FLEXIFORCE™ OEM DEVELOPMENT PRODUCTS

Version 1.0 (Rev B)

Tekscan

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WELCOME

ISO

Tekscan, Inc. commits to establishing and maintaining a quality system that meets or exceeds the requirements of ISO 13485 (2016) and applicable regulatory requirements for its medical products. Tekscan remains committed to administering a quality system that is structured around the requirements of ISO 9001 (2008) and applicable regulatory requirements for all other products.

Introduction

The FlexiForce Sensor Characterization Kit lets you measure and record force data collected using the Tekscan FlexiForce™ Sensors. It provides designers the software, hardware, and electronics that streamline mechanical load control, circuit selection, and calibration, all from one easy to use software interface. A thorough understanding of fundamental sensor performance in a known loading environment is essential for quantifying sensor configurations in prototypes and final embedded designs. Using a comprehensive characterization kit, you can establish a baseline sensor performance profile, reduce your design time, and gain an understanding of the technology needed to move forward with the design confidently in your prototype.

The assembled Desktop Loading Fixture, made up of a Load Cell, Actuator, Circuit Board, and FlexiForce Sensors, allows the user to run preprogrammed load profiles to characterize the Linearity, Hysteresis, Drift, and Repeatability of the sensors. Custom load profiles can also be user programmed via the open source software, and a manual control mode is available.

FlexiForce Sensor Characterization Kit features include:

1. Open-source software interface that allows users to control loading, record sensor data, adjust sensitivity and calibrate the sensor.
2. Three analog Circuit Modules (inverting op-amp, non-inverting op-amp, and voltage divider) with which users can test and characterize the functionality of each circuit.
3. A desktop Loading Fixture allows users to apply controlled loading profiles to the sensor and characterize sensor performance.

In addition, if the user is comfortable with DSP coding, they can adjust the code of the Arduino Nano chip that controls the Desktop Loader to their application and testing needs.

Warranty

Tekscan, Inc.
Limited 1-Year Warranty

1. **WARRANTY.** Tekscan, Inc. warrants to the original purchaser of this product that should it prove defective by reason of improper workmanship and/or materials:

   A. Tekscan Systems and Components:
   For one year from the date of original purchase at retail, Tekscan will repair or replace, at our option, any defective part without charge for the part or labor if an inspection proves the claim. Parts used for replacement may be used or rebuilt, and are warranted for the remainder of the original warranty period.

   B. Tekscan Sensors:
   Tekscan will replace any Tekscan Sensor which fails due to manufacturing defect if an inspection proves the claim. Claims must be made within 30 days of purchase.

2. TO OBTAIN WARRANTY SERVICE, call Tekscan at 1-800-248-3669, (617) 464-4500 in MA, for further instructions. Should you be asked to deliver your product to Tekscan, Inc. in Boston, MA, shipping expenses are the purchaser's responsibility. Proof of purchase is required when requesting warranty service.

3. THIS WARRANTY DOES NOT COVER defects caused by modification, alteration, repair or service of the enclosed product by anyone other then Tekscan or an authorized Tekscan service center, physical abuse to, misuse of, the product or operation thereof in a manner contrary to the accompanying instructions, or shipment of the product to Tekscan or an authorized Tekscan service center for service. This warranty also excludes all costs arising from installation, cleaning or adjustments of user controls. Consult the operating manual for information regarding user controls.

4. ANY EXPRESS WARRANTY NOT PROVIDED HEREIN, AND ANY REMEDY FOR BREACH OF CONTRACT WHICH, BUT FOR THIS PROVISION MIGHT ARISE BY IMPLICATION OR OPERATION OF LAW, IS HEREBY EXCLUDED AND DISCLAIMED. THE IMPLIED WARRANTIES FOR THE MERCHANTABILITY AND OF FITNESS FOR ANY PARTICULAR PURPOSE ARE EXPRESSLY LIMITED TO A TERM OF ONE YEAR. SOME STATES DO NOT ALLOW LIMITATIONS ON HOW LONG AN IMPLIED WARRANTY LASTS, SO THAT THE ABOVE LIMITATION OR EXCLUSION MAY NOT APLY TO YOU. THE WARRANTIES SET FORTH HEREIN ARE IN LIEU OF ANY AND ALL OTHER WARRANTIES EXPRESS OR IMPLIED INCLUDING THE WARRANTY OF MERCHANTABILITY AND FITNESS. THE BUYER ACKNOWLEDGES THAT NO OTHER REPRESENTIONS WERE MADE TO HIM OR RELIED UPON BY HIM WITH RESPECT TO THE QUALITY AND FUNCTION OF THE GOODS SOLD HEREIN. NO PERSON, FIRM OR CORPORATION IS AUTHORIZED TO ASSUME FOR US ANY LIABILITY IN CONNECTION WITH THE SALE OF THESE GOODS.

5. UNDER NO CIRCUMSTANCES shall Tekscan, Inc. be liable to purchaser or any other person for any special or consequential damages, whether arising out of breach of warranty, breach of contract, or otherwise. Some states do not allow the exclusion or limitation of incidental or consequential damages, so that the above limitation or exclusion may not apply to you.

08/11/03 – FORM-200-057-B

Safety

1. The use of accessories and cables other than those specified by the manufacturer as replacement parts may result in increased emissions or decreased immunity of the equipment or system.
2. Only use Tekscan supplied power sources to avoid damaging the system.
3. Do not use or attach any components that are not explicitly stated within this manual.
4. Do not connect any additional multiple portable socket outlet(s) or extension cord(s) to the system.
5. EMC (Electro-Magnetic Charge) can interfere with the system. If this occurs, or if there is a high level of noise on your display screen, try moving to a location that is not in proximity to other electrical devices (such as Televisions, radios, and cell phones).
6. ESD (Electro-Static Discharge) can halt the system. If the system stops functioning, shut down the system by removing the power cable from the fixture board and the other end from the wall socket. Shut down the software. Plug the power adapter back into the wall socket. and place the other end back into the Fixture Board's Power Input. Restart the software. If problem persists, make sure the humidity in the room is >30%. If you are still having difficulty in operating the system, contact your local Tekscan representative.
7. Dispose of applied parts in accordance with Federal and State guidelines pertaining to computer equipment.
8. Sensor Replacement/Disposal: Dispose of sensors in any waste container. Sensors are not biohazardous waste.
9. Protection against electric shock: Internally powered equipment.
10. If using parts other than those explicitly stated within this manual, always follow the manufacturer's cleaning instructions.
11. No user-serviceable parts. Do not try to service or take apart any Tekscan hardware. Consult with your Tekscan representative if a component is not working correctly, or is not working as it should.

FLEXIFORCE SENSOR CHARACTERIZATION KIT

Hardware

Components List

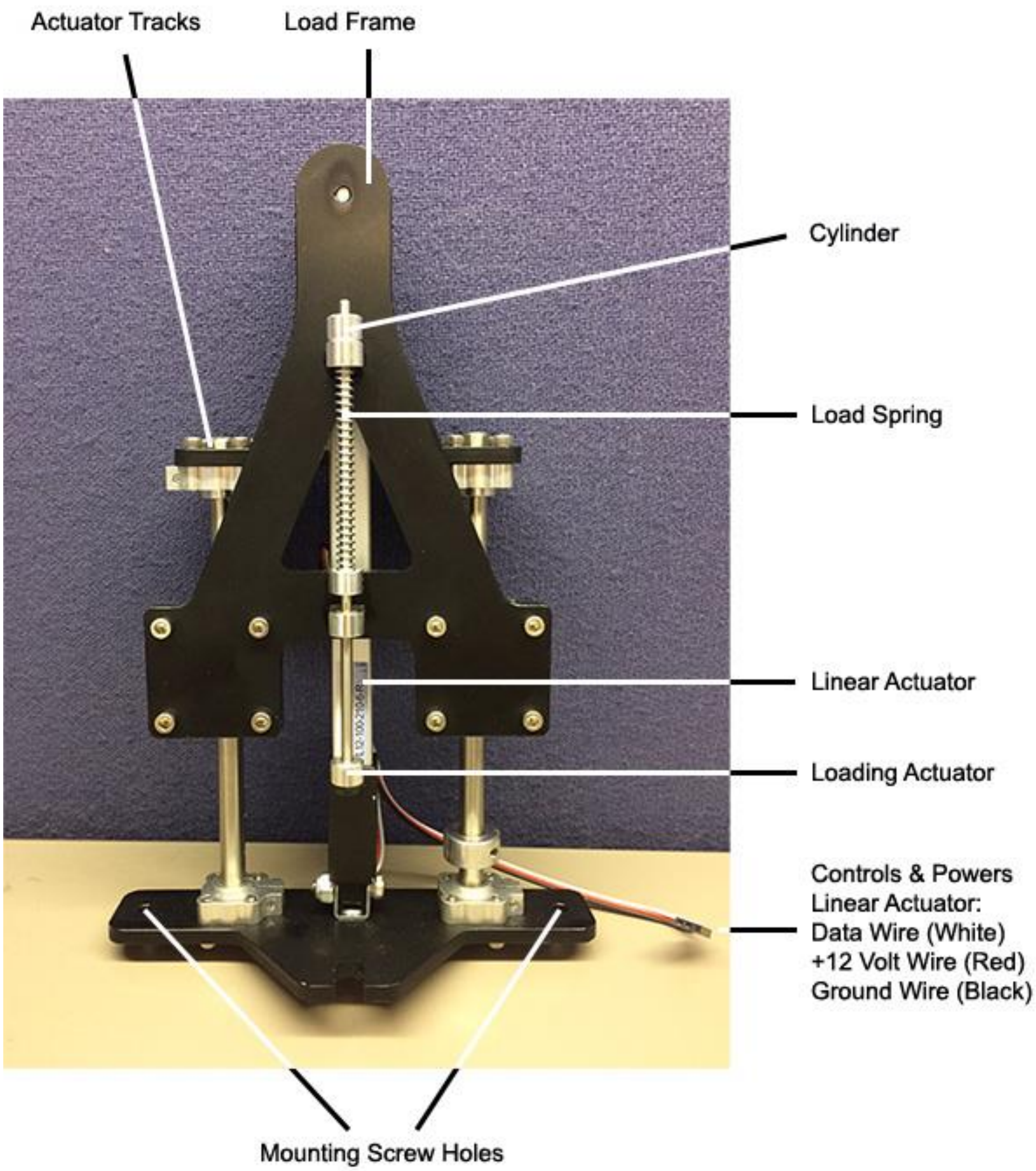
The FlexiForce Sensor Characterization Kit ships with the following components:

- (1) Desktop Load Fixture (1lb or 10lb)
  - (1) Linear Actuator* / Frame Sub Assembly with Cylinder, Load Spring, and Loading Actuator.
  - (1) Fixture Board / Base Sub-Assembly, with Arduino Nano Chip** / USB Connector, Load Cell (1lb or 10lb), Power Input, Actuator Power & Controls, Circuit Module Slots, Module Selection Buttons, Reference Voltage Display, Reference Voltage Increase / Decrease buttons, Test LED lights, and Test Selection / Run buttons, and universal power supply with interchangeable blades.
  - (2) Mounting Screws (used to attach the Linear Actuator / Frame Sub-Assembly to the Fixture Board / Base Sub-Assembly)
- (3) Interchangeable Testing Modules: Voltage Divider, Non-Inverting Op-Amp, and Inverting Op-Amp
- (4) FlexiForce Sensors (either A301-1 with 1lb load fixture, or A301-25 with 10lb load fixture)
- (1) 3-Foot USB Extension Cable
- Software Files (web download at https://www.tekscan.com/fir):
  - **FlexiForceCharKit.ino:** Arduino code for pre-programmed linearity, hysteresis, drift and repeatability load profiles (this also the default code pre-loaded on the unit). All functionality described in this document (with the exception of the “Software Setup” and “Manual Control” sections apply to this default code pre-loaded onto the PCB.
  - **FlexiForceCharKitManCont.ino:** Arduino code for manual control of the loading fixture (Refer to Manual Control section of this document for information on how manual control operates).
  - **Arduino Programming Environment download utility:** For modifying and/or uploading Arduino code to fixture PCB.
  - **(3) Arduino Libraries:** Arduino library files called by the **FlexiForceCharKit.ino** and **FlexiForceCharKitManCont.ino** code.
  - **FlexiForceCharData.xlsm:** Excel macro spreadsheet for recording sensor data
  - **Readme.txt:** Text file with information on how to use each file and where the libraries should be saved.

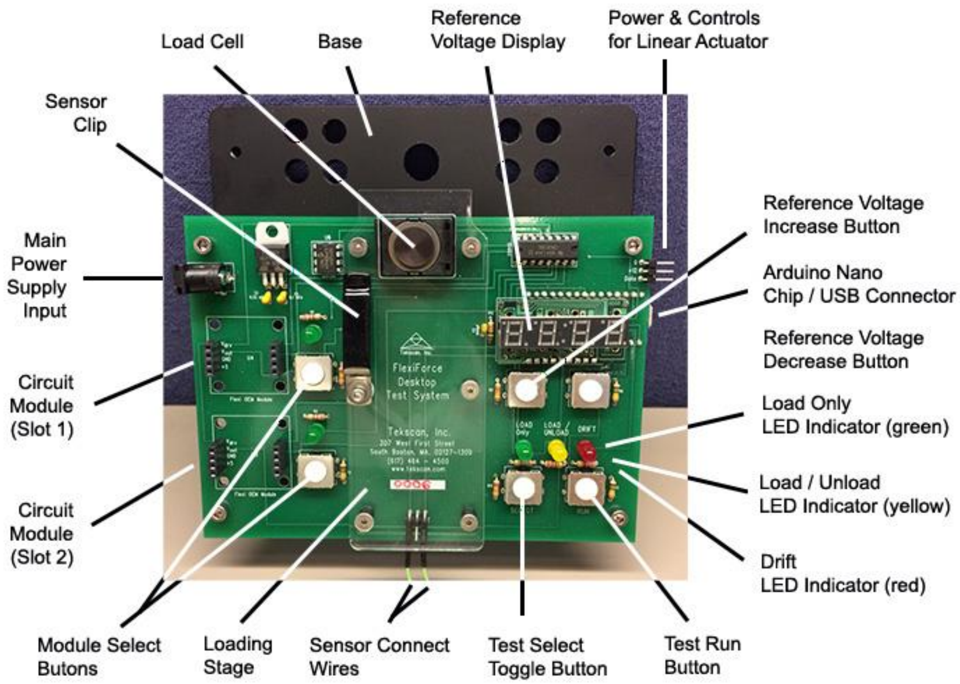
** Linear Actuator datasheet: https://s3.amazonaws.com/actuonix/Actuonix+L12+Datasheet.pdf*

*** Arduino Nano Chip datasheet: https://www.arduino.cc/en/uploads/Main/ArduinoNanoManual23.pdf*

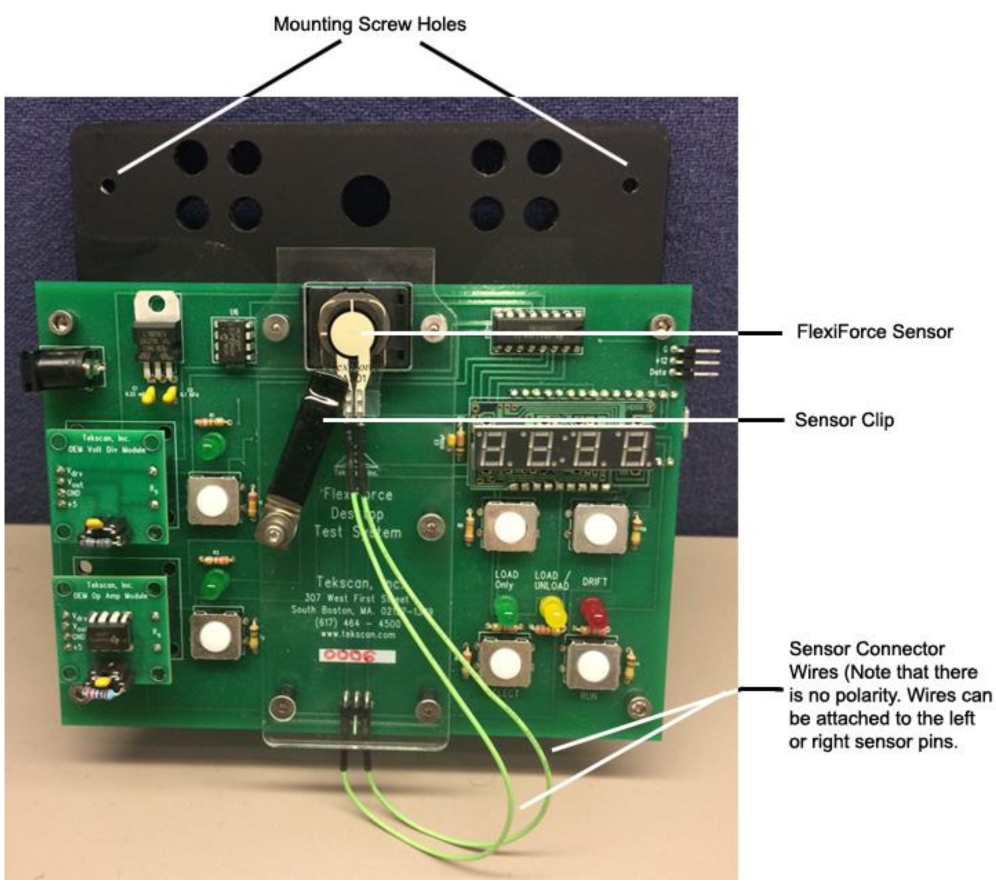
Actuator Assembly



Desktop Loader Baseplate/Circuit Board Assembly

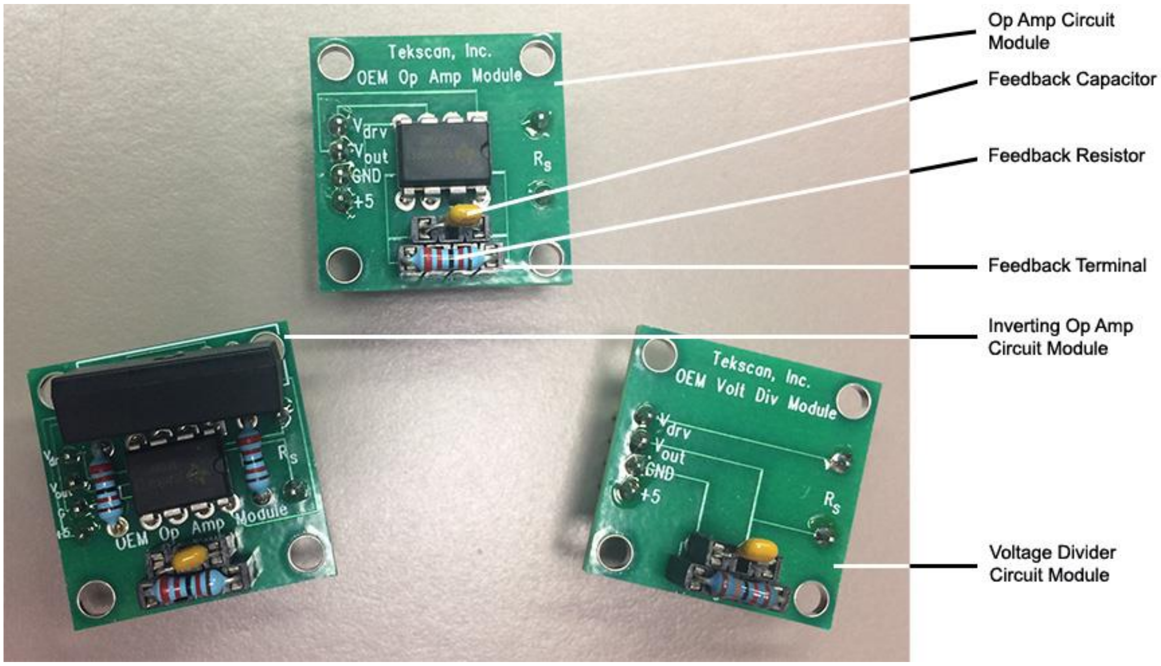


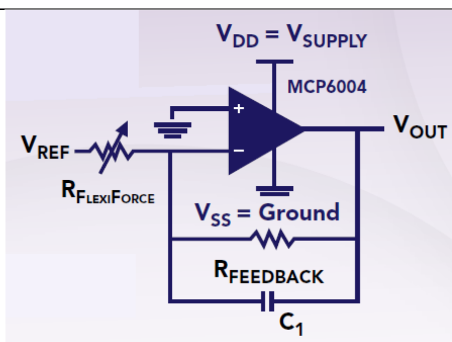
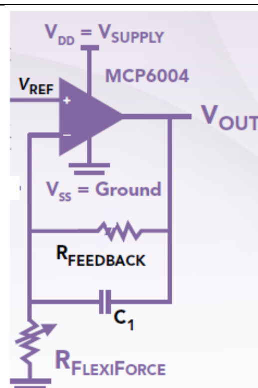
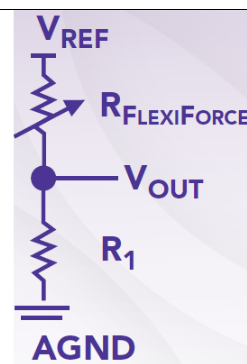
Note: These are the default button functions in the default program pre-loaded on the PCB (FlexiForceCharKit.ino)



Analog Circuit Modules

Three Analog Circuit Modules ship with the system: 1. Op Amp circuit module, 2. Inverting Op Amp circuit module, and 3. Voltage Divider circuit module. The Op-Amp Modules have a feedback capacitor and feedback resistor. The feedback resistors and capacitors can be changed if other resistor values are desired. The Voltage Divider Module has an in-line resistor included. The in-line resistor can be changed if other resistor values are desired. These are outlined below.

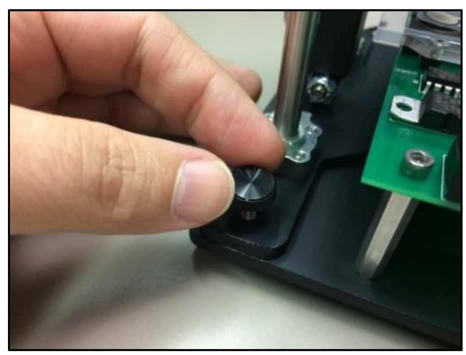


		
Inverting Op-amp Module	***Non-inverting Op-amp Module***	***Voltage Divider Module***
V_{DD} = 5 VDC V_{REF} = -5 – 0 V (adjustable), reference voltage pulsed via square wave at 20Hz, 20% duty cycle $R_{feedback}$ = 22 kΩ C_1 = 1000 pF	V_{DD} = 5 VDC V_{REF} = 0-5 V (adjustable), reference voltage pulsed via square wave at 20Hz, 20% duty cycle $R_{feedback}$ = 22 kΩ C_1 = 1000 pF	V_{REF} = 0-5 V (adjustable), reference voltage pulsed via square wave at 20Hz, 20% duty cycle R_1 = 120 kΩ Note: $R_{FEEDBACK}$, C_1, and R_1 in each circuit may be changed for other resistor/capacitor values if desired.

Specifications

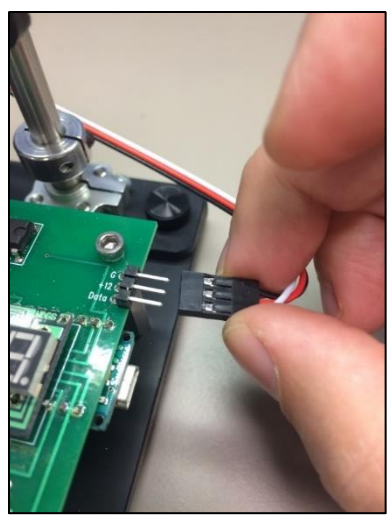
DESKTOP LOADER	
SIZE LxWxH in (mm)	6.00 x 6.00 x 9.14 (152 x 152 x 232)
WEIGHT lb (g)	2.14 (975)
APPLICABLE LOAD RANGE lb (g)	0-10 (0-4530)
POWER SUPPLY	
SIZE LxWxH in (mm)	3.30 x 1.85 x 1.50 (84 x 47 x 38)
WEIGHT lb (g)	0.24 (110)
POWER IN	100-240 VAC, 450mA max 50-60Hz
POWER OUT	7.5 VDC, 1.3A Max
DC CABLE LENGTH ft (mm)	4.9 (1500)
DC PLUG SIZE LxWxH mm	2.5mm x 5.5mm x 9.5mm
AC RECEPTACLE	Interchangeable Blades
USB CABLE	[USB-A to USB mini-B]
LENGTH ft (mm)	6.5 (2000)
WEIGHT lb (g)	0.11 (50)
AMBIENT OPERATING CONDITIONS	
RECOMMENDED TEMPERATURE RANGE °F (°C)	50-95 (10-35)

Hardware Assembly



When you receive your FlexiForce Sensor Characterization Kit, some assembly is required. Follow the instructions below.

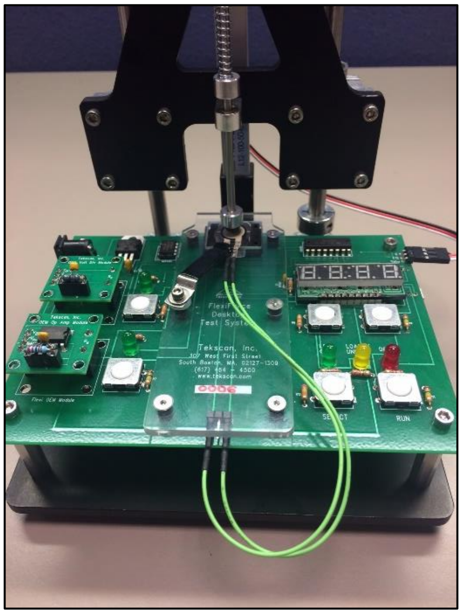
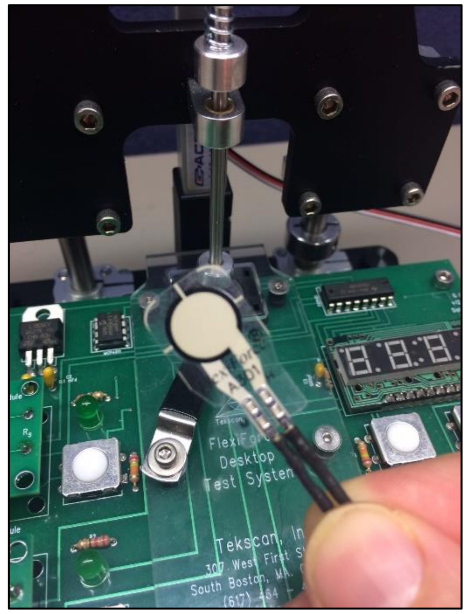
1. Place the “Linear Actuator / Frame Sub-Assembly” on top of, and at the back of, the “Fixture Board / Base Sub-Assembly,” so that the mounting screw holes line up. Then hand screw in the two screws so that both Sub-Assemblies are firmly affixed to each other.



2. Connect the Controls and Power for the Linear Actuator on the right side of the Fixture Board, just above the Arduino Nano chip / USB connector. Note that the black ground connector wire plugs into the “G” slot (top), the red +12 volt connector wire plugs into the “+12” slot (middle), and the white data connector wire plugs into the “Data” slot (bottom).

3. Attach the sensor connector wires to the sensor pins. Place the FlexiForce A301 Sensor underneath the sensor clip, so the sensing region is in position on top of the Load Cell and beneath the Loading Actuator.

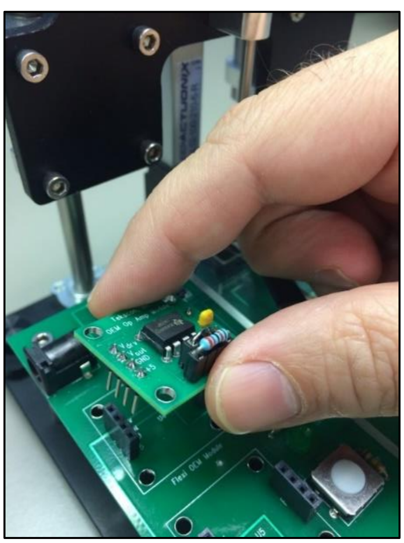
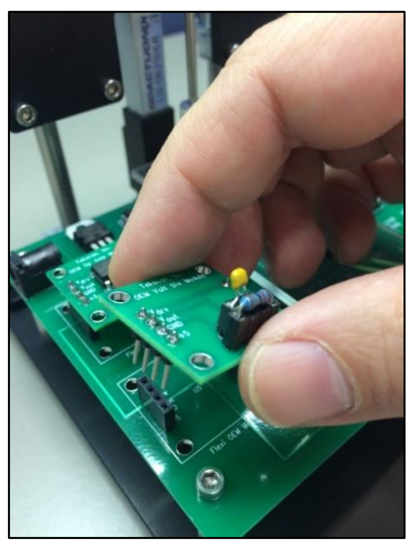
Note: There is no polarity associated with the wires. The left or right wire can be attached to the left or right sensor pin.

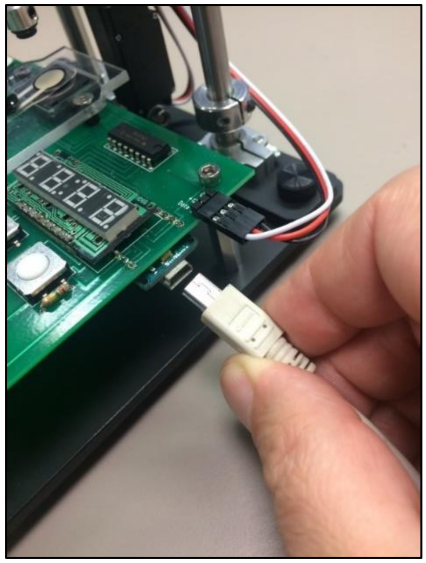
Note: If you are attaching a 3-pin sensor, such as the FlexiForce A201 Sensor, attach the Sensor Connector Wires to the two outermost Sensor pins, avoiding the middle pin (shown at right).

4. The three Op-Amps are interchangeable; however, only two modules can be inserted at any time. Insert the two modules with which you wish to test the sensor. The three modules are: 1. Voltage Divider 2. Non-Inverting Op-Amp, and 3. Inverting Op-Amp.

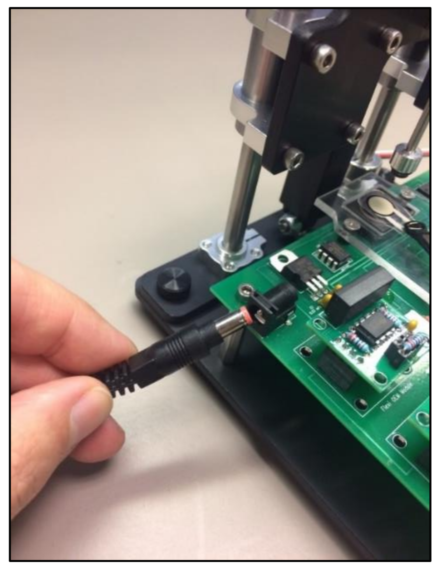
   Insert the first Circuit Module into Circuit Module Slot 1, ensuring the Voltage Drive (Vdrv) pin is at the top and the +5 Volts (+5) pin is at the bottom. Then do the same for the second Circuit Module, installing it into Circuit Module Slot 2 (shown below).

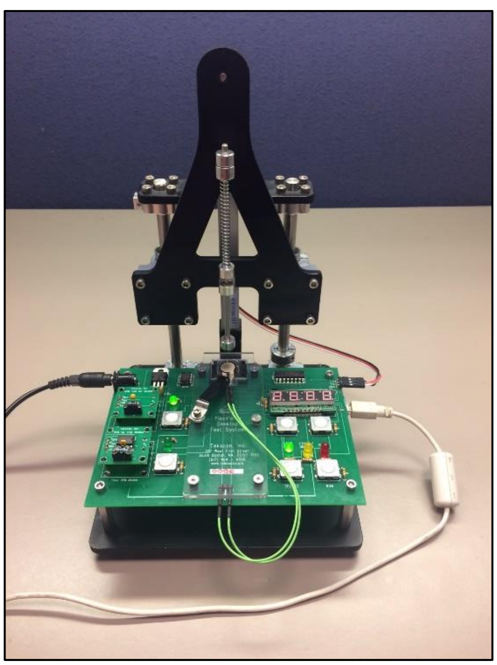
5. Plug the mini USB connector from the Arduino Nano chip into an open USB slot on your Computer.



6. Connect the Main Power Supply to a wall socket, and connect the other end to the Power Input on the Fixture Board's left side. The Red Test LEDs will light up in sequence from right to left (red, then yellow, then green), and then both the top Module Slot 1 and Load Test LEDs will light green and stay lit. At the same time that both these LEDs light up, the Reference Voltage Display will light red.



The fully assembled and powered Desktop Load Fixture (below):



Disconnecting the Power Supply

Remove the main power supply from the wall socket, and then remove the other end of the power cable from the Fixture Board's power input. There is nothing driven by the design that will make it difficult for the operator to unplug the wall adapters from the mains.

Maintenance and Care Instructions

- The FlexiForce Sensor Characterization Kit components cannot be autoclaved.

- Do not let any liquid spill onto the components. If this occurs, the components can stop working and must be allowed to dry for 24 hours. You can use your air syringe, however, to significantly reduce this drying time. Do not attempt to dry out the components using any other method, or you may destroy the delicate electronics.

- To properly clean the device, wipe down the non-electrical components with a 70% Isopropyl Alcohol solution. To do this, slightly dampen a cloth with the alcohol solution, careful not to soak or saturate the cloth. Then wipe the non-electrical parts.

Software

Software Setup

If using the system with the pre-loaded Arduino code (**FlexiForeceCharkit.ino**), go to the Data Capture and Performing a Test sections.

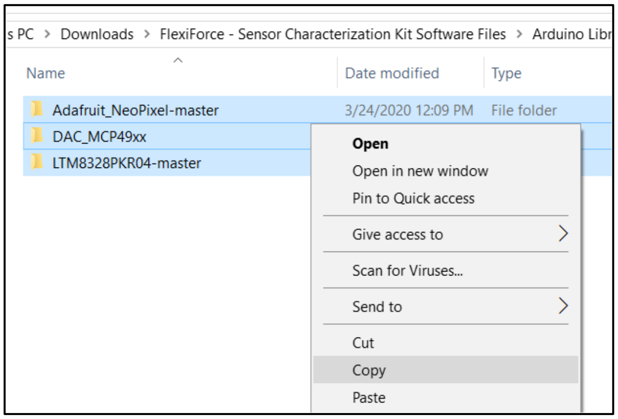
If, on the other hand, you wish to modify the Arduino code or switch to manual control of the fixture (**FlexiForceCharKitManCont.ino**), follow the instructions below

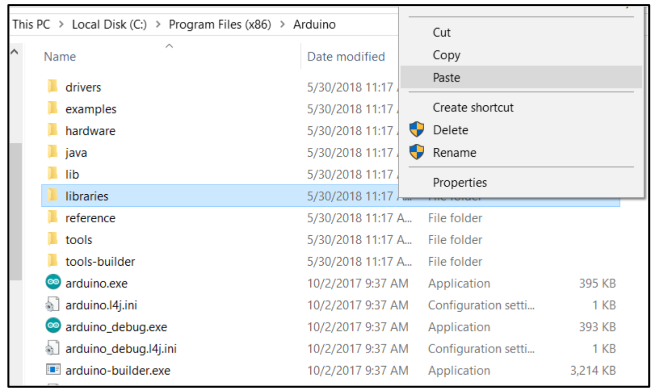
1. Go to www.tekscan.com/fir and download the software files (**.zip** package) for the FlexiForce Sensor Characterization Kit.

2. Run the **Arduino Programming Environment** download (**.exe**). This will install the Arduino Programming environment onto your computer

   Note: Windows download utility is included in this file. For Mac or Linux download, go to https://www.arduino.cc/en/Main/Software to download the applicable programming environment.

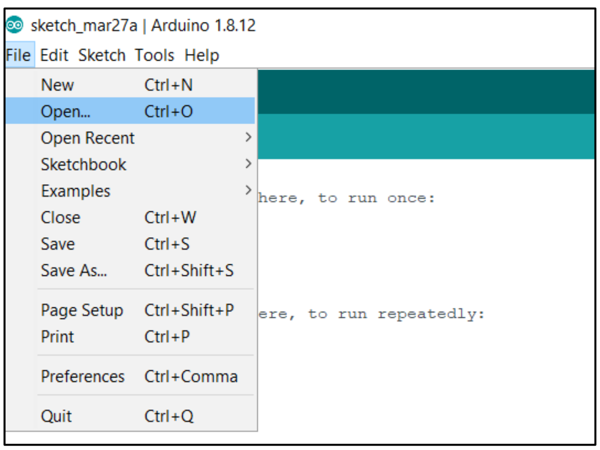
3. Open the file location of the installed Arduino programming environment and copy all folders in the "Arduino Libraries" folder over to the "Libraries" folder in the Arduino file location. On a windows computer this can be found at **C:\Program Files (x86)\Arduino**.

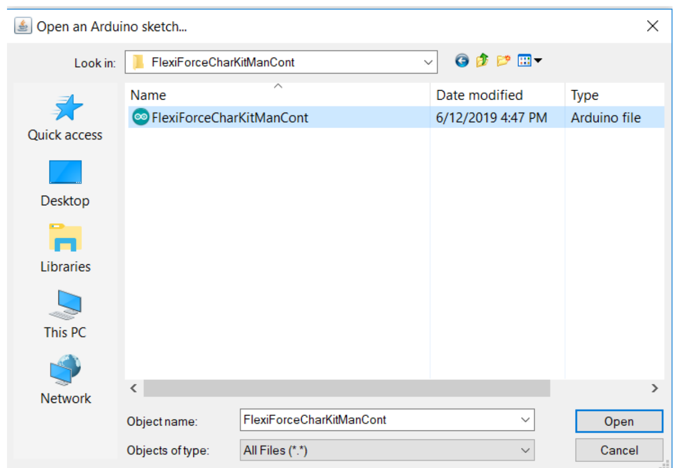




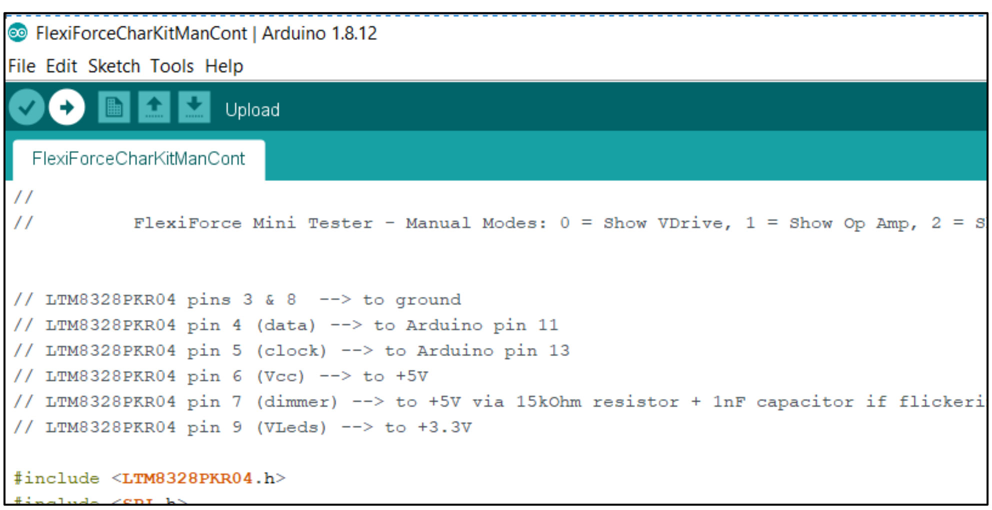
4. Open the **Arduino IDE** programming software.

5. If you wish to switch from the default code supplied with the fixture to manual control, click **File > Open**, and select **FlexiForceCharKitManCont.ino**.





6. Click the **Upload** button on the top toolbar of the **Arduino IDE** programming environment. The LEDs on the PCB will flash, and the bottom status bar of the Arduino programming environment will alert you when the upload is complete.



Note: You may be prompted to confirm the COM port the device is on. This is found in your computer's "Device Manager." When found, input the correct COM port number into the dialog box.

7. If you wish to modify the supplied code, click **File > Open** and select the **.ino** file you wish to modify. Once you have modified the code, save it, and then repeat step 6 to upload it to the Arduino Nano Chip on the PCB.

Data Capture

Analog Circuit Module Selection

Two Circuit Modules can be inserted into the two Circuit Module Slots. See Hardware Assembly for instructions on installing the Circuit Modules.

Once the Circuit Modules are in place, and the system is powered up, you can select which module to use for the Sensor In-Circuit Property Tests. Press the button to the right of the Module Slot. The green LED will illuminate, indicating the selected module slot.

Circuit Module Slot 1 (top) selected

Circuit Module Slot 2 (bottom) selected

Sensor In-Circuit Property Tests

You can perform four distinct tests to measure the Sensor's in-circuit properties. With three different circuit modules, 12 test variants can be achieved. The following outlines these four Sensor property tests:

Note: The "Select" button is a cycle button, which cycles through all four of the following test selections:

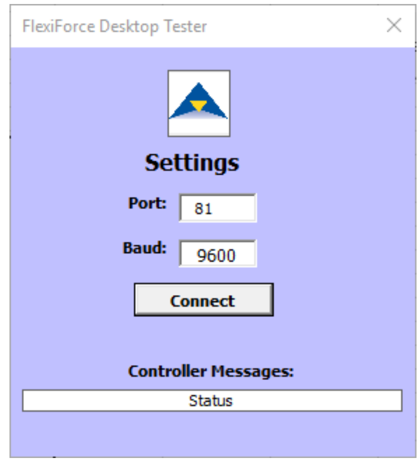
1. **Linearity test**
   Select Button: Green “Load Only” LED light on. All other test LED lights off.
   Load Profile: 5 steps up @ 20% / 40% / 60% / 80% / 100% of load.

2. **Linearity and Hysteresis test**
   Select Button: Yellow “Load / Unload” LED light on. All other test LED lights off.
   Load Profile: 5 steps up @ 20% / 40% / 60% / 80% / 100% of load, then 4 steps down @ 80% / 60% / 40% / 20% of load.

3. **Drift test**
   Select Button: Red “Drift” LED light on. All other test LED lights off.
   Load Profile: Static 50% of load for a duration of 60 seconds.

4. **Repeatability Test**
   Select Button: Green “Load Only” and Red “Drift” LED lights on. Yellow “Load / Unload” LED light off.
   Load Profile: Runs the “Linearity and Hysteresis” test for a consecutive number of iterations specified by the user.

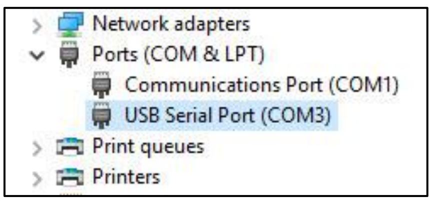
Performing a Test

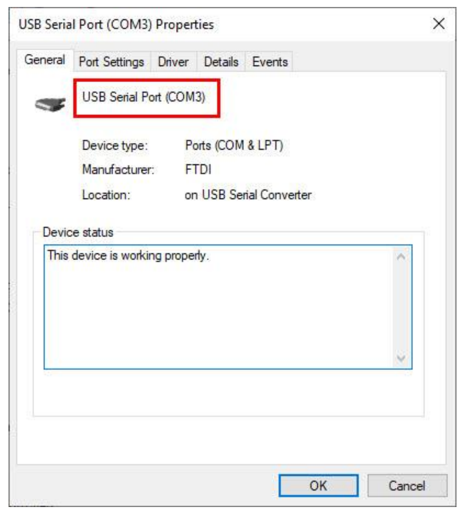


To perform a test, ensure the sensor is placed under the Sensor Clip. The Sensor's sensing area should be placed on top of the load cell, and beneath the Load Actuator. Ensure the Power Supply is connected to the power input, and the USB is connected to the Computer.

1. Open the software. The **FlexiForceCharData.xlsm** file opens up in Microsoft Excel. You are presented with the following screen:

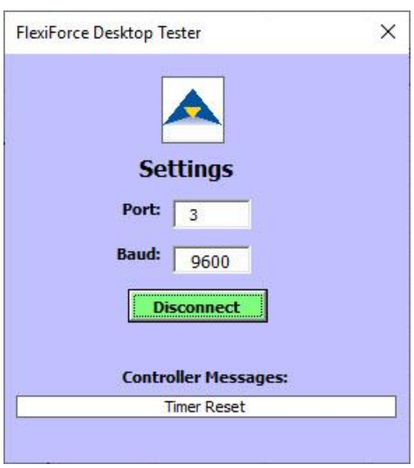
   The "Baud Rate" is always **9600**. However, you will have to open up your Device Manager (in the Computer's Control Panel) to obtain the "Port" number. This is the Port number for the USB connection to your computer, and is located under the **Tekscan Sensor Device** or **Ports** sub-heading. In this example, it is the **USB Serial Port (Com3)**, shown below.

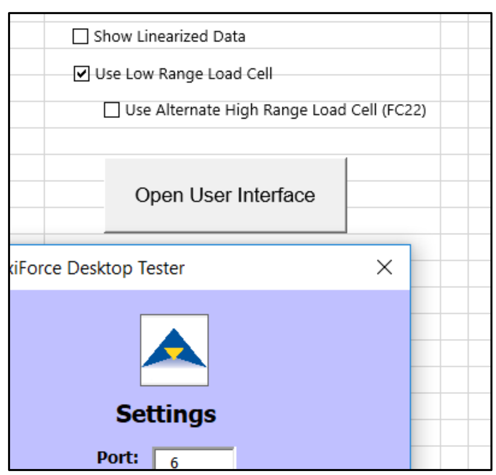




   Double-click on the selection to open up the device's Properties window. On this window, you will see the Port listed. In this case, the Port is "**3**".

   Once you enter the Port number, click the **Connect** button. This allows the software to connect to the computer. The Connect button also turns into a Disconnect button. This is a toggle and allows you to disconnect from the machine at any time. You can now move this window off to the side, and perform your tests. Note that the **Controller Messages** display each action performed by the combination of the Hardware and Software, as the test progresses through its stages.



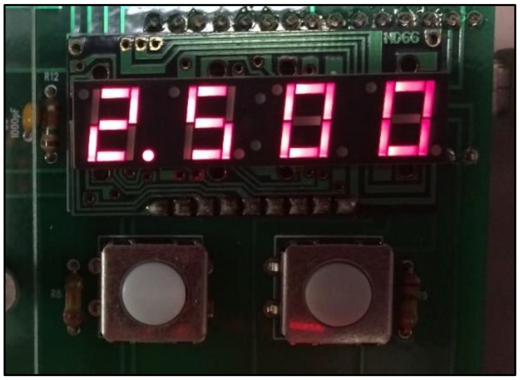


In the top-right of the spreadsheet, select the force range corresponding with the version of the product purchased (see image at right). Check the box near "use low range load cell" if using the 1lb version, or leave the box unchecked if using the 10lb version.

2. Ensure the correct Circuit Module is in Slot 1 or Slot 2, and press the "Module Select" Button to the right of the Module you want to use for the test.

3. Select the desired test using the Test Select button (see the Sensor In-Circuit Property Tests section above).

   The Reference Voltage Display shows a default 2.500 Volts (see image at right). Start with this as a reference.

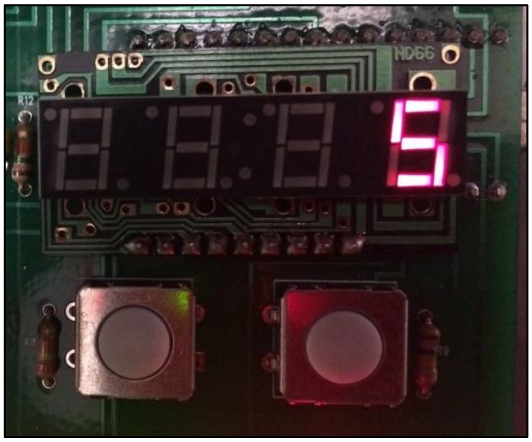


4. In the bottom left of the Excel Workbook, select the appropriate spreadsheet that matches the test profile you are running. “Data Graphs” will graph the sensor output vs. applied load (load cell data). This should be used for linearity and hysteresis measurements and calculations.

   “Drift” will graph temporal data with the load cell output on the left vertical (Y) axis, sensor data on the right vertical (Y) axis, and time (mS) on the horizontal (X) axis. Use this for sensor drift and repeatability measurements/calculations.

   Press the Test “**Run**” button on the PCB.

   a. If you are performing the **Linearity**, **Linearity and Hysteresis**, or **Drift** tests, the Actuator engages and the Load Actuator presses down on the Sensor and Load Cell. Depending on the test, several cycles or a period of time will pass before the test is complete. Note also that as the test is being performed, data for the test is displayed dynamically within the Excel software, so you can visually see the data as the test progresses.



   b. If you are performing the **Repeatability** test, the Actuator engages and the Load Actuator presses down on the sensor. The Reference Voltage Display changes to show you the number 5. This indicates the number of load cycles on the sensor. If you wish, you can decrease or increase the cycle number by using the Reference Voltage decrease / increase buttons below the display. Starting out with 5 cycles is recommended, until you become acclimated with the testing process.

   At this point, you must press the Test **Run** button again to begin the test. The Load Actuator then cycles through the different sensor loads, performing 5 steps up and then 4 steps down, for each cycle.

5. Once the test is complete, the software displays a measurement profile of the sensor’s in-circuit property. Refer to the appropriate spreadsheet that corresponds to the test selected for the data: “Data graphs” for linearity, hysteresis, and repeatability, and “Drift” for running a drift test profile. See the Sample Data below.

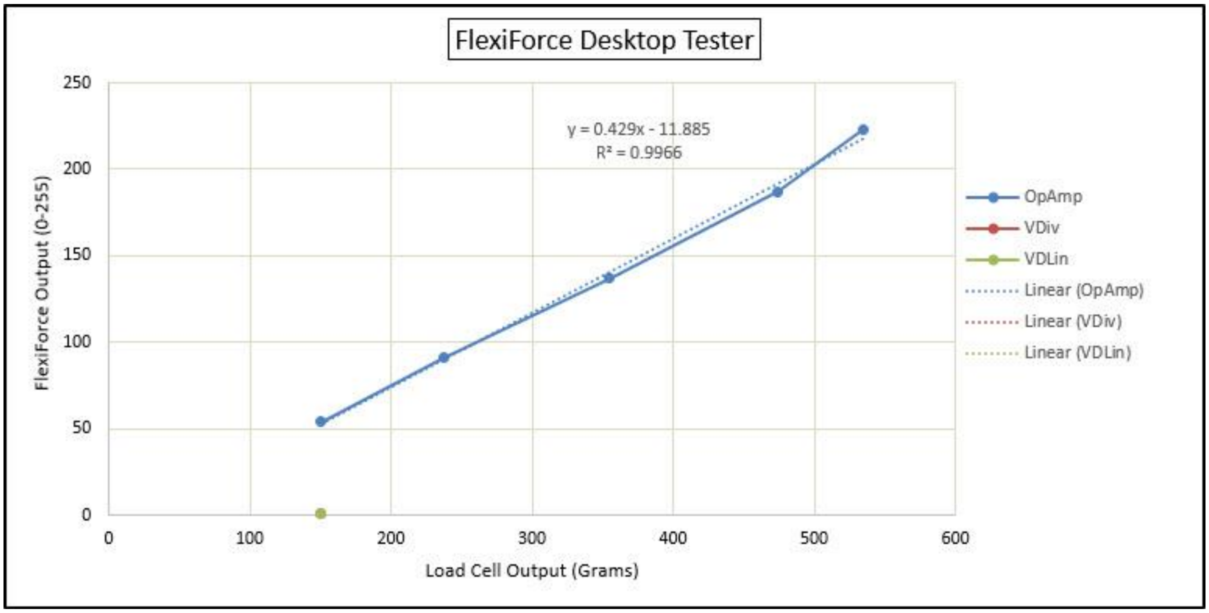
6. Go to **File > Save** or **Save As** to save the data as an Excel (**.xlsx**) file.

Note: If you have completed a test and wish to run another test, it is recommended you save the previous test as an Excel (.xlsx) file. As soon as the Test Run button is pressed for the new test, all the data from the previous test is deleted and cannot be retrieved.

Sample Data

Linearity Test

	A	B	C	D	E	F	G	H
1								
2		**Tekscan, Inc. - FlexiForce Desktop Tester**						
3								
4		Load	OpAmp	VDiv	VDLin	Grams		# Data Pts.
5		358	44			150		5
6		525	89			247		
7		731	136			366		
8		948	193			492		
9		1023	236			535		
10								



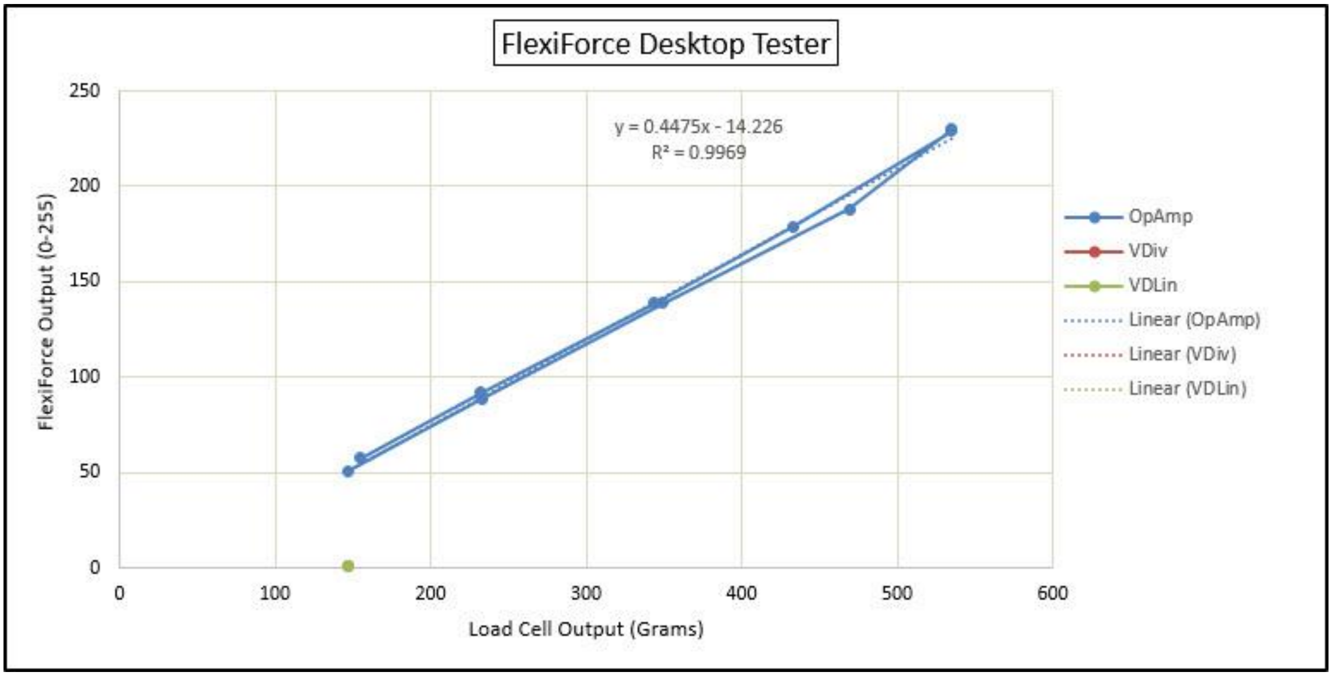
Load	OpAmp	VDiv	VDLin	Grams	Time (ms)	Raw Time		# Data Pts.		Absolute Drift		Drift per Log Time	
358	54			150	0	26866		5		0.00%		#NUM!	
508	91			237	6123	32989							
711	137			355	12245	39111		Op Amp		Delta		Max Time:	24490
918	187			474	18368	45234		Max Value:	223	0		1 sec time:	24490
1023	223			535	24490	51356		1 Sec. Value:	223	0.00%		Delta Time:	0
						0						Log Time:	#NUM!
						0		Volt. Div.		Delta			
						0		Max Value:	0	0			
						0		1 Sec. Value:		0.00%			
						0							
						0							
						0		LOAD CELL CALIBRATION					
						0		*Force (grams) = (0.5785 * DO) - 56.689*					
						0							

To calculate linearity:

1. Use the linear trend line equation to calculate sensor output at each load.
2. At each load, subtract measured sensor output from calculated sensor output.
3. **Linearity Error = Max (measured sensor output – calculated sensor output)/255 *100**. This results in linearity error as a percentage of full scale.

Linearity and Hysteresis Test

	A	B	C	D	E	F	G	H
1								
2		***Tekscan, Inc. - FlexiForce Desktop Tester***						
3								
4		Load	OpAmp	VDiv	VDLin	Grams		# Data Pts.
5		369	50			157		10
6		519	87			244		
7		721	136			360		
8		933	190			483		
9		1023	236			535		
10		1023	233			535		
11		842	173			430		
12		681	132			337		
13		497	87			231		
14		360	49			152		



To Calculate Hysteresis:

1. Split the loading and unloading portions of the curve in the "Data Graphs" spreadsheet into two different series.

2. Plot a 2[nd] order polynomial trend line through each curve. You should have a 2[nd] order polynomial trend line for the loading portion of the curve and the unloading portion of the curve.

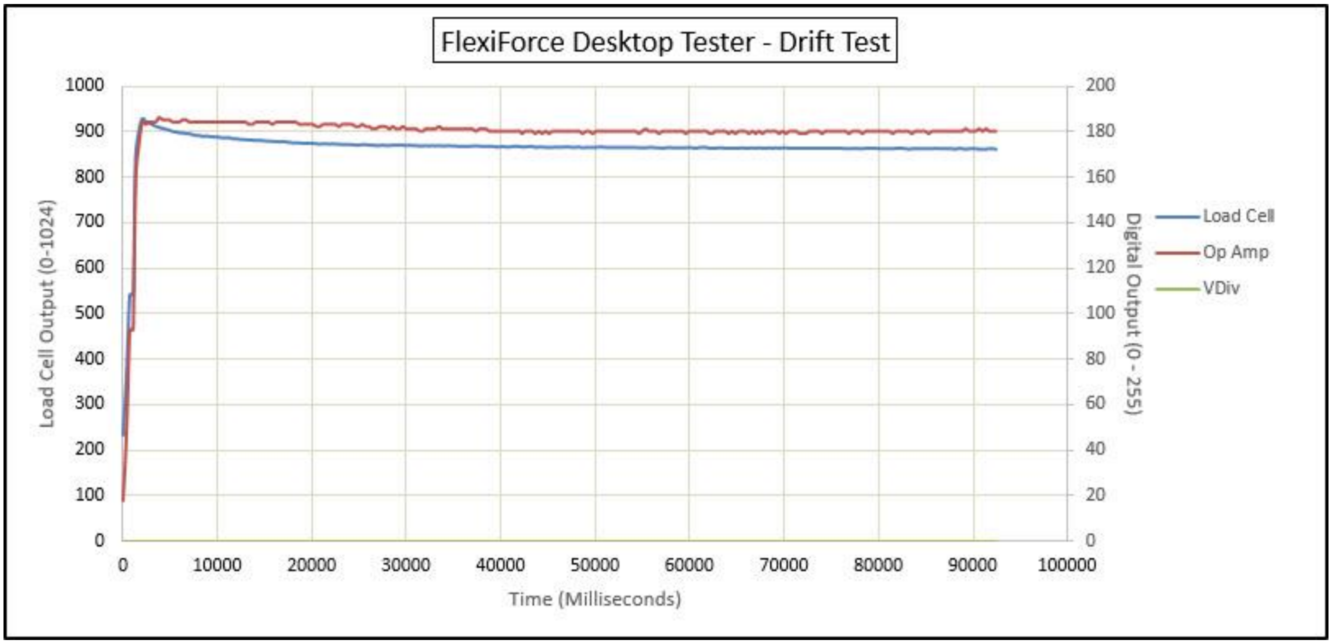
3. Use the trendlines to calculate sensor output at each load in the test. Subtract the sensor outputs in the loading curve from their corresponding loads in the unloading curve.

4. **Hysteresis = Max(loading – unloading)/255 *100.** This will result in hysteresis as a percentage of full scale.

Tekscan, Inc. - FlexiForce Desktop Tester											
Load	**OpAmp**	**VDiv**	**VDLin**	**Grams**	**Time (ms)**	**Raw Time**	**# Data Pts.**		**Absolute Drift**	**Drift per Log Time**	
352	51			147	0	636612	10		0.00%	0.00%	
501	89			233	6123	642735					
702	139			349	12245	648857	Op Amp		Delta	Max Time:	55104
909	188			469	18368	654980	Max Value:	230	0	1 sec time:	24491
1023	230			535	24491	661103	1 Sec. Value:	230	0.00%	Delta Time:	30613
1023	229			535	30614	667226				Log Time:	4.485906
847	179			433	36736	673348	Volt. Div.		Delta		
692	139			344	42859	679471	Max Value:	0	0		
499	92			232	48981	685593	1 Sec. Value:		0.00%		
366	58			155	55104	691716					
						0					
						0	**LOAD CELL CALIBRATION**				
						0	*Force (grams) = (0.5785 * DO) - 56.689*				
						0					

Drift Test

Tekscan, Inc. - FlexiForce Desktop Tester					
Load	**OpAmp**	**VDiv**	**VDLin**	**Grams**	**# Data Pts.**
234	18			79	265
364	47			154	
543	93			257	
543	93			257	
842	158			430	
902	174			465	
929	184			481	
923	183			477	
920	184			476	
916	184			473	
912	184			471	
910	186			470	
908	185			469	
906	185			467	
904	185			466	
901	184			465	
900	184			464	
898	184			463	
898	185			463	
896	185			462	
896	184			462	
894	184			460	
892	184			459	
892	184			459	
890	184			458	
891	184			459	
890	184			458	
889	184			458	
889	184			458	
888	184			457	
887	184			456	
887	184			456	
887	184			456	
885	184			455	

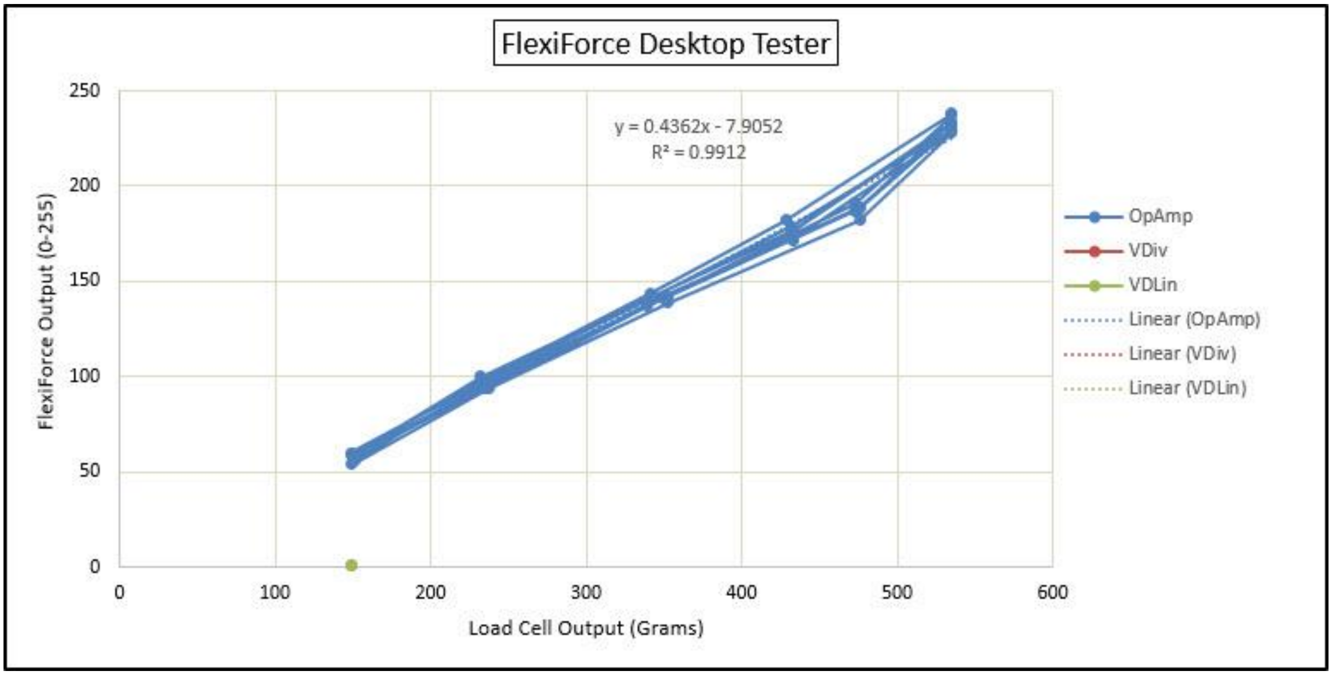


Note: There is an automated sensor drift calculation in the "Drift" tab of the spreadsheet. This calculation is ONLY applicable when running the "drift" test profile.

Repeatability Test

Tekscan, Inc. - FlexiForce Desktop Tester

Load	OpAmp	VDiv	VDLin	Grams		# Data Pts.
356	54			149		50
507	94			237		
707	142			352		
916	191			473		
1023	237			535		
1023	238			535		
838	182			428		
688	144			341		
500	98			233		
355	59			149		
357	59			150		
508	94			237		
708	139			353		
920	182			476		
1023	228			535		
1023	228			535		
846	172			433		
684	137			339		
500	95			233		
358	58			150		
359	56			151		
507	98			237		
704	141			351		
916	187			473		
1023	231			535		
1023	232			535		
844	176			432		

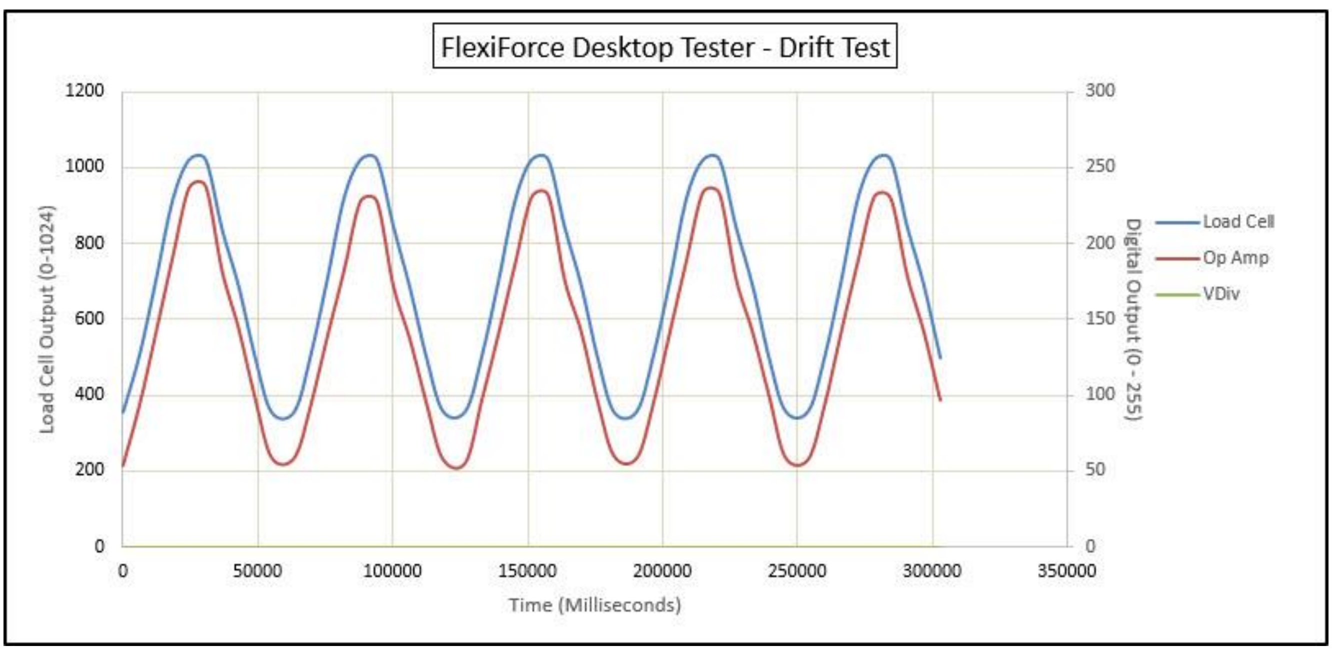


Tekscan, Inc. - FlexiForce Desktop Tester

Load	OpAmp	VDiv	VDLin	Grams	Time (ms)	Raw Time
356	54			149	0	1370243
507	94			237	6122	1376365
707	142			352	12245	1382488
916	191			473	18368	1388611
1023	237			535	24491	1394734
1023	238			535	30613	1400856
838	182			428	36736	1406979
688	144			341	42859	1413102
500	98			233	48982	1419225
355	59			149	55104	1425347
357	59			150	63481	1433724
508	94			237	69605	1439848
708	139			353	75727	1445970
920	182			476	81850	1452093

# Data Pts.		Absolute Drift		Drift per Log Time
50		0.42%		0.08%
Op Amp		Delta	Max Time:	309033
Max Value:	238	1	1 sec time:	24491
1 Sec. Value:	237	0.42%	Delta Time:	284542
			Log Time:	5.454146
Volt. Div.		Delta		
Max Value:	0	0		
1 Sec. Value:		0.00%		

LOAD CELL CALIBRATION
*Force (grams) = (0.5785 * DO) - 56.689*



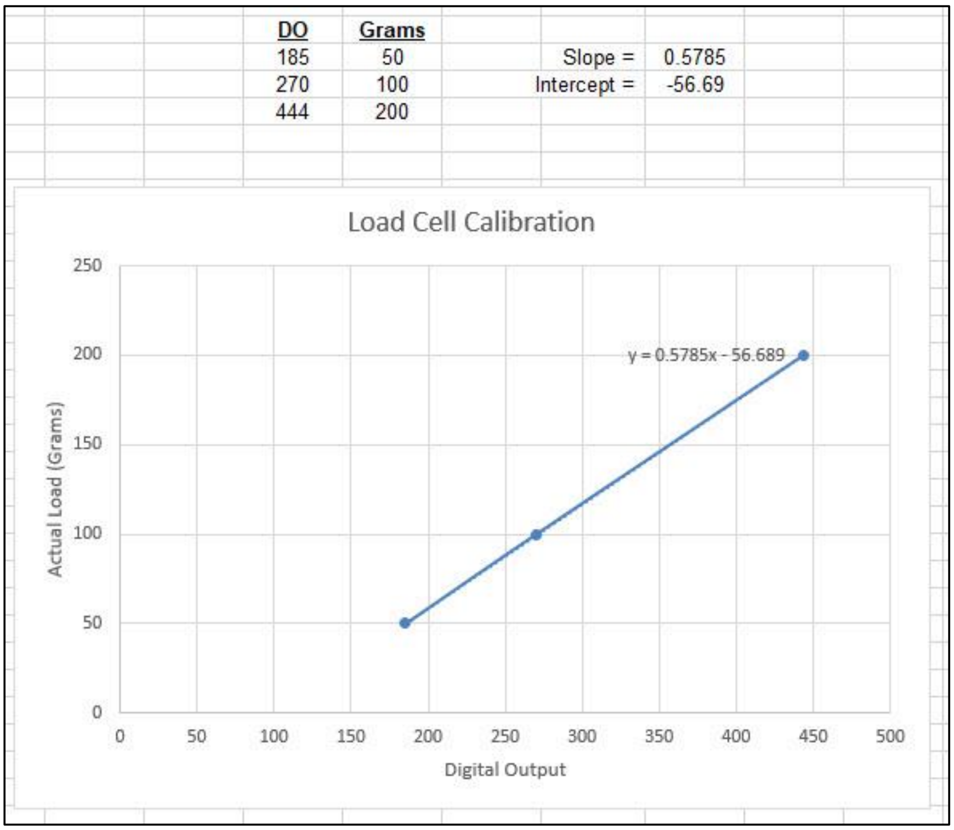
To Calculate Sensor Repeatability:

1. Note the sensor output at the same load in each cycle of the test.
2. Calculate the average of these outputs.
3. Calculate the standard deviation of the outputs.

Repeatability is defined as the **Coefficient of Variation (CoV) = standard deviation/average *100**. This results in Repeatability Error (CoV) as a percentage.

Load Cell Calibration

Note: The same data is displayed for all tests.



Changing Default Test Parameters

You can change the parameters for each of the four Sensor In-Circuit Property tests. For instance, if you would like the Drift test to take place for more or less time during its cycle, or if you would prefer to have the Hysteresis test load 6 times instead of 5. These parameters can be changed by updating the code that is being run on the Arduino Nano chip. To change these parameters, find the portion of the code in **FleixForceCharKit.ino** file, as shown below:

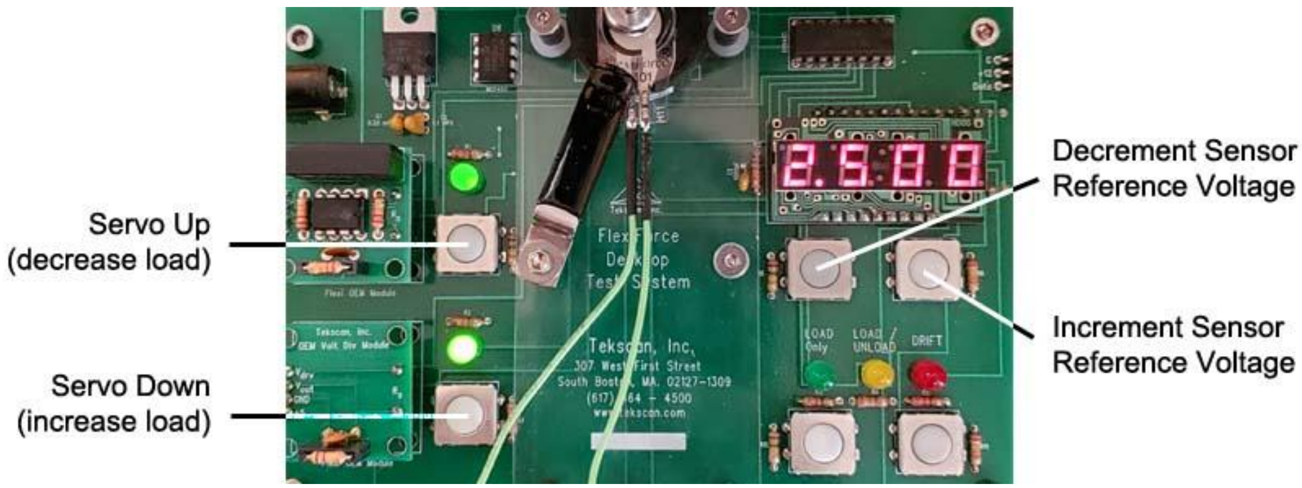
```
MoveServoSlow(PreLoadingPosition, 25);

if (TestMode == 1)         // LOAD Only - 5 Steps UP
  {
    Num_Steps = 5;
    Num_Cycles = 1;
  }
else if (TestMode == 2)    // LOAD/UNLOAD - 5 Steps UP, 5 Steps Down
  {
    Num_Steps = 10;
    Num_Cycles = 1;
  }
else if (TestMode == 3)     // DRIFT Test - hold @ 50% Load
  {
    Num_Steps = 10;
    Num_Cycles = 1;
  }
else if (TestMode == 4)     // Multi-Cycle
  {
    Num_Steps = 10;
    Get_Number_of_Cycles();
    Num_Cycles = Num_Cycles_Multi;
  }
```

“Num_steps” in each test mode controls how many loads are applied to the sensor. Enter the desired number of steps for the given test mode and upload the code back to the PCB as instructed in the Software Setup section. The loads are applied by a servo motor acting on a spring. Each step corresponds to a position movement of the servo, which displaces the spring and changes the force acting on the sensor. For those with programming experience, the movement of the servo, drive voltage increments, and other parameters, can be modified within this same code.

Manual Control Mode

Manual control mode can be used to apply loads to the sensor manually, and observe outputs on the PCB's digital display. This is useful for observing discrete loads on the sensor, other than the pre-programmed load profiles in **FlexiForceCharKit.ino**. It can also be used to set sensor reference voltage so that if falls within an optimal 75-80% of the dynamic range at maximum load. If, during the automated tests in **FlexiForceCharKit.ino**, it is observed the sensor output is in a low portion of the 0-255 dynamic range, this mode can be used to adjust that range.

To use manual control mode, upload the **FlexiForceCharKitManCont.ino** file onto the Characterization Kit PCB as instructed in the [Software Setup](#) section. In this mode, the white buttons on the PCB have different functionality than the default labels on them, as outlined below.

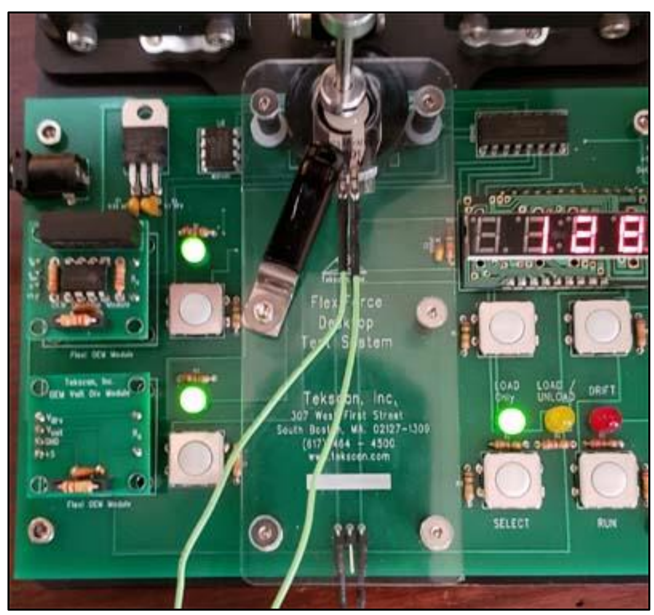


Press the **Select** button to cycle the on board display to show various outputs.

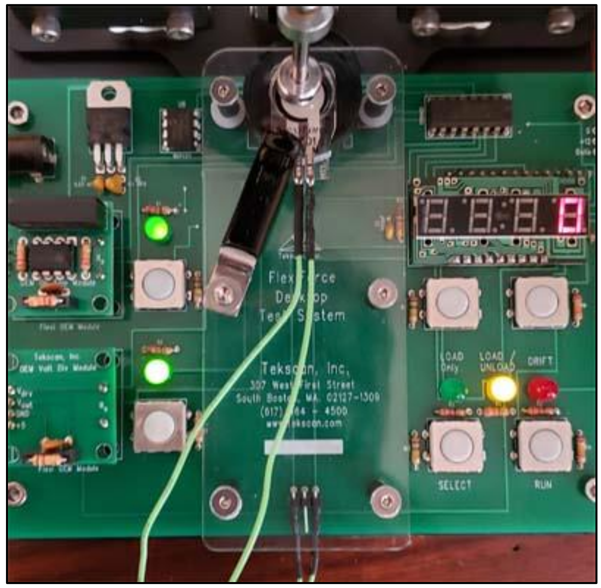
With none of the three profile LEDs at the bottom right lit, the display shows the current sensor reference voltage (shown above).

With the green LED at the bottom right of the board lit, the on-board display shows the sensor output of the circuit module closest to the load actuator.

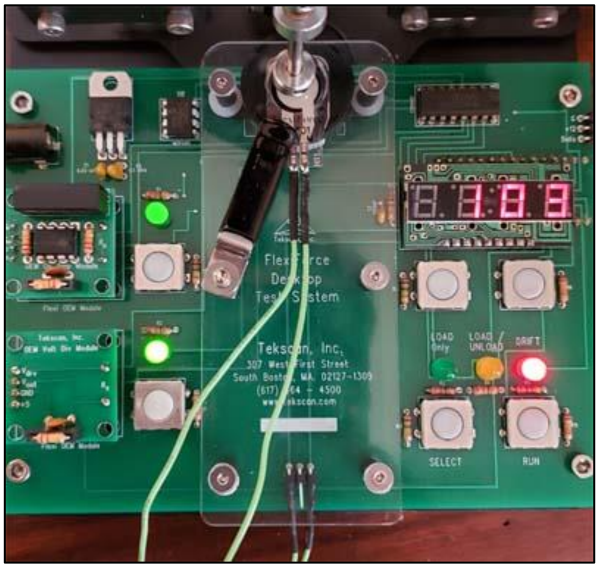
Note: if using manual control to tune the output for the pre-programmed test, set the reference voltage so that the output at max load is between 180-220 counts. This is because the sensor data transmitted when using the "FlexiForceCharKit.ino" code is 8 bit.



When the yellow LED at the bottom right of the board is lit (shown at right), the on-board display shows the sensor output of the circuit module furthest from the load actuator.



When the red LED at the bottom of the board is lit, the on-board display shows the 10-bit (0-1023 counts) output of the load cell (shown below).



Modifying the Arduino Code

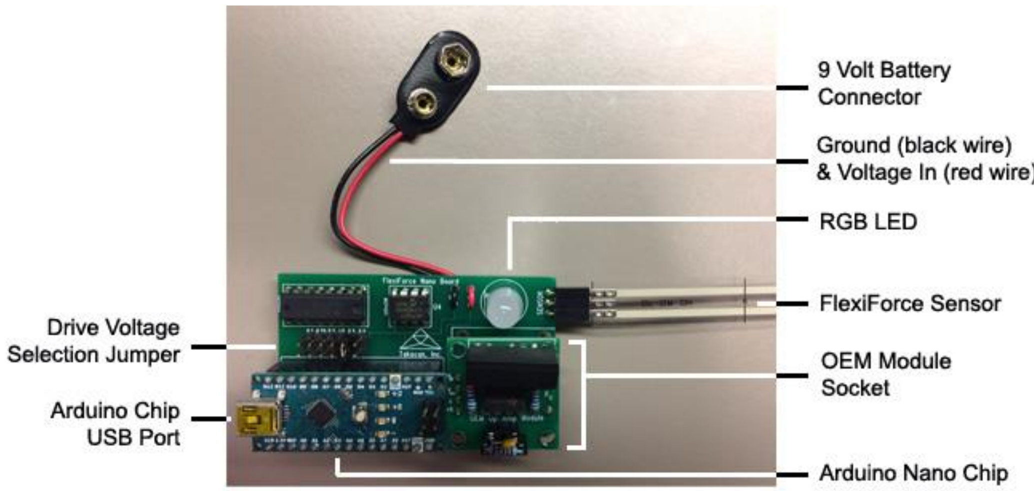
The FlexiForce Characterization Kit uses the Arduino code, and as such, it is open source. If you wish to modify the Arduino code and reprogram it to your specifications, the install utility for Arduino programming environment is in the software download for your product at www.tekscan.com/fir. You can also download the programming environment from Arduino directly. Follow the instructions below:

1. Go to https://www.arduino.cc/en/Main/Software
2. Click on “Windows Installer” and download the latest version from the Arduino download page.
3. Run “arduino-x.x.x.-windows.exe” from your download directory, where “x.x.x.” is the version you downloaded.
4. Install, using the default settings.

FLEXIFORCE PROTOTYPING KIT

The FlexiForce Prototyping Kit is composed of an Arduino Nano Chip USB Interface Board with OEM Module Socket, RGB LED, Drive voltage selection jumper, 3-pin Sensor connector, and an attached 9-volt Battery clip. The Arduino Circuit Board converts the analog signal coming from the Circuit Board into a Digital Signal, and outputs this signal via the RGB LED (and on the included Microview software).

The following image shows the components that make up the FlexiForce Prototyping Board:



Hardware

Components List

The Prototyping Kit comes ships with the following components:

- (1) Prototyping Board with Arduino Nano Chip*
- (3) Interchangeable Testing Modules: (1) Voltage Divider, (1) Non-Inverting Op-Amp, and (1) Inverting Op-Amp
- (2) FlexiForce Sensors: (1) A201-1, and (1) A201-25
- (1) 3-Foot USB Extension Cable
- 9 Volt Battery
- Software Files (web download at https://www.tekscan.com/fir): (
    - **FlexiForceProtoKit.ino:** Arduino code for controlling Prototyping Kit PCB (this also the default code pre-loaded on the unit).
    - **FlexiForceMicroView:** VB Interface – Ver3 – Visual Basic programming files for Prototyping Kit User Interface

- **Arduino Programming Environment download utility:** For modifying and/or uploading Arduino code to fixture PCB.
- **(3) Arduino Libraries:** Arduino library files called by the **FlexiForceProtoKit.ino** code.
- **FlexiForceProtoData.exe:** Visual Basic user interface for reading/recording sensor data
- **Readme.txt:** Text file with information on how to use each file and where the libraries should be saved.

FlexiMicroReader.xlsm-Macro enabled spreadsheet which imports data recorded using the FlexiForce Prototyping Kit.

** Arduino Nano Chip datasheet: https://www.arduino.cc/en/uploads/Main/ArduinoNanoManual23.pdf*

Specifications

Input	9V
Analog Output	0V-5V
Digital Output	up to 10 bit (8 bit default)
Sampling Frequency	20 Hz (adjustable in code)
Communication	USB
Operating Temperature	10C – 35C (50F-95F)
Weight	25g (0.06lb)
Dimensions (LxW)	38mm x 66mm (1.5" x 2.6")

Analog Circuit Modules

Three Analog Circuit Modules ship with the FlexiForce Prototyping Kit. See Analog Circuit Modules for information.

Drive Voltage Adjustment

The reference voltage on the Prototyping Kit PCB can be adjusted so that the optimal portion of the circuit's dynamic range is being used for the specific application. It is recommended that the reference voltage be set so that the output at maximum expected load is approximately 80% of the maximum output of the board (4V analog or 204 digital counts).

Reference voltage selection is performed using the jumpers on the pins above the Arduino Nano Chip. Each pin has their corresponding default reference voltage value printed directly on the PCB. Select the desired reference voltage by placing the jumper between the two corresponding pins (vertically). The picture below shows the headers and their labels, with the jumper at the 2.5V reference voltage selection.

If desired, the voltage values of each pin can be modified in the **FlexiForceProtoKit.ino** code.

FlexiForceProtoKit

```
//
//                          FlexiForce Nano Carrier Board - reads values from FlexiForce OEM Drive Module
//                               (Inverting Op Amp, Non-Inverting Op Amp, Voltage Divider Modules)
//

#include <SPI.h>
#include <DAC_MCP49xx.h>
#include <Adafruit_NeoPixel.h>

#define NeoPIN              2    //  DIO for NeoPixel
#define NUMPIXELS           1    //  # NeoPixels
#define dataPin             11    //  DIO for SPI Serial Data (DAC and 4 Seg Display)
#define clockPin            13    //  DIO for SPI Serial Clock (DAC and 4 Seg Display)
#define DAC_Select          4     //  DIO for DAC Select (Active LOW)
#define SensorDriveOnOff    3     //  DIO for switching Sensor Drive Voltage

int DriveVoltageIndex = 4;
int DriveVoltage[] = {100, 250, 500, 1000, 2500, 5000};   //  Drive Voltage Levels
                        //  Analog signals from Sensor Modules
```

The values in parenthesis at “int DriveVoltage” are the voltage levels of each pin set in millivolts. They can be modified as desired and the code uploaded back to the PCB as instructed in the Software Setup section.

Maintenance and Care Instructions

- The FlexiForce Prototyping Kit components cannot be autoclaved.
- Do not let any liquid spill onto the components. If this occurs, the components can stop working and must be allowed to dry for 24 hours. You can use your air syringe, however, to significantly reduce this drying time. Do not attempt to dry out the components using any other method, or you may destroy the delicate electronics.

Conditioning the Sensors

For best results, we recommend conditioning the sensors before each use and before calibration. This process “breaks in” the sensor.

Place 110% (or more) of the maximum test load on the sensor for approximately 3 seconds. For example, if the maximum test load is 10 pounds, place 11 pounds onto the sensor. Remove the load from the sensor. Repeat 4-5 times. When finished, proceed to “Calibration.”

Setting up the FlexiForce Prototyping Kit

Setting up the FlexiForce Prototyping Kit is quick and easy. Follow the procedure below.

1. Insert one of the FlexiForce Sensors face up into the white 3-pin connector slot on the Board.

2. Insert one of the three Analog Circuit Modules into the Module Socket.

3. Connect the 9-volt battery.

   a) If you are planning to take measurements using the **FlexiForceProtoData.exe** software on your computer, use the USB Extension Cable to power the FlexiForce Prototyping Board. Insert one end into the Arduino Circuit Board’s USB connector, and then insert the other end of the Cable into the USB port on your computer. The Arduino Chip’s LEDs will cycle and the ON LED will remain illuminated yellow. At the same time, the RGB LED briefly flashes blue.

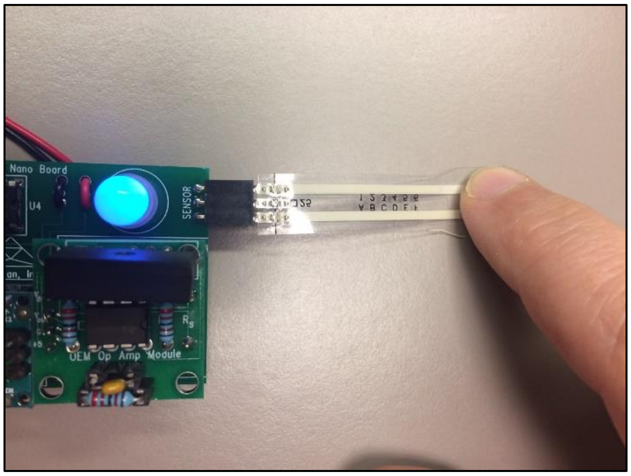
   Note: the USB Cable must be connected in order for you to use the “FlexiForceProtoData.exe” software to read the data.

   b) If you plan to power the FlexiForce Prototyping Board in a location without a computer, and view the measurements on the RGB LED only, you can connect a standard 9-volt battery to the Development Board’s battery connector clip. This allows the system to be fully portable. When the battery is connected, The Arduino Chip’s LEDs will cycle and the ON LED will remain illuminated yellow. At the same time, the RGB LED briefly flashes blue.

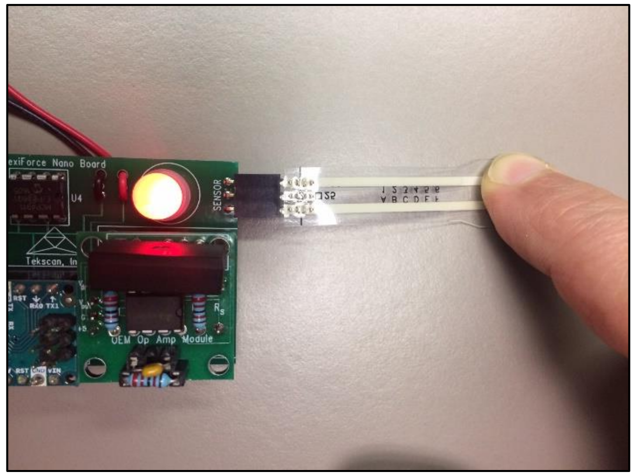
Viewing Measurements with the RGB LED

The RGB LED is a polychromatic light source that gradually shifts through the color spectrum as force on the sensor increases, from blue (low sensor force) to green, and then yellow (higher sensor force), and finally to red (saturated sensor force).

RGB LED showing Low force (blue)



RGB LED showing saturated force (red)



Using a Sensor with Two Pins

When using the FlexiForce Prototyping Board with a two-pin sensor, such as the A301 (not included) the center pin and the outer pin should be inserted in the top 2 pin connection ports on the Board, as shown below.

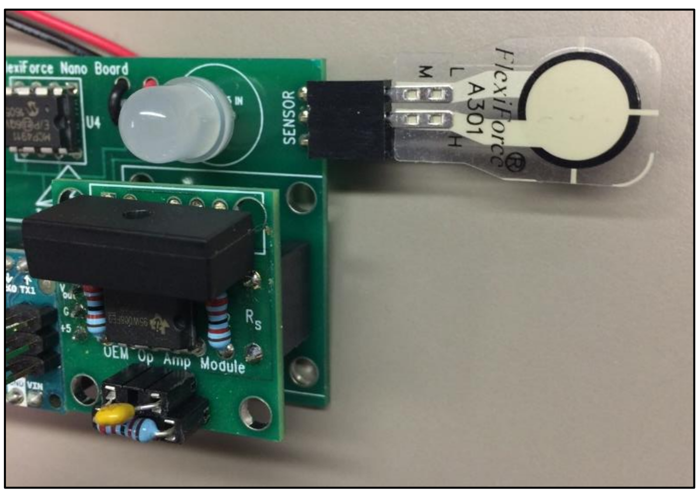


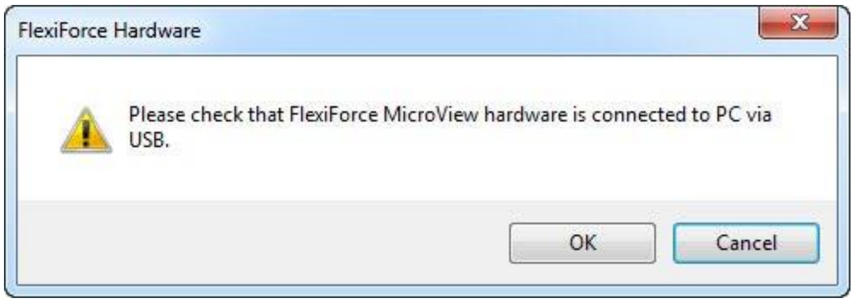
Figure 6 - Example of Using a Two Pin Sensor

Using the “FlexiForceProtoData.exe” Software

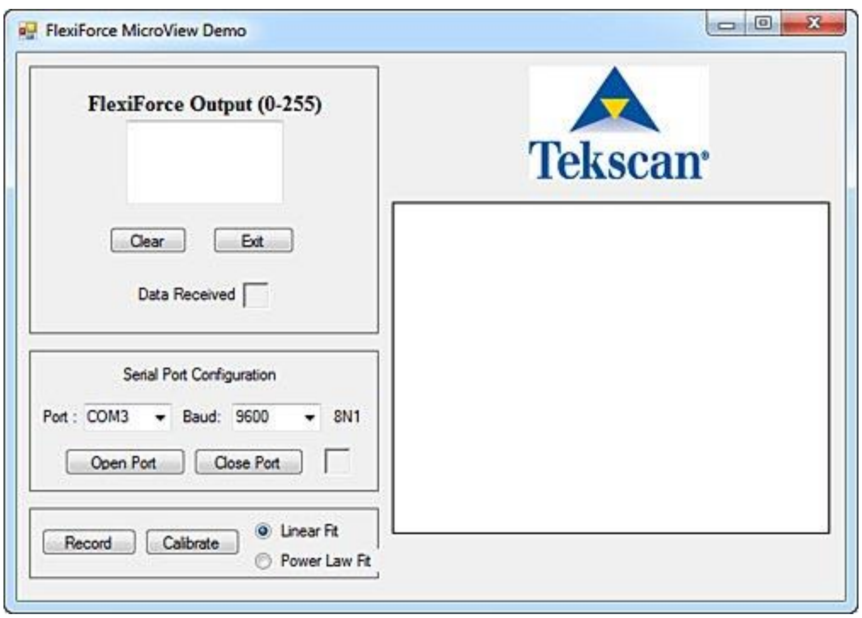
To use the software, follow the procedure below.

1. Set up the FlexiForce Prototyping Kit, as outlined above, via the USB Cable. After downloading the FlexiForce Prototyping Kit software from www.tekscan.com/fir, launch the **FlexiForceProtoData.exe** program.

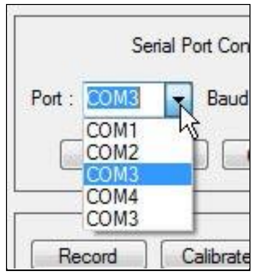
2. You may see the following dialog. Ensure your FlexiForce Prototyping Board is connected to the computer via the USB cable, and click **OK**.



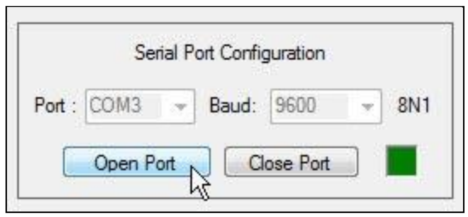
3. The FlexiForce Prototyping Kit software opens on-screen (shown below).



4. Select the last **COM Port** from the "Port" drop-down list (in the example below, it is **COM3**).

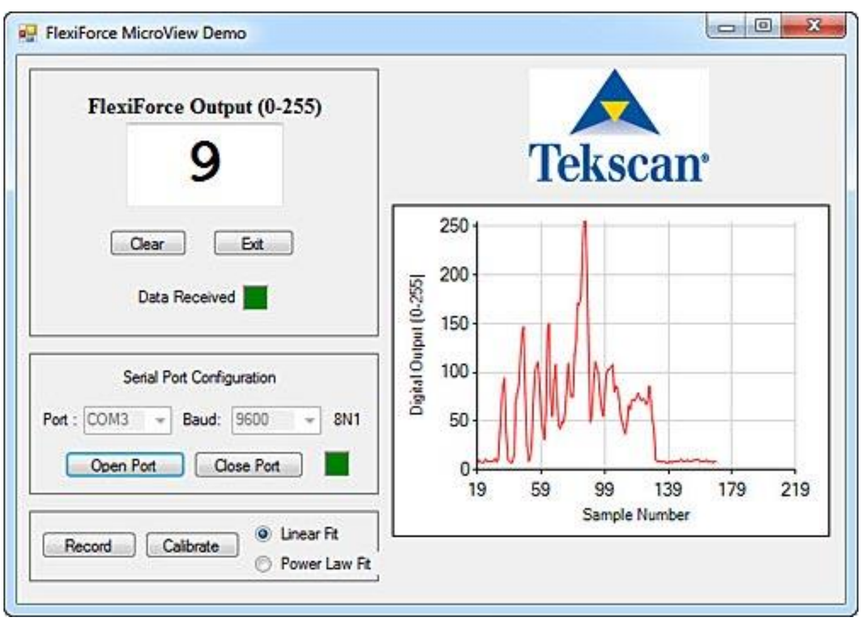


5. With the Port selected, click the **Open Port** button (shown below). You will see the color-square turn Green. This indicates the system is ready to display measurement data. If the square is red, this means you may not have the correct Port selected.



Note that the Port you should use for the Prototyping Kithardware is usually the last one in this list. But if this Port doesn't work, try each Port sequentially, until the correct one is found.

6. Once started, apply force to the sensor. The polychromatic LED on the Board will display colors in accordance with the force applied, from low force to high force (light blue to dark red). At the same time, the software will display measurement data. At the top left of the screen, you will see a numerical readout in the FlexiForce Output window. On the right of the screen, you will see the graph display the Sample Number along the X-axis, and the Digital Output along the Y-axis (shown below).



Calibration

There are two Calibration procedures that can be used: **Linear Fit** and **Power Law Fit**. These two Calibration procedures are explained below.

Linear Fit Calibration

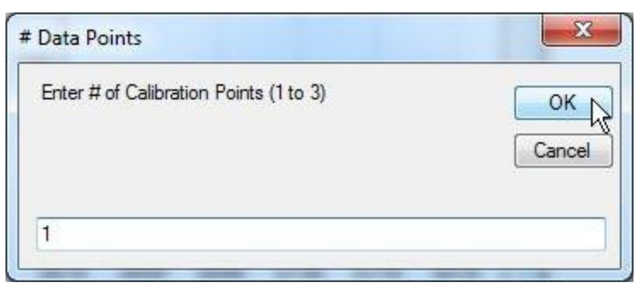
Linear Fit. Linear calibration is a Single-Load Calibration, and assumes the sensor has zero output with zero applied load. The board will output approximately 0.5V at no load. The user applies a known force to get a single calibration point. The software then draws a straight line between the two points (zero point and the calibration point). The line is extrapolated to a digital output of 255.

For experimental loads near the calibration load, single point calibration gives accurate results. If the experimental load is small or large compared to the calibration load, errors will grow. Typically, the graph of sensor Digital Output from varying load is a smooth curved line following a power law curve. A straight line from the origin is close to the curve near the calibration point, but increasingly divergent at the extremes.

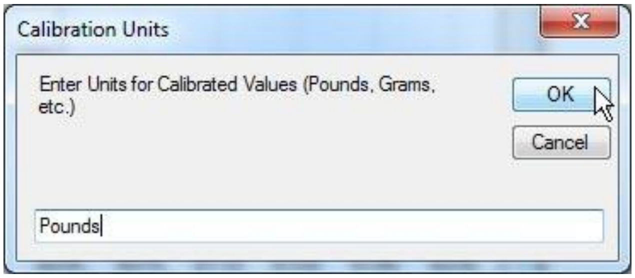
Follow the procedure below to perform a Linear Calibration.

1. By default the **Linear Fit** radio button is selected. If it is not, ensure that it is selected, and then click the **Calibrate** button (shown below left). The Calibration dialog opens asking if you want to calibrate the Sensor. Click **Yes** (shown below right).

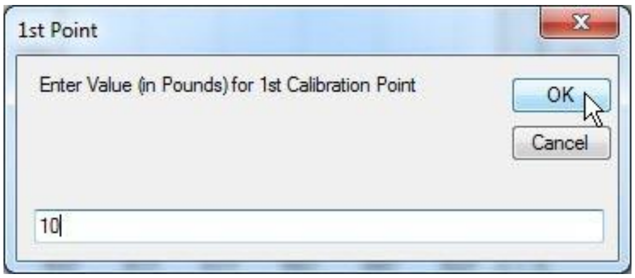
2. By default, 1 calibration point is selected. For most applications, this should be fine. However, you can select up to 3 Calibration points if you wish. When you've selected the number of Calibration points, click the **OK** button (shown below).



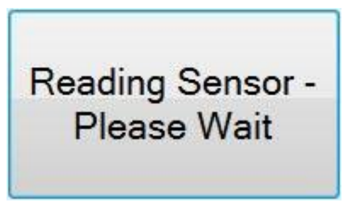
3. The next dialog asks you to specify the measurement units you are using. Enter this into the dialog and then click the **OK** button (shown below).



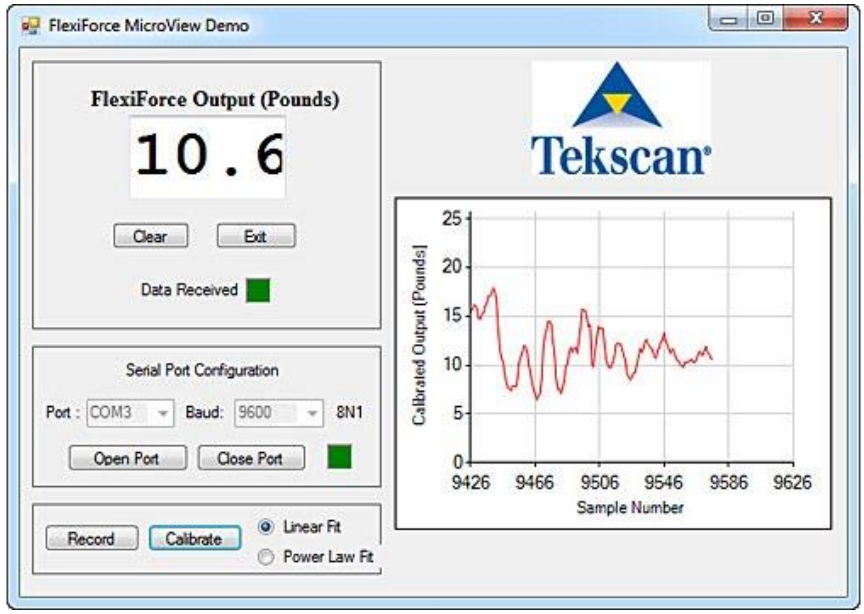
4. Enter the measurement Value in the next dialog. This is the number of units that the sensor will be measuring during the calibration process (shown below). After entering a value, click the **OK** button.



5. Apply the load to the sensor. In the example here, we are applying a 10 pound load to the sensor (shown below left). Next, click the **OK** button. The software takes a few seconds to Calibrate and displays the message shown below right.



6. When the Calibration process is completed, the dialog displays the new Calibrated Value (shown below left). Click the **OK** button. The Calibration process is now complete. You will now see output measured in Pounds within the FlexiForce MicroView software window (shown below right).



Power Law Fit Calibration

Power Law Fit: Power Law calibration is best used if you are using compliant (soft) material on top of the sensor, which affects load. Power Law calibration uses the load distribution information, algebra, and a numerical technique (iteration) to calculate the power law equation. For this reason, the applied loads must be precisely known and entered into the software correctly, and the calibration loads must generate different force distributions. Doing so will yield an accurate sensor calibration. In Power Law Calibration, multiple points are sampled to calibrate the sensor.

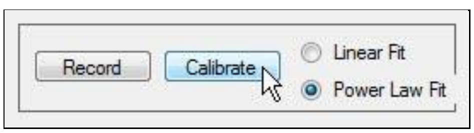
Power Law Calibration utilizes a sophisticated algorithm, which processes the distribution through a 'histogram' method. The two-point algorithm includes zero load to solve for the two constants in the exponential Power Law equation: $\mathbf{Y = AX^b}$

Y = force or load (in engineering units)
A = scale factor (determines slope)
X = raw digital output
b = exponent (determines curvature)

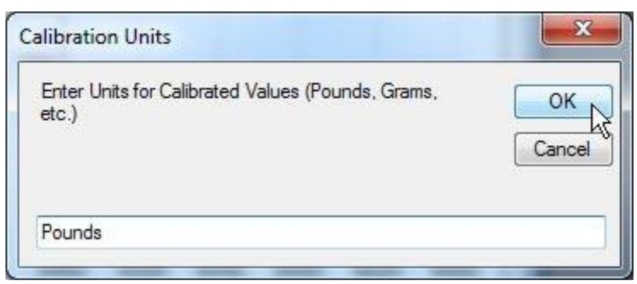
To perform a Power Law Fit calibration, the software requires 3 calibration points. We recommend setting Point 1 to 30% of the total experimental load, Point 2 to 60% of the total experimental load, and point 3 to 90% of the total experimental load.

Follow the procedure below to perform a Linear Calibration.

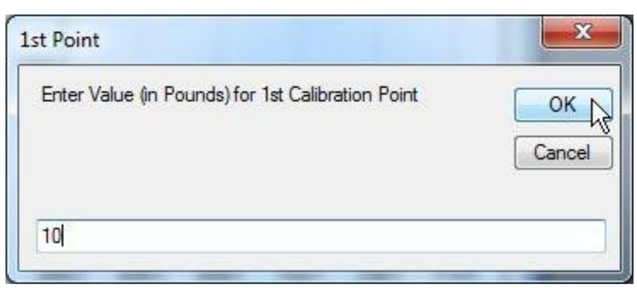
1. Select the **Power Law Fit** radio button. Then click the Calibrate button (shown below left). The Calibration dialog opens asking if you want to calibrate the Sensor. Click **Yes** (shown below right).



2. The next dialog asks you to specify the measurement units you are using. Enter this into the dialog and then click the **OK** button (shown below).



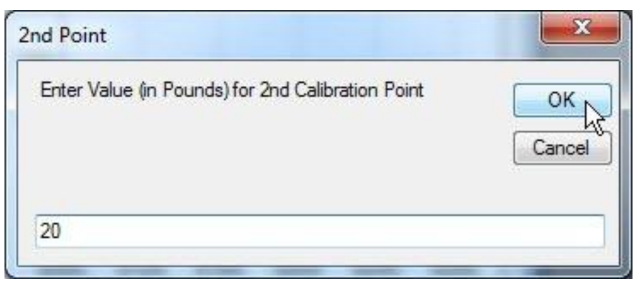
3. Enter the measurement Value in the next dialog. This is the number of units that the sensor will be measuring during the calibration process for the first point, which should be roughly 30% of the total test load. After entering a value, click the **OK** button (shown below).



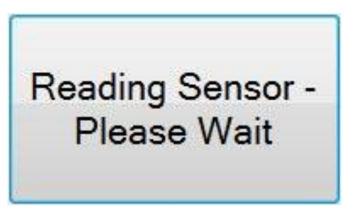
4. Apply the load to the sensor. In the example here, we are applying a 10 pound load to the sensor (shown below left). Next, click the **OK** button. The software takes a few seconds to Calibrate and displays the message shown below right.

5. When the first point in the Calibration process is evaluated, the dialog displays the new Calibrated Value (shown below). Click the **OK** button.

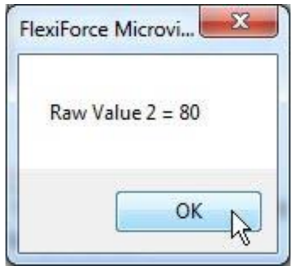
6. In the next dialog, enter the measurement Value for the second calibration point. This value should be roughly 60% of the total test load. After entering a value, click the **OK** button (shown below).



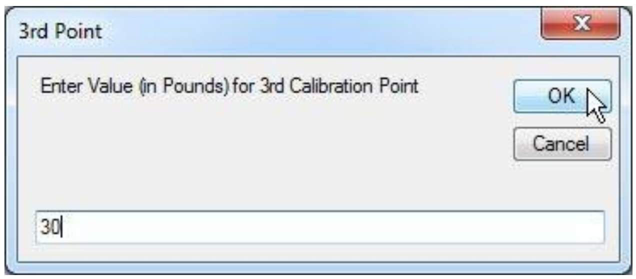
7. Apply the load to the sensor. In the example here, we are applying a 20 pound load to the sensor (shown below left). Next, click the **OK** button. The software takes a few seconds to Calibrate and displays the message shown below right.



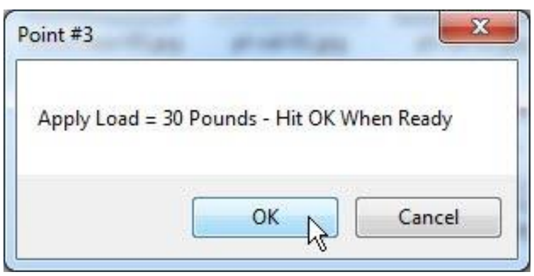
8. When the second point in the Calibration process is evaluated, the dialog displays the new Calibrated Value (shown below). Click the **OK** button.

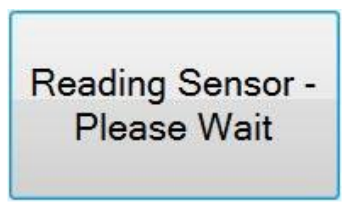


9. In the next dialog, enter the measurement Value for the second calibration point. This value should be roughly 90% of the total test load. After entering a value, click the **OK** button (shown below).

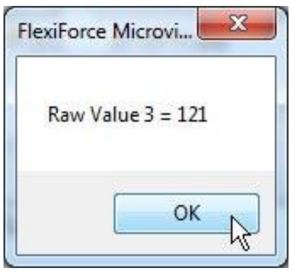


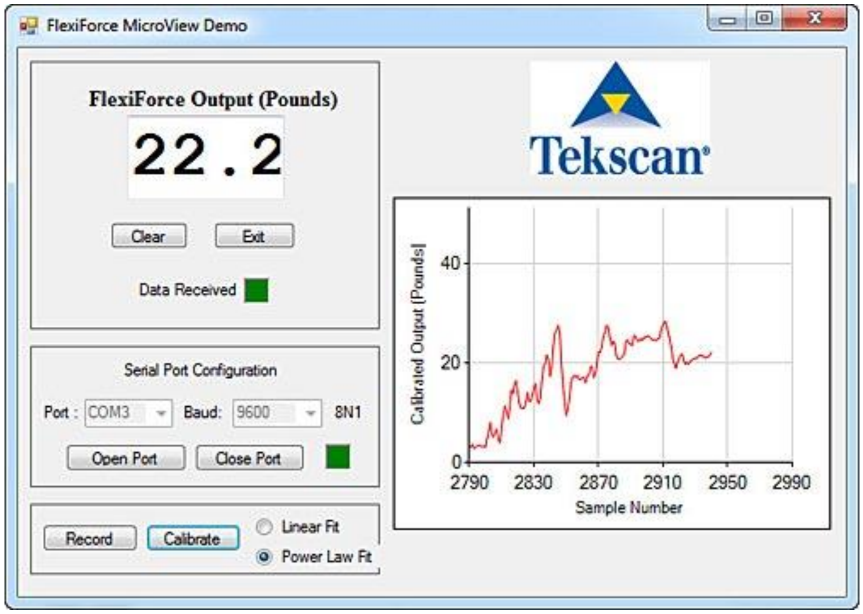
10. Apply the load to the sensor. In the example here, we are applying a 30 pound load to the sensor (shown below left). Next, click the **OK** button. The software takes a few seconds to Calibrate and displays the message shown below right.





11. When the third - and final - point in the Calibration process is evaluated, the dialog displays the new Calibrated Value (shown below left). Click the **OK** button. The Calibration process is now complete. You will now see output measured in Pounds within the FlexiForce MicroView software window (shown below right).



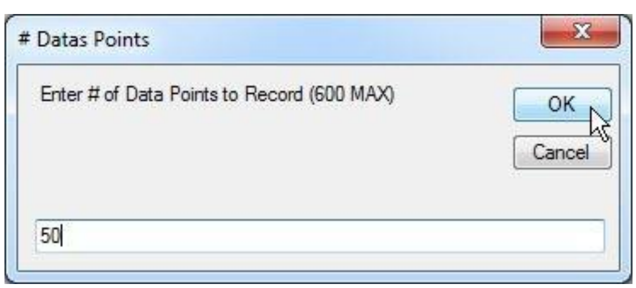


Using the Excel MicroView Reader

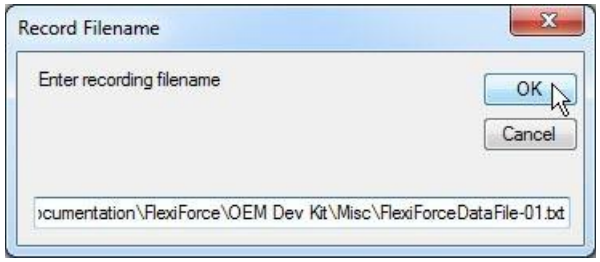
You can import the data provided by the FlexiForce Prototyping Board into Microsoft Excel using the **FlexiMicroReader.xlsm** (macro-enabled worksheet). To do this, open the **FlexiForceProtoData.exe** software, as outlined in the Using the "FlexiForceProtoData.exe" Software section. Then do the following:

1. Click the **Record** button (shown below).

2. On the next dialog, enter the number of Data Points (up to 600) that you want recorded (shown below). Then click the **OK** button.

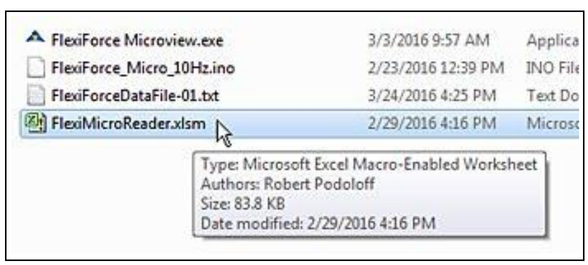


3. On the next dialog, enter the filename (along with the full path to the location of the file on your computer). Note: For easy retrieval later, it is recommended you place the file in the same folder as the **FlexiMicroReader.xlsm** file (shown below). When done, click the **OK** button.

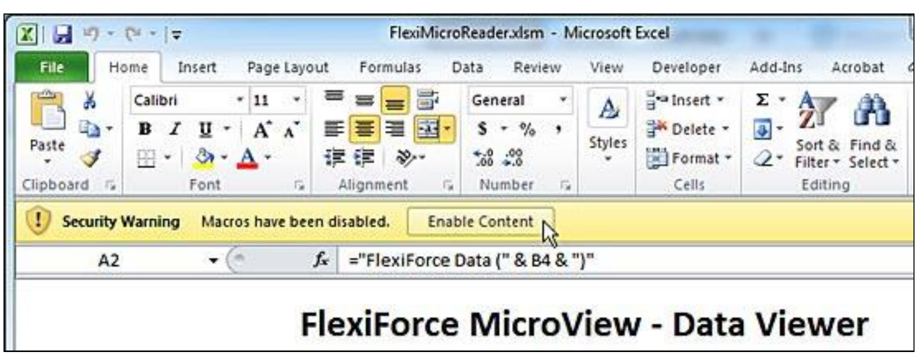


4. The next dialog puts the software in hold mode. Nothing will be recorded until you press the **OK** button to initiate the recording. Once this button is pressed, the recording immediately starts. When ready, press the **OK** button.

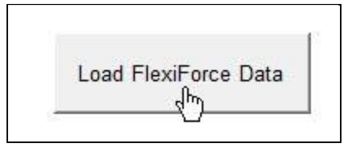
5. Once the number of points have been sampled, go into your Windows Explorer and locate the folder with both the **FlexiMicroReader.xlsm** and the data file you just recorded (in the example below, this is the **FlexiForceDataFile-01.txt** file). Double-click on the **FlexiMicroReader.xlsm** file (shown below).



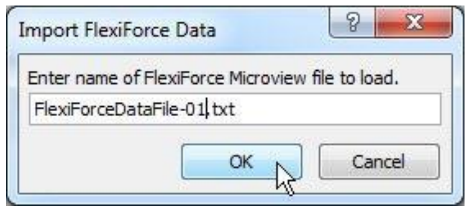
6. Microsoft Excel opens. Since this file contains Macros, you may have to first enable them by clicking on the **Enable Content** button (shown below). Do this now.



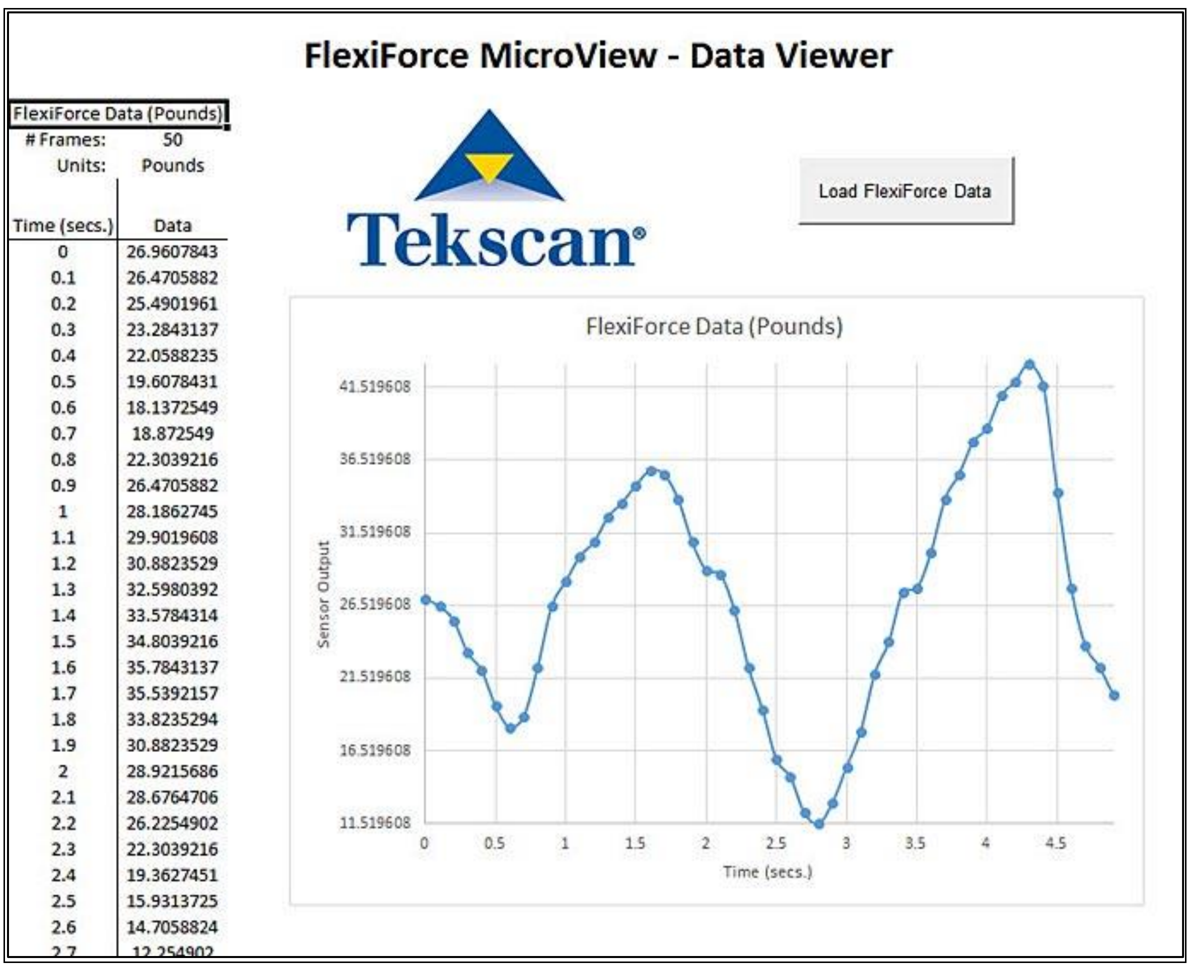
7. Next, click the **Load FlexiForce Data** button (along the right side of the screen – shown below).



8. The “Import” dialog opens. Since the data file is in the same location as the **FlexiMicroReader.xlsm** file, you do not need to enter the full path to find the file. Instead, simply enter the filename for the data file (in the example below, **FlexiForceDataFile-01.txt**). Then click the **OK** button (shown below).



The data from the file is loaded into the worksheet. The numerical data is displayed on the left side of the screen, and the data is plotted on the graph on the right side of the screen (shown below).



Note: You can load another file at any time by clicking the Load FlexiForce Data, entering a new file name, and clicking OK. The data from the new file overwrites the data from the old file.

SUPPORT

Write, call, or fax us with any concerns or questions. Our knowledgeable support staff is happy to help you. Comments and suggestions are always welcome.

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