



Lithium Batteries for Automotive



Automotive















eCall is the automatic emergency call system in Europe. Often, during a car accident, the car battery loses its function and a back-up battery is required to keep the system operating. **Tadiran Lithium Metal Oxide batteries** are suited for this application because they provide high power in a very wide temperature range.

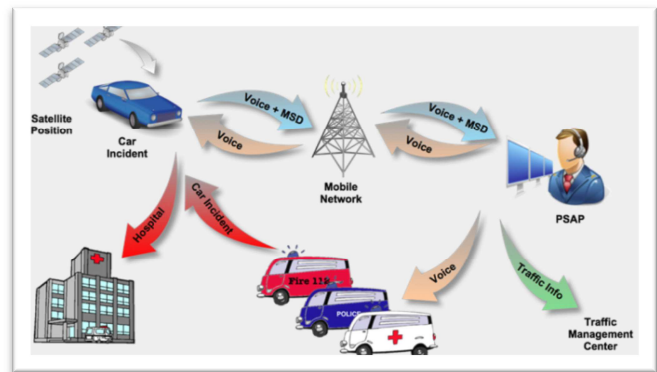
Telematic units in high end cars besides the eCall function also serve for stolen vehicle recovery. In these cases **Tadiran's TLI-battery** provides the additional capacity required, even after years of stand-by.

Tadiran's LTC-batteries are being used for tire pressure monitoring systems. Due to their outstanding temperature stability, they are even used in formula 1 racing car tires where they provide reliable power for the transmission of pressure and temperature data.





Reliability is the keyword for the application in airbag systems. Where other electrical power is not available, **Tadiran's lithium batteries** fire the gas generator inflating the airbag.

Automotive related application

-  Air bags
-  Automatic collision devices
-  Belt tensioners
-  Brake controllers
-  Communication systems
-  Digital tachographs
-  Doors / latches
-  Electronic toll tags
-  Engine controllers
-  GPS mobile asset tracking systems
-  In-car computers
-  Stolen vehicle recovery systems
-  Telematics / eCall
-  Tire pressure monitoring systems



Key:

-  Lithium Thionyl Chloride (LTC) Batteries
-  PulsesPlus™ Batteries
-  Tadiran Lithium Metal Oxide (TLM) Batteries
-  Tadiran Lithium Ion (TLI) Batteries



**Saft batteries to power emergency signals
for Actia Automotive's eCall units**



- *Primary lithium batteries selected for their ability to provide reliable power after many years on standby and withstand extreme conditions*

Paris, September 26, 2013 – Saft, the world's leading designer and manufacturer of advanced technology batteries for industry, has won a contract to supply batteries to Actia, the major player in automotive electronics. The batteries will provide emergency power for Actia's ACU-II (second generation Automotive Communications Unit), a device that will be installed in new vehicles for Actia's high-end European car manufacturer customers.

The ACU-II provides services that improve the connectivity of motor vehicles, with the main application being for *eCall*, the new safety system that will be mandatory for all new European vehicles from 2015.

The EU is introducing *eCall* to reduce injury and fatalities in the event of car accidents, with *eCall* devices detecting when a car has experienced a serious accident. The device then automatically contacts the emergency services with the car's exact location, direction of travel and number of passengers. This enables the emergency services to cut their response times and save lives. As well as *eCall* functionality, the ACU-II will also provide drivers with the ability to track their car and control aspects of their vehicle through a smartphone application, for example locking or unlocking doors, or turning on the heater.

The batteries selected will power the ACU-II in emergency situations and have been specially designed to cope with this demanding automotive application.

Although most vehicles do not experience a serious accident, for those that do, the ACU-II units need to perform with unquestionable reliability, meaning the batteries need to remain on standby and hold their charge for many years before powering the emergency signal with absolute reliability in an emergency.

The cells selected for this application are lithium chemistry with the capability to store energy for more than 10 years in driving conditions that might include extreme heat and cold as well as mechanical shocks before providing reliable energy when it is needed.

"Many thousands of drivers and passengers will benefit from the ability of Saft's lithium metal oxide batteries to hold a charge for many years." said Ralf Sauer, European Sales and Marketing Manager for Saft's Tadiran brand. *"The Saft group's AA sized batteries have a long shelf life, very low rate self discharge and a wide operating temperature range, making them ideal for providing reliable emergency power for in-vehicle electronic systems."*

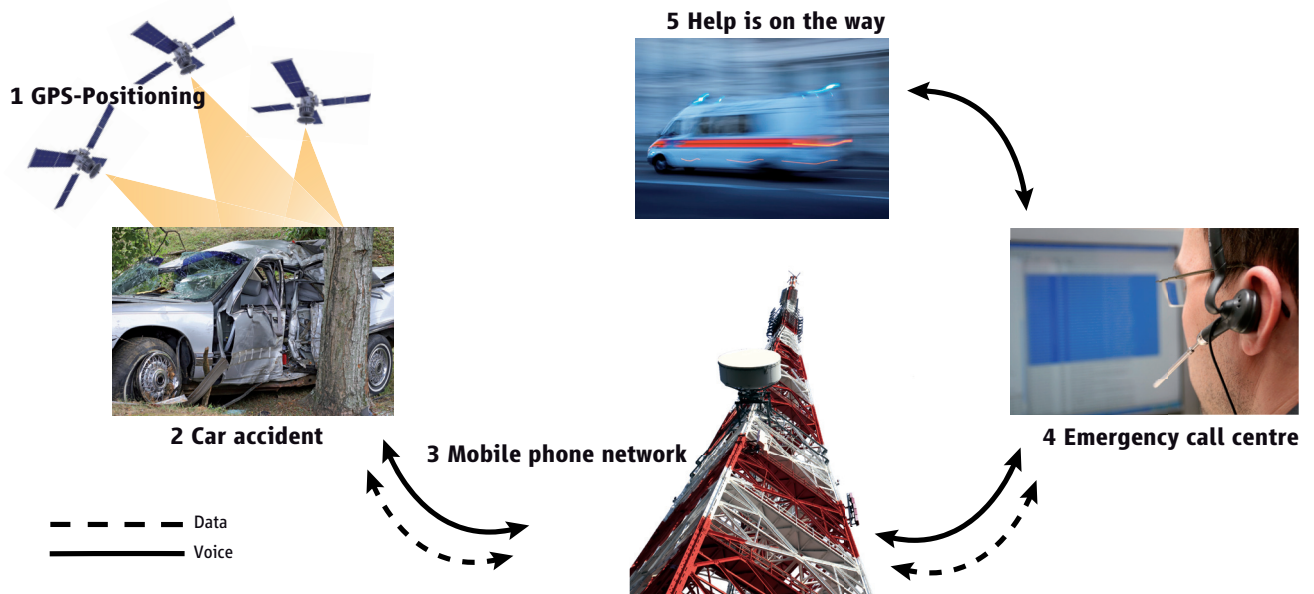
High-power battery for back-up of telematic systems in cars

by Dr. Thomas Dittrich, Tadiran Batteries GmbH

When it comes to batteries in cars, people usually refer to the SLI battery. Since fuel is getting more and more expensive, some already think of the traction battery in electric vehicles. An application that becomes necessary because the electronics in the car are getting more and more demanding is somewhat more special: A back-up battery for the entire electronic system, preventing its failure when certain power-consumers are activated.

All of this will not really help much when the automatic emergency call system eCall becomes mandatory in the first new cars in 2015. In about 15 to 25 per cent of all emergency call situations, after an accident, the vehicle battery or its supply line are no longer functional. An emergency battery in the telematics unit is required. The requirements on this back-up battery are quite demanding: Power output up to 15 Watt for 10 minutes at temperatures down to -20°C , smaller than a thumb, and it must live as long as the car itself.

A battery that actually meets all of these requirements did not exist until Tadiran developed its lithium-metal oxide battery. The battery is AA cell sized and supplies pulse currents up to 15 amperes at a rated voltage of 4 Volt. This paper deals with the construction of this battery, its performance in the temperature range from -40°C to $+85^{\circ}\text{C}$, its life time, and safety testing.



The introduction of eCall, the European emergency call system for cars, has been delayed several times. At the moment, it is assumed that eCall will become mandatory for new cars in 2015. This is not certain yet. The only thing that is certain is that some car manufacturers have already developed private eCall services in Europe, starting around the turn of the millennium, according to the impact assessment¹ published in 2011. Only the services of BMW, PSA (with the brands Peugeot and

Citroën) and Volvo were still operational in 2011, while the other manufacturers had discontinued their services by 2005. The private eCall services are characterised by market prices that generally are only affordable for a limited number of users, a non-EU-wide coverage and problems in maintaining PSAP² databases. To improve this situation, the EU commission is currently planning to make eCall mandatory from 2015 onwards. [Figure 1](#) shows the functional principle of eCall.

¹ SEC(2011) 1019 final *Impact Assessment Accompanying the Commission Recommendation on support for an EU-wide eCall service in electronic communication networks for the transmission of in-vehicle emergency calls based on 112 ('eCalls')*

² PSAP = Public Safety Answering Point (Emergency Call Centre)

Model	Number of cells. size AA	Nominal capacity	Nominal voltage	Type	Typical application requirements
TLM-1550HP	1	0.55 Ah	4 V	Primary	At -20 °C after 8 years: eCall: 2.5 A pulses for 2.5 ms every 6.25 ms at 500 mA basic current (average 1.3 A) for 11 min
TLM-1550HE	1	1.0 Ah	4 V	Primary	At +20 °C after 8 years: eCall: 750 mA with peaks of 2 A for 15 min; or SVT: 600 times 500 mA for 10 s for 2 days minimum voltage 2.0 V
TLI-1550A	2	0.33 Ah	4 V	Secondary	After 5 years at -40 °C ... +90 °C: eCall: on average 5 W, peak 20 W for 15 min SVT: optional, multiple

Table 1

Available batteries by Tadiran for eCall and similar applications (example AA-size)

Back-up battery – general requirements

The failure risk of the car battery during an accident is not negligible. Therefore, all three car manufacturers that offer a private eCall system today have included a back-up or emergency battery or are planning to include it in the future. This emergency battery ensures that the eCall telematics unit will work under all circumstances. Usually "under all circumstances" means that the battery supports emergency calls even at -20 °C or -40 °C and under comparatively poor radio conditions with data and audio transmissions for 8 or 10 minutes.

