Electronic Design

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GaN Spearheads Battery-Charging Revolution

Gallium nitride is becoming the technology of choice for charging EVs, HEVs, and other applications, bringing 3X greater speed when compared to silicon-based solutions.

Charging systems for electric vehicles (EVs) and hybrid-electric vehicles (HEVs) are, of course, crucial for powering batteries and ultimately having them operate efficiently. They can be divided into two main categories: off-board charging systems and on-board charging systems.

Types of batteries that can't be charged:

Non-rechargeable batteries, also known as primary cells, are designed to be used once and then discarded:

- Classic-style lead-acid batteries can power an electric motor, scooter, or bicycle, etc.
- Alkaline batteries (Kirkland has the AA and AAA versions)
- 9-V Duracell batteries
- C batteries
- Lithium batteries aren't rechargeable (primary cell) and use metallic lithium in the electrodes

Types of batteries that can be charged:

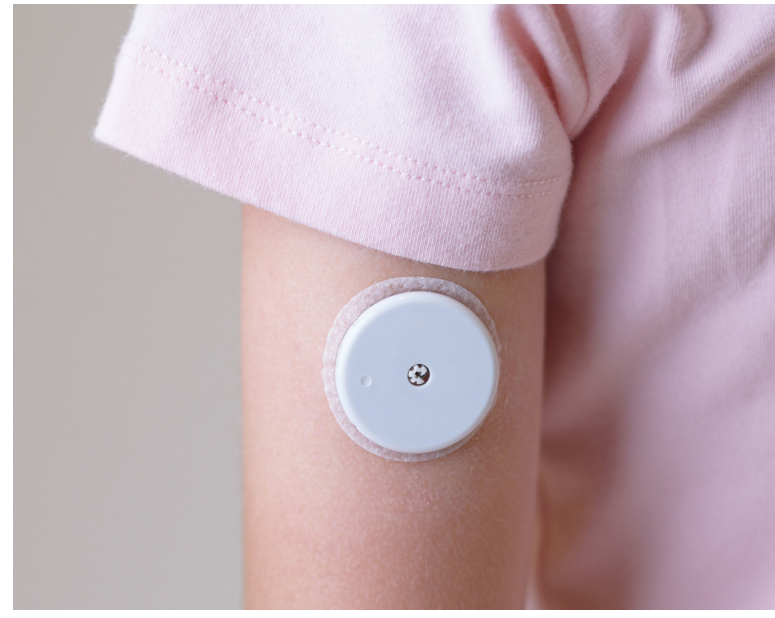
This class of battery is able to be recharged and used multiple times, making them a more cost-effective and environmentally friendly option in the long run. Equipment that typically contains rechargeable batteries include:

- The lithium-ion battery, a secondary cell, for iPhones, computers, and EVs. These batteries use a non-metallic compound of lithium ions. They're lighter and more energy dense, plus they have a higher charge density than lithium batteries.
- Lead-acid batteries
- Nickel-cadmium (NiCd) batteries
- Nickel-metal-hydride (NiMH) batteries

Understanding Battery Ratings

The lead-acid battery lists the voltage level, e.g., 12 V (be sure the battery charger is rated for 12V), and the amp-hour (Ah) rating, e.g., 7 Ah/20 HR. This indicates the capacity of the battery. Now, divide 20 by 7 and we get the amount of amps that can discharge in 20 hours.

Or take a lithium-ion battery that's 36 V (again, be sure the battery charger is rated for 36 V) and 30,000 mAh. It's a bit larger than the lead-acid battery. This is a battery pack that contains multiple individual cells in parallel with series connections to achieve the voltage and amp-hour rating. Circuitry inside the battery pack includes terminal wires, mostly with a connector, in addition to a wired charging terminal.



Shown is a 7.4-kW EV or hybrid EV bidirectional onboard charger reference design that implements GaN technology. (Courtesy of Texas Instruments)

There are various kinds of chargers. Smart chargers have electronic components to charge the battery safely, with the ability to stop charging when the battery reaches a certain level. Usually, the battery charger has a red indicator light for charging and a green light when the battery is fully charged. Most chargers plug into standard electrical outlets having 100 to 240 V @ 50/60 Hz. The charger outputs will be in amps.

Shallow discharges and recharges are much better than full ones because they put less stress on the battery and thus can last longer. When the battery is discharging, Battery University recommends that you only let it reach 50 % before topping it off again. When charging it back up, avoid pushing the lithium-ion battery all the way to 100%.

Advantages of GaN Chargers

Gallium-nitride (GaN) battery chargers are typically smaller than most chargers in the industry. That's because they can conduct much higher voltages over time than their silicon counterparts. Capacity typically ranges from 20 up to 300 W.

GaN chargers are also more efficient at transferring current, which means less energy will be lost to heat. And, consequently, more energy will go to the equipment being charged.

GaN chargers also have a higher switching frequency, enabling a quicker wireless power transfer. GaN semiconductors typically cost more than silicon. But thanks to improved efficiency, there's less dependence on additional materials, such as heatsinks, filters, and other circuit elements. This may also lead to cost savings of 10% to 20%. The *figure* shows an example of Texas Instruments' GaN-based onboard charger.

Next-Gen Charging Standards: USB-C PD 3.0 and PPS

The latest GaN chargers have USB-C Power Delivery (PD) charging technologies. They support up to 300 W of power and enable devices and chargers to talk to one other to determine an optimal charging power. So, when plugging in a laptop that demands 65 W of power, the charger will be able to identify it and can automatically adjust the power to other ports.

USB-C PD is compact enough that it can be used in small, thin devices such as smartphones. However, it's also able to charge larger devices such as laptops.

The Programmable Power Supply (PPS) standard is an advanced charging technology for USB-C devices. It allows for modification, in real-time, of the voltage and current by feeding maximum power that's based on a device's charging status.

On this front, the USB Implementers Forum (USB-IF) is a non-profit group that supports the marketing and promotion of the Universal Serial Bus (USB). The group added PPS Fast Charging to the USB PD 3.0 standard in 2017. Now data can be exchanged every 10 seconds, with the ability to make a dynamic adjustment to the output voltage and current based on the condition of the receiving device's specifications.

The key advantage of PPS over other standards is its capability to be able to lower conversion loss during charging. Therefore, less heat will be generated, which helps lengthen the device battery's lifespan.

Why GaN for Charging?

GaN technology significantly speeds up charging of hybrid and hybrid-electric vehicles. With 20- to 300-W capability, GaN on-board chargers in EVs range from one USB-C port to two or as many as three. Some even include a USB-A charging port to accommodate EVs with older cable technologies. And a number of the latest GaN chargers support USB-C PD and PPS, bringing greater versatility to EV charging design.

References

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2. "What Is a GaN Charger, and Why Will You Want One?," Tim Brookes, How-To Geek, Nov. 7, 2020.
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