Contact-less Battery Charger

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Acknowledgement

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Abstract:

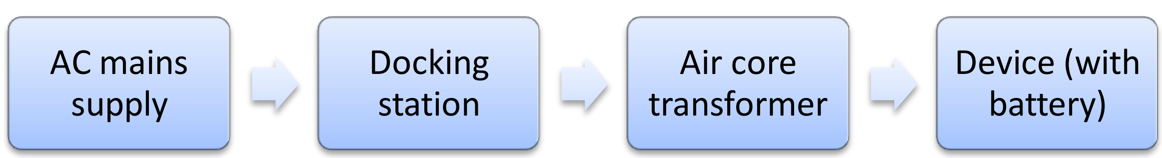
The report discusses the development of a contactless battery charger, devised for small-scale applications like mobile phones, ipods and mp3 players. These modern-day appliances are provided with their own battery chargers, creating a regiment of the chargers at modern homes. In addition to it, the constant plugging in and out of the charger cords results in the devices getting damaged over a period of time. Our project explores the possibility of devising a common battery charger for all these devices, which also eliminates the need for electrical contacts, an important step in making these devices waterproof. The basic principle involved is inductive power transfer from a docking station to the device, using an assembly similar to an air-core transformer. An in-built communication block enables the device to communicate its power rating to the docking station. At present, the circuit has been tested to provide FSK communication and transfer of about 300 mW of power.

1. *Introduction*

With the invention of the portable cells/batteries, the world essentially became more "portable". Mobile appliances like cellphones, ipods, mp3 players all work on batteries, which need to be charged regularly. The power requirement of the devices being all different, each device is provided with its own battery charger which regulates the power flow to the device and checks for its charging status. Carrying so many chargers with oneself can be tedious. The plugging in and out of the cords, as mentioned earlier, can (and does) damage the electrical contacts over a period of time.

A possible solution to these problems is the contact-less battery charger. The present design works on the principle of inductive power transfer, with an assembly similar to that of an air-core transformer. The primary coil, which is placed in the docking station is linked magnetically to the secondary coil, which is present in the device. The magnetic coupling couples power and by selecting appropriate values of the transformer specifications, we can achieve power transfer via the magnetic medium, which then drives the load (here the battery charging).

The block diagram of the battery charging scheme is as follows:



An interlude: the status as of the making of this report:

The project is incomplete as of the making of the report. However all individual components of the project have been made and tested successfully on breadboard, and most on PCB. We are in the process of transferring them onto PCB, which took more iterations for the power circuit than we had previously planned. The use of ac mains and better coils will help us to increase the wattage to the required levels. As of now, the communication part is working and tested on PCB, while the power circuit is to be completed on PCB. We have also begun interfacing with the mains power supply.

