How Ultracapacitors Improve Starting Reliability for Truck Fleets

BY MAXWELL TECHNOLOGIES

It is often said in the trucking industry that "if the wheels aren't turning, the business isn't earning." When fleets deliver freight on schedule, customers are pleased, drivers are less stressed, and fleet managers enjoy smooth operation of their businesses. However, when drivers are struggling with downtime caused by starting problems, battery-based engine starting may be an issue that needs examination.

How can fleet operators ensure that their drivers get through every day with no starting problems? In many cases, batteries are a less-than-dependable source of power for starting heavy and medium duty diesel trucks. Fortunately, using proven ultracapacitor technology for engine starting is an alternative choice that ensures reliable starting in the face of:

- Increasing accessory loads in the cab and sleeper
- Subfreezing overnight temperatures
- Excessive summer heat
- Many starts and stops during a day

Ultracapacitors provide a higher level of reliability and confidence in engine starting with minimal on-the-job hassle, keeping the "wheels turning" for your business.

This white paper will explore the advantages of ultracapacitor-based engine start technology for Class 6–8 trucks.

Industry Dynamics Influencing the Shift from Batteries to Ultracapacitors for Truck Starting

Some of the latest challenges fueling the growing trend toward ultracapacitor-based engine start technology include increased accessory and sleeper loads on the truck, anti-idle regulations, and reduced battery performance in cold weather, which has become more prevalent as electrical loads increase and anti-idle regulations propagate.

In order to attract and keep long-haul drivers, fleets are outfitting their trucks with sophisticated sleepers that provide drivers with the comforts of home—refrigerators, microwaves, television sets, and power for personal computers, GPS devices and

cell phones. Even CPAP machines have found their way into the modern-day sleeper. While truck features have become more advanced, lead-acid battery technology development has not kept up with growing energy demands. Some OEMs offer up to eight batteries to support the truck's power demands. More batteries result in increased tare weight and additional battery replacement costs.

Anti-idle regulation is another industry dynamic influencing the shift toward ultracapacitors for truck starting. According to the American Transportation Research Institute, 31 states and the District of Columbia have enacted anti-idle laws.[1] Unreliable battery starting causes drivers to idle the engine. Current battery technology doesn't make it easy for fleets to comply with anti-idle laws.

Lastly, while useful in many applications, batteries are notorious for failing to start engines in cold weather. Batteries that operate perfectly on an average autumn day can suddenly fail to start an engine during the first winter cold spell. Even though batteries will perform normally when warmed up, fleet operators typically replace them right away since they are likely to fail again during the ensuing winter.

The Challenges with Battery-Based Truck Starting

There are five primary challenges associated with battery-based truck starting: 1) batteries have many loads placed on them, 2) extreme cold weakens batteries, 3) temperatures above 100°F shorten battery life, 4) drivers tend to idle their trucks for long periods of time to avoid risk of a no-start, and 5) frequent stops and starts result in inadequate time for the alternator to recharge the batteries, often resulting in failure to start. This section examines each challenge in more detail.

Batteries have many loads placed on them.

Today's trucks demand more energy from batteries than ever before. Electrical loads from sleeper features such as lighting, television sets, microwaves, refrigerators, CPAP machines, cell phones and laptops often drain batteries during the night. Telematics systems are another example of a feature now commonplace on trucks, which typically draw current 24 hours a day, even when the truck's ignition is switched off.[2] A typical new truck includes anywhere from five to twelve onboard computers that continually draw energy from the batteries. Additionally, a mandate by the Federal Motor Carrier Safety Administration (FMCSA) will require fleets to adopt electronic logging devices (ELDs)—another load that will be placed on the batteries. All of these energy demands often discharge the batteries to the point where they are unable to start the truck.

[1] "Compendium of Idling Regulations." American Transportation Research Institute, Aug. 2015. Web. 7 Jan. 2016. <http://www.atri-online.org/research/idling/ATRI_Idling_Compendium>.
[2] Park, Jim. "Spec'ing Charging, Starting and Battery Systems." HDT. Truckinginfo.com, Nov. 2015. Web. 8 Jan. 2016. <http://www.truckinginfo.com/channel/equipment/article/story/2015/12/spec-ing-charging-starting-and-battery-systems.aspxx>.

