Portable Solar Charger using Solar and Vibrational Energy

Group - DD12

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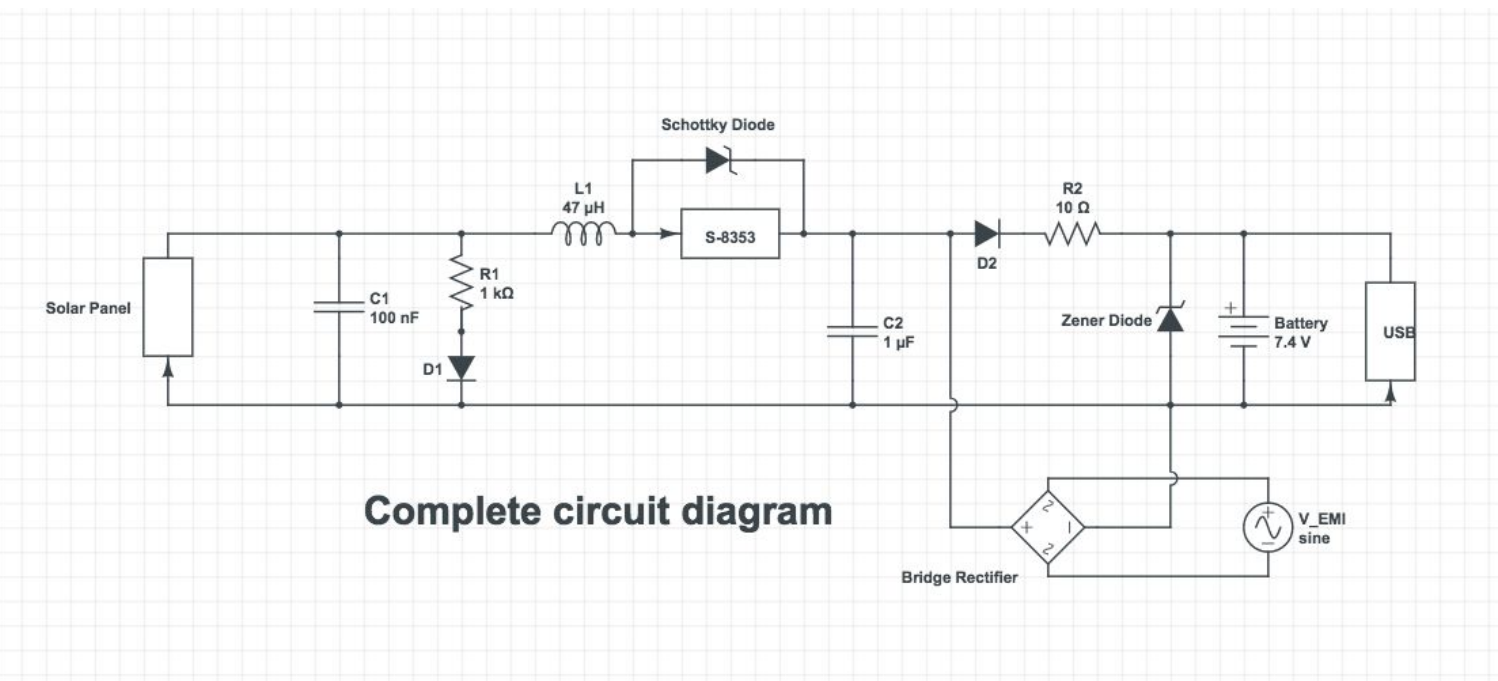
Project Abstract

Cell phones have become an integral part of our day to day life. They have become our primary source of communication and information exchange. With multiple applications working simultaneously on smartphones, the battery life has reduced drastically when compared with older handsets. Thus more frequent charging has become necessary.
During commute to work, in long distance trains or remote area, access to regular power supply from power outlets is not always available. This brings in the need of a portable charger which does not rely on the grid and is handy to carry everywhere easily.
The aim of this project is to build a portable charger which works by harvesting solar energy and vibrational energy. By using only renewable sources of energy we aim to design a green charger which can be used in places lacking the availability of a mobile charging facility.



