ACOUSTIC SPOKE TENSIOMETER FOR BICYCLE WHEELS

Andrius Bobbit

Sakeb Kazi

Xi Li

Objective

- Eliminates clamping of spokes
- Rapid measurement
- Easy recording of data
- No calculation required

Source: http://harriscyclery.net/merchant/370/images/large/tm1.jpg

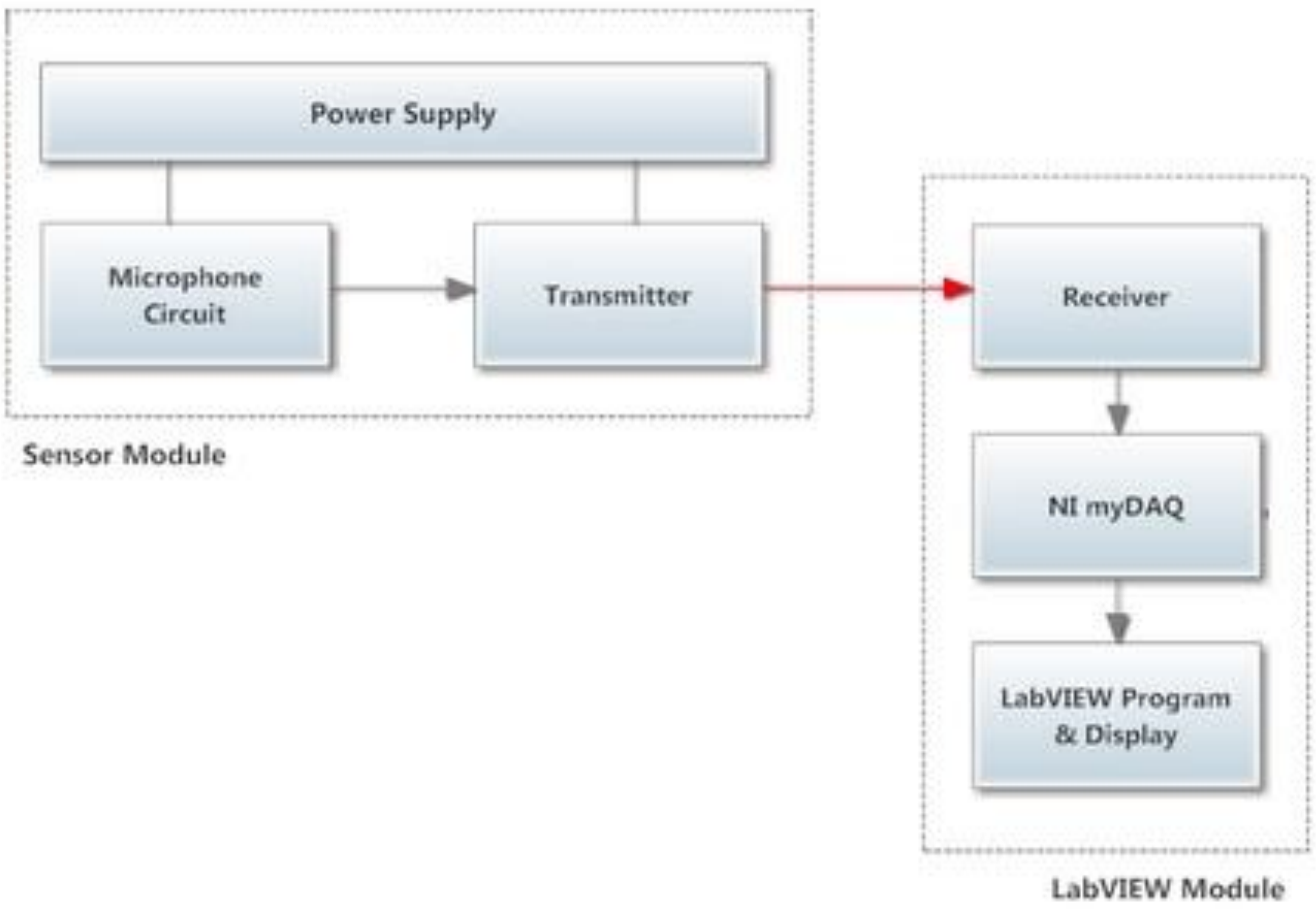
Features

- Wireless modules
- Consistent measurements
- Records data automatically
- Displays multiple parameters

Original Design Review

- A keypad matrix for user input was removed
  - Unnecessary because LabView is running on a computer which usually includes a keyboard
- An infrared spoke length measuring device was removed
  - Cluttersome, not practical
- Added On/Off Switch
  - Power supply needed a simple way to shut off to save energy

System Overview



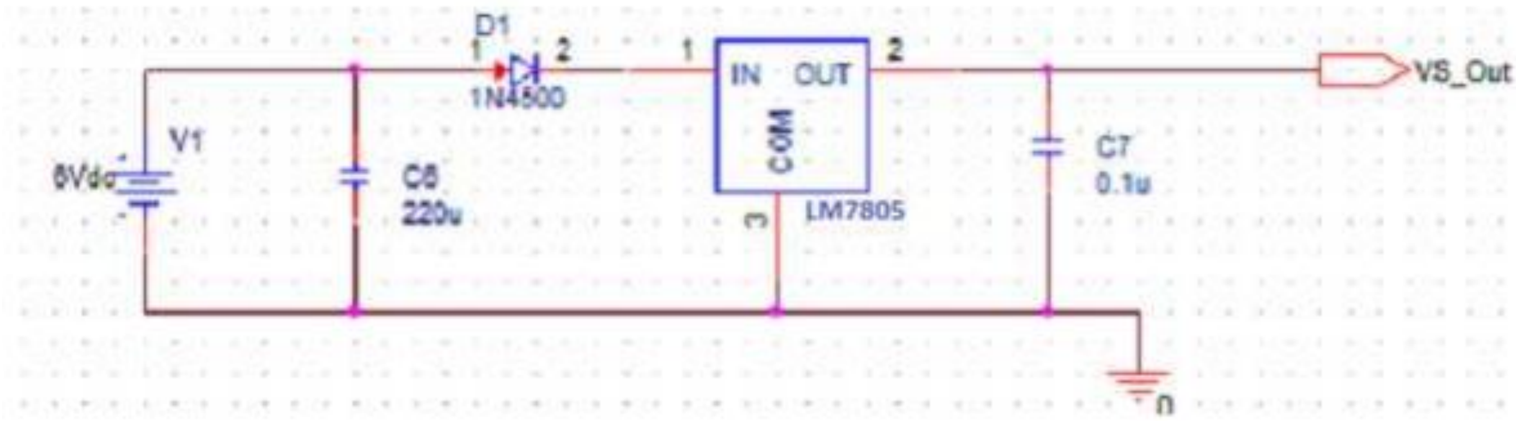
Sub-systems

Mic/Transmitter	Receiver	Labview
9V Battery Power Supply	Wireless Receiver, Antenna	myDAQ
Microphone, Audio Amplifier	3.5mm Jack	LabVIEW
Wireless Transmitter, Antenna		

Power Supply

- Based on a linear regulator
- Regulates power from a 9 volt battery to provide a constant 5 volts
- Limits the current to 1 amp

