HUMANIZING THE DIGITAL EXPERIENCE

TDK Developers Conference 2018

TDK InvenSense EPCOS tronics microsystems Chirp MICRONAS

CeraCharge™

World's first rechargeable solid-state SMD battery

TDK Developers Conference
September 17-18, 2018
Santa Clara Marriott

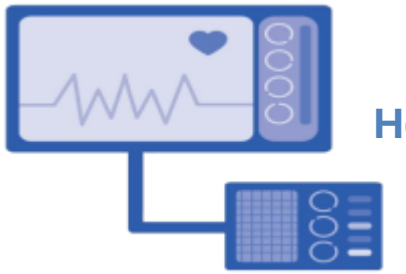
- Background
- Characteristic of CeraCharge
- Application of CeraCharge
  - Energy devices for RTC
  - Energy harvester Beacon
  - Other proposal

Demand for a new battery technology

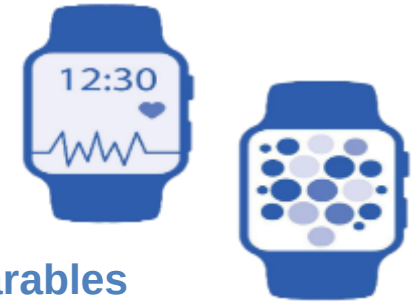
Billions of devices

Sensors everywhere

INTERNET OF EVERYTHING



Healthcare



Wearables

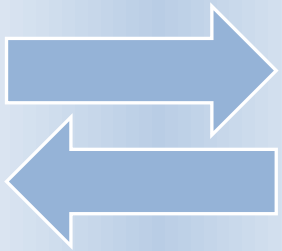
Energy harvesting

Smart home

New application fields driving demand for compact, safe, rechargeable energy sources

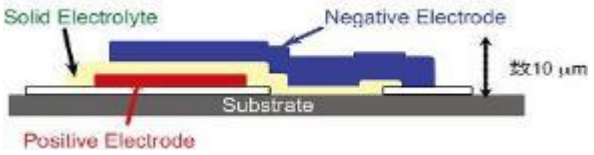
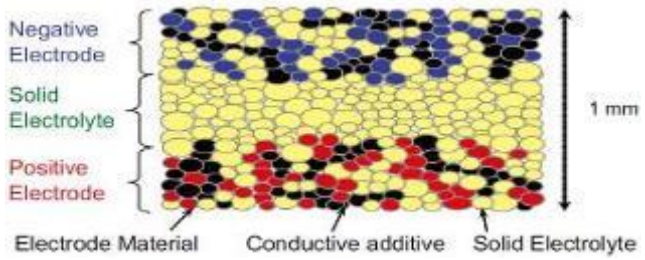
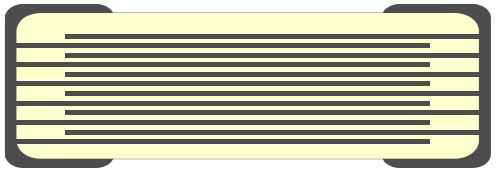
Requirements for new battery technology

Miniaturization	• Fit in tiny mobile devices
Ultra-low power	• Stand-alone power source
Rechargeable	• Up to 1000 charging cycles
SMT-compatible	• Cost-efficient mass production
Safe	• Must not leak, burn or explode



Solid-state batteries are the only solution able to meet all key requirements

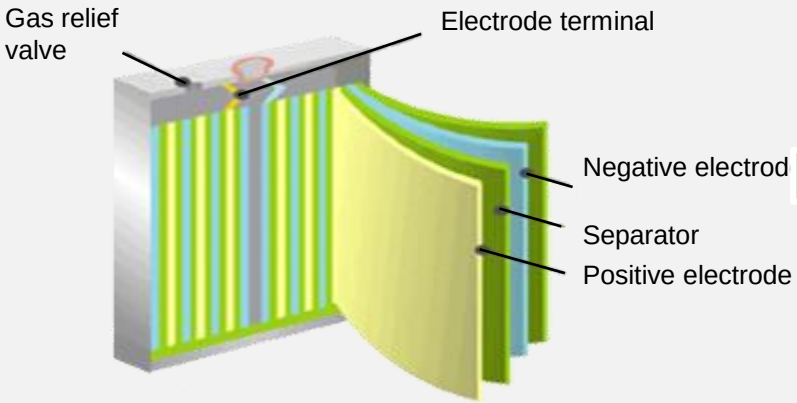
Comparison of solid-state battery technologies

	Thin-film	Bulk (pouch cell)	Ceramic multilayer
Structure			
Thickness	0.2 mm to ~1 mm	>1 mm	**0.2 mm to ~3 mm**
Smallest footprint	4 mm^2	>100 mm^2	**0.5 mm^2**
Process cost	High	Medium	**Low**
Limitations	Transport restrictions for Li metal (flights)	Must be waterproofed to prevent generation of H_2S	**None**

Ceramic multilayer technology offers the cost-optimized, high volume manufacture of safe batteries for IoT devices

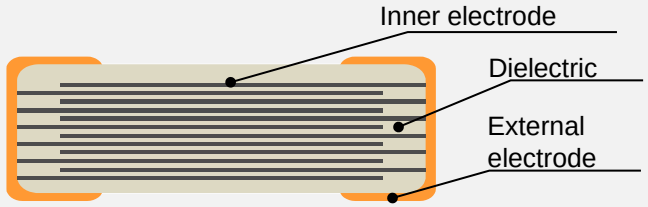
Introducing CeraCharge™ – the world's first solid-state, SMT-compatible Li-ion battery

Li-ion battery



Organic electrolyte (Li-ion)

Multilayer ceramic



High-energy Li-ion battery technology

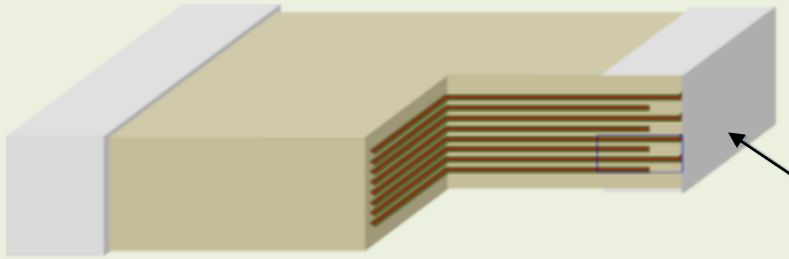
High-volume production process

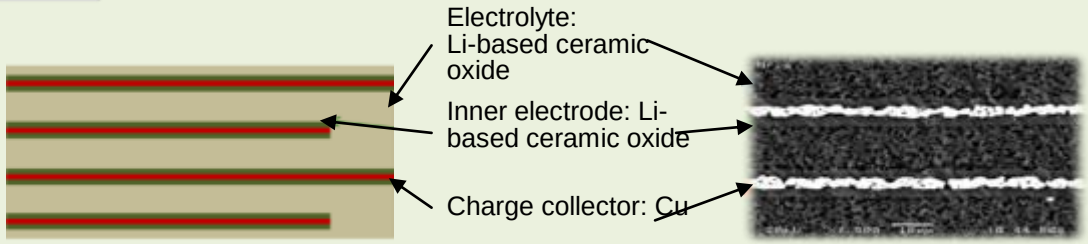
CeraCharge™

All solid state

All-ceramic multilayer battery

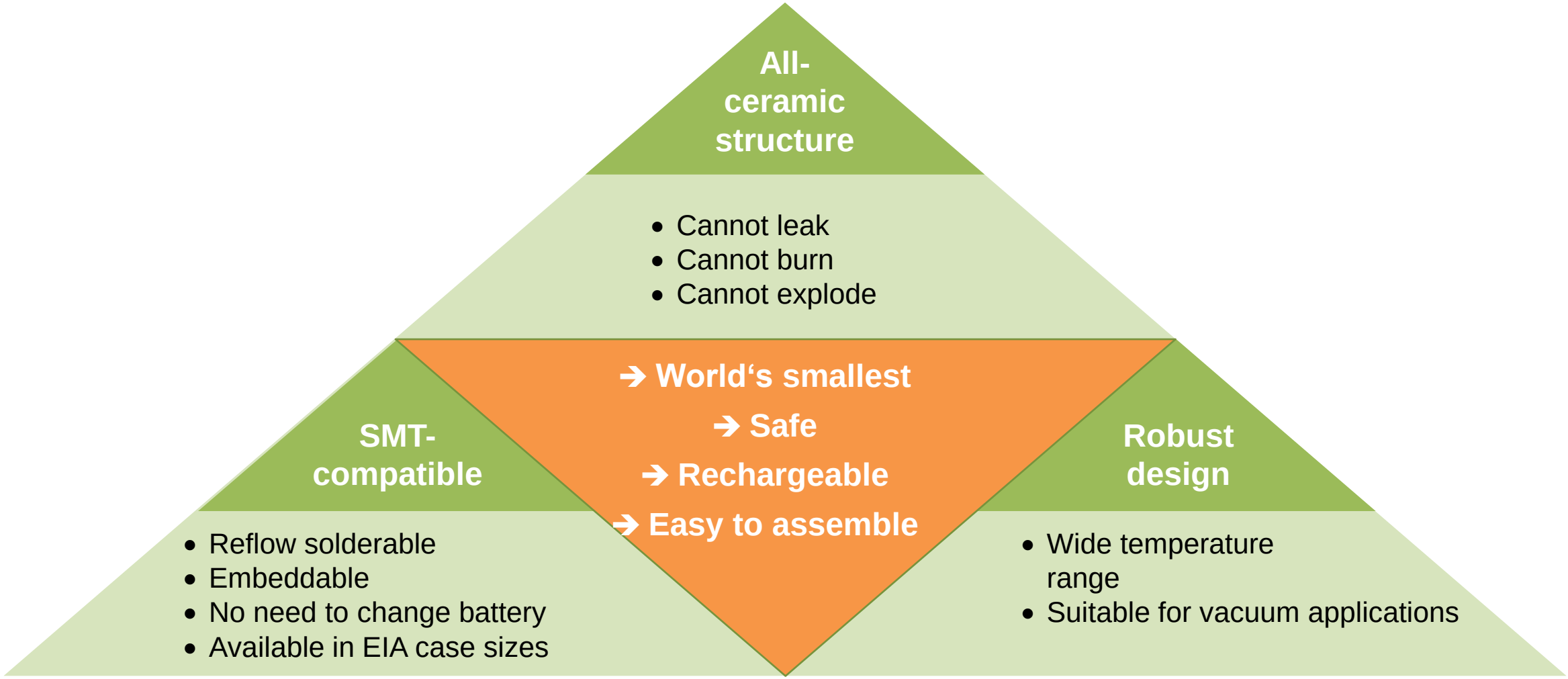
- High safety
- SMT-compatible
- Suitable for reflow soldering





CeraCharge combines the advantages of Li-ion batteries with the safety and manufacturing benefits of ceramic multilayer components

