Wireless power technology embraces user-friendly features

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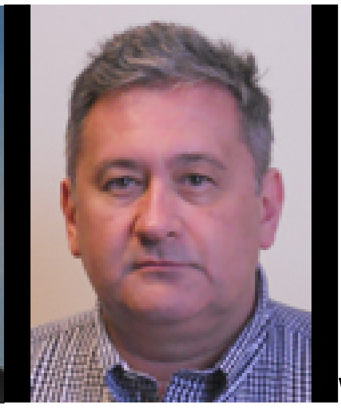

Wireless charging technology has been recognized as a very attractive solution to a wide range of applications because it conveniently replaces power cords and charging cables. This emerging technology is being adopted for charging mobile phones and other handheld devices [1]. Several major mobile communication service providers in Japan, Korea and the United States offer smartphones readily equipped with wireless chargers. As technology matures, wireless charging is also being considered for higher power applications. To ensure compatibility between devices from multiple manufacturers, the Wireless Power Consortium (WPC) developed an industry standard named Qi (pronounced chee).

This article explains how the typical Qi wireless power transfer system operates and near field magnetic induction interfaces between a power transmitter and a power receiver. The article also previews some of the recently developed novel features like foreign object detection (detects the presence of foreign metallic objects around the wireless charging system and prevents them from absorbing energy and overheating); and dynamic power limiting (allows wireless power transmitter operation from a 5 V supply with limited current capability such as a USB port) to enhance the user experience and safety with wireless charging.

System operation

The concept behind wireless power transfer basically is the same as in a transformer with loosely coupled windings. If an AC current is passed through a wire (primary coil), it generates a magnetic field. If some of that field is coupled by another piece of wire (secondary coil), it induces a current in the secondary coil. Facilitating resonance between primary and secondary coils makes wireless power more efficient. The concept goes back more than a century to experiments of the now famous Nikola Tesla [2].

A system block diagram of a practical small-power wireless-power system is shown in Figure 1. The transmitter provides power to the receiver by exiting magnetic field around the coupled coils. The system operates in a closed loop. The receiver regulates the output to the needs of the mobile device by sending messages to the transmitter via modulated coils mutual field per Qi specification. The transmitter de-modulates communication signals on the primary side and adjusts the system operating point accordingly. The AC/DC wall adapter provides energy to the wireless power system.

On the secondary side, the coil voltage is rectified, regulated by the low drop-out voltage (LDO) regulator and connected to the load through a load switch.

