# Magnetorheological suspension control using Matlab and Arduino PID controller for the Formula Malaysia Education Competition (Formula MEC)

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**DOI:** https://doi.org/10.37178/ca-c.23.1.203

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***Abstract***

*Formula MEC car development using a magnetorheological (MR) suspension system has become popular and necessary nowadays. There are less studies in this field. Some of literature review was done to gain basic information and knowledge of the FMEC formula car in designing a multiple degree-of-freedom mass-spring damper, the mathematical model involved, and the controller using Matlab/Simulink. The next step was to determine the parameters of the formula car, such as mass and damper spring resistance. Based on the mathematical model, the system was designed in Simulink using the force disturbance obtained from previous experiments. After successfully simulating the system, the controller was designed using Simulink and tested. The test results obtained from the MR damper were compared to determine the parameters that yielded the best performance towards reducing vehicle vibrations. A prototype of the MR damper was built in Simulink and Arduino microcontroller, which was a major contribution of this research. The MR Damper was designed according to the Formula MEC specifications. A quarter car system for the formula car was designed following the equations of a 2DOF system. In the next phase, a simulation was conducted to aid in the design of the MR Formula MEC damper.*

***Keywords:*** *Magnetorheological damper design, Formula Car Malaysia Education Competition (F-MEC), Matlab, Simulink, Arduino microcontroller*.

### *Introduction*

Nowadays, each vehicle must be equipped with a suspension system to absorb vibrations, especially on uneven road surfaces and to support heavy passenger weights. In this research, a 'smart' suspension system using fluid 'magneto rheological' (MR) technology is analysed. Formula MEC is a new formula car competition that is open to the public, private, colleges, polytechnics and technical higher institutions that serve education through motorsport in Malaysia. Formula MEC stands for Formula Malaysia Education Competition which is participated by various institutions in Malaysia. Participation from other Asian countries is planned and targeted in future events. The Formula MEC will be organized by Universiti Pendidikan Sultan Idris, Malaysia. The participant's score is split to 50 percent for presentation and 50 percent for time attack racing. This unique mark scoring combination is a new concept of the formula car competition in which the participant is not only judged solely based on their car performance but also on the capability of their formula car through analysis of suspension system [1] and finite element method i.e. bending test, crashworthiness test including torsional rigidity test. Figure 1 shows the logo of Formula MEC.

**Figure 1.** F-MEC logo

### *Methodology*

In recent years, several tools have been developed to design controllers, from the most basic systems up to advanced systems [2]. The ARDUINO system is ideal for this research, because of its straightforward approach and low cost. The equipment consisted of basic computer software for ARDUINO, an ARDUINO microcontroller, and an acceleration sensor. The ARDUINO system was paired with a specially designed MR damper for a Formula car. It was then tested using a quarter car suspension rig. Some adjustments were made, including the positioning of the sensors on the rig. Some ARDUINO programs are custom-made with a PID controller, which was the primary system used [3, 4]. The experiment found that the PID controller received information from the sensors well, processed the data, and sent the best signal to the MR damper. Figure 2 shows the PID controller for the quarter car semi-active suspension system. Vibration sensors used in this experiment are shown in Figure 3. The sensor collected the acceleration data from the sprung mass (body), and then the data were transferred directly to the ARDUINO microcontroller. Figure 4 shows the PCB circuit for the microcontroller, which was additional to the ARDUINO controller system. Figure 4 shows the PCB circuit for the microcontroller while Figure 5 shows the ARDUINO Mega microcontroller. This controller was selected because of its ability to connect with more hardware. The circuit diagram of the PID microcontroller system is shown in Figure 6, which is identical to the PCB circuit shown in Figure 4. Figure 7 shows the PID controller hardware set-up. The figure demonstrates the tuning process using a computer connected to the ARDUINO Mega microcontroller. The computer was used to process the input data from the acceleration sensor used for the MR damper[5, 6].

