

Sudan University of Science and Technology

Collage of Engineering

School of Electrical Engineering

Wireless Charging

الشحن اللاسلكي

**A project Submitted in partial Fulfillment for the Degree of B.Sc.
In Electrical Engineering**

Prepared By :

- 1. Amro Abd-Elhafeez Ahmed Abdullah**
- 2. Shihab eldin Ezz eldin Abdulrahman Ahmed**
- 3. Tasneem Alfatih Ahmed Albadawi**

Supervised By :

Ust. Jalal Abdalrahman Mohammed

October 2015

الآية

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قال تعالى :

{ وَقُلْ رَبِّ أَدْخِلْنِي مُدْخَلَ صِدْقٍ وَأَخْرِجْنِي مُخْرَجَ صِدْقٍ وَاجْعَلْ
لِي مِنْ لَدُنْكَ سُلْطَانًا نَصِيرًا } صدق الله العظيم – الإسراء 80

DEDICATION

The words and phrases aren't enough to describe our gratitude to all who supported this work. Family, friends and teachers . They have been the source of our inspiration and gave us the will power to do all what we can to make all of this possible .

AKNOLEDGEMENT

The great thanks always go first to Allah for giving us the strength to complete this project.

A great thanks for the staff of the School of Electrical Engineering specially for Ust.Jalal who provided us with the needed information and guidance .

ABSTRACT

Mobile phone has become the most used electronic device; it has become an essential in everyone's daily life because of the many tasks that can be done with it. With the great evolution of mobile phones came the problem of battery consumption, the more they evolve the bigger battery consumption gets.

This project aims to develop a new method of charging mobile phone from another mobile phone wirelessly.

المستخلص

اصبح الهاتف النقال أكثر الأجهزة الالكترونية استخداماً ، اصبح ضرورة في الحياة اليومية لكل شخص. مع التطور الكبير للهواتف النقالة جاءت مشكلة استهلاك البطارية، كلما تطورت كلما زاد الإستهلاك.

يهدف هذا المشروع لتطوير طريقة جديدة لشحن الهاتف النقال من هاتف نقال آخر لاسلكياً.

TABLE OF CONTENTS

	Page
الآية	I
DEDICATION	II
AKNOLEDGEMENT	III
ABSTRACT	IV
المستخلص	V
TABLE OF CONTENTS	VI
LIST OF FIGURES	IX
LIST OF TABLES	X
LIST OF SYMBOLS	XI
LIST OF ABBREVIATIONS	XII
CHAPTER ONE INTRODUCTION	
1.1 Historical Background	1
1.2 Problem Statement	1
1.3 Objective	2
1.4 Methodology	2
1.5 Layout	2

CHAPTER TWO	
GENERAL OVERVIEW	
2.1 Batteries	3
2.1.1 Lithium-ion battery	3
2.2 Battery Chargers	5
2.3 Wireless Charging	5
2.3.1 Magnetic inductive coupling	6
2.3.2 Advantages and disadvantages	6
2.4 Microcontroller	7
CHAPTER THREE	
MODEL AND CIRCUIT DESIGN	
3.1 Introduction	9
3.2 Model	9
3.3 Circuit components	10
3.3.1 Atmega16 Microcontroller	10
3.3.3 Transistor	11
3.3.4 Bridge Rectifier	12
3.3.6 Capacitor	13
CHAPTER FOUR	
METHODOLOGY	
4.1 Transmitter circuit	15

4.2 Receiver circuit	17
4.3 Procedure	17
4.4 Results	20
CHAPTER FIVE CONCLUTION AND RECOMMENDATIONS	
5.1 Conclusion	21
5.2 Recommendations	21
REFERENCES	22
APPENDIX	23

LIST OF FIGURES

Figure	Name	Page
2.1	Lithium-ion cell ion flow	4
2.2	Basic architecture of MCU	8
3.1	Charging circuit	9
3.2	Charging circuit model	10
3.3	MCU data sheet	11
3.4	Transistor	12
3.5	Bridge rectifier	13
3.6	Capacitor	14
4.1	Transmitter circuit diagram	15
4.2	Relation between the power and duty cycle	16
4.3	Transmitter circuit diagram	17
4.4	Circuit input	17
4.5	Transmitter circuit	18
4.6	The distance between coils	19
4.7	Receiver circuit	19
4.8	The mobile phone charging process	20