The battery must provide an average current of 350 mA at current peaks of 2 A for data transmission. The usual communication modules need a minimum voltage of 3.2 to 3.4 Volts. A voltage converter can reduce the minimum voltage for the battery by half, with the current increasing accordingly so that the power ($P = U \times I$) is maintained and the converter losses are compensated. This can be very helpful for the battery. It can supply higher current when lower voltage is acceptable, especially in a cold environment. Another 500 mA are needed for audio operation.

The functional range of telematic units for cars is continuously increasing. Besides eCall, audio, video navigation and even internet services are discussed³. Simultaneously, the space available for the emergency battery decreases. Above all, the battery must be small. Despite of that, it must also be able to take over the SVT⁴ function in high end cars in addition to or replacing eCall.

Solution by Tadiran Batteries

Tadiran is perfectly prepared for this market with its TLM, TLI and TLP series. These batteries are based on the

lithium-metal oxide technology introduced by Tadiran⁵. Tadiran batteries have been used for high volume production in this market segment. Table 1 shows a list of the available models based on the AA size.

Construction and materials

The electrode materials of the Tadiran lithium-metal oxide (TLM) battery are made of lithium intercalation compounds, based on the NCA technology.

Figure 2 explains the construction based on an X-ray.

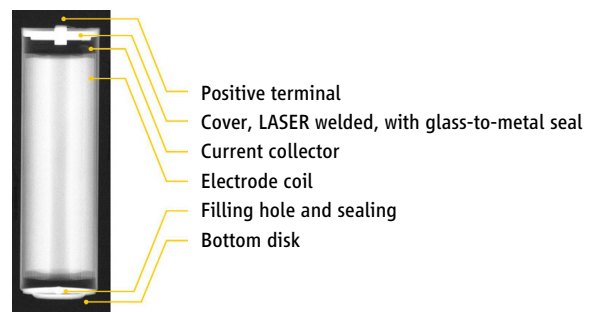


Fig. 2
X-Ray of the TLM cell

Electrical performance data

Figure 3 shows the temperature behaviour of the TLM battery. It shows 5 discharge curves at 1 A continuous current across a temperature range from -40 °C to +72 °C. At -20 °C, the battery delivers 350 mAh above 3 Volts – without any voltage drop – leaving any other battery system far behind. The curves at -30 °C and -40 °C show a slight voltage increase during

³ H. Scheitler, *3G Car Gateways, The Fully Networked Car Workshop*, Geneva, March 2009, ITU Final Report

⁴ SVT = Stolen Vehicle Tracking

⁵ H. Yamin, C. Menachem, *Tadiran High Power Cell – An Ultimate Power Source for Telematic Backup*, The 22nd International Seminar & Exhibit: March, 2005, Fort Lauderdale, Florida, USA

discharge. This increase is due to self-heating from the Ohmic power loss.

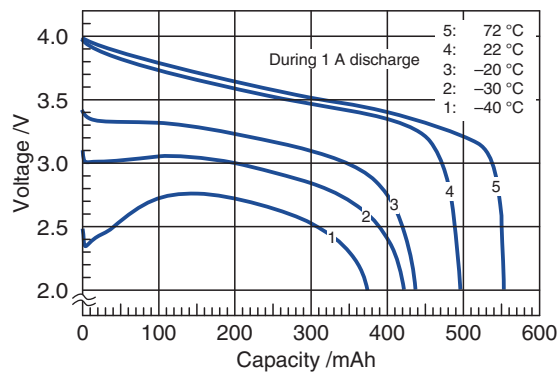


Fig. 3
Temperature behaviour TLM-1550HP (High Power version)

The High Energy Version TLM-1550HE has approximately twice the capacity and also higher current capability, see [Figure 4](#). This is achieved by optimisation of the electrode geometry and chemistry. Only in the low-temperature range below $-20\text{ }^{\circ}\text{C}$ does this version have disadvantages, which are reflected by the voltage dropping significantly before the self-heating effect occurs.

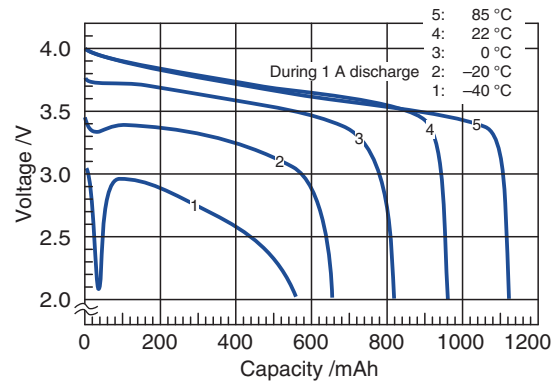


Fig. 4
Temperature behaviour TLM-1550HE (High Energy version)

TLM-1550A is a rechargeable lithium-ion battery otherwise similar to the two above versions in structure and composition. It has less capacity, compensating the cyclic loading during operation. [Figure 5](#) shows the temperature behaviour during discharge with 2 A.

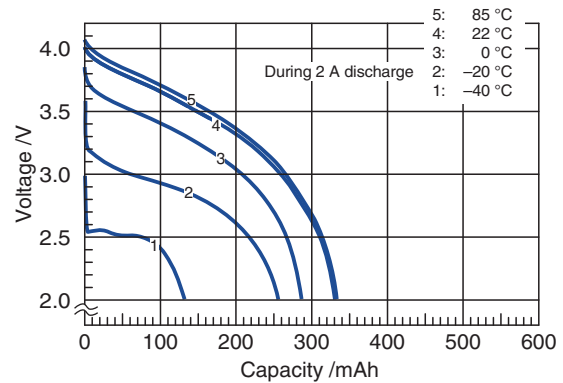


Fig. 5
Temperature behaviour TLI-1550A (Lithium-Ion version)

Comparison to common lithium batteries

A comparison study with conventional lithium batteries of type CR123A (size 2/3 A, system lithium / manganese dioxide) was performed in order to classify the performance of the new TLM battery. Both types have about the same volume. At a discharge current of 2 A, the TLM battery runs at a significantly higher voltage level while its capacity is similar ([Figure 6](#), curves 1 and 3).

At low temperatures, the benefit of the TLM-battery becomes even clearer. [Figure 6](#) shows discharge curves (curves 2 and 4) at $-20\text{ }^{\circ}\text{C}$ at a current of 1 A. The TLM battery still delivers about 75 % of its rated capacity, while the comparison battery only provides 2 % of its rated capacity, which is next to nothing.

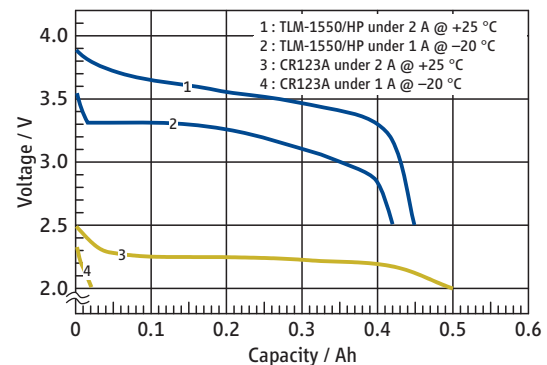


Fig. 6
Comparison of TLM and Li/MnO₂

TLM-battery meets eCall requirements

[Figure 7](#) shows the behaviour of TLM-1550HP under worst case conditions in the eCall application. The battery was subjected to accelerated aging by being stored at $+72\text{ }^{\circ}\text{C}$ for 3 weeks before the test. It was then cooled down to $-20\text{ }^{\circ}\text{C}$ and discharged with a simulated application load comprising pulses of 2.5 A for 2.5 ms every 6.25 ms

at a basic load of 0.5 A. This discharge principle corresponds to the CDMA multiplex channel access method. The figure shows the discharge results of in total 4 batteries that were pre-aged and discharged under the same conditions. Each battery is represented by 2 curves. The upper curve (1) shows the voltage at the basic load and the lower curve (2) shows the voltage during the 2.5 A pulse. The discharge duration is much longer than the required 10 minutes. TLM-1550HP is the smallest battery on the market that can meet such requirements.

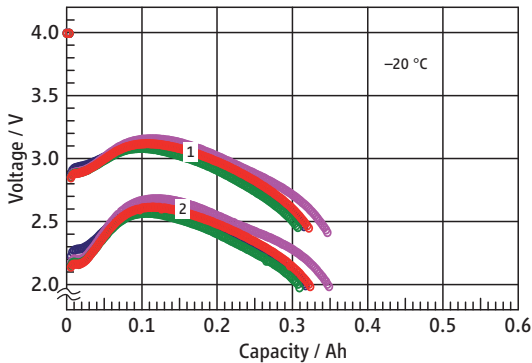


Fig. 7
CDMA discharge at $-20\text{ }^{\circ}\text{C}$ after accelerated aging TLM-1550MP after 3 weeks storage at $+72\text{ }^{\circ}\text{C}$
1: 0.5 A for 3.75 ms every 6.25 ms, followed by
2: 2.5 A for 2.5 ms

For the following 2 figures, the test was repeated with other batteries and discharge was performed at $+20\text{ }^{\circ}\text{C}$ (see Figure 8) as well as $+85\text{ }^{\circ}\text{C}$ (see Figure 9). Under these conditions, the eCall-emergency operation can be maintained for more than 20 minutes.

