B.C.E. ELECTRONICS

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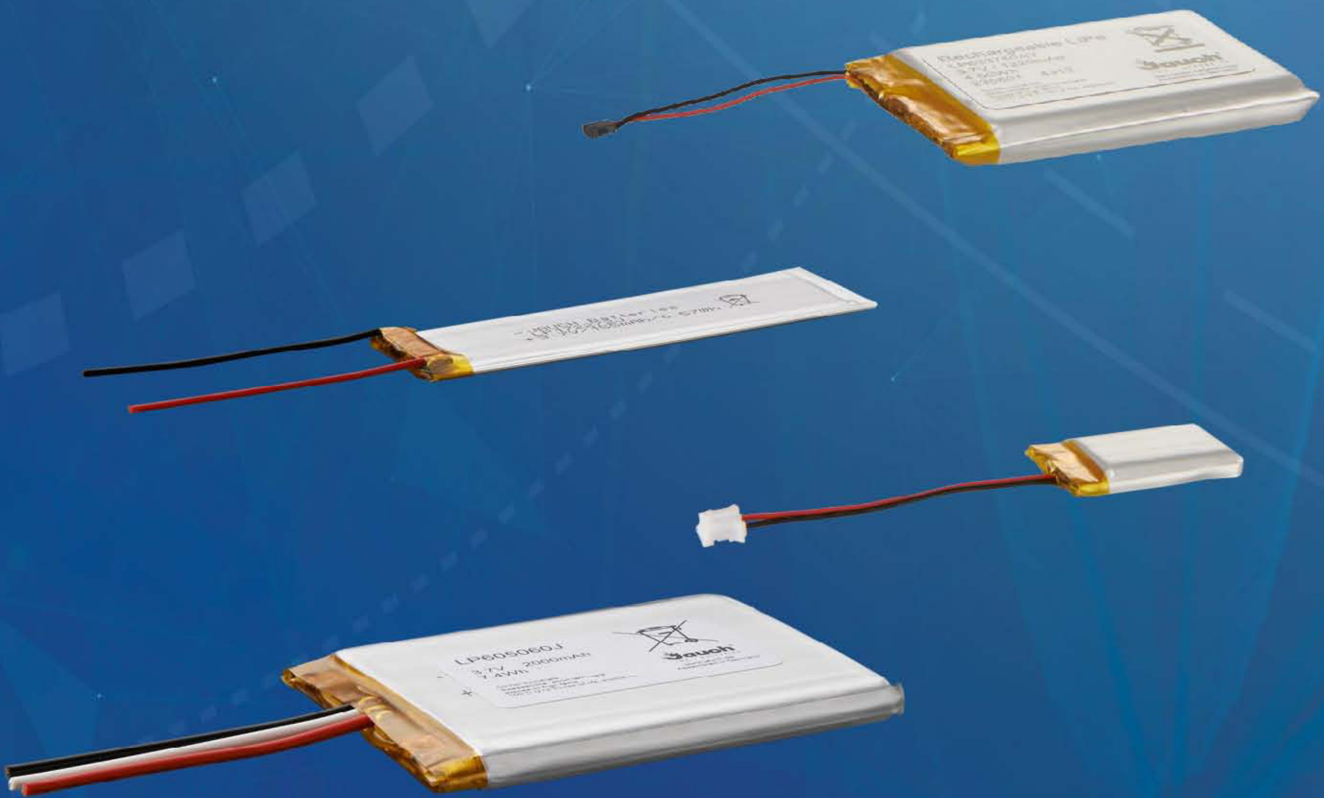
White Paper

Guide to the design of Lithium Polymer Batteries



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Options for product design

A standard battery cell fits into any compatible battery compartment. Standards and uniform dimensions will therefore apply. With lithium polymer batteries, the situation is somewhat different. The batteries can be integrated into almost any housing. Their structures, sizes and capacities vary – which is liberating when it comes to the design of the product itself. For that reason, defining the relevant parameters becomes all the more important. To get the design of the battery correct, the supplier of the Li-polymer batteries needs some parameters, which include information on the safety electronics (PCM, BMS). The assembly must then be precisely planned. This white paper serves as a guide for product developers during key project phases.

fig. 1. Lithium polymer batteries vary in size and design and can therefore be integrated into almost any housing. Image: Jauch

I. Considerations when using lithium ion/polymer technology

More and more manufacturers of battery-powered products are relying on energy sources based on lithium ion/polymer technology. The advantages speak for themselves: Lithium has a higher energy density and cell voltage than previously used materials. The application can run longer or with more power. The high number of charge/discharge cycles and the long service life are other benefits of lithium technology.

