ELECTRICAL ENGINEERING TECHNOLOGY PROGRAM
EET 433 – CONTROL SYSTEMS ANALYSIS AND DESIGN

MAGNETIC LEVITATION EXPERIENCES

Magnetic levitation systems are good examples of control systems. The load is levitated balancing the force of gravity on the load with the magnetic attraction from the control system. If the magnetic attraction is too small, then the force of gravity dominates and the load will fall onto the ground. If the magnetic attraction is too strong, then it will dominate and the load will be attached to the control system. In the state of equilibrium, the magnetic force is equal in magnitude and with opposite sign to the force of gravity and therefore the load will be suspended levitating as the resulting force is equal to zero.

The design of a magnetic levitation system is not obvious and requires careful consideration of several parameters. During the next three laboratory experiences we will explore the characterization and design of a small magnetic levitation system. This work has been divided into two different parts:

Part 1.- System evaluation. In this part students will evaluate the global performance of the magnetic levitation system, understanding its range of operation and its limitations.

Part 2.- System Characterization. In this part students will characterize the different electronic components that make up the magnetic levitation system and how they interact with each other.

MAGNETIC LEVIATION SYSTEM Part 2: SYSTEM CHARACTERIZATION

Goals: The goal of this laboratory experience is to characterize the electrical properties of the different components that make up the magnetic levitation system in order to understand how the different components of the control board interact together.

THE POSITION SENSOR

The position sensor is based in a Hall Effect transducer, Honeywell SS490 Series. These are 3-pin devices that look like a small signal transistor. The three pins are: Voltage Supply, Ground and Output Signal (see the figure below). For the devices that will be used in this laboratory experiment, the pins have been color-coded with the soldered wires as follows:

- Red wire: Power Supply Voltage (5 Volts)
- Black wire: Ground
- White wire: Output signal

STEP 1.- Download the Specifications for the Hall Effect transducer. **Read them!** Describe in your own words, how this type of sensors work.

Connect the Hall sensor to a +5 V power supply following the correct polarity. Keep the permanent magnets away from the sensor

STEP 2.- What is the output voltage in the absence of a magnetic field? Compare this value with the specifications. What is the measurement error?

STEP 3.- Using only one permanent magnet, measure the voltage at the output of the sensor at several distances between them, completing Tables 1a and 1b below:

Distance (cm)	2.5	2.0	1.5	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Sensor Voltage													

Table 1a: Measured voltage vs. distance between sensor and permanent magnet (from the right)

Distance (cm)	-2.5	-2.0	-1.5	-1.0	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1
Sensor Voltage													

Table 1b: Measured voltage vs. distance between sensor and permanent magnet (from the left)

Note that we have considered positive distances measured from the sensor to the right and negative distances measures at the left of the sensor.

STEP 4.- Create 2 new tables (Table 2a and 2b) by reversing the polarity of the permanent magnet.

Distance (cm)	2.5	2.0	1.5	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
Sensor Voltage													

Table 2a: Measured voltage vs. distance between sensor and permanent magnet (from the right)

Distance (cm)	-2.5	-2.0	-1.5	-1.0	-0.9	-0.8	-0.7	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1
Sensor Voltage													

Table 2b: Measured voltage vs. distance between sensor and permanent magnet (from the left)

STEP 5.- Plot the values from the tables created. Compare your results with the graph in page 2 of the specifications. Extract your conclusions.

STEP 6.- Would the measured voltage change if we change the voltage applied to the Hall Effect Sensor to 8 Volts? Check your answer by measuring selected points and compare the output voltage with those from Tables 1 and 2 (You don’t have to measure at all the points).

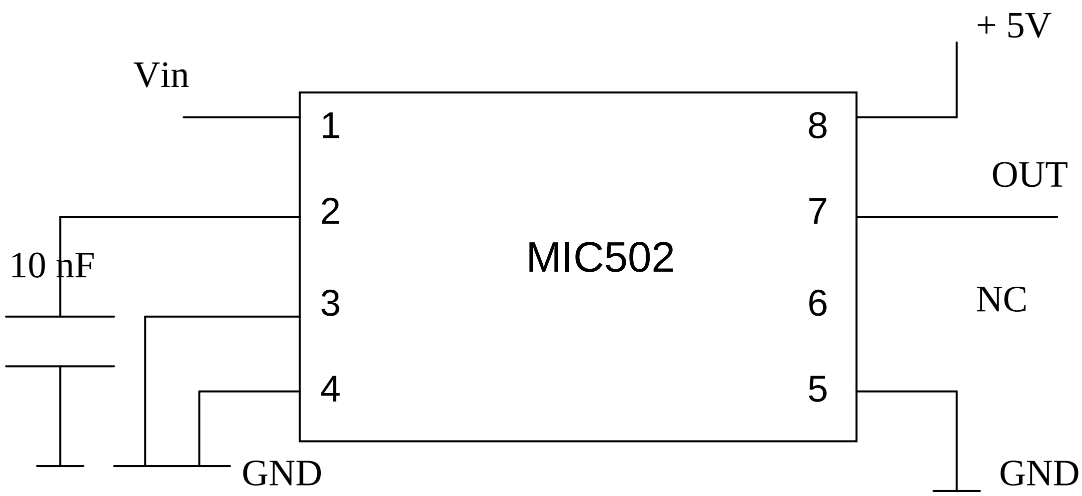
STEP 7.- Return the supply voltage to 5 Volts. Would you expect a change in the voltage at the output of the sensor if we add an additional magnet? Once again, check your answer by measuring selected points from Tables 1 and 2.