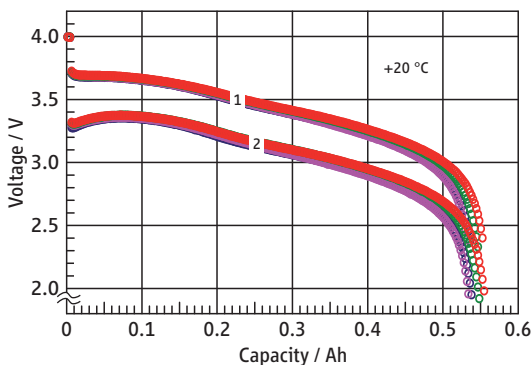


Fig. 8
CDMA discharge at $+20\text{ }^{\circ}\text{C}$ after accelerated aging TLM-1550MP after 3 weeks storage at $+72\text{ }^{\circ}\text{C}$
1: 0.5 A for 3.75 ms every 6.25 ms, followed by
2: 2.5 A for 2.5 ms

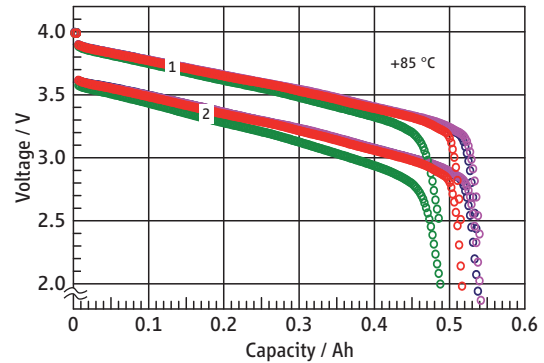


Fig. 9
CDMA discharge at $+85\text{ }^{\circ}\text{C}$ after accelerated aging TLM-1550MP after 3 weeks storage at $+72\text{ }^{\circ}\text{C}$
1: 0.5 A for 3.75 ms every 6.25 ms, followed by
2: 2.5 A for 2.5 ms

Nearly no self-discharge

One of the most important properties of the TLM-battery is its long storage life and low self-discharge. To reflect this, the open circuit voltage at room temperature and at $+72\text{ }^{\circ}\text{C}$ was observed for a period of nearly 2 years. The curves received are compared to a discharge curve ("titration curve") under a discharge current that is very low compared to the current capability of the battery, but much higher than the self-discharge rate. As a summary after about 600 days, the self discharge rate is $2\text{ }\mu\text{A}$ at room temperature and $10\text{ }\mu\text{A}$ at $+72\text{ }^{\circ}\text{C}$. The result can be illustrated in a graph showing the total capacity loss over storage duration (Figure 10).

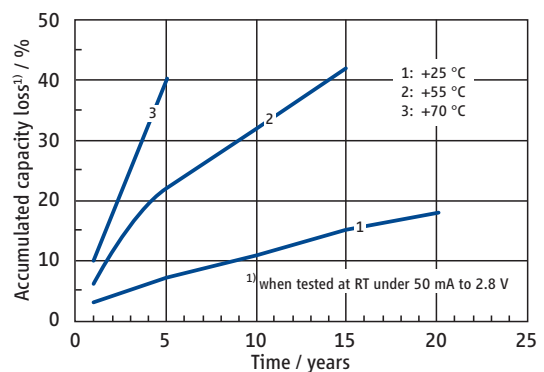


Fig. 10
Self discharge during storage

Permanently low impedance

Sophisticated applications such as backup batteries in eCall-systems require batteries that are long-lived across a large temperature range. Besides self-discharge, a low internal resistance is important. [Figure 11](#) shows the internal resistance of TLM-1550HP across the storage duration at two different temperatures. While it does increase, it remains within the specification limits even after storage for 3 years at +72 °C.

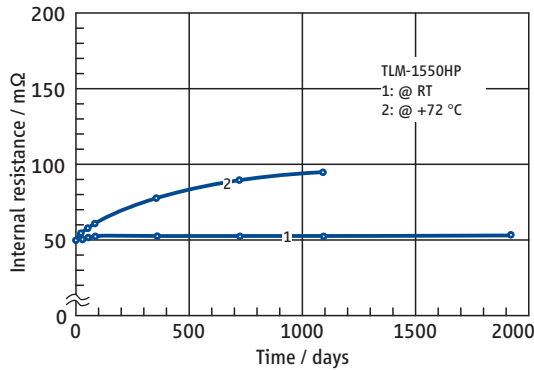


Fig. 11
Impedance growth during storage

Safety

The TLM-battery is very safe due to the chemical system and internal composition. The anode is far from being as reactive as the lithium metal usually used in non-rechargeable lithium batteries. The electrolyte is moderately flammable. The battery develops less heat if it is short-circuited and therefore is also safer than comparable other battery systems because it achieves the same power from a lower volume and thus for a shorter duration. The battery has passed the standardised safety inspections such as short-circuit, impact and over-discharge. Additionally, it has passed other, non-standardised safety tests.

[Figure 12](#) shows the behaviour of the TLM-battery under external short circuit. This test was performed at +55 °C. The voltage dropped to a low value right in the beginning while the current increased to approx. 45 A for a short time before being limited down to about 20 A instantly by the shut-down separator. After about half a minute, the battery was flat and the current dropped. The temperature curve shows a steady increase by about 65 degrees to 120 °C before it drops again. No other observations were made, particularly no fire and no explosion.

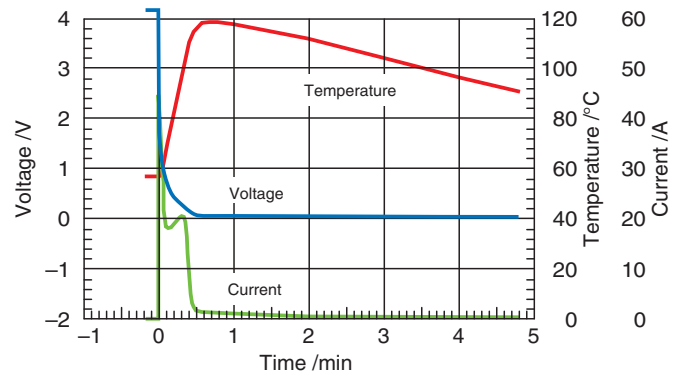


Fig. 12
Short circuit test at +55 °C

The impact test is one of 8 tests that lithium batteries must pass before being transported according to dangerous goods transport regulations. It is described in the IEC 62281 standard, among others. A metal rod is placed across the battery before a weight of nearly 10 kg mass is dropped onto this setup from a height of about 60 cm. The purpose is to cause an internal short circuit. The battery must not catch fire and must not explode. The temperature must not rise above 170 °C. As [Figure 13](#) shows, the TLM-battery meets these requirements. After the impact, the voltage dropped instantly. This suggests that there actually was an internal short circuit. The temperature rose from about 30 °C to about 90 °C within one minute and then dropped again slowly. No other observations were made, particularly no fire and no explosion.

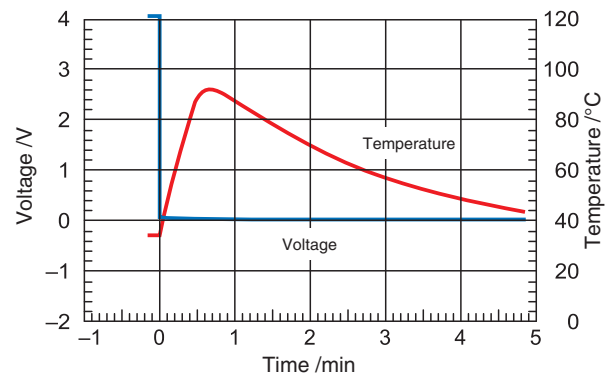


Fig. 13
Impact test

An over-discharge test is illustrated in [Figure 14](#). The battery was connected to an electronic current sink and discharged at a current of 2 A until it is empty. Then the discharge current is maintained. The battery is over-discharged into voltage reversal. The purpose of this setup is to illustrate the safety margin in a serial circuit when one cell is flat for any reason while the others are still providing full current that, of course, will also flow through the discharged cell unless – following the recommendations – a safety circuit comprising by-pass diodes is installed. Figure 14 shows that the voltage dropped once about 450 mAh had been discharged from the battery. The voltage then briefly remained at about 1.3 V before the battery reversed polarity down to -1.9 V. Then the voltage stabilised at -0.2 V. The temperature rose slowly at first, then faster, until it reached 74 °C, upon which it dropped continually. No other events were observed.

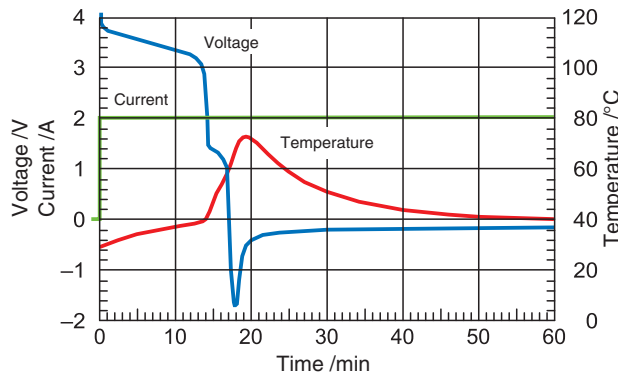


Fig. 14
Forced discharge test

The stability and safety of the substances used is specifically demonstrated by the high-temperature test as illustrated in [Figure 15](#). 4 batteries were stored and observed in a temperature chamber at different temperatures. The battery jacket temperature was recorded. It is clear that the battery only assumes the chamber temperature up to a temperature of about 165 °C without being additionally heated by reaction of the contents and only at 170 °C a noticeable reaction will occur. It disappears again after a short time. The test demonstrates that there is a safety margin of about 80 °C beyond the specified operating temperature range. No heat-emitting reaction and specifically no escaping electrolyte, no discharge of overpressure, no fire and no explosion were observed.

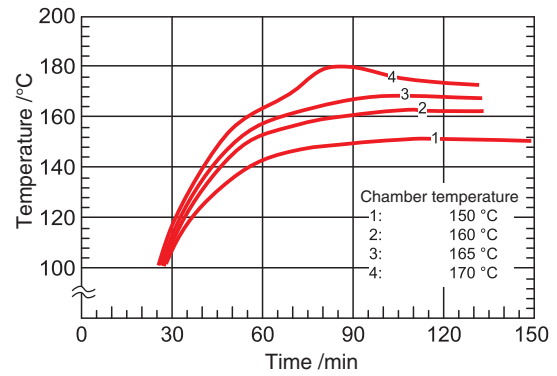


Fig. 15
High temperature test

Summary: enormously adaptive

The TLM-battery TLM-1550/HP is an organic primary battery of size AA that has a pulse current capacity of 15 A and a permanent current capacity of 5 A. The battery shows the best power properties down to -40 °C as compared to other conventional batteries. It is the smallest high-performance back-up battery and therefore very well suitable as an emergency battery in telematics applications such as eCall, but also for tracking of stolen vehicles, medical instruments and other demanding applications. If sized sufficiently, the non-rechargeable TLM-battery can meet the eCall requirements down to -40 °C without any additional heating. The rechargeable TLI-battery can be used for standby times of more than 8 to 10 years and additional SVT-operation. If a standby time in excess of 10 years without charger is needed, the PulsesPlus technology of Tadiran (TLP- series) can be used, which combines a non-rechargeable cell of the lithium / thionyl chloride (3.6 Volt) or the lithium / sulfuryl chloride (3.9 Volt) system with a rechargeable element (HLC).

