ASHESI UNIVERSITY

WIRELESS MOBILE PHONE CHARGING SYSTEM

CAPSTONE PROJECT

B.Sc. Electrical and Electronic Engineering

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WIRELESS MOBILE PHONE CHARGING SYSTEM

CAPSTONE PROJECT

Capstone Project submitted to the Department of Engineering, Ashesi University in partial fulfilment of the requirements for the award of Bachelor of Science degree in Electrical and Electronic Engineering.

Emmanuel Asare

2020

DECLARATION

I hereby declare that this capstone is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:

EMMANUEL ASARE

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Candidate's Name:

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Date: MAY 29, 2020 ………………………………………………………………………………………

I hereby declare that preparation and presentation of this capstone were supervised in accordance with the guidelines on supervision of capstone laid down by Ashesi University College.

Supervisor's Signature:

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Supervisor's Name:

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Date: ………………………………………………………………………………………

Acknowledgement

To my supervisor Mr. Richard Akparibo whose encouragement and academic advice helped me undertake this project. I thank my family and friends whose support was immensely helpful to keep me going especially in the period of the global pandemic that got me distress and demotivated most of the time.

ABSTRACT

A prototype of a wireless charging system was designed to tackle the problem of desks being messy as a result of electric cables that are used in charging mobile equipment and the inability to use the mobile devices when they are being charged. The design employs a method which is referred to as strongly coupled magnetic resonance which employs four coils to operate: two self-resonant and two inductors. The system was successfully designed in which power was successfully transmitted between the transmitter and receiver, and a range of about 6cm was achieved. Line of sight was not necessary for the transmission. The output was, however, a low voltage that could power an LED. Further work is required to be carried out to reduce the size of the system and incorporates it in charging mobile equipment.

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Chapter 1: General Introduction.

1.1 Introduction

Power transmission has almost always been carried out using electrical wires [1]. In charging simple equipment like mobile phones and speakers, electrical wires are usually used. This results in many inconveniences since the electrical cables inhibit free movement. The need for electrical cables in charging electrical equipment has curbed the development of some great technologies, like electric vehicles, that promise to solve some of the world's pressing problems like global warming [2]. This project will be a contribution to a field that engineers are increasingly paying attention to in recent years. In this project, consideration is given to the design and construction of a wireless charging system for small appliances like mobile phones and small speakers

1.2 Problem Definition

Electrical energy has increasingly become a necessity of life in this modern era. It holds very great importance because of the various usages and its requirement to drive various modern technologies [3]. Physical electric cables have usually transferred electricity. However, these cables come with some challenges, especially in their usage with small mobile equipment. The use of electric cables in charging results in many inconveniences and the most significant among them is that it inhibits the free movement of such devices, which are supposed to be mobile. Also, one of the setbacks in the manufacturing of electric vehicles is the unavailability of wireless charging systems [4]. Hence there is a need to make a wireless charger to give users convenience in the usage of mobile equipment.

1.3 Objectives of the Project Work

The main objectives of this project are outlined as follows:

1. The project seeks to underline some of the methods through which electricity can be transmitted wirelessly to charge equipment.
2. The pros and cons of these methods of wireless power transmission will also be investigated.
3. A wireless charger would be created to charge small appliances using the principles of one of the methods discussed.
4. The efficiency and the reach of the charger created would be tested to ascertain its effectiveness

1.4 Expected Outcomes of the Project Work

At the end of the project, the following outcomes are expected.

1. A deliverable in the form of a wireless charger that can work within a range of at least 3 centimeters.
2. The efficiency of the system should be at least 50%.
3. The system should be able to stop when the battery is charged fully.

1.5 Motivation of Project Topic

This project was motivated mainly by the great interest that the author has in the field of emerging technologies in automobile and small mobile equipment and also his passion for averting the dangers associated with working with electricity. Cables used in transmission has usually been associated with hazards and are usually disorganized [5]. This makes workspaces undesirable, and many people have received various degrees of electric shocks as a result of the cables being used in power transmission.

Furthermore, wireless power transfer technology is gaining much attention from the engineering ecosystem due to its potential in contributing to the success of some vital technologies like electric vehicles. The researcher seeks to add his expertise to the field and to contribute to the rapidly growing field as well as gained firsthand experience of the emerging technology.

1.6 Research Methodology Used

This project employs mainly two research methods, as outlined below.

1. Online Research: Literature review will be done using basic online research to find out about works that have already been carried out regarding the research topic. This will be done through reading, analyzing, and critiquing the peer-reviewed scholarly articles on the subject.
2. Lab work: This will mainly be geared towards building the actual equipment and using tools available to test its functionality and efficiency. This will be an elaborate step by step approach in testing the scientific concepts underlying the research field the researcher tends to learn about.

1.7 Facilities used for the research

This research employed different technologies and facilities as outlined below to attain the objectives.

1. Online libraries like IEEE and others will be used to get peer review materials about the topic that is being investigated into.
2. Software like Proteus and Multisim will be used to model the system.
3. The Ashesi Electrical and Electronic lab and its equipment will be employed in building the prototype.

1.8 Scope of Work

The scope of this project encompasses research about the various ways by which power can be transmitted wirelessly, which is the radiative and non-radiative methods. A prototype will be created, which should be capable of charging small appliances like a mobile phone wirelessly.

Chapter 2: Literature Review

2.1 Introduction

Mobile phones are currently usually charged with electric cable connectors [6]. The wired power transmission of electrical power to charge a mobile phone is associated with some inconveniences [7]. To eradicate these inconveniences related to the usage of electrical wires, scientists have shown great interest in transferring electrical power wirelessly [7].

2.2 Milestones in Wireless Power Transmission

There has been a recent upsurge in scientific researches in wireless transmission. However, wireless transmission of power is not a new phenomenon. The idea of wireless transmission of was first conceived by Nikola Tesla between 1900 and 1914 [8]. Nikola Tesla built a gigantic wooden tower with a round big copper electrode at the top of Colorado with the aim of supplying electric power wirelessly to the entire Earth [9]. Nikola Tesla eventually abandoned his idea due to a lack of funds, and there are no records to prove that he could transmit any significant amount of power wirelessly [9].

After Nikola Tesla's work, research work on wireless power transmission halted until in the 1930s when a scientist named H. V. Noble performed some lab experiment in which he could transmit some amount of power between dipoles, which were about 25ft apart [9]. This did not go further from the laboratory. The next phase of wireless power transmission occurred in the 1970s with the development of microwave transmission [9]. Scientists received various funding to perform various researches and experiments regarding microwave transmission; some of the experiments included the making of a small helicopter that received power via the microwave transmission system [9]. The system, however, proved to be inefficient since scientist at the time realized that the system's transmitter requires a line of sight with the receiver to be able to transmit an efficient amount and it the efficiency reduced drastically when the orientations changes [9].

The most recent works on wireless power transmission have been focused on near field power transmission due to its safety and efficiency [10]. A team of scientists from the Massachusetts Institute of Technology has proposed a new near field wireless power transfer, which is based principle termed as strong magnetic resonant coupling [11]. They could transmit a good amount of power over about 2m.

2.3 Methods of Wireless Power Transfer

Wireless power transfer has been classified in various ways based on various parameters. In this paper, the classification will be based on reach. Wireless power transfer can be classified as far-field or near-field based on reach [10]. The various technologies that make up these various methods are outlined below.