Another common scenario is the "Monday morning scramble" when batteries are discharged due to electrical loads that were unintentionally left on—most commonly in trucks that were not driven over the weekend. This typically results in a jump-start, with the driver incurring a late start on Monday. Refuse collection and ready-mix fleets are familiar with this problem.

Extreme cold weakens batteries.

A battery performs at its best at about 72°F. At this temperature, it can deliver optimum cranking power. When the battery is exposed to colder temperatures, the driver will experience slower cranking cycles for the duration of the cold temperature period. Cold cranking amps (CCA), measured at 0°F, gets progressively weaker at lower temperatures. According to Bruce Bowling's "CCA Temperature Adjustment Algorithm," a battery rated at 1,000 cold cranking amps can only produce 353 cranking amps at –40°F; a 64.7% loss of starting power.[3]

In addition to reduced battery performance, subfreezing temperatures also cause engine oil to thicken. As a result, the engine requires more power to crank over. A Catch-22 ensues: The colder it gets, the weaker the batteries get, while at the same time the engine needs more power to start. A jump-start is the common outcome, which can lead to several negative business implications including:

- Downtime
- Time and money spent on the jump-start
- Lost time on the work schedule and/or late deliveries
- Dissatisfied customer
- Driver frustration

Fleets operating in cold regions typically invest in block heaters and battery blankets to combat the problem of cold weather starting. The challenge with both options is that drivers need an AC outlet to operate both, and outlets are not always available, especially for trucks that drive remote routes. Connecting block heaters and battery blankets can be a cumbersome extra step for drivers who have to set up the heating device before going to sleep. Even if an outlet is available, it is not uncommon for a driver to forget to plug in the block heater and/or battery blanket.

[3]Bowling, Bruce. "Automotive Battery Cold-Cranking Amp Temperature Adjuster." N.p., n.d. Web. 18 Jan. 2016. <http://www.bgsoflex.com/ccatemp.html>.

Engine start technology that is not affected by subfreezing temperatures can eliminate the need to take these extra precautions and significantly improve uptime during the cold winter months.

Temperatures above 100°F shorten battery life.
Cold temperature temporarily weakens battery performance, but heat is detrimental and shortens product life. In hot climates, batteries typically fail with little or no warning.

In a Heavy Duty Trucking article titled "5 Tips to Keep Your Battery Running in the Summer Heat," authors Shumard and Orlando-Krick explained, "While warmer temperatures help to increase battery capacity, making it easier to turn over the engine, they also cause an increase in the rate at which the battery deteriorates. When the temperature is warmer, the current conducting grids corrode faster, reducing the life of your battery."[4]

A battery operating in the humid heat of South Florida will have a significantly shorter expected life than a battery operating in the colder temperatures of Maine. Trucking fleets that operate in hot climates generally experience higher battery failure rates, resulting in jump-starts and higher battery replacement costs. Keep in mind that heat-induced jump-starts will get the truck running again, but it's a temporary solution.

Ideally, a truck's starting reliability is not compromised by heat. Advanced engine start technology available on the market today is able to withstand high temperatures, giving drivers the confidence that their trucks will start despite extreme climate conditions.

Drivers tend to idle their trucks for long periods of time to avoid risk of a no-start.
Idling is a deeply entrenched problem that the majority of fleet operators deal with today. The problem stems from unreliable starting with batteries, especially in cold weather.

Before shutting off a diesel engine, every driver is forced to consider the question: "Will it start when I need it next?" If unsure of the answer, the driver will leave the engine idling instead of shutting it off and risking an expensive jump-start. The result is wasted fuel and non-compliance with anti-idle regulations.

Idle management systems are required by law for most new trucks, and there are two types: 1) those that automatically shut off an idling engine after a prescribed period of time (generally 5 minutes) and 2) those that allow the engine to be shut off in cold weather but will automatically re-start the engine when block temperature or battery voltage drops below certain levels. These systems generally reduce idling time, but are not an ideal solution. Idle management systems are also known to disrupt the driver's sleep, contributing to drowsiness and fatigue while driving the next day.