Temperatures up to $+85$ °C (or even $+90$ °C under the vehicle ceiling) are no problem for the Tadiran lithium batteries, but need to be considered in planning of the maintenance intervals. As safety tests demonstrate, the battery meets all requirements to safety. The safety margin exceeds the specified operating temperature range by about 80 °C.

Acknowledgement

This paper is based on the work of Dr. Herzal Yamin, Dr. Chen Menachem and Ms Aya Daniel, all Tadiran Batteries Ltd. The author would like to thank them for their contributions.

Tadiran Batteries GmbH

Tadiran is a world leader in design, development, manufacture and marketing of lithium batteries for industrial applications.

Tadiran **lithium / thionyl chloride (LTC) batteries** (series SL-) are suitable where a 3.6 Volt high energy primary battery is required for up to 25 years stand alone operation.

The **PulsesPlus** battery technology (series TLP-) is best where power is required such as long range GPRS and GSM applications. It offers a combination of a high energy lithium primary battery and a hybrid layer capacitor. This HLC adds the power capability for pulse currents.

The **TLM High Power Battery Technology** (series TLM-) offers a compact power source with high current capability, ideally suited for emergency back-up of automotive applications.

The **TLI battery** is Tadiran's new rechargeable lithium ion battery designed for long-life use in harsh environments.

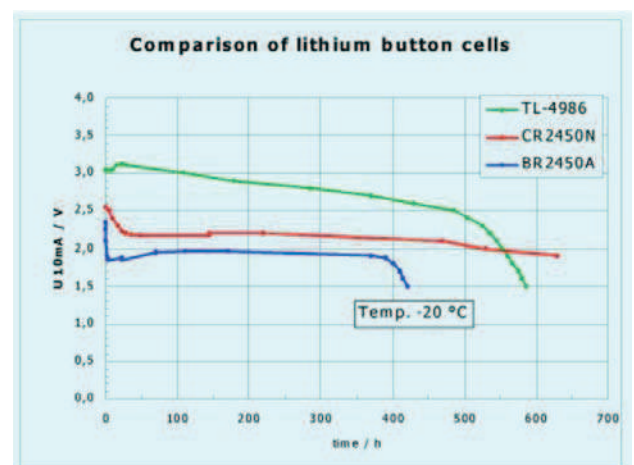
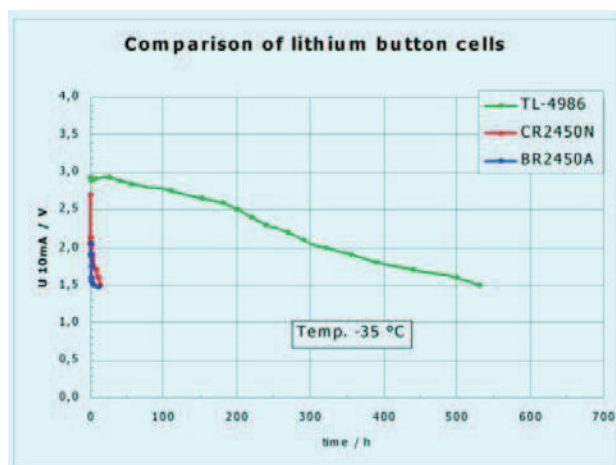


Implementing Lithium Batteries Into Automotive Applications

Depending on the application, the electrical and mechanical requirements differ widely from each other. A TPMS battery, for instance, should work for up to 10 years inside the wheel. The electrical load profile typically consists of a small (or no) background current and pulse currents in the vicinity up to 10 mA. Shock, vibration and centrifugal forces are very demanding. In the field of telematics, emergency, and safety devices, very high current pulses are drawn after a long standby time of up to 10 years. Very often, the suitability of lithium battery systems is limited by the temperature requirements. The standard temperature range for automotive applications is $-40\text{ }^{\circ}\text{C}$ to $+85\text{ }^{\circ}\text{C}$. The TPMS profile specifies temperatures from $-40\text{ }^{\circ}\text{C}$ to peaks up to $+150\text{ }^{\circ}\text{C}$ (for three hours within the total operating time).

The lithium thionyl chloride (Li/SOCl_2) technology covers the widest temperature range of all available battery systems. Nevertheless there is also a discussion about the suitability of 3 V lithium cells, as these might be less expensive than the Li/SOCl_2 batteries. In the TPMS field low temperature is the limiting factor for electrical performance of Lithium batteries, whereas high temperatures and extreme temperature cycles represent the limiting factor for mechanical robustness and leak proof.

Sonnenschein Lithium GmbH (SOLi) conducted a comparative test program with the following battery types: 3 V button cells LiMnO_2 (CR2450N) and $\text{Li}(\text{CF})_x$ (BR2450A), compared to the Li/SOCl_2 cell TL-4986/D, produced by Tadiran Batteries, the mother company of SOLi, optimised for the use in TPMS and used by the German car industry in all TPMS systems. As an example, Figures 1 and 2 show the electrical values of these three battery types at low temperatures of $-20\text{ }^{\circ}\text{C}$ and $-25\text{ }^{\circ}\text{C}$ respectively. The basis current for testing is 0 mA for 58 seconds, with pulses of 10 mA of 2 seconds.



As illustrated in figures 1 and 2, the low temperature performance is very poor for the CR and BR A cells. At $-20\text{ }^{\circ}\text{C}$, the cells do not deliver the pulse currents at the required voltage. A further test with extreme temperature cycles shows that mechanically both CR and BR types are weak due to the crimp seal. The Li/SOCl_2 technology, due to its composition and construction, especially the hermetic sealing (steel can, steel cover, laser welding of cover to can and glass to metal seal) meets the extreme temperature cycling requirements.

Several long term and real time tests had been conducted in the 90's, before the battery was approved by the German car manufacturers. These include 100,000 km of real time testing in Arizona/USA (summer), and down hill driving in the Alps with a fully loaded car (the battery experiences temperatures up to $+180\text{ }^{\circ}\text{C}$). Also, safety testing was carried out at $220\text{ }^{\circ}\text{C}$ for three hours. The cell TL-4986/D was chosen by the German car industry and introduced to the market in 1997. Up to date well over a million units are working in the field. Due to its construction, the Li/SOCl_2 technology, delivered either in bobbin or wafer construction, is highly intrinsically safe. In case of a short circuit, currents do not reach strong values and the heat generated is easily channelled to the outside. The hermetically sealed case guarantees a long shelf life as well as a long operating life under extreme temperature profiles. Unlike crimp seals, the hermetic sealing prevents leakage and thus capacity loss over the life time and damage to the application.

Emergency systems as well as tracking and monitoring devices as a part of a telematics system in the car typically need a low or zero continuous current coupled with high pulse currents up to several Amperes for a period of seconds or even minutes. Some applications will rely on one pulse after a standby time of up to ten years inside the car. These applications exceed the power capability of the lithium thionyl chloride technology in bobbin-type construction. Spirally wound lithium cells are able to deliver high currents. However, they have significantly less energy, much higher self discharge, limited temperature ranges and thus are not suitable for long-term applications in an automotive environment. For these reasons, Tadiran Batteries has designed cells with a so-called Pulses Plus technology that combines the very high energy of the lithium thionyl chloride bobbin-type cell with a novel hermetically sealed rechargeable high-power element, the Hybrid Layer Capacitor (HLC). This new technology can be used to efficiently deliver current pulses of up to several Amperes with a minimum voltage of more than 3 V per cell. Moreover, the basic battery can be connected both in series and in parallel to battery packs for higher voltages, current pulses and capacities. The Pulses Plus series combines high energy with high power capability on a high safety level.

from EPN 12/2004

<http://www.epn-online.com/page/16414/implementing-lithium-batteries-into-automotive-applications-depending-on-the-application----.html#>

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**RIM takes
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Long-lasting lithiums

Lithium batteries can handle the extreme temperatures and severe mechanical shocks and stresses of demanding automotive environments.

Sol Jacobs
Vice President
Tadiran Batteries
Port Washington, N.Y.

Mounted on automotive windshields, road-toll transponders must withstand extreme temperature ranges. Powering these devices are bobbin-type lithium thionyl-chloride batteries. These batteries got the nod for the Ez-Pass system because they can handle the severe temperature cycles that characterize car interiors. Heat soak can hit 113°C (according to SAE) when parked, cooling down rapidly to room temperature. In cold weather, of course, the battery must handle cold soak and a rapid temperature rise. The design is also hermetically sealed, an advantage over nonhermetically sealed battery systems such as lithium manganese-dioxide coin cells. Such cells may breathe over large temperature ranges, with electrolyte possibly diffusing out of the battery while heating up, and moisture from the air potentially diffusing into the



Currently used in over 9 million toll tags, lithium thionyl-chloride cells provide long life under extreme temperatures.

battery during cooling.

There are upwards of 10 million lithium batteries used in automobiles today. They power everything from electronics in toll-tag transponders such as the Ez-Pass system, to air-bag deployers, emergency mayday notification devices, GPS-tracking equipment, and engine controllers.

The extended operating temperatures that are a claim-to-fame for lithium cells are possible because the battery chemistry uses no water and

because battery materials are quite physically stable. Some lithium-based systems can operate at temperatures as low as -55°C and as high as 150°C.

How lithium batteries work

To understand the strong points of lithium cells, it is helpful to review their seven main components — the anode, separator, cathode, electrolyte, current collector, can and cover, and hermetic seal.

The anode is battery-grade lithium foil, pressed onto the inner surface of the cell to provide a mechanically sound and reliable electrical connection. The separator sits between the anode and cathode. Made of nonwoven glass, it prevents internal shorts while letting ions move freely between the electrodes.

The cathode is a highly porous Teflon-bonded carbon-based powder. Thionyl-chloride cathodic reduction occurs on its surface under load. A solution of lithium aluminum-tetrachloride in thionyl chloride creates the electrolyte. A metal current collector provides the electrical connection between the porous carbon cathode and position terminal of the battery.

The cell can and cover are nickel-plated, cold-rolled steel. The can withstands mechanical stresses over a range of service conditions. The positive cell termination of the lithium cell is insulated from the cell cover (which is the negative termination) by a glass-to-metal (hermetic) seal that uses compression-sealing

technology.

