

# Design and Analysis of Multi-functional PCB

Sarath Babu Kumar, Bharathi Thangaraj, Francois Bernot, P. Chandrasekar



**Abstract:** As the use of electric vehicle is increasing continuously. One form of such vehicle is electric bicycle (E-bike). This paper deals with a brief description of an Electronic Control Unit (ECU) for e-bikes and with enhanced motor control. It focuses on the description of the design of the basic types of this Electronic control unit. Electric bicycles use a three phase BLDC motor (Brushless Direct Current Motor). The aim is to implement the low power; 8-bit microcontroller and BLDC Controller can be used to drive such a three phase BLDC motor. The microcontroller manages the function like Pedal assist and wheel locker. An Electronic Control Unit comes with a standby mode and it can drive the Induction motor, the 8-bit microcontroller acts as a proxy shaft sensor and input provider to BLDC controller making it an all-purpose ECU.

**Index Terms:** BLDC motor, ECU, Microcontroller, BLDC Controller, Pedal assist, wheel locker, standby mode and proxy shaft sensor.

## I. INTRODUCTION

All over cities and countries the increase in mechanical vehicles has caused air pollution, the need of electrical vehicles can solve transportation in an environment. Electric E-vehicles are low cost and environmentally friendly vehicle suitable for all ages; they will not normally require licence registration. Electric vehicles mostly made using Brushless Direct Current Motor (BLDC), as the name implies motor does not have the brush, which uses the electronic circuit serving as a control unit (Controller) instead of the mechanical commutator. BLDC has an advantage of greater torque, noiseless operation, longer life and lower Electromagnetic interference radiation. ECU for E-bikes has two controllers, DC bus capacitors, Auxiliary source, gate drivers and switches.

To control BLDC motors, in all the electronic control unit, only the controller is used to control the motors. If in any case controller got fail or not able to generate the output at certain

period the whole system will shut down, and the IGBT produces more heat, which can damage the other IC used in control unit. So I proposed the controlling of motors with BLDC controller and instead of using IGBT, MOSTETs is preferred.

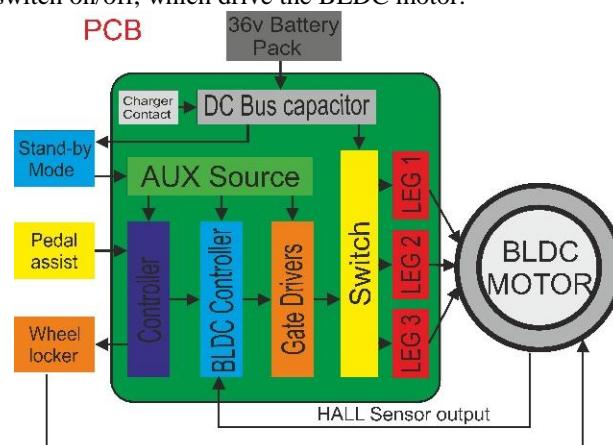
The Microcontroller in an electronic control unit is used for Controlling the pedal assist function and Wheel locker function, which will control the BLDC controller. The BLDC controller used to generate six PWM signal, PWM high and PWM low for driving the motor along with hall sensor input.

## II. BLOCK DIAGRAM

The block diagram of the designed electronic control unit is present in Fig. 1. The implementation of the proposed control unit is based on the BLDC controller and 8-bit microcontroller.

The BLDC controller receives information about the motor position (rotor angle), via three Hall-effect sensors, which is placed inside the motor to generate signals.

Using this data, the BLDC controller uses a simple commutation table and the six power MOSFETs transistors is switch on/off, which drive the BLDC motor.



**Fig. 1. Block diagram of an electronic control unit**

The battery pack is charged using charger contact, which is connected to the DC bus capacitor in order to protect the battery from input supply and motor.

Auxiliary source is electric power provided by the primary power source. Auxiliary source provides the power to the controllers and gate drivers.

## III. CONTROLLERS AND SWITCHES OPERATION

BLDC motor requires an electronic control unit for their operation. It consists of three parts: the controller's part, gate drivers and switches operation.