[4]Shumard, Phil, and Maria Orlando-Krick. "5 Tips to Keep Your Battery Running in the Summer Heat." Editorial. Truckinginfo.com. HDT, July 2014. Web. Jan. 2016. <http://www.truckinginfo.com/channel/maintenance/article/story/2014/07/5-tips-to-keep-your-battery-running-in-the-summer-heat.aspx>.

Excessive idling takes its toll on the fleet. Consequences for idling include:

- Wasted fuel
- Wear-and-tear on the engine resulting in increased maintenance costs[5]
- Potential fines for violating anti-idle regulations

Fortunately, new starting technology has emerged to help fleets avoid needless idling altogether and can eliminate cumbersome methods for idle reduction.

Frequent stops and starts result in inadequate time for the alternator to recharge the batteries, often resulting in failure to start.
This challenge applies particularly to fleets with routes of many closely-spaced deliveries, but also affects fleets that may work at job sites completing repetitive loads and offloads, or drivers working at rail yards. If the alternator system doesn't have sufficient charging time between stops to keep batteries fully charged, drivers may experience discharged batteries before they can complete the day's work. This often results in a jump-start.

Consider the example of a food delivery driver. The driver reaches the first stop and shuts off the engine because of anti-idle regulations in the area. The driver turns on the truck's flashers to alert passing traffic and uses the lift-gate to unload the delivery—both actions draw energy from the batteries. When the delivery is complete, the driver starts the engine, drives to the next location often only a few blocks away, and repeats the process. Before the end of the day, the batteries are insufficiently charged to start the truck.

Fortunately, fleet operators can avoid scenarios like the one described by integrating technology that is dedicated solely to starting the truck, allowing the truck to use battery power for loads other than starting.

Other challenges
Additional issues presented by battery-based truck starting include:

- The life of a battery is only thousands of start cycles
- Batteries need frequent replacement, particularly in hot climates
- Batteries may take hours to charge (depending on depth of discharge)
- Batteries are heavy and increase tare weight

A Brief History of Truck Starting with Lead-Acid Batteries

In the early days, batteries were responsible for starting the engine, powering lights when the engine is off, and supplying power to the ignition. Other than cold weather

[5]"Long-Haul Truck Idling." Rep. U.S. Department of Energy, Aug. 2015. Web. 13 Apr. 2016. <http://www.afdc.energy.gov/uploads/publication/hdv_idling_2015.pdf>.

starting issues, batteries have been a stable starting technology.

In the trucking world, things are now very different. Today, batteries in diesel trucks perform two demanding functions: 1) provide power to start a large diesel engine and 2) provide energy for onboard electrical loads. Wider acceptance and usage of lift-gates has also contributed to the problem. Power and energy demands have changed dramatically in recent decades, but lead-acid battery technology has undergone only incremental changes.

Battery manufacturers recognized the need for a more versatile battery and began offering a dual purpose battery—a combination of the starting battery and the deep cycle battery. Manufacturers also developed and now offer absorbed glass mat (AGM) batteries that offer longer life and somewhat improved performance. AGM batteries are more expensive and, as a result, have received limited acceptance by the trucking community. The majority of fleets continue to use flooded cell starting or dual purpose batteries in their trucks and tractors.

Auxiliary power units (APUs) are prevalent in modern trucks because they are more cost-effective for powering electrical loads (versus running the main truck engine) and address the need for more energy than batteries alone can provide.

APUs and the battery types discussed are the standard technologies used today that help to support the power demands of the modern truck. Despite these technologies, fleets still struggle with managing truck power demands. The future of Class 6–8 diesel truck starting requires two separate electrical systems that uniquely address the truck's engine starting and on-board computer/accessory needs.

The Solution: Ultracapacitor-Based Engine Start Technology

To overcome the multiple issues with battery-based starting for large diesel trucks, fleet operators are turning to ultracapacitor-based engine start technology. Using ultracapacitors for starting avoids many of the limitations associated with battery-based starting. Ultracapacitors deliver high power to the starter, ensuring fast, reliable starts.

Ultracapacitors are very different from batteries. Ultracapacitors are electrostatic storage devices that store and deliver power via the passage of ions in an electric field. Unlike batteries, ultracapacitors do not involve a chemical reaction. Ultracapacitors are unique because they maintain a more consistent power output in the face of extreme cold or hot temperatures.