Lithium cells often get specified for automotive uses because they offer benefits that are just not available from other battery chemistries. Lithium is an ideal material for battery anodes because its intrinsic negative potential exceeds that of all metals. Lithium is also the lightest nongaseous metal. Batteries based on lithium chemistries have the highest specific energy (energy per unit weight) and energy density (energy per unit volume) of all types. The high-energy density is a result of lithium's high intrinsic potential and the fact that lithium reacts strongly with water. Energy density of a battery depends mostly on cell chemistry and, to a lesser extent, on cell size and discharge rate. Generally speaking, increasing the cell size and decreasing the discharge current increases energy density.

Lithium is the lightest metal and has the lowest reduction potential (potential versus standard reference electrode). Therefore, batteries based

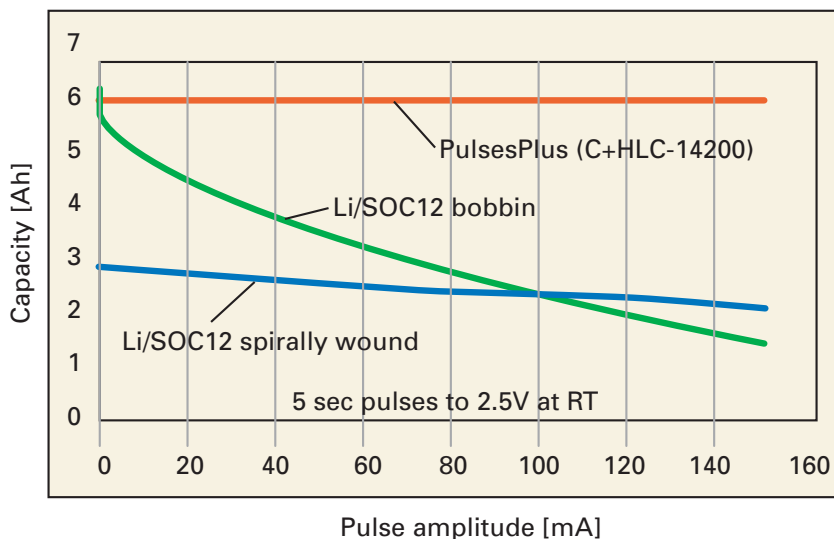
on lithium chemistry are expected to have a higher energy density than other kinds.

That precludes the use of any aqueous (water-containing) electrolyte because lithium reacts with water. But that turns out to be a benefit. Because the oxygen and hydrogen in water dissociate in the presence of a potential above 2 V, cells using aqueous electrolytes have a limited voltage. Lithium cells, all of which use a nonaqueous electrolyte, have nominal open-voltage circuits (OCVs) of between 2.7 and 3.6 V. However, the use of nonaqueous electrolytes results in those cells having a relatively high internal impedance.

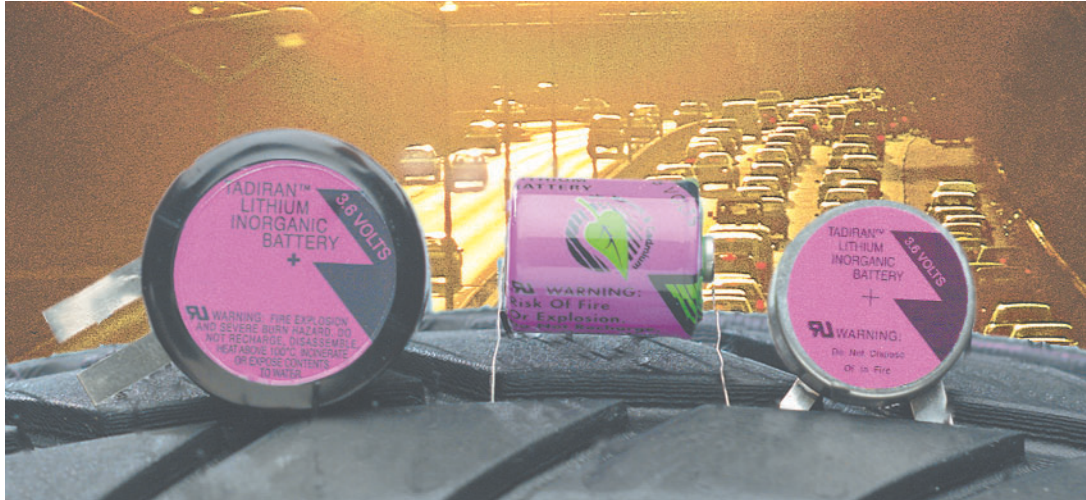
Comparing lithium chemistries

Lithium-battery chemistries differ in several important qualities. Critical considerations include nominal, minimum, and maximum voltage; initial, average, and maximum discharge current; the ability to handle continuous or intermittent operation; if intermittent, the amplitude and duration of minimum and peak current drains; service life; operating-temperature range; highest expected current at lowest expected temperature and permitted voltage-rise time to minimum voltage; and the storage duration conditions the battery can tolerate.

Under the broad category of primary lithium-battery types, several chemical systems are commonly in use. They are poly (carbon monofluoride) lithium, or (CF)X-Li; manganese dioxide-lithium (LiMnO₂); lithium thionyl-chloride (LiSOCl₂); sulfur dioxide lithium (LiSO₂); and lithium iodine (LiI₂). These systems derive their



Discharge characteristics of a PulsesPlus battery, in the form of available capacity as a function of pulse amplitude, compared to conventional lithium-based bobbin and spirally wound batteries.



Lithium batteries in tire-pressure monitoring devices withstand high shock and vibration in temperatures up to 150°C.

names from the type of cathode material they use. Poly (carbon monofluoride) cells have an OCV of 2.8 V and moderately high energy density. Cylindrical types are manufactured with a spiral-shaped cathode and crimped elastomer seals. Though generally safe, under extreme conditions the elastomer seals can fail before the case fails, letting the relatively reactive cell constituents escape.

Manganese dioxide-lithium cells are comparable to poly (carbon monofluoride) cells in their construction, energy density, safety, and OCV. But they typically have only

about half the service life.

Manganese dioxide-lithium cells are well suited to applications having relatively high continuous or pulse-current requirements, because the cell internal impedance is somewhat lower than for other types.

Lithium-iodine offers special safety qualities because it uses only solid constituents. The separator in a lithium-iodine cell can “heal” itself if cracks occur. The major drawback to lithium-iodine is its high internal impedance, which limits its use to very low-drain applications.

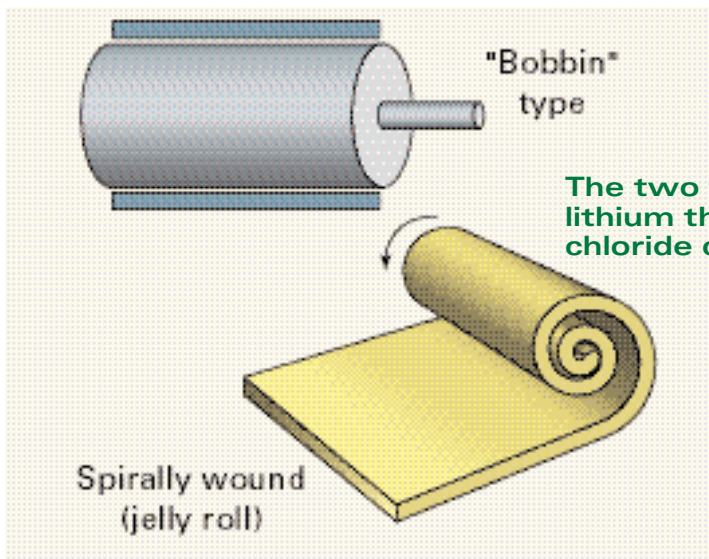
Sulfur dioxide-lithium cells, used almost exclusively in

military/aerospace applications, have lower energy density than manganese dioxide-lithium or poly (carbon monofluoride) lithium cells. Their service life and energy density are less than half that of lithium thionyl-chloride cells.

Lithium thionyl-chloride cells have the highest energy density of all lithium types. Service life is 15 to 20 years. These cells are best suited for applications having very low continuous-current and moderate pulse-current requirements. Their extremely long service life and low self-discharge rate make them ideally suited for long-term use in harsh environments.

Bobbins and spirals

There are two types of lithium thionyl-chloride cells, bobbin-type and spirally wound construction. Spirally wound lithium cells deliver high current, but with less capacity and much higher self-discharge compared to bobbin-type cells. This is because spirally wound cells, also known as jelly rolls, have wound layers of lithium compared to bobbin-type which has only one layer. The larger the lithium area (anode), the larger the current draw and rate of self-discharge.



The two types of lithium thionyl-chloride cells.

Characteristics of lithium-battery systems used in automotive applications

Li/System	Li/SOCL ₂ w/Hybrid Layer Capacitor	Li/SOCL ₂ Bobbin	Li/SOCL ₂ Jelly roll	Li/SO ₂	Li/MnO ₂
Energy density (Whr/liter)	1420	1420	800	410	650
Power	high	low	high	high	moderate
Voltage	3.6 to 3.9V	3.6V	3 to 3.6V	2 to 3V	2 to 3V
Pulse amplitude	high	small	moderate	high	moderate
Passivation	low	high	moderate	fair	moderate
Performance at elevated temperatures	excellent	fair	moderate	moderate	fair
Performance at low temperatures	excellent	fair	excellent	excellent	poor
Operating life	excellent	excellent	moderate	moderate	fair
Self-discharge rate	very low	very low	moderate	moderate	moderate
Operating temperature	-55 to 100°C	-55 to 150°C	-55 to 85°C	-55 to 60°C	0 to 60°C

Bobbin-type lithium thionyl-chloride technology is particularly well suited for low-current applications because of its high-energy density, low self-discharge rate and 10-year-plus operating life. Bobbin-type lithium thionyl-chloride cells feature an operating temperature range of -55 to 150°C, high capacity, small size, and an ability to withstand broad fluctuations in pressure, temperature, and shock.

Such qualities have allowed these cells to serve in numerous roles where other kinds of batteries are not an option. One example is in tire-pressure monitoring systems. A group of German carmakers now place lithium thionyl-chloride batteries inside each wheel on the rim. The batteries must be small and lightweight, last a long time, and be able to withstand extreme temperatures.

In one test on a mountain pass, a fully loaded car was driven for 45 min and saw extreme braking forces during that time. Brake disc temperatures hit 900°C and caused temperatures within the tire to exceed 100°C. This was no problem

for the lithium thionyl-chloride cells. They deliver a temperature range of -40 to 120°C, with a short term limit of 170°C.