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### A. Controllers operation

Microcontroller feature multiple PWMs and memory features like Memory Access Partition (MAP) to support data protection and Boot loader applications, Pedal assist will provide the pedal force to the microcontroller when pedaling. Depending on the pedal force microcontroller will generate a PWM, which will control the BLDC controller. The microcontroller is a program for different pedal assist modes, the modes are a low assist, medium assist, and high assist.

BLDC Controller features open loop, three-phase motor control, which act as a slave, the microcontroller sends a reference PWM to BLDC controller. BLDC controller receives information about the motor position (rotor angle), via three Hall effect sensors generate signals contained within the motor. BLDC Controller generate six PWM signal, PWM high and PWM low for driving the motor along with hall sensor input and has selectable 60/300 degree or 120/240 degree sensor phasing.

### B. Switches operation

The switching part also called as an inverter; the most often formed by the arrangement of bridge configuration of MOSFETS transistors. The High signal from the motor driver drives the Upper Switch and Low signal drives the Lower Switch. Three legs of MOSFETS pairs providing power to three phases of the BLDC motor.

TABLE I. INVERTER WAVEFORM

Switches	A	B	C
S1	+1	0	-1
S2	0	+1	-1
S3	-1	+1	0
S4	-1	-1	+1
S5	0	-1	+1
S6	+1	0	0

a. (Explanation of inverter waveform)

The three-phase inverter and inverter waveform is shown in Fig. 2a and 2b:

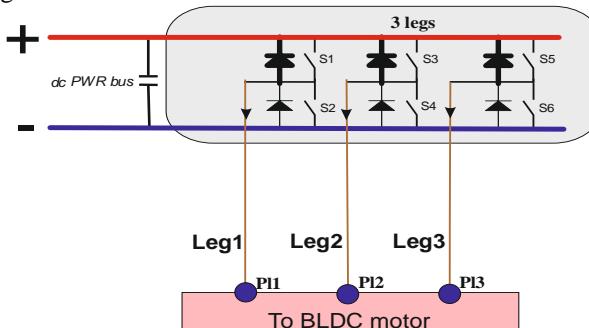


Fig. 2a. The three-phase inverter

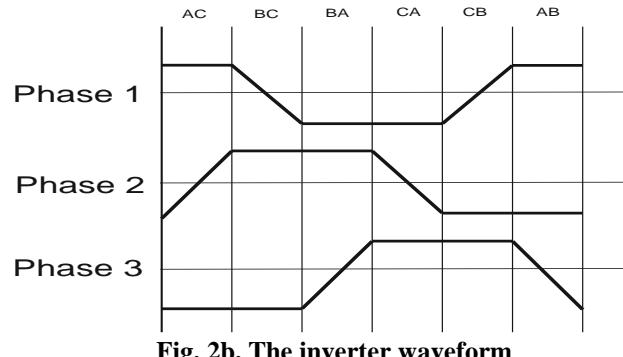


Fig. 2b. The inverter waveform

### IV. ELECTRONIC SYNOPSIS

The electronic synopsis consist of power section, auxiliary source, gate drivers and controllers.

#### A. Power section

The block diagram implementation of the power section is from Fig. 3. The power section designed to consist of charger contact, DC bus capacitor and Power MOSFETs.

The electrical vehicle has the Charger contact, which is the common type of connector for supplying input current to the battery pack. The DC bus capacitor is the most important passive component in a motor drive. The DC bus capacitor is connected in order to avoid the spike and noise in the power supply. The BLDC motor driven with six power MOSFETs transistors are arranged in a three-phase H-bridge configuration. The current through the power MOSFETs is limited using current sensors.

