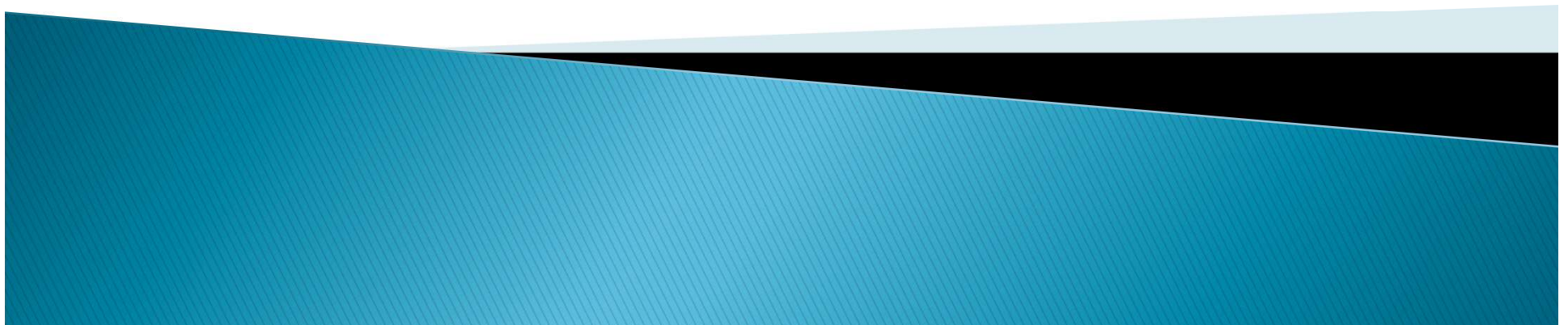


Working with Rechargeable Batteries

By Barry Basile KG5IRR
For the Oak Forest Amateur Radio Club
11/19/2022



Scope

- ▶ Nomenclature
- ▶ Rechargeable Lithium-Ion Chemistries
- ▶ Optimizations
- ▶ Discharge Characteristics
- ▶ Charging
- ▶ Packs and Protection Circuits
- ▶ Interpreting Datasheets
- ▶ Testing Capacity
- ▶ Prolonging Life



Background

- ▶ Rechargeable batteries are EVERYWHERE in appliances we rely on daily... your car, your cell phone, notebook computer, etc.
- ▶ Many hams use rechargeable batteries to power their rigs for portable and emergency operations
- ▶ Proper maintenance of these batteries is essential for maximum battery life and safety
- ▶ Understanding the fundamentals will help us achieve optimum performance and value from our rechargeable battery systems



Lithium Battery Characteristics

- ▶ Can be primary or secondary (rechargeable)
- ▶ Lithium is:
 - Metal for primary batteries (anode)
 - Oxide Compound for secondary batteries (cathode)
- ▶ One of the best energy-to-weight ratios
- ▶ High open circuit voltage
- ▶ Low self-discharge rate
- ▶ No memory effect
- ▶ Slow loss of charge when not in use



Chemistry

- ▶ The chemistry of the battery has the biggest influence on the nominal voltage, energy density and safety of the cell
- ▶ Without a doubt the most popular lithium battery among hams is the Lifepo4 battery
- ▶ Is this the best choice? What are the alternatives?



Physical Dimensions

- ▶ Batteries of all types use “standard” nomenclature that many of us are not aware of...
- ▶ One the most common cell sizes the world over is the “18650”.
- ▶ This number implies the approximate dimensions in mm, hence:
 - 18 mm in diameter by
 - 65 mm long
- ▶ A fairly common coin cell battery – CR2032 is 20 mm in diameter and 3.2 mm thick

