CeraCharge™

Application notes

Series/Type:
Ordering code:

Date: 2019-03-06
Version: P1

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1. Onboard coating

Onboard coating after soldering CeraCharge is recommended.

1) Surface preparation

The board surface CeraCharge is mounted should be free of dust, oil, grease or other dirt.

2) Dam-filling

Recommended coating material

Dam material:	Vitralit® 1671 (Panacol-Elosol GmbH)
Filling material:	Vitralit® 1680 (Panacol-Elosol GmbH)

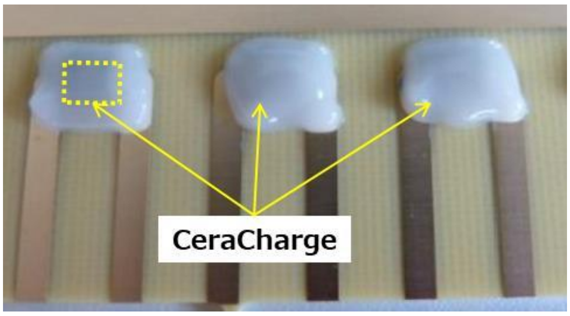
Thickness should be more than 0.5 mm from CeraCharge surface.

Curing conditions

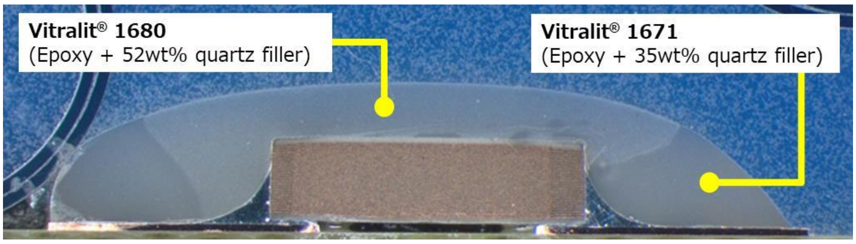
1. 90sec with ca. 350mW/cm² UV - A
2. Drying 30min at 120°C

3) Appearances

(Top view)



(Cross section)



2. Basic usage

1) Charging conditions

3 variants of charging conditions can be applied for CeraCharge.

- Constant current (CC) charging: setting current in range 10 µA up to 50 µA with end voltage 1.6 V.
- Constant voltage (CV) charging: setting voltage to 1.6 V with limited current under 200 µA, end current below 10 µA.
- CC-CV charging: 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.

