

BARFS

Breathing Analysis/ Rate bioFeedback System

Project ID: micro13AL294



microMedic
2013 National Contest

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31 July 2013
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Abstract

BARFS was conceived as an entry into the microMedic 2013 National Contest to develop a medical training device.

Breathing and heart rate control is recognized as a method to maintain effectiveness in stressful situations. Conscious control of breathing increases the ability to react rationally in stressful situations. Proper control of normally autonomous functions contributes to an increase in situational awareness, improved decision-making under duress, and increased effectiveness in weapons use and accuracy. Cardio-monitoring using oximeters has been used to provide biofeedback for control of heart rate in training. While there is a correlation between heart rate and breathing rate, there is causation between breathing and heart rate. It was proposed that use of a system that non-invasively analyzes breathing rate and provides intelligent feedback to the user during training would increase overall performance, especially under stress.

It was proposed that a composite set of sensors, mounted on the boom of an inexpensive headset, could provide the necessary inputs to a Parallax Propeller processor. Taking advantage of the multi-cog parallel processing architecture, powerful I/O, and communications capabilities of the Propeller, it should be possible to incorporate composite sensors in breathing rate analysis.

Based on the early success of investigations of the combined microphone input and humidity and temperature sensors, not only can this device be used by military personnel for training, but has potential for additional medical benefits related to non-intrusive methods of measuring breath parameters.



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Foreward – The Birth of BARFS

One late afternoon in the late spring, I happened to be speaking with a neighbor about my upcoming first year at college and what I was going to study. I mentioned that bio-mechanics and prostheses were of interest, and was considering getting a degree that would allow me to do that kind of work.

The neighbor mentioned that he had seen details of the 2013 microMedic National Contest, and that the goal was to develop a microprocessor-based device that could be applied to U.S. Army medical training. While I have had some robotics experience in high school, the hardware and software development were beyond me. He mentioned that the human factors in the design would present a serious introduction to bio-mechanics, and asked if I would like to do the human-interface design if he were to complete the hardware and software design based on my input. My responsibility would be to design the interface, submit the project proposal, and be responsible for the project submission.

We talked for about two hours in the hot sun about what we would do....

-Alec Levenhagen

Human Interface Design Team

About The Neighbor –

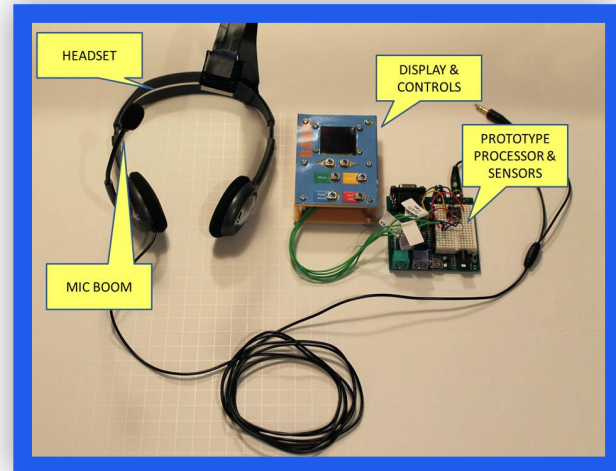
Wallace Willard is an engineer with NASA. He has coached two successful FIRST Lego League teams and believes that the most successful way to get kids into science is to show them how powerful and creative engineers and scientists can be. He tries not to pass up an opportunity to show them that they can do cool things.



1 Introduction

As a requirement for project submission, this document was prepared to describe the effort microMedic 2013 National Design Contest in the design and prototyping of the BARFS.

This report describes the scope, design, and testing of the BARFS to be used to perform breathing rate analysis, with application to stress training. It also alludes to possible extensions of the system to Describes the “what” and “why” of the report.



1.1 Importance of Breath Control

“Don’t be scared: When you’re threatened, your brain releases a flood of chemicals that jack up your heart rate, preparing the body to face danger and to fight and bleed. Gross motor skills—pushing and pulling—improve. But these chemicals also change how your brain works. Even simple actions can be fiendishly difficult. People under incredible stress have trouble dialing 911: They can’t see the numbers, they can’t press the buttons.

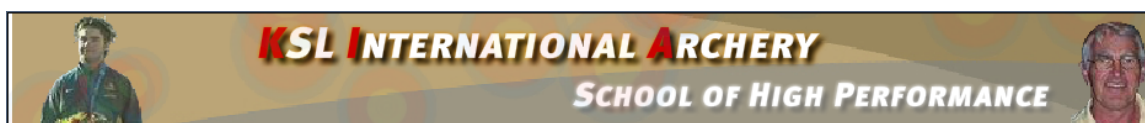
What can you do about it? Drill sergeants and coaches like to say, “You don’t rise to the occasion, you sink to the level of your training.” Repeat an action a thousand times so that when the stress hormones are ripping through your system, you do it on autopilot. A simple technique, sometimes called combat breathing, can help even an untrained person overcome extreme stress. Our breathing is automatic, but you can also control your breathing, unlike your heart rate or your adrenaline levels. In very stressful situations, take four deep breaths,

on a four-count (breathe in for four beats, hold, breathe out for four beats), and this can bring you back from a state of super-arousal.”¹

¹ From “The Disaster Diaries: How I Learned to Stop Worrying and Love the Apocalypse,” Sam Sheridan, Penguin Press



1.1.1 KSL international Archery



Breathing Cycle

THE KSL SHOT CYCLE III, INCLUDING BREATHING PATTERNS

The correct method of breathing is an essential part of the archer's system of control. Most archers know less about the proper method of breath control than any of the other fundamentals. Therefore, the archer who understands their breathing and its impact on performance and who can be aware of their own state of arousal is the archer who, everything being equal, is going to be the most successful.

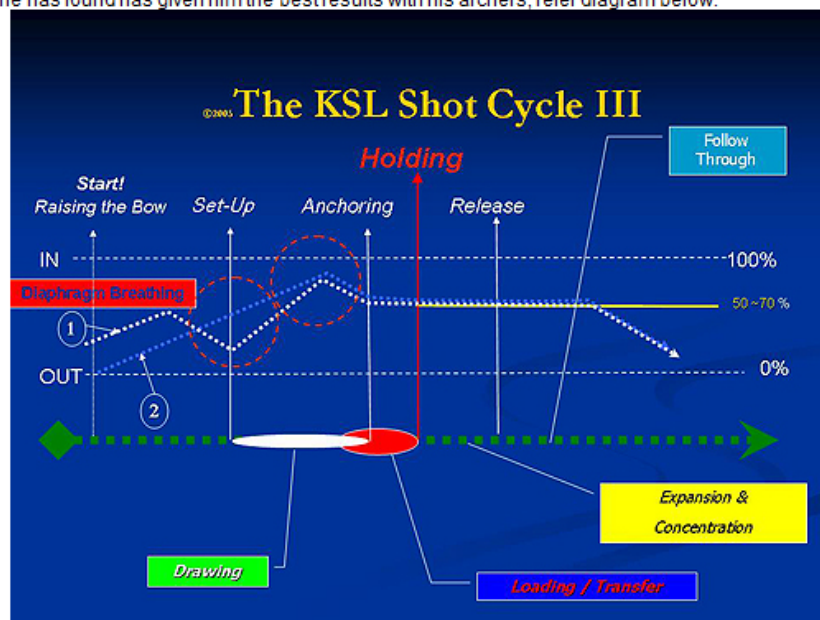
Bear in mind that an anxious mind cannot exist in a relaxed body or a quiet mind can not exist in a tense body. Also remember that thoughts associated with worry and anxiety, affect heart rate, muscle tension and breathing rate. This change in muscle tension and breathing rate will have a negative affect on an archer's fine motor coordination, focus, center of gravity and timing; all critical components in archery.

