# Response to Instructor Comments

## Movable Impact Testing Platform

## Team #2

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# 1. Summary

We sincerely thank you for taking the time to review our draft final report. Please find the detailed responses below and the corresponding revisions prepared for the supplementary document.

We acknowledge that the draft report did not fully present the design in a clear engineering format. In particular, the report included several photographs of the prototype, but it did not include enough labelled diagrams, quantitative verification information, a weekly project schedule, or a quantified uncertainty analysis. In response to these comments, we prepared this supplementary document to add the missing hydraulic circuit diagram, the voltage switching logic diagram, the PCB layout for the valve-command generation circuit, the project schedule table, a quantitative pressure-force calculation, a labelled pressure-sensor test photograph, and an uncertainty contribution analysis for the measured output-frequency deficit.

# 2. Questions for General Evaluation

| **Question for General Evaluation** | **Instructor's Evaluation** |
|---|---|
| Are the final hydraulic circuit and voltage switching logic diagrams included? | Must be improved |
| Is the PCB layout for the valve-command generation circuit included? | Must be improved |
| Is a weekly project schedule included? | Must be improved |
| Are pressure, force, and valve-command voltage results quantified? | Must be improved |
| Is the low-frequency behavior supported by uncertainty analysis? | Must be improved |
| Are all figures and tables clear and well-presented? | Must be improved |

# 3. Point-by-point response to Comments and Suggestions

## Comments 1

There are two missing figures for the final hydraulic circuit on page 9 and the voltage switching logic on page 11. Please add these, as well as the PCB layout if available. The report uses photographs instead of diagrams. Nicely labelled diagrams are usually easier to interpret than photographs.

## Response 1

We sincerely thank the instructor for this important comment. We agree that the draft report relied too heavily on photographs and did not provide enough labelled engineering diagrams. Although photographs are useful for showing the assembled prototype, they do not clearly explain the hydraulic flow path, the valve control logic, or the electrical signal routing. We therefore added labelled diagrams and the PCB layout for the valve-command generation circuit to the supplementary document.

First, a final hydraulic circuit diagram has been added. This diagram shows the hydraulic oil reservoir, hydraulic pump, relief valve or pressure-control component, pressure gauge, servo proportional directional valve, hydraulic cylinder, pressure line, and return line. The purpose of this figure is to make the fluid path clear and to show how the pump supplies pressurized oil to the valve and how the valve directs the flow to extend or retract the cylinder.

