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 **Vsensor** must be set to 10 Volts using Pot #2 (100kΩ). Connect the multimeter to measure voltage with the positive lead connected at **Vsensor** and the common lead connected to ground. Pot #2 is turned CW to increase the voltage at **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. $\mathbf{V_{bias}}$ must be set at **1.1 Volts** using Pot#3 (100kΩ). The multimeter is connected with the positive lead connected to $\mathbf{V_{bias}}$ and the common lead is connected to ground. Turning the adjusting screw on Pot #3 CCW decreases the voltage at $\mathbf{V_{bias}}$ and CW rotation will increase it. After adjustment the meter should read **1.1 Volts**.

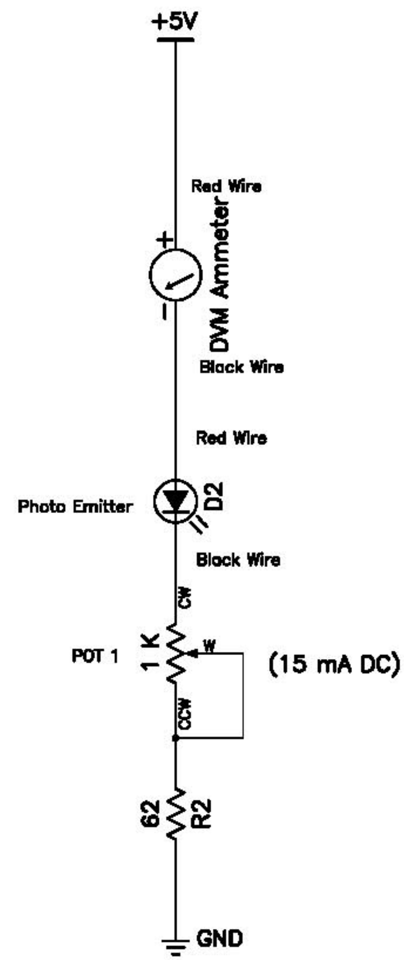
8. $\mathbf{V_A}$ must be greater than **1 Volt**. This voltage represents the in-phase output of the summing junction upstream of $\mathbf{V_A}$. The multimeter is connected with the positive lead connected at $\mathbf{V_A}$ and the common lead connected to ground. The meter should read more than **1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

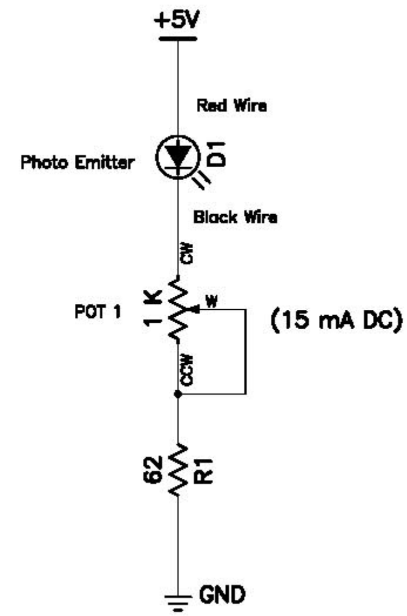
ground. Initially, adjust the voltage at **Vcollector** to **7.5 Volts** using Pot#4 (10kΩ). After adjusting **Vcollector** attempt to suspend the mass below the electromagnet. One of three things will happen, the mass will be suspended, the mass will drop onto the table, or the mass will become attached 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 form 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.

