Electromagnetic Levitation System

1. Description

The Electromagnetic Levitation System controls the magnetic field generated by an electromagnet to levitate a disc or sphere magnet. The vertical position of the levitating magnet is measured using a linear Hall effect sensor and the current through the electromagnet is controlled using a microcontroller to achieve stable levitation. The system has three push buttons to adjust the vertical position of the levitating magnet, apply a sinusoidal, square or sawtooth waveform reference signal, and save the current controller parameters into the nonvolatile memory of the microcontroller.

2. Circuit Schematic

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

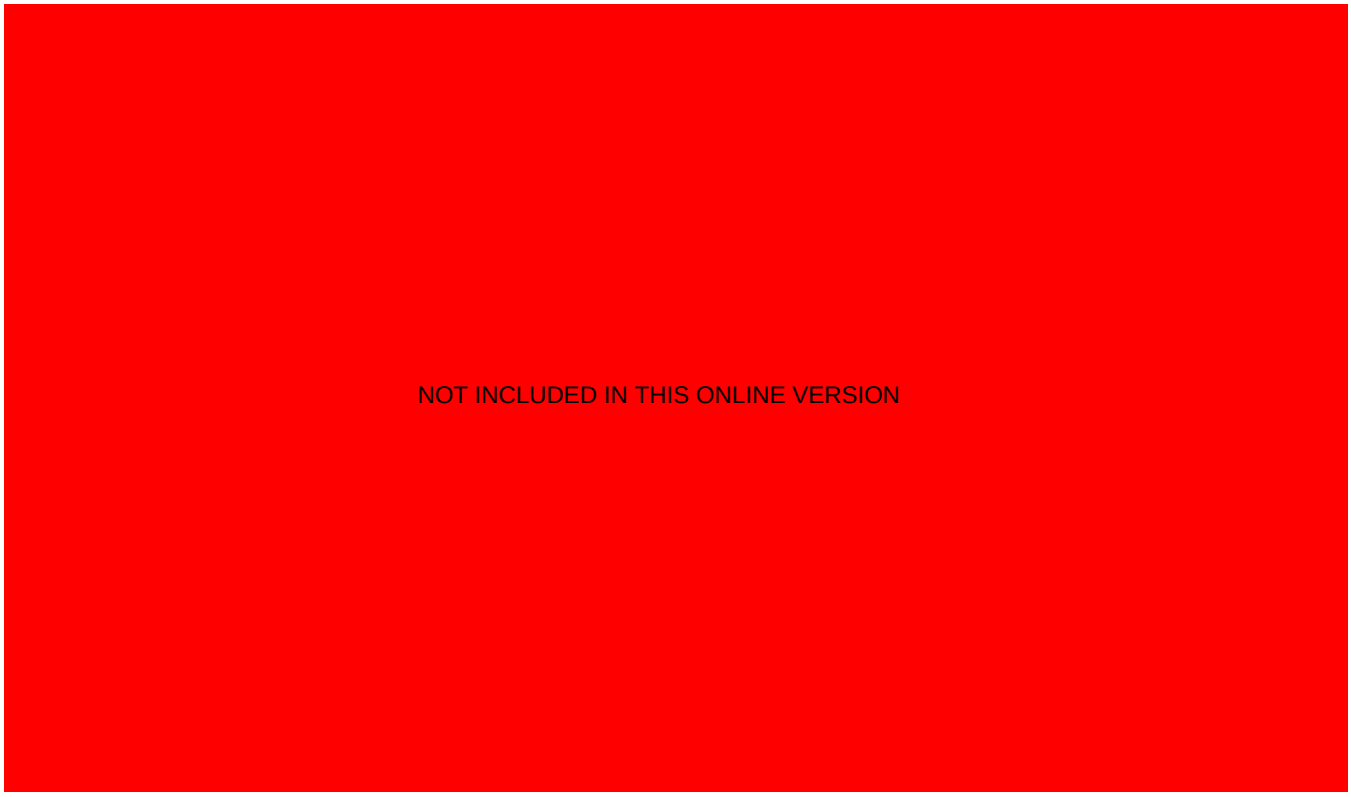


Figure 1. Circuit diagram of the system.

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. The magnet will levitate if its orientation is correct. Otherwise, flip over the magnet and try again. The magnet will try to move away or turn over if the orientation is not correct.

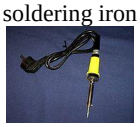
The system has three push buttons labeled as A, B and C to operate it in four distinct modes referred to as the constant mode, sinusoidal mode, square mode and sawtooth mode. In the constant mode, the small magnet levitates steadily. In the sinusoidal mode, square mode or sawtooth mode, the small magnet moves up and down within a range in accordance with a sinusoidal, square or sawtooth waveform reference signal. The transition from one mode to another is enabled by the push button A. In each mode, the vertical equilibrium position of the levitating magnet can be adjusted in 128 steps within a range by pressing the push button B (up) and push button C (down). The system initializes itself in the constant mode after each power up.

The current controller parameters can be saved (up to 100000 times) into the nonvolatile memory of the microcontroller by pressing the push button A approximately 8 s if desired. The LED will flash 4 times to indicate that the current configuration is saved (do not power down the system during this operation until the LED is continuously on). If the current configuration is not saved, then it will be lost when the power is cycled.

