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Kokam/FMA Lithium Polymer Cell application manual

Document provided by

FMA, Inc.

Exclusive North and South America distributor for Kokam Lithium Polymer Cells

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Contents

Introduction

This manual provides general information needed to use Kokam/FMA Lithium Polymer cells and packs (consisting of multiple cells) successfully in any application. The manual will be complemented by a series of Application Notes that provide information for specific applications.

This document will be periodically updated. The latest version is available for download from the FMA web site, www.fmadirect.com.

Your comments are welcome. Your feedback will be useful in improving this manual and making it as useful as possible. Please send your comments and questions via e-mail to fred@fmadirect.com.

General specifications

Kokam/FMA Lithium Polymer (LiPoly) cells are the next-generation replacement for NiCd, NiMH and Lithium Ion cells.

Summary specifications are as follows:

- Cell voltage: 3.7V, nominal; 4.2V maximum
- Nominal capacity, weight and dimensions per Exhibit 1B for all cells
- Discharge condition: 2.5V absolute; 3V nominal
- Cycle life: 600 cycles at discharge rate of 2C while maintaining >80% capacity
- Operating temperature: charge, 0° to 45°C.; discharge. -20° to 60°C
- Cell structure: copper foil with lithium and carbon active element
- Polymer separator and liquid polymer electrolyte
- Plastic enclosure sealed under heavy vacuum
- Ribbon tab terminals with one solderable side; a printed circuit terminal with solder pads is available

Cell structure is shown in Exhibit 1A.

Complete specifications for any capacity cell are available as an Applications Note.

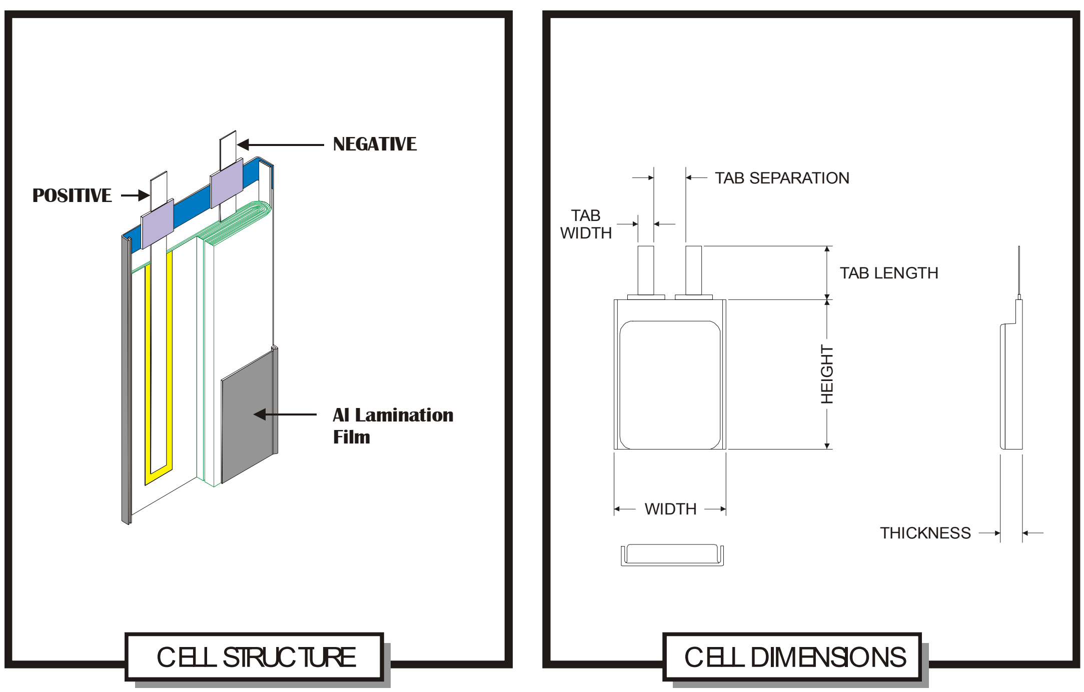

Exhibit 1A: Cell structure and general dimensions

Kokam part no.	FMA part no.	Capacity, mAh[1]	Thickness, mm	Width, mm	Height, mm	Weight, g
SLPB104330	KOK45*	45	0.8	43	30	1.8
SLB452128	KOK145*	145	4.5	20.5	27.5	3.5
SLPB353452	KOK560*	560	3.7	34	52	12
SLPB393452	KOK640	640	4.15	34	52	13.5
SLPB433452	KOK720	720	4.55	34	52	15
SLPB483452	KOK770	800	4.95	34	52	16.5
SLPB523452	KOK880*	880	5.45	34	52	18
SLPB523462	KOK1020*	1020	5.45	34	62	20.5
SLPB356495	KOK2070*	2070	3.7	64	95	44
SLPB396495	KOK2400	2400	4.15	64	95	49
SLPB456495	KOK2700	2700	4.55	64	95	54
SLPB486495	KOK3000	3000	4.95	64	95	59
SLPB526495	KOK3270*	3270	5.45	64	95	64

[1]Capacity is nominal. Each cell receives 2-1/2 cycles of charge/discharge at the factory. All cells are shipped with 50% charge.

*FMA, Inc. stock cells. Inquire for availability of other cells.

Exhibit 1B: Specifications for Kokam/FMA LiPoly cells

Charging

LiPoly cells are charged differently than NiCd/NiMH and all other chemistries except for Lithium Ion. **The charge schedule is different and you must use a charger designed for either Lithium Polymer or Li Ion cells**.

Charging requirements:

- Current must be limited to 1C, where C is cell capacity. For example, a 145mAh capacity cell must be charged at a maximum of 145mA.
- As cell voltage increases, charge voltage must also increase to force current through the cell until the voltage applied to the cell reaches a maximum of 4.235V.
- As cell voltage rises to 4.235V, current approaches zero.
- When charge current falls to 0.1C, the cell is fully charged.

The charging schedule is easily controlled, as shown in Exhibit 2.

