Wireless charging: advanced technology delivers consumer convenience

An integrated approach delivers real technical benefits in resonant solutions

Abstract

Wireless is not new; data became wireless some time ago. However, for all the mobility we enjoy these days, we still tether our mobile devices to the wall at the end of the day to recharge them. Slowly but surely a revolution is happening; consumers are demanding the ability to charge wirelessly and technology enablers are responding.

In this white paper, Infineon will review the current state-of-the-art, including the standards that drive this new sector. The paper compares technical approaches and technologies and explains the benefits of a totally integrated approach to delivering advanced wireless charging solutions.

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1 Introduction to wireless charging

Every electronic or electrical device we use these days requires power. While many devices still use mains power from a wall outlet, the trend is very strongly towards mobility, meaning that devices need to become fully wireless.

Due to wireless technology being hitherto mostly used for the transfer or streaming of data, video and audio, either via Wi-Fi or other standards such as Bluetooth, the term 'wireless' has become almost synonymous with data transfer. However, another important capability of wireless technology is the ability to charge device batteries by using electromagnetic fields to transfer power from a transmitter to a receiver application.

Many modern devices including smartphones, wearables, laptops, tablets, power tools, multicopters, service robots, electric toys and medical devices can benefit from the benefits that wireless charging brings.

One of the major advantages of wireless charging is convenience. There is no need to plug in the device, simply place it on the charging mat and charging begins. No plugs or cables are required, so compatibility issues become a thing of the past.

Wireless charging also enhances the robustness of the device; there are no physical cables or connectors to tangle, wear or break. By eliminating the charging connector, sealing devices for rugged environments becomes easier. Even consumer devices benefit from this; around one in five smartphones are dropped into liquid at some point, causing them to fail. The greatest advantage of wireless charging is to give the option to all users of portable devices to forget these bulky charger adapters and be capable of charging any device anywhere.

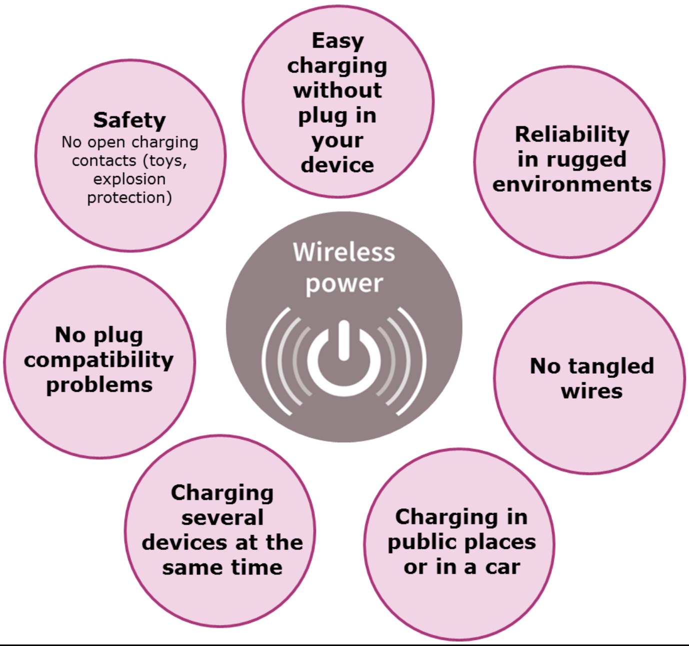


Figure 1 Wireless charging offers multiple benefits for users and device manufacturers

As the technology matures, standardization is increasing. As we move to a universal charging solution then the ability to provide highly compatible public charging stations is enhanced. Wireless charging stations are already appearing in airports, hotels, event venues, fast food chains and coffee shops, to name just a few.

With the multiple advantages and benefits, it is no surprise that the market for wireless charging is growing rapidly, even in this early phase. In fact, a recent Wireless Power Transmitter Market Report by leading market research firm IHS (www.ihs.com) estimated that the market for transmitter shipments will more than triple within the next four years.