Unique features of CeraCharge



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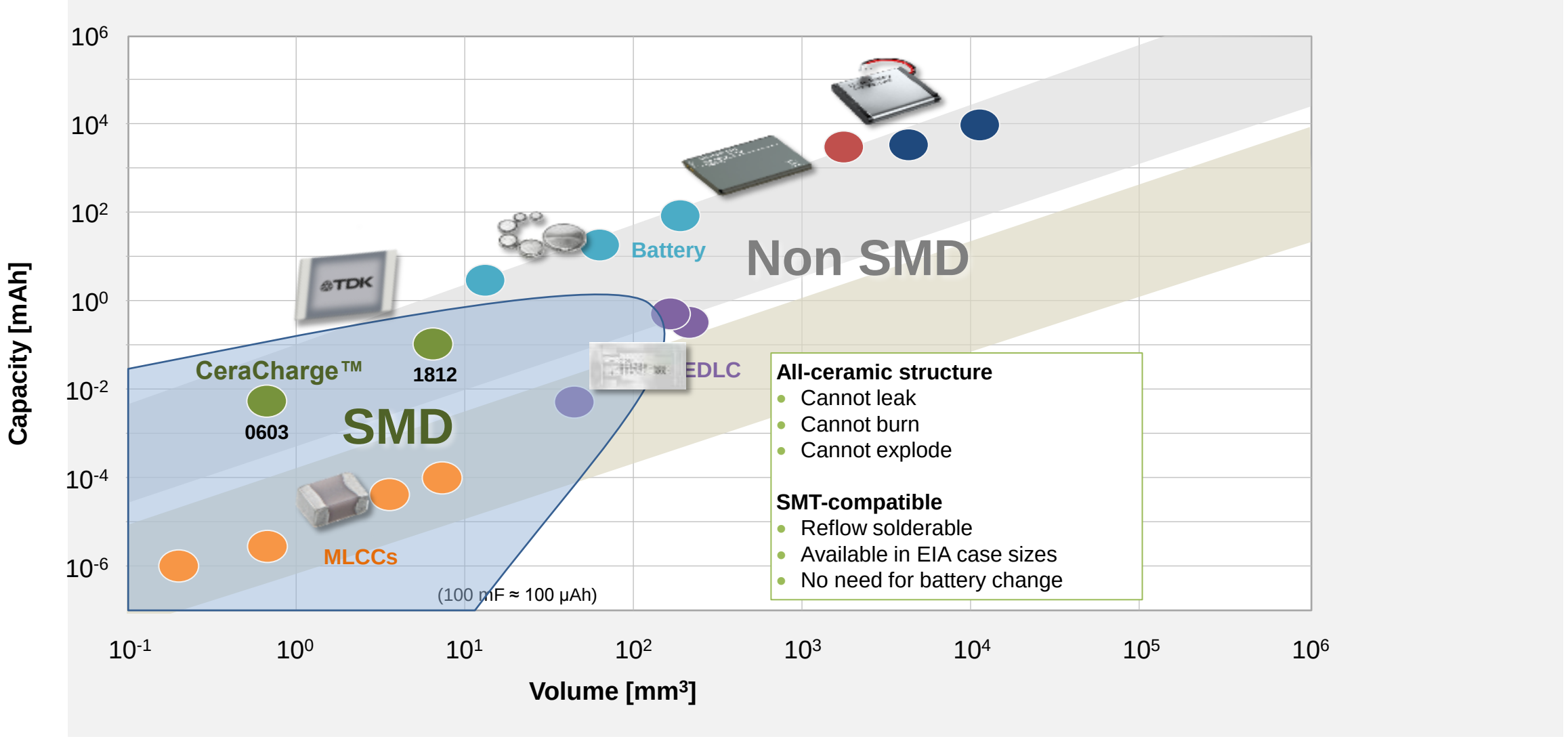
CeraCharge – World‘s first rechargeable solid-state SMD battery

CeraCharge 1812

Nominal voltage	[V]	1.4
Operating voltage	[V_{op}]	0 to 1.6
Nominal capacity	[µAh]	100 ±20
Nominal discharge current	[µA]	20
Operating temperature	[°C]	-20 to +80
Case size	[EIA]	1812
Dimensions	[mm]	4.5 x 3.2 x 1.1
Initial inner resistance	[Ω]	<200
Weight	[g]	0.045

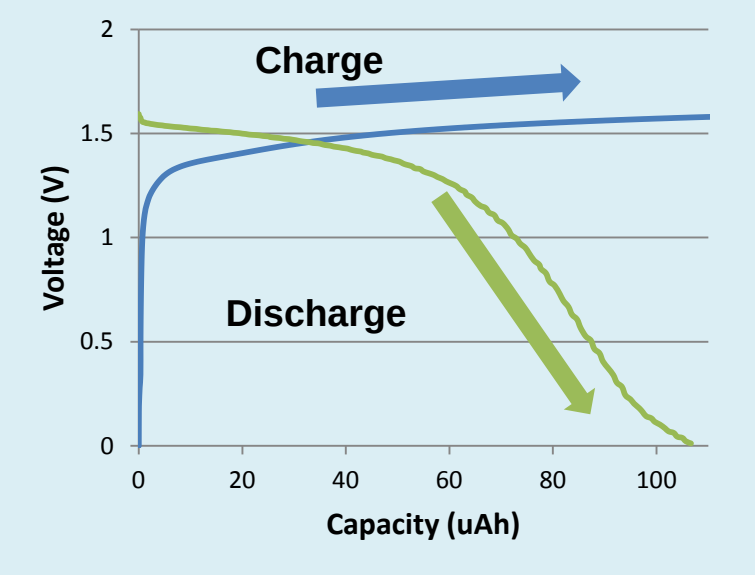
CeraCharge offers 1000 times the capacity of a capacitor in the same case size

Comparison of energy storage devices



What is CeraCharge ? → It is a rechargable chip battery

How does CeraCharge operate ?



Charge : supplied by main source, solar cell etc.
Discharge : provide energy to module(BLE etc.)
or IC(RTC etc)

Recommended charge profile

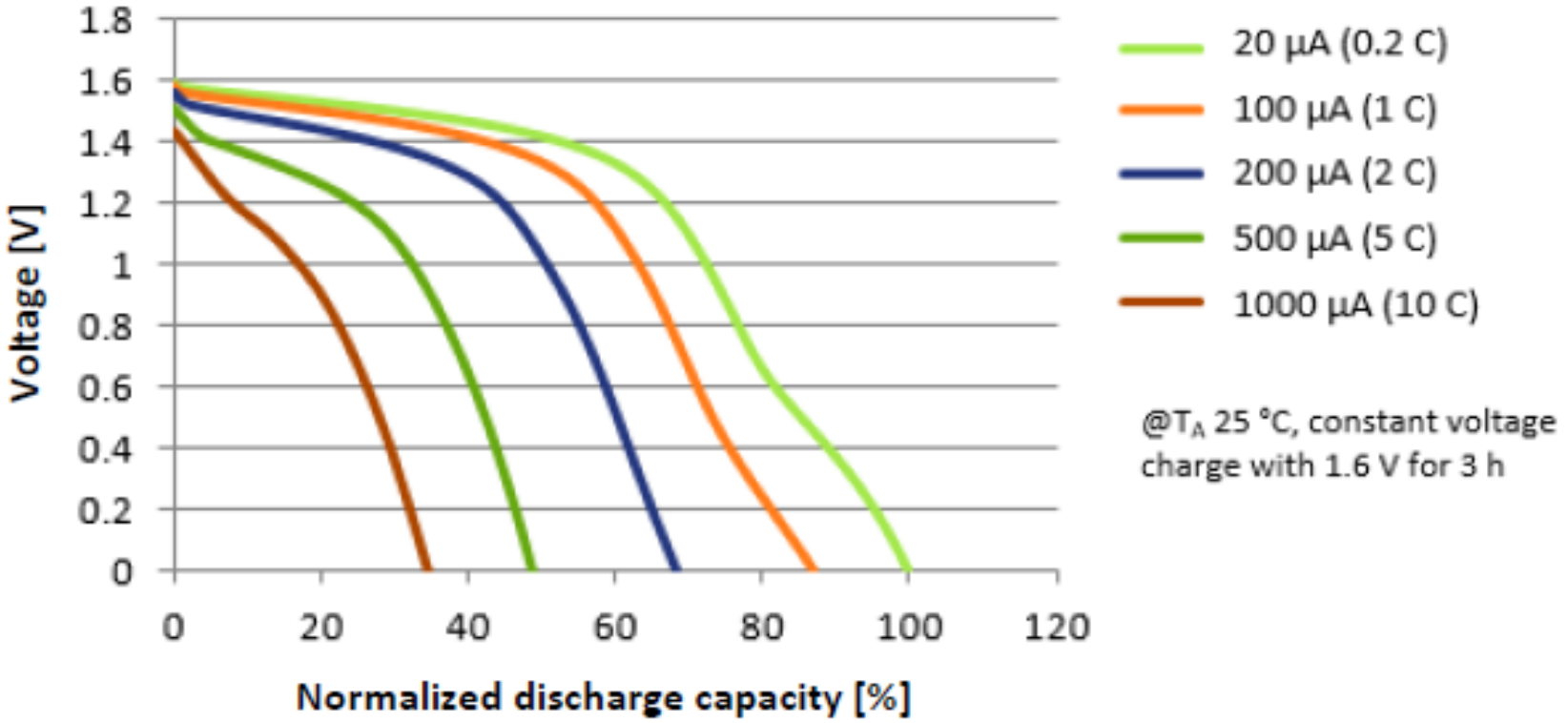
a)Constant current charge: setting current in range 10 µA up to 50 µA with end voltage 1.6 V.

b)Constant voltage charge: setting voltage to 1.6 V with limited current under 200 µA, end current below 10 µA.

c)Constant current charge / constant voltage charge: For constant current charge set current in range 10 µA up to 50 µA with end voltage 1.6 V; for constant voltage charge set voltage to 1.6 V with end current below 10 µA.

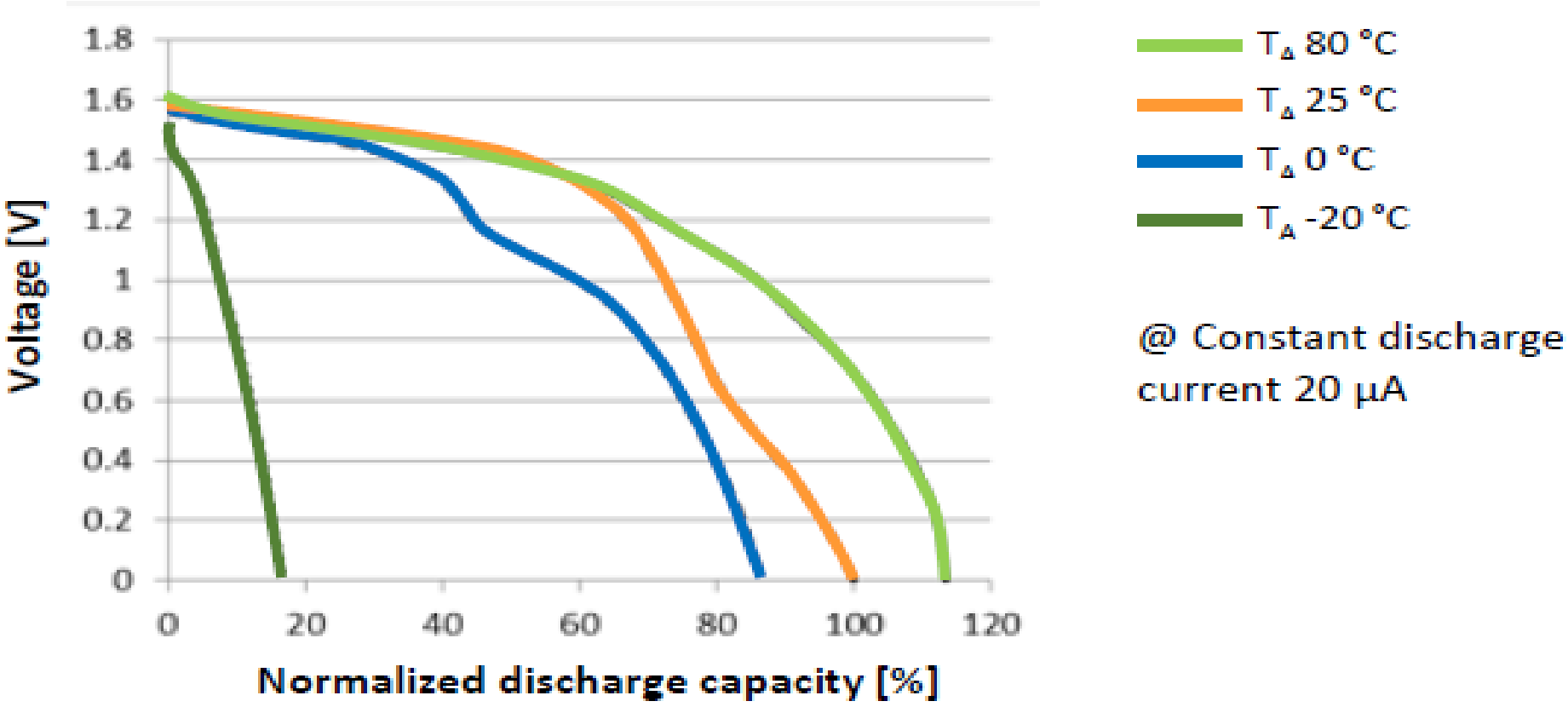
CeraCharge is an energy storage device which needs an energy source or power generation unit to be charged.
By using this charged energy, it powers functional components like BLE, RTC etc.