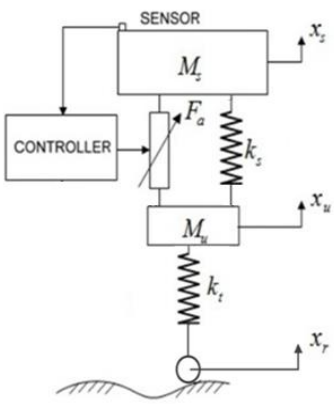


**Figure 2.** PID controller for the semi-active suspension system

***ARDUINO PID Microcontroller Experiment Setup***

A one degree of freedom (1DOF) experimental setup for the PID controller (spring and damper) was assembled, as shown in Figure 5 and Figure 6, In this experiment, wheels were neglected, because the focus was on the efficiency of the ARDUINO PID controller. Figure 5 shows a schematic of the experimental setup for the PID microcontroller and the diagram of the experimental setup for the MR damper. This figure was part of the experimental setup shown in Figure 6. The acceleration sensor was located on the sprung mass, which was referred to as the body of the rig with a mass of 250 kg. The MR damper was then assembled with the ARDUINO PID microcontroller. No previous experiments had been conducted in the field or on real road environments, while specifically focusing on the effective function of the ARDUINO PID microcontroller. An Agilent power supply was assembled and connected to the external PCB board of the microcontroller, which was not able to support high flow current. Hence, the maximum voltage to the microcontroller was only 5 V. The Arduino software then processed the acceleration data from the sensor into the PID controller system. Finally, the PID controller optimised the amount of the current input to stabilise the vibration of the quarter car rig[7, 8].

