Atsuko Hoffman
Field Application Engineer
KEMET Electronics

# Supercapacitor Leakage Current and Self Discharge Characteristics

## Introduction:

Supercapacitor is widely used for RTC backup application to provide power to RTC circuit in electronics when the power source to the system is disconnected. Self-discharge characteristics is one of the important characteristics to determine the backup time. Self-discharge current is often confused with leakage current characteristic. In this application note, difference between leakage current and self-discharge characteristic is explained and importance of self-discharge characteristic in backup application is explained.

## Absorption Current and Leakage Current:

The supercapacitor has a high internal resistance, and a small current is needed to keep the charge on the supercapacitor. Leakage current is a charge current measured from the pin-to-pin voltage across a charge resistor when the supercapacitor is charged for many hours and while the supercapacitor is on charge. Figure 1 shows measurement circuit of leakage current. When the supercapacitor is charged, there is stable parasitic current. Supercapacitor is charged by ion absorption and desorption, and the parasitic current at beginning of charge is high as ions are trying to reach deep inside of fine pores of activated carbon. This initial current is called “absorption current”. This charge current decreases as the time goes by, and it becomes stable over time. Long time stable current is called “Leakage Current”.

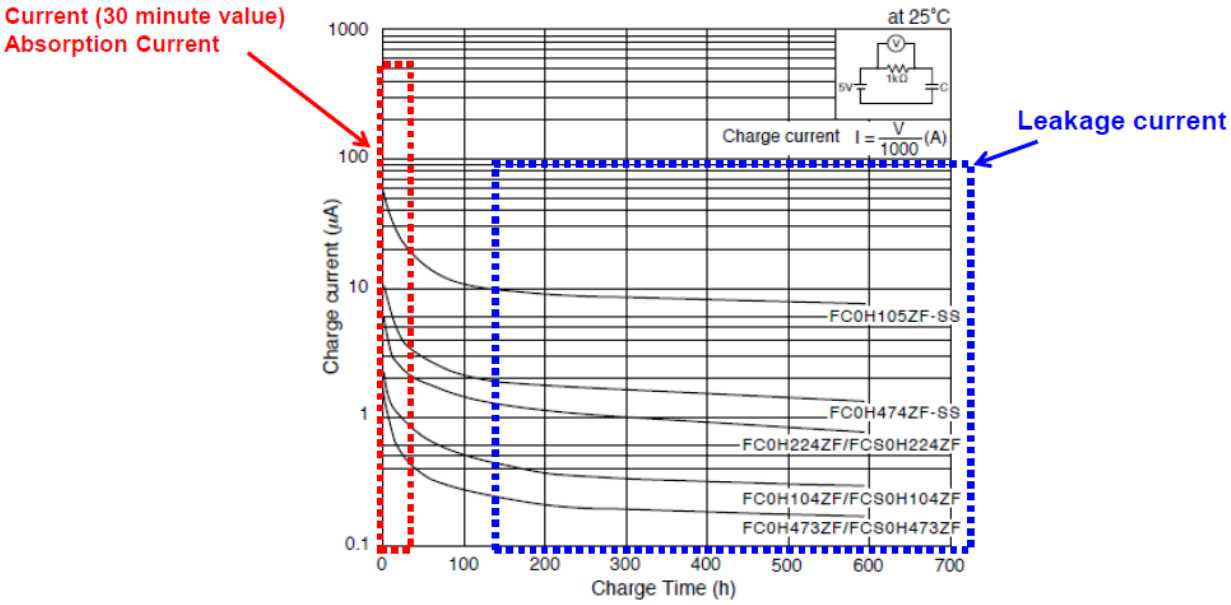


Figure 1) Leakage current characteristics at room temperature and measurement circuit

There is temperature dependency on leakage current. Higher the temperature, the higher the absorption current and leakage current are as shown in Figure 2.

