Lithium Ion Capacitors from Taiyo Yuden

for Data Storage Equipments

What is Lithium Ion Capacitor

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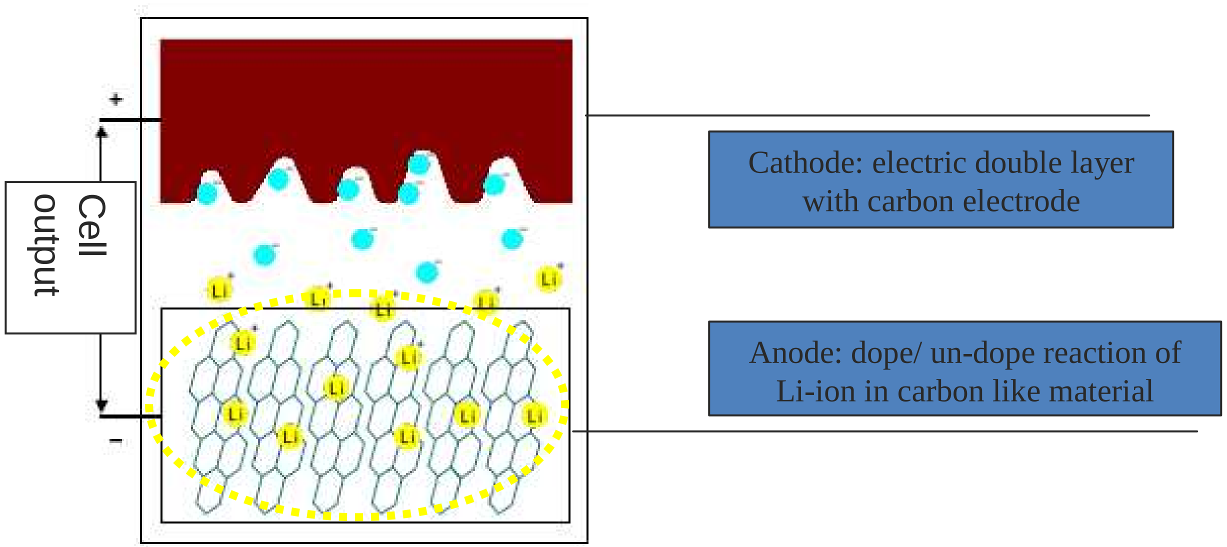
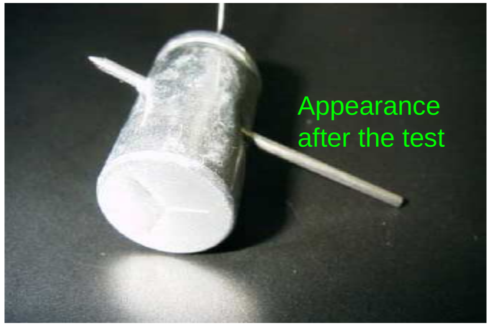
Lithium Ion Capacitors (LIC) are a new energy devices which featured both EDLC and Li-ion batteries. These electrodes are non-symmetrical using principle of Electric Double Layer and carbon electrode with lithium doped in anode (-). The cathode works physically as EDLC and the anode works by dope and un-dope reaction of lithium in carbon. This technology makes energy capacity much higher than conventional EDLC.
(*EDLC: Electric Double Layer Capacitor)

