Integrating Wireless Charging

How to integrate Wi-Charge wireless energy modules into products

Introduction

Everyone wants over-the-air wireless power. Not be confused with magnetic induction ("Qi") charging pads, we are focused on long-range, non-contact power delivery, where the power source can be a few meters away from the device receiving power. For instance, with long-range wireless power you can charge a phone across the room.

While there are many mobile and IoT devices that Wi-Charge can power wirelessly, wireless power is still a new technology and cannot yet power everything around us. For example, we can't power electric cars because they require extremely high power and need an ecosystem to work properly. We also can't power a router located in another room because our energy beam does not travel through walls.

This white paper explores those limitations and looks at the devices that we can power to help identify the best candidates for wireless integration based on hardware, optical and design considerations.

The three key requirements: device power level, line of sight and ROI

Wireless Power Wish List

There are three important things to consider when determining whether a device is capable of receiving power wirelessly.

1. Device Power Requirements - long-range wireless power technology is currently geared toward powering devices that have an average wattage of 10 milliwatts to about five watts. We will expand on this later, but please note that we focus on average (not peak) power requirement.
2. Line of Sight – infrared (IR)-based wireless power is a line-of-sight technology. You need to have line of sight most of the time between the energy source and the device that's being powered. This is an important consideration when deciding if a device is a good candidate for wireless power. Ask yourself: Can the transmitter and the client device all "see" each other?
3. ROI - is powering a device wirelessly the best solution? If you have a better solution such as a battery or a power cord, you wouldn't need wireless power. We'd like to focus on applications where not being able to provide wire-free power is a significant limitation.

Prepared by Wi-Charge,
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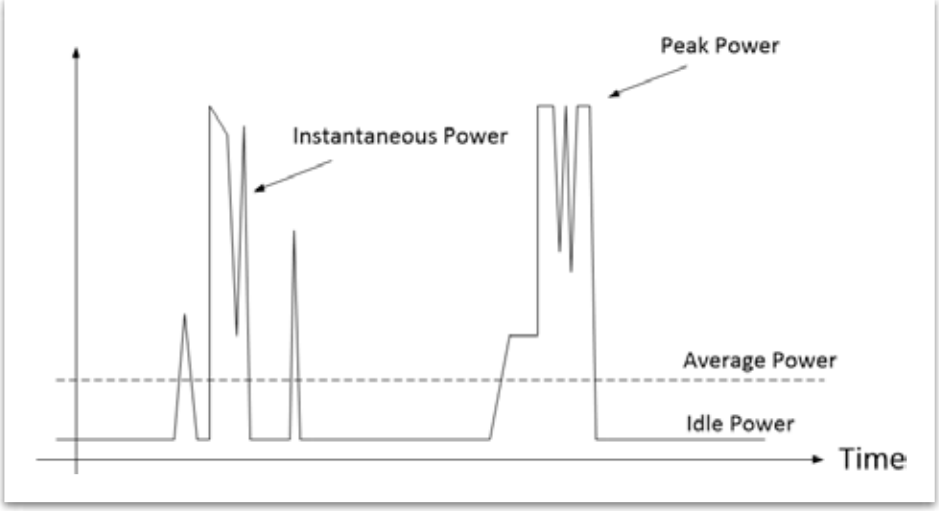
Let's dig a little further.

How Much Power A Device Consumes

1. **Understanding Wattage**
   Wi-Charge wireless power is applicable to devices with an average power range of 10 milliwatts to five watts. Why do we focus on 10 milliwatts? While it is possible to power a device with a range below 10 milliwatts, batteries may be a perfectly acceptable solution instead. However, above about 10 milliwatts, you would either need massive batteries or to replace the batteries too frequently. In this case, consider wireless power as the solution.

Average power, not peak power, is the key attribute to examine

2. **Average Power Vs. Peak Power**
   Devices do not consume the same amount of power all the time. Let's take a personal smart speaker as an example. The speaker sits on a table waiting to be activated. It is in listening mode (or in an idle state) until it is activated. It does not consume the same amount of power as when you ask it to play a song. While it is possible to constantly charge the smart speaker, the power it consumes during the day as it moves in and out of an idle state may vary. Thus, we look to the average power a device requires over time to determine how to best power it wirelessly.