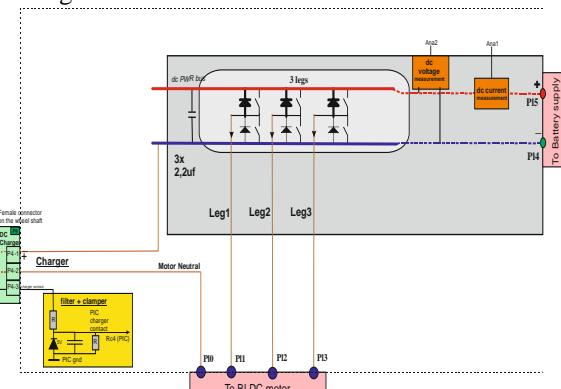


Fig. 3 Power section

#### B. Auxiliary source

The supply voltage, which is required for powering the microcontroller, BLDC controller and gate driver is provided by the Low drop out regulators, which maintaining good efficiency. Auxiliary source is also known as a secondary source. The block diagram of auxiliary source implementation is from Fig. 4.

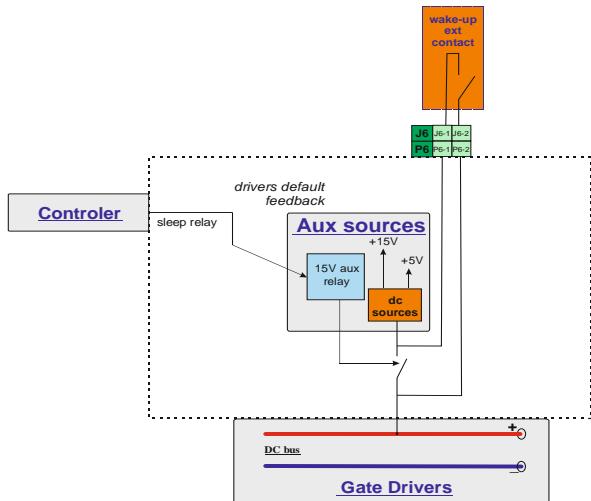


Fig. 4 Auxiliary source

### C. Gate drivers

The gate driver is an electrical power amplifier, that accepts a low-power input from a processor or controller IC and produces a high voltage/high current input to the gate of a power MOSFETs. The block diagram implementation of the gate driver is from Fig. 5

The PWM high and PWM low from the low-power BLDC controller signal amplified by the gate driver and provided to the gate of power MOSFETs.

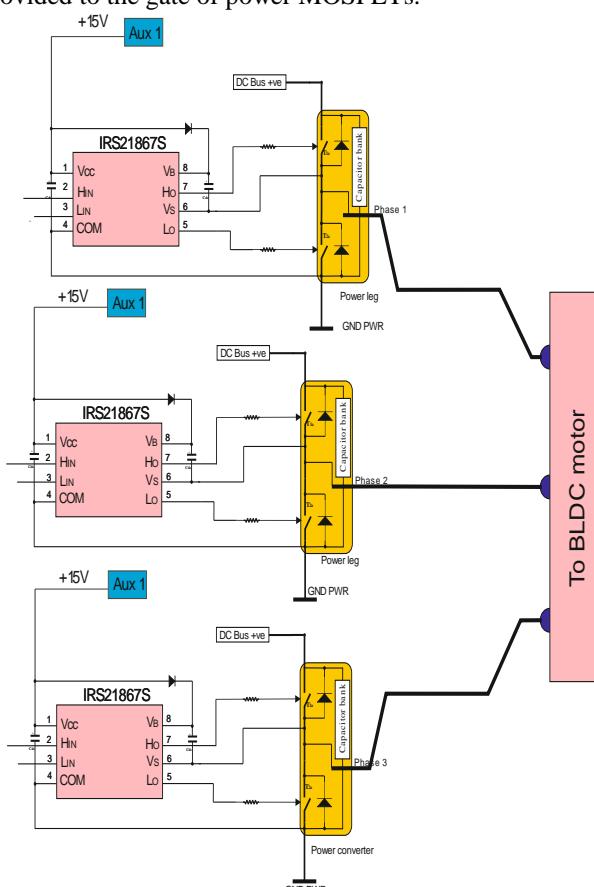


Fig. 5 the gate drivers

### V. CONTROL LOGIC

The control logic is been modelled as a combinational system. The inputs to this combinational system are the Hall position sensors signals and a master PWM, and the outputs

are the PWM signals.