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Li-polymer batteries are particularly popular. They can be designed to be extremely small, flat, lightweight and formed into almost any shape. Their casing is made of laminated aluminum foil. These factors grant a great deal of freedom in the design of the final product. If given the necessary information, a competent supplier such as Jauch can quickly come up with the appropriate solution: the mounting form, the cell design, and the capacity.

Because of the high energy density, however, lithium ion/polymer technology also carries potential risks. This applies primarily to the manufacture and transport of the batteries or of the end product that includes the batteries, as well as to the later use.

Further questions exist with regard to:

- environmental, temperature, application and operating conditions
- electrical parameters and safety criteria
- design, case construction
- handling during transport and production

All these points play a role in product development. To clarify the framework conditions, the manufacturers of battery-powered devices and the battery assemblers should cooperate at an early stage. How should they go about it, and which points need to be dealt with?

II. Application-specific data

First, product designers should create a detailed specification sheet for the desired energy storage. Data, dimensions, parameters, etc. must be worked out for seven key points.

Ideally, battery developers/suppliers need this information early in the project. Having that information allows the cells to be selected correctly and the batteries to be laid out precisely. But even in advanced project phases, experienced assemblers such as Jauch can help in selecting and designing batteries.

The seven points:

1. **Voltage:** The nominal single-cell voltage for Li-polymer cells is 3.6V, on average; the charge cut-off voltage is 3.0V; and the maximum charging voltage is 4.20V. On the market there are also cells with charging voltages of 4.35V and 4.40V. The required voltage should be defined.

   If a higher voltage is required, a series connection is possible. The mean voltages can then be represented by the factor N x 3.6V. This information is needed to design the electronics safely. For higher capacities, cells can also be connected in parallel.

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2. **Currents:** For discharging, the mean continuous currents should be given. The maximum pulse currents and the pulse lengths must be specified. The inrush currents and their lengths of duration in applications must be taken into account.

   Ideally, the current power load profiles of the application, taking temperatures into account as well, would be presented. The field of application and the prevailing temperature and environmental conditions play an important role. Low temperatures and higher currents lower the voltage level.

   The relationship between charge and required or desired currents must be taken into account. In principle, charging proceeds by the technical principle "constant current/constant voltage".

3. **Temperature:** The temperature conditions in the application area as well as during charging and discharging must be determined. This is necessary for cell selection and for possible adjustments. By default, Li-polymer batteries of today meet specifications for, among others, the following temperature ranges:
   a. Charging: 0°C to +45°C
   b. Discharging: -20°C to +60°C

   High and low temperatures affect the capacity. This must also be taken into consideration.

   For an extended temperature spectrum, special high-temperature cells, for example, are available. Similarly, some cells have been developed for lower temperatures or for higher currents.

4. **Dimensions:** To lay out the batteries correctly, the supplier must know the maximum dimensions of the installation space. Here it should be noted that Li-ion and Li-polymer cells swell up slightly over time. Over their lifetime, they can grow up to 10% thicker. The cause of this is related to chemical degradation. A further white paper from Jauch covers this aspect.

   Even the degree of charge (30% or 60% on delivery and 100% after a full charge) affects the cell thickness and therefore the dimensions of the installation space. When specifying the maximum thickness after cycles, the degree of charge is always assumed to be full.

5. **Capacity:** Armed with the data from points 1-4, the supplier can then define a cell and so determine the capacity of the battery.

   Experience shows that when new devices are designed the power source or battery is often neglected at first. Under some circumstances, this may result in the batteries requested later being unavailable or even impossible to execute.

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It is recommended that the requirements with regard to voltage, current and capacity be determined or specified as early as possible. The running time of the device, for example, depends on the temperature conditions and the current load.