Complete circuit diagram

Contents

Project Description

Background and motivation

Portable chargers are very convenient devices in today's world of smartphones. One of the common problems experienced while travelling in long distance trains is the non-availability of mobile charging facility due to a variety of reasons. Similarly electrical power supply is not available in remote areas.

Project Objective

The project is aimed at developing a portable charger using simplistically harvestable renewable energy sources. The charger is designed to use solar and vibrational energy.

Specifications

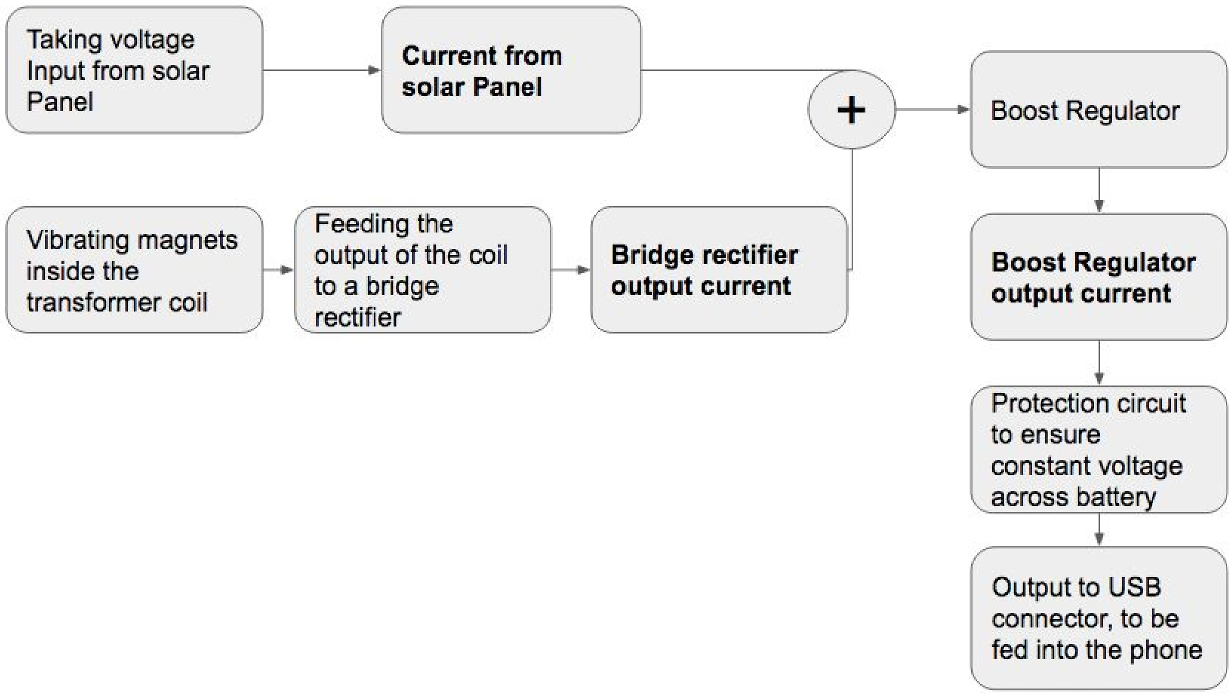
i) Customer specification

It should provide adequate current output and good charging speeds. It should give a voltage output of 5V. It should have features like voltage and current regulation, over-current protection, and high- and low-voltage cut-off.

ii) Technical specification (derived from the customer specs)

It should have a voltage of 5V.

It should have a current of approximately of 500mA.



