WHITE PAPER

WIRELESS CHARGING
THE FUTURE IS HERE!

An analysis of the technology, customer benefits, and how Datalogic has implemented the state of the art in Joya Touch

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DATALOGIC
THE VISION IS YOURS

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Introduction

The life of every mobile device depends on its battery and every battery depends on its charging system.

Users typically don't consider these characteristics, they simply demand long battery autonomy, long battery life cycles and short charging times. However there is also another very important step in this process: the charging method. Traditionally devices have been charged slowly by conduction using slow charging through copper contacts. Today, wireless charging, fast charging, and boost charging represent new charging methods that minimize charge times while providing other benefits.

Wireless charging technology was introduced in the consumer market by Nokia in 2012 with 2 Lumia models. Since then Samsung, Blackberry, Motorola, and now even Apple have introduced wireless charging devices. Retailers are using wireless charging to help keep consumers charged. Ikea for example is producing home furniture with an embedded charging mat and Starbucks has featured a number of stores with charging mats embedded into tables for customer use.

With wireless charging becoming more popular and common every day, this white paper will look at the various charging methods to show why wireless charging was selected for the Joya Touch and what the benefits of this new charging method are for the industrial user.

1 – Wired Charging

The classic way to recharge a battery is to use a low voltage wired power adapter typically supplied with the product. This system connects the device low voltage terminal input to the ubiquitous high voltage power grid.

1.1. Charging a Lithium Battery: Time & Temperature

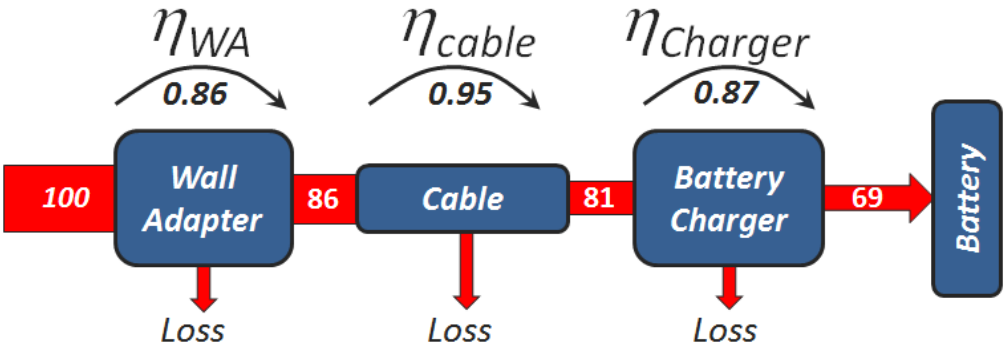
Battery recharge time depends on several factors. The most important one is the maximum safe charge current of the lithium cell. This value indicates the maximum current the battery can support without generating risk for the device or user. To do that, lithium ion cells are recharged initially at a constant current and finishing the charge applying the final constant voltage.

Another important point is the maximum temperature of recharge, usually around 45°C (113°F). Since the recharge process requires a considerable amount of energy, the charger circuitry will generate heat through dissipation loss. This heat can raise the cell above the

maximum recharge temperature and therefore block the recharge process in order to avoid damage to battery.

1.2. Charging a Lithium Battery: Efficiency

Efficiency is a key element in electronic design. For environmental policy and cost control, it is important to minimize wasted energy. As described in the figure below, the overall charge efficiency is measured across the process, from the AC power supply through all the electronic blocks up to the battery cell connector. A common value for the overall efficiency of a wired system is around 60% to 70%, not very efficient!



There are present in the market several standards to boost-charge the battery. Examples include *Quick charge 2.0/3.0, TurboCharger, and PumpExpress.* While these standards do provide a very powerful boost of energy, this energy also elevates charging temperature that in turn stops charging due to an elevated battery temperature. Therefore efficiency is not merely an environmental or cost matter, but it is also a charging performance matter.

1.3. Problems and Weaknesses of Wired Charging

Conventional wired connections like contacts charging, pogo-pin, micro-USB, USB-C, and custom connectors would seem to guarantee a stable and reliable connection between the mobile product and the power source. However, field experience shows that mechanical stress on metal connections weakens the wired connection over time. This is especially true for rugged mobile products that encounter frequent falls and intense usage along with dirty environments: the contacts can get dirty quite quickly, sometimes causing intermittent connection and losing charging efficiency, or worse – not charge at all.

