MECH 2502 Final Project Proposal
Winter 2022

Strike Board

GROUP 5

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Summary of Proposed Project

Goal of Proposed Project

The goal of this project is to innovate, develop and calibrate a boxing machine which incorporates the use of resistive force sensors and accelerometers. The resistive force sensors will measure the force applied by the user, converting the signal into a readable value that can be observed from Labview. The accelerometer will then measure the speed and rotation of the strike. Accuracy will also be measured by the arrangement of resistive force sensors which will take the form of a coordinate grid system. A bullseye will be placed on the panel and depending on how far the user punches for the bullseye, it will be able to be measured, as each force sensor will be treated as a single coordinate on the grid.

Rational for the sensor selected as well as an explanation of underlying physics of the proposed sensor

A resistive force sensor is used for measuring any applied force this can be in terms of pressure, weight and squeezing. As shown in figure 1. The resistive force sensor is made up of mainly 2 components separated by a plastic cover/ space. The top component of the sensor is essentially made of semiconductive material and the bottom is a thin film with conductive traces. The more force being applied to the top semiconductive material, causing it to then be pressed on the thin film, will make the resistance decrease. The force sensor will change the resistance depending on how much force is applied, changing in a predictable way [2]. The conclusion can be reached that the resistance decreases as you increase the amount of pressure applied [2]. When the user makes contact with the force sensor it will cause the thin film to be touched by the semiconductor and decrease the resistance.

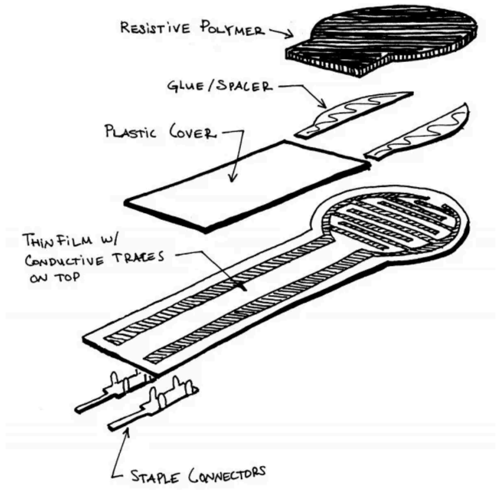


Figure 1. Schematic of resistive force sensor [1]

An accelerometer is used to measure the speed at which the strike is being thrown and wrist rotation. The purpose of this sensor is to determine the person's fitness level when it comes to speed of impact and eye-hand coordination. Not only is the speed of the hand important in the offensive action of boxing, but also the speed of retraction for defensive protection [3]. It will also measure the angle of the natural wrist movement as one throws a punch. The accelerometer is a micro electro-mechanical system (MEMS) that consists of a micro-machines structure on a silicon wafer [4]. The accelerometer has springs inside (Figure 2) that deflect inwards when acceleration is present in the X, Y and Z directions. The deflection causes a change in capacitance in each direction X, Y and Z, and outputs a voltage proportional to the acceleration in that direction [4].