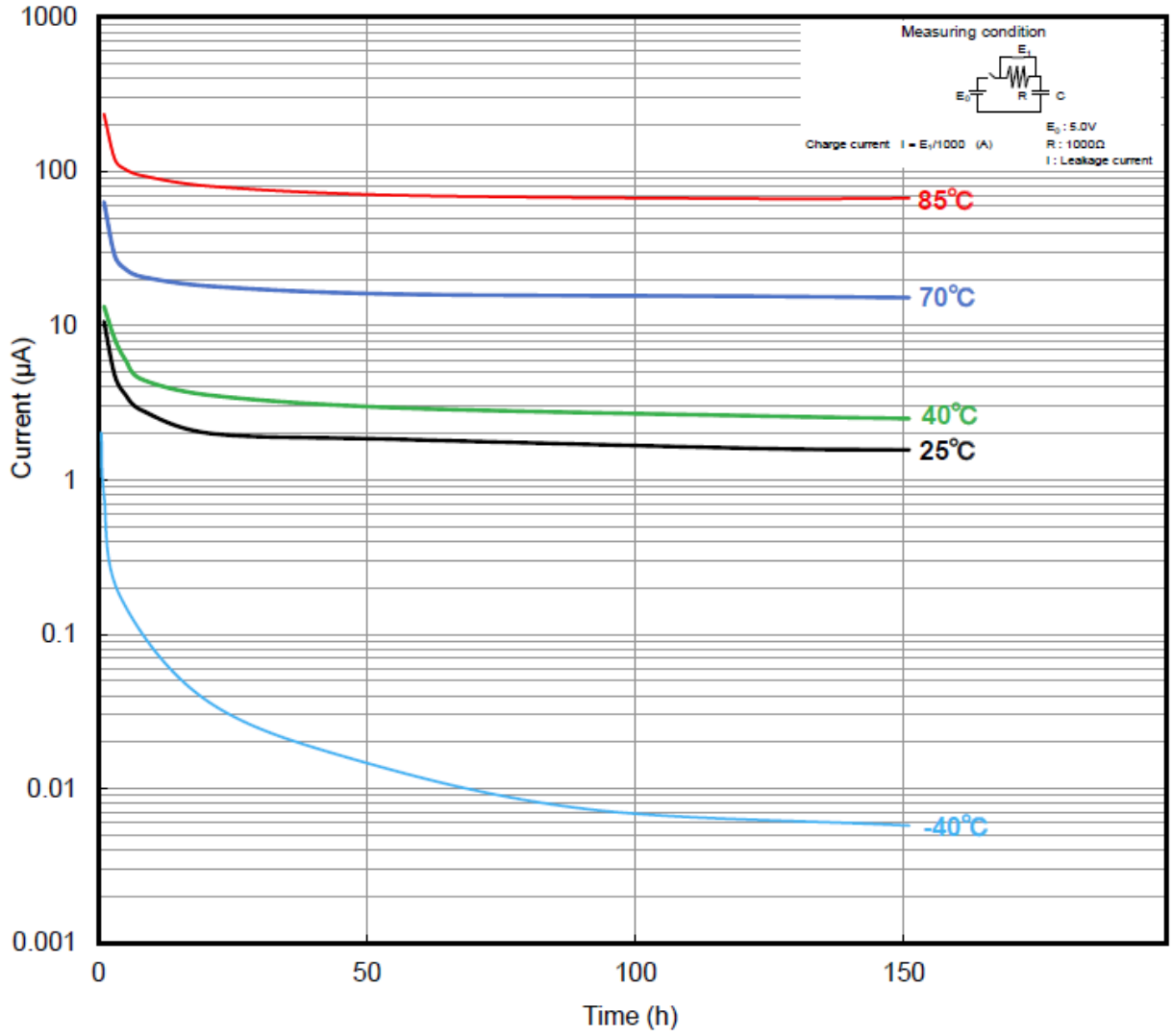


Figure 2) Leakage current characteristics of the FC0H224ZF at different temperatures

**Self-Discharge Characteristic:**

When the main charging source is disconnected from the supercapacitor, the supercapacitor starts losing its charge because of its high internal resistance. This is called Self-discharge characteristic. It is a voltage drop in charged capacitor after a period with no load condition. The voltage drop is measured after the supercapacitor is charged at 5V through a charge resistor=0 ohm for 24 hours and the charging source is disconnected, and pins are open for 24 hours. Figure 3 shows self-discharge curve for the FC series. There is a temperature dependency on self-discharge characteristics as in Figure 4.

