Trilogy of Wireless Power Transfer

Basic Principles

BASIC PRINCIPLES, WPT SYSTEMS AND APPLICATION

1 Basic Principles

Part 1: Basic Principles

Introduction of Wireless Power Transfer

Wireless power transfer (WPT) is an emerging technology that can transform the consumers experience with small electronic devices. Take for example the way consumers use their smart phones, how this has changed in recent years, and how this is constantly evolving. This applies not only to all mobile devices but also to all electric appliances in industrial, medical, automotive and consumer areas with and without batteries. The user now expects devices that have high power demands with longer usage times. This means devices need either higher-capacity batteries that require to be charged less frequently or lower-capacity batteries that require more frequent charging. In either case, integrating wireless power transfer has a multitude of advantages that can revolutionize the way consumers use devices.

To be successful, wireless power transfer must be simple, convenient and intuitive to the user requiring the best possible performance (e.g. charge time, efficiency) compared to conventional connector technology. Achieving the best performance is reliant upon choosing the correct component for the application.

The basic principles of wireless power transfer are discussed in Part 1, which will lay the foundation for the remainder of the book. In this part, the various ways of wireless power transfer are described, with their advantages and disadvantages discussed. The different standards that define and regulate the use of these technologies are summarized. This includes the leading standards in addition to power classes which are currently not covered by the Wireless Power Consortium [1] and the Airfuel Alliance™ [2]. These power classes can use different proprietary solutions, some of which are described. In the final section, the functionality of a wireless power transfer system is characterized with an equivalent circuit, definition of the resonance tank, coupling, efficiency, shielding and Spice simulations.

1 Basic Principles

Wireless Power Transfer Methods

1.1 Wireless Power Transfer Methods

There are a variety of methods to transfer energy without direct physical contact. The field of wireless power transfer can be divided into several categories, dependent on the electromagnetic principle that is predominantly used (Figure 1.1). These technologies are discussed in the following sections.

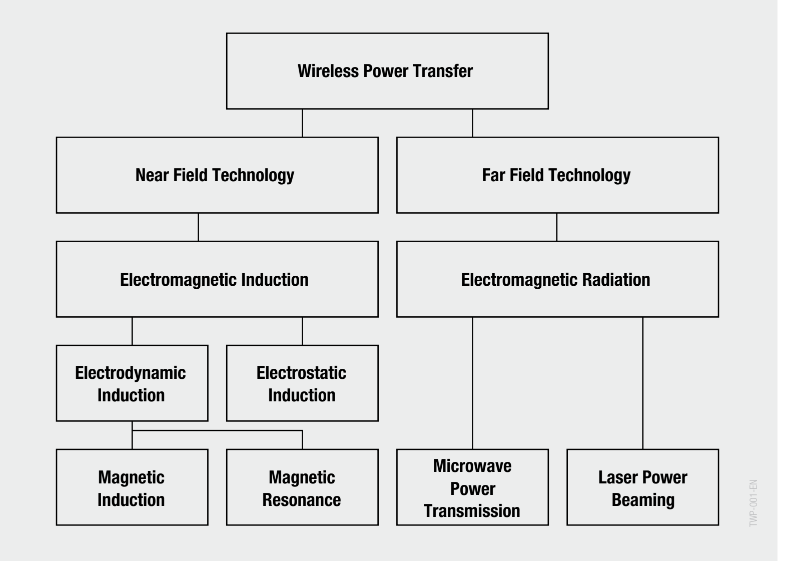

Fig. 1.1: Methods of wireless power transfer

Near-field Technology

1.1.1 Near-field Technology

Near-field wireless energy transfer can transmit energy using wire coils over a short distance. Near-field power transfer is a non-radiative power-transmission technique, but radiation losses may still occur due to lower efficiency. In the normal case, only ohmic losses occur.

Near-field technology is subdivided into the following categories:

- Electromagnetic resonance
- Electromagnetic induction
- Electrostatic induction

Electromagnetic Resonance

Electromagnetic Resonance

Electromagnetic resonance or resonant inductive coupled power transfer have low coupling between the coil pairs. The galvanically insulated coils have huge stray inductances. One of the reasons for poor efficiency between two coils with low coupling is primary leakage inductance. This stray inductance requires a large induced voltage on the primary circuit. A higher current on the primary coil results in a higher induced voltage on the secondary side and greater losses are generated in both coils driven by Q factor. Therefore, it is common practice to compensate the secondary leakage inductance with a capacitance for inductive connections.

In order to compensate this leakage inductance, a capacitance is added in series or in parallel to the coil depending on the type of resonant topology of interest. Magnetic resonance or resonant inductive coupling is one of the most popular and efficient techniques for wireless power transfer and is used in a vast number of consumer devices, biomedical implants, electric mobility, material handling systems, lighting applications and contactless underwater power delivery. In figure 1.2 the functional block diagram is shown for electromagnetic resonance.

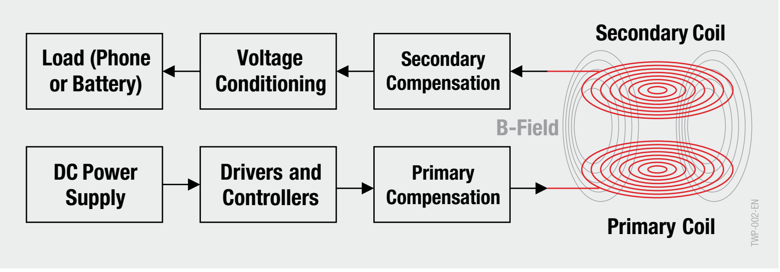

Fig. 1.2: Block diagram of a wireless power transfer sytem using electromagnetic resonance

Electromagnetic Induction

Electromagnetic Induction

Wireless power transfer with electromagnetic induction in the near field works up to a distance of 1/6 of the wavelength of the transmission frequency, e.g typically up to 10 mm for smartphone charging and up to 25 cm for electric vehicles. A straight conductor with a current flowing through it generates a magnetic field with a magnetic field strength H. When the wire is wound into a coil, the magnetic field is concentrated.

According to Ampere's law, the magnetic flux around a coil is directly proportional to the current flowing through the coil. The magnetic field strength of a coil is defined by the flux density. The more windings the coil has, the greater the magnetic field strength.

It is also possible to place a permanent magnet inside the coil instead. A voltage is induced in the coil by movement of the permanent magnet's magnetic field (figure 1.3). A voltage is also induced when the coil is moved over the permanent magnet. Thus, voltage can be induced by moving the coil or changing the magnetic field. This process is called electromagnetic induction, which is the basic principle of a transformer.