E-Space

Magnetic Resonance Power Transfer

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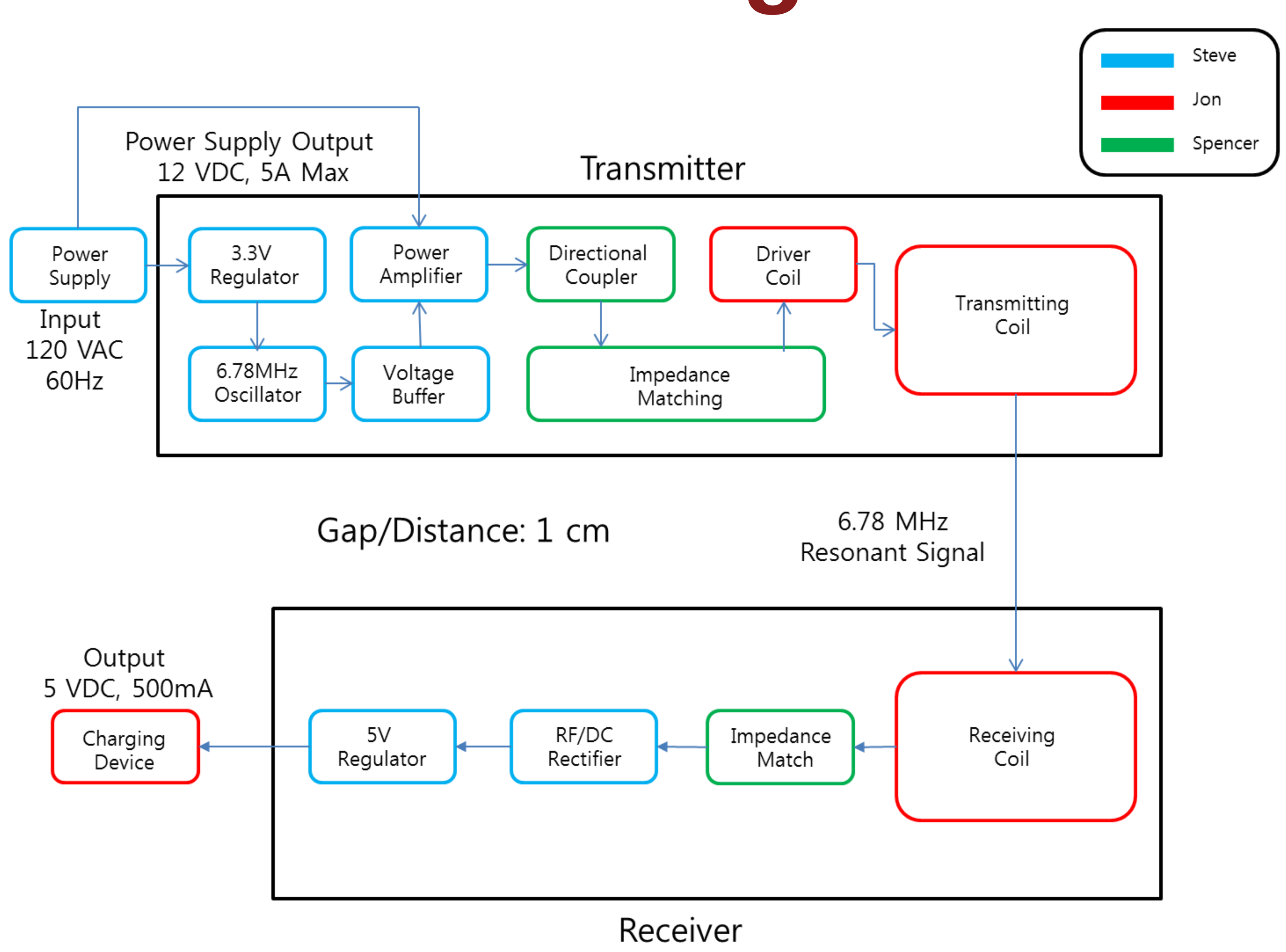
Abstract

