ECE 445 Senior Design Final Report Rebuttal

Project 41: OmniGrasp: A Teleoperated Mobile Manipulation Platform with a Custom Mecanum Base and Robotic Arm

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1. General Summary

Two evaluators reviewed the final report. Evaluator 1 awarded full credit and commented that the report was well written. No specific revision request was raised by this evaluator; therefore, no point-by-point response is necessary for that evaluation.

Evaluator 2 awarded full credit for Introduction, Cost and Schedule, Requirements and Verification, and Conclusion, but assigned 4/9 for Design. The evaluator requested more implementation-level detail about the mecanum chassis, robotic arm, gripper, electrical power system, and teleoperation system. In response, the Design section was expanded and aligned with the final presentation, which describes OmniGrasp as a teleoperated platform rather than a fully autonomous or VLA-driven system.

The revised response also adds explicit PCB-level evidence from the final presentation. In particular, the updated text now describes the in-house supercapacitor control board, its role in whole-platform power stabilization, and the schematic-level design blocks shown in the presentation, including reset, auxiliary power, voltage/current sampling, PWM selection, dissipation protection, optional fan support, and the supercapacitor charge/discharge topology.

2. Evaluator Feedback Summary

Evaluator	Score / Comment	Action Taken
Evaluator 1	Full credit in all categories; Total 30/30. Comment: “Well-written final report.”	No specific response required. We retained the report structure and applied only the Design-section improvements needed for Evaluator 2.
Evaluator 2	Design received 4/9; Total 25/30. Main request: add design details for the chassis, arm, gripper, electrical power system, and teleoperation system; clarify open-source/custom design basis.	A point-by-point response was added. The Design revision now follows the final-presentation wording: custom mecanum base, custom 7-DOF arm and gripper, DM-MC01 motor control, in-house supercapacitor control PCB, DJI VT-series visual feedback, and direct joint mapping without inverse kinematics.

3. Response to Evaluator 2 Comment

Comment 1: Provide design details for the mecanum chassis, robotic arm, and gripper. Are these based on open-source designs? Describe the electrical system powering the chassis, arm, gripper, and control system. Describe the teleoperation system.

Response 1: We thank the evaluator for identifying this important gap in the original Design section. We agree that the previous version explained the project goal but did not provide enough subsystem-level engineering detail for a reader to understand how OmniGrasp was mechanically constructed, powered, controlled, and teleoperated. We have revised the Design section to describe the implemented system and to align the wording with the final presentation.

The revised report now states that OmniGrasp is a teleoperated mobile manipulation platform with a custom mecanum base and robotic arm. The base uses a custom four-wheel mecanum chassis for holonomic motion. The manipulator is a custom 7-DOF robotic arm with a parallel gripper end-effector. The drivetrain uses four DJI M3508 motors controlled through DM-MC01 motor controller boards. The arm uses a combination of joint actuators from base to end, including DM-J606, DM-J10010, Lingkong GM5010, and three DM-J4310 actuators, while the gripper uses a DJI M2006 motor for open/close motion.

The revised report also clarifies that the platform is not a direct reproduction of an open-source robot. Instead, it is a custom senior-design integration using commercial motors, motor controllers, actuators, and in-house mechanical/electrical design. Standard robotics principles such as mecanum-drive holonomic motion and serial-arm joint control informed the design, but the final chassis layout, arm integration, gripper implementation, supercapacitor control board, power wiring, and teleoperation interface were built and integrated by the team.

Most importantly, the electrical-system description has been expanded. The report now explains that OmniGrasp is powered by a battery system with a supercapacitor-assisted power-stabilization module. The in-house supercapacitor control board is added to handle peak current demand and reduce voltage sag during simultaneous base and arm actuation. The PCB evidence shown in the final presentation includes the real board, PCB outline and dimensions, schematic blocks for reset, auxiliary power, current sampling, voltage sampling, PWM selection, dissipation protection, and optional fan support, as well as a topology sheet for the supercapacitor charge/discharge power stage.

The teleoperation description has also been revised. The system uses a DJI VT-series video link to provide low-latency visual feedback to the operator. Wireless commands are sent to the embedded controller, which distributes commands to the base, arm, and gripper. For arm operation, the team used a 3D-printed scaled replica arm as the operator-side input device. Seven joint angles are measured using I2C magnetic encoders (AS5600L) and mapped directly to the real arm joints, avoiding inverse kinematics and keeping the control strategy simple and reliable for a senior-design prototype.

4. Revised Design Content Added to the Report

The following text is intended to replace the previous Design-section placeholder and to match the terminology used in the final presentation.