EMITTER SETUP CIRCUIT



EMITTER USE CIRCUIT

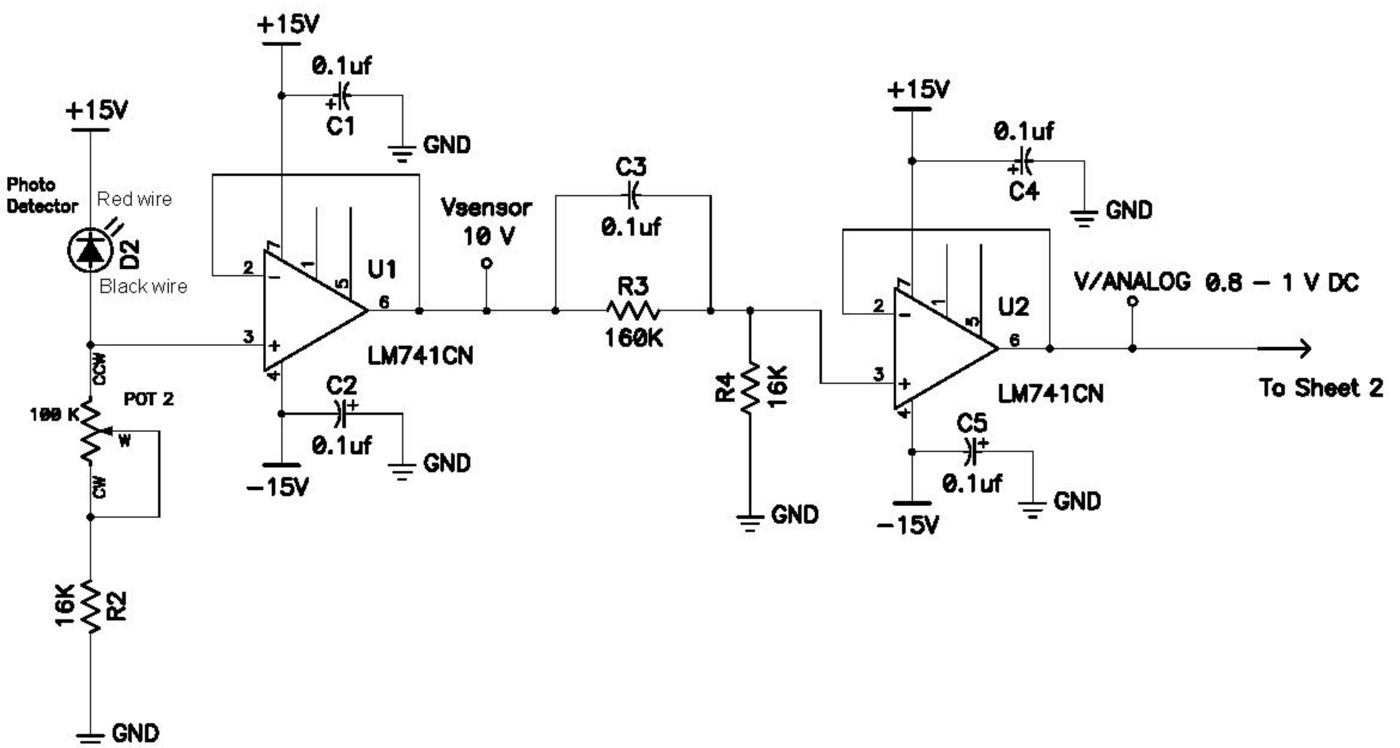
Remove the Digital Voltmeter and connect
the RED wire from emitter to +5 volts DC.