Typical discharge characteristic of CeraCharge



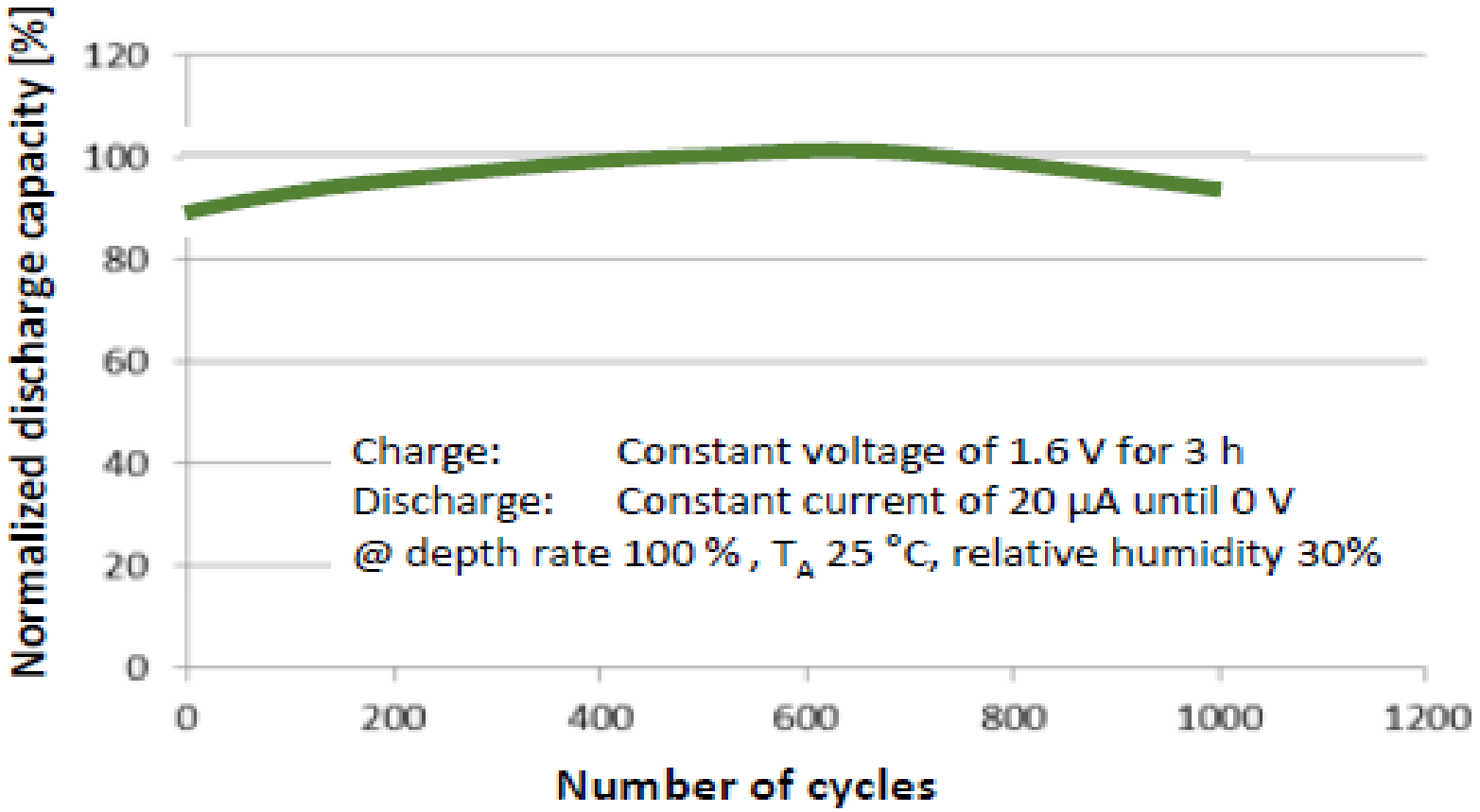
The nominal discharge current for CeraCharge is 20 µA,
but one CeraCharge component is also able to support a continuous discharge up to 1 mA (10 C)

Temperature characteristic of CeraCharge



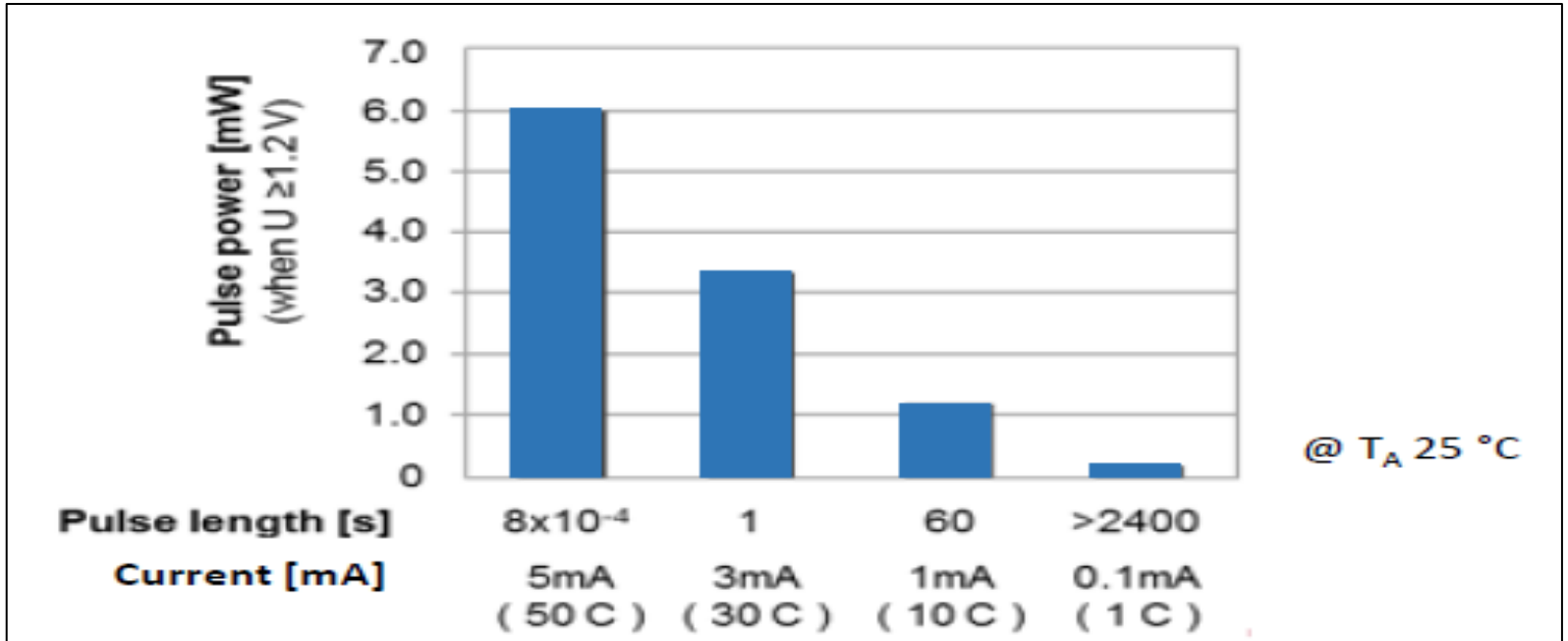
CeraCharge can operate in a temperature range from -20 °C to +80 °C.
This makes CeraCharge suitable for outdoor use, for example in weather stations.

Cycle characteristic of CeraCharge



CeraCharge is able to operate several dozens cycles up to > 1000 cycles without any significant loss in terms of electrical performance (up to 80 percent of the initial value)

Pulse discharge characteristic of CeraCharge

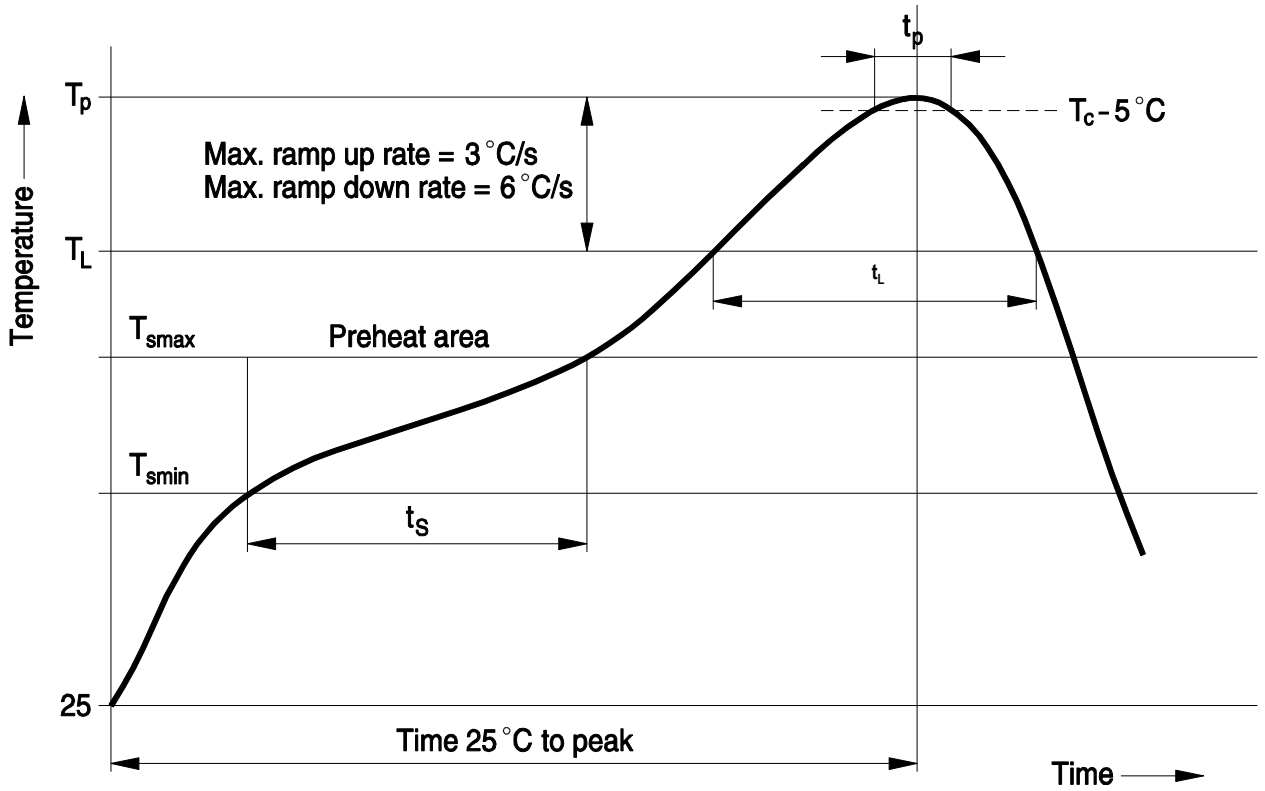


Current square pulse length	0.8 ms	1 s	60 s	> 2400 s
Interval	1 s	30 s	none (continuous)	none (continuous)

In pulsed operation mode – f.e. when supplying a Bluetooth beacon module during transmission– one CeraCharge component can supply currents up to a magnitude of about 5 mA/pulse.

Recommended reflow soldering profile

Temperature ranges for reflow soldering are according to IEC60068-2-58 recommendations.



Profile feature		Pb-free assembly
Preheat and soak - Temperature min - Temperature max - Time	 T_{smin} T_{smax} t_{smin} to t_{smax}	 150 ° C 200 ° C 60… 120 s
Average ramp-up rate	T_L to T_p	3 ° C/s max.
Liquidous temperature Time at liquidous	T_L t_L	217 ° C 40 … 150 s
Peak package body temperature	T_p [1)]	235 … 260 ° C [2)]
Time (t_p) [3)] within 5 ° C of specified classification temperature (T_c)	t_p [3)]	10±5 s [3)]
Average ramp-down rate	T_p to T_{smax}	6 ° C/s max.
Time 25 ° C to peak temperature		maximum 8 min

Standard SMD reflow soldering profile for Pb-free solder can be applied for CeraCharge.