Therefore, breathing properly is not only relaxing; it also facilitates performance by increasing the amount of oxygen in the blood, reducing blood pressure, heart rate, resulting in a drop of anxiety. Breathing properly also carries more energy to the muscles and facilitates the removal of waste products.

Consequently, proper breathing is an essential and fundamental factor of concentration. Ordinarily, when calm, we breathe 12 to 15 times a minute, but when anxious this can double. The majority of people only breathe superficially, using only the top part of their lungs or one-sixth of the capacity of their lungs. However, one can learn to breathe more deeply and slowly, about five to six deep calm breaths a minute. To this purpose the archer must learn diaphragmatic breathing, also known as Zen Breathing. This should be practiced every day, as a focus/relaxation exercise till it becomes second nature. This type of breathing has been described in detail in Total Archery and there are also many detailed references to it on the internet.

Breathing and breath control during the shot cycle.

There are various theories regarding this, but Coach Lee, from his twenty-five years of coaching, will discuss the two ways that he has found has given him the best results with his archers; refer diagram below.



These two ways are, Option 1 (white dotted line) mostly used with developing archers, but can work equally well with experienced archers, and Option 2 (blue dotted line) for the more experienced tournament archer, who has acquired good technique.


Option 1

1. A deep diaphragmatic settling breath should be taken prior to raising the bow.
2. With the focus on the target a normal breath, using diaphragmatic breathing, is taken between Raising the Bow and Set-Up. This not only has a settling effect, but will also lower the center of gravity. Further, it will help the archer to increase their focus and aids in not rushing the draw.
3. Whilst drawing from Set-Up inhale as part of the drawing rhythm, which will create a natural feeling of gaining strength.
4. From the beginning of the Loading/Transfer to the Holding phase, when aiming should commence, approximately 30-50% the breath should be let out slowly and naturally, allowing the sight to naturally settle in the aiming area.
5. From this point the breath must be held till after the release and let out naturally during the follow-through.


1.2 Investigation of Existing Patents, Devices and Research


1.2.1 Patent Search

The results of a patent search:

[12/14/06](#) | [Class 600](#) [Monitor](#) |
 [RSS](#) | Browse: [Prev](#) - [Next](#)

Breath biofeedback system and method



DOWNLOAD Full Patent PDF 

Abstract: A breath biofeedback method and system for encouraging a subject to modify respiration. The system includes a thoracic volume input module measuring thoracic volume data of the subject and a pattern module providing target breathing patterns in communication with a display generator. The display generator producing display information representing a displayable image including a first object having a first position determined as a function of the thoracic volume data and a second object having a second position determined as a function of the target breathing pattern and the thoracic volume data. The displayable image is designed such that when displayed on the display device the displayable image encourages the subject viewing the displayable image to modify respiration. ...

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Inventors: [Peter M. Bingham](#), [Jason H. Bates](#)
USPTO Appication #: [#20060282003](#) - Class: [600538000](#) (USPTO) - [12/14/06](#) - [Class 600](#)

BACKGROUND


[0003] Many individuals in society are afflicted with respiratory problems, some of which are chronic. These individuals and those that wish to take advantage of general benefits of controlled breathing exercises often require a compelling motivator to engage in breathing exercises. Benefits of breathing exercises have been known for centuries for such things as improving general, spiritual well-being. Many cultures, Eastern and Western, have embraced a connection between controlled breathing and this well-being. Those affected by respiratory problems, such as pulmonary disease, are often subjected to routine clinical diagnostic activities and/or therapeutic exercises focused on breathing.

[0004] Subjects, such as those suffering from respiratory problems and those choosing to undergo breathing exercises, face motivational problems. One way to measure breathing is to use a spirometer, which requires repetition of inherently uninteresting activity with no immediate motivation to the subject. Other diagnostic and therapeutic activities also suffer from a requirement of intense effort and focus of attention on the part of the subject with no immediate reward other than compliance with medical advice.

A review of the various embodiments described predominately a visual method of improving breathing methods with a therapeutic result. This differs markedly from the predominately audio method postulated with BARFS for training purposes.

1.2.2 Commercially Available Devices

1.2.2.1 emWave2



emWave[®]2
Item # 6310
Price: \$229.00
[Add to Shopping Bag](#)

[View larger image](#)

Currently on backorder - Estimated ship date, April 1st.

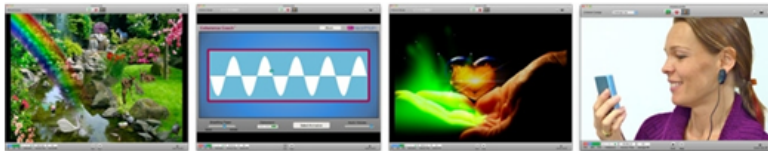
Take Charge of Your Mind and Emotions

If you sense that it's time for a positive change in your life, emWave2 can help. This unique training system helps you learn to build inner resilience — a state of poise and readiness for effectively dealing with stressful feelings and whatever challenges come your way. Practice for just five to ten minutes a day can bring more ease and mental and emotional flexibility into your life.

You'll find your attitudes, emotions and perspectives become more positive and resilient.

New and Versatile — On The Go or at Your Computer

The new emWave2 combines the portability of the original handheld emWave, which provides input via lights and sound, with a rich graphical interface which displays on your computer. Use it on the go, or at home or work — just plug into your computer to download and review previous sessions, run a new session with the real-time heart rhythm display, or play one of the interactive coherence-building games.



The Coherence Breakthrough

emWave2 technology is based on "the coherence breakthrough". Coherence is a state of synchronization between your heart, brain and autonomic nervous system which has been proven to have numerous mental, emotional and physical benefits. You can think of coherence as a simultaneous state of relaxation, readiness and revitalization. It's a first step in prepping for what athletes call "the zone". Coherence improves performance, health and emotional well-being.

Typical Benefits that People Notice With 2 Weeks of Genuine Practice:

- More calm
- Better sleep
- Less reactivity
- Less worry
- More alertness
- Better focus and decision making
- More positive attitudes
- More ease and inner peace

How it works

The emWave2 is an advanced heart rate monitor, able to measure subtle changes in your heart rhythms. This type of measurement is known as heart rate variability analysis or HRV. The analysis of HRV is a noninvasive measurement that reflects heart-brain interaction and autonomic nervous system dynamics, which are particularly sensitive to changes in your emotional state.

Heart Rhythms and Coherence

When you experience stressful emotions such as tension, anxiety, irritation, or anger, your heart-rhythm pattern becomes irregular and incoherent, negatively affecting your health, brain function, performance and sense of well-being. When you experience positive emotions such as appreciation, care, joy and love, your heart-rhythm pattern is more ordered and coherent.