4.1 Mecanum Chassis

The mobile base is a custom mecanum chassis designed for holonomic planar motion. Four DJI M3508 motors drive the mecanum wheels, with each wheel independently controlled through a DM-MC01 motor controller. This configuration allows forward/backward translation, lateral translation, and yaw rotation without a steering mechanism. The mecanum base was selected because omnidirectional mobility improves positioning flexibility during teleoperated manipulation, especially when the operator must align the arm with a target object in constrained spaces.

4.2 Custom 7-DOF Arm and Gripper

The manipulator is a custom-built 7-DOF serial robotic arm mounted on the mobile base. The joint actuator chain uses DM-J606, DM-J10010, Lingkong GM5010, and three DM-J4310 actuators from the base toward the end effector. The end effector is a parallel gripper with an integrated DJI M2006 motor for open/close actuation. The extra degrees of freedom provide practical redundancy for positioning the gripper while maintaining feasible joint configurations on a compact mobile platform.

4.3 Custom Design and Open-Source Clarification

The robot is not a direct copy of an open-source mobile manipulator. The final build combines commercial actuators and controllers with a custom mechanical structure, custom electrical integration, an in-house supercapacitor control board, and a custom operator-side replica arm. Publicly known design principles, such as mecanum-wheel holonomic drive and direct joint-space control, informed the engineering decisions, but the physical system was designed, assembled, and integrated by the team for this project.

4.4 Electrical System, PCB Design, and Power Stabilization

The electrical system is organized around a battery-powered actuation bus and a low-voltage control/sensing subsystem. High-current loads include the four base motors, the arm actuators, and the gripper motor. These loads can produce transient current peaks when the base accelerates or when the arm and gripper move at the same time. To improve power stability, the team designed an in-house supercapacitor module with a dedicated control PCB.

The final presentation shows both the physical supercapacitor control board and the schematic/PCB design. The board is not merely a wiring accessory; it forms a power-stabilization subsystem for the whole platform. The design includes reset circuitry, auxiliary power generation, current sampling, voltage sampling, PWM selection, dissipation-protection circuitry, and an optional fan interface. A separate topology schematic shows the supercapacitor charge/discharge stage and associated switching/protection structure. These details were added to the report to directly address the evaluator's request for the electrical system powering the chassis, arm, gripper, and control system.

- Base drive power: battery input distributed to four DJI M3508 drive motors through DM-MC01 controller boards.
- Arm and gripper power: joint actuators and the M2006 gripper motor are powered through the actuation bus and controlled through the embedded control system.
- Peak-power buffering: the in-house supercapacitor module supports transient power demand and reduces whole-platform voltage sag.
- PCB-level sensing and protection: the supercapacitor control board includes voltage/current sampling and dissipation-protection blocks for safer power stabilization.
- Control electronics: the embedded controller receives operator commands and coordinates the base, arm, gripper, and safety/power subsystems.

4.5 Teleoperation and Direct Joint Mapping

OmniGrasp is operated through teleoperation rather than autonomous planning. The operator receives low-latency visual feedback through a DJI VT-series video transmission link, similar in principle to drone-style first-person operation. The operator-side input device includes a 3D-printed scaled replica arm. The seven operator-side joint angles are measured using AS5600L I2C magnetic encoders and directly mapped to the corresponding real arm joints. This design avoids inverse kinematics, reduces software complexity, and provides an intuitive mapping between operator motion and robot-arm motion.

5. PCB and Electrical-System Evidence Added from the Final Presentation

The following figures from the final presentation are included to support the revised response and make the electrical-system explanation concrete. They should be used as supporting material for the Design-section revision, especially for the PCB and power-stabilization subsection.

Figure 1. Annotated mechanical/electrical design details of the real OmniGrasp build.

