C.E. Niehoff & Co.
CHARGING AND POWER MANAGEMENT SOLUTIONS™

Lithium-Ion Charging Technologies

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Li-Ion Battery Charging

Due to the unique characteristics of Li-Ion batteries including the importance of keeping them within a safe operating range, it is critical to avoid exceeding the battery maximum charging current At room temperature a Li-Ion battery can normally be charged with its data sheet maximum rated recharge current (fig 1). As the battery deviated from room temperature (either up or down) its maximum recharge current is reduced until, at critically high or low temperatures, the battery cannot accept charge. For this reason, Li-Ion batteries need the alternator to actively manage recharge current as a function of the real-time ability of the battery to accept charge based on temperature, SOC and other battery characteristics.

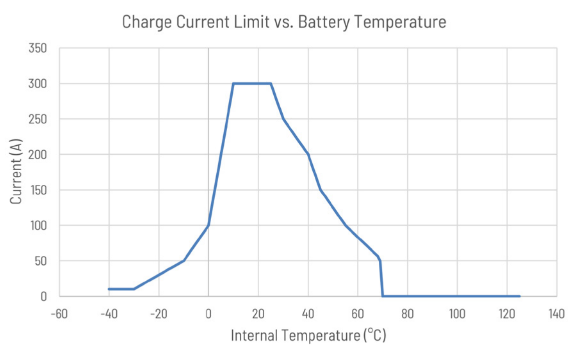
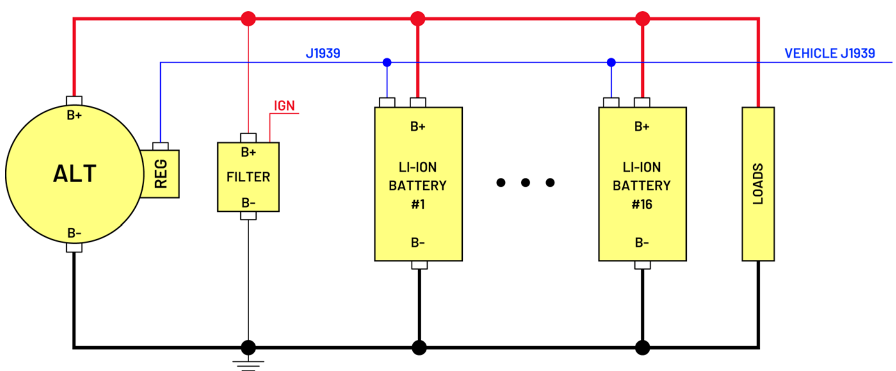


Figure 1 - Sample maximum charging current for Li-Ion Batteries

The CEN Plug-and-Play Li-Ion battery charging algorithm is implemented by constantly monitoring battery parameters and adjusting alternator output to ensure all charging system characteristics are within the safe operating ranges of both the battery and the platform electrical system. With this method compliance with a platform level power quality standard (J1113/11, J1455, ISO-7637-2, ISO-16750-2, MIL-STD-1275, etc.) is achieved.



In Military applications the batteries must comply with MIL-PRF-32565 Rev B (J1939 messages with PGNs 0xFF01, 0xFF02, 0xFF03 and 0xFF04) in order to use CEN's Plug and Play charging solution and the resulting system can support up to 16 Li-Ion batteries connected in parallel.

Basics of Li-Ion Battery Charging

- Chemistry is vastly different than lead acid
- Higher amount of energy in a smaller volume
- Does not require trickle/float charged once fully charged
- Charging is normally limited to a certain temperature range
- Requires a protection circuit (included in most Li-Ion battery types)
- Can utilize a constant current charging profile within a specific temperature range
- Need current limited, active charging across the entire temperature range
- Overcharge must be avoided to guarantee battery safety
- May disconnect completely from the DC bus in response to out of range parameters (temperature, voltage, state of charge)

Critical Data Requirements

System information required to safely and successfully charge Li-Ion batteries directly with the vehicle alternator via J1939 or utilizing the CEN Smart Battery Sensor (SBS).

