ISSN: 1863-5598

ZKZ 64717
01-13

Bodo´s Power Systems®

Electronics in Motion and Conversion

January 2013

Magnetic Induction or Magnetic Resonance for Wireless Charging?

Recent activities in wireless power technologies have created questions about the adoption direction of the ideal solutions. Magnetic Induction (MI) or Magnetic Resonant (MR) can both be considered for use in the consumer market. Regardless of which direction the consumer market takes, it is a given that the adoption of wireless charging will happen.

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Within next couple years we will see penetration starting around the cellular market ECO system mainly driven by cellular providers. The Computing environment with its strong ECO system will follow and generate the next phase of growth in the use of wireless charging technology. From there it is likely that wireless power will expand into infrastructures supporting cellular and computing solutions. These uses will represent just the beginning of how wireless power technologies will be utilized in tomorrow's architectures and solutions.

There have been many reports and market studies about adoption rates and the potential total available market (TAM) associated with wireless power technologies. It is challenging to provide accurate market information since adoption rates and the choice of technologies are the key parameters in these forecasts. For MI technology there are two main prevailing standards: Wireless Power Consortium (WPC) and Power Matters Alliance (PMA). Both standards are fairly mature with many products already in use in the consumer market. Alliance for Wireless Power (A4WP) is the first standard based on Magnetic Resonance. It should be noted that Intel’s Wireless Charging Technology, which is also based on Magnetic Resonance, is targeted at ultrabook and its own ECO system. Others such as Power by Proxy and WiTricity, which have already established their place in industrial and military applications, are now penetrating the consumer market too. All these standards and solutions have created questions of which direction wireless power technology will go and which solutions are the ideal to adopt. Before we can address this question, it is important to try to understand the fundamental differences between MI and MR technologies. Based on these understandings and application/system requirements one can choose the right solution for a given application.

Mobile Device Solutions

Mobile solutions are adopting wireless power solutions first in the consumer market. With LTE technology, communication speed and bandwidth they will not have any limitations for at least the next few years. Convenience is one of the key factors driving mobile solutions in the consumer market. Different mobile solutions such as cell phones, tablets, media players and mobile TVs require different adaptors with different interface connectors. One needs to carry many connectors and adaptors to serve the same purpose of transferring charge into a mobile device. A universal wireless adaptor with a powerful supporting infrastructure and ECO system could address the needs. Having the solution available in cars, coffee shops, libraries, restaurants, trains, airplanes, offices and conference rooms will create the needed convenience.

Every couple year’s mobile solutions are upgraded to enhance their cosmetic appearance, performance and features. These upgrades force changes in power requirements, connectors and interfaces, and as a result new adaptors are usually required. These changes and upgrades force the wasteful obsoleting and disposal of existing adaptors. Eliminating various adaptors and connections and using standard wireless charging will help to reduce e-waste and improve the ‘green credentials’ of mobile devices.

Another important factor is technology upgrades in mobile solutions with the adoption of display technologies such as 1080P and 3D providing a good example. Mobile solutions will increasingly use high resolution display technology supported by high performance graphics controllers with multi-core CPUs to enhance required performance. Integration of 3D GPS solutions, high performance video and audio technology, NFC technologies, portable TV and high-performance gaming are some of the examples and features that will be adopted in increasing numbers of mobile solutions. Most of these features and requirements will generate a greater demand for power from the device’s battery.

The source of energy in mobile solutions is typically Li+/Polymer battery packs whose energy density has been at saturation for several years already. Technology enhancements and the migration to different metallization in Li+ based battery packs to increase the capacity and longevity has not been able to keep up with increased energy demand placed upon them. Battery packs must also have small physical dimensions in order to meet the application requirements of mobile solutions. Since battery capacity per unit volume is at its limits, solutions will either require larger battery capacity or more frequent charging. While mobile solutions are getting smaller, fitting a larger capacity battery will impact the size and the cost of the overall solution. It should also be noted that larger battery capacities will require faster charging that may cause a change in the chemistry while maintaining battery life cycle and required longevity. It seems a more obvious solution to the situation is to enable more frequent charging.

It is feasible that every application surrounding us that uses electricity is a potential candidate for adopting wireless power technologies. In order to answer which wireless technologies - MI or MR - is best for a given application, we need to review the fundamentals of each.

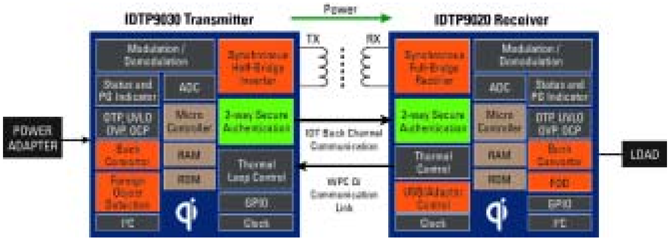

Figure 1: Wireless Charger System: Transmitter and Receiver Block Diagrams

Magnetics

There are many similarities in the architecture of MI and MR technologies. For example, both use a magnetic field as a bridge to transfer power.

