Digital Weight Scale Project

San José State University

Charles W. Davidson College of Engineering

EE98H Honors Introduction to Circuit Analysis

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October 23, 2018

Summary

For this project, we were tasked with constructing a digital weight scale. The scale was mechanically constructed using, what I presume is, acrylic as the top and bottom surfaces and strain gauges attached to an aluminum beam, which were held between the surfaces using screws and washers. The circuit was assembled using a breadboard, quad-amp IC, resistors, potentiometers, switches, 9-volt battery, digital display, and strain gauges. The scale was able to read the weight of objects placed upon it in either kilograms or pounds, being able to switch which units it read by the flip of a switch. After testing the final product, it was found that the scale was able to read the weight in kilograms with an accuracy of $\pm\ 0.04$kg.

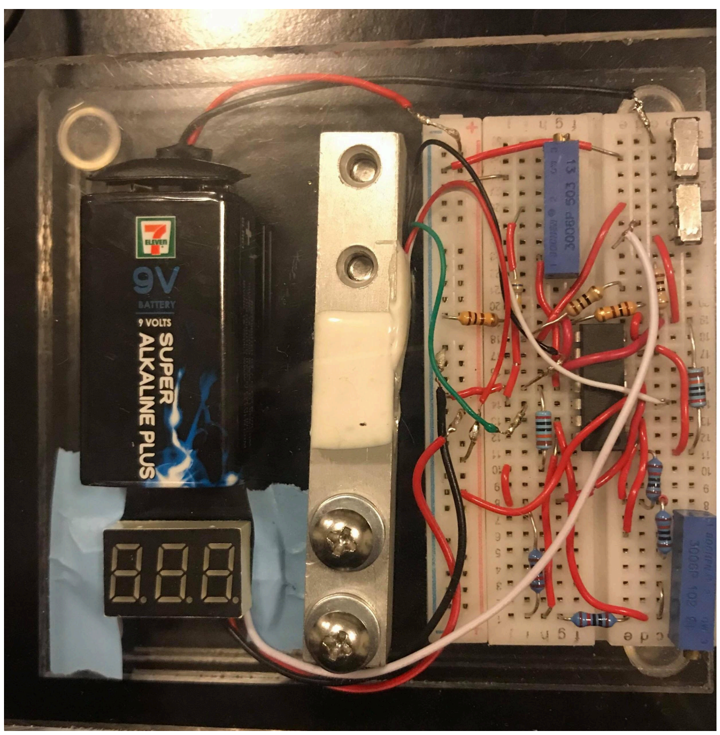

Figure 0: Fully Constructed Digital Weight Scale

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1.0 Circuit Design

For the circuit design, I basically followed the design that was provided in the project instructions, which had the strain gauges connected to an instrumentation amplifier with a voltage offset. Following the schematic of an instrumentation amplifier shown in Figure 1, $R_1 = 10k\Omega$, $R_2 = 200k\Omega$,$R_3 = 10k\Omega$and $R_4 = 693.522\Omega$, where $R_4$is a potentiometer whose resistance was determined through calculations found on page 3, **2.2** R_4**Calculation**. Additionally, a $660k\Omega$ resistor was connected to the non-inverting input of one of the buffer amplifiers and connected with another potentiometer, R_F, to serve as a voltage offset so that the display would display a value of zero when there was nothing on the scale. A $1M\Omega$ resistor was initially used for the offset, but it was found that the potentiometer did not have enough range to offset the voltage so that it would truly read zero when nothing was on the scale. In order to implement a way to switch the reading from kilograms to pounds, a non-inverting amplifier was introduced to the circuit. Since the instrumentation amplifier was tuned so that it outputs a voltage of 1V when a weight of 1 kg is placed upon the scale, and since 1 kg is about 2.2lbs, the output of the instrumentation amplifier could be connected to the non-inverting input of the non-inverting amplifier, which would have a gain of 2.2. In order to accomplish this gain, following the non-inverting amplifier schematic in Figure 2, $R_1 = 100\Omega$and $R_2 = 120\Omega$. However a resistor of 120Ω could not be obtained, so three resistors of values 100Ω, 10Ω, and 10Ω were connected in series to act as R_2. Two switches were used in the circuit, one to turn the scale on and off, and one to change the display from showing the weight in kilograms to pounds or vice versa.