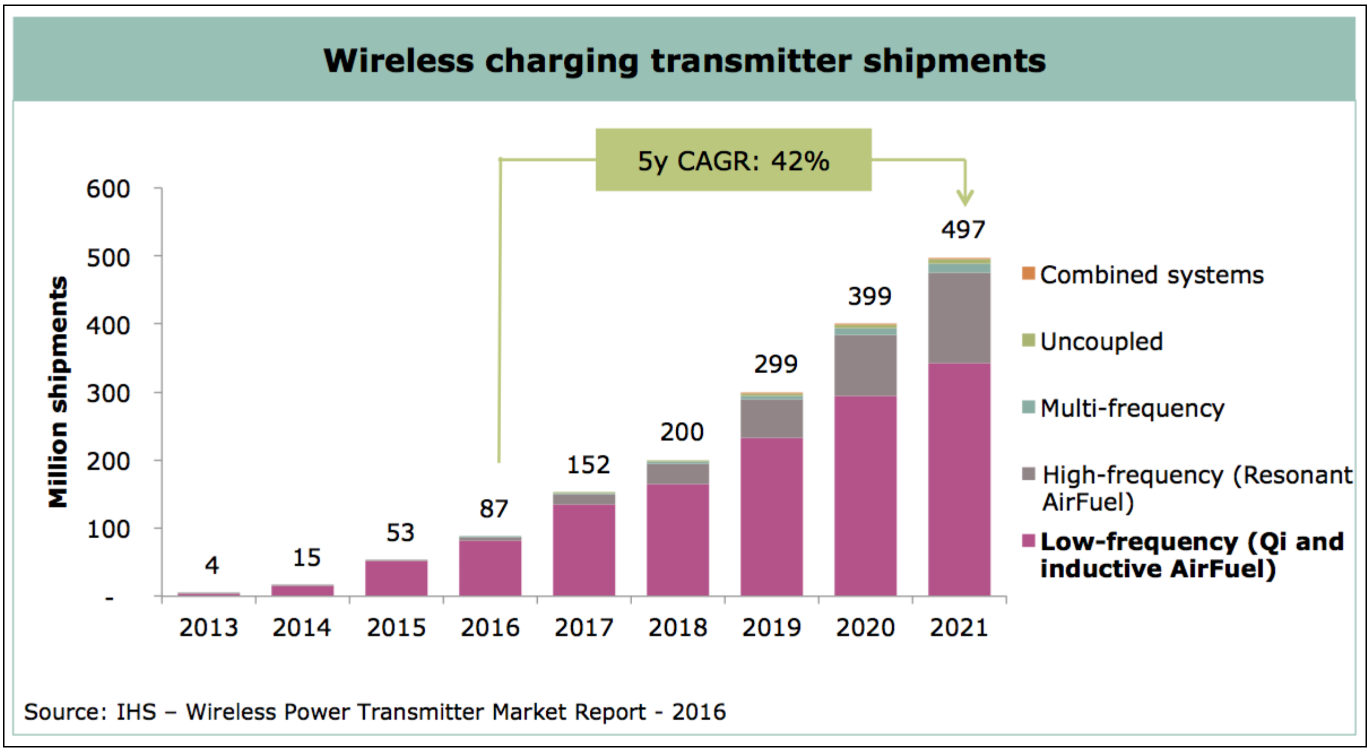


Figure 2 The market for wireless transmitters is estimated to show significant growth

The predicted 5-year compound annual growth rate of 42% will mean that 152 million devices shipped in 2017 will grow to almost half-a-billion devices annually by 2021.

2 The design challenge

There are a number of challenges for designers wanting to convert a wired charging approach to wireless, or those seeking to design from the ground up.

Just about every charger in use today is a Switched-Mode Power Supply (SMPS) where the AC mains voltage is converted into DC via a rectifier. This is then 'chopped' into a high-frequency AC signal and passed through a magnetically coupled transformer that changes the level of the voltage before rectifying and smoothing the waveform to supply DC to the load.

Conceptually, wireless charging works in a very similar way - except the transformer is split between the charger and the device to be charged. The primary winding is part of the charger and the secondary winding is within the device being charged. With this physical change, the terminology changes - the primary side becomes the 'transmitter' and the secondary is now the 'receiver'.