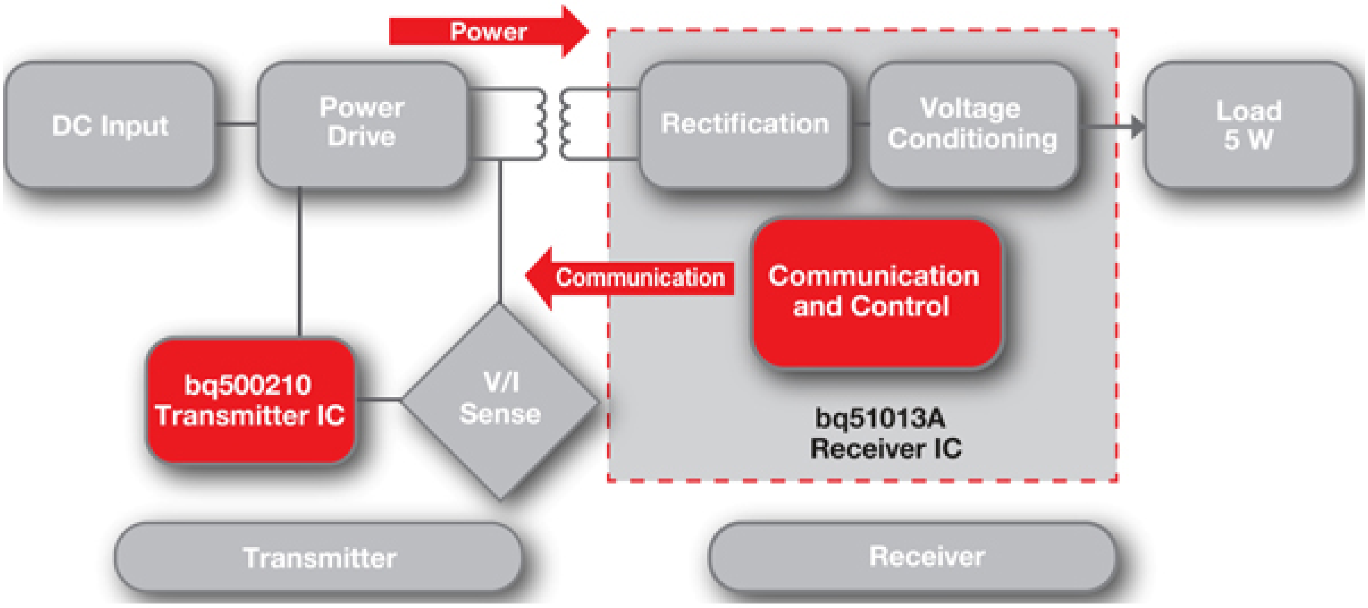

Figure 1. System block diagram of a wireless charging system.

System integration and careful balancing of conductive and switching losses in coils, shields and active components lead to achieving the industry's highest efficiency. Figure 2 shows the efficiency breakdown of the second generation bqTesla wireless power system. The overall system efficiency tops at about 75 percent with individual transmitter and receiver efficiencies exceeding 90 percent [3].