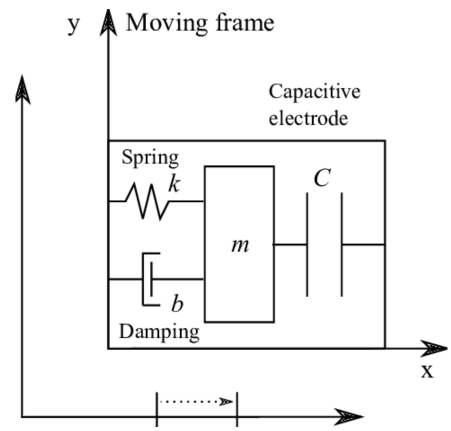
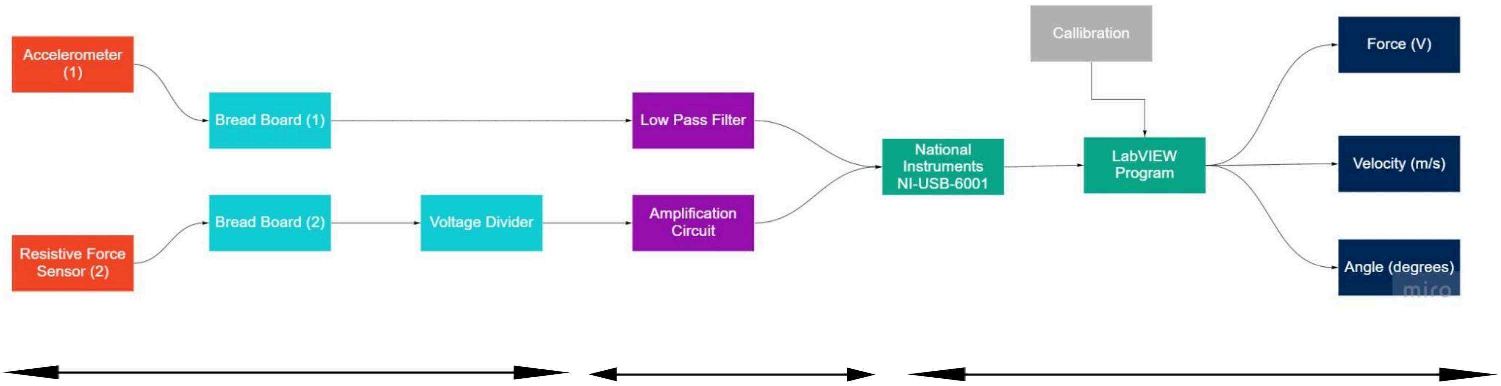


Figure 2. Schematic of Accelerometer [5]

System Design



Sensor/Transducer Stage **Signal Conditioning Stage** **Readout-recording/Output Stage**

Component’s Roles

Accelerometer

➔ The accelerometer will measure the speed, acceleration and rotational speed

Resistive Force Sensor

➔ The resistive force sensor transmits the force the user applies on the board and the closeness to the intended target

Breadboard

➔ The role of the breadboard is to secure proper connections between the accelerometer, resistive force sensor and national instrument; this enables the national instrument to read the data obtained from the accelerometer and force sensor.

Voltage Divider

- ➔ The voltage divider will act as the transducer of the system. The resistive force sensor will output a voltage described by the following equation. This output voltage will increase with increasing force. Then the measuring resistor R_M is chosen to maximize the desired force sensitivity range [6]

$$V_{OUT} = \frac{R_M V+}{(R_M + R_{FSR})}$$

Low Pass Filter

- ➔ The role of the low pass filter is to act as the signal amplification stage of the system. This will be applied to only the accelerometer. While using the accelerometer which will be placed within the boxing glove, the user may be doing additional movement besides the movement of punching the board. In order for the accelerometer to read only the punching movements a low pass filter can be used. This will filter out any other movements then the one required.

Amplification circuit

- ➔ The role of the amplification circuit is to also take part in the signal amplification stage of the system. This will be used for the resistive force sensor. The amplifier will take the small voltage variations from the voltage divider, and amplify them and then send them to the readout/NI-USB-6001 stage

National Instruments NI-USB-6001

- ➔ The NI-USB-6001 is the data acquisition used for this system. The voltage signals from the low-pass filter and the amplifier analog signals are sent to the NI-USB-6001 DAQ where the signal will change to digital and be inputted into LabVIEW to be used.

Calibration

- ➔ Calibration of the accelerometer and force sensor is needed in order to verify the precision and reproducibility of our data

LabVIEW Program

- ➔ The LabVIEW program is the data processing and user interface of our system, this is where our system data is acquired, displayed and accessible to the user in order to keep track of a user's progress or to analyze where and how a user can improve.

Design Specification

Specification of each Component

Our system will consist of a 16 inch by 16 inches soft foam board which can be mounted on various surfaces, this foam board has been supplied by a group member. The surface of our board will be divided into nine 5.33 inches by 5.33 inches squares and each force sensor will be installed in the center of each square evenly spaced to accurately determine the distance from the location force is applied to the intended target. Our system also consists of a pair of gloves equipped with an accelerometer installed at the wrist of the gloves to measure the acceleration and angular movement of the user's wrist. The configuration of the system will follow as shown in Figure 3.

