

Design and Implementation of Boost Converter for IoT Application

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ABSTRACT: This paper presents one of the applications of the Internet of Things. It highlights the design and implementation of a highly efficient closed loop boost converter used for powering the Arduino and the Bluetooth device for controlling the switching of the led and buzzer by using MIT Invent mobile APP. The boost converter step up the input voltage to the required value. The proper selection of the inductor ensures the continuous conduction mode (CCM) operation of the converter. The suitable capacitor selection helps in minimizing the ripple content in the output voltage. The closed loop boost converter circuit is simulated using the TINA software and the various waveforms are observed. The schematic diagram of proposed topology is drawn on the EasyEDA software. The hardware circuit is also completed and results are observed.

KEYWORDS: Boost converter, Arduino UNO, Bluetooth, Lithium polymer battery.

I. INTRODUCTION

The increased automation has lead to rapid industrialization across the globe. Computers, mobile phones and other electronic gadgets equipped with some wireless technology have made the remote access too easy and simple. This all have been possible not only because of the advancement in the field of the computer science but also because of the rapid advancement in the field of Power Semiconductor Devices. The Switch Mode Power Supplies (SMPS) has replaced the conventional linear power supplies used for step up or step down of the input DC voltage for various applications. In this paper, Lithium Polymer battery is used to feed the input to the closed loop boost converter powering the Arduino and the blue tooth device. The app is created on the android platform using MIT app Invent to control the switching of the led and the buzzer.

A basic linear regulator consists of a transistor as shown in Fig. 1. Adjusting the base current of the transistor operating in the linear region can vary the DC voltage level.

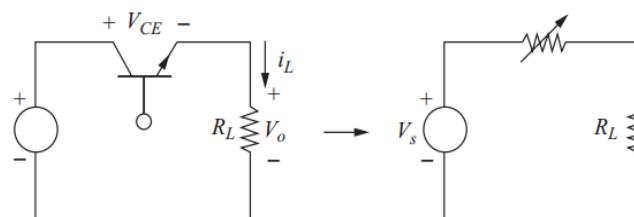


Fig. 1 A basic Linear Regulator

The load current (i_L) varies as the transistor base current is varied. Although the linear regulators are capable of converting one DC level to another but they incur huge power losses leading to the lower efficiency.

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The power absorbed by transistor is $V_{CE} \cdot i_L$ and the power across the load is $V_o \cdot i_L$. If the output across the load is one – quarter of the input voltage, means 75% power supplied by the load is dissipated across the transistor. Thus to overcome this problem switching regulators are used. A switching regulator is a circuit comprising of a switch, an inductor and a diode for the purpose of transferring the energy from the input to the output. These components can be rearranged to form a step down (Buck Converter), step up (Boost converter) or an inverter.

The buck converter topology is use to convert higher DC voltage to lower DC voltage by adjusting the duty cycle of switching device. The basic buck converter topology is shown in Fig. 2. The boost converter topology is use to convert lower DC voltage to higher DC voltage by adjusting the duty cycle of switching device. The basic boost converter topology is shown in Fig. 3.

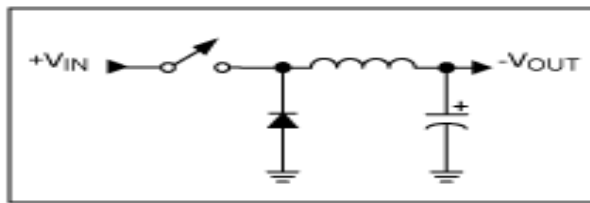


Fig. 2 Simple Buck Converter Topology

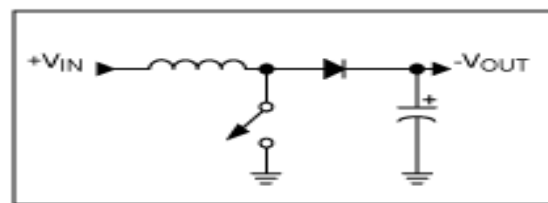


Fig. 3 Simple Boost converter Topology

The feedback and control circuit can be designed for each of the above-mentioned topology to regulate the energy flow, thereby obtaining a constant DC output within the normal operating conditions.

The difference between the linear power supply and switch mode power supply (SMPS) is listed in Table 1.

