DESIGN OF ULTRA LOW POWER ENERGY HARVESTER SYSTEM USING VIBRATION INPUT FOR MOBILE PHONES.

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ABSTRACT

In this work a design of Ultra Low Power Energy Harvester (ULP EH) using vibration source for Mobile Phone is presented. Using mobile phone everywhere in this world become very common because of varies services and applications offered by this device. Mobile phone needs a power to function, and charging it considered as a time consuming process. Beside that is not all the time the power source for charging mobile phone is available everywhere. This design introduces a solution of energy constraints in mobile phone. Vibration source is related to the shaking of the mobile phone by human to generate an AC voltage. The aimed output is 5V DC resulting from vibration input of 0.5V and 2 kHz. A rectifier is used to convert the AC signal resulting from vibration source to DC voltage. Boost converter is designed to boost the small input voltage to the desired voltage. Metal Oxide Semiconductor Field-Effect Transistors (MOSFETs) are the main components used in rectifier and boost converter circuits. The Integrated Circuit (IC), 555 Timer, is used to generate a Pulse Width Modulation (PWM) signal which controls the switching of MOSFET in boost converter circuit. Regulator circuit is added after boost converter circuit in order to obtain an constant output voltage. All the circuits are integrated and combined in one circuit to make the complete energy harvester system. In this work, PSPICE software is used to design, model and simulate the circuits.

Keywords: Ultra Low Power Energy Harvester; rectifier; boost converter; MOSFET.

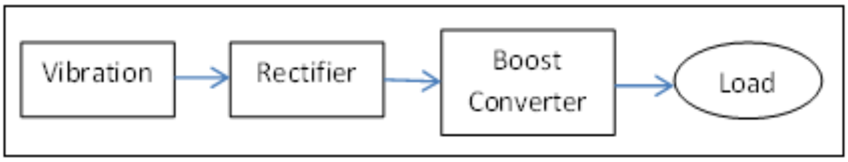
INTRODUCTION

Energy harvesting system is becoming very popular in the field of low power electronic devices (Semsudin, Sampe, Islam, Zain, & Berhanuddin, 2015). Energy can be obtained from surrounding sources such as water, solar, thermal, vibration and wind (Yao, Yeh, Hsu, Yu, & Lee, 2009). Mobile phones are widely used and people usually fall into a situation where batteries of their mobile phones are discharged, and cannot find power to recharge them on time (Albrni, Sampe, Islam, & Majlis, 2016). Charging mobile phones process is considered as a time consuming practice. It needs user's attention, appropriate electric source and specific electric wiring and connections which are considered as limitations in mobile phone (Pandey, Khan, & Gupta, 2014).

This paper illustrates an energy harvesting circuit for charging mobile phone. Vibration source produces voltage by converting mechanical energy into electrical energy. Mechanical Energy can be produced by shaking mobile phone by man hand or just by normal walking. By utilizing energy harvester source, the low power technique is developed to recharge the battery continuously for achieving success independent operation (Carreon-Bautista, Eladawy, Mohieldin, & Sanchez-Sinencio, 2014). The objective of this paper is to design a suitable circuit for harvesting the vibration energy and use it for charging mobile phone continuesly without assistance from human.

Vibration source produces AC voltage. Recifier circuit is used to convert the AC voltage into DC voltage. Power obtained from vibration source is so small and the voltage is approximately 0.5 V. Boost converter circuit is used to step-up the source voltage to the required value of 5V. Ultra Low Power Energy Harvester (ULP EH) is designed to provide an appropriate output power that can be utilized for mobile phone devices. **Error! Reference source not found.** shows the block diagram of the energy harvesting system. Next sections will explain the individual and overall circuits of energy harvester system. Then, Result from the simulation using PSpice software will be analsyed and discussed. Finally, we will conclude our research finding.