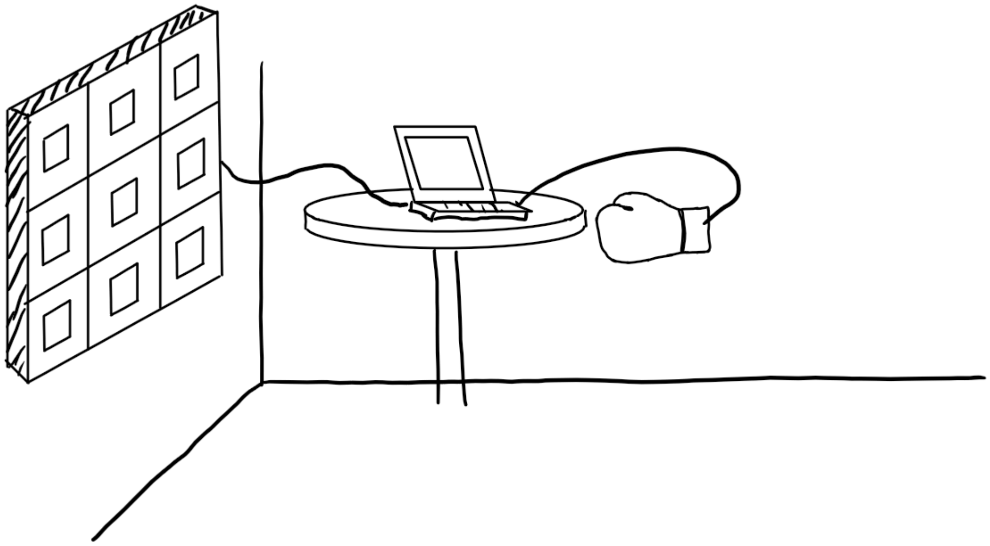


Figure 3. Schematic of configuration of system.

The resistive force sensors (part number 1027-1002-ND) which is abundantly available in the lab will be used. The average punch of an average man is approximately 360-450 lbf. As a result, our force sensors must withstand a maximum of 500 lbf [7]. According to the manufacturer's specification data sheet [6] these force sensors are a size of 38mm by 38mm, the actuation force being approximately 0.2Nmin and the force resolution is continuous (analog). The specific resistive force sensor we are using is made up of robust polymer thick film that executes a decrease in resistance when there is an increase in force.

To complete the transducer stage of the instrumentation design system we have chosen to use a voltage divider. This will be needed for the resistive force sensor, which is tied to a measuring resistor in the voltage divider [6]. These resistive force sensors will allow us to measure the output voltage by dividing smaller sections of the larger voltage. As stated earlier the expected output voltage will follow the following equation

$$V_{OUT} = \frac{R_M V+}{(R_M + R_{FSR})}$$

Although each resistive force sensor is built in with a voltage divider there may be some disadvantages to using this, our goal is to measure the change in resistance for the force sensor. This output will be very small, meaning that the variation in measured voltage is significantly smaller causing some uncertainty ranges. In addition to this the resistance dividers will cause some power to be lost. In order to account for these measures of uncertainty we will use an amplification circuit to account for the smallness of the output voltage.

Anticipating the voltage output will be significantly small to obtain any actual information by the NI-USB-6001 especially since a voltage divider will be used and an amplification circuit will assist in helping the NI-USB-6001 read the measurements from the resistive force sensor. To specify the amplification circuit being used we propose using a non-inverting amplifier

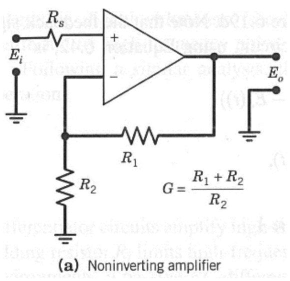


Figure 4. Circuit of noninverting amplifier

The reason for using a non-inverting is because we are outputting high impedance when throwing a punch and will have varying gains, therefore this circuit is needed to amplify these factors.