Think of power (or energy) like a pool. A hose fills the pool with water (i.e. power) and from time to time, as someone drains the pool (an arbitrary amount of power), the water (power) level varies. But as long as the "pool" is not empty, you can supply the required power for the device. This concept is also similar to the water tank in a toilet. You can fill it up slowly over time, but then when you need to flush, you can get a lot of water quickly.

Let's illustrate this with some numbers. If we have a pair of speakers and each speaker needs four watts while playing music, we need a total of eight watts.

IR-based wireless power requires line of sight, but it can deliver about 1000x the power of other technologies

What is the average power? And what do you need to power these devices wirelessly, assuming they have a rechargeable battery inside? The answers depend on how much the devices are used. If they're used for two hours a day, then the total energy they need is eight watts x two hours. To determine the average power, we divide this by 24 hours. Let's say the speakers are constantly charging for 24 hours. The daily average power is roughly 0.66 or 0.7 watts, meaning that your transmitter delivers 0.66 watts You can use those speakers two hours a day, four watts for each one of them.

It's the same principle if you go to four hours a day. Then you need a transmitter that can deliver 1.33 watts. If you use the speakers for nine hours a day each day, then the average power equals about three watts.

- Example: A pair of rear speakers for home theatre
- Each speaker needs 4W (total of 4W x 2 = 8W)
- What is the average power? Depends on how mcuh the are used...

- 2 hours/day: Average power is 8W x 2hrs/24hrs = 0.66W
- 4 hours/day: Average power is 8W x 4hrs/24hrs = 1.33W
- 9 hours/day: Average power is 9W x 9hrs/24hrs = 3W

This is the difference between average power and peak power.

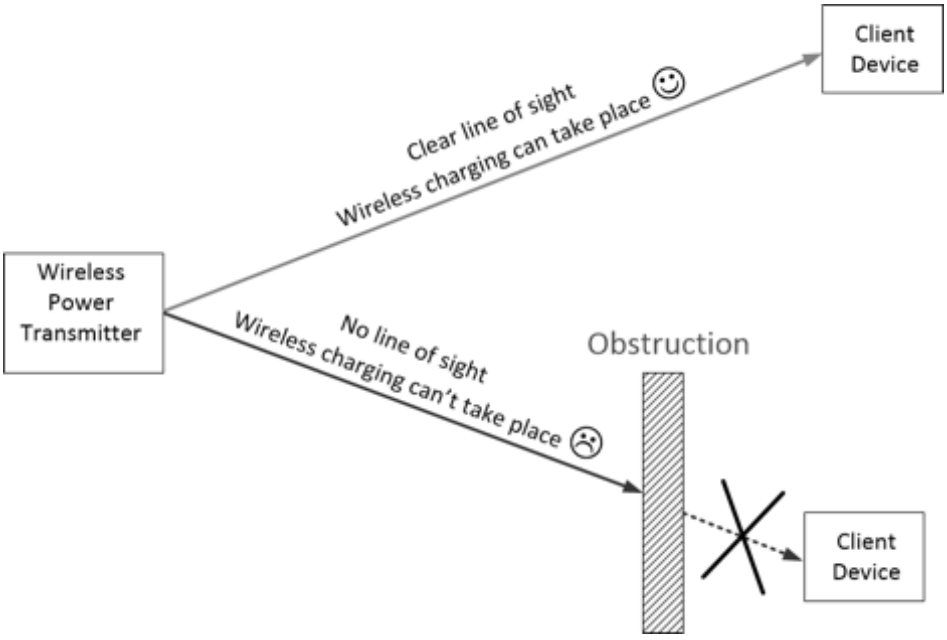
Line of Sight

Line of sight is one disadvantage of IR-based wireless power. Unfortunately, it currently cannot be done any other way. We use directional light to deliver power. This allows us to safely deliver 1000 times more power than any other long-range wireless power method. We can also do this more efficiently, as well as deliver power over distance to a small receiver that can fit into a consumer electronic device. Using directional light is how we keep wireless charging safe and effective.

But IR has drawbacks. Since light travels in straight lines and cannot penetrate opaque objects, there must be line of sight between the transmitter and the receiver for the majority of the "charging" time. It's not necessary to have direct

line of sight 100% of the time, but there must be enough time for the device to get enough energy. The device then stores the energy in an internal battery and uses it when needed.

