Low-cost Spirometer

Andrew Bremer, Andrew Dias, Jeremy Glynn, Jeremy Schaefer
Advisor: Professor Mitch Tyler, Dept. of Biomedical Engineering, UW-Madison
Client: Dr. David Van Sickle, UW Dept. of Population Health Sciences

Problem Definition

Background:
- Spirometry measures respiratory volume and flow rate
- Test results displayed as a spirogram (Figure 1)

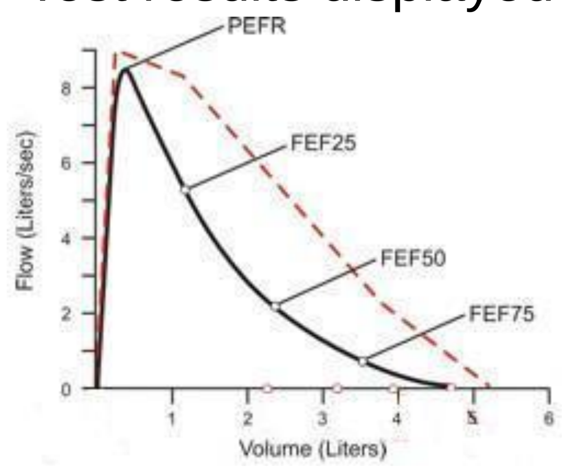


Figure 1: An example of a spirogram. Air flow rate as a function of the volume of air a person expires. PEFR is peak expiratory flow rate and FEFx is forced expiratory flow rate at x% of the forced vital capacity maneuver.[1]

Motivation:
- Common tool for COPD diagnosis
  - ➢Fourth leading cause of death in the world
  - ➢600 million diagnosed worldwide, many lack treatment[2]
- Used to monitor drug efficacy, lung growth and aging[3]
- Commercial spirometers cost upwards of $1000 (Figure 2)

Figure 2: Examples of spirometers on the market. SDI Diagnostics[4] (left, $2395) and MicroDirect SpiroUSB [5] (right, $1419.55)

Design Criteria

- Spirometer connects to computer via USB
- Affordable for use in emerging countries
- Handheld and durable
- Standardized A/V coaching for patient
- Easy to disinfect
- Minimize calibration
- Simple and universal instructions for operation

Budget

Prototype Cost per Unit	
Body	
Nylon	$1.40
PVC	$2.00
Cardboard mouthpiece	$0.07
Vinyl tubing	$0.10
2 Tubing connectors	$3.98
Circuit	
Sensor	$7.24
Signal conditioner	$2.00
FTDI FT232RL	$3.95
ATtiny microcontroller	$1.85
Circuit filtering components	<$1.00
TOTAL	**$19.64**

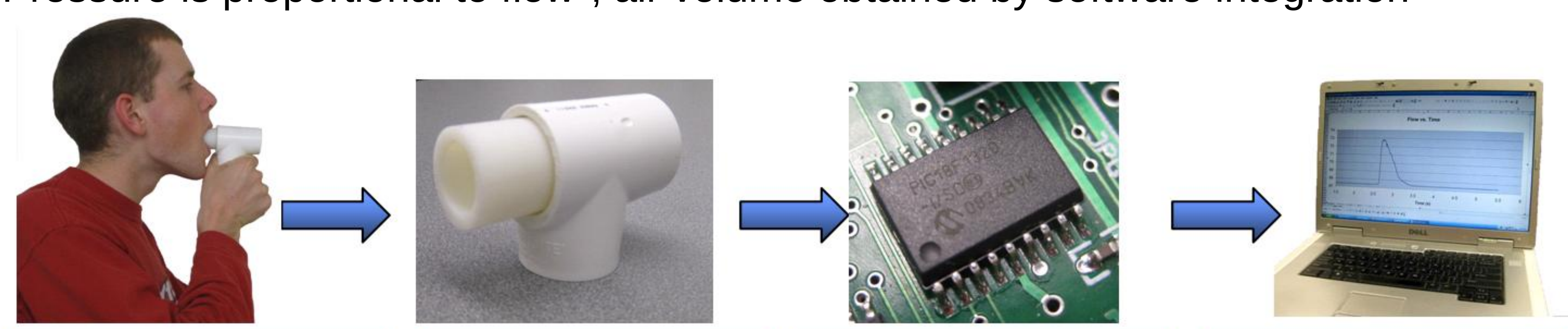
- •Target cost per unit: <$50
- •Prototype meets target

Abstract

Current spirometers on the market often have retail prices of over $1,000, making them unaffordable to physicians in emerging nations. We have designed and built a low-cost spirometer model costing less than $50 that consistently generates a precise signal output based on airflow and measures volume with <3.0% error. We are developing a standardized coaching program so that motivation is constant across sites. Over the summer and next two semesters, we will develop open-source software to display and analyze the data in real time. Following clinical testing, the end product will be a mass producible device that can be sold for profit in emerging countries.