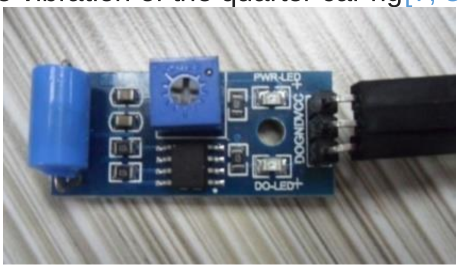


**Figure 3.** Acceleration sensor

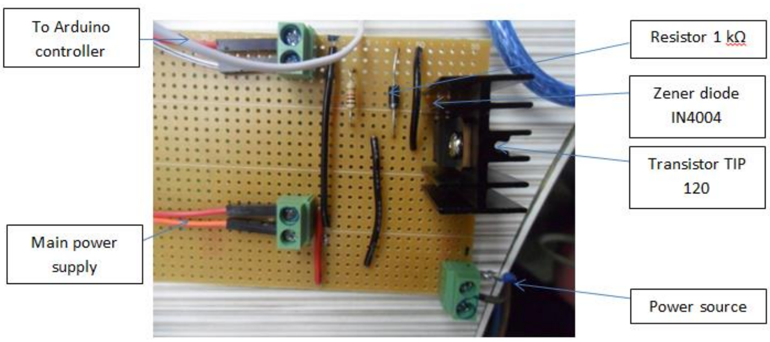


**Figure 4.** PCB circuit for the microcontroller

**Figure 5.** ARDUINO Mega microcontroller

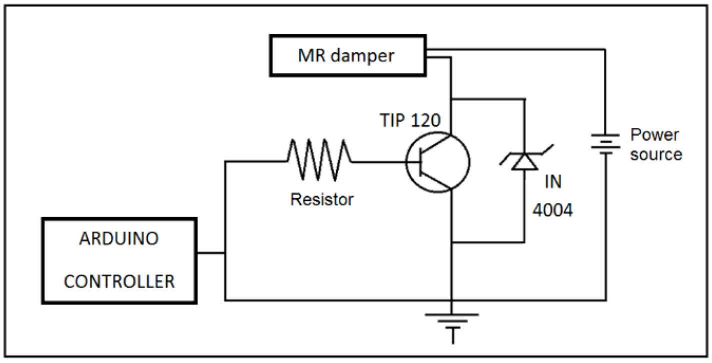


**Figure 6.** Circuit diagram of the PID microcontroller system for the MR damper

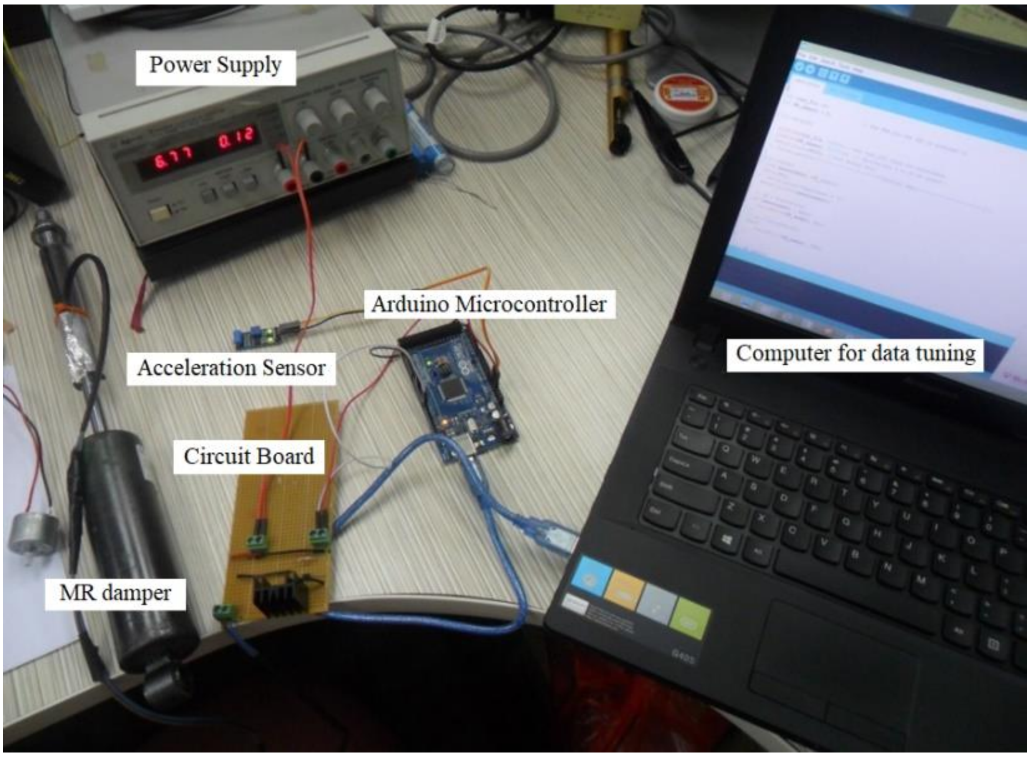


**Figure 7.** PID controller hardware set-up

### *Results and Discussion*

Based on the PID microcontroller experiment, a combination of results was selected and compared, as illustrated in Figure 8. The graph summarises the significance of the ARDUINO PID microcontroller in reducing the sprung mass displacement [9]. The results presented here may facilitate improvement of the controller system for the MR C-class damper. The results also showed that the highest displacement from these experiments was 27 mm, with $K_P$ = 150, $K_I$ = 50, and $K_D$ = 30. The second set of results obtained for $K_P$ = 135, $K_I$ = 35, and $K_D$ =15 yielded a reduced displacement of the sprung mass to 13 mm, indicating the successful implementation of the PID microcontroller. Lastly, the best results obtained were for $K_P$ = 135, $K_I$ = 15, and $K_D$ = 8, where the displacement was reduced to 4 mm. Another advantage of this controller was that it operated on its own without any tuning or reset after testing [3]. In the future, it is hoped that this system will need to be less maintained for usage on a normal road condition [10]. In addition, a mileage test must be conducted to ensure the durability of the ARDUINO PID microcontroller before it can be commercialised for the formula car [11].

