Software development of electric scooter

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Abstract. The Electric scooter is one which can be used to overcome the various problems faced by mankind in terms of the increase in price rates of petrol and diesel and also help us reduce the pollution in society. This project is a development of software for the low-cost electric scooter which uses a BLDC Motor as the primary motor as they have a feedback circuit and helps in identifying the problems when faced. We use 48V LifePO4 Battery (Lithium Ferro Phosphate) and developed charger which is compatible with E-scooter with 40kmph speed and 50 km mileage. We use a DC-DC converter to power up the E-scooter accessories which is sized at 1000W and 48V battery. The main accessories in E-scooter are display, headlights, horns all are 12V supplied, controlled by the software programmed, we have also designed a step-down converter. Then we have a solar panel which produces 125W and it reduces the voltage up-to 56V of constant supply DC. We have mainly designed software for the accessories and also for the proper operation of the BLDC Motor. This is done by the process of providing the PWM output to the power electronic device.

1. INTRODUCTION
The main purpose of developing an electric scooter is to overcome the various problems facing the environment and also the universe. The major part of our project lies in the process of developing software for the proper running of the Electric scooter and also for the proper working of the main accessories. For the running of the Brushless DC Motor, we need a driver circuit that drives the Motor and we have used a Power Electronic Device namely Power MOSFET’s which can drive the 48V rated Brushless DC Motor. The MCU will get the supply voltage value and the current battery voltage value and depending upon the comparison value the MCU drives the Driver circuit using the pulse produced by the PWM technique and charges the battery of the e-scooter. As per the algorithm designed, the three-phase voltage of the Brushless DC Motor is controlled with the help of the Pulse Width Modulation Technique. Using the PWM process an average output voltage is provided to the driver circuit which in this case is a MOSFET. The driver circuit is necessary because we won't be able to produce the maximum voltage to control the BLDC Motor and thus we require a driver circuit.

The driver circuit is mainly used for speed control of the BLDC Motor. To develop and software for the headlights because it is essential to work it out in a software environment and we have used Proteus 8 Professional for the simulation. For the process of developing the code which is to be dumped into the E-scooter, we have used MPLAB X IDE which uses XC8 Compiler which converts the high-level language into low-level language. The microchip laboratory provides us with various data about the PIC Microcontroller which is used for the control of E-scooter. The PIC microcontroller has 40 pins in total and has various input and output pins which can be used for the accessories used in the Electric scooter. The PWM input to the Brushless DC Motor is provided via the PIC8 Microcontroller which is done using the CCP/PWM Module which also the part of the
MCU. The Code of the BLDC Motor is one that has the stator and rotor which is different from many other traditional motors as it has stator Coils and the rotor is made up of the permanent magnets and the permanent magnets on the rotor. The major reason we go for BLDC Motor with Hall effect sensors will turn on the supply for any two phases at a time depending upon the rotor position. The BLDC motor has various advantages such as speed, torque characteristics which are much better compared to other motors and higher torque, higher efficiency, silent operation, and various speed ranges. The stator winding is of two types namely trapezoidal motors and sinusoidal motors. Depending on various factors, the motor with the 48V rating is chosen and they are proceeded to use in the electric vehicles. The rotor of the BLDC Motor is made up of permanent magnets with the south and north poles designed alternatively. We use the electronic way of controlling the commutation process of the motor which also helps in the process of maintaining the effectiveness of the motor and also is used to rectify any mistake if a problem arises this can be done using the software code developed. The working of headlights is simulated using the LED in the Proteus 8 Professional environment and the battery indication is done using a bar graph in the same environment.

In this paper, we provide the overview of the electric scooter designed in Section 2 along with the various novelities in the electric scooter such as the charging on the drive, etc; Section 3 gives information about the way the software is being developed for the proper running the Scooter and also discusses the components used to achieve the same. Section 4 gives information about the major component in the Brushless DC Motor. Section 5, gives an overview of the various tools used to design the software. Section 6 gives the Hardware implementation of the electric scooter set-up. Finally, Section 7 gives the conclusion obtained from the software development of an electric scooter.

2. VARIOUS COMPONENTS OF THE ELECTRIC SCOOTER
In this section, the main components of the low-cost electric scooter is given an overview

2.1 DC-DC CONVERTER:
The DC-DC converter is designed in the process of making an electric scooter because it is required to achieve the working of the accessories by providing them supplies. The supply voltage of these main accessories is 12V but we have a battery which is 48V and it is not possible to power them with that voltage. This is the main reason why we prepare this DC-DC Converter. We have designed a Step-Down converter. There are various converters used in the research topologies but the perfect converter for the low-cost electric scooter is the buck converter as the output power is about 36W.