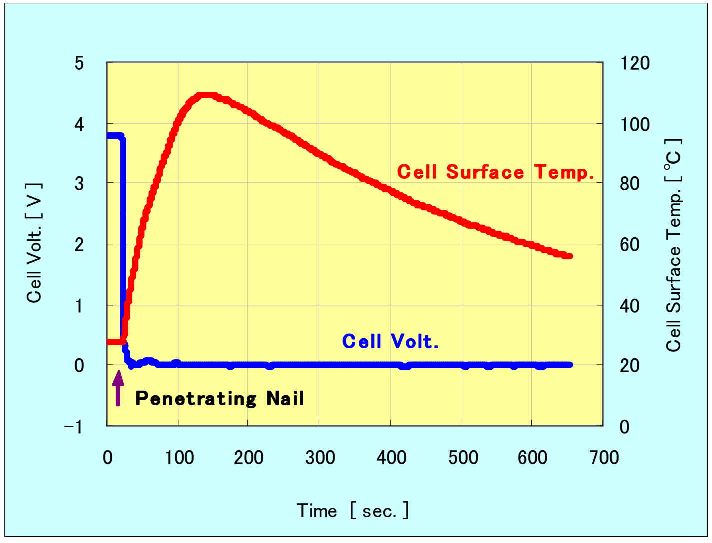


Lithium Ion Capacitor Safety Feature

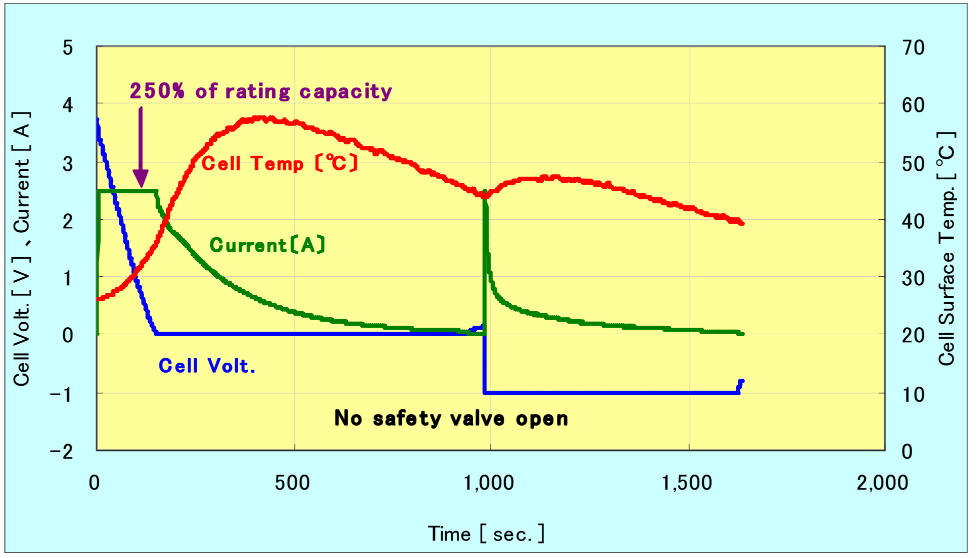
Nail penetration test



No pressure valve open and No swell



Over discharge test at 50C current density



Lithium Ion Capacitor doesn't include oxygen or oxide therefore no thermal runaway by chemical reaction. Thermal heating is only by electrical charge and it will be loosed away by time. No possibility to fire or explosion.

Features of Lithium Ion Capacitors

- Very low self-discharge
- Low thermal-runaway effect compared with Li-ion battery
- Good performance at high temperature better than EDLC
- High current density, long life-time as same as EDLC

Item	Diameter		Working voltage		Capacitance Capacity		ESR (@1k HZ)	High Temp. Float Charging Characteristics			Operating Temp. Range	Extended Operating Temp. Range (*1)
	φ mm	L mm	Max. V	Min. V	F	mAh	(typ) Ω	Time h	Capacity Change %	ESR Change %	℃	℃
LIC1235R 3R8406	12.5φ	35	3.8	2.2	40	17.77	0.15	1000	＞70	＜200	−25 to +70	−25 to +85
LIC1840R 3R8107	18φ	40	3.8	2.2	100	44.44	0.1	1000	＞70	＜200	−25 to +70	−25 to +85
LIC2540R 3R8207	25φ	40	3.8	2.2	200	88.88	0.05	1000	＞70	＜200	−25 to +70	−25 to +85
LIC2540R 3R8277	25φ	40	3.8	2.2	270	120	0.05	1000	＞70	＜200	−25 to +60	-

(*1) Max. working voltage : 3.5V

Merit of LIC

compared to general EDLC(1)

~ Back Up Time and Mount Area~

Example - High Power Back Up for a Raid controller, CPU and etc

- 31W constant power discharge
- Space saving against EDLC

31W constant power discharge time

Simulation condition (LIC 100F 3series & 3 parallel connection)

- CV charge = 30sec
- Ambient temperature : 40℃
- Discharge power : 31W
- Discharge voltage : 10.18V – 6.8V
- long time degradation of capacitance and DC-R were estimated form 3.5V and 3.8V high temperature floating characteristics data (showed page 9). In this time. DC-R is estimated from DC-R actual value.
- Capacitance and DC-R degradation of charge / discharge cycle is considered based on one cycle per day.
- Initial capacitance value Typ.= 100F/Min. = 90F、Initial DC−R value Typ. = 91mΩ/Max = 150mΩ

▪Setup constant number for Simulation

	BIggining of usage		1year later		2 yeas later		3 years later		4 years later		5.5years later		6years later		7years later		8years later		9years later		10yeas later	
	Typ.	Worst	Typ.	Worst	Typ.	Worst	Typ.	Worst	Typ.	Worst	Typ.	Worst	Typ.	Worst	Typ.	Worst	Typ.	Worst	Typ.	Worst	Typ.	Worst
Capacitance(F)	65.2	58.7	61.3	55.2	58.3	52.5	55.8	50.2	53.9	48.6	52.4	47.2	51.9	46.7	51.1	46.0	50.1	45.1	49.1	44.2	48.5	43.7
DC-R(mΩ)	69.3	114.2	73.1	120.5	75.2	124.0	75.8	124.8	76.1	125.3	77.0	126.9	77.2	127.3	77.8	128.2	78.3	129.0	78.7	129.7	78.9	130.1

▪Back up time simulation result

	Initial	1year	2years	3years	4years	5.5years	6years	7years	8years	9years	10years
Typ Value	53.8	50.3	47.7	45.6	44.0	42.7	42.2	41.6	40.7	39.9	39.4
Worst Value	44.8	41.7	39.4	37.6	36.4	35.2	34.8	34.3	33.5	32.8	32.4