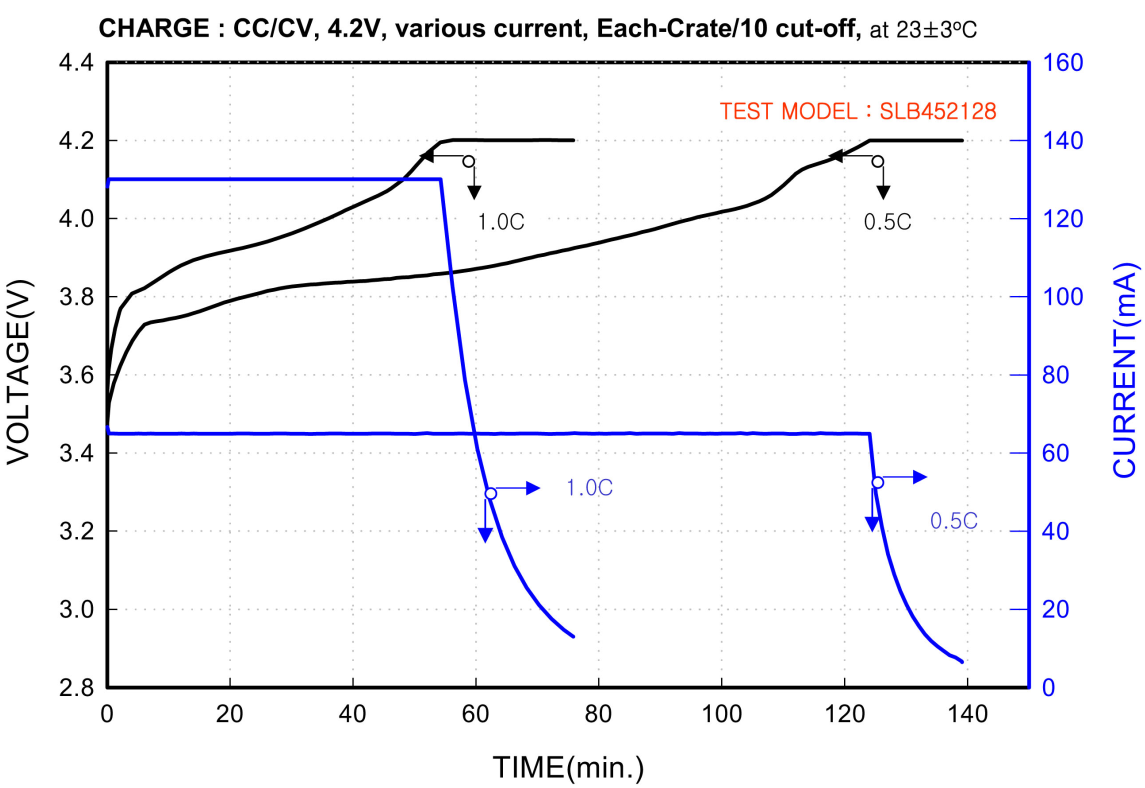

Exhibit 2: Charging algorithm

At the 1C charge rate, a cell can be charged in one hour if the charger is designed to hold charge current at 1C without exceeding 4.235V/cell maximum charge voltage. Lower charge rates are satisfactory if longer charge time is acceptable. Charge rates greater than 1C may reduce cell capacity. Extreme charge rates **will** damage the cell. LiPoly cells **cannot** be charged at high rates such as 2C, 3C or 4C.

Approved chargers are available from FMA. Specifications for FMA chargers are posted on the Kokam/FMA web site. Other vendors sell appropriate LiPoly chargers.

The two most important charging rules:

- Never exceed a 1C charge rate, and
- Never exceed a maximum charge voltage of 4.235V/cell ±1%.

Discharging

Kokam cells are warranted to deliver nominal capacity at discharge rates not greater than 2C, where C is cell capacity. All battery manufacturers warranty their products for a 2C discharge rate.

Typical discharge curves up to 2C are shown in Exhibit 3. Although Kokam/FMA warrants performance to the 2C discharge rate, operating experience indicates that cells can be used at discharge rates above 2C if the user assumes all risk.

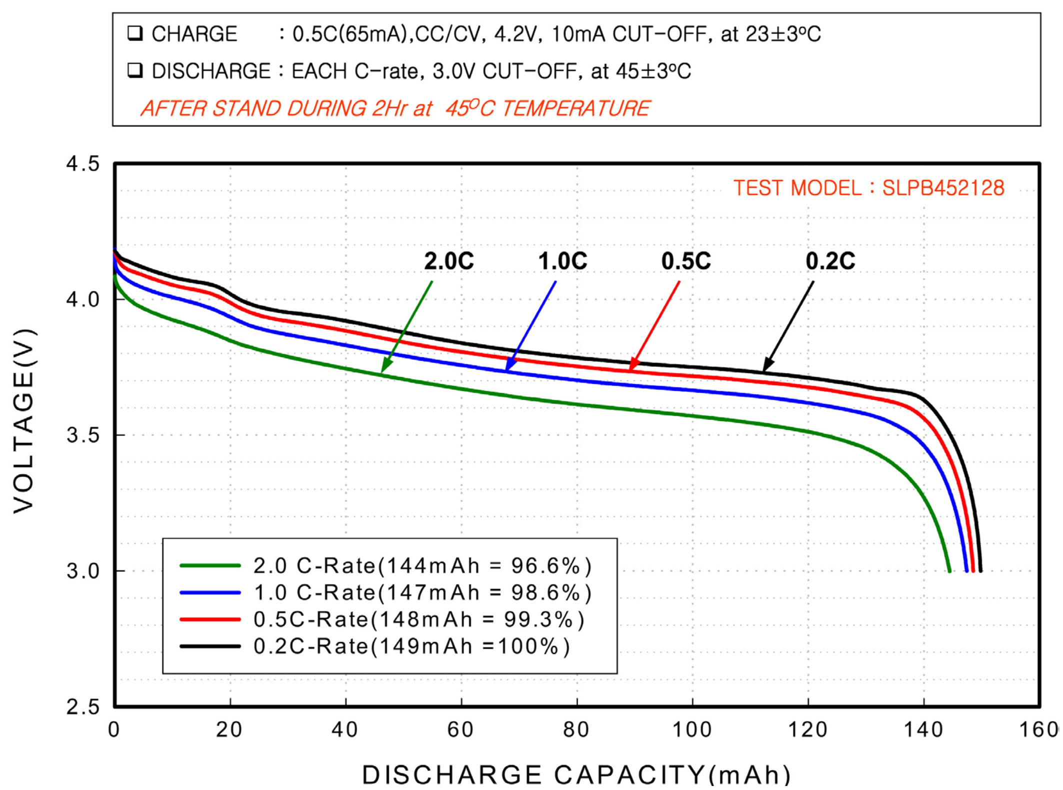

Exhibit 3: Discharge at various rates for warranted performance

Exhibit 4 shows the performance achievable at discharge rates above 2C and at cut-off voltages down to 2.5V.

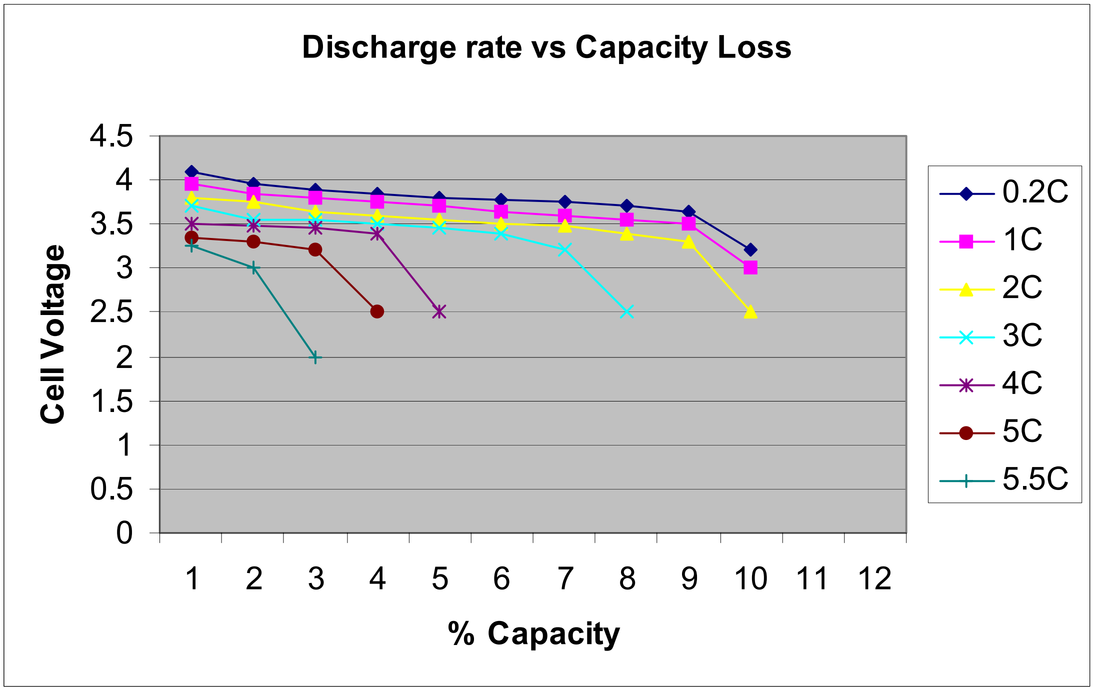

Exhibit 4: Discharge at rates exceeding warranted performance

Cells must not be discharged below an absolute minimum of 2.5V/cell (measured under load). Lower voltage than that may result in rapid deterioration of cell performance. It is generally desirable to provide a margin by cutting off current flow when voltage drops below 3V. Exhibit 3 shows that very little capacity remains below 3V. LiPoly cells do recover and a few minutes rest will restore some capacity.