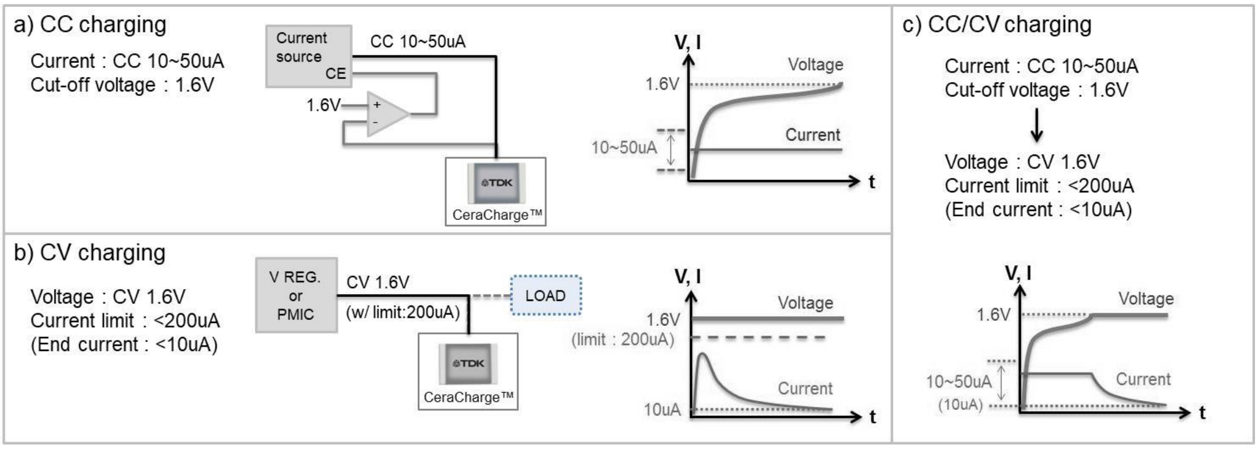


Figure 1
Charging conditions of CeraCharge

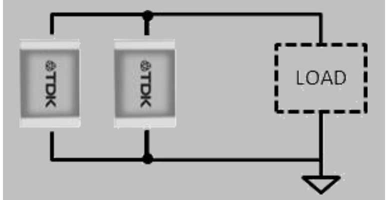
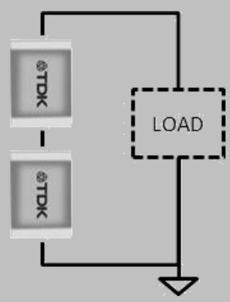
In the CC charging mode, a control circuit which has a function to stop charging by detecting the voltage to reach the upper control limit (Vucl) is needed.
In the CV charging mode, a control circuit which has a function to stop charging by detecting the charging current lower than 10µA is needed, or you can make the charging time a rough guide to judge the end of charging, but it is not a problem to continue CV charging even after the charging current falls below 10µA.
The CC-CV charging is the same method as general LiB batteries, a control circuit which has a function to switch to CV charging after detect reaching to the Vucl is needed.

The full charged in CV charging is based on the point that the charging current is below 10µA, the charging time what is from capacity empty state to the charging current below 10µA is around 3 hr. (Initial charging will take 5~6hr.)

The tendency that the charging capacity is bigger than discharging capacity (Low efficiency of discharging / charging) is observed during initial several cycles. It will be improved by repeating cycles.

2) Voltage / Capacity calculation in series / parallel

The following chart provides the information that how we can calculate the voltage / capacity / inner resistance in multiple connection of CeraCharge.

Series & Parallel	1 series & 2 parallel	2 series & 1 parallel
Circuit diagram		
Discharging Capacity	200 uAh	100 uAh
Output Voltage	1.6 V (max.)	3.2 V (max.)
Inner Resistance	100 Ohm	400 Ohm

If you connect CeraCharge components in parallel, the discharging capacity becomes a parallel number multiple, the apparent inner resistance becomes as fraction of parallel numbers, and the discharging voltage remains unchanged.
If you connect CeraCharge components in series, the discharging voltage becomes a series number multiple, the apparent inner resistance becomes a series number multiple, and the discharging capacity remains unchanged.

Voltage: Series number multiple
Capacity: Parallel number multiple
Inner resistance: Multiplied with series number and divided by parallel number

e.g. The CeraCharge unit with 2-series-3-parallel (2S3P) connection becomes,

Voltage of upper control limit: 3.2 V (1.6V * 2-series)
Discharging capacity: 300 µAh (100µAh * 3-parallels)
Apparent inner resistance: 133 Ω (200 Ω * 2-series / 3-parallel)

3) Series / Parallel connection (Voltage balancing & current limitation)

To prevent voltage deviations of CeraCharge components connected in series, some controlling circuits are recommended to use.

In case of 2 in series connection, balancing resistor circuits are recommended.
The resistance value of the resistors should be considered with balancing current (balancing speed) and leakage (current consumption). It should be kept in mind that these are trade off relationship.

To align the maximum current between parallels, Current regulative diodes (CRD) can be used for CeraCharge parallel line. The power supply capacity of charging power line should be higher than the total current of every CRD in parallel.

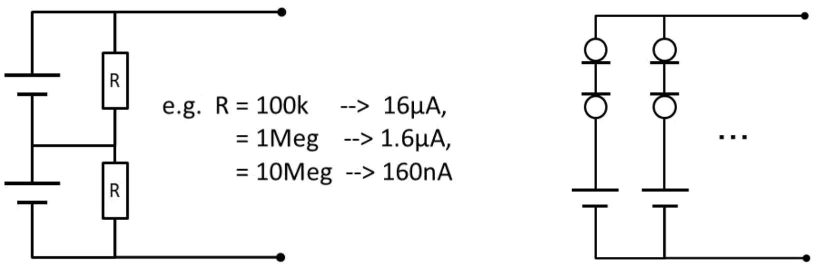


Figure 2
Balancing resistor circuit and current regulated circuit

In case of 3 in series or more, OPAMP circuits are also proposed in addition for balancing resistor circuits. It should be considered about leakage of resistors and current consumption of OPAMP.

