NEW HORIZON COLLEGE OF ENGINEERING
New Horizon Knowledge Park, Ring Road, Marathalli
Autonomous College Permanently Affiliated to VTU, Approved by AICTE & UGC
Accredited by NAAC with 'A' Grade. Accredited by NBA

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

MINI PROJECT

ELECTROMAGNETIC LEVITATION

GROUP MENTOR

Mr. VINOD KUMAR S

SUBMITTED BY

K. ABISHEK (USN:1NH18EE719)

K. AJAY (USN:1NH18EE720)

SANDESH VANTAGODI (USN:1NH19EE408)

DEEPAK BAALAJI (USN: 1NH17EE712)

CERTIFICATE

This is to certify that K.Abishek , K.Ajay, Sandesh Vantagodi and Deepak Baalaji bearing USN 1NH18EE719, 1NH18EE720, 1NH19EE408 and 1NH17EE712 respectively have submitted mini project titled "**ELECTROMAGNETIC LEVITATION"** in partial fulfilment for the course of the EEE Department. This report has been prepared as per the given format and is approved for the submission and presentation.

Signature of the guide **Signature of the HOD**

(Mr. Vinod Kumar S) (Dr. Mahesh M)

ACKNOWLEDMENT

With immense pleasure and deep sense of gratitude. We wish t express our sincere thanks to our supervisor **Mr. VINOD KUMAR S**, Senior Assistant Professor, Department of Electrical and Electronics Engineering, New Horizon College of Engineering, without his motivation and continuous encouragement, this mini-project would not have been successfully completed.

We are grateful to the Chairman of the New Horizon Educational Institution, **Dr. MOHAN MANGHNANI** for motivating us to carry out research in the NHCE and for providing us with infrastructural facilities and many other resources needed for our project work.

We express our sincere thanks to **Dr. MAHESH M**, HOD, Department of Electrical and Electronics Engineering, New Horizon College of Engineering, for his kind words of support and encouragement.

We wish to extend our profound sense of gratitude to our parents for all the sacrifices they made during our project and providing us with moral support and encouragement whenever required.

ABSTRACT

The magnetic levitation is the phenomenon of levitating a device/ object by using or exploiting magnetic fields.

There are two types of magnetic levitation.

1. By using the magnetic **force of attraction** and it is known as **magnetic suspension**.
2. By using magnetic **force of repulsion** and it is known as **magnetic levitation**.

Magnetic levitation cannot be achieved by static permanent magnets.

Earnshaw's Theorem proves that, no combination of static magnets can stably levitate an object.

- The exception for this theorem, is the **Meissner Effect** – levitation can be easily achieved by using static permanent magnets with super conductors. Super-conductors have zero internal resistance. Therefore, when a permanent magnet is brought over a super conductor, since the internal resistance is zero. The currents persist, as a result the magnetic fields also persist.
- Dia-magnetic materials have relative permeability <1. Therefore, it repels magnetic flux.

So, magnetic levitation can be achieved through the above exceptions.

TABLE OF CONTENTS

INTRODUCTION

The magnetic levitation is the phenomenon of levitating a device/ object by using or exploiting magnetic fields.

There are two types of magnetic levitation.

3. By using the magnetic **force of attraction** and it is known as **magnetic suspension**.
4. By using magnetic **force of repulsion** and it is known as **magnetic levitation**.

Magnetic levitation cannot be achieved by static permanent magnets.

Earnshaw's Theorem proves that, no combination of static magnets can stably levitate an object.

- The exception for this theorem, is the **Meissner Effect** – levitation can be easily achieved by using static permanent magnets with super conductors. Super-conductors have zero internal resistance. Therefore, when a permanent magnet is brought over a super conductor, since the internal resistance is zero. The currents persist, as a result the magnetic fields also persist.
- Dia-magnetic materials have relative permeability <1. Therefore, it repels magnetic flux.

So, magnetic levitation can be achieved through the above exceptions.