As the windings are separated (by the case thickness and air), the coupling is looser than with a normal SMPS. However, if certain basic criteria are met (alignment of charger and device, size of coils and distance between coils relative to the size of the coil) then a good coupling factor can be achieved and power can be transferred with unexpected efficiency.

Most SMPS designs require a good understanding of the magnetics, which is a specialist discipline - and considered by many engineers to be something of a 'black art'. In wireless charging the coils and coupling have a far greater impact on the overall performance than with an SMPS.

Other than overcoming the issues associated with the magnetics, wireless charging challenges designers with issues including efficiency, mechanical packaging and electromagnetic interference (EMI). On top of this, issues such as not being able to control whether metallic foreign objects (such as coins and keys) interfere with the charging create further challenges for the designers.

Essentially, designers desire efficient and easy to design transmitters, including higher power ratings for faster charging and the ability to serve multiple devices. As with any power solution, good thermal management is critical and made more challenging by the need to deliver small form factor designs to suit modern portable devices, especially wearables.

3 Standards overview

As with many emerging technologies, especially those with huge revenue potential, multiple (often incompatible) standards develop which, while they serve to develop the technology, in some ways stifle progress until a truly universal solution emerges. The wireless charging arena is driven by two industry alliances and two standards.

The Wireless Power Consortium (WPC) was founded in 2008 and supports the Qi (pronounced "chee") standard for wireless charging. The WPC verifies product compliance through a network of authorized labs. From a technical perspective, Qi is an inductive standard that supports tightly coupled charging. It has largely become the mainstream standard, with backing from 230 leading companies and well over 80% dominance of all wireless charging receivers.

The Power Matters Alliance (PMA) and the Alliance for Wireless Power (A4WP) were both formed as separate organizations in 2012. PMA was primarily focused on tightly coupled inductive solutions whereas A4WP was working on loosely coupled resonant technology.

In June 2015, the two organizations were formally merged and later that year rebranded as the AirFuel Alliance (AirFuel). The merger reduced the number of organizations (and competing standards) from three to two and was praised for bringing the goal of a single, interoperable standard one step closer.

Airfuel has a broad technology platform encompassing inductive, resonant, and uncoupled technologies. The inductive technology is relatively mature and is deployed in millions of devices worldwide. This close-coupled technology offers efficiencies up to 80% with scalable charging to suit devices with different power requirements.

AirFuel's resonant technology allows for a "drop and go" charging experience, and offers considerable user experience benefits over inductive solutions.

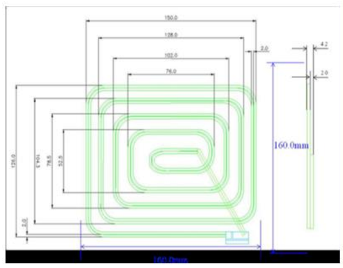
	Inductive single-coil	Inductive multi-coil	*Magnetic Resonance*
	 Topology dominating the volume in the market		
Standard	***Qi or inductive AirFuel*** 100-300 kHz	***Qi or inductive AirFuel*** 100-300 kHz	***Resonant AirFuel*** 6.78 MHz
Positioning of receiver application	Exact positioning	Positioning more flexible (typical <10mm vertical freedom)	Free positioning (up to 50 mm vertical freedom)
# of devices charged	Charges only one device	Charges multiple devices	Charges multiple devices
Rx-Tx communication	In-band communication		Communication on Bluetooth Low Energy

Figure 3 Wireless charger transmitter topologies based on 3 dominating standards

Currently, there are three topologies available for wireless charging each an evolution of another, and offering different advantages.

The single-coil inductive approach is the simplest and most prevalent solution and consists of a single transmitter coil operating between 100-300 kHz. Supported by both Qi and AirFuel, this approach required exact positioning of the device to be charged in relation to the transmitter coil. The device needs to be placed very close to the coil vertically, which precludes charging through surfaces, such as being embedded in furniture. Due to these proximity requirements, the single-coil inductive approach is only able to charge a single receiver device at a time.