LIST OF TABLES

Table	Name	Page
4.1	Input voltage, frequency and output voltage	18

LIST OF SYMBOLS

kHz	Kilo Hertz
mAh	Mill Ampere per hour

LIST OF ABBREVIATIONS

AC	Alternating current
ADC	Analogue-to-Digital converter
ALU	Arithmetic and logic unit
AVR	Alf-Egil Bogen and Vegard Wollan RISC
CPU	Central processing unit
DC	Direct current
EMF	Electro-Magnetic field
EEPROM	Electrically Erasable Programmable read only memory
IC	Integrated circuit
I/O	Input Output
μC/MCU	Microcontroller
PIC	Peripheral Interface Controller
PMU	Power management unit
PWM	Pulse width modulation
RF	Radio Frequency
RAM	Random access memory
ROM	Read only memory
SIM	Subscriber identification module
USB	Universal Serial Bus
VIP	Very important person

CHAPTER ONE

INTRODUCTION

1.1 Historical Background

In 1973 Motorola had demonstrated the first handheld mobile cell phone in the world it was somehow a small machine with a simple task calling or receiving calls and which only used by businessmen and very important persons (VIP) no one had imagined that this device one day will be one of the most fastest developing devices in the world which will be used in every house by everyone that it will be one of the basic personal equipments.

Mobile phones has taken the place of cameras, music players, recorders and even the wallets in some advanced countries , and by the years the needs for developing and improving this device has raised and the mobile phones has transformed to be mini computers , but that huge developing and the concentrating on improving in the mobile performance had created a real problem which is fast battery exhaustion, the mobiles became bigger and contain many power consuming components, also the personal usage of the mobile has been increasing to a level which we can call it addiction.

1.2 Problem Statement

According to the International Energy Agency, in 2011 one billion and four hundred people around the world did not have access to electricity. Despite the many additions to improve the performance of the phone batteries there are still some problems that face the mobile phone users where there find themselves

unable to charge their mobile phones because there is no alternating current (AC) plugs available.

1.3 Objective

The project has two goals first is to find a new technique to charge a mobile phone and the second is to give a source of power in the critical situations.

1.4 Methodology

The main devices in this project are the microcontroller and coils used in the wireless power transfer.

1.5 Layout

The project contains five chapters, the first chapter is an introduction to the project, second chapter is a general overview, third chapter contains the model and circuit design, fourth chapter shows the methodology of the project and the fifth chapter is the conclusion and recommendations.

CHAPTER TWO

GENERAL OVERVIEW

2.1 Batteries

A battery is an electrochemical means “A device that converts the chemical energy contained in its active materials directly into electric energy by means of an electrochemical oxidation-reduction (redox) reaction”. Batteries are typically classified into one of two categories: either primary or secondary. Primary batteries are not rechargeable, secondary batteries are rechargeable.

2.1.1 Lithium-ion battery

Lithium has the lightest weight, highest voltage, and greatest energy density of all metals. There were occasional unfortunate events pertaining to safety (often an audible with venting and flame). These events were often due to the reactivity of metallic lithium (especially electrodeposited lithium with electrolyte solutions) but events were also attributed to a variety of other reactive conditions. Primary and secondary lithium batteries use non-aqueous electrolytes, which are inherently orders of magnitude less conductive than aqueous electrolytes.

In the lithium-ion battery, energy flow is created as the lithium-ions within the cathode are transferred through an electrolyte medium into the anode, this represents a charging event. A discharging event is represented by the lithium-ions being transferring through an electrolyte medium from anode into the cathode.

