

Using Arduino & LabView for Teaching MEMS Devices

Andrew G. Bell

July 28, 2016



**CHANGING LIVES
MAKING INDIANA GREAT**

Ivy Tech Community College is Indiana's largest public postsecondary institution and the nation's largest singly accredited statewide community college system. Ivy Tech serves nearly 200,000 students annually and has campuses throughout Indiana.

We offer Associates of Science degrees in:

Electrical Engineering Technology
Mechanical Engineering Technology
Engineering Technology
Pre- Engineering
Nanotechnology
Design Technology

over 40 degree programs



What is an Arduino?

So what is an Arduino?

Arduino is a inexpensive Microcontroller CCA that interface to your PC via USB

They typically cost ~ 20 to 25 and are available many places online

Software to program them is free, open source. <https://www.arduino.cc/>

Arduino Uno (and other models) have daughter boards call “shields” that you can stack

Shield include Motor Drives, Prototype boards, Displays, etc.

Arduino microcontrollers have become very popular with hobbyist, students and colleges.

<http://www.jameco.com/>

<https://www.adafruit.com/>

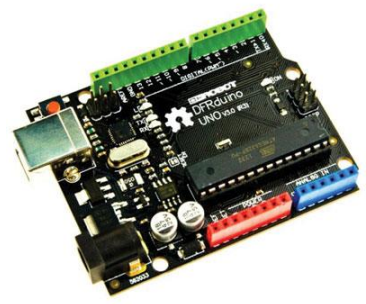
<http://www.elexp.com>



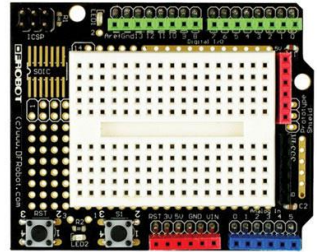
What is an Arduino?

Arduino Uno Rev3 is a 8-bit microcontroller board based on the ATmega328P,

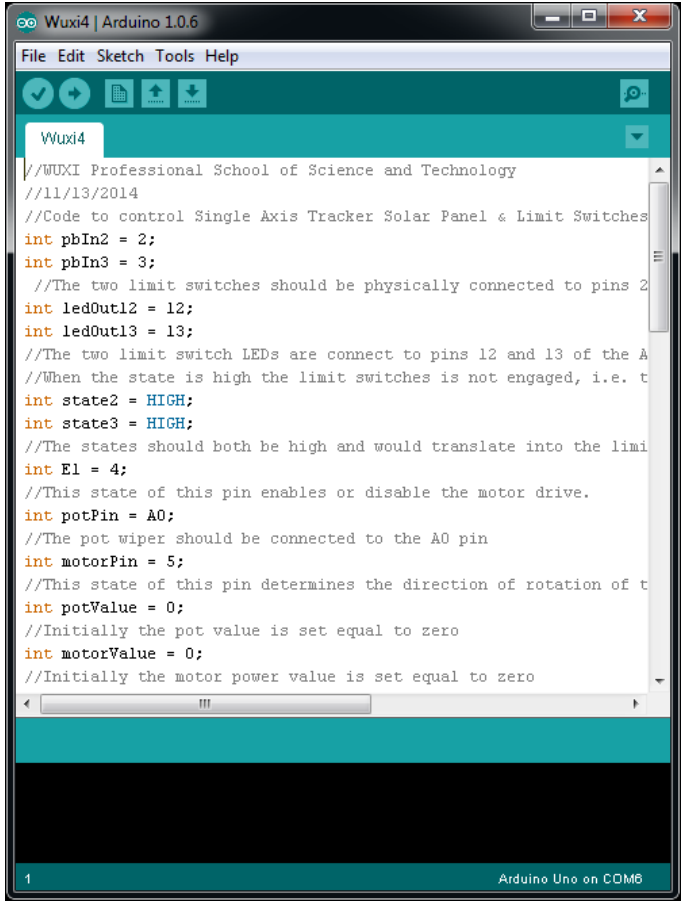
Specification	
Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage	7-12V
Digital I/O Pins	14
Analog Input Pins	6
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz
PC Interface	USB