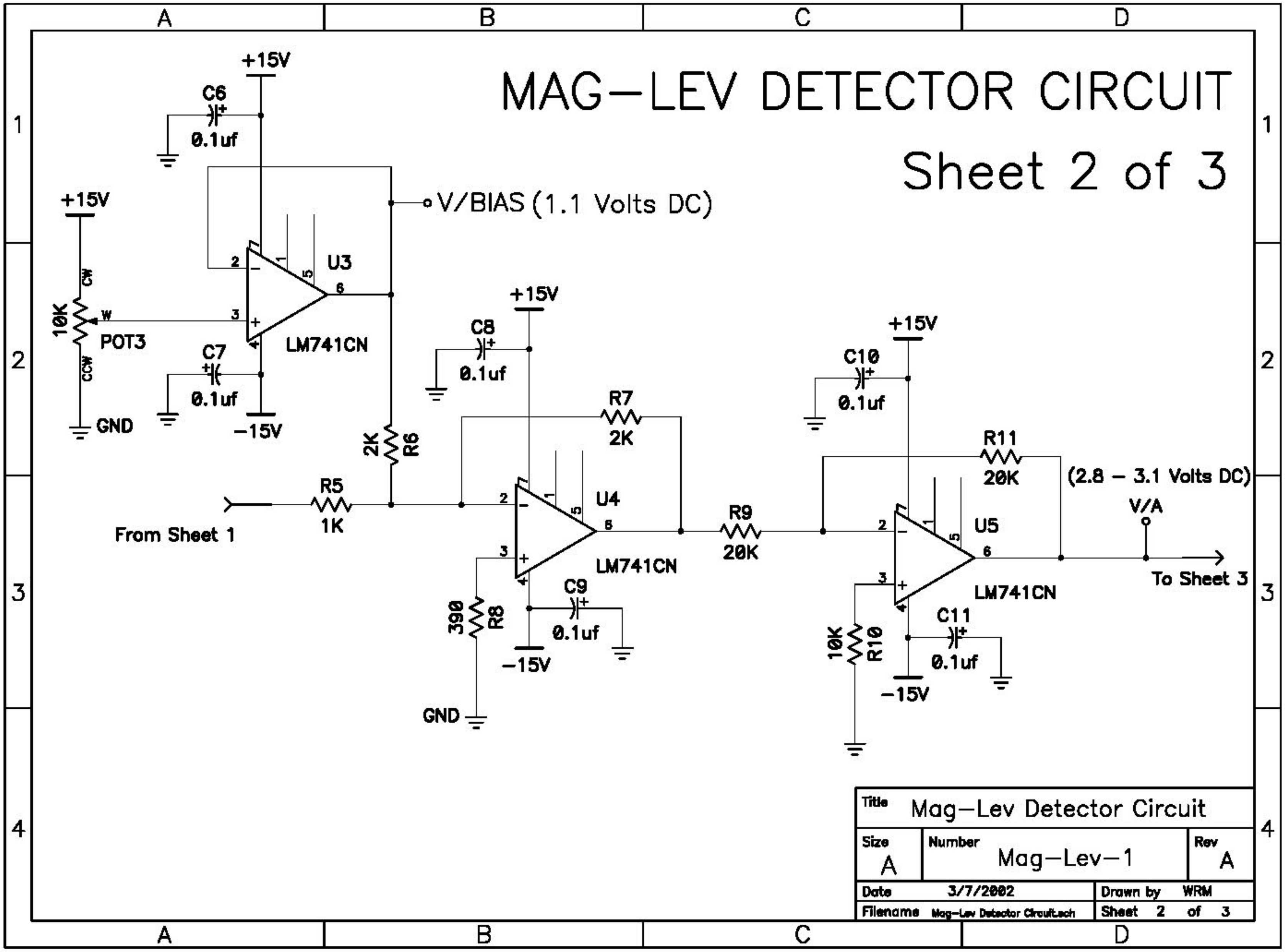
This is a separate circuit from the detector.
DO NOT disassemble this circuit once you get it working!

Title	Mag—Lev Emitter Circuit		
Size: A	Number: Mag—Lev—2		Rev: A
Date	7/18/2000	Drawn by	WRM
Filename	Mag—Lev Emitter Circuit.sch	Sheet	1 of 1