Unit : sec

Space sever against EDLC

LIC 3.8V 100F ϕ18 x 40mm 3series & 3 parallel connection

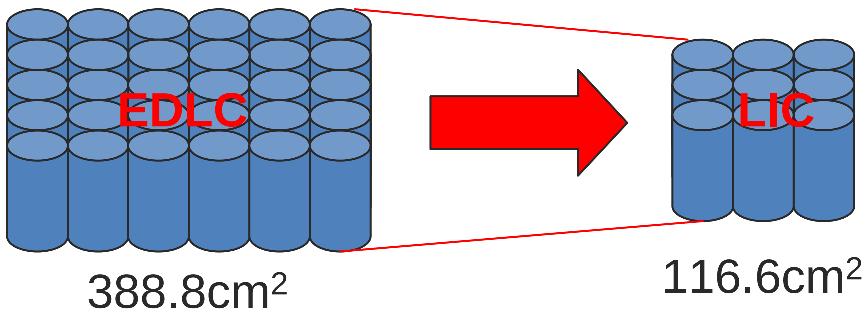
Energy calculation : $\frac{1}{2}CV^2 = \frac{1}{2}(3.4V^2 - 2.2V^2) =$ 336.5J

336.5J x 9pcs = 3334.5J

Competitor A 2.7V 60F ϕ18 x 40mm

Energy calculation : ½ CV2 = $\frac{1}{2}(2V^2 - 0.5V^2) =$ 112.5J

To meet LIC energy : 3334.5J / 112.5J = 30pcs

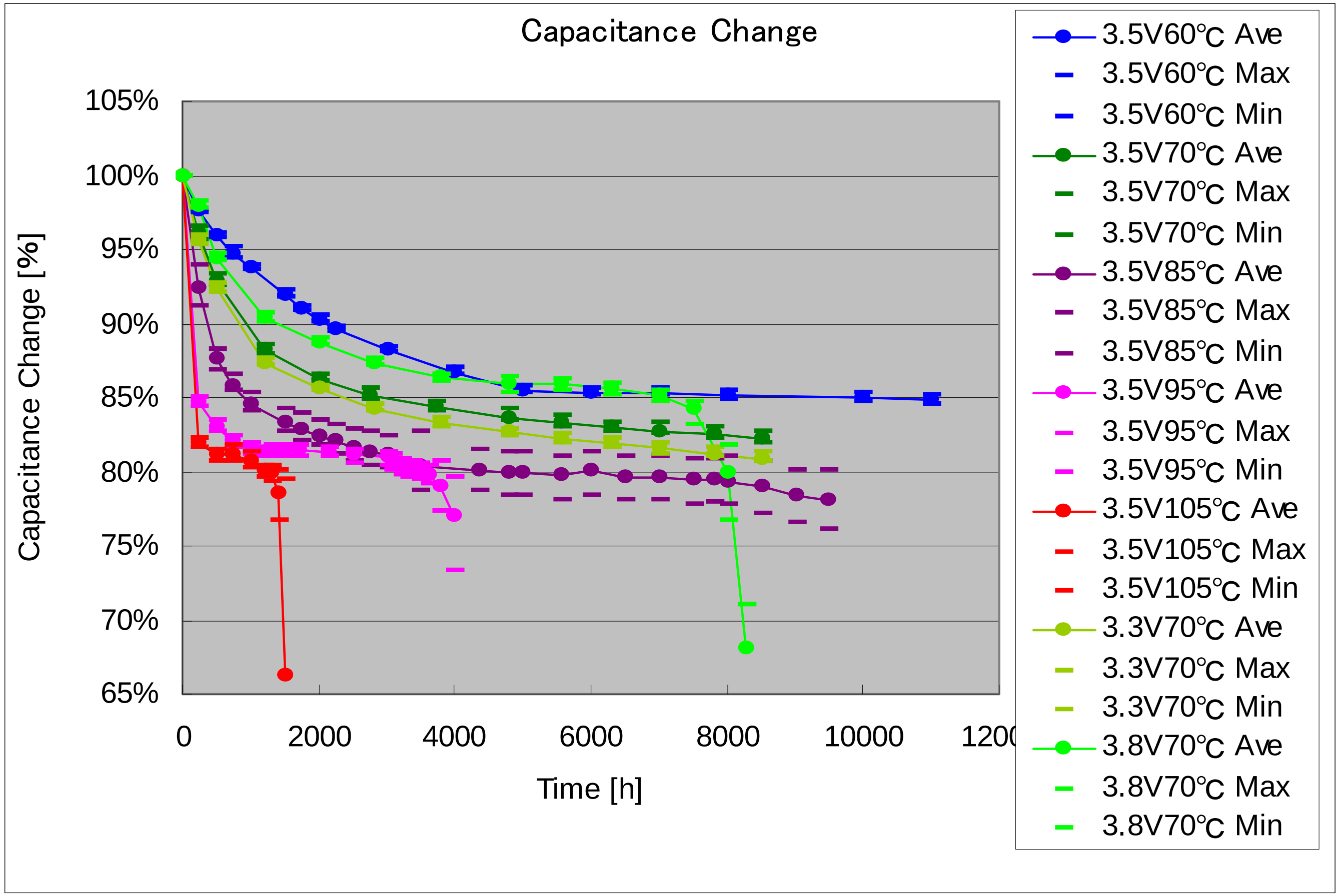


Over 3times smaller mounting space requirement!