Power Supply Schematic

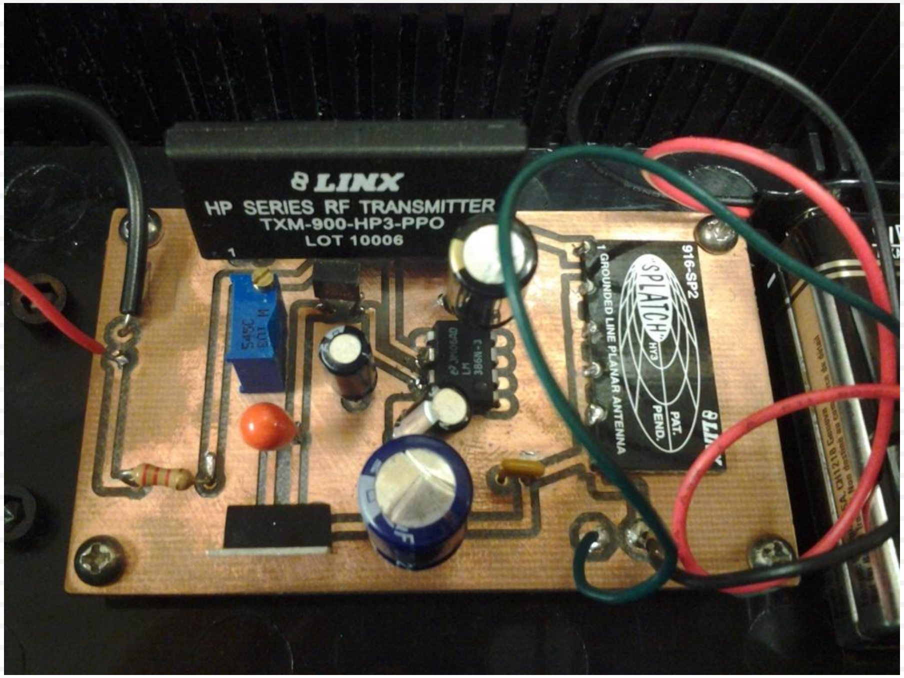


Power Supply Test

V_s (V)	Vout (V)	V_{out} With Diode (V)
5	3.57	2.65
6	4.46	4.11
7	4.96	4.96
8	4.96	4.96
9	4.96	4.96
10	4.97	4.97

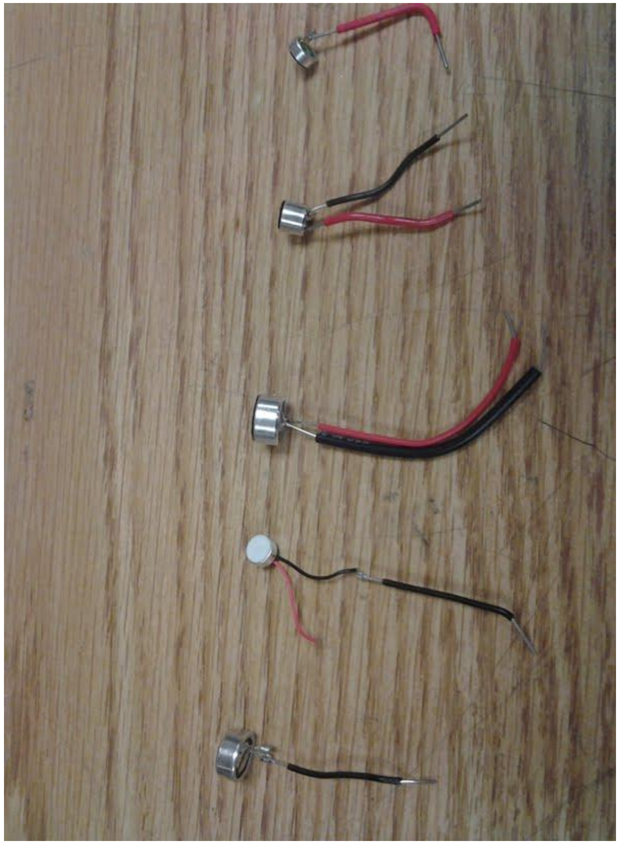
Microphone-Amplifier

- Picks up Resonant frequencies
- Amplifies voltage output from mic
- Interfaces with the Transceiver modules



Microphone Selection

- Small form factor
- Able to pick up frequencies between 100 Hz – 1000 Hz
- Highest possible voltage output at given distance
- Relatively flat frequency response throughout



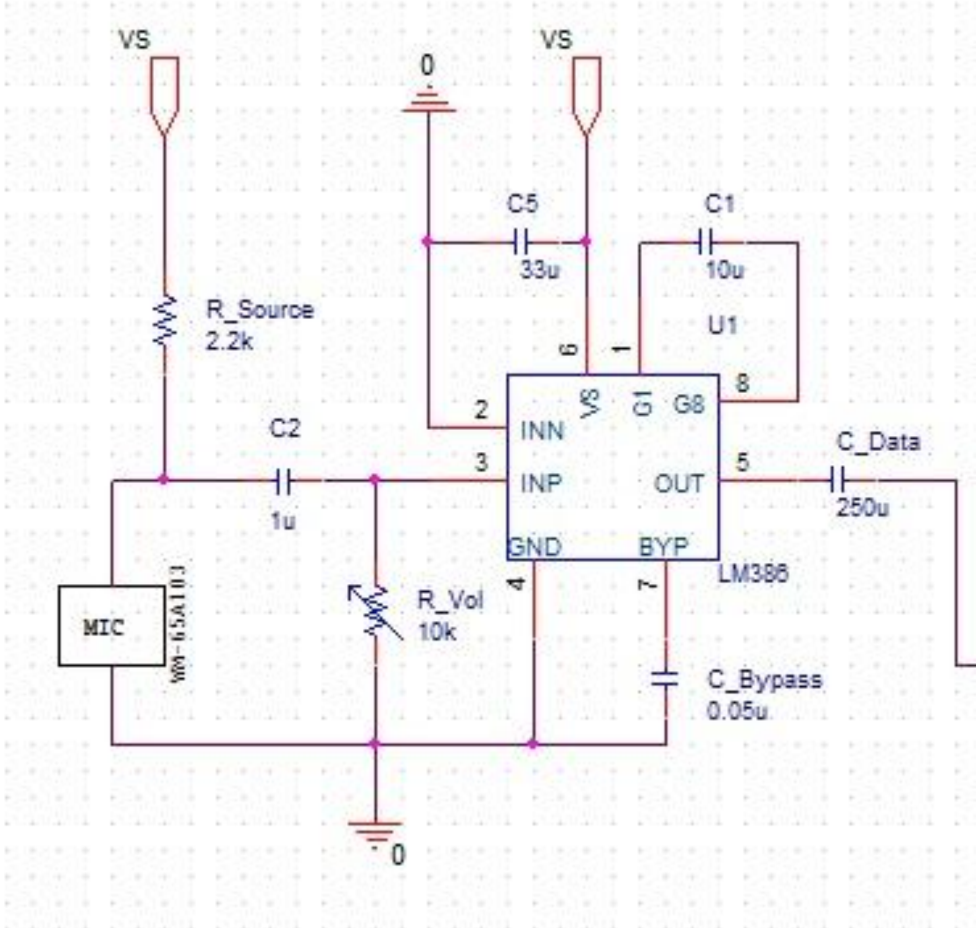
Microphone Test

Model Name	Directionality	Source Frequency (Hz)	Max Distance (cm)	Amplitude (uV)
WM65A	Omni	196	91.5	35
		493.8	92.8	40
		987	84	60
WM55D	Uni	196	13	50
		493.8	45.3	50
		987	73.9	48
CMI-5247	Uni	196	89.1	75
		493.8	150	105
		987	148	85
CMC-2242	Omni	196	0.1	650
		493.8	11.5	800
		987	5.4	600
54C6	Omni	196	NA	NA
		493.8	0.5	1500
		987	NA	NA

Amplifier

- Op-amp based design
- Ensure correct resonant frequency transmitted
- Minimizes effect of ambient noise
- Limit effective error in tension calculation

