5°C).

Retain the original product literature for future reference.

Batteries must be recycled or disposed of properly. Follow local regulations & ordinances for the disposal of the batteries. Recycle facilities may not be available in all areas.

17 CONTACT DETAILS

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