*For easy understanding, voltage set 3.5V/LIC cell and 2V / EDLC cell
(EDLC 2V usage is common voltage for extending life time)

Estimation method of life time for LIC

Raw data of High Temperature loading test

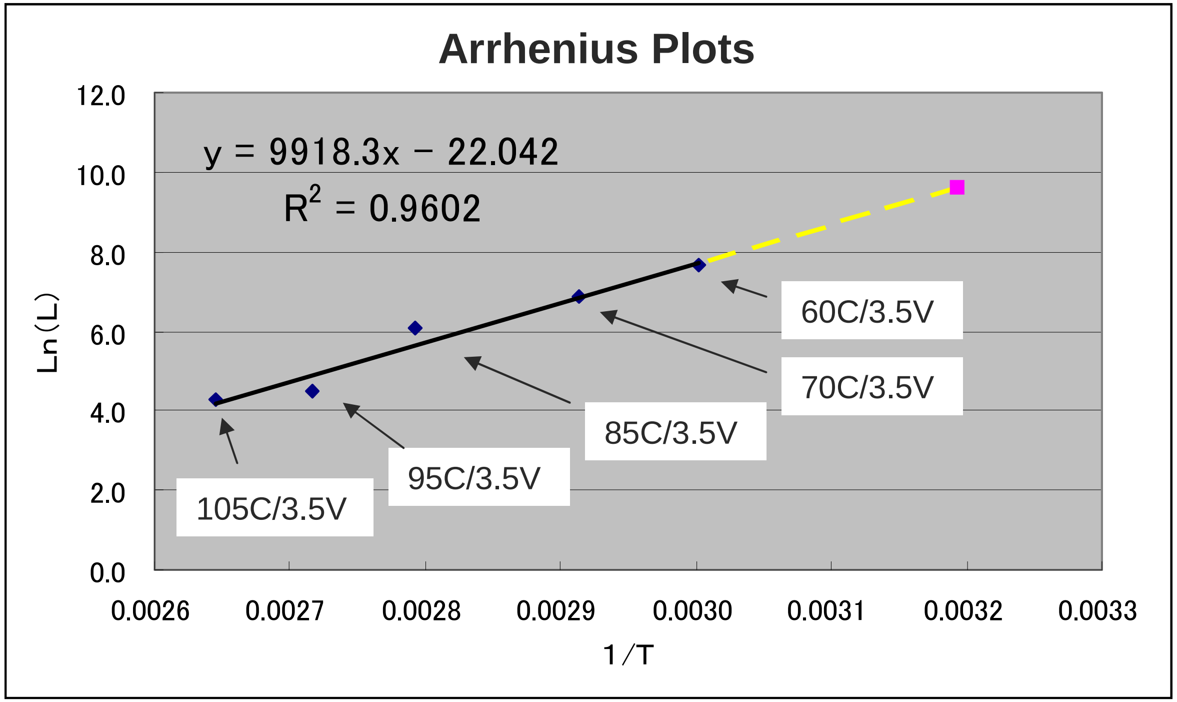


Life acceleration rate is defined at arbitrary temperature and voltage if voltage acceleration factor “m” and temperature acceleration factor “ θ ” in the following formula are calculated.

Life formula

$$L = \left(\frac{V0}{V1}\right)^{m} \times 2^{\frac{T0-T1}{\Theta}} \times L0$$

Temperature acceleration factor “ θ ”



＊Arrhenius plots are made from median value of ”Failure time" at each tests

It is evaluated that all plots are on approx. line area.
= It is confirmed that acceleration test is worked out correctly.

Calculated temperature acceleration factor for capacitance degradation at K reaction rate. Calculated defined failure point.

Calculated “K” in the common formula which is used for capacitor life estimation.