Extending this approach to multi-coil brings a number of benefits. The positioning of the device is much less precise and intelligent systems can detect which coil is closest to the device being charged and direct the power accordingly. With its broader charging field, the multi-core approach is able to charge multiple devices at a time. It also allows devices to be up to 10 mm from the coil vertically, enabling charging through non-metallic surfaces - allowing the charger to be invisibly integrated into furniture.

Moving away from the purely inductive approach, the AFA supports a resonant approach that moves wireless charging significantly further forward. Operating at 6.78 MHz, this approach relies on resonance between the transmitter and receiver to transfer energy far more efficiently.

The resonant approach is able to charge multiple devices from a single coil and allows for a greater distance (up to 50 mm) between the transmitter and receiver. This allows for far greater flexibility in positioning of the device being charged giving a much improved 'drop and go' experience for the user, as well as facilitating far easier fitting into existing furniture. It also allows the achievement of efficiencies up to 80%, but to reach these levels an optimal placement is needed and the benefits of free positioning cannot be enjoyed.

Although a very closely coupled inductive solution can deliver more power in a very precisely defined and controlled scenario, as soon as the placement alters then the resonant approach gives a far more efficient energy transfer with spatial freedom.

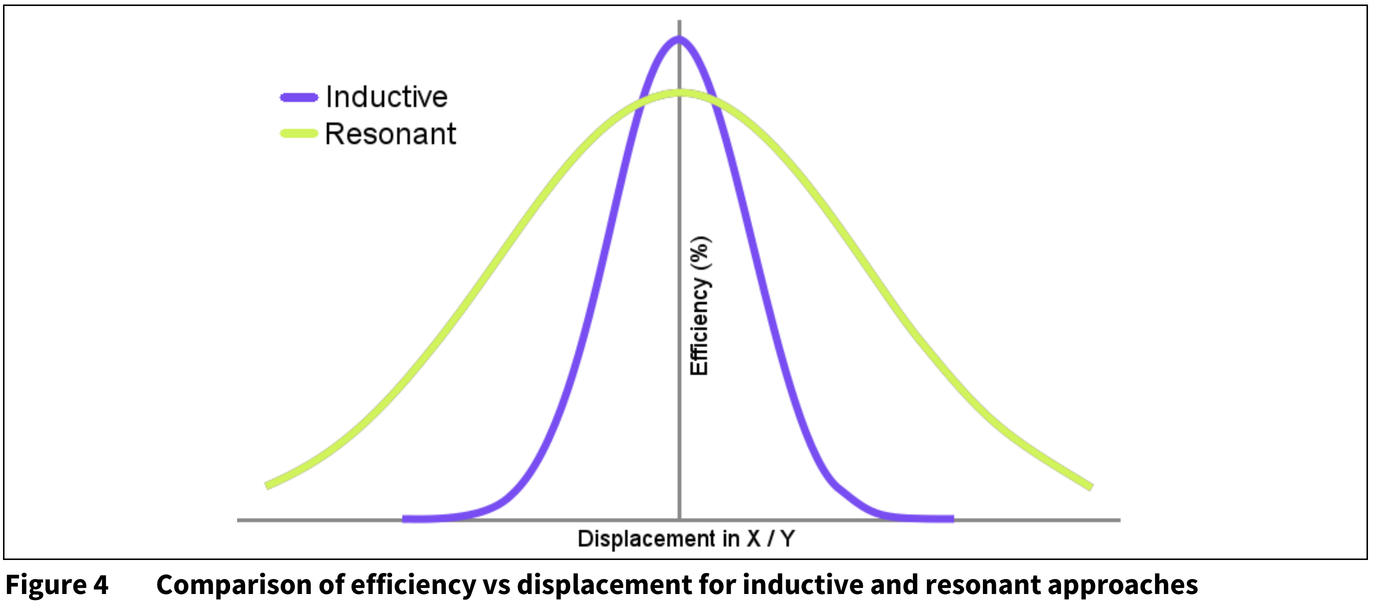


Figure 4 Comparison of efficiency vs displacement for inductive and resonant approaches

The resonant approach also allows for higher power ratings, allowing more device types (e.g. laptops and power tools among others) to be charged wirelessly. The technology is not affected by the presence of metallic objects in the charging area and is therefore more immune to foreign objects such as keys and coins. It also allows for the charging of metal-backed smartphones, tablets and wearables, but this remains a very challenging implementation.