LIST OF COMPONENTS

1. Arduino Nano
2. Electronic Speed Controller
3. BLDC Motors (4)
4. Magnets
5. HC-05 Bluetooth Receiver
6. Copper Sheet
7. Switch Mode Power Supply (SMPS)

BLOCK DIAGRAM

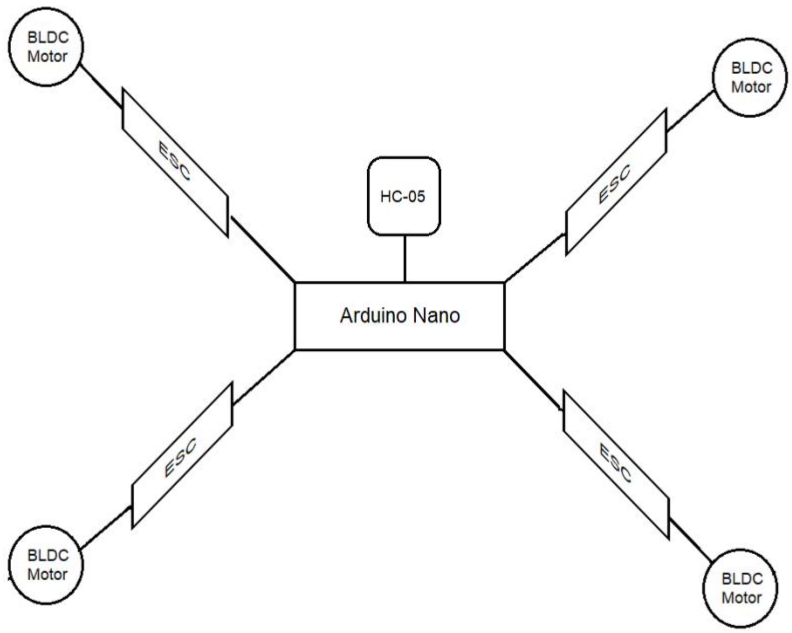

Fig.1: Block diagram of the project

WORKING

The project is based on Faraday's laws and Lenz law.

If the magnetic force of attraction is used, it is known as magnetic suspension. If magnetic repulsion is used, it is known as magnetic levitation.

There are two ways of achieving levitation.

1. Generating required magnetic fields using permanent neodymium magnets.
2. Generating magnetic fields using electromagnets.

- For the project, we are going to use the first method i.e. using permanent neodymium magnets.
- To maximize efficiency and avoid interfere with the control circuits, we could use a special arrangement of the magnets which intensify the magnetic fields on one side of the magnet and weakens the magnetic fields on opposite side. This special arrangement is known as 'Halbach Array'.

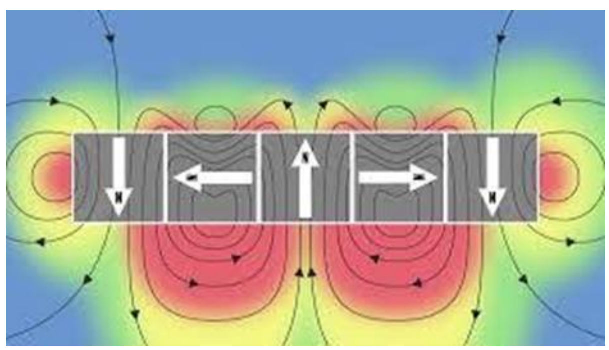

Fig. 2: Halbach Array

- As the magnets spin, they create a rotating magnetic field in the copper (due to its low resistance) sheet beneath the magnet.
- These rotating magnetic fields induce current in the copper sheet, which in turn creates opposing magnetic fields. These fields oppose the fields generated by the rotating magnets.
- The result is a repulsive force that is effectively lift for the levitation. This process generates heat in the copper sheet as losses due to the resistance of the copper.
- This machine can be more efficient, if we use conducting sheet with lower resistance (super conductor).

