Overview of Fast Charging

Fast Charging Every Time

Extended Cycle Life

The 10 Minute Advantage

FAST CHARGING

- DC fast charging without degradation and loss of battery life
- Up to 10 minutes faster charge time
- Minimize range reduction over life of the vehicle (90% at 600 cycle)
- Up to 50 percent cycle life extension
- Use 50-,100-,150-, 250- or a 350-kW chargers across wide temperature range of 0 °C to 60 °C
- Maintain battery health
- No additional hardware required
- Integrates with any BMS in the power train

WE SUPPORT

OEM

- Vehicles for mass-market adoption
- Fast, safe charging with extended cycle life to exceed EV driver expectations
- Worry-free fast charging

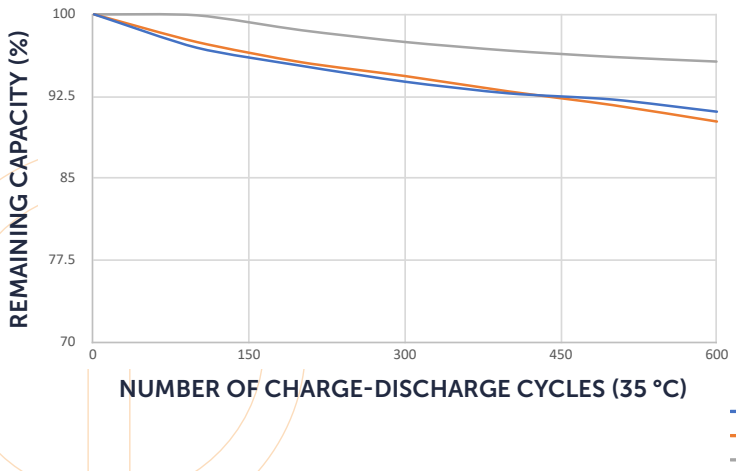
Drivers

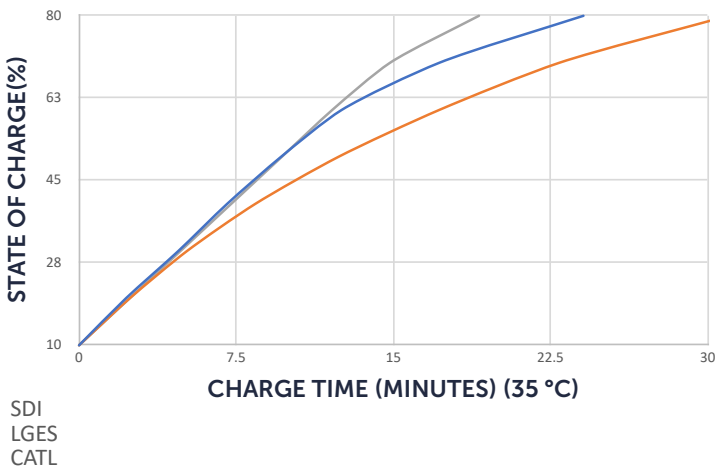
- Up to 100 hours less spent at the pump over the life of the vehicle
- Fast charging all the time

Fleets

- Additional 20–50 hours of uptime per year per vehicle
- 8 x higher efficiency at the pump
- Increases battery usage up to 24 months

Fast Charging Without Compromising Performance





SDI
LGES
CATL

EXCEPTIONAL FAST CHARGING AND CYCLE LIFE PERFORMANCE ACROSS ALL TOP VENDOR CELLS

- Fast charge from 10% to 80% in 30 minutes every charge cycle without compromising cycle life performance
- > 90% retained capacity at 600 cycles with fast charging at wide range of temperatures

Cell Information

Cell Vendor	SDI	SDI	LGES	CATL
Gravimetric energy density (Wh/kg)	220	265	266	255
Volumetric energy density (Wh/l)	530	635	575	573
Chemistry	NCA/NCM	NCA	NCM 712	NCM 811
Formfactor	Prismatic	Prismatic	Pouch	Prismatic

Performance

Depth of Discharge (%)	70		70		70		70	
SOC range (%)	10 to 80		10 to 80		10 to 80		10 to 80	
Fast charging frequency (%)	100		100		100		100	
Remaining capacity at 600 cycles (%)	92		90		90		90	
Temperature	25 °C	15 °C	35 °C	15 °C	35 °C		35 °C	15 °C
Charge time (min)	23	29	24	32	31		20	30