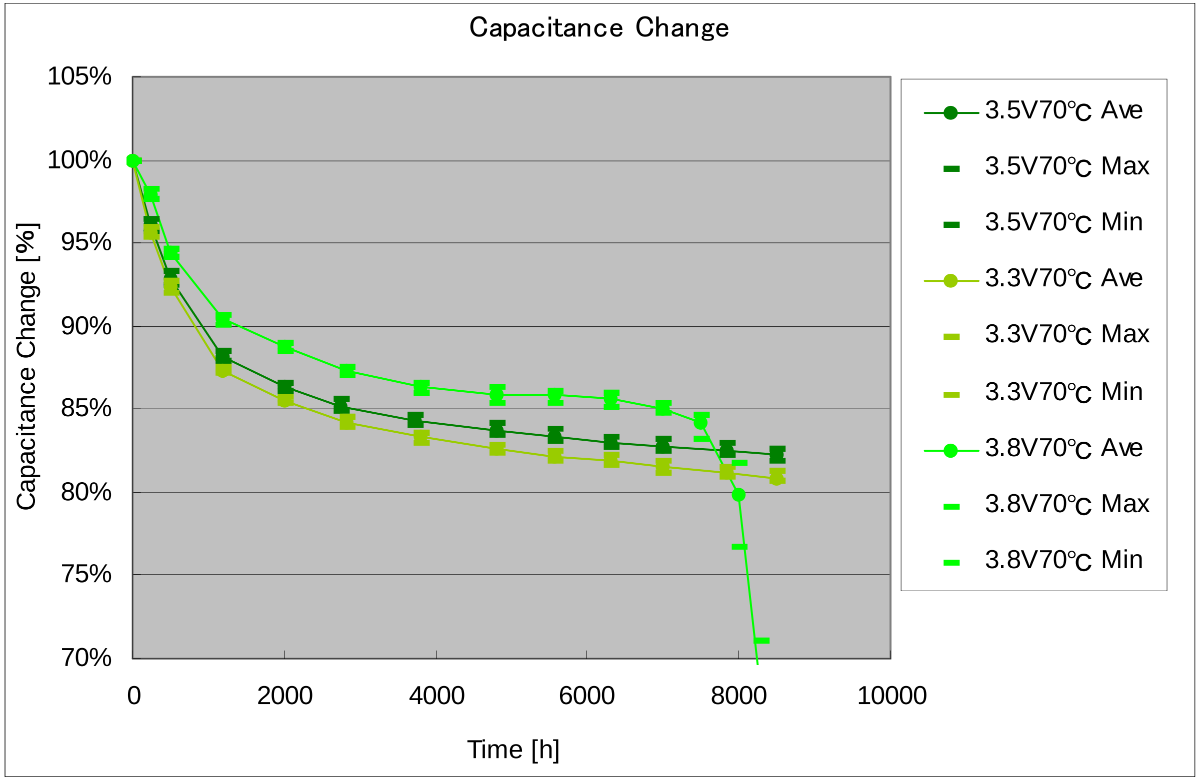
$$\frac{L2}{L1} = 2^{\frac{T1-T2}{k}}$$

Following chart is obtained from the relation formula of life and temperature in previous page.

Life Time L (Hours)	Life Time (Years)	Ln(L)	1/T	T	Celsius C	ΔC
32000	3.65	10.373	0.00327	305.974	32.824	
64000	7.31	11.067	0.00334	299.568	26.418	6.406

Temperature acceleration factor “k” is estimated to “k＝6.4” from above chart.

Voltage acceleration factor "m"



Regarding the voltage acceleration, acceleration of degradation by voltage has not been found yet therefore both capacitance and DC-R is recommended to design at voltage acceleration factor = 1 at the moment.

Life acceleration calculation formula

Life formula

$$L = \left(\frac{V0}{V1}\right)^{m} \times 2^{\frac{T0-T1}{\Theta}} \times L0$$

L ： Estimated life（h）
L0： Actual life data
V0： Rating voltage（V)
V1： Usable voltage (V)
T0： Maximum usable temperature（℃）
T1： Usable temperature（℃）
Θ： Temperature accelerating factor
m： Voltage accelerating factor

Recommended life acceleration factor “m” and “ θ ” in the life acceleration formula from the examination.

$m=1$

$\theta=6.4$

Estimation of life time of LIC

1) Estimation of life time under 3.5V/50C

Temperature life acceleration ＝2^((95-50)/6.4)= 130

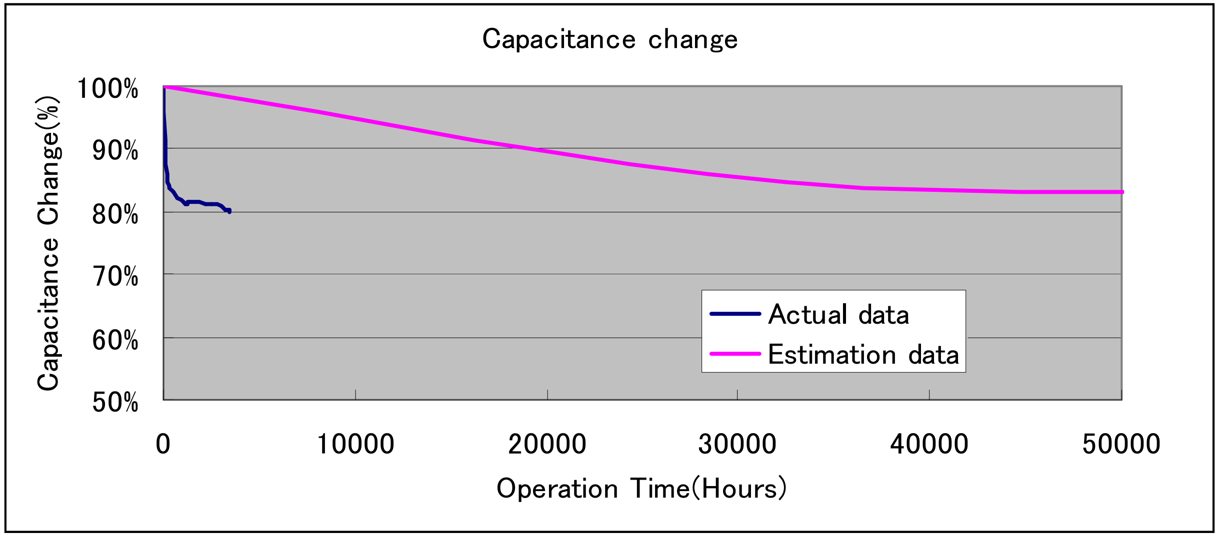
Actual measured data under 3.5V/95C

Test Duration (Hours)	0	250	500	750	1000	1200	1300	1400	1500	1700	2153	2500	3000	3100	3218	3334	3400	3491
Capacitance Change	100.0%	84.7%	83.0%	82.1%	81.6%	81.4%	81.4%	81.4%	81.4%	81.4%	81.3%	81.1%	80.9%	80.7%	80.4%	80.2%	80.2%	80.1%