2.3.1 Far-field Wireless Power Transfer

As the name suggests, far-field wireless power transfer refers to the type of power transfer that can transmit power over a longer range of about over 2m in the distance. This technology emerged in the 1970s, and it was mainly based on microwave transmission of power [9]. A more recent type, also known as laser-based power beaming, has been identified. This far-fields technology has, however, not been able to be adopted due to their effects on living tissues [12].

Microwave Power Transmission

Microwave power transmission involves converting electric power to microwave and transmitting it via microwave transmitter to be received at the receiver end and converted back to electric power [13]. Even though this technology has the capability of transferring electric power over longer distances, they are usually affected by factors such as diffraction, interference, cost of the system is high, poses health hazards, and other environmental issues [13]. These effects, together with its inefficiencies in long-distance transmission as well as a line of sight requirement, has prevented it from further development and application.

Laser-Based Power Beaming

This involves converting electrical power to a beam of laser and then pointed towards its receiver for it to be transmitted back into electricity. The receivers are usually made of photovoltaic cells that reconvert the laser beam to electricity [13]. There have been various scientific research about this Technology [14]. Unlike the microwave power transfer, it is not affected by interference with other radio waves and Wi-Fi. However, there are inefficiencies in conversion from electricity to laser beam and further inefficiencies in converting from the laser beam to electricity, which tends to make the system inefficient overall [15].

2.3.2 Near-field Wireless Power Transfer.

Near-field wireless power transfer, which is also referred to as the non-radiative method of power transfer, is the method of wireless power transfer that has a reach of from few mm to about 2km. The near field is further classified to short-range near field power transfer and mid-range near field power transfer [10].

Inductive coupling:

This form of wireless transfer depends on the mutual coupling between two coils. An alternating current in a transmitting coil generates a varying magnetic field that induces a voltage across the terminals of a receiving coil [16]. The efficiency of transmission decreases abruptly as the distance between the transmitting coils and the receiving coil increases.

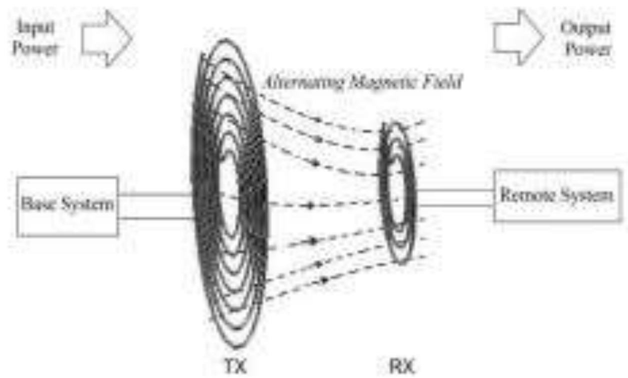

Figure 2.1 : Operation of Inductive coupling

Capacitive Coupling:

It utilizes high-frequency electric fields to transfer electric power, which has three distinguishing advantages: negligible eddy-current loss, relatively low cost and weight, and excellent misalignment performance [17]. It is, however, able to operate only within a short-range. Figure 2.2 shows a typical circuitry for the capacitive coupling method of wireless power transfer.

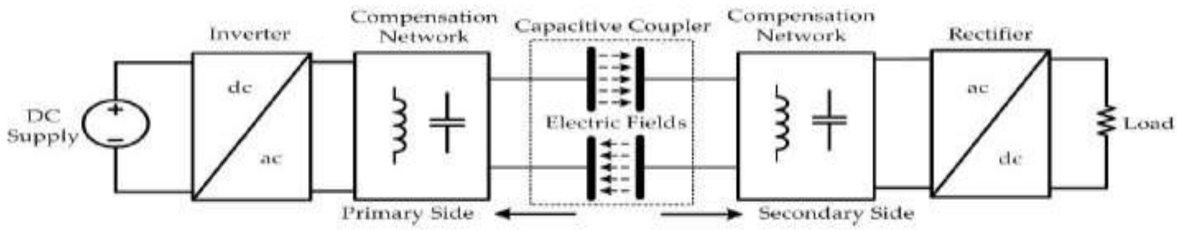

Figure 2.2: Capacitive coupling

Strong Magnetic coupling resonant

Strong magnetic resonant coupling is an extended form of the inductive and capacitive coupling to improve its reach. This is a new method of transmission that has received a lot of interest from researchers in recent years.

2.4 Survey of Related Work

Olvitz et al. [6] made a prototype wireless charger for mobile phone which could transfer about 0.5W of energy and through a distance of about 2.5cm maximum. The system consists of a transmitter and a receiver that transmits the power from the source and receives the power at the load side, respectively. The transmitter part consists of an oscillator made from 16 MHz crystal oscillator and an inverter. The transmitter coil and a variable capacitor are connected to ensure parallel resonance is attained. The receiver part consisted of an LC oscillator (for both the parallel and series resonance), one diode rectifier, a filtering capacitor, and a Zener diode. The receiver was designed to receive power from the transmitter. For prototype testing reasons, four LEDs were powered in place of a mobile phone battery.

Yanping et al [18] created a prototype wireless electric charger to charge a NOKIA cell phone over a distance 32cm with an input power of fewer than 4 watts, which resulted in about 52% efficiency. Their prototype was based on strong coupled magnetic resonance. Four coils were used in all for making this prototype. The excitation coil and the source resonant coil, the device resonant coil, and the work coil were fabricated on a PCB, respectively. A full-wave rectifier was used to convert the output voltage at the device side from ac to dc to be used for the charging.

Ismail et al [8] conducted an experiment and created prototypes of wireless power transfer based on coupled magnetic resonance to charge mobile phones. They made different prototypes of both a single transmitter and a single receiver; they also created a single transmitter and multiple receivers as well as multiple transmitters and multiple receivers. They could charge a phone within 5 cm to 20 cm. They realized that charging multiple phones from a single source resulted in the nearer phone getting a better charging; however, the overall efficiency increased with multiple receivers.

Ijhar et al [7] created a bench-top wireless power transfer also based on strongly coupled magnetic resonance principle. Their design placed the transmitter of the power beneath the bench and the receiver with the phone on top of the bench. The idea is to create a bench-top charger that the device to be charged, whether a phone or laptop, is placed on the bench to get it charged. A very high-frequency power source is supplied to the transmitter coils, which is coupled with the receiver coiled. Energy is transferred between them from the transmitter coils to the receiver coils. They could charge handheld devices through magnetic resonance to power two-three mobile phones of 8 watts each on the table. They achieved about 75% efficiency in the transmission.

Chapter 3: Theory and Design

3.1 Product Design Requirements

3.1.1 Introduction

The entire system will consist of two parts: the transmitter part and the receiver part. The transmitter would be connected to the power source; the transmitter will be the source of power to the receiver, which is on the mobile phone side. The receiver receives the power being transmitted by the transmitter and uses it to power the device that is connected to it. The entire system operates on a principle known as a strong magnetic resonant coupling, which is an extended form of generator action [19]. It is, however, able to transmit power over a longer distance compared to the normal Generator action since this is done at resonant frequencies.

3.1.2 Product Functionalities.

1. The wireless charger should be able to charge a mobile phone within a range of 5cm.
2. It should be able to detect the charging battery of the phone within the right range and display it on an LCD display.