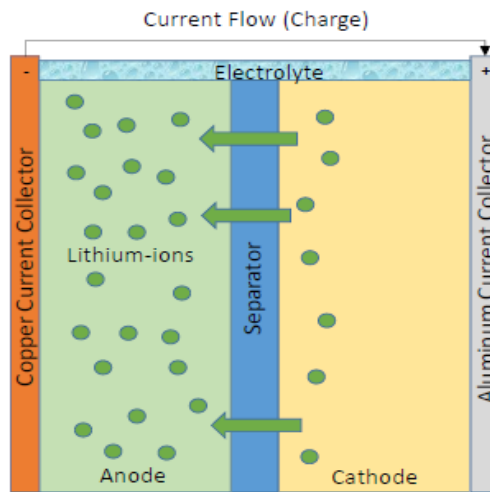


Figure 2.1: Lithium-ion cell ion flow

In addition to having higher voltage and energy density, lithium-ion also has a lower rate of self-discharge this means that its natural capacity loss over time when the batteries are in storage is less than that of other chemistries with many lithium-ion chemistries losing only 1–5% per month.

Capacity loss during storage comes in two types, reversible and permanent.

Reversible capacity loss is that energy that is lost during storage but will be regained once the battery is cycled again. Permanent loss is that portion that will never be regained again.

Virtually all lithium-ion chemistries have some amount of reversible capacity loss over time, some of which is generally always permanent.[1]

2.2 Battery Chargers

Most cell phone chargers are not really chargers; they are only a power adaptor that provides a power source for the charging circuitry which is almost always contained within the mobile phone. They are notoriously diverse, having a wide variety of direct current (DC) connector-styles and voltages, most of which are not compatible with other manufacturers' phones or even different models of phones from a single manufacturer.

Cell phone chargers are nothing but AC to DC converters. They take an input of 220 volt AC and give an output voltage around 5Volt DC.

The mobile phone chargers contain four main components, step-down transformer, bridge rectifier, filtering circuit and a voltage rectifier.

2.3 Wireless Charging

Wireless charging technology enables wireless power transfer from a power source to a load across an air gap.

Recently, wireless charging is rapidly evolving from theories toward standards, and being adopted in commercial products, especially mobile phones and portable devices.

Three major techniques for wireless charging are magnetic inductive coupling, magnetic resonance coupling, and microwave radiation.

The magnetic inductive and magnetic resonance coupling work in the near field, the generated electromagnetic field dominates the region close to the

transmitter or scattering object. The near-field power is attenuated according to the cube of the reciprocal of the distance. Alternatively, microwave radiation works in the far field at a greater distance. The far-field power decreases according to the reciprocal of the distance.

2.3.1 Magnetic inductive coupling

Magnetic inductive coupling is based on magnetic field induction, which delivers electrical energy between two coils. Magnetic inductive coupling happened when a primary coil of an energy transmitter generates a predominant varying magnetic field across the secondary coil of the energy receiver within the field, generally less than the wavelength. The near-field power then induces voltage/current across the secondary coil of the energy receiver within the field. This voltage can be used by a wireless device.

The energy efficiency depends on the tightness of coupling between two coils and their quality factor. The tightness of coupling is determined by the alignment and distance, the ratio of diameters, and the shape of two coils. The quality factor mainly depends on the materials, given the shape and size of the coils as well as the operating frequency. The advantages of magnetic inductive coupling include ease of implementation, convenient operation, high efficiency at close distance (typically less than a coil diameter), and safety, therefore, it is applicable and popular for mobile devices.

2.3.2 Advantages and disadvantages

Inductive coupling is safe for humans, simple to implement in circuits, but it has Short charging distance, heating effect and also needs tight alignment between chargers and charging devices.

Magnetic resonance coupling chargers and charging devices can charge multiple devices simultaneously at different powers but it's not suitable for mobile applications and has a complex implementation.

Microwave radiation has a long effective charging distance but it's not safe when the radio frequency (RF) density exposure is high and has low charging efficiency.[2]

2.4 Microcontroller

A microcontroller is a self-contained single chip processor with all constituent subsystems of a larger computer system. Within the confines of a single integrated circuit it contains input/output capability, a time base, a timing system, memory, an Arithmetic and Logic Unit (ALU) providing the capability to perform arithmetic and logic processes, and also the capability to generate output control signals. A microcontroller is usually employed when a moderate amount of local intelligence is required within a given application. It is best suited for applications involving integer-based processing although floating point calculations are possible.[3]

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems.

Microcontroller can be termed as a single on chip computer which includes number of peripherals like random access memory (RAM), electrically erasable programmable read only memory (EEPROM), Timers etc., required to perform some predefined task.

