Wireless charging: The state of disunion

Brian Dipert - March 28, 2019

Toward the end of my recently published teardown of a wireless charging pad, I wrote:

"In doing the research for this teardown, I realized that a near-future background-info blog post might also be in order. Before beginning my work, for example, I’d thought that Qi (from the Wireless Power Consortium) was still officially specified as only working up to 5W, and that the higher-power "fast" charging approaches from Apple, LG, Samsung, and others were all proprietary ... this ends up not being the case, at least not exactly. Then there's the dueling dual-standard alternative approach offered up by the merged-in-2015 Alliance for Wireless Power (A4WP) and Power Matters Alliance (PMA), now known as the AirFuel Alliance. And what about medium-power applications like home appliances and power tools ... and high power applications like electric vehicles? I'll touch on all of these topics in coverage to come."

That "coverage to come" is indeed this, at least in part, and I'll begin with some background. Wireless charging, more generally referred to by terms such as wireless power transfer or wireless energy transmission, involves the transfer of energy from a charger "source" to a destination device "sink" without use of a conventional power cable. This energy transfer may be undertaken primarily-to-completely to recharge a battery at the "sink"; more broadly, it can find use in directly powering the destination device. However, as the title of this post suggests, I'm going to focus on recharging applications, somewhat out of necessity ... today's Qi implementations (by far the most common approach currently) have insufficient output to directly power all but the most elementary devices.

This particular writeup will also focus on near-field (i.e. close-distance) implementations of wireless charging versus far-field (i.e. long-distance) wireless energy transmission approaches. Long-distance wireless transmission might find use in, for example, providing electricity to a remote facility for which a conventional power line installation is cost-prohibitive or otherwise infeasible, or in powering a drone or other aboveground-operating product. Conversely, close-range wireless transmission is commonly used for recharging the batteries built into smart watches, mobile phones, tablet computers, electric toothbrushes, and other consumer electronics devices, for example, along with pacemakers and other products surgically implanted into the human body.
If you own an electric toothbrush, you may not realize it but you're benefitting from wireless charging (and yes, I really do need to clean mine).
And finally, I personally don't include conductive wireless charging in the implementation-option list that I'll go through next. That's because it, commonly used (for example) for recharging removable battery packs in conjunction with charging stations, is only "wireless" in the strictest sense. Granted, a primary-to-secondary power cord (and associated secondary connector) isn't necessary, but it still relies on a conductor-to-conductor (i.e. metal-to-metal) physical connection between the energy source and destination. As such, the potential for electric shock and other usage issues remains, although it's somewhat mitigated by the fact that primary power often isn't switched on until the presence of a valid secondary is first confirmed (via a physical switch flipped during battery "docking," for example, or a low-voltage signal "handshake" between the two devices).

**Inductive coupled wireless charging**

Inductive wireless charging leverages the well-known phenomenon initially referred to as [Ørsted's Law](http://example.com/orsted), which observes that a steady electrical current passing through a wire creates a transmitted magnetic field around the wire (follow-on Faraday's Law similarly notes that a change in magnetic flux can induce current flow in a nearby wire, and Maxwell's equations expand Ørsted's Law to cover the alternating-current case). Subsequent electromagnetic coupling to another nearby wire generates electrical flow in the second wire.

Transformers use electromagnetic phenomenon in conjunction with AC electricity and magnetic permeability cores in order to step up or down voltage, by varying the wire winding count at the source (primary) and destination (secondary). Inductive charging more generally harnesses the magnetic field-based transmission effect to transfer energy across a narrow air gap between two inductors. Simple designs may directly leverage the 50 Hz or 60 Hz mains frequency; more complex designs boost the transmission frequency in order to boost efficiency. And a rectifier converts the induced alternating current back to direct current for battery-charging purposes.

Add a capacitor to the inductor at either end of the wireless energy transmission chain and you end up with a resonant circuit, therefore the name resonant inductive coupled wireless charging. If the resonant frequency at the primary and secondary circuits is the same (and matches the transmission frequency that's employed), you're able to achieve efficient transmission at longer air-gap distances than would otherwise be the case. However, keep in mind that at close range, the most efficient resonant frequency is different than it is at longer primary-to-secondary spans, thereby requiring dynamic frequency tuning capabilities at both ends of the charger design.

**Capacitive coupled wireless charging**

Consider the basic elements of a capacitor: two conductive elements, with a dielectric in-between them. Now mentally replace the conductive elements with the primary and secondary nodes of a wireless charger; the dielectric in this case is the air gap between them, along with the plastic enclosures and other intermediary insulating materials. This, simply stated, is (as its name implies) how capacitive wireless charging works, in conjunction with alternating current transmission. This approach is comparatively uncommon versus inductive wireless charging, because of the high voltage necessary to transmit tangible power, along with other issues. However, the technology also offers a few comparative advantages; a more confined electromagnetic field, for example, along with less precise primary-to-secondary alignment requirements.

