Wireless power transfer from the antenna side of the design

Steve Taranovich - February 13, 2015

We all hear about the wireless power transmitter/receiver ICs that Texas Instruments, Linear Technology, IDT, Toshiba and countless others have developed for this rapidly growing market. An often overlooked, but nonetheless, key component of the solution are the transmit/receive antenna coils. Designers can design their own coils, but there are two very prominent and most capable companies that expertly design a variety of such coils for the user.

During this year’s DesignCon 2015 exhibition, I stopped by the Würth Elektronik booth and was pleasantly surprised regarding the depth of design that this company has gone to in their wireless power charging and transmitter coils.

First of all, I strongly favor standards and interoperability in any wide-reaching technology as wireless power. Würth Elektronik eiSos (Passive and mechanical components) is a member of the Wireless Power Consortium (WPC) as well as the Alliance for Wireless Power (A4WP) also known as “Rezence”. To further solidify and unify the standards, A4WP has agreed to merge with the Power Matters Alliance (PMA). This will help the industry move to a universal standard, hopefully in the near future with the WPC.

The next most important issue for designers is good demo boards. Würth Elektronik eiSos has a 5W design kit which meets the Qi standard with optimized components. Designers need quick time to market and tools like this expedite their design efforts. Digi-Key offers the kit on their website. Mouser also offers the kit on their website.
The Würth 5W Design Kit is essential for designers to refine their Wireless Power creations using the Qi standard. Texas Instruments ICs are used in these demo boards with various charging and transmitter coils from which the user can choose.
There are various coil sizes and shapes offered to designers for their creations. See Table 1 for the various sizes available in this kit.

Table 1: Various wireless power coils for 5 W Demo kit

<table>
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<tr>
<th>Order Code</th>
<th>L (μH)</th>
<th>$R_{\text{typ}}$ (Ω)</th>
<th>$I_{\text{tr}}$ (A)</th>
<th>$I_{\text{op}}$ (A)</th>
<th>$f_{\text{opt}}$ (MHz)</th>
<th>Q</th>
<th>Size</th>
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* Depending on the application all WE-WPC coils can be used as transmitter or receiver coils referring to 40 K self-heating above ambient temperature.

Image courtesy of Würth Elektronik eiSos

The principle of Wireless Power transfer

NuCurrent coils
NuCurrent coils

NuCurrent has a wireless power antenna technology that is compliant across A4WP, Qi and PMA standards. Their solutions simplify the standards question by eliminating the need for consumers to think about standards. By using their multi-mode solutions, the receiver coil will work with every type of transmitter including Qi, PMA and A4WP. As a matter of fact, NuCurrent’s high-efficiency resonators were selected for the first commercially available A4WP certified products and Wireless Power Consortium’s standard antenna for in-car charging (i.e. charging a mobile phone by placing it on the center armrest of a car). The company has also announced its strategic partnership and investment from Molex and has been selected as the reference antenna for the systems of other wireless power industry leaders like Broadcom and Efficient Power Conversion Corp.

Well, if Efficient Power Conversion Corp. is choosing NuCurrent as a partner, then I am convinced they have something special. Efficient Power Conversion makes the rugged high speed, high power eGaN MOSFETs that are the power drivers of the Wireless Power coils and their applications engineering staff is a savvy group.

So I investigated this designer of printed coil technology and recently spoke to Jacob Babcock, their CEO. What is different about NuCurrent coils? Babcock told me that they have the highest Quality Factor out there.

What is Quality Factor Q?

The WPC defines Q as:

The ratio of the inductance L to the resistance R of a coil remains constant for different winding arrangements in the same volume and shape. It makes sense to define this value as a figure of merit to distinguish different coil structures. The quality factor Q is defined by this ratio. The voltage, which is induced by the same current in an inductor scales with the frequency f and thus the apparent power in the device. The general definition of the quality factor is based on the ratio of apparent power to the power losses in a device. From this definition, the quality factor of a coil results to:

\[ Q = \frac{\omega L}{R} \]

with \( \omega = 2\pi f \):

The quality factor Q can have a value between 0 and infinity, although it is difficult to obtain values far above 1000 for coils. For mass production you may expect values around 100. A quality factor below 10 is not very useful. These values have to be considered as the typical order of magnitude. For a fixed operating frequency, the quality factor Q is mainly dependent on the shape and size of the coil as well as the materials used. Quality factors are generally provided for standard coil techniques (e.g. wire-wound coils, PCB coils).
More details on the Q of coils is at the WPC website here.

As compared with conventional wireless power antennas, NuCurrent devices are smaller, extend battery life, can reach greater distances and have lower heating and increased alignment flexibility.

The two most common antenna frequencies used by the WPC and A4WP are 150 kHz and 6.78 MHz respectively.

NuCurrent technology is able to create efficient and flexible Wireless Power Antennas (Image courtesy of NuCurrent)

At low frequency (Qi compliant), where systems usually operate in closer distances of about 2 cm, the benefit of printed coils allow durability, flexibility, scalability and are easily integratable.

At the higher frequency (A4WP compliant), potential benefits are greater power transfer distance, improved orientation flexibility and smaller sizes. The antennas are called “resonators” here and provide the best Q possible along with their small sizes and low pricing because of the ability to implement the design into standard fabrication processes like PCB and flex circuits.

Two breakthroughs in coil technology

Babcock told me that two fundamental breakthroughs made his technology rise to the surface in Wireless Power. His first endeavors were wirelessly powering implants.
One is the natural “skin effect” and the other is the “proximity effect”.

High frequency “skin effect” and “proximity effect” was prominent in Babcock’s wireless power implant designs. He took a look at how these could be minimized and saw that if the current in the wires was split over multiple, smaller diameter wires, the resistance was significantly reduced and efficiency was far better than other printed options and magnet wires. In some ways, this is like placing a vulnerable, inconsistent yet low resistance Litz wire in a rugged and scalable printed substrate.

Efficiency

Efficiency is a function of the application, but, in general, NuCurrent’s inductors will be more efficient than any alternative inductor at high frequency (1 MHz+). They commonly experience improvements in Q greater than 20% at 150KHz and 60% at 6.78MHz.

The basic premise of their proprietary technology is mitigation of the typical high frequency “skin effect” that occurs in conductive wires at higher frequencies. Their designs provide more available surface area for the current to flow. This lends itself to higher efficiency, smaller size, better durability and lower cost to the designer.

Their design tools and proprietary algorithms take multi-layer (ML) wires and turn the design into inductive structures with lower resistance and higher Q than most other solutions. The design allows for different shapes of Multi-layer, Multi-turn (MLMT) wire on FR-4 or Flex polyimide. NuCurrent structures are more consistent from unit 1 to 1,000; more robust in harsh environments; more cost effective in large quantities and can be integrated directly into a PCB or other substrates without any soldering. (The latest developments are inside of furniture like dressers, tables, etc.)

NuCurrent patented technology de-links frequency and resistance; mitigates high frequency effects in inductors which in turn enable higher efficiency/high Q inductors. (Image courtesy of NuCurrent)
Be sure to watch this technology closely in 2015 because more technical developments will appear as companies find new applications and improve this technology vying for a big piece of this growing market.