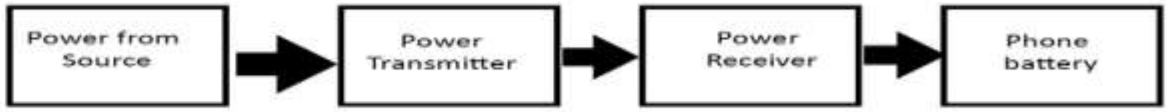

Figure 3.1: Functional Block diagram for the system

3.1.3 Non-Functional requirement.

1. The device should be harmless and pose no health hazard to its users.

3.1.4 Design Decision

In deciding on the best method of power transfer to suit the design requirements, a PUGH chart, as shown below, is designed. In this product, the safety of users is the most important parameter. The capacitive coupling method was selected as the baseline for comparison, and the criteria on which they were compared included reach, efficiency, and safety. Microwave transmission has a better(highest) reach. It is, however, the most dangerous especially when used in high power transmission, and its efficiency is comparable to that of the capacitive coupling method. The inductive coupling is comparable to the capacitive coupling in terms of reach. It is, however, slightly more efficient and safer. Strong magnetic resonant coupling is safer, has better efficiency, and reach as well. The result is shown in the PUGH chart below.

Table 3.3-1: PUGH chart

Criteria	Weight	Types of wireless Transfer			
		Baseline: Capacitive Coupling	Strong magnetic resonant coupling	Inductive Coupling	Microwave power transfer

Reach	3	0	+1	0	+1
Efficiency	4	0	+1	+1	0
Safety	5	0	+1	+1	-1

From the result of the PUGH chart, it becomes clear the method of strong coupled magnetic resonance is the most suitable method of power transfer to undertake this project.

3.2 Hardware Components

The project was conducted with several electronic components. These components formed the physical part of the project. They were chosen based on research and engineering concepts. Among the components are jumper wires, breadboards, capacitors, resistors, etc. The key components are described below:

3.2.1 Bifilar Coils

Bifilar coil, also known as self-resonant coil have properties that make them suitable for transferring power wirelessly. At the resonant frequency, self-resonant coils, if connected appropriately, can transfer power wirelessly at a relatively higher efficiency mid-range [20]. The self-resonant coil is a coil that is wounded radially outward as shown in

Figure 3.2 below. This coil has a property of resonating with its intrinsic or stray capacitance [20]. The system works best with two of the resonating connected between two inductors, and the system operates at the resonant frequency of the coils because when bifilar coils are directly connected to a voltage source, it results in parallel resonance which makes the impedance that appears to be too high hence making the transmission inefficient [20].

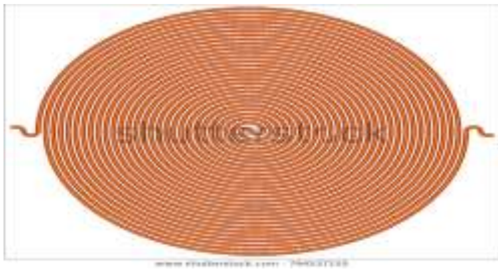

Figure 3.2: Bifilar coil or self-resonant coil

3.2.2 Kl25z Microcontroller

Microcontrollers can be referred to as small computers that are usually on a single board, and they usually contain a microprocessor. In this project, the Kl25z microcontroller is used. As shown in Figure 3.3, it has various pins that can be configured to do a variety of functionalities based on the project requirement. The Kl25z microcontroller will be used to create the square wave that will gate the various TIP NPN power transistors that are used in creating the square wave inverter. It would also be used for programming the LCD display.

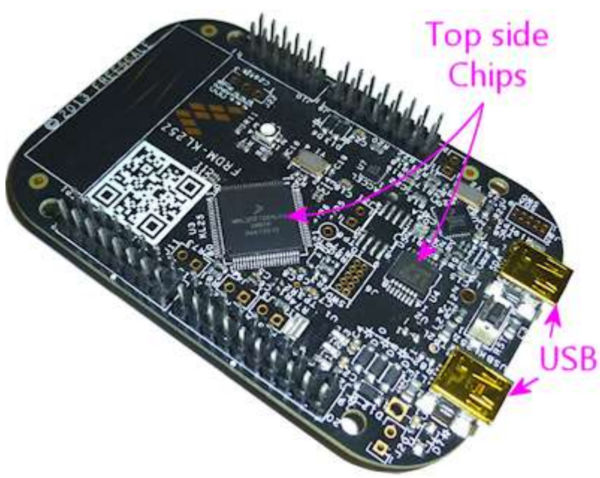

Figure 3.3: Kl25z microcontroller

3.2.3 LCD display

In this project, a 16 by 2 characters LCD was used. It had 16 pins and had a relatively easy mode of configuration and programming. It is also cost-effective and preferred over other displays like seven segments and the other segments. The kl25z microcontroller is used to program the LCD display to display a successful transmission of power wirelessly. The

Figure 3.4 below shows and image of a 16 pin LCD display

Figure 3.4: 16 pins LCD

3.2.4 TIP 31c Power Transistor

A transistor is a semiconductor device that is used for various functionalities. The functionality that makes transistors useful for this project is their ability to be used as switching devices. The TIP 31c power transistor is the preferred transistor in this project because it can handle higher power. As shown in Figure 3.5, it has three pins, which are the base, emitter, and collector. Four of these transistors are used in this project to create an H bridge square wave inverter. The kl25z microcontroller is used to gate the base appropriately to ensure this.

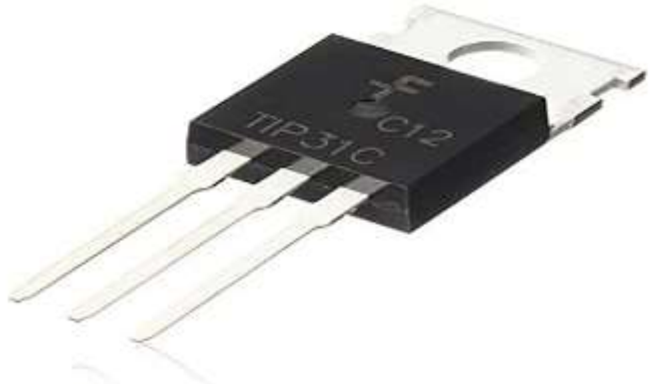

Figure 3.5: TIP 31c power transistor

3.2.5 DC Power Source

To be able to regulate the frequency of the power source to the resonant frequency, a DC source was used, which was later inverted to AC with the square wave inverter. In this project, four 1.5V batteries connected in series to create a total of 6V voltage source as shown in Figure 3.6 is used in this project.

Figure 3.6: Four 1.5V batteries connected in series

3.3 Various Parts of Circuit Design.

3.3.1 Inverter

The inverter forms an important part of the design. To be able to operate at the required working voltage and, more importantly, the right working frequency. The operation of the strongly coupled magnetic resonance method of wireless transfer of power is most efficient when the working frequency is the resonant frequency of both the transmitter and the receiver circuits [11]. Since the input power is a DC, an inverter is required to convert it to AC and with the right. The inverter is used, as shown in Figure 3.7, employs an H bridge with four transistors that are gated by kl25z Microcontroller programmed to give out an AC power with the right frequency, which is supplied to an inductor.

