Development of an optimized wireless charging application solution

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Wireless charging eliminates the need for cords, connectors and electrical plugs and allows any user with a compatible device to use the same wireless charging pad. Users simply place the portable device on the charging surface to complete the wireless connection.

In terms of unit deployment, the consumer wireless power market is still in its infancy. As new design options for smaller and cheaper solutions become available, the adoption rate for mobile and consumer electronics will increase significantly. Within the next 2 years, the installed base for wireless charging enabled devices is forecasted to exceed 100 million units.
The wireless power market

There are three standardization bodies striving to take a leading position in the wireless charging market. NXP is a member of each of these 3 standardization bodies.

 The Wireless Power Consortium (WPC), which has established the Qi standard, today has the strongest footprint in the market with more 180 members and more than 380 certified products. The WPC has a global footprint and a well defined certification procedure.

 The Power Matters Alliance (PMA) was formed in 2012 and has more than 100 members. The PMA 3.0 standard and related certification procedure is under construction and certified products are expected for 2014.

 The Alliance for Wireless Power (A4WP), founded in 2012, has more than 60 members. First A4WP products are expected in 2014.

The growth of the wireless charging market is currently being hindered by the lack of a common standard that guarantees interoperability between devices (clients) and charging pads (hosts) from different vendors. The solutions available in the market today force the end user into a “closed” system based on an individual standard or protocol. This closed system limits the user ability to charge their device only with a compatible charging pad. The lack of a global standardization will in short term, continue to limit the adoption rate by consumers.

Nevertheless even with the lack of standardization, the market for wireless charging enabled devices (clients and hosts) is expected to be ~300 million units by the end of 2016.

Inductive versus resonant charging

Current standards as established by WPC and under development by PMA are based on inductive charging and are considered tightly coupled systems. This means that receiver and transmitter must be closely aligned and therefore distance between receiver and transmitter coil is limited to a few mm. The advantage of these tightly coupled systems is a higher efficiency compared to resonant charging.

Resonance charging as proposed by A4WP enables loosely coupled systems which allows the user more “spatial freedom” or positioning freedom in x, y and z direction when placing a device on the charging pad. Additional benefits are the possibility of a larger charging area and ability to simultaneously charge multiple devices. Challenges of a resonant solution are the increased EMI and a lower efficiency compared to inductive charging.

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1 As of the publication date of this paper there are multiple standards and protocols that have been introduced to the market:
   i) WPC- Wireless Power Consortium (Qi Standard)
   ii) PMA- Power Matters Alliance (Powermat/Duracell)
   iii) A4WP- Alliance for Wireless Power (Qualcomm)
   iv) WiTricity- Magnetic Resonant technology
   v) Proprietary Resonant Solutions (Others)

2 GBI Research- February 2012
Efficiency and standby power

Efficiency and low standby power are important aspects for wireless charging systems. Lower efficiency translates into longer charging times, increased heat dissipation, and overall waste of electrical energy. The wireless charger should also contain intelligence to detect presence of a client. In case there is no client the wireless power transmission should be switched off to have a low or preferably near-zero standby power consumption.

The efficiency of the total solution, composed of the energy transmitter (TX, or wireless charging pad) and the energy receiver (RX, or the device to be charged) depends on the efficiency of (see figure 1).

1. AD/DC wall charger ~ 90% efficiency
2. Wireless charging transmitter $\eta_{TX}$
3. Wireless charging receiver $\eta_{RX}$
4. Power transfer technology (Inductive or resonant)
5. Distance between transmitter and receiver

The efficiency of inductive transmitters varies and is dependent on factors such as
1. The design of the transmitter power stage
2. The quality of the transmitter components (LC tank)
3. The power consumption of the controller in the system

Qi transmitters with higher supply voltages (typically 12-19 V) have a higher efficiency than Qi transmitters with lower supply voltages (typically 5 V).

Total wireless charging efficiency $\eta_{SYS}$ (TX+RX) for Qi based chargers varies per implementation. An optimized tightly coupled inductive charging system can reach >70% efficiency whereas an optimized loosely coupled resonance system will be close to 60% overall efficiency.

![Figure 1: Inductive WPT system](image-url)
Charging power and related charging times

Qi charging supply voltages, power levels and related charging times
The low power Qi standard supports up to 5 W at the receiver output. To compensate for the system losses the AC/DC charger needs to deliver approx 7 W. This can easily be achieved with 19 V and 12 V chargers as related currents are relative small.

For wireless charging transmitters with a 5 V supply input the AC/DC wall charger needs to supply approx 1.3 A at 5 V to compensate for the system losses $\eta_{SYS}$. Therefore a 2 A USB charger (10 Watt) is recommended since a low cost 1A USB charger will limit the receiver output power to approximately 3.5 W. This will result in a ~30% longer charging time compared to the 5 W solution.