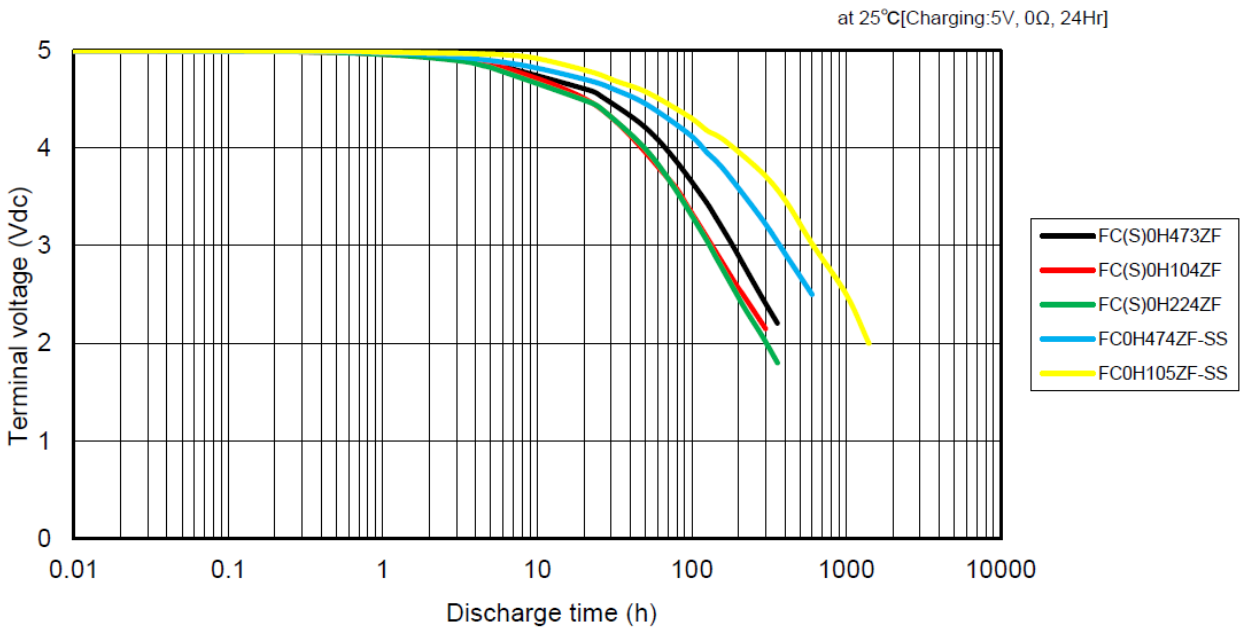


Figure 3) Self-discharge characteristics of the FC series supercapacitor

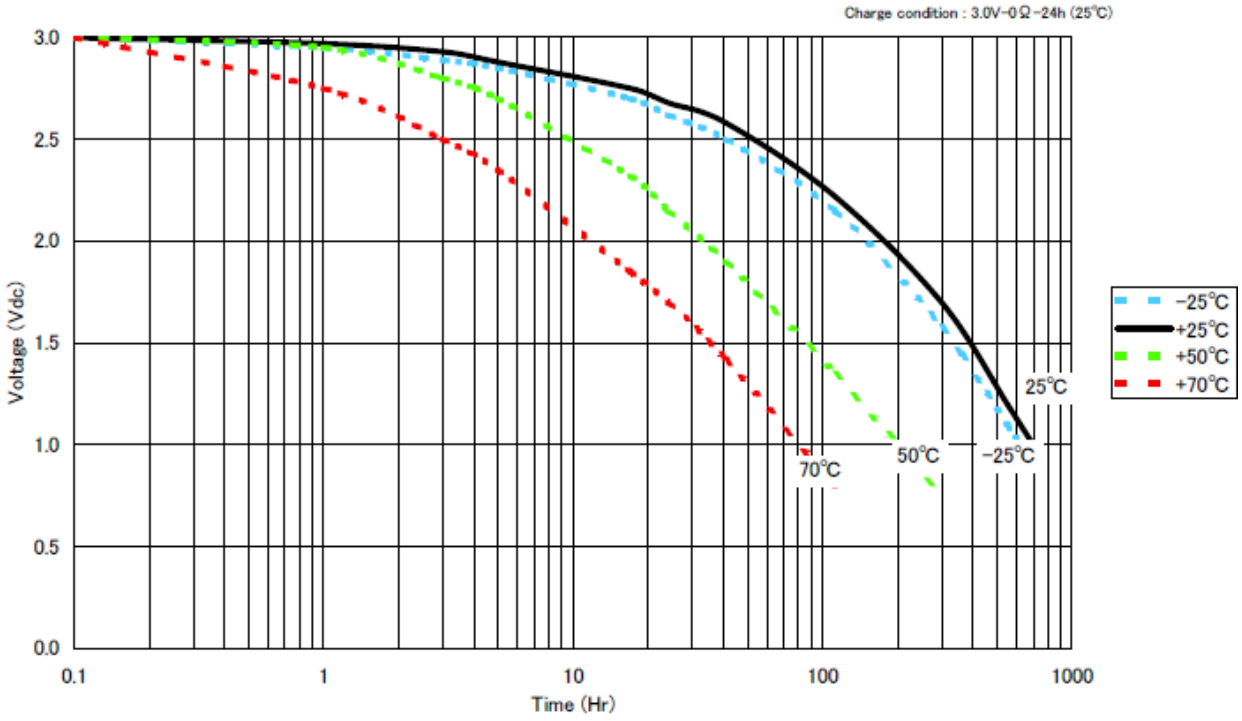


Figure 4) Self-discharge characteristics of the FC0V474ZF supercapacitor at different temperatures

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In RTC backup application where the supercapacitor provides power to the RTC circuit in case of main power source disruption, self-discharge characteristic has impact on backup time and needs to be taken in consideration to provide sufficient backup time.