Amplifier Schematic



- **R_Source** | Pull Up Resistor
- **C2** | Input Coupling Capacitor
- **R_Vol** | Variable Gain Resistor
- **C5** | Decoupling Capacitor
- **C1** | Gain Capacitor
- **C_Bypass** | Bypass Capacitor
- **C_Data** | Output Coupling Capacitor
- **LM386** | Instrumentation Amplifier

Factors Affecting Amplifier Performance

- **R_Vol |** Variable Gain Resistor
- **C1 |** Gain Capacitor
  - Bypasses internal1.35 kΩ resistor between pin 1 and 8, with default gain at 20
  - Provides a low impedance path
  - Effectively removes the 1.35 kΩ resistor from the signal path allowing the internal 150 kΩ resistor to set the gain at 200

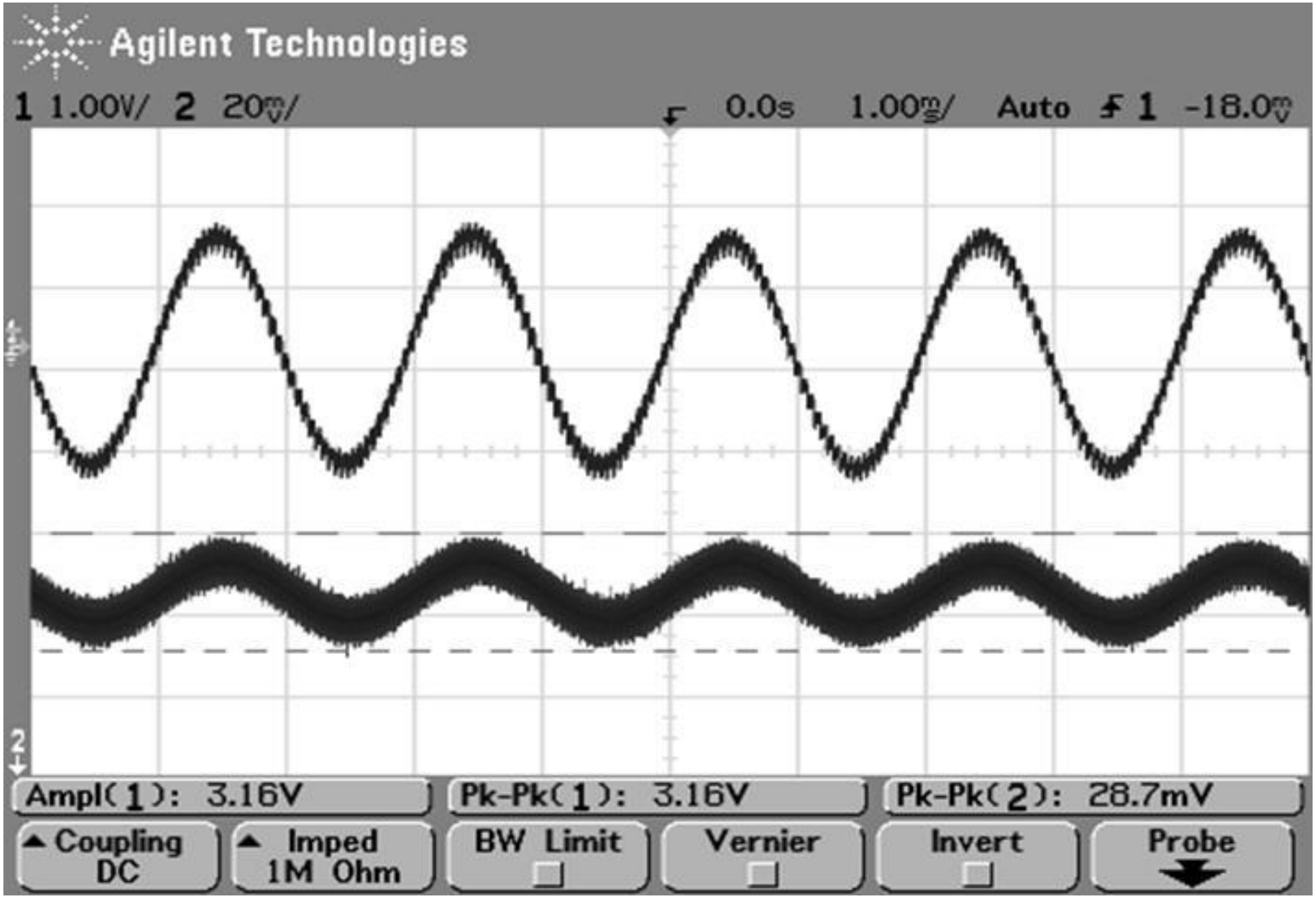
Factors Affecting Amplifier Performance

- Magnitude of **C1 | Gain Capacitor**
  - The smaller the value, the more low end frequencies get cut off:

$$f = \frac{1}{2\pi C X_c}$$

  - Do not want too small a value for C1, which results in a large cutoff frequency – Undesirable