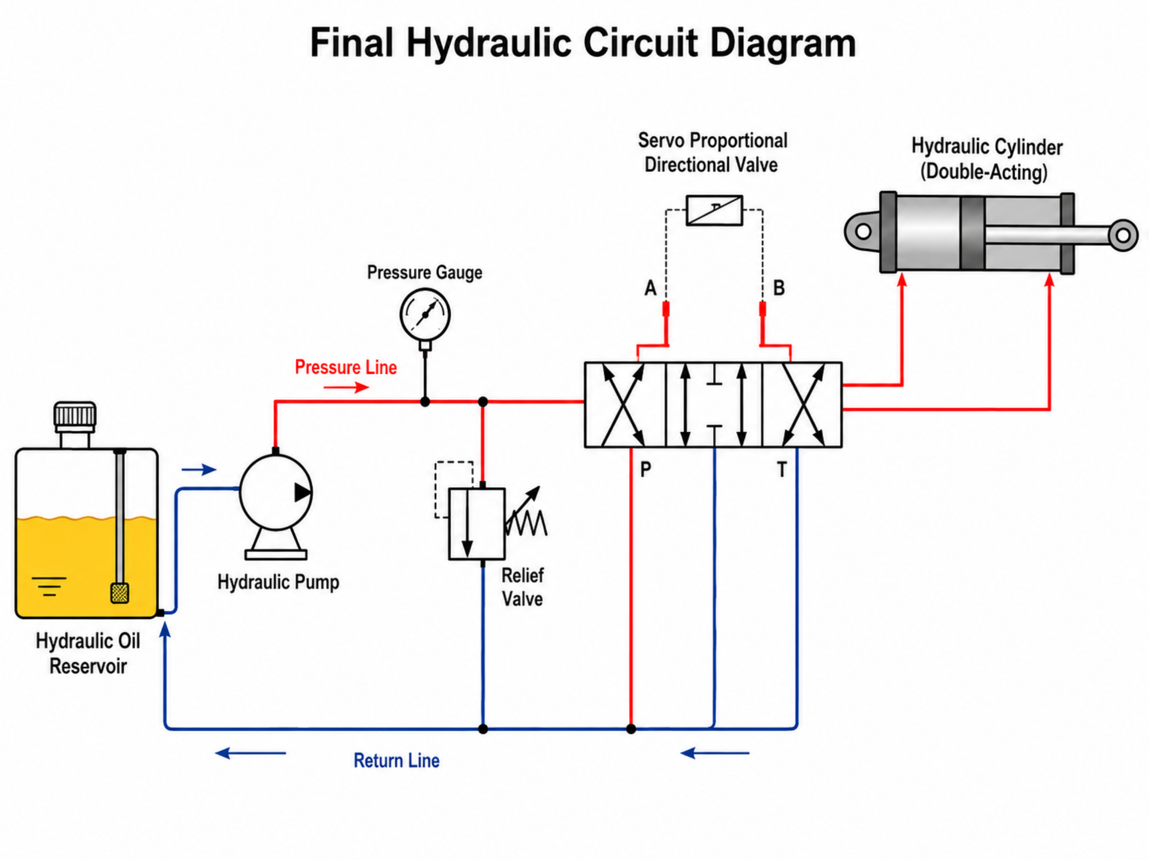

Figure 1: Final hydraulic circuit diagram of the Movable Impact Testing Platform. The diagram shows the hydraulic oil reservoir, hydraulic pump, relief valve, pressure gauge, servo proportional directional valve, double-acting hydraulic cylinder, pressure line, and return line.

Second, a voltage switching logic diagram has been added. This diagram shows the 72 V battery, 72 V to 24 V DC-DC converter, 72 V to 5 V DC-DC converter, microcontroller, PCB control circuit, fixed-frequency $\pm 10$ V command output, servo proportional directional valve, and hydraulic cylinder. This figure clarifies that the 24 V line powers the valve, while the $\pm 10$ V command signal controls the valve position and hydraulic flow direction.

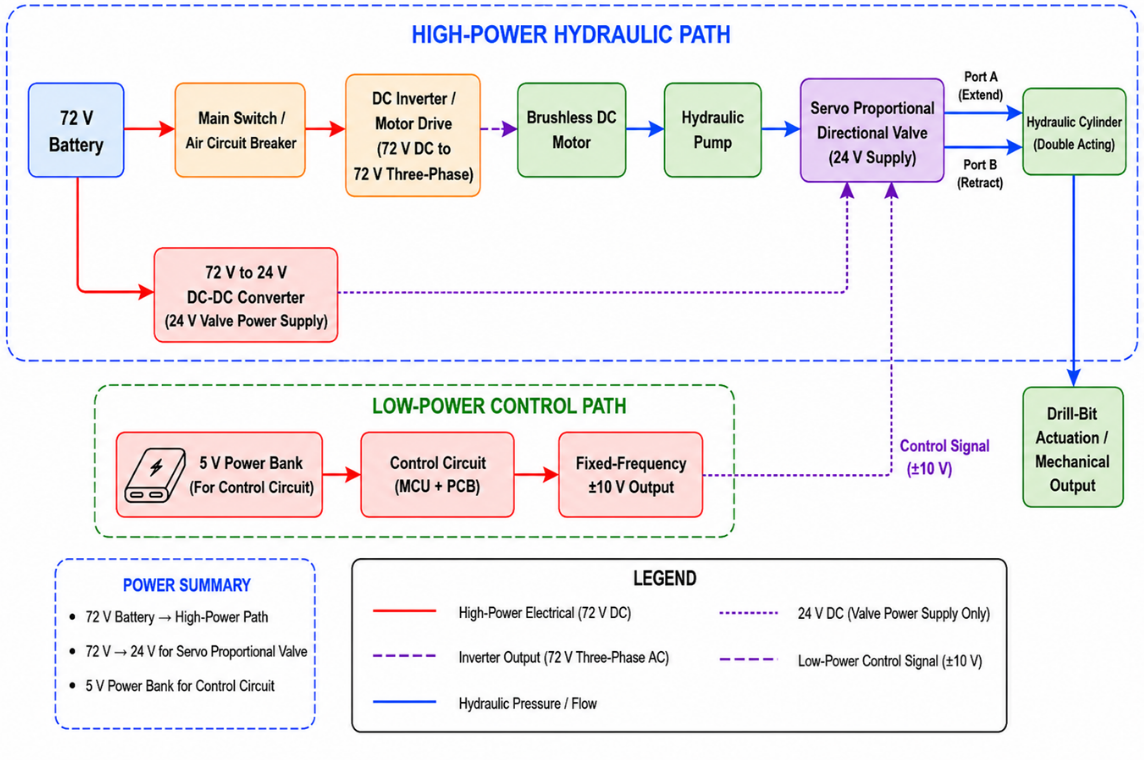

Figure 2: Voltage switching logic for the servo proportional directional valve. The diagram shows how the 72 V battery supplies the 24 V valve power path and the 5 V control path, while the microcontroller and PCB generate the fixed-frequency $\pm 10$ V command signal for valve-direction control.