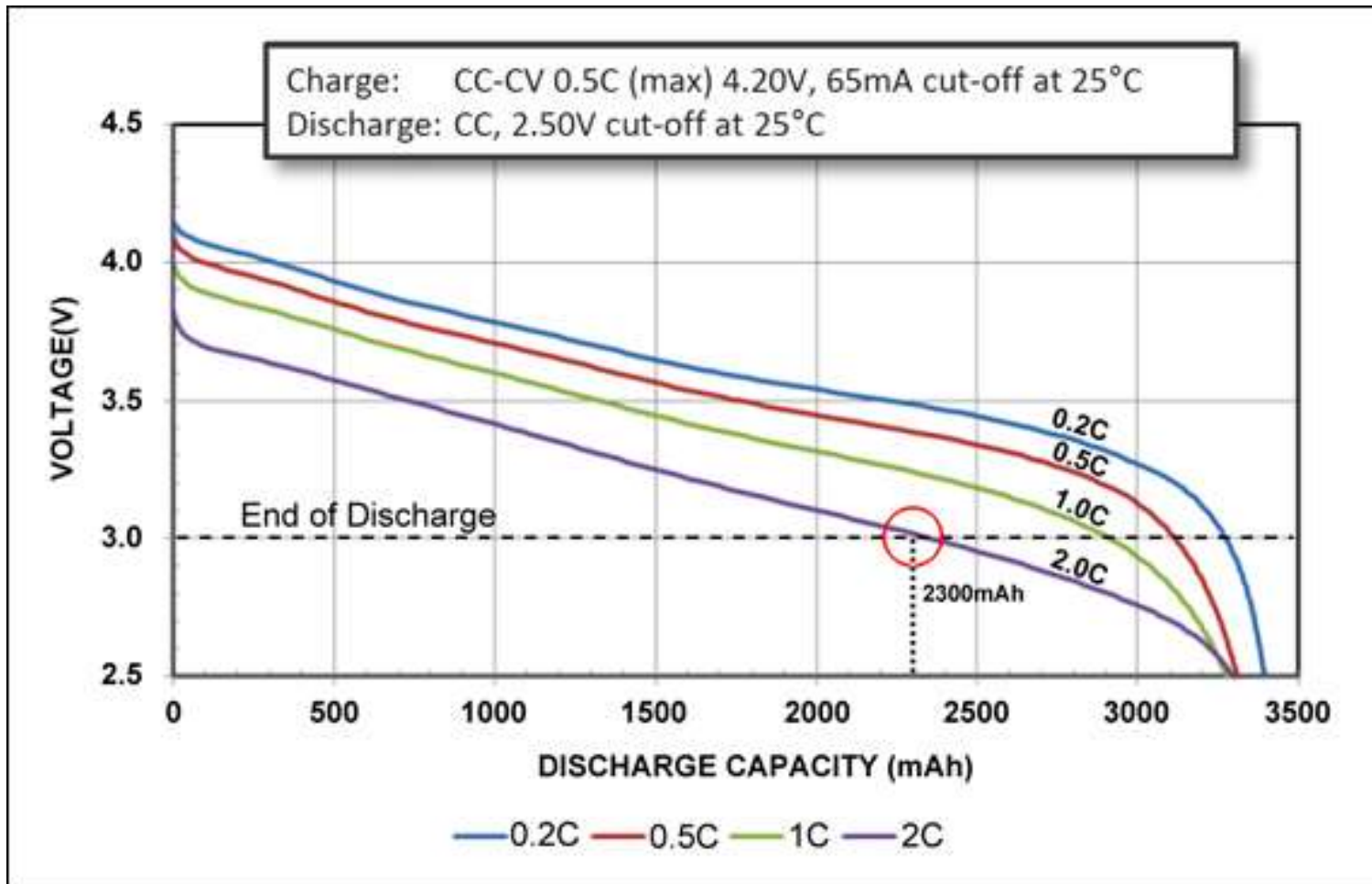


Capacity

- ▶ The capacity rating is given in AH or maH
- ▶ Multiples of the term “C” indicate the capacity of a cell in AH. For example, a 3200ma battery has a 1C capacity 3.2Ah
 - Can source 3.2 A for 1 hour
 - 6.4 A for 0.5 hours
 - 0.64 A for 5 hours
- ▶ Battery manufacturers optimize their designs for maximum energy or high power or somewhere in between
- ▶ The chemistry and cell design determine
 - How the cell performs under heavy load
 - The minimum cell voltage (end of discharge)

