



Boosting Battery Density with Flexible Solutions

Learn why integrated FPC-based cell contact solutions are essential to high-efficiency Lithium-ion battery manufacturing.



From the smallest components to the highest-level business decisions, Lithium-ion battery (LiB) manufacturers are rethinking the way they design, assemble, and market batteries. They're seeking cost reductions everywhere as margins shrink, competition intensifies, and global material oversupply drives down selling prices.

These factors are part of why the data gurus at CRU Group proclaimed to battery manufacturers that "[only the lowest-cost producers will survive](#). In doing so, they challenged the world's producers to do better, with one exception: China is the global benchmark for battery production efficiency at scale, accounting for roughly 85% of global LiB manufacturing capacity, according to [Volta](#).

In response, Western markets, already challenged to improve battery manufacturing efficiency and quality, must reduce costs. They can succeed, but they will need to focus mightily on supply chain efficiencies, manufacturing excellence, and continued technical innovation. And they must do this while operating new and extremely efficient large-scale battery plants, or gigafactories.

The same imperatives are also driving Western producers to leverage Asian partnerships. This is especially true in North America due to an uncertain political and economic climate. Volta's annual Battery Report for 2024 noted that U.S. manufacturing capacity for EV batteries grew by almost 50%, "led by Korean companies attracted by tax credits, which accounted for nearly 70% of the growth in 2024."

Continued investments are at risk in light of the Trump Administration's "One Big Beautiful Bill Act," reducing incentives for clean energy and electric vehicles. This creates additional pressure on the country's battery manufacturers, but they can still succeed by cutting costs while continuing to innovate.

The road to greater integration and energy density

From top-level executive suites to design, engineering, and all operational areas, one critical need is evident: To become more cost-efficient, manufacturers must simultaneously improve performance and energy density. At the top level, this effort must accompany accelerated adoption of technology standardization and manufacturing efficiency to achieve low cost at high scale.

It's a major industry imperative to reduce the number of parts that must be assembled, and to eliminate the complexity, space (volume), and weight of non-essential components. Doing so carries economic benefits and can also improve energy density by reducing the ratio of volume and mass devoted to non-energy-producing components relative to energy storage components.

At the OEM vehicle level, this is playing out as traditional cell-to-module-to-pack battery system designs are giving way to vehicles whose cells are directly mounted in the chassis or vehicle body. OEMs, including Tesla and BYD, employ this strategy to reduce parts and weight, which improves manufacturing economics and greater energy density.

A step upstream in the supply chain, the same trend is occurring. Battery manufacturers are turning to the use of preassembled modules with integrated components to eliminate assembly steps, labor, and improve manufacturing efficiency. While reducing volume and mass, these modules also increase the proportion of energy storage content in the pack and, in turn, can help improve energy density. This can lead to packs containing more or larger cells, or new, optimal designs.

These considerations, for example, are leading to a steady migration from traditional cell contact systems (CCSs) to modern, integrated modules that use flexible printed circuit (FPC) modules. Below, we explore this evolution, the benefits of FPCs, and how those benefits serve the broader needs of modern battery manufacturing facilities.

The rise of modern cell-contact modules

The first function of any CCS system is to establish electrical connections between each cell and the battery management system (BMS). Another basic function is to help the BMS monitor the temperature of each cell by using NTC (negative temperature coefficient) thermistors mounted at each cell; lower resistance indicates higher temperature. While traditional and FPC systems share these functions, the latter offers several key advantages:

- FPC-based systems integrate NTC thermistors directly onto the flexible circuit, placing them precisely in hollow areas of nickel sheets near cell connections. Wire harnesses require separate thermistor components to be attached at connection points.
- FPC systems provide more consistent and accurate measurements due to uniform electrical characteristics and precise sensor placement. Wire harnesses have greater variability in sensor positioning and connection quality.
- FPCs can accommodate more measurement points in the same space, allowing for more comprehensive temperature and voltage monitoring across the battery pack.
- FPCs deliver cleaner signals with less noise and interference compared to wire harnesses, resulting in more reliable data transmission to the BMS.

In the effort to improve upon traditional wire and cable solutions, early variants using rigid printed circuit boards and hybrid rigid-flexible solutions provided incremental advantages. Today's FPC-based solutions, however, are the state of the art for superior integration, consistency, and measurement reliability, and energy density potential.

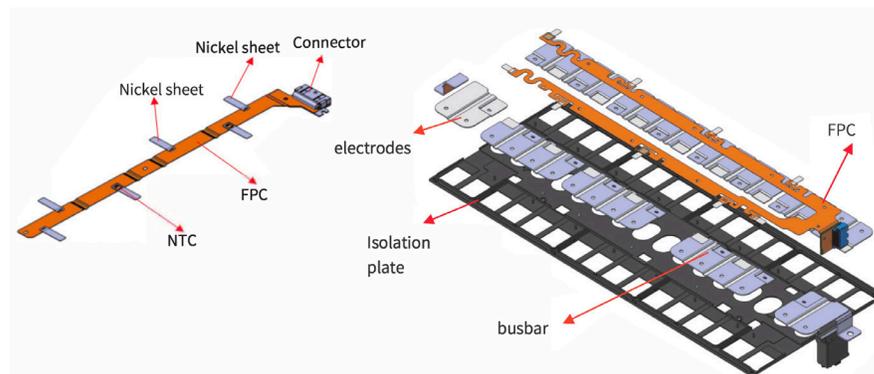
The modern, integrated FPC module for EV and ESS applications

The integrated Churod flexible printed circuit cell contact system measures and communicates battery cell voltage and temperature to the BMS while supporting energy-dense system designs and automated gigafactory manufacturing excellence.