Also from cost perspective, a very stable connection requires specific connectors that require expensive material and very precise mechanical designs.

2 – Wireless Charging

2.1 Wireless Power Transfer

Wireless charging is a recent technology that exploits the well-known principle of electric induction. The first wireless power transfer experiments of this nature were conducted by Nikola Tesla about one hundred years ago. Basically wireless power transfer is an electrical transformer with a primary coil and secondary coil coupled in air forming a ferromagnetic circuit. This technology transfers power using a pair of coupled planar coils, a transmitter that supplies a magnetic field on the cradle side and a receiver that harvests the magnetic field on the terminal side.

For inductive wireless charging, the typical distance between coils is between 2 to 10mm and the coils work close to their resonant frequency. The below graphic depicts the inductive wireless power transfer using a charging pad.

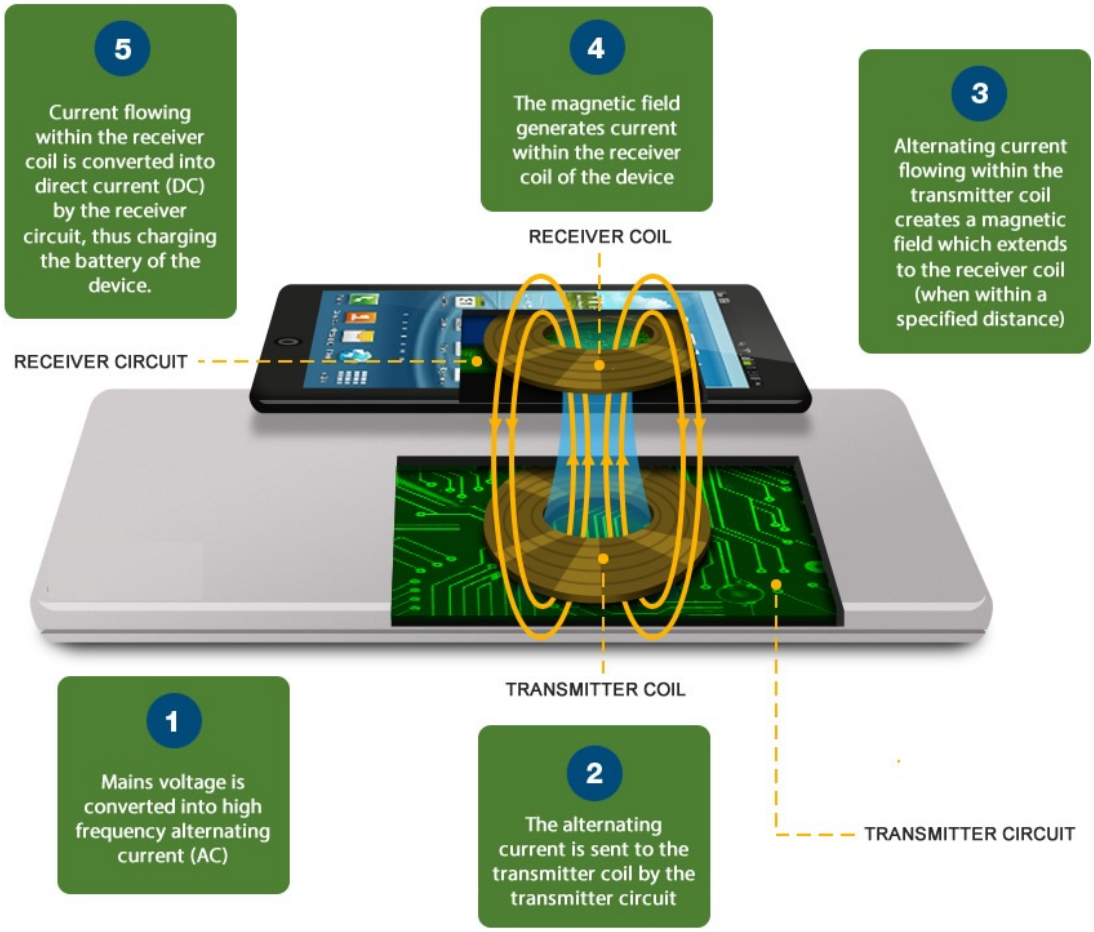


Image: power by proxy.

When needing to transmit power over greater distances, 5-20 cm, resonant charging can be used as depicted below.