The battery supplier should therefore be contacted during the design phase. The supplier can help find the right power supply and draft it into the plan.

6. **Safety:** The parameters for the design of the protection electronics or safety circuit (Battery Management System = BMS, Protection Circuit Module = PCM) are of great importance. Deep discharge, short circuits and excessive currents and overcharging must be prevented.

   In this context, the supplier needs information about the current profile and the potential voltages desired during switch-off. The internal resistance of the battery should be known.

   For multi-cell batteries, a BMS with fuel gauging, balancing and communication via SMBus and I^2C is recommended. This creates a "smart battery". Information on this can be offered by Jauch via direct communication with our experts.

   Which standards, approvals and certifications have to be observed (see below) must also be checked.

7. **Other information:** For softpacks that have protection circuit modules (PCM), cables and plugs, the parameters of the PCM should be precisely defined. (See point 6.) Alternatively, a standard PCM can be selected.

   It should also be specified whether a Negative Temperature Coefficient (NTC) should be taken into account. Standard parameters for resistance and temperature are: 10 kOhm 1%, Beta value 3435 1%. Alternatives can also be specified.

   Information about the cables (AWG, UL) and connectors (type, manufacturer) is also needed.

   For packs with plastic housings the dimensions, position of the contacts, etc., should be worked out together with drawings. It is best to use three-dimensional CAD data.

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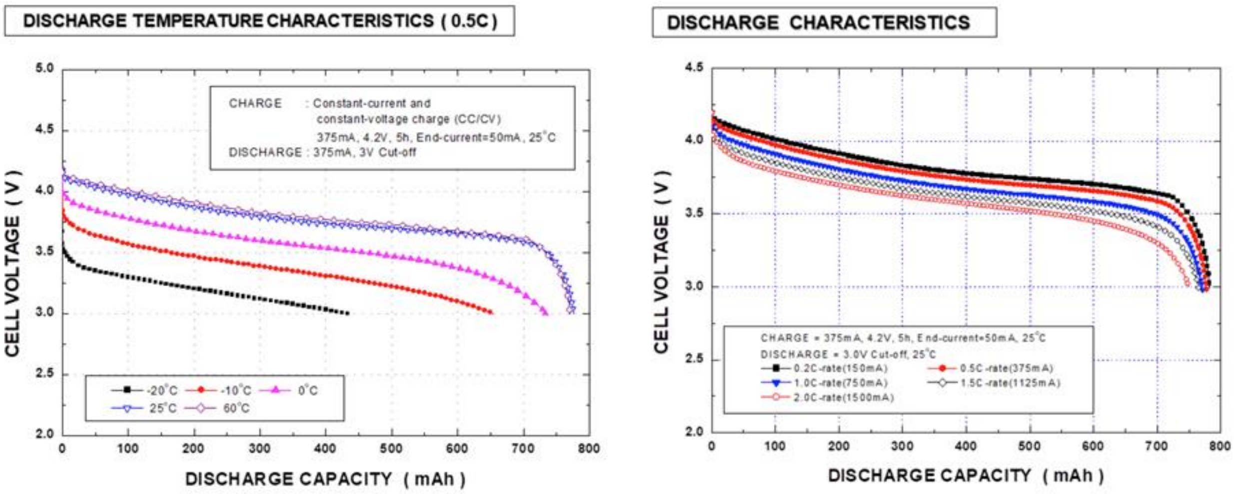

fig. 2. Relationships between capacity, discharge, voltage and temperature conditions, which are to be differentiated among in the selection of cells and design of batteries. Diagram: Jauch

III. Construction of the battery compartment

There are seven important points to consider when designing the device housing and battery compartment:

1. **Fixed mounting:** Soft packs should be used, in principle, only as permanently installed batteries (batteries that cannot be replaced by the customer). There is a risk that the film housing will be damaged during installation or removal.

2. **Tolerance:** The battery compartment should be large enough to allow installation without mechanical stress or damage.

3. **Swelling:** The mentioned expansion must always be taken into account. For this, a corresponding clearance is to be built into the battery compartment.

