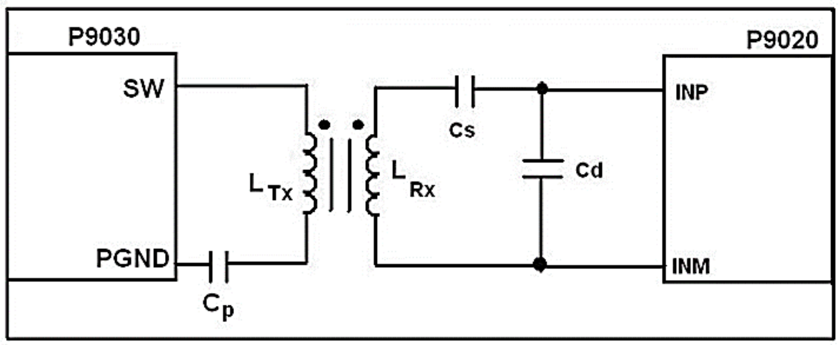
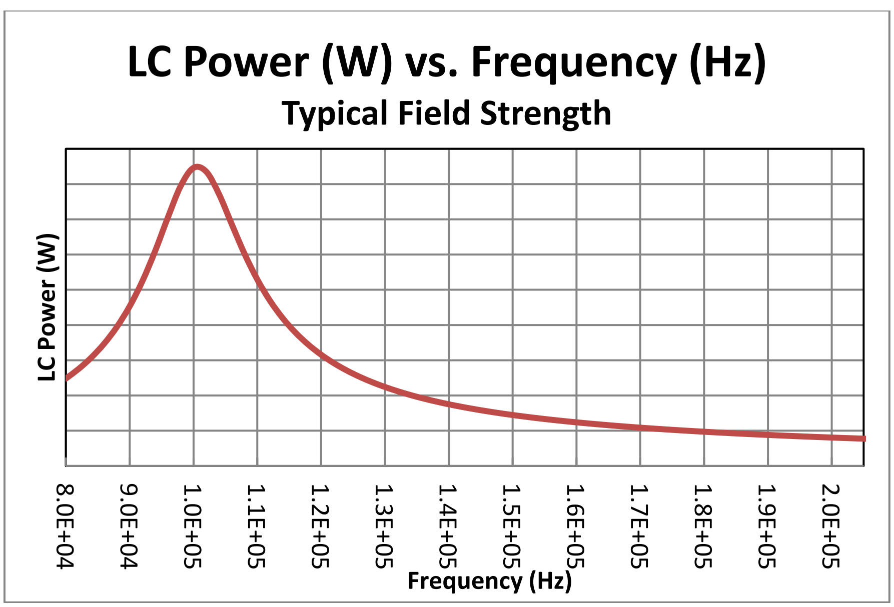
IDT's wireless power transmitter integrated circuits operate by using air core transformers to transfer energy in the form of a magnetic field and comply with Qi (pronounced Chi) wireless power transmission standards. In order to attain optimal efficiency and hazard-free wireless power transfer, IDT operates using an Inductor-Capacitor (LC) resonance circuit with a high Quality factor (Q), and communicates from the receiver to the transmitter wirelessly to supply required power delivery levels while detecting for foreign objects inadvertently placed in the power transmission field. The definitions of two particular transmission coil inductance values must be introduced prior to the calculation of the proper resonance components to use in order to safely transmit power across the air medium. However, before the definitions are introduced, the general scheme of the resonance and power transmission will be discussed.

Figure 1. P9030 to P9020 Simplified Power Transfer Circuit



In Figure 1, the P9030 A1 wireless power transmitting solution is shown with only the most basic components displayed and connected to the P9020 wireless power receiver block. The two sides of the wireless connection are set to form a pair of resonant tank circuits (LC), both set to resonate at 100kHz plus or minus the tolerance of the inductors and the capacitors. On the receiver side, there are two resonant tanks; the first is composed of LRX (or L_S) and C_S (S for Secondary) and is set to resonate at 100kHz, while the second resonant circuit operates at 1MHz and is composed of LRX and Cd. The power is received by the LRX and CS combination, and the second resonant circuit is used for fast detection and communication. The bandwidth is much higher in order to produce effective data communication packets. On the Tx side, the LC resonance circuit is composed of L_{TX} (or L_P) and C_P (P for Primary) and should be selected by following the appropriate Qi Tx type being designed to. The theory of operation is that the P9030 will energize the transmit LC circuit from 110 to 205kHz which will be received by the P9020.

