WHITE PAPER

LEVERAGING SUPERCAPACITORS FOR EFFICIENT WIRELESS POWER IN SMART LOGISTICS

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Smart warehousing involves the strategic deployment of robotics and automation to optimize the day-to-day operations and management of warehouses. Implementations traditionally include a combination of automation, Internet of Things (IoT), artificial intelligence (AI), warehouse management systems (WMS), advanced robotics, augmented and virtual reality (AR/VR) and cloud computing.

In concert, these systems enable seamless and uninterrupted connectivity, predictive capabilities and real-time adaptation for logistics-reliant companies looking to improve efficiency. In 2022, Robin, one of Amazon's robotic handling systems, sorted one-eighth of all packages that Amazon delivered worldwide. At the time, they had over 750,000 mobile robots deployed across their operations. Effective implementation is an attractive prospect when looking for opportunities to minimize errors, reduce costs, improve scalability and increase customer satisfaction.

Here, we'll explore how supercapacitors support or even overtake battery technology in key smart warehousing technologies. We'll also offer guidance for supercapacitor selection for these systems.

Rising Stars in Smart Warehousing: AGVs and AMRs

In smart warehousing applications, robots are designed to perform tasks autonomously or alongside humans to reduce manual labor, fatigue (e.g., lifting and walking) and risk of injury for employees. Smart logistics leverages robotic arms, automated guided vehicles (AGVs), automated mobile robots (AMRs), goods-to-person systems and drones for common tasks like order picking, replenishment and goods transportation.

AGVs assume a transport function and act in place of forklifts, conveyors, towing machines and carts. AMRs serve a moving, picking and/or sorting function. For example, AMRs include expandable arms with sensors that can perceive item shape and size. AGVs and AMRs are growing in popularity because they present opportunities to scale operations without changing a warehouse's existing floor plan or infrastructure, which can be costly and time-consuming. Automated storage and retrieval systems (AS/RS) offer similar benefits, but they require the installation of racking systems and automated handling equipment.

Supercapacitors vs. Batteries for Powering AGVs and AMRs

AGV/AMR power systems typically include a combination of motors, wheels, breaks, sensors and lead-acid or lithium batteries. However, batteries aren't the most effective option when it comes to instant power availability, rapid charging or energy efficiency (Table 1). Shortcomings in these areas contribute to the growing popularity of supercapacitors, or supercapacitor modules (SCAP), in smart logistics applications. Supercapacitors are capable of energy storage and can supplement or replace batteries in large-scale applications like electric cars, smart grids and smart warehousing. They can do the heavy lifting with exceptional power density, literally and figuratively.

Parameter	Lead-Acid Battery	Lithium-Ion Battery	Supercapacitor
Specific energy density (Wh/kg)	10-100	150-200	1-10
Specific power density (Wh/kg)	<1000	<2000	<10,000
Cycle life	1000	5000	>50,000
Charge and discharge efficiency	70-85%	99%	85-98%
Fast charge duration	1-5h	0.5-3h	0.3-30s
Fast discharge duration	03.-3h	0.3-3h	0.3-30s
Shelf life (years)	5-15	10-20	20
Operating temperature (°C)	-5 to 40	-30 to 60	-40 to 75

Table 1: Comparison of key specification differences between lead-acid batteries, lithium-ion batteries and supercapacitors. Abbreviated from: Source.

Conventional capacitors and other passive components are the backbone of electronic systems. Capacitors, often responsible for regulating power, gather electrical charges from circuits, store them for a short period, and release them in a burst of energy. Supercapacitors have high energy density and can store as much as one hundred times the energy per unit volume an electrolytic capacitor can provide at peak power. In contrast, batteries store electrical energy in electrochemical cells. They carry large amounts of electrical charge for long periods and slowly release that charge over time.

As AGVs and AMRs become more common in smart logistics, supercapacitors are becoming a more popular and effective means of powering them. Supercapacitors store potential energy electrostatically rather than relying on chemical reactions, which enables rapid charging/discharging, and by extension, brief or non-existent downtime via wireless charging, Figure 1. In other words, supercapacitors charge and discharge faster than batteries, and by design, supercapacitors can also endure more charge/discharge cycles than traditional rechargeable batteries.

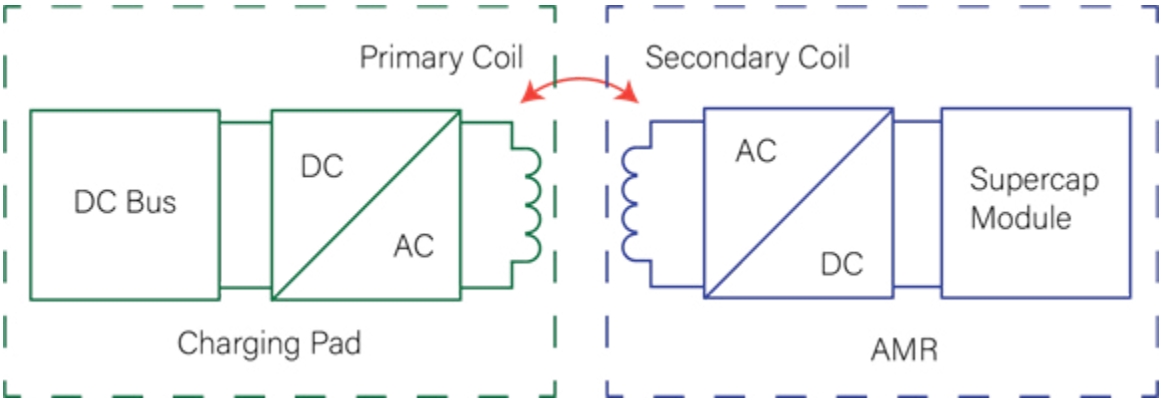

Figure 1: Supercapacitor charging via inductive coupling.

Wired and wireless power are the key technologies behind several of the core benefits offered by AGVs and AMRs, including:

- **Adaptability:** Easy to change layouts or paths in the event the company or customer priorities change
- **Safety:** Minimize or eliminate cables from the warehouse floor and implement electrical isolation by design
- **Operational Efficiency:** Systems can recharge quickly, or during operation with in-floor inductive charging, to minimize downtime and improve productivity; no regular battery replacements, hybrid solutions or backup AVGs sitting in inventory
- **Power Efficiency:** Operating at high power for short bursts of time extends operational life span and improves energy efficiency
- **High Value:** Lower installation and maintenance costs

Supercapacitors are less likely to generate heat than battery systems and can operate across wider temperature ranges, so there's less concern with the thermal runaway that can lead to short circuits or fires. They can also be designed more sustainably with fewer harmful materials and less concern about end-of-life decay and leak than batteries.

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Considerations for Selecting Supercapacitors for Smart Logistics

Performance improvements at the highest levels of design come down to component selection. When selecting supercapacitors for AGVs and AMRs, look for:

- Low self-discharge rates and comparably low equivalent series resistance (ESR) than other electrolytic capacitors
- High energy density and large capacity, making it possible to support brief power interruptions and to supplement or replace batteries altogether
- Charging/discharging time within seconds
- Low-loss characteristics
- 10+ year operating life; designed to withstand over 500,000 charge/discharge cycles with degradation

For more information on supercapacitors and supercapacitor selection for smart logistics systems, review our DSM module specifications or contact our engineering team for a consultation.