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Trumpet & Sax Input Impedance

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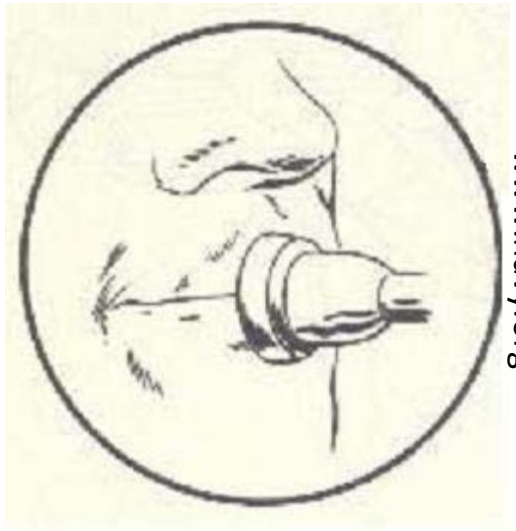
Outline of Presentation:

- Brief Music Theory
- Construction of Trumpet
- Experimental Apparatus
- Future Work

How Do Wind Instruments Work?



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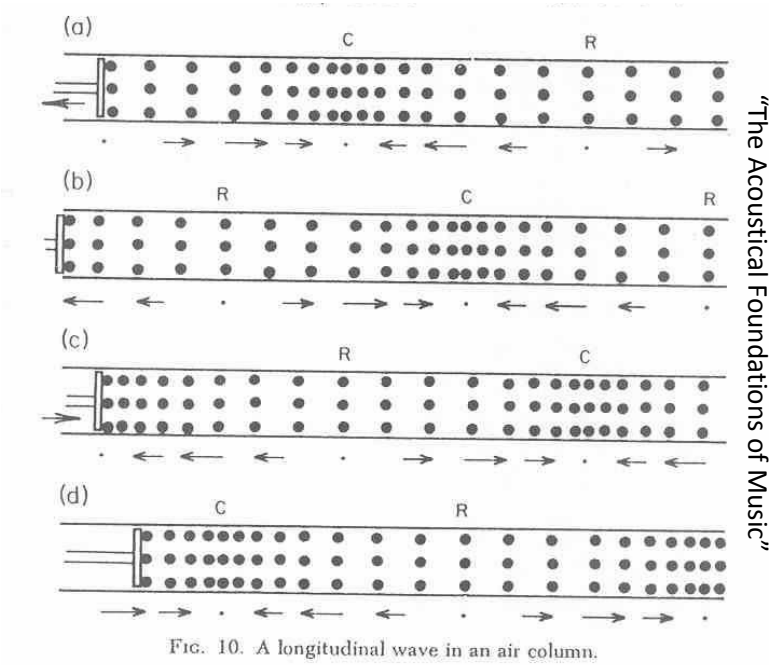


FIG. 10. A longitudinal wave in an air column.

"The Acoustical Foundations of Music"

Reed or player's lips excites air in tube

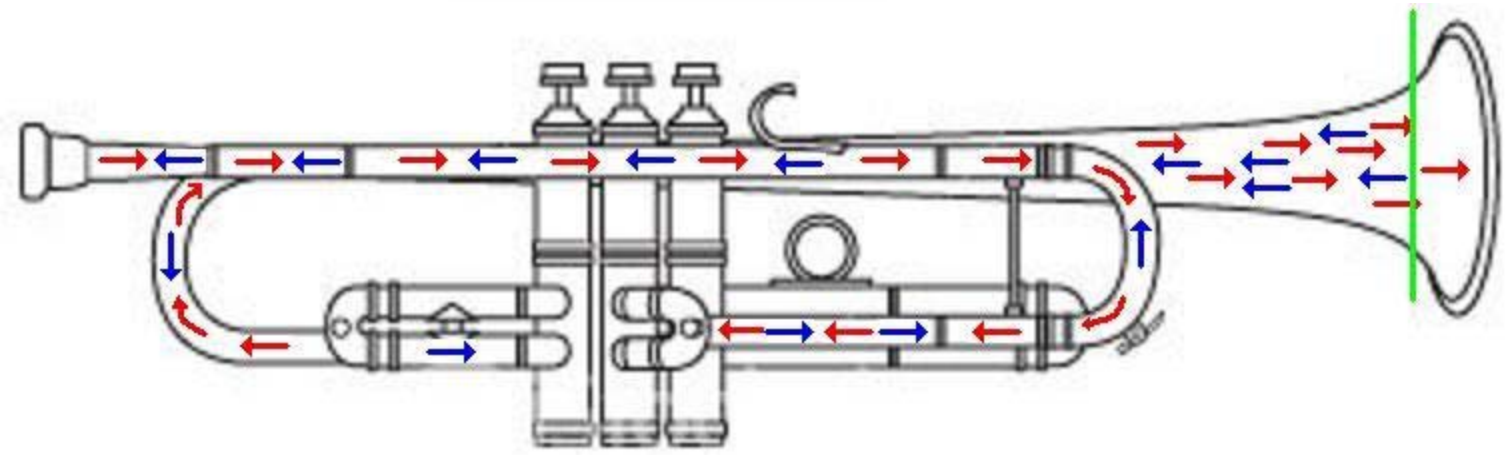
Air in tube resonates at natural frequency plus harmonics