The Arduino and Bluetooth receiver

The Arduino receives the command “X” from the Bluetooth controller app which then calibrates the four ESCs to make them rotate in sink with each other. We can control the speed of the motors by sending commands from the Bluetooth RC Controller app.

Then we can use the following commands to control the speed of the motors.

- Calibrate ESC → X
- Speed 0 → 0
- Speed 10 → 1
- Speed 20 → 2
- Speed 30 → 3
- Speed 40 → 4
- Speed 50 → 5
- Speed 60 → 6
- Speed 70 → 7
- Speed 80 → 8
- Speed 90 → 9
- Speed 100 → q
- Stop All → D

First, turn on the Bluetooth in your smartphone, pair with the Bluetooth receiver HC-06, the password is usually '1234' or '0000'. After successfully connecting with the Bluetooth module, if we click on the Delta option ,the app sends the command "X" (through the Bluetooth RC controller application) to the Bluetooth receiver HC-06 which then sends the data to the Arduino microcontroller which then interprets these commands and then turns the 46th digital i/o pin of the microcontroller.

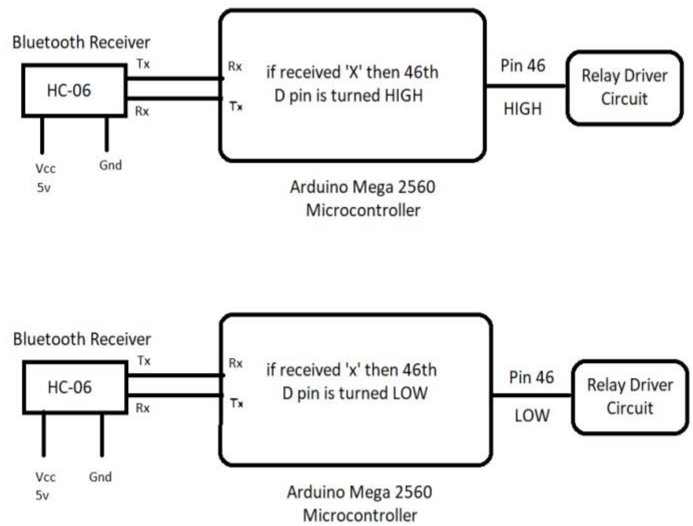

Fig.3: Block diagram for Arduino and Bluetooth receiver

If we click on the Delta option again the app sends the command "X" is received then the Arduino turns the 46th digital i/o pin low.

NOTE: The commands are case sensitive.