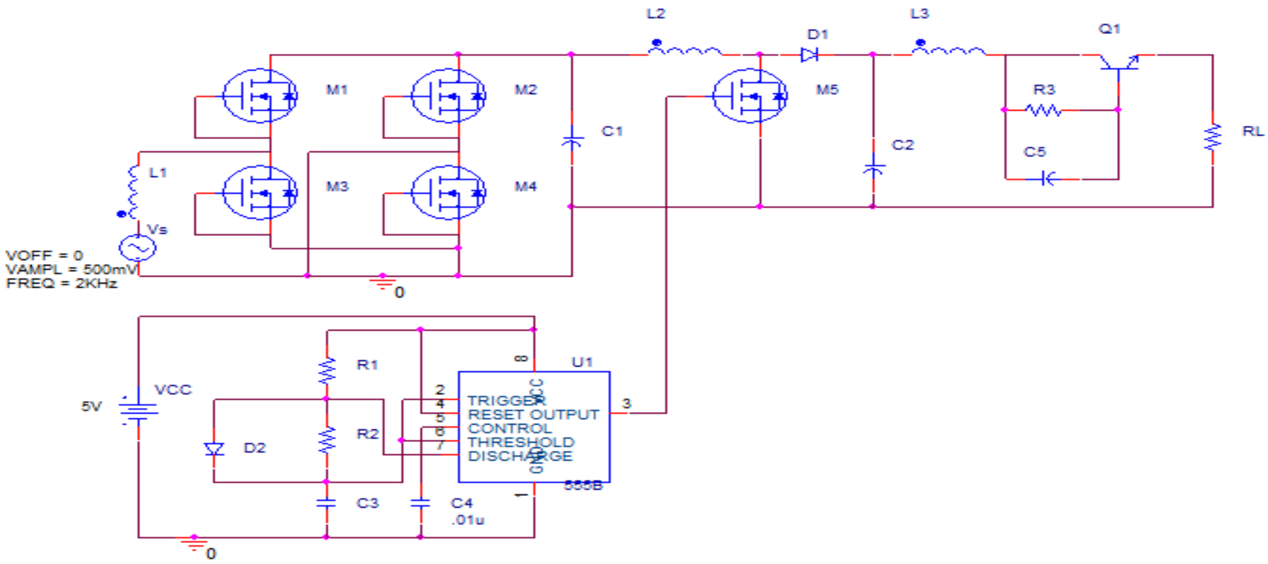
Figure 1: Block diagram of energy harvesting system



HARVESTER CIRCUIT DESIGN

The harvester system consists of two main circuits, namely: Rectifier circuit and Boost Converter circuit. Boost converter circuit supported by Pulse Width Modulation (PWM) circuit for driving the N-channel power Metal Oxide Semiconductor Field-Effect Transistor (MOSFET) which used to step up the DC voltage to a required value (Jahariah Sampe & Razak, 2017) .Once the voltage is boosted up, a regulation circuit is used to obtain the exact output voltage. **Error! Reference source not found.** shows the complete circuit of energy harvesting system.

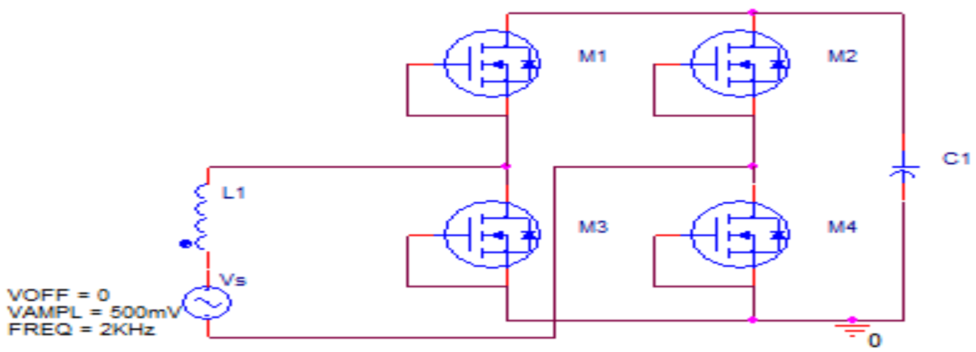
Figure 2: Ultra Low Power Energy Harvester System



RECTIFIER

Vibrational input vibrates at different frequencies, depending on movement of the mobile phone due to shaking strength. The full-wave rectification with four MOSFETs is used to avoid the problems of power losses and voltage drop. MOSFETs have lower constant resistances when they are conducting (Rao & Arnold, 2011), which makes leakage current is very low. Capacitor with reasonable value is connected at the output of the rectifier to smoothen the rippled output. In our design diodes are not suitable to be used in full wave rectifier because the voltage generated from vibration is less than the diode junction voltage. Figure 3 illustrates the proposed full wave rectifier circuit which consists of four switching N-channel power MOSFETs (M1, M2, M3 and M4), inductor source (L1) and load capacitance (C1). The function of this circuit is to convert the AC input voltage of 0.5V and 2 KHz to a DC voltage.