The current implementation of wireless power transfer uses inductive power transfer, involving strongly coupled coils and high efficiency, close range transfer. This technology only works with ranges less than a few centimeters, and the coils must be orientated correctly to affect efficient power transfer. A different technology known as Magnetic Resonant Power Transfer has emerged that promises mid range, yet still high efficiency power transfer. The transmitting and receiving coils are loosely coupled, meaning the distance between them and their relative orientation is much more flexible, but resonate at a fixed frequency that still facilitates efficient transfer between them. Using this technology we are implementing a wireless power transfer system to charge a wireless phone at farther ranges than is possible with inductive technology.

System Overview

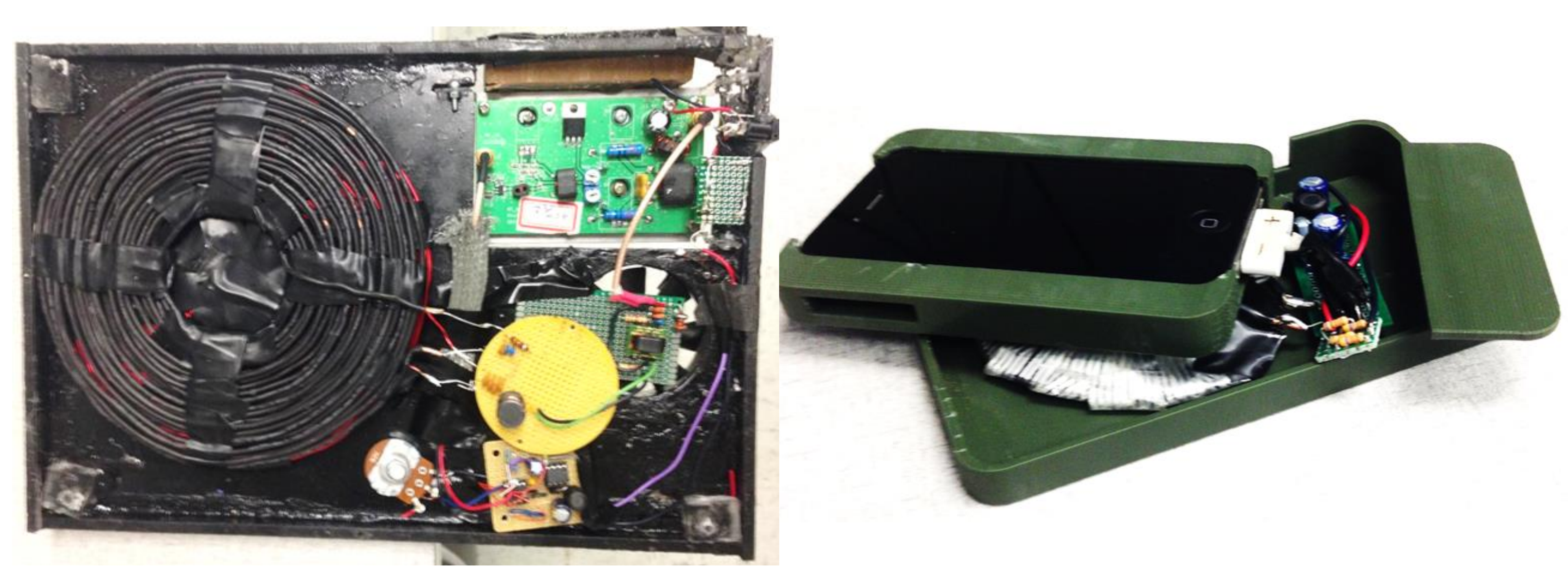
The design for the magnetic resonant wireless phone charger can be broken into two main blocks with several subsystems each. The first major subsystem is the transmitter that consists of a power supply, an oscillator, a voltage buffer, a power amplifier, an impedance matching network, a driver coil, and a resonant transmitter coil. The transmitter coil and circuitry is enclosed within a plastic case that can be attached underneath a desk or any other location desired by the user. The receiver consists of a resonant coil, an impedance matching network, a rectifier, and a DC/DC converter. A 3D printed phone case houses the receiver coil and circuitry. A small USB cable then connects the phone to the output of the DC/DC converter to charge the phone.

