Thin and efficient power transmission

Smartphones and other mobile devices feature an increasing range of functions that support people in nearly every aspect of their lives. TDK offers a broad portfolio of Tx and Rx coil units that are designed to satisfy growing user demand for easy and frequent charging.

In recent years, much research has been conducted for many different systems of wireless power charging. In the meantime, the Qi low-power standard (≤ 5 W), which was developed by the Wireless Power Consortium (WPC) with the support of the IEEE Industry Standards and Technology Organization (IEEE-ISTO), has emerged as the leading wireless power transmission standard for mobile devices. The Qi standard, which has already been put to practical use in mobile devices, is based on electromagnetic induction. The high-frequency magnetic flux generated in the Tx coil in the charging pad (primary side) is received by the Rx coil of the mobile device (secondary side), where the magnetic flux is then converted to power to charge the device’s battery. While wireless power transmission using electromagnetic induction is characterized by relatively low costs, it can only function effectively over short transmission distances of approximately 10 mm, making accurate alignment of the Tx and Rx coils essential. The WPC has established specifications for the following three positioning types:

- Guided positioning with magnetic alignment
- Free positioning with a movable coil
- Free positioning with a coil array.

Of the three Qi power transmitter designs, the first using magnetic alignment is the simplest. Nevertheless, its magnetic circuit design poses significant challenges because the alignment of the two coils requires the magnetic force of the magnet to be placed on the center of the Tx coil in order to attract the magnetic material at the center of the Rx coil (Figure 1).

Qi guided positioning with magnetic alignment

Figure 1: The force of the magnet at the center of the Tx coil attracts the magnetic material at the center of the Rx coil and aligns the two coils.

Figure 2: The structure is simple, but the magnetic circuit design is challenging. High-performance magnetic materials for the magnetic sheet are crucial to protect the battery from overheating and to ensure the overall performance of the system.

In addition, Rx coils cannot obtain Qi standard certification unless they can operate normally in all of these three power transmitter types. For this reason, TDK has designed Tx and Rx coil units that conform to the most demanding magnetic alignment design. Based on this design, TDK has also developed a variety of Tx and Rx coil products that support the movable coil and coil array power transmitter designs as well.
Advanced ferrite technology for high-frequency applications

Designing a coil for the magnetic alignment design requires outstanding magnetic materials technology. For this purpose, the ferrite material of the core is the same as that used for transformers or choke coils. Such a magnetic material is able to sufficiently absorb the magnetic flux generated by the coil and provide high inductance values. Qi-compliant wireless charging systems operate at a frequency of about 100 kHz to 200 kHz. Because the coil used for wireless charging also transmits high-frequency magnetic flux efficiently, it is used in combination with a magnetic material sheet. TDK employs advanced ferrite materials for both the transmitter coil and the magnetic sheet.

Figure 3 compares the characteristics of magnetic metal and ferrite materials. The magnetic metal materials are characterized by a high-saturation magnetic flux density, but due to their low electrical resistivity, they experience increased heat generation losses caused by an eddy current in the high-frequency range. Ferrite material, however, which is a magnetic ceramic, combines high electrical resistivity with low eddy current losses, and is thus an indispensable magnetic material for the high-frequency range. TDK Rx coils also employ magnetic sheets made of ferrite materials.

The magnetic sheets mounted in smartphones and other mobile devices must be as thin as possible, but if they are too thin, magnetic saturation problems are likely to occur. When this happens, the coil inductance abruptly decreases and results in the failure of normal wireless charging operations. To prevent the charging system from reaching the magnetic saturation point, it is thus necessary to select high-performance magnetic materials, particularly for the magnetic sheet of the receiver coil.

Figure 3: Comparison of magnetic metal and ferrite materials:
Ferrite materials (blue) are characterized by their high electrical resistivity range. This contributes to a low level of eddy current loss even in a high-frequency range. By contrast, magnetic metal materials (red) offer high-saturation magnetic flux density. Thus, magnetic saturation is hardly ever reached, even with a large current.
Magnetic shield boosts inductance and reduces losses

In the magnetic alignment design, the magnetic sheet on the Rx side shields against both the high-frequency magnetic flux generated by the Tx coil and magnetic flux from the magnet. The Rx coil in smartphones is typically located between the battery and the back cover of the device. If the magnetic shielding is insufficient, high-frequency magnetic flux will reach the battery case, which is often made of aluminum. The magnetic flux can create an eddy current on the aluminum surface, which, in turn, can result in abnormal heat generation in the battery case.

In transmitter designs without a magnet, even a very thin magnetic sheet is able to provide sufficient shielding of the high-frequency magnetic flux. In magnetic alignment designs, however, the thickness of the sheet must be dimensioned in order to absorb both the magnetic flux from the magnet and the high-frequency magnetic flux. In such cases, the magnetic sheet needs to be thicker than in transmitter designs without a magnet.