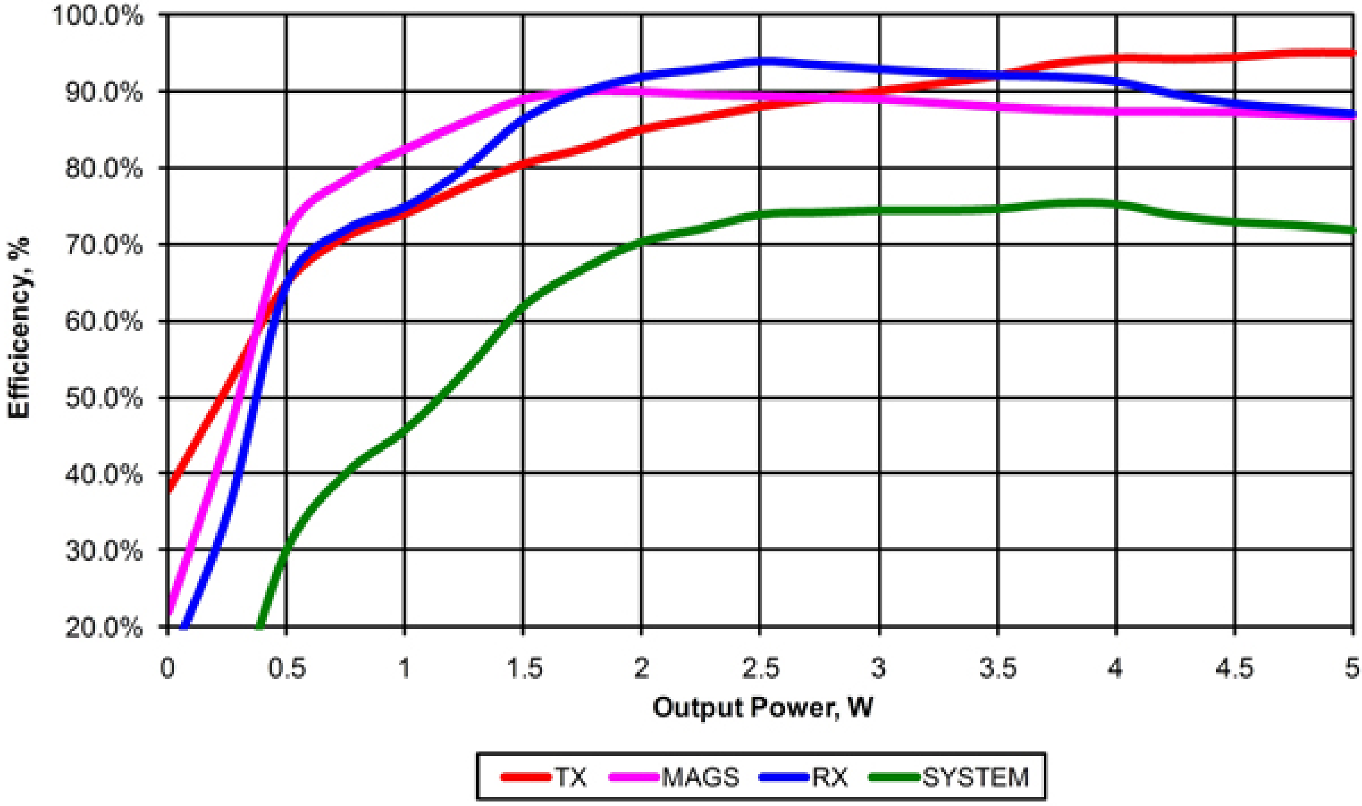

Figure 2. Wireless power system efficiency breakdown.

Foreign object detection

Safety is one of the major concerns when adopting wireless power transfer technology. Metal objects getting in close proximity with a wireless power transfer system may couple a portion of an electromagnetic field and become a hazard – getting hot enough to mar plastic surfaces or burn skin on contact. In simulations and experiments show that just 500 to 1000 mW of power dissipated in the metal object like a coin, metalized pharmaceutical wrapping, a paper clip, or gold ring, can raise the object temperature above 80°C. The new generation of wireless power systems can be capable of detecting such parasitic coupling and inhibit wireless power transfer when energy leakage exceeds a predetermined level. Of the various methods available to detect foreign objects, the most promising from a precision and response-time standpoint are based on loss reconciliation mechanism [4, 5].

Figure 3 shows typical losses encountered during a wireless power transfer. The power received accounts for all the power captured on the secondary side, including power delivered to the load and losses in coils, shields, rectifiers, friendly metals and control circuits. The transmitted energy accounts for the energy delivered to the transmitter coil, with the exception of losses incurred in the transmitter coil, its shield, and MOSFETs.