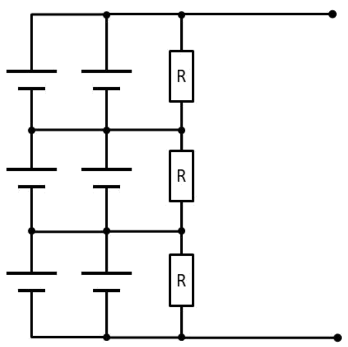
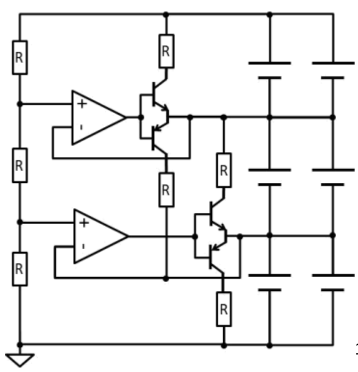
Resistor	**Operational Amplifier**
	 [1]

Figure 3
Balancing resister (passive) circuit and Operational amplifier (active) circuit

[1] US 20050077875 A1

3. Application guide

1) Application for CeraCharge

Power backup	IoT (Energy harvesting)	Sub battery	Wearable, Health care
e.g. Real Time Clocks	e.g. Beacons Environment sensor	e.g. Battery life extender	e.g. Thermometer Hearing aid

2) Use case

Low current output (e.g. RTC backup battery)

CeraCharge is suitable for applications which require long time discharging with slight current.

Discharging with few current continuously like a backup battery of Real Time Clock (RTC) IC is one of most suitable usage. CeraCharge what has 100µAh in its small 1812 case will contribute to reduce the mounting area of PCB surface with replacing coin-cell batteries.

Although leakage current of a backup battery also affects to the operating time of RTC-IC, CeraCharge can be reduced its leakage current with extending charging time. Compare with several hour charging, the leakage current after charging 100hr will decrease to 0.1µA.

(And in normally the upper control limit of charging voltage is 1.6V, increasing this voltage to 1.8V can reduce its leakage current. But this method will make its cycle performance degrade, it should be used only for the usage which does not need cycle performance.)

Connection image

Connecting variations are generally divided into 2 types as Figure 4.

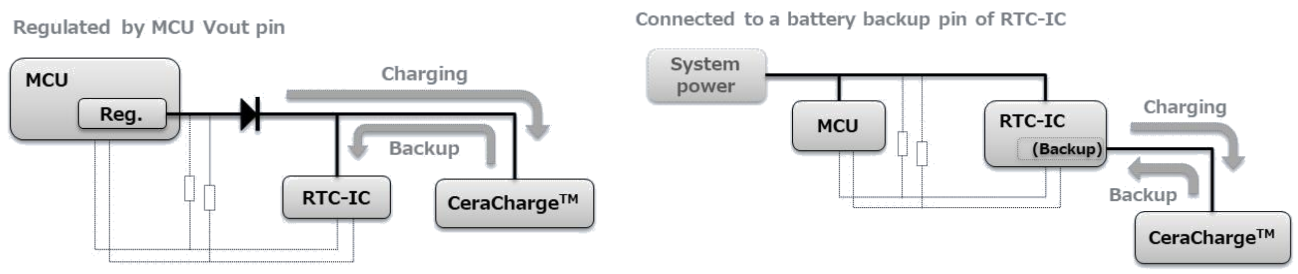


Figure 4

Block image of CeraCharge connection for RTC backup circuit

In some products of RTC-IC have battery backup mode and those IC are equipped with a pin for connecting a backup battery. CeraCharge can be connected to this pin.

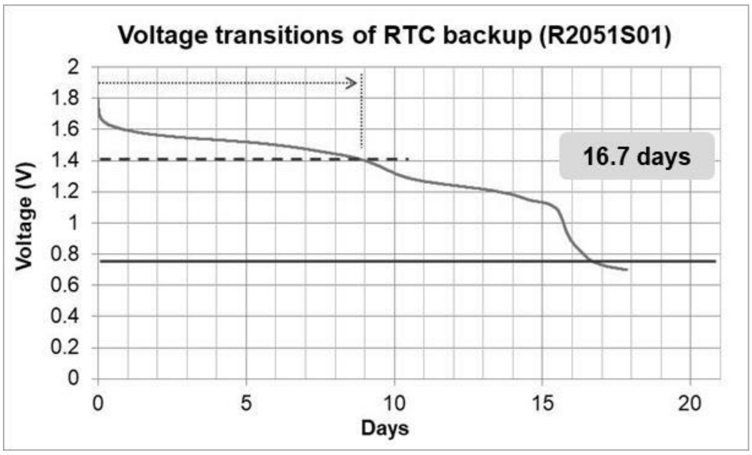
The RTC-IC which does not have a backup mode can also be used with a CeraCharge backup circuit. In this case, CeraCharge should be connected to VDD pin in parallel with main power source, and to prevent a current backflow from CeraCharge to system power line when the system power shut down, a diode before the parallel point of RTC and CeraCharge on the system power line is recommended.