Figure 3: The full-wave rectifier circuit

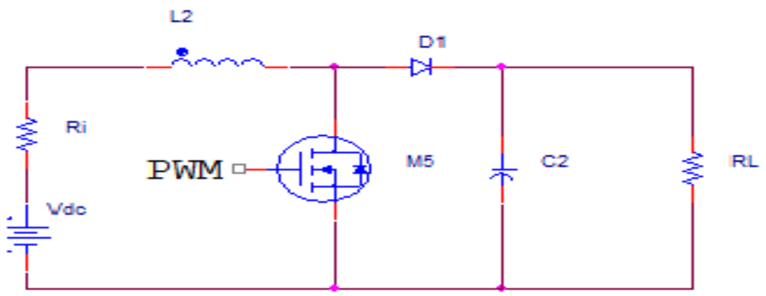


BOOST CONVERTER

A step-up DC-DC converter is used to boost up the DC voltage (Nadzirin, Sampe, Islam, & Kamal, 2016), resulting from rectifier to the desired output voltage. In our case the desired output is about 5.0V which is suitable for mobile phone devices. N-channel power MOSFET is used as a switch in the DC_DC boost converter circuit because of its fast switching, capability for high frequency and cost effectiveness (Carreon-Bautista et al., 2014). A diode with a low voltage drop is used in the design as a switch to solve the problem of voltage drop(Sampe, Zulkifli, Semsudin, Islam, & Majlis, 2016). The boost converter works in either continuous or discontinuous mode according to the on or off switch. For continuous conduction mode, the current is allowed to flow continuously in the inductor during the entire switching cycle in steady state operation. On the other hand, for discontinuous conduction mode, current is not allowed to flow from negative side which means the current is zero for the switching cycle (Carlson, Strunz, & Otis, 2010). Pulse Width Modulation (PWM) is used to trigger the MOSFET and thus the MOSFET function as switch and step up the DC voltage.

Figure 4 shows the proposed circuit of the boost converter. The circuit consists of Pulse Width Modulator (PWM), N-channel MOSFET (M5), Schottky diode (D1), internal source resistance (Ri), inductor, (L2), load capacitance, (C2), and load resistance, (RL). The parameter of the inductor is varied to achieve the desired output voltages.

Figure 4: The boost converter circuit



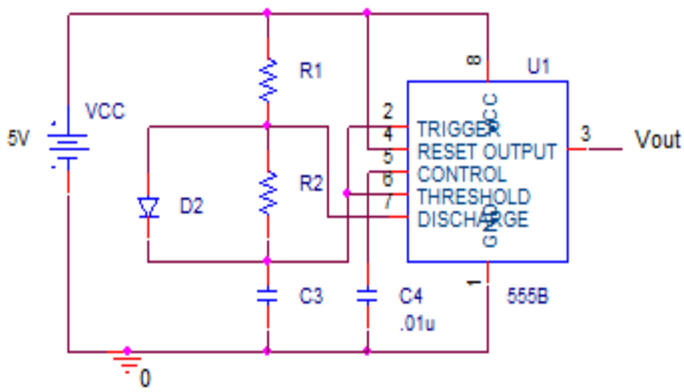
PULSE WIDTH MODULATION (PWM)