In both technologies current is induced into a resonant circuit, creating a magnetic field to transfer the power. Magnetics specification has a big impact on how the electromagnetic field is shaped. The magnetic flux can be contained and / or directed using electromagnetic shields and / or shaping the physical dimensions of the magnetic core. The flux density and containment is improved by improving the permeability of the electromagnetic shield. Cost and thickness are key drivers for selecting the appropriate electromagnetic shield. The alignment of the receive and transmit coils in the flux field and the distance between them will determine how efficiently energy is transferred; greater separation between transmit and receive coils results in less efficient power transfer. Resonant frequency, the ratio of transmit to receive coil dimensions, coupling factor, coil impedance, skin effect, AC and DC elements and the parasitic of the coil are other factors that have a large impact on how efficiently energy is transferred.

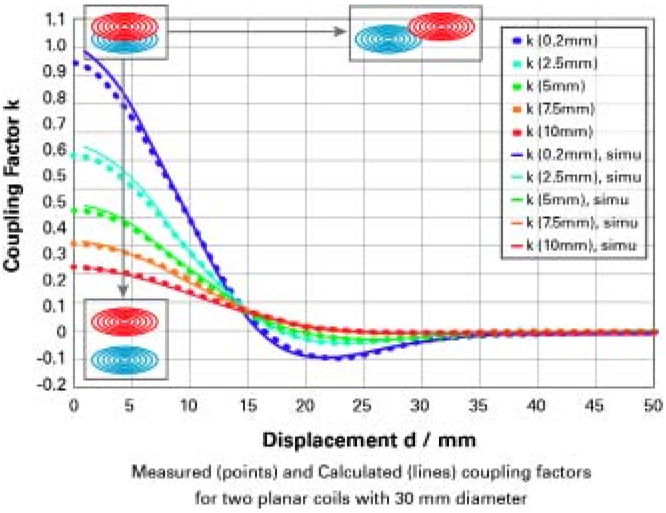

Figure 2: Coupling Displacement

It is given that as the x, y and z separation and the proportional angle between transmit and receive coils increases, the losses and efficiency will be greatly impacted.

In the WPC specification, there are specific requirements for the positioning of the receiver coil on the transmitter to address efficiency. This requires alignment by the user to maximize the coupling factor between the two coils. In the case of MR technology, freedom of positioning and the ability to place single or multiple devices in the flux field creates more convenience for the user. However, one needs to understand the impact on transferred efficiency as the separation distance between coupled devices increases.

Depending on the requirement, including cost and size considerations, a single or multiple coil solution can be utilized in all technologies.

In WPC and PMA based MI technologies, power can be transferred over a wide range of frequencies. The resonant frequency at which the power is transferred is selected based on the load impedance. Due to this variation, the Q factor is relatively low compared to MR solutions. Optimum efficiency can only be achieved at selected frequency and load impedances.

In the case of MR technologies, since the power is transferred only at a certain resonant frequency, Q factor is larger and requires very close resonant impedance network matching in the receiver and transmitter.

In both MR and MI technologies, the variation in matching network parameters needs to be tightly controlled since it directly impacts the transferred power.

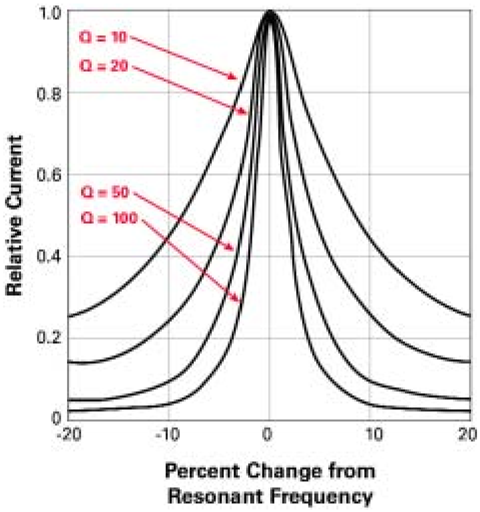

Figure 3: Q-factor percentage

In WPC 1.1, the resonant frequency can be selected over a wide range from 100 KHz to 205 KHz. The situation is similar in PMA, but the frequency range changes to 277 KHz to 357Khz. Typical Q factors for these solutions are in the region of 30 to 50. In A4WP based solutions, the resonant frequency and impedance networks between receiver and transmitter need to be reasonably closely matched since the frequency is fixed. Typically MR solutions require higher Q Factors (50 to 100) compared to MI solutions.

Power Management

Development of high performance power management architectures has a big impact in the implementation of successful MR and MI solutions. On the transmitter side, in order to induce current into the resonant circuit, a DC to AC conversion takes place. In MI technology, a half-bridge or full-bridge inverter is utilized for this conversion whereas in MR technology current is induced through a power amplifier. The power amplifier architecture and classification can vary based on the frequency, standby current, efficiency, size, cost, and integration requirement of the application. During these conversions, careful consideration needs to be given to reducing losses in gate drivers, switching, conduction, biasing, body diode losses and parasitics such as equivalent series resistance (ESR) and equivalent series inductance (ESL) of external components. These are some of the key challenges for developing high performance integrated solutions.