Microcontrollers contain main/basic resources which are inside any type of microcontroller and these are the microprocessor (μ P), EEPROM, RAM and Input/output (I/O) Ports. The microcontroller (MCU) also contains optional resources such as an analogue to digital converter (ADC), pulse width modulation (PWM) and so on, and these resources depend on the MCU. (Figure 2.2) shows the basic architecture of the MCU.

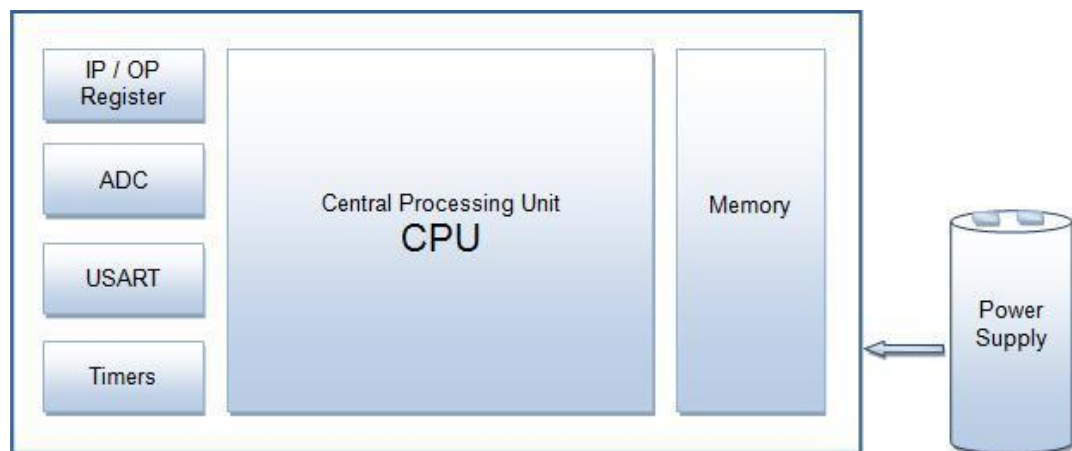


Figure 2.2: Basic architecture of MCU

CHAPTER THREE

MODEL AND CIRCUIT DESIGN

3.1 Introduction

In order to transfer electric power wirelessly the DC voltage must be converted into AC voltage with a high frequency to be transmitted into magnetic field through copper coils then converted back again into DC power and regulated to give the desired charging voltage.

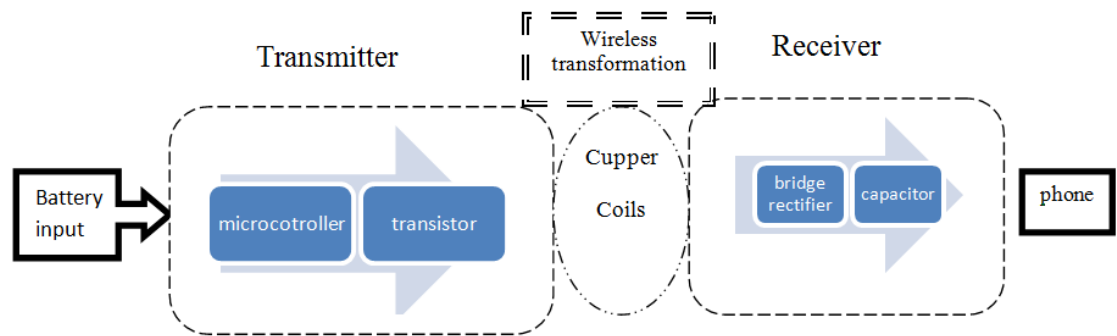


Figure 3.1: Charging circuit

3.2 Model

Battery's DC voltage is inputted to the microcontroller to be converted to a high frequency AC voltage. The AC voltage is then transmitted using the coils into magnetic field. The magnetic field is received on the other side using also the copper coils which convert it back into AC voltage. The AC voltage is

converted back to DC voltage using bridge rectifier. Bridge rectifier output is inputted to a capacitor to filter the value of the rectifier's voltage.