Arduino Uno



Prototype Shield

A screenshot of the Arduino IDE software interface. The window title is 'Wuxi4 | Arduino 1.0.6'. The menu bar includes 'File', 'Edit', 'Sketch', 'Tools', and 'Help'. The code editor shows a sketch for a solar panel tracker. The code includes comments in Chinese and C++ code for pin definitions and state management. The status bar at the bottom indicates '1' and 'Arduino Uno on COM8'.

```
Wuxi4
//WUXI Professional School of Science and Technology
//11/13/2014
//Code to control Single Axis Tracker Solar Panel & Limit Switches
int pbIn2 = 2;
int pbIn3 = 3;
//The two limit switches should be physically connected to pins 2
int ledOut12 = 12;
int ledOut13 = 13;
//The two limit switch LEDs are connect to pins 12 and 13 of the A
//When the state is high the limit switches is not engaged, i.e. t
int state2 = HIGH;
int state3 = HIGH;
//The states should both be high and would translate into the limi
int E1 = 4;
//This state of this pin enables or disable the motor drive.
int potPin = A0;
//The pot wiper should be connected to the A0 pin
int motorPin = 5;
//This state of this pin determines the direction of rotation of t
int potValue = 0;
//Initially the pot value is set equal to zero
int motorValue = 0;
//Initially the motor power value is set equal to zero
```

<https://www.arduino.cc/en/Main/ArduinoBoardUno>

What is LabView?

LabView is a graphical programming language made by National Instruments (NI)

<http://www.ni.com/labview/>

Designers can use LabView to build custom compiled software.

LabView training has three basic level: LabView Core 1, 2 and 3

LabView can be used for control, data acquisition and displaying results using custom

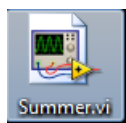
LabView can interface with other NI software and hardware products use in both educational and industry

LabView can also be used with microcontrollers like the Arduino Uno

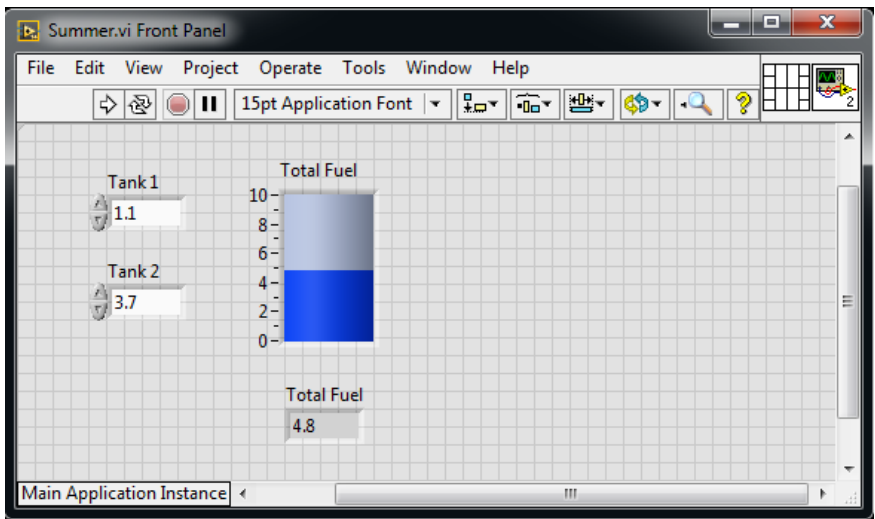
Support for this is now provided by MakerHub @ <https://www.labviewmakerhub.com/>



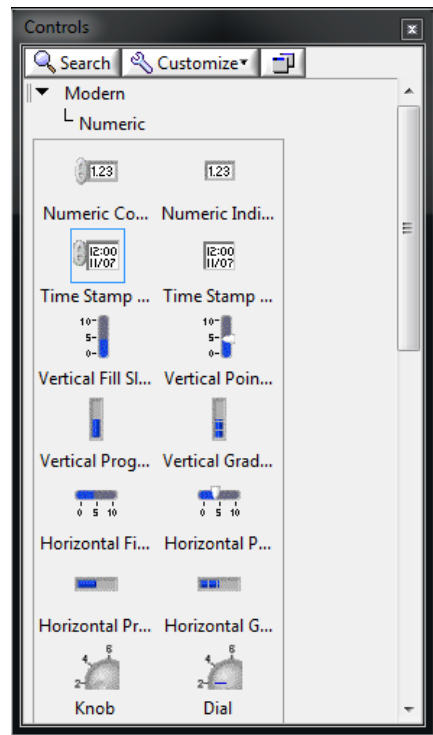
What is LabView?