Powertrain Support

ALL CELL CHEMISTRIES/FORM FACTORS/ VENDORS SUPPORTED

- Cathode chemistry:
  LCO, NCA, NCM (622,811), LFP
- Anode chemistry:
  Graphite (C), Silicon (Si),
  Graphite-silicon (Si-C)

Vendors
- CATL
- LG Energy Solutions
- Samsung SDI
- SK on

Cell formats
- Prismatic/jellyroll
- Prismatic/stacked
- Pouch/stacked
- 21700/jellyroll

Cell chemistry
- NCM 622/C
- NCM 712/C
- NCM 811/C
- NCMA/C
- NCA/C
- NCA/Si-C
- LFP

SOFTWARE/VEHICLE OS ARCHITECTURES

- Runs as an AUTOSAR application
- Integrates with RTOS based BMS architectures
- Standardized, documented interfaces (APIs) to BMS sub-systems
- Over-the-air (OTA) updates supported

CHARGING SUPPORT

- Optimum charging current and voltage computed every 1–5 seconds over entire charge cycle to enable safe, fast charging
- Charging speed adjustments based on weakest cell health
- Intelligent health balancing

DIAGNOSTICS

- Diagnose weakest cell in the pack
- Health map of the pack
- Detects internal battery faults, shorts and leakages and flags to higher applications

MITIGATION

- Avoids unsafe charging due to temperature, cell health, operating conditions and presence of defects
- Prevents charging events resulting in excessive degradation
- Detects onset of lithium-metal plating and takes corrective actions

Qnovo™

PACK CONFIGURATIONS

- Scalable software compatible with BMS solution supporting 1 to > 800 cells
- Supports single pack multi-module and multi-pack configurations
- Supports centralized and distributed BMS architectures
- 400 V, 800 V configuration

CELL AND PACK HEALTH MANAGEMENT

- 3-level extension to traditional capacity-based SOH
  - Level 1: cell-level aging gradient, remaining useful life (RUL) to indicate end-of-life
  - Level 2: predictive health and safety fault indicator
  - Level 3: instantaneous and predictive state of health and state of power

BMS FUNCTION AUGMENTATION

- Intrinsic cell temperature to minimize the detrimental effects of temperature gradients
- Tolerant to the state of charge calculation errors
- Detects cell-level imbalances
- Provides BMS an accurate view of how much power is available for discharge

CHARGER SUPPORT

- L1, L2, DC fast chargers (up to 350 kW)
- Wired, wireless and inductive charger agnostic

COMMUNICATION

- Support centralized, distributed daisy chain, distributed CAN
- Unicast and broadcast on CAN
- Can be configured to communicate with J1939 devices and other CAN standards
- Wired and wireless BMS agnostic

RUNTIME SOFTWARE

- Precompiled binary links into BMS ECU executable
- AUTOSAR application

HARDWARE SUPPORT

- No additional hardware is required
- Analog front end (AFE) from NXP, Infineon, Maxim, Renesas, TI, and analog devices