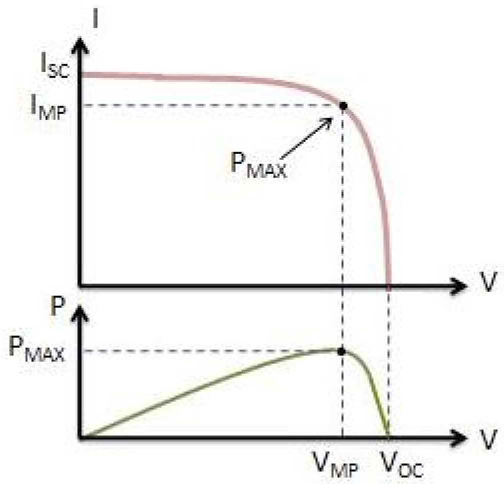
Block Diagram

Circuit Diagram

Project Design

Solar Component

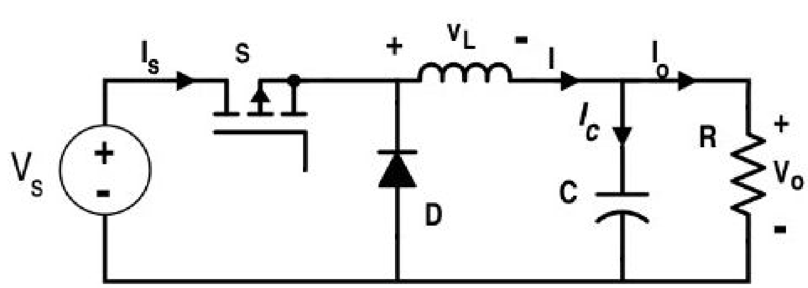
The output of the solar panel, has a voltage current curve, that looks as follows in theory.



We checked the output of the solar panel, i.e. the current and voltage at various loads, keeping it in sunlight. The solar panel had to be resoldered again, as to ensure sturdy connections (since the plug extension had to be removed from it). We can obtain a rough estimate of the operating point, using this characterization, the V-I table for different loads is at the end of this section. The output from the solar panel is not always a constant voltage, due to change in the angle subtended by the sun on the panel. Hence, we get a slightly fluctuating voltage. But, the main concern is that when a user will move with this charger, the change in illumination with time can be very random hence the solar panel output will be very fluctuating. To ensure that the battery gets constant current, we used a regulator circuit, the working of which is described below.

Linear regulators are a great choice for powering very low powered devices or applications where the difference between the input voltage and output voltage is small. They are a simple and cheap solution, but linear regulators are normally inefficient because the difference between the input voltage and regulated output voltage is continually dissipated as heat, hence we use switching regulators for this purpose. Also linear regulators are bulky as compared to switching which makes switching regulators more preferable for this application. We have used a generic boost regulator, which will be discussed in the report ahead.

Boost converter



A Boost converter is a switch mode DC to DC converter in which the output voltage is greater than the input voltage. It is also called as step up converter. The name step up converter comes from the fact that analogous to step up transformer the input voltage is stepped up to a level greater than the input voltage. By law of conservation of energy the input power has to be equal to output power.
Boost converter is suited for our application, because the voltage we normally get from the solar panel is less than 5V as we can see from the table. The regulator we use, regulates the voltage at a constant of 5V, which is necessary for charging the battery.

The main working principle of boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is OFF the inductor stores energy in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures a constant output voltage. Analyzing the circuit in the ON and OFF state of the switch, and using the 2 principles that -:

1) inductor does not allow sudden change of current
2) the currents at the start and end of a duty cycle are the same
The relation between the input and output voltages of the boost converter is as follows-:

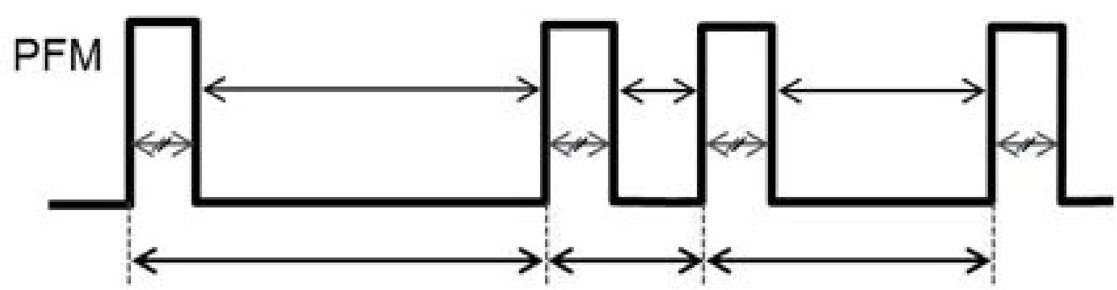
$$\frac{V_o}{V_i} = \frac{1}{1-D}$$

Pulse Frequency Modulation

The boost converter mentioned above, works on the idea of switching regulators. The expression we derived above, holds for a PWM based boost converter, where the duty cycle changes with feedback. The boost converter switching IC can be fed the output of the boost converter, based on which the duty cycle of the boost converter can be changed to regulate the output. This is how conventional PWM regulation works.