1.2.3 Research With Similar Application

Estimation of respiratory flow rate by analysis of breath sounds at the external ear

[Gary A Pressler, Purdue University](#)

Abstract

Respiratory monitoring during athletic activity or other clinical and occupational settings would benefit from a method that does not obstruct the airway. Previous studies have demonstrated the utility of breath sound measurements performed on the chest or neck to detect airflow. This dissertation investigates a novel location for breath sound measurements: the external ear. In all of the experiments, a miniature electret microphone, set within a disposable rubber earplug, was placed in each subject's external acoustic meatus. The first experiment demonstrated the passive transmission of sound from the oropharynx to the external ear in nineteen adults. Broadband noise was introduced to each subject's pharynx via a tubular mouthpiece and was recorded by both an accelerometer affixed to the subject's cheek and the ear microphone. Near-unity coherence estimates (>0.9) were observed up to 800 Hz, indicating a low-frequency region of preferred transmission. The earplug provided at least 25 dB of acoustic isolation from environmental noise. In the second experiment, the ear microphone detected tidal and shallow breath sounds in twenty adults. A third experiment studied eleven adults to determine the relationship between respiratory flow rate and average sound power (300--600 Hz). Six different configurations were used: oral, nasal, and open (oral and nasal) breathing, each with and without a pneumotachograph. Sound spectra for a given subject and configuration maintained a characteristic shape but varied in amplitude with flow. The flow (F) to average sound power (P) relationship followed the form $P=AF^B$. Values of B were typically between 3.5 and 5 and varied by subject, respiratory phase, and breathing route. The final experiment estimated flow rate from the breath sounds of ten subjects using the above relationship. Coefficients from one session calibrated sounds from the same subject two days and two weeks later. While the variance of individual flow estimates was relatively large for instantaneous flow predictions, average flow estimates typically had only 10% error for open (oral and nasal) breathing. Nasal breathing demonstrated relatively large variances between successive sessions. More complex mathematical relationships are likely needed for more accurate flow estimation from breath sounds measured at the ear. ^

Degree

Ph.D.

Advisors

George R. Wodicka, Purdue University.

Subject Area

Engineering, Biomedical

The abstract alludes to the viability of using an ear-type microphone to perform volumetric analysis, one of the possible extensions of the BARFS system.

A Novel Method for Extracting Respiration Rate and Relative Tidal Volume from Infrared Thermography

Gregory F. Lewis, BA,¹ Rodolfo G. Gatto, MD, PhD,¹ and Stephen W. Porges, PhD¹

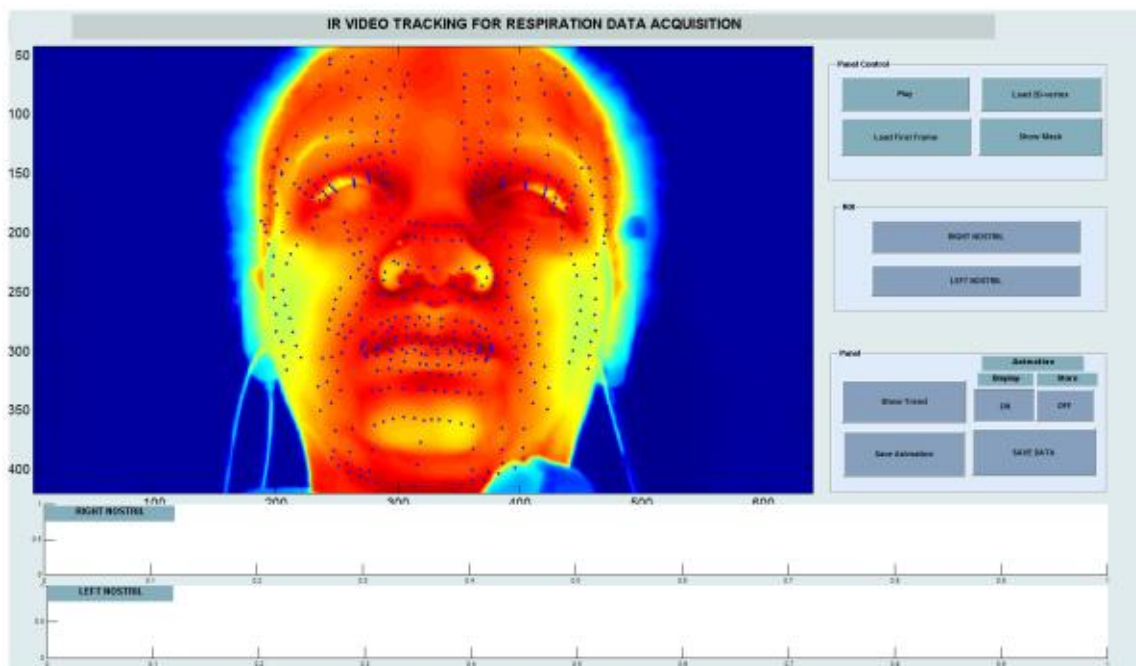
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The publisher's final edited version of this article is available at [Psychophysiology](#)

Abstract

In psychophysiological research, measurement of respiration has been dependent on transducers having direct contact with the participant. The current study provides empirical data demonstrating that a noncontact technology, infrared video thermography, can accurately estimate breathing rate and relative tidal volume across a range of breathing patterns. Video tracking algorithms were applied to frame-by-frame thermal images of the face to extract time series of nostril temperature and to generate breath-by-breath measures of respiration rate and relative tidal volume. The thermal indices of respiration were contrasted with criterion measures collected with inductance plethysmography. The strong correlations observed between the technologies demonstrate the potential use of facial video thermography as a noncontact technology to monitor respiration.

Keywords: respiration, facial thermography, infrared video



This research provides a visual indication of the zones and type of rates necessary to develop a relative tidal volume using thermography. The sample rates and analysis appear to be a good indicator that the dual Humidity/ Temperature sensors in conjunction with the microphone analysis is a viable candidate for an extension of BARFS to a non-invasive medical type diagnostic/ monitoring device.

Step 1: Dominant Breathing Rate (BR)

Thermal and LifeShirt® volume time series were linearly detrended and zero-padded to a length of 1024 samples. A 1024-point fast Fourier transform (FFT) was used to calculate the spectral density distribution. This spectrum was stabilized by convolution with a 9-point Parzen window.

Within an expanded range (due to the variations in breathing frequencies across the three conditions) of 3 to 65 cycles per minute (cpm), the frequency with the greatest spectral density was selected as the Breathing Rate (BR). Analyses of variance identified significant differences among the three breathing conditions for both the TVS-700 and SC-6000 groups (all $p < .05$) and confirmed participant compliance with the breathing instructions. The mean BR (SD) for the TVS-700 group was 41.38 (9.98) cpm in the rapid and shallow condition, 15.08 (3.67) cpm in the spontaneous condition, and 10.02 (4.98) cpm in the slow and deep condition. For the SC-6000 group, the BR was 47.17 (15.20) cpm in the rapid and shallow condition, 19.94 (8.88) cpm in the spontaneous condition, and 13.28 (5.45) cpm in the slow and deep condition. Correlations were calculated between BR measures derived from the LifeShirt® and thermal signals (see Table 1).