The filtering device being used will be a low-pass filter which will efficiently pass frequency components lower than a certain cut of frequency. This will work to filter any additional movements that is not the user punching the strike board. When measuring the data from the accelerometer this will output as a graph on labview and applying a low-pass filter will remove any of the signals lower then the cut of frequency which will be when there is a sudden change of movement, being when they punch the board

The accelerometer ADXL326 which we would be using has a range of -16G to 16G in the X, Y and Z axis making it ideal for measuring the angular acceleration of our user wrist, according to the data sheet.

In order to calibrate the accelerometer we need to use gravity as a reference, and determine the sensor output for each axis when it is precisely aligned with the axis of gravitational pull or use precision positioning jigs [4]. The calibration for the force sensor would be to ensure that the sensor is outputting a signal to labview.

Detailed Characteristics of signals

Since we want to obtain the force of each punch from the boxer, a graph of force against time would be suitable for this case. When plotting force against time, if the boxer strikes the board, it will show a result similar to Figure 5 and the peak of the graph will represent the force punched.

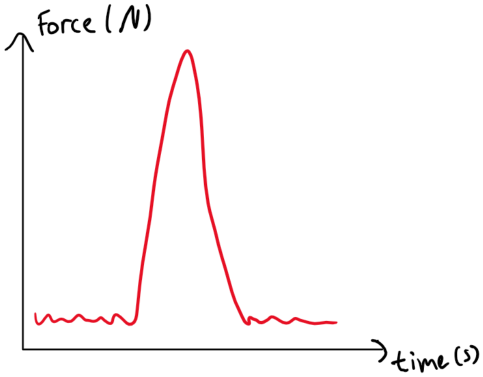


Figure 5. Graph of force vs. time

Figure 6. represents a typical acceleration of a punch where a punch is striked and retracted. When observing the x axis, it is expected for the acceleration to increase and decrease until the punch is in contact with the wall/board. The first will be retracted into the opposite direction and there is a slight jolt before going back to the original position. [3]

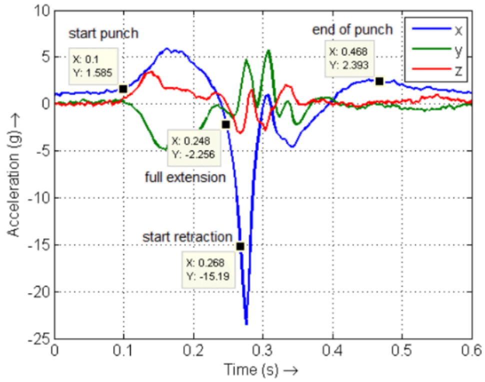


Figure 6.

Measurement Characteristic of the System

Since the system is meant to measure force in volts, velocity in meters per second and angles in degrees.

When measuring the force, the initial output will be in volts. This is done by a force-to-voltage conversion:

$$V_{OUT} = \frac{R_M V+}{(R_M + R_{FSR})}$$

The FSR device is tied to a measuring resistor in a voltage divider (see figure below) and the output is described by the following equation.In the configuration shown, the output voltage increases with increasing force. The measuring resistor, RM, is chosen to maximize the desired force sensitivity range and to limit current. Depending on the impedance requirements of the measuring circuit, the voltage divider could be followed by an op-amp [6].

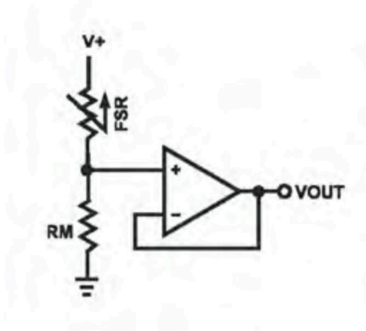


Figure 3. FSR attached to voltage divider and resistor [6]

