

An Overview on PCB Designing

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Abstract—This report thoroughly examines the complexities of Printed Circuit Board (PCB) design methodologies, with a focus on fundamental principles, design factors, software applications, and evolving patterns. The importance of effective PCB design in contemporary electronic systems is underscored, emphasizing its influence on system performance, dependability, and manufacturability. The report investigates PCB constituents, layers, and design limitations, elucidating the processes of schematic creation and layout using widely-used tools like Altium Designer and Eagle. It also delves into optimization strategies such as thermal control, EMI/EMC considerations, and Design for Manufacturability (DFM). Advanced discussions cover techniques for high-speed PCB design and emerging manufacturing technologies. Real-world case studies and future PCB design trends are also addressed.

Keywords—*component, formatting, style, styling, insert (key words)*

I. INTRODUCTION (*HEADING I*)

PCB designs have made significant strides in recent years, emphasizing size and weight reduction alongside enhanced environmental sustainability. This trend aligns with the growing preference for smaller, eco-friendly electronic devices. Concurrently, there's a strong emphasis on improving EMI (Electromagnetic Interference) and EMC (Electromagnetic Compatibility) properties to boost performance and streamline manufacturing processes.

The rise of high-speed applications in digital computing and communication has posed new challenges for PCB designers, particularly concerning signal integrity and electromagnetic compatibility. To address these challenges, modern PCB design techniques leverage advanced

methodologies to optimize performance. Engineers strategically select and place digital components, carefully route interconnections to minimize signal interference, and implement effective measures for RF and EMI suppression.

Adherence to fundamental design guidelines and standards is vital for ensuring PCB reliability in complex electronic systems. Emerging technologies like 5G, IoT, and autonomous vehicles continue to push PCB design boundaries, necessitating ongoing innovation in materials, manufacturing techniques, and signal integrity management. This ongoing evolution underscores the critical role of PCB design in driving advancements across diverse industries.

II. PCB DESIGN FUNDAMENTALS

Printed Circuit Boards (PCBs) serve as the backbone of modern electronic devices, providing a platform for integrating and connecting electronic components. Understanding the fundamentals of PCB design is essential for achieving optimal performance, reliability, and manufacturability. This section delves deeper into key aspects of PCB design:

A. *PCB Components and Layers*

PCBs consist of various components and layers that contribute to their functionality and structure:

- **Components:** PCBs incorporate a range of components such as resistors, capacitors, diodes, transistors, ICs (Integrated Circuits), connectors, and more. These components are selected based on the circuit requirements and are mounted onto the PCB using soldering techniques.

- **Layers:** A typical PCB comprises multiple layers, including signal layers (for routing electrical signals), power planes (for distributing power), and ground planes (for providing a reference voltage and shielding against noise). Understanding the purpose and arrangement of these layers is crucial for effective PCB layout.

B. Design Constraints and Considerations

Several design constraints and considerations influence PCB design decisions:

- **PCB size** directly impacts the overall dimensions of the electronic device. Miniaturization is a key trend, necessitating compact PCB layouts while accommodating all required components.
- **Proper power distribution and management** on the PCB are critical for ensuring stable operation and preventing overheating or voltage drops.
- **Maintaining signal integrity** is essential, especially in high-speed digital circuits. Factors such as trace length, impedance matching, and routing techniques influence signal quality.
- **Efficient heat dissipation** is vital for preventing component overheating. Techniques like thermal vias, heat sinks, and copper pours help manage thermal issues.

III. DESIGN PROCESS

The process of PCB design comprises various stages, each fulfilling a vital role in guaranteeing the functionality, performance, and manufacturability of the eventual PCB.

A. Requirements Analysis

The design process starts by conducting a thorough analysis of project requirements and specifications:

- **System Requirements:** This involves comprehending the overall system functionality, encompassing input/output connections, power requirements, and performance criteria.
- **Component Selection:** The process involves identifying and choosing suitable

components based on technical specifications, availability, and cost considerations.

- **Environmental Considerations:** Environmental factors such as temperature range, humidity, and operating conditions are taken into account to ensure the PCB's reliability and durability..

B. Schematic Capture

Schematic capture plays a critical role in the PCB (Printed Circuit Board) design process by allowing engineers to create a detailed representation of the electronic circuit using specialized software. This stage forms the basis for subsequent PCB layout and manufacturing processes. Let's delve deeper into schematic capture:

• Purpose of Schematic Capture

The primary objective of schematic capture is to translate the conceptual circuit design into a structured and organized diagram that accurately represents electronic components, their connections, and functionalities. This schematic serves as a blueprint or roadmap for the PCB layout phase.

Key Components of Schematic Capture

Component Placement:

- Engineers select and place electronic components onto the schematic canvas from libraries within the software.
- Each component is depicted by a graphical symbol reflecting its physical appearance and electrical properties.
- Components are logically arranged based on their interconnections and roles within the circuit.

Symbol Creation and Customization:

- Schematic capture tools offer a library of predefined symbols for common electronic components (resistors, capacitors, ICs, etc.).
- Engineers can customize symbols or create new ones to represent unique or specialized components not in standard libraries.