Block Diagram



Results

We were able to achieve our goal of wirelessly charging a phone, successfully delivering at least 2.5 W of DC power. However, we are only able to do this over a range of 1 cm, significantly less than what we aimed to achieve. While delivering this power our system is roughly 10% efficient end-to-end.



Specifications

Input Specifications	120 VAC at 60Hz
Frequency	6.78 MHz
Distance/Range	1 cm
Minimum Output Power	2.5W
Minimum Total System Efficiency	~10%
Maximum Receiver Size	115.316 mm X 58.674 mm

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Team Members

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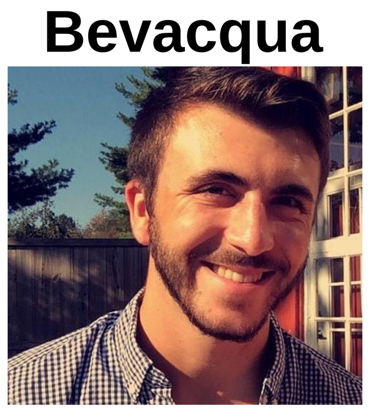

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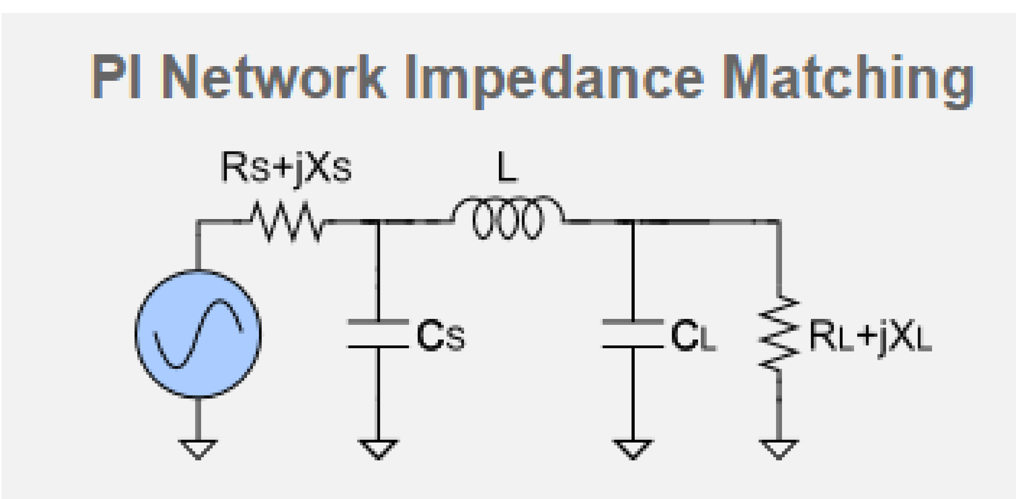
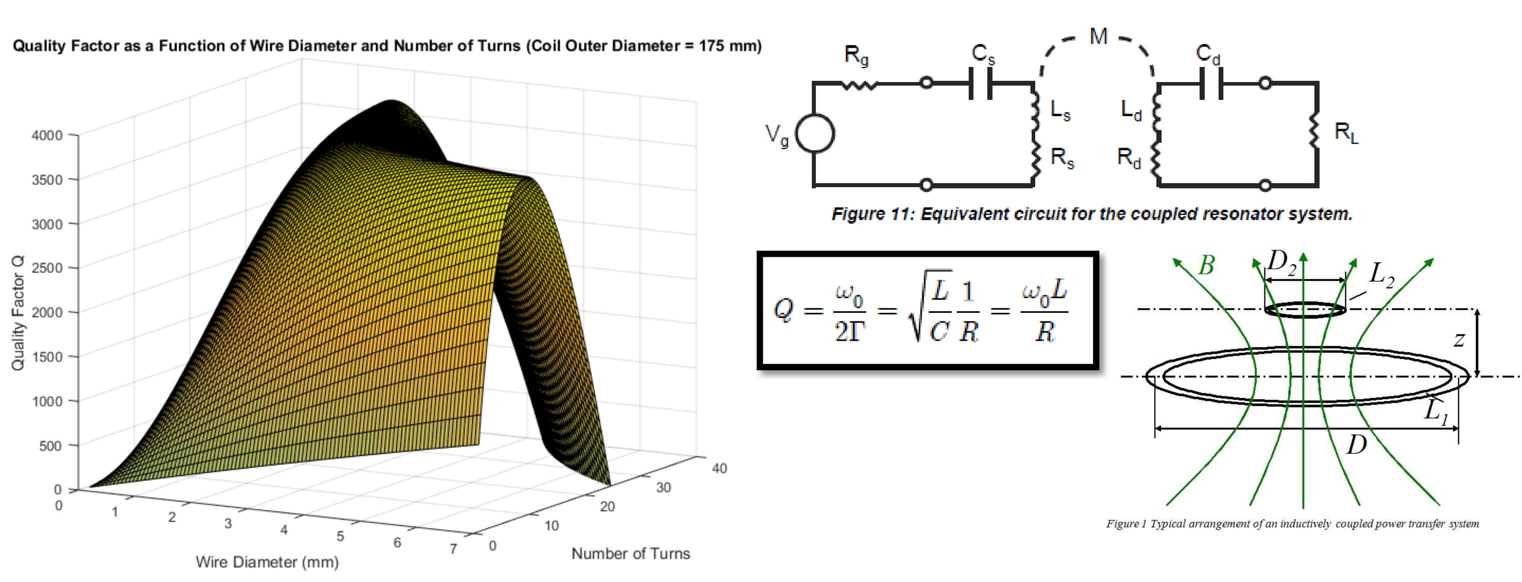
Transmitter Circuitry

