Lab 5. Magnetic-Levitation Controller

Laboratory Instruction

In this lab you will build a 5 op-amp module magnetic levitation controller. Many ideas and concepts from previous labs will be incorporated in this control circuit. You will be instructed as to where to place your components in order to maximize your success when building this circuit. Each output defined in the instructions presupposes that the circuit has been built up to this point.

1. **DO NOT HAVE THE POWER ON WHEN BUILDING CIRCUITS.**
   **ANY TIME YOU APPLY POWER MAKE SURE YOU VERIFY THE CONDITIONS (VOLTAGE, CURRENT, RESISTANCE, ETC.) ARE CORRECT SO THAT COMPONENTS WILL NOT BE DESTROYED.**

2. The intensity of the light coming from the infrared emitter is controlled by the amount of current going through the emitter. To make sure the current going through the emitter is at a minimum, turn the adjusting screw on Pot #1 (1kΩ) 25 revolutions CCW or until the wiper stops turning or begins to click, before placing Pot #1 on the circuit board. This adjustment will create the largest amount of resistance in the emitter circuit and will thus allow the minimum amount of current to pass through when power is applied.

3. **THE EMITTER CIRCUIT MUST BE CONNECTED TO +5 VOLTS. A VOLTAGE GREATER THAN +5 VOLTS WILL DESTROY THE EMITTER.**

4. Configure the multimeter so that it can measure current. Attach the positive lead (red min-grabber) from the multimeter to the wire you connected to the +5Volt supply. Connect the common lead (black mini-grabber) from the multimeter to the red wire of the emitter (labeled E) in the Mag-Lev frame. Connect the black wire from the emitter to the CW pin on Pot #1.

   **DO NOT TURN POWER ON UNTIL AN INSTRUCTOR CHECKS OUT YOUR CIRCUIT.**

   Clockwise rotation of the adjusting screw will increase current through the emitter. **Adjust Pot #1 until the current through the diode is 15 mA.** Once you have adjusted the emitter current to 15 mA turn off the power and remove the meter from the system and connect the emitter red wire to +5Volts wire.

5. The voltage at \(V_{\text{Sensor}}\) must be set to 10 Volts using Pot #2 (100kΩ). You do not need to adjust this potentiometer before using it. Configure the
multimeter to measure voltage with the positive lead (red mini-grabber) connected at $V_{\text{Sensor}}$ and the common lead (black mini-grabber) connected to ground. Pot #2 is turned CW to increase the voltage at $V_{\text{Sensor}}$ and CCW to decrease it. With the multimeter still connected to $V_{\text{Sensor}}$, test the detector by placing an object such as your hand or a sheet of paper in front of the emitter. If the output from the detector displayed on the meter goes to zero then the emitter/detector is working properly.

6. Connect the multimeter to measure voltage with the positive lead (red mini-grabber) at $V_{\text{Analog}}$ and the common lead (black mini-grabber) connected to ground. The resistors/capacitor that follows in the circuit is arranged as an 11 to 1 voltage divider. The meter should read between 0.8 volts and 1.0 volt.

7. In order to avoid confusion, build the $V_{\text{bias}}$ circuit on the left side of the protoboard, under the emitter bias circuit. You will have to run +15 volts and (-15 volts) to the op-amp. $V_{\text{bias}}$ must be set at 0.65 Volts using Pot#3 (100kΩ). Connect the multimeter positive lead to the $V_{\text{bias}}$ output pin and the common lead to ground. Turning the adjusting screw on Pot #3 CCW decreases the voltage at $V_{\text{bias}}$ and CW rotation will increase it. After adjustment the meter should read 0.65 Volts. $V_{\text{bias}}$ IS THE POTENTIOMETER USED TO CONTROL THE STRENGTH OF THE MAGNETIC FIELD SO THAT THE MASS CAN SUSPенд.

8. Connect the multimeter to measure voltage with the positive lead (red mini-grabber) connected at $V_{A}$ and the common lead (black mini-grabber) connected to ground. This voltage represents the in-phase output of the summing junction upstream of $V_{A}$. The meter should read between 2.3-2.7 Volts.

9. In order to be able to produce a voltage at the collector of the transistor, the electro-magnet and diode must be connected to +15 volts and the collector of the TIP 31 power transistor.

READ NUMBER 9 AGAIN. READ NUMBER NINE AGAIN. READ 9 AGAIN.

**DID YOU READ NUMBER NINE?**

10. A heat sink is attached to the back of the TIP31 transistor. Looking at the transistor from the front, the pin on the left is the base, the pin in the middle is the collector, and the one on the right is the emitter. Check the voltage from the collector to the emitter on the transistor. This is measured by placing the multimeter positive lead (red mini-grabber) at $V_{\text{Collector}}$ (clip onto the diode)
and the common lead (black mini-grabber) to ground. Adjust the voltage at $V_{\text{Collector}}$ to **3 Volts** using Pot#4 (10kΩ). The adjustment is as follows:

$V_{\text{Collector}} > 3$ volts – This means there is not enough current flowing through the magnet and the transistor to produce a large enough magnetic field to suspend the mass. To increase the current and make the voltage decrease, turn pot#4 (10KΩ) clockwise until you reach 3 volts.