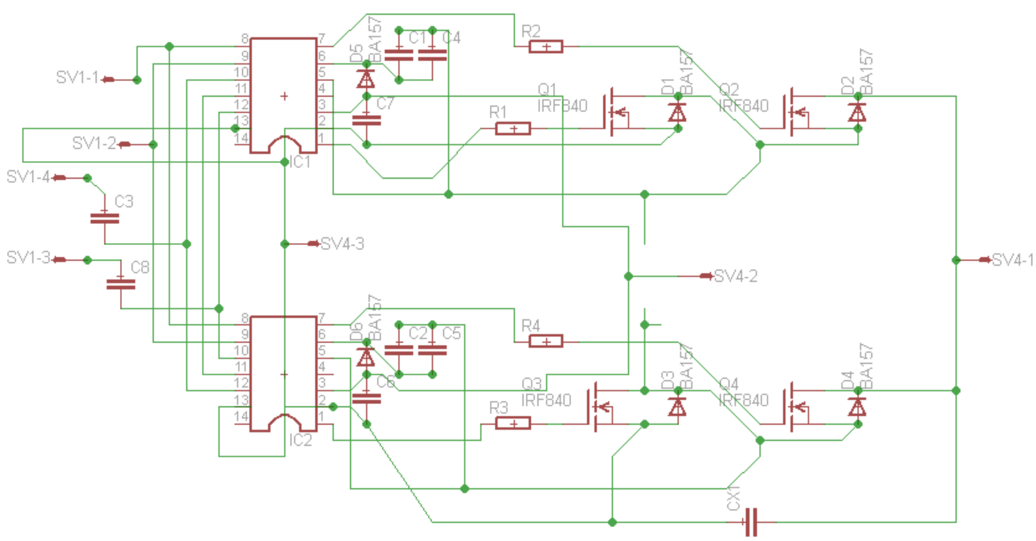
2. *Implementation*

2.1 Docking Station

The docking station is the heart of the battery charger. The docking station hosts the power supply circuit, the primary coil, and the communication block to communicate with the charging device. The essential parts are (the communication is an extra feature and has been explained in section 1.4):

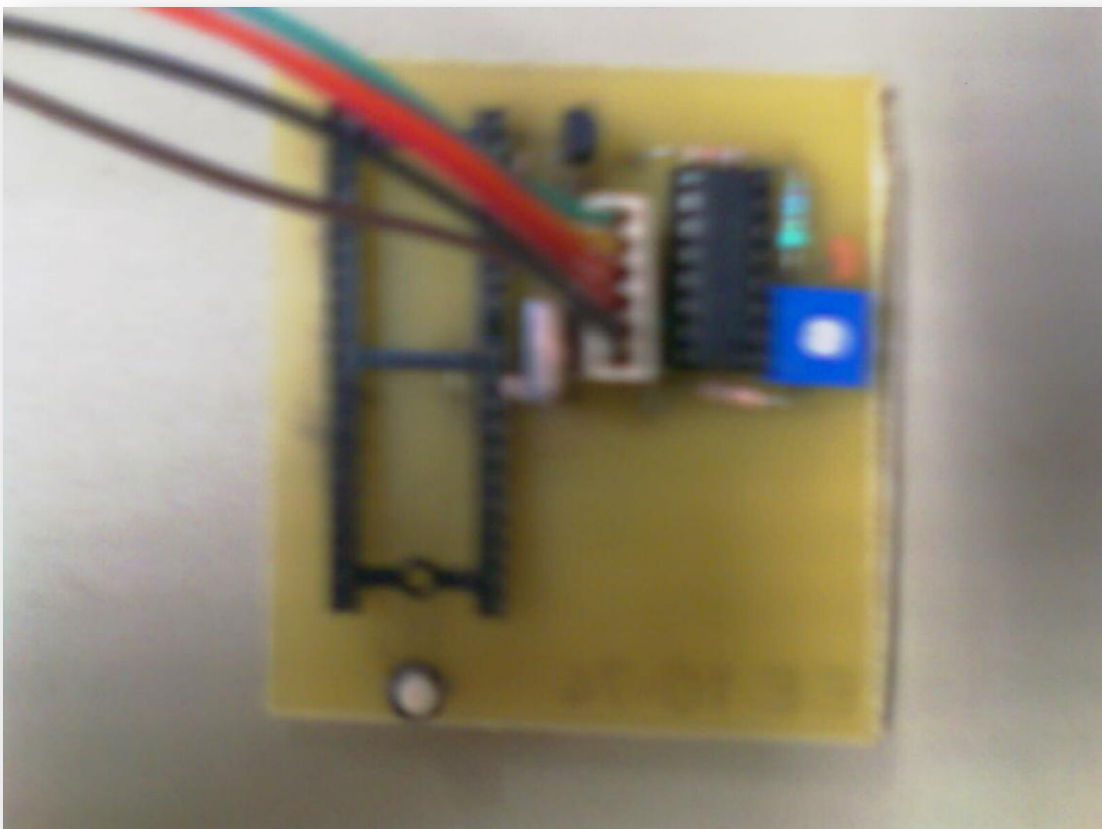
a) Power supply circuitry – The charger works on 230 V mains, hence the voltage needs to be stepped down to what the circuit can sustain. This is done with a small 50Hz step-down transformer, after which the voltage is rectified, regulated and brought down to normal 15V and 5V supplies. The high voltage rail is obtained by rectifying the input mains with a full wave rectifier. This brings that voltage to about 300V, with a small ripple. The circuits used in this section are fairly standard.