Construction of instrument determines tuning

Impedance spectrum gives behavior of instrument

Acoustical impedance is a measure of resistance to putting a pressure wave though a tube

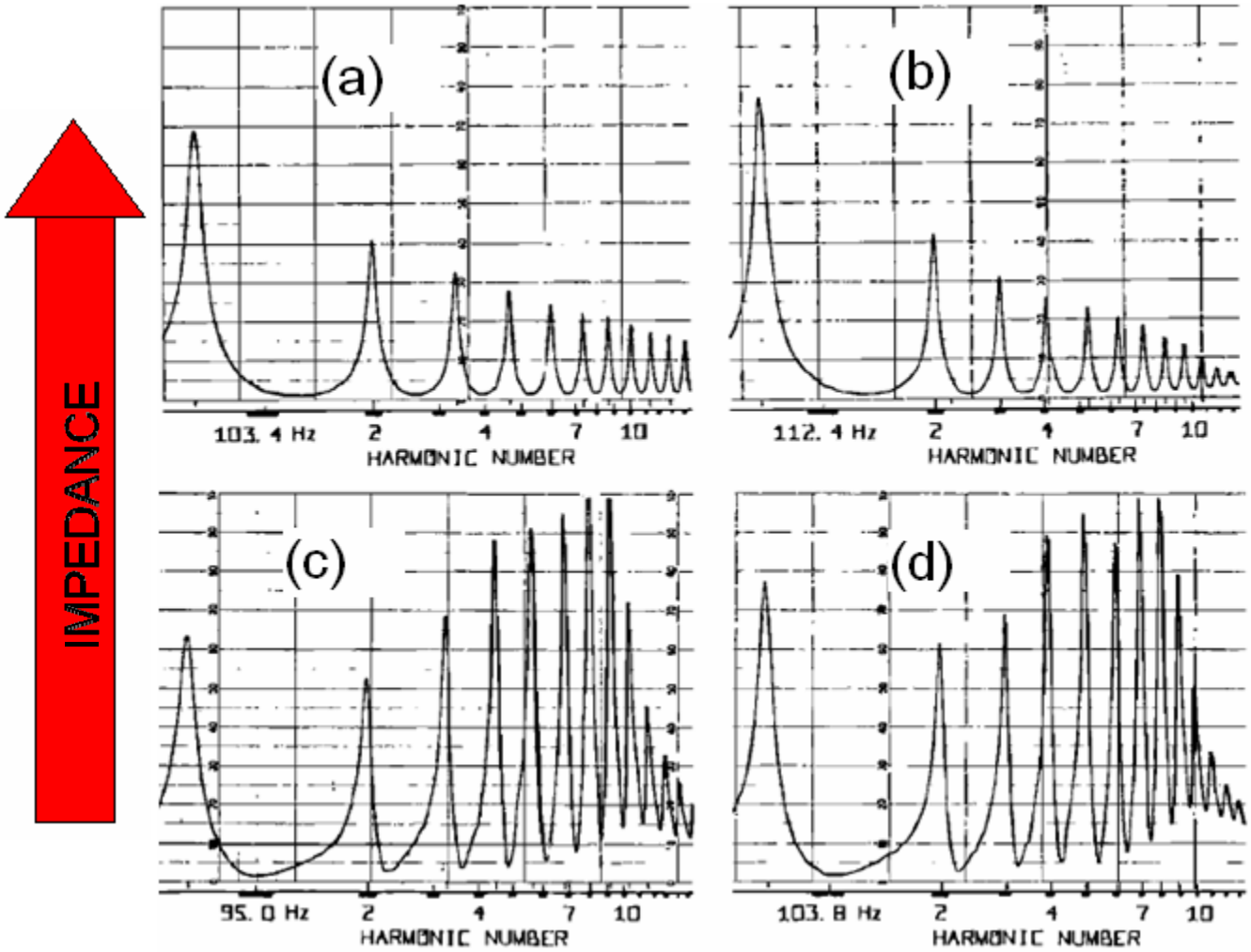
$$\tilde{Z} = \tilde{P}/\tilde{U}$$



At impedance mismatches, pressure waves are reflected back to player's lips

Reflected waves give player's lips "information" on vibration frequency

Impedance Spectra For Construction Of A Trumpet



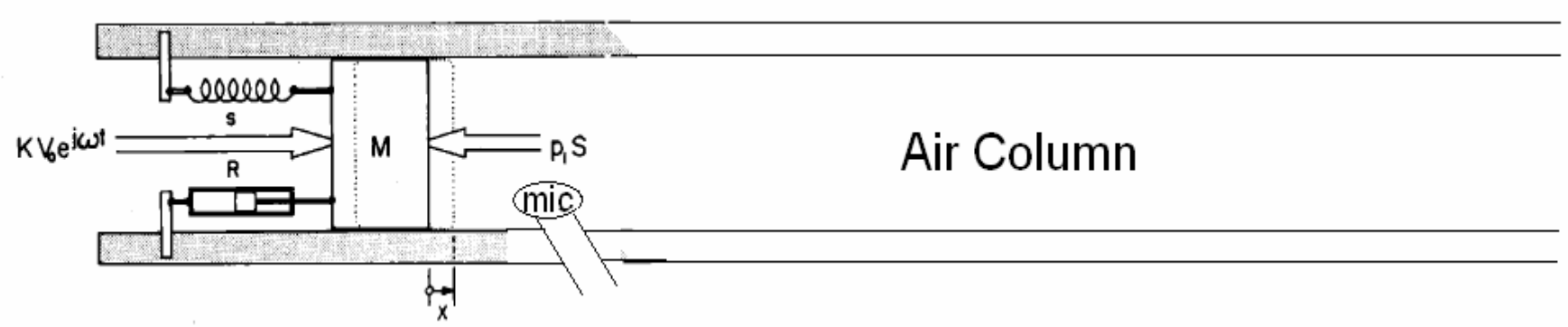
(a) Cylindrical tubing

(b) Tubing plus trumpet bell

(c) Tubing, lead pipe, and mouthpiece

(d) Tubing, lead pipe, mouthpiece and trumpet bell

Sinusoidally excited piezoelectric driver method of impedance measurement



Journal of the Acoustical Society of America

Piezoelectric driver frequency proportional to driving voltage

Use microphone to measure pressure

Air particle velocity is determined by the assumption that flow amplitude is known for the piezoelectric driver

Can we do better?

