VARTA

CoinPower Rechargeable Li-Ion Button Cells

Technical Handbook

www.varta-microbattery.com

CONTENT

1. GENERAL INFORMATION

VARTA Microbattery is a leading manufacturer of batteries and provides professional support worldwide to customers to help them to design VARTA batteries into their applications. Quality, reliability, high performance and customer satisfaction are the main reasons for our leading position in the market. VARTA Microbattery provides solutions to major OEM companies for high-tech applications such as Bluetooth headsets, activity trackers, heat cost allocator devices, back-up for memory and the real-time clock in PCs/notebooks as well as alarm systems, medical equipment, consumer electronics and many more product type.

VARTA Microbattery produces all major chemistries in various form factors. We are fully equipped to produce customized batteries. We are confident that we can provide an optimized battery solution for most application requirements. VARTA Microbattery provides rechargeable batteries in NiMH, Li-Ion and Lithium Polymer chemistries.

Product Highlights of VARTA CoinPower Batteries

- 6 patented innovations
- Capacity from 60 mAh to 120 mAh
- Low internal resistance
- For discharge currents up to 3C
- Fast charge capability : ready to go in 15 min.
- Long life expectancy
- Excellent charge & discharge characteristics
- Safe & reliable (UL and IEC recognition)
- Smaller designs and lighter products for increased user comfort
- Produced on highly automated production lines in Germany

Comparison of the energy density of various rechargeable battery systems:
A = Lithium Polymer
B = Lithium-Ion
C = Ni-MH
D = Ni-Cd
E = Lead acid

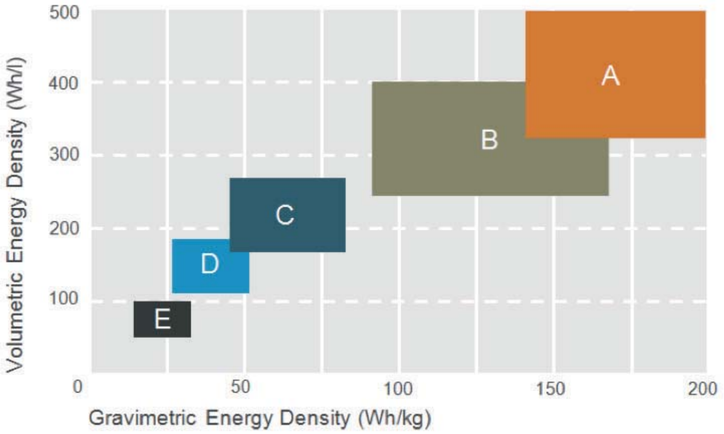


FIG. 1 Comparison of different rechargeable battery systems

1.1 DEFINITIONS

Unless otherwise stated, specified values are valid for operation at room temperature 20°C ± 2°C.

Specific Data

The gravimetric energy density of the Li-Ion Coin Power series depends on battery size, and is in the range 180-210 Wh/kg. Volumetric energy density is in the range 370-410 Wh/l.

Voltage Definitions

Open Circuit Voltage (OCV):
Equilibrium potential 3.0 V to 4.2 V on average, dependent on temperature, storage duration and state of charge. Nominal Voltage of Li-Ion cells is 3.7 V
End of Discharge Voltage (EOD):
The voltage at the end of discharging is nominally 3.0 V per cell, but depend on discharge rate and temperature.
End of Charge Voltage: (EOC)
Terminal voltage after charge is 4.2 V.

Capacity Definitions

The capacity C of a cell is defined by the discharge current I and the discharge time t: $C = I \cdot t$
I = constant discharge current
t = duration from the beginning of discharge until the end of discharge voltage is reached

Nominal Capacity

The nominal capacity C denotes the energy amount in mAh (milli-Ampère hours) that the cell can deliver at the 5 hour discharge rate (0.2 CA). The reference temperature is +20°C ± 2°C, and the final discharge voltage is 3.0 V.

Typical Capacity

The typical capacity is the average capacity at a discharge rate of 0.2 CA to a final discharge voltage of 3.0 V.

Available Capacity

Li-Ion cells deliver their nominal capacity at 0.2 CA. This assumes that charging and discharging is carried out as recommended.
Factors which affect the available capacity are:

- Rate of discharge
- End of discharge voltage
- Ambient temperature
- State of charge
- Age
- Cycle history

At higher than nominal discharge rates the available capacity is reduced.

Current Definitions

Charge and discharge rates are given as multiples of the nominal capacity (C) in Amperes (A) with the term CA.
Example:
Nominal capacity C = 1000 mAh
0.1 CA = 100 mA, 1 CA = 1000 mA

Nominal Discharge Current

The nominal discharge current of a Li-Ion cell is the 5 hour discharge current (0.2 CA).
It is the current at which the nominal capacity of a cell is discharged in 5 hours.

1.2 FEATURES

VARTA CoinPower batteries are the first choice for a number of modern high-tech portable products. They provide a long lasting, reliable main power source which is lightweight and occupies a minimum of space in the host device.

VARTA CoinPower batteries meet the most important design requirements of these products:
Reliable high-power output, design flexibility with a minimum of space requirement and a round form factor.

Feature	Advantage	Customer Benefit
High energy density	Lightweight and small size	Best performance and long battery life
Wound electrode design	High discharge currents	Suitable for applications with high peak currents
Built-in safety device with chemical safety components	The market's best safety performance	Additional cell protection in case the electronic circuit malfunctions
Fully automated production in Germany	High reliability and consistent quality	High reliability in the field
Worldwide branch offices with technical support	Close customer relationship	Local contact, local knowledge, local language

TAB. 1

1.3 APPLICATIONS

VARTA CoinPower batteries are especially suitable for modern electronic applications such as **Bluetooth Mono/Stereo Headsets, Sensors for Fitness/Sport/Healthcare, Smart Watches, Wearable Technology, Smart Car Keys** and many more. These cells are the ultimate power source for your electronic devices and make your products smaller, lighter and more attractive. VARTA CoinPower provides outstanding performance and reliability, excellent quality along with very safe operation.

Smart Watch

Bluetooth Headsets

Smart Key

Body monitoring system

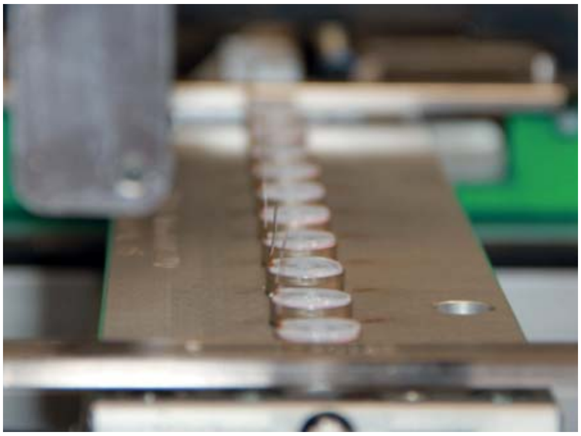
1.4 GENERAL DESIGN AND APPLICATION CRITERIA

Choose the most suitable battery from our range of VARTA CoinPower cells for the needs of your application and the conditions in which it is expected to operate.
The most important criteria for the selection of battery type are these:

- Required minimum operating time
- Max. and average current drain
- Min. and max. operating voltage
- Operating temperature range
- Mechanical properties
- Available space
- Environmental conditions

You can choose a cell from the VARTA CoinPower range for operate within the following limits:
Operating Voltage: 3.0 V … 4.2 V
Capacity: 60 … 120 mAh
Height: 5.4 mm
Diameter: 12 mm, 14 mm or 16 mm

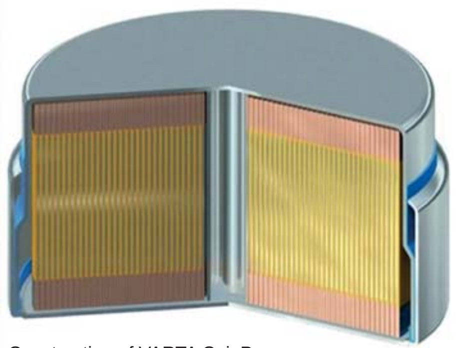
VARTA Microbattery's professional design-in team, available worldwide, will be happy to assist you with further recommendations and will guide you through the whole design and production process.



VARTA CoinPower production in Ellwangen/Germany

1.5 CONSTRUCTION AND ELECTROMECHANICAL PROCESSES OF COINPOWER

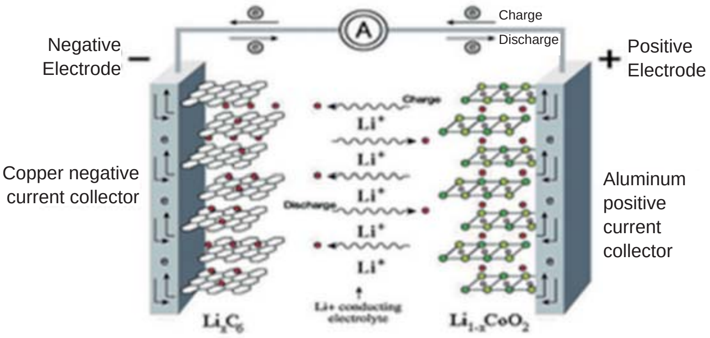
The housing of the CoinPower cells consists of two stainless steel parts. This gives the cell very high mechanical stability during assembly in the end-product as well as during the product's use by the customer. Inside the cell the anode, cathode and separator are wound to a coil. The connection of the electrodes to the housing is made by welding from the inside to the lid and cup. The innovative design of the housing, combined with its foil gasket, provides for the most efficient use of the space inside the cell for energy-storing material. This is why the energy density of the CoinPower batteries is one of the highest of any cell in this small form factor.