4 Key topologies and enabling technologies

The three key elements of a wireless charging solution are the adapter / charger, the transmitter and the receiver and shown below.

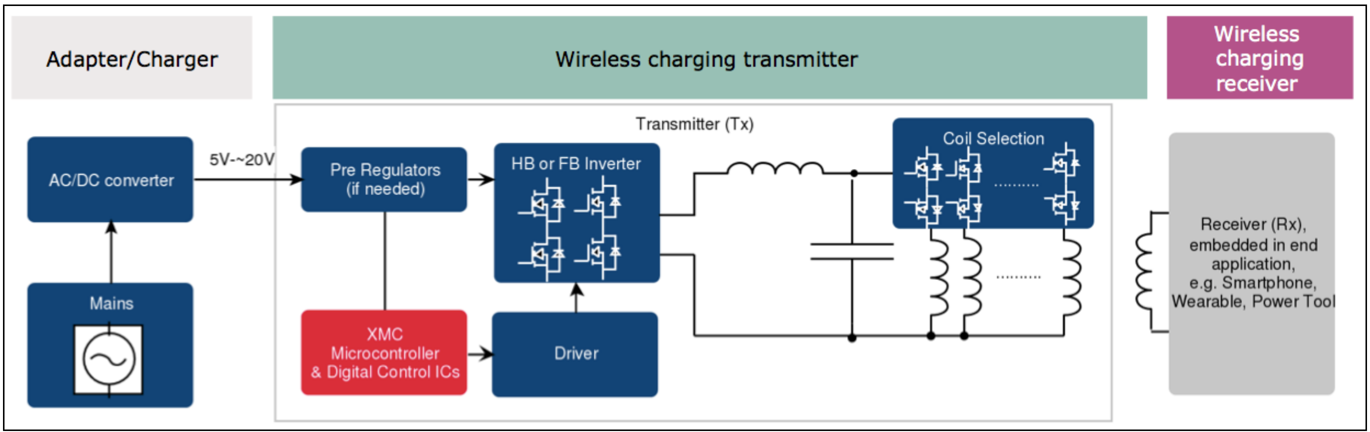


Figure 5 Typical inductive wireless charging systems consist of three main elements

The adapter connects to the mains supply and powers the transmitter, usually with a regulated DC voltage in the range 5-20 V. This will most often be a separate device connected to the transmitter via a cable, although the adapter and transmitter could equally be combined into a single unit.

The transmitter contains a MOSFET-based inverter to convert the DC power into an AC waveform and create the alternating magnetic field; this is often a half-bridge or full-bridge topology. In order to provide the flexibility and functionality required, the inverter is controlled by a microcontroller and associated MOSFET driver components.

There are two primary topologies used for resonant (AirFuel) applications, Class D and Class E. Although quite similar in a number of aspects, each approach offers slightly different benefits making each suitable for different applications.