MAG–LEV DETECTOR CIRCUIT



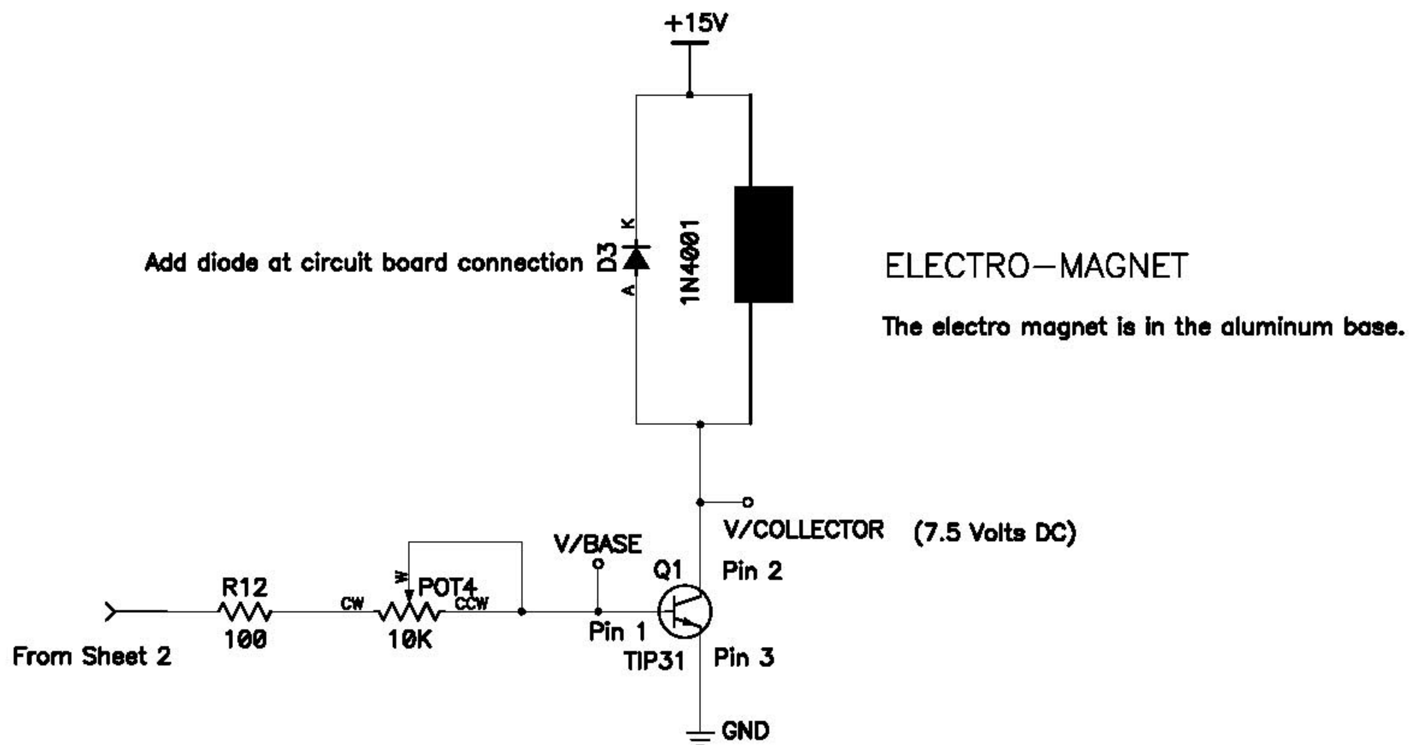
Title: Mag–Lev Detector Circuit		
Size: A	Number: Mag–Lev–1	Rev: A
Date: 3/7/2002		Drawn by: WRM
Filename: Mag–Lev Detector Circuit.sch		Sheet 1 of 3



MAG—LEV DETECTOR CIRCUIT
Sheet 2 of 3
V/BIAS (1.1 Volts DC)
+15V
C6
0.1uf
U3
LM741CN
10K
POT3
CW
CCW
W
GND
C7
0.1uf
-15V
2K
R6
R5
1K
From Sheet 1
C8
0.1uf
R7
2K
U4
LM741CN
390
R8
GND
C9
0.1uf
R9
20K
C10
0.1uf
R11
20K
(2.8 — 3.1 Volts DC)
V/A
U5
LM741CN
To Sheet 3
10K
R10
C11
0.1uf
Title Mag—Lev Detector Circuit
Size A
Number Mag—Lev—1
Rev A
Date 3/7/2002
Drawn by WRM
Filename Mag-Lev Detector Circuit.sch
Sheet 2 of 3

MAG–LEV DETECTOR CIRCUIT Sheet 3 of 3

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



Title	Mag–Lev Detector Circuit		
Size A	Number Mag–Lev–1		Rev A
Date	3/7/2002	Drawn by	WRM
Filename	Mag–Lev Detector Circuit.sch	Sheet	3 of 3

National Semiconductor

August 2000

LM741
Operational Amplifier

General Description

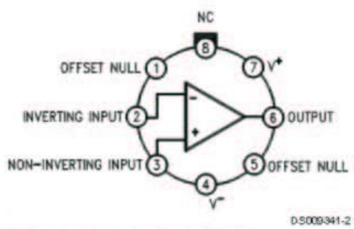
The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

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.