Table 1: Difference between the Linear Regulators and Switching Regulators

Power Supply	Linear	SMPS
Size	Large and Heavy	Small and Light
Efficiency	30-40%	70-95%
Complexity	Simple	Complex
EMI	Low noise	Filters Required
Cost	Expensive (due to material)	Less expensive

IBM design the very first switch mode power supplies based on vacuum tube technology. General Motor Corporation also filed several patent on SMPS. With the enhancement in field of power electronics, the sizes of power devices became very small. During this era the research on wireless technology also became a topic of interest. This paper highlights the application of boost converter (SMPS) to power the arduino and the Bluetooth device. The selection of inductor for continuous current mode (CCM) operation is described. The output capacitor selection is also described to keep the ripple contain less than 2% in the output voltage. This setup up is used to control the switching of the led and the buzzer using the mobile app invented using MIT App inverter.

II. RELATED WORK

The block diagram representing the wireless control of the switching of the LEDs and the buzzer is shown in Fig. 4. The MIT Invent mobile App and Bluetooth modules communicate wirelessly with the help of arduino. The various components for the circuit are chosen to obtain maximum efficiency and minimum regulation.

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Component selection:

Battery

Lithium polymer battery or the lithium-ion battery is a rechargeable battery, most commonly known as LiPo battery. It uses a polymer electrolyte. These batteries possess about four times the energy density of nickel cadmium or nickel metal hydride batteries and require lesser need for maintenance. A LiPo battery of 3.7V is selected.

Step up converter

The step up or the boost converter is required to step up the voltage from 3.7V to 5V needed for supplying power to the Arduino and the Bluetooth module.

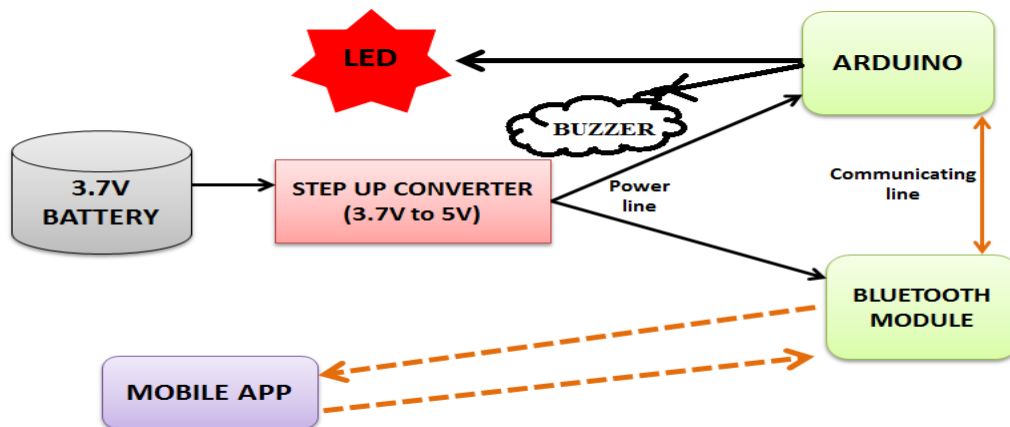


Fig. 4 Block diagram to control switching

Arduino UNO

It is a board based on microcontroller ATmega328. It is equipped with a total of 14 input/output pins. It has a ceramic resonator of 16KHz, an ICSP header, a USB connector, six analog inputs, a power jack and a reset button. This device in this application is programmed and linked with the mobile App and the blue tooth device.

Logic of operation

The LEDs must switch ON/OFF based on the numerical value pressed in the mobile phone by the user.

- Numeric 0- Red LED ON, Numeric 1-Red LED off
- Numeric 2- Yellow LED ON, Numeric 3-Yellow LED off
- Numeric 4- Blue LED ON, Numeric 5-Blue LED off
- Numeric 6- Buzzer ON, Numeric 7- Buzzer off

Blue tooth device

The Bluetooth device is required for transferring the data from the mobile to the arduino. HC-05 is a six-pin serial port protocol (SPP), easy to use Bluetooth module for the wireless serial communication. Thus it has a great resolution for the wireless communication and consumes very small amount of power.

Mobile App

The mobile App for accomplishment of the project is created on the Android platform using the MIT App Inventor tool. The App helps in sending the choice 0-6 to switch the LED ON/OFF and 7 or 8 to ON/OFF the buzzer.

