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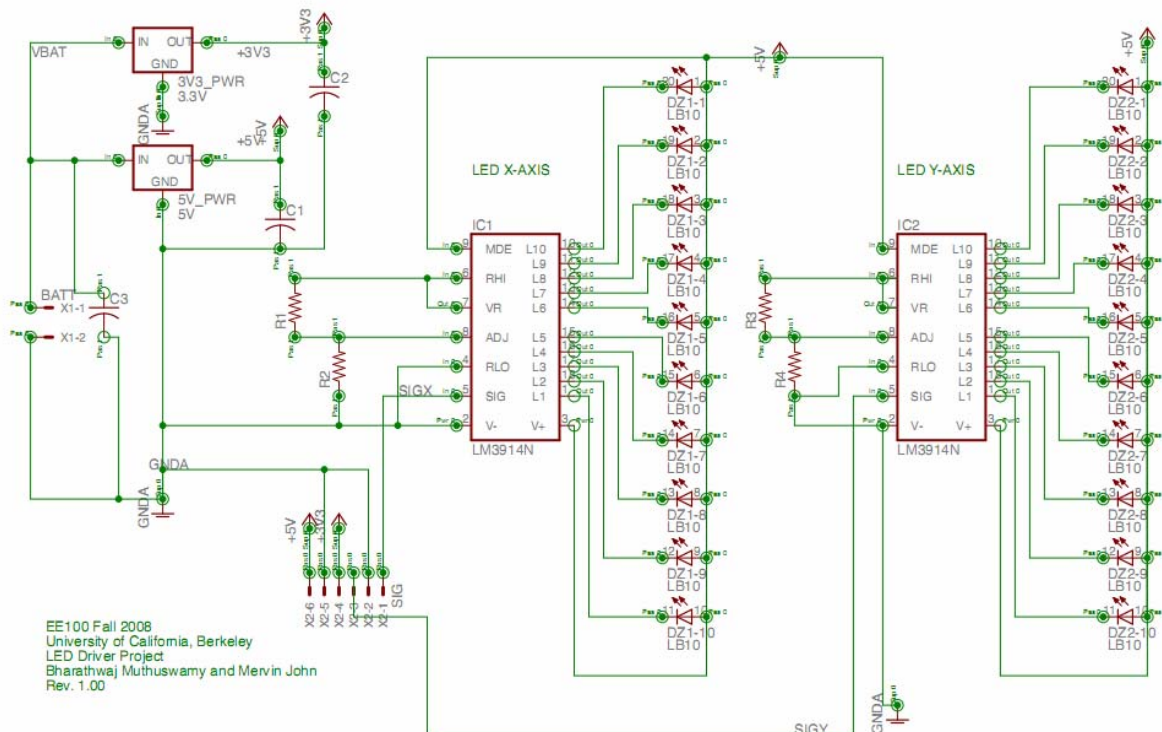
## LED DISPLAY DRIVER BOARD

### 1. Introduction

In this project, you will build an LED display driver board. **The goal of the circuit is to visually display sensor voltage output(s).** The board takes in two analog inputs and provides a linear analog display on two Bar LEDs proportional to the voltage level. Since this is your first electronics class, we have already designed and fabricated the **Printed Circuit Board (PCB)**. Your job will be to solder the correct components onto the board. **The goal(s) of the project are:**

- a. Understand how to solder
- b. Understand how to use a linear regulator
- c. Understand how to use datasheets to design (or understand) circuit functionality
- d. Interface two external sensors - Strain Gauge and Accelerometer – to your PCB

Figures 1 and 2 below show the schematic and PCB layout of your circuit respectively.