Amplifier Test



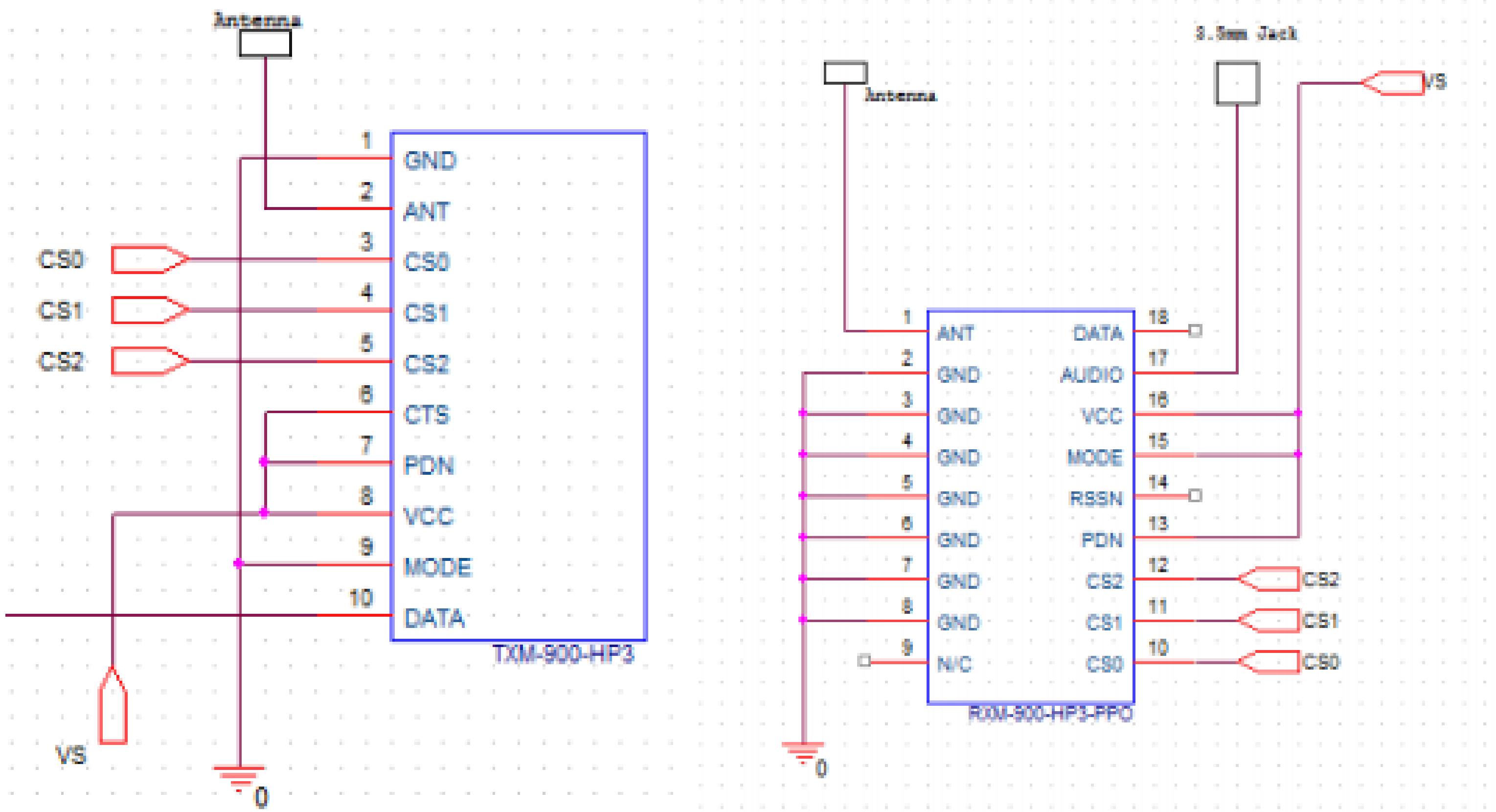
Mic-Amp Recommendations

- Try different microphones even if they look identical in terms of specifications
- Trade-offs between uni-directional and omni-directional depending on application
- The cutoff frequency of the amplifier should be set much lower than the lowest values in the desired frequency range

Transceiver Module

- Allows wireless communication between the recording unit and the analysis unit.
- Makes device easier to set up in a shop.

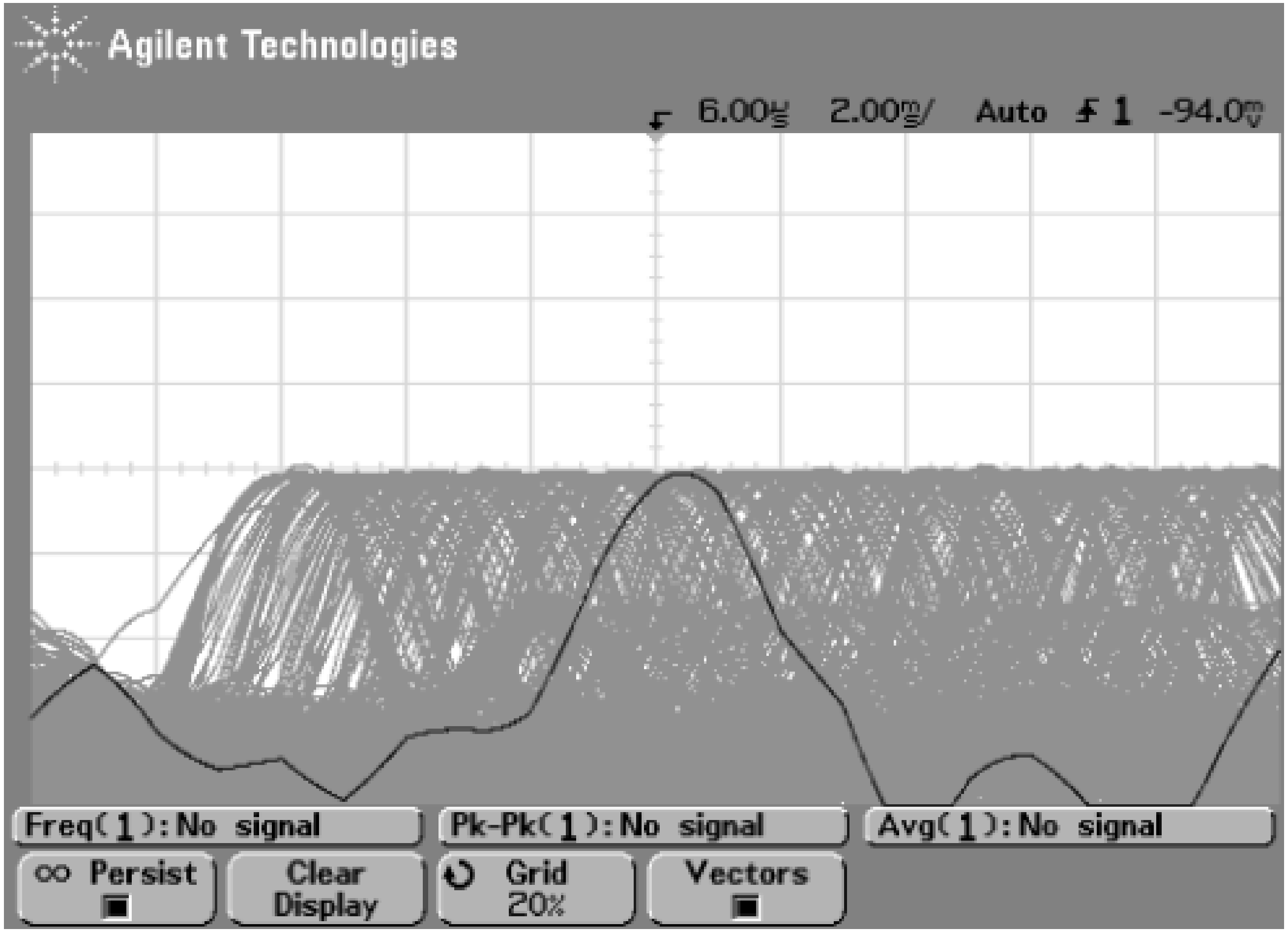
Transceiver Schematic



Transceiver Setup Details

- Transmitter chip set to continuously transmit a signal as long as the power is switched on.
- Set for parallel channel selection using
  - [C0 C1 C2] = [1 0 0] (f=906.37 Hz)
- Connected to Linx SP series surface mount antennas.
- Used the receiver's analog output connected to a 3.5mm jack to provide signal to a myDaq for processing.

Transceiver Testing



Transceiver Performance

- Worked without issue for a range of 25+ feet.
- When hooked up to myDaq unit output an ambient noise ~10 uV.
- Flat signal response for 20 to 1000 Hz range.
- No noticeable distortion of signal from outside sources.

Transceiver Recommendations

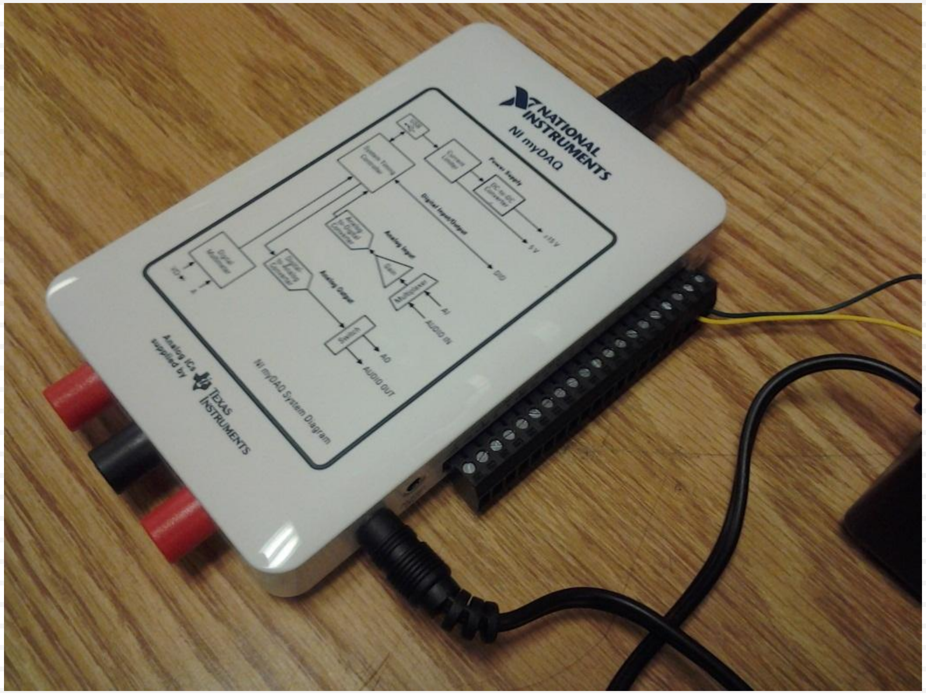
- Switches for channel select inputs to allow for user selection of transmission frequency.
- Trade-offs associated with antenna selection. Surface mount chips keep the size of the module small but reduce operation range.