A4WP charging
The Alliance for Wireless Power baseline specification (version 1.2) specifies 3 different power classes for a transmitter (or power transfer unit, PTU) and receiver (or power receiver unit, PRU). These range from 10 W PTU, suitable for charging a single PRU up to 22 W PTU that can charge three devices (PRUs) simultaneously.

Initially the A4WP receivers will support the PRU Class 2 and 3, with respectively 3.5 W and 6.5 W output power to the battery. Efficiency for a large part is related to the matching and the Q-factor of the resonators. The PRU efficiency from resonator input to 5 V output using a monolithic integration device is in the range of ~85 % for the receiver and integrates the rectifier, a DC/DC converter, LDOs and the various control functions required for house keeping.

Interoperability

Communication between the transmitter and the receiver is needed to enable a working charging process. Without a reliable and interoperable communication the charging process will not start, or charging may be interrupted during the charging process.

For device communication, the Qi / PMA systems typically perform data modulation on the power carrier frequency (ASK or FSK). This in-band communication requires advanced signal processing to ensure a reliable interoperability.

A4WP systems perform bi-directional communication over completely separate Bluetooth-Low Energy communication channel.

Foreign Object Detection and safety features

System safety for wireless charging, as with any power transfer system, is a major concern. Typically, such wireless power transfer systems are required to (i) have Foreign Object Detection (FOD), e.g., to prevent heat generation in metal objects that are accidentally placed on the power transmitter, and (ii) communication between transmitter and receiver for to control the transferred power level and detection of exceptional power losses in the channel. In addition the temperature of the charger is measured to ensure that system temperature will not exceed a defined maximum safety level. The required FOD level and safety is depending on the transmitted power, use case and wireless charging standard.
The level of required FOD detection and safety is depending on power level, use case and wireless charging standard.

**A Differentiated Approach**

1. **Support all eco systems**
   Given the various (competing) standards, NXP Semiconductors supports all of the primary standards. NXP is a member of WPC, PMA and A4WP and is developing architectures for all standards.

2. **High system efficiency and lowest standby power**
   NXP solutions are optimized for highest efficiency ($\eta_{TX} > 80\%$) and lowest standby power of less than 60 mW. In combination with NXP’s NFC “Tap to power on” functionality a true zero-standby-power can be achieved.

3. **Flexible system architecture**
   NXP is developing Qi & PMA wireless charging transmitters based on a flexible platform which supports single or multi coil configurations.

4. **Interoperability and Safety**
   NXP’s advanced digital processing ensures a high interoperability and reliable FOD with a low number of external components.

5. **Enhanced Functionality with NFC**
   Near Field Communication (NFC) is a short range inductive communication technology. NXP can leverage its industry leading expertise in NFC by combining this technology with wireless charging solution. In combination with wireless charging NFC can also be used to design zero-standby power charging pads that will utilize the NFC to “wake” the pad when it detects a client. This type of solution enhances safety and reduces standby energy consumption.
   Next to that NFC can enable
   - “Billable charging solutions” or enhanced system security via authentication.
   - “Smart” wireless charging systems with automatic network pairing.
   - Tailored advertisement in shops and public places.
Use Cases

NXP provides solutions for multiple use cases and is continuously looking for new ways to improve wireless charging solutions and enhance the end-user experience. Wireless charging solutions being addressed are:

1. **Automotive Applications:** Bluetooth and WiFi require authentication to connect phones to the car electronics. Combining NFC with wireless charging enables the user to connect automatically a phone to the car network and charge it at the same time without going through a specific setup process.

2. **Public Access Charging Terminal:** Deployment of charging pads in the public domain requires systems to be safe and secure. Our solutions can enable “Smart” charging systems that go beyond stand alone charging pads to enable network connected solutions and potential “billable charging stations”.

3. **Smart Phones, Tablets, Wearable’s:** Consumers demand easy-to-use solutions, increased freedom of positioning and shorter charging times. This will drive development of multi standard receivers, resonance charging and fast wireless charging solutions. Furthermore wireless charging will need to co-exist with NFC in the same design.

4. **Accessories:** Headsets, wireless speakers, mice, keyboards and many other applications can benefit from the combination of wireless charging and NFC technology. Pairing devices can be done by simply ‘tapping’ the device with the phone while the wireless charging eliminates the need for any mechanical connectors.

5. **Computer Systems:** Laptops, notebooks, ultra books and tablet PCs are all candidates for wireless charging as either clients or hosts. NXP is exploring the numerous ways in which computer appliances can take advantage of wireless charging.

Conclusions

The market adoption of wireless charging will be determined by the availability of worldwide mature standards, and the availability of simple to use and affordable charging products. Developing flexible hardware solutions can help to reach this goal. Adding application expertise and system enhancements beyond simple charging can improve the user experience and therefore help to drive the demand for these new technologies. NXP has the technology and expertise to support NFC enabled “smart” wireless charging solutions for multiple standards. In this way NXP’s Smart Wireless Charging solutions enable Secure Connections for a Smarter World.