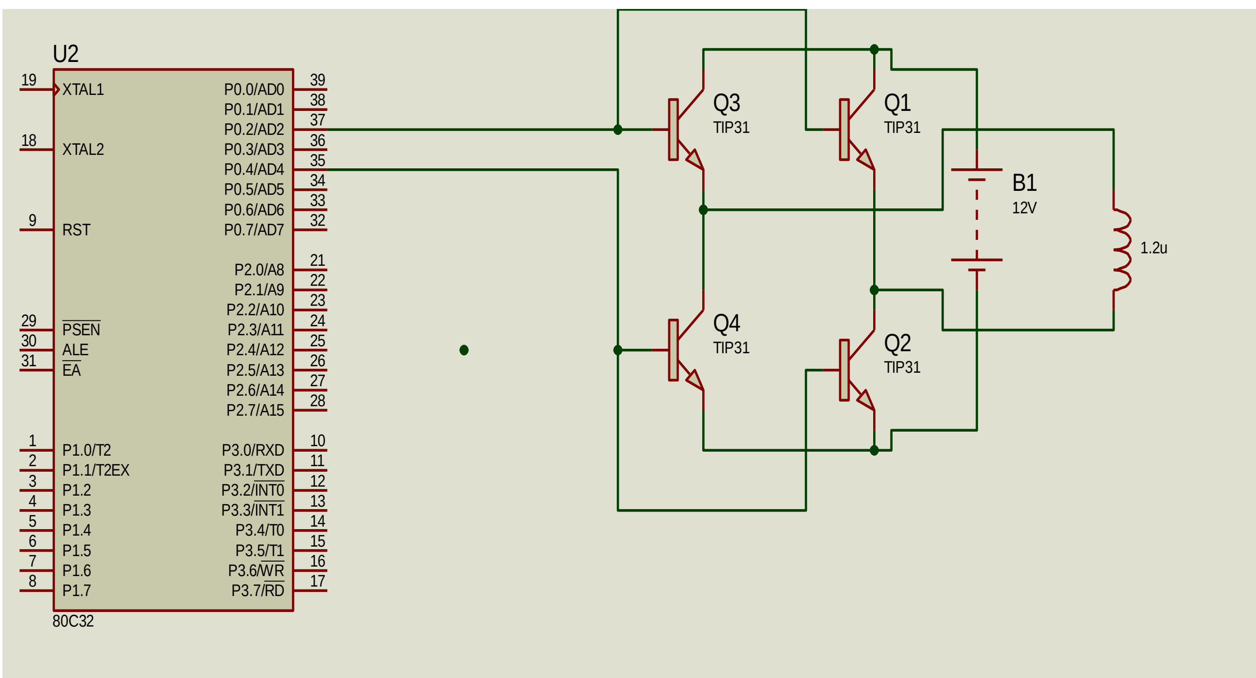

Figure 3.7: : Square wave inverter.

3.3.2 The transmitter circuit:

The transmitter consists of two loops that are placed close to each other but are not physically in contact or wired together. The output of the inverter is connected directly to the first loop, which is referred to as a driver loop. This power is transferred to the transmitter coil, which is a self-resonant coil. The transmitter further exchanges power with the receiver coil. The schematic of the transmitter side is shown in figure 3.8 below.

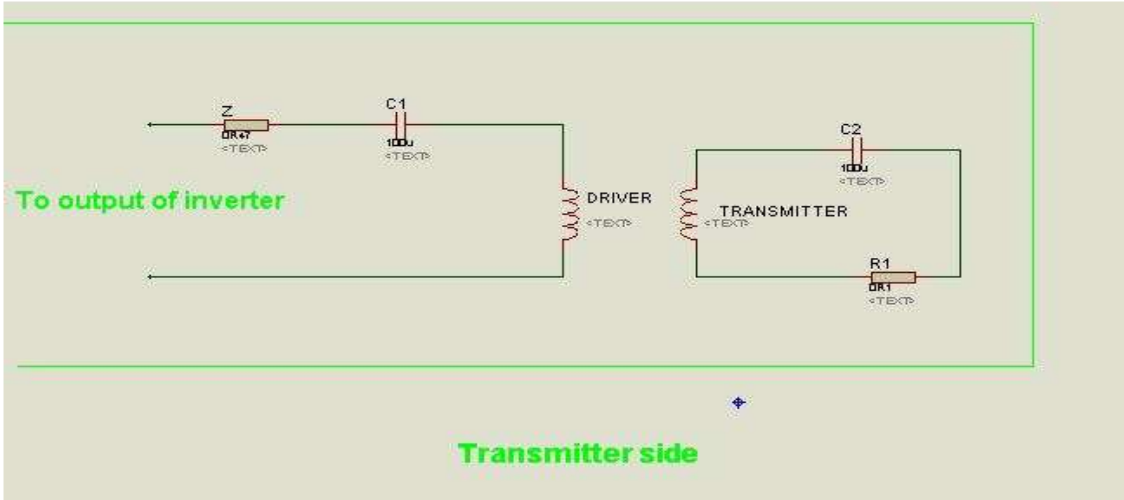

Figure 3.8: Transmitter circuit

3.3.3 The Receiver Circuit:

The receiver circuit is similar to that of the transmitter. It consists of the receiver coil, which is on the left-hand side. The receiver coil is also a self-resonance coil. The other loop, which is referred to as the load loop, is directly connected to a rectifier then to the load. The receiver loop is not in physical contact with the load loop. They also interact via transformer action; the distance between them is fixed as well.

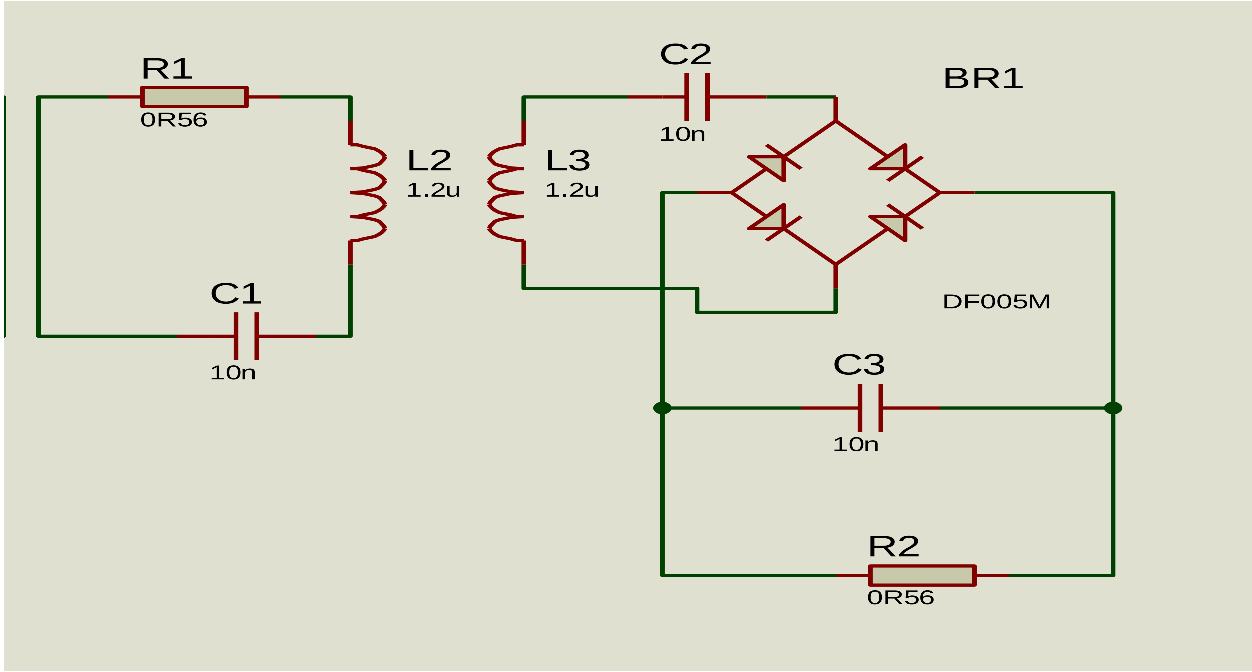

Figure 3.9:The Receiver circuit

3.3.4 Full-wave rectifier:

Since the load requires a DC input, a full-wave rectifier is used to rectify the AC output from the load loop before it is supplied to the loop. This full-wave rectifier uses four diodes to rectify the power and uses an additional capacitor to smoothens out the output power.