LabVIEW/myDAQ Module

- Receiver outputs signal to the myDAQ
- LabView performs signal processing on the data
- A user friendly interface will be created

myDAQ

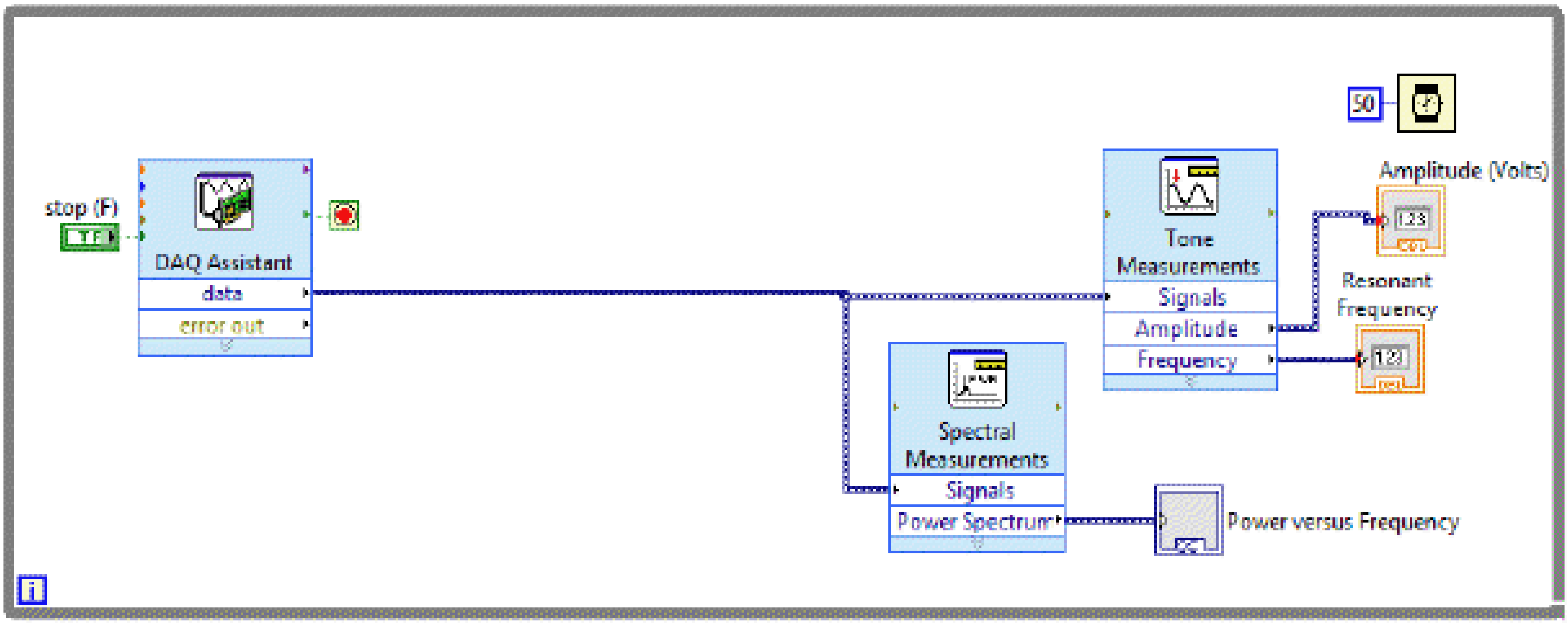
- The NI myDAQ board will supply 5 Volts power to the receiver module
- The outputted signal will be connected to the AUDIO IN jack of the myDAQ via 3.5mm cable
- The myDAQ connects to a computer with LabView via a USB cable



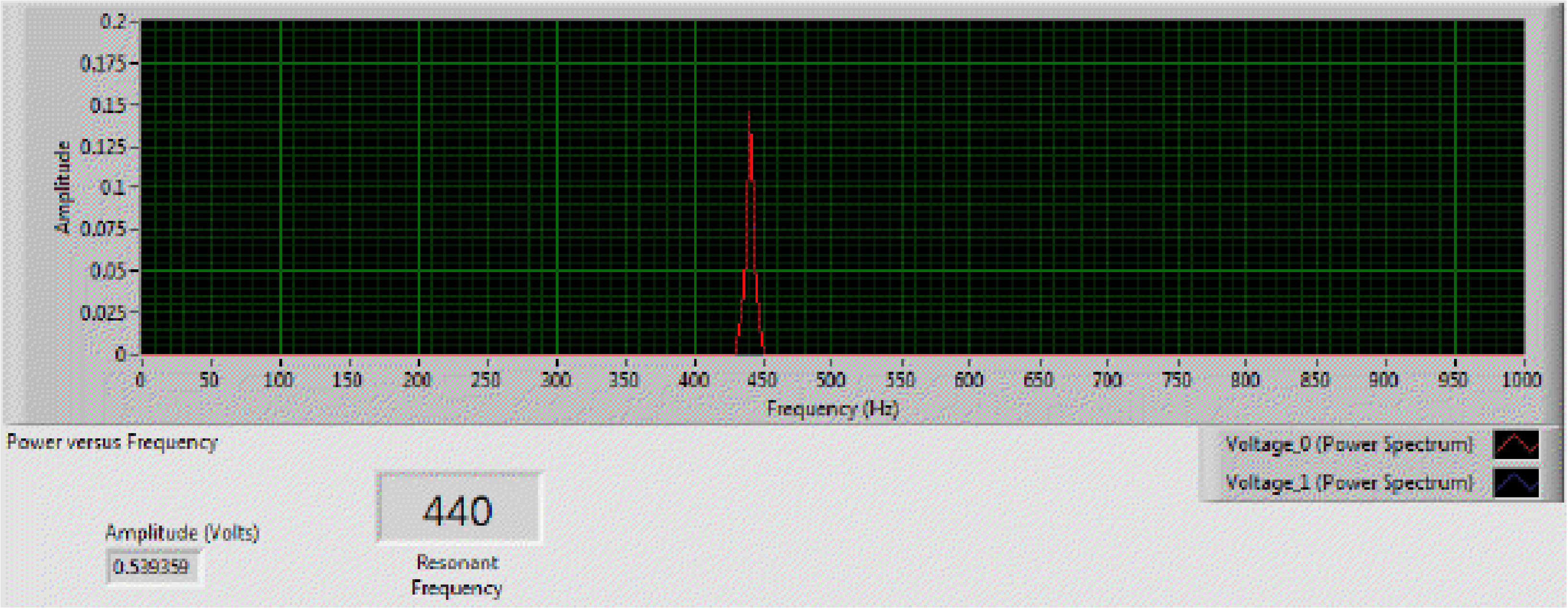
LabView

- Power software tool that allows processing of signals through graphical coding
- Allows for unique customization of analyzed data
- Provides flexibility for user input