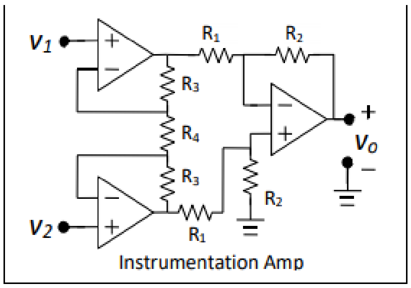


Figure 1: Instrumentation Amp Schematic

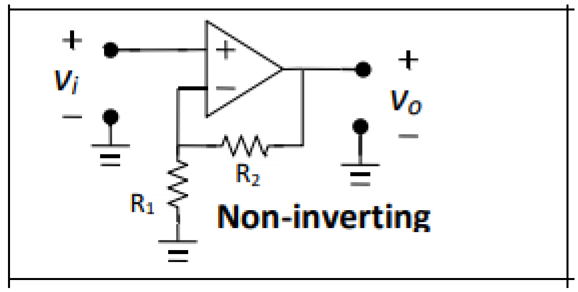


Figure 2: Non-inverting Amp Schematic

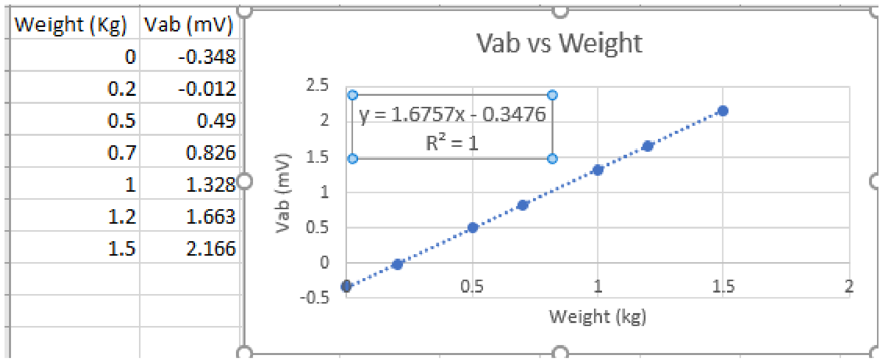
2.0 Calculations

2.1 Gain Calculation

In order to calculate the required gain of the instrumentation amplifier, V_{ab} was measured after placing different weights upon the scale. The recorded data was then plotted and the equation of the linear fit was obtained, as seen in Figure 3 . The linear fit equation corresponds with the equation model $V_{ab} = (k \times Weight) + V_{offset}$. In this case, the gain is the inverse of the constant k. Therefore,

$$Gain = \frac{1}{k}(1000) = \frac{1}{1.6757}(1000) = 596.76.$$

Here we are multiplying the inverse of k by 1000 because V_{ab} was measured in millivolts rather than volts.



Weight (Kg)	Vab (mV)
0	-0.348
0.2	-0.012
0.5	0.49
0.7	0.826
1	1.328
1.2	1.663
1.5	2.166

Figure 3: Plotted data of Vab vs Weight

2.2 R_4 Calculation

To find the appropriate resistance value for R_4, we use the following equation:

$$Gain = \frac{R_2}{R_1}\left(1 + 2\frac{R_3}{R_4}\right)$$

Solving for R_4, we get:

$$R_4 = \frac{2R_3}{Gain \times \frac{R_1}{R_2} - 1} = \frac{2 \times 10k\Omega}{596.76 \times \frac{10k\Omega}{200k\Omega} - 1} = 693.522\Omega$$

3.0 Performance

After the scale was fully constructed and calibrated, its performance was tested. The scale was tested using weights ranging from 0 kg to 2 kg in increments of 0.5 kg. The scale was also tested measuring in pounds, but only for one weight to show that the circuit was capable of switching between kilograms and pounds. The results of the scale can be found in Table 1 below. Proof that the scale was tested among the instructor can be found in Figure 4.