Construction of VARTA CoinPower

FIG. 8

In Li-Ion batteries such as in the CoinPower cells lithium ions move from the anode to the cathode during discharge and from the cathode to the anode when charging. Aluminum and copper are used for the positive and negative current collector. A liquid electrolyte provides for the movement of lithium ions through the separator.



Chemical reaction in Li-Ion rechargeable battery

FIG. 9

2. MISCELLANEOUS

2.1 SPECIFICATION TABLE VARTA COINPOWER

The CoinPower cell is available in three different diameters. The overall height of the bare cell is 5.4 mm. See specification table below.

Type Designation	Voltage (V)	Capacity (mAh)	Diameter (mm)	Height (mm)	Weight (mg)
CP 1254 A3	3.7	60	12.1	5.4	1.6
CP 1454 A3	3.7	85	14.1	5.4	2.3
CP 1654 A3	3.7	120	16.1	5.4	3.0

Model Number

The model numbers are two uppercase English letters and a figure consisting of four digits. The version number consists of one letter and one figure as shown in the example below.

CP 1654 A3

1 2 3 4

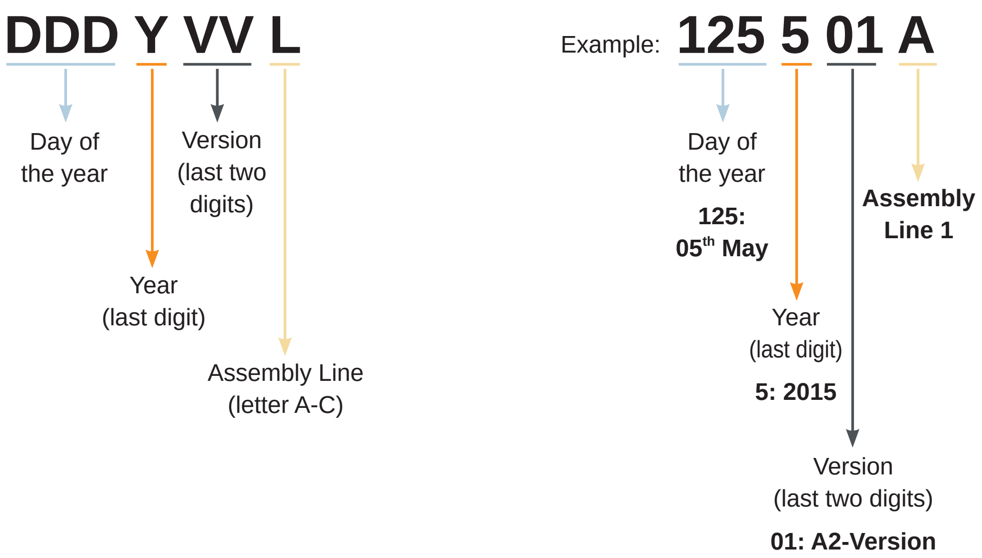
1. Battery Type (CP – CoinPower)
2. Cell Diameter (here: 16 mm)
3. Cell Height (here: 5.4 mm)
4. Version

2.2 IDENTIFICATION CODE

In order to make every single cell fully traceable, a cell code is printed on the housing of each one. This code provides information about the production date, the version and the assembly line.

The products are coded with a **7-digit code** which refers to the day it was manufactured, the version and the assembly-line:

Digit 1–3: Ongoing day of the year
Digit 4: Year (last digit)
Digit 5–6: Version (last two digits)
Digit 7: Assembly Line (Line 1: A, Line 2: B, Line 3: C, ...)



Please note that this code is printed on every individual cell produced in Germany. The battery code is different, and is indicated on the battery drawing.

3. CHARGING AND DISCHARGING

3.1 CHARGING

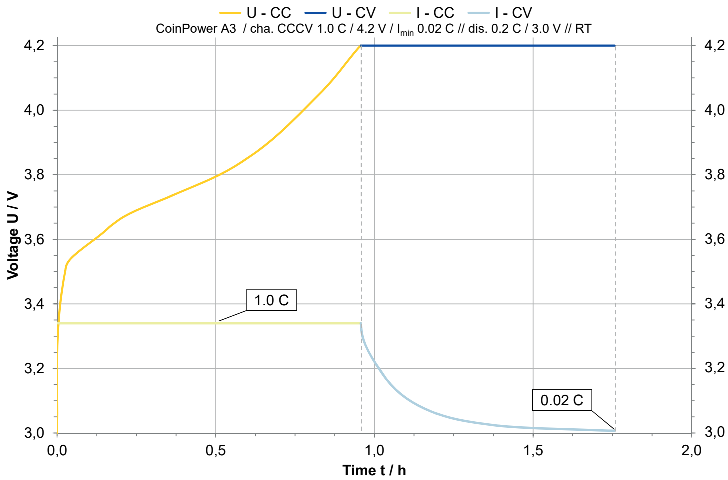
The CoinPower battery can be charged at various charging rates and with various charging profiles. In order to find the best solution for any given application, see the different options below. For more information please consult your Key Account Manager or use the contact information on the last page of this document.

Standard Charging

The standard charging profile for a CoinPower battery has a maximum C-Rate of 0.5C over the entire temperature range between 0°C and 45°C. The charging procedure must be Constant-Current Constant-Voltage (CCCV).

Fast Charging

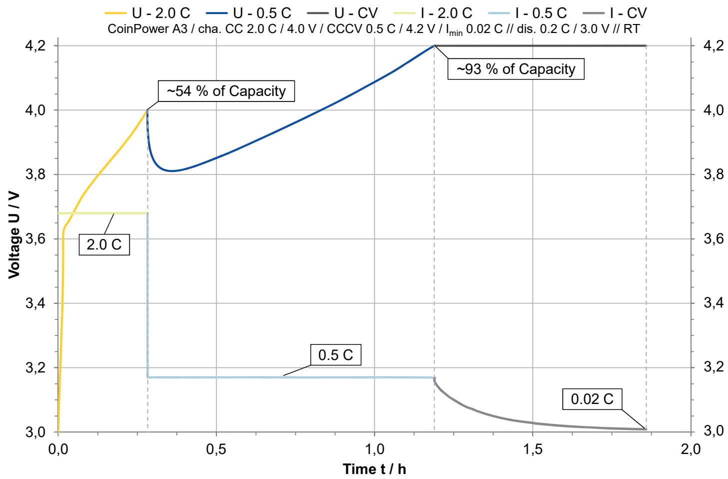
The CoinPower can be fast charged with a maximum C-Rate of 1C over the entire temperature range between 0°C and 45°C. The charging procedure must be Constant-Current Constant-Voltage (CCCV). When fast charging the capacity and cycle life may be less than the values stated in the datasheet.



1C-Fast Charge Procedure for CoinPower

Rapid Charging

The A3-version can be rapid charged with a two-step procedure: A charging rate of 2C can be applied up to max 4.0V, before continuing at the standard rate of 0.5C up to 4.2V. The charging voltages should be controlled within tolerances of ± 50 mV. The charging procedure must be Constant-Current Constant- Voltage (CCCV). The temperature range for this two-step procedure must be between 15°C and 45°C. When rapid charging, the capacity and cycle life may be less than the values stated in the datasheet.



2C-Rapid Charge Procedure for CoinPower

Comparison of Charging Procedures

An overview of the various charging procedures and the related time and charged capacity can be found in the table below.

Charged Capacity	**Standard Charge (0.5C)**	**Fast Charge (1C)**	**Rapid Charge (2C // 4.0V - 0.5C // 4.2V)**
25 %	35 min	15 min	8 min
50 %	65 min	30 min	15 min
75 %	95 min	45 min	50 min
100 %	165 min	105 min	100 min

3.2 DISCHARGING

Thanks to its coiled electrode design the CoinPower series can handle very high discharge currents without any damage or reduction in cycle life while operating with a very low voltage drop. The cell can be discharged at **2C continuous and 3C in pulse mode for 2s.** This makes it possible to run power-hungry devices and to support even high pulse load profiles. The supported discharge current can be even higher than 3C for shorter durations than 2s.

Discharge Temperature

The cell should be discharged within a temperature range between -20°C and 60°C.

Over Discharging

If not used for a long time, the cell(s) might become over discharging. In order to prevent over discharging, the cell(s) should be charged periodically to maintain a voltage in the range of 3.0 V to 3.8 V.

