ESP32 Swarm Rover - Dead Reckoning Navigation System (Q&A Format)

Q1: Which type of protocol is used?

A1: ESP-NOW is used for low-latency, connectionless communication between the master ESP32 and five slave rovers.

Q2: What does the connection and PID diagram consist of?

A2:

- Sensor Inputs: Wheel encoders, MPU6050, Ultrasonic sensors.
- Dead Reckoning Algorithm: Combines encoder odometry and MPU6050 orientation.
- PID Controller: Manages movement based on position error.
- Motor Driver: Cytron MDDRC10 receives PID output.
- Dynamic Braking: Uses Cytron's brake mode to instantly stop motors.

Q3: What dynamic braking system is used?

A3: The Cytron MDDRC10's BRAKE function is used by setting both motor terminals to GND, instantly stopping the motors.

Q4: How is PID control managed?

A4: PID tuning is done using the Ultimate Gain Method (Ziegler-Nichols). Steps include setting Ki and Kd to 0, increasing Kp until oscillation, and calculating parameters from Kc and Pc.

Q5: Why is PID used?

A5: PID ensures smooth and accurate motion, reducing overshoot and keeping the robot stable during navigation.

Q6: What is the accuracy of the system?

A6: The expected positional error is around ±2-3%. This is based on encoder resolution and drift-corrected IMU data. Periodic calibration can improve accuracy.

Q7: What is the response time of the system?

A7:

- Rise Time: ~300ms
- Settling Time: ~600ms
- Overshoot: Less than 10% (based on simulated response)

Q8: How do you deal with time delays in a multi-robot setup?

A8:

- Time-slot based communication (TDMA-like)
- Acknowledgment (ACK) for critical commands
- Prioritizing obstacle data over movement
- Timestamping packets to discard delayed data

Q9: What are the criteria for tuning PID controller parameters?

A9:

1. Start with open-loop (no PID) testing.
2. Increase Kp to quicken response without oscillation.
3. Add Ki to eliminate steady-state error.
4. Add Kd to control overshoot.
5. Test performance under different load/speed conditions.
6. Use step input response to fine-tune rise and settling time.

Q10: What are the PID values for each rover?

A10:

- Rover 1: Kp=139.5, Ki=7, Kd=1
- Rover 2: Kp=115, Ki=4.6, Kd=0.05
- Rover 3: Kp=136, Ki=5.5, Kd=0.1
- Rover 4: Kp=100, Ki=5, Kd=1
- Rover 5: Kp=100, Ki=5, Kd=1