**Wireless charging strengths**

One potentially obvious advantage of the inductive and capacitive coupled approaches in particular, thereby explaining the technology's frequent use with appliances found in bathrooms and other
environments where water-induced electrocution is a possibility, is that both the energy source and battery can be completely embedded within the (respective) charger and destination device, electronically insulated not only from each other but also more generally from all other environmental factors. Water-resistant and -proof system attributes are also attractive for products that will be used under water (exercise watches when swimming, for example), while it's raining or snowing, or if the owner is perspiring.

Environmental imperviousness is equally beneficial when dust and other potential contaminants are considered. The lack of a required charge cable connector on the device can also reduce the device's thickness and other dimensions, along with its weight and bill-of-materials cost, the latter counterbalanced by the incremental expense of the wireless charging hardware. And wireless charging is also a consumer-friendly approach. There's no need to clumsily find and connect a charger to the device; instead, just place it in proximity to a charging dock.

**Wireless charging shortcomings**

Inefficiency versus traditional corded charging schemes is one key shortcoming of any wireless charging approach, with the degree of inefficiency being to some degree implementation-dependent. A late-2013 test of the wireless charging technology built into Google's second-generation Nexus 7 tablet, for example, revealed it as taking more than twice as long to fully recharge the tablet's built-in battery as compared to the micro USB-based alternative, although the wireless charger drew approximately the same power from the wall outlet.

Charging efficiency is also somewhat dependent on how precisely the consumer places the device on the wireless charging dock or mat. Careful wireless charger physical design can be beneficial in this regard: a charging "cradle" that automatically guides a smart watch to the optimum orientation, for example. Regular readers will recall that orientation issues were behind my wife's displeasure with the wireless charging pad that I ended up recently tearing down instead; she's much more fond of this alternative:
The other notable downside to wireless charging, at least for the moment and as is seemingly the case with any emerging compelling technology, is that several incompatible wireless charging standards currently exist. Conceptually, many of the contending approaches are quite similar. But "the devil's in the details," as the saying goes ... protocols, voltages, frequencies, antenna characteristics, and other attribute specifics are capable of creating incompatibility between various competitors. And although A4WP and PMA agreed to merge their efforts in June 2015, as mentioned earlier in this writeup, the two approaches will remain distinct; dual-mode chipsets and other "bridge" technologies will be necessary in order to ensure interoperability under the "AirFuel Alliance" umbrella.

Qi specifics

As mentioned earlier, the Wireless Power Consortium's Qi is the predominant wireless charging approach in the market today, courtesy of its widespread (and growing) adoption in smartphones, tablets, smartwatches, and the like. Also as mentioned earlier, Qi was initially specified as supporting "Basic Power Profile" transmission and reception up to 5W (and often less, for small-capacity battery applications such as wearables).

However, as the consortium's specification revision history notes, beginning with spec v1.2 (albeit not absent controversy), the "Industrial and Consumer Extended Power Profile" (EPP) expanded power transfer capabilities up to 15W. Widespread adoption of EPP, as far as I can tell, didn't start happening until spec revision 1.2.2; the current public spec is v1.2.3 (v1.2.4 has been released, but currently only privately to the consortium membership). A PDF I found of a May 2017 slide deck from Qi chipset supplier NXP also gives some useful background information. And here's an example
of a commercially available 15W charging pad.

*Wikipedia says* (and other online materials concur) that spec v1.2.2 was published in mid-2017. How, then, was Samsung selling "fast charge" pads and compatible phablets (followed by broader adoption in the company's smartphones, tablets, and the like) *beginning in mid-2015*? Presumably, the company had insight into under-development Qi technologies (and the specs documenting them) and made the strategic decision to "jump the gun" on implementation (in *partnership with chipset manufacturer IDT*) in the hopes that the rest of the industry would follow.

Which it did, albeit with a "gotcha" or few. Samsung officially specs its "fast charge" at 9W (thereby explaining the 9V@1A specification of the charging pad I tore down). Competitor LG followed with "10W" one-upmanship. Always-conservative Apple eventually launched its first wireless charging-capable phone, the iPhone X, at 7.5W in late 2017. And Google added native (versus clumsy *accessory-supplemented*) wireless charging to the Pixel 3 smartphone family in late 2018. That last one's the source of a "gotcha" qualifier ... *unlicensed third-party chargers are restricted to 5W capabilities*. Even now, *six months later*, your only option for 10W charging on Pixel 3s is Google's own $79 Pixel Stand (due to concerns about compatibility? Profitability? Both? You decide). And speaking of branded chargers, I should also note that Apple's own AirPower charging mat, launched in September 2017 with a "2018" production estimate, exited last year still MIA, although another in a long lineage of rumors suggests (as I write this in late March 2019) that it's *coming "soon."*

Clearly, wireless power transmitter design isn't easy.

That's all I've got for you for now, aside from the guesstimate that whereas the AirFuel Alliance competitor to Qi is still *fighting the good fight publicly*, behind the scenes it's probably retooling for those medium- and high-power alternative applications that I mentioned earlier (which, to be clear, is a smart move IMHO). I'll plan to cover those higher-power applications, along with far-field (long-distance) ones, in future blog posts. Until then, as always, I welcome your comments!

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