M E M O R A N D U M

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To:	Dr. Hemanth Porumamilla, Professor Dr. Stephen Kwok-Choon, Postdoctoral Lecturer	
Subject:	**Load Cell Calibration**	

Introduction

The objective of this experiment is to compare the published calibration constant of a load cell to a value that we obtained through the use of an accelerometer, proof mass, and force transducer system on top of a shake table (Figure 1). The shake table is powered by a signal generator at an either 90Hz or 900Hz sin wave at an increasing peak voltage from $0.5V_{pp}$ to $3.0V_{pp}$. As it increases, we record peak and rms voltage data from the accelerometer and force transducer and use the known calibration constant for the accelerometer to calculate the force in the load cell.

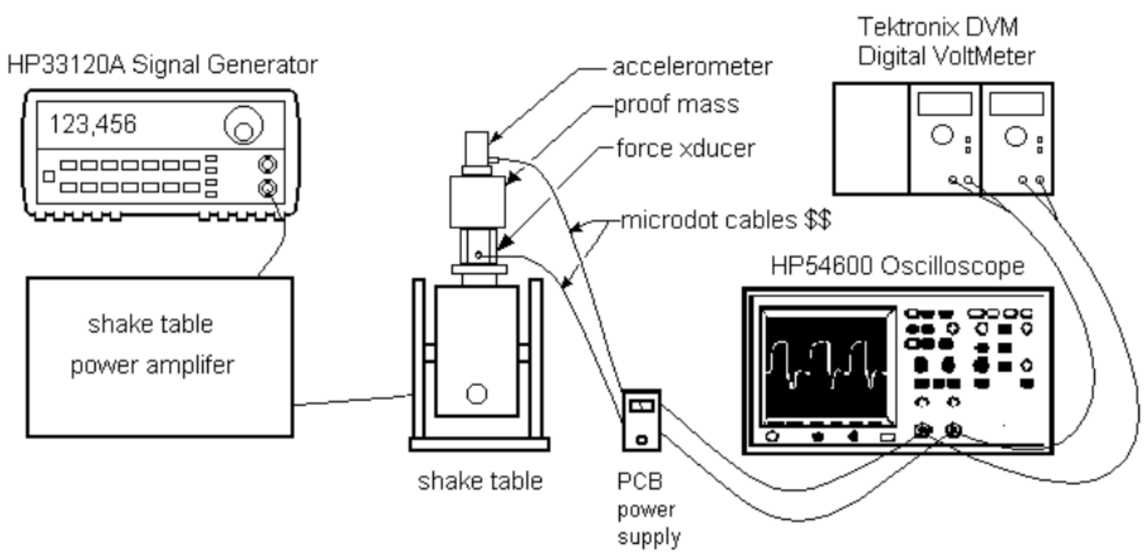

Figure 1. Load Cell Experiment Setup - Image from Lab Procedure

To calculate the force in the load cell, we use the peak or rms voltage of the accelerometer (V_a) with the accelerometer's calibration constant. We start by converting voltage to acceleration in multiples of gravity (g) in Equation 1.2 using Accelerometer Model 308B, Serial #8610's calibration constant (k_a) of

$$k_a = 100.6\, mV/g \tag{1.1}$$

$$a_g = \frac{V_a}{k_a} \tag{1.2}$$

The acceleration in Equation 1.2 then needs to be converted to units of ft/s^2.

$$a = a_g\left(\frac{32.17 ft/s^2}{1g}\right)$$

$$a = \frac{V_a}{k_a}\left(\frac{32.17 ft/s^2}{1g}\right) \tag{1.3}$$

Equation 1.3 leaves us with an acceleration of the proof mass and accelerometer mass, but we need to find the force in the load cell. To do this, we first measure the total mass of the two (Variable 1.4), then use Newton's Second Law to get the force in the load cell (Equation 1.5).

$$m_{tot} = 0.02265\, lbfs^2/ft \tag{1.4}$$

$$F_{net} = ma \tag{1.5}$$

The result of the three equations is

$$F = m_{tot}\frac{V_a}{k_a}\left(\frac{32.17 ft/s^2}{1g}\right)$$

$$F = 0.00724 V_a\, lbf/mV \tag{1.6}$$

For each voltage recorded on the accelerometer, there is also one for the force transducer. To calculate the calibration constant of the force transducer (k_{FT}), we plot the forces using Equation 1.6 for each accelerometer voltage, then plot it against the force transducers' voltages. The calibration constant is the slope shown as

$$k_{FT} = \frac{V_{FT}}{F} \quad \text{in mV/lbf} \tag{1.7}$$

We can finally compare this experimental calibration constant to the Force Transducer Model 208 C01, Serial #24297's value of

$$k = 483.6\, mV/lbf \tag{1.8}$$

Experimental Data

	Model #	Serial #	Calibration Constant
Force Transducer	208 C01	24297	483.6 mV/lbf
Accelerometer	308B	8610	100.6 mV/g