Table 1 Correlation between thermal and mechanical breathing rates (BR)		
Respiratory Condition	Thermal Imaging System	
	TVS-700	SC-6000
Shallow	0.996 (N = 10)	1.000 (N = 4)
Normal	0.941 (N = 12)	1.000 (N = 7)
Forced	1.000 (N = 12)	0.990 (N = 6)

Table 1

Correlation between thermal and mechanical breathing rates (BR)

2 Design

2.1 System Considerations

2.1.1 Breathing

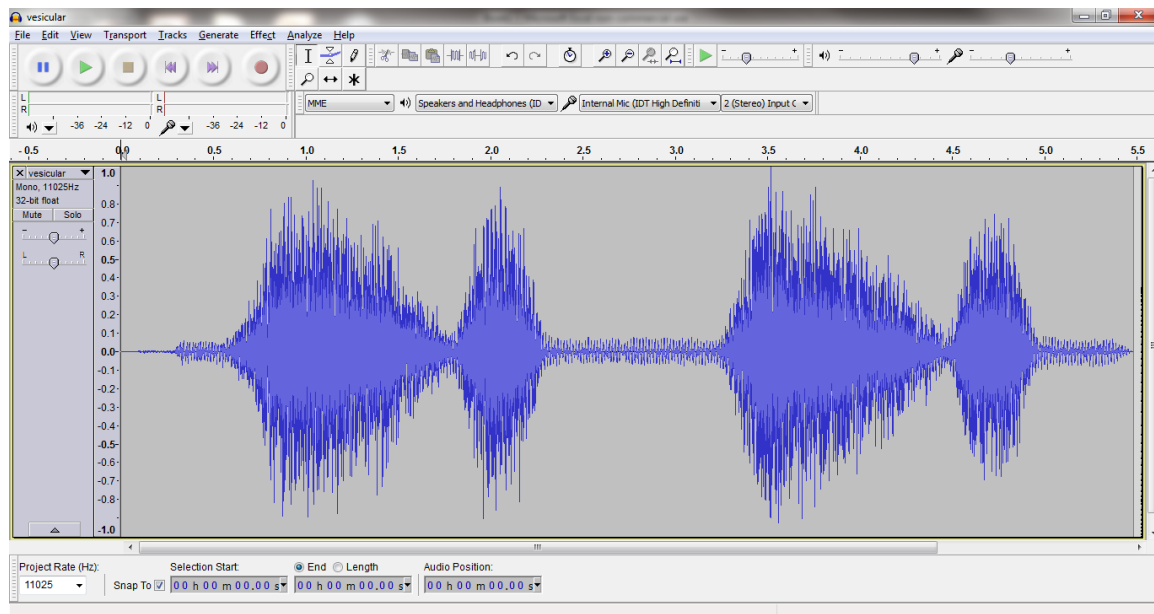
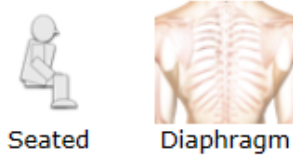
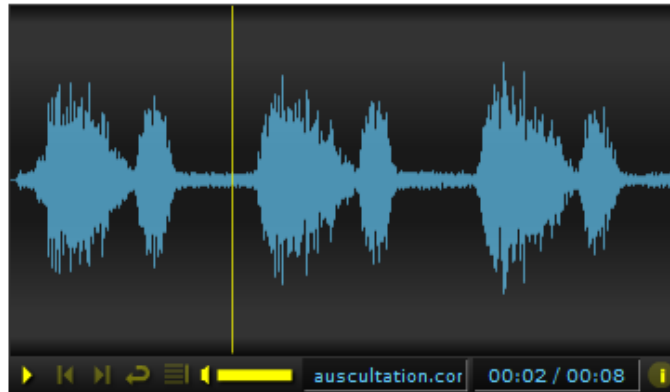
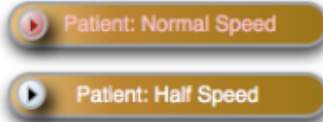


Figure 1 - Vesicular Breathing Waveform

Vesicular - Normal



Play Auscultatory Sounds



Listening Tips

Soft and low pitched with a rustling quality during inspiration and even softer during expiration. Inspiration to expiration ratio of 3:1 or 4:1.

Figure 2 - Breath Sounds, Colorado State University Auscultation Library

These figures show the audio spectrum of a captured, normal breath. By analyzing the frequency spectrum of such samples, the necessary sampling frequency can be determined.

2.1.2 Sampling Rates

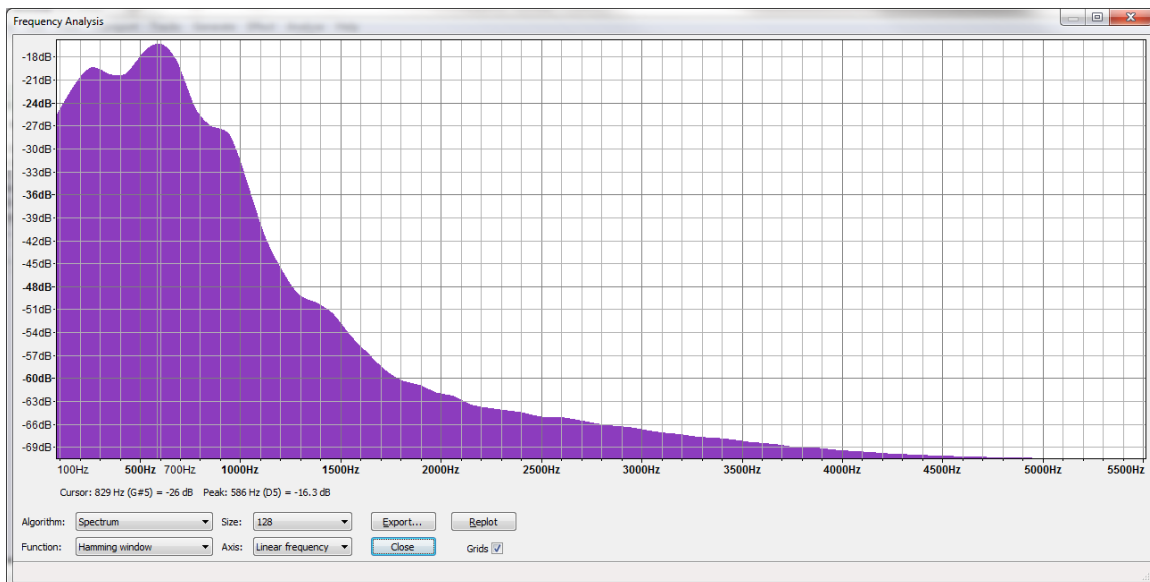
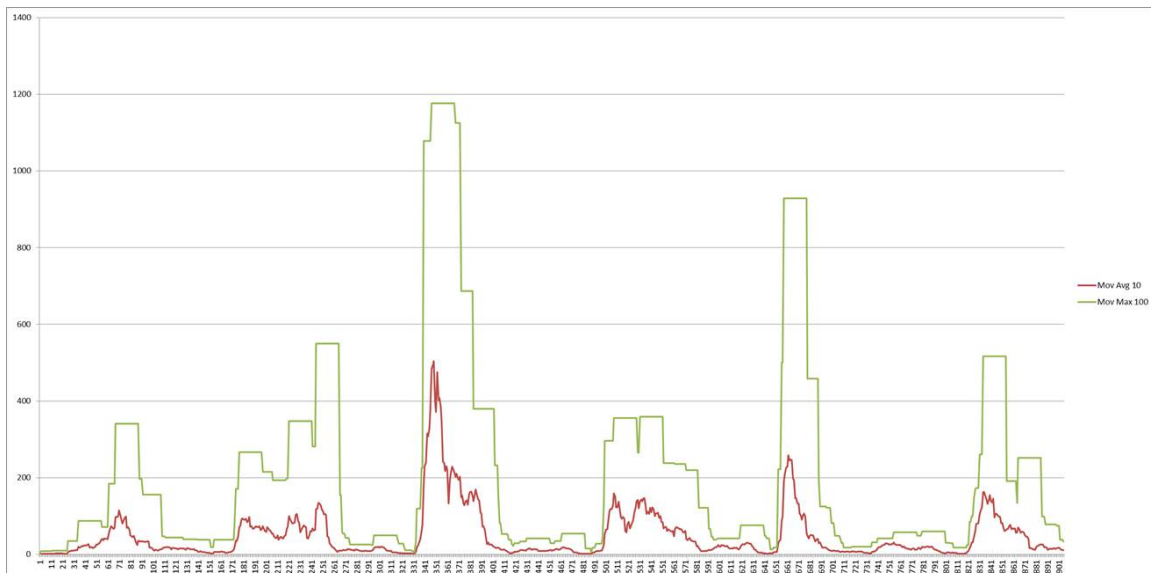
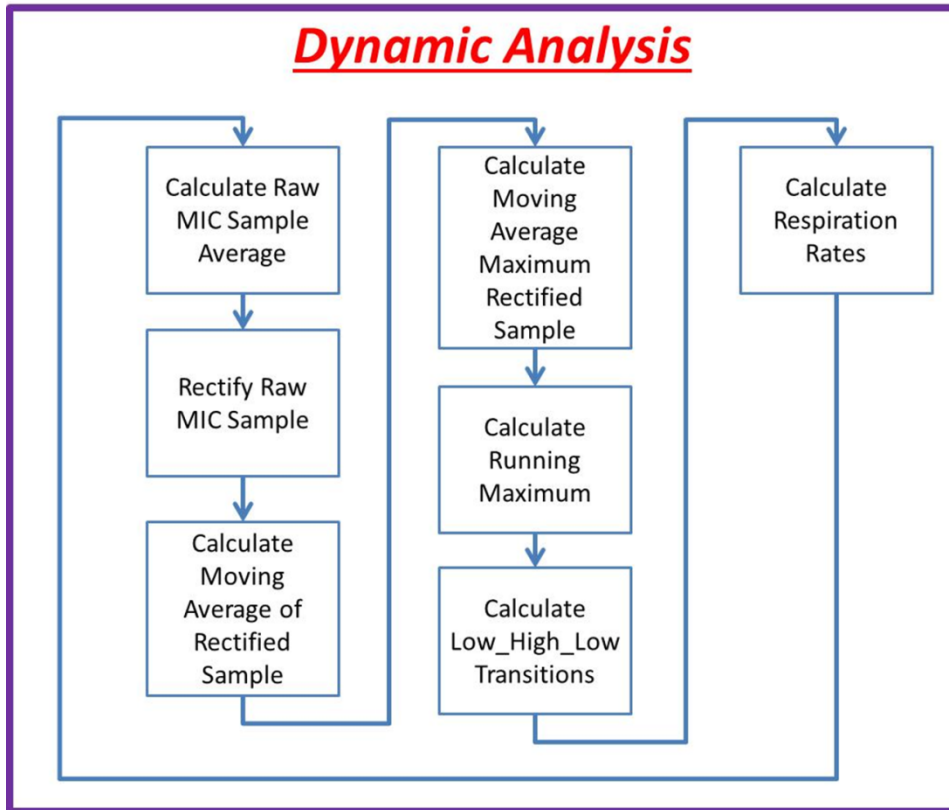