Besides temperature fluctuations, the batteries see the mechanical shock and stress of a vehicle in motion. In the course of high-speed tests on the road and on dynos, lithium thionyl-chloride cells withstood over 300 km/h, mechanical shock 100g half sine, and static centrifugal forces of 2,000g. Performing in these extreme conditions, the Tadiran T-4986/D is presently the only battery used by the German car industry for their tire-pressure monitoring systems.

High-current pulse hybrid solutions

Over the past decade, there has been a dramatic rise in automotive applications involving high-current pulses, including automotive emergency-roadside assistance systems and GPS tracking and vehicle-safety monitoring systems.

High-current pulse applications typically require a low continuous

current (or no continuous current) coupled with high-pulse currents of up to several amperes for anywhere from a few seconds to almost 20 min.

Lithium thionyl-chloride batteries deliver the energy density to handle high-current pulse applications. However, these chemistries have drawbacks. Spirally wound cells lack enough capacity. And their comparatively high rate of self-discharge limits their long-term operation. Bobbin-type cells have ideal capacity and energy density, but suffer from two main drawbacks: severe passivation problems after storage at high temperatures and low current due to its design.

To overcome these obstacles, engineers at Tadiran designed a hybrid-lithium battery called Pulses-Plus which combines bobbin-type construction with hybrid-layer capacitors (HLCs). This hybrid-lithium technology is currently finding use in GPS vehicle tracking and emergency call (Mayday) systems. ■

For more information, contact Tadiran Batteries, 2 Seaview Blvd., Port Washington, NY 11050, (800) 537-1368

Tadiran High Power Lithium Organic Cell Model TLM-1550HPM

1. Scope

This data sheet describes the mechanical design and performance of Tadiran high power lithium organic cell model TLM-1550HPM.

2. Characteristics

2.1. Physical

- 2.1.1. Length: 51 -1 mm.
- 2.1.2. Diameter: 14.8 ± 0.3 mm.
- 2.1.3. Weight: 20 gr. max.

2.2. Electrical

- 2.2.1. Open Circuit Voltage (for batteries stored at RT for 1 year or less) 3.95 to 4.07 V
- 2.2.2. Closed Circuit Voltage (at 0.1 sec) at 0.5 A load 3.88 V minimum
- 2.2.3. Discharge
 - Discharge capacity at 20 mA @ RT to 2.8 V 500 mAh
 - Discharge capacity at 500 mA @ RT to 2.8 V 420 mAh
 - Maximum discharge current
 - Continuous to 2.5 V: 7 A
 - 1 second pulse to 2.6 V: 15 A

2.3. Operating Temperature Range: -40 °C to 85 °C

2.4. Accumulated Capacity Loss*:

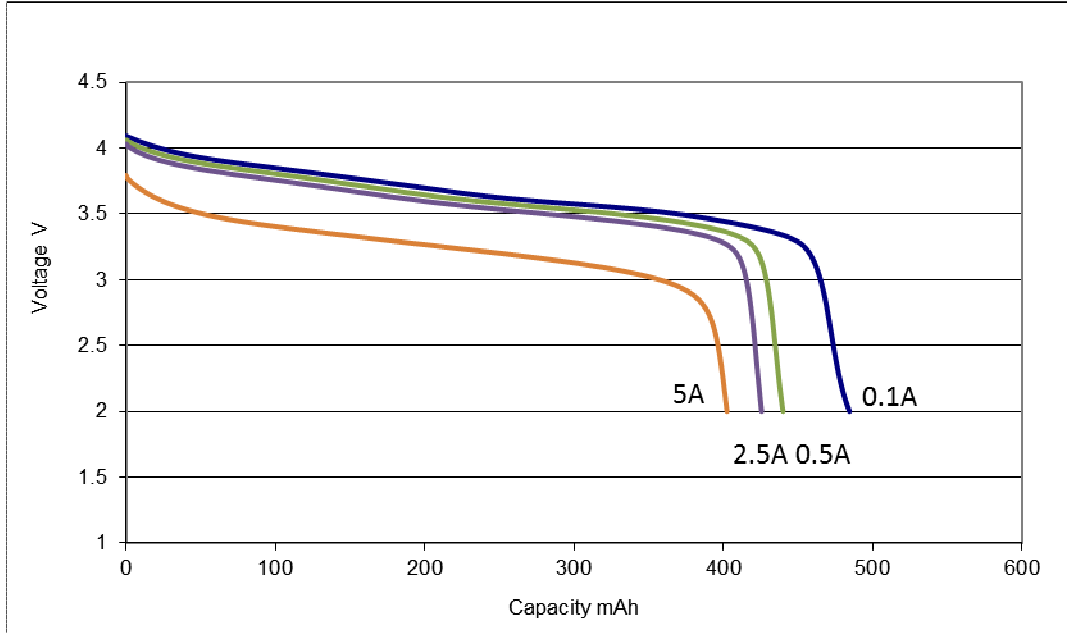
Storage Temperature	22 °C	55 °C	72 °C	85 °C
Storage Time [Y]				
1	3 %	6 %	10 %	TBD
5	7 %	22 %	40 %	N/A
10	11 %	32 %	N/A	N/A
15	15 %	42 %	N/A	N/A
20	18 %	N/A	N/A	N/A

* When tested at RT at 5 mA to 2.8 V

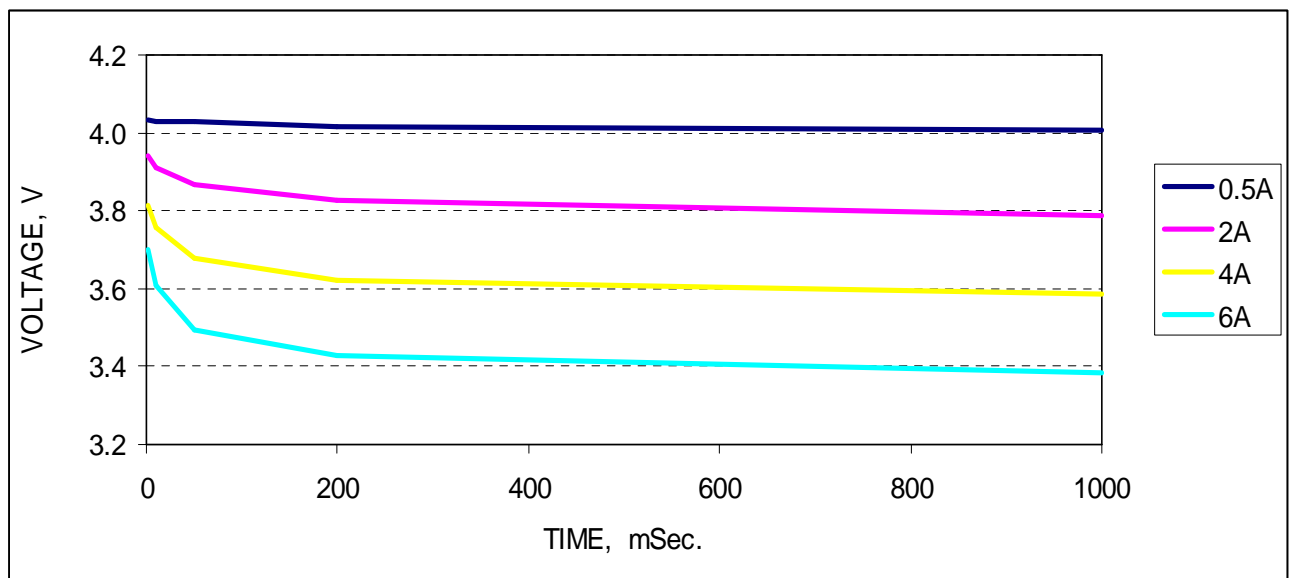
2.5. Cell impedance: Less than 100 mOhm @ 1kHz at room temperature.

2.6. Performance Data (Typical results for up to 5 years old cells):

Discharge capability at RT



Pulse capability at RT



Tadiran Lithium Ion Rechargeable Battery Model TLI-1550A

1. Scope

This **data sheet** apply to the AA size Lithium Ion Rechargeable battery supplied by Tadiran Batteries Ltd.

Notice: Charging circuit and application load profile have to be approved by Tadiran prior to the use of this cell.

2. Characteristics

2.1. Physical

- 2.1.1. Length: 53 mm Max.
- 2.1.2. Diameter: 14.8 ±0.3 mm.
- 2.1.3. Weight: 20 ±0.2 gr. Max.

2.2. Electrical / Charge

- 2.2.1. Charge Voltage: 4.1 V
- 2.2.2. Charge Current: 100 mA Max.
- 2.2.3. Charge Method: CCCV (Constant Current/Constant Voltage)
- 2.2.4. End of Charge: 20 mA Max. per cell
- 2.2.5. Charge Temp. Range: -20 to +50 °C

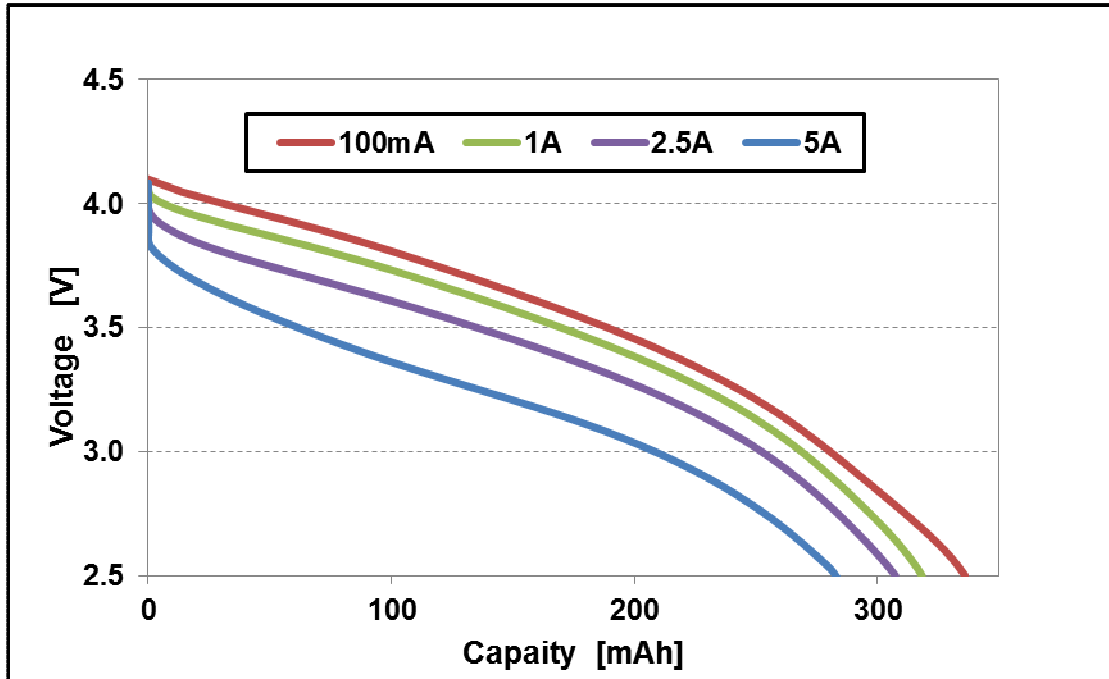
Charge temperature can be extended to -40 ÷ +85 °C provided that the max. charge current is limited to 20 mA.