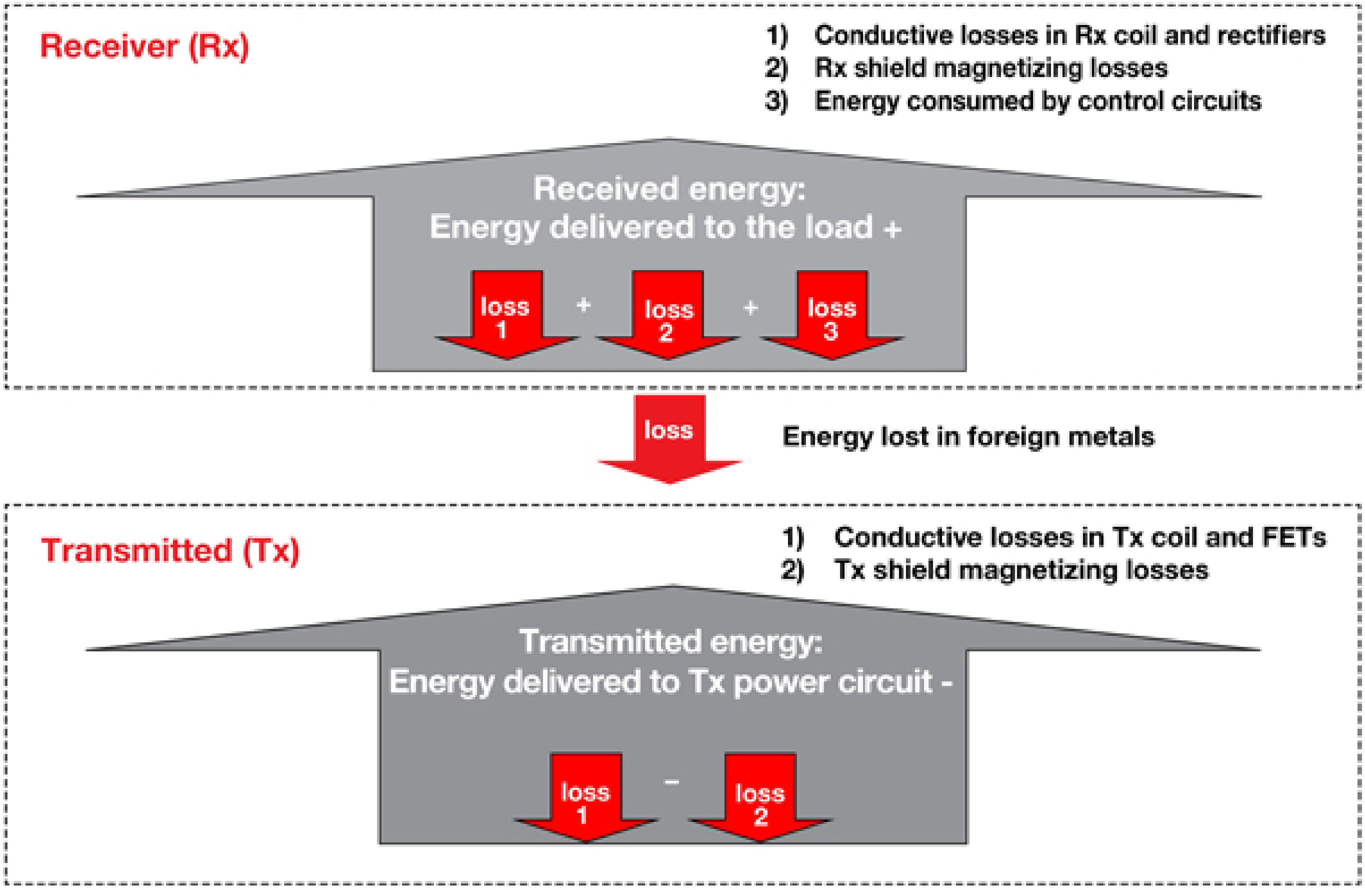

Figure 3. Energy losses during wireless power transfer.

The practical wireless power system continuously monitors and periodically balances received and transmitted energy by exchanging information via communication protocol.

When non-reconciled power, PFO, trips the wireless system set safety level, the transmitter is stopped, which prevents the hazard from occurring. In practical systems, safety thresholds below 300 mW are feasible, bringing wireless power system safety to the new level.

Dynamic power limiting
Most first-generation low-power wireless systems used voltages ranging from 10 to 19 V. The 5 V power rail became very popular in recent years due to increasing growth of smartphones and tablet PCs. Use of this wide variety of 5 V wall adaptors and USB ports to power wireless power systems can be advantageous to proliferation of wireless chargers in the smart gadgets market. As power capability of various wall adapters and USB ports can vary, wireless power systems have a better chance of delivering a consistent user experience when adapting to various input power levels. The feature known in the world of wired chargers as dynamic power management (DPM) allows the mobile device to scale down charging current when powered by the USB port or wall adapter with reduced current capability. A similar feature extends across the wireless power boundary called dynamic power limiting which works in tandem with DPM and allows power to be delivered to the mobile device wirelessly at a reduced rate without interruption. Without the DPL function wireless power transfer can be unpredictably interrupted. This can frustrate

the end-user when the transmitter attempts to pull more power from the wall adaptor or USB port than for which they are rated.

Dynamic power limiting can be used in two selectable modes. In the first mode, the wireless power transmitter monitors its input voltage and initiates power-delivery limiting when the input voltage is observed to be drooping below a certain level. This operating mode is the most flexible for accommodating a wide range of input DC sources to the wireless power system. It also allows the most power to be extracted from the DC source of choice in given circumstances, Figure 4. The second method uses dynamic power limiting and is designed specifically to not exceed 500 mA loading of the USB port or wall adapter. This mode is more conservative and restrictive. With any use mode dynamic power-limiting-enabled wireless power transmitter enhances how the wireless power can be incorporated in emerging appliances.