Netlist Generation:

- As components are connected on the schematic, the software automatically generates a netlist.
- A netlist is a textual representation of circuit connections, listing all nodes (terminals) and their interconnections.

Functions and Features of Schematic Capture Software (ALTIUM DESIGNER)

Ease of Use and Interface:

- User-friendly interfaces with drag-and-drop functionality for placing components and routing connections.
- Tools for zooming, panning, and organizing the schematic canvas efficiently.

Design Rule Checking (DRC):

- Built-in design rule checking to identify errors or violations in the schematic (e.g., unconnected pins, short circuits).
- DRC ensures the schematic adheres to design constraints and specifications

Annotation and Documentation:

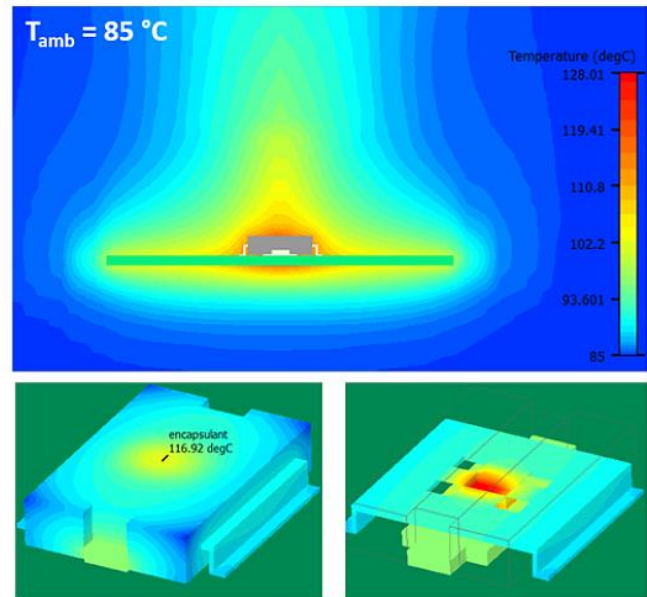
- Ability to add annotations, comments, and documentation directly onto the schematic for clarity and future reference.
- Automatic part numbering and labelling of components for BOM (Bill of Materials) generation.

Importance of Accurate Schematic Capture

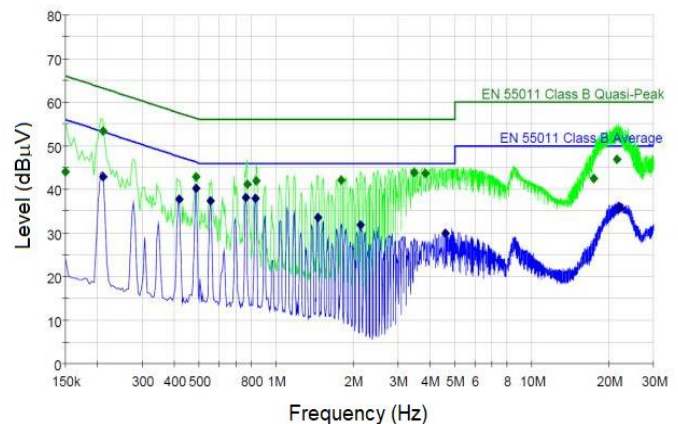
- Design Validation: The schematic serves as a tool for verifying the circuit design's functionality and correctness before proceeding to PCB layout.
- Collaboration and Communication: The schematic facilitates effective communication between design team members, allowing them to review and discuss the circuit design.
- PCB Layout Preparation: A well-crafted schematic expedites the PCB layout process by providing clear instructions on component placement and connectivity.

C. Simulation Tools

Simulation tools are used to analyze PCB designs for signal integrity, thermal performance, and electromagnetic compatibility (EMC).



○ Thermal Simulation of a PCB board



○ EMI simulation result of a PCB.

Popular Tools

- Cadence Allegro PCB Editor: Industry-standard tool for high-speed PCB layout with advanced routing capabilities and constraint-driven design.
- Mentor Graphics PADS: Affordable PCB design software suitable for small to medium-sized projects, featuring interactive routing and design rule checking.

- KiCad: Open-source PCB design software offering schematic capture, PCB layout, and 3D visualization capabilities

These features in a PCB designer software helps us in Pre-layout and post-layout simulation to predict performance and identify potential issues.

It also helps in optimization of PCB designs for signal integrity, power distribution and thermal management.

IV. DESIGN OPTIMIZATION

Design optimization in PCB layout involves implementing strategies to achieve optimal electrical performance, thermal management, and EMC (Electromagnetic Compatibility) while considering design constraints and manufacturability.

Routing Optimization

Routing optimization focuses on minimizing signal integrity issues and electromagnetic interference by optimizing the layout of electrical traces on the PCB. Key considerations include:

Trace Length and Impedance Control: Keeping trace lengths short to reduce signal degradation and maintaining consistent impedance throughout the routing. The characteristic impedance (Z_0) of a trace can be calculated using the formula:

$$Z_0 = \sqrt{\frac{60}{\epsilon_r}} \ln\left(\frac{4h+t}{w}\right)$$

Where,

- ϵ_r : Relative permittivity of the PCB material
- h : Height of the dielectric material
- w : Width of the trace
- t : Thickness of the copper trace

Differential Pair Routing: Routing differential pairs close together with consistent spacing to minimize skew and enhance signal integrity, especially in high-speed data transmission.