b) Full bridge – Use of the full bridge topology ensures that power is not wasted even though the secondary is only loosely coupled. Power built in the ON time is not dissipated across parasitic (or other) resistances, but is dumped back into the supply in deadtime. The schematic is shown below:



The IC packages shown are IR2110 power MOSFET drivers. The MOSFETs we used were IRF840 power MOSFETs. These were chosen in accordance with the expected rail voltage and current capacity required for our application. All capacitors shown are 1nF and the resistances we used are 10 ohm. Free-wheeling diodes are ultrafast power diodes, while the bootstrap diodes are fast BA159's. Ringing is brought down through splitting the above onto two PCB's and closely packed design of the half-boards thus obtained. Use of lakes for power (i.e. high current) tracks reduces the parasitic inductances involved, as does the low area design. Placing a polyester capacitor across the rails reduces noise interference due to the RF operation of the circuit.

c) Pulse Width Modulation circuit – This circuit is used, ultimately, to create a square wave to drive the MOSFET bridge. The two frequencies used are 200 kHz and 225 kHz. These are close enough that the magnetic circuit is practically the same and there is sufficient resolution in a phase locked loop output. A picture of the completed board is included:



d) Primary Coil – The raison d'etre of the docking station is the primary coil. We have tried multiple topologies from smaller circular coils to PCB printed spiral coils. The coil we are presently testing is a rectangular (10.5 by 6 cm) coil of 20 turns with 33 SWG wire. The inductance, as measured using an inductometer, is 63uH. This ensures that the IRF840 rating is not exceeded when there is no coupling and provides sufficient area for placement of the secondary.

2.2 Device

The device is the second half of the assembly, and is designed in a manner a lot similar to the modern day devices, except that it contains the secondary coil, and no electrical opening. The device has the following blocks:

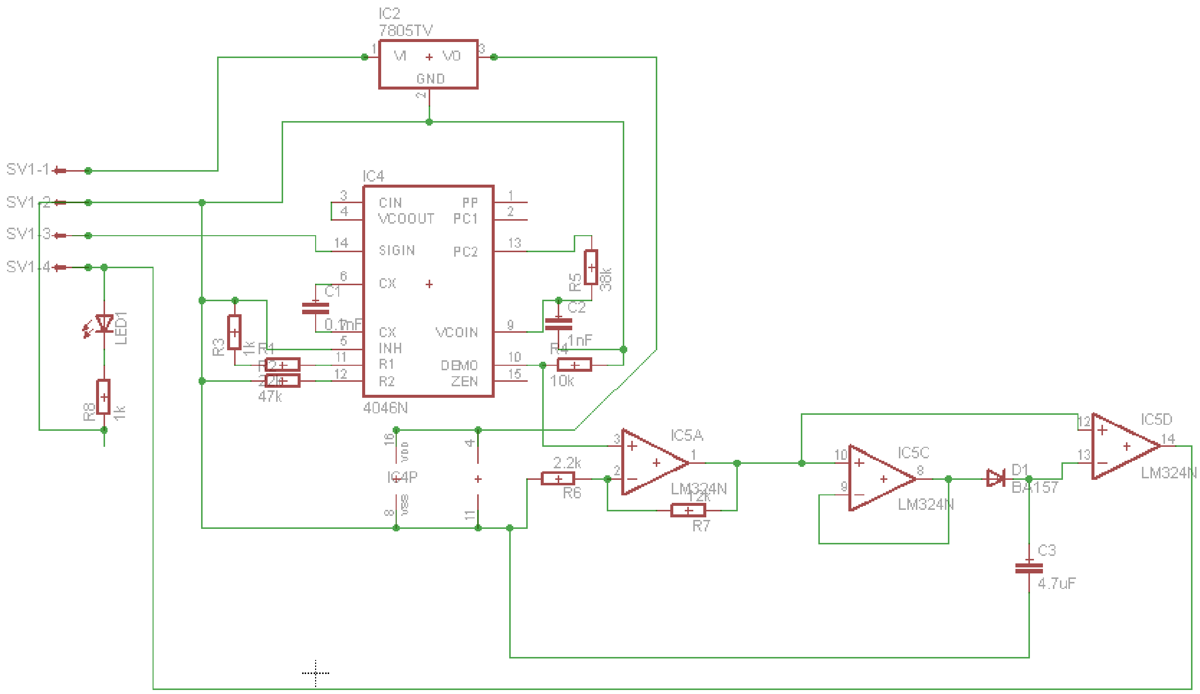
a) Secondary coil – The device contains the secondary coil, which responds magnetically to the varying current in the primary coil, to develop a voltage across itself and supply the required current to the battery charging circuit.
b) Rectifier and regulator circuitry – The rectifier circuitry is a simple full wave rectifier, employing fast power diodes. The waveform obtained at the output is provided to the regulator circuit. The regulator is a standard circuit. The regulator operating values have been decided according to the battery charging circuit. Again, as in the mains supply part, these circuits are standard.
c) The battery charging circuit – The battery charging circuit (which has been constructed to charge only Li-ion batteries for now, but the theory and construction is exactly similar for other batteries) consists of a BQ24086, which has in-built functions of the 3 stages of battery charging, checking for over and under-voltage and terminating the charging by checking the temperature of the battery pack. Temperature check is the most reliable method of checking whether a Li-ion battery is charged, as opposed to checking the voltage across or the current through the battery.