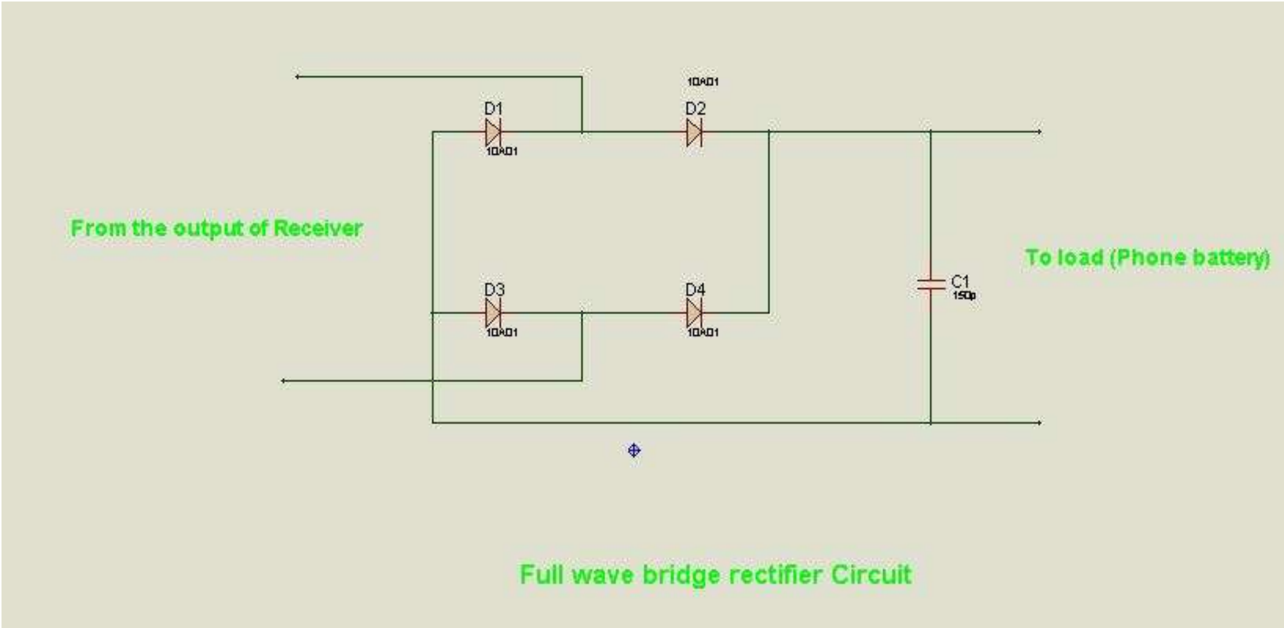

Figure 3.10: Full-wave Rectifier

3.3.5 Overall combined circuitry:

Figure 3.11 above shows the overall circuitry of a four coil strongly coupled magnetic resonance method of wireless power transfer. It operates on an extended form of transformer action to achieve mid-range power transfer.

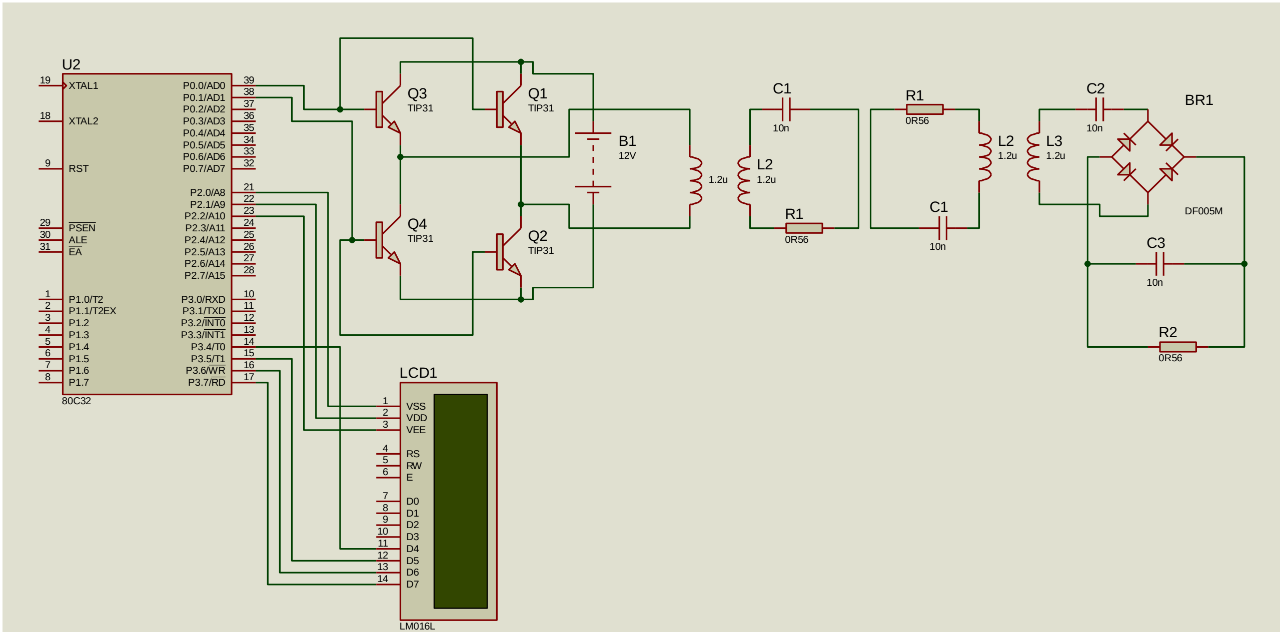

Figure 3.11:Overall circuit of a wireless transmitter

3.4 Design Theory

The main theory behind the design is an extended form of transformer action. However, it employs two resonant coils that operate at

$$f_o = \frac{1}{2\pi\sqrt{LC}} \qquad (1)$$

Where f_o is the resonant frequency.

Both the transmitter and the receiver circuit must be operating at the resonant frequency, and the resonant frequency must be the same for both the transmitter and the receiver.

$$f_o t = f_0 r \qquad (2)$$

Combining equations (1) and (2)

$$L_T C_T = L_R C_R \qquad (3)$$

Since the two self-resonant coils are identical with similar inductance and parasitic capacitance(neglected), identical capacitors are used in place. Hence,

$C_T = C_R$, that is, the internal circuits have identical components, as shown in Figure 3.11.

Also, L3c2 = L2C1 since the overall system is in resonance.

Chapter 4: Results And Discussions

4.1 The Transmitter Results:

The transmitter part of the device consisted of a power source (which is a battery), an inverter, and the disc coil that acts as the main transmitting component.

4.1.1 The Transmitter Hardware

The transmitter part of the design consists of the inverter that changes the DC power from the battery to AC. As shown in figure 4.1 below, the DC source is supplied to the inverter, which in turn changes it to an AC and supplies it to the disc type inductor, which transmits the power wirelessly to the coil(inductor) at the receiver end of the system. An Arm Kl25z is used to gate four TIP 31c power transistors at a predetermined frequency (resonant frequency of the network) to create the inverter.