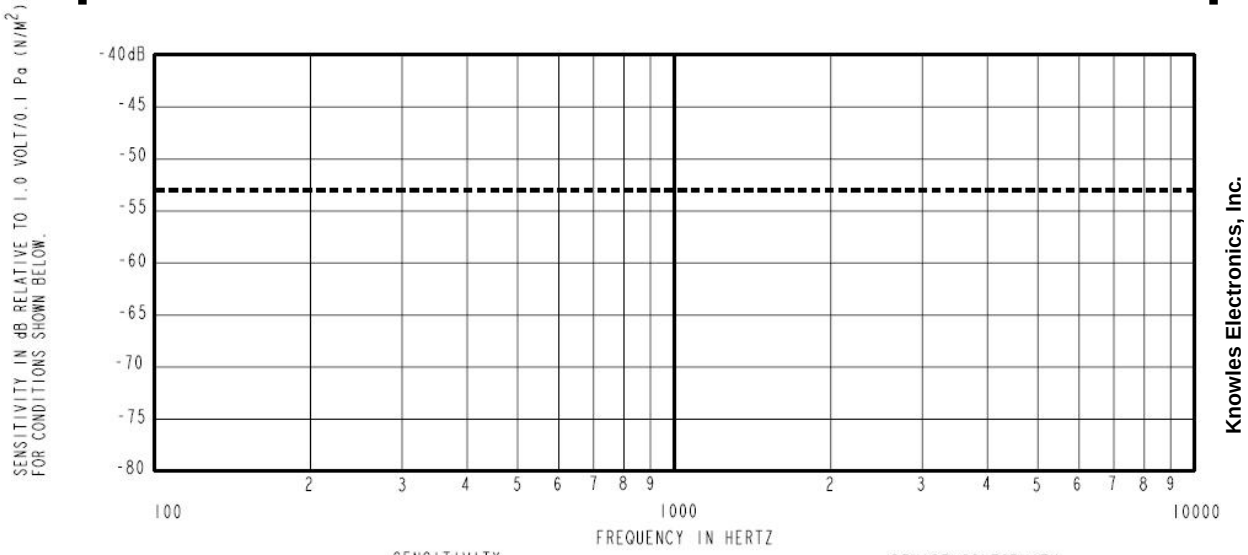
Our Plans To Get Impedance Spectrum

Use a variation on piezoelectric driver method

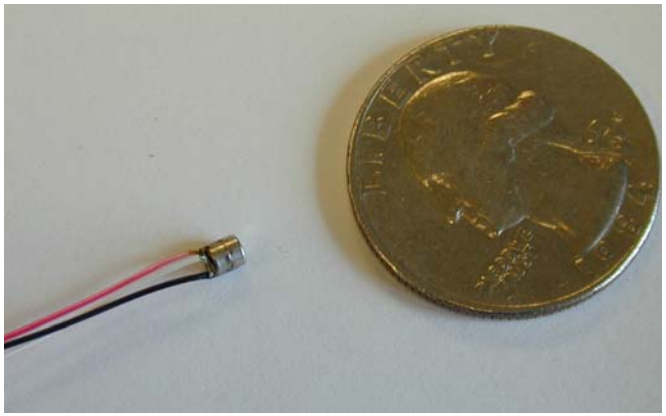
Currently plan to measure air particle velocity directly using newly developed particle velocity sensor

Will measure complex pressure and particle velocity using an