X 130   X 130

Estimation data under 3.5V/50C

Test Duration (Hours)	0	32500	65000	97500	130000	156000	169000	182000	195000	221000	279890	325000	390000	403000	418340	433420	442000	453830
Capacitance Change	100.0%	84.7%	83.0%	82.1%	81.6%	81.4%	81.4%	81.4%	81.4%	81.4%	81.3%	81.1%	80.9%	80.7%	80.4%	80.2%	80.2%	80.1%



Estimation of life time of LIC

2) Estimation of life time under 3.5V/70C

Temperature life acceleration ＝2^((95-70)/6.4)= 15

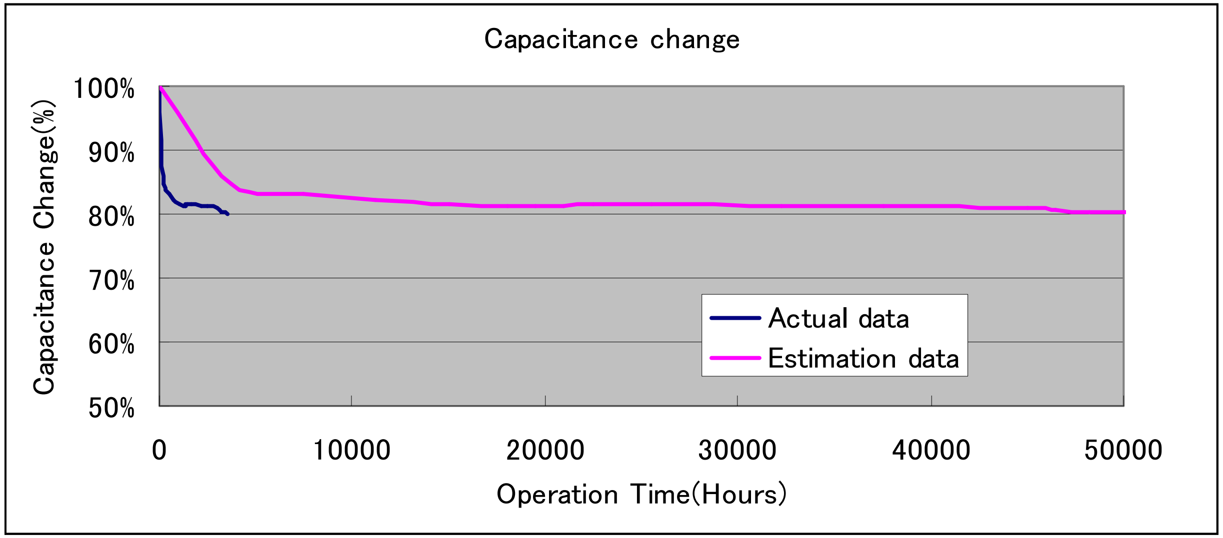
Actual measured data under 3.5V/95C

Test Duration (Hours)	0	250	500	750	1000	1200	1300	1400	1500	1700	2153	2500	3000	3100	3218	3334	3400	3491
Capacitance Change	100.0%	84.7%	83.0%	82.1%	81.6%	81.4%	81.4%	81.4%	81.4%	81.4%	81.3%	81.1%	80.9%	80.7%	80.4%	80.2%	80.2%	80.1%