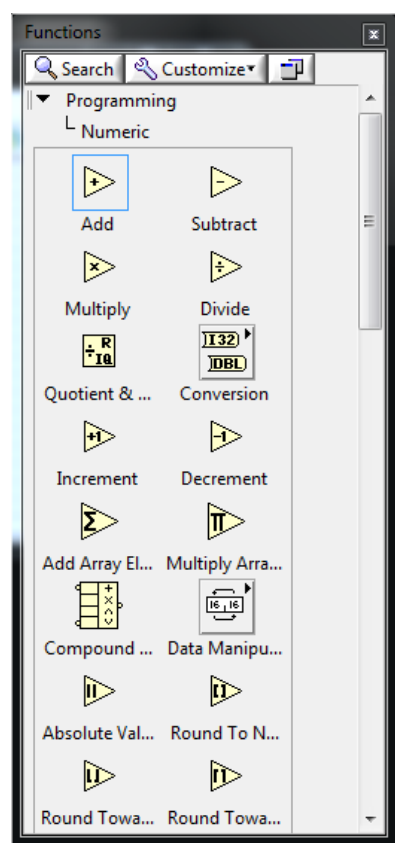
GUI Interface



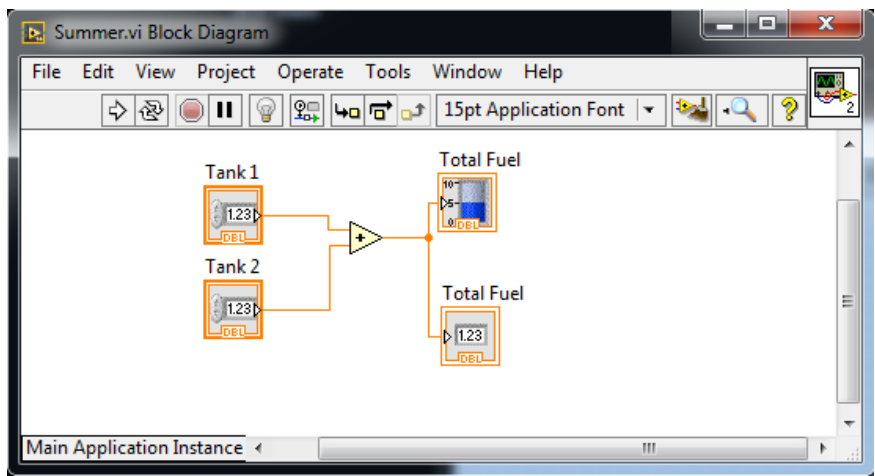
GUI Controls



Numeric Functions



Graphical Program



What are MEMS?

MEMS stands for MicroElectroMechanicalSystems

MEMS from my perspective are sensors: pressure, accelerometer, gyroscope, etc.

They also include actuators and transducers

MEMS are microscopic devices that contain both electronics and mechanical parts

They translate physical, environmental phenomena into electrical signals

They are manufactures using the same types of ways that semiconductor devices are made: photolithography, etching, deposition, lift-off

MEMS are used in automotive, defense, biomedical, etc.

MEMS devices are based on the same type of electrical and mechanical principles as can be found in the macro world.

<http://www.scme-nm.org>

Ivy Tech started its associating with SCME in the Fall of 2012 and has been a Co-PI on Southwest Center for Microsystem Education (SCME) NSF ATE Grant.

MEMS Kits Implementation Plan IVY TECH (Fort Wayne & Valparaiso)								
		ENGT 120	METC 111	METC 143	EECT 111	EECT 112	ENGR 251	ENGT 279
1	MEMS: Making Micro Machines Kit	X						
2	Dynamic Cantilever Kit		X	X			X	
3	Crystallography Kit			X				
4	Pressure Sensor Model Kit	X			X	X	X	
5	GeneChip Model Kit	X						
6	MEMS Innovators Kit							X
7	Lift-off Kit			X	X			
8	Pressure Sensor Process Kit				X			
9	LIGA Micromachining Simulation Kit			X				
10	Anisotropic Etch Kit			X	X			
11	Rainbow Wafer Kit	X						

The scope of our effort was to integrate the SCME material into some of our engineering programs courses

Ivy Tech started its associating with SCME in the Fall of 2012 and has been a Co-PI on Southwest Center for Microsystem Education (SCME) NSF ATE Grant.

Microcantilever Model Kit

This kit contains most of the materials for the Microcantilever Model Activity in Book 2 of the *Microcantilever Learning Module*. This activity provides participants an opportunity to explore the motion of a cantilever under a varying mass and to determine the relationship that expresses the resonant frequency of a cantilever as a function of mass. This activity simulates the dynamic mode of operation for microcantilevers used in MEMS sensors.

Modeling a Micro Pressure Sensor Kit

This kit contains most of the materials for the Modeling a Micro Pressure Sensor Activity in the *Micro Pressure Sensors and the Wheatstone Bridge Learning Module*. This activity provides participants an opportunity to study how a micro pressure sensor works and how a change in pressure affects the output of a Wheatstone bridge sensing circuit. Participants build a macro-size pressure sensor model with a Wheatstone bridge sensing circuit using pencil lead (graphite), rubber cement, a balloon (diaphragm), and a paint can (substrate). Participants test the operation of the model by creating calibration curves of the output of the sensing circuit as pressures are applied to the diaphragm.