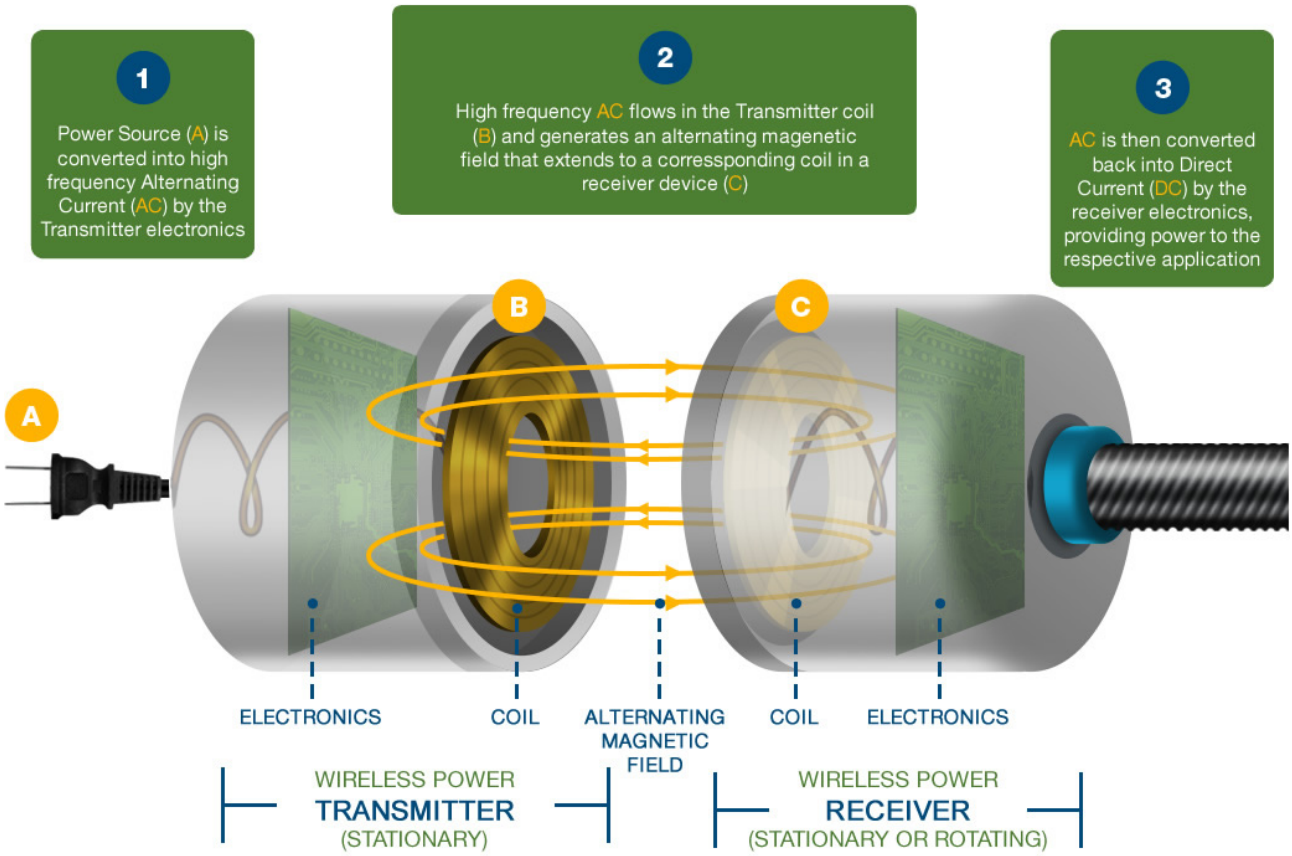


Image: power by proxy.