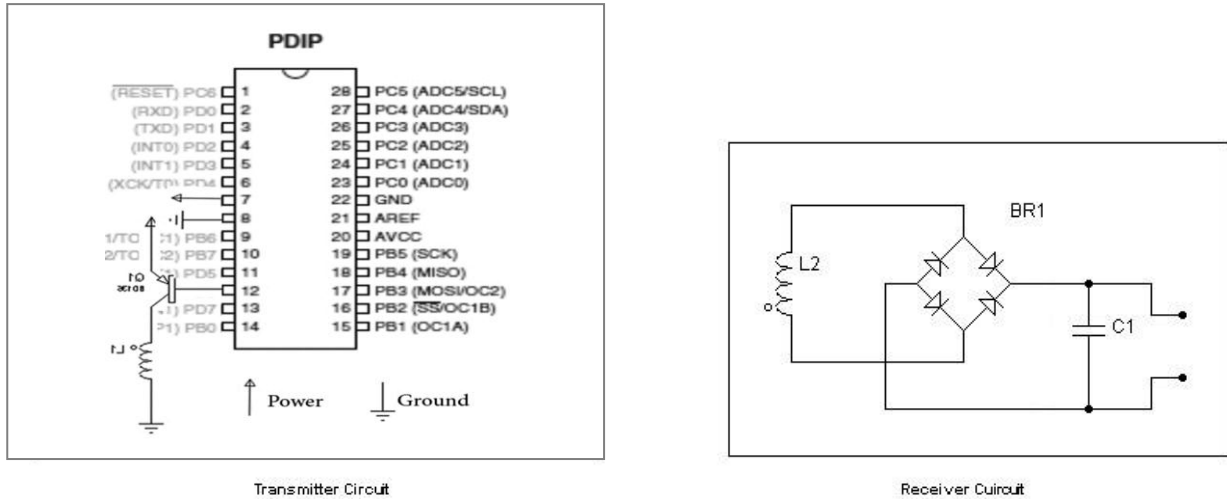


Figure 3.2: Charging circuit model

3.3 Circuit Components

The circuit contains:

3.3.1 Atmega16 microcontroller

The Alf-Egil Bogen and Vegard Wollan RISC (AVR) line provides a full range of processing power, from small 8-pin processors to complex 100-pin processors. The same compiler and programming hardware may be used with a wide variety of microcontrollers. Many of the AVR microcontrollers are available in dual inline package, which makes them readily useable on a printed circuit board prototype.

The Atmega16 microcontroller is a type of AVR microcontrollers, the features of the Atmega16 are:

- high performance coupled with low power consumption,
- outstanding flash memory technology,
- reduced instruction set computer Harvard Architecture,
- single-cycle instruction execution,
- wide variety of operating voltages (1.8--5.5 VDC),
- architecture designed for the C language,
- one set of development tools for the entire AVR line, and
- in system programming, debugging, and verification capability.[4]

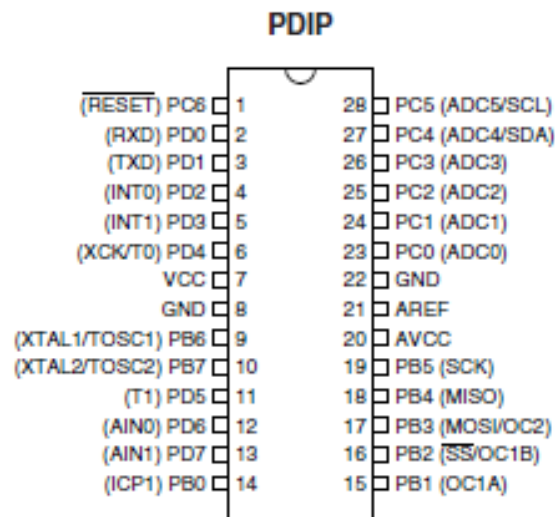


Figure 3.3: MCU data sheet

3.3.2 Transistor

A transistor is a semiconductor device used to amplify and switch electronic signals and electrical power. It is composed of semiconductor material with at

least three terminals for connection to an external circuit. A transistor must be properly biased with a DC voltage in order to operate as an amplifier. A voltage or current applied to one pair of the transistor's terminals changes the current through another pair of terminals. Because the controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal. Today, some transistors are packaged individually, but many more are found embedded in integrated circuits.[5]