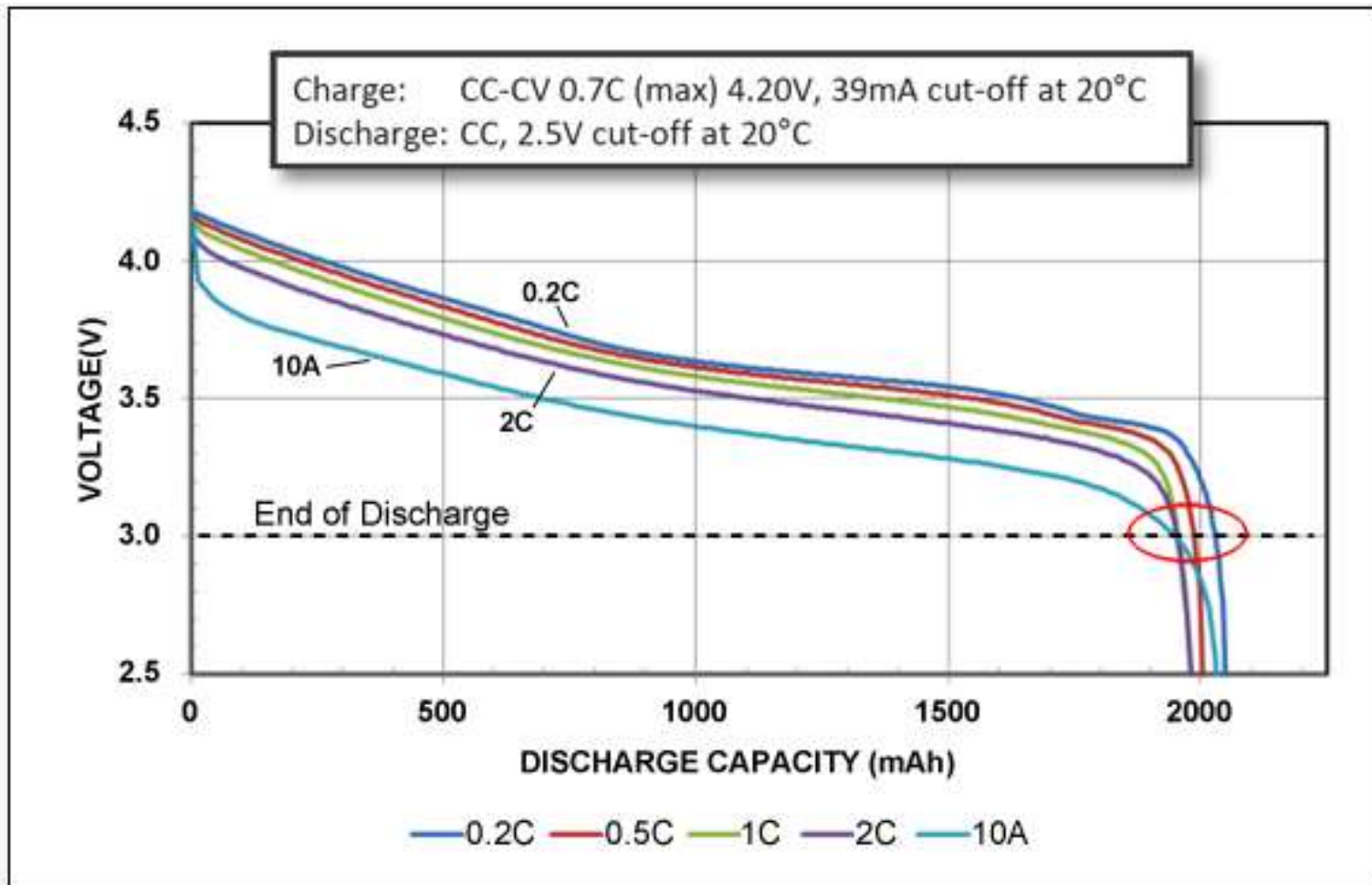


Energy Cell Discharge



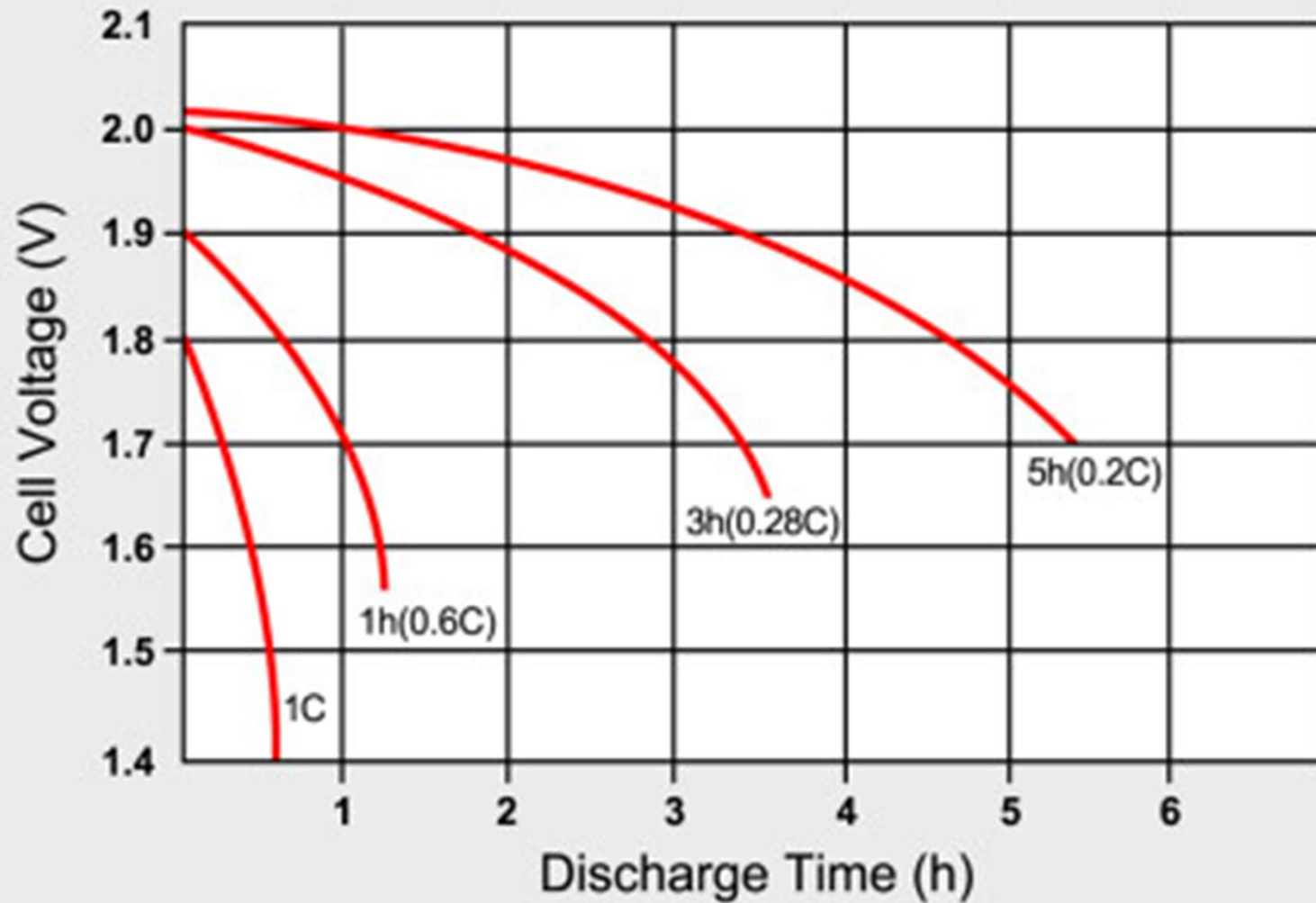
Discharge characteristics of NCR18650B Energy Cell by Panasonic
NCA type, 3.2 AH rating

Power Cell Discharge



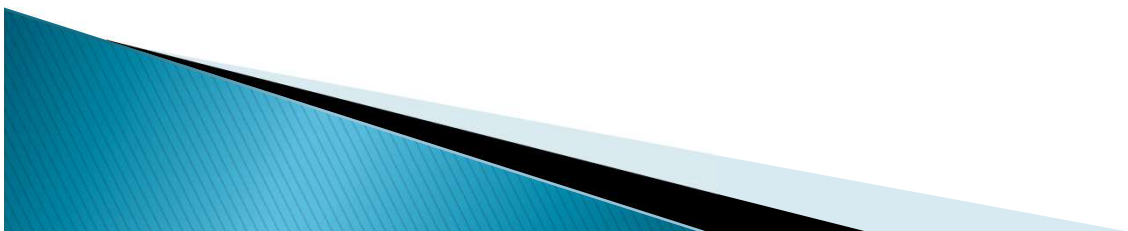
Discharge characteristics of UR18650RX Power Cell by Panasonic NMC type, 1950 mAh rating

