

Closed Loop Magnetic Levitation Control of a Rotary Inductrack System

Functional Description and Complete System Block Diagram

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Background:

Magnetic levitation (Maglev) is changing the way people live and travel in the future. Maglev trains are lifted off the track and propelled forward, eliminating friction and allowing the train to travel at higher speeds than normal trains.

Maglev works by creating magnetic repulsion between the train car and the track. The train car has a special arrangement of magnets that cancel any magnetic field above the Halbach array and creates a magnetic field below the array. This arrangement of magnets is called a Halbach Array. Fig. 1 below shows the polarity of each magnet and illustrates how they only intensify the magnetic field below them. Since this arrangement of magnets results in a more powerful magnetic field than a magnetic pole arrangement with all the poles aligned, the Halbach array is much more useful for large scale projects.

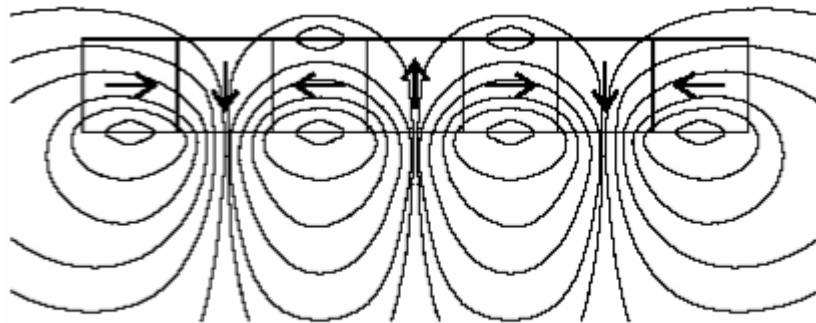


Fig. 1. Halbach Array Magnetic Fields

It is well known that alternating current produces a magnetic field, and a changing magnetic field can induce currents in nearby conductors. As the Halbach array moves across a conductor in the track, it changes the magnetic field around the conductor and induces a current in the conductor. At the same time the induced current will be changing, creating another magnetic field. Fig. 2 and Fig. 3 show the Halbach array device and its magnetic field shown in blue and red. The pink and light blue magnetic fields are created by an induced current in the inductrack. At a low velocity the magnetic fields will not align. Once the velocity increases, the induced current begins to lag, and the magnetic fields will align. The magnetic field will produce lift forces, resulting in levitation of the train car above the track.

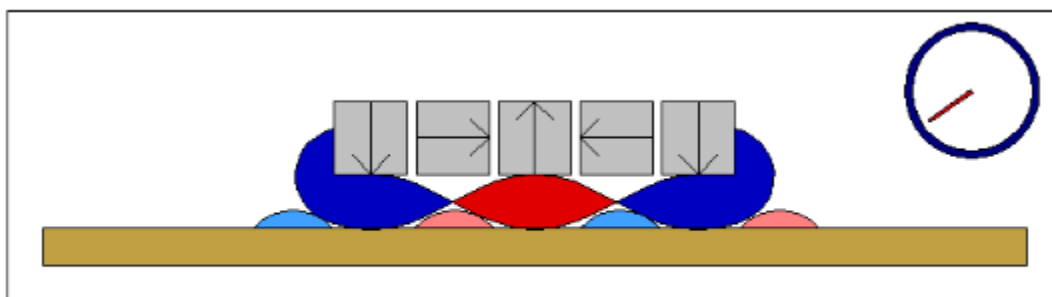


Fig. 2. Inductrack and Halbach Array Interaction at Low Velocity

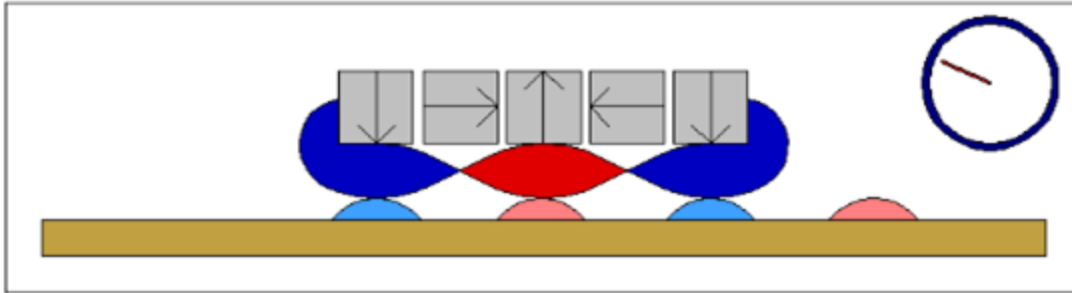


Fig. 3. Inductrack and Halbach Array Interaction at High Velocity

In this project the Halbach array is stationary and the conducting inductrack is the moving part. In Fig. 4 below is a picture of the inductrack. The inductrack is just acting as a conductor in this project.