- Quartz crystal oscillator sets the 6.78MHz resonant frequency and is the input to the voltage buffer
- High frequency voltage buffer prevents the power amplifier input impedance from loading the oscillator output
- Power amplifier takes 1-5mW signal from the voltage buffer and outputs a 6.78MHz signal up to 45W to the coupler
- Bi-directional coupler repurposed as a circulator with coupled ports terminated in matched loads (51 ohm resistors) to sink reflections and protect amplifier



Cs = 1.11 nF
L = 6.7 uH
Cl = 60 pF

- Thru port of the coupler connected to an impedance matching network that powers the driver coil
- Driver coil and resonant transmitter coil operate as step down transformer
- Transmitter was designed and optimized for high quality factor Q to ensure efficient power transfer
- Transmitter coil diameter restricted to ratio of receiver coil diameter



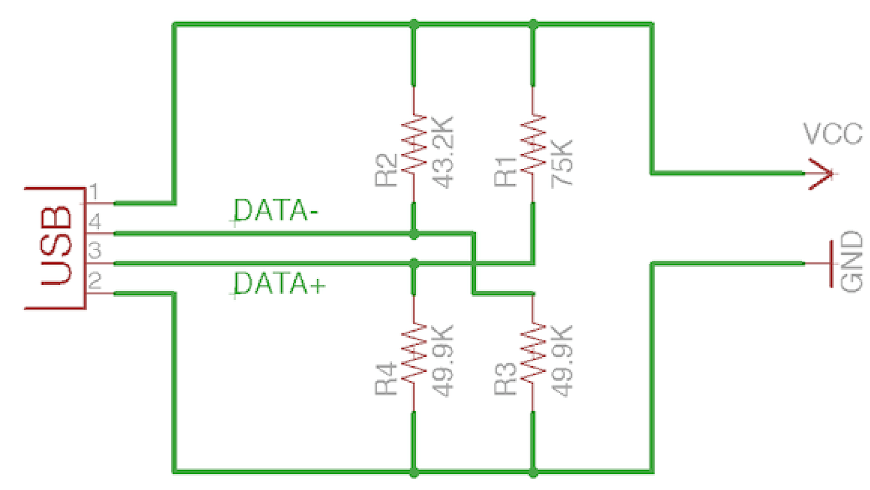
Cost

Item	Quantity	Prototype Price	1000 Unit Price
Coupler	1	$ 39.95	$ 32.95
6.8 uH Inductor	1	$ 0.59	$ 0.47
2.2 pF Capacitor	3	$ 0.29	$ 0.07
10 pF Capacitor	5	$ 0.20	$ 0.04
68 pF Capacitor	1	$ 0.25	$ 0.05
5 pF Capacitor	1	$ 0.49	$ 0.14
330 nH Inductor	1	$ 0.49	$ 0.22
1 uF Capacitor	1	$ 0.40	$ 0.11
51 ohm Resistors	2	$ 0.10	$ 0.01
75 kohm Resistor	1	$ 0.10	$ 0.01
43.2 kohm Resistor	1	$ 0.10	$ 0.01
49 kohm Resistor	2	$ 0.10	$ 0.01
Power Supply	1	$ 23.94	$ 19.59
3.3 Reg	1	$ 2.86	$ 1.42