2.2 BATTERY CHARGER:
The Battery charger is developed which is used to control the 48V based BLDC Motor controller, Throttle sensors, Mid-drive motor, and charger stations. The battery which we have used is Lithium Phosphate which has a cell made up of 3.5V, 6Ah capacity. The major reason to use the Lithium Phosphate batteries is that it will not catch fire even if punctured and is the safest among all Lithium Batteries. The typical estimated life of the Lithium-Ion battery is about 300 to 500 charge-discharge cycles. The life expectancy of the 48V Lifep04 battery charger is 7 yrs. We have added an important novelty that is not available in the industry is the BMS shows the Dead Battery Indication and also the BMS parameter indication.

2.3 SOLAR DESIGN:
As of now, there are only AC mains charging option is available for Electric scooter. But, our Electric scooter is one that uses the solar panel which helps in charging the system while driving. To provide novelty to the Electric Scooter designed we have introduced "Charging On Drive". The panel produces 125W and its peak time supply open-circuit voltage of 70V with a charge controller and it reduces the
voltage up-to 56V for the constant supply DC. The disadvantage with the charge on a drive is it may take about 3 to 4 hours to charge the vehicle (i.e.) the battery.

2.4 SOFTWARE DEVELOPMENT:
Currently, the software industry has developed so much that various methods of software development have arrived to help us overcome the tedious and confusing software coding for electric scooters. Also, to designing software for a particular hardware is difficult with the traditional process. Thus, we have used modern technology to overcome the problems using the Microchip Laboratory environment for dumping the code into the PIC Microcontroller which is the MCU in the electric scooter and it’s checked for the proper working in the Proteus 8 Professional environment by simulation. We use a Microcontroller Unit (MCU) along with a driver Circuit and a converter which provides the output to the battery management system of the e-scooter. The main purpose of the MCU is to get the supply voltage for the BLDC Motor and to compare that voltage with the output from the battery voltage obtained from the battery management system of the e-scooter. The voltage and the current value are obtained from the V & I Sensing which is attached to the Battery Management System.

3. BLOCK DIAGRAM OF PROPOSED SYSTEM
The Proposed system is that we can see that there is an LCD Display which will provide all the update regarding the electric scooter condition. Now we get the supply voltage from the device which is the motor and we also get the battery voltage regarding the battery status. Now the output obtained from the MCU which is called the Microcontroller unit is provided to the Driver circuit which is nothing but the PWM value. We normally know that the PWM value is nothing but an average voltage value which can be obtained as one which is the maximum and the minimum voltage is 0V and 5V respectively. The average voltage obtained from the PWM output is about 2.5 V which cannot be used to drive the Brushless DC Motor which has a rating of about 48V. The driver circuit includes the Power MOSFETS which can drive the circuit smoothly and also helps in getting the position of the rotor and now we can get the speed control and other things in the system. Thus, the need for a driver circuit is very important for the proper running of the electric scooter. Usually, the driver circuit that is being used includes the MOSFET or the IGBT but we are using MOSFET because of its ability to be very efficient whilst having a good and efficient structure. The MOSFET also has a great driver speed low switching loss. This is a major advantage compared to IGBT. Now the MOSFET is various in number and can be used to run a BLDC Motor depending on the two of the three Phases switched On. Then, the PWM output is there which is the pin that gets the PWM values. The PIC microcontroller can also be used for various other processes such as developing the charging circuit for electric vehicles and also for various controller purposes.

![Figure 1](image-url) – The MCU gets the voltage value and battery voltage value compares them and drives the entire electric scooter.

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The PIC Microcontroller is very useful. Also for the working of the main accessories and the other spare parts, we need to code them using the PIC Microcontroller and this can be done in such a way we need to switch on the light when necessary and to use the horn when necessary which has to be coded using the Microchip Laboratory environment. Also, we display the battery charged condition and the amount of charge remaining in the Electric scooter using the code developed by the software components used. This can be represented using the bar graph which indicates the percentage remaining in the battery in terms of percentage and in case of charging needed we can use the inbuilt 125W solar panel in the electric scooter. The battery indication is very important because we need to know when to charge the battery and when not or else it may damage the battery.

4. HALL EFFECT SENSOR
The Hall effect sensor is a major reason in the wide use of Brushless DC Motor because in other DC Motors there is commutation which is not controlled electronically but in BLDC Motor it is controlled electronically. For the BLDC Motor to rotate the stator coils of the motor has to be energized in a sequence. To understand which winding will be energized following the sequence we need to know the position of the rotor. This is done easily in a BLDC motor as it has the Hall effect sensors embedded in the stator part of the motor. The BLDC motor has the sensors present in the non-driving end of the motor. When the magnetic poles of the rotor come near the sensors we get a high signal or low signal which helps us in determining which pole is passing through or nearer to the sensor embedded in the stator of the motor. Based on the Hall sensor signals, the commutation sequence of the BLDC motor is determined easily.