Figure 3 - Spectrum Analysis - Vesicular Breathing Waveform - Linear

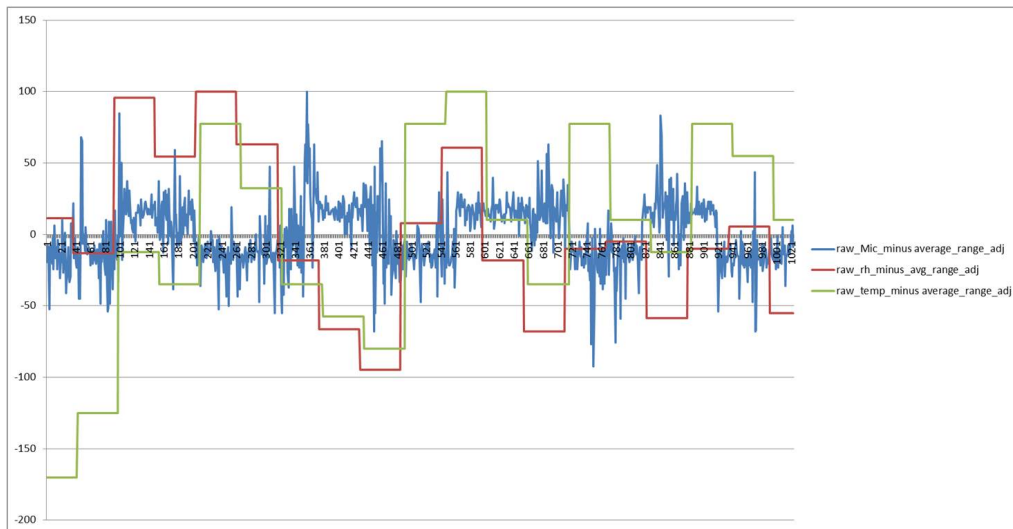
This figure illustrates the frequency distribution of a typical vesicular breath. One extension of the BARFS analysis technology would be to provide real-time

analysis and simulation of breathing sounds that duplicate issues such as bronchial, bronchophony, bronchovesicular, crackles, diminished vesicular, egophony, harsh vesicular, lobarpneumonia, pulmedema, and wheezing.



This figure illustrates the results of applying the 20 sample moving average (red) to the rectified audio sample with the bias removed. The green represents the moving average of the 'maximum' value of the last 20 samples. By counting the low-high-low transitions of the green trace, the breath count can be made, as well as form the basis for a breathing rate. This is how BARFS calculates breathing rates.

Comparison of MIC/ RH/ Temp Signals (2Hz)



Finally, the figure above illustrates the relationship between the raw audio sample taken at 4.11 KHz, and the temperature and relative humidity sampled at 2 Hz. While they show some lag, there appears to be a high correlation and a usable relationship for use in developing relative tidal volume measurements.

2.1.3 Human Factors Design

The original idea was to make a training device to help military personnel focus and control their breathing rates to bring their anxiety to a low and controllable rate while maximizing accuracy and focus on the firing range. This device would monitor breathing rates and alert the user as to how fast he/she is breathing, guiding them using audio and visual cues to a slower, more controlled rate. Soon the hardware was being pictured. I imagined that BARFS would use a set of glasses with a heads up display, a microphone headset and humidity sensors to bring our project to life. Down the road my heads up display glasses began to fade as it was too complicated and expensive, thus I developed a simpler and streamlined approach, the LED bar. The LED bar would be positioned in front of the left eye and would, one by one, empty until the user was in the target breathing range, coupled with a audio alert system that changes tone as the user approaches the target breathing range.

2.1.3.1 MIL-STD-1472G Guidelines

MIL-STD-1472G (11 January 2012) was used as a guide for selection of specific audio and visual feedback criteria.