The two most important discharging rules:

- Exceeding a 2C discharge rate will reduce cell life, and
- Never discharge below 2.5V/cell (measured under load).

Cell protection in most applications is to be provided by a **Protection Circuit Module (PCM)** described in “Protection circuits,” later in this manual.

Exhibit 5 shows how cell voltage is impacted by discharge rates higher than 2C. Cell voltage holds very well, even at discharge currents greater than 2C. This characteristic is important in designing protective circuits for cell discharge. If a Protection Circuit Module (PCM) permits a cell to sustain current higher than 2C for an extended period, cell damage will occur.

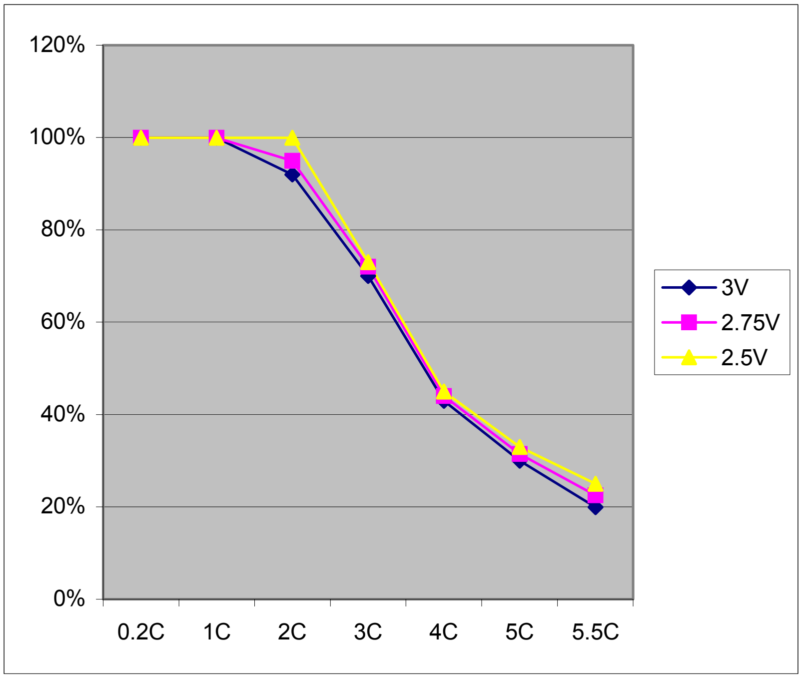

Exhibit 5: Impact of discharge rate on cell voltage

Exhibit 5 replots the data of Exhibit 4 to show the effect of selection of cut-off voltage. Clearly, the cell delivers maximum capacity if cut-off voltage is set for 2.5V. The user must also recognize that the precision of the cut-off must be accurate if the lower threshold is selected.

Short bursts of current drain greater than 2C are sustainable. However, cycle life may be shortened by such heavy use and the extent is not known. For specific applications, it is important to know what the current demand of the application is as measured using an ammeter or from calculated circuit current drain.

When an over-discharge condition exists, cell capacity is impacted as shown in Exhibit 4, if the condition is permitted to continue. However, removal of the overload does permit the cell to regain almost full capacity. Thus, cells can sustain brief periods of overload without apparent harm. Frequent or long periods of overload will shorten cell life.

When a cell is loaded for the initial period out to about 20% of capacity, voltage drop is from 4.2 at 0.1 C to 3.7 at 5C. At discharge rates up to the warranted 2C, voltage drop is not significant. However, as a heavy load is applied, voltage drop is significant. At up to 3C, the cells retain about of 85% of capacity. If cell configuration can be designed to operate at 2 to 3C, maximum, then performance can usually be sustained.

Because Kokam LiPoly cells weigh 1/5 as much as NiCds in a given capacity, a pack can be assembled by paralleling cells to deliver the required current. Unlike NiCds or NiMH cells[1], LiPoly cells can be discharged in parallel.

LiPoly packs can also be charged in parallel, without disassembling, provided you follow these guidelines:

- Packs must have the same rated capacity.
- Packs must have about the same level of charge *before* they are connected to the charger in parallel. (For example, do not charge two packs in parallel if one is at 80% of capacity and the other is at 10% of capacity.)

If packs are at different charge levels (or if you are not sure of their charge levels), use one of these techniques to prepare them:

- Charge the packs independently for a short time before charging them in parallel, or
- Discharge the packs to a voltage of 2.5 to 3.0V/cell before charging them in parallel.

[1] If capacities are carefully balanced, NiCd cells can be discharged in parallel.

Exhibit 6 is an aid to selection of cell capacity and pack configuration. Series-parallel packs not only increase the current capability by the multiples shown in Exhibit 4, this strategy also increases total capacity available.

ONE CELL							
Initial single cell capacity	**1C**	**2C**	**3C**	**4C**	**5C**	**Weight, g**	**FMA part no.**
45	45	90	135	180	225	2	KOK45
145	145	290	435	580	725	4	KOK145
560	560	1120	1680	2240	2800	12	KOK560
880	880	1760	2640	3520	4400	18	KOK880
1020	1020	2040	3060	4080	5100	21	KOK1020
2070	2070	4140	6210	8280	10350	44	KOK2070
3270	3270	6540	9810	13080	16350	64	KOK3270

TWO CELLS IN PARALLEL							
Initial single cell capacity	**1C**	**2C**	**3C**	**4C**	**5C**	**Weight, g**	**FMA part no.**
45	90	180	270	360	450	4	KOK45-1S2P
145	290	580	870	1160	1450	8	KOK145-1S2P
560	1120	2240	3360	4480	5600	24	KOK560-1S2P
880	1760	3520	5280	7040	8800	36	KOK880-1S2P
1020	2040	4080	6120	8160	10200	42	KOK1020-1S2P
2070	4140	8280	12420	16560	20700	88	KOK2070-1S2P
3270	6540	13080	19620	26160	32700	128	KOK3270-1S2P

THREE CELLS IN PARALLEL							
Initial single cell capacity	**1C**	**2C**	**3C**	**4C**	**5C**	**Weight, g**	**FMA part no.**
45	135	270	405	540	675	6	KOK45-1S3P
145	435	870	1305	1740	2175	12	KOK145-1S3P
560	1680	3360	5040	6720	8400	36	KOK560-1S3P
880	2640	5280	7920	10560	13200	54	KOK880-1S3P
1020	3060	6120	9180	12240	15300	63	KOK1020-1S3P
2070	6210	12420	18630	24840	31050	132	KOK2070-1S3P
3270	9810	19620	29430	39240	49050	192	KOK3270-1S3P

Exhibit 9: Capacity (mAh) and current delivery (mA) as multiples of capacity

Example: A 12 volt (10-cell) 3000mAh NiCd pack weighs 32 ounces and delivers the rated capacity. It will sustain brief periods of current at up to 10C (30A). By using three cells of 3270mAh LiPoly in series with two sets in parallel, brief periods of current can be drawn from the LiPoly pack at 5C (30A). However, total capacity available is

6740mAh at a pack weight of 13.6 ounces. With five three-cell LiPoly packs in parallel, then 16,350Ah is available in a 32 ounce pack.