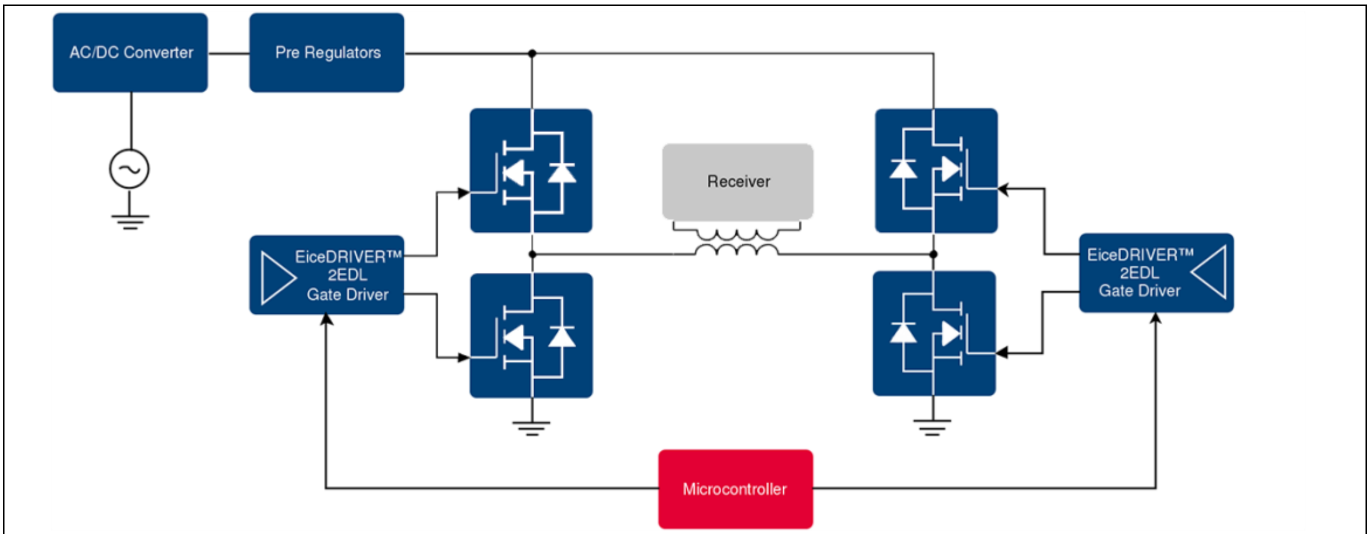


Figure 6 Class D topology for resonant applications

Figure 6 shows a Class D wireless charging implementation. Although a full-bridge topology is shown, a half-bridge topology is also suitable. Class D offers an almost-flat efficiency curve over a wide load range and is therefore suited to general-purpose wireless charging stations, such as those found in public places where a wide variety of devices could be charged. Class D is suitable for a wide range of power levels.