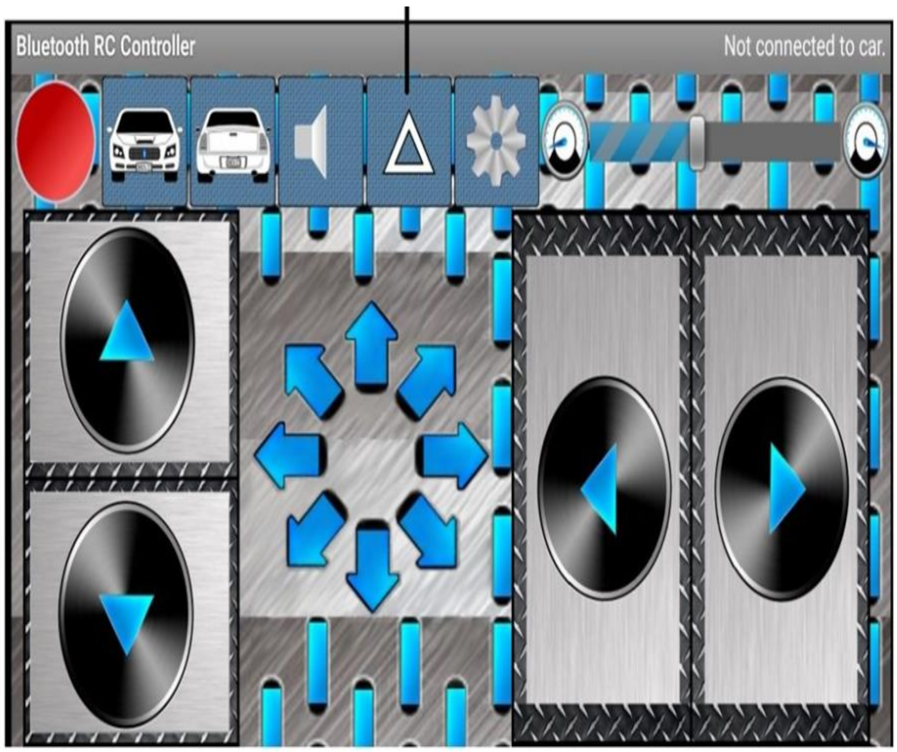

Fig. 4: Bluetooth controlled App

The Switch Mode Power Supply (SMPS)

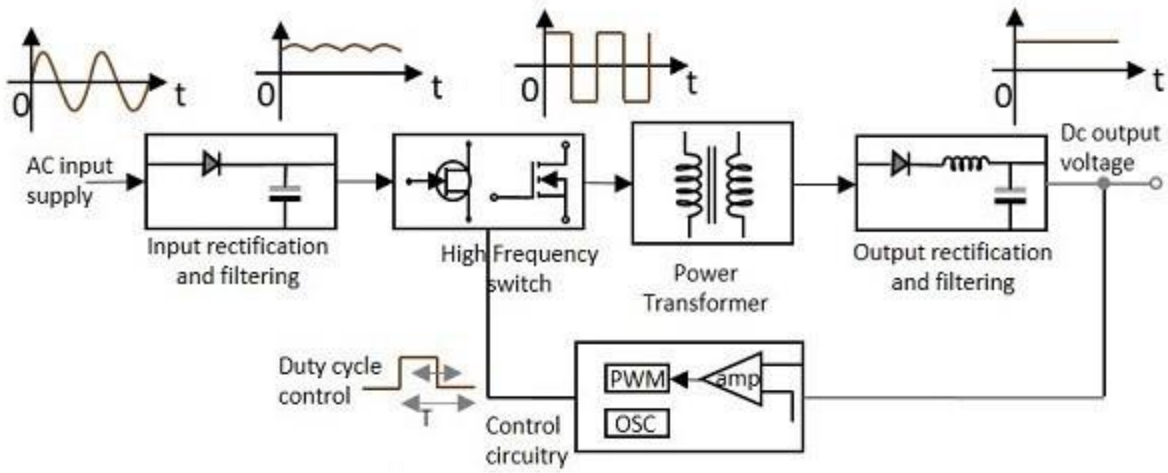

Fig.5: functional block diagram of SMPS

- <u>Input stage:</u>
    - ➢ The AC input supply signal 50Hz is given directly to the rectifier and filter circuit combination without using any transformer.
    - ➢ This output will have many variations and the capacitance value of the capacitor should be higher to handle the input fluctuations.
    - ➢ This unregulated dc is given to the central switching section of SMPS.

- <u>Switching section:</u>
    - ➢ The fast switching device such as a power transistor or a MOSFET is employed in this section, which switches ON and OFF according to the variations and this output is given to the primary of the transformer present in this section.

- The transformer used here are such smaller and lighter ones unlike the ones used for 60 Hz supply. These are much efficient and hence the power conversion ratio is lighter.

- <u>Output stage:</u>
  - the output signal from the switching section is again rectified and filtered, to get the required DC voltage.
  - This is a regulated output voltage which is then given to the control circuit, which is a feedback circuit. The final output is obtained after considering the feedback signal.

- <u>Control unit:</u>
  - This unit is the feedback circuit which has many sections. The output sensor senses the signal and joins it to the control unit.
  - The signal is isolated from the other section so that any sudden spikes should not affect the circuitry.
  - A reference voltage is given as one input along with the signal to the error amplifier which is a comparator that compares the signal with the required signal level.
  - By controlling the chopping frequency, the final voltage level is maintained. This is controlled by comparing the inputs given to the error amplifier whose output helps to decide whether to increase or decrease the chopping frequency.
  - The PWM oscillator produces a standard PWM wave fixed frequency.