Third, the PCB layout for the valve-command generation circuit has been added. This layout documents the low-power control-board implementation used to generate and route the fixed-frequency $\pm 10$ V valve-command signal. It shows the control-circuit layout at the PCB level, including the microcontroller interface, power input, ground reference, signal-output path, and valve-command connection. This addition directly addresses the instructor's request to include the PCB layout if available and makes the control-circuit implementation easier to interpret than photographs alone.

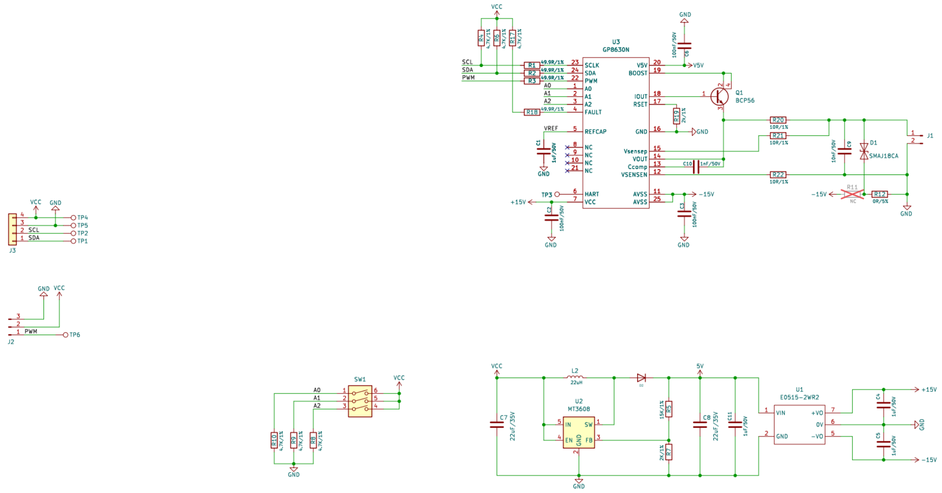

Figure 3: PCB layout for the valve-command generation circuit. The layout documents the control-board implementation used to generate and route the fixed-frequency ±10 V command signal for the servo proportional directional valve, including the microcontroller interface, power input, ground reference, signal-output path, and valve-command connection.

## Comments 2

No project schedule is included in the report. Please provide a table that shows what work was being done each week, and which students were working on each task.

## Response 2

We agree with this comment. The draft final report described the final design, verification, and cost analysis, but it did not include a project schedule. To address this issue, we added a weekly project schedule table. The table summarizes the major tasks completed during the semester and identifies the responsible students for each task. Since the system integration required cooperation across the electrical, hydraulic, mechanical, and documentation work, we list the responsible students as "All team members" for each task.

Table 1: Weekly project schedule and team responsibilities

| **Week** | **Work Completed** | **Responsible Students** | **Status** |
|---|---|---|---|
| Week 1 | Defined the project objective, main functional requirements, and the overall concept of a vehicle-mounted electro-hydraulic impact testing platform. | All team members | Completed |
| Week 2 | Developed the preliminary system architecture, including the high-power hydraulic path, low-power control path, and vehicle-mounted mechanical structure. | All team members | Completed |
| Week 3 | Selected major hydraulic components, including the hydraulic pump, oil reservoir, proportional directional valve, relief valve, hydraulic cylinder, hoses, and fittings. | All team members | Completed |
| Week 4 | Selected major electrical components, including the 72 V battery, DC inverter/motor drive, 72 V to 24 V DC-DC converter, and 72 V to 5 V DC-DC converter. | All team members | Completed |
| Week 5 | Designed the voltage-based valve switching control method and established the relationship between the 10 Hz electrical switching signal and the 5 Hz ideal mechanical reciprocation frequency. | All team members | Completed |
| Week 6 | Built and tested the microcontroller-and-PCB-based control circuit for generating the fixed-frequency ±10 V valve-command signal. | All team members | Completed |
| Week 7 | Assembled the hydraulic pump, reservoir, valve block, relief valve, hydraulic cylinder, and hydraulic lines on the vehicle platform. | All team members | Completed |
| Week 8 | Integrated the electrical, hydraulic, and mechanical subsystems on the vehicle frame and checked the wiring, hose routing, and mounting structure. | All team members | Completed |
| Week 9 | Performed power-supply voltage verification, valve-command waveform verification, and integrated motion testing using video-based cycle counting. | All team members | Completed |
| Week 10 | Prepared the final report, supplementary response document, labelled diagrams, quantitative verification explanation, uncertainty analysis, and final presentation materials. | All team members | Completed |

## Comments 3

Please add some additional quantitative results, such as measured pressure and force. If you cannot obtain the force measurement, explain why not. It is also noted that the valve command voltage test produces no specific quantitative metric but only a qualitative claim that the requirement is satisfied. Please add some type of quantification of this verification.