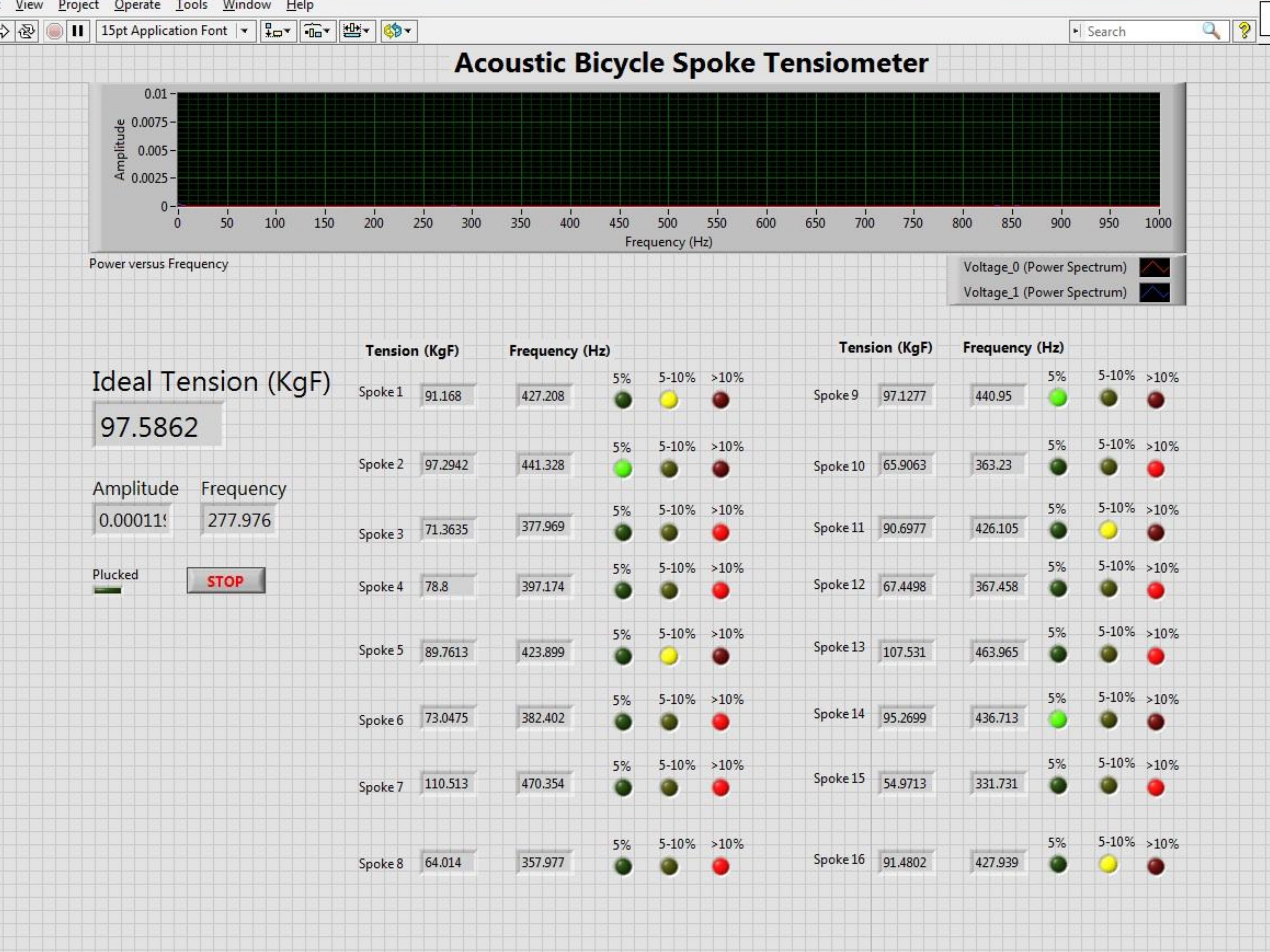
Signal Processing



Testing

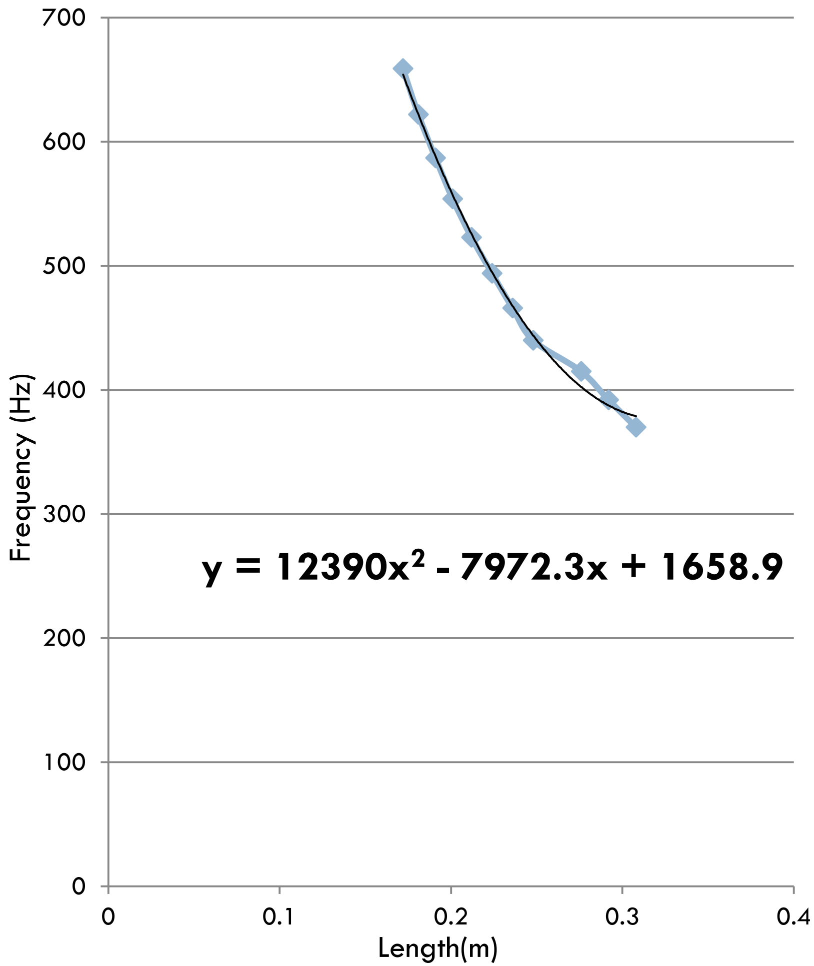


- A signal was generated by online software and was inputted into the myDAQ to see if LabView processed it successfully