5. DESCRIPTION OF TOOLS
In this section, the various tools to design the software has been discussed.

5.1 PROTEUS 8 PROFESSIONAL
The Proteus 8 Professional environment is a software environment used for simulation of electronic devices and their automation. These are usually used for the design of PCB’s by the design engineers. But, it can also be used to simulate the PIC microcontroller within the Proteus environment. We have used a 40 Pin PIC Microcontroller and some of the main simulations done using the PIC in Proteus are software implementation of the headlights and the horns as well as the pulse production of the PWM circuit which is necessary for the proper control of the BLDC Motor. Thus, Proteus is one of the modern methods of controlling the software part of the low-cost electric scooter.

5.2 MPLAB X IDE
MPLAB X IDE is a software program that is used to develop applications for Microchip microcontrollers and digital signal controllers. This development tool is called an Integrated Development environment, or IDE because it provides a single integrated environment to develop code for embedded microcontrollers. MPLAB X IDE is one that is like an interactive console between the IDE and programming language. Using this IDE, we as a user can dump codes into the Microcontroller unit in a language understandable by the devices for proper operation of the low-cost electric scooter. The MCU is called the target microcontroller and does all the work for the functioning of the electric scooter. MPLAB X IDE is one of the most used tools for performing the software development of various devices in the field of the microcontroller. The MPLAB X IDE is one where we give the code to the system in terms of the C Language Program and the XC8 compiler converts it to Assembly Language.

6. IMPLEMENTATION
The above diagram is the design implementation of our whole hardware setup but before that, we decided to implement it in the software to check whether it is producing the intended results. The PIC
Microcontroller plays a major role in the project as you can see from the diagram it has a lot of inputs and outputs and the required PWM inputs are connected to the CCP1 Pin and is called as the pin 16. The CCP2 Pin in the PIC Microcontroller is also used for the PWM outputs and it can be used to obtain the increase the voltage provided to the BLDC Motor and we can vary the PWM output (ie) the average output voltage is controlled and in that way, the speed is also controlled. We also see that the LED Pin is connected to the device which is the PIC Microcontroller in the Pin 14 and thus we can produce the night vision for the electric scooter during night times. The LEDs will be turned ON when the vehicle is turned and thus we can reduce the button required to turn on the Light or also called the headlights.

The buzzer which is to be implemented in the device because we require and horn for the electric scooter is connected to the PIC Microcontroller and the PIN to which it is connected 4. This enables the user to indicate that to other vehicles on the road so that we can avoid accidents. The hall sensors are three in number and the feedback regarding the rotor position is provided to the PIC Microcontroller and thus the required phases are turned on to obtain the required positive and the negative torque and to obtain the maximum torque and thus the BLDC Motor is operated at its maximum rated speed which is about 5000 RPM in its full load.

Figure 2 - It represents the simulation performed to indicate the charge status in the Electric scooter. It has about 10 indication bars and each indication step shows the percentage of the charge present in the electric scooter.
Figure 3 - It represents the PWM simulation process. The PWM output voltage value given to the system is that of about 5V but it is not enough to drive a Brushless DC Motor thus we have installed a Power Electronic Device which is used to drive the 48V Motor. The PWM input has an average voltage of about 2.5V and this can be achieved by varying the potentiometer present in the simulation. The device is connected to the pin 18 because it is a specially made pin PWM working within the PIC microcontroller.

Figure 4 – The Digital Oscilloscope output figure is about 2.5V which is the average output voltage which we get when we have 50% duty cycle. The channel A is the yellow colour which gives square wave output as the pin from PIC Microcontroller is connected to channel A. The other lines are flat.
Figure 5 - It represents the main parts of the electric scooter. The charge controller(a) at the top and the 48V battery(b) at the bottom and the Brushless DC Motor(c) on the left corner with the charging pin.

7. CONCLUSION
The results obtained help to understand that the above-designed software development is much efficient and simple for the BLDC Motor control. This method of developing software can also be implemented in the control of various other devices when used in the development of the electric scooter and as well as the Brushless DC Motor control. The major portion in the proper design of the electric scooter is done using the selection power driver circuit. Though various power converters are present, the Power MOSFET’s is the most efficient and used in various applications including electric scooters. Also, we have developed a charger controller system in the scooter which shows the defects when there is one which is indicated by the sparkling of the red light. This is a new method of identifying errors within the system. Also, our system has a solar panel that helps us to charge the system while driving instead of searching for a charging station nearby and reduces the time needed for the charging of the system which could be useful in many ways. We have also developed software to control the BLDC Motor Driver that helps us to get an indication of whether it is running properly or not with the help of the feedback sensors connected to the system driver in the motor.

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