



*On-board Battery Charger Reliability for*

# **ELECTRIC DRIVE VEHICLES AND INDUSTRIAL MACHINES**

The past 15 years have been transformative for industrial battery charger design, as high-frequency, solid state designs have become the norm in many applications. High frequency chargers offer smaller footprints, reduced weight and more precise microprocessor control of the charging process. Power electronics and printed circuit boards (PCBs) have been miniaturized to the point where chargers are small enough to be installed on-board electric drive machines, such as lift trucks, floor cleaning machines, and aerial work platforms.

With on-board chargers, the simplicity of plugging a machine into the nearest electrical outlet is a compelling benefit. It makes the machine more portable and encourages the habit of plugging in the machine for a quick charging top-up when needed. Putting a charger on-board also exposes it to a greater array and severity of risk factors for damage, which would prevent the machine from being charged.

Delta-Q Technologies designed its newest product, the IC650 Industrial Battery Charger to be a reliable, durable charging solution for on-board applications. Throughout its product validation, the IC650 Charger was subjected to durability tests based on an automotive standard, attempting to simulate a long service life when mounted on-board.

This article explains Delta-Q's process in validating the IC650 Charger for on-board use and provides practical tips for original equipment manufacturers (OEMs) looking to integrate chargers on-board their vehicles or machines.

# Design and Testing for Reliability

Durability is essential to an on-board charger, as the charger needs to reliably put energy into the batteries. Charger failure equals customer dissatisfaction, as their battery-powered equipment will no longer operate productively. Using our application knowledge from years of serving OEMs, we designed the IC650 Charger to resist the failure modes common in on-board chargers.

Vibration is a particular challenge because every environment—in lift trucks, aerial work platforms, floor machines, etc.—subjects the charger to a different vibration profile, varying from high frequency low-g to significant mechanical shock. Vibration can shake components inside the charger loose, or cause components to make contact with the inside of the enclosure.

In a break with traditional practice, we developed a fully sealed, rigid die cast aluminum construction. The casting provides enhanced mechanical support to the power electronics components, helping the charger to resist the effects of vibration and shock.

The die cast construction also allows for multiple features to be cast-in. This approach of integrating multiple features into key components has been used extensively throughout the product design concept, significantly reducing the secondary parts count and assembly time. This is formally known as Design for Manufacture (DFM). By using a die cast housing which also doubles as the heat sink, we were able to provide the charger with distinctive angled fins that allow equally effective cooling when mounted in any orientation. In all of the applications we are discussing, space for integrating a charger is at a premium, making positional flexibility of utmost importance.

To effectively protect on-board electronics from dust and liquids, the enclosure, including all connections, must be fully sealed. The IC650 Charger is sealed at all points where water or dirt could enter the charger, including its USB host port, AC inlet and DC connection block.

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To create a more durable overall charging system, Delta-Q designed a new product—a sealed, locking AC power cable. This new design maintains a firm connection between the charger and power cable, while also protecting the AC inlet from water or dirt ingress.

Sealing presents its own challenges, not the least of which is the ability for the charger to reject heat effectively. The IC650 Charger was designed to operate at higher temperatures than competing options, and to de-rate itself for safety at a higher temperature. Proper de-rating is an important feature, as it means the charger continues to put energy into the batteries, while preventing its internal components from failing. The key performance criterion is whether the

batteries are charged and ready by the time the machine is needed. If the charger shuts off because of overheating, the machine is prevented from being productive.

Delta-Q's engineers assembled all of the electronics onto one printed circuit board with maximum use of machine-placed components. This approach minimizes inter-connections and manual processes, which are a significant cause of reliability issues.

The selected concept design was analyzed using state of the art techniques such as finite element analysis for mechanical durability, computational fluid dynamics for heat rejection and worst case analysis for circuit design. These detailed analyses, coupled with stringent de-rating for all components, help guarantee that the final design will meet requirements optimally the first time through.



## IC650 Charger Validation Testing

The IC650 Charger had to pass a battery of tests to validate its tolerance for “worst case” operational conditions when mounted on-board and verify that it could still perform at a high level despite these factors.



### MECHANICAL SHOCK FATIGUE

This test looks at the possible fatigue of components due to shock, such as the machine being driven over a speed bump, or running into a wall.



### THERMAL SHOCK & TEMPERATURE CYCLING

Chargers can become damaged when a quick shift occurs from a low- to high-temperature environment, such as driving a forklift from a drive-in freezer into a hot warehouse. This test simulates that shift, with the charger spending time at intervals from -40°C to 105°C (-40°F to 221°F)



### MECHANICAL VIBRATION FATIGUE

This test analyzes how the charger can tolerate vibration, including at different temperatures, such as when a burnisher vibrates when it removes the top layer of finishing from a floor.



### HIGHLY ACCELERATED LIFETIME TESTING (HALT)

This type of testing attempts to simulate real-world conditions and puts multiple stresses on the design in order to induce failures. In between testing sessions, root cause analysis is conducted on failure modes to improve on the design.

# 3 Tips for Better On-board Charger Integration

These are ways to improve the integration of an on-board charger into your machine design. Find out more by requesting the IC650 Charger Design Guide.



A sealed charger keeps the dirt of on-board environments out of the charger.

## MAKE THE CHARGER SMALL AND SEALED

Small things fit better in tight spaces.

The quality of design and efficiency of the charger's power electronics matter most when space is scarce and maximum output power is required to charge the battery pack within an expected time frame. Efficient power electronics can be packaged in a smaller enclosure, since they don't create as much waste heat. Sealing the charger prevents those well-designed components from being damaged by fluids or dirt.



Convection airflow allows the charger to reject heat and operate at full power.

## GIVE THE CHARGER SOME SPACE

Providing a sealed battery charger with space for convection air cooling will help it to operate better.

Given some space, the charger can operate at its peak output power throughout the charging cycle. Every application is different in how an on-board charger is typically installed, so there is no hard rule for how much space is necessary. It is also advisable to position the charger away from sources of dirt and water. In the case of the IC650 Charger, the diagonal heat sink fins are where the heat is rejected, so giving this area adequate clearance is important for its peak performance. The mechanical design of the IC650 Charger assists convection airflow from many angles, providing flexibility for where the charger can be mounted inside the machine.



A simple, clearly lit display enables the customer to see when charging is complete.

## MAKE THE CHARGER'S DISPLAY VISIBLE

The end user needs to be able to understand when the charging cycle is completed.

With the IC650 Charger, we painstakingly worked on making sure the charger's display was simple and brightly lit. The IC650 Charger can also incorporate signaling from its DC connection block, or CAN bus communications port, if the charger is installed deep within a machine. Every OEM with whom Delta-Q works can relate to the customer that never completes a charging cycle and wears out their batteries as a result. A clear display helps prevent that possibility.

IC650 ON DELTA-Q.COM



IC650 "Durability" Videos on YouTube



Connect directly with Delta-Q's application engineering team to find out more about integrating one of our chargers into your vehicles or machines.

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