Battery Holder Design and Selection Guide

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To meet customer requirements, designers continue to push the limits of system performance, size, power consumption and cost. Often these limits are extended without a clear understanding of the many nuances of battery cavity design and its role in a system. In a best-case scenario, the outcome is user dissatisfaction with performance and usability. Worst-case scenarios include catastrophic system failures leading to recalls, higher costs, and potentially serious injury.

With a better understanding of battery-cavity electrical and mechanical properties, physical sizing, and materials, such scenarios can be avoided. Going further, with a firm grounding in cavity-design principles and selection, designers can better understand how to optimize their systems in almost all directions, including performance, size, and cost, without compromising safety and reliability.

Pushing the battery-to-system boundaries

Despite the proliferation of electronic systems, from consumer gadgets and smartphones to industrial, transportation, military, aerospace and medical applications, standard battery performance continues to lag requirements in terms of capacity and shelf life. Lithium-ion (Li-ion) chemistries have largely replaced alkaline and nickel-cadmium (NiCad) chemistries due to their inherently higher capacity and low self-discharge, leading to longer shelf life. Though they are well understood, Li-ion chemistries are close to their theoretical density limits. For more on Li-ion standards and testing, see UL 1642.

For system designers, further improvements in performance, longevity, reliability and safety can be achieved through a more “holistic” approach to battery integration, starting at the point at which the battery meets the system: the battery cavity.

First contact: battery-to-cavity

The battery’s first point of contact with the system, literally, is with the contacts of the battery cavity. Much innovation has taken place at this juncture to minimize electrical resistance and galvanic corrosion, while balancing reliable contact and small form factor with user accessibility and safety (Figure 1).

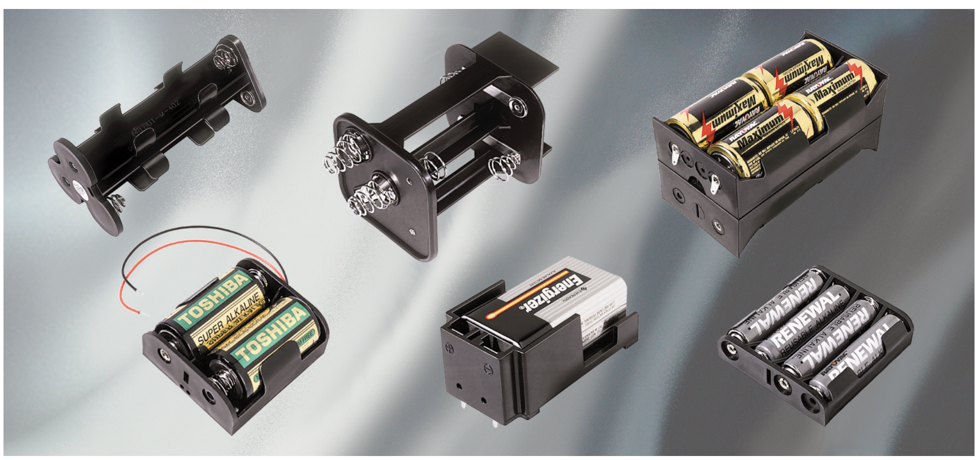


Figure 1
When given due consideration early in the design cycle, the battery cavity can help optimize a system for performance, low power, size, cost, and reliability.
(Image source: BatteryHolders.com)

Electrical resistance and galvanic corrosion: Battery manufacturers have spent many years researching the best materials to use for the battery contacts. While gold plating combines low resistance with the highest tolerance of metal-on-metal contact in extreme environments, nickel-plated contacts give the best balance between cost, corrosion resistance, and electrical conductivity. To avoid galvanic corrosion, battery-cavity contacts therefore also need to use nickel-plating, usually over stainless steel.