Over discharging may cause some loss of cell performance or impair battery function. The host product should be equipped with a device which prevents further discharging below the cut-off voltage specified in the data sheet.

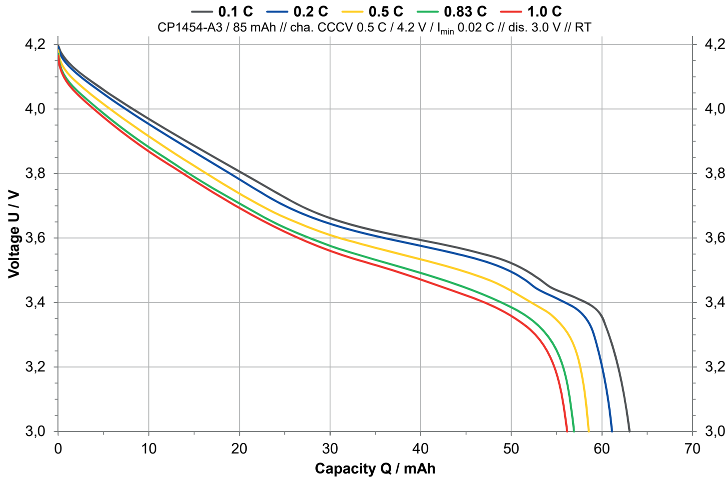
Important: The PCM over discharge detection threshold/voltage must not be used as the cut-off voltage for the battery.

Also the charger shall be equipped with a device to control the recharging procedure as follows:
In case of over discharging, the cell(s) should be charged with a low current (0.01 – 0.07 C) for 15-30 minutes, i.e. pre-charging, before standard charging starts. Charging according to the data sheet should be started after the individual cell voltage has risen above about 3.0 V and within 15-30 minutes. This timing can be controlled by the use of an appropriate timer for pre-charging.

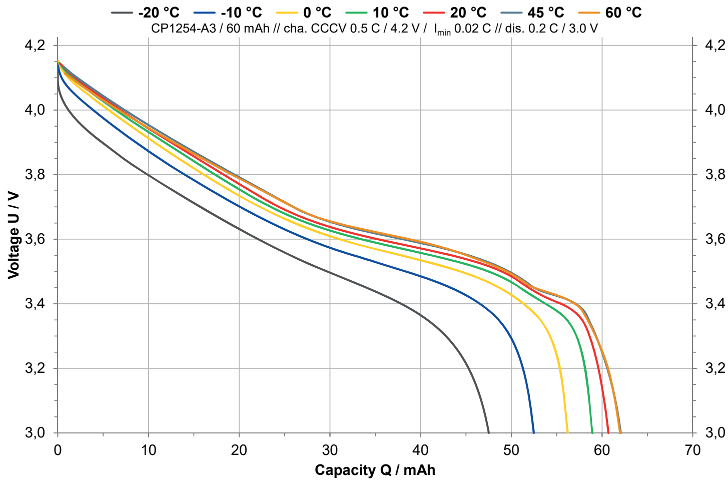
If the individual cell voltage does not rise to about 3.0 V within the pre-charging time, the charger should be able to stop charging and display a notification that the cell(s) is/are in an abnormal state.

Discharging Performance

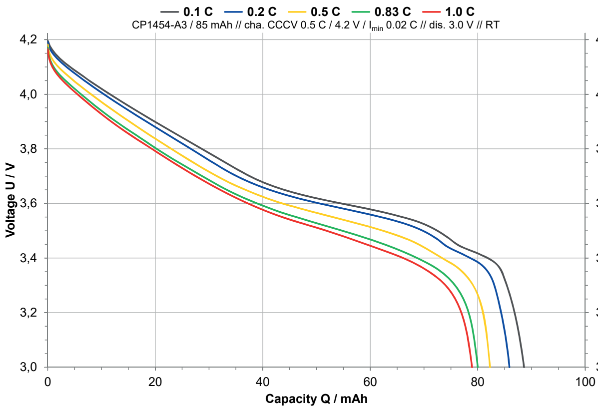
The graphs below show the discharge curves of all three cell sizes of the CoinPower series at various currents (C-rates) and temperatures. The discharge capacity can be determined when the colored lines reach the 3.0V level (End-of-Discharge Voltage). In every header there is detailed information about the discharge procedure.
The second graph in each example shows the discharge performance at a 0.2C-rate at various temperatures (-20°C to +60°C).



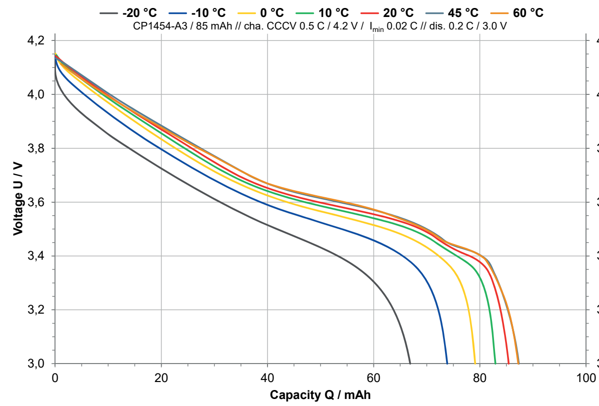
CP1254 A3 – Discharge Characteristic with different loads



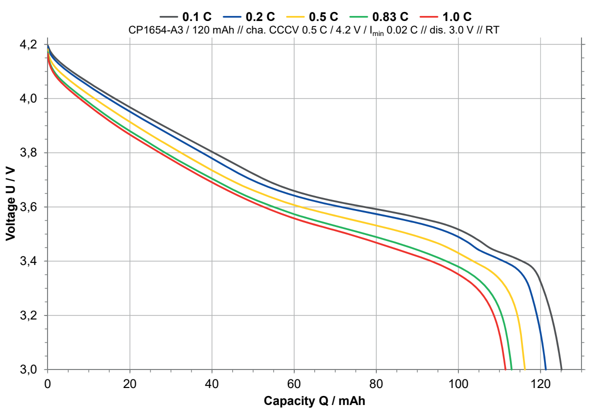
CP1254 A3 – Discharge Characteristic at various temperature



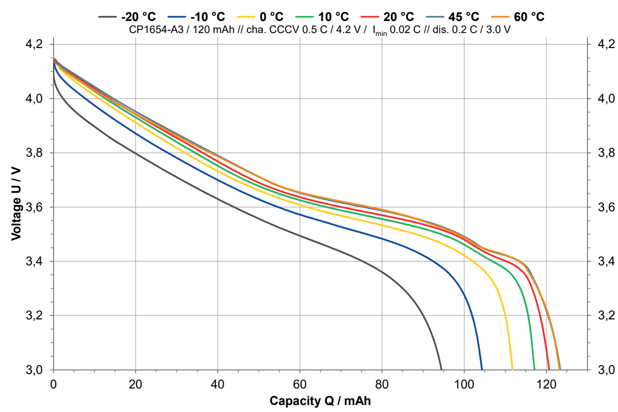
CP1454 A3 – Discharge Characteristic with different loads



CP1454 A3 – Discharge Characteristic at various temperatures



CP1654 A3 – Discharge Characteristic with different loads



CP1654 A3 – Discharge Characteristic at various temperatures

3.3 CHARGING IC

CoinPower batteries may be charged with any standard single-cell lithium charging-IC which implements the CC/CV-procedure for lithium systems.
Important: The charging current control have low level setting. The charging procedure can also be implemented by a microcontroller or DSP.

A Constant-current Constant-voltage (CC/CV) controlled charge system is used for charging lithium and some other battery types that may be vulnerable to damage if the upper voltage limit is exceeded. The manufacturers‘ specified constant current charging rate is the maximum charging rate that the battery can tolerate without damaging the battery. Special precautions are needed to maximize the charging rate and to ensure that the battery is fully charged while at the same time avoiding overcharging. For this reason it is recommended that the charging method switches to constant voltage before the cell voltage reaches its upper limit. Note that this implies that chargers for lithium-ion cells must be capable of controlling both the charging current and the battery voltage.

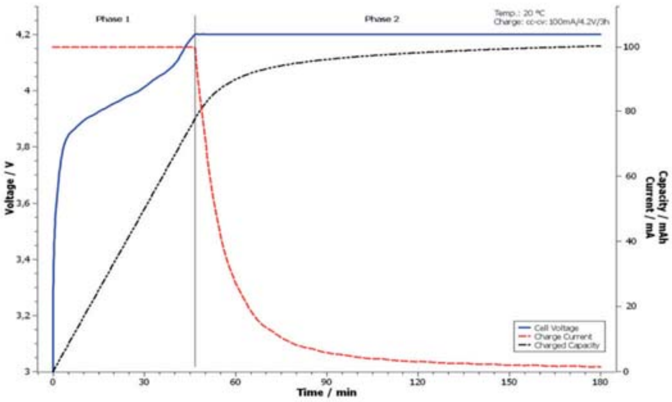
Recommended Charging ICs for VARTA CoinPower batteries:
Texas Instruments

- BQ 24040
- BQ 24050
- BQ 24052

Linear Technology

- LT 4070
- LT 4071

Please note: There are many more charging ICs available on the market for use in charging VARTA CoinPower batteries

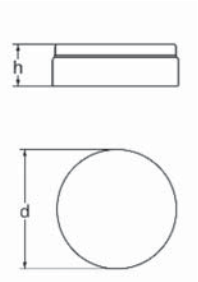


Illustrates the different phases during a charge cycle

4. INDIVIDUAL SPECIFICATION

Below are the datasheets of the three available CoinPower cell sizes. They provide all the necessary technical information at a glance. If you have any questions please consult your Key Account Manager.