- Terminal Voltage
- Current
- State of Charge (SOC)
- Maximum Charging Current vs. Temperature / SOC / SOH
- Battery Disconnect (Contactor) State

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The CEN Li-Ion Battery Charging Algorithm

As the alternator is energized, the regulator reads the information from all batteries and calculates a starting alternator voltage set point higher than the battery voltage. From there, it slowly ramps up the set point to the maximum default alternator set point. During that process, the regulator monitors the charging current in each connected battery and compares it to the maximum current each battery can accept. If the charging current exceeds the maximum value, the regulator changes the alternator control to limit the charging current of the battery to be the maximum allowed under that limit. This enables the battery to be safely charged as fast as possible. If the regulator loses communication with the batteries, it will default to a "Safety Default Set Point" that is defined by a switch on the back of the regulator set to 25.0V, 26.0V, 27.0V or 28.0V. It may also be overridden via J1939.

Additional Protection

Because Li-Ion batteries have the ability to disconnect from the DC bus in the presence of full state of charge or other unsafe parameters measured by the battery, the usage of a voltage capacitive filter is recommended.

The CEN capacitive filter, installed in parallel with a CEN alternator, is designed for improved alternator output power quality should such a battery disconnect occur. This is especially true if the platform loads are considered sensitive to high voltage ripple and spikes/surges. The filter implements capacitor pre charging and post discharging circuits that are controlled by the vehicle's Ignition signal. An LED indicator visualizes the filter state.

Algorithm Features

- Dynamic battery recharge Current control s accomplished using an advanced patented technique rather than simply lowering the alternator voltage. Alternator shutdown is prevented when the voltage required for battery recharge/protection falls below the battery open circuit voltage (OCV).
- Transportability SOC management in accordance with battery manufacturer requirements.
- Battery-less management of platform power quality via optional voltage filters for cases where the batteries are removed from, or self-disconnect from, the vehicle system.
- Option for the vehicle/application controllers to override some of the algorithm's parameters such as: Maximum Default Alternator Set Point Override, Safety Default Alternator Set Point Override (for when communication with the battery/SBS is lost), Battery Charging Current Limit Override, and Maximum Battery SOC Override.

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PGN Name	PGN	Source Address	BYTE 1	BYTE 2	BYTE 3	BYTE 4	BYTE 5	BYTE 6	BYTE 7	BYTE 8
Charging Parameters Override Command	0xFFCC	0xFA	Regulator Source Address	Maximum Default Alternator Setpoint		Maximum Battery Charging Current Override		Maximum Battery SOC	Safety Default Alternator Setpoint	
Battery Readings	0xFF01	0xE8-0xF6 0xFE	Internal Pack Voltage		Battery Temperature					
Battery Calculations	0xFF02	0xE8-0xF6 0xFE		Battery State of Charge	Battery State of Health					
Battery Regulation Information 1	0xFF03	0xE8-0xF6 0xFE	Battery Voltage		Open Circuit Voltage		Battery Current		Maximum Charge Current	
Battery Regulation Information 2	0xFF04	0xE8-0xF6 0xFE	Charging Contactor Status			Transportability SOC				

Example of the J1939 messages supported by the CEN Li-Ion battery charging algorithm

Each of the 4 messages (0xFF01, 0xFF02, 0xFF03 and 0xFF04) from the battery are mandatory for the algorithm to work properly, but not all of the information in those messages is needed. Values marked in green are mandatory while values marked in yellow are optional. The values marked in blue are unnecessary. If some of the yellow or blue information is not available, it should be broadcast as 0xFF or 0xFFFF (not available per the J1939 standard).

Messages with PGN's 0xFF01 and 0xFF02 from the batteries (from source addresses 0xE8-0xF6, 0xFE) have a 20 sec time out period and messages with PGN's 0xFF03 and 0xFF04 have a 3 sec time out period.

Messages with PGN's 0xFFCC need to be sent only once, or as needed, and will latch the regulator parameters until it is sent again or until the regulator is power cycled. If these messages are not sent, the regulator will use it's internal parameters and/or the data from the batteries. This command can change the parameters only once every 60 sec. If it is sent earlier, the regulator will ignore it. The "Maximum Battery Charging Current Override" cannot be lower than "Maximum Charging Current" coming from a battery. "Maximum Default Alternator Set Point" and "Safety Default Alternator Set Point" should be in the range of 20.0V to 30.0V. Maximum Battery SOC can range from 0% to 100%. Outside of those ranges, the regulator will default to its internal limits. This command is Destination Address specific - it will be accepted only from the regulator with a source address that matches Byte 1 in this command. The regulation band for the maximum charging current is between 85% and 100% of the values specified in "Maximum Battery Charging Current Override". The regulation band for the maximum SOC is between 90% and 100% of the value specified in "Maximum SOC".

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