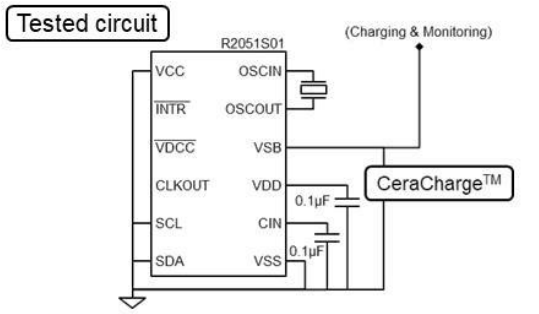
As in the above 2 points, when the CeraCharge is connected to RTC circuits as a backup battery with charging and discharging, CeraCharge will be connected to power line from MCU (system power) or backup pin of RTC-IC. And series number of CeraCharge (=charging voltage) will be decided with the supply voltage from MCU (system power) or a backup pin of RTC-IC.

Operating time calculation

Figure 5 is an example of measurement results of RTC backup circuit with CeraCharge.

RTC-IC: R2051S01 (RICOH Electronic Devices Co., Ltd.)
  Current consumption: 0.4uA
  Minimum Timekeeping Voltage: 0.75V Typ.
CeraCharge:
  Charging: CV1.8V, 100hr → connected to the backup pin of RTC-IC as 1 cell





Backup of R2051S01	
Driving time (measured)	401.17 hr
Discharging capacity (calculated)	160.47 uAh
Leakage (*if CeraCharge=190uAh)	0.074 uA

Figure 5
RTC (R2051S01) backup circuit test result

In this case, CeraCharge could backup 16.7days (400hr) from 1.8V to 0.75V. With considering the current consumption of this RTC-IC, CeraCharge supplied 160 uAh to RTC-IC until reach the minimum timekeeping voltage. And a full discharging capacity of CeraCharge charged to 1.8V is roughly 190 uAh, the leakage current during this operating can be calculated 0.074uA.

Operating time calculation should be considered with current consumption of RTC-IC and leakage of CeraCharge as in the above. And in addition, the operating voltage range of RTC-IC is also should be considered to use CeraCharge capacity more efficiently. A solid line in the graph is the minimum timekeeping voltage of this RTC-IC (0.75V). But if its value is 1.4V as the dashed line, CeraCharge couldn’t supply 50% of capacity to RTC-IC. In this case, CeraCharge can drive only around 200hr with its capacity cannot be fully demonstrated.

Figure 6 is a measurement result with another IC has lower current consumption than R2051S01.

The actual driving time cannot be calculated with only a current consumption and capacity, leakage is also needed.

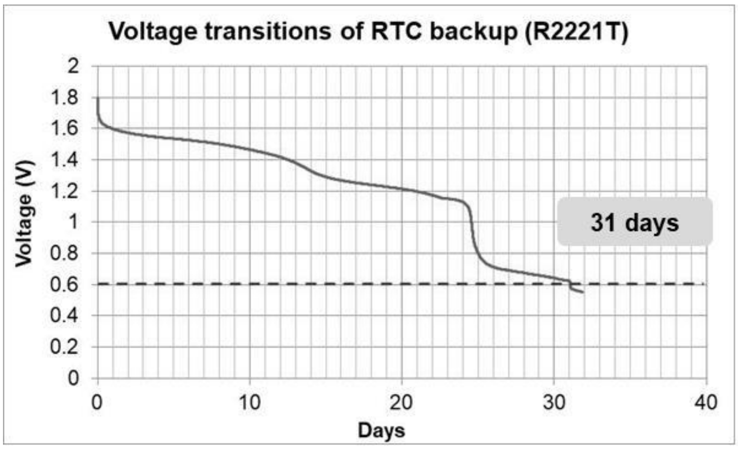
RTC-IC: R2221T (RICOH Electronic Devices Co., Ltd.)