Galvanic corrosion occurs when two dissimilar metals make contact in the presence of an electrolyte, such as moisture. When considering contact metals, consult the anodic index (Figure 2)

Metallurgical Category	Anodic Index (V)
Gold, solid and plated: Gold-platinum alloy	0.00
Rhodium-plated on silver-plated copper	0.05
Silver, solid or plated, Monel metal. High nickel-copper alloys	0.15
Nickel, solid or plated; titanium and alloys, Monel	0.30
Copper, solid or plated; low brasses or bronzes; silver solder, German silvery high copper-nickel alloys; nickel-chromium alloys	0.35
Brass and bronzes	0.40
High brasses and bronzes	0.45
18% chromium-type corrosion-resistant steels	0.50
Chromium-plated, tin-plated; 12% chromium-type corrosion-resistant steels	0.60
Tin-plated; tin-lead solder	0.65
Lead, solid or plated; high lead alloys	0.70
Aluminum, wrought alloys of the 2000 Series	0.75
Iron, wrought, gray or malleable, plain carbon and low alloy steels	0.85
Aluminum, wrought alloys other than 2000 Series aluminum, cast alloys of the silicon type	0.90
Aluminum, cast alloys other than silicon type,cadmium, plated or chromite	0.95
Hot-dip-zinc plate; galvanized steel	1.20
Zinc, wrought; zinc-base die-casting alloys; zinc-plated	1.25
Magnesium and magnesium-base alloys, case or wrought	1.75
Beryllium	1.85

Figure 2
The anodic index shows the electro potential of different metals. Ideally, two metals in contact should not have a difference of more than 0.25 V. For harsh environments and military applications, a difference of <0.15 is recommended.

(Data source: EngineersEdge)

Depending upon the application and the customer's reliability requirements, it's worth considering upgrading from nickel-plated contacts to a more noble metal, such as gold. For example, if the system is intended for extreme climates, such as a military system outdoors in a rain forest, gold contacts are advisable.

Galvanic corrosion can eventually lead to loss of electrical contact, but before that happens, the increasing resistance, or loss of conductivity, can drain the battery more quickly than expected. For consumers, this is an irritant, but for military or medical applications, it can have more serious consequences.

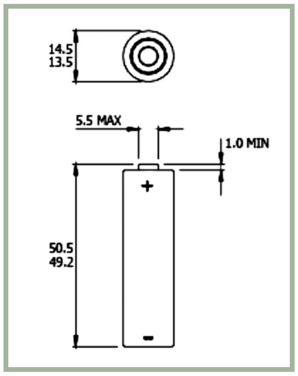
That said, some level of resistivity in contact metal is unavoidable. The natural resistivity of gold, for example, is 2.4 x 10-8 Ω. Copper, aluminum, and nickel have resistivities of 1.7 x 10-8, 2.8 x 10-8, and 7 x 10-8 Ω, respectively. Designers of ultra-low-power applications will need to factor in losses due to contact conductor resistance over time.

Battery contact stability: Under certain circumstances, a battery cavity's contact can physically disengage from the battery completely, causing complete system failure. This can happen for a number of reasons, including:

- Cavity-to-battery size mismatch.
- Vibration.
- Poorly designed contact mechanism.
- User intervention, such as contact damage or battery not inserted fully.

Many of these can be prevented early in the design process. For example, don't design or select a battery cavity or holder based on a particular brand of battery. The reason is that battery companies may market batteries of a standard specific size, such as AA or 18650 for Li-ion rechargeables (18 mm by 65 mm), as being capable of longer life (good, better, best). Instead of being an improvement in the chemistry, this often translates to different physical sizes (standard, larger, largest) that may not be noted in the advertisement.
As a result, customers may buy what should be the same-size battery from a different brand, and find it doesn't fit.

Individual drawings of our products are available online at www.battery-contacts.com



Instead, design the cavity around IEC/ANSI standard specifications (Figure 3).

Figure 3
To ensure a good battery fit, design to IEC/ANSI standard sizes (AA shown) instead of to a particular brand of battery. Dimensions in millimeters.

(Image source: IEC/ANSI)

The IEC standards also accommodate slight variations in battery style, such as negative contacts that may be either slightly protruding or slightly recessed. The battery cavity must be a good structure for both.

Ventilation and positioning: The structure of the cavity must also factor in ventilation. This is required to accommodate the build-up of gas in a battery. This can occur for a number of reasons, including:

- Oxidation of zinc prompting the release of hydrogen from the electrolyte.
- When a battery is discharged below a safe cut-off level.
- Faulty charging (current reversed or battery inserted backwards).