4. **Smoothness:** Sharp edges or burrs should be avoided or smoothed out. The battery cover must not be damaged.

5. **Isolation:** Metallic parts should be separated from the battery by insulation films. Insulation films should also be inserted between PCB and device components.

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6. **Fixing:** For applications with high mechanical loads (rotation, shock) the battery should be fixed in place. Components of the pack should be prevented from moving.

7. **Hot Spots:** Li-polymer cells are relatively temperature-sensitive because of the material they are made of. The battery compartment should therefore be designed in such a way that no hot spots are in contact with or near the cell while applications are running.

IV. Handling lithium polymer batteries

Careful handling is one of the most important issues in the transport and installation of lithium-polymer batteries.

The following instructions are meant to protect the batteries and equipment that they are installed in:

1. The batteries should be transported in safe and stable trays. The assembler usually provides them as part of the delivery.
2. The batteries should also be transported in the trays while the devices are being produced or until they are made available on the production line.
3. Li-polymer batteries must not be placed or stored on metallic surfaces.
4. Short circuits and excessive storage temperatures must be avoided.
5. Damage caused by tools during installation must also be avoided.
6. Mechanically damaged batteries must not be used.

fig. 3. Suitable trays are used to transport lithium-polymer cells safely.
Image: Jauch

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V. Laws, standards, certifications

Many national, European and global laws, standards and certifications apply to batteries – especially Li-ion/polymer batteries. Some of them must be considered as early as the product and battery design stages. Regulations can also play an important role in production, logistics and disposal. The focus is on the protection of users and the environment and on the recycling of valuable raw materials

It is important to work together with an assembler such as Jauch as early as possible in the design phase of the final product. Jauch is familiar with the risks and regulations and can monitor your project. This means advising the manufacturer not only in terms of safety and battery performance, but also in terms of compliance.

The necessary, compulsory or optional verification should be worked out together, during the project phase. Corresponding processes must be carried out by the assembler or battery supplier.

Important compliance topics are:

1. **Transport test:** The UN38.3 Transport Test is the world's mandatory United Nations safety test for Li-ion batteries. A product may be transported by road, rail, ship or air only with the appropriate documentary evidence. In this test, potential hazards arising from the battery are checked.

2. **Transport regulations:** Other standards such as ADR, IATA, RID, IMDG regulate shipping by different modes of transport. The standards contain regulations for the transport and packaging of batteries.

3. **UL-certification:** It is recommended to use cells that are undergoing or will undergo UL1642 testing. The test must be carried out according to the instructions of Underwriter Laboratories (UL). UL 2054 can also be stipulated for battery packs.

4. **IEC-certification:** The IEC62133 test is a certification procedure of the International Electronic Commission (IEC). As with UL1642, these tests go beyond the requirements of the UN test, to ensure the safety of the battery.

   Based on IEC standards, a CB procedure can also be carried out and a CB report can be created. The CB seal facilitates market access in many countries. It can be used directly or rewritten into national test marks with no further testing.

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5. **Explosion protection:** If the product is used in potentially explosive atmospheres, the entire device including the battery must be ATEX-certified. The battery must therefore meet certain requirements.

   Not every cell is suitable, as every danger must be excluded. Here, too, the expertise of an experienced assembler such as Jauch, who has already managed corresponding projects, comes in useful.

6. **Industry-specific tests:** Application of the product in specific industries may require further testing. Medical devices, for example, have various certifications to ensure that the product meets additional safety requirements when used on or in humans.

7. **Further tests and certifications:** In addition, there are other optional or mandatory tests and certifications that are not uniformly regulated worldwide (for example, KC, NEMA, SAE, IEEE, and JIS). The assembler/supplier of the batteries should clarify the situation to the customer and provide competent assistance in matters of compliance.

8. **Legal requirements:** In addition, many statutory obligations regarding batteries must be met. These include the German Battery Act (BattG), the rules of CE conformity, and the requirements of the RoHS and REACH regulations. The suppliers must prove that they fulfil the relevant requirements.

9. **Quality management:** All battery manufacturers must provide evidence that they work under a quality management system (QMS). Relevant norms: ISO 9001, ISO 14001. Adherence to these norms ensures that samples and series of batteries are manufactured in consistently high quality.