This FPC module is manufactured using unique fabrication techniques and features that result from a successful track record working with leading LiB manufacturers in China and worldwide. It also addresses a key requirement for larger battery systems: a longer, 2,000-millimeter busbar.

Components of an FPC-Based Cell Contact System Solution

FPC solutions are widely used for a wide range of Lithium-ion battery vehicle and energy storage applications. The image at left shows the key components of an integrated FPC-based solution. The image at right shows how an FPC-based solution integrates with the battery pack's busbar.



Higher-order benefits of FPCs

Battery manufacturers are choosing the FPC design not only for their immediate component-level performance. This design also enables more compact, energy-dense battery system designs. Being literally flexible, lightweight, and bendable, it enables tighter packaging and more intricate routing than traditional approaches. It also supports complex battery geometries to advance design innovation.

Furthermore, FPCs are ideally suited for use in modern battery assembly. With increasing demands for automation and higher throughput rates, FPCs cut production complexity to reduce manual labor and significantly reduce failure rates. The FPC solutions from Churod

are manufactured using a highly automated production system. This provides consistent quality and supports greater reliability of components serving critical safety functions such as voltage, temperature, and current sensing – and in a unified, space-saving design.

The use of flexible circuits is extremely mature for miniaturizing electronics such as smartphones, touch panels, wearable/implantable medical devices, and other applications that place a premium on design flexibility, space savings – especially battery systems.

Advanced FPC solutions yield myriad advantages over previous cell contact methods. These benefits, in turn, can drive higher-order benefits to battery products and the manufacturing processes used to produce them. Consider the following:

- **Space & Design Efficiency:** FPCs are thin, bendable, and conform to tight spaces and curved sections, increasing wiring design freedom while reducing overall battery pack size and enabling more compact designs.
- **Integration Advantage:** FPCs integrate circuits, connectors, negative temperature coefficient (NTC) thermistor sensors, and nickel sheets into a single assembly, eliminating multiple connection points and separate components required in traditional wiring harnesses.
- **Enhanced Reliability:** FPCs offer fewer connection junctures, have no movable components, and are specifically engineered for superior resistance to thermal, vibrations, and mechanical stresses, resulting in higher assembly reliability and reduced failure rates.
- **Manufacturing Simplification:** FPCs replace multi-step wiring harness assembly (cutting, stripping, crimping, soldering) in automated environments, fostering consistent quality and dimensional uniformity.
- **Performance Benefits:** FPCs deliver stable signal transmission, uniform dimensions, and consistent electrical characteristics, improving overall battery management system performance and monitoring accuracy.
- **Space Optimization:** FPCs' minimal footprint offers manufacturers the option to add additional cells in the same volume or free up valuable space for other vehicle components, enabling more compact and efficient electric vehicle (EV) and battery electric storage system (ESS) products.

FPC Solutions for All Applications



FPC solutions are widely used for a wide range of Lithium-ion battery vehicle and energy storage applications. These include passenger cars (pictured, top), commercial vehicles, residential energy storage applications from residential and large-scale storage systems (pictured). Churod designs and manufactures FPC solutions to exacting specifications to meet the requirements of each application.

Suitability across battery EV and ESS applications

As demand grows for higher-performance LiBs, so does the need for robust, scalable, and thermally stable interconnect solutions — and integrated FPC solutions are the standard choice. Their global dominance applies to both electric vehicle and storage categories. In the North American BEV segment, high-end or high-volume electric and hybrid passenger vehicles are the FPC leaders, followed by electric bikes/scooters, commercial vehicles (buses, vans, trucks), and specialty and industrial vehicles (forklifts, AGVs, construction vehicles). In all cases, they ensure the highest level of performance and reliability.

The energy storage segment is a bit slower to adopt in North America; however, residential implementations lead in this category, followed by commercial and industrial storage systems. This is likely due to the difficulty North American manufacturers have sourcing FPC solutions to accommodate the often-larger battery modules of non-residential storage systems. Churod has global experience and can accommodate these systems.

In summary, FPC contact modules are the global standard, and North America is primed for greater adoption. The most widespread FPC use is in EV passenger vehicles and residential storage. This is likely because both require compactness, safety, and high production volumes, which represent prime targets for business justification. Adoption in heavier vehicles and large-scale storage applications is growing, if less mature on this continent.

Demand continues to grow for cost-efficient, robust, scalable, and thermally stable interconnect solutions. The need for innovation and high efficiency positions flexible printed circuit (FPC) solutions as vital enablers of modern battery pack engineering and mass production scalability.



Churod designs and manufactures modules in many application-specific configurations help high-efficiency manufacturers every day, around the world.

About Churod Americas

Churod Americas is a subsidiary of Dongguan Churod Electronics Co., a leading relay solution provider and manufacturer based in China. Since its founding in 2009, the company has expanded from relays to high-voltage DC contactors, semiconductor products, and sensors. The company maintains five manufacturing campuses in China, along with offices and sales support around the world. Our mission is to provide customers across the globe with a full range of cutting-edge products and value-added services. Visit us on the web at www.ChurodAmericas.com or email CAsales@ChurodAmericas.com.

At Churod, everything we do is for our customers' advantage.