Mobile phone battery with 5V is used as a source to the PWM generator circuit. The PWM signal needed for switching the boost converter MOSFET is 219 KHz with duty ratio of 50 percent (Sathya & Natarajan, 2013). The 555 timer must work in astable mode in order to produce a 50 percent duty cycle (Sathya & Natarajan, 2013). Diode, D2, is connected between the *trigger* and the *discharge* to allow the timing capacitor to charge up directly via resistor R1 only, while resistor R2 is shorted out by the diode. Then the capacitor will discharge normally through resistor, R2. The charging time without connecting the diode (t1) is:
t1 = 0.693(R1 + R2) C

When the diode is connected, the charging time will be faster because R2 is shorted out. Thus, new charging time (t2) will be given as:

t2 = 0.693(R1.C)
The duty cycle (D) will be consequently given as:
D = R1 / (R1 + R2).
Thus, to produce a duty cycle of 50%, resistors R1 and R2 need to be equals.
Figure 5 shows the PWM generator circuit.

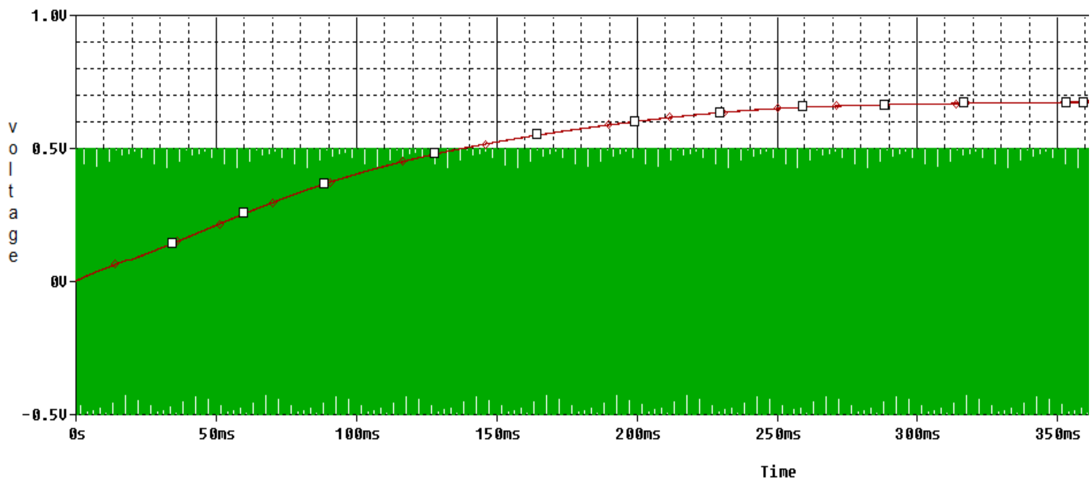
Figure 5: PWM generator circuit



SIMULATION AND RESULTS

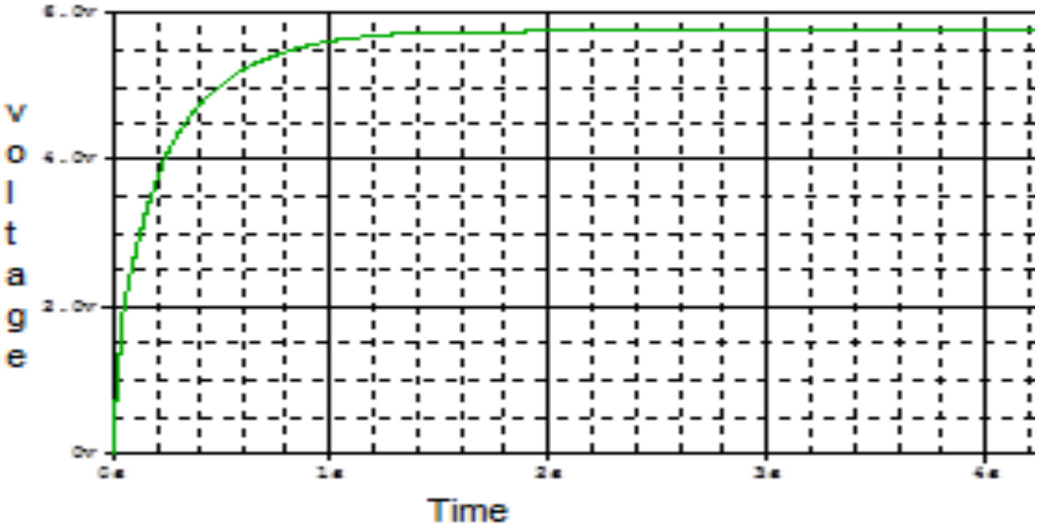
Table 1 shows a summary of output voltage obtained comparing to input voltage in energy harvester from past researchers. The energy harvesting circuit is simulated by using PSPICE software. The rectifier circuit is used to convert the vibrational input from AC to DC. The boost converter circuit is used to step-up the rectified voltage to the required regulated voltage. Input voltage of the rectifier is 500 mV with frequency of 2 KHz and the output is a rectified DC voltage with value of 0.67V.
Figure 6 shows the input and the output of rectifier circuit.