Via Placement and Optimization: Strategic via placement to minimize impedance mismatches, reduce inductance, and optimize thermal dissipation.

EMI Reduction Techniques

Effective EMI reduction techniques aim to suppress electromagnetic interference from the PCB:

Grounding and Decoupling: Implementing proper grounding techniques and placing decoupling capacitors to offer a low-impedance path for return currents and stabilize power supply lines.

Shielding and Enclosure Design: Using shielding techniques like grounded metal enclosures or shielding layers within the PCB stack up to contain electromagnetic emissions and prevent external interference.

Filtering Components: Integrating EMI filtering components such as ferrite beads, common-mode chokes, or RC filters to attenuate high-frequency noise and harmonics.

Signal Integrity Analysis and Simulation

Utilizing advanced simulation tools to analyse and optimize signal integrity and EMI performance:

Reflection Analysis: Simulating signal reflections using tools like TDR (Time Domain Reflectometry) to identify and mitigate impedance mismatches and signal integrity issues.

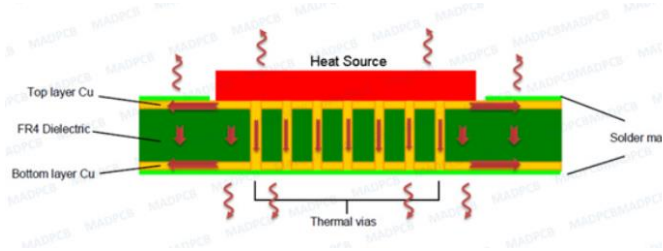
Crosstalk Analysis: Analysing crosstalk effects between adjacent traces and implementing spacing and shielding techniques to minimize interference.

EMI Simulation: Conducting electromagnetic simulation (EM simulation) to predict and mitigate electromagnetic interference, ensuring compliance with EMC standards.

PCB Design Consideration for Power Electronics

- Thick Copper Traces: Use thicker copper traces to reduce resistance and handle higher currents without excessive voltage drops.
- Low Impedance Paths: Design PCB layouts to minimize impedance in power paths, especially critical for high-frequency switching applications.
- Separation of High and Low Current Traces: Keep high-current paths separate from low-current signal paths to prevent interference and noise coupling.

- **Heat Sink Placement:** Ensure adequate space and mounting provisions for attaching heat sinks to power components.
- **Thermal Vias:** Integrate thermal vias to enhance heat dissipation by providing a direct path for heat transfer to inner copper layers or ground planes.



- **PCB Material Selection:** Choose PCB materials with high thermal conductivity to enhance heat dissipation capabilities.
- **Ground Plane Design:** Implement solid ground planes to act as shields against electromagnetic interference and ensure a low-impedance return path.
- **Filtering and Decoupling:** Incorporate EMI filtering components and decoupling capacitors to suppress noise and stabilize power supply lines.
- **Clearance and Creepage:** Maintain sufficient clearance and creepage distances between high-voltage and low-voltage traces to ensure safety and prevent arcing.
- **Isolation Barriers:** Use isolation barriers and conformal coatings to enhance safety and protect against electrical breakdown.

Advanced Techniques for Power Electronics PCBs

- **Multi-Layer Stackup:** Utilize multi-layer PCBs to accommodate power planes, signal layers, and ground planes effectively.
- **High-Frequency Design:** Apply controlled impedance techniques for high-frequency switching applications to maintain signal integrity and minimize EMI.
- **High-Voltage Isolation:** Incorporate isolation techniques such as slotting and creepage to ensure safe operation at high voltages.

V. ADVANCED TOPICS IN PCB DESIGN HIGH-SPEED PCB DESIGN:

High-speed PCB design focuses on ensuring signal integrity and minimizing issues like reflections, crosstalk, and electromagnetic interference (EMI) in circuits operating at frequencies typically above 1 GHz. Key aspects include:

- **Transmission Line Theory:** Understanding transmission line behaviour to maintain controlled impedance and minimize signal distortions.
- **Impedance Matching:** Implementing techniques to ensure maximum power transfer and minimize signal reflections.
- **Differential Pair Routing:** Routing differential pairs with precise length matching and consistent spacing to minimize skew and improve noise immunity.
- **Via Design:** Optimizing via structures (e.g., microvias, buried vias) to minimize signal discontinuities across multiple layers.
- **EMI Mitigation:** Incorporating shielding techniques, ground planes, and EMI filters to suppress electromagnetic interference and comply with EMC regulations.