Lead Acid Cell Discharge



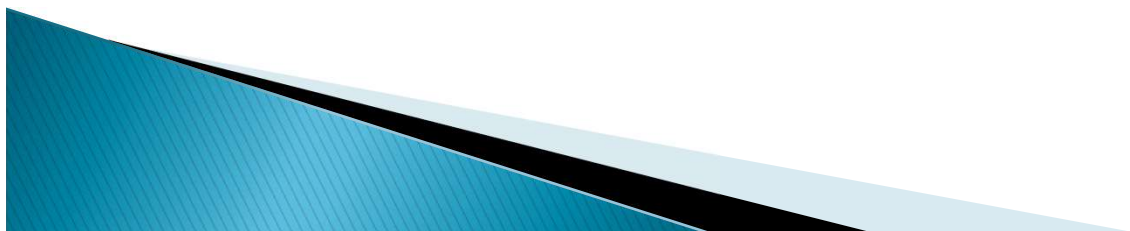
Temperature Effects

Temperature	Energy Cell	Power Cell
25 C	100%	100%
0 C	~83%	~92%
-10 C	~66%	~85%
-20 C	~53%	~80%



Chemistries, General Characteristics

Type	Chemistry	Volts	Specific Energy (Wh/kg)	Rel. Safety	Cycle Life	\$/kWh	18650 Capacity	18650 WH
LTO	Lithium Titanate	2.4	80	4	7000	1005	1300	3.12
LFP	Lithium Iron Phosphate	3.2	120	4	2000	580	1100	3.52
LCO	Lithium Cobalt Oxide	3.6	200	2	1000	201	2600	9.36
LMO	Lithium Manganese Oxide	3.6	150	3	700	196	3000	10.80
NCA	Lithium Nickel Cobalt Alum Oxide	3.6	260	2	500	350	3450	12.42
LMC/NMC	Lithium Nickel Manganese Cobalt Oxide	3.6	220	3	2000	420	3500	12.60



Samsung Examples (~3.6V)

Model	Capacity (mAH)	Wh	Discharge Current Limit	Chemistry
15M	1500	5.4	23.0	LCO
20R	2000	7.2	22.0	LMO
22PM	2150	7.78	10.0	NMC
24F	2400	8.88	5.0	LCO
25R5	2500	9	20.0	NMC
26FM	2600	9.62	5.2	NMC
28C	2800	10.42	5.6	LCO
29E	2850	10.4	2.8	NMC
30Q	3000	10.8	15.0	NCA
33G	3150	11.34	9.75	?
35E	3500	12.6	8.0	NMC



Cycle Life (EOL = 70% 1C)

Depth of Discharge	Discharge cycles	
	NMC	LiPO ₄
100% DoD	~300	~600
80% DoD	~400	~900
60% DoD	~600	~1,500
40% DoD	~1,000	~3,000
20% DoD	~2,000	~9,000
10% DoD	~6,000	~15,000



Charging Systems

- ▶ 2 and 3 stage chargers are most common
 - Constant Current
 - Constant Voltage
 - Trickle Charge (NOT with Lithium Ion Cells)
- ▶ Stage 1:
 - Constant current not to exceed the maximum shown in the datasheet
 - Can charge for max capacity or max cycle life
- ▶ Stage 2:
 - Constant voltage not to go below the cutoff current



Battery Packs

- ▶ Obviously we can create battery packs consisting of multiple cells to increase voltage or maximum current delivery
- ▶ For safety reasons, even single cell “packs” should be protected with appropriate circuits that attempt to limit various harmful conditions:
 - Max and min voltage
 - Max and min current
 - Temperature
- ▶ To get the longest life from a multi-cell pack, cell balancing circuits ensure that all cells have the same voltage during charge cycles and can isolate bad cells when discharge voltages are unmatched



Battery Data Sheets

- ▶ What will you find there?
 - Physical Dimensions
 - Weight
 - Chemistry
 - Capacity (AH)
 - Voltage and current specifications
 - Discharging limits
 - Charging limits
 - Impedance
 - Temperature Limits
 - Storage
 - Operating
 - Charging
 - Cycle Life