Table 1. Force Transducer and Accelerometer Published Information

	Accelerometer		Force Transducer		Acceleration				Calculated Force F=ma	
	O'scope	Voltmeter	O'scope	Voltmeter						
	V_{pp} (mV)	V_{rms} (mV)	V_{pp} (mV)	V_{rms} (mV)	g_{pp}'s	ft/s^2_{pp}	g_{rms}'s	ft/s^2_{rms}	lbf_{pp}	lbf_{rms}
~90 hz: 89.93 hz	35.62	12.45	126.6	44.75	0.3541	11.3917	0.1238	3.9816	0.2580	0.0902
	70.7	24.3	250	86.77	0.7028	22.6106	0.2416	7.7714	0.5121	0.1760
	104.7	36.83	375	130.1	1.0408	33.4842	0.3661	11.7786	0.7584	0.2668
	139.1	48.41	500	173.5	1.3827	44.4857	0.4812	15.4821	1.0076	0.3507
	175	60.82	625	217.1	1.7396	55.9669	0.6046	19.4509	1.2677	0.4406
	209.4	72.55	750	260.1	2.0815	66.9685	0.7212	23.2023	1.5168	0.5255
~900 hz: 900.9 hz	33.75	11.55	117.2	41.38	0.3355	10.7936	0.1148	3.6938	0.2445	0.0837
	66.25	23.01	234.4	82.25	0.6585	21.1875	0.2287	7.3589	0.4799	0.1667
	98.44	34.4	350	122.6	0.9785	31.4822	0.3419	11.0015	0.7131	0.2492
	129.7	45.65	475	162.5	1.2893	41.4795	0.4538	14.5994	0.9395	0.3307
	164.1	57.43	587.5	204.8	1.6312	52.4810	0.5709	18.3668	1.1887	0.4160
	196.9	68.56	706.2	245.6	1.9573	62.9708	0.6815	21.9263	1.4263	0.4966

Table 2. Experimental Load Cell Calibration Data and Calculations

Results

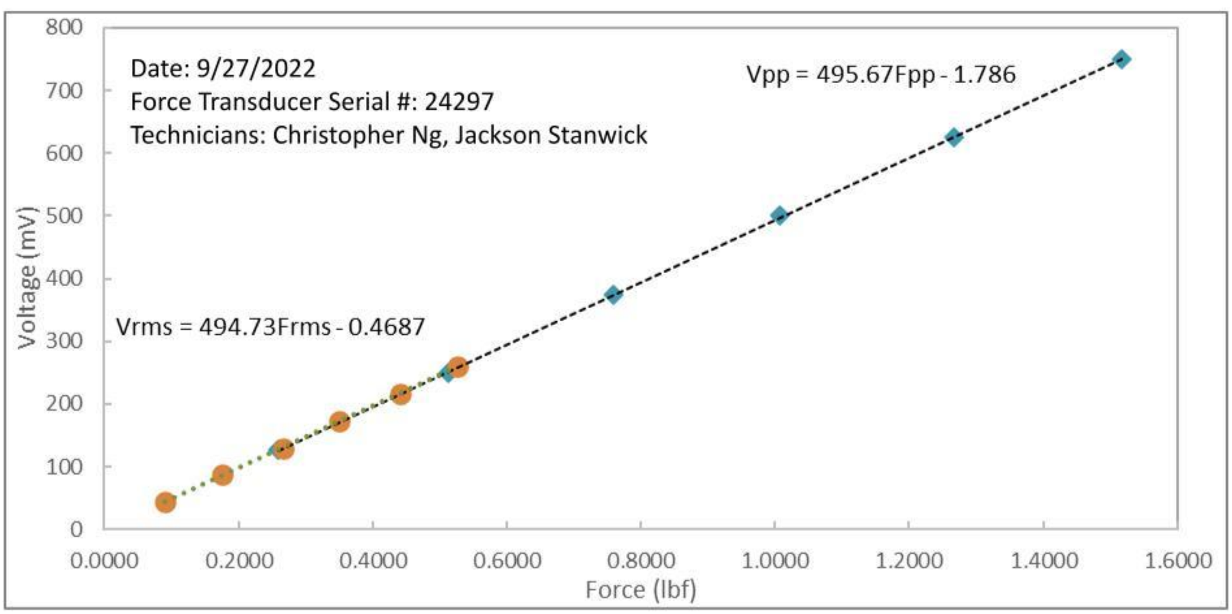

Figure 2. Load Cell Force vs Voltage at 90Hz

With the signal generator set to a 90Hz frequency, we plotted the data from Table 2 using the peak and rms voltage and force values. As seen in Figure 2, the peak and rms data generate almost identical trendlines with slopes of about 495mV/lbf. This slope is the experimental force transducer constant k_{FT} which has 2.36% error from the published value of 483.6mV/lbf (Table 3).