Buffer	1	$ 8.63	$ 4.53
Oscillator	1	$ 1.79	$ 1.44
Amplifier	1	$ 45.92	$ 45.92
5V reg	1	$ 2.89	$ 1.42
Power Conn	1	$ 1.12	$ 0.47
Fan	1	$ 5.07	$ 2.90
Coil Wire	1	$ 36.00	$ 8.40
Case Materials	1	$ 5.00	$ 1.00
TOTAL		$ 176.28	$ 121.19

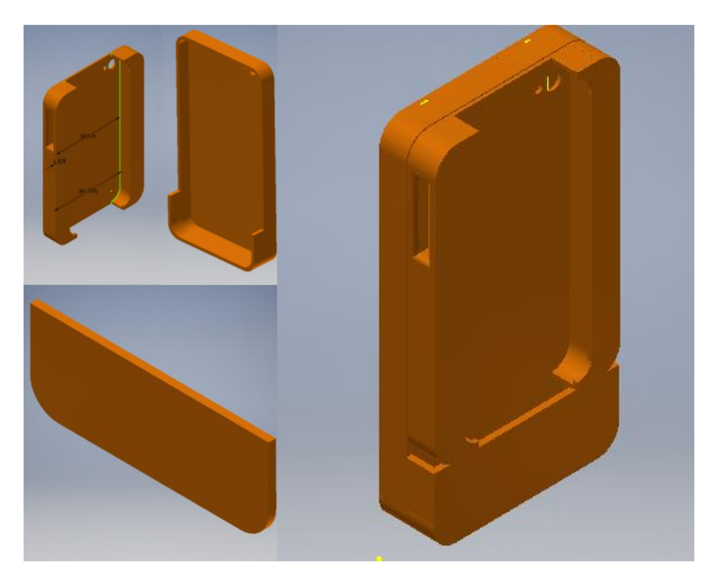
Receiver Circuitry

- Receiver coil designed to optimize quality factor with a diameter size restricted to dimensions of phone case

- Received signal is converted from RF to DC using a bridge rectifier
- Rectified signal is fed to a 5V switching voltage regulator
- The regulated 5V signal is fed to the USB cable to charge the phone
- Voltage divider resistor network implemented to bias data pins for USB connection to phone



- Phone case, receiver coil holder, and lid designed in Inventor and 3D printed according to phone, coil, and circuitry dimensions



Experiment

Prior to testing with the phone, a bank of LED's was used in the receiver to give quantitative results of available power and tuning effectiveness. We also used vector network analyzers to view complex input impedance and better inform our matching networks. The resonant frequency was confirmed by checking the output of the oscillator and the amplifier with an oscilloscope. Our final experiment involved placing the receiver centered over the transmitter circuitry and lifting it until the phone stopped charging due to lack of available power.