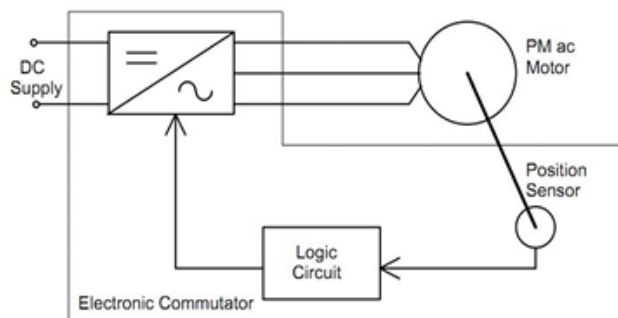
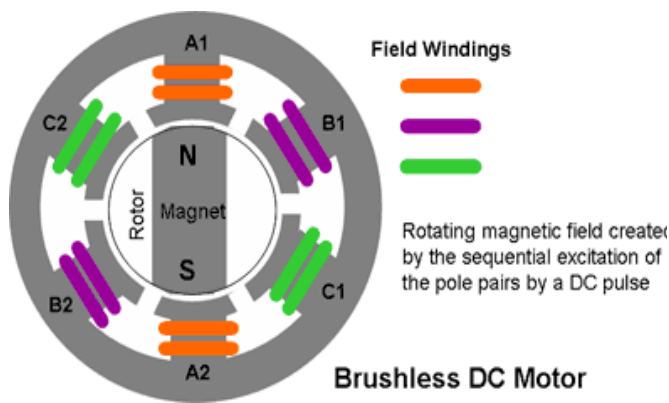
VI. DESIGNING A BLDC MOTOR CONTROLLER PCB:

Brushless DC (BLDC) motors are renowned for their efficiency, reliability, and versatility. Unlike traditional brushed DC motors, BLDC motors operate using electronic commutation, which eliminates the need for mechanical brushes, enhancing their efficiency and reducing maintenance requirements. Key characteristics of BLDC motors include:

Efficiency: BLDC motors boast higher efficiency compared to brushed DC motors due to their lack of friction-inducing brushes.

Reliability: With fewer mechanical components prone to wear and tear, BLDC motors offer enhanced reliability and longevity.

Versatility: BLDC motors find applications across various industries, including automotive, industrial automation, consumer electronics, and renewable energy systems, owing to their adaptability to diverse operating conditions.



- Block Diagram for Motor Controller

B. PARAMETERS

BLDC Motor Parameters:

Voltage (V): The electrical potential difference across the motor terminals.

Current (A): The flow of electric charge through the motor windings.

Speed (rpm - revolutions per minute): The rotational speed of the motor shaft.

Torque (N·m - Newton-meters): The rotational force exerted by the motor shaft.

Power (W - Watts): The rate at which the motor performs work, calculated as the product of voltage and current.

Efficiency (%): The ratio of output power to input power, expressed as a percentage.

Inertia ($\text{kg} \cdot \text{m}^2$ - kilograms per square meter): The resistance of the motor to changes in its rotational motion.

Temperature ($^{\circ}\text{C}$ - degrees Celsius): The operating temperature of the motor, affecting its performance and longevity.

Back EMF (V): The voltage generated by the motor due to its rotational motion, opposing the applied voltage.

Phase Resistance (Ω - Ohms): The resistance of each phase winding in the motor.

Inductance (H - Henrys): The property of the motor windings that resists changes in current flow.

Pole Count: The number of magnetic poles in the motor, influencing its speed-torque characteristics.

Rotor Position: The angular position of the rotor relative to the stator, crucial for commutation.

BLDC Motor Controller Parameters:

PWM Frequency (Hz - Hertz): The frequency at which the PWM signals are generated for motor commutation.



Duty Cycle (%): The ratio of the ON time of the PWM signal to its total period, controlling the average voltage applied to the motor.

Dead Time (μs - microseconds): The time delay between turning off one switch and turning on the complementary switch in the H-bridge configuration, preventing shoot-through current.

Control Loop Bandwidth (Hz): The bandwidth of the control loop, determining the responsiveness of the controller to changes in motor parameters.

Overcurrent Limit (A): The maximum current threshold beyond which the controller limits the current flow to protect the motor and driver circuitry.

Startup Voltage (V): The minimum voltage required for motor startup, ensuring reliable motor operation.

Hall Sensor Inputs: Signals from Hall effect sensors used for rotor position detection and sensor-based commutation.

Current Sensing Resolution (mA - milliamps): The smallest change in current that the controller can detect.

Voltage Regulator Output Voltage (V): The regulated voltage supplied to the MCU and other control circuitry.

Communication Interface: The interface used for external communication with the controller, such as UART, SPI, or CAN.

C. EQUATIONS

1. Back EMF (Electromotive Force)

$$E_b = K_e \cdot \omega$$

Where:

E_b is the back EMF (volts)

K_e is the motor's back EMF constant (volts/Sec)

ω is the angular velocity of the rotor (radians/Sec)

2. Torque Equation:

$$T = k_t \cdot I$$

Where:

T is the torque (Newton*meters)

- . T is the torque (Newton-meters).
- . k_t is the motor's torque constant (Newton-meters per ampere).
- . I is the current flowing through the motor windings (amperes).

3. Electrical Power Equation:

$$P_{\text{electrical}} = V \cdot I$$

Where:

- . $P_{\text{electrical}}$ is the electrical power input (watts).
- . V is the voltage applied to the motor (volts).
- . I is the current flowing through the motor windings (amperes).