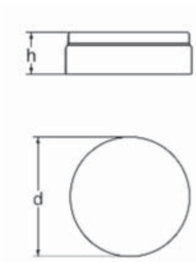
Data Sheet – CP 1254 A3 (CoinPower®)[1]



Type Designation	CP 1254 A3
Type Number	63125
Cell Code	ICR1254
System	Graphite – layered metal oxide ($LiNi_xMn_yCo_zO_2$)
UL Recognition	MH13654
Nominal Voltage [V]	3.7 (average)
Typical Capacity C [mAh]	63 (at 0.2C from 4.2 V to 3.0 V at 20 °C)
Nominal Capacity C [mAh]	60 (at 0.2C from 4.2 V to 3.0 V at 20 °C)
Dimensions [mm] (without Tags)	
Diameter	12.1 +0.0/-0.3
Height	5.4 +0.2/-0.1
Weight. approx [g]	1.6 +0.2/-0.2
Charging Method	Constant Current + Constant Voltage
Charge Voltage [V]	4.20 ± 0.05
Initial Charge Current [mA]	Standard Charge: 30 Fast Charge[2]: 60 Rapid Charge[3]: 120
Charging Cut-Off (a) or (b)	
a) by time [h]	Standard Charge: 5 Fast/Rapid Charge: 3
b) by min current [mA]	1.2
Discharge Cut-Off Voltage [V]	3.0
Max. Pulse Discharge Current [mA]	180 @ 2s
Max. Continuous Discharge Current [mA] ...	120
Operating Temperature [°C]	Charge: 0 to 45 Discharge: -20 to 60
Storage Temperature .... **Capacity Recovery Rate[4] [%]**	1 Year at -20 to 20 °C > 90 3 Month at -20 to 45 °C > 90 1 Month at -20 to 60 °C > 85
Impedance Initial [Ω]	< 0.5 @ 1kHz
Cycle Life 0.5C/0.5C, 20 °C[5] [Cycles]	> 500 (> 80% of C_{ini})
Safety	UN 38.3 passed relevant tests acc. IEC 62133 passed
Internal Approval	
Overcharge Test (12V, 3C, 12h)	passed
Overcharge Test (5V, 1A, 12h)	passed

1) Recommendations regarding Charging/Discharging and Safety (cf. Handling Precautions/Advanced Product Information) have to be accepted. Cell must not be used without external safety electronics (PCM – Protection Circuit Module)! The CoinPower cell may exclusively be used for the intended purpose. For medical applications please contact VARTA Microbattery. This product is protected by at least one of the following patents: US 6265100 B1,US 6066184 A,US 9178251 B2,US 9231281 B2,US 8586232 B2,US 9153835 B2,CN 102318122 B,CN 102804473 B,EP 2628203 B1,EP 2443691 B1,EP 2415101 B1,EP 2394324 B1,JP 5767115 B2,DE 19647593 B4. 2) "CoinPower A3-Version Charging Document" must be observed.
3) "CoinPower A3-Version Charging Document" must be observed. Max. charging voltage: 4.00V ± 0.05V; min. charging temperature: 15°C.
4) After storage at initial cell voltage of 3.6 to 3.7 V / cell. 5) typical values

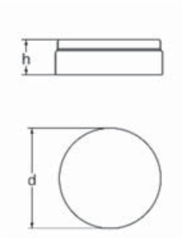
Data Sheet – CP 1454 A3 (CoinPower®)[1]



Type Designation	CP 1454 A3
Type Number	63145
Cell Code	ICR1454
System	Graphite – layered metal oxide ($LiNi_xMn_yCo_zO_2$)
UL Recognition	MH13654
Nominal Voltage [V]	3.7 (average)
Typical Capacity C [mAh]	90 (at 0.2C from 4.2 V to 3.0 V at 20 °C)
Nominal Capacity C [mAh]	85 (at 0.2C from 4.2 V to 3.0 V at 20 °C)
Dimensions [mm] (without Tags)	
Diameter	14.1 +0.0/-0.3
Height	5.4 +0.2/-0.1
Weight. approx [g]	2.3 +0.2/-0.2
Charging Method	Constant Current + Constant Voltage
Charge Voltage [V]	4.20 ± 0.05
Initial Charge Current [mA]	Standard Charge: 42.5 Fast Charge[2]: 85 Rapid Charge[3]: 170
Charging Cut-Off (a) or (b)	
a) by time [h]	Standard Charge: 5 Fast/Rapid Charge: 3
b) by min current [mA]	1.7
Discharge Cut-Off Voltage [V]	3.0
Max. Pulse Discharge Current [mA]	255 @ 2s
Max. Continuous Discharge Current [mA]	170
Operating Temperature [°C]	Charge: 0 to 45 Discharge: -20 to 60
Storage Temperature Capacity Recovery Rate[4] [%]	1 Year at -20 to 20 °C > 90 3 Month at -20 to 45 °C > 90 1 Month at -20 to 60 °C > 85
Impedance Initial [Ω]	< 0.5 @ 1kHz
Cycle Life 0.5C/0.5C, 20 °C[5] [Cycles]	> 500 (> 80% of C_{ini})
Safety	UN 38.3 passed relevant tests acc. IEC 62133 passed
Internal Approval	
Overcharge Test (12V, 3C, 12h)	passed
Overcharge Test (5V, 1A, 12h)	passed

1) Recommendations regarding Charging/Discharging and Safety (cf. Handling Precautions/Advanced Product Information) have to be accepted. Cell must not be used without external safety electronics (PCM – Protection Circuit Module)! The CoinPower cell may exclusively be used for the intended purpose. For medical applications please contact VARTA Microbattery. This product is protected by at least one of the following patents: US 6265100 B1,US 6066184 A,US 9178251 B2,US 9231281 B2,US 8586232 B2,US 9153835 B2,CN 102318122 B,CN 102804473 B,EP 2628203 B1,EP 2443691 B1,EP 2415101 B1,EP 2394324 B1,JP 5767115 B2,DE 19647593 B4. 2) "CoinPower A3-Version Charging Document" must be observed.
3) "CoinPower A3-Version Charging Document" must be observed. Max. charging voltage: 4.00V ± 0.05V; min. charging temperature: 15°C.
4) After storage at initial cell voltage of 3.6 to 3.7 V / cell. 5) typical values

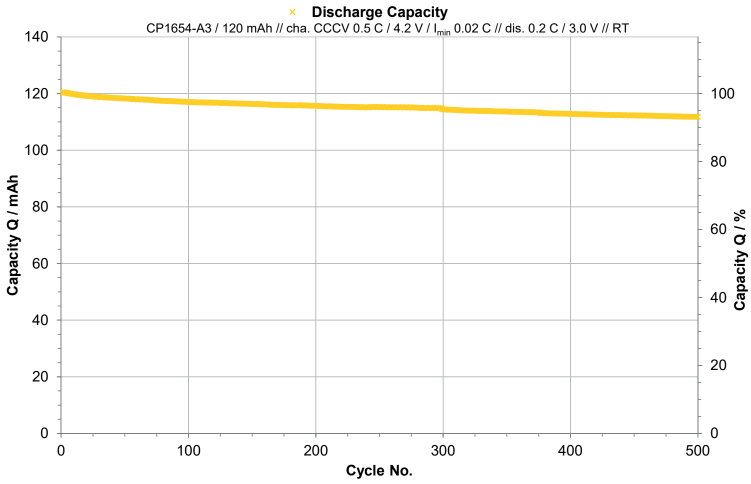
Data Sheet – CP 1654 A3 (CoinPower®)[1]