The material and thickness of an Rx-side magnetic sheet, therefore, must be designed so that it does not reach the magnetization saturation point. In this case, magnetic flux from the magnet will pass through the Rx-side magnetic sheet. Tests using an aluminum sheet to simulate a real-life environment show that the inductance of the Rx coil decreases significantly if the magnetic sheet is too thin.

Comprehensive portfolio of Tx and Rx coils

In order to meet the wireless charging demands of manufacturers and users alike, TDK has developed a broad lineup of primary and secondary coil solutions for the key WPC Qi specifications.

Primary coils

TDK Tx coils have been developed for a range of WPC low-power (<= 5 W) specifications (Table 1). These include single primary coils with magnetic alignment (specifications A1 and A9) and without magnets (specifications A10 and A11). A linear array with three coils is also available for chargers that allow free positioning with an array. All Tx coils use WPC-approved ferrite sheets. Extremely thin flexible sheets are available. The performance of the coils has been confirmed based on WTC equipment.

Table 1: Portfolio of TDK Tx coil units

<table>
<thead>
<tr>
<th>A10 – single primary coil without magnet</th>
<th>A11 – single primary coil without magnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 and A9 – single primary coil with magnetic alignment</td>
<td>A6 – linear array of primary coils</td>
</tr>
</tbody>
</table>
**Secondary coils**

The spectrum of TDK Rx coils covers a wide range of thicknesses from 0.50 mm to 1.25 mm to meet the requirements of many wireless charging applications (Table 2). All Rx coils are designed with magnetic attractor materials in order to support magnetic alignment. The lineup also includes Rx coils with a combined antenna for near field communications (NFC). Pre-cracked ferrite sheets are available to ensure a durable construction under real-life conditions. In 2012, TDK introduced the world’s thinnest Rx coil with a thickness of 0.57 mm. In the meantime, an even thinner coil with a typical thickness of just 0.48 mm has been launched.

Rx modules represent a turnkey wireless charging solution that consists of an Rx coil with attractor and control unit. The modules feature a very thin maximum thickness of just 1.0 mm. Custom designs are available on request.
Table 2: Portfolio of TDK Rx coil units

Rx coil units

Rx coil units with combined NFC antenna
Rx coil modules
<table>
<thead>
<tr>
<th>Type</th>
<th>Rx coil units</th>
<th>Rx coil units with combined NFC antenna</th>
<th>Rx coil modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions [mm]</td>
<td>30 × 30</td>
<td>52 × 48</td>
<td>48 × 32</td>
</tr>
<tr>
<td></td>
<td>40 × 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>48 × 32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness [mm]</td>
<td>0.52 to 1.25</td>
<td>0.52 to 0.62</td>
<td>1.0</td>
</tr>
<tr>
<td>Efficiency [%]</td>
<td>66 to 73</td>
<td>69</td>
<td>72</td>
</tr>
<tr>
<td>Inductance [µH]*</td>
<td>12.3 to 19</td>
<td>16.5 to 19.5 (Rx coil)</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.75 to 1.95 (NFC antenna)</td>
<td></td>
</tr>
<tr>
<td>Max. DC resistance [Ω]**</td>
<td>0.20 to 0.70</td>
<td>0.75 to 0.80 (Rx coil)</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.46 to 0.52 (NFC antenna)</td>
<td></td>
</tr>
<tr>
<td>Output voltage [V]</td>
<td>-</td>
<td></td>
<td>4.95 to 5.05</td>
</tr>
<tr>
<td>Output current [A]</td>
<td>-</td>
<td></td>
<td>0.5 to 0.7</td>
</tr>
</tbody>
</table>

* at 100 kHz, 1 V\text{RMS}  
** at 25 °C

**Growing field of applications for wireless charging**

The benefits of wireless power transmission technology are not limited to low-power mobile devices. In the future, market researchers expect more and more wireless charging applications to emerge, freeing all kinds of electrical devices and equipment from the power cable, such as home appliances and PCs, vehicles, and robots.

In particular, the automotive industry is seeking viable wireless charging solutions for the electric vehicle (EV) market. TDK is currently working on wireless power transmission solutions for EVs based on the magnetic field between a primary Tx coil located on the pavement and a secondary Rx coil in the vehicle (Figure 4). The major aim is to develop suitable components for this new high-power application.

TDK's high-performance ferrite materials exhibit low core losses over a wide temperature range, making them suitable for EV wireless power transmission systems. Thanks to cutting-edge materials and advanced simulation tools, a prototype Rx module features a footprint about the size of a sheet of copying paper.
In addition to the WPC, TDK is a member of both the Power Matters Alliance (PMA) and the Alliance for Wireless Power (A4WP), and has committed itself to offering advanced wireless power transmission solutions based on both electromagnetic induction and magnetic fields.

Figure 4:
Wireless power transmission solutions for EVs are based on the magnetic field between a primary Tx coil located on the pavement and a secondary Rx coil in the vehicle.