## Response 3

We sincerely thank the instructor for this comment. We agree that the original verification section did not provide enough quantitative evidence. To address this issue, we added a quantitative force verification based on the hydraulic impact experiment.

As part of the experimental work, which also forms part of Yihang Shen's senior thesis, the hydraulic exciter was tested with a steel impact head striking an asphalt road surface at an approximately 4.2 Hz operating frequency. In this setup, the circular component mounted between the actuator output and the steel impact head was the pressure sensor used in the test, as shown in Fig. 4. The hydraulic cylinder piston diameter was 50 mm, and the directional valve supplied hydraulic oil at approximately 4 MPa.

The theoretical cylinder output force can be estimated from the pressure-area relationship

$$F = PA, \tag{1}$$

where $F$ is the output force, $P$ is the hydraulic pressure, and $A$ is the piston area. For a piston diameter of 50 mm,

$$A = \frac{\pi d^2}{4} = \frac{\pi(0.050)^2}{4} = 1.9635 \times 10^{-3}\ \mathrm{m}^2. \tag{2}$$

Using the operating pressure of 4 MPa,

$$F_{\text{theoretical}} = (4.0 \times 10^6)(1.9635 \times 10^{-3}) = 7854\ \mathrm{N} \approx 7.85\ \mathrm{kN}. \tag{3}$$

The experimentally obtained impact force was approximately

$$F_{\text{experiment}} \approx 7.9\ \mathrm{kN}. \tag{4}$$

The relative difference between the theoretical estimate and the experimental result is

$$\frac{|7.90 - 7.85|}{7.85} \times 100\% \approx 0.64\%. \tag{5}$$

This result shows that the experimentally obtained force is in close agreement with the theoretical hydraulic-force estimate. Therefore, the supplementary document now includes a clear quantitative verification of the hydraulic output. In addition, the valve-command verification will be quantified in the revised report by reporting the measured positive voltage, negative voltage, and switching frequency of the $\pm 10$ V control signal.

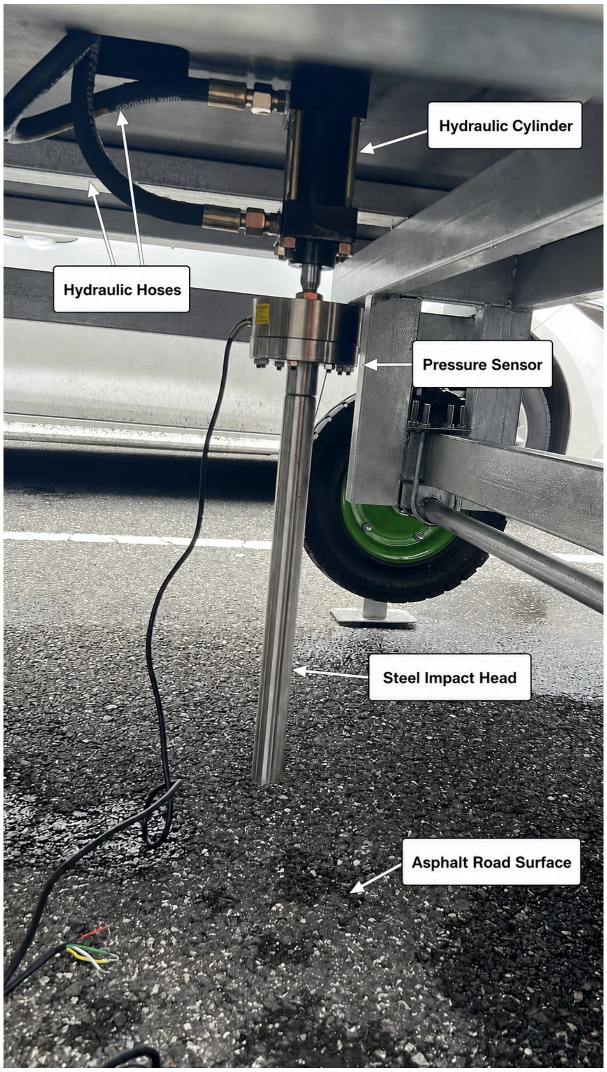

Figure 4: Experimental setup for the hydraulic impact test. The circular component mounted between the actuator output and the steel impact head is the pressure sensor used in the experiment. The test was conducted with the hydraulic exciter operating at approximately 4.2 Hz while the steel impact head repeatedly struck the asphalt road surface.