When measuring the velocity of the accelerometer, we need to convert volts to meters per second squared. We know the sensitivity of this specific accelerometer (ADXL326 3AXIS ACCEL BREAKOUT BRD) being 57 mV/g [8]. Acceleration is measured in units of gravitational force or "G", where 1G represents the gravitational pull at the surface of the earth [4]. With this gravitational force, 1 g is approximately 9.81 m/s^2. Knowing this conversion, we can calculate the velocity of the punch by converting mV to V (divide by 1000) and then multiplying the voltage out by the gravity in meters per second:

$$Vout \times 9.80665\, m/s^2$$

When measuring the wrist rotation, our desired unit is the angle in degrees. Basic trigonometry can be used on the X-axis for example. The projection of the gravity vector on the x-axis produces an output acceleration equal to the sine of the angle between the accelerometer x-axis and the horizon [9]. The horizon is typically taken to be the plane orthogonal to the gravity vector. We can use this formula to convert the acceleration (in m/s^2) to degrees and get the angle of wrist rotation where k is equal to 1 (scaling factor), g is the gravitational force and Ax,out is the acceleration output from the accelerometer sensor.

$$\theta \cong k \times \left(\frac{A_{X,OUT}\,[g]}{1\,g} \right)$$

Figure 7. Formula to measure angle of rotation [9]

Bill of Materials

Part name	Part Number	Quantity	Cost and source
Resistive Force Sensors	1027-1002-ND	9	Available in lab https://www.digikey.ca/en/products/detail/interlink-electronics/30-73258/2476470
Accelerometer	1528-1011-ND	2	Available in lab
National Instruments	NI-USB-6001	1-2	Available in lab
Jumper cable 1	N/A	10-20	Available in lab
Foam board	N/A	1 (16” x 16” x 2”)	Available from group member
Boxing gloves	N/A	2	< $30 Thrift store or Amazon
Breadboard	N/A	2	Available in lab
Long breadboard Cables	N/A	5 (10-15ft)	Approx. $30 unless available in lab https://www.amazon.ca/TUOFENG-Wire-Solid-Different-Colored-spools/dp/B086WF1WD1/ref=asc_df_B086WF1WD1/
Double sided gorilla tape	N/A	1	Approx. $15 https://www.amazon.ca/Indoor-Outdoor-Black-Mounting-Tape/dp/B0833DT387/
Total	N/A		$75

Project Planning and Management

Initiation				
System Design	Project name:	Project Duration (Days)	Start date	End date
System Development	**Strike Board**	57	2/14/2022	4/12/2022
System Presentation				

Task Name	Start Date	End Date	Duration (Days)	Assigned
Brain storming & gain Quansar Aproval	2/14/2022	2/14/2022	1	All Memebers
Solidifying Idea	2/15/2022	2/20/2022	6	All Memebers
Video pitch	2/21/2022	2/23/2022	3	All Memebers
Finalizing the Project idea	2/24/2022	2/27/2022	4	All Memebers
Conceptual Design	2/27/2022	3/1/2022	3	All Memebers
List all the material needed	3/2/2022	3/3/2022	2	All Memebers
Detailed design of the board	3/2/2022	3/7/2022	6	All Memebers
Deatiled design of the gloves and accelerometer	3/2/2022	3/7/2022	6	All Memebers
In-lecture Feedback session on proposal	3/7/2022	3/7/2022	1	All Memebers
Improve and finalise project based on feedback	3/7/2022	3/9/2022	3	All Memebers
Aquire all material needed for the project	3/4/2022	3/14/2022	11	All Memebers
Build the punching board	3/14/2022	3/20/2022	7	All Memebers
Build a VI for the board	3/20/2022	4/2/2022	14	All Memebers
Build the Accelerometer glove	3/14/2022	3/20/2022	7	All Memebers
Build a VI for the accelerometer glove	3/20/2022	4/2/2022	14	All Memebers
System assembly and calibration	4/3/2022	4/8/2022	6	All Memebers
Presentation of the system in a conference	4/9/2022	4/10/2022	2	All Memebers
Prepare and submit final group report through moodle	4/11/2022	4/12/2022	2	All Memebers
Submit peer evaluation of group members' performance	4/11/2022	4/12/2022	2	All Memebers

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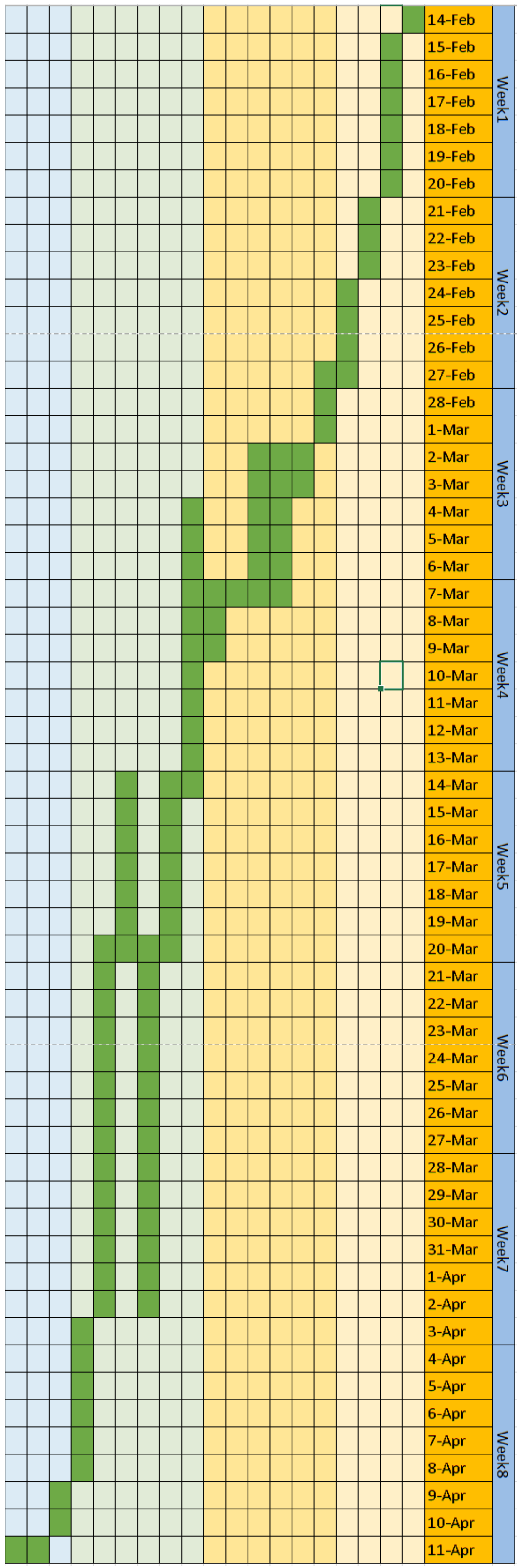
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Appendix

Resistive Force Sensor

Device Characteristics	
Actuation Force*	~0.2N min
Force Sensitivity Range*	~0.2N – 20N
Force Resolution	Continuous (analog)
Force Repeatability Single Part	+/- 2%
Force Repeatability Part to Part	+/- 6% (Single Batch)
Non-Actuated Resistance	>10 Mohms
Hysteresis	+10% Average (RF+ - RF-)/RF+
Device Rise Time	< 3 Microseconds
Long Term Drift 1kg load, 35 days	< 5% log10(time)
Operating Temperature Performance Cold: -40ºC after 1 hour Hot: +85ºC after 1 hour Hot Humid: +85ºC 95RH after 1 hour	 -5% average resistance change -15% average resistance change +10% average resistance change
Storage Temperature Performance Cold: -25ºC after 120 hours Hot: +85ºC after 120 hours Hot Humid: +85ºC 95RH after 240 hours	 -10% average resistance change -%5 average resistance change +30% average resistance change
Tap Durability Tested to 10 Million actuations, 1kg, 4Hz	-10% average resistance change
Standing Load Durability 2.5kg for 24 hours	-5% average resistance change
EMI	Generates no EMI
ESD	Not ESD Sensitive
UL	All materials UL grade 94 V-1 or better
RoHS	Compliant

Accelerometer

Ratiometric Output

For the ADXL335, that is approximately 0v at -3G to 3.3v at +3G.
For the ADXL326, that is approximately 0v at -16G to 3.3v at +16G.
For the ADXL377, that is approximately 0v at -200G to 3.3v at +200G.
For all modules, the output at 0G in each axis, is about 1/2 full-scale, or 1.65v.

