# Non Vibration and Safe Electromagnetic Regnerative Suspension Lift Design (MAGLIF)

S.Suresh[1] & Raghu M[2]
[1]M.Tech, A.P/ECE, Dr.Pauls Engineering College, Tamil Nadu India
[2] *M.Tech, A.P/ECE, Dr.Pauls Engineering College, Tamil Nadu India*

***Abstract*-- This project is to focus on to design an electromagnetic lift based on the principle of electromagnetic levitation. MAGLIF (magnetic lift) According to the above principle the lift moves up and down due to the magnetic field produced on either side of the lift. The magnetic field is produced from the magnetic coils placed around the lift. Proper power supply is given to the coils to produce the magnetic field. An additional generator supply can be given to the magnetic coil in case of power failure. The magnetic coils attached along the sides of the lift will produce magnetic flux around certain area and the followed embedded design is to make an magnetic levitation to maintain the lift.**

***IndexTerms*—arduinomega2560, magnetic levitation, Lift, electromagnetic suspension.**

## I. INTRODUCTION

Magnetic levitation, maglev, or magnetic suspension is a method by which an object is suspended with no support other than magnetic fields. Magnetic force is used to counteract the effects of the gravitational and any other accelerations.

The two primary issues involved in magnetic levitation are *lifting force*: providing an upward force sufficient to counteract gravity, and *stability*: ensuring that the system does not spontaneously slide or flip into a configuration where the lift is neutralized. Magnetic levitation is used for maglev trains, contactless melting, magnetic bearings and for product display purposes. Magnetic materials and systems are able to attract or press each other apart or together with a force dependent on the magnetic field and the area of the magnets, For example, the simplest example of lift would be a simple dipole magnet positioned in the magnetic field of another dipole magnet, oriented with like poles facing each other, so that the force between magnets repels the two magnets.[1]

Essentially all types of magnets have been used to generate lift for magnetic levitation; permanent magnets, electromagnets, ferromagnetism, diamagnetism, superconducting magnets and magnetism due to induced currents in conductors. To calculate the amount of lift, a magnetic pressure can be defined, the magnetic pressure of a magnetic field on a superconductor can be calculated by:

$$P_{mag} = \frac{B^2}{2\mu_0}$$

where $P_{mag}$ is the force per unit area in pascals, $B$ is the magnetic field just above the superconductor in teslas, and $\mu_0$ = $4\pi\times10^{-7}$ N·A$^{-2}$ is the permeability of the vacuum the simplest example of lift with two simple dipole magnets repelling is highly unstable, since the top magnet can slide sideways, or flip over, and it turns out that no configuration of magnets can produce stability. However, servomechanisms, the use of diamagnetic materials, superconducting, or systems involving eddy currents allow stability to be achieved. In some cases the lifting force is provided by magnetic levitation, but stability is provided by a mechanical support bearing little load. This is termed *pseudo-levitation*. Static stability means that any small displacement away from a stable equilibrium causes a net force to push it back to the equilibrium point. Earnshaw's theorem proved conclusively that it is not possible to levitate stably using only static, macroscopic, paramagnetic fields. The forces acting on any paramagnetic object in any combinations of gravitational, electrostatic, and magneto static fields will make the object's position, at best, unstable along at least one axis, and it can be unstable equilibrium along all axes. However, several possibilities exist to make levitation viable, for example, the use of electronic stabilization or diamagnetic materials, it can be shown that diamagnetic materials are stable along at least one axis, and can be stable along all axes. Conductors can have a relative permeability to alternating magnetic fields of below one, so some configurations using simple AC driven electromagnets are self stable.

Dynamic stability occurs when the levitation system is able to damp out any vibration-like motion that may occur. Magnetic fields are conservative forces and therefore in principle have no built-in damping, and in practice many of the levitation schemes are under-damped and in some cases negatively damped.[4] This can permit vibration modes to exist that can cause the item to leave the stable region.

