Non-contact Human Machine Interaction Using Wireless Power Transfer Features: Model Analysis and Circuit Design

Chenhui Liu, Changzhi Li

***Abstract*—The interaction between human and smart phones is mainly based on button pressing and screen touching. As wireless charging which is based on wireless power transfer (WPT) is standardized and becoming a very competitive feature for smart phones in recent years, it is also possible to interact with smart phones without contact by interacting with their wireless charging coils. In this paper, a non-contact method to interact with smart phones based on their wireless charging coils is proposed and investigated. A Colpitts oscillator is built and tested using a standard WPT coil as part of the resonant tank elements to demonstrate the feasibility of the concept. Furthermore, a differential structure is designed to improve the sensitivity of the system based on preliminary experiment result. Finally, the whole system is designed into and integrated chip to demonstrate the feasibility to embed the system into smart phones.**

***Index Terms*—Colpitts oscillator, non-contact interaction, wireless power transfer.**

I. Introduction

SMART phones have been enjoying a boom in the 21st century. The interaction between human and smart phones gradually changed from button pressing to screen touching in the past decade. Since the applications of smart phones have largely extended from traditional communication purpose to various areas such healthcare, gaming and utility control, it will be very beneficial if smart phone users can interact with their devices without physically touching the phone.

Lately, as a trend if wireless applications, wireless charging is growing up as a competitive feature for smart phones. The basic idea of wireless charging is that power is wirelessly transferred based on the electromagnetic coupling between two planar coils. Two devices are used – the base station and mobile device which provides and consumes inductive power with the planar coil, respectively.

In terms of the non-contact interaction between human body

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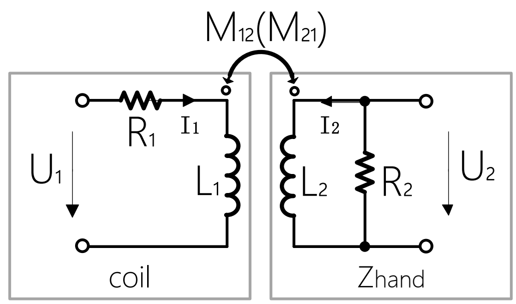

Fig. 1. Circuit model of inductive non-contact interaction.

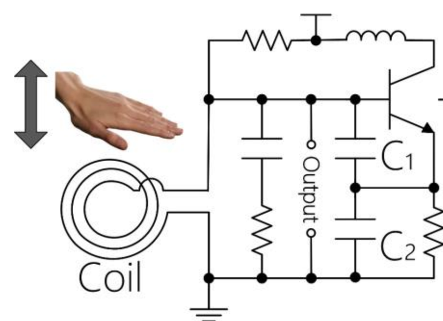

Fig. 2. Oscillator circuit with inductive coil

and the planar coil, instead of using the coil in the smart phone as a power receiver, the coil is designed as part of an oscillator to send out alternating electromagnetic field to interact with human body The hand movement in front of the coil changes its conductivity distribution, which in return creates an effective coil impedance that is also called reflected impedance. Furthermore, the impedance change will show up in the resonant frequency of the oscillator, which can be easily observed using frequency measurement instruments.

After proof of concept, a differential structure based on two adjacent oscillators and a mixer was designed to improve the sensitivity of the system. Finally, a mixed-signal integrated chip was designed using Cadence.

II. Physical Model and System Description

The interaction between coil and human hand can be modeled as shown in Fig. 1.Instead of using the coil in the smart phone as a power receiver, the coil is designed as part of an oscillator to send out alternating electromagnetic field into

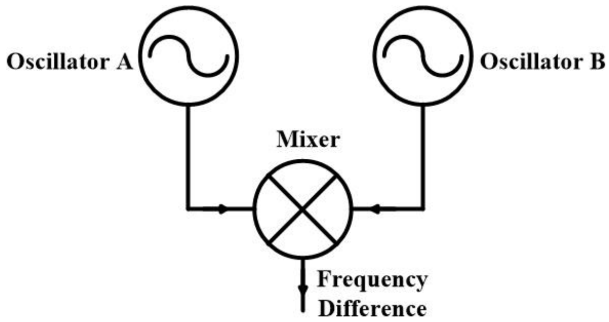

Fig. 3. Differential structure based on two adjacent oscillator and a mixer to improve sensitivity