Final Design

- Utilizes a differential pressure sensor to measure drop through spirometer (Figure 3).
- Pressure is proportional to flow[2], air volume obtained by software integration



User	Spirometer	Microcontroller	Computer
Expires through spirometer	Records Pressure Drop	Converts signal to flow and volume	Final calculations and data display

Figure 3: The proposed final layout of the operation of our spirometer.

Materials

- ➢Plastic body is durable, easily disinfected
- ➢Potential materials: nylon, polyethylene, PVC
- ➢ Disposable cardboard mouthpiece cheap and reduces risk of disease

Shape

- ➢Internal constriction increases pressure drop while maintaining low overall resistance
- ➢ T-shaped handle encourages good posture

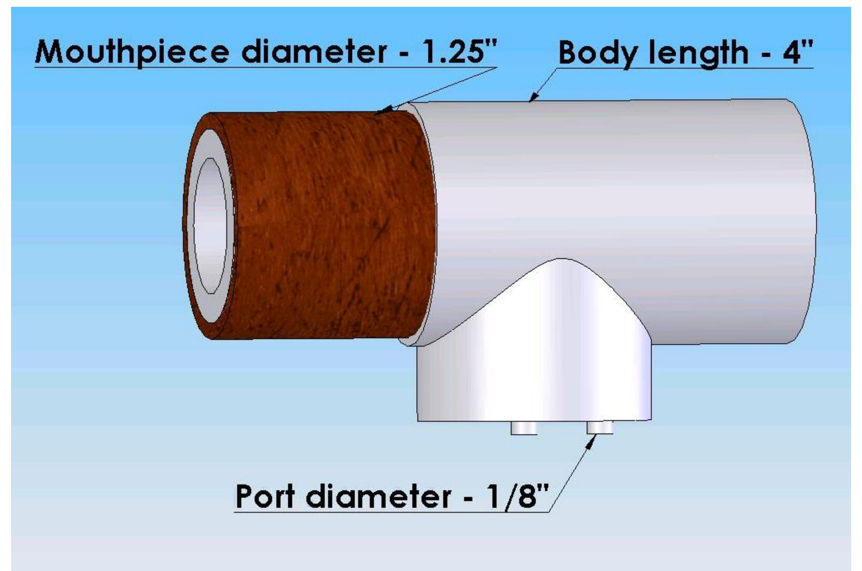


Figure 4: External view of spirometer with mouthpiece

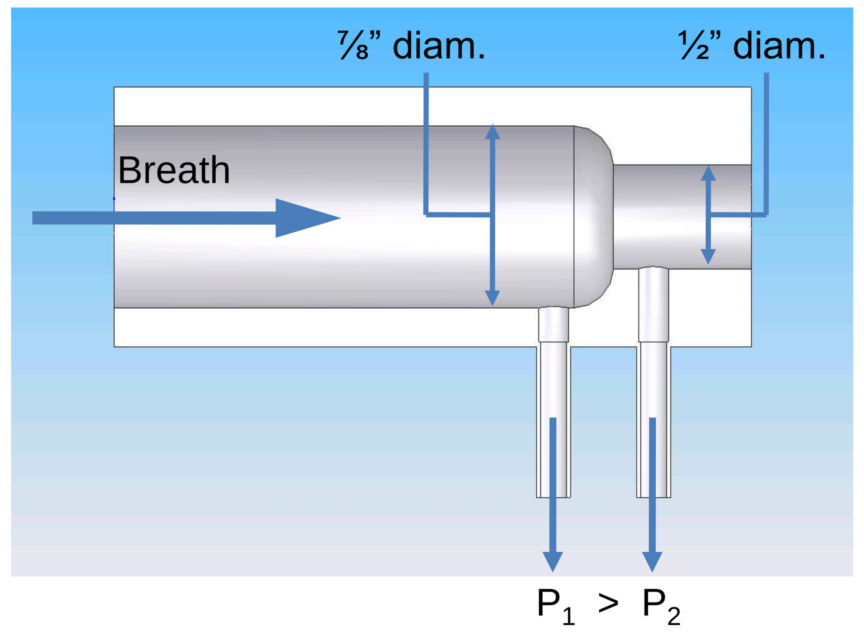


Figure 5: Cutaway view of spirometer showing constriction

Testing

Testing systems
- •Measured constant air flow (Figure 6)
- •Tested volume with 3L syringe

Design revision
- •Constant diameter → low output
- •Added internal constriction

Flow calibration testing
- •Measured velocity, related to flow
- •Flow measurement (Figure 7)