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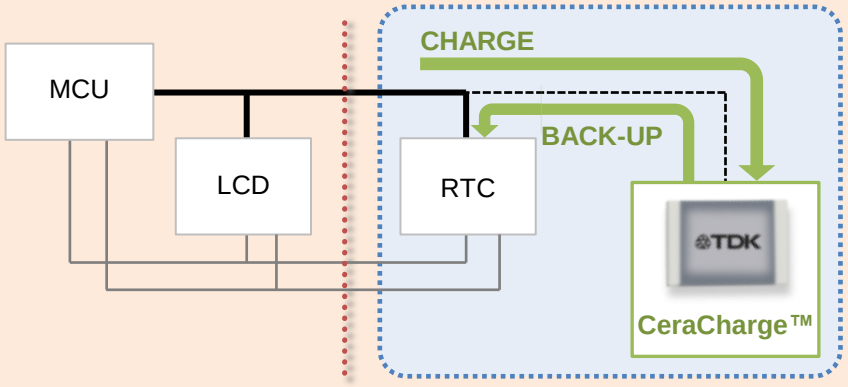
Main applications for CeraCharge

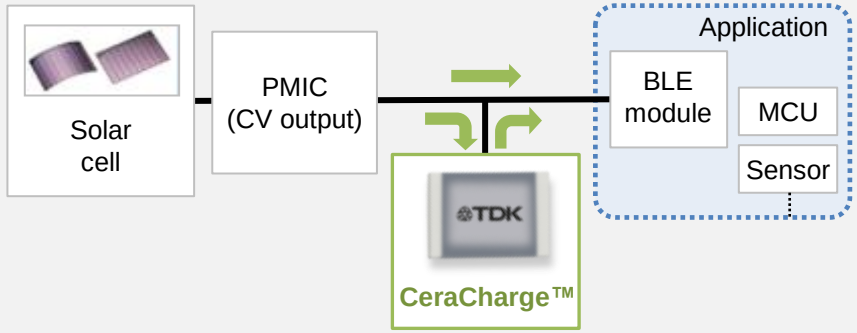
Real-time clock

Backup battery



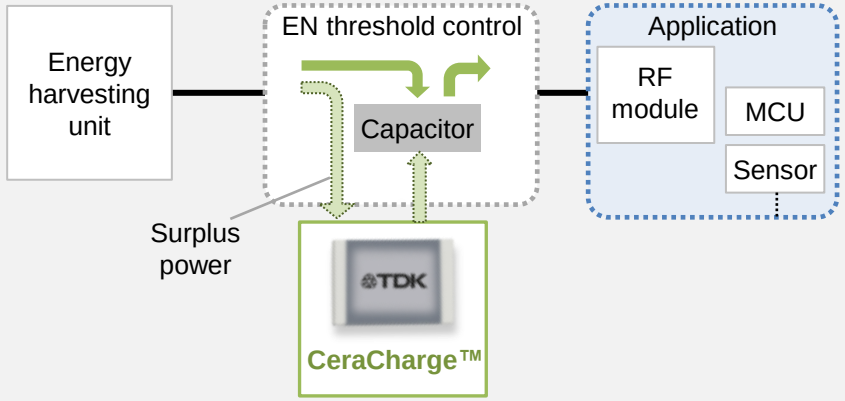
Internet of Things: Beacon

Energy storage (battery)



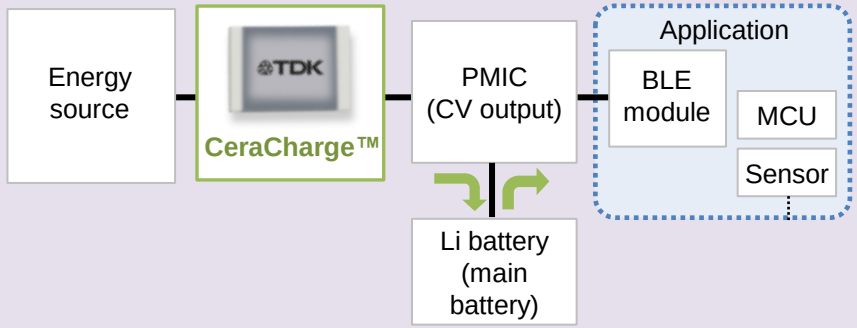
Energy harvesting

Energy storage



Wearables

Sub-battery for voltage and current smoothing



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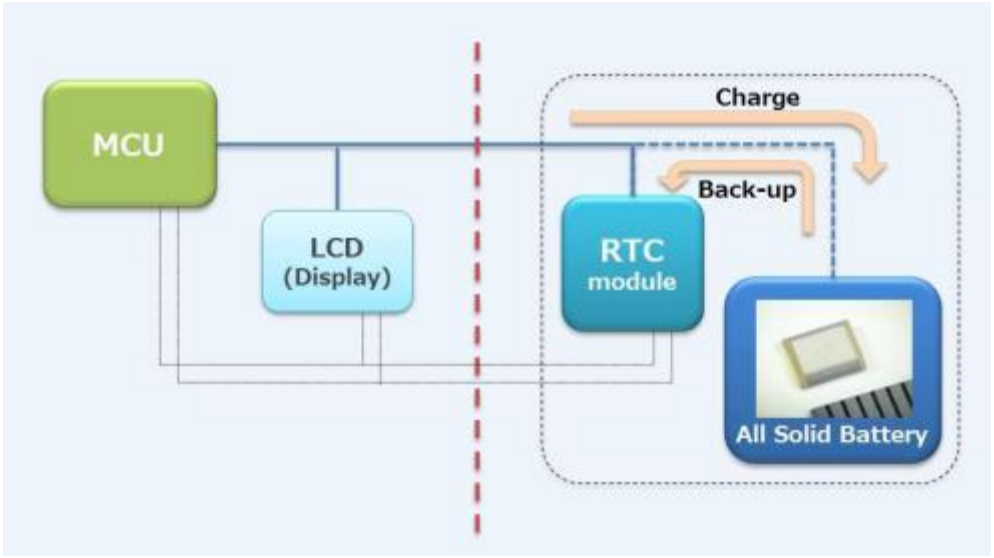
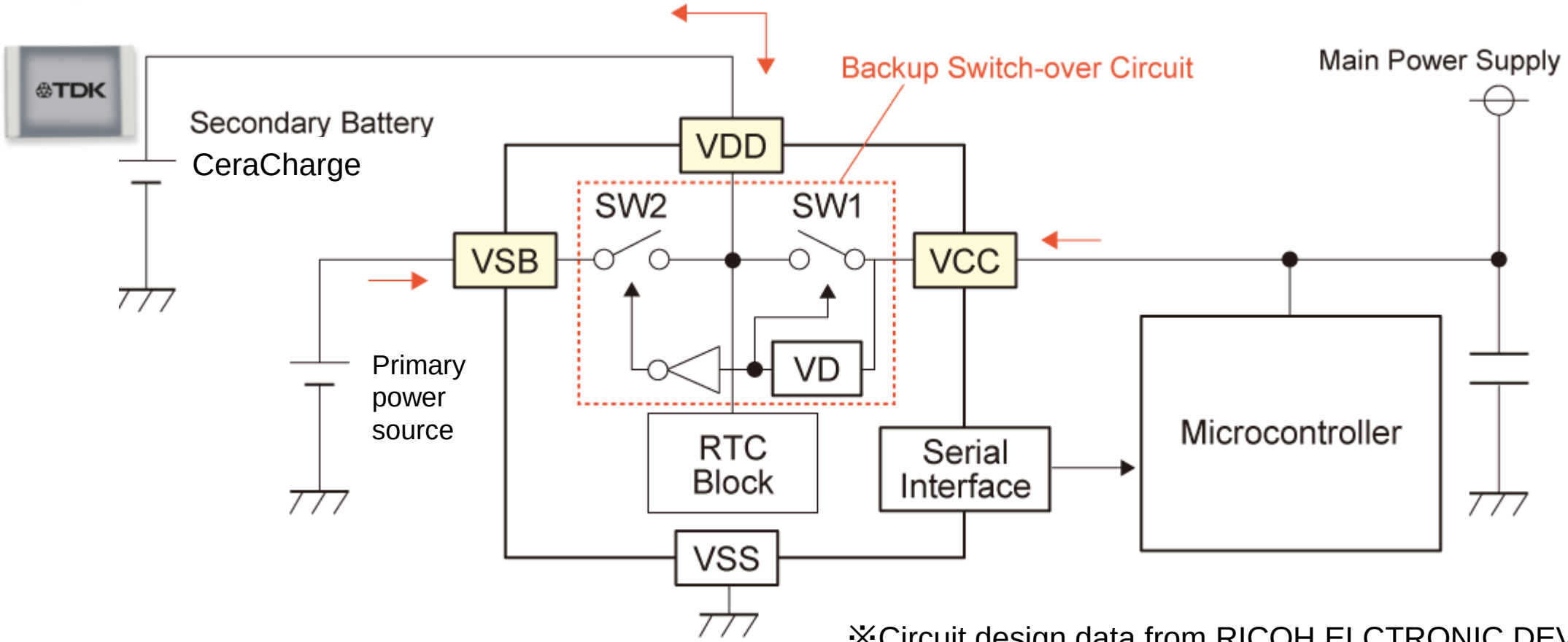
RTC Requirements specifications

- **RTC backup circuits**
  - ¬To keep an internal clock of µController or computer running

    - **Leakage** → Smaller than current consumption of RTC-IC of ~ 0.4uA
    - **Capacity** → Depends on the target operating term (100uAh backups RTC-IC around 10 days)
    - **Float charging** → when main power is supplying, CeraCharge is always fully charged in parallel.