Datasheet Deep Dive

- ▶ Capacity rating is given in AH or maH but we saw a big difference in AH depending on load
- ▶ Energy cell datasheets have begun to use new nomenclature to set appropriate expectations
- ▶ Energy Cell datasheets may use a spec like $1C_5A$, indicating the number of amps that can be delivered in 5 hours
- ▶ The actual 1C rating will be somewhat less than the rating given



Typical Datasheet

4. Battery Classification and Type

4.1 Battery Classification

SANYO Lithium Ion Battery

4.2 Battery Type

NCR18650B

5. Nominal Specifications

Items	Specifications	Notes
5.1 Rated Capacity (Minimum)	3200 mAh	0.64A discharge at 20°C
5.2 Nominal Capacity (Minimum)	3250 mAh	0.65A discharge at 25°C
5.3 Nominal Capacity (Typical)	3350 mAh	Reference only
5.4 Nominal Voltage	3.6V	0.65A discharge at 25°C
5.5 Discharging End Voltage	2.5V	
5.6 Charging Current (Std.)	1.625A	
5.7 Charging Voltage	4.20 ± 0.03V	
5.8 Charging Time (Std.)	4.0 hours	
5.9 Continuous Discharging Current (Max.) ^{*1}	4.875A	0 ~ +45°C
5.10 Internal Resistance	less than 48mΩ	AC Impedance 1 kHz
5.11 Weight	less than 47.5g	

Typical Datasheet (2)

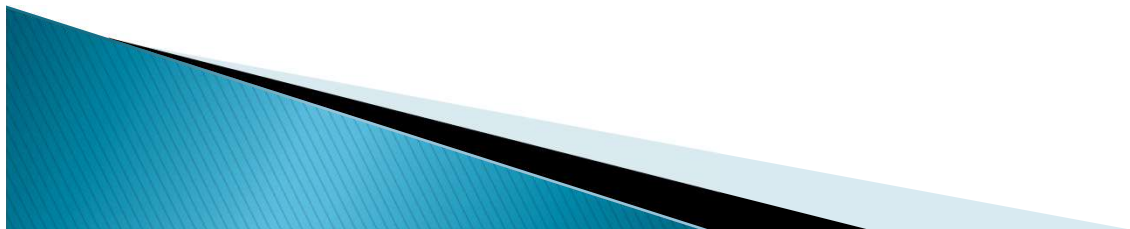
5.12 Operating Temperature	Charge	0 ~ +45°C	
	Discharge	-20 ~ +60°C	
5.13 Storing Conditions	less than 1 month	-20 ~ +50°C	Percentage of recoverable capacity 80% ^{※2}
	less than 3 months	-20 ~ + 40°C	
	less than 1 year	-20 ~ + 20°C	

※1 The maximum discharge current for a single cell use. However after the battery pack assembly , there will be a limitation of maximum discharge current due to a protection circuit or a protection device.

※2 Percentage of recoverable capacity

= (Discharging time after storage / Initial discharging time) ×100

The discharging time is measured by the discharge current of 0.65A until 2.5V of end voltage after the battery is fully charged at 25°C.



Typical Datasheet (3)



Description

Lithium Ion INR18650 HG2 3000mAh

Document No.

BCY-PS-HG2-Rev0

Date

2014-10-13

Rev

0

1. General Information

1.1 Scope

This product specification defines the requirements of the rechargeable lithium ion battery to be supplied to the customer by LG Chem.

1.2 Application: Power Tools

1.3 Product classification: Cylindrical rechargeable lithium ion battery

1.4 Model name: 18650 HG2

2. Nominal Specification

Item	Condition / Note	Specification
2.1 Capacity	Std. charge / discharge	Nominal 3000 mAh (C_{nom})

Typical Datasheet (4)