The hall effect sensors measure the rotor position of the BLDC motor and provided to the Controller to perform the Combinational operation.

$$\begin{aligned}
 AHS &= \text{PWM} \cdot (\text{HallA} \cdot \overline{\text{HallB}}); \\
 BHS &= \text{PWM} \cdot (\text{HallB} \cdot \overline{\text{HallC}}); \\
 CHS &= \text{PWM} \cdot (\text{HallC} \cdot \overline{\text{HallA}}); \\
 ALS &= \overline{\text{HallB}} \cdot \overline{\text{HallA}}; \\
 BLS &= \overline{\text{HallC}} \cdot \overline{\text{HallB}}; \\
 CLS &= \overline{\text{HallA}} \cdot \overline{\text{HallC}};
 \end{aligned}$$

Choosing the commutation scheme the following factors simplicity of implementation, delivered performances motor speed.

### VI. SOFTWARE SIMULATION

The system is been simulated using Proteus 8 and the simulated model is shown in Fig. 6a. In addition, the Power MOSFETs output is shown in Fig. 6b.

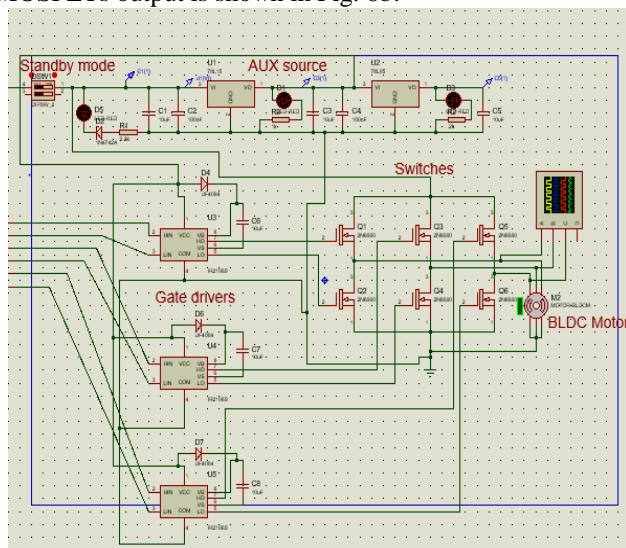


Fig. 6a. The proposed system

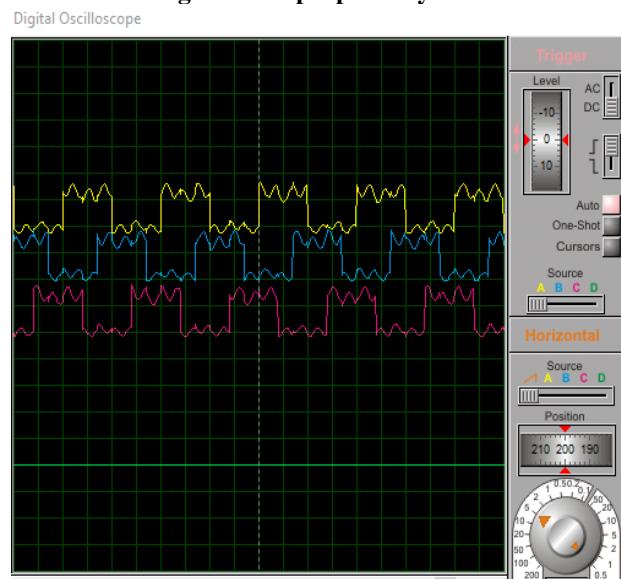


Fig. 6b. Power MOSFETs output

## VII. CONCLUSION

This project is used to control the 3-phase BLDC motor using BLDC controller, which is used to drive the motor. Gate driver individually controls separate phase of the motor. The circuit is simulated using proteus8 software, the future enchantment for this project is Bluetooth control system, it will be more effective to find the system and it is compact as inside the motor pack. The anti-locking system is proposed with this project, which is used for secure system and focus on improving control and improving the power section of the controller.

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Sarath Babu Kumar pursuing my M.Tech in Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai. Completed my Bachelor of Engineering in Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai as first class in the stream of Electrical and Electronics Engineering during the year 2016, Later joined Francecol Technology research lab in Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology as Apprentice, My area of research interest are Printed Circuit Board design, Electric Machine Design.



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