The cells chosen may be sized for the application. Cells or packs of cells may be discharged in parallel. The discharge rate may be increased by paralleling packs during discharge; e.g., two 3Ah cells or packs in parallel can deliver twice the maximum allowable current that a single pack can deliver. Exhibit 7 plots the data from Exhibit 6, and will assist in selecting pack capacity and configuration. Performance can be extrapolated by adding parallel sections.

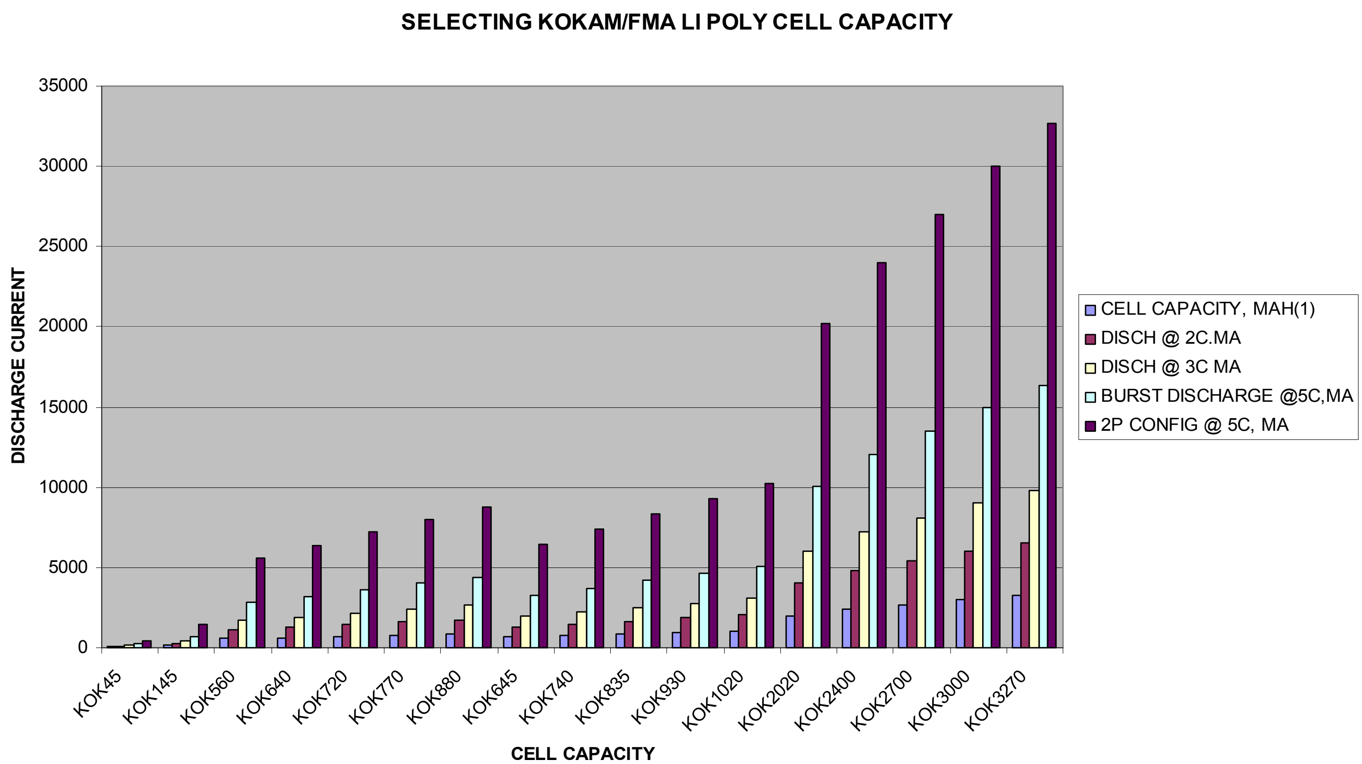

Exhibit 7: Discharge currents for various Kokam LiPoly cells

Exhibit 8 shows the effect of ambient temperature on capacity. Room temperature is typically 22°C (72°F). Elevating temperature to 45°C (113°F) has almost no effect on capacity. However, as with any battery chemistry, lower temperatures decrease capacity. In the example of Exhibit 3, lowering temperature to -10°C reduces capacity by about 20%. Application analysis for LiPoly must consider temperature effects.

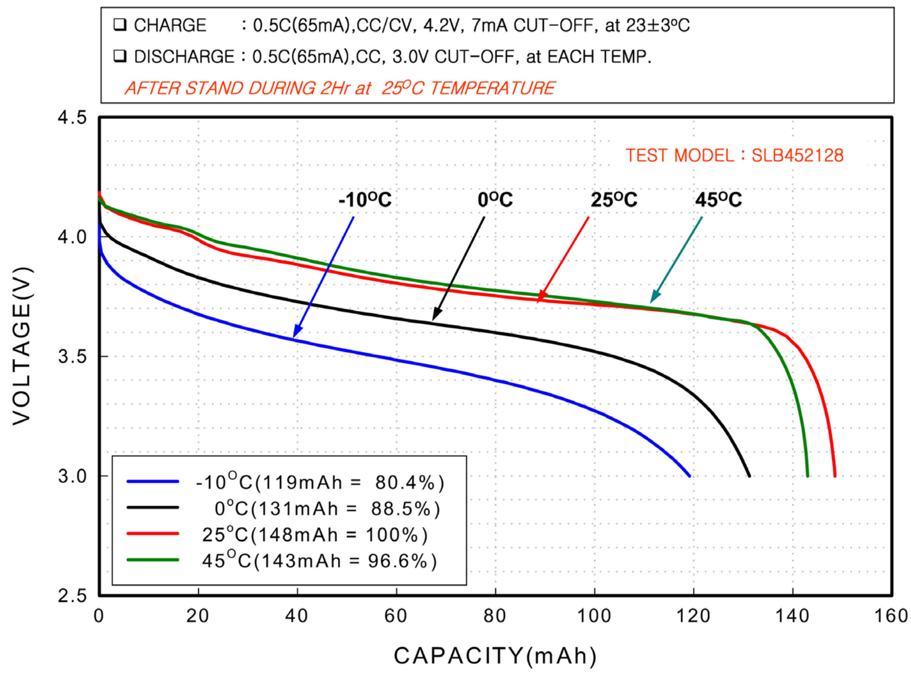

Exhibit 8: Impact of ambient temperature on cell performance

Life cycle characteristics

The ideal life cycle for any type cell is related to charge rate, discharge rate, storage conditions, and general maintenance. The ideal conditions for long life for any cell or battery is greatest when the cell is in a temperate environment, is charged at the ideal rate, never over-charged, never discharged at a rate over specification, and not physically abused. As a cell ages, it becomes more vulnerable to abuse. Even under ideal operating conditions, a cell ages because it is a chemical device.

Kokam cells are rated for life cycle under specification conditions. End-of-life is arbitrarily defined as loss of 20% of capacity. Exhibit 9 presents the measured and projected life cycle for a LiPoly cell from actual measurement. Deterioration is linear and the expected life cycle for the engineering sample is 600 cycles.