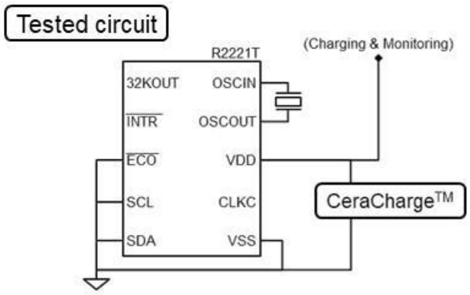
Current consumption: 0.18uA

Minimum Timekeeping Voltage: 0.6V Typ.

CeraCharge:

Charging: CV1.8V, 100hr → connected to the backup pin of RTC-IC as 1 cell





Backup of R2221T	
Driving time (measured)	744.8 hr
Discharging capacity (calculated)	134.06 uAh
Leakage (*if CeraCharge=190uAh)	0.075 uA

Figure 6
RTC (R2221T) backup circuit test result

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High C rate output (Intermittently operating RF devices, e.g. IoT sensors like Beacon)

CeraCharge is not suitable for continuously discharge in a range of mA current since its high inner resistance (e.g. driving LEDs, blight graphic displays, high quality speakers.). In the applications which need mA current consumption, the discharging voltage of CeraCharge may drop by its inner resistance and it could not supply power to a load enough.

But in some applications which requires mA current discharging can be supported by CeraCharge. Figure 7 “Typical pulse power” shows the potential of CeraCharge in “some applications”. If the usage of applications is some intermittently driving system like a RF beacon, its current consumption should be several mA pulse current with interval of several time (sec. ~ min.).

Typical pulse power in this sheet means, if an interval has 30s between each square pulse, CeraCharge can discharge maximum 1s of 3mA current square pulse.

Typical pulse power

(T_A = 25 ℃)

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

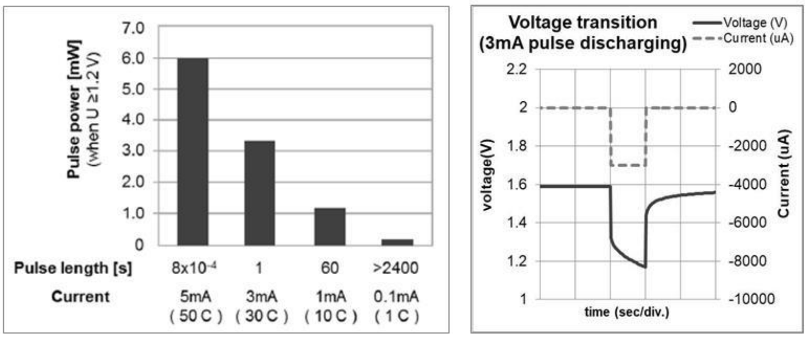


Figure 7

Typical pulse power and pulse discharging test result of CeraCharge

Connection image

In case for transmitting devices what is driving in intermittently operating mode with several mA pulse current, CeraCharge can prevent a voltage drop of power line with connecting low impedance capacitors in parallel.The capacitors supply the power needed for a transmitting one time, and then CeraCharge charges capacitors for next transmitting.

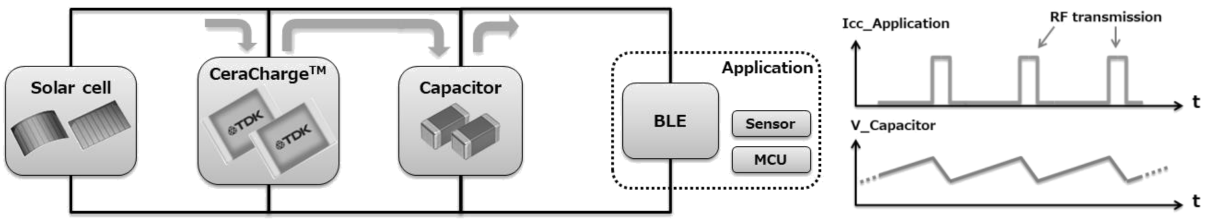


Figure 8

CeraCharge connection & operating image for intermittently operating RF devices

Energy calculation

If you want to know how long can your application drive with CeraCharge, you can calculate to convert power consumption of applications to capacitance of capacitors and capacity of batteries. (*This is an ideal value in a case if we can convert all energy of battery capacity to an electric energy with some voltage value.)