We tried an approach different from PWM, namely Pulse frequency modulation. Instead of modifying the duty cycle of a fixed-frequency square wave to regulate the output of a power supply, it is also possible to use a constant duty cycle and then modulate the square wave's frequency (PFM) to achieve regulation. When the load increases, the number of on-times in a given length of time is increased to keep pace with the load. Which in other words means that under a heavy load, the frequency increases, and under a light load it diminishes.

This is an advantage in case of light-load operations, because not a great deal of power needs to be added when the switching frequency is reduced. As the number of required switching operations decreases, the switching losses also decrease. As a consequence, the PFM method ensures that high efficiency is maintained even at a light load. But it also has a disadvantage that , when the frequency varies, the noise associated with the switching remains indefinite, making the filtering process difficult to control and the noise difficult to remove.



Circuit Explanation of IC

Dummy calc of diff values

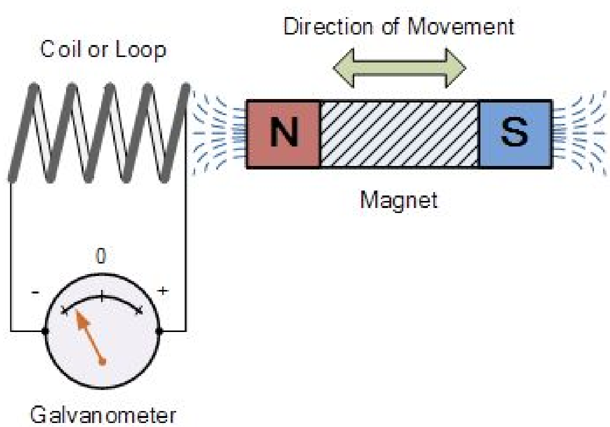
Final summary

The Vibration Component -:

The second orthogonal component of our project was to harvest the energy in vibrations and oscillations as to generate EMF. The generated EMF then charges the battery, which in turn is then supposed to charge the phone.

Electromagnetic Induction using Vibrations

It is a well known fact, that If we keep a bar magnet stationary and move a coil back and forth within the magnetic field an electric current would be induced in the coil. The relative motion between the coil and the magnetic field induces a voltage and current within the coil and this process is known as Electromagnetic Induction and is the basic principle of operation of transformers, motors and generators. Hence, the motion (vibrations) of a magnet in the vicinity of a coil can in principle generate alternating voltage. We have tried to incorporate this idea in our project for the



vibrations part.
The EMF generated due to Electromagnetic induction is given by the formula
$$ E = - Nd(phi)/dt$$.
$$E = - NAd(B)/dt$$
Hence, a coil with higher number of turns per unit length as well as magnets with high enough magnetic strength are required for charging the battery successfully, and in turn charging the phone.

<Insert inductance current relations and calculations>

Transformer Coils and Related Experiments

We started off with a primary construction of a coil with roughly 120 turns per metre.
On characterizing that coil, we obtained the following readings

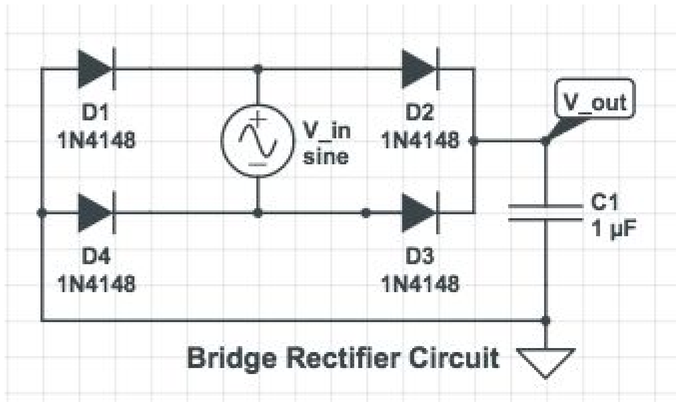
Voltage Output	**Load**
0.07 V	Open Circuit
0.04V	10 Ohm
1mV	1 KiloOhm

It is clearly visible that such a coil is not sufficient for generating a high enough voltage, hence we obtained the coil of a transformer with 5000 turns per metre to see the performance.