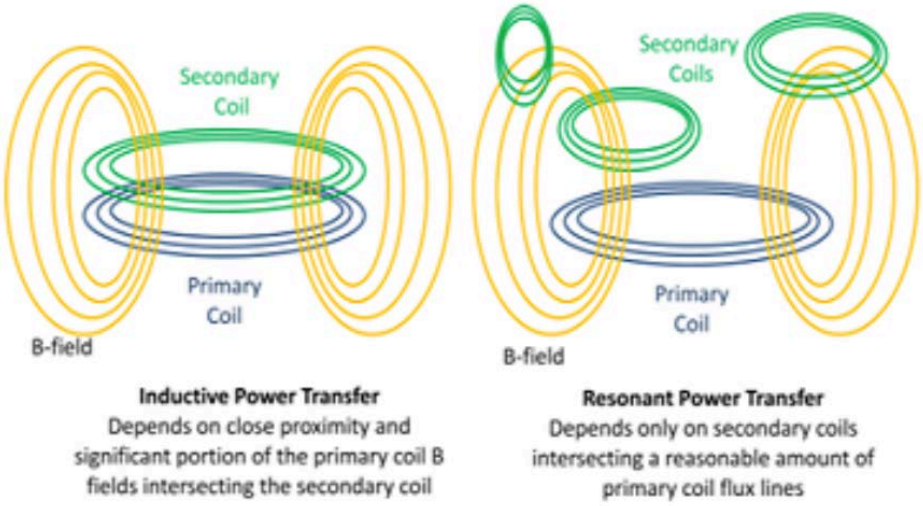
2.2 Magnetic Wireless Power Technologies: Inductive vs. Resonant

Magnetic transfer works by creating an alternating magnetic field (flux) in a transmitter coil and converting that flux into an electrical current in the receiver coil. Depending on the distance between the transmit and receive coils, only a fraction of the magnetic flux generated by the transmitter coil penetrates the receiver coil and contributes to the power transmission. The more flux reaches the receiver, the better the coils are coupled.

Magnetic Inductive type wireless transfer exploits tightly coupled systems, where distance of the RX TX coils are in the order of 2 to 10 mm. The working frequencies of the TX and RX coils are relatively close to resonant frequency offering the best performance in term of efficiency and EMI emission along with low complexity and cost.

In loosely coupled systems, where the distance between TX and RX coil are comparable to the coils dimension, only a fraction of the transmitted flux is captured in the receiver. In this scenario, magnetic resonant technology can transfer power even if at a cost of more EMI

content, lower efficiency, higher power semiconductor cost (using non-standard Silicon GaAs power semiconductor) and higher system complexity. In a resonant system the RX and TX coils are kept strictly on their resonant frequency.



Source: MediaTek

2.3 Wireless Power Transfer Efficiency

Wireless power transfer requires specific power architecture and therefore a different efficiency consideration. As seen earlier, charging systems lose energy during migration. Compared to a wired system, the wireless charging system substitutes the wired connection with a wireless transmitter, an air interface between the two coils, and a wireless receiver. If the wireless power system is well designed, the energy transfer has the same efficiency as wired power.

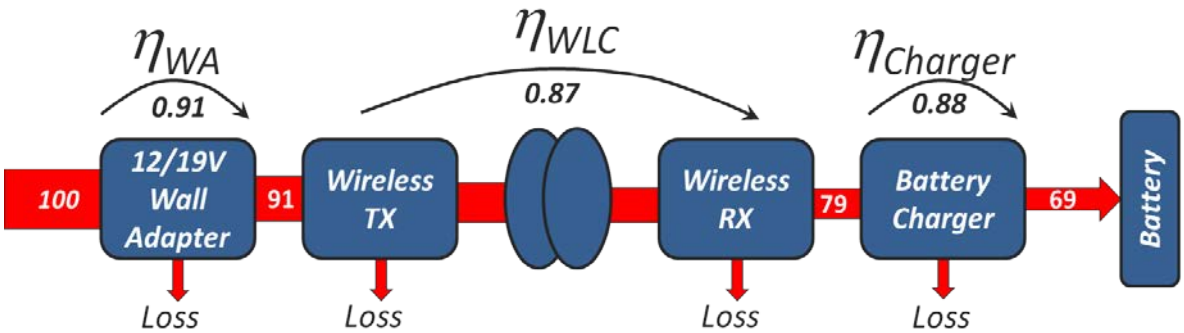
3 - Datalogic Joya Touch™

The key advantage of wireless charging technology has been to offer consumers the ability to easily recharge their device in restaurants, airports and at home. For Joya Touch, the advantages are even more appreciable. Wireless charging removes a connector that effectively eliminates a potential failure point of mobile computers. This in turn makes it easier to achieve ever higher IP sealing protection ratings. Less mechanical tolerance in the interaction between terminal and cradle also enables different form factors and innovative industrial designs. The need to clean the contacts, both on the device and on the cradle is eliminated. Since Datalogic offers a proprietary fast recharge solution inside our cradle that is Qi certified, this allows extremely fast charging of the Joya Touch while maintaining full compatibility with industry standards. Datalogic's Joya Touch can also be recharged using readily available wireless charging mats available on the consumer market. Together these benefits of wireless charging not only provide an innovative product but also lower the total cost of ownership.