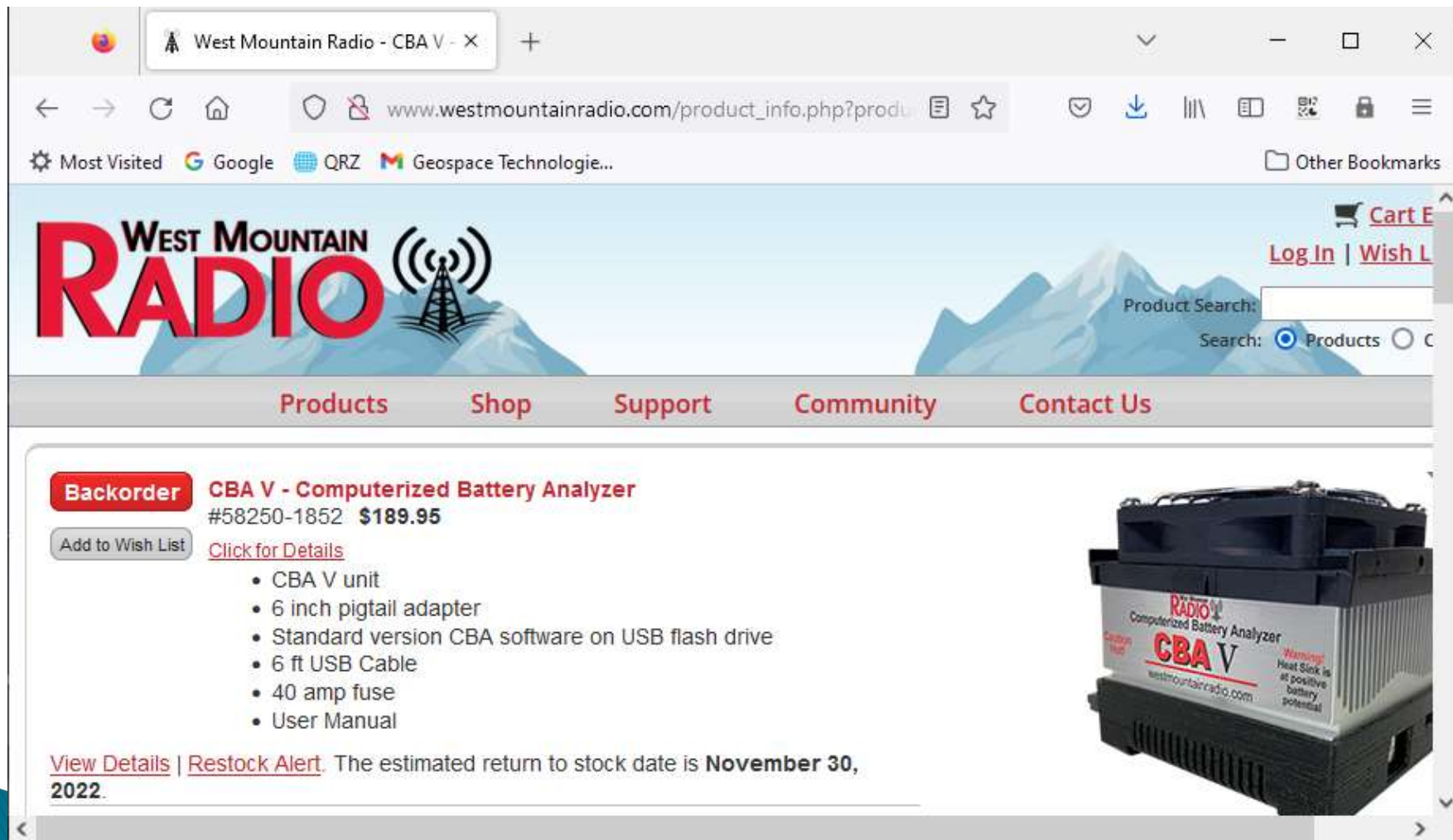
Item	Condition / Note	Specification
2.1 Capacity	Std. charge / discharge	Nominal 3000 mAh (C_{nom})
2.2 Nominal Voltage	Average for Std. discharge	3.60V
2.3.1 Standard Charge (Refer to 4.1.1)	Constant current	1500mA
	Constant voltage	4.2V
	End condition(Cut off)	50mA
2.3.2 Fast charge (Refer to 4.1.3)	Constant current	4000mA
	Constant voltage	4.2V
	End condition(Cut off)	100mA
2.4 Max. Charge Voltage	-	$4.20 \pm 0.05V$
2.5 Max. Charge Current	-	4000mA
2.6.1 Standard Discharge (Refer to 4.1.2)	Constant current	600mA
	End voltage(Cut off)	2.5V
2.6.2 Fast Discharge (Refer to 4.1.3)	Constant current	10000mA , 20000mA
	End voltage(Cut off)	2.5V
2.7 Max. Discharge Current	For continuous discharge	20000mA
2.8 Weight	Max.	47.0 g