5. Kit Assembly

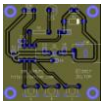
The electromagnetic levitation kit requires both electrical and mechanical assembly. The assembly instructions are detailed below.

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.

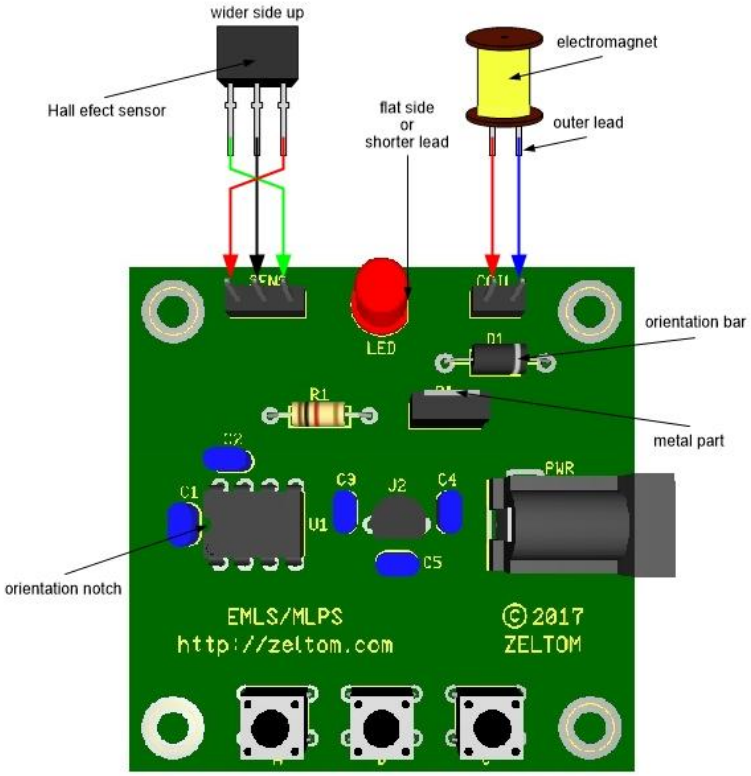


Figure 2. Electrical assembly.

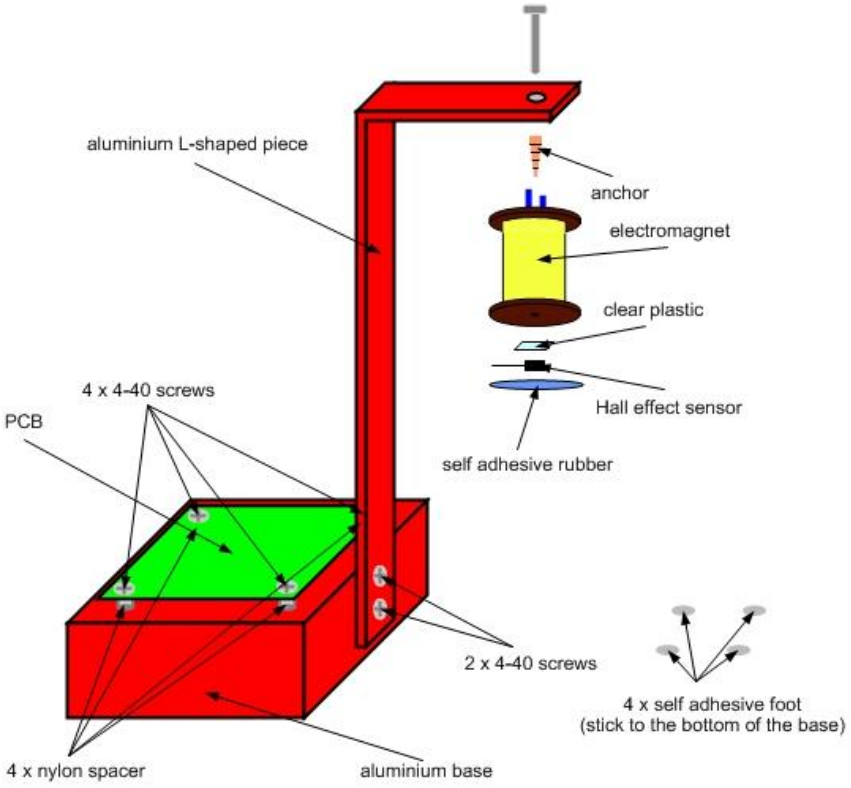


Figure 3. Mechanical assembly.

6. Calibration

The system can be calibrated (up to 100000 times) to eliminate slight sensor misalignment that may occur during the mechanical assembly in a special calibration mode. The calibration mode is activated if the button A is pressed and held before applying power to the system, and then released. The LED flashes 4 times to indicate that the system is calibrated and calibration data is saved into the nonvolatile flash memory of the microcontroller. The magnet must be kept far away from the system during the calibration mode until the LED turns continuously on.

7. Troubleshooting

- Make sure that the electrical and mechanical components are assembled correctly.
- Check the sensor and coil cables and ensure that they are connected correctly.
- If the LED is not lit, check the power adapter (or the battery) connections.
- If the LED is lit but the magnet does not levitate, use the push buttons to adjust the controller.