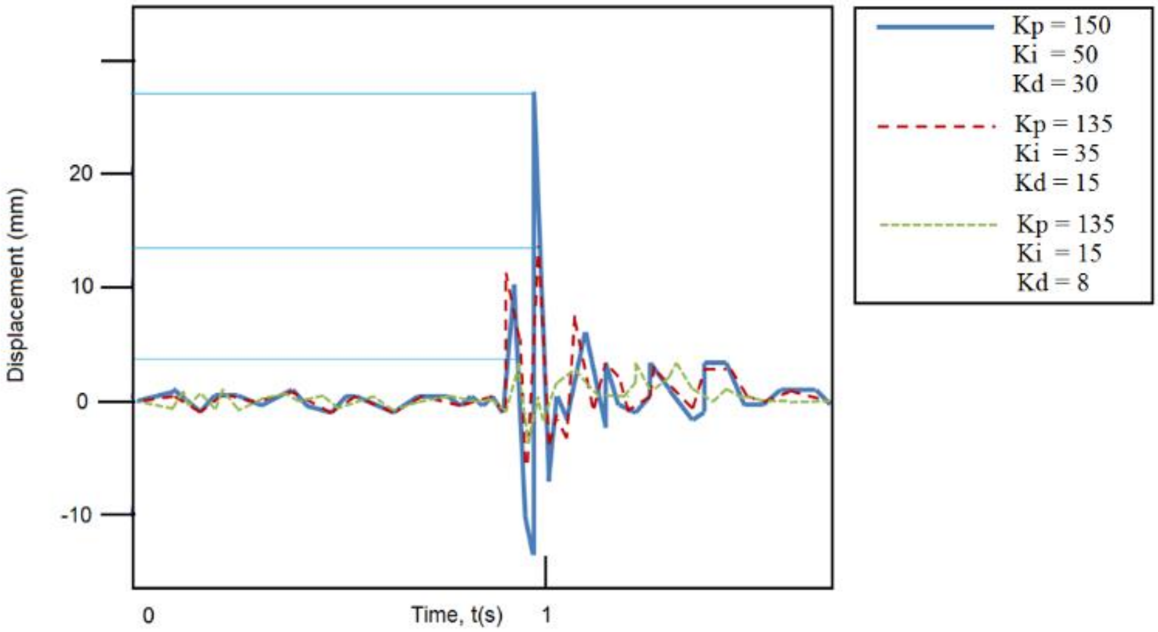


**Figure 8.** Sprung mass displacement tuning comparison

*Table 1*

Results of the PID ARDUINO microcontroller tuning

| No | $K_P$ | $K_I$ | $K_D$ | Displacement (mm) | Settling time (sec) | Acceleration (g) | Displacement Reduction % |
|---|---|---|---|---|---|---|---|
| 1 | 150 | 50 | 30 | 27 | 1/2 | 4 | - |
| 2 | 145 | 40 | 25 | 20 | - | 3.8 | 25 |
| 3 | 140 | 45 | 25 | 20 | - | 4 | 25 |
| 4 | 135 | 50 | 20 | 20 | 1/2 | 4 | 25 |
| 5 | 135 | 45 | 10 | 20 | 1/4 | 3.8 | 25 |
| 6 | 135 | 35 | 15 | 13 | 1/4 | - | 51 |
| 7 | 145 | 20 | 10 | 10 | - | - | 52 |
| 8 | 140 | 20 | 8 | 9 | 1/5 | 2 | 66 |
| 9 | 135 | 15 | 8 | 4 | 1/2 | 1.5 | 85 |

### Conclusion

The primary objective of this work was to test the feasibility of the ARDUINO PID microcontroller for an OEM Lord Damper [12, 13]. The goal was to control the performance of the OEM Lord damper with the same suspension package in a Formula car. The experiment showed that the ARDUINO PID microcontroller for an MR C-class damper would be an excellent application to a local car. An ARDUINO PID microcontroller was designed and built specifically to test an OEM Lord damper on an actual road surface. An ARDUINO PID microcontroller was built together with the MR C-class damper. This experiment was important to determine the actual response of the controller. Various tuning sets for $K_P$, $K_I$, and $K_D$ were used. Multi-level tests proved the efficiency of the ARDUINO PID microcontroller for the MR Lord Damper for the formula car [14]. The system was found to be suitable for application on local vehicle suspension systems, such as the MR C-class damper [15, 16]. The effectiveness of reducing vibrations using the ARDUINO PID microcontroller showed an 85% improvement compared to that of the OEM C-class damper. The MR C-class damper with the ARDUINO PID microcontroller was successful at increasing the performance of the suspension.