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Calculations:

Inductor

The inductor selection is important for continuous current conduction mode.

$$L = \frac{V_{in} * (V_{out} - V_{in})}{\Delta I_l * f_s * V_{out}} \quad \Delta I_l = 0.4 * I_{out(max)} * \frac{V_{out}}{V_{in}}$$

Where,

$I_{out(max)}=0.5A$, $V_{out}=5V$, $V_{in}=3.7V$, $f_s=520kHz$, $\Delta I_l=0.270A$

Thus calculating and approximating $L=10\mu H$ is chosen.

Capacitor

The capacitor selection is important as it helps in minimizing the ripple content in the output voltage.

$$C_{out(min)} = \frac{I_{out(max)} * D}{f_s * \Delta V_{out}} \quad D = 1 - \frac{V_{in(min)} * \eta}{V_{out}}$$

Where,

Estimated Efficiency (η) =80%, $V_{in (min)}= 2.7V$, $D = 0.5680$

$$\Delta V_{out} = 2\% V_{out}$$

Thus calculating and approximating $C=10\mu F$ is chosen.

III. SIMULATION

It is always preferable to simulate the circuit before implementing the same using the hardware. This helps in more accurate selection of the components. Thus reduces the chance of any risk while implementation of the hardware circuit.

The TINA software is used for the simulation of the designed topology.

Boost Converter

The closed loop boost converter circuit using IC LM2735Y is shown in Fig. 5 and the output waveforms are shown in Fig. 6

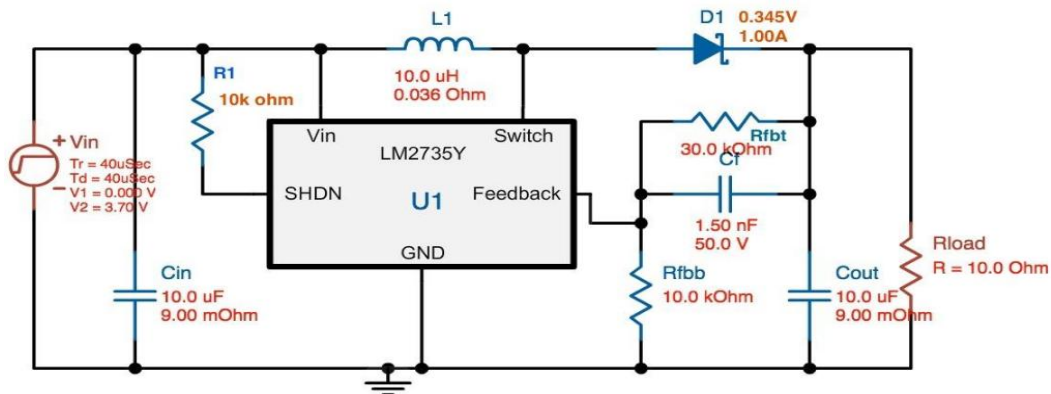


Fig. 5 Closed loop boost converter

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LM2735Y is an easy to use, space efficient, 2A load side regulator capable of stepping up the voltage. The IC along with the passive components like inductor, capacitor and resistor forms a closed loop boost converter. The waveform is shown in Fig. 6. The inductor value and the capacitor value play a vital role in the design of the boost converter circuit.

