

# Complete System Level Block Diagram

## Mag Lev Train I

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**Overview –**

The Mag Lev Train project is to design and implement an active levitation, guidance, and propulsion system for a model sized train. Figure 1 illustrates the model train levitating.

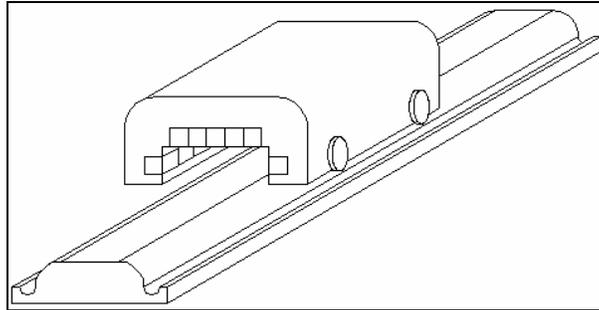


Figure 1 – Mag Lev Train Levitating Over Track

The methods to be used are currently being researched. The method of a passive levitation and guidance system will be shown using block diagrams. Figure 2 shows the overall system block diagram. The system has one user input of velocity. The outputs of the system are the levitation, guidance, and propulsion of the train.

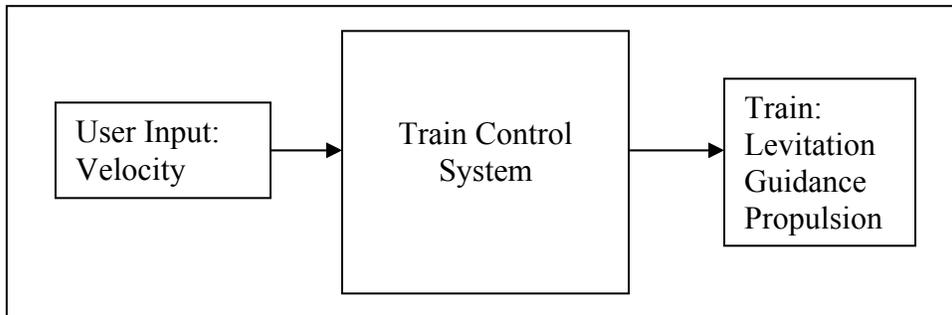


Figure 2 – Overall System Block Diagram

**Propulsion –**

The propulsion of the train will be created via a Linear Inductive Motor (LIM). The LIM will be integrated in the track using electromagnets with corresponding sensors. The method of sensing the train position will be either optical or magnetic. The sensors will be placed one train length from the magnet that will correspond to it. When the sensor senses the train, the electromagnet will receive a surge of current creating a magnetic pulse. The “same-polarity” magnetic pulse will move the train with a force proportional to the current in the electromagnet. This allows for the velocity to be controlled by controlling the current allowed to each electromagnet. Figure 3 illustrates the sensors and magnets integrated in the track.

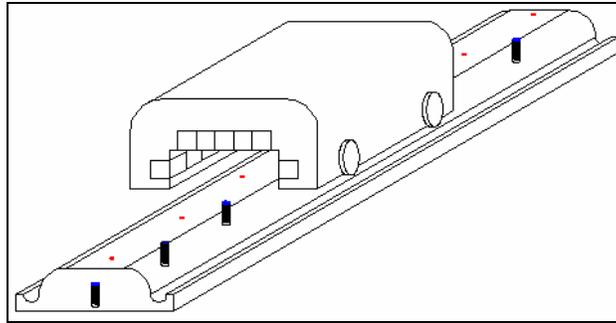


Figure 3 – Integration of Position Sensors and LIM

The red in figure 3 represents position sensors, and the blue represents electromagnets. The block diagram of the propulsion subsystem is shown in figure 4.