100uAh = 360000uA*s = 360000uC = 257142.86uF*1.4V

So, a 100µAh of CeraCharge capacity is compatible to a 250mF of capacitance.
CeraCharge which has 100µAh capacity in this 1812 case size contributes to miniaturization of beacon devices and environment sensing devices as a new power supply for IoT edge devices.

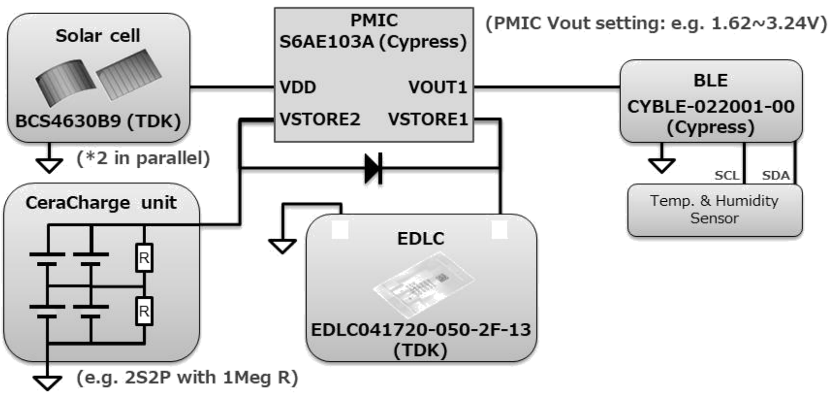
In addition, a transmitting power of RF devices can be calculated as follows for example. And the average power consumption should be calculated with this value and transmitting interval.

Energy consumption of an application
Voltage: 3.0V, Current: 10mA, Pulse width: 10ms (as 1 pulse for RF transmitting)

Energy (uJ)=3.0V*10mA*10ms=300uJ

Recommended circuit

For example, Energy harvesting RF sensor devices what has some intermittently driving system with CeraCharge and low impedance capacitors can be designed as Figure 9.



Energy harvester:	BCS4630B9 (TDK)
Power Management IC:	S6AE103A (Cypress)
Parallel capacitor:	EDLC041720-050-2F-13 (TDK)

Figure 9
Block diagram of Energy harvesting RF sensor devices with CeraCharge and capacitor

In this case, CeraCharge should be used as 2 in series for the operating voltage range (1.62~3.24V). The parallel number of CeraCharge and a capacitance of the EDLC will be defined with the energy harvester, BLE power consumption and environment (e.g. Duration of bright / dark for solar cells.).

Voltage adjusting to system requirement

If you connect CeraCharge components in series, the output voltage becomes to (1.6V multiplied with series number) V, but to use CeraCharge capacity efficiently, the series number should be set with considering the operating voltage range of applications.

If the operating voltage range of an application is 2.7 to 3.6V, CeraCharge can be connected as 2 in series (Vucl: 3.2V) or 3 in series (Vucl: 4.8V). If you connect CeraCharge as 2 in series, the each CeraCharge components can be charged to 1.6V, and then it can discharge to 1.35V in each component. In this case, the application is operated in the range of 3.2 to 2.7V. If you connect CeraCharge as 3 in series, you can charge it to 3.6V (1.2V in each) and can discharge to 2.7V (0.9V in each). To make full use of the CeraCharge voltage range, you can charge to 4.8V (1.6V in each) with some regulating circuits to output 3.6V below for the voltage range of the application.

Capacity calculation for operating time of load

As we showed in the above section about RTC backup circuits, this voltage range also should be considered to calculate an operating time of applications.
The 100µAh as nominal capacity of CeraCharge is a capacity in the measurement with 0.2C discharging rate to 0V condition. If the low limit voltage of the application is 1.4V, the actual discharging capacity value what can be used in this application is in the range from 1.6V to 1.4V.

It is recommended that charging and discharging voltage transition move in the "Efficient range" of each series number as follows.
Fig.11 is an example circuit of "3V output with back-boost DC/DC from 2 in series CeraCharge".