Figure 1 illustrates the output power difference between ultracapacitors and lead-acid batteries as temperature drops.

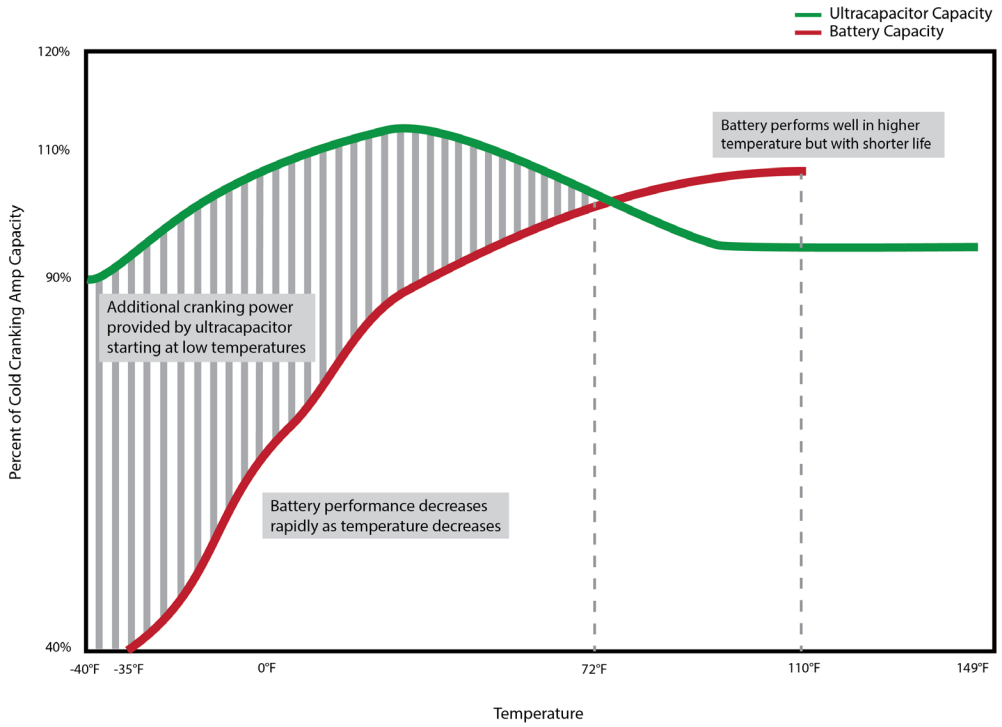

Figure 1: Ultracapacitor vs. Battery Performance at Variance Temperature

Note that ultracapacitor cranking power stays within a relatively tight power band (90% to 110%) across the full temperature range of –40°F to 149°F. Battery cranking power, on the other hand, varies widely (40% to 105%) across the same temperature range. At –35°F the ultracapacitor still has 95% of the cranking power that it has at 72°F; the cranking power of a battery has only 40% of what it provides at 72°F.

Ultracapacitor-based engine starting is best implemented when it is isolated from the battery system and charged separately—this allows the ultracapacitors to remain fully charged even if the batteries' charge is depleted. The result is a battery-ultracapacitor system in which the ultracapacitor module is responsible for starting the truck while the batteries provide energy to all other loads.

How it Works

Ultracapacitor-based engine start technology, in a Group 31 enclosure, is capable of cranking and starting engines up to 16 liters. The ultracapacitors inside the module can deliver higher burst power to the starter than the batteries can. Less than 3% of the total energy in the batteries is required to fully charge the ultracapacitors from a completely discharged state.

Figure 2 shows a typical configuration of four lead-acid batteries as installed in today's heavy duty trucks.