X 15 X 15

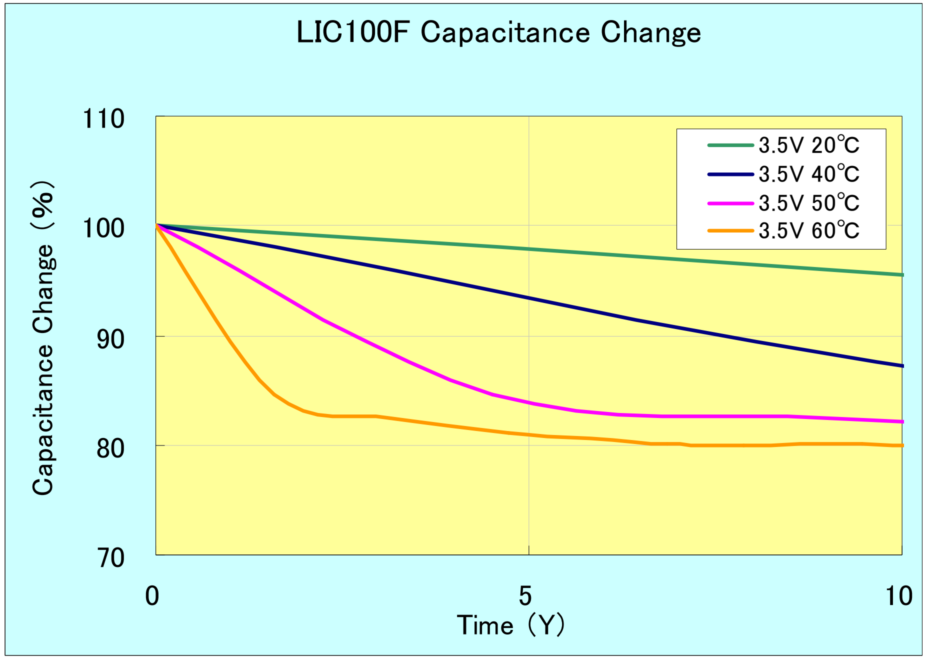
Estimation data under 3.5V/70C

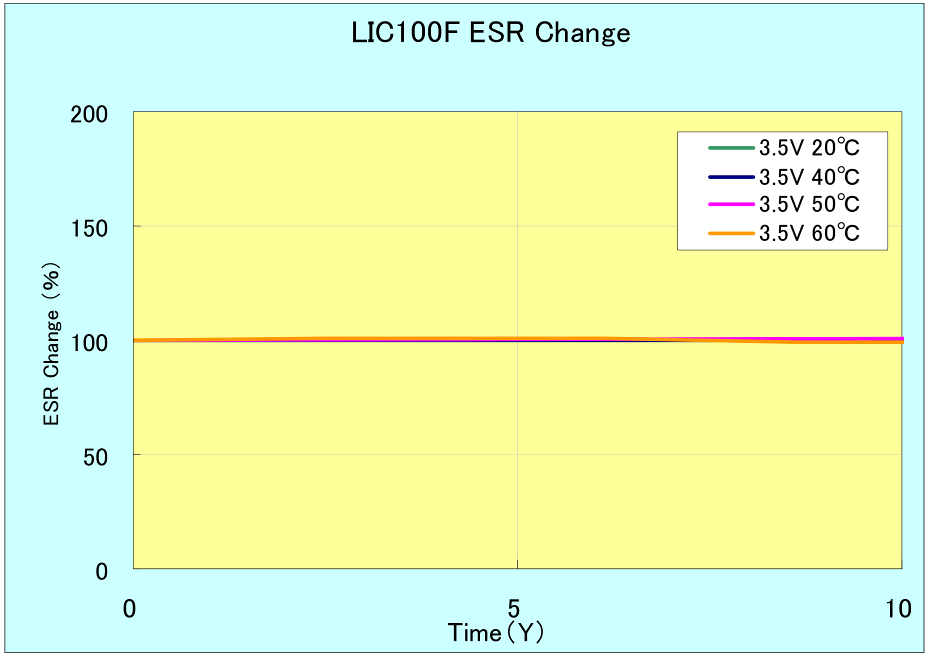
Test Duration (Hours)	0	3750	7500	11250	15000	18000	19500	21000	22500	25500	32295	37500	45000	46500	48270	50010	51000	52365
Capacitance Change	100.0%	84.7%	83.0%	82.1%	81.6%	81.4%	81.4%	81.4%	81.4%	81.4%	81.3%	81.1%	80.9%	80.7%	80.4%	80.2%	80.2%	80.1%



We continue our life test to get more accurate data.