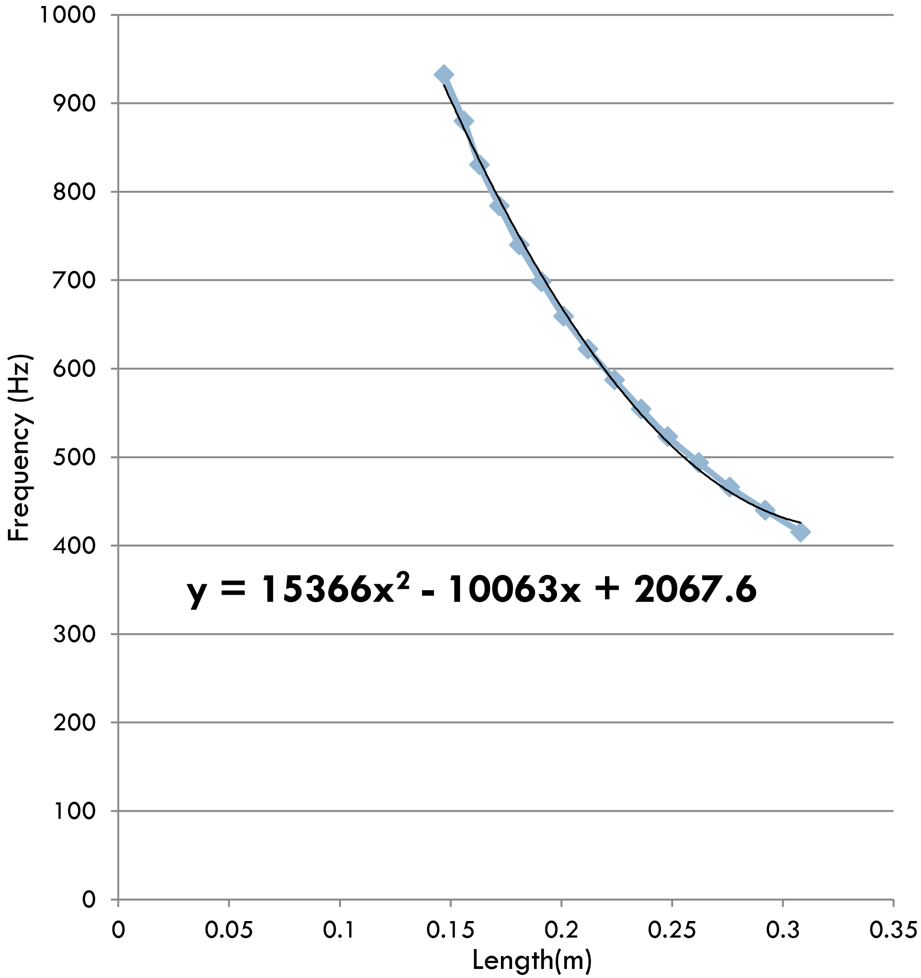


View Project Operate Tools Window Help
15pt Application Font
Search
Acoustic Bicycle Spoke Tensiometer
Amplitude
0.01
0.0075
0.005
0.0025
0
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1000
Frequency (Hz)
Power versus Frequency
Voltage_0 (Power Spectrum)
Voltage_1 (Power Spectrum)
Ideal Tension (KgF)
97.5862
Amplitude
0.00011
Frequency
277.976
Plucked
STOP
Tension (KgF) Frequency (Hz)
5% 5-10% >10%
Spoke 1 91.168 427.208
Spoke 2 97.2942 441.328
Spoke 3 71.3635 377.969
Spoke 4 78.8 397.174
Spoke 5 89.7613 423.899
Spoke 6 73.0475 382.402
Spoke 7 110.513 470.354
Spoke 8 64.014 357.977
Spoke 9 97.1277 440.95
Spoke 10 65.9063 363.23
Spoke 11 90.6977 426.105
Spoke 12 67.4498 367.458
Spoke 13 107.531 463.965
Spoke 14 95.2699 436.713
Spoke 15 54.9713 331.731
Spoke 16 91.4802 427.939

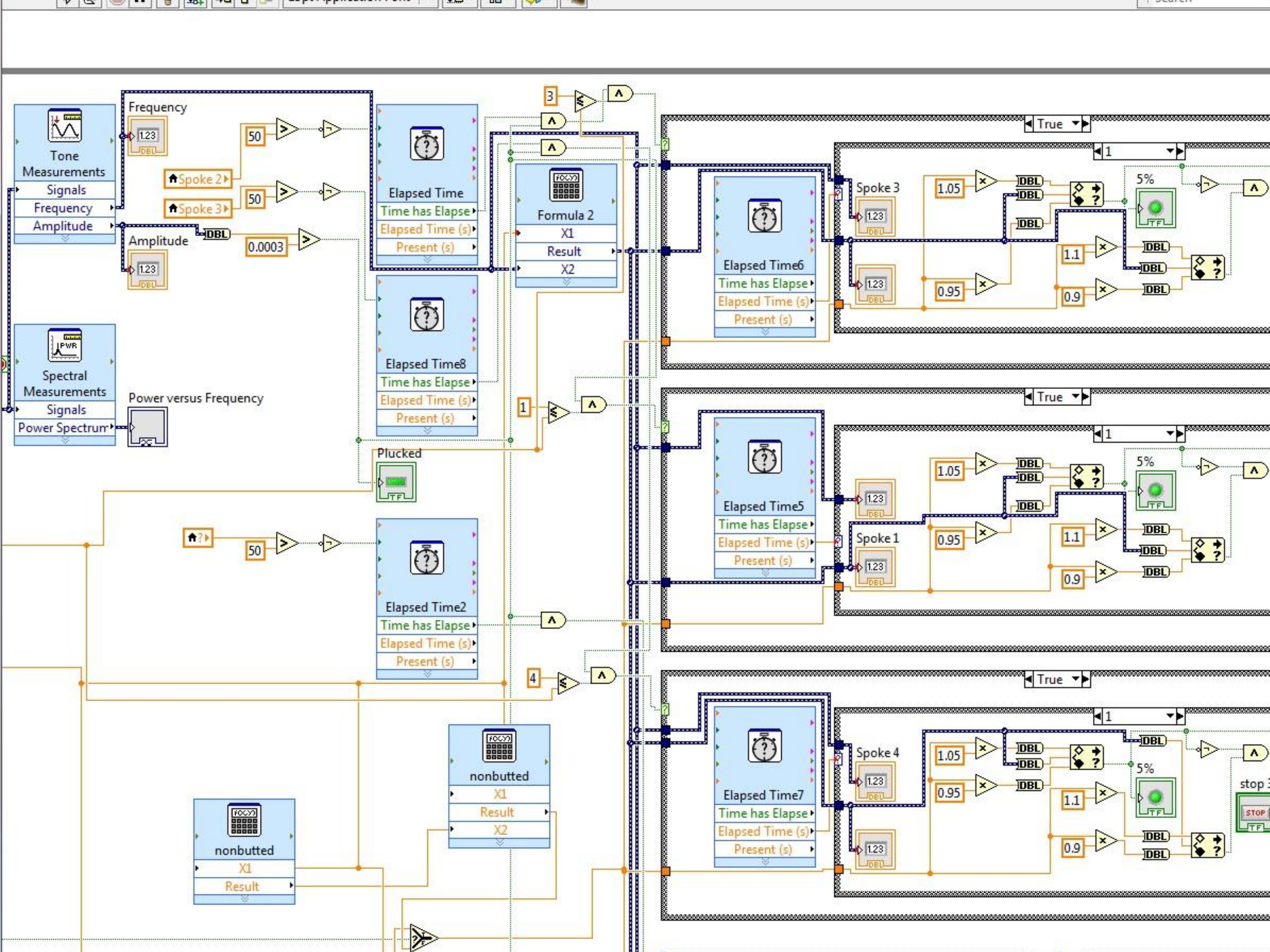
Ideal Tension Formulas



Butted



Non-Butted

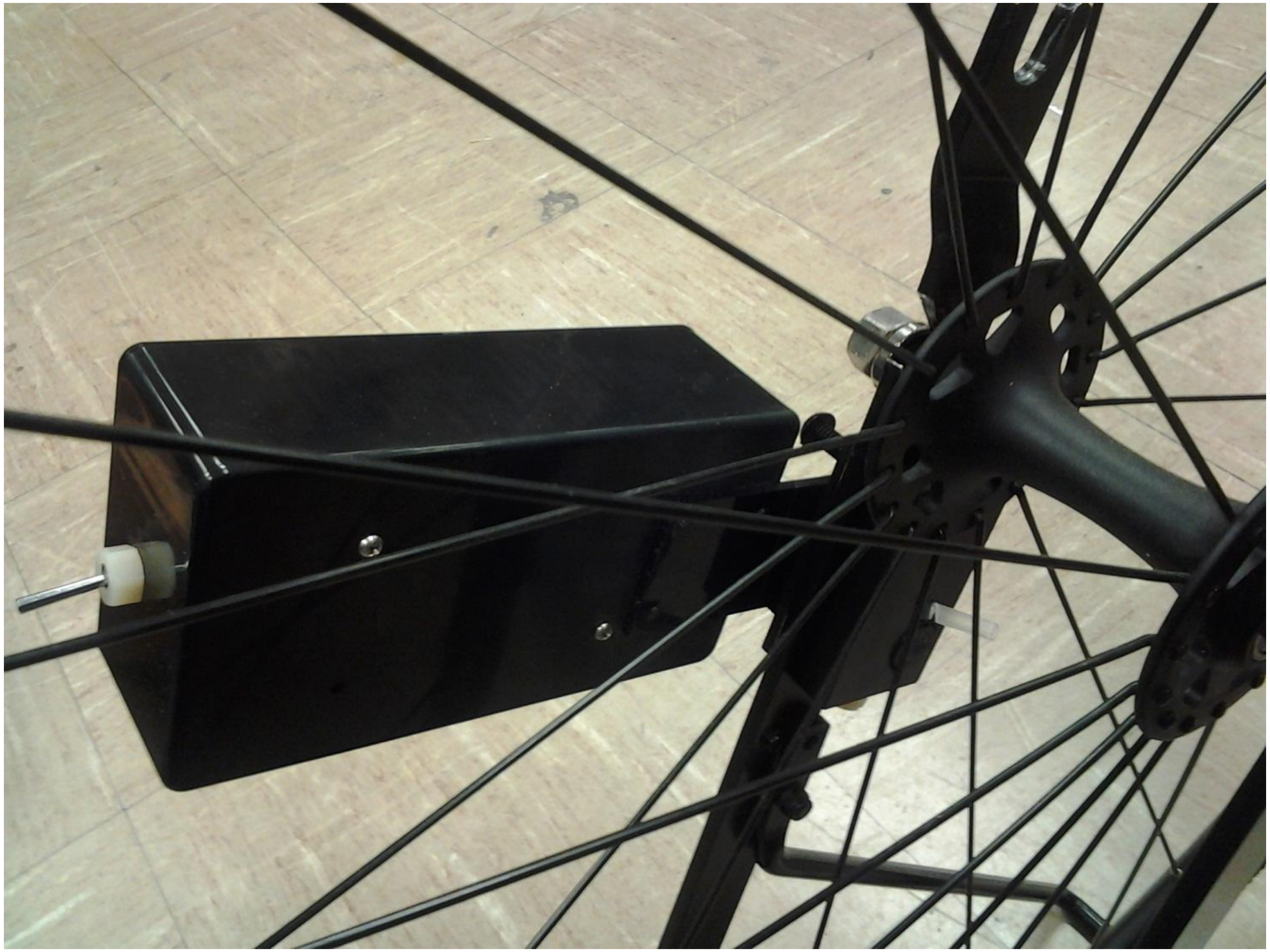


Tone Measurements
Signals
Frequency
Amplitude
Frequency
Amplitude
Spoke 2
Spoke 3
50
50
0.0003
Elapsed Time
Time has Elapse
Elapsed Time (s)
Present (s)
Formula 2
X1
Result
X2
3
True
1
Spoke 3
1.05
0.95
1.1
0.9
5%
Elapsed Time6
Time has Elapse
Elapsed Time (s)
Present (s)
Spectral Measurements
Signals
Power Spectrum
Power versus Frequency
Elapsed Time8
Time has Elapse
Elapsed Time (s)
Present (s)
Plucked
1
Elapsed Time5
Spoke 1
50
Elapsed Time2
4
Elapsed Time7
Spoke 4
stop
nonbutted
X1
Result
X2
nonbutted
X1
Result

Recommendations

- By using an amplitude triggered virtual instrument, it allows complete user control over measurements
- Set the tone measurement to search for a certain range of frequencies to avoid measuring second harmonic frequencies

Packaging

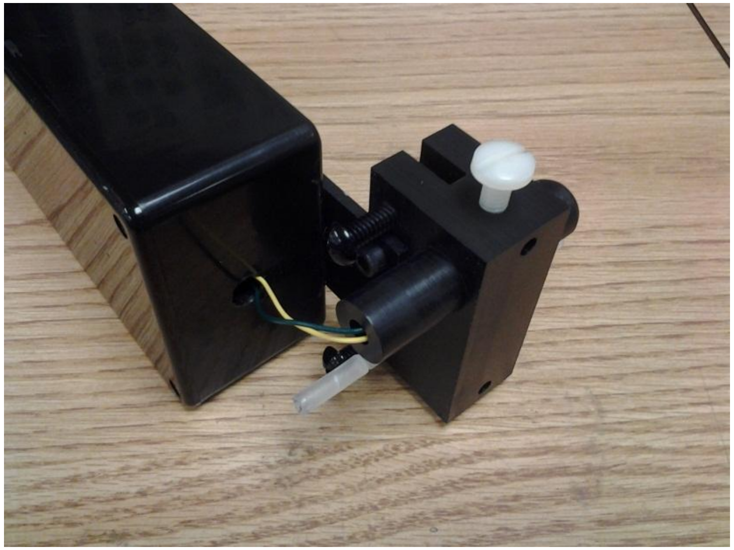


Unit Design Concerns

- Need a plucker sturdy enough so that plucked spokes generate a voltage amplitude significantly larger than ambient noise.
- Transmitter needs to be mounted to truing stand requiring a smaller unit.
- Microphone needs to be close in proximity to both the spoke as well the plucker, but separated enough to not be affected by vibrations.

Unit Features

- Easily to mount and adjust on truing stand.
- Plucker and Microphone with adjustable distance.
- Inexpensive plucker, easy to replace



Error Testing (TM-1 Comparison)

Calculated Tension (kgf)	Control Tension (kgf)	Percent Difference (%)
91.2	94	3.023758099
97.22	105	7.69459005
69.99	77	9.538063814
78.2	94	18.35075494
89.67	94	4.71497795
72.71	77	5.731080088
109.63	105	4.314401528
63.82	70	9.23628755
96.99	94	3.131053982
67.67	70	3.384905934
90.85	94	3.408168786
65.27	70	6.993420566
107.54	105	2.390138327
94.25	94	0.26560425
54.91	64	15.28887394
91.65	94	2.53164557

- Avg Diff: 6.25%; 4.74% w/o outliers

Challenges

- Coding in LabView
  - Difficult to learn detailed coding in a new language
  - Implementing something easily in C programming is much more difficult in graphical programming
  - Disorganized layout which is difficult to read
- Plucker
  - The sturdiness of the plucker would diminish over time
  - Proper placement of the plucker where the spoke wouldn't be damaged and the noise would be loud enough to be picked up by the microphone

Successes

- The amplifier was able to amplify the input signal
- The Transceiver unit was able to transmit the frequency of the signal without distortion
- LabView was able to conduct measurements based on amplitude of plucked spoked

Credits

- Prof. Carney
- Tom Galvin
- Craig Zeilenga – ECE Machine Shop
- Mark Smart – ECE Part Shop
- John S. Allen – League of American Bicyclist New England Regional Director
- Sheldon Brown – Sheldon Brown
- *The Art of Wheelbuilding* – Buonpane Publications, 1999
- *Fundamental University Physics* vol. 2, Fields and Waves – Addison Wesley, 1967

http://24.media.tumblr.com/tumblr_l74289rkPk1qz7t0xo1_500.jpg

THANK YOU!