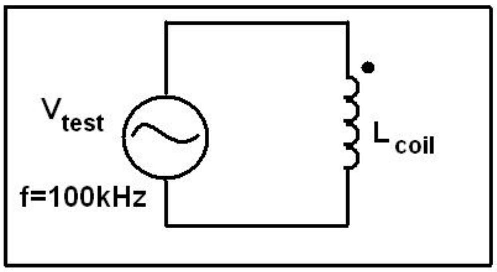
Figure 2. Power Available vs. Frequency Curve



Since the P9030 will energize the LC circuits above the frequency of resonance, the circuit will deliver more power while the LC circuit is energized closer to 110kHz and will deliver less power when the LC circuit is energized at 205kHz. As a safety mechanism, the circuit will not operate at or below the resonance point ensuring that more power is available when lowering the operating frequency and that less power becomes available when the operating frequency is increased as can be seen in the LC Power curve shown in Figure 2.

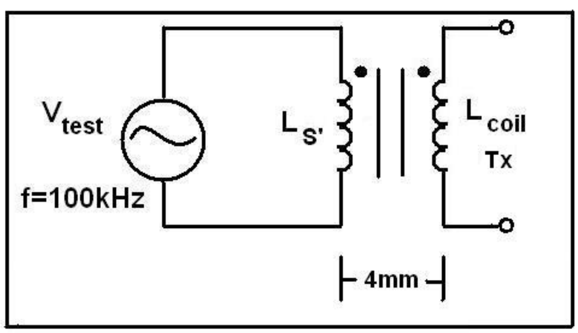
With the theory of operation in mind, the calculation of the LC components can be defined. The first definition is of the transmit coil inductance which is provided in the component datasheet produced by the coil manufacturer. Figure 3 shows the test setup of the single coil using the Agilent 4285A Precision LCR Meter.

Figure 3. Transmit Inductor Single Coil Test Setup



The peak-to-peak voltage of the V_{test} voltage source should be as close as possible to the operating Vin voltage of the system. Since the components values used on the Tx side come from direct calculation and datasheet values (and the Qi Specification), this document will now shift focus to the Rx side since this is where the freedom of design exists. This Rx inductance value is identified as L_S for the remainder of this document. The second inductance value of interest is the measured effect the Tx coil has on the secondary (receive coil) measured inductance (L_S'). This effective change in Rx inductance ($L_S \rightarrow L_S$') results from the mutual inductance loading the Tx coil imposes upon the Rx coil (L_S).

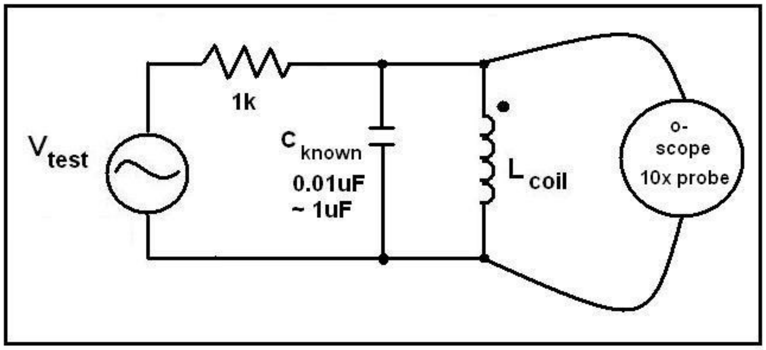
Figure 4. Rx Coil Inductance change from the Transmit Inductor Coil Test Setup (LS')



The Rx coil L_S' test setup is shown in Figure 4 and is measured with the typical Tx coil expected to face the Rx coil during power transfer (L_S' is the effective Rx coil inductance due to mutual inductive of loading from L_{COIL} Tx). This is known as the receiver coil operating inductance value and is identified as L_S' for the remainder of this document. It is recommended to make this measurement using the Tx design and coil that will be sold for the Rx being design or the most common and readily available type (such as A11 or A28 BPP Tx types) so that the friendly metals and most common Transmitter coils are used for measuring L_S'. Furthermore, it is ideal if the Tx coil is not connected to the electrical drivers to avoid additional loading from the semiconductors connected to the Tx coil, and in no case should L_S' be measured while facing a powered and active Tx.

The value of L_S should come from the manufacturer's datasheet; however, it can also be measured. Several techniques can be used to measure the inductance L_S. A simple method which takes advantage of the high Q of the coil under test is to sweep the frequency of V_{test} while monitoring the voltage across the inductor with an oscilloscope triggered by the input voltage V_{test}. In this case a series resistor should be placed between the voltage source and the coil, and a known capacitor (with C0G type dielectric preferred) is placed in parallel with the coil. The voltage measurement of interest is the peak voltage that occurs across the coil while the frequency is swept.