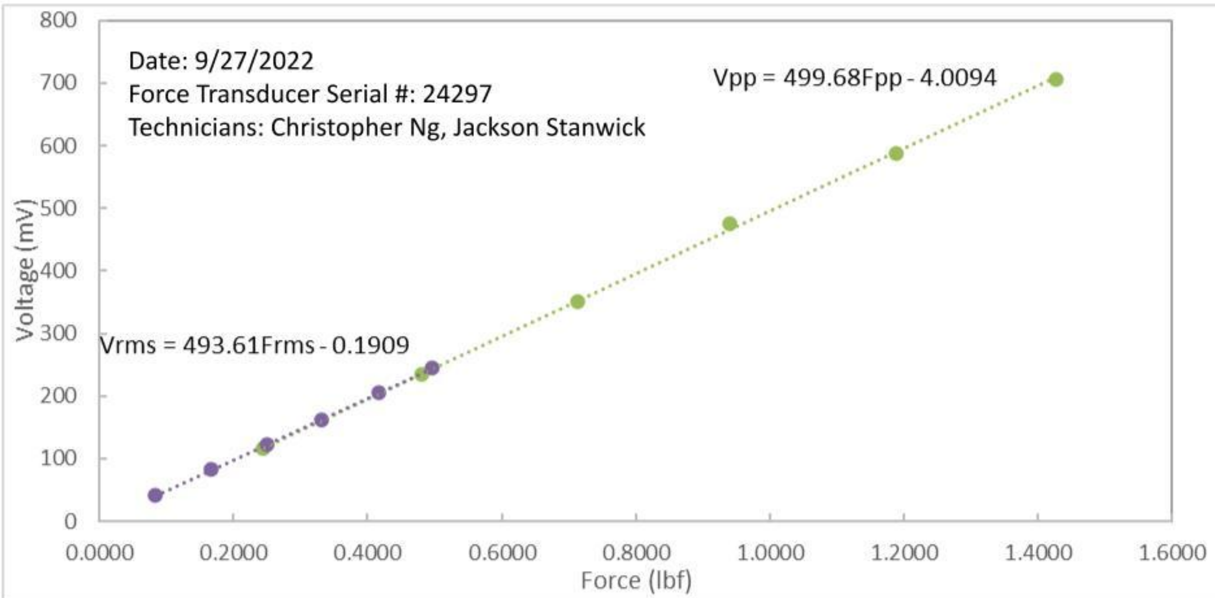

Figure 3. Load Cell Force vs Voltage at 900Hz

For this plot, the signal generator was instead set to a 900Hz frequency with peak and rms voltage and force values plotted from the second half of Table 2. Similar to Figure 2, the peak and rms data on Figure 3 generate relatively close trendlines, but the slopes have more variance from about 500 to 494mV/lbf. This experimental force transducer constant k_{FT} has respective 3.39 and 2.15% errors from the published value of 483.6mV/lbf (Table 3).

Error Analysis

		Plot Slopes (mV/lbf)	Published Value (mV/lbf)	%error (%)
90Hz	O'scope	495.67	483.6	2.4958644
	Voltmeter	494.73	483.6	2.3014888
900Hz	O'scope	499.68	483.6	3.325062
	Voltmeter	493.61	483.6	2.0698925

Table 3. Tabulated %error of Experimental to Published Force Transducer Constants

The error that we calculated from our experimental data's force transducer constants were very minimal, with all of our errors being less than 4% off from the published values (Table 3). Some sources of error likely came from the oscilloscopes resolution and reading limitations, inexact values for constants and masses, and lack of multiple data points for each voltage. When recording values on the oscilloscope, like any device, it has a resolution, but more noticeably, the voltage values would only fluctuate between two or three voltages at odd intervals apart. While we took the most average value, it's unlikely that the oscilloscope could read between the values it showed. Furthermore, we only took one of these voltage values at each 0.5V interval when we could have produced better data from multiple measurements or smaller intervals. Finally, the measurements for masses might not have been accurate since we didn't measure them ourselves, and since we use the accelerometer's constant to calculate the force transducer's constant, we likely incurred statistical error from the published accelerometer's constant along with our own data's error. All this being said, the error that these created were small.

Conclusions

In this experiment, we were able to accurately, to 4% error, reproduce a force transducer's constant through the use of semi-common electrical-mechanical equipment and relationships between different calculated variables. We also gained experience using oscilloscopes and learned the basics of how load cells with force transducers and accelerometers function.