2.3. Electrical / Discharge

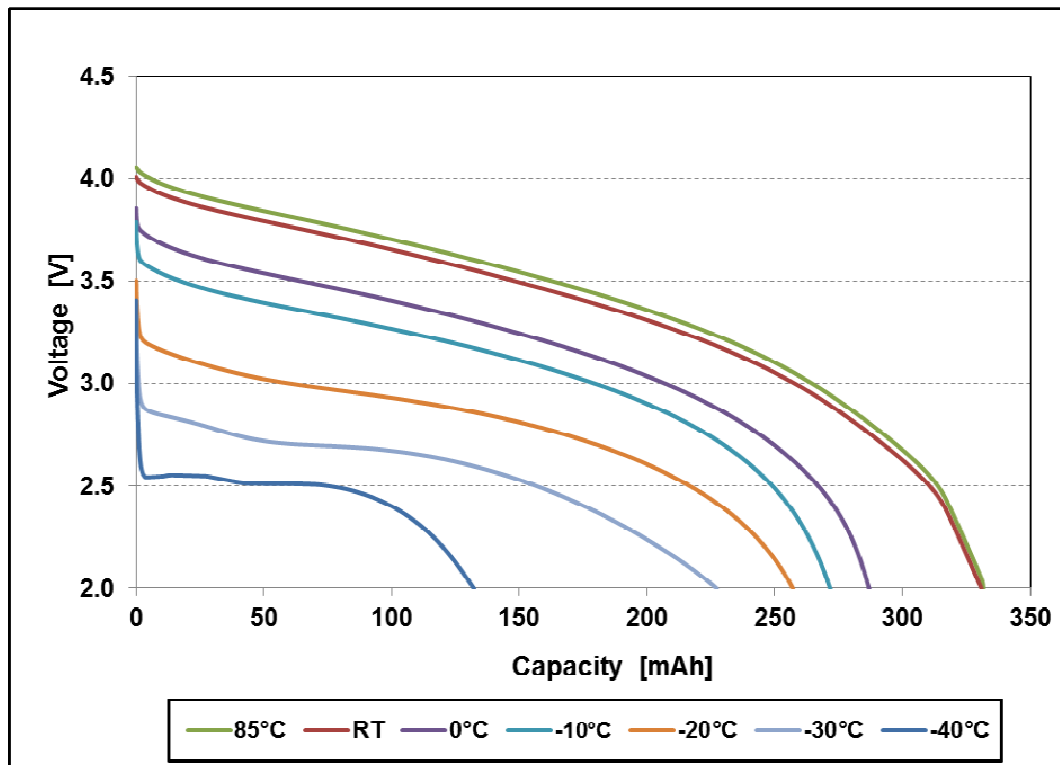
- 2.3.1. Nominal Current: 250 mA
- 2.3.2. End of Discharge: 2.5 V @ Room Temperature
- 2.3.3. Discharge Temp. Range: -40 to +85 °C
- 2.3.4. Performance Characteristics:

Item	Performance	Conditions
Battery Capacity	330 [mAh]	Discharge at 100 mA
	310 [mAh]	Discharge at 1000 mA
Charge Discharge Cycles	310 [mAh]	After 100 cycles Discharge at 250 mA
Temperature	285 [mAh]	Discharge at -20 °C at 250 mA
	330 [mAh]	Discharge at 60 °C at 250 mA
Charge Retention (reversible)	285 [mAh]	After 5 years at RT, Discharge at 250 mA
Impedance	Less than 100 mohm	Impedance at 1 KHz

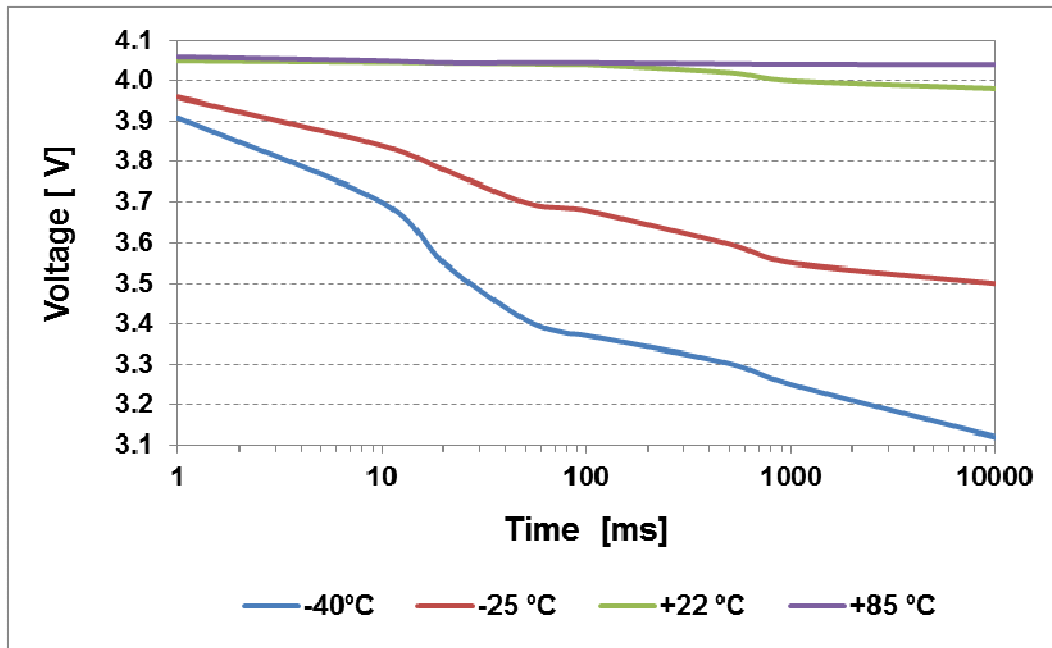
Discharge curves at Room Temperature



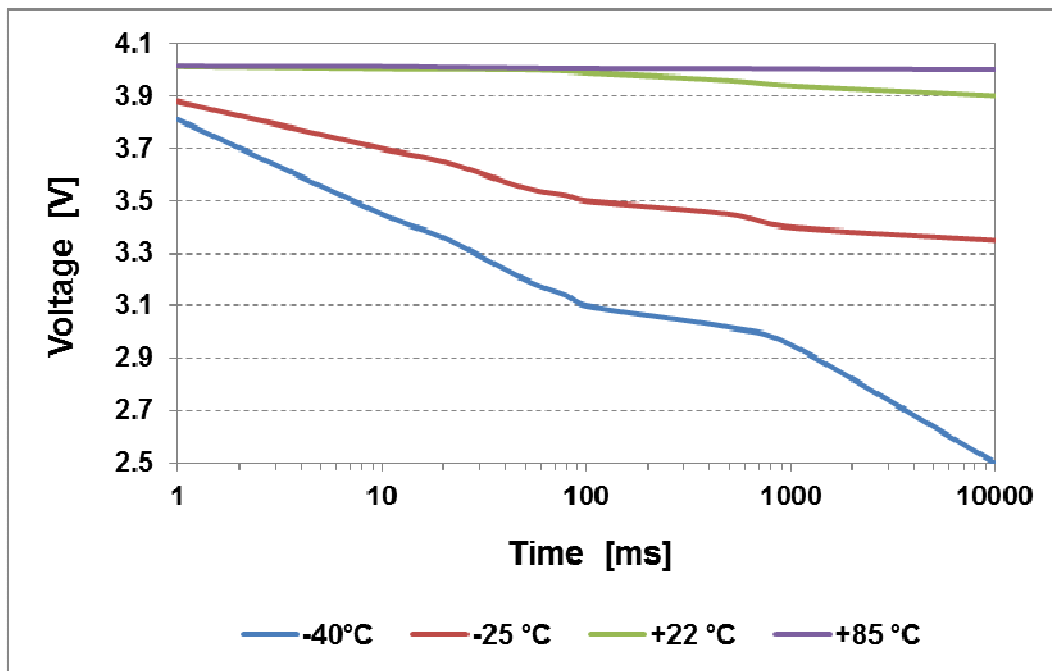
Discharge Curves at Several Temperatures, @ 2 A