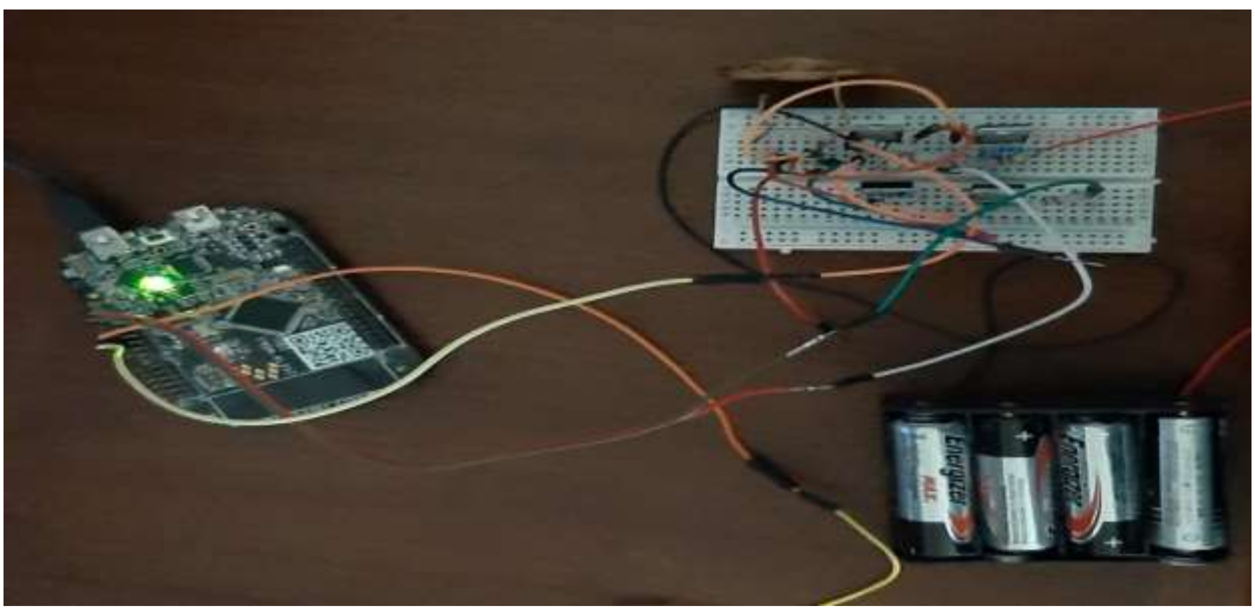

Figure 4.1: The hardware design of the transmitter

4.1.2 Results from Square-Wave Inverter:

The output of the square wave inverter was connected to Analog discovery to measure the output. This output is connected to the disc inductor that transmits it to the receiver side. The output of the inverter, as shown in figure 4.2 below, shows that about 3.03V and frequency of 1.74kHz.

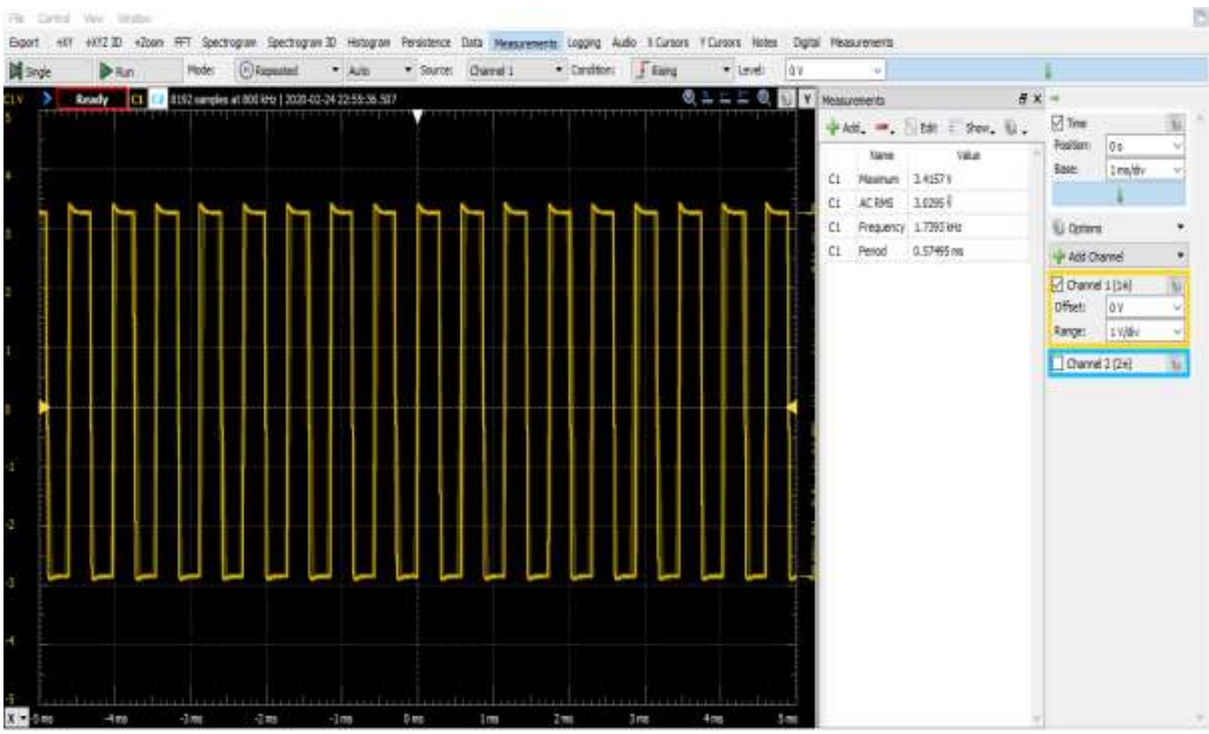

Figure 4.2: Output of square-wave inverter on Analog discovery

4.2 Receiver Results

The receiver part of the system consisted of the self-resonant coil that received the power from the self-resonant coil of the transmitter. The power is then transmitted into the inductor, which is rectified by the full-wave rectifier into a dc, which is supplied to power an LED. The overall circuitry of the system is shown in Figure 4.3, as shown below. The power received at the receiver end is supplied to power LED, as shown in figure 4.3 below. Power is successfully transferred between the transmitter and the receiver.