$V_{\text{Collector}} < 3$ volts – This means there is too much current flowing through the magnet and the magnetic field is too strong. The mass clings to the magnet instead of being suspended. To decrease the current and increase the voltage, turn pot #4 (10KΩ) counterclockwise until you reach 3 volts.

After adjusting $V_{\text{Collector}}$, attempt to suspend the mass below the electromagnet. One of three things will happen, the mass will be suspended, the mass will drop onto the table, or the mass will become attached to the magnet. Because the amount of current flowing through the electromagnet is directly proportional to the magnetic force produced, the magnetic force will increase as the current flow increases and the magnetic force will decrease as the current flow decreases. This means that we can control the position of the mass via the magnetic force applied to the mass by adjusting the current flow through the magnet.

Turn the power off. Place the aluminum stand and the mass under the electromagnet and turn the power back on. Observe if it suspends or not.

If the mass does not suspend from the magnet, slowly increase $V_{\text{bias}}$ until the mass just lifts off the pedestal. If the mass becomes attached to the magnet, pull the mass away from the magnet and adjust the $V_{\text{bias}}$ potentiometer counter-clockwise such that the $V_{\text{Collector}}$ voltage measured decreases by 0.1 volts. Attempt to suspend the mass again. A few iterations of the above steps may be necessary to properly suspend the mass below the electromagnet.
EMITTER SETUP CIRCUIT

EMITTER USE CIRCUIT

Remove the Digital Multimeter and connect the RED wire from the emitter to the +5V wire using the protoboard.

Any Color Wire (not black)

Red Mini-Grabber

DMM (Ammeter)

Black Mini-Grabber

Red Wire

Photo Emitter

Black Wire

POT 1

(15 mA DC)

Photo Emitter

Black Wire

POT 1

(15 mA DC)

Any Color Wire (not black)

Red Wire

POT 1

(15 mA DC)

Photo Emitter

This is a separate circuit from the detector. DO NOT disassemble this circuit once you get it working!
MAG–LEV DETECTOR CIRCUIT  Sheet 3 of 3

You must connect the diode and electro–magnet for the transistor to work.

Add diode at circuit board connection

ELECTRO–MAGNET
The electro magnet is in the aluminum base.

From Sheet 2
R12 100
10K

POT

Q1
Pin 2
Pin 1
Pin 3

V/COLLECTOR
(3 Volts DC)

GND
LM741
Operational Amplifier

General Description
The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709G, LM201, MC1499 and 748 in many applications. The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

Connection Diagrams

Typical Application

Order Number LM741J, LM741J883, LM741CN
See NS Package Number J08A, M08A or N08E

Order Number LM741W883
See NS Package Number W10A
TIP31A, TIP31B*, TIP31C, (NPN), TIP32A*, TIP32B*, TIP32C, (PNP)

Complementary Silicon Plastic Power Transistors

Designed for use in general purpose amplifier and switching applications.

- Collector-Emitter Saturation Voltage –
  \[ V_{CEO} = 1.2 \text{ Vdc (Max)} @ I_C \]
  \[ = 3.0 \text{ Adc} \]

- Collector-Emitter Sustaining Voltage –
  \[ V_{CEO} = 60 \text{ Vdc (Min)} \]
  \[-80 \text{ Vdc (Min)} \]
  \[-100 \text{ Vdc (Min)} \]
  \[-TIP31A, TIP32A \]
  \[-TIP31B, TIP32B \]
  \[-TIP31C, TIP32C \]

- High Current Gain – Bandwidth Product
  \[ h_T = 3.0 \text{ MHz (Min)} @ I_C \]
  \[ = 500 \text{ mA} \text{dC} \]

- Compact TO-220 AB Package

MAXIMUM RATINGS

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<tr>
<th>Rating</th>
<th>Symbol</th>
<th>TIP31A</th>
<th>TIP31B</th>
<th>TIP31C</th>
<th>TIP32A</th>
<th>TIP32B</th>
<th>TIP32C</th>
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<td>Collector-Emitter Voltage</td>
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<td>80</td>
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<td>Collector-Base Voltage</td>
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<td>Collector Current,</td>
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<td>Adc</td>
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<td>4.0</td>
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<td>@ ( T_J = 25°C )</td>
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<td>Undamped Industry Load</td>
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<td>Junction Temperature</td>
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<td>°C</td>
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</table>

1. \( I_C = 1.5 \text{ A}, L = 20 \text{ mH}, f = 10 \text{ Hz}, V_{CC} = 10 \text{ V}, V_{RE} = 100 \text{ Ω} \)

MARKING DIAGRAMS

MARKING DIAGRAMS

TO-220AB
CASE 221A-09

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section beginning on page 6 of this data sheet.

Preferred devices are recommended choices for future use and best overall value.

- Pin 1 = Base
- Pin 2 = Collector
- Pin 3 = Emitter
What is the amplitude of the signal on the scope?
What is the frequency?
Is there a DC offset?
Draw a sketch of the signal and show all calculations.

10.4 Record emitter current

10.5 Record $V_{\text{Sensor}}$ voltage.

10.6 Record $V_{\text{Analog}}$ voltage.

10.7 Record $V_{\text{bias}}$ voltage.

10.8 Record $V_A$ voltage.

10.10 Record $V_{\text{Collector}}$ when the mass suspends.