**Figure 1.** LED Display Driver Schematic

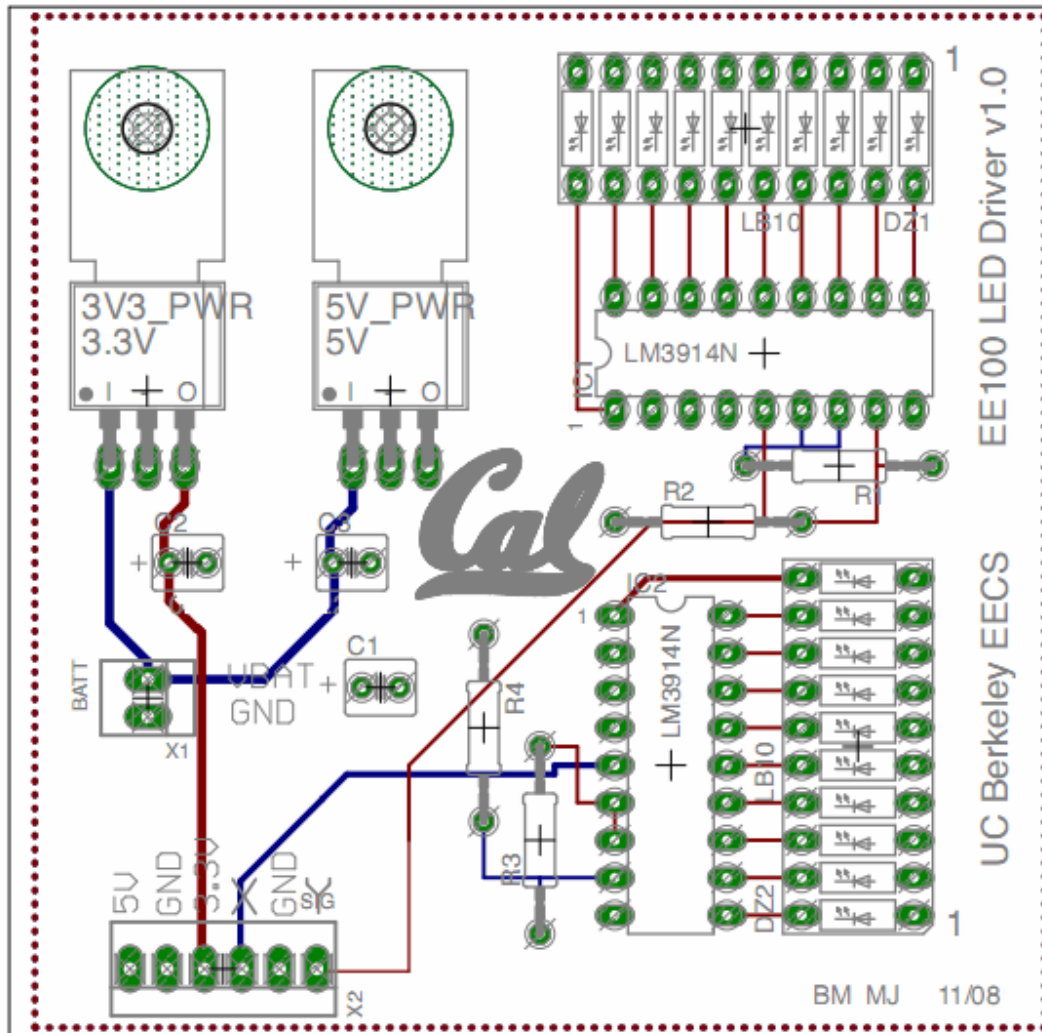


Figure 2. LED Display Driver PCB showing top layer and silkscreen

## 2. Theory

### a. Soldering Concepts

Soldering is defined as "the joining of metals by a fusion of alloys which have relatively low melting points". In other words, you use a metal that has a low melting point to adhere the surfaces to be soldered together. Soldering is more like gluing with molten metal than anything else. Soldering is also a must have skill for all sorts of electrical and electronics work. **It is also a skill that can only be developed with practice [1].** The steps involved with soldering could be loosely classified as shown below:

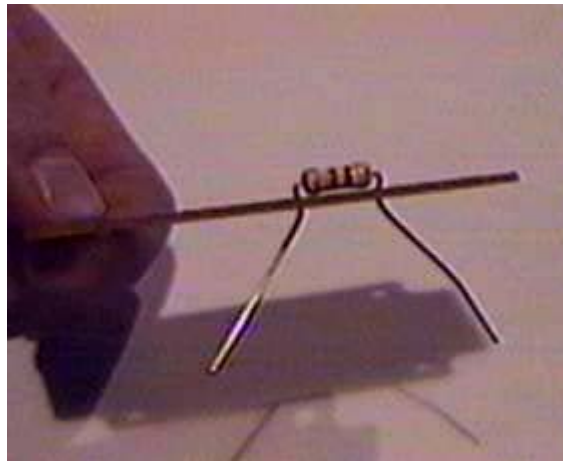
**Equipment:** Soldering requires two main things: a soldering iron and solder. Soldering irons are the heat source used to melt solder. Irons of the 15W to 30W range are good for most electronics/printed circuit board work. Anything higher in wattage and you risk damaging either the component or the board. Note that you should not use so-called soldering guns. These are very high wattage and generate most of their heat by passing an

