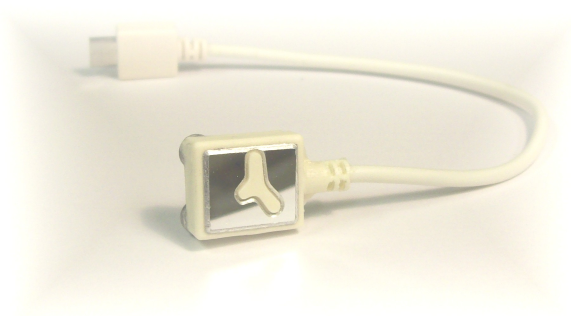
The AudeoSensor
User's Guide
Rev. 12.02.2009



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General Overview

Introduction

The AudeoSensor is a fully integrated neuromuscular interface with revolutionary implications in a variety of fields. By utilizing muscle activity below the threshold of physical movement, Ambient Corporation has demonstrated exciting applications of the AudeoSensor in the areas of communication, mobility, gaming, robotics, prosthetics, biofeedback, and more.

Background

In order to control the muscles, the brain sends tiny electrical signals through the nerves which then stimulate particular muscles into action. This stimulation occurs in the form of Motor Unit Action Potentials (MUAPs), and the cumulative electrical activity cascades through the muscle and causes it to contract. In general, most muscles have a kind of threshold which this electrical activity must surpass in order to produce physical movement. This is similar to the concept of a dead-zone in DC motors. Most people have very refined muscle control above this threshold, but without any kind of feedback have neither the ability nor the motivation to develop sub-threshold control.

Technology

The AudeoSensor non-invasively detects and processes electrical signals generated when a user activates a nearby muscle. In particular, the AudeoSensor was specifically developed around the laryngeal muscles controlling speech production (although the sensor can perform equally well on most other muscles). When placed directly over a muscle of interest, it reads an ultra-clean differential voltage from two stainless steel electrodes. The highly localized signal can be as small as 10μV (10E-6 Volts), so it is amplified x1000 and digitized in order to maintain signal integrity. Additionally, the signal is filtered and processed to result in the most useful and intuitive representation of muscle activation.

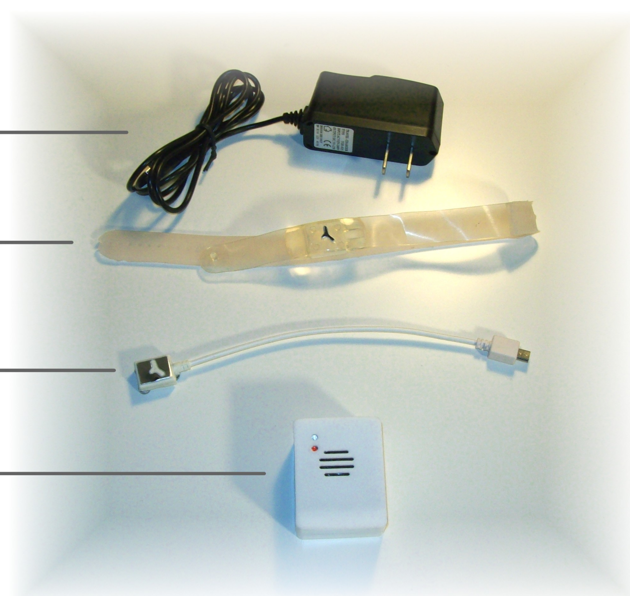
This signal can be accessed by a computer or cell phone through a Bluetooth connection, however the AudeoSensor is much more than just a passive signal stream. Included is a broad array of feedback mechanisms including visual, tactile, and 2-channel audio, all fully controllable through the same Bluetooth connection. The compact and highly integrated design of the AudeoSensor includes a standalone biofeedback mode which activates when no wireless connection is present, allowing basic usage even in the absence of a computer.