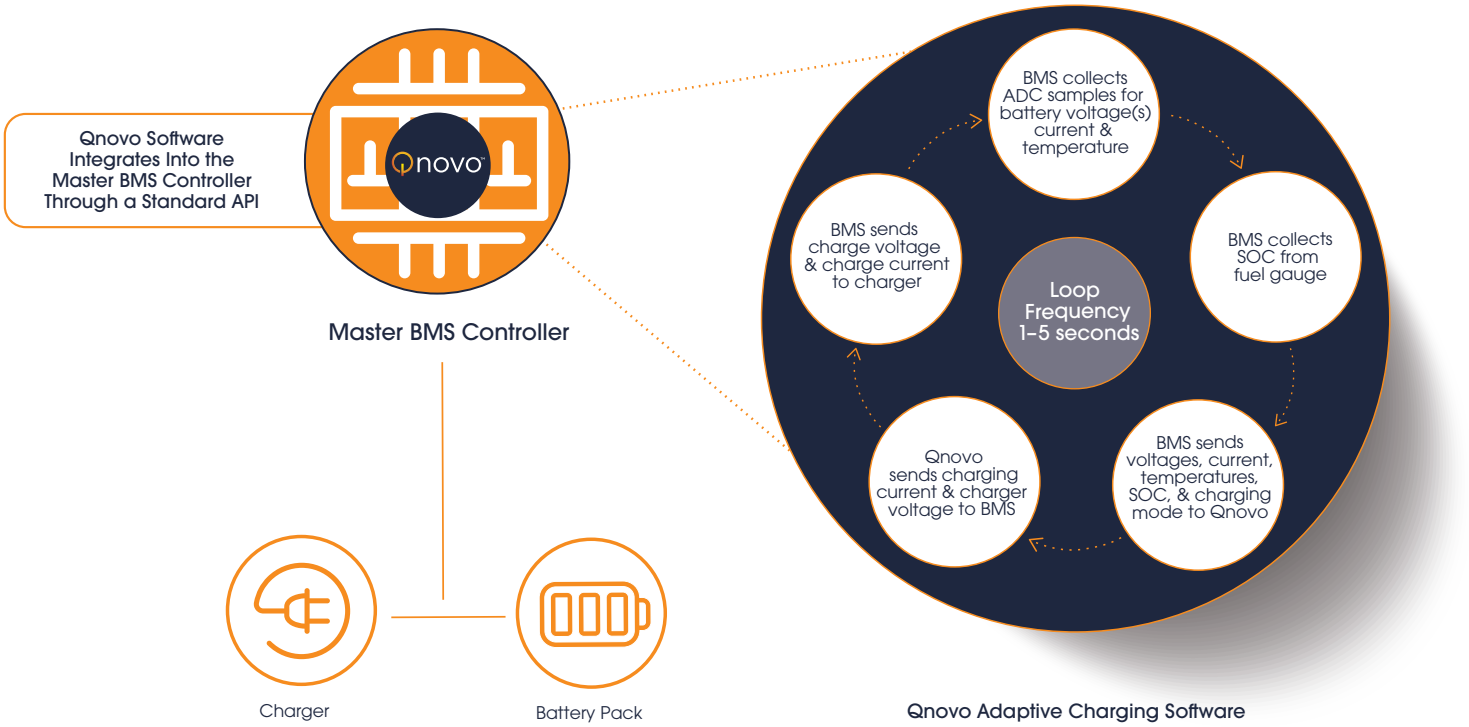
AUTOMOTIVE-GRADE

- Fault tolerant to avoid failure in noisy environments
- Supports low power sleep mode when the vehicle is off
- Quickly resumes operation when vehicle restarted

How Qnovo Fast Charging Works

Qnovo software stack runs as standard AUTOSAR application and integrates into a non-AUTOSAR RTOS based BMS architectures through a well-defined input and output interfaces.

- The code is compiled into a binary and integrated into BMS controller code.
- Qnovo software receives voltage, current, SOC and temperature from BMS, and sends charging parameters to BMS software. BMS will control the final output to charger leaving safety protections in places.
- Qnovo software works in conjunction with existing cell balancing (active or passive) for improved performance.
- The software is flexible and adapts easily to different battery configurations. The computation and storage requirements scale modestly with more cells in pack.
- The Qnovo software monitors each series element (single cell or set of parallel cells) individually. The algorithm runs independently on each series element to identify the weakest series element.
- The software adjusts charge rate based on the weakest series element — a pack is only as good as its weakest series element.
- The algorithm loops through each series element in round robin fashion every 1–5 seconds. This frequency is determined at the time of initial design based on the application requirements.



System Requirements

Data Acquisition (Cell Level)	
Voltage resolution after noise (series element)	2 mV 0–5 V after noise and error, 12-bits effective
Voltage sampling rate	10 Hz
Absolute voltage sampling accuracy	10 mV
Relative voltage sampling accuracy	2 mV
Current resolution	100 mA
Current sampling rate	5 Hz Voltage and current measurements should be synchronized within a 10 ms window
Current sampling accuracy	1.5%
State-of-charge accuracy	± 3%; 0–60 ^{0}C

Charger Requirements (Pack Level)	
Current programming steps	1 A
Float voltage	Cell and topology dependent
Voltage programming steps	10 mV per series element

Memory Requirements	**96s Configuration**
NVRAM	15 kB
RAM	15 kB
Executable Footprint	48 kB (typical)

SIMPLE BMS INTEGRATION

The battery parameters collected and computed by the BMS must be communicated to the Qnovo software stack. They include:

Input Arguments	**Type**	**Units**	**Usage**
Series element voltage	16 bit unsigned integer array	mV	Most recent voltage sample for each series element
Pack current	32 bit signed integer	mA	Most recent pack current sample
SOC	16 bit unsigned integer array	0.10%	Most recent pack State of Charge estimation
Temperature	16 bit signed integer array	°C	Most recent temperature measurement
Charging state	8 bit unsigned integer	n/a	Charging or not charging

Output Values	**Type**	**Units**	**Usage**
Charger current	16 bit unsigned integer	A	Set charger to this current
Charger float voltage	16 bit unsigned integer	V	Set charger to this float voltage

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