Figure 5. LS Coil Inductance Bench Test Setup



With the frequency at which the peak voltage appears across the coil and capacitor combination in mind and the capacitance known, the L_S value can be calculated using the following formula:

$$f = \frac{1}{2\pi\sqrt{L_{Coil}C_{known}}} \quad \text{Equation 1}$$

where $L_S = L_{Coil}$ (H) from Figure 5,

An even simpler technique is to use a precision inductance measurement device such as the Agilent 4285A Precision LCR Meter to measure this value. A decent inductor will have the same inductance over a wide frequency range, thus the measurement taken with an LCR meter at 100kHz should produce the same value of inductance as the measurement method described above. Next, the measurement of L_S' can be performed in the same manner with the addition of the L_{coil} added in close proximity to L_S. The following images show the actual coils and test configurations described above.

Figure 6. Single Rx Coil Alone in Free Space for LS Measurement

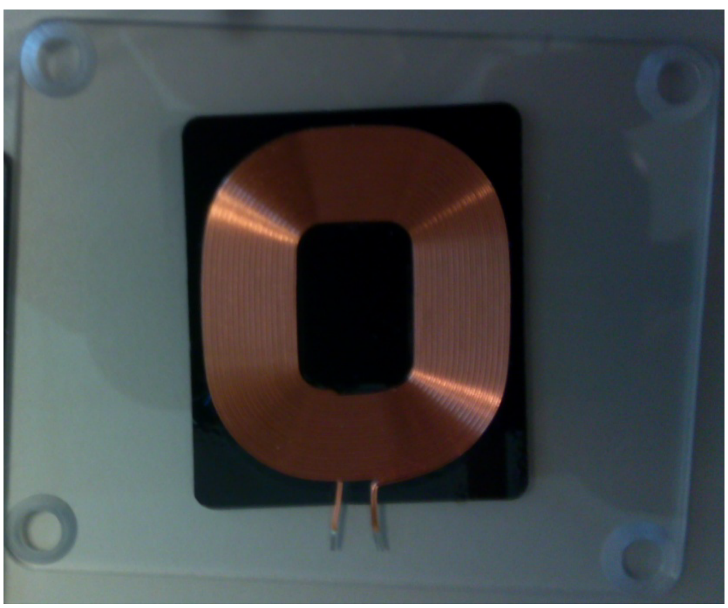


Figure 7. Mutually Coupled Tx and Rx Coil from LS' Measurement (Top View)

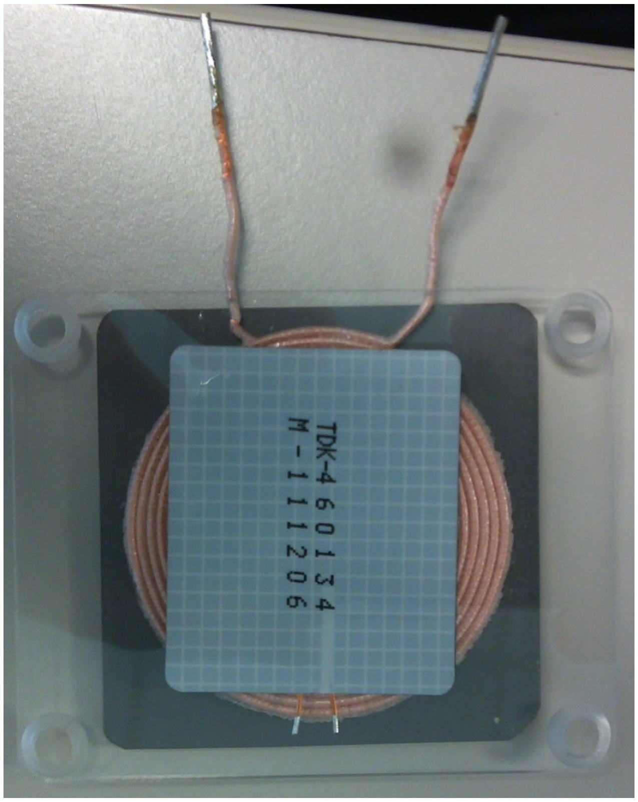
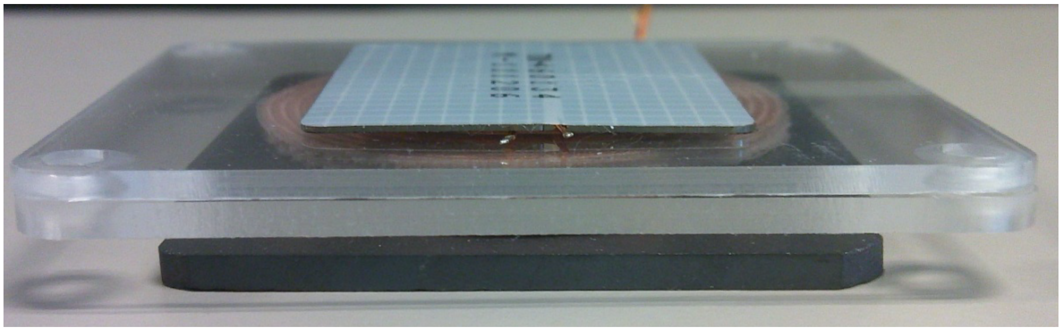