   The UN38.3 transport test requires mandatory proof of QMS. This concerns cell manufacturers and assemblers.

10. **Staff training:** The responsible employees of the supplier should be trained according to the IATA Dangerous Goods Regulations (IATA/ICAO - TI) and be able to confirm this training. They must know how to pack and label lithium batteries into or using equipment for transport in accordance with the regulations, what accompanying documents are required, and how to correctly prepare these documents.

    Regular further qualification should also be demonstrated.

11. **Disposal:** The supplier may have to offer or secure the return and proper disposal of the batteries. This point should also be queried during product development.

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12. **Corporate Social Responsibility:** In many cases, contracting authorities or corporations expect suppliers to act in a socially, hygienically, financially and ecologically responsible manner. They should also comply with the relevant security and data privacy standards. Evidence can be presented in voluntarily compiled Corporate Social Responsibility (CSR) reports in accordance with the GRI standard or certifications by neutral auditors (e.g. Achilles).

VI. Storage and transport

One further criteria for a successful project is the storage of the batteries until the delivery of the device to the end customer. In this context, various basic conditions and the continuous self-discharge of the battery must be considered.

If devices or Li ion/polymer batteries are to be transported by airfreight, IATA only allows load levels of <30%. When sending by sea, batteries holding a 50-60% charge can be shipped. Depending on the storage time and duration of the transport, the end customer receives more or less ready-to-use batteries. Fortunately, the self-discharge of rechargeable lithium cells is very low.

To delay the aging process, storage at room temperature and at medium charge level is recommended.

VII. Summary

As a supplier of battery solutions with decades of experience, Jauch recommends

- giving the assembler as much detail as possible about the planned device and the energy storage requirements. Hold discussions early on with the professionals. This allows them to design and offer the optimal battery.
- Jauch is, if required, willing to sign a Non-Disclosure Agreement (NDA).
- These precautions should not be a deterrent. They are intended solely for the safety and satisfaction of the end customer, manufacturer and battery supplier.

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VIII. Development and design

Battery manufacturers such as Jauch help engineers, product designers and project managers develop a product-specific and optimal solution for every application and device. One advantage is that Li-polymer batteries can be easily adapted to custom plans. They can be designed and produced quickly in the required quantity, even in small batches.

Often there is only a small space available for the fitting of a battery. Under some circumstances, the dimensions of the battery compartment may already be fixed before the first contact with the assembler is sought. At moments like this it proves advantageous to have access to a large repertoire. Jauch has numerous samples and proven designs of lithium-polymer batteries. This repertoire makes it possible to select suitable cells at short notice as well – even if the project has reached an advanced stage.

Jauch develops, manufactures and tests battery packs for all industrial sectors. Those decades of experience benefit the customers. Jauch has been working with mobile electricity supplies since 1974.

Safety and function come first. That is why global experts from Jauch help guide cell development to meet very specific requirements right from the start. Our experts ensure that all parameters, international certifications, approval and transport regulations are met precisely.

The cells are manufactured in fully automated production plants. All plants are ISO9001- and ISO14001-certified as standard, which ensures compliance with international safety and environmental standards.

The quality management system at Jauch encompasses:

- Goods receipt and outgoing inspection
- Tests according to customer specifications
- Temperature-range checks
- Component and circuit analysis
- Use of special measuring equipment for comprehensive investigations
- Mechanical, electrical, climatic tests, X-ray analysis
- 8-D reports and detailed analysis reports in a short time
- Components qualification
- Determination of the reliability numbers of special components
- Internal audits of systems, processes and procedures
- Audits in the production facilities as well as supplier audits

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About the author:

Dr. Jürgen Heydecke is an acknowledged expert in his field with decades of experience at home and abroad. Throughout his working life he has been involved with different battery chemistries and he knows the requirements of the industry like few others. He and his partner set up Batteries and Powersolutions GmbH (BAPS) in 2009. Since the merger with Jauch Quartz GmbH in 2018, Jürgen Heydecke has acted as technical director of the newly-established Jauch Battery Solutions GmbH and also leads seminars at the Jauch Battery Academy.

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