2.1.3.1.1 Audio Signals

- 5.3.1.1.1 Use. Audio displays shall be provided under the following conditions:
- a. When information to be processed is short, simple, and transitory, requiring an immediate or time-based response.
 - b. When the common mode of visual display is restricted by over-burdening, ambient light variability or limitation, user mobility, degradation of vision by vibration, high G-forces, hypoxia, or other environmental considerations, or anticipated user inattention.
 - c. When the criticality of the event makes supplementary or redundant notification desirable.
 - d. When it is desirable to warn, alert, or cue the user to subsequent additional response.
 - e. When custom or usage has created anticipation of an audio display.
 - f. When voice communication is necessary or desirable (e.g., hands-busy situations).

5.3.1.1.2 Signal type. When an audio presentation is required, the optimum type of signal shall be presented in accordance with [table XIX](#) and shall be in accordance with the following.

a. Audio signal interference. Audio signals shall not interfere with other sound sources, including verbal communication.

b. Auditory presentation. Auditory presentation is preferred over visual presentation under any of the following circumstances:

- (1) For signals of acoustic origin.
- (2) For warning signals to call attention to imminent or potential danger.
- (3) For situations when many displays are visually presented (e.g., piloting an airplane).
- (4) For presenting information independently of head orientation.
- (5) For situations when environmental conditions limit vision or makes seeing impossible.
- (6) For conditions of anoxia or high positive G-forces.
- (7) When signals must be distinguished from noise, especially periodic signals in noise.

TABLE XIX. Functional evaluation of audio signals.

Function	Type of signal		
	Tones (periodic)	Complex sounds (non-periodic)	Speech
Quantitative indication	Poor, maximum of 5 to 6 tones absolutely recognizable.	Poor, interpolation between signals inaccurate.	Good, minimum time and error in obtaining exact value in terms compatible with response.
Qualitative indication	Poor-to-fair, difficult to judge approximate value and direction of deviation from null setting unless presented in close temporal sequence.	Poor, difficult to judge approximate deviation from desired value.	Good, information concerning displacement, direction, and rate presented in form compatible with required response.
Status indication	Good, start and stop timing. Continuous information where rate of change of input is low.	Good, especially suitable for irregularly occurring signals (e.g., alarm signals).	Poor, inefficient; more easily masked; problem of repeatability.
Tracking	Fair, null position easily monitored; problem of signal-response compatibility.	Poor, required qualitative indications difficult to provide.	Good, meaning intrinsic in signal.
General	Good for automatic communication of limited information. Meaning must be learned. Easily generated.	Some sounds available with common meaning (e.g., fire bell). Easily generated.	Most effective for rapid (but not automatic) communication of complex, multi-dimensional information. Meaning intrinsic in signal and context when standardized. Minimum of new learning required.

c. Cueing signals. Cueing signals may be used in combination with visually presented messages providing specific task-element instructions.

d. Nature of cueing signals. Cueing signals shall be short, tonal, and non-annoying but distinctive in character. As a general rule, cueing signals shall exceed the noise level in the critical band by at least 20 decibels.

e. Appropriate use of cueing signals. Audio cueing signals shall be provided for pacing user actions in situations requiring timely execution of task elements but where: (1) user attention may be diverted from the task at hand, or (2) the user depends on the cueing signal to know when to perform the task. Consideration shall be given to instrumenting the cueing signal system so as to generate a repetition of the signal if the user fails to perform the desired action.

5.3.1.3.3 Frequency. Frequency shall meet the following:

a. Frequency range. The frequency range shall be between 250 and 8000 Hertz and, if possible, between 500 and 2000 Hertz.

Note	Frequency (Hz)	Wavelength (cm)
G ₃	196	176
G [#] ₃ /A ^b ₃	207.65	166
A ₃	220	157
A [#] ₃ /B ^b ₃	233.08	148
B ₃	246.94	140
C ₄	261.63	132
C [#] ₄ /D ^b ₄	277.18	124
D ₄	293.66	117
D [#] ₄ /E ^b ₄	311.13	111
E ₄	329.63	105
F ₄	349.23	98.8
F [#] ₄ /G ^b ₄	369.99	93.2
G ₄	392	88
G [#] ₄ /A ^b ₄	415.3	83.1
A ₄	440	78.4
A [#] ₄ /B ^b ₄	466.16	74
B ₄	493.88	69.9
C ₅	523.25	65.9
C [#] ₅ /D ^b ₅	554.37	62.2
D ₅	587.33	58.7
D [#] ₅ /E ^b ₅	622.25	55.4
E ₅	659.26	52.3
F ₅	698.46	49.4
F [#] ₅ /G ^b ₅	739.99	46.6
G ₅	783.99	44
G [#] ₅ /A ^b ₅	830.61	41.5
A ₅	880	39.2
A [#] ₅ /B ^b ₅	932.33	37
B ₅	987.77	34.9
C ₆	1046.5	33
C [#] ₆ /D ^b ₆	1108.73	31.1
D ₆	1174.66	29.4
D [#] ₆ /E ^b ₆	1244.51	27.7
E ₆	1318.51	26.2
F ₆	1396.91	24.7

Figure 4 - Note/ Frequency Conversion (Physics of Music - Notes, <http://www.phy.mtu.edu/~suits/notefreqs.html>)

d. Headset. When the user is wearing earphones covering both ears during normal equipment operation, the audio alarm signal shall be directed to the user's headset as well as to the work area. Headset shall not block outside critical alarms. Binaural headsets shall not be used in any operational environment below 85 dBA where sounds that provide the user with useful information cannot be directed to the user's headset. Such sounds may include voices, machine noise that indicates wear or malfunction, and other audible indications of system performance/mission status.

a. Use of different characteristics. When several different audio signals are to be used to alert an user to different types of conditions, discriminable differences in intensity, pitch, beats and harmonics, or temporal patterns shall be provided. If absolute discrimination is required, the number of signals to be identified shall not exceed four. Signal intensity shall not be used alone as a means of discriminating between signals. Warnings shall differ on two or more parameters.

2.1.3.1.2 Visual Display

TABLE XV. Common color association meanings.

Color	Maps and tactical meaning	Classification meaning	Alarm, alert, threat meaning	Equipment meaning	Other common meaning
Red	Red alert Forces or situation at critical condition Hostile target identification	Secret	Critical consequences Danger or unsafe Severe threat Emergency Alarm	Closed/stopped Oxygen Malfunction Ordnance handling	Stop Heat or fire Failure OFF (as opposed to ON)
Orange		Top Secret	Alarm, alert, or hazard High threat		Value between red and yellow
Yellow	Forces or situation at marginal condition Unknown target affiliation CBRNE areas		Warning, caution, or hazard Elevated threat Approaching critical Extreme Caution Impending danger	Oil	Abnormal state Delay Check/recheck
Green	Non-alert Neutral target affiliation Obstacles Forces or situation at acceptable condition	Unclassified	Normal Safe Low threat	Open/flowing	Maintenance personnel ON (as opposed to OFF) Intolerance/ acceptable Ready, proceed, satisfactory

Figure 5 - Table XV Excerpt

2.2 System Architecture

2.2.1 General

The Parallax Propeller multi-processor architecture provided the mechanism to do an orderly and segmented development of BARFS.