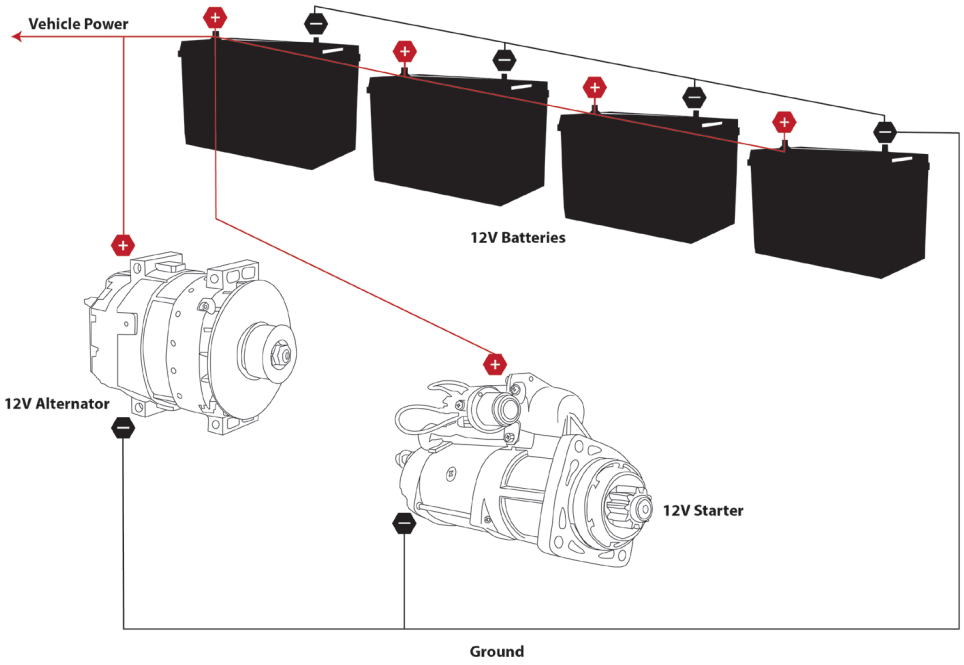

Figure 2: Before Installation of Ultracapacitor-Based Engine Start Module

Figure 3 shows how the ultracapacitor-based engine start module replaces one lead-acid battery, with the module's third terminal connected directly to the starter.

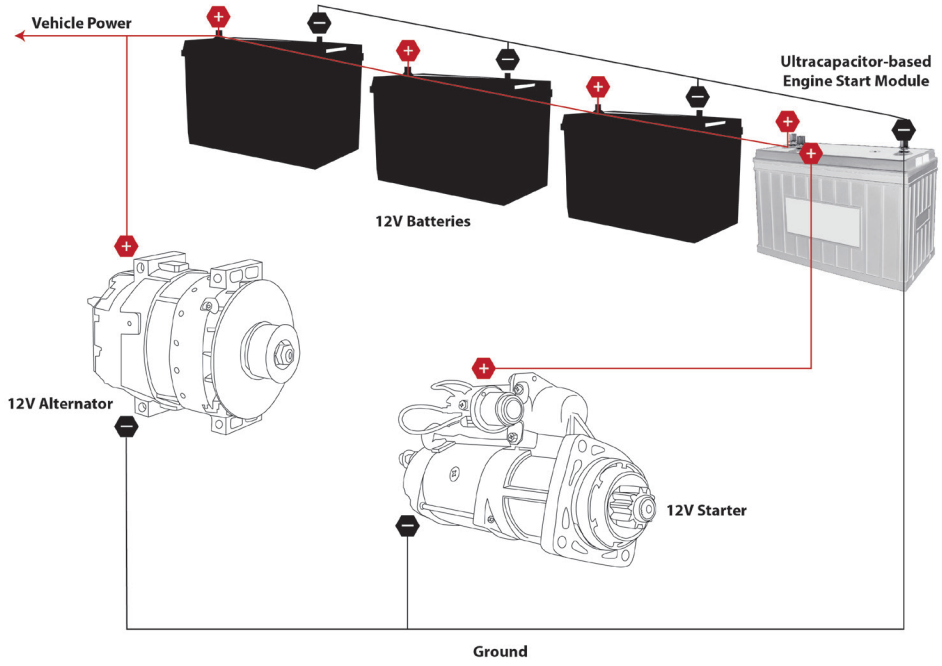

Figure 3: After Installation of Ultracapacitor-Based Engine Start Module

Key points about the ultracapacitor-based engine start module:

Replaces one battery in the battery box
One battery in the truck's original battery system is removed and replaced by one ultracapacitor-based engine start module. Sometimes it's possible to replace two lead-acid batteries with one ultracapacitor starting module—this is possible in day cabs because once an ultracapacitor module takes over the responsibility of starting, other truck and cab loads often place a relatively small energy demand on the batteries. The ultracapacitor module is connected in parallel with the batteries and requires only a very small amount of energy to stay fully charged. Both the ultracapacitor module and batteries stay fully charged by the alternator. When the engine isn't running, the ultracapacitor module stays fully charged by its internal charger.