impedance measuring apparatus designed for use with electric guitar pickups

Microphone is used to measure pressure



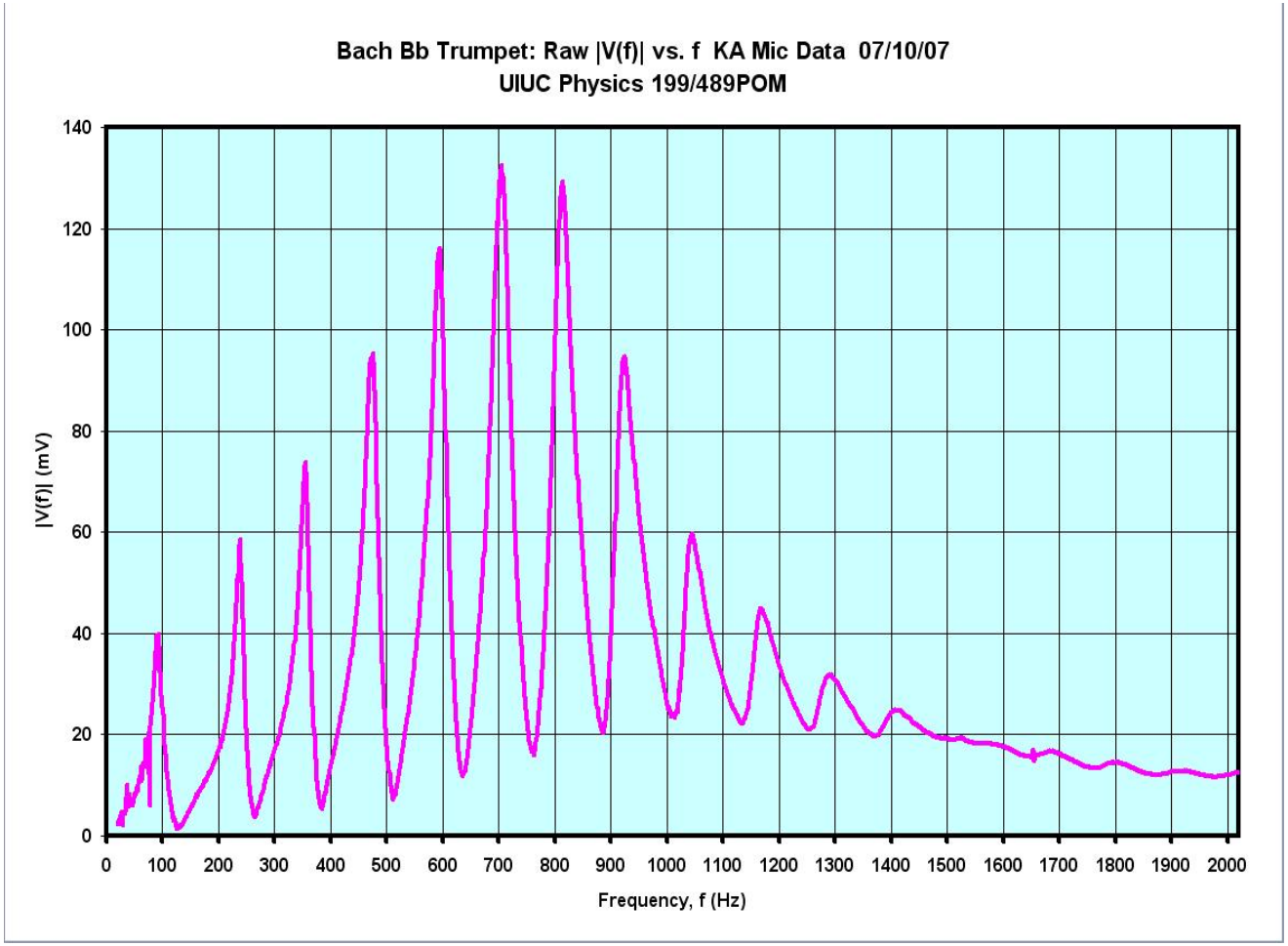
	SENSITIVITY			DEVICE CONFORMITY	
FREQUENCY	MIN.	NOM.	MAX.	RANGE OF DEVIATION FROM 1KHz	
100	---	-53.0	---	-3.0	+3.0
1000	-56.0	-53.0	-50.0	0.0	0.0
10000	---	-53.0	---	-3.0	+3.0