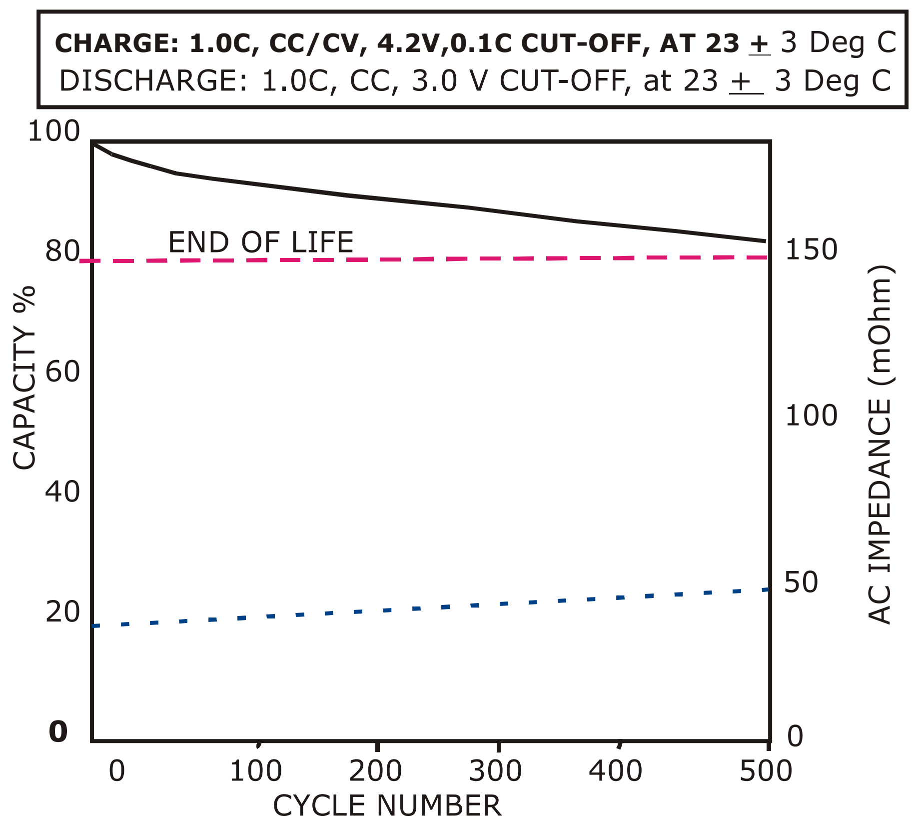

Exhibit 9: Life cycle measurements

Note, however, that LiPoly cells have about five times the capacity of a NiCd cell. Thus, a LiPoly cell undergoes 1/5 the number of cycles for a given time and load cycle, compared to a NiCd cell. It follows that the LiPoly cell will have five times the operating life of an equivalent NiCd cell.

If cells are operated outside the specification range, particularly at very high discharge rates, more rapid deterioration is expected. However, out-of-spec operation is not a normal condition and is not tested for evaluation *by any battery manufacturer*. At the user's own discretion and own risk, cells may be operated at higher discharge rates. Separate Application Notes address such operation and provide reasonable guidelines for out-of-spec operation.

Storage, self-discharge and memory

Besides significantly higher energy-density and greater safety, LiPoly cells enjoy two distinct advantages over other chemistries: low self-discharge rate and no memory effect.

LiPoly cells have a self discharge rate of about 5% in six months at room temperature (increasing to 10% in one month at 60°C). In contrast, NiCds can decay as much as 10% per day. Exhibit 10 shows the effects on charge retention of storage as a function of storage temperature. Loss of retention for the first cycle after storage is greatest at elevated temperature.

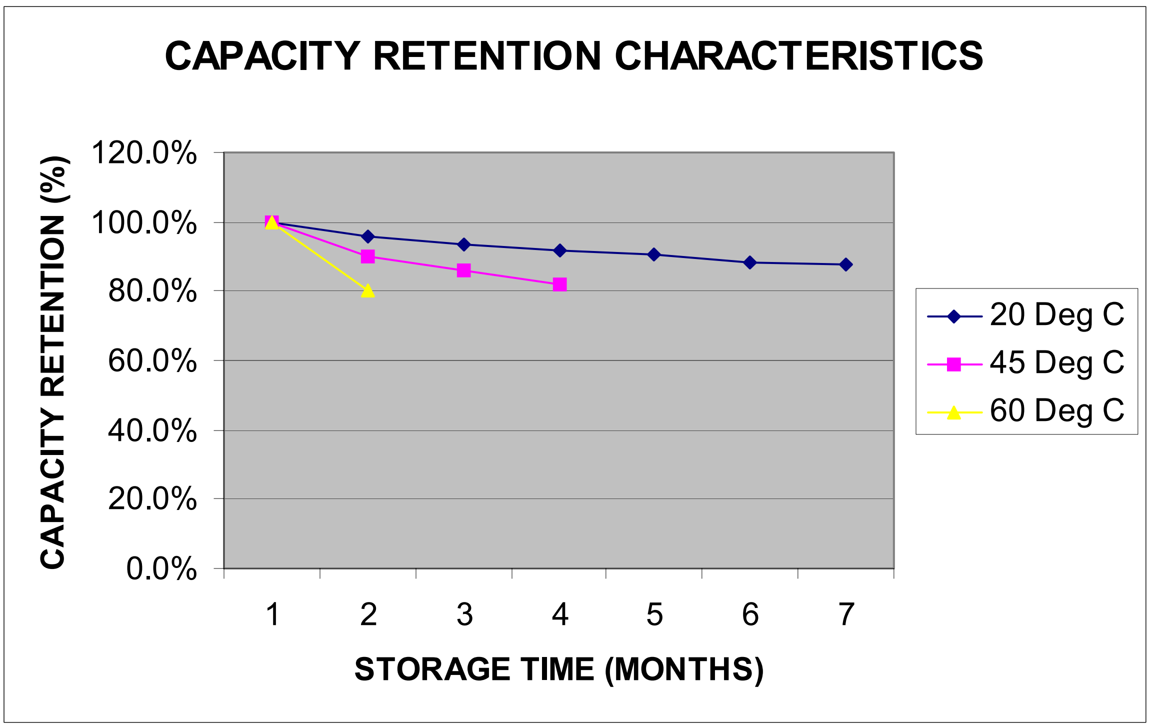

Exhibit 10: Capacity retention at various temperatures

The guideline for applications is to store cells in a temperate environment whenever possible. Exhibit 11 shows clearly that LiPoly cells have very good recovery characteristics when cycled after storage at elevated temperature. The design guideline here is that it might be desirable to cycle a cell for up to three cycles before placing it in service after storage at elevated temperature.