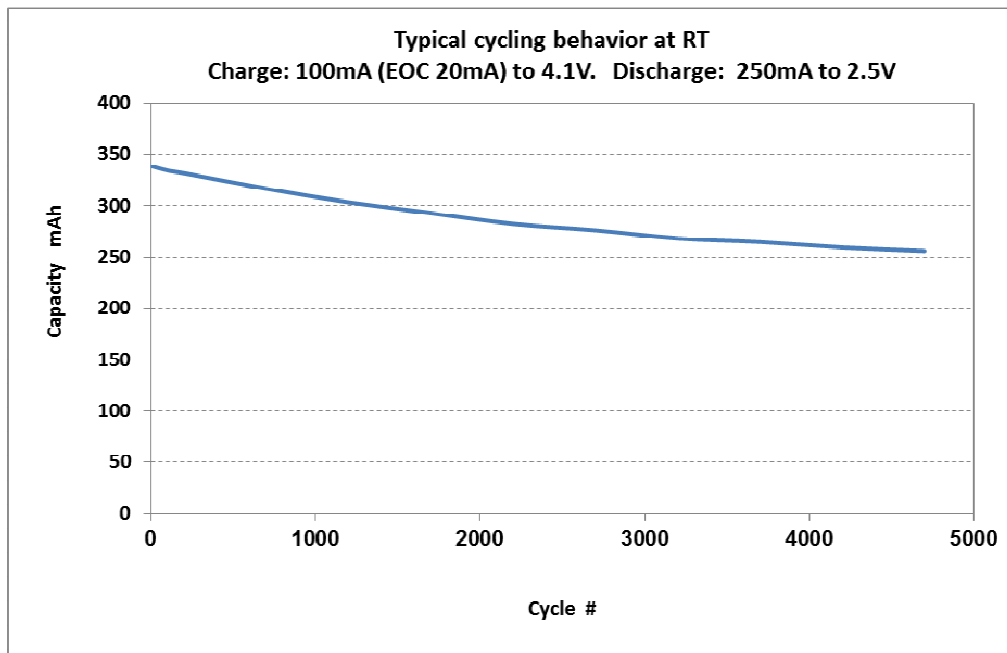
Voltage curves @ 750 mA, 10 sec pulse



Voltage curves @ 1200 mA, 10 sec pulse



Charge/ Discharge Cycling Performance



2.4. Cell / Battery Protection (to be applied by the user)

Item	Specifications
Over charge protection	Cell voltage should not be higher than 4.2 V
Over discharge protection	Cell voltage should not be lower than 2.4 V

2.5. Safety Characteristics

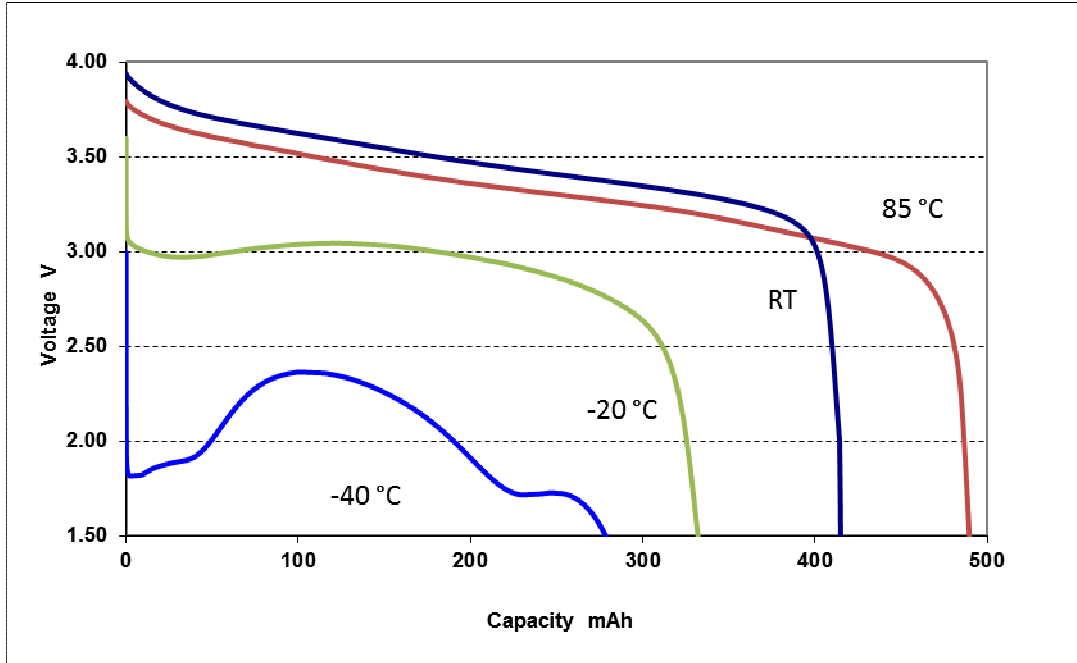
The cells successfully passed the following safety tests:

- Short circuit at RT, 55 °C and 85 °C.
- Temperature test up to 170 °C.
- Crush.
- Impact.
- Nail penetration.
- Over charge up to **0.5 A**, 12 V.
- Over discharge (300%) up to 2 A.

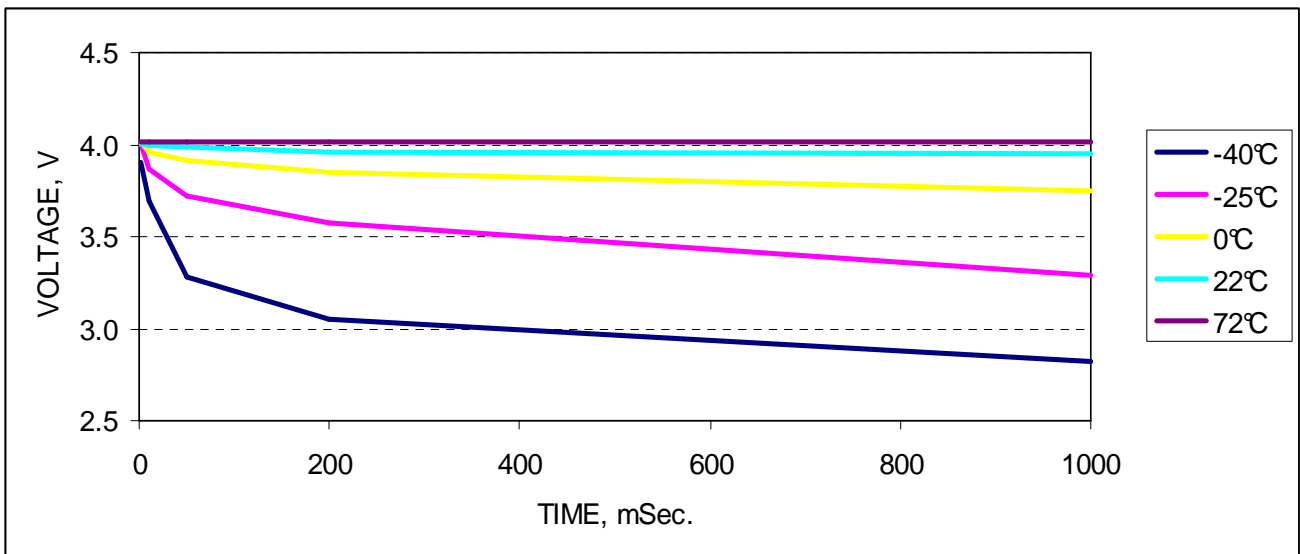
2.6. Battery pack assembly and usage considerations

- For 2 cells or more in series, voltage shall be monitored on each cell.
- For more than 2 cells in parallel, maximum charge current shall be limited to 250 mA for the whole pack.

Discharge capability @ 2A at several temperatures



Pulse capability @ 1A at several temperatures

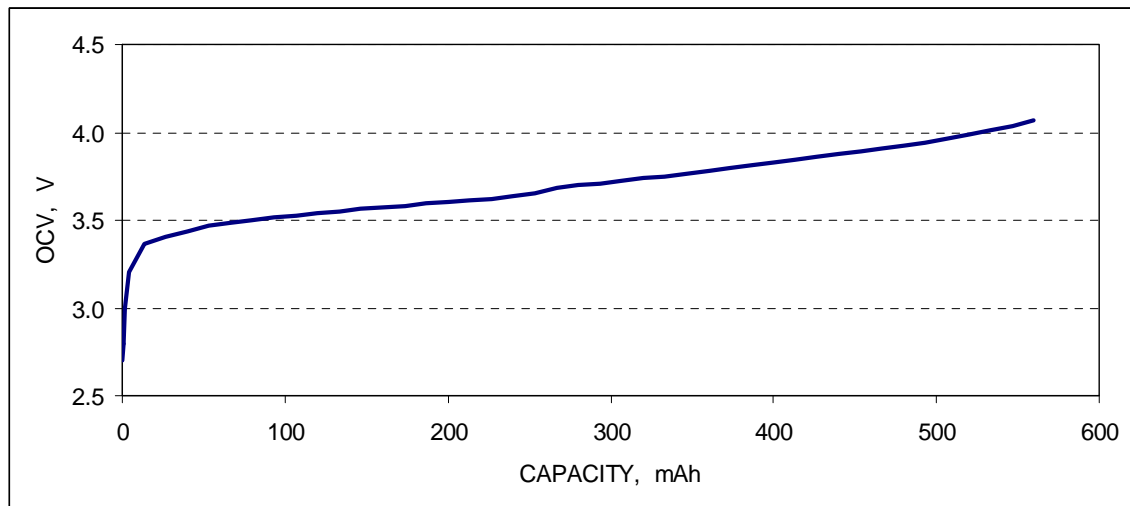


* Performance at 85°C is close to that at 72°C

2.7. End of life indication:

OCV measurements can provide a good estimation for the remaining capacity of the cell as shown below .

Capacity vs. OCV



2.8. Safety tests:

The cell has successfully passed the following safety tests:

- Short circuit at RT and at 55 °C
- Oven at 150 °C
- Impact
- Nail penetration
- Over charge and over discharge (200 % at currents up to 2 A)

Lithium Battery Application Questionnaire



To enable Tadiran to provide the most appropriate solution to your battery requirement, kindly fill in this questionnaire with the maximum data you can provide. Your data will be treated with full confidence and be used only for optimizing our solution.

Company: Address:
Contact Person: Title:
Tel: Fax: E-mail:

Application Details:

Brief Description:

Battery is used for: Back up Main power source

Electrical Requirements:

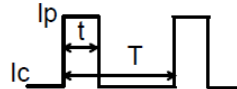
Operating Voltage: Maximum Nominal Minimum (cut-off) volts

Constant Current: $I_c =$

Pulse Current: $I_p =$; Duration: $t =$; Every: $T =$

Pulse Load Profile: Please enclose a drawing if needed

Qualification Tests: Please enclose specifications



Expected Operating Life: ; Storage of battery before use:

Environmental Requirements

Please specify percentage (%) of time per temperature

Storage Temperature (°C): Max. % ; Average % ; Min. %

Operating Temperature (°C): Max. % ; Average % ; Min. %

Special conditions of humidity, shock, vibration etc.:'

Please enclose specifications or list in the remarks below

Size and Dimensions of cell: (Please attach a drawing if a battery pack is required)

Preferred Cell Size ; Max. Space Available (mm): L= W= H=

Estimated Annual Requirement: 1st year 2nd year 3rd year

Qty for First delivery ; Expected during , 2017

Alternative Battery: Type Maker Model

Remarks:

Form filled by: Customer Tadiran REP. Name: Date: