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 three 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.

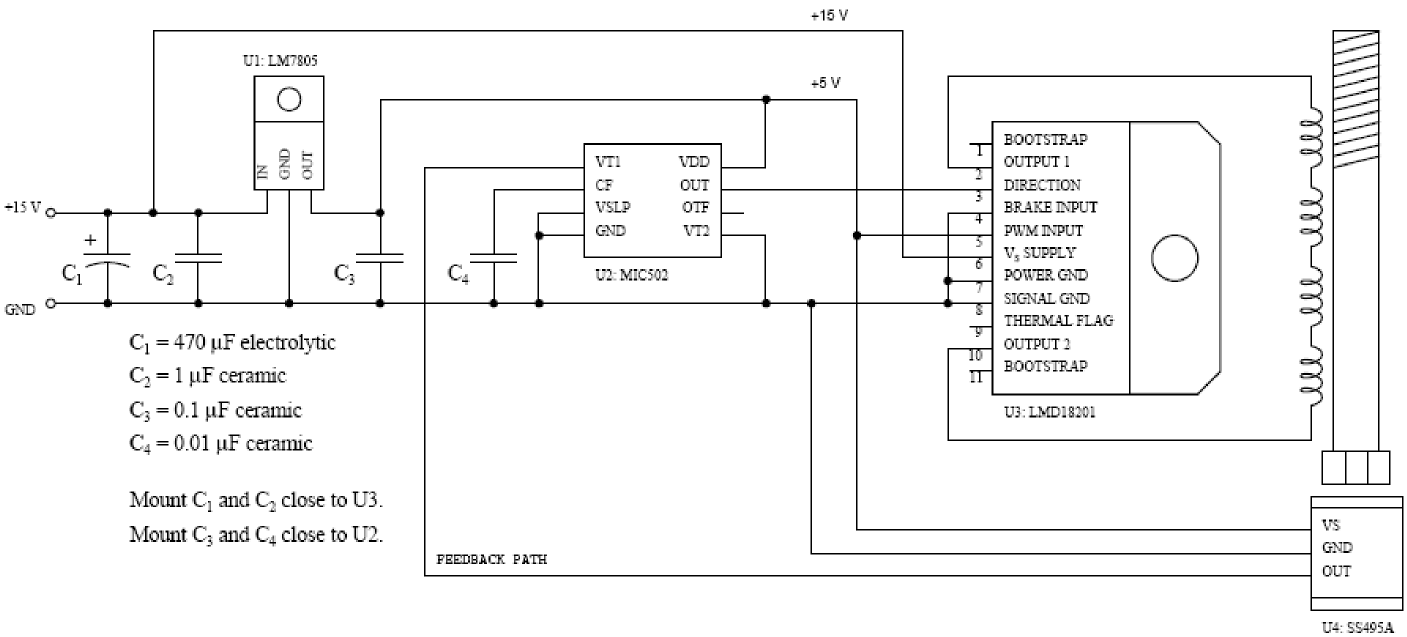
Part 3.- Improvement on the System. In this part students will build an external network that will be introduced in the feedback path in order to improve the response of the system and its limitations.

MAGNETIC LEVIATION SYSTEM - Part 3: SYSTEM COMPENSATION

Goal.- The goal of this laboratory exercise is to evaluate the effect of different compensation networks on the overall response of the magnetic levitation system.

The experiences with the magnetic levitation system from Part 1 have shown that this is system is, at its best, marginally stable. Having the levitated object suspended depends on the initial conditions; furthermore, small disturbances cause the system to become unstable and the levitated object to either fall to the ground or to become attached to the electromagnet. In this last part of this experiment, students will work with several compensation networks in order to improve the stability of the magnetic levitation system.

STEP 1.- Assemble the components that you have characterized in the previous lab experiment in order to replicate the magnetic levitation system studied in the first lab experiment. The following circuit diagram shows the interconnections:



STEP 2.- Very that the circuit is working correctly by levitating an object. The circuit that you have built should behave approximately similar to the board studied in the first laboratory experiment. You might have to adjust the polarity of the magnet, the direction of the Hall Effect sensor and/or interchange the wires for the electromagnet. Eventually one of the combinations will be correct.

STEP 3.- The two critical signals in this control system are the output of the sensor (feedback into the PWM controller) and the output of the PWM controller. These signals can be measured on the Pins of the MIC502 IC:

- Output of the Hall Effect Sensor: Pin 1
- Output of the PWM controller, driving the H-bridge: Pin 7

Visualize these two signals with the oscilloscope and sketch them for different positions of the levitated object (no object, suspended, attached to the electromagnet).

STEP 4.- What is the difference between these signals and the signals observed in the second laboratory exercise for the magnetic levitation system? Why is this happening?

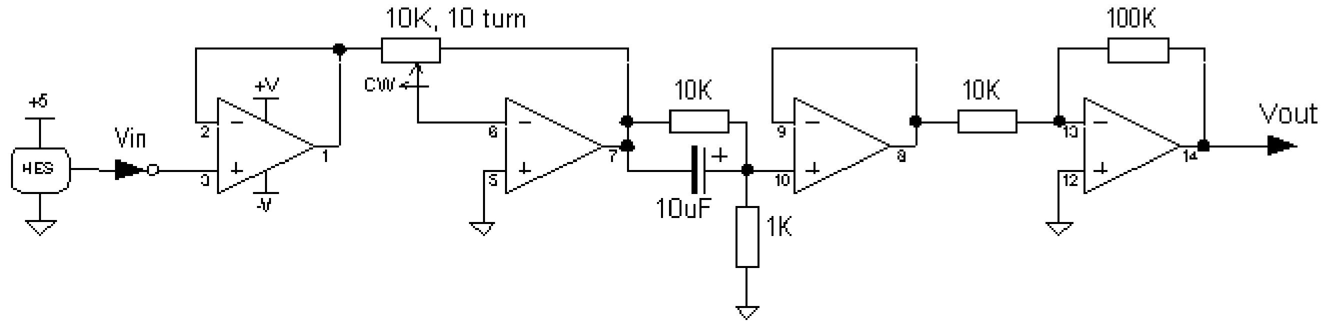
STEP 5.- A common technique to reduce the effect of high-frequency interference is the use of a capacitor of the appropriate value. Experiment with diverse values of capacitors connected between Pin 1 of the MIC502 and ground and observe their effects on the signal at that Pin. Comment on your findings.

STEP 6.- Verify that by reducing the amount of interference in this signal, it should also reduce the oscillations on the levitated object. You might have to experiment with different values of capacitors again. What is the value or range of values for that capacitor that best reduces the oscillations in the levitated object?

Although the reduction in interference may reduce the oscillations in the levitated object, this does not solve the main problem of this control system that is its marginal stability. As you have observed, the stability of the levitated object strongly depends on the initial conditions. Also, small disturbances are enough to send the system into an unstable region that will result in the object falling down or becoming attached to the magnet.

A common technique to improve the stability of any system is by the use of the appropriate compensated networks. These networks are introduced in the system, normally in the feedback path. Although the formal study and design of compensation networks are beyond the scope of this course, we will evaluate the performance of one of these networks on our magnetic levitation system.

STEP 7.- Build the network shown in the figure below. This network is designed to compensate for the response of the magnetic levitation system.



Note: We will use the TL072 ICs from Texas Instruments for the Operational Amplifiers. These are Dual Op Amps meaning that each chip contains 2 Operational Amplifiers. Disregard the pin numbers in the circuit above and consult the specifications for the TL072.

STEP 8.- Calculate theoretically, by analyzing this circuit, the values of the pole and zero introduced by this network.

STEP 9.- Verify the previous calculations experimentally on the network by finding the response of the network in a range of frequencies appropriate to the values of the pole and zero. Plot the magnitude and phase of the frequency response.

STEP 10.- Adjust the value of the potentiometer for the overall gain in the low-frequency range is approximately equal to 1. You might have to readjust this gain in a later stage, but this is a good way to start.

STEP 11.- We will introduce now this compensation network into the magnetic levitation system. The input for the network will be the output of the Hall Effect sensor. The output of the network will be Pin 1 of the MIC502 chip. Note that Pin 1 of the MIC502 chip was connected earlier to the output of the sensor. In this new configuration, Pin 1 is connected to the output of the Hall effect sensor after passing through the compensation network.

STEP 12.- Verify that the system is working correctly by trying to levitate the object, similar to Step 2. You might have to re-adjust the potentiometer slightly. At this point, the object should levitate in a more stable way than in Step 2.

Troubleshooting.- In case of problems you can follow these steps:

- While maintaining the object at the correct separation, vary slightly the value of the potentiometer. The object should "lock" onto the signal and levitate.
- Slightly modify the value of the resistance in parallel with the 10 μF capacitor.

STEP 13.- Comment on the effects of this network, in particular to the range of weight that is able to levitate and stability against disturbances.

STEP 14.- 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.