Figure 3.4: Transistor

3.3.3 Bridge Rectifier

A rectifier is an electrical device that converts AC, which periodically reverses direction, to DC, which flows in only one direction. The process is known as rectification. Physically, rectifiers take a number of forms, including vacuum tube diodes, mercury-arc valves, copper and selenium oxide rectifiers, semiconductor diodes, silicon-controlled rectifiers and other silicon-based semiconductor switches. Historically, even synchronous electromechanical switches and motors have been used. Early radio receivers, called crystal radios,

used a “cat’s whisker” of fine wire pressing on a crystal of galena (lead sulfide) to serve as a point-contact rectifier or “crystal detector”.

Rectifiers have many uses, but are often found serving as components of DC power supplies and high-voltage direct current power transmission systems. Rectification may serve in roles other than to generate direct current for use as a source of power. As noted, detectors of radio signals serve as rectifiers. In gas heating systems flame rectification is used to detect presence of a flame.

Because of the alternating nature of the input AC sine wave, the process of rectification alone produces a DC current that, though unidirectional, consists of pulses of current. Many applications of rectifiers, such as power supplies for radio, television and computer equipment, require a steady constant DC current (as would be produced by a battery). In these applications the output of the rectifier is smoothed by an electronic filter (usually a capacitor) to produce a steady current.

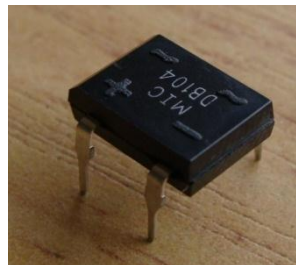


Figure 3.5: Bridge rectifier

3.3.4 Capacitor

A capacitor (originally known as a condenser) is a passive two-terminal electrical component used to store electrical energy temporarily in an electric field. The forms of practical capacitors vary widely, but all contain at least two

electrical conductors (plates) separated by a dielectric (i.e. an insulator that can store energy by becoming polarized). The conductors can be thin films, foils or sintered beads of metal or conductive electrolyte, etc. The non-conducting dielectric acts to increase the capacitor's charge capacity. A dielectric can be glass, ceramic, plastic film, air vacuum, paper, mica, oxide layer etc. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, an ideal capacitor does not dissipate energy. Instead, a capacitor stores energy in the form of an electrostatic field between its plates.



Figure 3.6: Capacitor

CHAPTER FOUR

METHODOLOGY

4.1 Transmitter Circuit

The core of the transmitter circuit is Atmega16 microcontroller. The microcontroller transfers the power to the transmitter coil through the PNP transistor BD135 as shown in the figure below.

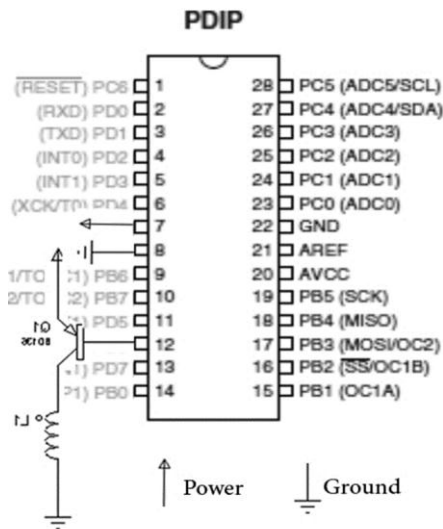


Figure 4.1: Transmitter circuit diagram

The microcontroller acts as a function generator to produce a square wave applied to the transmitter coil through the transistor. The square wave could be generated using any multivibrator circuit – like 555 timer circuit- but these circuit has limited frequency generation which solved by using the microcontroller. The square wave is used instead of the direct DC voltage to obtain the current change across the coil which leads generate the Electro-Magnetic Field (EMF) around the coil which is then received by the receiving coil. Increasing the frequency of the square wave increases the EMF around the coil which increases the power delivered to the receiving coil as well, but this

has some limitations. The coil length, the diameter of the coil wire, the number of turns and the coil diameter all these parameters limits the frequency applied to the coil and the EMF generated around it. Also the duty cycle of the square wave determine the power delivered to the coil through the transistor but also with some limitations. The duty cycle should be as much as possible so as to deliver much power, but it should not be as much as the coil could not have enough off time. The figures below show the relation of the square wave power with different duty cycles.