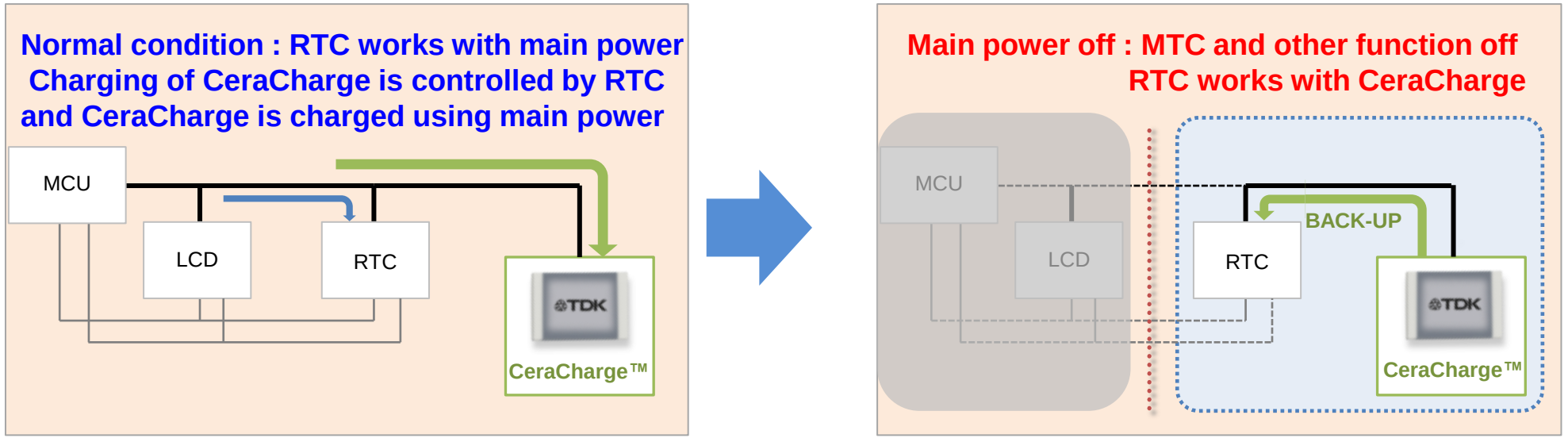
Circuit design of RTC



※Circuit design data from RICOH ELCTRONIC DEVICES

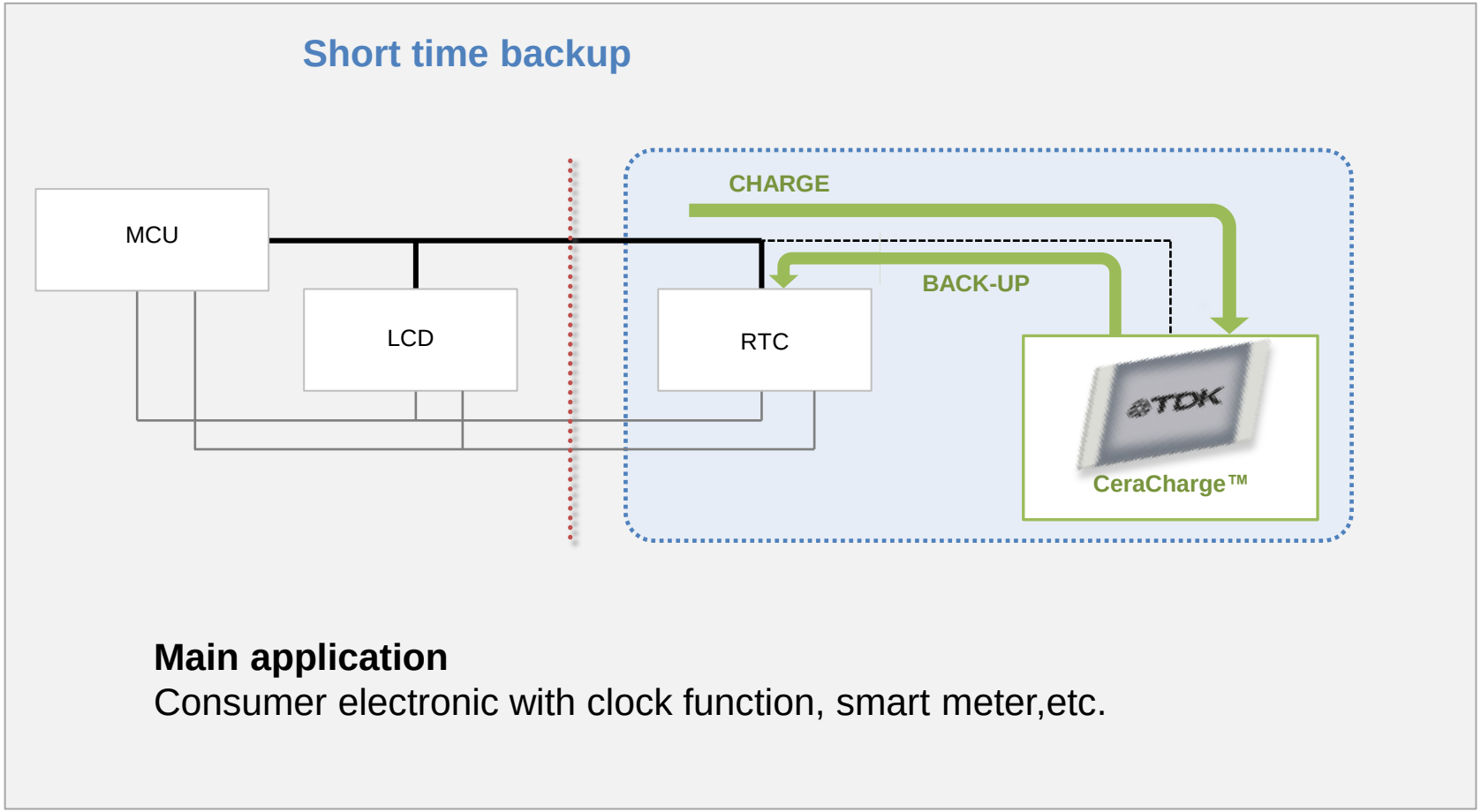
Most of RTC have VDD function to charge secondary battery

How CeraCharge work with RTC



CeraCharge is used only in case on main power cut off

Proposal circuit of RTC with CeraCharge

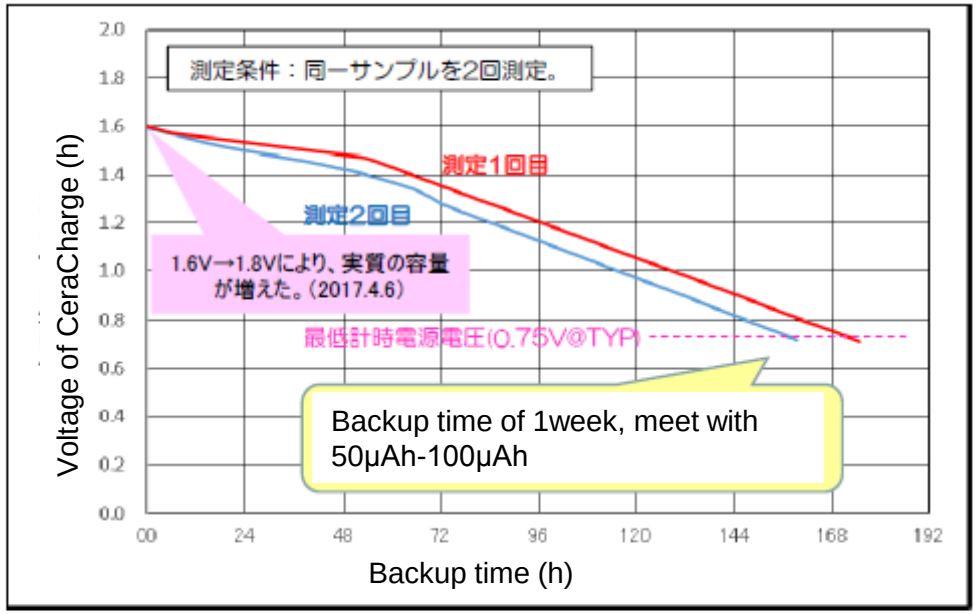


Main application
Consumer electronic with clock function, smart meter,etc.

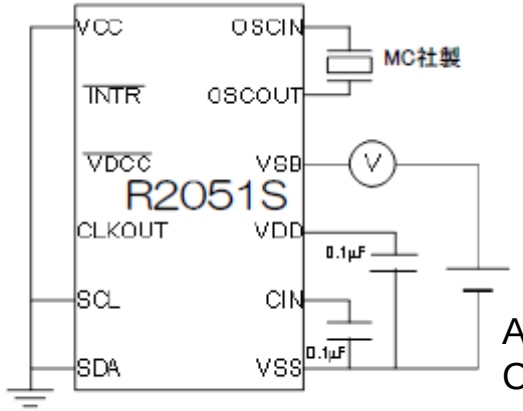
CeraCharge can be backup the system up to 10days

RTC backup time evaluation result with CeraCharge

■ RICOH R2051S Backup time evaluation result

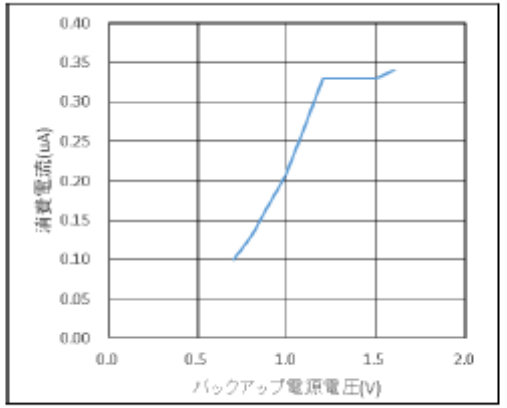


■ Measurement circuit



ASB
CeraCharge

■ R2051S Current consumption characteristic



■ Measurement procedure

1. 1.6V Charge for 1day
2. Connect to R2051S and measure RTC time (start time)
3. Measure CeraCharge voltage constantly (1measure/1day)
4. Check R2051S stop time

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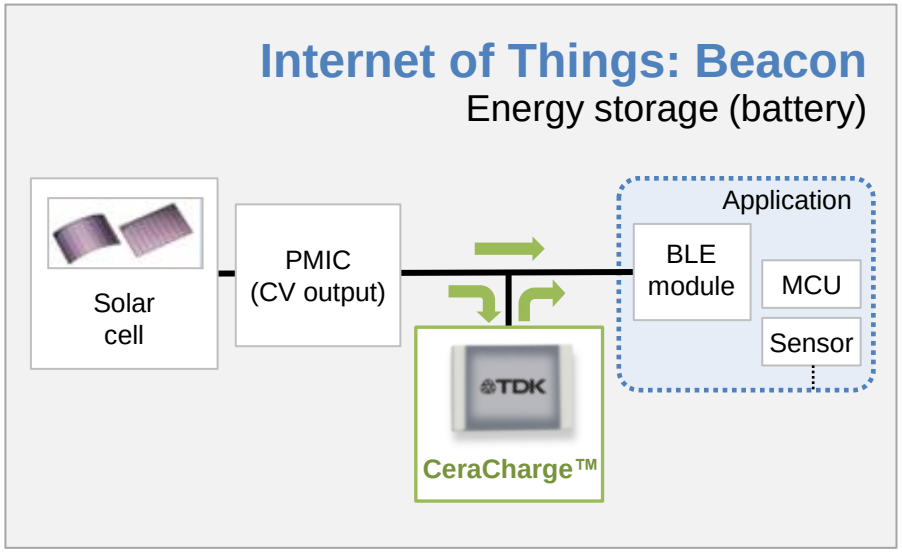
Energy Harvesting

Energy type	W/cm^2 *
Vibration	10^{-3}～10^{-4}
Light	10^{-4}
Heat	10^{-5}
Radio wave	10^{-6}

Need to collect low level of energy

*) Roundy, S. et al., "A study of low level vibrations as a power source for wireless sensor nodes,"Computer Communications 26, Issue 11, pp.1131-1144, Jul. 2003

Solar powered Beacon



Concept of Solar powered Beacon:

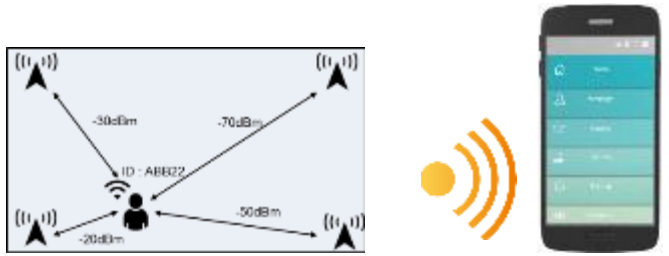
- No need to change battery
- Charged to battery during daytime and using battery when light is off

Which parts are used ?

- Solar Cell
- Power management IC
- Energy storage device (battery, capacitor)
- MCU (BLE, sensor)

Where can you use an indoor solar Beacon?

- Sensing of equipment, instruments (positioning, temp etc.)
- Sensing human information (positioning, temp etc.)
- Shop : Sending information of Bargen items etc.
- Museum : Sending information of exhibition



Can CeraCharge be used for energy storage device using solar powered Beacon ?

Scheme of Solar powered Beacon

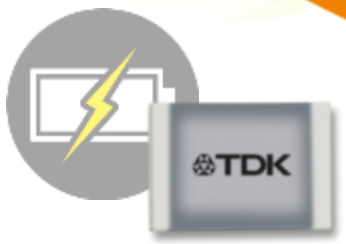
Sensing from everywhere under light using the Thin, Small IoT solution. It brings new value to lives of people.

