Electromagnetic Levitation System

1. Description

The electromagnetic levitation system controls the magnetic field generated by an electromagnet to levitate a small magnet in midair. The small magnet levitates in the air indefinitely without any disturbance. The vertical position of the levitating magnet is measured using a linear Hall effect sensor and the current in the electromagnet is controlled using a microcontroller. The system has three push buttons to adjust the vertical position of the levitating magnet and to apply a sinusoidal, square or sawtooth reference signal.

2. Circuit Schematic

The circuit diagram of the system is as shown in Figure 1.

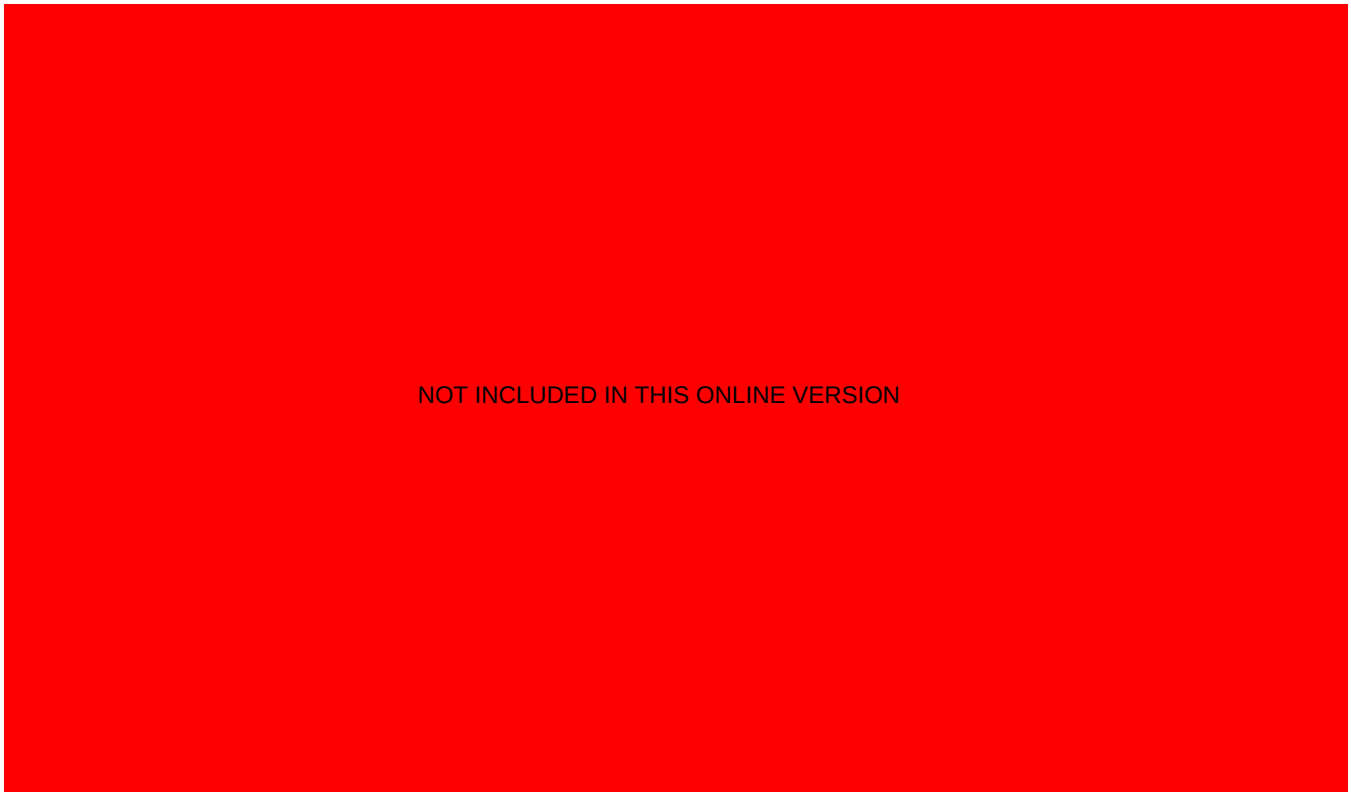


Figure 1. Circuit diagram of the system.

3. Operating Conditions

- Supply voltage range: 6.0 V DC to 12.0 V DC (7.5 V recommended)
- Ambient temperature: 10 °C to 60 °C (50 °F to 140 °F)

4. Operating Instructions

Connect a 7.5 V DC power adaptor or standard 9 V battery to the system. The LED should light up when power is applied. Hold the small magnet about 2 cm (3/4") below the electromagnet while the power is on. If the orientation of the magnet is correct, the magnet will levitate in the air. If the orientation of the magnet is not correct, it will try to flip.