Electronic Speed Controller (ESC)

An ESC or an Electronic Speed Controller controls the brushless motor movement or speed by activating the appropriate MOSFETs to create the rotating magnetic field so that the motor rotates. The higher the frequency or the quicker the ESC goes through the six intervals, the higher the speed of the motor will be.

However, we need to know the position of the rotor and there are two common methods used for determining the rotor position.

- The first common method is by using HALL EFFECT sensors embedded in the stator, arranged equally 120 or 60 degrees from each other. As the rotors permanent magnets rotate the Hall-Effect sensors sense the magnetic field and generate a logic “high” for one magnetic pole or logic “low” for the opposite. According to this, the ESC knows when to activate the next commutation sequence or interval.

- The second common method used for determining the rotor position is through sensing the back electromotive force or back EMF. The back EMF occurs as a result of the exact opposite process of generating a magnetic field or when a moving or changing magnetic field pass through a coil it induces a current in the coil.

- So, when the moving magnetic field of the rotor pass through the free coil, or the one that’s not active, it will induce a current flow in coil and as a result a voltage drop will occur in that coil. The ESC captures these voltage drops as they occur and based on them it predicts or calculates when the interval should take place.

- So that’s the basic principle of the brushless motor and ESCs and it’s the same even if we increase the number of poles of the both the rotor and the stator. We will still have a three-phase motor, only the number of intervals will increase in order to complete a full cycle.

BLDC Motors

We know that when a current is applied through a coil, a magnetic field is generated and the orientation of the field lines i.e. the poles of generated magnet will depend on the direction of the current flowing through the coil.

Using this principle, if we supply current to the coil A so that it will generate a magnetic field and attract the rotor magnet. The position of the rotor magnet will shift slightly clockwise and will again with A.

If we now pass current through coils B and c one after the other, the rotor magnet will rotate in clock wise direction.

To increase the efficiency, we can wind the opposite coils using a single coil so that we get double attraction. Further increasing the efficiency, we can energize two coils at the same time so that one coil will attract the magnet and the other coil will repel it. During this time, the third will be idle.