Figure 7: Input ~ and output — of rectifier



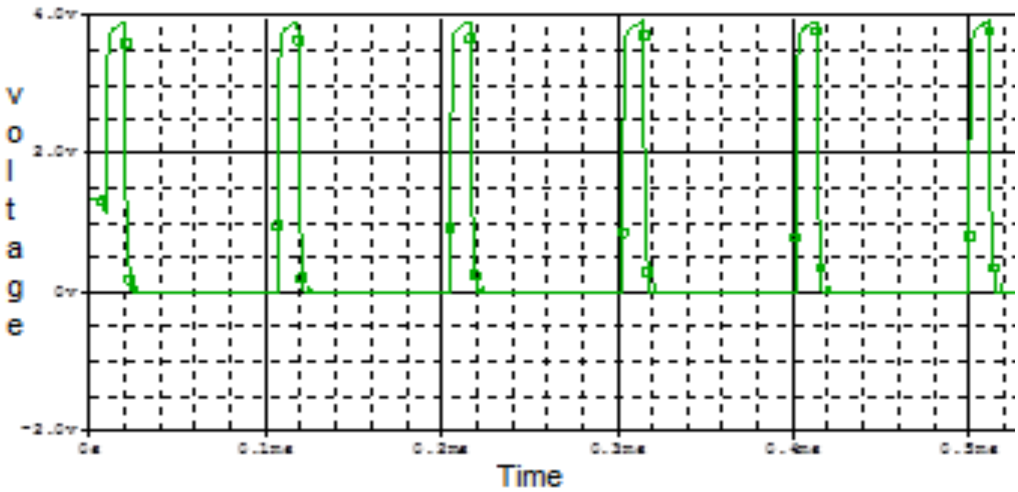
Output of the rectifier is applied to the boost converter circuit to be boosted to the required value. Voltage obtained from boost converter should be higher than the desired value to avoid any voltage drop. Regulator is used at the end to get exact output value. Figure 7**Error! Reference source not found.** shows the boost converter output.

Figure 8: Boost Converter output



PWM is used to trigger the boost converter MOSFET. The signal of PWM generator output is shown in Figure 8
The pulse duty cycle is depending on the value of R1 and R2 as mentioned earlier. In our case the value of R1 is 1KΩ and R2 is 10KΩ.