## II. LEVITATION DESIGN

The general setup is quite straightforward. The main part is an electromagnet consisting of a coil on an iron core. The current through my coil from a push-type solenoid is 300mA at 12V. At the bottom of the electromagnet, there is a Hall effect sensor directly on the iron core, positioned in such a way that the sensor detection axis is aligned with the core axis. The first part is the coil driver. I used a small transistor to turn the coil on or off, added a reverse-biased diode across the coil for protection of the transistor against fly-back currents, and put a capacitor across the supply for noise reduction. The base of the transistor is connected to a Arduino digital output through a 1k resistor, with an extra LED to indicate the pin state.

The second part is a bit more involved. I used linear Hall effect sensor SS19 from Honeywell. It is a tiny black box that has 3 pins, 2 of which are connected to GND and +5V, the 3rd one is the output. The sensor translates the perpendicular (to the two largest faces of the sensor) component of a magnetic field into voltage on the output. In my case, it was 2.15V with no field and 3.0 V with the maximal field (coil on and magnet nearby). Thus I attached 2 Norton operational amplifiers (out of 4 in MC3401). The first stage subtracts ~1.5V while the second amplifies it by a factor of ~3. That gives a signal in the range 1.8 — 4.5V, in the working range of the amplifier. This amplified signal then connects to an Arduino analog input pin. Note that I used a Norton op amp. It amplifies current difference, unlike the usual op amp that amplifies voltage difference. That’s why the wiring is slightly different. I also had to add a load resistor 5k6 on the sensor output to make it work properly

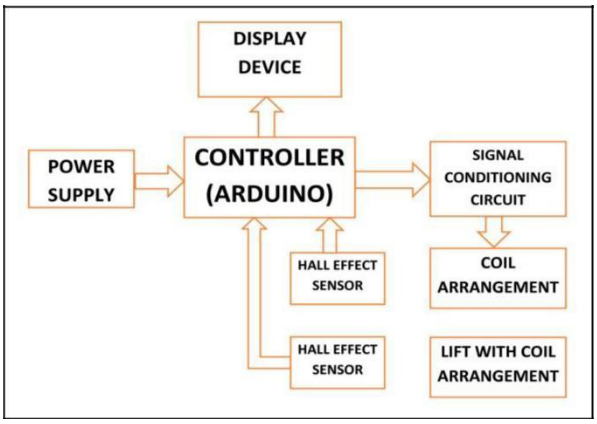

Figure 1.Block diagram of complete system

## III. THEORITICAL PRINCIPLE

The magnetic field needed to keep a magnet from falling changes with the distance from the electromagnet. In our case, the position of the magnet is monitored by the Hall effect sensor. The closer the magnet is to the sensor the higher voltage is on the output. And the closer the magnet is the smaller field is required to keep it from falling. The purple straight line represents the magnetic field required to keep a magnet from falling with respect to the reading on the sensor. In reality, it is nonlinear curve but that’s not important for us. We need to produce a field that will keep a magnet at a specific position. For that we will modulate the coil’s power so that the field produced is given by the blue line in the previous plot. The two extreme values are the maximal field of the coil and the field when the coil is off. If we are successful, the magnet should be stable at the intersection of the two curves in the middle of the plot. If the magnet gets too close to the iron core the shear attractive force of these two is enough to attract it. That is represented by the rightmost intersection. We need to prevent this situation. That sounds quite easy, doesn’t it? But there is a small complication. The reading on the sensor includes the magnetic field of the coil. In fact, because the sensor is right on the core this component will probably be bigger than the component we are interested in, the field of the magnet itself. Fortunately for us, we know what signal we use to drive the coil. However, if we plot the driving signal and the magnetic field of the coil This behavior is caused by the large inductance of the coil. When the transistor is open, the there is +12V on the coil. But the change in current induced magnetic field that resist this change and it takes more time for the full current to flow. When the transistor is closed, the current continues to flow through the diode in parallel. The resistance of the coil and the diode dissipates the energy and the current decreases to zero. In my case, it takes around 5ms for the coil to energize or de energize. That is way too long for us to ignore. But we can model this behavior. A coil can be approximated as a resistance R and inductance L in series The differential equation for the current I through the coil then reads