electrical current through a wire. Because of this, the wire carries a stray voltage that could damage circuits and components. The choice of solder is also important. One of the things to remember is to never use acid core solder. Acid core solder will corrode component leads, board traces and form conductive paths between components. The best solder for electronics work is a thin rosin core solder [1].

**Remember that when soldering, the rosin in the solder releases fumes. These fumes are harmful to your eyes and lungs. Therefore, always work in a well ventilated area. Hot solder is also dangerous. Be sure not to let it splash around because it will burn you almost instantly [1]. Eye protection is mandatory.** After you are done soldering, you must wash your hands thoroughly.

**Surface Preparation:** A clean surface is very important if you want a strong, low resistive solder joint [1]. Since you already have a PCB design, you don't have to worry about your board being clean. But, make sure that your component leads are clean.

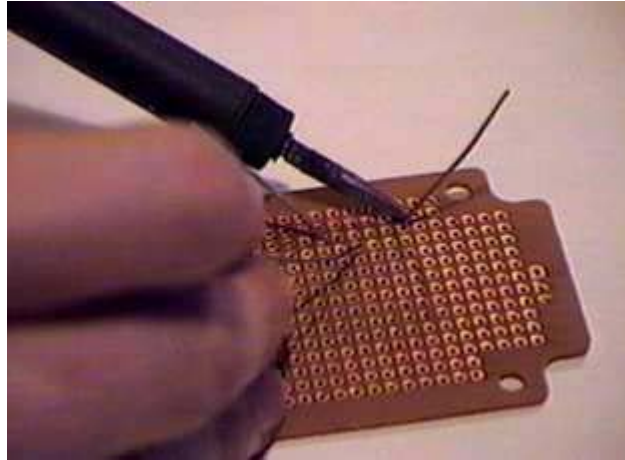
**Component Placement:** Bend the leads as necessary and insert the component through the proper holes on the board. To hold the part in place while you are soldering, you may want to bend the leads on the bottom of the board at a 45 degree angle [1], refer to figure 3 below.



**Figure 3.** Resistor ready to be soldered

**Apply Heat:** Apply a very small amount of solder to the tip of the iron. This helps conduct the heat to the component and board, but it is **NOT** the solder that will make up the joint. Now you are ready to actually heat the component and board. Lay the iron tip so that it rests against both the component lead and the board. Normally, it takes one or two seconds to heat the component up enough to solder, but larger components and larger soldering pads on the board can increase the time. Refer to figure 4 for a picture [1].

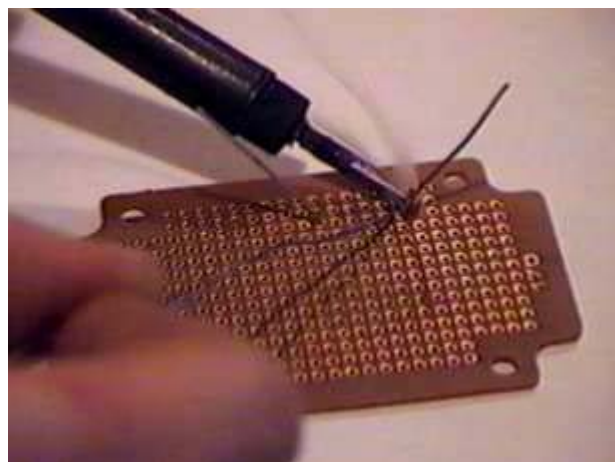
As a general rule of thumb, you should solder passive components (resistors, capacitors, diodes etc.) first. The reason is that passives can be more easily mounted as compared to transistors and integrated circuits (ICs). Make sure you solder polarized capacitors and diodes correctly. You should also use sockets for ICs when available.