Fig. 4. Inductrack rail

Introduction:

Fig. 5 shows the Halbach array and the inductrack system developed by senior ECE students in previous years. The system currently functions in open-loop mode, but the next step is to make the system operate using closed-loop control. The motor is currently driven by a direct voltage input, but the primary goal of this project is to drive the motor using a PWM signal to control the motor's velocity, thereby controlling the levitation height directly from a microcontroller.

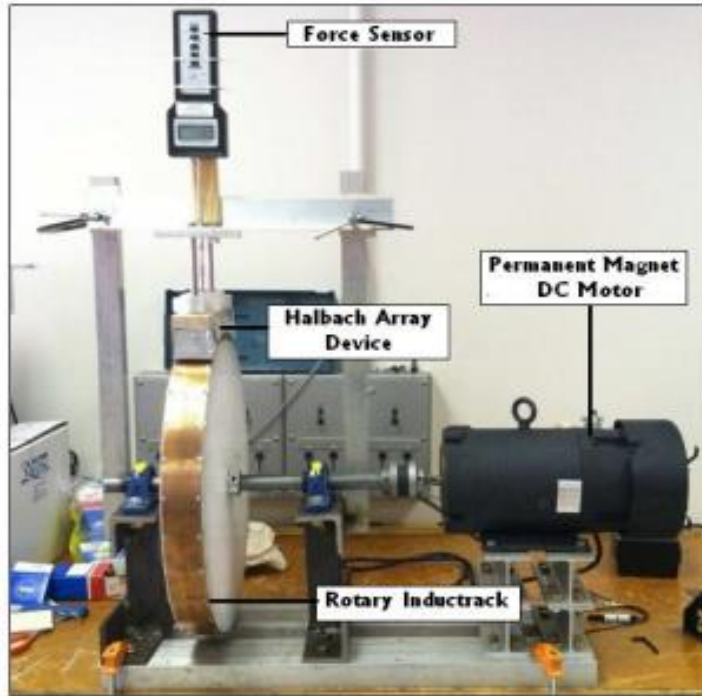


Fig. 5. Laboratory Model of Halbach Array Magnetic Levitation System

After deciding on a platform for implementing the controller, the next goal is to select and add a speed sensor which will send inductrack velocity to the controller.

Project Description:

This project will take the previously created Halbach array magnetic levitation system and add a controller to make the system a closed-loop control system. The primary focus of the project will be to choose a platform and design a controller that can process a user's input, and convert it into a PWM signal to drive the motor of the Maglev system. The overall system will look like the block diagram below in Fig. 5.