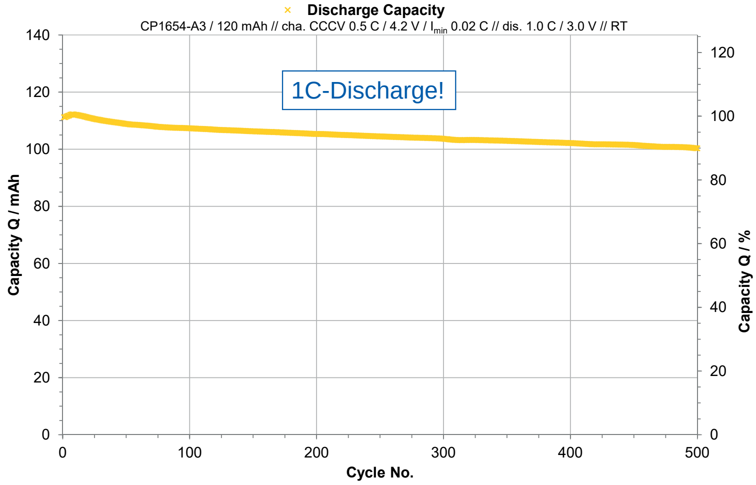
Type Designation	CP 1654 A3
Type Number	63165
Cell Code	ICR1654
System	Graphite – layered metal oxide ($LiNi_xMn_yCo_zO_2$)
UL Recognition	MH13654
Nominal Voltage [V]	3.7 (average)
Typical Capacity C [mAh]	122 (at 0.2C from 4.2 V to 3.0 V at 20 °C)
Nominal Capacity C [mAh]	120 (at 0.2C from 4.2 V to 3.0 V at 20 °C)
Dimensions [mm] (without Tags)	
Diameter	16.1 +0.0/-0.3
Height	5.4 +0.2/-0.1
Weight. approx [g]	3.0 +0.2/-0.2
Charging Method	Constant Current + Constant Voltage
Charge Voltage [V]	4.20 ± 0.05
Initial Charge Current [mA]	Standard Charge: 60 Fast Charge[2]: 120 Rapid Charge[3]: 240
Charging Cut-Off (a) or (b)	
a) by time [h]	Standard Charge: 5 Fast/Rapid Charge: 3
b) by min current [mA]	2.4
Discharge Cut-Off Voltage [V]	3.0
Max. Pulse Discharge Current [mA]	360 @ 2s
Max. Continuous Discharge Current [mA]	240
Operating Temperature [°C]	Charge: 0 to 45 Discharge: -20 to 60
Storage Temperature Capacity Recovery Rate[4] [%]	1 Year at -20 to 20 °C > 90 3 Month at -20 to 45 °C > 90 1 Month at -20 to 60 °C > 85
Impedance Initial [Ω]	< 0.4 @ 1kHz
Cycle Life 0.5C/0.5C, 20 °C[5] [Cycles]	> 500 (> 80% of C_{ini})
Safety	UN 38.3 passed relevant tests acc. IEC 62133 passed
Internal Approval	
Overcharge Test (12V, 3C, 12h)	passed
Overcharge Test (5V, 1A, 12h)	passed

1) Recommendations regarding Charging/Discharging and Safety (cf. Handling Precautions/Advanced Product Information) have to be accepted. Cell must not be used without external safety electronics (PCM – Protection Circuit Module)! The CoinPower cell may exclusively be used for the intended purpose. For medical applications please contact VARTA Microbattery. This product is protected by at least one of the following patents: US 6265100 B1,US 6066184 A,US 9178251 B2,US 9231281 B2,US 8586232 B2,US 9153835 B2,CN 102318122 B,CN 102804473 B,EP 2628203 B1,EP 2443691 B1,EP 2415101 B1,EP 2394324 B1,JP 5767115 B2,DE 19647593 B4. 2) "CoinPower A3-Version Charging Document" must be observed.
3) "CoinPower A3-Version Charging Document" must be observed. Max. charging voltage: 4.00V ± 0.05V; min. charging temperature: 15°C.
4) After storage at initial cell voltage of 3.6 to 3.7 V / cell. 5) typical values

VARTA CoinPower batteries provide outstanding cycle-life performance. All cell types have a cycle life which is greater than 500 cycles with a remaining capacity of >80% of its nominal value when new. Even at elevated temperature and higher discharge currents the VARTA CoinPower cells show excellent performance. This will provide extended battery life even after daily usage and in high consumption applications.
The graphs below show the discharge performance of the CP1654 A3. For the other types the remaining capacity can be calculated by pro rata (see second y-axis on the far right).



CoinPower CP1654 A3 Discharge Performance – 0.5C/0.2C

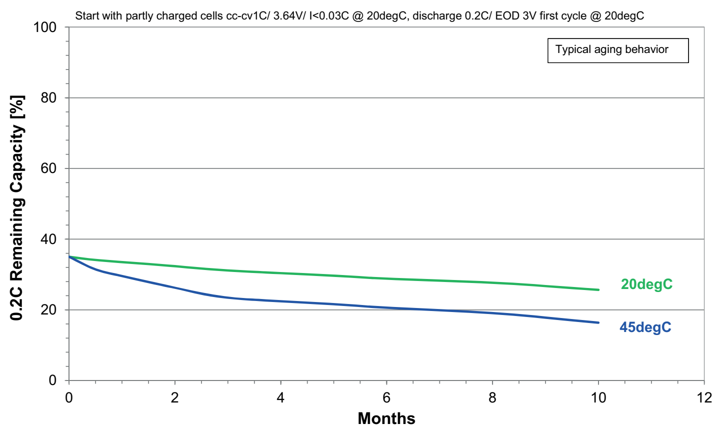


CoinPower CP1654 A3 Discharge Performance – 0.5C/1C

VARTA CoinPower batteries are delivered in a state-of-charge (SoC) of approximately 30 % of their full capacity. This provides the best condition for long-term storage at the lowest self-discharge rate. Higher temperatures increase the rate of self-discharge. It is recommended to store the cell at a state-of-charge between 30% and 50% at room temperature (20°C) or lower.

The graph below shows the **storage characteristic** of a CoinPower cell after 6 months of storage at 20°C and at 45°C. When first going into storage, the cells had an SoC of approximately 30%.

Since the self-discharge rate of the CoinPower cell is very low, cells may be stored for several months without periodic recharging. This offers convenience and flexibility for the owners of cells in stock as well as in the application for the end-user.



Storage Characteristic @ Various Temperatures Remaining Capacity

7. SAFETY

Product safety has always been a very important consideration for VARTA Microbattery. Besides all the technical features which give its high performance, the CoinPower series also provides the highest safety level in the market for small lithium rechargeable batteries. In the following sections is more information about various safety features of the CoinPower series.

7.1 SAFETY TESTS

Safety Tests

The CoinPower is certified for the three main safety standards which are applicable to rechargeable lithium batteries. Below are more details about the various safety tests which are performed to verify a battery's compliance with the requirements of each of the three standards. VARTA Microbattery regularly performs additional safety tests in order to ensure the high safety level of the CoinPower series.

UL 1642
UL (Underwriters Laboratories) Standard for Safety for Lithium Batteries. These requirements cover primary and secondary lithium batteries for use as power sources in products.

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.

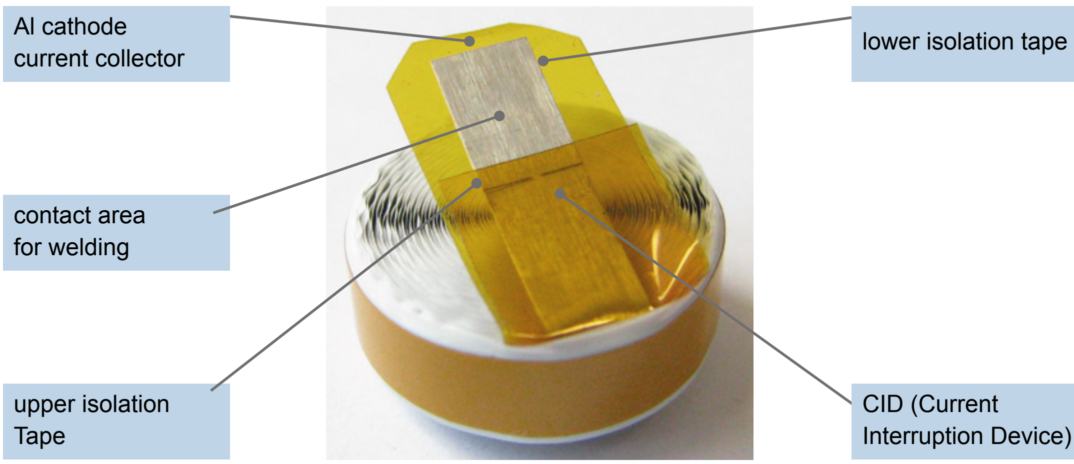
UN IATA 38.3
Transport regulations for air shipment for lithium batteries according to section 38.3 of the UN Manual of Tests and Criteria published by the United Nations.

No	Test Item	UL 1642	IEC 62133	UN38.3	VARTA internal test
1	Short Circuit Test (at 20°C)	✓	✓	✓	✓
2	Short Circuit Test (at 55°C)	✓			✓
3	Abnormal Charging Test	✓	✓	✓	✓
4	Forced discharge	✓	✓	✓	✓
5	Crush Test	✓	✓		✓
6	Impact Test	✓		✓	✓
7	Shock Test	✓	✓	✓	✓
8	Vibration Test	✓	✓	✓	✓
9	Heating Test	✓			✓
10	Temperature Cycling Test	✓	✓	✓	✓
11	Altitude Simulation Test	✓	✓	✓	✓
12	Projectile Test	✓			✓
13	Continuous low rate charging		✓		✓
14	Free Fall, Drop Test		✓		✓
15	Thermal abuse		✓		✓
16	Overcharge 12V/3C				✓
17	Overcharge 5V/1A				✓

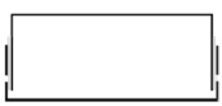
7.2 PRODUCT SAFETY

The CoinPower Series provides for very safe operation. Safety features in the components used in the CoinPower battery, as well as in its mechanical design, ensure that the CoinPower cell will be safe even when subject to severe abuse conditions.