Figure 9: PWM generated signal



Finally, output of boost converter is regulated to 5V on RL as shown in Figure 9

Figure 10: Energy Harvester output

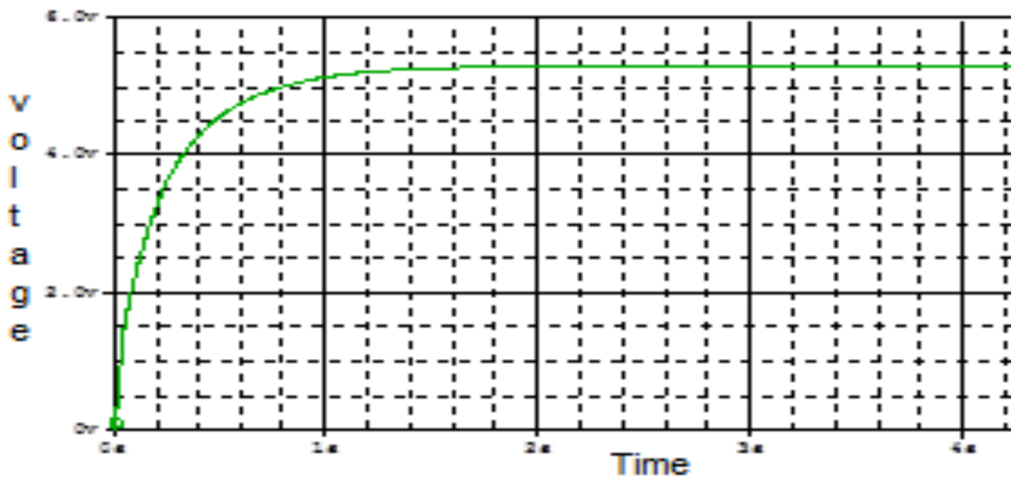


Figure 10 shows the boost converter output before and after regulation. Before regulation it was 5.8V and after regulation it is reduced to about 5.2V.

Figure 11: Boost converter output — EH output —

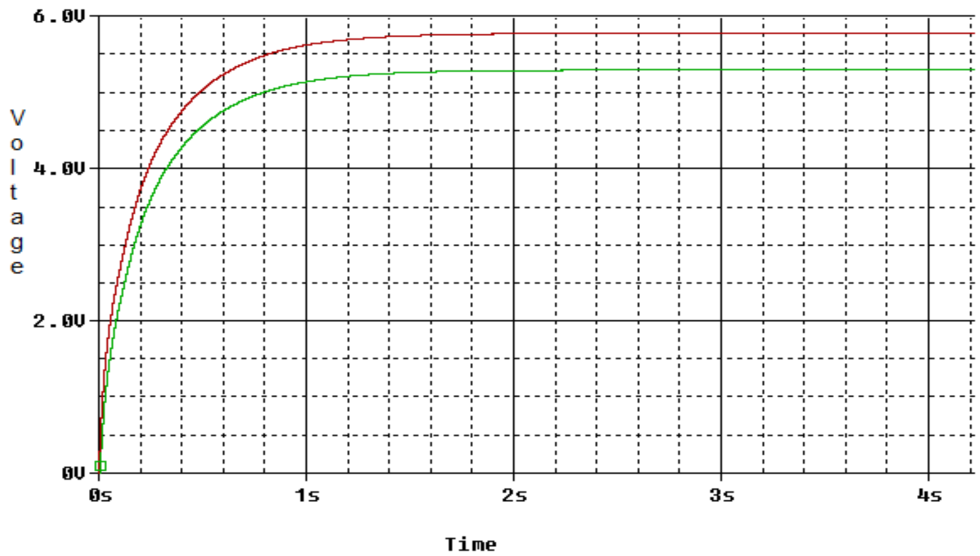


Table 1: Voltage improvement comparison from previous literature

V_{in} (V)	V_{out} (V)	Voltage Improvement (%)	Application	reference
3.6	5.5	34.5%	WSN	(Tan & Panda, 2011)
0.5	1	50%	WBAN	(Wang, Im, & Cho, 2011)
0.5	3.0	83%	Battery and super capacitor charger	(Kadirvel et al., 2012)
0.3	3.0	90%	Body worn devices cum charger	(Smith et al., 2013)
0.071	1	93%	WSN	(Teh & Mok, 2014)
0.030	1.8	98%	WSN	(Chen, Zhao, Liu, Wang, & Wu, 2014)
0.018	0.31	94%	Quartz watches, WSN	(Lim, Ali, Jahariah, & Islam, 2014)

0.6	4.0	85%	Micro biomedical	(Semsudin et al., 2015)
0.5	5	90%	Mobile phone	(This work 2017)

CONCLUSION

Architecture of Ultra Low Power Energy Harvester system using vibration resulting from shaking the mobile phone is designed and simulated by using PSpice software. Input of 0.5V, 2 KHz is used to represent vibration. Vibrational input is rectified then boosted up to 5V which is sufficient to be used for charging mobile phone. The simulation shows that the target output of 5.0V is achieved. Using ULP EH system to charge mobile phone is a new idea that we expect to be a reality in the future.It is recommended to download the ULP EH system into a FPGA board using 0.13 µm CMOS technology for real time verification.

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