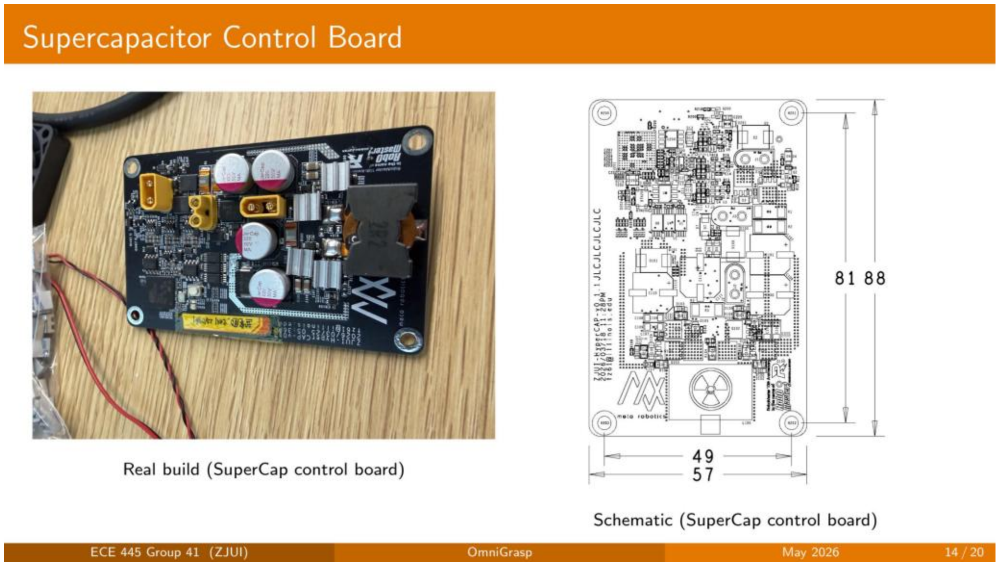

Figure 2. Supercapacitor control board: real build and PCB outline/dimension drawing.

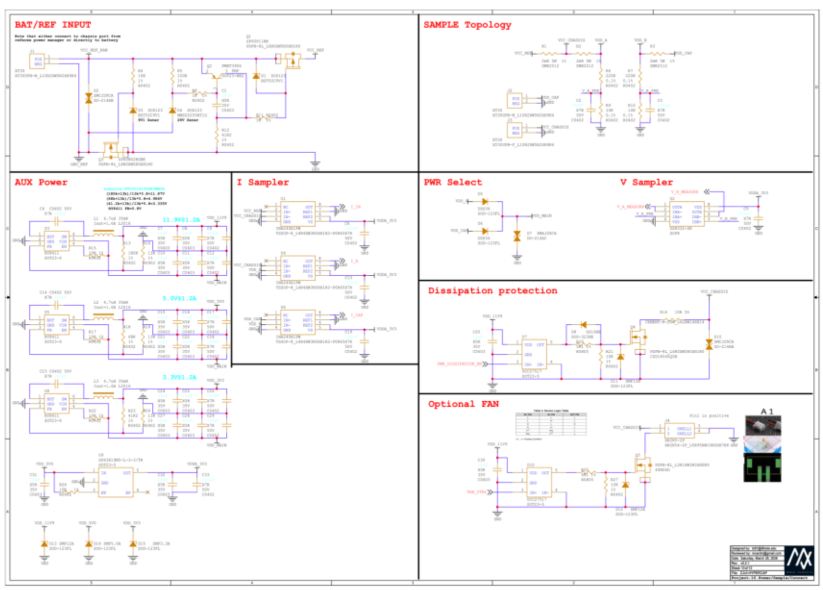

Figure 3. PCB schematic sheet showing reset, auxiliary power, sampling, PWM selection, dissipation protection, and optional fan blocks.

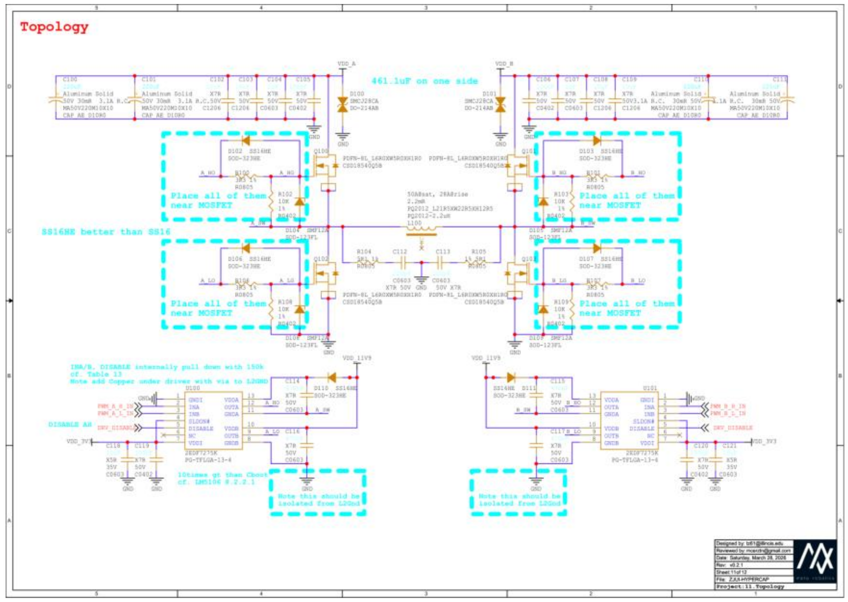

Figure 4. PCB topology sheet for the supercapacitor charge/discharge power stage and related switching/protection blocks.