7.2.1 CURRENT INTERRUPTION DEVICE (CID)

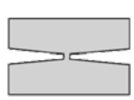


Normal state <u>during use</u> (charge/discharge/storage)	Abusive Case <u>during Overcharging</u>



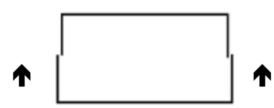
CID is in normal status

minus-contact



coil

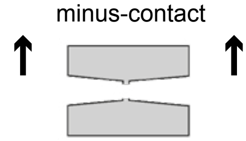
Current flows via CID



<u>Cup will move up</u> due to internal pressure
tag with CID is welded on cup inside

Lifting force will tear off the CID and current flow is <u>interrupted.</u>

minus-contact

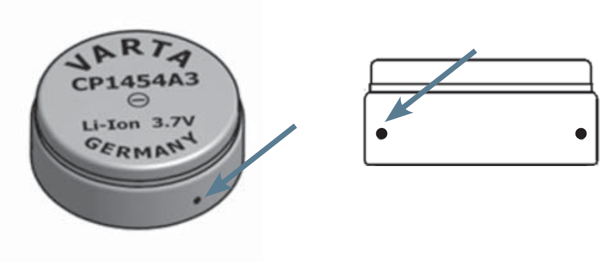


coil

Cell is disconnected and save

7.2.2 VENTING HOLES

The cup of every CoinPower battery is designed with three venting holes around the circumference. (every 120°)

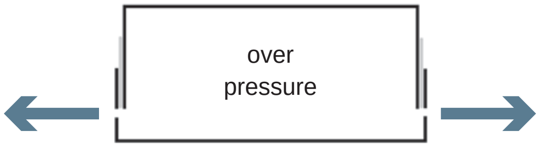


In the normal state these venting hole are covered by the foil gasket on the inside. When subject to abuse (e.g. continuous overcharging) the lid will lift up and excessive pressure can be released through these holes. This mechanism will prevent the cell from overheating and bursting when subject to severe overcharging.

normal state

venting holes are covered

abusive case



venting holes are open
pressure can be released

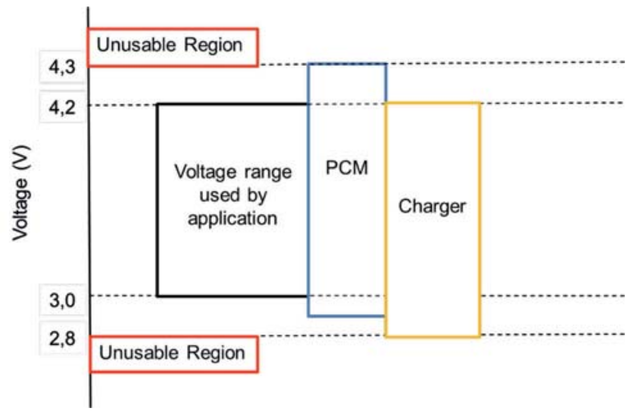
7.3 PROTECTION CIRCUIT MODULE (PCM)

The Protection Circuit Module (PCM) is a device to protect a battery against the risk of abnormal events such as over-discharging or short circuits. This is mandatory for all lithium cells.

A PCM is not only used to protect the cells and applications from excessive discharge and recharge current, but also to maintain the nominal operating conditions for the cell and battery pack.

A CoinPower battery must be operated with a PCM which provides the following protection functions:

- **Over-charge protection**
- **Over-discharge protection**
- **Over-current protection**
- **Short circuit protection**
- **Optional additional functions: Over-temperature protection, ESD protection, Code identification, Power management, Fuel gauge**



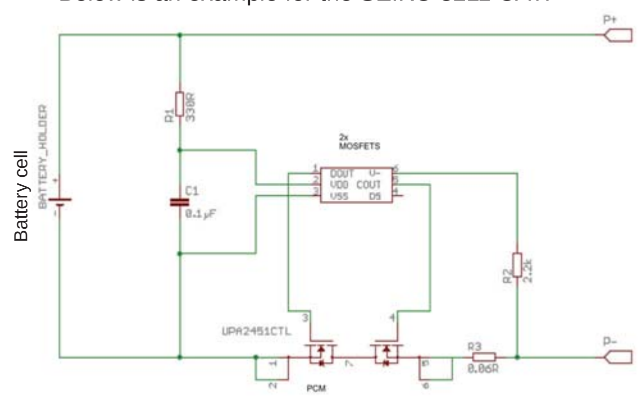
Voltage range for PCM and Charger

Safety Tests

Recommended PCM for CoinPower Series:

- Seiko (S8211CAY, S8200A)
- Mitsumi (MM 3077 LY, MM 2511 K56)
- Texas Instruments (BQ 29700, BQ 29707)
- Diodes (AP 9211)

The schematic for using a PCM for the CoinPower is quite simple, just a few external components are necessary to build a fully functional safety circuit. Below is an example for the SEIKO 8211 CAY:



Example for the SEIKO 8211
FIG. 23

8. HANDLING PRECAUTIONS AND PROHIBITIONS

In this section there is information about the handling precautions and prohibitions for the VARTA CoinPower series.
If you have any questions regarding any point please consult your Key Account Manager.

8.1 GENERAL INFORMATION

Lithium batteries provide a high energy density and a high discharge-rate capability to meet the demanding requirements of today’s high-tech portable products. These excellent characteristics of lithium batteries entail a certain safety risk. If short-circuited, heat and sometimes sparks may be generated. Mistreatment outside the recommended limits can cause gas generation, leakage and fire.

The guideline „Handling Precautions and Prohibitions for VARTA Microbattery GmbH Li-Ion Batteries and General Supply Notices“ should be applied to VARTA „CoinPower Li-Ion“ batteries. It should be be brought to the attention of all people who handle the batteries.

The customer is requested to contact VARTA Microbattery GmbH in advance, if and when the customer needs other applications or operating conditions than those described in this document, because additional tests and experiments may be necessary to verify performance and safety under such conditions. VARTA Microbattery GmbH shall not be responsible for safety, performance, functionality, compatibility or fitness for a particular purpose unless such features have been expressly communicated and described in the specification.

VARTA Microbattery GmbH will take no responsibility for any accident when the cell is used under conditions other those described in this guideline. VARTA Microbattery GmbH will inform, the customer in writing of improvement(s) affecting the proper use and handling of the cell, if it is deemed necessary.

8.2 CHARGING

Charging Current

Charging current should not exceed the maximum charge current specified in the data sheet.
Charging with a higher current than the recommended value might impair cell performance and safety features, and can lead to heat generation or leakage.

Charging Voltage

Charging at above 4.250 V, which is the absolute maximum voltage, is strictly prohibited. The charging procedures specified in the data sheet should be followed. The operation of the charger should conform to these conditions. Use a specified charger only.
Charging at a higher voltage than specified might cause damage to cell performance and safety features, and can lead to fire, heat generation or cell leakage.

Charging Temperature

The cell shall be charged within the range of temperatures specified in the data sheet. If the cell is charged at a temperature outside the specified range, leakage, heat generation, or other damage may occur.
Repeated charging and discharging at high or low temperature might impair cell performance even within the specified temperature range.

Prohibition of Reverse Charging

Reverse charging is prohibited. The cell must be connected correctly. The polarity has to be confirmed before connecting any wires.
Reverse charging will cause damage to the cell(s), will lead to a loss of cell performance and will pose a risk to safety (including heat generation or leakage).

Prohibition of Trickle Charging or Continuous Charging

Trickle charging or continuous charging is prohibited. Trickle charging conditions or continuous charging can lead to overcharging, generation of internal pressure and degeneration of the cell.
The cell shall be charged with a constant current up to a cell voltage 4.2 V ± 50 mV, then at a constant voltage and tapering current. At approx. 0.02 C current charging must stop. Charging should restart only if a measurable quantity of energy has been discharged from the cell, or the cell voltage has fallen below 4.0 V.

8.3 DISCHARGING

Discharge Current

The cell shall be discharged at less than or equal to the maximum discharge current specified in the data sheet.
High discharge current may reduce capacity significantly, or cause overheating.

Discharge Temperature

The cell shall be discharged within the temperature range specified in the data sheet.

Over-Discharging

If not used for a long period, the cell(s) may become over-discharged. In order to prevent over-discharging, the cell(s) shall be charged periodically to maintain a voltage in the range of 3 V to 3.8 V.
Over-discharging might impair cell performance, or damage battery function.
The host produce should be equipped with a device to prevent further discharging below the the cut-off voltage specified in the data sheet.
The PCM over-discharge detection threshold/voltage must not be used as the cut-off voltage for the battery.