For example, IR-based wireless power technology can't charge a phone in your pocket because the fabric in your clothes blocks the light. Of course, no other long-range wireless technology can charge a phone in your pocket. In fact, RF can't safely charge a phone even out of your pocket either, not to mention in your pocket -- it just doesn't work. On the other hand, if you have a device like a transmitter on your TV and a rear speaker on your back wall, it's OK for people to occasionally walk in front of it. That's because there is line of sight most of the time and your device will charge.



Devices that Run on Battery Power

Devices that are designed to run on battery power often consume a lot less than similar devices that operate on line power

When considering wireless power, why is it useful that a device is already battery operated? Engineers that design battery-operated devices often already optimize the device in terms of power consumption. In contrast, when a device is constantly plugged into a wall, the engineer that designed it is not typically cognizant of the need for any power optimization requirements. They tend to see the device as "constantly on", so they have less regard for its idle and average ranges of energy consumption. However, when a device is designed for battery operation, the designer is more aware of how much power it is consuming.

We often see this when looking at two similar devices made by the same company when one is battery operated and the other is not. The idle power and the power consumption levels between the two devices are different. That's a result of designer awareness.

Since it is important how much power a battery-operated device consumes, it's easier to transition battery-operated devices to wireless power. USB-powered devices are often even easier. If the device is already USB-powered, since the output of our wireless receiver is USB compatible, simply plug the receiver into the USB port and you might be done.

Integration

Let's look at how to integrate a receiver into a client device. This process has two steps.

Electrical integration is often as simple is connecting the +5V output of the receiver to the device being powered

1. **Electrical Integration -** this is often simple if the device meets the average power and the line-of-sight criteria. You can look at the Wi-Charge product simply as a wireless power supply. However, the client device that we are connecting to doesn't know if the power it receives is wired or wireless.
   Typically, devices that are battery-operated (and sometimes USB battery-operated) accept 5 or 3.7 volts. Simply connect as you would any other USB charger.

Client device type	Receiver output	Device input	Comments
Battery-operated device with internal rechargeable battery	**Usually 5V (can also be configured for 3.7V)**	**Usually 5V. Can be higher voltage as well.**	**Integration usually takes a few minutes**
Other devices	**Usually 3V – 12V Often includes internal rechargeable battery**	**Usually 3V – 12V**	**Wi-Charge receiver output voltage is determined by client device**

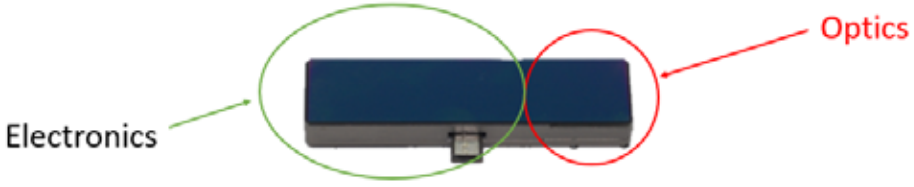
   If a device is not battery-operated, it is usually working with a power supply and the device input voltage varies. For example, DC power supplies are usually valid between three volts and 12 volts (and on rare occasions, 24 volts). We can adjust as necessary. We first add an internal rechargeable battery so we can charge it over time. We then adjust the output voltage when the power flows from the rechargeable battery to the client, based on what the client needs. This is called a boost converter because it boosts the voltage from the 3.7 volts of the lithium ion battery to the required voltage of the client device.

2. **Mechanical and Optical Integration -** we already know that the receiver needs to have line of sight to the transmitter or at least face its general direction. Ultimately, we need an aperture in the device the size of the optical receiver, roughly 15 x 15 millimeters with a six-millimeter thickness. The

rest of the electronics can be folded into the device itself. Once placed, the transmitter will know how to find the receiver. It will generate the power delivery, and the electronics will do the matching needed between the wireless power source and the client device facing in the same general direction.

From here, the system is plug and play. The receiver entrance has a field of view of roughly a cone of 100 degrees, +/- 50 degrees. Even if the receiver is not parallel to the transmitter, the transmitter will find it and the charging will take place. This whole process of finding a device and initiating charges takes just a few seconds.