**Figure 4.** Applying heat

**Apply Solder and Remove Heat:** Once the component lead and solder pad has heated up, you are ready to apply solder. Touch the tip of the strand of solder to the component lead and solder pad, but **NOT** the tip of the iron. If everything is hot enough, the solder should flow freely around the lead and pad. Once the surface of the pad is completely coated, you can stop adding solder and remove the soldering iron (in that order). Don't move the joint for a few seconds to allow the solder to cool. If you do move the joint, you will get what's called a "cold joint". A cold joint is a joint in which the solder does not make good contact with the component lead or printed circuit board pad. Cold joints occur when the component lead or solder pad moves before the solder is completely cooled. Cold joints make a really bad electrical connection and can prevent your circuit from working [1].

Cold joints can be recognized by a characteristic grainy, dull gray colour, and can be easily fixed. This is done by first removing the old solder with a desoldering tool or simply by heating it up and flicking it off with the iron. Once the old solder is off, you can resolder the joint, making sure to keep it still as it cools [1]. Refer to figure 5 for a picture of correctly applying solder.



**Figure 5.** Applying solder

## b. Using Linear Regulators

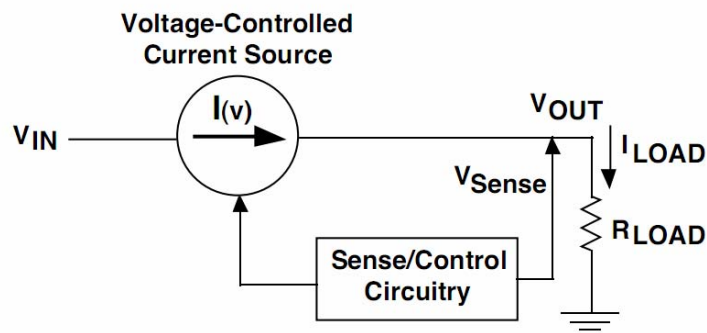
The linear regulator is the basic building block of nearly every power supply used in electronics. The IC linear regulator is so easy to use that it is virtually foolproof, and so inexpensive that it is usually one of the cheapest components in an electronic assembly [2]. Figure 6 shows a typical linear regulator you will use in this project – the LM2940 [3].



**Figure 6.** The LM2940 regulator from National Semiconductor, TO-220 package

Obviously every electronic circuit needs a constant voltage or current supply. We will not deal with constant current supplies in this project. A voltage regulator provides a constant DC output voltage (we assume that the load current and input voltage are within the specified operating range for the part) [2].

The basic linear regulator operates by using a VCCS to force a fixed voltage to appear at the regulator output terminal (figure 7) [2]. The control circuitry monitors (senses) the output voltage and adjusts the current source (as required by the load) to hold the output voltage at the desired value. The design limit of the current source defines the maximum load current the regulator can source and still maintain the desired output voltage [2]. The output voltage is controlled using a feedback loop, which requires some type of compensation to assure loop stability. This is usually done by using external capacitors [2].



**Figure 7.** Linear regulator functional diagram

### c. Understanding Datasheets

Obviously, figure 7 is just an illustration of the internal workings of a linear regulator. In order to fully utilize a regulator or any electronic component, you need to read the associated **datasheet**.

Aptly named, datasheets specify the functionality (with block diagrams and pin assignments or pinouts) of the device in question. Although a plethora of manufacturers make electronic components, datasheets usually follow a standard format: a short description of the part, the pinout, the absolute maximum ratings, typical DC/AC characteristics, sample applications and a mechanical drawing.

Based on your circuit functionality, you pick the correct components using a datasheet. However, since this is your first electronics class, we have designed the circuit for you. Again, the goal of the project circuit is to visually display sensor voltage output(s). So, ideally we would like to light LEDs proportionally to increasing sensor values. For example, if the sensor output is 2.5 V, we light up 3 LEDs. If it is 5 V, we light up 6 LEDs and so on.