PV

Generating

Generate electric power from Outdoor & Indoor Lights

CeraCharge



Charging

Store Energy generated by PV

Capacitor EDLC

Supply High-power from stored electric energy

Operating

Sensor

BLE

IoT

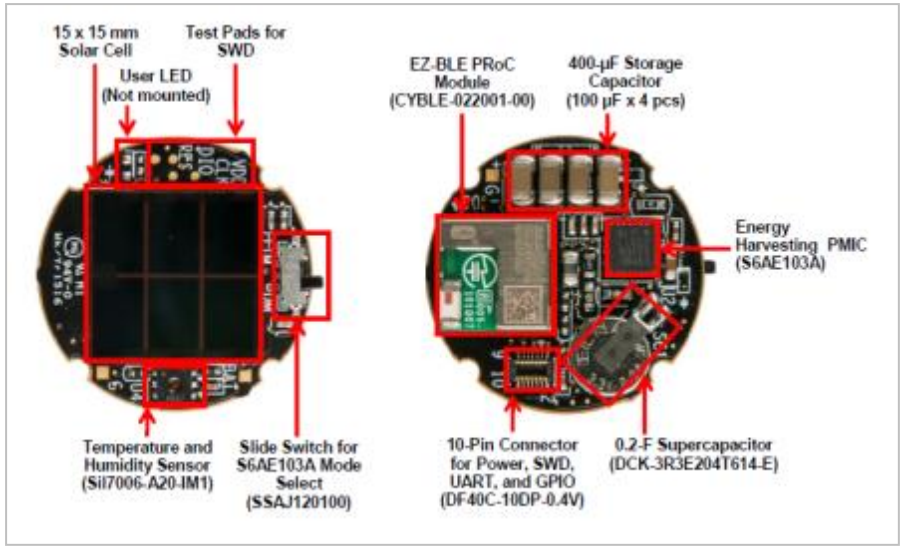
Low-power data transmission

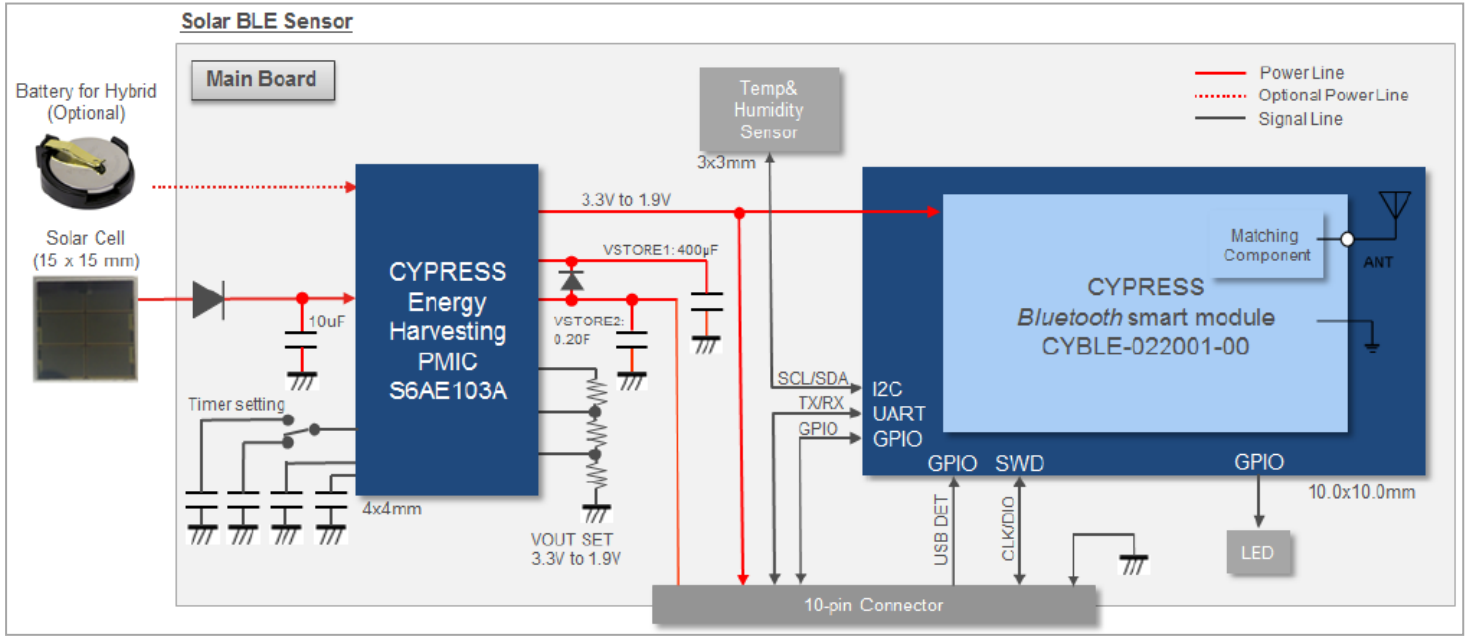
Transmitting

Verifing with CYPRESS Demo kit CYALKIT-E03

■ Appearances & block diagram of “CYALKIT-E03”

- Solar cell : 6-cell, 3.6V,3.5uA (AM-1616 Panasonic) ➔ replace to TDK PV (BCS4630B9, 2-para)
- EDLC : 0.2F, 3.3V (DCK-3R3E204T614-E : ELNA) ➔ replace to TDK EDLC (5mF)
- Capacitor : 400uF (100uF*4) ➔ replace to CeraCharge (2S2P, 3.2V, 200uAh)
- PMIC : S6AE103A
- RF module : CYBLE-022001-00
- Sensor : Temp. and Humidity Sensor (Sil7006-A20-IM1)

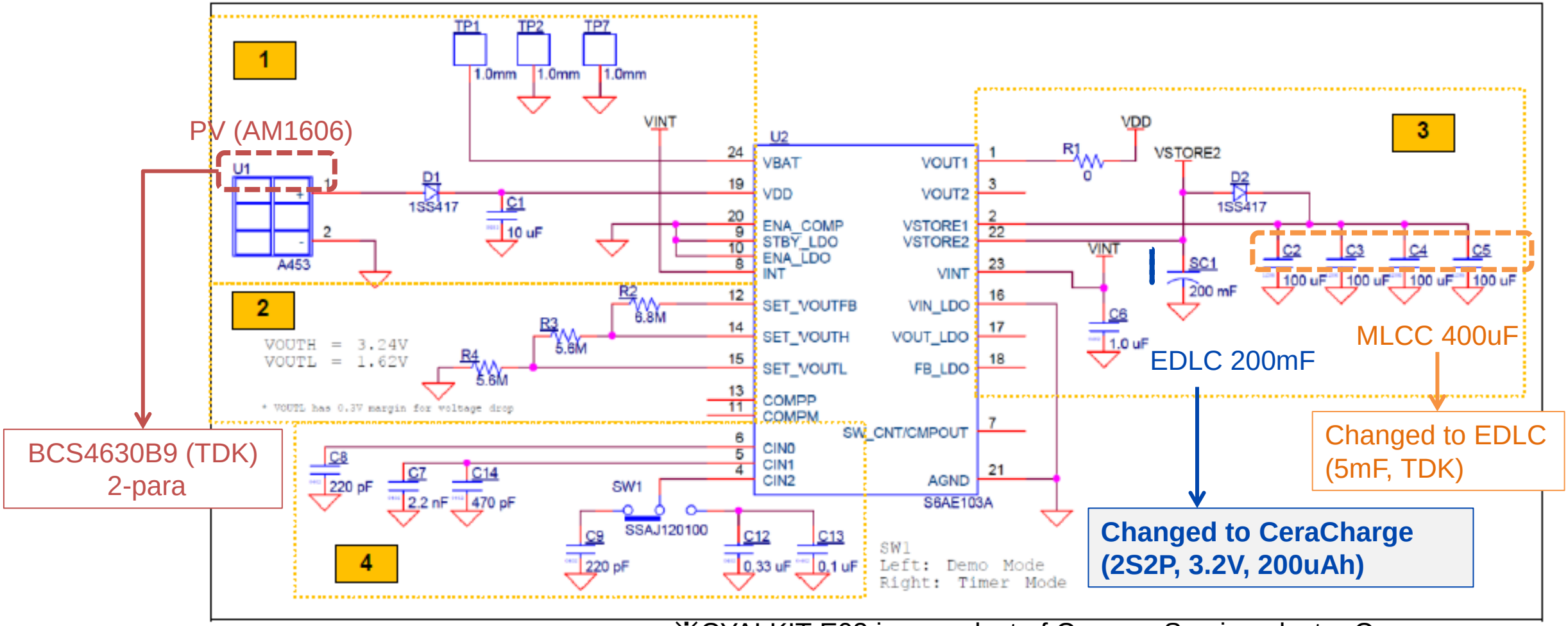




※CYALKIT-E03 is a product of Cypress Semiconductor Corp.

Circuit design of CYALKIT-E03

■ Circuit diagram of the S6AE103A PMIC



※CYALKIT-E03 is a product of Cypress Semiconductor Corp.

PMIC operation verification with CYALKIT-E03

■ Results

1. Over Voltage Protection (OVP) for Solar-cell under high illumination environment
   → The voltage of the solar cell in VDD pin was controlled to <5.4V by the PMIC function.

2. Voltage control for CeraCharge unit connected in VSTORE2 pin
   → The voltage of the CeraCharge unit was controlled in the range of “VoutL” to “VoutH”.

* The voltage range of Vout, VSTORE1, and VSTORE2 are controlled to the same range with resistors connected to FB pin.
(e.g. VoutH=3.24V, VoutL=1.62V in this kit “CYALKIT-E03”)

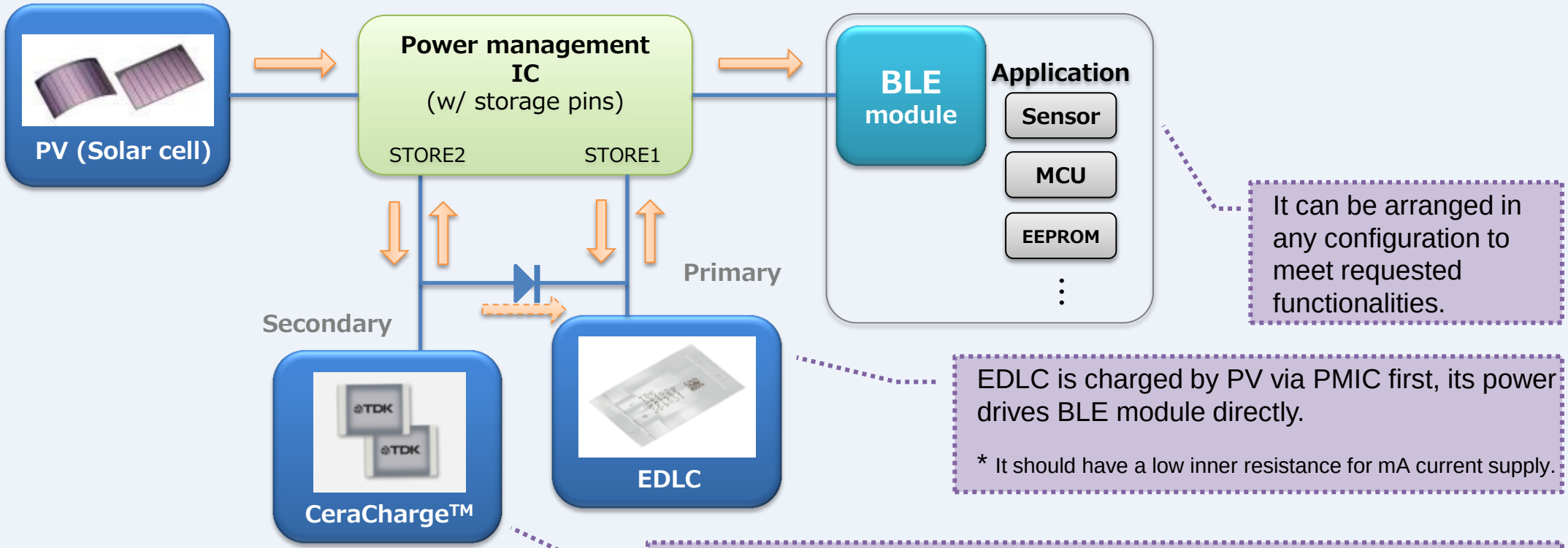
→ S6AE102A can prevent the over voltage of solar cell,
and can control the voltage range of CeraCharge unit without external switching.

* The power control logic & pins (VSTORE1, 2) of “S6AE103A” mounted CYALKIT-E03 is the same as S6AE102A’s one,
both of “102A” and “103A” can provide these functions.