Also, the charger should be equipped with a device to control the recharging procedures as follows:
In case of over-discharging, the cell(s)/battery pack should start with a low current (0.01 – 0.07 CmA) for 15-30 minutes, i.e. precharging, before rapid charging starts.
Charging according to the data sheet should be started after the individual cell voltage has risen above about 3 V and within 15-30 minutes. This may be controlled by an appropriate timer for precharging.
If the individual cell voltage does not rise to about 3 V within the pre-charging time, the charger should stop charging and display a notification that the cell(s) is/are in an abnormal state.

8.4 PROTECTION CIRCUIT MODULE (PCM)

The cell(s) shall be provided with a PCM which can protect cell(s) properly, e.g. in case of a failing Charge Control Circuit.

The PCM shall implement the functions of (i) overcharging prevention, (ii) over-discharging prevention, and (iii) over-current protection, to maintain safety and prevent significant deterioration of cell performance. Over-currents can be caused by an external short circuit.

Over-Discharge Prohibition

An over-discharge prevention function should work to minimize dissipation current and avoid a drop in cell voltage to below 2.5 V. It is recommended that the dissipation current of the PCM should be designed to be minimized to 0.5 microamperes or less after the over-discharge prevention function is activated in order to minimize the effect on the shelf life of the battery.

8.5 APPLICATION

For the batteries approved by UL (File MH13654) the intended use is at ordinary temperatures, and where high temperature excursions are not expected to exceed 70 °C. Nevertheless under reasonably foreseeable misuse conditions at temperatures up to 85 °C over 4 hours no safety risk should arise.

Technician-Replaceable Appliances

VARTA Li-Ion batteries of the CoinPower type do not fulfil the requirements for being user-replaceable, as the reverse polarity installation cannot be prevented. Therefore the VARTA „CoinPower Li-Ion“ batteries can be used only in devices where servicing of the battery circuit and replacement of the lithium battery will be done by a trained technician.

The instruction manual supplied with the end product shall contain the following warning notice:
„Replacement of battery has to performed by trained technician. For replacement only batteries with (Battery Manufacturer‘s name or endproduct manufacturer‘s name), Part No. ( ) may be used. Use of another battery may present a risk of fire or explosion.“

Or „The battery used in the (End Product Name) must be replaced at (End product manufacturers) service center only.“
Caution: The battery used in this device may present a fire or
chemical burn hazard if mistreated. Do not disassemble, heat above 100°C (212°F) or incinerate.
„Dispose of used battery properly taking account of local laws and rules. Keep away from children – harmful if swallowed!”

WARNING: Risk of Fire, Explosion, and Burns. Do Not Disassemble, Crush, Heat Above 100ºC (212ºF), Short-Circuit or Incinerate.

8.6 STORAGE

The CoinPower cells should be stored within the correct temperature range as specified in the data sheet. The state of charge shall be 30 % of the nominal capacity; open circuit voltage (OCV) about 3.6 V. When stored for a long time, care has to be taken that the battery voltage does not drop below the cut-off voltage due to self-discharge (see 2.3).

8.7 OTHERS ISSUES

Cell Connection

Soldering or welding of wires or other types of connectors directly to the cell is strictly prohibited.
A proper cell connection can only be done by the cell manufacturer itself. If soldering or welding of wires or other types of connectors directly to the cell is performed by any entity other than the cell manufacturer, all claims regarding warranty, performance and safety will be invalidated.

Prevention of Short-Circuit in Application

Enough insulation layer(s) between the wiring and the cells shall be used to maintain multiple safety protection.
The battery housing shall be designed to prevent short-circuits while the cell is assembled into the end product, and when the device is in use.
This is because short circuits may generate smoke or fire.

Assembly

Important!! Always avoid any possible contact between the cell housing and sharp objects, corners, or points which could puncture or damage the cell.
Avoid applying mechanical stress (such as tension, pressure) to the cell itself during assembly. Do not remove or disassemble any component from the original VARTA supply configuration.
Do not subject the cell to higher temperatures than specified in the datasheet provided.
Do not subject the cell to ultrasonic weld process vibration or energy.
Avoid accidentally short-circuiting cell during assembly and finishing processes.
Avoid accidental mechanical damage to the cell during assembly and finishing processes.
Packaging for the cell has to be made of insulating material, avoiding discharge or short-circuiting.

Prohibition of Disassembly

Never disassemble the cells.
Disassembling cells may cause an internal short-circuit in the cell, which could in turn generate gas, start a fire, or cause other problems.

Harmful Electrolytes:

Any electrolyte which leaks from the cells is harmful to the human body. If the electrolyte comes into contact with the skin, eyes or any other part of the body, the electrolyte should be washed off immediately with water. Seek medical advice from a physician.

Prohibition of Short-Circuit

Never short-circuit the cells. It causes generation of very high currents resulting in heating of the cells, which may cause electrolyte leakage, gassing or fire.

Prohibition of Burring

Never incinerate cells or dispose of cells in fire.
Prohibition of immersion into liquid.
Cells should never be soaked with liquids such as water, sea water, drinks such as soft drinks, juices, coffee or other fluids.

Battery Cell Replacement

Battery replacement should be done only by the end product supplier and never by the user.

Prohibition of Use of Damaged Cells

Cells may be damaged during shipping by shocks, or other causes.
If any abnormal features are found in cells such as: damage to the stainless steel housing of the cell, deformation of the cell container, smell of electrolyte, an electrolyte leakage, or other abnormalities, the cells should not be used.
Cells with a smell of electrolyte or leakage should be kept away from fire to avoid ignition.

General Supply Notices and Responsibilities

The customer agrees to manufacture, assemble, sell, transport and/or dispose of the Finished Products in a way that the health and safety of people, including workers and general public, and environmental protection can always be assured. The customer agrees to and promises to comply with any and all relevant safety and environmental requirements, laws and regulations in the countries where the products are sold, manufactured, transported, stored or disposed.

The customer shall be solely responsible for health, safety and environmental matters arising from its manufacture, assembly, sales, use, transportation and/or disposal of the finished products, and shall defend, indemnify, and hold VARTA Microbattery GmbH, its subsidiaries, customers, and suppliers and its and their respective representatives and employees harmless from and against all costs, liabilities, claims, lawsuit, including but not limited to attorney's fees, with respect to any pollution, threat to the environment, or death, disease or injury to any person or damage to any property resulting, directly or indirectly, from the manufacture, assembly, purchase, sales, use, operation, transportation or disposal of the finished products; except to the extent that the customer shall be exempted from such obligation if and so long as the cause of such damage is attributable directly and solely to VARTA Microbattery GmbH.

Battery Compartment Design

The protection circuit should be isolated from the cell to reduce the risk of damage from any electrolyte leakage which may occur by mishap. The battery compartment shall be designed so as not to allow leaked electrolyte to reach the protection circuit.

The resistance of the battery case's material to damage by electrolyte should be taken into account when the material is selected.

Under abusive conditions the cell may vent; to ensure safe venting, up to 1.5 mm of additional space in axial direction is necessary.

Protection Circuit Module Design

Electrolyte has corrosive characteristics.

The protection circuit module might not work correctly if exposed to electrolyte.

This should be considered in the design of the protection circuit module.

The main wiring patterns should be separated from each other as much as possible.

Conductive patterns and connection terminals which may be short-circuited by electrolyte leakage should be separated from each other as much as possible. Another valid protection technique is to cover the whole surface of the module with a conformal coating.

8.8 MARKING

The customer should prepare comprehensive instructions and appropriate markings for end users. The assembled device should be provided with packing, handling and safety instructions regarding cell usage, storage, and replacement, and should be marked with information in accordance with applicable regulations. The prohibitions mentioned in this document, regulations in UL 1642 (and other specifications) should be clearly explained to users. The markings should also be made accordance with the guidelines for rechargeable Lithium Ion batteries on maintaining cell safety.

Example for marking according to the UL 1642 regulation:

Mark the manufacturer‘s name, business name or trademark, and specified model name.

Use the word „Warning“ and indicate the statement “Risk of Fire, Explosion, and Burns. Do Not Disassemble, Crush, Heat Above 100ºC (212ºF), Short-Circuit or Incinerate” or equivalent.

Final product should be marked with the following statement or equivalent: „Replacement may only be made with cell specified by the final product manufacturer, with correct part number. Fire or burning may occur if the customer uses a cell other than that specified by the final product manufacturer. The customer shall refer to the handling instruction issued by the final product manufacturer.“

If it is not possible to mark the warnings mentioned above on the final products, the final product manufacturer shall mark and print the warnings in the handling or maintenance instructions or manuals of the products.

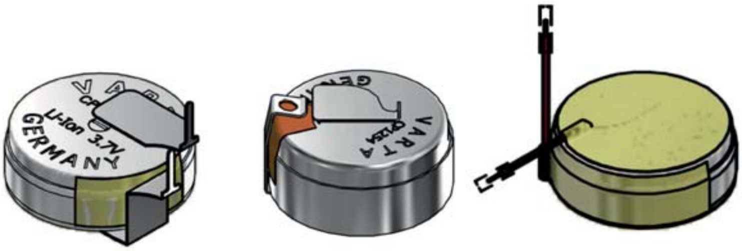
In particular the marking should contain the advice in Chapter 4 relevant to the type of usage.