An integrated optical power receiver needs an aperture of about 15x15 mm



Software Integration

Software integration is not something that everyone wants, but it is an option. There are devices like smart door locks where the functionality is pretty simple. Just get them power, and that's it. They do not need any software integration. But there are other devices where you would want to know the statistics and power that they use and their status.

In this case, we provide an API so that you can determine:

- how many devices are connected to the transmitter,
- how much power is consumed,
- where the devices are located,
- when they consume power,
- and much more.

The API is useful in public spaces where the business owner needs additional business intelligence on how a service is being used. This is similar to the information needs for a WiFi router: at home, you may have a WiFi router where statistics don't matter, but if you're running a coffee shop, you may want to see how much bandwidth you have, who is logging in and what kind of applications are being run.

Case Study: Smart Door Lock

The smart door lock is a very interesting product from several aspects. We selected a biometric door lock with facial recognition and fingerprint ID functionality. Some products like this also have WiFi connectivity and video

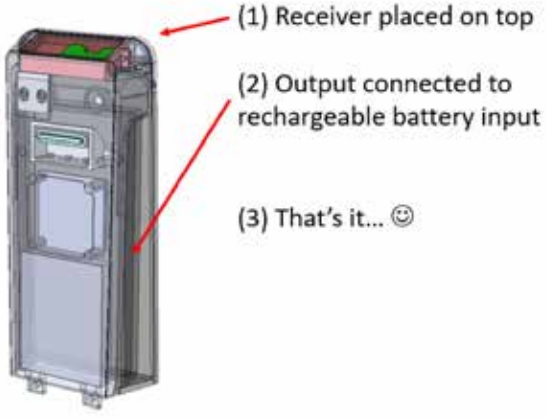
streaming capability that allow people to open their door (to a courier, for example) while they're at work or in another part of the world, or to simply open their door while sitting on the sofa. There are plenty of useful things to do with smart door locks.

However, the problem is that these smart lock devices are power hungry. They need average power above 10 milliwatts, which is problematic because they need to be frequently charged. To overcome this, you need to either accept that you have to frequently charge your smart door lock batteries or give up on some of its advanced features and use it as a bare-bones lock instead.

While smart door locks provide peace of mind because you have better control over who's in and who's out of your home, if you're always worried that you're going to run out of batteries and get locked out, then that's another problem. Hiring an electrician to run electricity to your door is also not a walk in the park. Therefore, the ability to suddenly deliver all the power that you need to enable you to use all the features of your smart door lock is really a godsend.

In speaking with door lock manufacturers, we found that the number one requested feature is that when someone comes in to a customer's home, they would like the door lock to record and upload a short video, so they know who it is (e.g. a neighbor, Amazon delivery courier, or a stranger). Unfortunately, recording and uploading that video is incredibly power- intensive and would require a battery change nearly every week!

By integrating the wireless power receiver into a smart lock, batteries are no longer required



To solve this problem, we tested powering a smart lock device wirelessly. We decided to place the receiver on top of the battery compartment. It's the red part on the left-hand side of the above illustration. On the bottom part, you can see the battery. This particular lock already had a rechargeable battery, so we only needed to change the door lock cover. Instead of its original cover, we added our cover with our receiver inside it. Two wires went from the output of the receiver to the battery charger PCB. That's the electric circuit. We

also added an indicator. That's the green LED in the middle, which was not essential, but we wanted an indicator to display when the device is charging and when it is not.

The most time-consuming task was the mechanical design of the cover. Other than that, it worked pretty simply and very quickly. On the left, you can see the assembly in testing. The receiver is on top, we're seeing its transmitter, and when the green LED is on, charging takes place. On the right is the outer side of the smart door lock with a facial recognition and fingerprint reader that would be facing to the outer side of your home.

Numerous devices can be powered with long-range wireless power

Summary and Resources

We explored many aspects of wireless power throughout this paper that you can use as a guide to help you determine if your device is compatible for wireless charging and how to integrate this technology into your product.

To learn more about Wi-Charge and other applications beyond those discussed in this paper, visit www.wi-charge.com.
Follow us on Twitter @WiChargeLTD
For one-minute demos of the W-Charge technology, please visit www.will-it-charge.com.

WI-CHARGE
TO POWER WITH LIGHT