Testing Capacity

- ▶ Will want to measure Coulombs (AH) going out and in to the pack during discharge and charge
- ▶ Monitor current and voltage during charge and discharge cycles at regular periods
- ▶ Typically will use a constant current for discharge down to the minimum voltage specified by the datasheet
- ▶ What may be more meaningful is to mimic the dynamic load seen by your rig when chasing QSOs
- ▶ Use two different discharge rates during the test with some defined duty cycle



Discharge Instrument



The screenshot shows a web browser window displaying the product page for the CBA V - Computerized Battery Analyzer on the West Mountain Radio website. The browser's address bar shows the URL www.westmountainradio.com/product_info.php?product_id=58250-1852. The website header features the West Mountain Radio logo, a search bar, and navigation links for Products, Shop, Support, Community, and Contact Us. The product listing includes a "Backorder" badge, the product name, a price of \$189.95, and a list of included items. A "View Details" link is highlighted in red, and a "Restock Alert" is displayed with an estimated return to stock date of November 30, 2022. An image of the CBA V unit is shown on the right side of the page.

West Mountain Radio


Products Shop Support Community Contact Us

Backorder CBA V - Computerized Battery Analyzer
#58250-1852 **\$189.95**

Add to Wish List [Click for Details](#)

- CBA V unit
- 6 inch pigtail adapter
- Standard version CBA software on USB flash drive
- 6 ft USB Cable
- 40 amp fuse
- User Manual

[View Details](#) | [Restock Alert](#). The estimated return to stock date is **November 30, 2022**.



The image shows the CBA V unit, a rugged, black and silver device with a heat sink and a warning label that reads "Warning! Heat Sink is at positive battery potential".

CBA V Specs

Features

Specifications

Contents

Manual

Software

Accessories

Specifications

* Improvement/Enhancement on CBA V

Maximum continuous discharge (at ambient 75°F) *	1.5V: 60W 3V: 80W 6V: 120W 9V & up: 150W		
Short term maximum discharge *	200W Example: 12V / 200W 1 minute max		
Discharge current range	0.01A to 40A		
Current Accuracy		Typical	Max
	Standard CBA V		
	0.01A-1.5A	+/-25ma	+/-75ma
	1.5-40A	+/-2%	+/-5%
	CBA V Pro		
	0.01A-1.5A	+/-3ma	+/-7ma
	1.5-40A	+/-0.5%	+/-1%
Current Rise/Fall Time	<300 ms		
Voltage Accuracy	At CBA V connector: +/-1% Remote sense cable: +/-1%		

Simple Guidelines to Prolong Li-ion Battery Life

- ▶ Do not discharge Li-ion too low; charge more often. A random or partial charge is fine. Li-ion does not need to be fully charged as with lead acid.
- ▶ Heat the battery to room temperature before charging. Do not charge below freezing.
- ▶ Limit the time the battery resides at 4.2V/cell (full charge), especially when warm.
- ▶ Moderate the charge current to between 0.5C and 0.8C for cobalt-blended lithium-ion. Avoid ultra-fast charging and harsh loading.
- ▶ When possible, lower the charge voltage limit to prolong battery life.
- ▶ Keep the battery cool. Move it away from heat-generating environments. Avoid hot cars and windowsills that are exposed to the sun.
- ▶ It is not necessary to unplug the laptop from the power grid when not in use. The charger stops charging when the battery is fully charged.
- ▶ When the SoC (state of charge) fuel gauge becomes inaccurate, calibrate smart batteries by applying a deliberate full discharge and charge.
- ▶ Add some charge before a long storage. The charge level is not as critical as cool storage.



References

▶ Overview

- <https://www.sciencedirect.com/topics/chemistry/lithium-ion-battery>

▶ Battery University

- <https://batteryuniversity.com/article/bu-205-types-of-lithium-ion>

▶ 18650 Lithium Ion Battery Identification Reference – Google Drive

- <https://docs.google.com/spreadsheets/d/1fYjDxxCJXfm2wdpGWCaOUGq8V8TOEgsnplHQa4YQpRQ/htmlview>