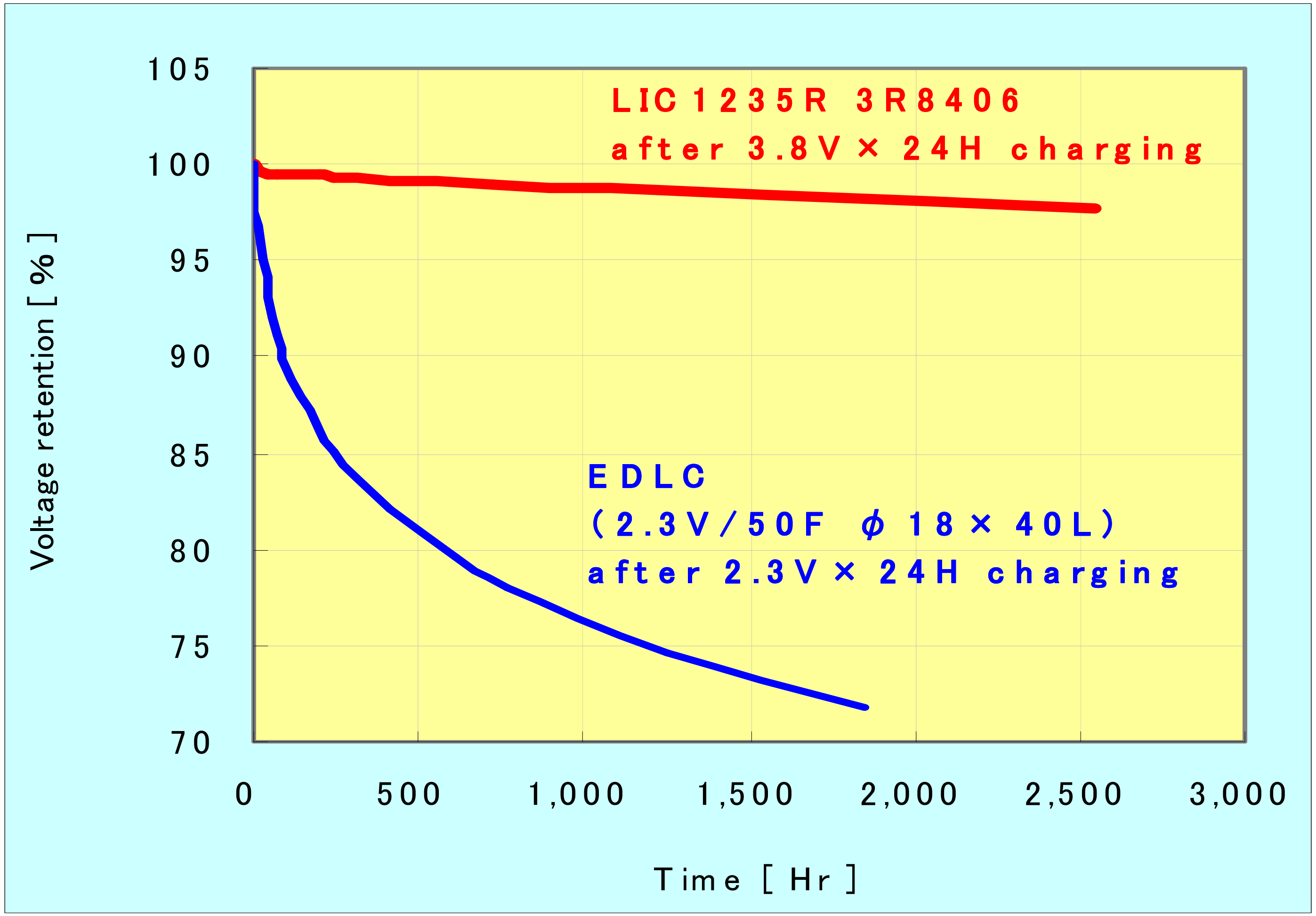
Estimation of life time of LIC100F





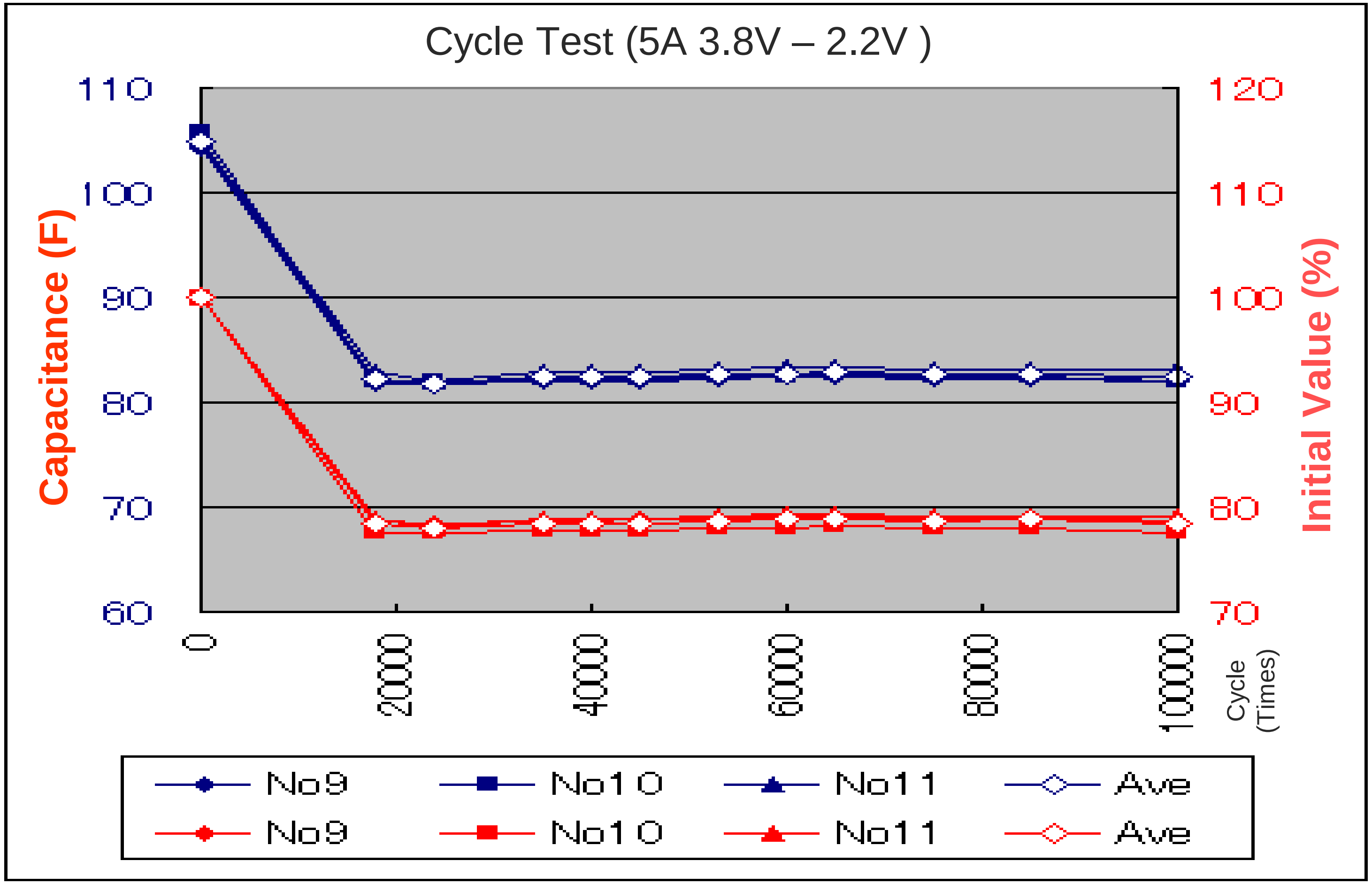
Self Discharge Characteristics

Self Discharge Characteristics



Cycle Test

Cycle Test (Reference)



Capacitance degradation is significantly until 20,000hrs but over 20,000 times, degradation is stable.