Knowles Acoustics omnidirectional condensor electret microphone is 0.1” in diameter – world’s smallest !!!

Sensitivity is flat up to 10 kHz

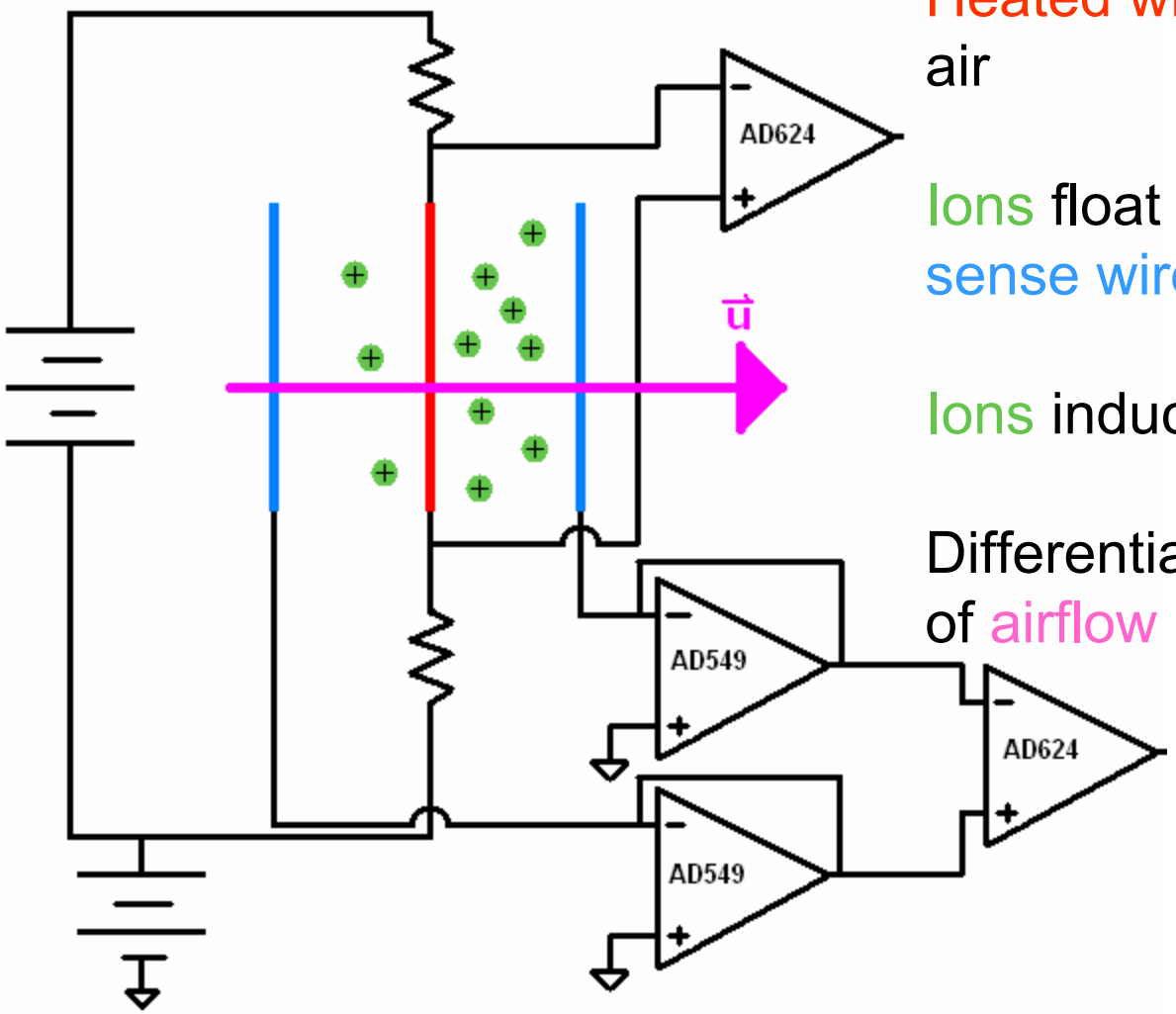
Pressure peaks correspond to allowed note frequencies of the trumpet