4. Mechanical Power Equation:

$$P_{\text{mechanical}} = T \cdot \omega$$

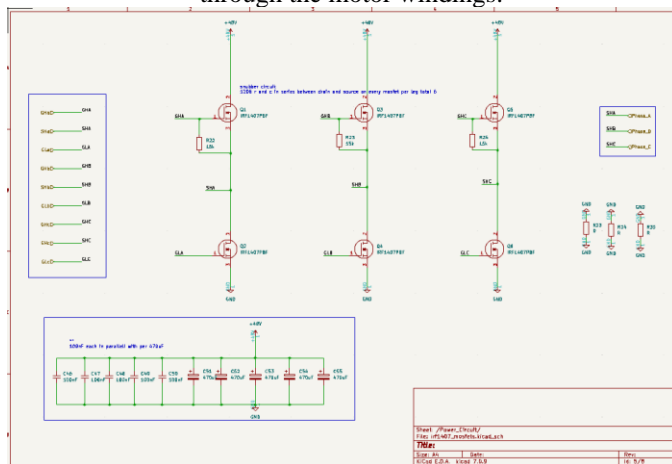
Where:

- . $P_{\text{mechanical}}$ is the mechanical power output (watts).
- . T is the torque produced by the motor (Newton-meters).
- . ω is the angular velocity of the rotor (radians per second).

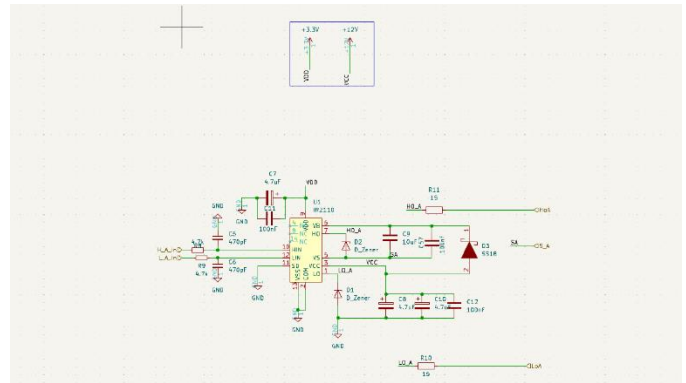
D. SUBSYSTEMS OF THE CONTROLLER

Subsystems of BLDC Motor Controller

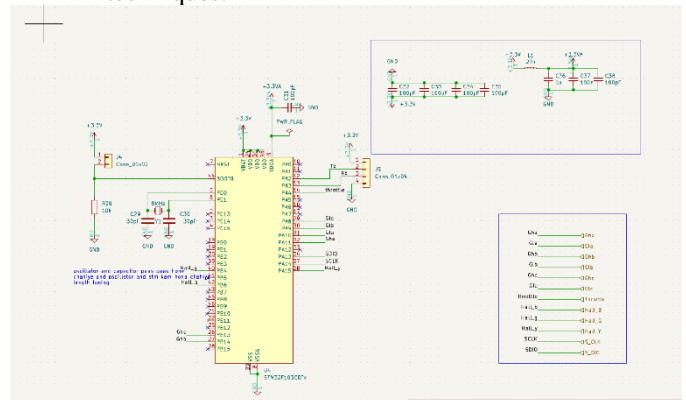
- **Power Block:** The power block is a crucial component of a BLDC motor controller responsible for converting the low-voltage control signals from the controller into high-power signals capable of driving the motor. It typically consists of power MOSFETs or IGBTs arranged in an H-bridge configuration to control the current flow through the motor windings.



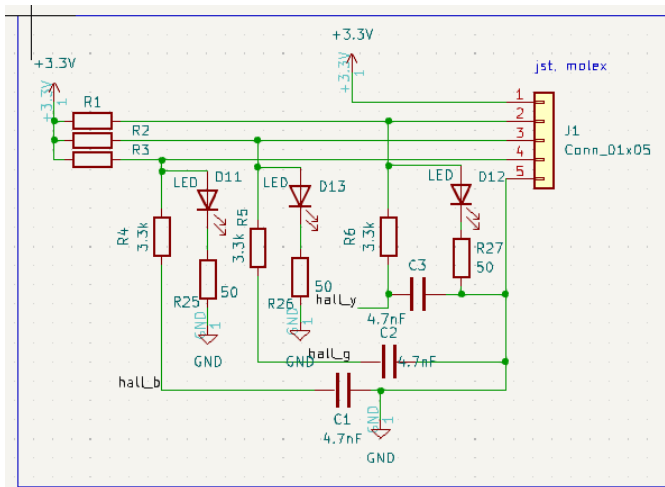
- **Gate Driver Block:** The gate driver block serves as the interface between the controller and the power block, ensuring efficient switching of the power devices. It generates the appropriate gate drive signals to turn the MOSFETs or IGBTs on and off at the right time, preventing shoot-through currents and optimizing motor performance.



- **Controller Part:** The controller part is the brain of the BLDC motor controller, executing control algorithms to regulate the motor's speed, direction, and torque. It typically consists of a microcontroller unit (MCU) or a digital signal processor (DSP) programmed with sophisticated control algorithms such as field-oriented control (FOC) or sensorless control techniques.



- **Hall Sensor Part:** The Hall sensor part provides feedback on the rotor position to the controller, enabling accurate commutation of the motor phases. It consists of Hall effect sensors mounted on the motor stator, which detect the magnetic field changes due to the rotor's movement and provide signals to the controller for precise timing of the commutation sequence.