Venting generally results from poor charge/discharge circuitry or user error. These are unavoidable, so battery manufacturers accommodate venting from the battery itself. The amount of venting required depends on the chemistry. For example, a 2/3A lithium battery generates <0.2 ml of methane during over-discharge or overcharge. An AA alkaline battery generates <0.05 ml/day through oxidation, and 20 ml through over-discharge/charge. Consult the battery manufacturer for their specific ventilation specifications, as it can vary depending upon chemistry, battery size, and the materials.

For small underwater or waterproof systems, such as a simple flashlight, ventilation becomes an interesting challenge. This is met through the use of an enclosure made from a gas-permeable material, such as polypropylene or polyethylene. If the design requirements are for a different type of enclosure material, such as metal, it may be possible to assign a certain portion or area of the enclosure to a gas-permeable material.

This is where it's useful to have the battery-manufacturer's venting specifications, as the size and thickness of the material will depend on the amount of gas to be vented. For example, a 2-mm-thick patch of polypropylene measuring 0.07 cm2 will suffice for each AA alkaline battery used.

If enough hydrogen gas builds up in a waterproof battery compartment it can become explosive. If it isn't possible to use a venting material, another option is to use hydrogen catalyst pellets. These react with the hydrogen to produce water vapor.

Ventilation is also tightly coupled with positioning: a cavity may allow venting, but that's not much good if the cavity itself is placed too closely to the surrounding board or system elements. For safety reasons alone, the cavity should be well isolated from the surrounding electronic components. The battery's metal container for the chemicals is an active part of the circuitry.

In addition, heat from the electronic components can affect the battery state and lifespan, and if gassing occurs, liquids may also be leaked from the battery that can cause short circuits or otherwise destroy electronic components.

Ensuring reliable contact

For many reasons, this deserves its own section, as all is for naught if the battery can't maintain contact with the battery. Overuse, abuse, vibration, and user inattention when installing batteries can all be contributing factors to poor cavity-to-battery contact.

This has resulted in many innovations in the area of battery-cavity contacts and battery structures in general.

However, designers should start at the structure of the contacts: are they spring, fixed point, pressure contacts, or a mix? Here is a simple rule of thumb to use when choosing:

- *Good:* One spring and one fixed point (a flat spot).
- *Better:* One pressure contact.
- *Best:* Two pressure contacts: one on each end.

Of course, cost can be a factor. A spring contact costs $0.03 or $0.04, while pressure contacts cost $0.04. However, for high-reliability designs, lifespan must be considered: spring contacts last 6 or 7 years, while pressure contacts easily outlast most system designs.

Another factor to consider is mobility and vibration: if the device is going to be bounced around, pressure contacts are advisable to reduce the likelihood of break/make contact bounce. Here's a quick list of common contact types:

- *Miniature snap terminals:* Recommended when the battery will be changed often.
- *Printed circuit board pins:* Used when the battery is a permanent component.
- *0.005" flat nickel tab stock:* Used for a permanent soldered connection.
- *Single point spring or clip:* For use with miniature cells or a low current drain. Material must provide a spring pressure of 50 to 80 grams (0.49 to 0.78 N) on small button cells. *(Caution should be taken to prevent denting cells with excessive pressure.)*
- *Multiple point contact:* Here, the contact point is divided into several individual points or prongs. This approach is recommended for higher current drains. For larger cylindrical cells, a pressure of 150 to 175 grams (1.47 to 1.72 N) is recommended.
- *Standard Electrical Connector:* Terminals made by a contact manufacturer.

Prismatic batteries have a more challenging contact requirement, in that the battery contacts need to have enough travel to penetrate the recess while having sufficient contact pressure to minimize contact resistance. A minimum travel of 2.5 mm and a minimum force of 200 grams are used to ensure reliable performance in high-drain devices.

Along with having low resistance and compatible on the anodic index with the nickel-plated battery contacts, the cavity must also maintain their structural integrity over long periods and many battery remove-insert cycles. This ability to resist permanent set is a feature of pressure contacts, but all contacts may be subject to some degree to the various failure modes, such as temperature-related stress relaxation and fretting wear. Fretting wear is a result of small-amplitude oscillations that cause a build-up of oxide and increased resistance.

While there are many contact types, designers should start with nickel-plated, cold-rolled steel contacts, which have the added advantage of being highly solderable. This is useful at the other end, where the contact is soldered to the pc-board surface-mount reflow solder processes. However, for some designers in the prototyping stage, being able to solder a power supply lead to an empty cavity contact can also be quite useful.