$$\frac{dI}{dt} = V - RI,$$

Where V is the voltage on the coil. In our case, it is +12V when the driving signal is 1 and -0.6V (the diode voltage) when the signal is 0. The magnetic field is proportional to the current. For simplicity, we rewrite the equation for dimensionless field power y and applied voltage x, x being -0.05 = -0.6/12 or 1 and y being in the range 0 — 1. That yields the equation

$$\frac{dy}{dt} = \lambda(x - y).$$

λ is a parameter depending on the coil. But this is a equation for a low-pass filter. This continuous form can be discredited, see Low-pass filter . Assuming constant time steps,   t = 1, we get the final formula

$$y_n = y_{n-1} + \alpha(x_n - y_{n-1}).$$

The parameter α depends on the coil and on the timestep. It can be found using

$$\alpha = \frac{1}{T+1},$$

A. Where T is the number of time steps it take for the coil to energize from 0 to 0.632 of its maximal field. This has to be found by some experimentation. Generally, α is different for the energization and deenergization phase since the diode gives rise to extra resistance in the circuit

## IV CONTROL ALGORITHM

Now with some theoretical background, we can proceed to describe the algorithm that controls the output signal. First, we have to find the following parameters (field shall denote the reading on the sensor):

Sample frequency = how often to sample field and adjust the output signal, I use 10 kHz

baseline = field with no magnetic fields

coilMag = the maximal strength of the coil, i.e. the difference of field with the coil on and baseline

alphaInc = the constant α from above for energization of the coil

alphaDec = the constant α from above for deenergization We have to keep track of the following variables:

signal = last signal output, 0 or 1

filter = value in the range 0 to 1, this is the field of the coil in the last step, the result of the discretized formula.

With these parameters, we perform the following steps with the sample frequency:

## V IMPLEMENTATION

To achieve a constant sampling and output rate, some constant time-base is necessary. The standard millis() method doesn't allow for the desired precision. One option is to use the build-in timers, like millis() is using, and change their resolution. But the simplest way is to use the A/D converter itself for timing purposes. The time it takes for ADC to perform a reading is constant and can be changed by changing the ADC prescaler settings. It is given by the formula

Clock = 16,000,000

prescaler = 2, 4, 8, 16, 32, 64 or 128

Conversion Cycles = 13 * clock / prescaler;

The default prescaler value is 128, which gives the maximal conversion rate to be ~~9.6kHz. I'm using 64 which leads to 19230.8Hz sampling rate. The ADC clock value, clock/prescaler, affects the ADC accuracy. ATMEL recommends the range 50-200kHz for maximal accuracy, with rates up to 1MHz if less accuracy is needed. My choice gives 250kHz ADC clock, that's quite close to the recommendation. Now for the synchronization. When a conversion is finished, an interrupt flag in the ADC registers is set. Waiting for this flag provides the necessary synchronization. To ensure that the next conversion is started as soon as one is finished, the ADC is configured to work in a free running mode with an auto-trigger enabled. The functions analog Setup and analog Start configure the ADC and start the first conversion while analog Next waits for a conversion to finish and thus provides the synchronization for the program. Multiplication code The coil simulation is done by fixed-point integer math. That means that values offilter, alphaDec and alphaInc in the range 0 — 1 are multiplied by 2^16 = 65536. When a multiplication such as coilMag * filter is performed, the actual code is result = coilMag * filter >> 16 Since AVG GCC is adding extra unnecessary instructions for multi byte multiplications like this, I implemented my own assembler routines. This is not really required for this simple code, but I also experiment with additional digital signal processing to achieve greater stability of the magnet, and this processing is quite costly in terms of multiplications. Also, my own multiplication routine allows me to perform rounding of the result of >> 16 and that adds extra precision to the computation.

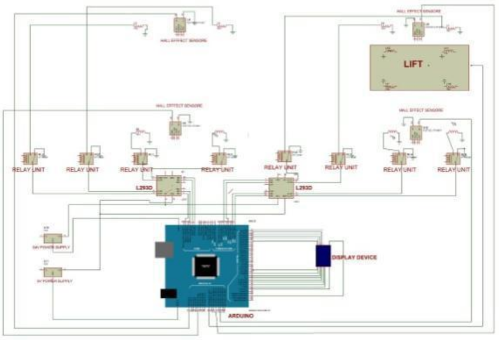

Figure 2.schematic diagram of complete system

## VI CONCLUSION

Thus the an electromagnetic lift in more secure and non-vibrative in nature has been designed and tested in laboratory . The magnetic coils attached along the sides of the lift will produce magnetic flux around certain area. This flux will tend to move the lift up and down. magnetic levitation concepts has been implemented in many ways of lifting .hope this proposed design will leads to a future technologies of lifting purpose further design will leads to lower the energies and light weight and for high end design.