- These subsystems work in tandem to ensure efficient and reliable operation of the BLDC motor controller, facilitating precise control of motor speed and torque in various applications.

• 120 DEGREE COMMUTATION

==> PWM Technique for BLDC Motor Control

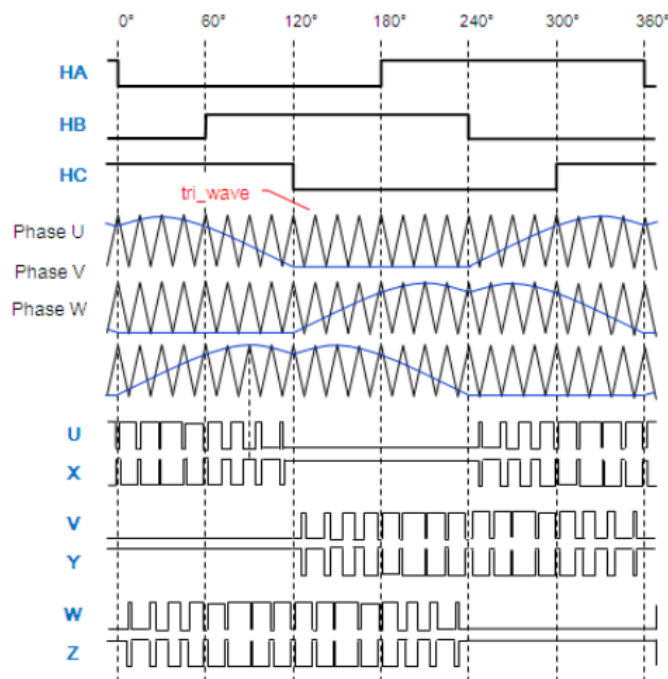


Figure 17. Sine-Wave Output at CW=1

No	Ha	Hb	Hc	S1	S2	S3	S4	S5	S6
1	1	0	0	0	1	1	0	0	1
2	1	1	0	1	0	1	0	0	1
3	0	1	0	1	0	1	1	0	0
4	0	1	1	1	1	0	1	0	0
5	0	0	1	1	1	0	0	1	0
6	1	0	1	0	1	1	0	1	0

- Table for 120 degree commutation of BLDC motor.

1.

I. Technique1

In BLDC motor control, Pulse Width Modulation (PWM) is a widely employed technique for precisely regulating the motor's speed and torque. One common approach involves utilizing PWM signals on the high side and simple high or low signals on the low side, according to the motor's state.

High-Side PWM: On the high side of the motor phase, PWM signals are employed to control the voltage applied to the motor windings. PWM involves varying the duty cycle of the signal, which determines the average voltage applied to the motor. By adjusting the duty cycle, the effective voltage across the motor can be controlled, thereby regulating the motor's speed and torque.

Low-Side Control: In contrast, the low side of the motor phase typically utilizes simple high or low signals to switch the MOSFETs or IGBTs on and off. These signals determine whether the current flows through the corresponding phase winding or not, based on the motor's commutation sequence. Unlike PWM signals, which modulate the voltage, these signals primarily control the current flow through the motor windings.

Commutation Strategy: During motor operation, the PWM signals on the high side are synchronized with the commutation sequence, ensuring smooth and efficient operation. The low-side signals complement the high-side PWM signals by facilitating the switching of the power devices at the appropriate times, according to the motor's rotor position.

Advantages of High-Side PWM and Low-Side Control:

Efficiency: PWM control on the high side allows for precise voltage regulation, optimizing motor efficiency.

-> **Smooth Operation:** By modulating the voltage on the high side, PWM ensures smooth and precise control of motor speed and torque.

-> **Simplified Low-Side Control:** Using simple high or low signals on the low side simplifies control circuitry and reduces complexity.

-> **Effective Commutation:** The combination of high-side PWM and low-side control facilitates effective commutation of the motor phases, ensuring seamless operation across a wide range of speeds and loads.

II. Technique2

==>The PWM on-off-on technique, also known as the "PWM with complementary mode" technique, is a method used in BLDC motor control to improve efficiency and reduce losses in the motor driver circuitry. In this technique, the PWM signal is applied not only to the high side (upper switch) of the H-bridge but also to the low side (lower switch), creating an on-off-on pattern for each PWM cycle.

...Here's how the PWM on-off-on technique works:

High-Side PWM:

The PWM signal is applied to the high side of the H-bridge, controlling the voltage applied to the motor windings. This PWM signal determines the average voltage applied to the motor and thus regulates the motor's speed and torque.

Low-Side PWM with Complementary Mode:

In addition to PWM on the high side, the low side of the H-bridge also utilizes PWM signals, but with a complementary mode. This means that when the high side is on (PWM signal is high), the low side is off (PWM signal is low), and vice versa.

During the "off" period of the high-side PWM, the low-side PWM is turned on. This allows for faster recovery of the freewheeling diode and reduces losses in the low-side switch. During the "on" period of the high-side PWM, the low-side PWM is turned off, preventing shoot-through current and reducing losses in the low-side switch.