Figure 8. Mutually Coupled Tx and Rx Coil from LS' Measurement (Side View)



Now, with the concepts and values of L_S and L_S' in mind, the calculation of the series capacitor (C_S) and the parallel capacitor (C_d) can be made. First, calculate C_S by using the measurement of L_S' and the following formula:

$$C_S = \frac{1}{4\pi^2 L_{S'} f_S^2} \qquad \text{Equation 2}$$

where, $L_{S'}$ = nominal mutual inductance of Rx coil with Tx coil within 4mm of Rx coil

f_S = 100kHz ±x/y %

x = y = 5 for power levels under 3W and x =5, y = 10 for all other power levels.

Now plugging C_S and utilizing L_S, calculate C_d using the following equation:

$$C_d = \frac{C_S}{4\pi^2 C_S L_S f_d^2 - 1}$$ Equation 3

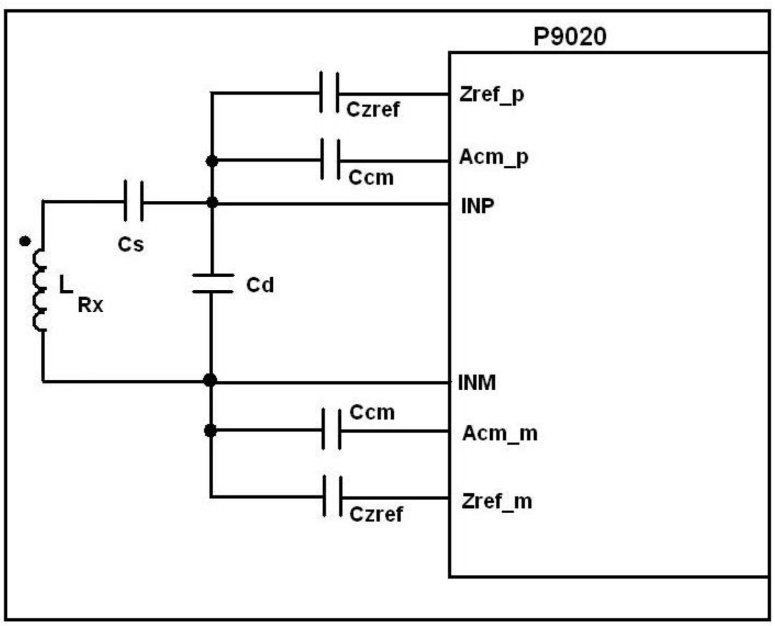
where, L_S = nominal inductance of coil in free space

f_d = 1MHz ±10%

If desired it is mathematically possible to calculate the mutual inductance value Ls'; however, the calculation will depend on many factors that make the calculation extremely complex, such as the coupling factor (a variable of proximity and physical construction geometries) and the inductance of each coil along with the composition of the ferrite shielding material behind the coils. Additional variables will be temperature and humidity along with the Vtest voltage and orientation of the coils relative to each other referenced to the physical construction of each coil. As a result, the measurement is a much simpler and faster way to determine the Ls' value and is the recommended way to find Ls'.

Finally, the Wireless Power Consortium (WPC) specifies the C_{CM} values for the communications modulator to be set to 22nF ±5% for A1 coils. IDT complies with these values and uses these for controlling power transfer using all IDT transmitter and receiver combinations in order to assure compliance is kept interchangeable. We have also developed an advanced zero reference detection circuit (Z_{ref}) which is used to for tracking the zero cross-over time and phase of the circuit as an added level of safety and control. This capacitor should be set to 330nF ±10%.

Figure 9. P9020 Typical Application Component Connection and Designations



If you have additional questions about Qi compliance and physical constructions, please see the *WPC Qi System Description Wireless Power Transfer Volume 1*. Furthermore, additional questions and application-specific questions are always welcomed by the knowledgeable IDT Applications department.

Revision History

Revision Date	Description of Change
June 12, 2018	▪ Updated the document to the latest IDT template ▪ Completed several minor technical changes
January 17, 2014	Initial release.

IDT

Corporate Headquarters
6024 Silver Creek Valley Road
San Jose, CA 95138
www.IDT.com

Sales
1-800-345-7015 or 408-284-8200
Fax: 408-284-2775
www.IDT.com/go/sales

Tech Support
www.IDT.com/go/support