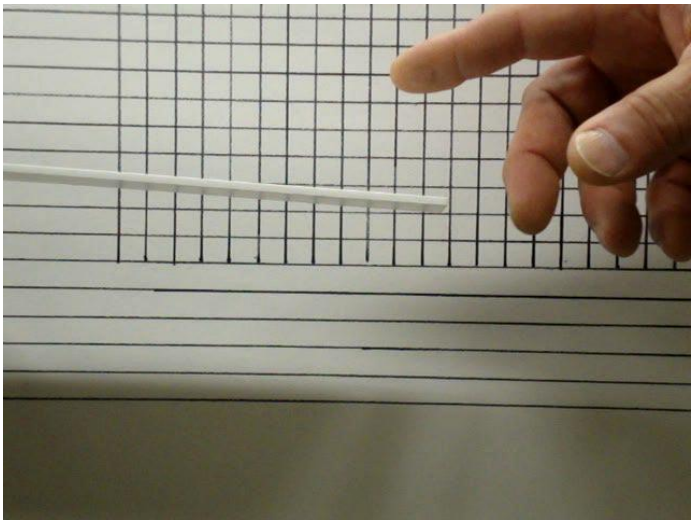
Crystallography Kit

This kit contains the materials for two activities in the *Crystallography Learning Module*. Through these activities, participants explore the crystal structure of silicon. In *Breaking Water*, participants determine the crystal orientation of two silicon wafers by carefully breaking the wafers and identifying the crystal planes on which the wafers break.

In *An Octahedral Crystal*, participants construct a 3-dimensional representation of a silicon crystal showing the different crystal planes as defined by Miller indices.

www.scme-nm.org

In Fort Wayne we have used three basic kits:



In 2014 we decided to develop supplemental data acquisition electronics for two of the kits.

Reasons

 To improve on data collection of the experiments

 Add more "electronics" to the kit material

Approach

Use LabView and Arduino micro-controllers

Reasons

 Knowledge of LabView can help students get a job

 Arduinos are cheap, popular and very flexible



Microcantilever Model Kit
This kit contains most of the materials for the Microcantilever Model Activity in Book 2 of the Microcantilever Learning Module. This activity provides participants an opportunity to explore the motion of a cantilever under a varying mass and to determine the relationship that expresses the resonant frequency of a cantilever as a function of mass. This activity simulates the dynamic mode of operation for microcantilevers used in MEMS sensors.

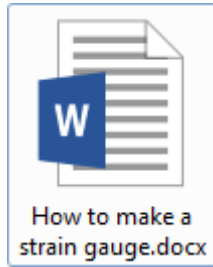
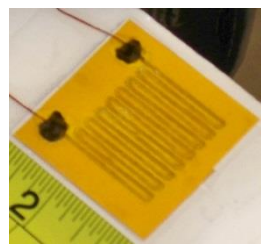
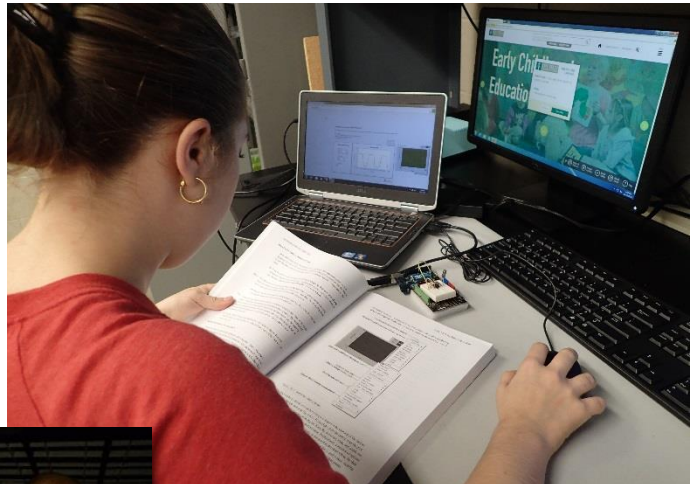
Modeling a Micro Pressure Sensor Kit
This kit contains most of the materials for the Modeling a Micro Pressure Sensor Activity in the Micro Pressure Sensors and the Wheatstone Bridge Learning Module. This activity provides participants an opportunity to study how a micro pressure sensor works and how a change in pressure affects the output of a Wheatstone bridge sensing circuit. Participants build a macro-size pressure sensor model with a Wheatstone bridge sensing circuit using pencil lead (graphene), rubber cement, a balloon (diaphragm), and a paint can (substrate). Participants test the operation of the model by creating calibration curves of the output of the sensing circuit as pressures are applied to the diaphragm.



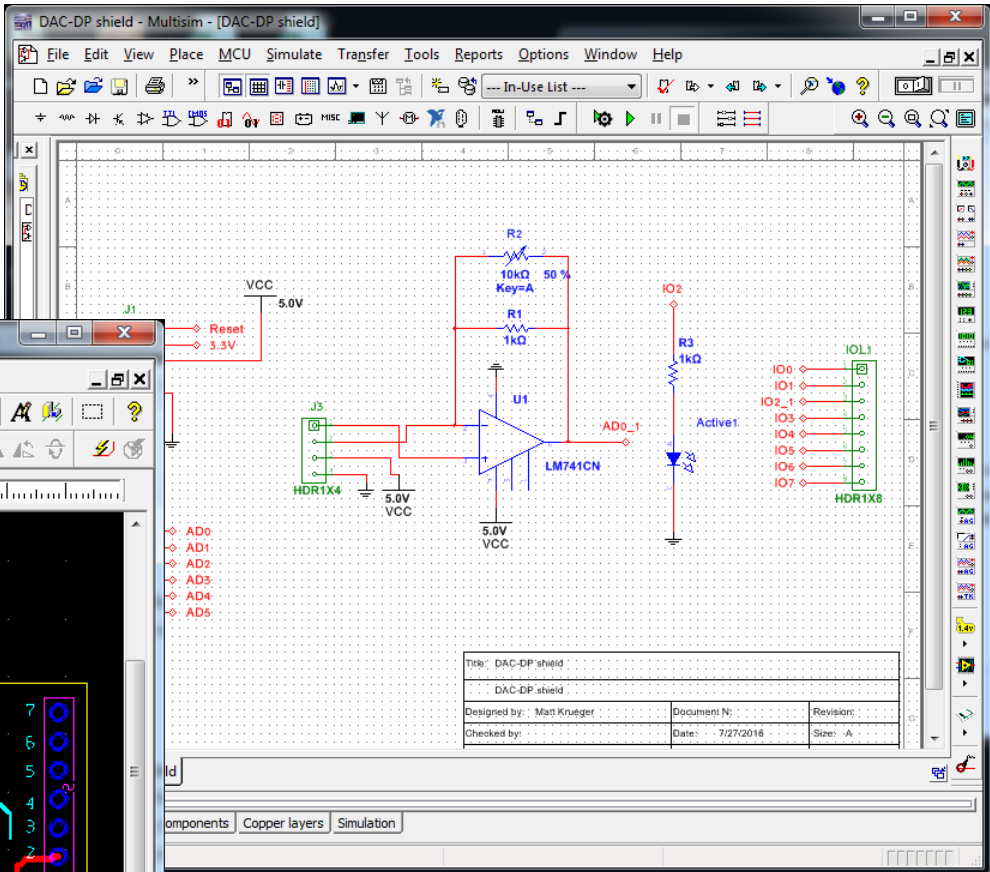
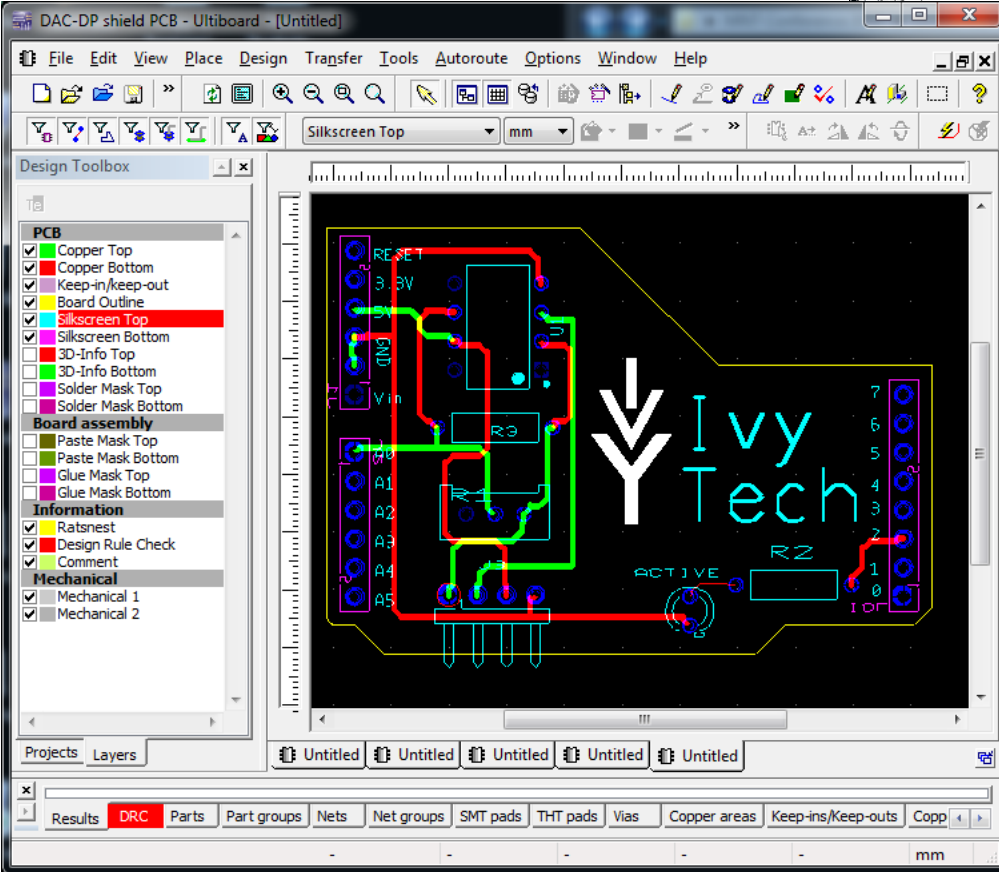
MEMS: Data Acquisition Kit
This kit is an electronic extension of the SCME pressure sensor model kit. DAC-DP interface module and LabView software allows the SCME pressure sensor model kit to interface to a computer provides a graphical display pressure sensor differential output voltage. Includes - Arduino Uno based DAC-DP interface module, instruction manual, executable LabView Data acquisition software, USB cable, and pressure sensor interface cable.

Use Discovery Based Learning Approach

- 1.) Give students general idea and requirements for design
- 2.) Provide students with resources to design, build and test
- 3.) Provide feedback as needed but don't micromanage
- 4.) Allow students time to learn, fail and succeed
- 5.) Provide positive feedback and recognition
- 6.) Step back and let them learn ...



Multisim schematic Ultiboard PWB



The new DAC-DP Kit for Pressure Sensor Kit

Includes - Arduino Uno based DAC-DP interface module, instruction manual, Executable LabView Data acquisition software, USB cable, and pressure sensor interface cable.

Wheatstone bridge (Serial Interface)

This program will graph the output of a Wheatstone Bridge

Instructions

1. Select the COM Port associated with the device.
2. Click the Run Arrow.
3. Adjust the Sample rate using the control knob

Connection Diagram

This is a simulated wheatstone bridge

This is the basic form of the arduino shield

Device Settings

Serial Port: COM26

Sample Rate: 100

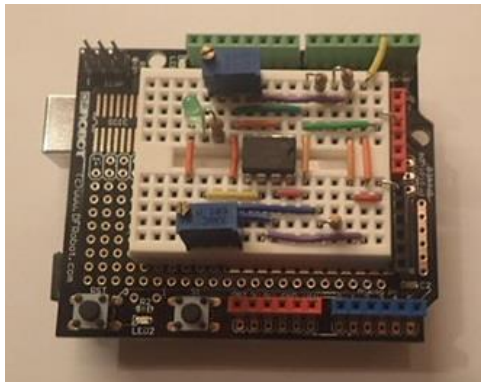
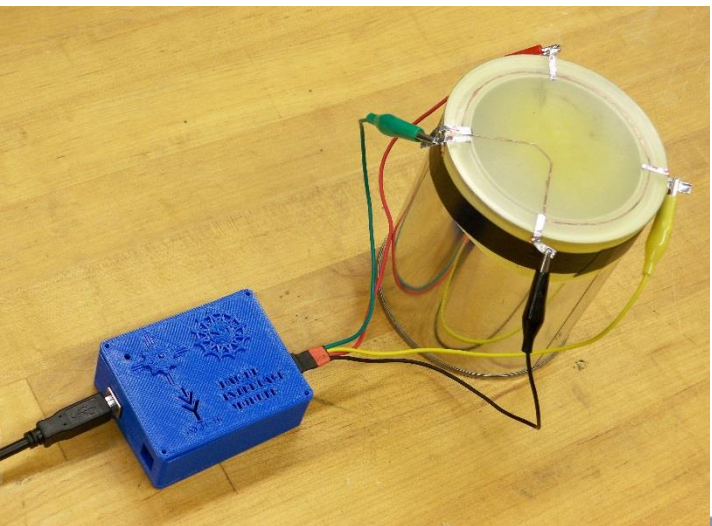
Analog Value

Amplitude vs Sample graph showing a fluctuating signal between 1.5 and 4.0.

0.00

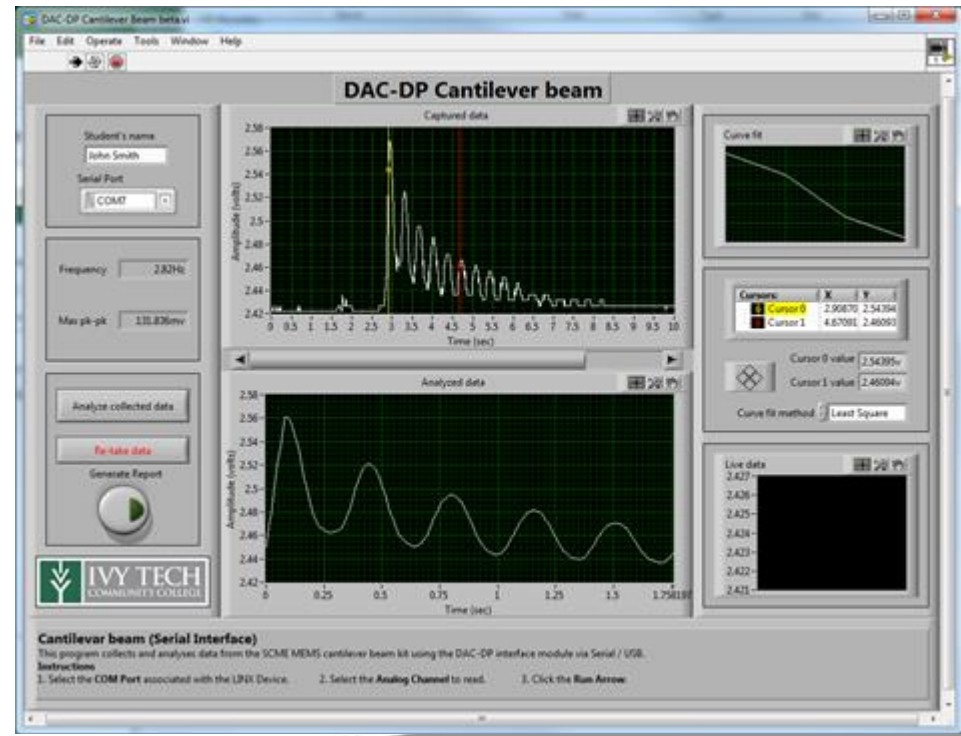
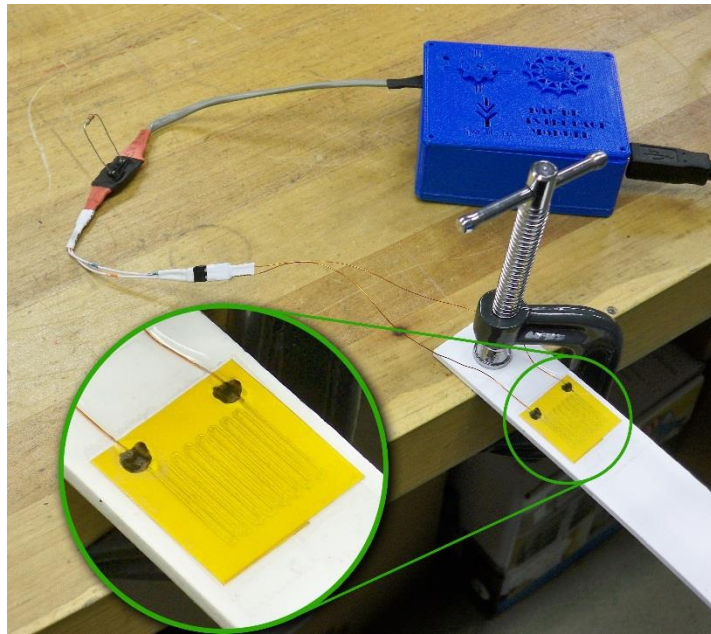
0 Samples per second

Stop



The new DAC-DP Kit for Cantilever Kit

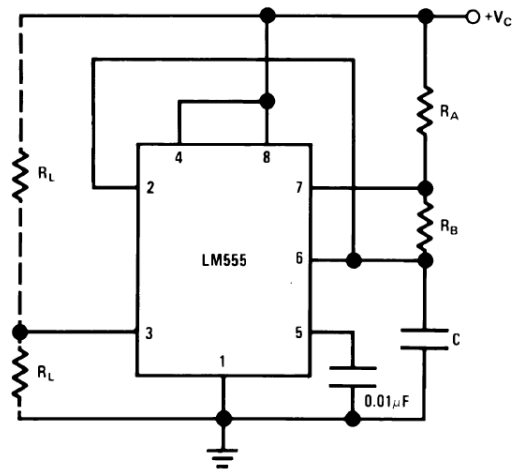
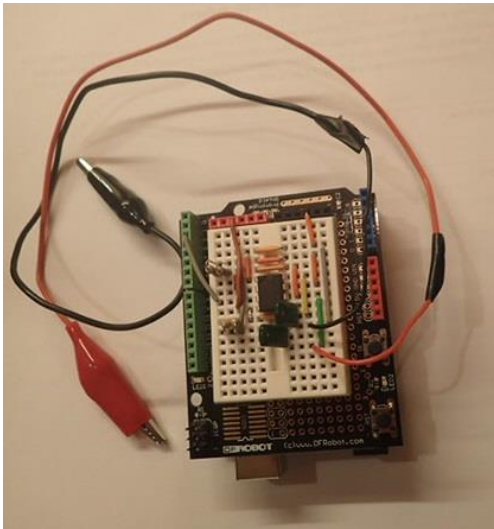
Includes - Arduino Uno based DAC-DP interface module, instruction manual, executable LabView Data acquisition software, USB cable, and Cantilever beam Strain gauge interface – Discovered “How to make a Strain Gauge”



New Variable Capacitor design

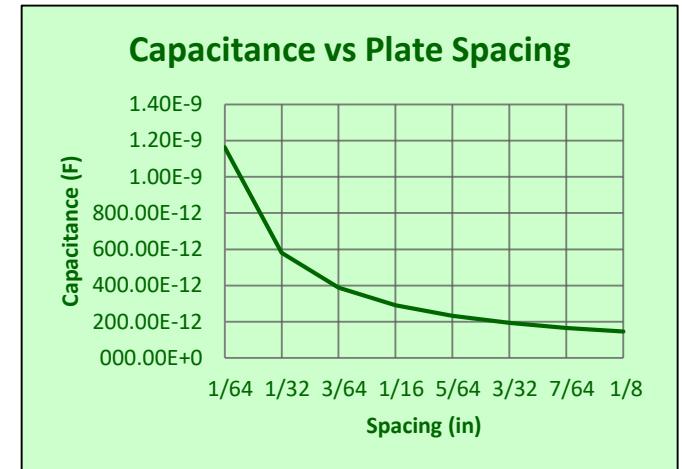
Can use same code as Cantilever LabView code

Based on common 555 Timer design



DS007851-8

FIGURE 4. Astable



New Variable Inductor design

Want to use same code as Cantilever LabView code

Could be based on oscillator design

Could be based on LCR design

Could be based on DC-DC converter design

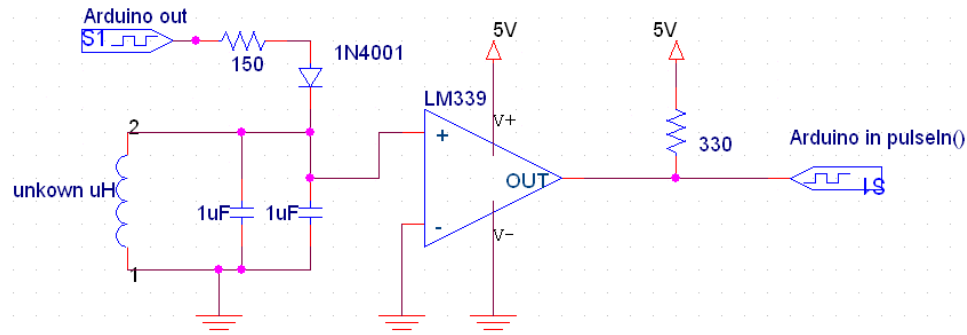
<http://langster1980.blogspot.com/2013/07/arduino-lc-meter-shield.html>

<https://forum.arduino.cc/index.php?topic=80357.0>

<http://mchp.blogspot.com/2014/11/arduino-rclf-meter.html>

<http://hackaday.com/2011/07/24/using-an-arduino-to-measure-inductance/>

<https://reibot.org/2011/07/19/measuring-inductance/>





Building more electronic kits based on Arduino and LabView

Developing three new MEMS course to focus on “how to use MEMS devices” with electronics

Continue to use discovery based learning

<http://www.scme-nm.org/>

<http://www.ivytech-mems.org/>



Andy Bell
Department Chair – Engineering
Ivy Tech Community College – Northeast
Phone: 260-481-2288 : Fax: 260-480-2052 : abell118@ivytech.edu
SDKB Technology Center, Room TC1240R, 3800 N. Anthony Blvd.,
Fort Wayne, IN 46805