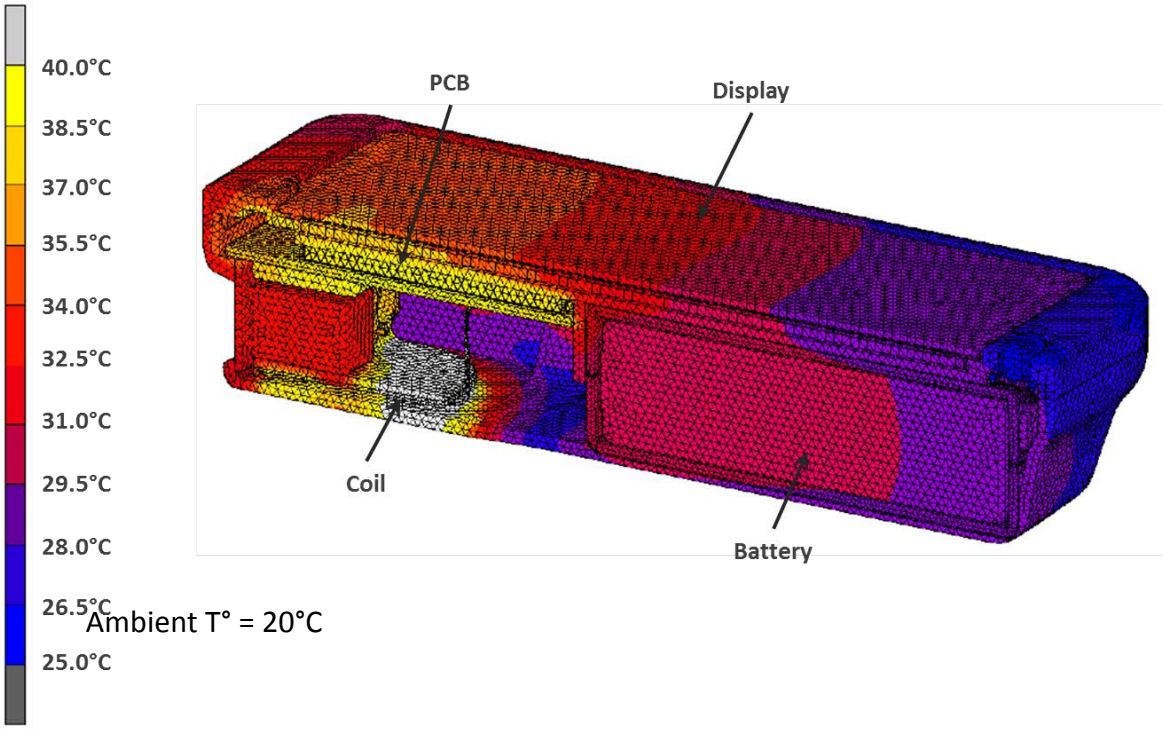
Datalogic is the first major company to implement wireless charging in industrial mobile computers. Before Datalogic introduced its Joya Touch, all the (consumer) devices present in the market featured 5 watt standard chargers with long charge times. Datalogic introduced wireless charging on Joya Touch in 2016 with a 10 watt charging cradle capable of three charging protocols (now 6 with Joya Touch A6) able to charge a 3,000 mAh battery in less than 2 hours while reducing battery stress and improving battery longevity. Cradle control is realized by a stand-alone integrated circuit paired to the device via NFC.

3.1 Joya Touch™ Efficiency

Datalogic wireless charging applied to Joya Touch™ uses state of the art integrated circuits and recharge optimized coils that lead to more than 87% in block efficiency. This provides a system with a wireless efficiency equal to or exceeding most wired charging systems even with more transfer steps.



Also from a thermal management point of view, the additional power loss has been dissipated in a clever way in Joya Touch™ to minimize the influence on battery temperature during recharge.



Ambient T° = 20°C

The coil temperature is usually 20° hotter than ambient temperature. In the Joya Touch, since the battery is placed far away and isolated by plastic from the dissipation sources, the battery temperature is just 10°C above ambient temperature. Also the cylindrical battery form factor helps to limit the conductive surface between the battery and power source because its shape allows a better heat dissipation.