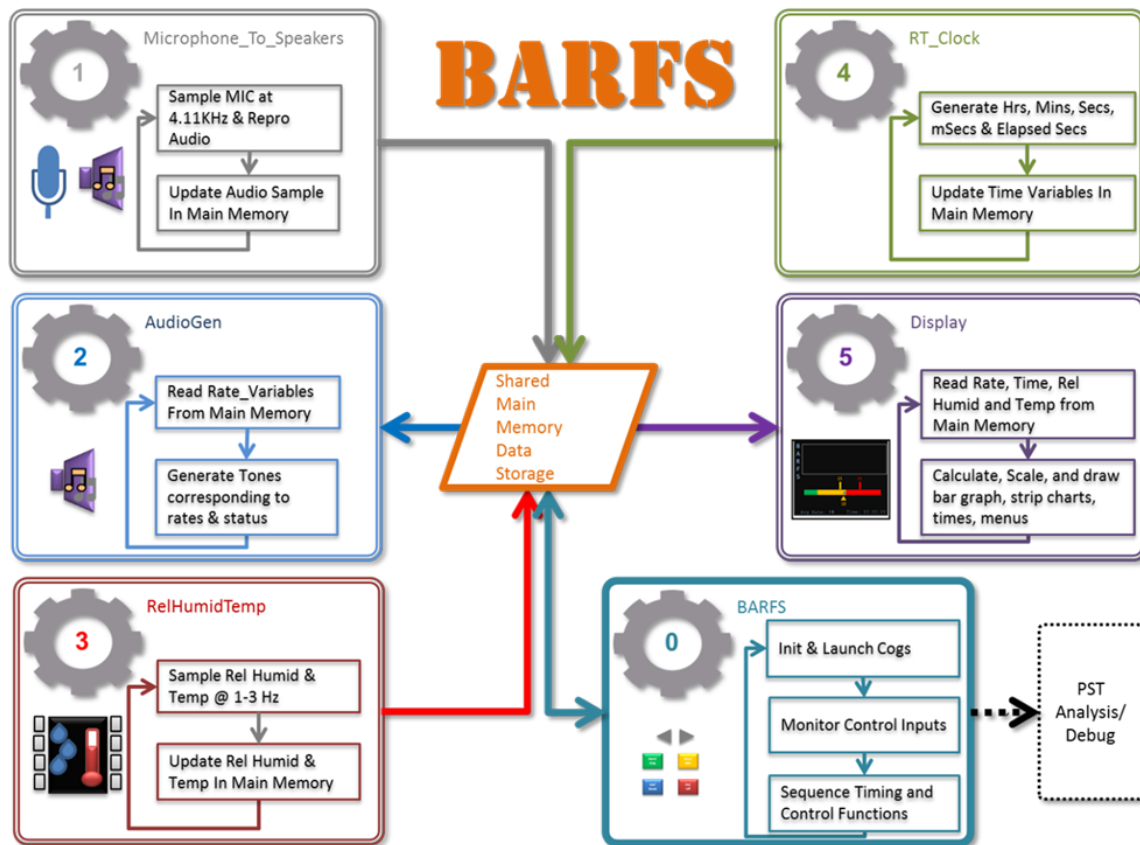


Figure 6 - BARFS Multi-Cog Processor Allocation

2.2.2 Hardware

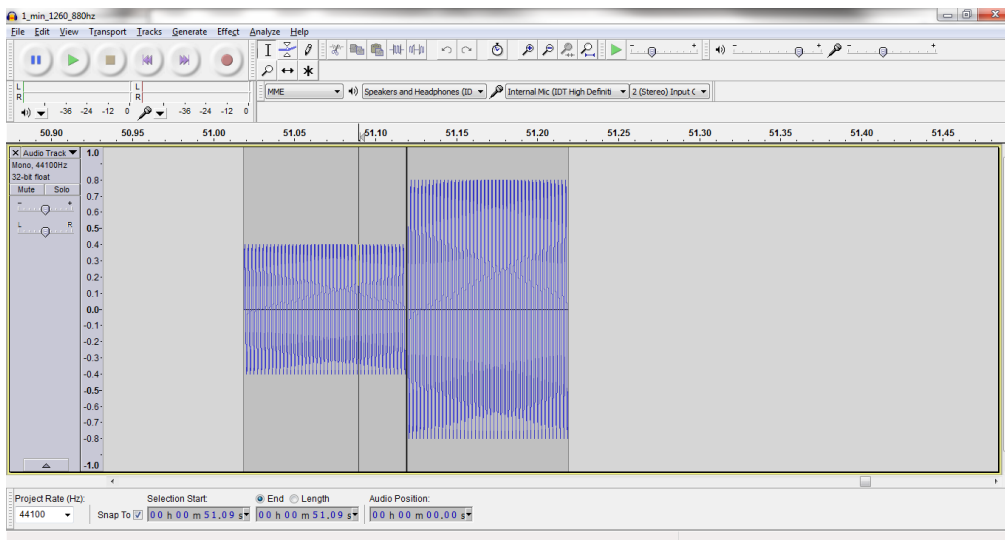
2.2.3 Menu

POWER-ON	Splash Screen	
	About	
MAIN MENU	SYSTEM SETTINGS	BRIGHTNESS VOLUME SENSITIVITY NEXT
	TARGET SETTINGS	TARGET MAX TARGET MIN NEXT
	ANALYSIS	START PAUSE STOP RESET
	SUMMARY	AVG RATE MAX MEASURED MIN MEASURED TIME TO MIN

Eventually, it is anticipated that menu selectable functions for adjusting volumes, speaker destinations, target ranges, and summary and logged information would be incorporated.

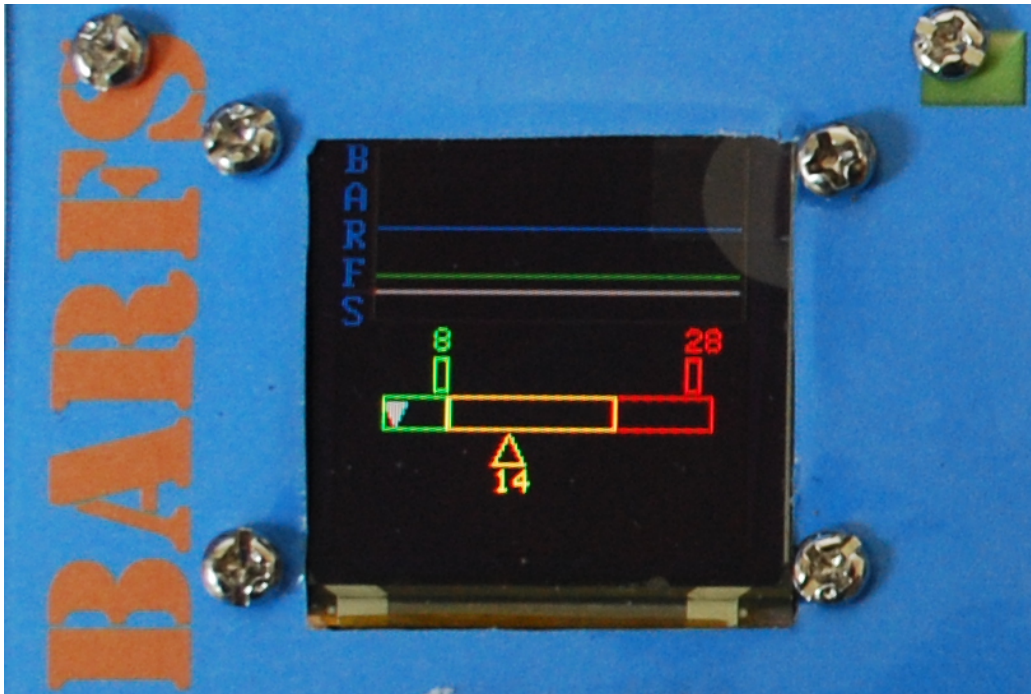
2.2.3.1 Outputs

Audio



The figure shows a two-toned generated sound that was used for the basis of the AudioGen tones in BARFS.