Test Weight (kg)	Reading	Absolute Error	Error %
0.00	0.00	0.00	--

0.50	0.52	0.02	4%
1.00	1.00	0.00	0%
1.50	1.48	0.02	1.33%
2.00	1.96	0.04	2%

Table 1: Results of Scale Performance

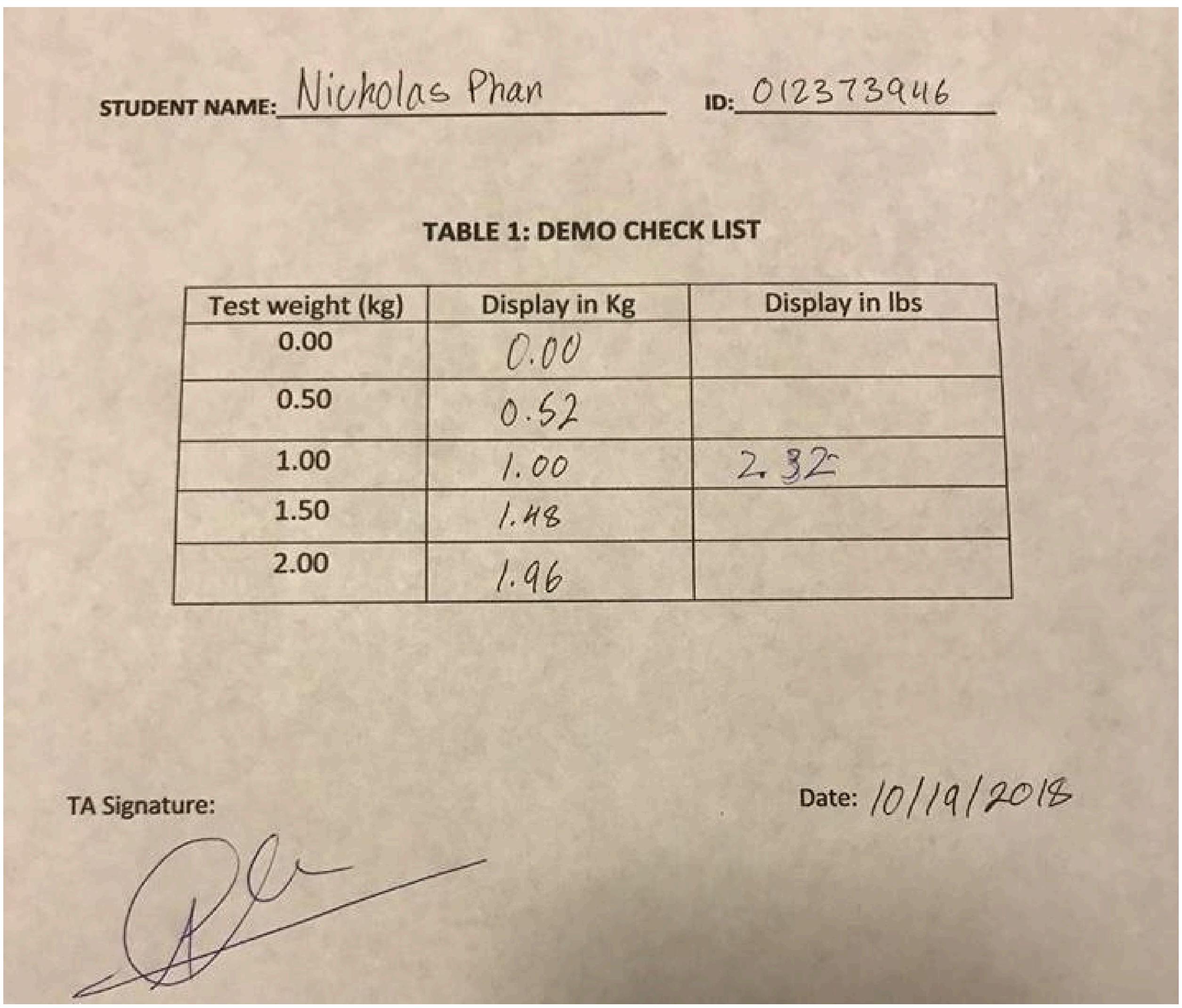


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TABLE 1: DEMO CHECK LIST

Test weight (kg)	Display in Kg	Display in lbs
0.00	0.00	
0.50	0.52	
1.00	1.00	2.32
1.50	1.48	
2.00	1.96	

TA Signature:

Date: 10/19/2018

Figure 4: Proof that Scale was tested among the instructor