Voltage Output	**Load**	**Current**
12V	Open Circuit	0
10V	10 KiloOhm	1mA
5V	1 KiloOhm	5mA
1.5V	100 Ohm	15mA

We used a stack of 8 Neodymium magnets, each of which had a strength of 1-1.3 T. To and fro motion of this magnetic stack in the coil, when connected across a load, generates the EMF and currents as mentioned in the above table. Since the current is of the order of milli Amperes, it is sufficient to light up an LED and also to charge a battery. Since vibrations give rise to alternating EMF, we need some apparatus to ensure a constant DC (or unidirectional input to the battery). For this purpose we use a bridge rectifier as follows -:

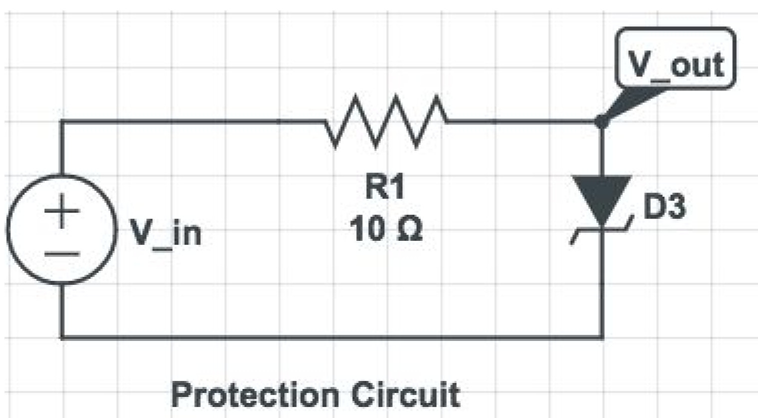
Augmenting Bridge Rectifier to the Vibration Module



The above diagram shows the circuit of a bridge rectifier. Voltage generated by vibrations is bound to have a time varying AC component, hence irrespective of whatever we use for generating vibrations we will need to use a bridge rectifier as to get a positive DC valued output to feed to the battery.

Integrating both subsystems -:

Protection Circuit -:



V_in is the input from the battery, which is then fed to the USB connector for charging the phone. Due to the zener diode, even if there is a voltage surge, the output will never cross 5V, as to prevent damage to the device. The characterization of the V_in and V_out was done to see whether this works properly, the table is as follows -:

V_in	V_out
1V	0.83V
2V	1.77V
3V	2.6V
4V	3.55V
5V	4.4V
6V	5V

Project Implementation

Experiments related to project

A brief summary of the experiments to find an appropriate characterization of the required subsystems is hence as follows -:

Solar Panel

We used a solar panel that gives an open circuit voltage of 5.5 V and a maximum current of 220 mA (acc. To specifications). Measured the output of solar panel under different lighting conditions:- indoors ambient light, under an incandescent lamp and outdoors in sun. It was observed that the output current was negligible indoors under ambient light even if it gave small amount of open circuit voltage. It was further characterized by varying the load resistance.

<Insert table of solar panel>

Piezoelectric

The piezoelectric sensors are devices sensitive to variation in pressure. On applying pressure on the sensor the capacitance across it changes. This causes an electrical impulse proportional to applied pressure in the piezoelectric material.

We tested them by connecting 10 sensors in parallel, to add the current through each sensor. Pressure impulses were applied with the help flat objects, so as to affect each sensor equally.
It was observed that while they output voltages up to few milliVolts, their current output was in the range of microAmperes. This can be explained as they have internal resistance of the order megaohms.

