# Wireless Charging

## Introduction

Yesterday's dream of distributing power wirelessly is becoming a reality based upon exceptional efforts of industry regulatory agencies, component manufacturers, and design engineers with long-term vision. The use of wireless charging is expected to increase dramatically as consumers are freed from carrying bulky cables that have extra weight and the potential to wear out the mechanisms associated with them. Implementation of wireless charging schemes are easier than ever thanks to a wide availability of dedicated chip sets.

Within the topic of wireless charging - there are several different power levels, architectures, and design approaches associated with wireless power transfer.

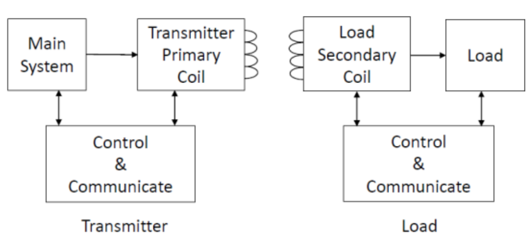
This paper will serve as a starting point and describe the families of capacitors most commonly selected for use in electromagnetic wireless chargers.

## Background

Wireless charge systems consist of two basic sub-systems: the source of power (transmitter) and the device that will be charged (load). In this scenario power is transferred from the transmitter to the load through coupling of the transmitters coil to the loads coil.

A control & communicate board is used on both transmitter and load block to determine if there is a coupling between an identifiable load and the transmitter. Additional functions of the control & communicate board are to accomplish regulation of the transmitter power, control the charge rate and charge duration on the load battery, detect foreign objects within the coupled field and systems, and to identify end load users for billing at a later time.

Roughly speaking we can consider the transmitter's coil to be the primary winding, and the load's coil to be the secondary winding of a transformer. When coupled they create the two halves of a coreless resonant transformer.



From this point onward, in a very abbreviated sense – work is mostly dedicated to increasing the efficiency of energy transfer in order to maximize the energy transfer, overall.

Physical efforts to maximize efficiency range from minimizing the spacing between the primary and secondary coils, forming the shape of the magnetic field to conform to the optimized size of the end products charger, and possibly aligning the primary and secondary coils for maximum coupling.

Electrical efforts to maximize efficiency range from selection of specific frequencies to reducing the resonant primary and secondary coils loss characteristics. Within that goal, two separate efforts are applied; the first is achieved by careful material selection and dimensional design of the coil. The second is the selection of high Q capacitors that exhibit low loss and stability at frequency. Further, these capacitors must be stable over time, temperature and load, plus exhibit the ability to withstand potentially high voltages when in near ideal resonance conditions.

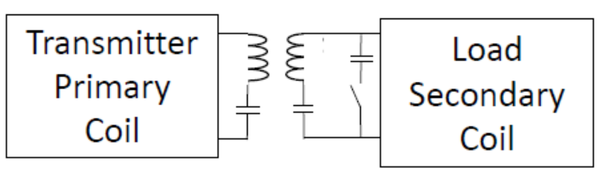
**Capacitor Options**

A very generic example of the series inductor-capacitor (LC) circuit for the transmitter and dual resonant power receiver/secondary is shown below. In this particular example, the load circuit consists of a series resonant capacitor to match the primary LC circuit's resonant frequency. The switched capacitor is used enable a resonant detection method.

The goal of wireless charging is to transfer the maximum power from primary to secondary without loss. In order to do that both the transmitter and load circuits should be highly coupled. The Q of the LC is maximized when the loss elements within the inductor and capacitor are minimized. Maximum power transfer occurs when both primary and secondary Qs' are maximized and their resonant frequencies are matched.

Capacitor selection is limited to high Q NPO dielectrics or better because of the need to minimize loss and maintain stable capacitance over time, temperature, and voltage bias.

Several different series of C0G (NPO) capacitors are available depending upon the exact values/voltage and configuration.




**Capacitor Selection**

SMT C0G (NPO) capacitor options

It is common for multiple capacitors to be placed in parallel to attain capacitance and current goals in the design.

In many lower power designs, relatively small case size C0G (NPO) grade capacitors are able to be considered. Common values for SMT C0G dielectrics range from sub pF to 100nF. The most common voltage ratings for C0G dielectrics range from 6.3V (not acceptable for wireless charging) to 500V. Additional high voltage C0G capacitors available in voltages up to 5kV. Simulation software for high voltage C0G (NPO) capacitors is available which allows the designer to enter a case size, voltage & value rating of the desired capacitor, select an operating frequency, ambient temperature and maximum limit for temperature rise, and then graph the allowed RMS voltages and currents of the capacitor. A free copy of SPICALCI 10.0 is available for download at:

http://www.avx.com/resources/design-tools/

Regardless of the operating voltage, the C0G (NP0) class is the most popular formulation of the "temperature-compensating," EIA Class I ceramic materials in wireless charging. These capacitors have wide availability and exhibit a capacitance change with temperature of 0 ±30ppm/°C from -55°C to +125°C.

Capacitance drift / hysteresis for C0G (NP0) class ceramics is negligible at less than ±0.05%.

C0G (NP0) formulations show no aging characteristics. Typical capacitance change with life is less than ±0.1% for C0G (NP0).

For additional information regarding AVX U Dielectric Series Capacitors:
http://www.mouser.com/new/AVX/avx-rf-products/

Leaded C0G (NPO) capacitor options

AVX manufactures both high capacitance value and high voltage multi-layer radial leaded capacitors with special internal designs minimizing the electric field stresses within the capacitor. These special design criteria result in significant reduction of partial discharge activity within the dielectric and therefore has a major positive impact on long-term reliability of the product. These radial capacitors are conformally coated with high insulation resistance, high dielectric strength epoxy eliminating the possibility of arc flashover. Both series have extremely low ESR in small packages.

AVX SK radial leaded COG capacitors are available in voltage ratings from 25V to 500V and values from 1nF to 680nF.

AVX SV high voltage radial leaded C0G capacitors are available in voltages ratings from 630V to 5kV and values from 10pF to 150nF.

Simulation software for SV and SK series leaded C0G capacitor series is available and contained within the SPICALCI 10.0 download found at:

http://www.avx.com/resources/design-tools/

Axial Ribbon Leaded & SMT High Power C0G (NPO) capacitor options

AVX HQ Series (Hi-Q®), is available from 1pf to 51nf at voltages up to 7.2Kv. This SMT/Ribbon leaded MLCC is designed for ultra-low ESR and to be used in high power applications. Added information is available at:

http://www.mouser.com/new/AVX/avxHQCCcaps/

**Summary**

NPO MLCC options exist to solve the wide array of capacitors needed in wireless power transfer applications. Packaged modules also exist that are matched to specific coil configurations. As charge circuits evolve, so will NPO capacitors – from the possibility to being embedded within laminate coils to being placed in high power modules.