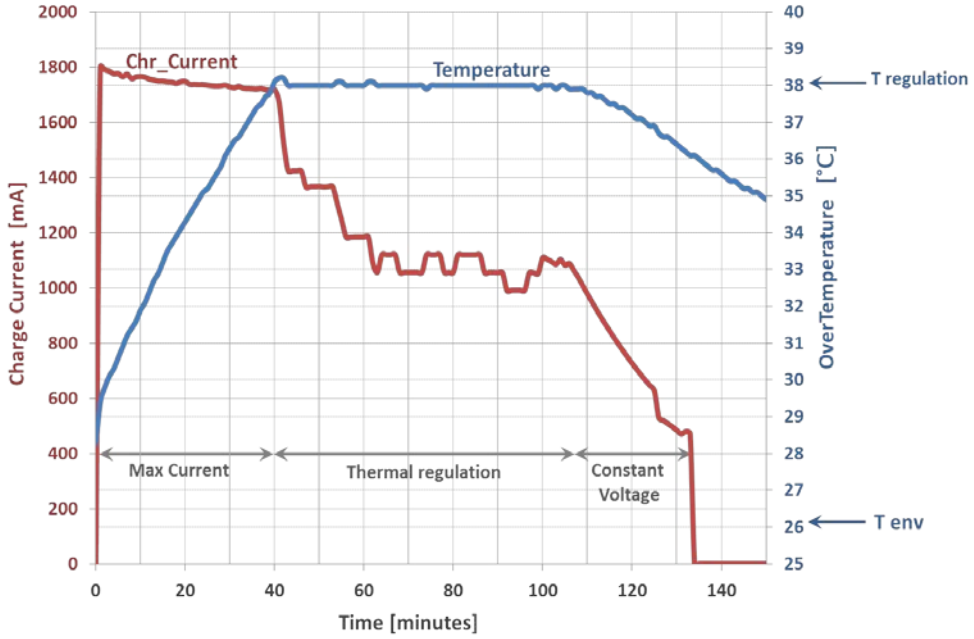
3.2 Joya Touch™ Smart Thermal Management

As described, the fast recharge process involves a large amount of power, even if the system efficiency is high, dissipation loss will heat the battery. For safety reasons, the maximum recharge temperature needs to be less than 45° C and the recharge should not be stopped unless necessary to avoid long recharge times.

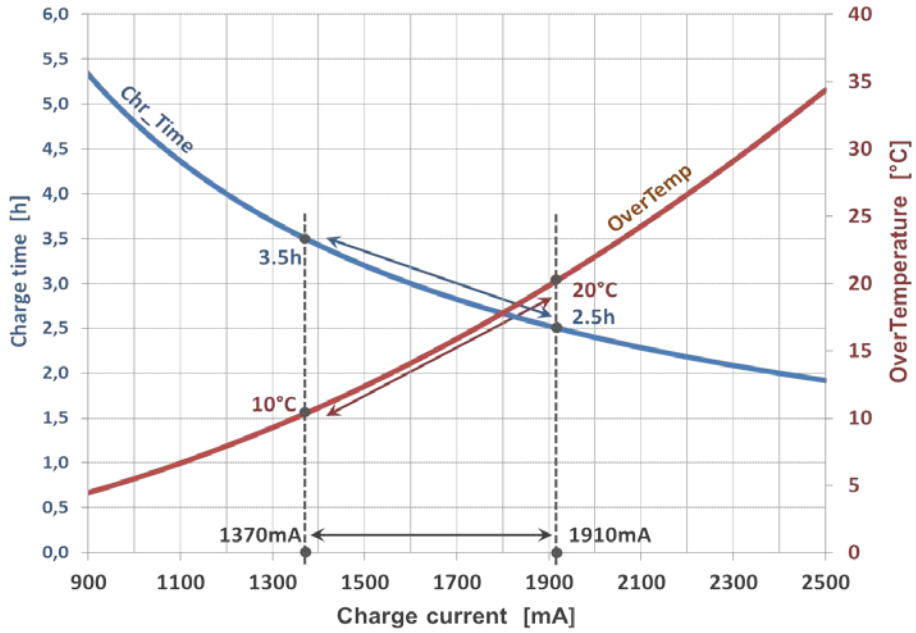
It is also well known that high temperatures during recharge increases the lithium plating of the electrodes resulting in increased internal resistance. Recharge temperatures that are too high can reduce the lifetime of the cell and lead to a capacity loss. To better manage the cell

temperature and lifetime, a very accurate temperature control optimizes the maximum recharge current to extend cell lifetime.