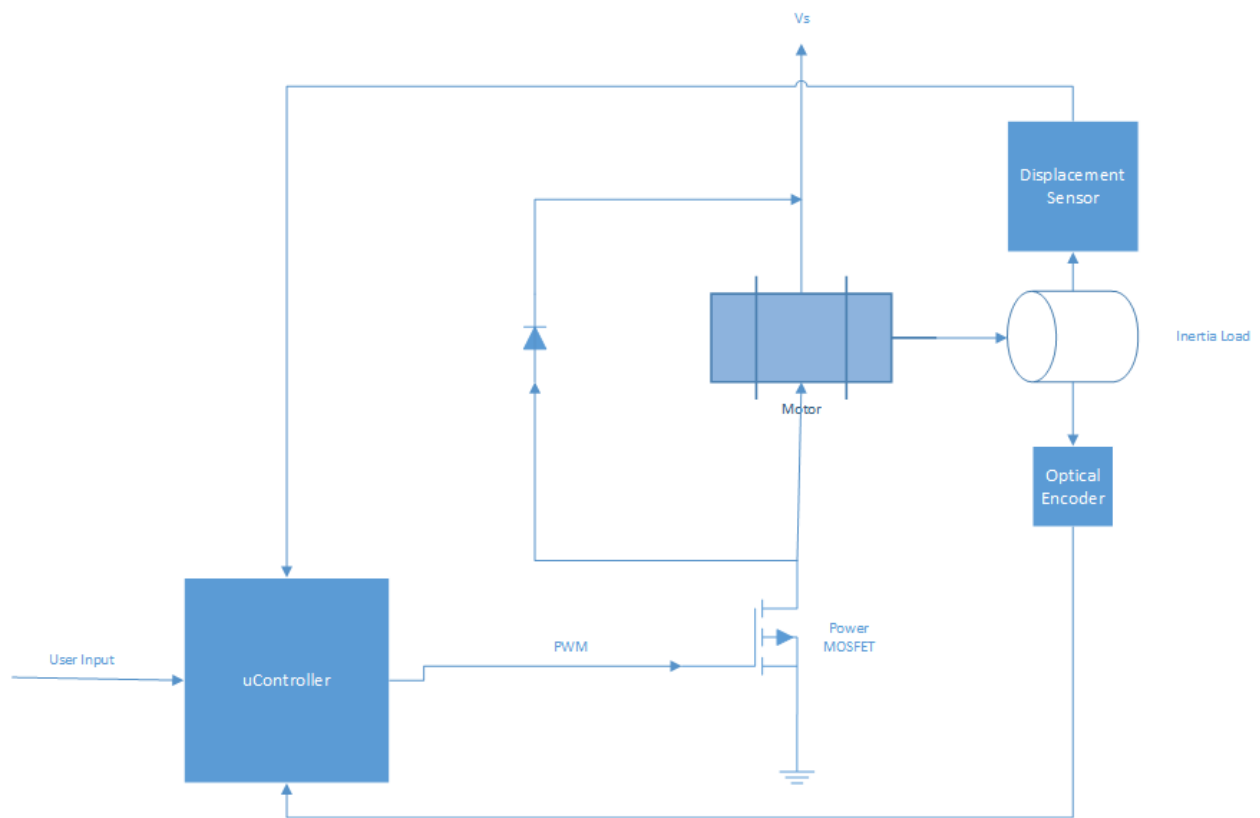


Fig. 6. High Level Block Diagram of Magnetic Levitation System

The controller design will use a lookup table and a classical digital control law to generate the PWM signal required to drive the motor. Classical digital control law design uses root locus and Bode methods instead of state variable feedback control theory. The initial input will be entered in millimeters and then converted to the desired velocity. Separately, an optical encoder will produce a frequency which will be converted to velocity. The controller will then generate the PWM signal based on the velocity error found by subtracting the current velocity from the desired velocity. This process is shown in Fig. 6.

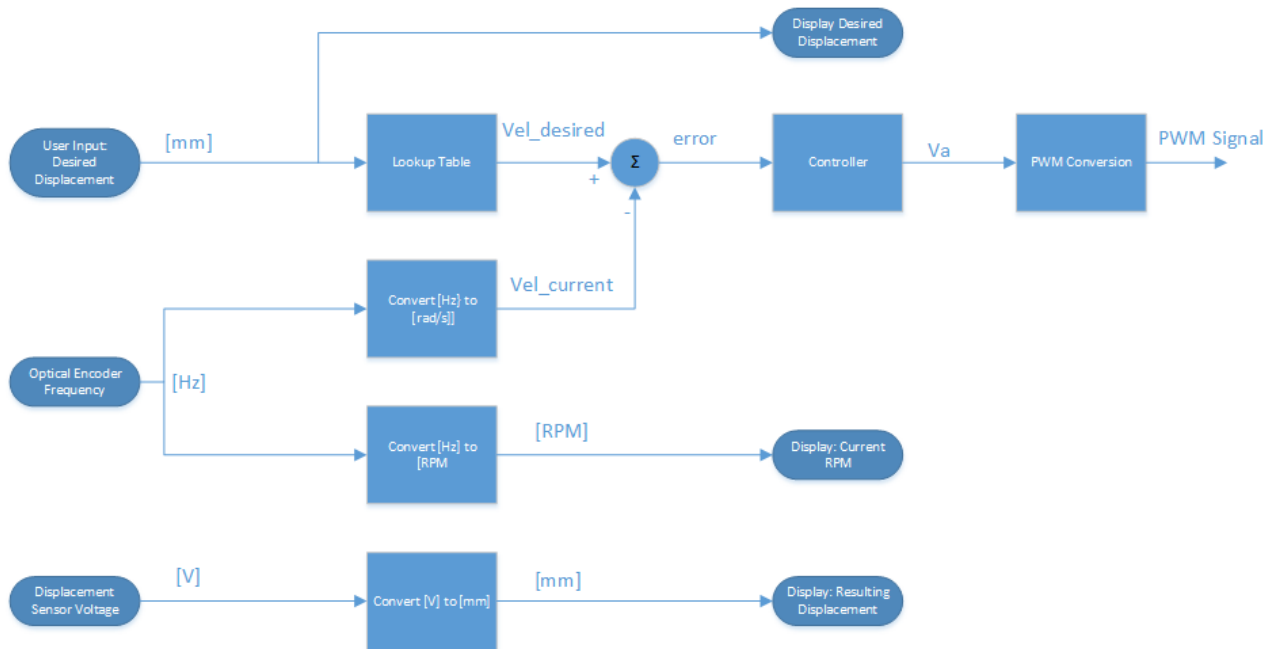


Fig. 7. Block Diagram of Controller

Goals:

- Selection of a suitable platform for controller implementation which will allow a user to enter desired levitation height
- Selection and design of appropriate power electronics which will allow control of the motor with a PWM signal
- Use of the selected platform to generate a PWM signal to drive the power electronics to obtain a relationship between PWM duty cycle and motor speed experimentally
- Selection and installation of a motor speed sensor which will allow feedback of motor velocity to the controller
- Feedback of actual levitation height to the controller for display
- Implementation of a classical digital control law
- Conversion of the control signal to a PWM signal to drive the power electronics to control the motor
- A standalone system for demonstration to prospective students and parents on visit days

Conclusion:

The controller will be integrated with the system built in previous years, providing a complete standalone levitation system. The first goal of the project will be to select a suitable platform for the controller implementation. Once the platform has been chosen, the next step will be to design the control algorithm to provide a PWM output signal. The last goal will be to combine the PWM signal with power electronics to drive the motor.

References

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