<Insert image of piezo sensors>

Buck-boost converter simulation
The output voltage from solar panel was measured to be fluctuating, depending on lighting conditions. Thus to convert it to desired regulated voltage value a buck boost converter is needed. Simulink model of the buck-boost converter was prepared and simulations were done by varying the resistance, inductance and duty-cycle of switch. It was observed to give constant stepped up/down, according to duty cycle. This was done as an ephemeris to see what kind of performance we can expect from a boost converter based regulator given a time varying input.
$$ V_{out} = D/(1-D) V_{in} $$

<Insert simulink image of circuit and plot>

Arduino
To regulate the output from solar panel we initially made a pwm based buck-boost converter with feedback. The pwm pulse for modulating the switch was generated using an arduino. The width of pwm was decided based on the output (feedback) and input voltage. The system was able to give regulated output. But since for the complete realization of project, power consumption of arduino was much larger than harvested by solar panel and vibration source, arduino was rejected.

ATtiny

The second option considered for pwm pulse generation was ATtiny, as it’s size was much smaller than arduino and power consumption was nominal. But since switching regulators were far more efficient at the task, ATtiny was also rejected.

Sustained vibration using a bell
We

Performance Evaluation

Prototype Details

The prototype we made consists of 2 sub systems, namely solar and vibrational, both of which ar then subsequently connected to protection circuit followed by the battery

The solar part is a PCB which houses the boost converter setup. The SMD components like schottky diode, inductor, capacitor and the switching IC E50D are soldered appropriately on the board. The schottky diode has a lesser voltage drop than normal diodes, and has a faster response due to which it is much better for switching applications. The output of this IC is used later. The IC regulates the voltage output to 5V, which is suitable for our application since the maximum voltage given by the solar cell is also of the order of 5V.
<insert PCB part solar photo>

The vibrational part
To harness the voltage generated by relative motion of the coil due to EMI, we used a transformer coil with 5000 turns, and connected it to two cylindrical extensions as to ensure smooth motion of the magnet across the coil. The alternating EMF generated through the motion of magnet across the coil, fed to a bridge rectifier which is soldered on another PCB. the output of the bridge rectifier vs Input is shown in a table above.

The Protection circuit
The output currents of the solar and vibrational part are added together and then fed to the battery. The output of the battery is connected to a protective circuit, which has a zener diode to ensure that the circuit does not have a surge of output voltage. The final output then is fed to the USB connector that charges the phone.
<Insert prototype image>

Testing and Verification Results

We adopt a general characterization strategy for **solar, vibrational** as well as a **combination** of both the subsystems. We first measure the current across various loads covering a spectrum of magnitudes, and then connect the phone across the charger. We then note the voltage across the phone, as well as the current being sent in the phone from the USB connector. Later, we charge the battery using the solar and vibrational components, and charge the phone using them Below we tabulate the results for each of the 3 cases. The testing setup is as shown in the image
<Insert image - complete setup>

Solar Component -:

Load Resistance	**Current**	**Voltage**
100 ohm	7.5 mA	0.7 V
1 Kohm	3.3 mA	3.3 V
10 Kohm	0.5 mA	5 V
Phone		

Open circuit voltage across solar panel was -: 5.13 V
Voltage across the phone obtained was -:

Vibrational Component -:

The outputs depend on how vigorously the magnetic coils is vibrated. We are reporting the values at highest frequency of vibration possible. The coil is moved by hand only as of now.

Load Resistance	Current	Voltage
100 ohm	3.4 mA	0.34 V
1 Kohm	0.61 mA	0.61 V
10 Kohm	0.215 mA	2.15 V
Phone		

Open circuit voltage was -: 3.83 V
Voltage across the phone obtained was -:

Combination of both -:

Load Resistance	Current	Voltage
100 ohm	8.3 mA	0.83
1 Kohm	4.56 mA	4.56
10 Kohm	0.512 mA	5.12
Phone		

Open circuit Voltage -: 5.3 V
Voltage across the phone obtained was -:

Final specifications

	Current	**Voltage**
Solar Panel	50mA	4.3V
Boost + Solar	39mA	5.1V
Vibrational	4mA	1.3V
Boost + Vibration	1mA	5.1V
Battery	450mA	7.5V
Phone	500mA	7.5V

F

Failures and Problems Faced