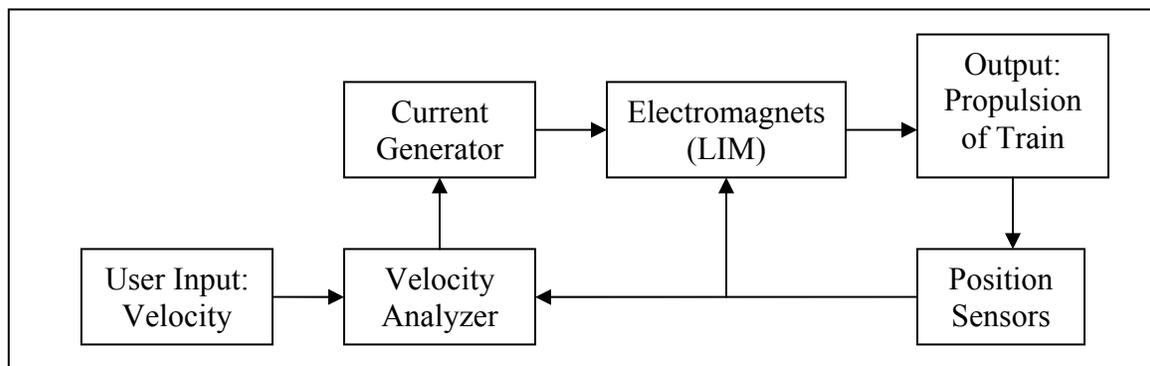


Figure 4 – Propulsion Subsystem Block Diagram

The user places an input velocity into the system. The velocity is then compared to the current velocity in the Velocity Analyzer which analyzes the switching of the position sensors. The Velocity Analyzer determines if the Current Generator should increase or decrease the current drive to the Electromagnets (LIM) based on the comparison of velocities. The Current Generator then increases or decreases the current allowed to the Electromagnets (LIM). This creates a greater or lesser propulsion of the train. The Position Sensors control the Electromagnets (LIM), and provide input to the Velocity Analyzer. The Velocity Analyzer then restarts the cycle of compensating the current from the Current Generator.

*User Input: Velocity –*

The method of the user input velocity may be a dial that corresponds to a reference voltage if an analog approach is taken. A digital input may be used via a keypad on an EMAC board.

*Velocity Analyzer –*

The Velocity Analyzer can be analog or digital. A subsystem block diagram of the Velocity Analyzer is shown in figure 5.

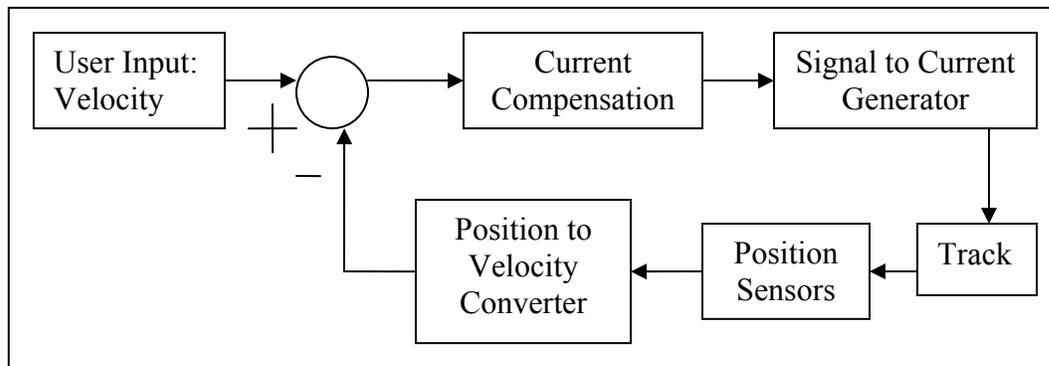


Figure 5 – Velocity Analyzer Subsystem Block Diagram

If analog, a model of the system must be created to find the order of the system in order for steady state error control. Control system theory will then be used to create a system with the lowest error for a valid range. A method must also be implemented to convert the signals from the position sensors to a velocity. A signal is then sent to the Current Generator.

If an EMAC board is used, then software will be used to monitor the position sensors. A velocity will be determined and compared to the User Input Velocity. A signal will be created digitally or via a D/A converter to control the Current Generator. The rate of current change will be limited to allow the train to increase or decrease in velocity.