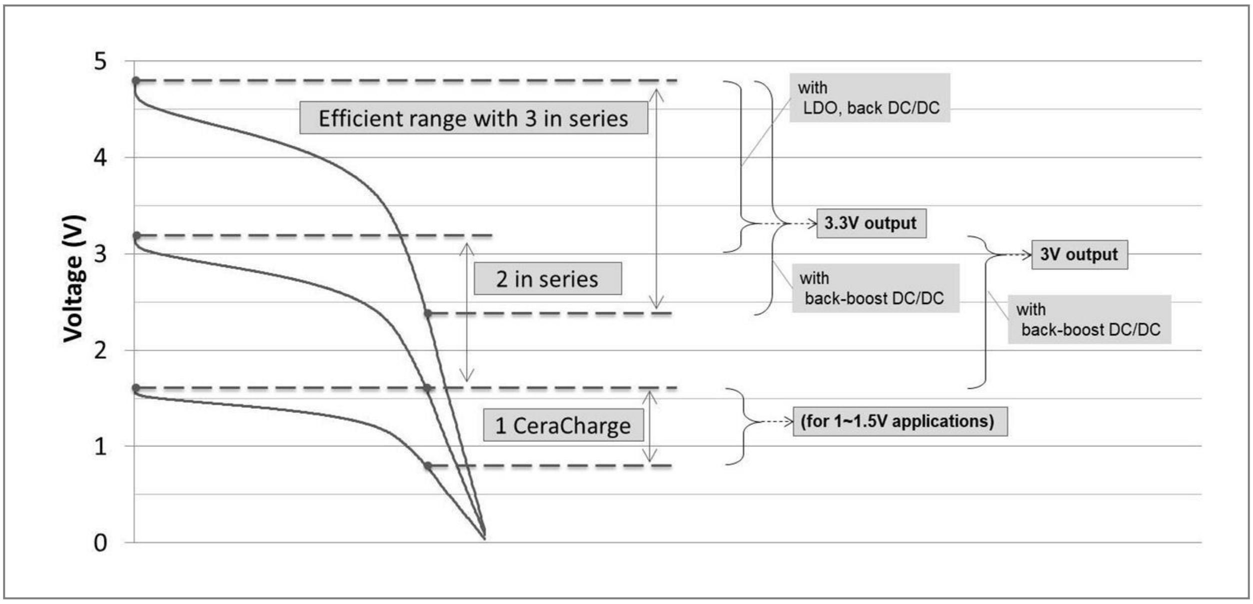


Figure 10
Efficient voltage range of CeraCharge and output example

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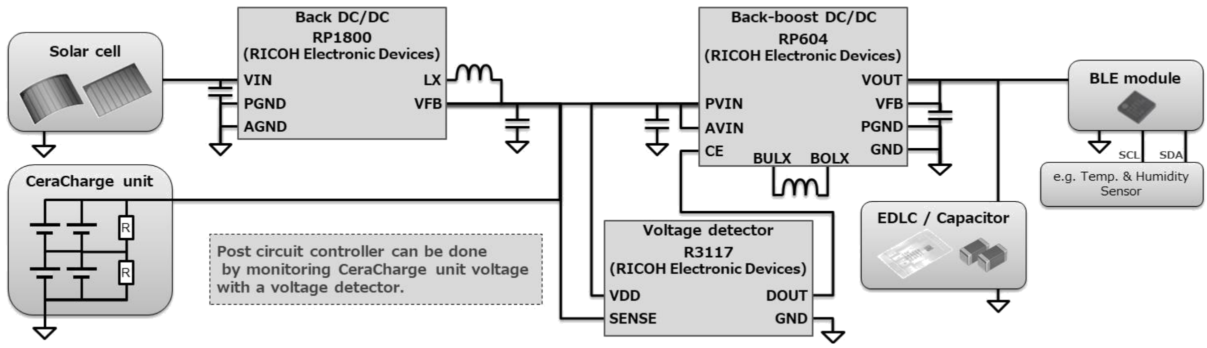

Figure 11
Block diagram of “3V output with back-boost DC/DC from 2 in series CeraCharge”

4. Charging source

1) From system power

In applications which has a power supply for normal operation like RTC-ICs, CeraCharge can be connected in parallel line with power supply and CeraCharge will start discharging to load when the power supply is shut off. It is necessary to consider the voltage range of the power supply and CeraCharge.