The system has three push buttons labeled as A, B and C to operate it in four distinct modes referred to as the “constant mode”, “sinusoidal mode”, “square mode” and “sawtooth mode”. In the “constant mode”, the small magnet levitates in the air steadily. In the “sinusoidal mode”, “square mode” or “sawtooth mode”, the small magnet moves up and down within a range in accordance with a sinusoidal, square or sawtooth reference signal. Transition from one mode to another is enabled by Button A. In each mode, the vertical position of the magnet can be controlled within a range by pressing Button B (up) and Button C (down). The system initializes itself in the “constant mode” after each power up.

5. Kit Assembly

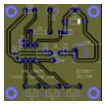
The electromagnetic levitation kit requires both electrical and mechanical assembly. Assembly instructions are detailed below.

5.1. Items Required (not included)

7.5 V power adapter 	9 V battery 	Screw driver 	Diagonal cutter 
Needle-nose pliers 	Soldering iron 	Solder wire 	Super glue 

5.2 Parts Included

1 x PIC12F1571  U1	1 x LM78L05 5 V regulator  U2	1 x OH49E Hall effect sensor  U3	1 x NTD4963N MOSFET  Q1
1 x 1N5817 Schottky diode  D1	1 x LED  LED	1 x 1 kΩ resistor  R1	1 x 15 mH inductor (coil)  L1
3 x 100 nF capacitor (104)  C1, C2, C5	1 x 1 µF capacitor (105)  C3	1 x 10 µF capacitor (106)  C4	3 x tactile switch  A, B, C
1 x power jack  PWR	1 x 2 pin header  COIL	1 x 3 pin header  SENS	1 x 2-conductor cable  K1

1 x 9 V battery snap  B1	1 x 2" x 2" PCB  P1	1 x aluminum base  A1	1 x aluminum piece  A2
4 x nylon spacer  H1, H2, H3, H4	6 x 4-40 screw  S1, S2, S3, S4, S5, S6	1 x flat-top screw  S7	1 x screw with anchor  N1
1 x magnet (either)  M1	4 x self-adhesive rubber  F1, F2, F3, F4	1 x self adhesive rubber  F5	1 x clear plastic piece  P1

5.3 Assembly Instructions

Electrical assembly

- Mount the components U1, U2, Q1, D1, R1, C1, C2, C3, C4, C5, A, B, C, LED, PWR connector, COIL header and SENS header on the PCB as shown in Figure 2. The orientations of U1, U2, Q1, D1 and LED are important and they should be mounted according to their footprints on the top side of the PCB. The orientations of R1, C1, C2, C3, C4 and C5 are not important.
- Solder each component carefully and trim its leads if necessary using the diagonal cutter.
- Solder the 2-conductor cable to the coil (the blue cable to the outer lead and the red cable to the inner lead).

Mechanical assembly

- Stick the rubber feet under the base aluminum block to prevent it from scratching, and mount the PCB on top of the base using 4 x 4-40 machine screws and 4 nylon spacers as shown in Figure 3.
- Fasten the L-shaped aluminum piece to the base block using 2 x 4-40 machine screws as shown in Figure 3.
- Fasten the coil using the screw and anchor as shown in Figure 3.
- Glue the wider side of the Hall effect sensor to the bottom of the coil symmetrically by using the clear plastic piece in between the coil and sensor.
- Stick the self adhesive rubber to the bottom of the coil to protect both the Hall effect sensor and coil.