→CeraCharge can be used for energy storage device for solar powered Beacon

Block diagram and driving model of solar powered Beacon with CeraCharge

■ Block diagram & driving model



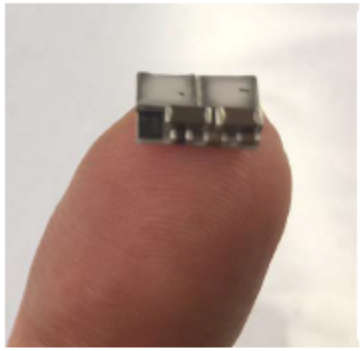
Solar powered Beacon

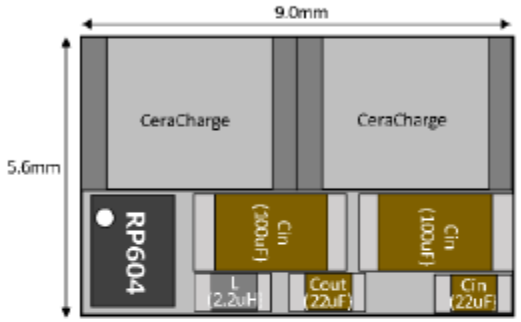
You can see these Beacon working at CeraCharge booth today!

TDK CeraCharge™ × RICOH power supply IC

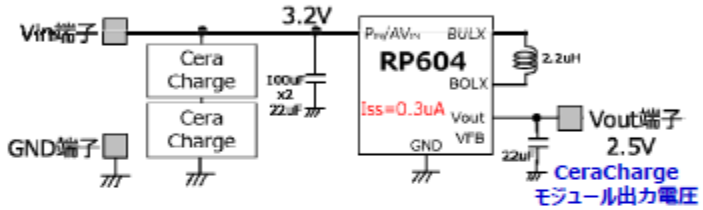
RICOH imagine. change.

Fingertip size voltage controllable and stable voltage battery

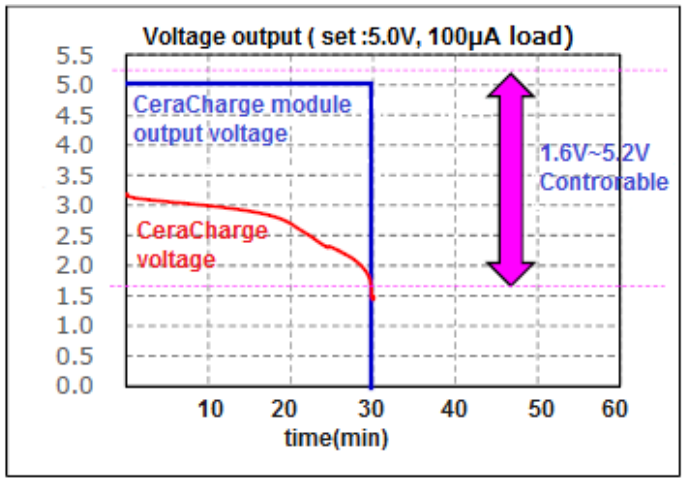


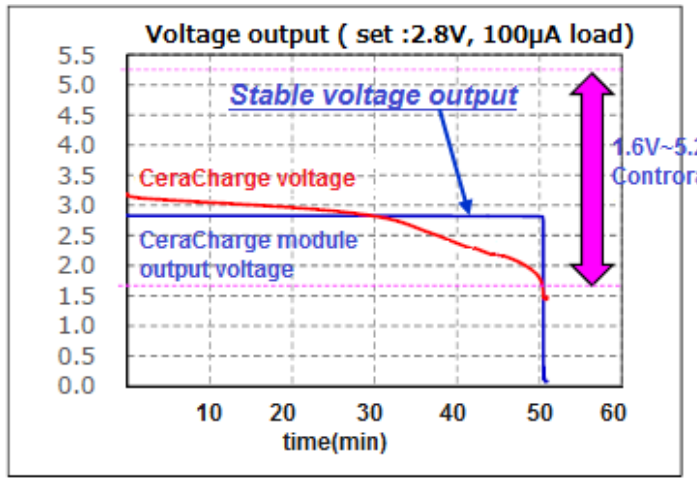


・CeraCharge module circuit



Base technology : Small PKG/ Low leak current / Low power consumption





How to use CeraCharge in combination of DC/DC convertor?

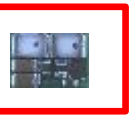
This concepts enables to use the full power of CeraCharge

Energy harvesting devices with CeraCharge

Energy-harvesting devices with all solid state rechargeable battery module

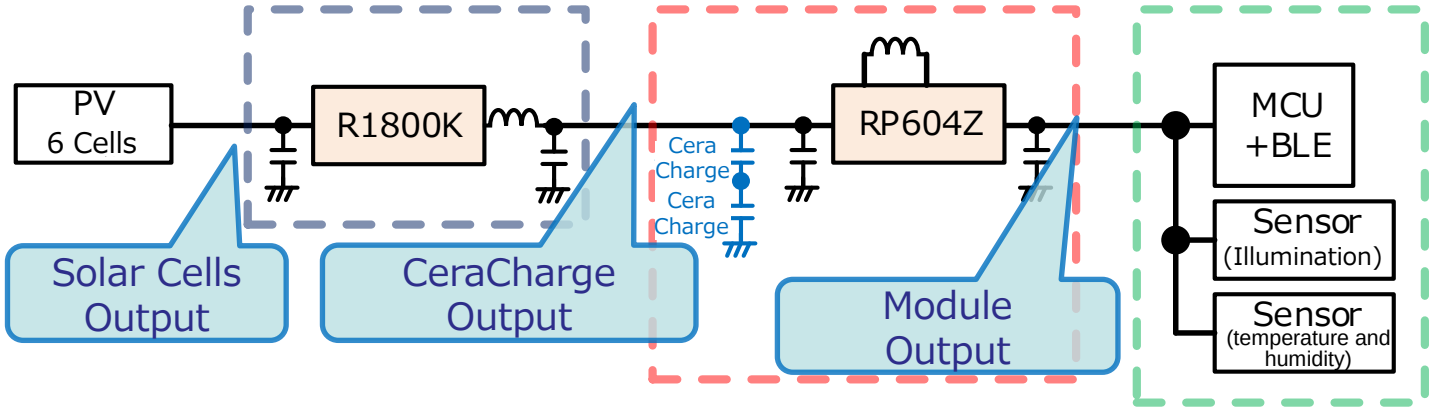
Amorphous silicon solar cells (TDK)

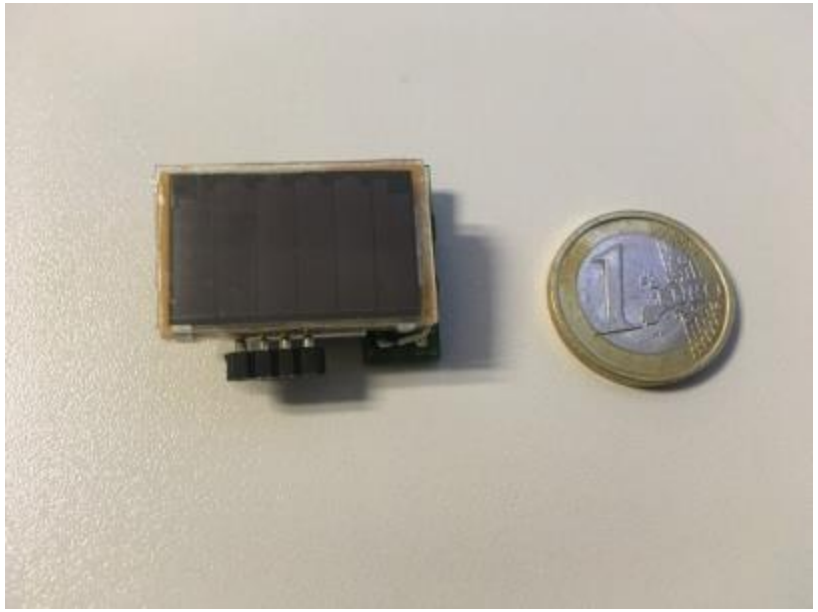
R1800 module (Ricoh)



CeraCharge+RP604 module (TDK+Ricoh)

Sensor, microcomputer and RF module





Film Solar Cell (PV Device)

Good power generation efficiency for Indoor Lights .
No need to replace battery → Low maintenance costs. No electric wire → Low initial cost of introduction.
Thin, Small and Lightweight → easy to place/mount

Features

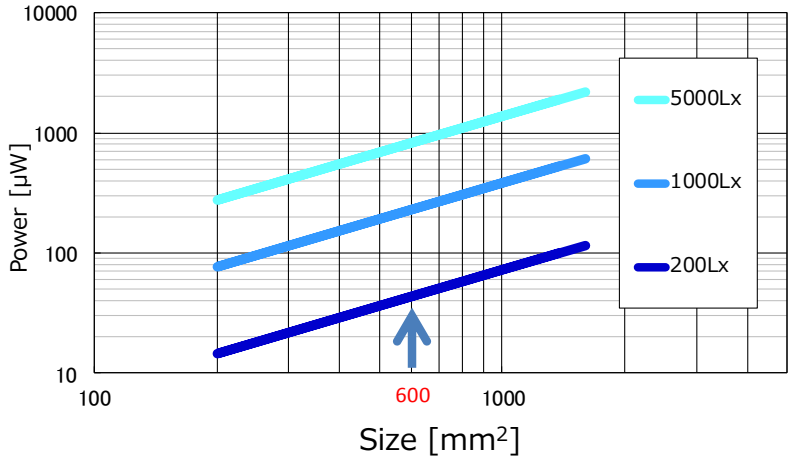
Solar Cell

- Indoor light generation (Good efficiency for indoor lights)
- Thickness≦0.2mm
  thin & flexile → easy to mount on curved places
- Lightweight → hard to break even dropped
- Various shapes, support custom specifications

Applications

- Watch, Wearable devices
- Power source for Sensors･Beacon
- Other Energy harvesting power sources

PV device size and Generation power (Indoor lights)



【output power (example)】
Size 20×30㎜
⇒ ～220μW under 1000Lx illuminance

RICOH R1800 Buck DC/DC converter for Energy Harvestor

RICOH **R1800K Series**

144 nA I_Q Low Quiescent Current Buck DC/DC Converter for Energy Harvester

No. EA-414-180410

OVERVIEW

R1800K is a power-storing buck DC/DC converter for a photovoltaic and vibration energy harvester. A low operating quiescent current allows a harvester to be used under a low-illumination environment, and it is suitable for an equipment with low power supplied from a harvester.

KEY BENEFITS

- Providing a low operating quiescent current (I_Q 144 nA) and a high efficiency (approximately 90%@10 µA).
- A Control function that enables a maximum power optimizes a power supply from an energy harvester.

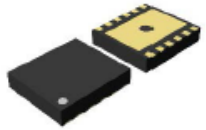
KEY SPECIFICATIONS

- Input Voltage Range: 2.0 V to 5.5 V
- Output Voltage Range: 2.0 V to 4.5 V
- Output Voltage Accuracy: ±3.0%
- Operating Quiescent Current:
  Typ.144 nA (Ta = 25°C, at no load)
- Starting Power: 720 nW
- Reverse Current Protection (V_{IN} ≥ 2.0 V)
- Accuracy of Maximum Power Voltage: 200 mV

APPLICATIONS

- Energy harvesting module of a photovoltaic and vibration energy harvester

PACKAGE



DFN(PLP)2730-12

Tjmax = 85°C, θja = 32°C/W
2.7 mm x 3.0 mm x 0.6 mm (Max.)