## REFERENCES

[1] *K Huang, F yu and Y Zhang "Active controller design for an electromagnetic energy regenerative suspension"*

[2] *P Li, C Zhang and L zuo "Review of power electronics for kinetic energy Harvesting systems"*

[3] *Levitated Ball-Levitating a 1 cm aluminum sphere. Sprott.physics.wisc.edu. Retrieved on 2013-07-12*

[4] *L. Zuo, and P. Zhang, "Energy harvesting, ride comfort, and road handling of regenerative vehicle suspensions," Journal of Vibration and Acoustics, Vol. 135, no. 1, 2013, pp. 011002.*

[5] *C. Chen, and W. H. Liao, "A self-sensing magnetorheological damper with power generation," Smart Materials and Structures, Vol. 21, no. 2, 025014, 2012*

[6] *I. Martins, J. Esteves, G. D. Marques, and F. Pina da Silva, "Permanent-magnets linear actuators applicability in automobile active suspensions," IEEE Trans. Vehicular Technology, Vol. 55, no. 1, pp. 86-94, 2006.*

[7] *K. Huang, F. Yu, and Y. Zhang, "Active controller design for an electromagnetic energy-regenerative suspension," International Journal of Automotive Technology, Vol. 12, no. 6, pp. 877-885, 2011.*

[8] *R. B. Goldner, P. Zerigian, and J. R. Hull, "A preliminary study of energy recovery in vehicles by using regenerative magnetic shock absorbers," Society of Automotive Engineers, 2001*

[9] *J. R. Powell and G. R. Danby, "High Speed Transport by Magnetically Suspended Trains," ASME Publication No. 66 WA/RR5 (December 1966)*

[10] *P. J. Geary, Magnetic and Electric Suspensions, British Scientific Instrument Research Association, 1964*

[11] *Marc T. Thompson, Richard D. Thornton and Anthony Kondoleon, "Scale Model Flux-Canceling EDS Maglev Suspension—Part I: Design and Modeling," IEEE Transactions on Magnetics, vol. 35, no. 3, May 1999*

[12] *Marc T. Thompson, "Inductance Calculation Techniques—Part I: Classical Methods," Power Control and Intelligent Motion, vol. 25, no. 12 December 1999, pp.40-45*

[13] *G. Verros, S. Natsiavas, and C. Papadimitriou, "Design optimization of quarter-car models with passive and semi-active suspensions under random road excitation," Journal of Vibration and Control, Vol. 11, no. 5, pp. 581-606, 2005*

[14] *M. Adler, "A Field-Theoretical Approach to Magnetic Induction Heating of Thin Circular Plates," IEEE Transactions on Magnetics, vol. MAG-10, no. 4, December 1974, pp. 1118-1125.*

## BIOGRAPHIES

**Mr S. Suresh** received the B.Tech. degree in the department of ICE from Sri Manakula Vinayagar College Of Engineering, Pondicherry, in 2007, and the M.Tech degree in the department of E&C from SRM University, Chennai. He is currently an Assistant Professor at Dr. Pauls Engineering College, Pulichapallam, Villupuram district, TamilNadu. His current research interests include MEMS computer-aided simulation techniques, distributed generation, and renewable energy, especially energy followed by advanced embedded system with automation.

M.Raghu was born on 1982 at Puducherry, India. He has received D.E.E.E in 2002 Bachelor of engineering in Electronics and Instrumentation Engineering in 2002 to 2005 at Anna University and Master of Technology in Power Electronics and Drives from 2009 to 2011 at Prist University. At present working as Assistant Professor in Dr. Pauls Engineering College. Experience more than 9 years and research area interest in communication, digital electronics, Instrumentation and Power Electronics.