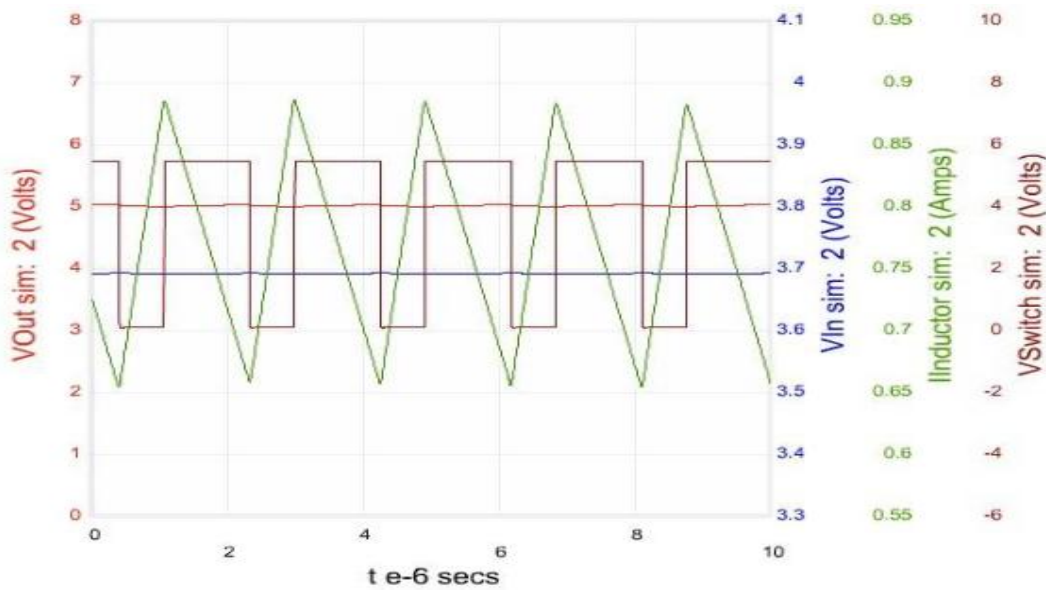


Fig. 6 Boost Converter Waveforms

- (a) Input Voltage (b) Inductor Current
(c) Switch Voltage (d) Output Voltage

The simulation result in Fig. 7 shows that the efficiency of the boost converter varies with the load current. As the load current rises, the power dissipated in the circuit also increases. Fig. 8 shows that the power dissipation varies linearly the load current.

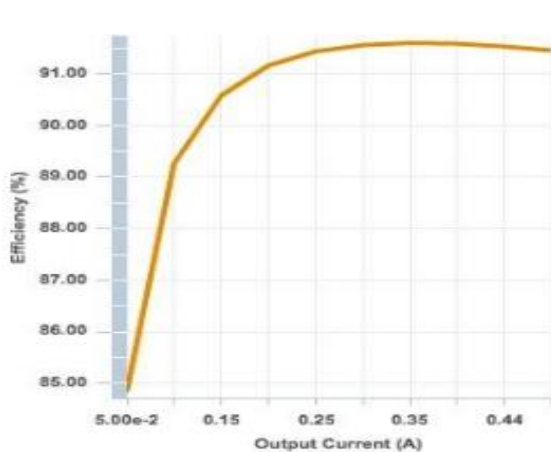


Fig. 7 Efficiency variation with load current

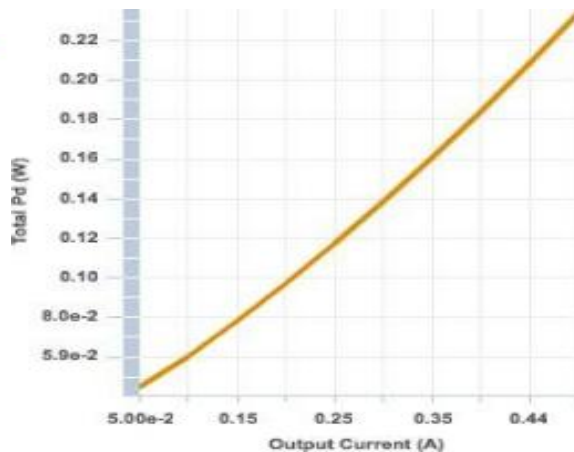


Fig. 8 Power Dissipation variation with load Current

VI. SCHEMATIC DIAGRAM

The EasyEDA software is used for designing the schematic diagram of the boost converter for IOT application. The schematic diagram is shown in Fig. 9.