### Acknowledgements

This research is a collaboration with the Department of Mechanical Systems Engineering, Tokyo City University, Japan and Korean Armed Forced Nursing Academy, Daejeon, Korea. This research was supported by the GUP Grant number 2020-0173-104-01 from Universiti Pendidikan Sultan Idris, Malaysia.

### REFERENCES


1. Unuh, M.H., et al. *Vibration isolation analysis of new design OEM damper for malaysia vehicle suspension system featuring MR fluid*. IOP Publishing.
2. Amiruddin, I.M., et al. *Design and development of the Macpherson Proton Preve Magneto rheological damper with PID controller*. IOP Publishing.
3. Green, H., C. Hunter, and B. Moore, *Application of the Delphi technique in tourism.* Annals of Tourism Research, 1990. **17**(2): p. 270-279.DOI: https://doi.org/10.1016/0160-7383(90)90087-8.
4. Hassan, M.F.C. and T. Malim, *Design and Development of Pahang Black Sambal Cooking Machine for Small and Medium Enterprises.*
5. Nashir, I.M., et al., *Delphi Method: the Development of Robotic Learning Survey in Tertiary Education.* Journal of Vocational Education Studies, 2019. **2**(1): p. 13-22.DOI: https://doi.org/10.12928/joves.v2i1.761.
6. Hassan, M.F.C., et al., *Application of TRIZ method in a product design and development tertiary technical education course.* International Journal, 2020. **8**(6).DOI: https://doi.org/10.30534/ijeter/2020/21862020.
7. Park, G., et al., *The use of active materials for machining processes: A review.* International Journal of Machine Tools and Manufacture, 2007. **47**(15): p. 2189-2206.DOI: https://doi.org/10.1016/j.ijmachtools.2007.06.002.
8. Rosly, M.A., Z. Samad, and M.F. Shaari. *Feasibility studies of Arduino microcontroller usage for IPMC actuator control*. IEEE.
9. Vajravelu, K. and R.N. Mohapatra, *On fluid dynamic drag reduction in some boundary layer flows.* Acta Mechanica, 1990. **81**(1): p. 59-68.DOI: https://doi.org/10.1007/BF01174555.
10. Cohen, R.J., *Aerodynamic characteristics of four bodies of revolution showing some effects of afterbody shape and fineness ratio at free-stream Mach numbers from 1.50 to 1.99*. 1951.
11. Al-Obaidi, A.S.M., *Implementation of semi-empirical models to enhance the accuracy of panel methods for drag prediction at supersonic speeds.* IIUM Engineering Journal, 2011. **12**(3).DOI: https://doi.org/10.31436/iiumej.v12i3.71.
12. Brebner, G.G., *A brief review of air-flight weapons.* In Von Karman Inst. for Fluid Dyn. Missile Aerodyn, 1974. **1**.
13. Kim, B. and P. Roschke. *Linearization of magnetorheological behaviour using a neural network.* IEEE.

14. Muldrow, J. and S. Yoder, *Out of cite! How reference managers are taking research to the next level.* PS: Political Science & Politics, 2009. **42**(1): p. 167-172.DOI: https://doi.org/10.1017/S1049096509090337.
15. Lempert, R., *The significance of statistical significance: two authors restate an incontrovertible caution. Why a book?* Law & Social Inquiry, 2009. **34**(1): p. 225-249.DOI: https://doi.org/10.1111/j.1747-4469.2009.01144.x.
16. Ahmadian, M. and J.C. Poynor, *An evaluation of magneto rheological dampers for controlling gun recoil dynamics.* Shock and Vibration, 2001. **8**(3-4): p. 147-155.DOI: https://doi.org/10.1155/2001/674830.