#### *Current Generator –*

The method to be used for the generation of current has not been determined. The current generator must change based from the Velocity Analyzer.

#### *Electromagnets –*

The electromagnets to be used will either be metal pieces (bolts) wrapped an equal amount of times per electromagnet, or inductors within the track.

#### *Position Sensors –*

The position sensors to be used will either be optical or magnetic.

### **Levitation and Guidance –**

The current method of levitation and guidance is a passive system based from the velocity of the train. Halbach Arrays will be used to create a strong magnetic field below and on the sides of the train to induce a current in the track. As the train's velocity increases the track will create a "same-polarity" pole magnetic field from the induced current of the train passing over it. The "same-polarity" poles will repel each other levitating and guiding the train. As the train levitates it induces less current in the track. Therefore, a stable levitation and guidance system is created. The track must be made of an inductive material that can be induced to create a magnetic field. The two options for this are inductors and aluminum sheets. The passive levitation and guidance subsystem block diagram is shown in figure 6.

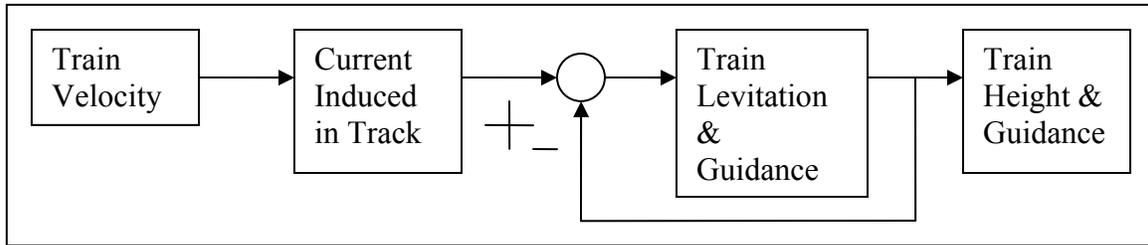


Figure 6 – Passive Levitation and Guidance Subsystem

*Halbach Arrays –*

Halbach Arrays create a quasi-unipolar magnet. The Halbach Array is created by placing Neodymium-Iron-Boron (NdFeB) magnets at 90 degree angles to each other. This is shown in figure 7.

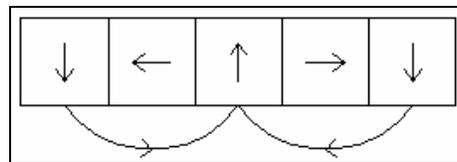


Figure 7 – Halbach Array

*Inductor Track –*

The method of using inductors in a track has been implemented at the Lawrence Livermore National Laboratory under the U. S. Department of Energy for a similar model train experiment with out a propulsion component. The Physicist who led the team, Dr. Richard F. Post, has provided information about the creation of their track using inductors. Figure 8 illustrates the use of inductors for the passive levitation and guidance system.

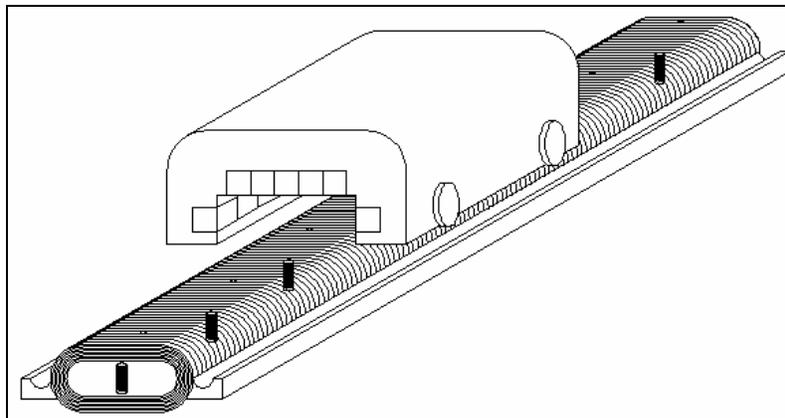


Figure 8 – Passive Levitation and Guidance By Use of Inductors

The track used at the Livermore National Laboratory utilized 53 turns of 0.080” diameter litz wire to create ½” deep coils. The coils were 6” wide, and 3” tall. A wood block was used to give the coils strength. Ferrite “tiles” were used above and below the bottom portion of the coils to load the inductive coils yielding a higher inductance. The

schematic drawing of the Inductrack model track is shown in figure 9. A similar track may be used for the project.