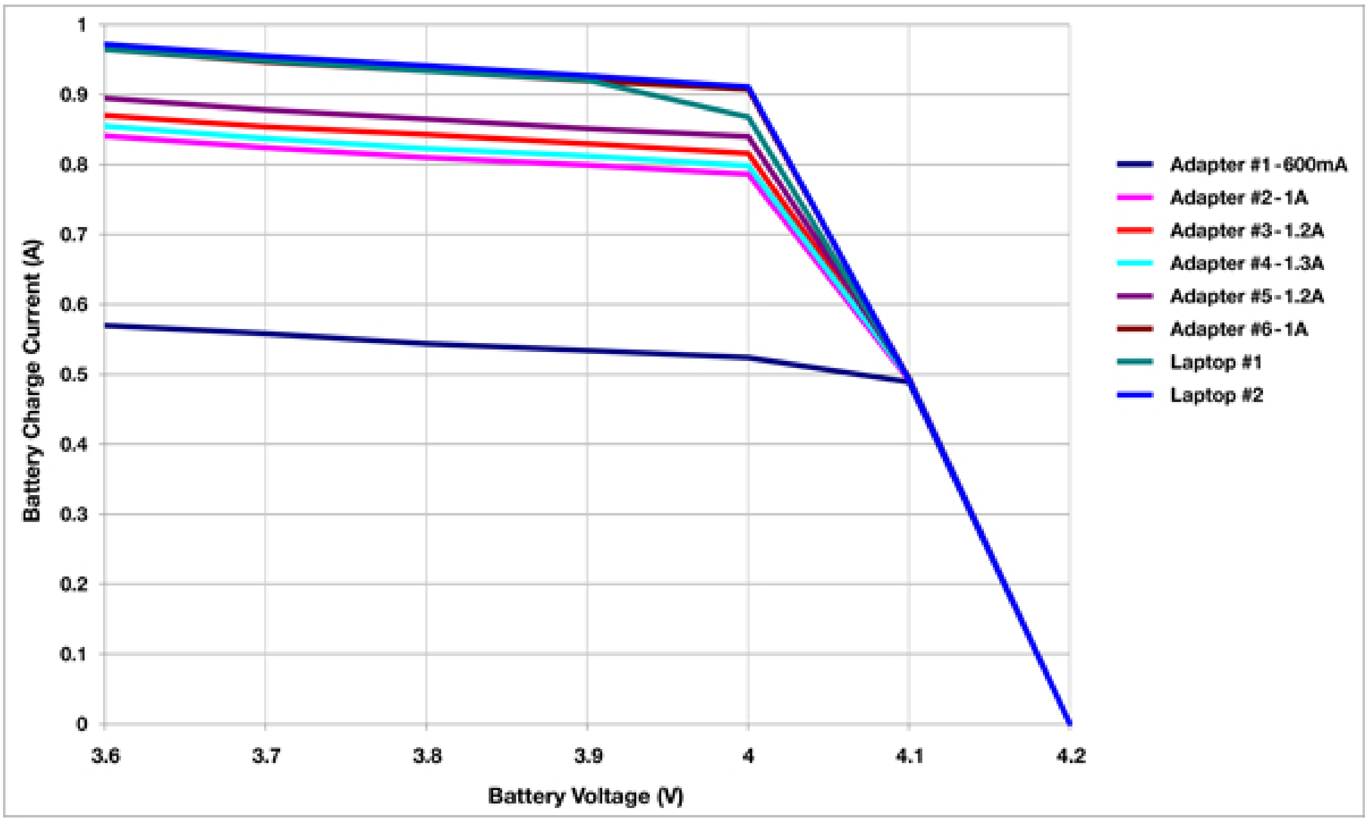

Figure 4. Wireless Charging with DPL.

Conclusion
Wireless power systems are constantly evolving as more and more practical options for conveniently charging smartphones and other mobile devices. User experience is the key factor that drives technology development, paving the way for safer and more convenient devices accompanying us in everyday life.

References

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Pearl (Ke) Cao is a systems engineer with the wireless power group at Texas Instruments. Pearl is responsible for defining wireless power transmitter charging solutions for cell phones and notebook applications. Pearl also participates in creating industry standards such as Qi interface to guarantee product interoperability for wireless battery charging and to provide design freedom. She received her Bachelor and Master degrees in electrical engineering from University of Toronto, Canada.

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