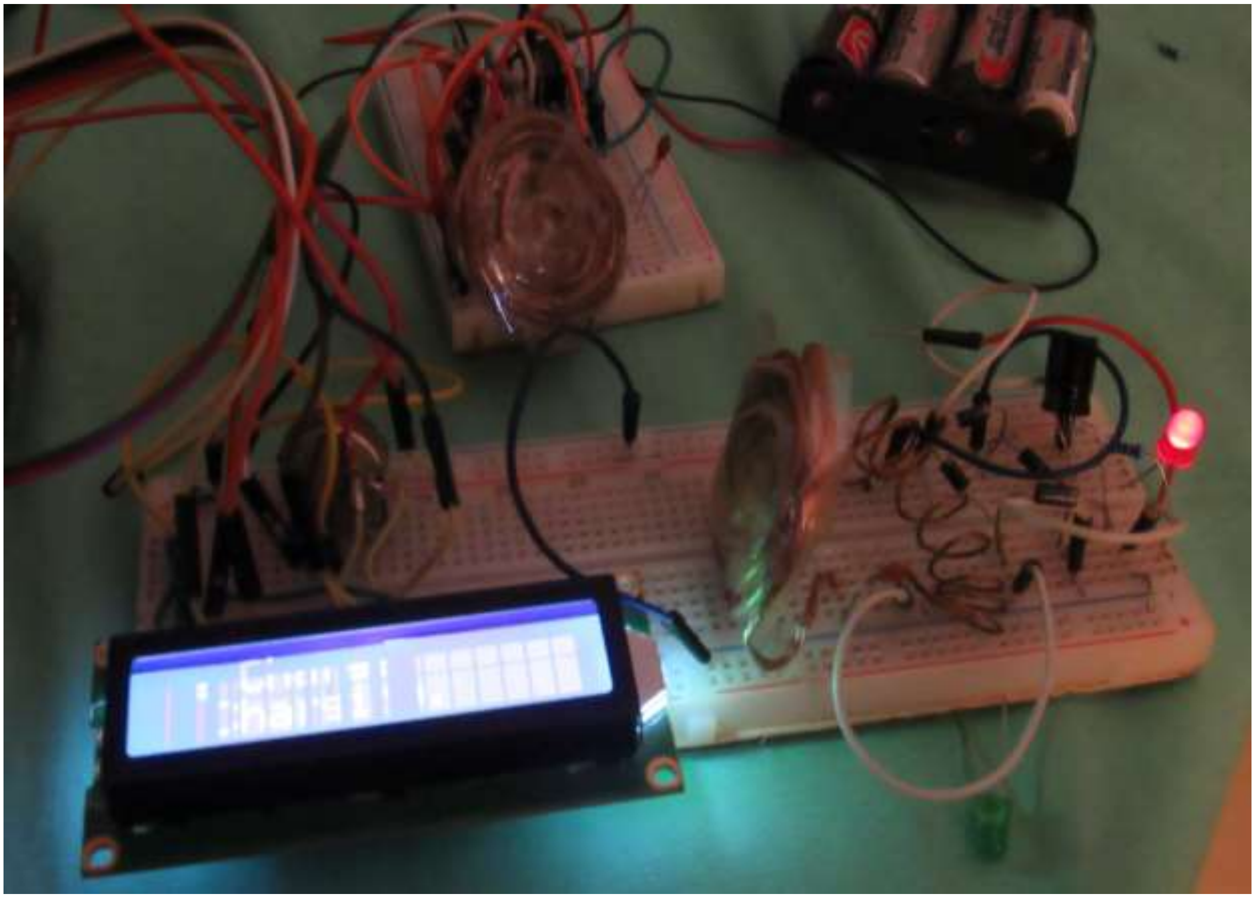

Figure 4.3:The overall hardware design of the system

The voltage received at the receiver end of the system is measured to be about 4.7V as shown in

Figure 4.4 below. With a DC to DC voltage booster, the voltage would be able be stepped up to the required voltage to power any DC load.

Figure 4.4*:* Output of the receiver after it has been rectified

Chapter 5: Conclusion, Limitations, And Future Work

5.1 Conclusion

The system created can transfer power wirelessly and use to power a DC resistive load. By doing this, it has tackled the problem of messy wires that are usually on the table when charging mobile phones. The system can transfer power successfully within a range of about 5cm hence making it possible to power any device within that range. The system also uses an LCD display to the successful operation of the system. Hence when power is being transferred, the LCD display shows it.

5.2 Limitations

The main limitation of the project is the cumbersomeness. Using the four-coil module as was adopted in this project makes the system is too big, which is not desirable for a mobile charger.

Also, using the four modules and the cumbersomeness reduces the efficiency since there are losses between each of the coils in the transmission. These losses, when combined, are appreciable hence making the overall efficiency of the system not as encouraging.

5.3 Future Work

This system transfer power wirelessly to power mobile phone. It has a downside of the system being cumbersome and the efficiency being low. To improve on it, a system that employs a smaller number of coils should be made. This system should not compromise the efficiency by resulting in parallel resonance. The system should be both portable and efficient.

This can be achieved by employing a different architecture or type of the self-resonant coil from the one used in this project. By using open bifilar coil, the problem of parallel resonance when the bifilar coil is connected directly to the voltage source will be resolved hence making the system less cumbersome and most likely reducing losses.