9. BATTERY ASSEMBLY

Besides the bare cells, VARTA Microbattery provides customized solutions for all kinds of battery assembly in order to meet customers' individual requirements. VARTA can offer many different cell configurations together with the necessary connections such as wires and tags. Multicell assembly is possible as well.

9.1 SINGLE CELL ASSEMBLY

For some applications, a bare cell is not the ideal solution for connecting the battery to the PCB. Therefore VARTA Microbattery offers standard cell configurations with solder tags for THT connection and wires.
If a customized assembly is required, VARTA can also offer individual battery assembly including solder tags, wires and insulation tape. Please contact your Key Account Manager for more details.



Examples for different battery assemblies

9.2 MULTICELLULAR ASSEMBLY

If a larger capacity and/or higher discharge currents are required, two or more cells may be connected in a cell pack. These packs can be assembled in various shapes, depending on the customer’s requirement. The cells can be also connected in series in order to produce a higher output voltage. Below are shown examples of multicellular configurations of the CoinPower cell.

9.3 SOLDERING

With assembled tags or wires, the CoinPower battery may be soldered onto a PCB. For this purpose, every tag supplied by VARTA is tin-plated in order to improve its solderability. Please consider the following guidance on the solderability of the CoinPower cell.

Using a Soldering Iron

Do not allow the soldering iron to make direct contact with the body of the cell. Proceed with soldering quickly within 3 seconds while maintaining the iron tip temperature at about 320 ºC, and do not allow the temperature of the cell body to exceed 60 ºC.

Dip Soldering/Wave Soldering

These two soldering procedures will short circuit the battery. This will cause irreversible damage to the cell. This will impair performance dramatically and might lead to safety risks as well.

Reflow Soldering

NEVER USE REFLOW SOLDERING
During a standard reflow process the temperature on the body and inside the cell will rise to a level which will cause irreversible damage to the cell. This will impair performance dramatically and might lead to safety risks as well.
There is a risk of explosion/bursting and electrolyte leakage during reflow soldering due to excessive temperatures.

In order to find the best possible energy solution for your application, VARTA Microbattery needs certain information. Below you can find a blank version of our application check list. If you have any questions on this, please contact your Key Account Manager.

Resp. Sales Representative / KAM: ______ (also general contact person/person in charge)		Involved Distributor or Agent or Rep.: ______ Involved CEM / ODM: ______
Customer: ______ (Account)		
Application: ______ Please describe.		Automotive Project: ______ Special Approvals needed: ______ UN-IATA 38.3 UL1642 UL2054 IEC 62133 CE Others: please specify.
Expected Volume: ______ (per year)		Product type: ______
Timing Quantity: ______	Samples A Samples B Samples C Samples D	Product type:
Additional Information:		

Customer Specific Technical Requirements

No.	Description	
1	**Charging Conditions**	
1.1	Charging Voltage [V]: (What is the maximum voltage available? Is it adjustable? If yes, in which range)	(with + Tolerances)
1.2	Charging Time [Minutes]: (What is the maximum charging time that is acceptable? Why?)	
1.3	Charging Current [mA]: (What charging current is available? Is it adjustable? If yes in which range?)	
1.4	Information on Charging Technique (IC): (General information, what is possible for the customer. Only cc? cc-cv? Trickle charge? Timer? Temperature compensation? Combination of techniques possible?)	
1.5	Information on Power Source: (Wallplug/USB,…)	Available Voltage[V]: Current[mA]: Power [W]:
1.6	Temperature Range at Charging [°C]: (Additional information is welcome, does the temperature change during a single charge process, if yes profile etc. …)	Min. Max. Typical
2	**Discharging Conditions**	
2.1	Operating Temperature Range [°C]: (for a wide distribution, a detailed temperature profile would be helpful)	Min. Max. Typical
2.2	Operating Voltage [V]: (What is the minimum/maximum voltage, required by the application? When does the processor stop working or when is the deep discharge cut –off activated)	Min. Max. Typical Cut-off Voltage:

2.3	Required Power [W]: (Is it constant? If not, profile such as pulse duration etc.)	Min. Max. Typical
2.4	Required Discharge Time [sec/min/h.]:	
2.5	Required Energy [J = Ws]:	
2.6	Pulse profile (please specify current and time profile for discharge.e.g.: 1500mA/0,5ms+200mA/4.5ms) repeat 10 times then 0,1mA 1h then repeat.	
3	**Other Operating Conditions**	
3.1	Expected Cycle Life [Cycles per Time]: Please specify the number of charge / discharge cycles that is required	
3.2	Expected Life [Years]:	
3.3	Shelf-Life (before use) [Month]: (How long is the board with connected battery on shelf before the next recharge. Please note that deep discharge has to be avoided, e.g. leakage current when connected to board, …)	
3.4	Other Requirements: Please let us know if there are any special requirements / approvals / environmental requirements that need to be considered.	
4	**Product Design**	
4.1	Space available [mm]:	
4.2	Wire/Connector	e.g. 100mm Molex connector 5264-N
4.3	Safety Elements e.g. Polyswitch	e.g. LR4-380F
4.4	Temperature Sensor	e.g. NTC 10 kOhm
4.5	Proposal of prefered product:	Article Designation: Article No=VKB No:

OEM (Original Equipment Manufacturer)
is a broad term whose meaning has evolved over time. In the past, OEM referred to the company that originally built a given product, which was then sold to other companies to rebrand and resell. Over time, however, the term is more frequently used to describe those companies in the business of rebranding a manufacturer's products and selling them to end customers.

Battery
One or more electrochemical cells electrically connected in an appropriate
series / parallel arrangement to provide the required operating voltage and current levels including, if any, monitors, controls and other ancillary components (fuses, diodes), case, terminals and markings.

Cell
The basic electrochemical unit providing a source of electrical energy by direct
conversion of chemical energy. The cell consists of an assembly of electrodes, separators, electrolyte, container and terminals

Secondary battery
Battery that can be reused after it is charged. There are Ni-Cd and Ni-MH rechargeable carbon batteries in addition to Li-Ion rechargeable battery.

Primary battery
is a battery that is designed to be used once and discarded, and not recharged with electricity and reused like a secondary cell

Separator
A microporous thin film inserted between cathode and anode to prevent short-circuits and maintain spacing. Polyethylene film, polypropylene film, or other film is used.

Cathode
An electrode at higher potential than the anode, passing electric current to the outside circuit during discharge.

Anode
An electrode at lower potential than the cathode, into which current flows from an external circuit during cell discharge.

Open circuit voltage (OCV)
The voltage of the battery when it is disconnected electrically from outside circuits.

Closed circuit voltage (CCV)
The voltage of the battery when it is connected electrically to an outside circuit.

Nominal Capacity
Capacity used to represent a battery capacity. Usually means capacity in ampere hours, indicated by Ah or mAh.

Nominal Voltage
The nominal voltage of a battery is a measure of the expected voltage of a battery or cell over its entire discharge cycle. The nominal voltage of Coin Power is 3.7V.

Cycle Life
The number of cycles under specified conditions which are available from
a secondary battery before it fails to meet specified criteria as to performance.

Cut off voltage
The limiting voltage which terminates discharge. This voltage generally corresponds to the lower usable voltage limit.

Self-discharge
When battery capacity declines without current flowing to an outside circuit

Energy Density
The amount of energy that can be extracted per unit battery weight, or per unit battery volume. Expressed in units of Wh/kg or Wh/l.

Overcharge
Charging the battery after it has reached the fully-charged state. If a battery is overcharged, lithium metal is precipitated on the anode surface, and the battery becomes extremely chemically unstable.

Overdischarge
Discharging the battery after the voltage has fallen below the specified cutoff voltage. If a battery is over discharged, the anode current collector copper is dissolved.

Lithium-Ion Charger (CCCV)
Li-Ion batteries commonly require a constant current, constant voltage (CCCV) type of charging algorithm. In other words, a Li-Ion battery should be charged at a constant set current level until it reaches its final voltage. At this point, the charger circuitry should switch over to constant voltage mode, and provide the current necessary to hold the battery at this final voltage (typically 4.2 V per cell).Thus, the charger must be capable of providing stable control loops for maintaining either current or voltage at a constant value, depending on the state of the battery.

PCM
Protection Circuit Module is a device to protect a battery against risk of abnormal events such as over-discharge , overcharge, or short circuit.

PCB
A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto a non-conductive substrate.

THT connection
Through-hole technology, also spelled „thru-hole“, refers to the mounting scheme used for electronic components that involves the use of leads on the components that are inserted into holes drilled in printed circuit boards (PCB) and soldered to pads on the opposite side either by manual assembly (hand placement) or by the use of automated insertion mount machines

SMD connection
SMD (surface-mount device) is an electronic device whose components are placed or mounted onto the surface of the printed circuit board (PCB). This method of manufacturing electronic circuit boards is based on the surface-mount technology (SMT), which has largely replaced the through-hole technology (THT) especially in devices that need to be small or flat.

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