THE PWM CONTROLLER

Pulse Width Modulation (PWM) signals are commonly used in control systems to encode the signals that will be sent to the actuator. The magnetic levitation system that we are characterizing is based on using a MIC502 integrated circuit from Micrel. Although this chip was specifically designed for fan management in power supplies, it is more than suitable for our purposes.

STEP 8.- Download the Specifications for the MIC502 IC. **Read them!** Describe in your own words how it operates.

In order to characterize this chip, we will use the following circuit:



Pin 1 is the input voltage to the system, where the output of the Hall Effect sensor is connected. However, to characterize this chip, we will use an adjustable DC source connected to this Pin.

STEP 9.- Based on the specifications of the chip (page 2), what is the voltage needed in Pin 1 to have a PWM signal with a duty cycle of 50%.

STEP 10.- Adjust the DC voltage source to the value found in the previous question. Measure the frequency of the PWM signal and its duty cycle.

Frequency =
Duty Cycle =

Is the measured duty cycle different than 50% Why?

STEP 11.- Maintain the DC source at the value used in the previous question. Based on the information given in the specifications, re-design the circuit to achieve a PWM frequency of approximately:

- 10 Hz
- 2 kHz

Verify your design experimentally measuring the frequency of the PWM signal and comment on any possible discrepancies.

STEP 12.- The PWM signal that has been characterized in this section controls the current that will flow through the electromagnet after it has passed through the appropriate drivers. Comment on how this PWM signal is suitable for the task of keeping the levitated object stable.

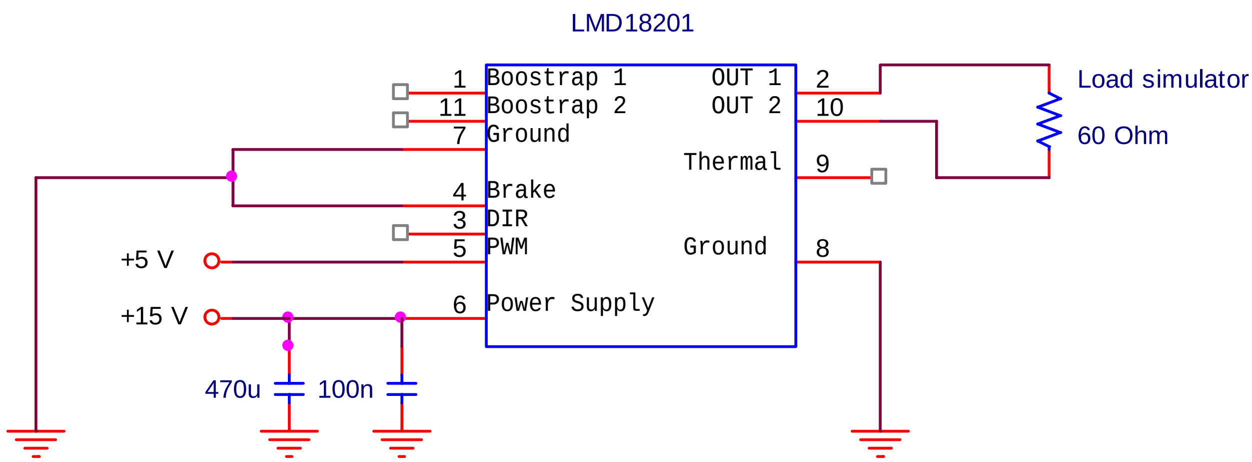
THE DRIVER CIRCUIT FOR THE ELECTROMAGNET

The driver for the electromagnet current is based on the Integrated Circuit LMD18201 from National Instruments. This is a 3A, 55 V H-Bridge designed for motion control applications. This chip can stand a larger amount of current than will be used in this case. It has, however, a heat sink to dissipate excessive heat in case of a bad connection. Because the pitch between pins in the same row is not standard (consult last page of its specifications), it has been soldered to a breakout board that will allow the use of the LMD18201 in our breadboards. Pay special attention when connecting the different pins in the circuit.

STEP 13.- Download the Specifications for the LMD18201 IC. **Read them!** Describe in your own words how it operates.

STEP 14.- What is the thermal flag in this chip? How does it operate? What is its use?

Build the circuit in the figure below leaving Pin 3 (DIR) unconnected. To simplify the analysis process, we will substitute the electromagnet by a high-power 60-Ohm resistance with a nominal value similar to the DC resistance of the electromagnet. This will allow to perform these measurements on an resistive load instead of an inductive load.



STEP 15.- Connect Pin 3 (DIR) to +5 V. Using a Multimeter, estimate the current through the load by measuring the voltage drop. We need to use the multimeter instead of the oscilloscope because none of the load terminals are grounded.

STEP 16.- Repeat the previous question, now connecting Pin 3 (DIR) to Ground. Verify your agreement with the first two lines in Table 1 for the H-bridge specifications.

STEP 16.- Write a lab report using the appropriate format. The lab report should contain, at least, the answers to all the previous questions. The conclusions section of the report is especially important as you will be giving your opinion on the work you have done as well as the laboratory experience by itself.