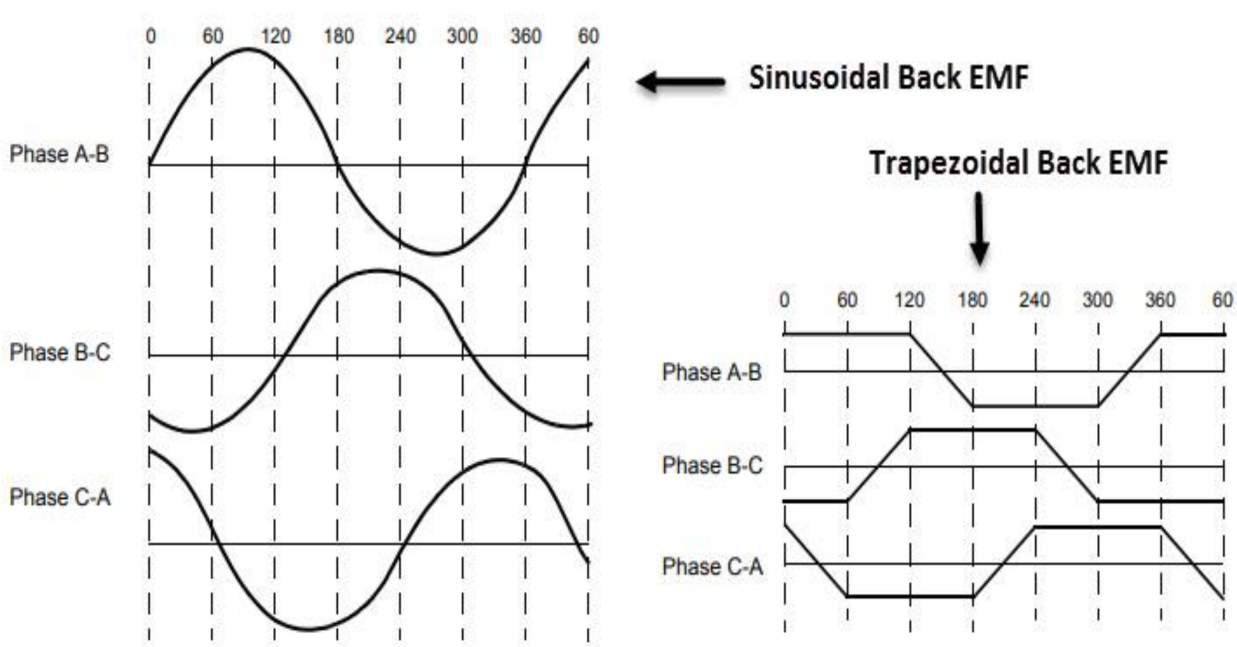

Fig. 6: graphical and timing diagram if BLDC motor induced back EMF

For a complete 360 degree rotation of the rotor magnet, six possible combinations of the coils A,B and C are applicable.

Based on the above diagrams, we can confirm that at any time, one phase is positive, one phase is negative and the third phase is idle. So, based on the inputs from the Hall sensors, We have two switch the phases as per the above diagram.

Driving Brushless DC Motors

If stator and rotor are essential parts of the BLDC Motor that are integral to it, then the driving electronics are equally essential. Block diagram of a typical Brushless DC Motor or drive system is shown in the following diagram.

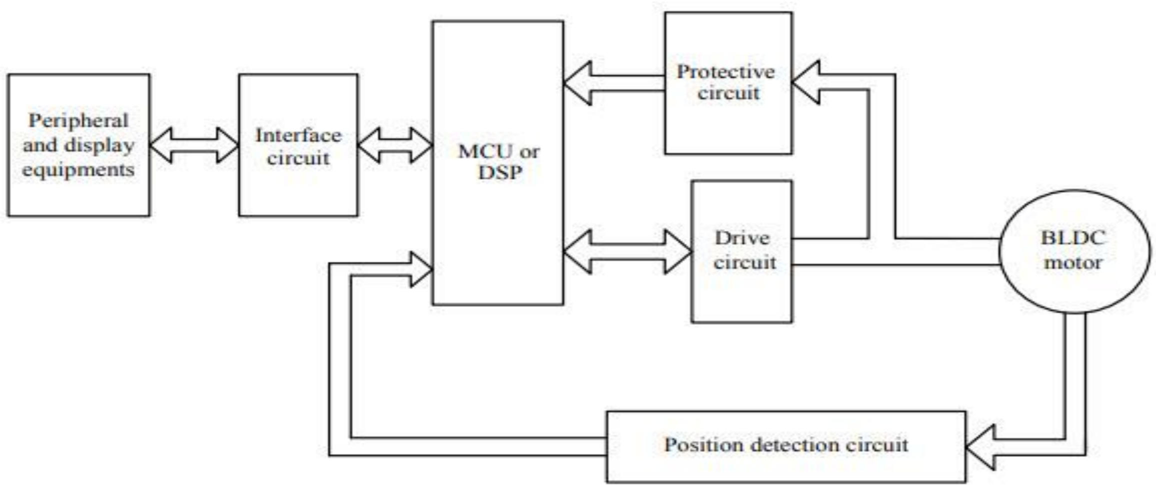

Fig.7: Block diagram of a typical BLDC Motor

This drive circuitry is often known as Electronic Speed Controller System or simply an ESC. One common setup is called the Full Bridge Drive Circuit. It consists of an MCU with PWM outputs, six MOSFETS for the three phases of the stator windings feedback from the Hall sensors and some power supply related components.

The MCU can be programmed to appropriately switch the MOSFETS based on the data from the Hall Sensors.