## Comments 4

There is some discussion of uncertainties, including multiple physical reasons for the low frequency, including valve response, pump flow, hose losses, friction, and inertia. However, the discussion is qualitative and lacks an actual uncertainty analysis estimating the contribution of each factor. Please add these.

## Response 4

We agree with this comment. The draft report identified the major physical reasons for the lower-than-ideal output frequency, but the discussion was qualitative. To improve this section, we added a quantified uncertainty contribution analysis.

The ideal output frequency is determined by the relationship between the electrical switching frequency and the mechanical reciprocating frequency:

$$f_{\text{drill,ideal}} = \frac{f_{\text{switch}}}{2}. \tag{6}$$

For the implemented 10 Hz electrical switching command,

$$f_{\text{drill,ideal}} = \frac{10\ \text{Hz}}{2} = 5.0\ \text{Hz}. \tag{7}$$

The measured output frequency was obtained by counting 21 complete reciprocating cycles in 5.0 s:

$$f_{\text{drill,measured}} = \frac{21\ \text{cycles}}{5.0\ \text{s}} = 4.2\ \text{Hz}. \tag{8}$$

The absolute frequency deficit is therefore

$$\Delta f = 5.0\ \text{Hz} - 4.2\ \text{Hz} = 0.8\ \text{Hz}. \tag{9}$$

The relative deficit is

$$\frac{\Delta f}{f_{\text{drill,ideal}}} = \frac{0.8}{5.0} = 16\%. \tag{10}$$

The estimated contribution of each factor is summarized in Table 2. These percentages are engineering estimates based on the observed system behavior and the physical role of each subsystem. They are not isolated single-factor experimental measurements, but they provide a clearer estimate of how each factor contributes to the difference between the ideal 5.0 Hz output and the measured 4.2 Hz output.

Table 2: Estimated contribution of each factor to the measured frequency deficit

| **Factor** | **Main Effect** | **Share of Deficit** | **Frequency Effect** |
|---|---|---|---|
| Valve response delay | The valve spool needs finite time to respond after each voltage transition, reducing the effective motion time in each half-cycle. | 25% | 0.20 Hz |
| Pump flow limitation | The available pump flow limits the cylinder speed and may prevent the actuator from completing the required stroke within each half-cycle. | 35% | 0.28 Hz |
| Hose and fitting losses | Pressure losses through hoses, fittings, and the valve block reduce the effective hydraulic power delivered to the cylinder. | 15% | 0.12 Hz |
| Cylinder and mechanical friction | Seal friction and mechanical resistance consume part of the available hydraulic force and slow the actuator response. | 15% | 0.12 Hz |
| Moving-part inertia | The impact head and connected moving parts require acceleration and deceleration during every cycle. | 10% | 0.08 Hz |
| **Total** | Difference between the ideal 5.0 Hz output and the measured 4.2 Hz output. | **100%** | **0.80 Hz** |

This added analysis shows that the frequency reduction is not caused by a single issue. Instead, it is mainly caused by pump flow limitation and valve response delay, with additional contributions from hose losses, friction, and inertia. Future improvements should therefore focus on increasing pump flow capacity, selecting a faster valve, shortening hydraulic lines, reducing mechanical friction, and decreasing the moving mass of the impact-end assembly.

# 4. Summary of Revisions

Based on the above comments, the supplementary document and revised report will include the following changes:

(1) A labelled final hydraulic circuit diagram has been added.

(2) A labelled voltage switching logic diagram has been added.

(3) A PCB layout for the valve-command generation circuit has been added to document the low-power control implementation.

(4) A weekly project schedule table has been added, with all tasks assigned to all team members.

(5) The valve-command voltage verification will be quantified by reporting the measured positive voltage, negative voltage, and switching frequency of the ±10 V control signal.

(6) A quantitative pressure-force calculation has been added using a 4 MPa hydraulic pressure and a 50 mm cylinder piston diameter, giving a theoretical force of approximately 7.85 kN.

(7) A labelled pressure-sensor test photograph has been added to show the hydraulic impact test setup and the location of the pressure sensor.

(8) A quantified uncertainty contribution table has been added to estimate the effects of valve response, pump flow, hose losses, friction, and inertia on the 0.8 Hz output-frequency deficit.