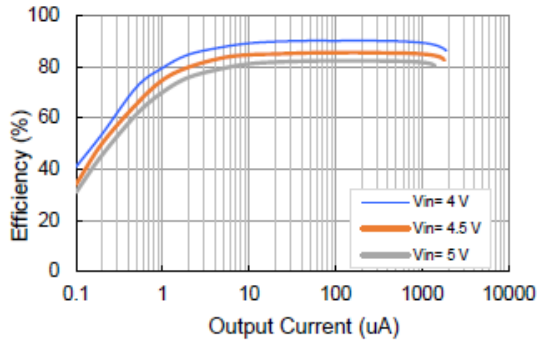
SELECTION GUIDE

Product Name	Package	Quantity per Reel
R1800KxxxA-TR	DFN(PLP)2730-12	5,000 pcs

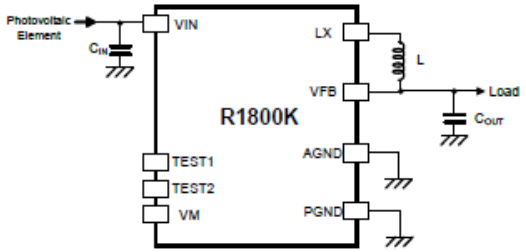
xxx: Select the ideal combination of the set output voltage (V_{SET}) and the set maximum power voltage (V_{MPSET}) from the code number starting from 002.

TYPICAL CHARACTERISTICS

Efficiency vs. Output Current V_{SET} = 3.3 V



TYPICAL APPLICATION



L = 22 µH, C_{IN} = 10 µF, C_{OUT} = 47 µF

RICOH RP604 Buck-Boost DC/DC Convertor

RICOH **RP604x Series**

Ultra-low Quiescent Current (I_Q = 0.3 µA), 300 mA, Buck-Boost DC/DC Converter

No. EA-415-180502

OVERVIEW

The RP604x is a buck-boost converter featuring a minimum supply current and a high efficiency at low-load. The device operates at the low operating quiescent current (I_Q = 0.3 µA) to make the most of battery life for the battery driver operated intermittently.

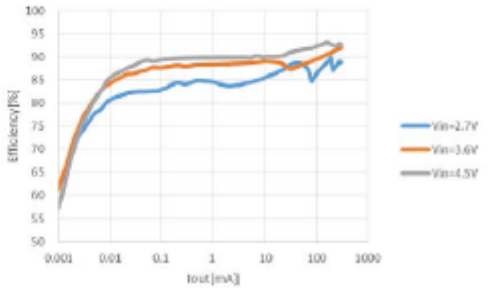
KEY BENEFITS

- The low supply current (I_Q = 0.3 µA) can achieve making battery life longer and battery's size-reduction.
- Wide range of input voltage (1.8 V to 5.5 V) can support for every batteries from a coin-type battery to a USB port.
- Selectable package: WLCSP-20-P2 or DFN(PLP)2730-12

KEY SPECIFICATIONS

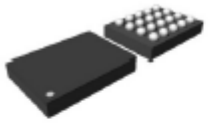
- Input Voltage: 1.8 V to 5.5 V
- Output Voltage: 1.6 V to 5.2 V, 0.1 V step
- Output Voltage Accuracy: ±1.5%
- Maximum Output Current: 300 mA at Buck
- Built-in Driver On-resistance (RP604Z, V_{IN} = 3.6 V): PMOS = Typ.0.12 Ω, NMOS = Typ. 0.12 Ω
- Operating Quiescent Current (I_Q): 0.3 µA
- Standby Current: 0.01 µA
- Protection Features: UVLO, OVP, LX Peak Current, and Thermal Shutdown

TYPICAL CHARACTERISTICS

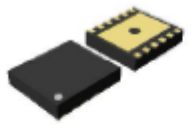


V_{OUT} = 3.3 V

PACKAGES



WLCSP-20-P2
1.71 x 2.315 x 0.40(1) mm
(1) maximum dimension



DFN(PLP)2730-12
2.70 x 3.00 x 0.6(1) mm
(1) maximum dimension

OPTIONAL FUNCTIONS

The auto-discharge function and the set output voltage (V_{SET}) are user-selectable options.

Product Name	Auto-discharge Function	V_{SET}
RP604xxx1A	Disable	1.6 V to 5.2 V (0.1 V step)
RP604xxx1B	Enable	

APPLICATIONS

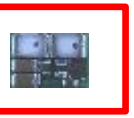
- Wearable Appliances: SmartWatch, SmartBand, Healthcare
- Li-ion/Coin Battery-used Equipment
- Low-power Wireless Communication Equipment: *Bluetooth®* Low Energy, ZigBee, WiSunm, ANT
- Low-power Devices for CPU, Memory, Sensor Device, Energy Harvesting

Energy harvesting devices with CeraCharge

Energy-harvesting devices with all solid state rechargeable battery module

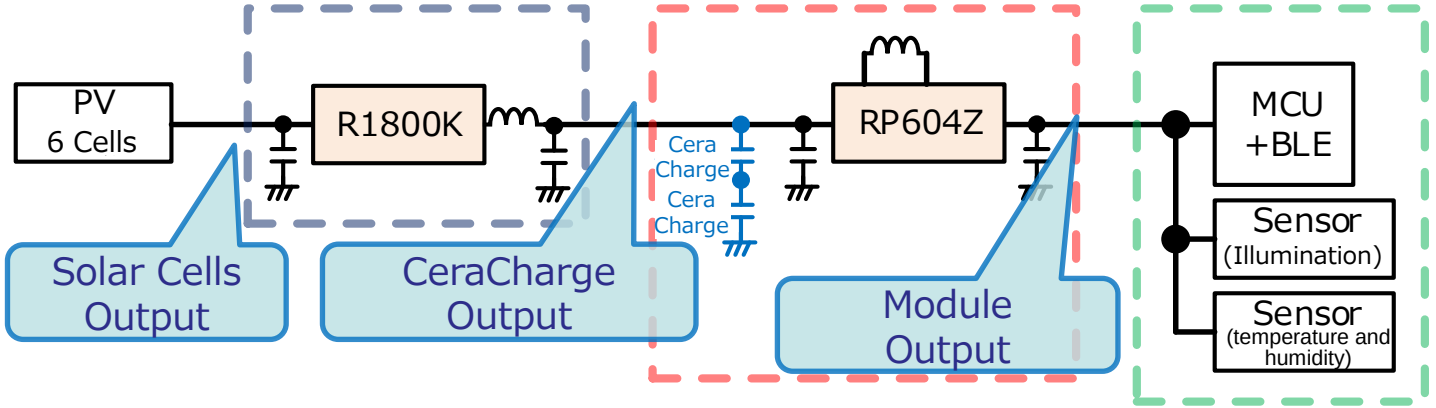
Amorphous silicon solar cells (TDK)

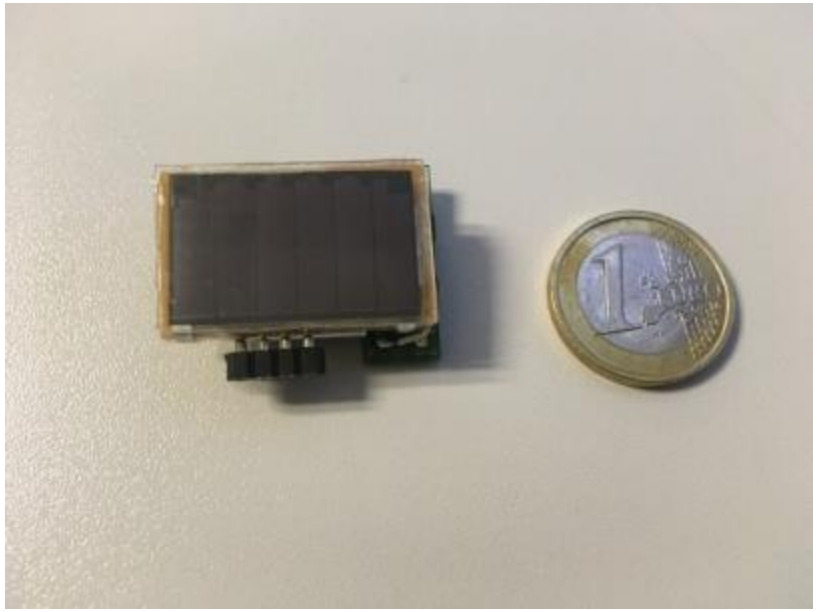
R1800 module (Ricoh)



CeraCharge+RP604 module (TDK+Ricoh)

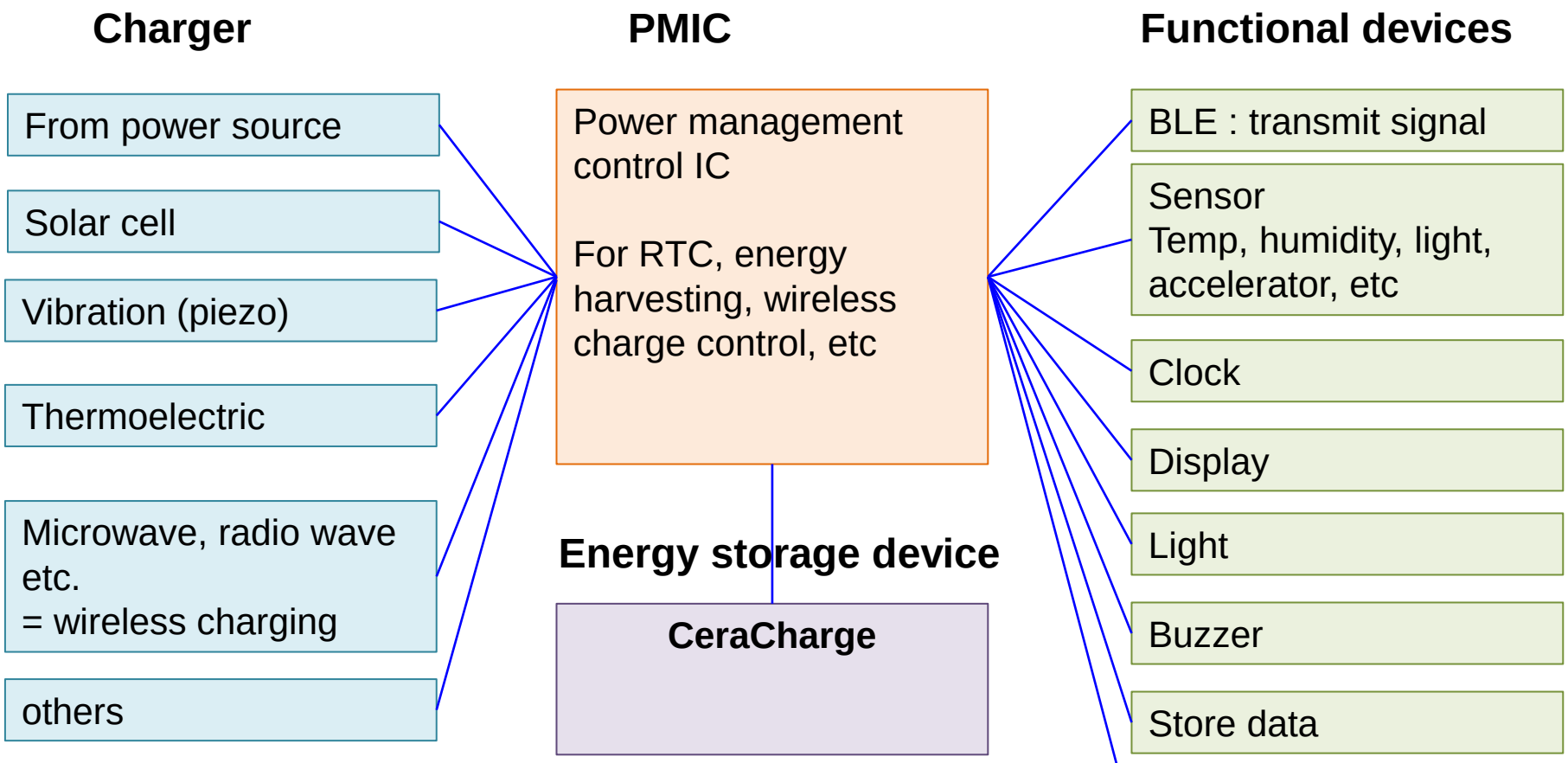
Sensor, microcomputer and RF module





These module demo will be shown at Electronica 2018

Other applications



c.f) RTC = From power source + clock function included in PMIC (RTC chip)
Solar Beacon = Solar cell + PMIC + BLE

We are open to discuss further applications !!!

If you are interested in CeraCharge please contact us!

Thank You!