Only gives the numerator {p(f)} of the impedance equation

p(f) info alone – Cannot tell the relative ease of playing each note – need Z(f) = p(f)/u(f) info

U sensor will provide the denominator of the impedance equation



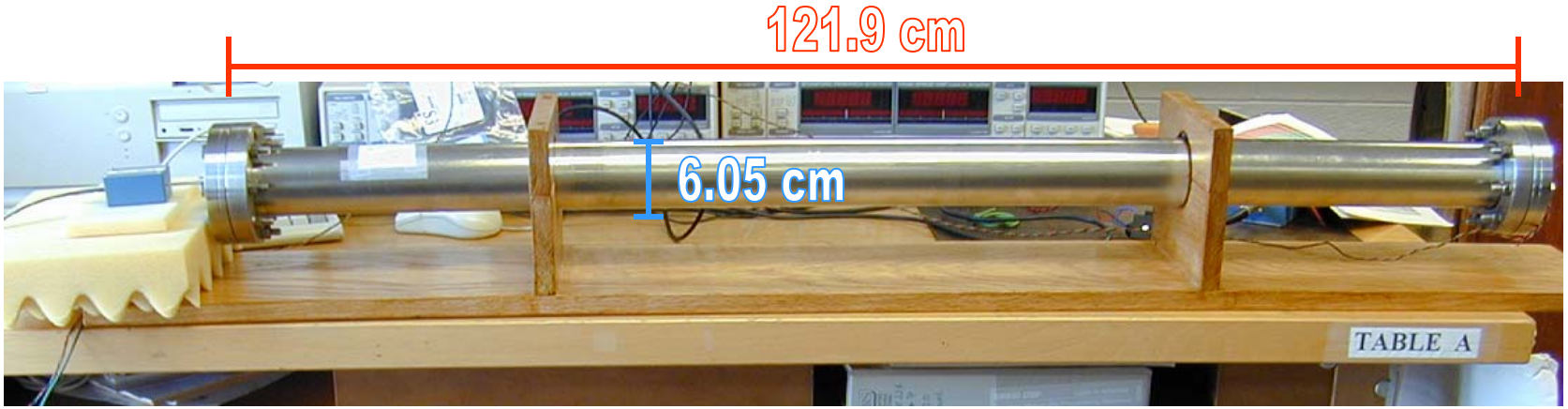
Heated wire ionizes surrounding air

Ions float to negatively biased sense wires

Ions induce current in sense wires

Differential signal gives direction of airflow