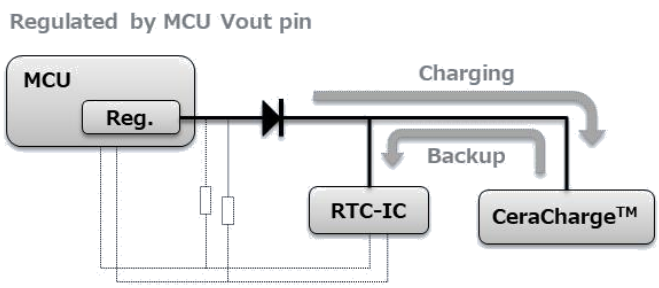

Figure 12
RTC backup circuit with parallel connecting on system power line

2) By energy harvesting

In a case to generate a power with solar cell or piezo or thermoelectric elements as energy harvesting devices in an environment where a generating power is not stable, it is recommended to stabilize the charging power with voltage regulators or Power management ICs.

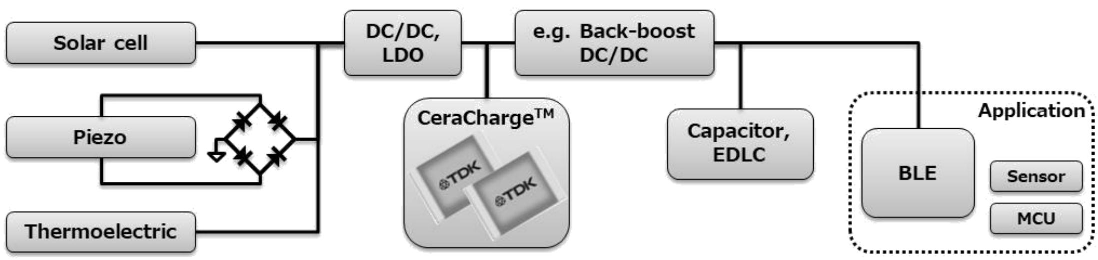

Figure 13
Energy harvesting RF device with PMIC (Power Management IC) control circuit

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3) With others, e.g. from WPT (“Wireless Power transfer”)

CeraCharge can be charged with a power from a wireless power supply coil like Qi, NFC…
These power should be rectified to DC power by a rectifier circuit (e.g. with diodes and capacitors).

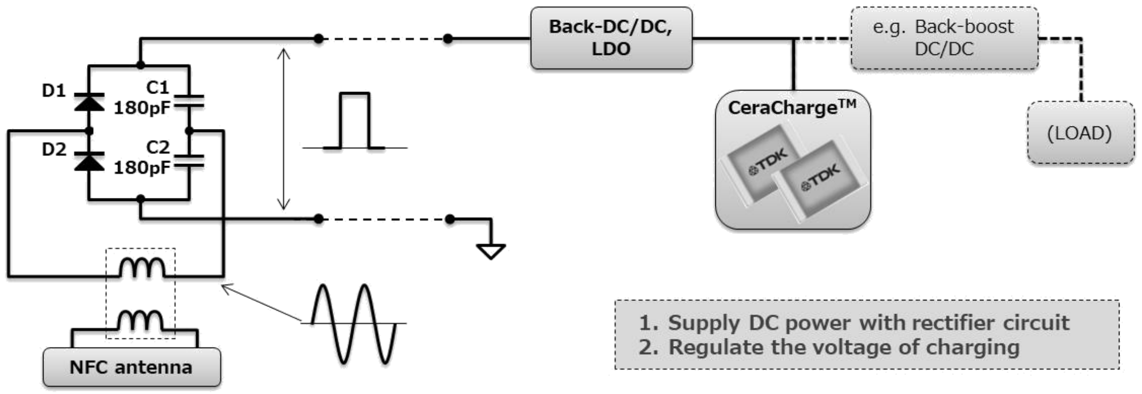

Figure 14
Rectifier circuit example for charging from NFC power

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8. The trade names EPCOS, CeraCharge, CeraDiode, CeraLink, CeraPad, CeraPlas, CSMP, CTVS, DeltaCap, DigiSiMic, ExoCore, FilterCap, FormFit, LeaXield, MiniBlue, MiniCell, MKD, MKK, MotorCap, PCC, PhaseCap, PhaseCube, PhaseMod, PhiCap, PowerHap, PQSine, PQvar, SIFERRIT, SIFI, SIKOREL, SilverCap, SIMDAD, SiMic, SIMID, SineFormer, SIOV, ThermoFuse, WindCap are **trademarks registered or pending** in Europe and in other countries. Further information will be found on the Internet at www.tdk-electronics.tdk.com/trademarks.

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