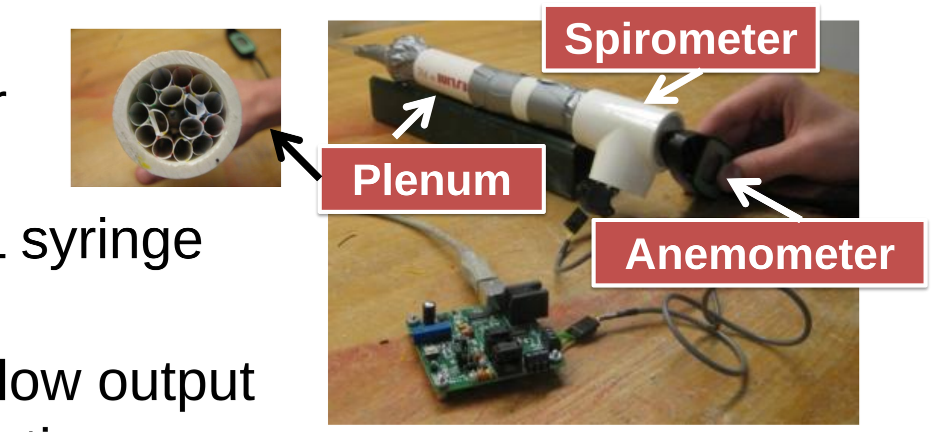


Figure 6: Spirometer testing setup.

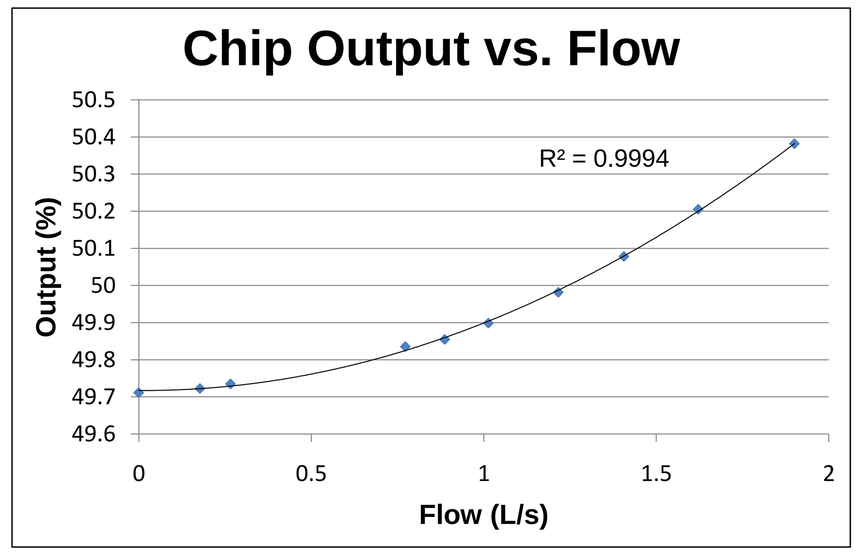


Figure 7: Average flow values taken over 10 seconds, sampling rate 10 ms (1000 samples)

Results
- •Correlation of chip output vs. flow
- •Quadratic fit
- •Largest sample STDV <0.05%
- •Volumes within 3% error

Future Work

Summer 2009	Fall 2009	Spring 2010
➢Additional Flow and Volume Testing ➢ Software & Coaching Development ➢ Adjust to Body Temperature & Humidity	➢Finalize hardware and software ➢ Test effectiveness of coaching protocol ➢ Prepare design for clinical testing	➢Perform extensive clinical testing ➢Prepare to mass-produce device

References

1. *Morgan Scientific. 2008. What is a Pulmonary Function Test. <http://www.morgansci.com/customer-resource-center/pulmonary-info-for-doctors/what-is-a-pft-test-2.php> Morton, JL.*
2. *AARC (American Association for Respiratory Care). 2008*. <http://www.aarc.org/headlines/08/11/copd_month/>.
3. American Thoracic Society. Pulmonary Function Tests. *Patient Information Series* 2007. <http://www.thoracic.org/sections/education/patient-education/patient-information-series/resources/en/pulmonary-function-tests.pdf>.
4. SDI Diagnostics. SpirolabII. 2009. <http://www.sdidiagnostics.com/spirometers/spirolab.php>
5. Medical Device Depot. 2006. MicroDirectSpiroUSB(with Spida5 Software). <http://www.medicaldevicedepot.com/MicroDirect-SpiroUSB-with-Spida-5-Software-p/ml2525.htm>.

Acknowledgements

We would like to give special thanks to David Hubanks, David Hoffman, and Isaac Wiedmann from ZMD who kindly donated us an A/D converter chip and software. We also want to thank our client, Dr. David Van Sickle who has given us a lot of support on this project. Thanks also to Professor Mitch Tyler who served as our advisor and gave us invaluable guidance and to Amit Nimunkar, Jon Baran, and Chris Esser who helped with big picture logistics. With these people's help, we were able to design and build what we hope is a good proof of concept.