Therefore, a more advanced system needed to be developed by Datalogic to maximize battery life while minimizing charge time.



Interesting to observe in the graphic below that a nominal reduction of charge current (from 1,910 mA to 1,370 mA) keeps the maximum cell temperature in a safe and healthy region (from 20° C above Ambient T to only 10° C above Ambient T) while the charging time only increases from 2.5 hours to 3.5 hours.



Therefore assuming to move from 1370mA up to 1900mA the recharge time would be reduced only by one third but at cost of 100% increase in dissipation temperature. This shows how much the current chosen can affect the dissipation temperature

The Joya Touch uses a "digital closed loop" temperature control to maintain the right balance between the various possible current provided by the power supply and keep always temperature at the right value.

4 – Safety

Both overheating from foreign objects and EMI concerns are potential safety risks associated with wireless charging.

With a wireless transmitter generating a 130 Khz variable magnetic field, a conductive element placed close to the transmitter source could be problematic. Probably the worst case scenario is where a piece of metal is accidentally placed between the wireless charging cradle and the terminal: aluminum paper, metallic key, or a small metal object. Datalogic's system recognizes this anomalous situation and automatically stops the system from providing energy. This safety mechanism is called Foreign Object Detection. The working principle is very simple and is based on an accurate power accounting in the transmitter and receiver side. During the Joya Touch design, a number of tests have been done to accurately calibrate the system, ensuring reliability of operation and extreme safety.

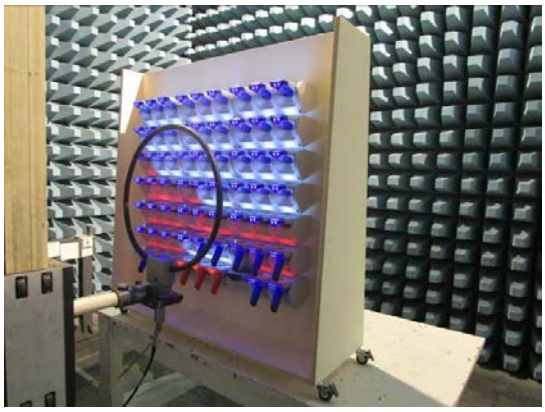
Wireless charging has recently been a trendy topic and in some cases has recalled a presumption of danger for human health for those with complex medical devices like pacemakers. Datalogic's Joya Touch and its cradle have been certified considering the severe limits imposed by CE and FCC regulatory requirements. Specifically for wireless power transfer, non-radiative electrical and magnetic field strength is within the regulatory limits set by these organizations. The magnetic field used by the wireless charging does not radiate substantial energy, and the magnetic field is equal to zero once leaving the immediate charging area. In addition the Joya Touch cradle only enables the wireless transfer when a terminal is present in the cradle, otherwise all the wireless charging electronics are turned off.

4.1 Radio Frequency Exposure

Nowadays we are surrounded by electronic equipment emitting various levels of RF, while the study of its influence on the human body has been ongoing for many years.

Differently from mobile phones, access points or cordless phones, wireless charging technology is based on non-radiative electromagnetic emissions. Wireless charging technology creates a variable magnetic field that is no greater than the magnetic field created by a desktop power supply. Essentially, the intensity of the magnetic field is decaying very, very fast, and after a few centimetres the intensity is nearly zero.
Datalogic products have to pass severe FCC and CE tests in order to be compliant with international regulations, and the tests are done considering the basic set of product with accessories. So, a three slot dock, a three terminal setup and a cradle have been tested and passed all applicable regulations.

As depicted in the figure below, our grocery self-scanning design has a large set of terminal dispensers, and the environmental effect of the multitude of objects needs to be studied.



As described previously, the magnetic field decay is very fast and a specific test on a typical installation of a 7x3 cradle (63 terminals and 21 cradles) provides very conservative results. The magnetic field is between 40 to 228 times less than the international regulatory limits and its maximum intensity is in the center of the dispenser.

5 - The standards: WPC and AirFuel

When it comes to wireless power standards, there were three key players: the Wireless Power Consortium (Qi), the Power Matters Alliance (PMA), and the Alliance for Wireless Power (A4WP). To compete with Qi, the latter two have combined to form the AirFuel Alliance.
Qi is possibly the most versatile alliance in wireless power transfer. There are many companies in many different markets driving Qi's technology advancements. Essentially, Qi is trying to touch everywhere they can with wireless power. There are 289 member companies and more than 794 Qi certified products as of Fall 2017. Its power class is impressive, reaching anywhere from less than 1W to 2.4kW of power. Qi uses inductive charging mainly, but more recently it also supports resonant charging technology.