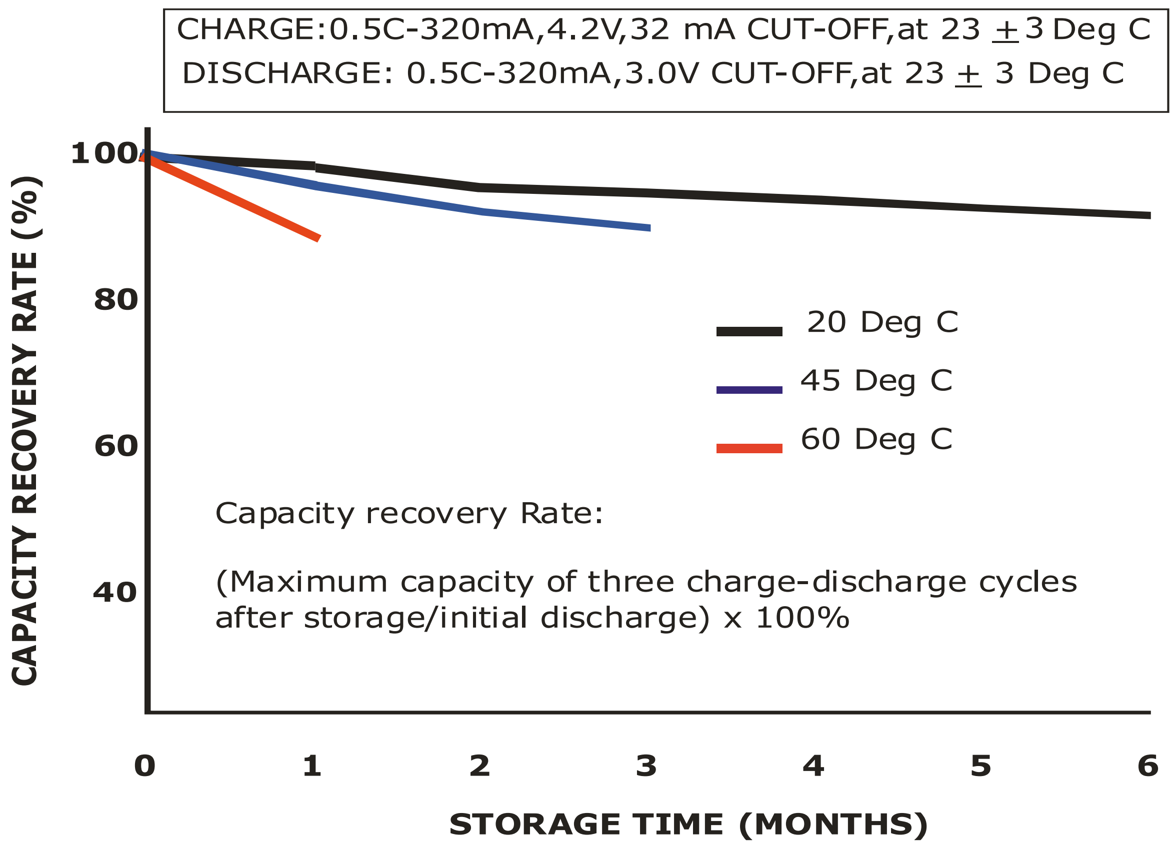

Exhibit 11: Effect of recharging on recovery characteristics

Exhibit 11 shows that storage at room temperature enhances charge retention. Clearly, storing the cells in a cool environment is an alternative to cycling to restore capacity from storage at elevated temperature.

Under any storage conditions, LiPoly cells have vastly better charge retention than other battery chemistries. As seen in Exhibit 10, retention of 95% of capacity after 6 months storage at room temperature is vastly superior to loss of 10% per day for NiCds.

Kokam cells are shipped with a 50% charge and should receive charge to full capacity with the appropriate charger before use. LiPoly cells may be stored at full charge or discharged to 50% capacity for storage. It is desirable to store the cells at room temperature as shown in Exhibit 10 unless cells will be cycled before use in packs.

LiPoly cells don't have the memory effect exhibited by NiCds. This assures consistent capacity after charging, throughout cell life.

Safety

Exhibit 12 summarizes the test conditions and results for UL approval of the Kokam Lithium Polymer cells. Users should note that modern storage cells such as NiCd, NiMH, LiIon, and LiPoly have very high energy density, with LiIon and LiPoly being the highest.

Item	Test	Battery state	Battery condition	Test method	Results
Vibration	0.8mm / 10-50 Hz (90-100 min)	Charged	Fresh	UL1642 SBA G1101	No explosion No fire No deformation
Forced discharge	1.0C mA for 2.5h	Discharged	Fresh	SBA G1101	No explosion No fire
Short circuit	1.3mm square Cu wire	Charged	Fresh	UL1642	No explosion No fire
Nail penetration	5mm nail	Charged	Fresh	SBA G1101	No explosion No fire
Crush	13Kn pressure	Charged	Fresh	US1642 SBA G1101	No explosion No fire
Overcharge	0.5C mA	Discharged	Fresh	UL1642	No explosion No fire

Exhibit 12: Kokam LiPoly safety specifications

A selected sampling of each lot of cells is subjected to such abuse to confirm safety. LiPoly cells will swell and suffer reduction of performance under most of those conditions. However, the user must treat all types of cells with caution and observe the following guidelines:

1. If a cell is penetrated, electrolyte may leak and can contaminate the skin. The solvents used in the electrolyte are an irritant to the skin and eyes. Any such contamination should immediately be washed with clean water.

2. If a PCM in the pack is damaged by external shock or if the PCM should fail, the cell could be driven outside specification conditions and cell damage can occur. Periodic inspection of the cells and PCMs is recommended.

3. Never place an unprotected cell in your clothing pockets. Keys or other metal objects may short the terminals resulting in extremely hot metal that can cause fire and burn the skin.

4. When working with high discharge capacity sources of electricity, remove all jewelry, particularly gold rings. A short across a gold ring can vaporize one’s finger instantly.

5. Do not exceed the maximum specified discharge current.

6. Do not exceed 1C charge current.

7. Do not puncture or abrade the cell envelope. At minimum, capacity will be lost, and fire may result if the cell is also discharged at a very high rate.

8. Use only chargers designed for LiPoly or LiIon cells, and be certain that the charger is designed to charge at the current and voltage level for the pack to be charged.

9. Do not store cells near an open flame or heater. Very high temperatures may cause cell separators to melt and short.

10. Do not use LiPoly cells in series or parallel with other type cells.

11. When using LiPoly packs in parallel, all cells in a pack must be the same capacity.

12. Use only Protection Circuit Modules (PCMs) approved for use by Kokam.

13. If cells are to be stored for more than one month, discharge the cells to 50% to 70% of capacity before storage. Remember, LiPoly cells self-discharge very slowly, so do not depend on self discharge to achieve the 50% charge level.

14. If charging is not complete—even though the specified maximum charge time is exceeded—stop the charge and determine the cause before using the cells.

15. Cell polarity is identified on each cell. Damage to circuitry may occur if polarity is not correct.

16. If the terminal tabs are bent 180 degrees, be certain to use insulating tape between the tabs and the aluminum lamination; otherwise, the cell may short across the aluminum.

17. Do not bend or deform cells, as this may cause internal damage.

18. Make series or parallel connections only after consulting the appropriate Application Note and observing the general guidelines presented in “Assembling multi-cell packs,” later in this manual.

19. LiPoly cells are environmentally friendly and no special precautions are required for disposal. Discharge cells before disposal to prevent a fire hazard if the cell becomes shorted.

Unlike Li Ion cells, LiPoly cells do not explode when vibrated, overcharged, over-discharged, short circuited, or penetrated. Exhibit 13 presents visual evidence of the safety of LiPoly cells subjected to deliberate damage.

Exhibit 13A: Crushed cell

Exhibit 13B: Overheating

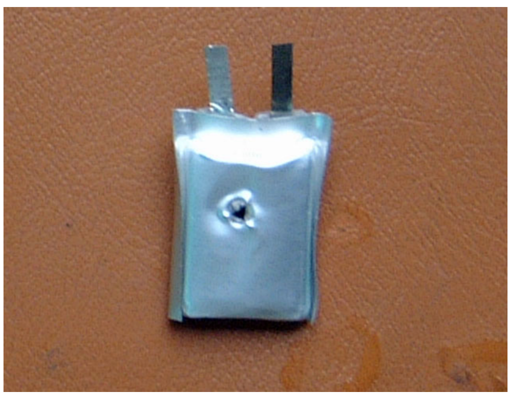

Exhibit 13C: Penetration

Exhibit 13D: Impact

Protection circuits

Kokam cells may be purchased with a Protection Circuit Module (PCM) for general application to an individual cell or to cells in series. Exhibit 14 presents the general schematic diagram for a PCM for a single cell.