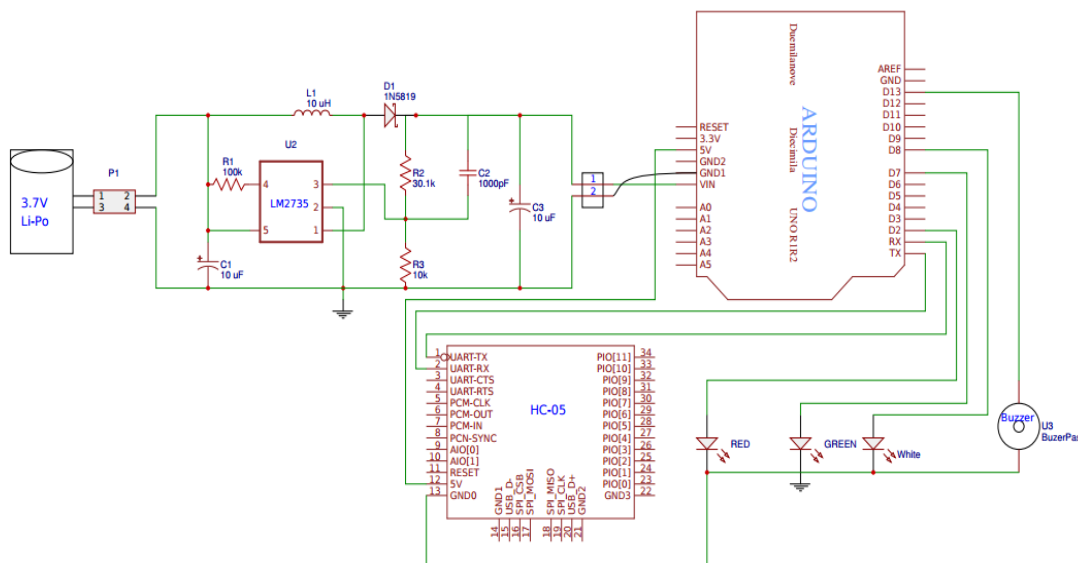


Fig. 9 Schematic using EasyEDA software

Working

- Battery supply 3.7V DC is fed as an input to the closed loop boost converter circuit. A regulated output of 5 V DC is obtained with regulation $\leq 2\%$.
- The 5V DC is given to power up the Arduino UNO and also 5V DC is used to power HC-05 Bluetooth module.
- The digital output is fed to the LED and the buzzer.
- The mobile App is created using the MIT App Inventor.
- The Arduino is programmed to set up a link between the App and the Bluetooth device.
- The numbers on the mobile keypad thus controls the switching of the LEDs and buzzer.

V. HARDWARE IMPLEMENTATION

As the simulation result was well within the required range, the hardware components were obtained as shown in Fig. 10. The various components used for this project are listed below:

- LiPo battery of 3.7V
- LM3725Y as boost converter IC
- Bread Board
- Wires
- Smart Phone
- HC-05 Bluetooth module
- Arduino UNO

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➤ LED and Buzzer

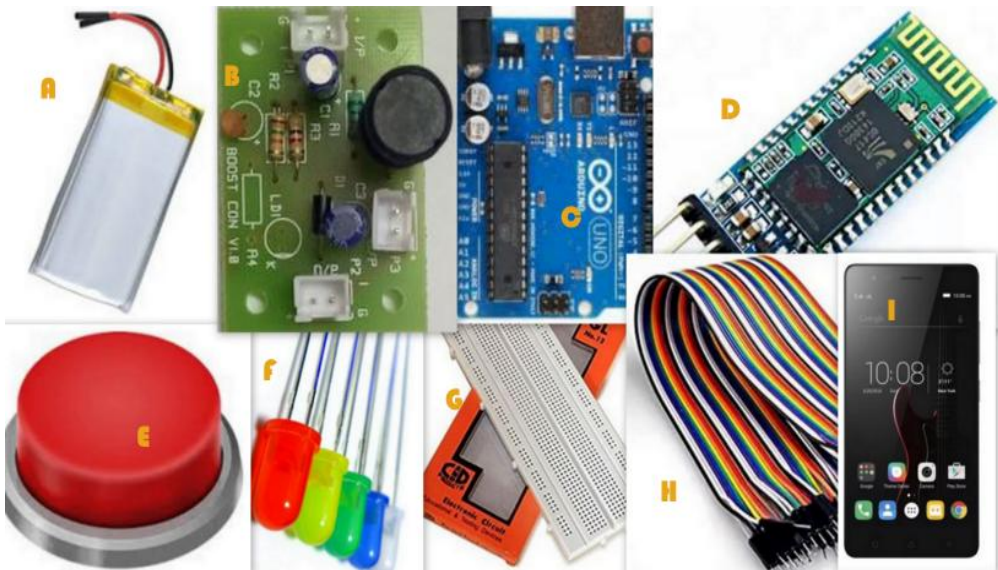


Fig. 10 Hardware Components Used

The PCB designing for the boost converter is carried out on EasyEDA software and then single layer boost converter PCB board is fabricated. The various passive components are soldered as per schematic diagram. The top and the rear view of the hardware circuit of boost converter are shown in Fig. 11.