Magnets

Neodymium magnets are, as of 2009, the strongest kind of permanent magnet available. Their strength, small size and low cost have made numerous advances in personal audio, electric motors and other areas possible.

Neodymium magnets are made of an alloy called NIB---neodymium, iron and boron. They belong to the rare-earth class of magnets, i.e. metal magnets made with rare-earth elements. The arrangement of electrons in rare-earth elements lets them develop strong magnetic fields. Rare-earth elements are expensive, but the magnetic fields are so strong that you can make the magnets very small. The smaller magnets end up being less expensive

As with other strongly magnetic materials, NIBs are brittle, so the magnets get a protective coating of a stronger metal, like nickel, or a more resilient material, such as plastic.

All ferromagnetic materials lose their magnetism with heating; the temperature where they lose their magnetism is called the Curie Point. Neodymium magnets lose their strength between 80 degree C and 230 degrees C, depending on the grade. While this is higher than room temperature, it’s lower than many other magnetic materials.

Program Code

```
#include <Servo.h>
#define MIN_PULSE_LENGTH 1000
#define MAX_PULSE_LENGTH 2000
char command;
int i;
Servo motA;
Servo motB;
Servo motC;
Servo motD;
void setup() {
  Serial.begin(9600);

  motA.attach(4, MIN_PULSE_LENGTH, MAX_PULSE_LENGTH);
  motB.attach(5, MIN_PULSE_LENGTH, MAX_PULSE_LENGTH);
  motC.attach(6, MIN_PULSE_LENGTH, MAX_PULSE_LENGTH);
  motD.attach(7, MIN_PULSE_LENGTH, MAX_PULSE_LENGTH);
  }
void loop(){
  if(Serial.available() > 0){
  command = Serial.read();
  switch(command){
   case 'X':
   motA.writeMicroseconds(MIN_PULSE_LENGTH);
   motB.writeMicroseconds(MIN_PULSE_LENGTH);
   motC.writeMicroseconds(MIN_PULSE_LENGTH);
   motD.writeMicroseconds(MIN_PULSE_LENGTH);
   delay(4000);
   motA.writeMicroseconds(MAX_PULSE_LENGTH);
   motB.writeMicroseconds(MAX_PULSE_LENGTH);
   motC.writeMicroseconds(MAX_PULSE_LENGTH);
   motD.writeMicroseconds(MAX_PULSE_LENGTH);
   delay(1000);
   i=0;
   break;
   case '0':
   i=1050;
   break;
```

```
case '1':
i=1100;
break;
case '2':
i=1200;
break;
case '3':
i=1300;
break;
case '4':
i=1400;
break;
case '5':
i=1500;
break;
case '6':
i=1600;
break;
case '7':
i=1700;
break;
case '8':
i=1800;
break;
case '9':
i=1900;
break;
case 'W':
i=0;
break;
}
motA.writeMicroseconds(i);
motB.writeMicroseconds(i);
motC.writeMicroseconds(i);
motD.writeMicroseconds(i);
}
}
```

Applications

- **High Speed Transportation**
    - Magnetically Levitated Trains
    - Flying cars

Magnetically Levitated Trains

Among useful usages of magnetic levitation technologies, the most important usage is in operation of magnetically levitated trains. MagLev trains are undoubtedly the most advanced vehicles currently available to railway industries.

Because, they move without any contact,

- Wear and tear of materials is less.
- Highly efficient.
- Low energy consumption.

References

1. J.D. Livingston, Rising force: The Magic of Magnetic Levitation, Harvard University Press, 2011.
2. H. Yaghoubi, N. Barazi, and M.R. Aoliaei, “Maglev, ch 6,” in Infrastructure Design, Signalling And Security in Railway, pp.123-176, InTech, Rijeka, Croatia, 2012.

Conclusion

Magnetic levitation is a highly advanced technology. It has various uses.

The common point in every use is that the lack of contact and thus no wear and friction. This increases efficiency, reduces maintenance cost and increases the useful life of the system.

As, a result we achieved levitation using the first method i.e. using permanent neodymium magnets.