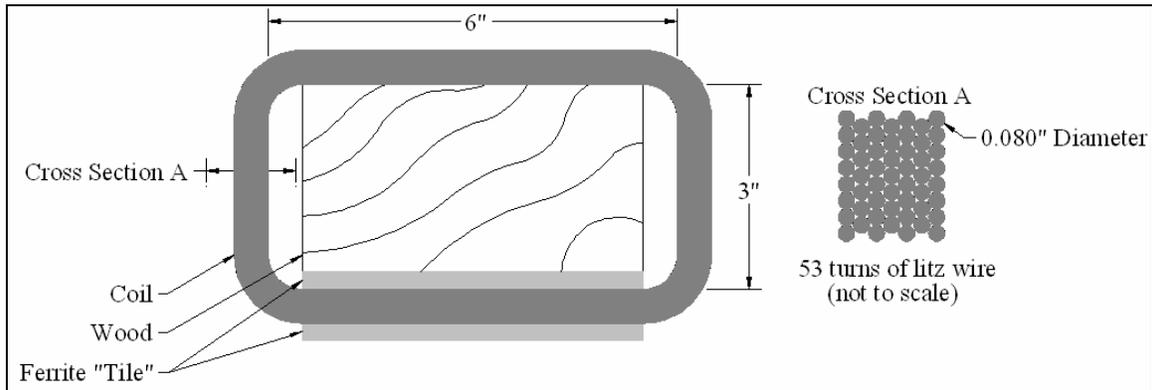


Figure 9 – Schematic Drawing of Inductrack Model Track

#### *Aluminum Track –*

An aluminum track is created by laminating thin sheets of aluminum together. The aluminum must be bent to create lateral guidance. Aluminum sheets create large drag forces compared to the levitation forces at low velocities. The aluminum sheets can be chemically etched to create slots. The specifications given by Dr. Richard F. Post for using chemically etched aluminum sheets as simulated by Lawrence Livermore National Laboratory are ten 0.5 mm thick aluminum sheets. The chemically etched slots would be 0.5 mm wide terminating 25 mm from the edge of the track. The “lands” between the slots would be 4 to 5 mm wide. An illustration of the aluminum track being used for project is shown in figure 10.

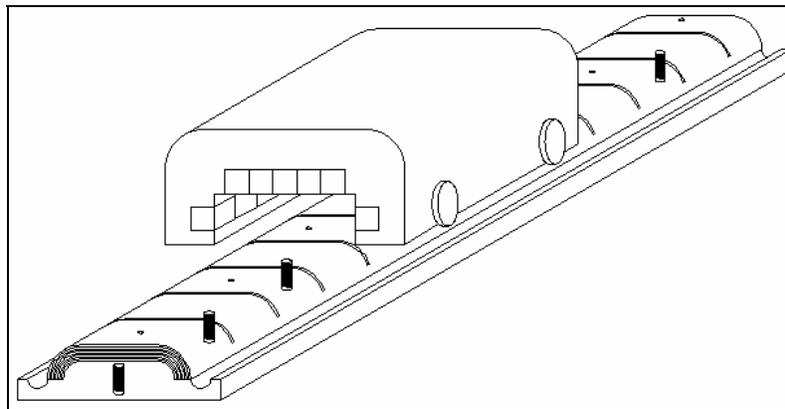


Figure 10 - Passive Levitation and Guidance By Use of Aluminum Sheets

## References

Post, Dr. Richard F. Interview by email, October 23, 2003.

Post, Dr. Richard F. Inductrack Demonstration Model, February 3, 1998. U.S. Department of Energy by Lawrence Livermore National Laboratory. UCRL-ID-129664