The third terminal isolates batteries from the starter
An ultracapacitor engine start module should feature a third terminal that is connected exclusively to the starter. Once the ultracapacitor module is connected to the batteries, an additional cable connects the module's third terminal—the starter terminal—directly to the starter. When the installation is complete, the truck is now set up with two separate electrical systems: the ultracapacitor engine start module is connected directly to the starter and is dedicated to starting the truck, while the batteries are isolated from the starter and are used only to power the truck's onboard energy loads. The ultracapacitor module stays fully charged regardless of battery voltage.

Note that battery energy is necessary to power the truck's engine control unit (ECU). Ultracapacitor-based engine start technology does not replace batteries—it complements them by taking responsibility for starting the truck and allowing batteries to do what they do best: supply energy to electrical loads when the engine is shut off.

Ultracapacitor Engine Starting in Day Cab Trucks and Trucks with Sleepers

Ultracapacitor-based engine start technology can be used in day cab trucks and in trucks with sleepers. The system wiring is the same in both cases. Here's how it works in each type of truck.

Trucks with sleepers

An ultracapacitor engine start module can replace one battery in trucks with sleeper loads. If the fleet operator prefers to keep all of the truck's lead-acid batteries, an alternative is to install another battery box to accommodate the ultracapacitor engine start module. With an ultracapacitor engine start module, the driver doesn't have to conserve enough power in the batteries to start the engine. The ultracapacitor module minimizes the risk of not being able to start in the morning.

Trucks with lift-gates

Oftentimes a truck's lift-gate is powered by the same batteries that start the engine. Overuse of the lift-gate can result in discharged batteries and a jump-start. An ultracapacitor engine start module solves that problem by taking over the starting function. The module will remain fully charged and will start the truck even when batteries are severely discharged due to lift-gate use.

Important Benefits

Ultracapacitor-based engine start technology provides fleets with the following business advantages:

- Provides burst power to start the engine, regardless of the charge state of the batteries, ensuring that batteries are left free to power other loads
- Increases the output voltage as temperatures get colder, ensuring successful cold-weather starts and preventing drivers from being stranded after lengthy engine shutdowns
- Resilient in hot temperatures
- Ensures drivers can reliably shut off the engine for long periods of time without worrying about being able to restart the engine, helping drivers to comply with anti-idle laws and avoid excessive fuel consumption due to idling
- Enables drivers to confidently shut off and re-start the engine as many times as needed throughout the day without risking that the alternator will not be able to sufficiently charge the batteries to keep up with starting demands
- Provides hundreds of thousands of start cycles during its lifetime, compared to thousands of start cycles for batteries
- Provides longer product life than lead-acid batteries
- Recharges in minutes after a successful engine start
- Reduces tare weight (up to 120 pounds) by replacing one or more heavier batteries

What to Look for in a Solution Provider

When seeking the right brand manufacturer for ultracapacitor-based engine start technology, multiple factors should be considered. Here's what to look for:

Reputation and testimonials: Does the product do what the company claims it will do? Be sure that the company you choose to work with can offer customer testimonials and references. Contact those references to confirm their positive experience with the product.

Years of experience: Look for a company that has been in business for more than 20 years with significant experience in the design and manufacture of ultracapacitor technology and the application of ultracapacitors to engine start technology for the trucking industry.

Product quality and testing: To what standards and quality certifications has the product been tested and validated during its development? SAE J1455 and ISO/TS 16949 are two important industry standards to look for when purchasing a factory op-

tion or aftermarket solution.

Availability on new trucks: Find out whether or not the company's ultracapacitor engine start technology is available as a factory-installed option on new trucks.

Ease of installation: The product should be easy to install, with minimal rewiring to accomplish the installation. No additional solenoids, relays, switches, or oil pressure sensors should be required.

Qualified installers: Inquire whether the company's distributors offer installation services by fully qualified installers.

Ease of use: Starting should always be transparent to the driver, and should not require more actions than simply turning the key.