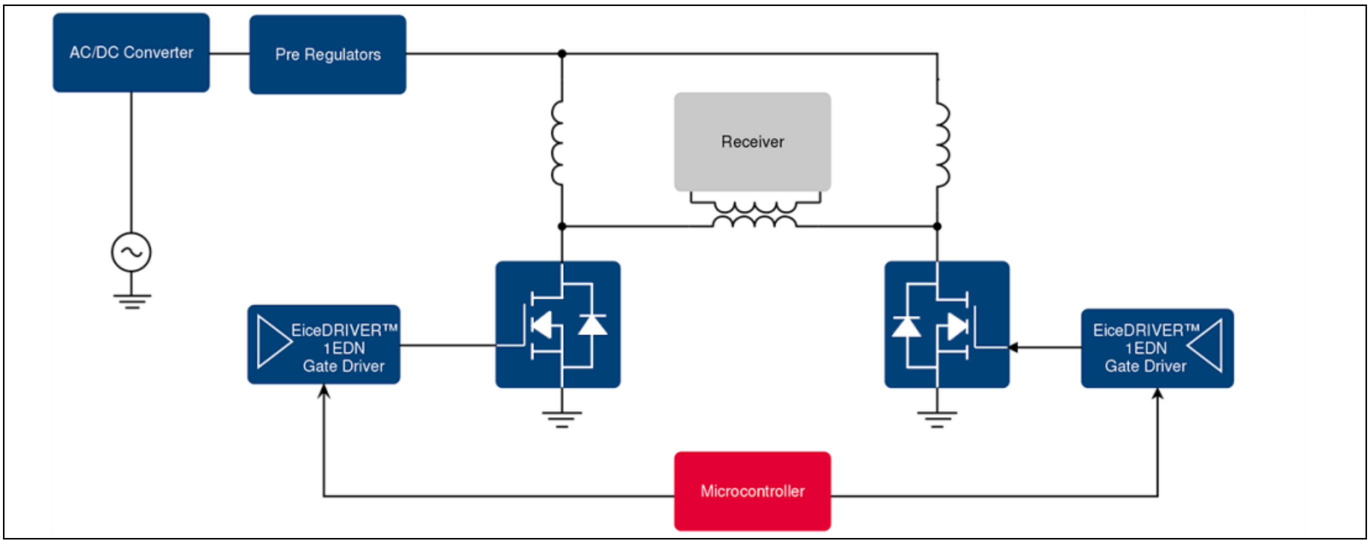


Figure 7 Class E topology for resonant applications

The Class E topology is shown in Figure 7. Either a single-ended (as shown) or a differential Class E layout can be used. In contrast to the Class D topology, Class E is optimized for a particular design point and, at this point, will show greater efficiency. However, the Class E efficiency falls off more rapidly away from this point. Thus this topology is best suited to high power and for 1:1 charging of a specific device that is either charged close to target power or not charged at all. The BOM costs associated with Class E are very similar but tend to be slightly lower than those of Class D.

As a leading semiconductor manufacturer, Infineon offers a broad range of components that includes a full suite of solutions for wireless charging transmitters, as well as the associated charger.

Key enabling products come from throughout the range bringing the advantage of using components and subsystems with known compatibility.

At the heart of the transmitter design is the microcontroller that provides the system control and intelligence. The Infineon XMC™ range offers multiple options, although the XMC1302, XMC1404 and XMC4108 are most suited to the Class D and E topologies.

The EiceDRIVER™ gate drivers take the microcontroller signals and translate these to drive the MOSFETs directly. The new 2EDL71 is most suited to the Class D designs and the established 1EDN is preferred for Class E applications.

The choice of MOSFETs from Infineon is, as you might expect, extensive. The available options include choice of package size as well as key operating parameters including RDS(ON) and Qg. The range supports multiple voltage classes from 30 V to 250 V and gives designers flexibility to design wireless chargers at multiple power levels, each with the same base technology. Infineon's market leading OptiMOS™ are used for the Class D or E power Inverter (as well as synchronous rectification topologies) and CoolMOS™ devices in CE and P7 versions provide switching capabilities for the ACDC Adapter.

Table 1 Key Infineon MOSFETs suitable for Class D topologies

Voltage Class	Package	Part number	RDS(on) max @ VGS = 4.5V [mΩ]	Qg [nC] typical	Coss [pF] typical	Topology
30 V	2x2 PQFN Dual	IRLHS6376PbF	48	2.8	32	Class D
	3.3x3.3 PQFN Dual	BSZ0909ND	18.5	2.0	~120	Class D
	3.3x3.3 PQFN	BSZ0506NS	4.4	5.7	220	Class D
		BSZ065N03LS	6.9	5.2	270	Class D
60 V	2x2 PQFN	IRL60HS118	23.5	5.3	110	Class D
80 V		IRL80HS120	42	4.7	70	Class D
100 V		IRL100HS121*	59	3.7	60	Class D

* under development ** @Vgs=8V

Table 2 Key Infineon MOSFETs suitable for Class E topologies

Voltage Class	Package	Part number	RDS(on) max @ VGS = 4.5V [mΩ]	Qg [nC] typical	Coss [pF] typical	Topology
80 V	2x2 PQFN	IRL80HS120	32	3.5	68	Class E
100 V		IRL100HS121*	42	2.7	62	Class E
150 V	3.3x3.3 PQFN	BSZ900N15NS5	75**	4.1	46	Class E
200 V		BSZ900N20NS3	78**	7.2	52	Class E
		BSZ22DN20NS3	200**	3.5	24	Class E
250 V		BSZ42DN25NS3	375**	3.6	21	Class E

* under development ** @Vgs=8V

Infineon also offers a range of Flyback controllers for the power adapters as well as the line of CoolSET™ integrated IC/MOSFET products.

Alongside the component solutions Infineon also offers a newly developed test board for a Class D power amplifier transmitter to allow designers to get started quickly with designing and developing highly efficient and compact solutions.