The LM741C is identical to the LM741/LM741A except that the LM741C has their performance guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Connection Diagrams

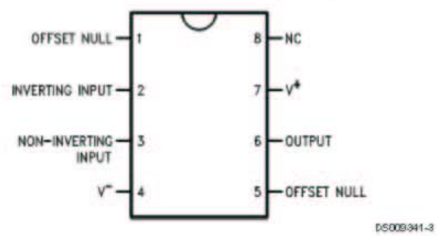
Metal Can Package



Note 1: LM741H is available per JM38510/10101

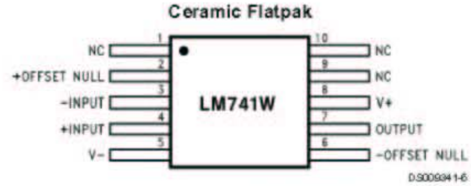
Order Number LM741H, LM741H/883 (Note 1), LM741AH/883 or LM741CH
See NS Package Number H08C

Dual-In-Line or S.O. Package



Order Number LM741J, LM741J/883, LM741CN
See NS Package Number J08A, M08A or N08E

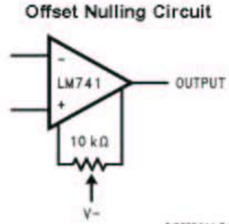
Ceramic Flatpak



Order Number LM741W/883
See NS Package Number W10A

Typical Application

Offset Nulling Circuit



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

*Preferred Devices

Complementary Silicon Plastic Power Transistors

Designed for use in general purpose amplifier and switching applications.

- Collector–Emitter Saturation Voltage –
  $V_{CE(sat)}$ = 1.2 Vdc (Max) @ I_C
  = 3.0 Adc
- Collector–Emitter Sustaining Voltage –
  $V_{CEO(sus)}$ = 60 Vdc (Min) – TIP31A, TIP32A
  = 80 Vdc (Min) – TIP31B, TIP32B
  = 100 Vdc (Min) – TIP31C, TIP32C
- High Current Gain – Bandwidth Product
  f_T = 3.0 MHz (Min) @ I_C
  = 500 mAdc
- Compact TO–220 AB Package

MAXIMUM RATINGS

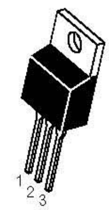
Rating	Symbol	TIP31A TIP32A	TIP318 TIP32B	TIP31C TIP32C	Unit
Collector–Emitter Voltage	V_{CEO}	60	80	100	Vdc
Collector–Base Voltage	V_{CB}	60	80	100	Vdc
Emitter–Base Voltage	V_{EB}		5.0		Vdc
Collector Current Continuous Peak	I_C		3.0 5.0		Adc
Base Current	I_B		1.0		Adc
Total Power Dissipation @ T_C = 25°C Derate above 25°C	P_D		40 0.32		Watts W/°C
Total Power Dissipation @ T_A = 25°C Derate above 25°C	P_D		2.0 0.016		Watts W/°C
Unclamped Inductive Load Energy (Note 1)	E		32		mJ
Operating and Storage Junction Temperature Range	T_J, T_{stg}		–65 to +150		°C

1. I_C = 1.8 A, L = 20 mH, P.R.F. = 10 Hz, V_{CC} = 10 V, R_{BE} = 100 Ω..

ON Semiconductor™

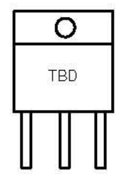
http://onsemi.com

3 AMPERE POWER TRANSISTORS COMPLEMENTARY SILICON 60–80–100 VOLTS 40 WATTS



TO–220AB CASE 221A–09

MARKING DIAGRAMS



xx = Specific Device Code
A = Assembly Location
WL, L = Wafer Lot
YY, Y = Year
WW, W = Work Week

ORDERING INFORMATION

See detailed ordering and shipping information in 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

October, 2001 – Rev. 5
Publication Order Number: TIP31A/D

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.