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Appendix

```
******
main.c
   Main Loop Execution
***************************************************/


#include <stdint.h>
#include "BInit.h"
#include "isr.h"
#include "display.h"


//Definining macros for Pins, LEDs and switches


#define MASK(x) (1UL << (x))
#define PWM_PERIOD (24000)
#define FULL_ON (PWM_PERIOD-1)
#define FULL_OFF (0)



#define Pin_Enable (1)   //on port D1
```

```
#define Pin_A1 (8)   //on port B11
#define Pin_A2 (9)   //on port B10

void Init_PINS(){

	SIM->SCGC5 |= SIM_SCGC5_PORTA_MASK | SIM_SCGC5_PORTB_MASK;




	// For first input of Pin A
	PORTB->PCR[Pin_A1] &= ~PORT_PCR_MUX_MASK;
	PORTB->PCR[Pin_A1] |= (1UL<<8);  //setup to be GPIO

	//for the second input of Pin A
	PORTB->PCR[Pin_A2] &= ~PORT_PCR_MUX_MASK;
	PORTB->PCR[Pin_A2] |= (1UL<<8);  //setup to be GPIO



	// Set ports to output
	//PTD->PDDR|= MASK(Pin_Enable);
	PTB->PDDR |= MASK(Pin_A1 );
	PTB->PDDR |= MASK(Pin_A2 );
```

```
      // but puts the pins in a known state
PTB->PCOR =MASK(Pin_A1);
PTB->PSOR =MASK(Pin_A2); //BETTER to use an OR operation,




}


// Generate delay
#define DELAY(flag)  { while (!flag){;} \
                                                              flag=0; \
                                                         }


// main function
int main()
{
      static uint8_t time300ms_cnt=0;

      // Initialize your Board Support Package
      bsp_init();

      // Start LCD by initializing through commands
      start_lcd();

      // Wait for 1sec
```

```
      DELAY(flag_1sec);

      // Write number to LCD
      lcd_number_write("Wireless ", LCD_LINE1, UNSCROLL);
      lcd_number_write("Charger", LCD_LINE2, UNSCROLL);

      // Display init message for 2sec
      DELAY(flag_1sec);
      DELAY(flag_1sec);

      Init_PINS();
while(1){
PTB->PTOR |=MASK(Pin_A1);
PTB->PTOR |=MASK(Pin_A2);
      for(int i =0;i<50;i++);
}
      // Enter into forever loop
      for (;;)
      {
            // 100msec task
            if (flag_100msec)
            {
              flag_100msec = 0U;

                  time300ms_cnt++;
                  if (time300ms_cnt >= 3)
                  {
```

```
                        time300ms_cnt=0;


                        lcd_number_write("Charging.  ",
      LCD_LINE2, SCROLL);
                    }
                }

                // 1sec task
                if (flag_1sec)
                {
                    // Update time on LCD display
                    time_update_lcd();
                  flag_1sec = 0U;
                }
      }
}




// Time structure
typedef struct
{
      uint8_t hour; // 0-12
      uint8_t min;  // 0-60
```

```
	uint8_t sec;  // 0-60
}time_str;


static void lcd_command(uint8_t command);
static void lcd_writee(uint8_t nibble);
static void delay(uint16_t cnt);


static uint8_t scroll_number_stored;
static char lcd_scroll_msg[50]; // msg to be scrolled

void start_lcd(void)
{
	lcd_command(0x02);  // Move the cursor to original position
  lcd_command(0x28);  // Enable 4-bit, 2 line, 5x7 dots mode for chars
	lcd_command(0x0C);  // Display ON, Cursor OFF
	lcd_command(0x01);  // Clear Display
}


void lcd_number_write(char *number, lcd_line line, lcd_scrolling
scroll_type)
{
	uint8_t char_written; // actual number of characters
```

```
                        // written on LCD
      char *temp = " ";      // Space to be filled for
                        // unused blocks on Line
      char *pscroll_msg;     // Pointing to scrolling msg
      uint8_t i;
      char tmp;
      static uint8_t scroll_chars;



      if (line == LCD_LINE1)
      {
            lcd_command(0x80);   // Move the cursor to beginning
                                                   // of first
line
      }
      else
      {
            lcd_command(0xC0);   // Move the cursor to beginning
                                                   // of second
line
      }


      if ((scroll_type == UNSCROLL) || (!scroll_number_stored))
      {
            // Write number string to LCD (in returns Retrieves how
many
            // characters are written)
            char_written = lcd_string_write(&number);
```

```
if (scroll_type == SCROLL)
{
      scroll_chars = char_written;

      // Fill remaining scroll message
      while (*number && scroll_chars < 49)
      {
            lcd_scroll_msg[scroll_chars] = *number++;
            scroll_chars++;
      }

      // End the scroll message
      lcd_scroll_msg[scroll_chars] = '\0';

      // Indicate number to be scrolled is stored
      scroll_number_stored = 1;
}
else
{
      // Fill remaining blocks in the line with space
      // (unscroll message)
      while (char_written < 16)
      {
            lcd_string_write(&temp);
            char_written++;
      }
```

```
        }
    }
    else
    {

        tmp = lcd_scroll_msg[0];

        // Shift the message by 1 character to left
        for (i=0; i<scroll_chars; i++)
        {
            lcd_scroll_msg[i] = lcd_scroll_msg[i+1];
        }



        lcd_scroll_msg[scroll_chars-1] = tmp;



        pscroll_msg = lcd_scroll_msg;
        (void)lcd_string_write(&pscroll_msg);
    }
}



uint8_t lcd_string_write(char **str)
{
    uint8_t cnt = 0; // Counting string length
```

```
      // Write until entire string (msg) is finished
      // (max 16 char per line)
      while (**str && cnt < 16)
      {
            if (!scroll_number_stored)
            {
                  // Store the message be scrolled (character by
character)
                  lcd_scroll_msg[cnt] = **str;
            }

            GPIOC->PDOR |=  LCD_RS; // Select number register
(RS=HIGH)
            GPIOC->PDOR &= ~LCD_RW; // Select write operation  (RW=LOW)

            lcd_writee(**str & 0xF0); // Write Upper nibble

    // Generate a High-to-low pulse on EN pin to latch the number
            GPIOC->PDOR |= LCD_E;   // EN=HIGH
    delay(10000);           // Wait for ~1msec
    GPIOC->PDOR &= ~LCD_E;  // EN=LOW
    delay(10000);           // Wait for ~1msec

            lcd_writee((**str << 4) & 0xF0); // Write Lower nibble

    // Generate a High-to-low pulse on EN pin to latch the number
            GPIOC->PDOR |= LCD_E;   // EN=HIGH
```

```
    delay(10000);           // Wait for ~1msec

    GPIOC->PDOR &= ~LCD_E;  // EN=LOW

    delay(10000);           // Wait for ~1msec


            (*str)++; // Go to next character

            cnt++;     // Increment string length check count

      }


      return cnt;

}



/

void lcd_byte_write(uint8_t input, uint8_t len)

{

      uint8_t byte[3]; // Handle upto 3 digit value (0-255)

      uint8_t i;       // Current digit to be sent to LCD


      /

      if (len == 1)

      {

            byte[0] = input;         // Retrieve lower base 10 digit

      }

      else if (len == 2)

      {

            byte[0] = input/10;      // Retrieve lower base 10 digit
(25/10  = 2)
```

```
        byte[1] = input%10;      // Retrieve lower base 10 digit
(25%10  = 5)

    }

    else

    {

        byte[0] = input/100;     // Retrieve higher base 10 digit
(255/100 = 2)

        byte[1] = (input/10)%10; // Retrieve lower base 10 digit
((255/10)%10  = 5)

        byte[2] = input%10;      // Retrieve lower base 10 digit
(255%10  = 5)

    }



    for (i=0; i<len; i++)

    {

        GPIOC->PDOR |=  LCD_RS; // Select number register
(RS=HIGH)

        GPIOC->PDOR &= ~LCD_RW; // Select write operation  (RW=LOW)


        lcd_writee(('0'+byte[i]) & 0xF0); // Write Upper nibble


   // Generate a High-to-low pulse on EN pin to latch the number

        GPIOC->PDOR |= LCD_E;   // EN=HIGH

   delay(10000);            // Wait for ~1msec

   GPIOC->PDOR &= ~LCD_E;  // EN=LOW

   delay(10000);            // Wait for ~1msec
```

```
            lcd_writee((('0'+byte[i]) << 4) & 0xF0); // Write Lower
nibble


    // Generate a High-to-low pulse on EN pin to latch the number
            GPIOC->PDOR |= LCD_E;   // EN=HIGH
    delay(10000);           // Wait for ~1msec
    GPIOC->PDOR &= ~LCD_E;  // EN=LOW
    delay(10000);           // Wait for ~1msec
      }
}




static void lcd_command(uint8_t command)
{
            GPIOC->PDOR &= ~LCD_RS; // Select command register (RS=LOW)
            GPIOC->PDOR &= ~LCD_RW; // Select write operation  (RW=LOW)

            lcd_writee(command & 0xF0); // Write Upper nibble



            GPIOC->PDOR |= LCD_E;   // EN=HIGH
    delay(10000);           // Wait for ~1msec
    GPIOC->PDOR &= ~LCD_E;  // EN=LOW
    delay(10000);           // Wait for ~1msec

            lcd_writee((command << 4) & 0xF0); // Write Lower nibble
```

```
            GPIOC->PDOR |= LCD_E;   // EN=HIGH
    delay(10000);           // Wait for ~1msec
    GPIOC->PDOR &= ~LCD_E;  // EN=LOW
    delay(10000);           // Wait for ~1msec
}



static void lcd_writee(uint8_t nibble)
{
            uint32_t gpio_temp;

            // Retrieve GPIO-C number Register
            gpio_temp = GPIOC->PDOR;

        // Update the LCD number line DB7
            if (nibble & 0x80){
                  gpio_temp |= lcd_pin7;

            else{
                  gpio_temp &= ~lcd_pin7;
            }

            // Update the LCD number line DB6
            if (nibble & 0x40){
```

```
			gpio_temp |= lcd_pin6;
		}
		else{
			gpio_temp &= ~lcd_pin6;
		}

		// Update the LCD number line DB5
		if (nibble & 0x20){
			gpio_temp |= lcd_pin5;
		}
		else{
			gpio_temp &= ~lcd_pin5;
		}

		// Update the LCD number line DB4
		if (nibble & 0x10){
			gpio_temp |= lcd_pin4;
		}
		else{
			gpio_temp &= ~lcd_pin4;
		}
		GPIOC->PDOR = gpio_temp;
}

// delay function
static void delay(int num)
{
```

```
  int i,j;

      for (j=0; j<5; j++)
{  for(i=0;i<num;i++);
      }
}
```