Commutation Strategy:

-->The PWM on-off-on technique is synchronized with the commutation sequence of the motor. The PWM signals are adjusted according to the rotor position feedback (from Hall sensors or back EMF) to ensure smooth and efficient commutation of the motor phases

By carefully timing the PWM signals on both the high and low sides of the H-bridge, the motor's speed and torque can be precisely controlled while minimizing losses in the driver circuitry.

Advantages of PWM On-Off-On Technique:

Improved Efficiency: By utilizing PWM signals on both the high and low sides of the H-bridge, losses in the motor driver circuitry are reduced, leading to improved overall efficiency.

Reduced Heat Generation: The complementary mode of the low-side PWM helps reduce switching losses and heat generation in the motor driver components.

Enhanced Motor Performance: Precise control of the PWM signals allows for smoother operation and better performance of the BLDC motor, especially at lower speeds and under varying load conditions.

..Overall, the PWM on-off-on technique is an advanced method for BLDC motor control, offering improved efficiency, reduced

losses, and enhanced motor performance compared to traditional PWM techniques.

III. Technique3

==>Field-Oriented Control (FOC) in BLDC Motor Control

Field-Oriented Control (FOC) is an advanced control technique used in the operation of Brushless DC (BLDC) motors. FOC offers precise control over the motor's speed and torque by directly controlling the magnetic field orientation of the motor, resulting in improved efficiency, smoother operation, and higher performance compared to traditional control methods.

Key Principles:

Vector Control: FOC is based on the concept of vector control, where the stator current and voltage of the motor are represented as vectors in a rotating reference frame. By controlling the magnitude and phase angle of these vectors, the motor's torque and flux can be precisely regulated.

Decoupling of Torque and Flux: FOC separates the control of torque and flux components, allowing independent control of motor speed and torque. This decoupling simplifies the control algorithm and improves dynamic response and stability.

Transformation to Synchronous Reference Frame: FOC transforms the three-phase stator currents from the stationary reference frame (ABC) to a rotating synchronous reference frame (d-q). In this frame, the direct-axis (d) represents the magnetic flux linkage, and the quadrature-axis (q) represents the torque-producing current.

Control Strategy:

Current Control Loop:

FOC includes a current control loop to regulate the d and q-axis currents to desired reference values. Proportional-Integral (PI) controllers are commonly used to adjust the motor's current to track the reference values accurately.

Voltage Control Loop:

The voltage control loop generates the PWM signals required to produce the desired d and q-axis currents. By adjusting the PWM duty cycles, the voltage applied to the motor windings is controlled, allowing precise regulation of motor speed and torque.

Rotor Position Estimation:

Accurate rotor position feedback is essential for FOC. This can be obtained using Hall effect sensors, encoders, or sensor less techniques based on back EMF estimation. The rotor position information is used to transform the stator currents into the d-q reference frame and synchronize the PWM signals with the rotor position.

Advantages of FOC:

Improved Efficiency: FOC optimizes the motor's operation by aligning the magnetic field with the rotor flux, reducing losses and improving efficiency, especially at low speeds and high loads.

Precise Control: FOC offers precise control over motor speed and torque, resulting in smoother operation, reduced torque ripple, and improved dynamic response.

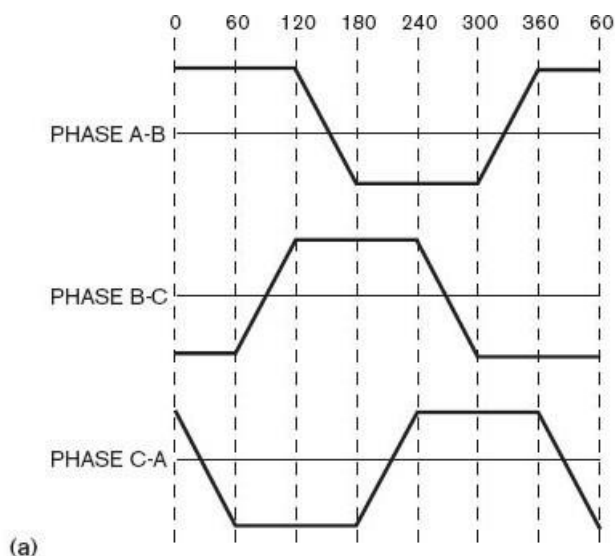
High Performance: FOC enables BLDC motors to achieve higher performance levels, including faster response times, higher torque density, and wider speed ranges, making them suitable for a wide range of applications.

Conclusion:

Field-Oriented Control (FOC) is a sophisticated control technique that revolutionizes the operation of BLDC motors. By controlling the magnetic field orientation and decoupling torque and flux control, FOC offers superior performance, efficiency, and precision compared to traditional control methods, making it an essential tool for modern electromechanical systems.

We are using trapezoidal back emf method to control bldc motors speed and using technique1 .