Standing wave tube used to calibrate microphone and eventually the U sensor

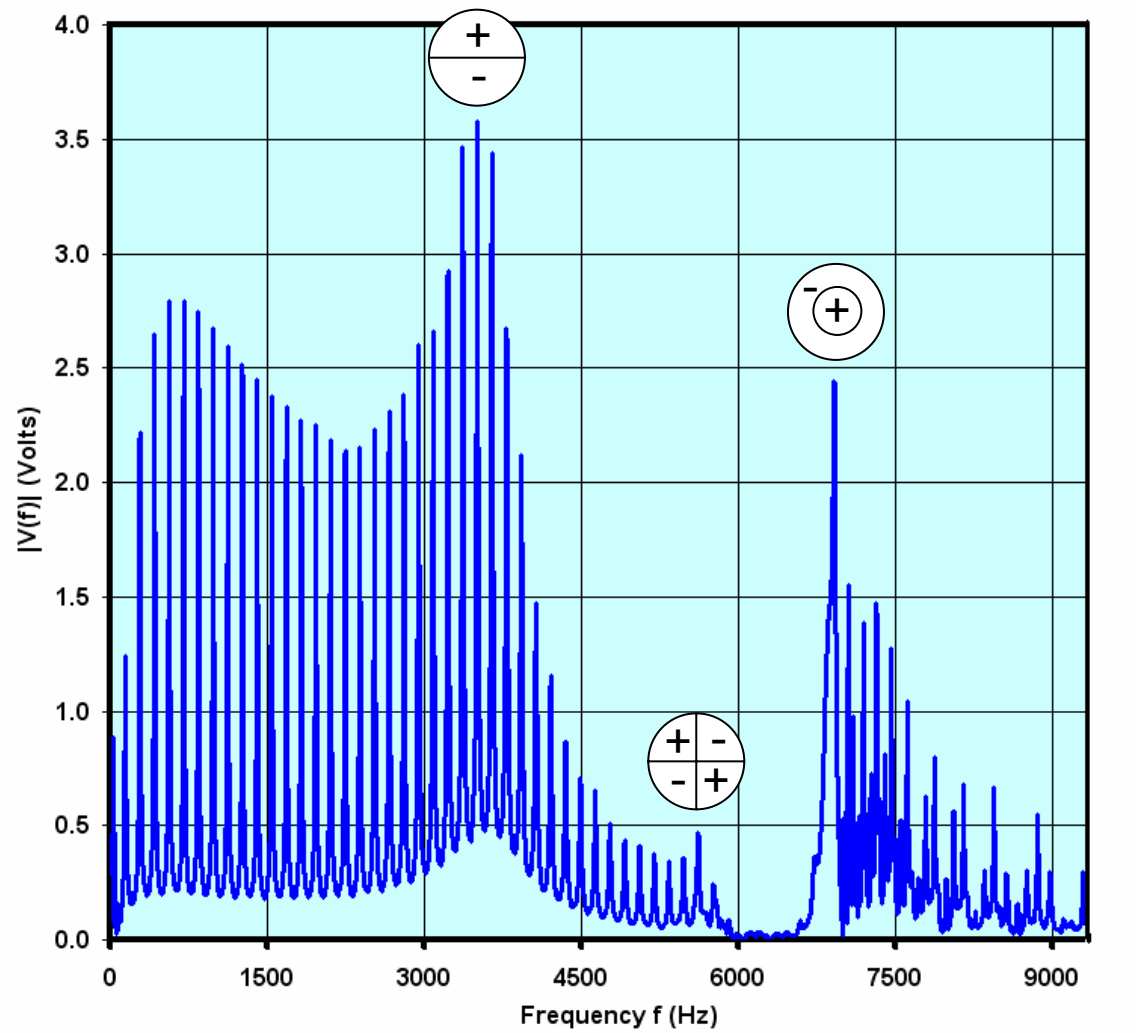


Piezo-driver rigidly attached to side of tube to excite air

Apiezon putty is used to dampen resonant frequencies of the piezo

Microphone attached at opposite end detects induced pressure in the tube as a result of the standing waves

SWT clearly shows excitation of higher modes:

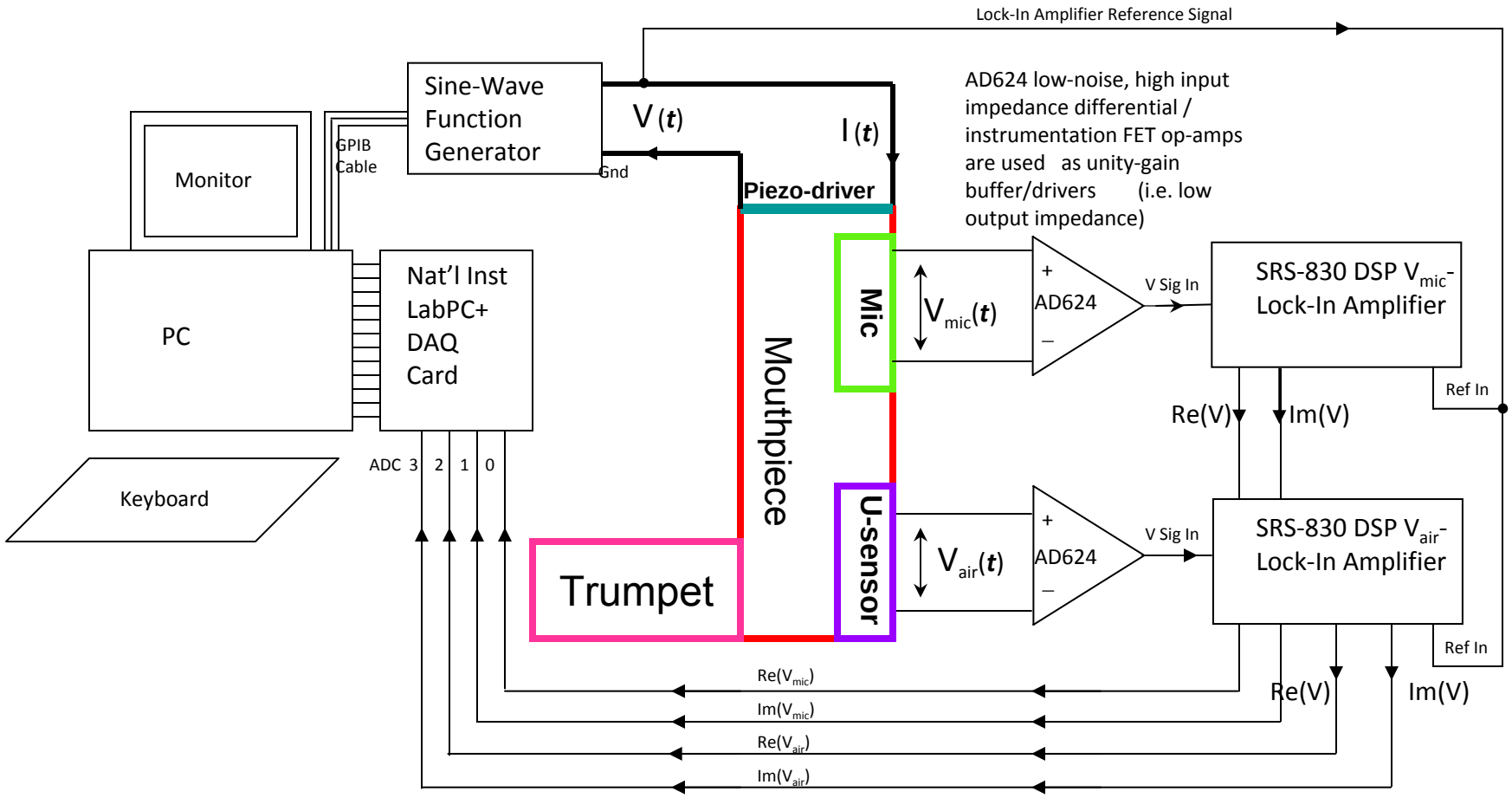


Cutoff frequencies of higher-order modes at:

(1,0): 3330.8 Hz,
(2,0): 5520.2 Hz,
(0,1): 6931.9 Hz, etc.

$\Rightarrow$ Longitudinal mode (0,0) useful up to 3.3 KHz, which encompasses the frequency range of the trumpet and most musical instruments.

***The UIUC Physics 498POM PC-Based Pickup Impedance Measuring System*:**



Slide courtesy of Steve Errede "Electronic Transducers For Musical Instruments"

Example Results:

- Experiment covers entire human audio range (20 Hz → 20,000 Hz in 10 Hz steps)
- Program takes ~3 hours to run (~5 s wait for lock-ins to settle/frequency point)
- Results plotted on 21 separate on-line graphs (Re(Z) vs. f, Im(Z) vs. f, Re(P) vs. f, Re(U) vs. f, etc…, writes out data file for offline analysis…)

Long-term Plans:

- Construction of air particle velocity sensor

- "Universal" apparatus: can be used for measuring complex $Z = p/u$ and $I = pu$ for any wind instrument, as well as for arbitrary sound fields!

Questions?

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