**Calculating Backup Time:**

Example application: RTC backup using supercapacitor FC0H105ZFTBR44-SS. Charge voltage is 5V, cut off voltage is 2V and current that RTC circuit consumes during power loss event is 0.5uA.

The self-discharge current can be calculated by using slope of the self-discharge characteristic curve (Figure 5).

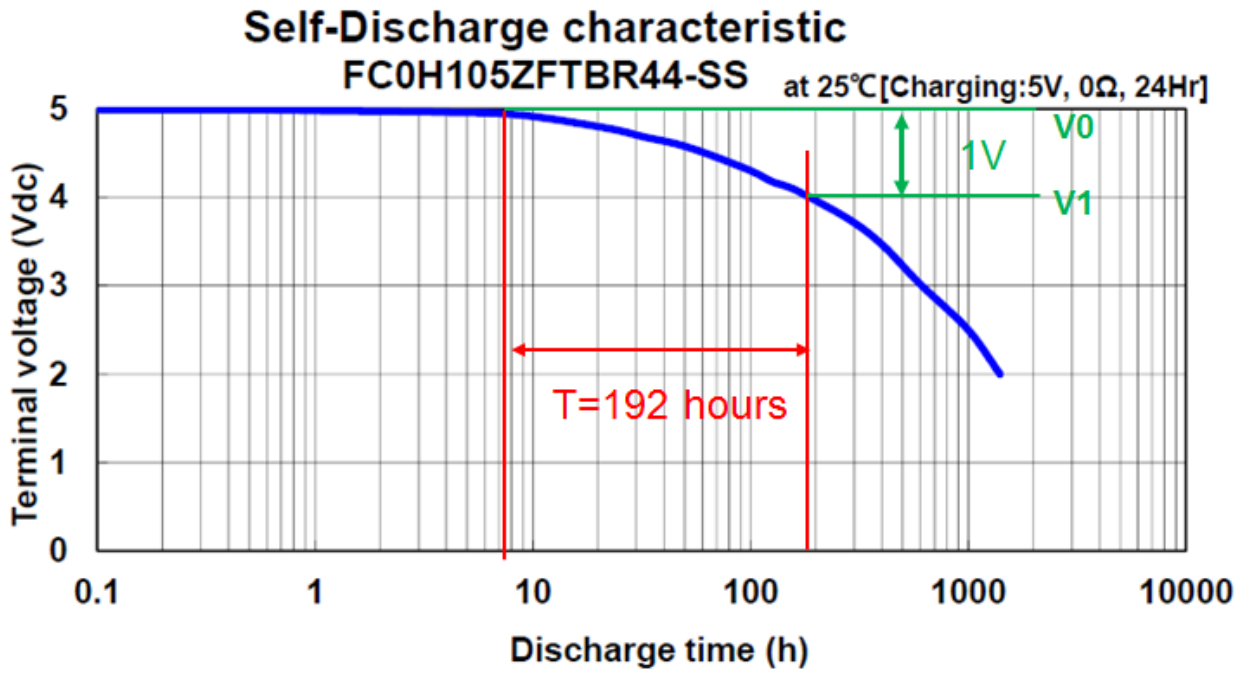


Figure 5) Self-Discharge Characteristics of the FC0H105ZFTBR44-SS

**Self-Discharge Current, $I_{SD}$ = (C x (V0 - V1 - $V_{drop}$) ) / T**
**= (1 x (5 – 4 - 0)) / (691,200) = *1.45uA***

$I_{SD}$ : Self-discharge current (A)
C: Capacitance (F), 1F for the FC0H105ZFTBR44-SS
V0: Voltage (V), 5V from Figure 5)
V1: Voltage (V), 4V from Figure 5)
$V_{drop}$: Voltage drop due to DCR (V), Negligible for the RTC backup application
T: Time (sec)

Backup time can be calculated as follows.

**Backup Time Estimation, T = (C x (V0 - V1 - Vdrop) ) / $I_{backup}$**

**= (1 x (5 – 2 – 0) ) / (0.0000005 + 0.00000145) = *427 hours***

T: Backup time (sec)
C: Capacitance (F), 1F for the FC0H105ZFTBR44-SS
$V_{max}$: Maximum chargeable voltage (V), 5V
$V_{min}$: Minimum required voltage for a backup circuit (V), 2V
Vdrop: Voltage drop by DCR (V), negligible for RTC backup application
$I_{backup}$: Backup current needed (A), 0.5uA + Self discharge current, $I_{SD}$

**Summary:**

Leakage current is a charge maintaining current while the supercapacitor is on charge. In order to calculate required backup time over system operating temperature range, designers need to take a look at self-discharge characteristic of the supercapacitor and its temperature dependency.