Reaction Wheel Project: Component Justification, Layout Design, and Power Optimization

1. Justification for Choice of Components

NEMA17 BLDC Motor

- Compact size and high torque-to-inertia ratio for precise torque control.
- Supports accurate angular momentum adjustment in small satellites.
- Preferred over brushed DC motors due to better efficiency, longer lifespan, and smoother control without brush wear issues.

VESC (Vedder Electronic Speed Controller)

- Features bi-direction control of BLDC.
- Can be configured via VESC tool, and supports FOC (field oriented control).
- Offers fine torque/speed control and supports UART/CAN with telemetry.

Arduino Nano Microcontroller

- Low-power and compact with sufficient control and communication features.
- Interfaces easily with IMU, VESCs and SD module.

MPU9250 (IMU Sensor)

- Integrates 9-DOF(degrees of freedom) sensing in a low-power chip.
- Provides accurate real-time orientation data.

LM2596 Buck Converter

- High-efficiency step-down converter for voltage regulation.
- Powers both logic and motor components with stability.

2. Layout Arrangement

MT60 connectors are used for BLDC phase wires and XT60 for 28V DC input. These connectors ensure secure, high-current connections, suitable for compact and reliable system integration, and can withstand rugged space environment.

Mechanical Layout

- Flywheel Placement: Mounted on the BLDC motor shaft and aligned with the center of mass of the system to minimize unwanted torques.
- Motor and ESC Positioning: VESCs/PCB are placed close to motors to reduce phase wire length.
- Controller and IMU: Positioned near the system center to reduce vibrations and increase accuracy of orientation measurements.

Electrical Layout

- Power Lines: Short, thick wires for power delivery; twisted pairs used to minimize inductive noise.
- PCB Integration: All connections are routed through the custom PCB except for the BLDC motor wires and input DC wires, which are directly soldered onto the PCB for improved current handling and mechanical reliability.

3. Strategies for Low Power Consumption

Physical connectors such as MT60 and XT60 also contribute to power efficiency by reducing contact resistance and improving current transfer, thus minimizing power losses at connection points.

Motor Control Efficiency

- Use of Field Oriented Control (FOC) on the VESC to reduce power loss and improve motor efficiency.
- RPM, input voltage, input current, and motor current limits are configured via VESC Tool to prevent excessive power draw and ensure energy-efficient operation.
- The motor automatically slows down at defined temperature cutoff and shuts off at endpoint values set through the VESC Tool, protecting the system and conserving power during thermal stress.

Efficient Power Conversion

- LM2596 chosen for its high-efficiency conversion (up to 85%).
- Voltage levels chosen to match component requirements precisely, avoiding unnecessary conversion losses.

Minimized Communication Overhead

- Use of UART/CAN instead of high-power wireless communication modules.
- Efficient, lightweight data protocols for communication between Arduino and VESC.

THIS APPROACH ENSURES THAT THE REACTION WHEEL SYSTEM REMAINS COMPACT, EFFICIENT, AND RELIABLE—KEY CHARACTERISTICS FOR SPACE-CONSTRAINED, POWER-LIMITED ENVIRONMENTS LIKE SATELLITES OR SPACECRAFT.

NEXT PAGE CONTAINS THE REACTION WHEEL BLOCK DIAGRAM INDICATING COMMUNICATION TYPE AND POWER DISTRIBUTION AMONG THE COMPONENTS OF THE PCB.

SYSTEM BLOCK DIAGRAM & POWER DISTRIBUTION