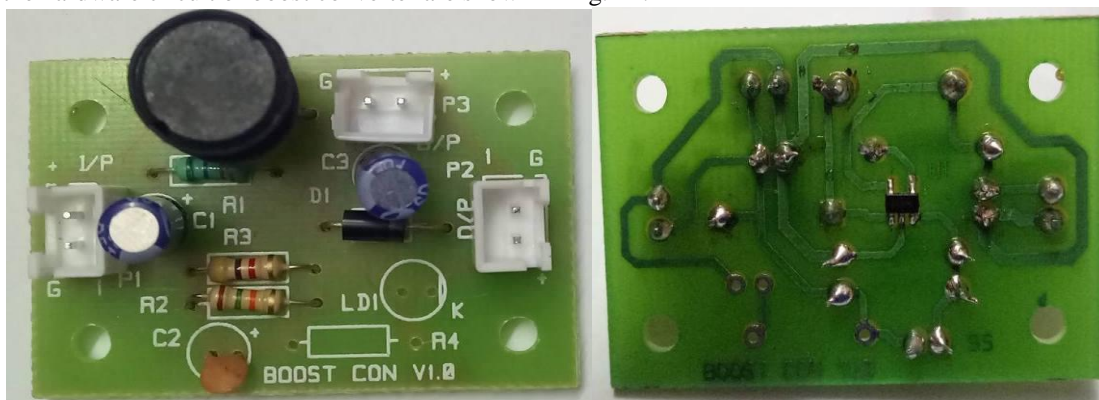


Fig. 11 top and rear view of boost converter

Experimental set up of the entire hardware module as shown in Fig. 12 is operating properly. The program and the MIT Invent App are also working as per the requirement. The device operates for a sufficiently long time and is devoid of any heating problem.

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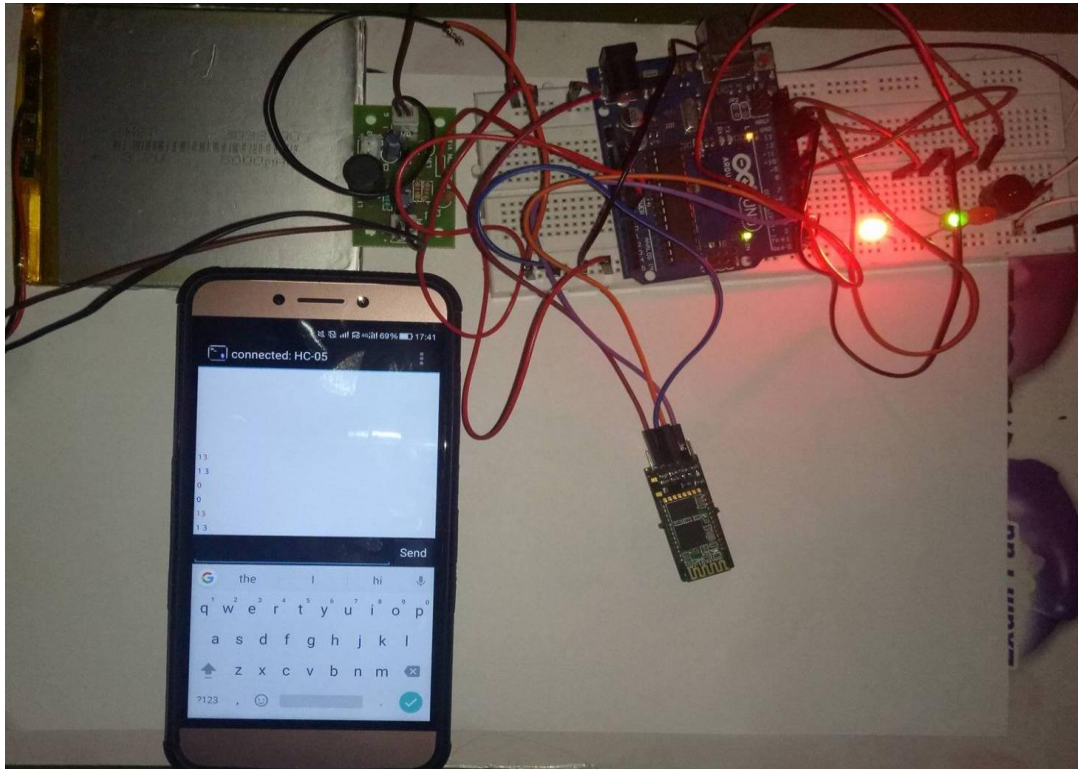


Fig. 12 Two LEDs are ON using Mobile App

VI. CONCLUSION

The output of boost converter is 5.02V. It is powering the arduino and Bluetooth module. The switching of the LEDs and buzzer is controlled successfully. One or more than one LED can be switched on or off depending upon the user's choice sent via MIT Invent App.

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