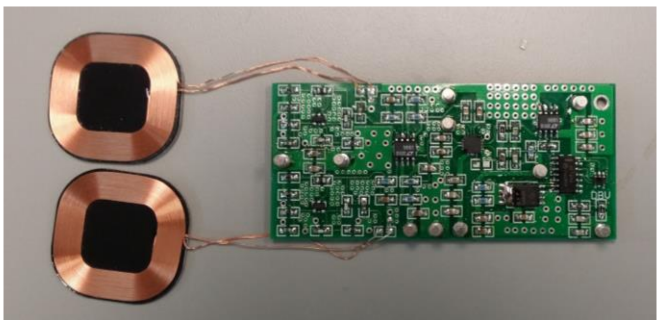

Fig. 4. Differential structure on PCB

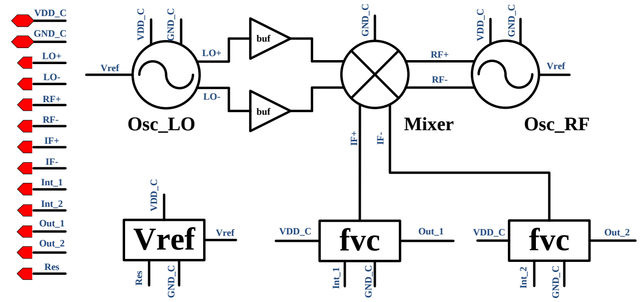

Fig. 5. System diagram of differential structure

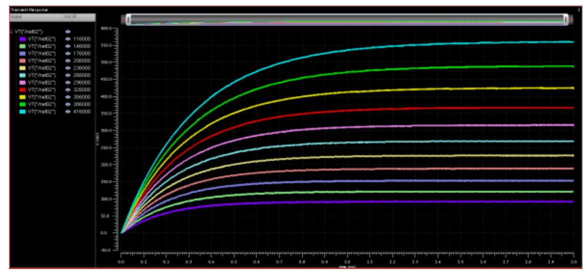

Fig. 6. Simulation results of frequency to voltage converter

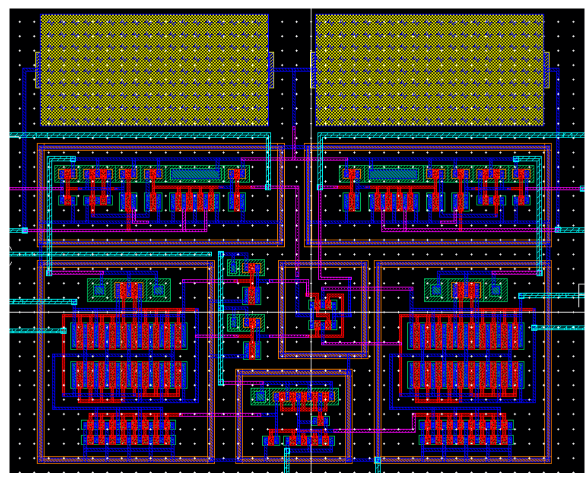

Fig. 7. System layout

the air to interact with human body.

A prototype oscillator shown in Fig. 2 was built to demonstrate the feasibility of non-contact interaction. The output node was connected directly to an oscilloscope to measure the waveform. As has been discussed in the previous proposal, the frequency change due to hand movement is very small comparing to the free running frequency of the oscillator. In order to improve the sensitivity of the system, a differential structure based on two adjacent oscillators and a mixer was designed and tested. The diagram is shown in Fig. 3.

Two oscillators are running at a small frequency offset and the mixer is used to down-convert the frequency difference between two oscillators to much lower frequency. After filtering, the signal is injected into a frequency to voltage converter to change the low frequency signal to a DC voltage that is proportional to the frequency difference of two oscillators. The DC level can be easily interpreted by a processor to recover the original information of human hand activity in front of the coils. The PCB is shown in Fig. 4.

In order to make it possible to embed the non-contact system into smart phone or any other machines, the system is designed into an integrated chip using Cadence. The system diagram is shown in Fig. 5.

An on-chip voltage reference was designed to bias the oscillators. Cross coupling oscillators are designed with different capacitor value to make oscillators running with a frequency offset. A double-balanced passive mixer was designed to down-convert the frequency difference between two oscillators to a much lower frequency for processing. After off-chip filtering (capacitors are too big to be designed on-chip), the signal was injected into frequency to voltage converter to change the low frequency to a DC voltage. Fig. 6 is the simulation results of the frequency to voltage converter. X axis is time and Y axis is voltage. Different color represents frequency. It's obvious that the DC voltage is proportional to frequency once it's stable. Fig. 7 shows the layout of the whole system. The layout measures 175um × 120um in total.

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