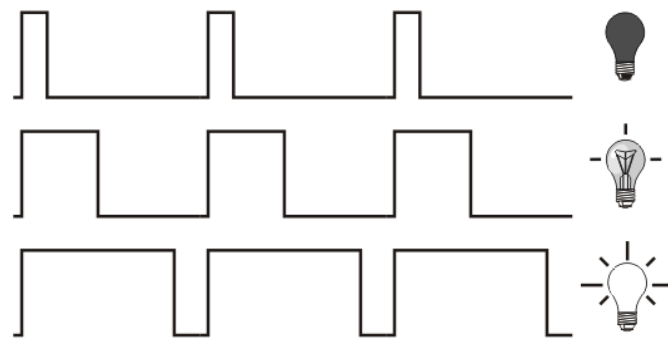


Figure 4.2: Relation between the power and duty cycle

The frequency generated from the microcontroller is about 75 kHz and the duty cycle is about 50%. This signal is fed directly to the DB136 transistor and then to the coil. The signal comes from the microcontroller has low power, so the microcontroller drive the transistor on and off and the transistor supply the coil from the power supply power.

4.2 Receiver Circuit

The coil in the receiving side receives the EMF generated by the transmitter coil and transforms it to current. The amount of the current is proportional to the EMF received and of course to the coil specifications. The current generated by

the receiving coil is fed to a bridge rectifier and a small resistor could be used to convert current to voltage. A capacitor is used after the bridge to get a pure DC power and store the power for further use.

The figure below shows the receiving coil with its circuit.

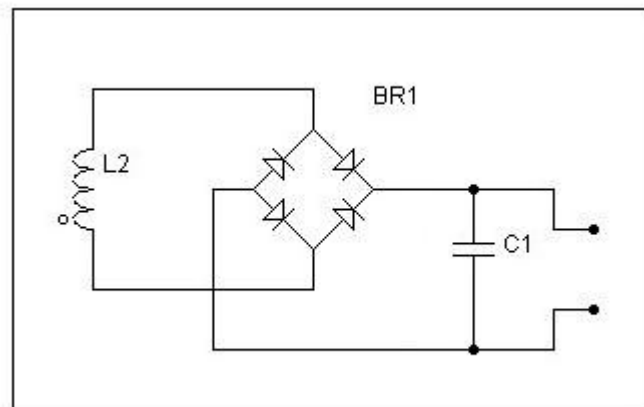


Figure 4.3: Receiver circuit diagram

4.3 Procedure

The circuit input is taken from the charging mobile's battery directly with a voltage equal to 3.7 Volts as shown in figure below.



Figure 4.4 Circuit input

The battery input goes directly to the microcontroller which converts it to AC voltage with a frequency 50-70 kHz, then to the transistor to raise the value of the current before going into the transmitter coil.

Table 4.1 Input voltage, frequency and output voltage

Input voltage	Frequency	Output voltage
5 Volts	70.48 kHz	3 Volts
5 Volts	45 kHz	3.2 Volts
3.7 Volts	73.5 kHz	3.5 Volts

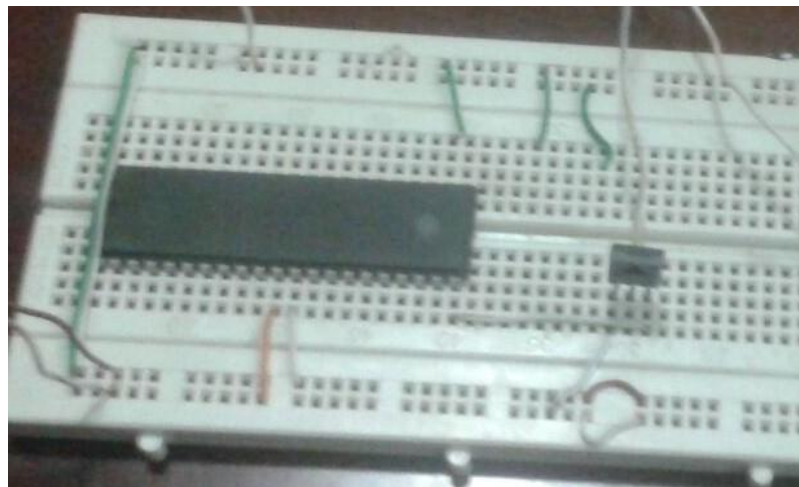


Figure 4.5 Transmitter circuit

The voltage received in the receiver circuit is proportional to conversion of the distance between the two coils so in order to get high voltage the coils must be close to each other as shown in figure below.