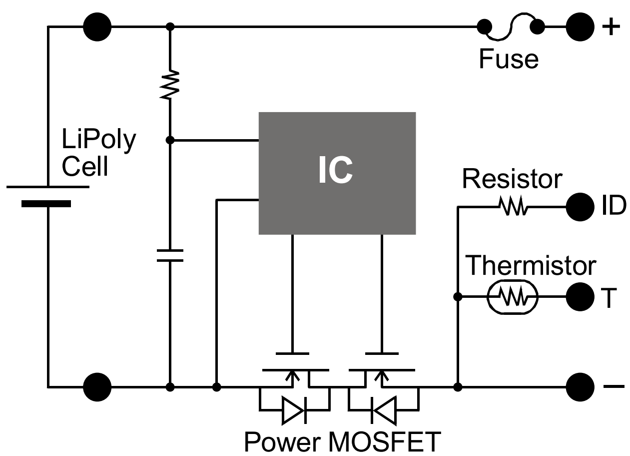

Exhibit 14: Schematic for Protection Circuit Module (PCM)

It is important to understand how the PCM works and what it does to protect the cell. PCMs were originally developed for LiIon cells, which tend to explode when subjected to the conditions described below. Protective circuits may also be built into products designed for LiPoly cells to ensure that an unprotected cell is not inadvertently installed.

A LiPoly or LiIon cell will be damaged:

- When cell voltage drops below 2.5V absolute minimum (although 3V is the recommended minimum) either due to normal discharge or when the load applied is so great that cell voltage drops below 2.5V for more than a brief period.
  or
- When the applied charge voltage is more than 4.235V per cell.

The PCM is wired in-line with the negative terminal of an individual cell. The sensing IC is connected to and senses the voltage at the positive terminal of the cell. The cell is an integral part of the circuit. When too large a load is imposed on a LiPoly cell (as illustrated in Exhibit 4), cell voltage drops because of the internal resistance of the cell. As long as the current demanded is at or close to 2C, cell voltage does not drop appreciably. As current demand increases, cell voltage drops as shown in Exhibit 4. At some point between 4C and 6C discharge rate, cell voltage can drop rapidly to 2.5V and the PCM cuts off current flow.

The IC is an Application Specific Integrated Circuit (ASIC) developed specifically for protecting cells and batteries. It has internal cell voltage sensing and logic to command shut-off. The cut-off switch is a dual-Field Effect Transistor (FET) device. During operation, current flows from the positive battery terminal through the load, through the steering diode on the right, *through the left FET* and to the negative terminal of the battery. The sensor in the IC shuts off the left FET when sensed cell voltage declines below 2.5V for either of the above reasons. Logic holds the right FET off during cell discharge.

During charge, current flow is reversed. The left FET is held off by IC logic, and the right FET is on so that charge current flows from the charger, through the cell, through the left steering diode and to charger ground via the right FET. If charge voltage exceeds 4.235V, IC logic turns off the right FET to control current flow.

It is important to understand that the PCM does not function to control current; that is, it operates on cell voltage only. The cell can deliver considerably more than 2C current before the PCM shuts down. Therefore, it is important to know the application's current demand so that current flow can be maintained at ≤2C. Pack voltage and cell capacity must be selected to match the load requirements.

Any PCM used on a cell must have be able to conduct the amount of current the circuit demands and that the cell can deliver. The PCM in general use by Kokam, et al, is designed to handle 2.5A. This means it *could not* handle the current, for example, that a 1.575Ah or larger cell at 2C could deliver. Designs are in process as of this writing that can handle significantly more current. If the user wants to include a PCM in a circuit or in a LiPoly pack, it would be necessary to use separate FETs or a dual FET package that can handle the current desired and to conduct tests to assure that the logic of the ASIC can drive those FETs.

It is mandatory that LiPoly cells have a PCM on each cell or pack for all applications, with the exception of remote control models or medical use where current cut-off is intolerable, even if the cell may be damaged.

In the special case of medical equipment, it is mandatory that the potential user contact Kokam engineers or a Kokam agent before any such application is considered.

For the special case of model craft, two specific applications are extant:

- Use as primary power for the receiver and servos in non-electric powered models (engine powered, gliders, cars, boats, toys, etc.).
- Use as motive power for electric powered models.

In general, neither class model should have power to the receiver and servos interrupted by a PCM. In the first case, the pack must have an appropriate aural or light warning of impending under-voltage to prevent loss of a model with possible harm to equipment and/or personnel. This is not a new consideration: over the years, more model airplanes have been lost to "one last flight" than to any other cause.

In the latter case, power must remain available to the receiver and servo, but must be terminated either by a special PCM, manually by retarding throttle based on run time, or by an electronic speed control (ESC) specifically designed to cut off motor power when under-voltage is imminent. Design criteria and specifications for such devices are covered in Application Notes separate from this manual. Appropriate devices are available from stock as catalog items from FMA.

Assembling finished individual cells

Kokam LiPoly cells are available with tabs that may be soldered or welded to appropriate connecting devices or pc board(s). Cells with pc terminals already attached are available (these cells are identified by a suffix **T** in the part number; e.g. KOK145T).

Note that solder will adhere only to one side of the tabs: the side of the tab on the same side as the + and – markings. The negative tab has a nickel-plated strip welded to the negative terminal.

To solder directly to the bare tabs:

- Use an iron with adjustable temperature or with 25 watts capacity.
- Make sure the solder tip is clean.
- When connecting directly to bare tabs, use very flexible wire to minimize bending of the tabs. Highly flexible, high strand-count wire in appropriate gauges is available from FMA Direct (go to **Store > Wiring** at www.fma.direct.com).
- With the cell lying flat or held in a jig, support the tab so that application of the solder tip and solder do not bend the tab markedly.
- Tin the tab, then solder a connecting wire or terminal to the tab. Minimize the application of heat to just that needed to reflow the solder to prevent melting the cell's plastic envelope.
- If soldering to bare tabs, secure the tabs from cyclic bending by insulated mechanical means.

If the cell has pc terminations, use normal soldering techniques. If the customer elects to weld the tabs, the tabs should be secured from periodic bending that can break them.

Secure the cell from physical abuse by enclosing it in a heat shrink envelope or by enclosing it in a molded plastic housing.

Application Notes will cover typical assembly configurations and techniques.

Assembling multi-cell packs

Standard multi-cell series-connected or parallel-connected packs may be purchased as catalog items. See "Ordering information, the last section in this manual, for details.

Retail customers may build custom packs and most OEM customers will want to build custom packs.

Recommendations for assembling multi-cell packs:

- Use bare cells.
- Use pc boards to make connections.
- Solder or weld tabs to the pc board(s).
- Design pc boards to make parallel or series connections as needed. Assure pc traces have the thickness and width to support the maximum expected current flow.
- Select connecting wire gauge so that no temperature rise occurs at the rated current. (Temperature increase in a wire indicates that the wire is resisting flow and creating a voltage drop.)
- For high-current packs, separate cells by 1 to 2mm to permit air circulation for cooling.
- Secure a pack using shrink wrap, or enclose it in an appropriate housing.
- Include a PCM in the pack, or add protection circuitry to the product's circuit. Depending on product design, the charger may require protection circuitry.

Application Notes will cover additional pack assembly techniques.

Design assistance is available from FMA, Inc.