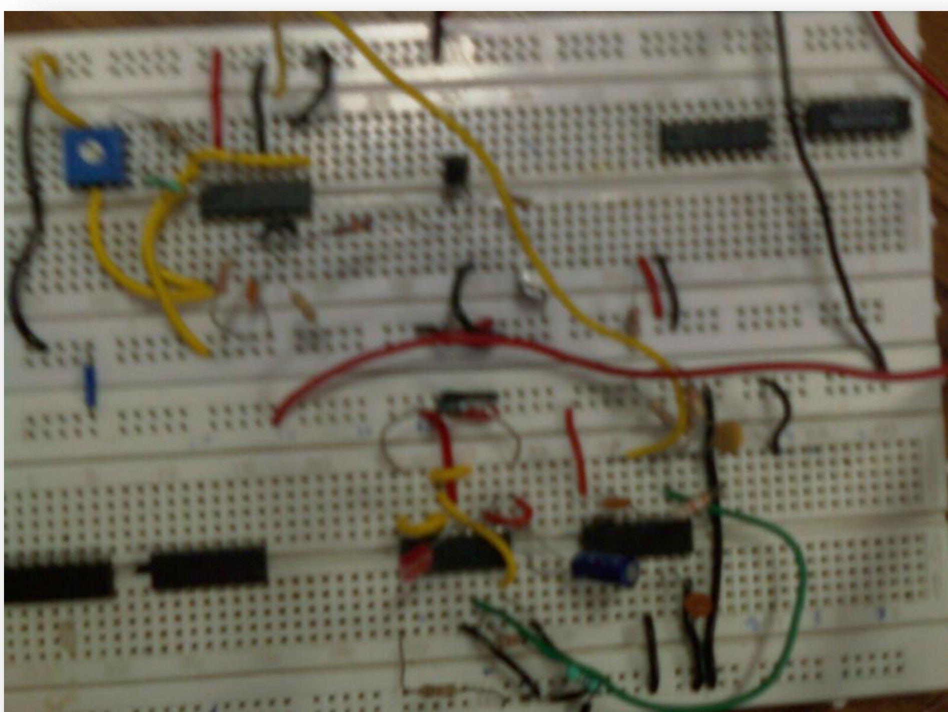
3. *Communication*

The communication is an extra feature provided in the contact-less battery charger. FSK modulating scheme is used for communication, and wireless communication, through the coils themselves, is a special feature of the scheme. The communication circuitry is as follows:

a) Frequency Shift Keying – The frequencies used in the scheme are 200 kHz and 225 kHz, for HI and LO respectively. The shifting is made possible by varying the resistance (R_T) and hence, the charging and discharging time of the oscillator of the PWM IC SG3525.
b) ATMEGA 16 – The information to be sent is through the USART scheme of the uC. Baud rate used is 2400 baud. Communication is by the packet system, every byte being a packet. Our choice of the microcontroller was determined mainly by our ease and familiarity with the ATMEG16. Earlier on, we had thought that the uC would be used extensively to actually regulate the charging of the battery. However, this proved unnecessary due to the available BQ240XX series which takes care of intelligent charging, including thermal sensing. However, the uC remains to demonstrate the proof of concept of communication. Integrated into a larger appliance, the circuit would naturally change and the uC chosen would then depend on the type of application.
c) Phase Locked Loop – A phase locked loop circuit employing the CD4046 is used to demodulate. This is then fed to a level translator circuit, which converts the HI and LO levels given by the CD4046 to standard TTL 5V-0V. CD 4046 has been used as the PLL IC and it supplies about 0.3V and 0.6V for HI and LO levels respectively. Forward communication occurs through the coils in a

smooth manner without hindering the power transfer. Back communication (from the device to the docking station) can be made possible by temporarily making the primary “float”. The circuitry on the device side need to work only for some milliseconds and a 10uF capacitor suffices to store enough charge for this. A schematic of the circuit used is included below:





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4. *Further work*

PCB testing of the power circuit was delayed due to the iterations we went through while designing the power board. As of now, the boards are made and we will test them subsequently. As for the project itself, the scope of the application we have chosen is wide. Extending the charger for different types of batteries, allowing multiple devices to charge simultaneously are some possibilities that can be explored. The use of resonant circuits can bring down the voltages we have employed extensively. However they also require fine tuning in terms of the In addition, the concept itself has far reaching applications. Referring to our preliminary discussions with Prof. Dipankar, the idea could be used to make an efficient desoldering gun, which works on SMD components as well.

5. *Conclusion*

Inductive Power Transfer has been used for near-field applications till now. This project uses the concept for power transfer through an air core, with no RF intervention. Seeing the efficiency and the clarity of the concept as well as its byproducts like more robust, water-proof devices, this technology is one that can provide a detour to the future of hand-held appliances as well as, more generally, to the field of power systems.

Of course, a lot of work still needs to be done to make the charger compatible with all kinds of batteries at the same time, as well as make it more efficient so that it can charge more than one batteries at the same time.

6. *References*

Datasheets of the following IC’s: IR2110, IRF840, SG3525, CD4046, BQ24086,

Application notes: AN-978

Electronics club’s very helpful AVR tutorial

Prof. Dipankar ☺

Appendix:

The code for transmission is as follows:

```
#include <util/delay.h>          // contains the function _delay_ms()
#include <avr/interrupt.h>

void uart_init(unsigned int ubrrval){

        UCSRA = 0b00100000;
        UCSRB = 0b00011000;
        UCSRC = 0b10000110;
        UBRRH = (unsigned int) (ubrrval>>8);
        UBRRL = (unsigned int) ubrrval;
}

void uart_tx(unsigned char data){

        while ( !(UCSRA & _BV(UDRE)) );    // wait until UDR is empty
        UDR = data;
}

int main(){

        uart_init(0x19);
        char data[15];
        int i =14;
        while (i>=0){
                data[i] = 65+i;
                uart_tx(data[i]);
                _delay_ms(1000);
                i--;
        }
        return 0;
}
```

The reception code is:

```
#include <avr/io.h>                      // contains definitions for DDRB, PORTB
#include <util/delay.h>          // contains the function _delay_ms()
#include <avr/interrupt.h>
#include "lcdroutines.h"

void uart_init(unsigned int ubrrval){

        UCSRA = 0b00100000;
        UCSRB = 0b00011000;
        UCSRC = 0b10000110;
        UBRRH = (unsigned int) (ubrrval>>8);
        UBRRL = (unsigned int) ubrrval;

}
```

```c
unsigned char uart_rx(void){

        while ( !(UCSRA & _BV(RXC)) );   // wait until receive complete
        return UDR;

}


int main(){

        MCUCSR |= _BV(JTD);
        MCUCSR |= _BV(JTD);

        uart_init(0x19);
        lcd_init();
        char data[10];
        int i =9;
        while (i>=0){

                data[i] = uart_rx();
                lcd_clear();
                display_char(data[i]);
                i--;

        }
        return 0;
}
```