AirFuel Alliance has approximately 150 member companies including Qualcomm, Dell, Duracell, and Samsung. The origins of the AirFuel Alliance, A4WP (Rezence) used resonant technology and had only a few certified product categories. PMA was driven primarily by Duracell-Powermat, and like Qi, used inductive technology for its products. AirFuel today only has about 10% of the wireless charging market, and with Apple now supporting Qi in its latest iPhones, it seems that will slip further.

5.1 Qi Standard

The companies supporting Qi aren't just small companies. Brands like Apple, Nokia, HTC, Energizer, Qualcomm (they support both standards), Sony, Samsung, Panasonic, and others are backing it as well. There are many companies in many markets interested in what Qi can do.
So when we say "Qi Standard," what are we talking about? Basically, Qi power transfer specifications have three main parts: interface definition, performance requirements and compliance testing.
The interface definition includes the transmitter and receiver design requirements, system control and communications interface. Foreign object detection must also be present. The coils need to be able to recognize they're in the presence of another Qi-compliant coil so they're not transmitting power into the air, draining needless energy. Part one also dictates the operating frequency of the integrated circuits in the range of 100-205 kHz, defines the resonant tank circuit, and defines coil construction with both mechanical and electrical parameters.

The performance requirements listed on the Qi website are only available to paying members. For simplicity 70% efficiency at 1cm can be assumed. If efficiency drops below 70%, the controller will shut off power and will not transmit until efficiency reaches 70% again.
Compliance testing specifies Qi authorized test centers. There are four testing locations around the world: one in the U.S., one in Germany, and two in Asia.

5.2 Why Datalogic chose Qi?

- Widely adopted: Backed by almost 300 companies including Samsung, Apple, Sony, and LG. Qi is already the most widely adopted global wireless power standard that continues to grow rapidly.
- Future proof: New Qi standards and specifications are backwards compatible, ensuring simplicity and seamless consumer adoption.
- Available now: Qi is a proven standard, used by leading manufacturers in more than 750 certified products in the hands of 50 million consumers.
- Open standard: Qi is a mature, open standard designed to help consumers with the most advanced technology.

6 – The Consumer Market

Wireless charging technology was introduced in the consumer market by Nokia in 2012 with 2 Lumia models, then Samsung launched the Galaxy (S4) starting in 2013, and most recently Apple has announced the introduction of wireless charging in their latest iPhone models.
Now more and more devices are featured with wireless charging technology, here is a short list of wireless charging consumer devices:

- iPhone 8 and iPhone X
- Samsung Galaxy Note 6, 8
- Samsung Galaxy S6, S7, S8
- Blackberry Priv
- Moto Z, Z Force
- Google Nexus 6, 7
- LG G6

These devices typically have only 5 watt chargers and only one charging protocol (except Galaxy S7 and S8 that supports proprietary fast charging protocols, and iPhone that offers a 7.5Watt charger).

Now large retailers are getting interested in wireless charging and they are featuring their stores with wireless charging mats for customers, or even producing items with wireless charging integrated.
Even the automotive industry is adding charging mats in their latest models for quick and easy charging by just tossing your phone on the console (with built in charging mat). Wireless charging is becoming more popular and common every day.

Now that Apple has introduced the iPhone 8 and iPhone X with Qi wireless charging, it is quite clear that this technology (especially the Qi standard) is now fully mature and ready for mainstream. The huge popularity of iPhone devices will soon shift the market and wireless charging will fast become a standard in everyday life.

7 – Summary

Joya Touch is equipped with advanced technologies that offer our customers a superior user experience.
The 10 watt wireless charging and all its intelligence ensures a safe and fast charge yet preserving the health of the battery, and offering long battery life.
The QI certification and the continuous research Datalogic Labs is doing in this field confirm the company commitment on this innovative technology. Now with 4 patents pending, Datalogic is the leader in the rugged Auto-ID industry.
Datalogic wireless charging is also environmentally (and electricity bill) friendly. Using state of the art integrated circuits and components, the Joya Touch wireless charging offers the same level of efficiency as a wired charging system.
Once again Datalogic is a pioneer in new technologies for a better data capture & user experience!

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