Maintenance

Kokam/FMA LiPoly cells are virtually maintenance-free if assembled and protected as recommended. Follow these guidelines:

- Store cells and packs in a clean, dry environment. Prevent exposure to corrosive materials. Maintain moderate temperature and humidity.
- Visually inspect cells periodically to assure that a cell is not swelling or suffering abuse.
- Discard cells that deteriorate to 80% of capacity.

Measure capacity using a battery management system, such as the FMA Einstein battery management system. When using Einstein, program the discharger for three NiCd or NiMH cells per LiPoly cell. Using this ratio, LiPoly cell discharge stops at 2.7V (that is, 3 x 0.9V, where 0.9V is the cutoff for NiCd cells). This limits discharge to 0.2V above the minimum cutoff per LiPoly cell, as shown in Exhibit 15, below.

NiCd / NiMH				**LiPoly**				**All**
No. cells	Nominal voltage	Peak charge	Desired discharge cut-off	No. cells	Nominal voltage	Peak charge	Desired discharge cut-off	Use for cut-off
1	1.2	1.4	0.9					0.9
2	2.4	2.8	1.8					1.8
3	3.6	4.2	2.7	1	3.7	4.2	2.5	2.5
4	4.8	5.6	3.6					3.6
5	6	7.0	4.5					4.5
6	7.2	8.4	5.4	2	7.4	8.4	5.2	5.4
7	8.4	9.8	6.3					6.3
8	9.6	11.2	7.2					7.2
9	10.8	12.6	8.1	3	11.1	12.6	7.5	7.5
10	12	14.0	9					9
11	13.2	15.4	9.9					9.9
12	14.4	16.8	10.8	4	14.8	16.8	10	10

Exhibit 15: Peak charge and minimum discharge voltage versus number of series-connected cells

Product configurations and ordering information

High volume OEM customers

Single cells in all available capacities may be purchased in large quantities. Additionally, custom cells and battery packs for OEM applications can be designed and manufactured, subject to certain minimum order quantities. As Kokam's agent for North and South America, FMA, Inc. works directly with OEM customers. In this role, FMA:

- Helps OEMs determine requirements and address design issues for LiPoly applications.
- Works with Kokam to define manufacturing details.
- Provides price quotations to OEMs.
- Accepts purchase orders from OEMs on behalf of Kokam.

Stock and custom LiPoly products are manufactured by Kokam in Korea and shipped directly to the customer.

To discuss OEM applications and arrangements, send your application requirements by e-mail to sales@fmadirect.com , or call 800-343-2934 or 301-668-7614.

Low volume and hobbyist customers

FMA Direct stocks LiPoly products in several forms, described in this section. Order stock products on the FMA Direct web site at www.fmadirect.com under **Store > Kokam USA**. The Kokam/FMA catalog is also available on the web site.

FMA Direct stocks cells and packs in these capacities: 45, 145, 560, 880, 1020, 2070 and 3270 mAh.

Single cells

Single cells are offered in all stocked capacities. They can be used individually, or assembled into multi-cell packs by the user. Single cells have pc terminals. The terminals facilitate soldering, making it easy to assemble cells into packs, and to attach wires.

Cells without pc terminals are available in limited quantities. These are stocked primarily for sampling to OEM customers.

Radio control receiver packs

Battery packs for powering radio control receivers/servos are offered in all stocked capacities. Each pack has two cells in series (2S configuration) to provide 7.4V nominal output. The attached twisted pair wire and standard FJ universal radio control connector enable these packs to be used with virtually all RC flight systems.

> **Note:** Radio control receiver packs must be used with the voltage regulator/LED indicator module described in "Related products," later in this section.

Radio control power packs

Battery packs for powering motors/receivers/servos in radio-controlled electric models are offered in most stocked capacities. Three output voltages are available:

- 3.7V nominal (one cell; 1S configuration).
- 7.4V nominal (two cells in series; 2S configuration).
- 11.1V nominal (three cells in series; 3S configuration).

Connectors on these stock battery packs depend on capacity:

- Low capacity packs (45 and 145mAH) have a micro power connector (-125MM) with 1.25mm pin spacing.
- Medium capacity packs (560 to 1020mAh) packs have a Molex locking connector (-3MM) with 3mm pin spacing.
- High capacity packs (2070mAh and up) packs have a Deans Ultra connector (-DNS).

Pack configuration

All packs are assembled as a stack consisting of individual, flat, rectangular cells separated slightly by double-sided tape to allow cooling. A printed circuit cell inter-connector board is mounted to the terminal end of the pack and the solder tabs are attached to the board to establish a series or parallel connection as appropriate. The pc board provides excellent protection for the tabs.

The assembly is housed in a tough, heat-shrink sheath. All stock packs have an output wire and connector (see descriptions earlier in this section). Parallel connections between packs can be made using external connections (as described in "Assembling multi-cell packs").

Related products

- Voltage regulator/LED indicator module for radio control receiver packs. Connected between the switch harness and receiver, this module supplies 5V (regulated) to the receiver. The three-color LED provides an indication of battery charge level: high (green), moderate (yellow) or low (red).

- PC terminals in for serial and parallel connections. Using pc terminals, customers can assemble cells and packs in configurations suitable for a wide range of radio control and other applications.

- Chargers optimized for LiPoly cells and packs.

Part numbering

The basic part number scheme is as follows:

- All cells are designated as KOK with the capacity in mAh as the number. Example: KOK145 has a capacity of 145mAh.

- If the basic cell is to have a pc terminal for soldering of individual cells, add the suffix T to the basic part number; e.g., KOK145T.

- If the basic cell is to have a protective circuit mounted on it, add the suffix P; e.g., KOK145P.

Part number details for cells and battery packs are shown on the next page.

Part number scheme for individual cells

KOK = Kokam LiPoly cell

cap = capacity in mAh, selected from this list:
45 145 560 640 720 800 880 1020 2070 2400 2700 3000 3270

x = terminal type, selected from this list:
[blank] = bare solder tabs
T = printed circuit solder terminals
P = Protective Circuit Module (PCM)

KOK [cap] [x]

Examples

- **KOK45** is a 45mAh cell with bare solder tabs
- **KOK145T** is a 145mAh cell with printed circuit solder terminals
- **KOK560P** is a 560mAh cell with PCM

Part number scheme for battery packs

KOK = Kokam LiPoly cell

cap = capacity in mAh, selected from this list:
45 145 560 640 720 800 880 1020 2070 2400 2700 3000 3270

n = number of single cells in series in the pack
S = series connected

np = number of parallel packs in a series-parallel pack
For packs in the catalog, **np** is 1 or 2
P = parallel connected

conn = connector type, selected from this list:
[blank] = no connector
125MM = 1A micro power connector
D3P = Deans 3-pin
3MM = 5A, 3mm power connector
DNS = Deans Ultra
BLT = Bullet
TAM = Tamiya
FJ = RC industry standard 3-pin connector

KOK [cap] – [n] S [np] P – [conn]

Examples

- KOK3270-3S1P-DNS is a 3-cell pack consisting of three 3270mAh cells in series with Deans Ultra connector; output is 12.6V, 3270mAh
- KOK1020-2S2P-D3P is a 4-cell pack consisting of two parallel sets of two 1020mAh cells in series; output is 7.4V, 2040mAh
- KOK45-2S2P-125MM is a 4-cell pack consisting of two parallel sets of two 45mAh cells in series, with 1A micro power connector; output is 7.4V, 90mAh
- KOK880-2S1P-FJ is two 880mAh cells in series, with FJ-style connector; output is 7.4V, 90mAh; typical application is flight pack for gliders, engine-powered models, or any application requiring two cells in series; for model use, a 5-6V regulator is required as part of the power harness