Designers can go to extremes to maximize contact integrity; this must also be balanced with the need to allow access by users to replace batteries. Getting this balance right is tricky and is an on-going area of innovation by battery-cavity designers. For example, the Snap Dragon coin-cell battery holder holds the battery tightly in place with a snap-on cover (Figure 4).

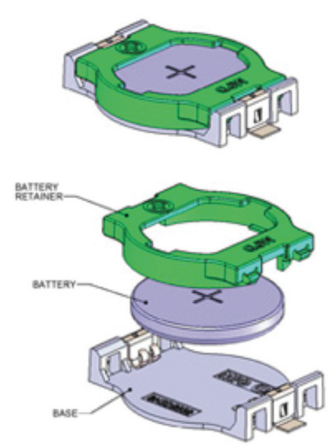


***Figure 4:** Battery cavities are an on-going area of innovation as suppliers work with system designers to meet increasingly demanding applications. The Snap Dragon, for example, keeps coin-cell batteries tightly in place, while still allowing easy user access. (Image source: BatteryHolders.com)*

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However, users get ready access by snapping back the cover and simply removing the battery. It adds only 1 mm to the total height of the coin cell, its LCP base is suited to solder-reflow processes, and its polypropylene cover is strong, yet flexible enough for many battery-replacement cycles.

Designing for careless users

As one of the system interfaces to the user, battery-cavity designers need to factor in user accessibility, error, and carelessness. This translates to making cavities accessible, but also applying nuances such as ribbons beneath the batteries so users don't require a tool to remove the batteries, which puts the contact's plating at risk.

Also, it's important to clearly label battery cavities so the user doesn't insert the wrong batteries, or insert the right batteries backwards. This can cause accidental battery charging in serial or parallel configurations. Often, labels or inscriptions aren't enough, so it is mandatory to have terminals that prevent reverse installation.

If a designer chooses to not have terminals to prevent reverse insertion, it's advisable to limit the number of cells: the more cells there are, the shorter the time to venting of a cell that is being accidentally charged. A good guide is to allow the user enough time to check whether or not the device is working, and then adjust the battery placement as needed. With four cells, one cell being charged by other three takes 2 minutes to vent.

Engineering devices for human factors

Glucose meters, thermometers or wearable drug delivery systems are examples of some portable medical devices. These devices must be designed according to FDA regulations (FDA-21) with a need for human factors assessed such as age and functional capabilities that could impact the safe and effective use of the device. Designing for safe and effective use is difficult, given the many ways a human can accidentally or purposely misuse or abuse a device. In fact, it's so difficult and so varied that figuring out and accounting for the human factor is a discipline unto itself, called human factors engineering (HFE). To help, the FDA publishes a document of non-binding recommendations for designers of medical devices, called, "Applying Human Factors and Usability Engineering to Medical Devices." In it, the FDA defines HFE as the application of knowledge about human behavior, abilities, limitations, and other characteristics of medical device users. It covers everything from mechanical design to documentation. However, as any designer knows, it can be summed up as Murphy's Law: when it comes to the human factor, what can go wrong, will go wrong, and designers need to account for every conceivable misstep. The FDA guide is therefore a good resource, but each application and user is different, and that must be factored in.

Selecting a battery cavity vendor

It's important to understand the nuances of battery cavities, but often it's not a company's or a designer's value add. It's wise to take this understanding and apply it toward selecting a good vendor. The right vendor typically has a strong track record of meeting the demands of challenging markets and applications, such as military and space. Check their background and ask for samples.

Also, a good provider will be able to guide a designer to what's needed if it's off the shelf, or help with a custom design if the need arises. Find out by calling them directly and vetting their technical abilities and domain knowledge.

Finally, a battery cavity supplier should already understand the designer's target market as well as the designer does. For example, if the application is medical, they should know "insider" requirements such as the plastic material not supporting organic growth.

Conclusion

Designers are under constant pressure to reduce size, cost, and power consumption, while improving performance, safety, and reliability. Enabled by a good understanding of battery cavity design and options, and by working with a knowledgeable supplier, it's possible to incorporate the battery cavity holistically into a system design to better meet all of these objectives.

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