Calibration Sketch Output:

Raw Ranges: X: 408-616, Y: 398-610, Z: 422-625 511, 511, 625 :: -0.01G, 0.07G, 1.00G Raw Ranges: X: 408-616, Y: 398-610, Z: 422-625 511, 511, 625 :: -0.01G, 0.07G, 1.00G Raw Ranges: X: 408-616, Y: 398-610, Z: 422-625 511, 511, 625 :: -0.01G, 0.07G, 1.00G Raw Ranges: X: 408-616, Y: 398-610, Z: 422-625 511, 511, 625 :: -0.01G, 0.07G, 1.00G Raw Ranges: X: 408-616, Y: 398-610, Z: 422-625

Amplifier

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	LM2900	LM3900	UNIT
Supply voltage, V_{CC} (see Note 1)	36	36	V
Input current	20	20	mA
Duration of output short circuit (one amplifier) to ground at (or below) 25°C free-air temperature (see Note 2)	unlimited	unlimited	
Continuous total dissipation	See Dissipation Rating Table		
Operating free-air temperature range	−40 to 85	0 to 70	°C
Storage temperature range	−65 to 150	−65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260	260	°C

recommended operating conditions

	LM2900		LM3900		UNIT
	MIN	MAX	MIN	MAX	
Supply voltage, V_{CC} (single supply)	4.5	32	4.5	32	V
Supply voltage, V_{CC+} (dual supply)	2.2	16	2.2	16	V
Supply voltage, V_{CC-} (dual supply)	−2.2	−16	−2.2	−16	V
Input current (see Note 3)		−1		−1	mA
Operating free-air temperature, T_A	−40	85	0	70	°C

NI-USB-6001

Input range..±10 V

Working voltage...±10 V

Overvoltage protection

Powered-on...±30 V

Powered-off..±20 V

Input impedance...>1 GΩ

Input bias current..±200 pA

Absolute accuracy

Typical at full scale....................................6 mV

Maximum over temperature, full scale.....................26 mV

System noise...0.7 mVrms

DNL...14-bit, no missing codes

INL...±0.5 LSB

CMRR..56 dB (DC to 5 kHz)

Bandwidth...300 kHz

Analog outputs...2

DAC resolution...14-bit

Output range..±10 V

Maximum update rate...5 kS/s simultaneous per channel, hardware-timed

AO FIFO...2,047 samples

Trigger sources...Software, PFI 0, PFI 1

Output current drive...±5 mA

Short circuit current...±11 mA

Slew rate...3 V/µs

Output impedance...0.2 Ω

Absolute accuracy (no load)

Typical at full scale....................................9.1 mV

Maximum over temperature, full scale.......34 mV

DNL...14-bit, no missing codes

INL...±1 LSB

Power-on state...0 V

Startup glitch..-7 V for 10 µs

References

[1] https://makezine.com/2011/09/21/force-sensitive-resistors-how-do-they-work/

[2] https://learn.adafruit.com/force-sensitive-resistor-fsr

[3] https://www.researchgate.net/publication/282553007_Hand_Speed_Measurements_in_Boxing#pf2

[4] https://cdn-learn.adafruit.com/downloads/pdf/adafruit-analog-accelerometer-breakouts.pdf#page4

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[6] https://cdn2.hubspot.net/hubfs/3899023/Interlinkelectronics%20November2017/Docs/Datasheet_FSR.pdf

[7] https://wayofmartialarts.com/average-force-of-a-punch/#:~:text=The%20average%20human%20punch%20generates,both%20sides%3B%20lower%20and%20higher.

[8] https://www.digikey.ca/en/products/detail/adafruit-industries-llc/1018/4990760

[9] https://www.analog.com/en/app-notes/an-1057.html