Display



2.2.4 Software

2.2.4.1 OBEX Library Objects

Available OBEX objects for the target hardware were used to the maximum extent possible. Every effort was to use them un-modified.

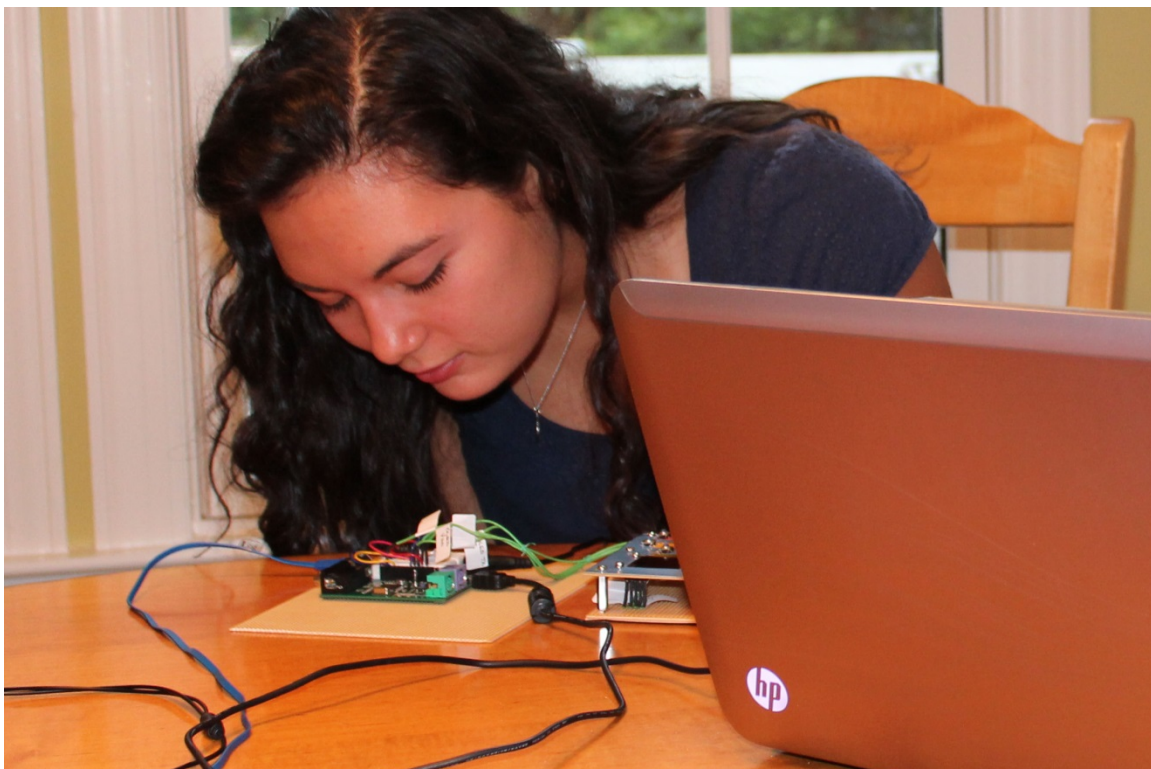
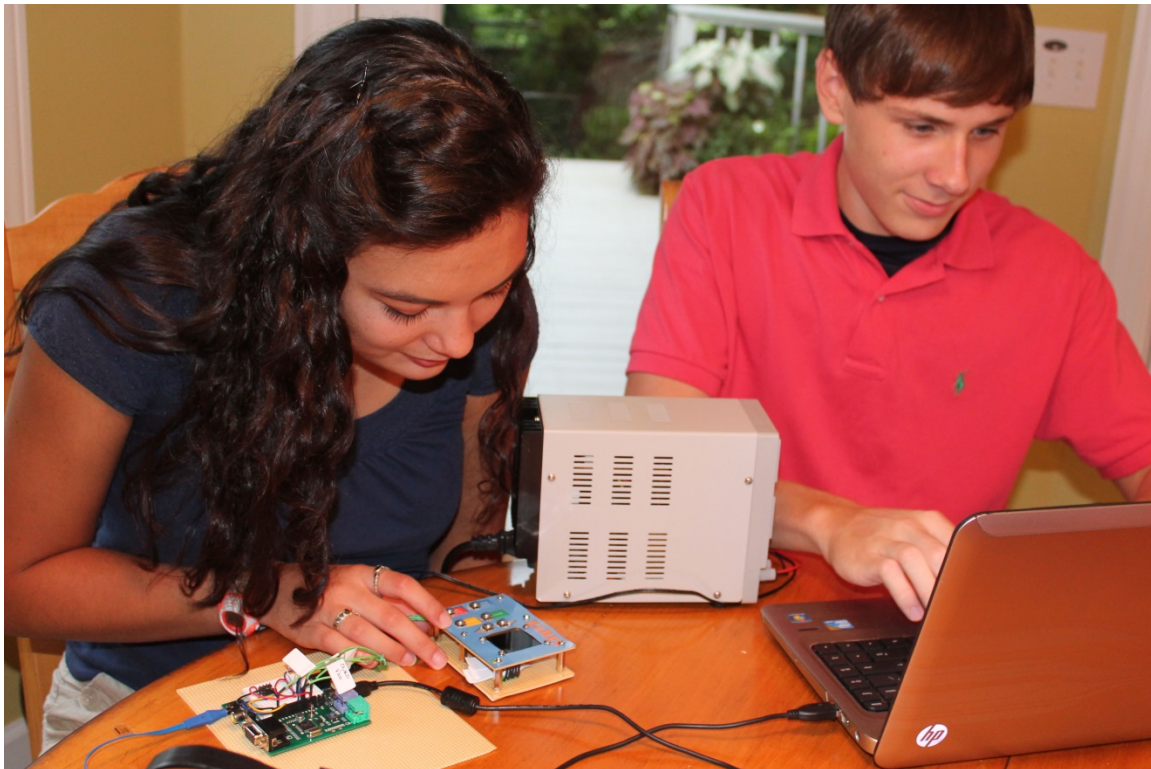
```
OBJ
delay      : "clock"                'unmodified OBEX object providing timing functions
sound      : "synth"                'unmodified OBEX object providing sound generation for AudioGen
microphone : "mic_to_phones_with_sample" 'slightly modified OBEX object providing Sigma-Delta sampling of microphone
pst        : "Parallax Serial Terminal" 'unmodified OBEX object providing terminal interface for development and debug
sht        : "Sensirion_full"        'unmodified OBEX object providing interface to Sensirion SHT-11 Humidity Sensor
oled       : "uOLED-128-GMD1_mod"    'MODIFIED OBEX object that provides interface to the OLED-128 LED Display
```

3 Tools Used

Propeller Editor/ Development System Version 1.3.2

Audacity Version 2.0.3 (<http://audacity.sourceforge.net/>)

Microsoft Excel 2010



5 Conclusions and Recommendations

Based on the early success of investigations of the combined microphone input and humidity and temperature sensors, not only can this device be used by military personnel for training, but has potential for additional medical benefits related to non-intrusive methods of measuring breath parameters.