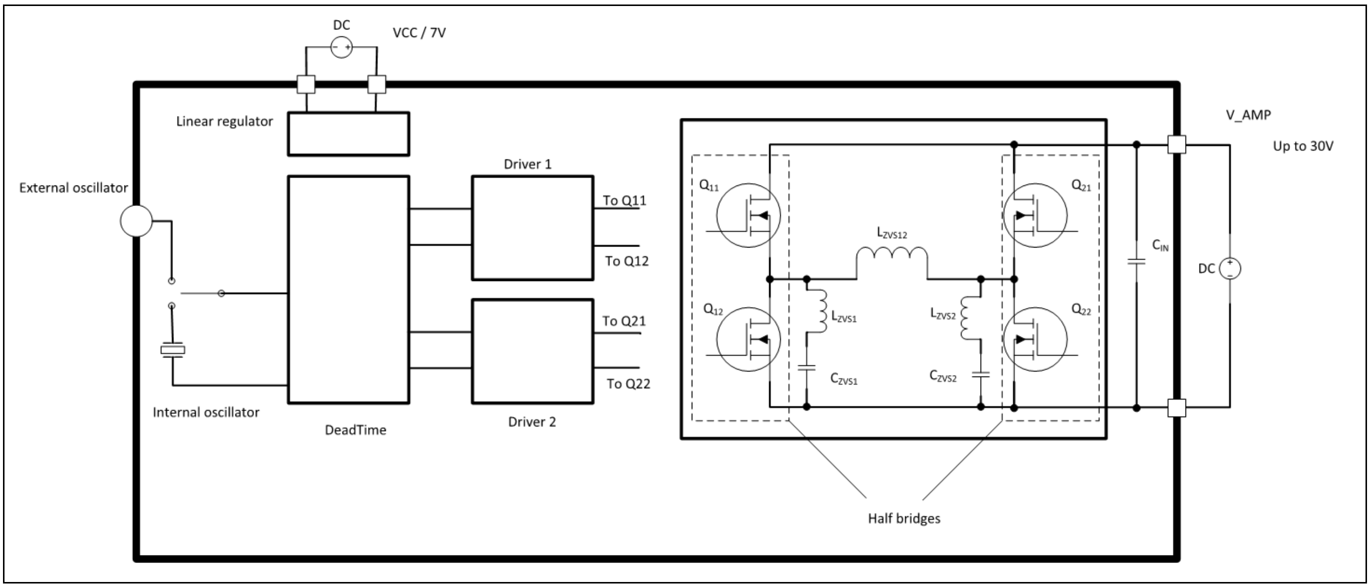


Figure 8 Simplified block diagram of the Class D test board

The test board allows designers to evaluate the functionality and performance of Infineon MOSFETs in a Class D configuration power amplifier. Containing two half bridges constructed with 80 V 2x2 Infineon MOSFETs (IRL80HS120) and the related driver, the test board allows users to switch between single ended configuration (only one half bridge is active) and differential configuration (both half bridges are active).

An embedded oscillator ensures an accurate 6.78 MHz operating frequency, and also provides a pin to set the switching frequency externally with a waveform generator, via a BNC connector.

All of the required components to design the Zero Voltage Switching (ZVS) power solutions are included in order to achieve the highest possible efficiency. An on-board linear regulator provides a stable supply voltage for the board logic.

A second BNC connector allows the connection of an external transmitting coil for wireless power transfer. If a wireless charging capable receiver device is available then a complete wireless charging design can be created.

5 Summary

Wireless charging brings multiple benefits to many devices in the modern world, not least increased convenience and enhanced reliability. Technical standards are maturing and consolidating, ensuring greater future compatibility between all chargers, transmitters and portable devices. As these standards evolve the convenience is being enhanced to bring true 'drop and charge' convenience as well as increasing power levels, thereby enabling more device types to be charged wirelessly.

Infineon is a leading supplier with a comprehensive product range that addresses all of the critical components in the AC adapter and transmitter. Each of the components brings individual strengths that include low switching and conduction losses, low parasitic packages that in many instances allow the designer to realize his solution with mature and reliable silicon MOSFET technology. Infineon has long experience in power semiconductors and microcontrollers and is known as a technology and quality leader.

With this broad product offering, backed by test boards for rapid evaluation and development, Infineon offers a fully comprehensive solution for highly efficient, reliable and compact wireless charging designs.

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