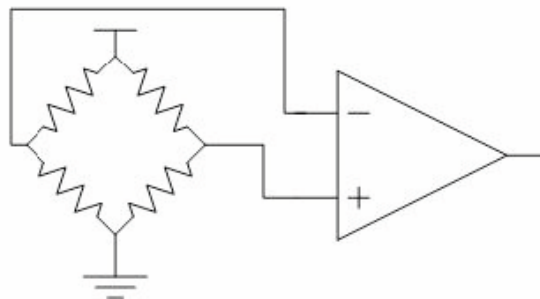
A first pass design would be to simply use op-amps as comparators to do this task. Each comparator would turn on once a voltage threshold is reached (i.e. if  $V_{in} > 2.5V$ , comparator may output high). Although this would work, we would require an enormous number of op-amps if we decide to have fine granularity in the display of our sensor values. Turns out there is a component which does the task: the LM3914 LED display driver.

Using the LM3914 is very simple: **READ** the datasheet. You can download a copy from the EE100 lab website. Pay special attention to pages 1, 2, 7 and 8. The datasheets for the other components can also be found on the EE100 website.

Once you have mastered the datasheets, you should be able to understand the detailed functionality of the circuit in figure 1. Nevertheless, now would be a good time to wrap up the prelab for week 1 so that you understand how the circuit works before going into lab.

### d. Sensor Interface

In the second week, you will interface two sensors to your display driver. One of them is the strain gauge circuit from lab 4. Figure 8 is a repeat of the schematic.



**Figure 8.** Strain Gauge circuit from EE100 Fall 2008 Lab #4 with AD623 instrumentation amplifier



You need to redesign the circuit so that the full scale reading is 3.3 V, not  $\pm 5$  V. Look at the datasheet for the AD623. You will need to setup the amplifier for single-supply basic connection. You will also need to revise the full-bridge strain gage circuit. Now would be a good time to answer the strain gauge prelab question for week 2.

The next sensor that you interface will be an accelerometer, the MMA7260Q. Again, read the MMA7260Q datasheet on the EE100 website to understand accelerometer functionality.

#### e. Hints

1. **DO NOT** try to solder all the components and then test the circuit. This will not work, moreover, this approach is **NOT** a systematic. One of the fundamental approaches to engineering design is to decompose a system into subsystems and then design/debug each individual subsystem. For example this project is subdivided into the power circuitry and the display driver circuitry.
2. **DO NOT** forget the output capacitors for the regulators, you will not get reliable voltage output without them.
3. The components (especially the regulators) get hot when all the LEDs are on. This is normal, usually a heatsink is used. We don't use a heatsink here so just be careful with the regulator when the circuit is on.
4. When you insert the LM3914 IC and the LED displays, remember the pin numbering! For the LM3914, consult the datasheet. Look on the backside of the LED display for the pin numbering

PRELAB WEEK 1

Lab Session:

Name 1:

SID:

**NOTE: READ THE THEORY SECTION BEFORE ATTEMPTING THE PRELAB!**

**I. WEEK 1**

**a. Soldering Concepts**

1. Which should you solder first: the LM3914 LED driver IC or the resistors that set the LED current? Why? **[1 point]**

2. Once you complete soldering, should you cool the joint down by blowing air over it? Why or why not? **[1 point]**

**b. Using Linear Regulators**

1. Why can't we use a battery as a constant voltage source (in reality)? **[3 points]**

2. Why can't we use a voltage divider to obtain different voltage values from a battery? **[3 points]**



3. Briefly describe the functionality of a Low Drop Out (LDO) linear regulator. **[5 points, HINT: Read [2]]**

**c. Understanding Datasheets**

4. Using the LM2940 datasheet, what is the value of the output capacitance required for regulator stability? Note that this is the value of C1 in figure 1. Write down this value in your project report. **[1 point]**
5. Using the LM2937ET-3.3 datasheet, what is the value of the output capacitance required for regulator stability? Note that this is the value of C2 in figure 1. Write down this value in your project report. **[1 point]**
6. Assuming a LED on-current of 18 mA, pick a value for R1 from the LM3914 datasheet. Show your work below. Write down the value of R1 in your project report. **[3 points]**
7. Assuming a 3.3 V full scale and the value of R1 from above, pick a value for R2 (again, use the LM3914 datasheet). Show your work below. Write down the value of R2 in your project report. **[5 points]**

8. Suppose we have configured the LED displays for two 3.3 V full scale sensors. Assume one sensor reads 1.2 V and the other reads 2.3 V. The 1.2 V sensor is connected to one of the LED displays and the 2.3 V is connected to the other one. How many LEDs light up in each display? Show your work below. **[5 points, Hint: how many LEDs light with a full 3.3V input]**