Figure 4.6 The distance between coils

The received AC voltage is then inputted to a bridge rectifier and then to a capacitor to give DC voltage with a value of 3.7 Volts which is enough value to charge a mobile phone.

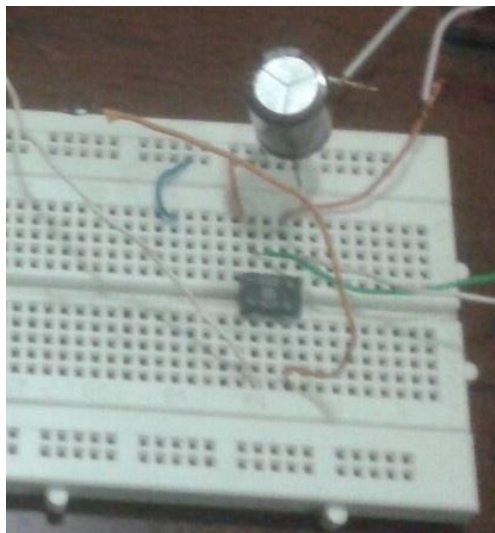


Figure 4.7 Receiver circuit

The receiver circuit's output is used to charge the mobile phone through a USB cable.



Figure 4.8 Mobile phone charging process

4.4 Results

The receiving mobile phone battery charges with 78 mAh over one hour while the charging battery consumes 360 mAh over the same period of time because of the low current received from the coils due to power losses through the coils.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The charging technique is invented to solve to the problem of battery consumption which became a major problem that faces most of mobile phone users. To apply this technique a basic knowledge in Li-ion battery, charger, wireless charging techniques and microcontrollers must be available.

The components of the circuit are the Atmega16 microcontroller, a transistor, copper coils, bridge rectifier and a capacitor. The circuit input is taken directly from the charged mobile phone's battery to the Atmega16 MCU; the MCU converts the battery's DC voltage to an AC voltage then to the transistor which acts as a current amplifier then to the transmitter coils to transfer voltage as a magnetic field to the receiver coil, the AC voltage received in the coil is converted to DC voltage using the bridge rectifier and filtered using the capacitor and inputted to the charging mobile phone through a USB cable.

5.2 Recommendations

To continue studying this field the following points must be taken in consideration:

- Replacing the transmitting coils with less impedance coils.
- Increasing the received current.
- Tuning the frequency of the transmitting circuit in order to provide a long charging range.

REFERENCES

- [1] John Warner , “The Handbook of lithium-ion battery pack design , chemistry, components, types and terminology” ,XALT energy ,Midland ,MI ,USA , 2015
- [2] Xiao Lu, Dusit Niyato, Ping Wang, Dong In Kim and Zhu Han, Research about “WIRELESS CHARGER NETWORKING FOR MOBILE DEVICES: FUNDAMENTALS, STANDARDS, AND APPLICATIONS”, IEEE 2015
- [3] Steven F. Barrett and Daniel J. Pack,” Microcontrollers Fundamentals for Engineers and Scientists”, Morgan and Claypool publisher series
USA, 2006
- [4] Steven F. Barrett and Daniel J. Pack,” Atmel AVR Microcontroller Primer: Programming and interfacing”, Morgan and Claypool publisher series
USA, 2008
- [5] Thomas L. Floyd, “Electronic Devices”, Pearson Education Inc., USA, 2005

APENDIX

Microcontroller code

\$regfile "m32def.dat"

\$crystal = 8000000

Config PORTD = Output

Do

PORTD.6 = 0

Waitus 6

PORTD.6 = 1

Waitus 6

Loop