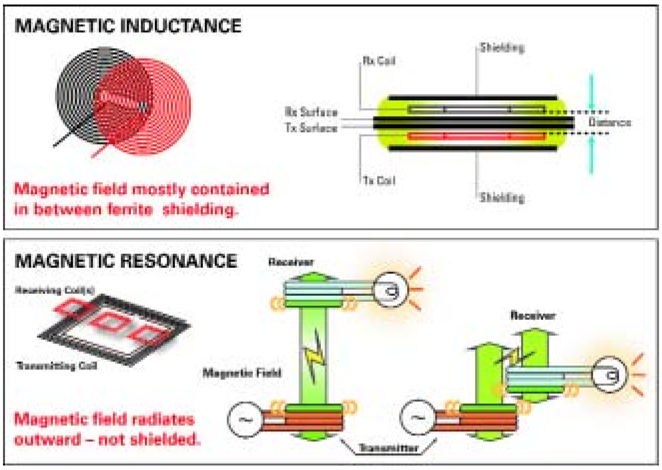

Figure 4: Magnetic fields

Depending on the input voltage requirement and design architecture, process selection has a big impact on optimizing integrated solutions. There are multiple control loops in the system upon which the stability of the complete control loop has a big impact on the overall success of a high performance solution. In both MI and MR technologies, similar performance and efficiencies can be achieved through effective power management.

Communications

In order that power transfer is achieved successfully, the transmitter needs to recognize the correct coupled receiver. In WPC and PMA solutions, the transmitter 'pings' periodically to search for the receiver. As the receiver is recognized, the power transfer takes place. These solutions use fixed frequency modulations to communicate. Some other methods of communication are amplitude, power, current, and pulse width modulation (PWM). All of these options can be utilized if the matching network between transmit and receive can tolerate wider frequency variations.

Because in an A4WP magnetic resonant solution the matching networks in transmit and receive are tightly matched, frequency modulation cannot be used. However, if the load is fixed, then it is possible to use amplitude modulation. Power and current modulation can be utilized if the receiver performance is not affected. Because in mobile applications the load varies based on functionality requirements, it would be challenging and probably not size and cost effective to develop a solution based on the above mentioned modulation schemes. A4WP selected either Bluetooth or ZigBee as a standard method for their communications. These methods are convenient since they already exist in mobile solutions. It is also convenient for the transmitter to transfer power to multiple devices by identifying different receivers. Other similar methods are available to achieve the same objectives.

Communication is also utilized to inform the status of power transfer such as foreign object detection (FOD), status of coupling, and maybe even alignment guidance information (AGI). Foreign objects such metals in the electromagnetic field can potentially cause a temperature rise based on the conductivity of the materials. This is a potential problem regardless of the technology.

Accurately monitoring voltage and current on both transmit and receive sides is necessary in order to maximize efficiency in magnetic induction technologies. Other functions such as the effect of load reflection, current induction and the timing of modulation and demodulation and impact of them in the closed loop systems are critical to help maintain the stability of the system and ensure successful communication. Other challenges including meeting regulations such as California Environmental Association (CEA) and Federal Communication Commission (FCC) part 15 and 18 may also impact the overall efficiency of the system.

It is reasonable to conclude that the best potential solution for a specific application will be based on the required features and performance. If free positioning or multi-device charging capability in X, Y and Z directions is required then magnetic resonance could be the preferred solution. If high efficiency performance with strong standards compliance is required, then WPC compliant solutions may represent the optimum choice. However, there is no question that a multi-mode solution able to seamlessly recognize the coupled magnetic Induction or Resonant based device and transfer power effectively and efficiently will be the ideal solution to serve such applications.

IDT has been developing solutions in both MI and MR technologies. The company's highly integrated MI solution is architected to meet and exceed WPC (Qi) requirements. These solutions use highly advanced process technologies to integrate power devices and intelligence to effectively communicate and control the closed loop function between receiver and transmitter. IDT's IDTP9020, IDTP9030, IDTP9035 and IDTP9036 all meet WPC requirements. These integrated solutions require a minimal number of external components helping reduce BOM cost and total required PCB real estate.

Integrated Device Technology and Qualcomm have collaborated to support IDT's development of an integrated circuit for consumer electronics devices based on Qualcomm's WiPower Technology. This IC is being designed to meet the requirements of Qualcomm's new near-field magnetic resonance wireless power charging solution. They are designed to provide spatial freedom for charging consumer electronics, such as mobile phones and other battery-powered / low-power direct-charge devices.

IDT's magnetic resonant solution portfolio is expanding by developing receiver and transmitter solutions based on Intel's technology for ultrabook ECO system. Intel and IDT also team up for Wireless Charging Technology Chips. Intel Corp. has selected IDT to develop an integrated transmitter and receiver chipset for its wireless charging technology based on resonance technology. Intel along with IDT aims to deliver validated reference designs that are targeted for deployment in ultrabooks, all-in-one (AiO) PCs, smart phones, and standalone chargers.

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