PRELAB WEEK 2

Lab Session:

Name 1:

SID:

**II. WEEK 2**

9. Redesign the strain gauge circuit from lab #4 for a full scale reading of 3.3 V (i.e. the output from the amplifier should range from 0 to 3.3V). Show your schematic below. **[10 points]**

10. Using the datasheet for the accelerometer, briefly explain sleep mode. **[5 points]**

## PROJECT REPORT

Lab Session:

Name 1:

SID:

Name 2:

SID:

**NOTE: IF YOU CAN'T DO THE PRELAB, YOU CAN'T DO THE PROJECT!****I. WEEK 1**

1. Value of C1 in figure 1 from prelab:\_\_\_\_\_ TA Checkoff:\_\_\_\_\_
2. Value of C2 in figure 1 from prelab:\_\_\_\_\_ TA Checkoff:\_\_\_\_\_
3. Value of R1 in figure 1 from prelab:\_\_\_\_\_ TA Checkoff:\_\_\_\_\_
4. Value of R2 in figure 1 from prelab: \_\_\_\_\_ TA Checkoff:\_\_\_\_\_

Note:  $R_4 = R_2$ ,  $R_3 = R_1$ . You don't have to use C3. Get these components from your TA.

5. Functional regulator circuit. TA Checkoff:\_\_\_\_\_ [10 points]
6. Soldered R1, R2, R3, R4. TA Checkoff:\_\_\_\_\_ [5 points]
6. Soldered 1 DIP socket properly. TA Checkoff:\_\_\_\_\_ [5 points]
7. Soldered LED display properly. TA Checkoff:\_\_\_\_\_ [5 points]

**NOTE POLARITY OF LED DISPLAY!**

8. Soldered LED driver properly. TA Checkoff:\_\_\_\_\_ [5 points]
9. First LED display and driver works. TA Checkoff:\_\_\_\_\_ [5 points]

**NOTE: DO NOT SOLDER SECOND DISPLAY DRIVER WITHOUT STEP 9 CHECKOFF!**

10. Second LED display and driver works. TA Checkoff:\_\_\_\_\_ [5 points]

**II. WEEK 2**

10. Verified functionality of Strain Gauge sensor circuit for 3.3 V full scale. TA Checkoff:\_\_\_\_\_ [15 points]
11. Verified functionality of Strain Gauge interfaced to LED display. TA Checkoff:\_\_\_\_\_ [5 points]
12. Verified functionality of accelerometer circuit. TA Checkoff:\_\_\_\_\_ [15 points]
13. Verified functionality of accelerometer circuit interfaced to LED display. TA Checkoff:\_\_\_\_\_ [15 points]

## **SUGGESTIONS AND FEEDBACK**

Time for completing prelab:

Time for completing project:

Please explain difficulties you had and suggestions for improving this laboratory. Be specific, e.g. refer to paragraphs or figures in the write-up.

## REFERENCES

1. How To Solder. <http://www.aaroncake.net/electronics/solder.htm> Available Online: Nov. 7th 2008
2. Linear and Switching Voltage Regulator Fundamentals.  
[http://www.ece.uidaho.edu/ee/digital/donohoe/ECE440/resources\\_files/National\\_VoltageRegulators.pdf](http://www.ece.uidaho.edu/ee/digital/donohoe/ECE440/resources_files/National_VoltageRegulators.pdf)  
Available Online: November 7<sup>th</sup> 2008
3. LM2940 picture from digikey.  
<http://media.digikey.com/photos/National%20Semi%20Photos/14-TO-220-3.jpg>  
Available Online: November 10<sup>th</sup> 2008

## REVISION HISTORY

Rev. 1/Nov 7 <sup>th</sup> 2008	Bharathwaj Muthuswamy: Typed up initial report
Rev. 1.1/Nov. 11 <sup>th</sup> 2008	Mervin John: Minor revisions
Rev. 1.2/Nov. 12 <sup>th</sup> 2008	Mervin John and Bharathwaj Muthuswamy: Reduced LED on-current requirement, replaced LM1086 with LM2937 (pin compatible with LM2940)