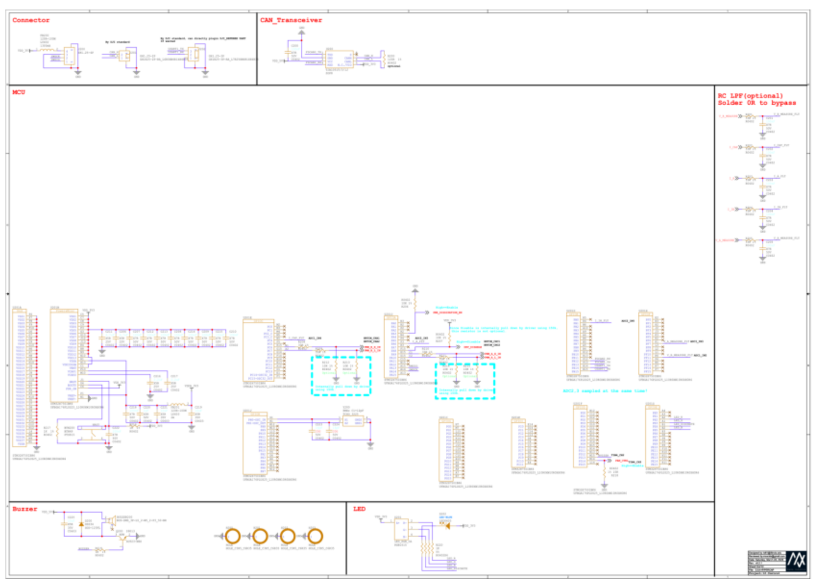

Figure 5. PCB connector, MCU, communication, voltage-regulation, and interface details.

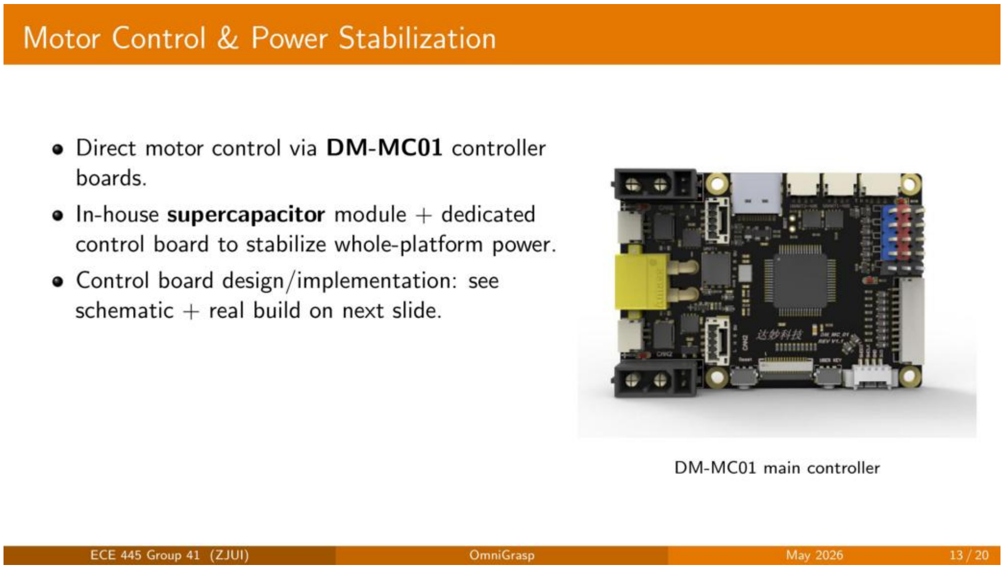

Figure 6. DM-MC01 motor controller and the overall motor-control/power-stabilization description.

6. Closing Statement

These revisions directly address Evaluator 2's concern that the Design section lacked sufficient technical detail. The updated response now explains the implemented mecanum chassis, 7-DOF arm, gripper, motor controllers, power distribution, in-house supercapacitor control PCB, and teleoperation interface. The response is also aligned with the final presentation terminology: OmniGrasp is presented as a teleoperated mobile manipulation platform with a custom mecanum base and robotic arm, DM-MC01-based motor control, DJI VT-series visual feedback, direct joint mapping, and an in-house supercapacitor control board for whole-platform power stabilization.