Number of available distribution locations in North America: Look for a company with distribution locations across the area where you do business. Distributors should be capable of handling installation and service issues. Additionally, the product should be available from the companies your fleet already purchases trucks, parts, and/or services from—whether you buy from the OE dealer, an independent parts/service supplier, or both.

Technical support: Ensure that the company you work with provides a dedicated technical support number staffed by specialists who are available to answer installation or ongoing ownership questions. Trucks are on the road 24 hours a day—be sure your provider offers a 24/7 technical support line.

Reasons to Partner with Maxwell Technologies for Reliable Engine Starting

Maxwell Technologies is an American company and the recognized leader, designer and manufacturer of ultracapacitor cell technology. In 2011, Maxwell focused on challenges in the trucking industry and recognized the extent of downtime due to starting problems. With the drive of true American entrepreneurship, Maxwell engineers set out to fill the industry need for reliable engine starting by designing the ultracapacitor-based Maxwell Engine Start Module (ESM).

The Maxwell ESM is assembled at the Maxwell Technologies manufacturing plant in Peoria, Arizona and is shipped to hundreds of distribution locations across North America.

The Maxwell ESM is an ultracapacitor-based engine start module that meets all of the requirements outlined in this paper. Maxwell provides these unique advantages:

Extensive client base: Maxwell has a proven client base, with more than 6,000 Maxwell ESMs in heavy and medium duty diesel trucks across North America. Installed in day cab trucks, vocational trucks and sleeper trucks, the ESM has been successfully deployed by a wide variety of private and for-hire fleets, including ready-mix, food delivery, long haul, LTL, auto-transport, refrigerated transport, and fleet lease/rental trucks. Maxwell has a solid portfolio of customer testimonials and can offer references.

Product quality and testing: The Maxwell ESM has successfully passed the testing requirements of SAE J1455, J1113-13 Part 13, and J2464(R) for electronic equipment in heavy duty applications. Additionally, Maxwell has the following Quality Management System Certifications: ISO/TS 16949, ANSI/ISO/ASQ Q9001, and ISO 14001.

The Maxwell Engine Start Module installed with three lead-acid batteries in a Class 8 tractor (left) and in a day cab ready-mix truck with one battery (right).

Over 2,000 distributor locations across North America: Maxwell's distributor network offers over-the-counter sales and turnkey installation by qualified installers, from both factory and independent parts and service organizations. Working with Maxwell provides a location near your facility with which you already do business.

Available on new trucks by major truck manufacturers: The Maxwell ESM is available as a factory-installed option on new trucks by major truck manufacturers, including Kenworth and Peterbilt.

24-hour technical support line: Customers have access to Maxwell's 24/7 technical support line, which is staffed by experienced U.S.-based support specialists. Solid customer service is core to Maxwell's principles.

Unique technology: The Maxwell ESM is the only product that increases output voltage as temperature drops. Engines require more starting current in cold temperatures, but battery output power drops in cold temperatures—the Maxwell ESM addresses that problem. In addition, the Maxwell ESM's DC-DC converter allows charging to a higher voltage than batteries, resulting in faster starts. Once installed, the ESM integrates seamlessly into the truck's electrical system and the driver won't need special knowledge for ongoing use of the product. The only difference the driver will

notice is reliable starting cycles that are faster and shorter.

Easy to install: Maxwell's ESM is a Group 31 ultracapacitor-based engine start module that easily replaces one battery in the battery box. The Maxwell ESM requires one additional cable with minimal rewiring and no wiring to the cab.

More than 50 years of experience: Maxwell Technologies was established in 1965 and has pioneered the way in high-performance, durable ultracapacitor cells. Maxwell began building ultracapacitors in 1992 and has developed in-depth knowledge about ultracapacitor technology and its specific application in the trucking industry.

How to Get in Touch with Maxwell

To bolster your bottom line, improve uptime and gain a competitive edge with the Maxwell ESM, please contact a Maxwell trucking specialist who can:

- Assist you with performing a customized ROI payback analysis
- Arrange an on-site visit and presentation that addresses your fleet's requirements
- Work with you to plan an ESM product evaluation program

Call (858) 503-3253 or email StartStrong@maxwell.com today.

Maxwell TECHNOLOGIES
Enabling Energy's Future™