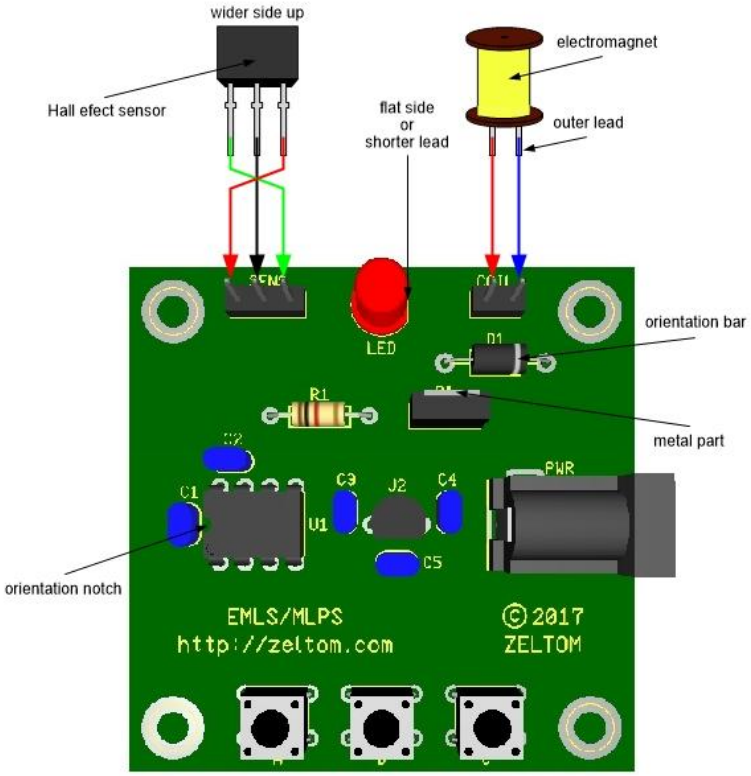


Figure 2. Electrical assembly.

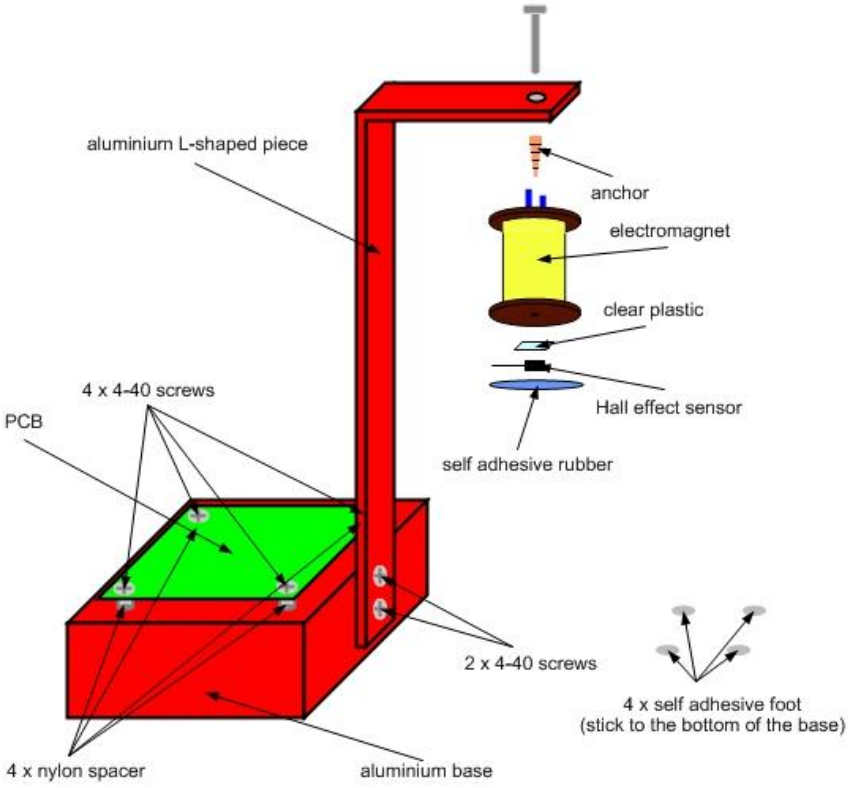


Figure 3. Mechanical assembly.

6. Calibration

The equilibrium level of the system can be adjusted in a special programming mode within a range to eliminate possible slight sensor misalignment that may occur during the mechanical assembly. The programming mode is activated if button A is pressed and held before applying power to the system. The LED flashes 4 times and then turns off when the system is in the programming mode. The magnet must be kept far away from the system when entering into the programming mode until the LED turns off. In the programming mode, button B moves the equilibrium level up and button C moves the equilibrium level down. After the adjustment of the equilibrium level, pressing button A saves the current equilibrium level and exits the programming mode by flashing the LED 4 times (do not power off the system during this operation until the LED is continuously on). The programming can be done up to 100000 times (typical).

7. Troubleshooting

- Make sure that the electrical and mechanical components are assembled correctly.
- Check the wiring and ensure that the wires are connected correctly.
- If the LED is not lit, check the power adapter connections (or the battery).
- If the LED is lit but the magnet does not levitate, check the connections of the coil and the sensor.