BACK EMF WAVEFORM



Trapezoidal Back EMF in BLDC Motors

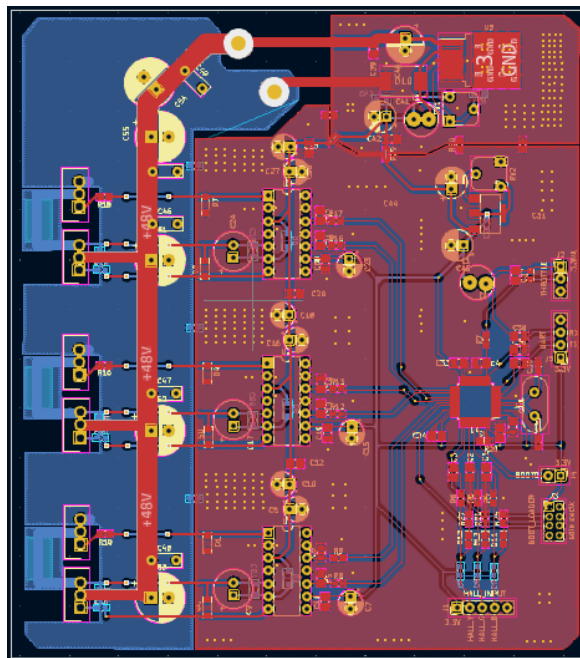
The trapezoidal back electromotive force (EMF) is a characteristic feature of Brushless DC (BLDC) motors, distinguishing them from other types of electric motors. This type of back EMF waveform is generated due to the motor's three-phase winding arrangement and the rotor's magnetic interaction with the stator windings.

Key Features:

Trapezoidal Shape: Unlike the sinusoidal back EMF waveform found in AC induction motors, the back EMF waveform in BLDC motors has a trapezoidal shape. This waveform consists of distinct rising and falling edges, resembling a trapezoid when plotted against time.

Two-Phase Energization: The trapezoidal back EMF is a result of the two-phase energization of the motor windings during each commutation cycle. As the rotor rotates, the back EMF waveform transitions between the phases, producing the characteristic trapezoidal pattern.

PCB FOR THE CONTROLLER



We designed this layout of the pcb using kicad.

This pcb is designed for a 200 W BLDC motor max operating conditions of 48V and 15A instantaneous current.

--> This PCB consists of 48V bus for power side of switches, 12V for powering gate drivers , 3.3V for powering the microcontroller along with Hall sensors within the motor, Throttle and UART, I2c communication with external devices.

Trace Widths of the PCB

48V bus: 4mm
12V bus: 0.55mm
3.3V bus: 0.3mm
Signal bus: 0.3mm

ICs USED:

- 1.IRF1407PBF -POWER MOSFET
- 2.IR2110 -Gate Driver (both HIGH and LOW side)

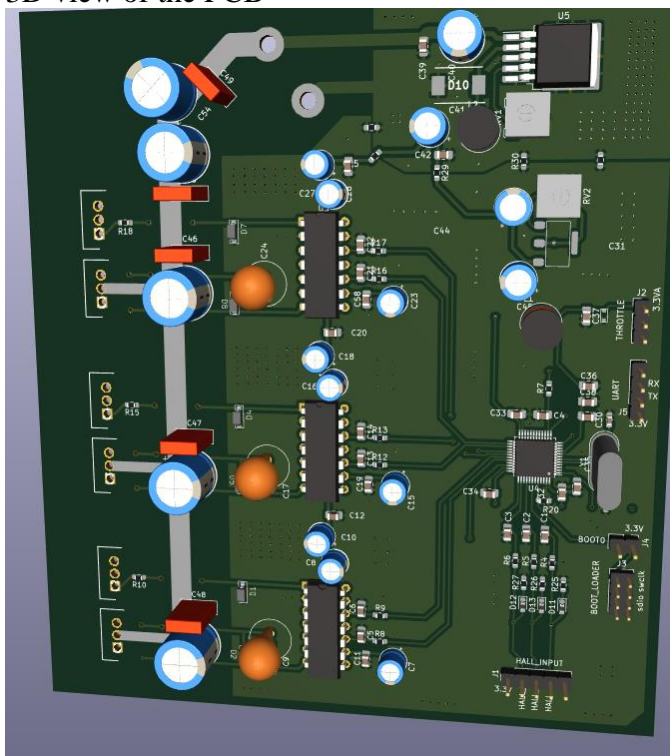
3. STM32F103C8Tx - Micro controller
4. SS13 -- Diode for boot strapping
5. LM2576HVS-ADJ – buck converter 48v to 12v
6. LM1117S -Voltage regulator 12v to 3.3v
7. 1N4728A -Zener diode for 3.3V

Other components:

1. potentiometers (10Kohm and 50Kohm)
2. Resistors
3. Capacitors
4. Inductors

performance and reliability. Simulation tools predict and enhance PCB behavior, while emerging materials drive innovation in RF/microwave and flexible circuits. Looking forward, PCBs will support IoT and Industry 4.0, demanding enhanced connectivity and efficiency. Green electronics and AI integration will shape future developments. PCB designers must adapt to evolving technologies, creating smarter, sustainable systems. Continuous improvement and interdisciplinary collaboration drive innovation in this dynamic field.

3D view of the PCB



VII. CONCLUSION:

The PCB design process is pivotal for modern electronics, requiring a balance of electrical, mechanical, and thermal considerations. Advanced techniques like high-speed design and thermal management optimize PCB layouts, ensuring

IEEE conference