Lab 10. Magnetic-Levitation Controller

INTRODUCTION

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. The instructions below give you the freedom to mount the components on the protoboards anywhere you deem best. 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.**

2. Before adjusting the emitter current, turn the adjusting screw on Pot #1 (1kΩ) 20 revolutions CCW or until the wiper stops turning. This will immediately limit the amount of current passing through the emitter circuit protecting the emitter during initial power-up.

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

4. Connect the multimeter so that it can measure current. Attach the positive lead (red wire) from the multimeter to the +5Volt supply. Connect the common lead (black wire) from the multimeter to the red wire of the emitter (labeled E) in the MagLev frame. Connect the black wire from the emitter to the CW pin on Pot #1. Turn on the power. 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.

5. The voltage at \textbf{Vsensor} must be set to 10 Volts using Pot #2 (100kΩ). Connect the multimeter to measure voltage with the positive lead connected at \textbf{Vsensor} and the common lead connected to ground. Pot #2 is turned CW to increase the voltage at \textbf{Vsensor} and CCW to decrease it. With the
multimeter still connected to Vsensor, test the detector by placing an object such as a 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 detector is operational.

6. Since Vsensor has been set to 10 Volts, and the resistors that follow in the circuit are arranged as a 10 to 1 voltage divider, Vanalog should read 1 Volt. The multimeter is connected with the positive lead connected at Vanalog and the common lead connected to ground. The meter should read approximately 1 Volt.

7. Vbias must be set at 1.1 Volts using Pot#3 (100kΩ). The multimeter is connected with the positive lead connected to Vbias and the common lead is connected to ground. Turning the adjusting screw on Pot #3 CCW decreases the voltage at Vbias and CW rotation will increase it. After adjustment the meter should read 1.1 Volts.

8. VA must be greater than 1 Volt. This voltage represents the in-phase output of the summing junction upstream of VA. The multimeter is connected with the positive lead connected at VA and the common lead connected to ground. The meter should read more than 1 Volt.

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.

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 at Vcollector and the common lead is connected to
ground. Initially, adjust the voltage at $V_{\text{collector}}$ to 7.5 Volts using Pot#4 (10kΩ). 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 flowing through the magnet. If the mass drops from the magnet, adjust Pot #4 clockwise such that the voltage measured by the meter decreases, increasing current flow and magnetic force; attempt to suspend the mass again. If the mass becomes attached to the magnet, pull the mass away from the magnet and adjust Pot #4 counter-clockwise such that the voltage measured by the meter increases, decreasing current flow and magnetic force; attempt to suspend the mass again. A few iterations of the above steps may be necessary to properly suspend the mass below the electromagnet.
DO NOT disassemble this circuit once you get it working!

This is a separate circuit from the detector.

Remove the Digital Voltmeter and connect the RED wire from emitter to +5 volts DC.

EMITTER USE CIRCUIT
The electo-magnet is in the aluminium base.

ELECTRO-MAGNET

You must connect the diode and electo-magnet for the transistor to work.

MAC-LEV DETECTOR CIRCUIT SHEET 3 OF 3
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 709C, LM201, MC1499 and 748 in most 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

Dual-In-Line or S.O. Package

Offset Null

Inverting Input

Non-Inverting Input

Output

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

Ceramic Flatpak

Order Number LM741W883
See NS Package Number W19A

Typical Application

Offset Nulling Circuit

LM741

10 kΩ

Output

V−
TIP31A, TIP31B*, TIP31C, (NPN), TIP32A*, TIP32B*, TIP32C, (PNP)

Preferred Device

Complementary Silicon Plastic Power Transistors
Designed for use in general purpose amplifier and switching applications.

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

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

- High Current Gain - Bandwidth Product
  \[ h_{fe} = 3.0 \text{ MHz (Min) @ } I_C = 500 \text{ mA} \]
- Compact TO–220 AB Package

MAXIMUM RATINGS

<table>
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<tr>
<th>Rating</th>
<th>Symbol</th>
<th>TIP31A</th>
<th>TIP32A</th>
<th>TIP31B</th>
<th>TIP32B</th>
<th>TIP31C</th>
<th>TIP32C</th>
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1. \( I_C = 1.8 \text{ A, } V_C = 20 \text{ mV, } \text{f} = 10 \text{ Hz, } V_{CE} = 10 \text{ V, } R_{EE} = 100 \Omega \).

MARKING DIAGRAMS

TO–220AB CASE 221A–09

ORDERING INFORMATION

For detailed ordering and shipping information, refer to the package dimensions section 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
Lab 10. Mag-Lev Controller Answer Sheet

Name: ___________________________  Section Number: __________________
TA init: ______________  Date: ____________________

10.4 Record emitter current.

10.5 Record Vsensor voltage.

10.7 Record Vbias Voltage.

10.8 Record Va voltage.

10.10 Record Vcollector voltage to suspend the mass.