Features

- Self-contained, highly integrated form factor
- 560mAh rechargeable battery for day-long usage
- Class 1 (100m range) wireless Bluetooth interface
- Biofeedback mode works out of the box
- Robust to EMI/RFI
- High spatial selectivity
- Intuitive signal output
- Visual and tactile (vibration) feedback
- Selectable output (speaker, headphone) audio feedback
    - Customizable musical tones
    - On-board speech synthesis
    - Up to 33 minutes of indexed sound files (on select models)

Components

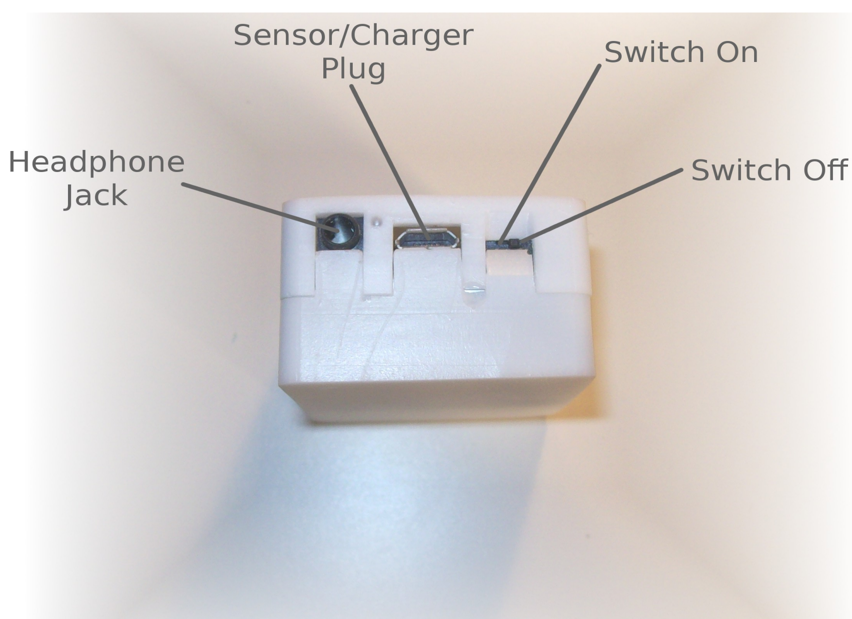
The AudeoSensor includes the core sensor, the control module, the attachment band, and a wall charger.



Getting Started

Charging

To charge the control module, move the switch into the off position and disconnect the core sensor. Plug the charger into the module and a standard wall outlet (120VAC, 60Hz). The red LED on the module will light up to indicate that the unit is charging, and will turn off when charging is complete.



Attachment

The AudeoSensor includes an elastic band for attachment to the neck. First, connect the core sensor to the wireless unit. Place the core sensor into the band as shown, then press it onto the neck such that the two smaller discs are slightly offset from the center of the throat and the larger disc is even more offset. This is the optimal position for acquiring signals from the laryngeal muscles. While holding the sensor in place, wrap the band around your neck and secure it so that the sensor maintains good skin contact. The control module can be clipped to a shirt collar, noting that the tactile feedback works best when the unit is in close contact with the user. Also note that the feedback will remain constantly on if the sensor is not well secured to the neck.

Biofeedback

To activate the biofeedback mode, simply turn on the control module. In this mode, the visual and tactile feedback will activate in proportion to your muscle activity. The harder your muscles work, the more pronounced the feedback. Although very rudimentary, this mode allows the user to train themselves to selectively activate the muscle, vary the level of activation, and minimize the effort required for activation. An expert user is capable of a fine degree of control with no visible signs of muscle activity!

Wireless Interface

Communication

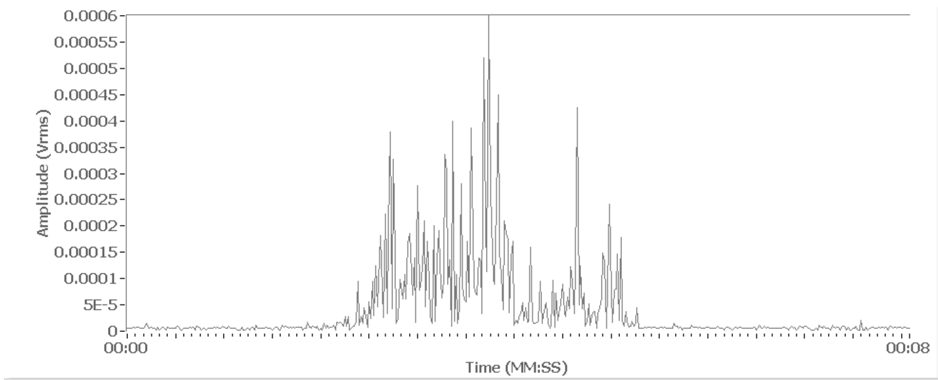
Every AudeoSensor control module will broadcast itself as *BlueAudeo-XXXX*, where the X's uniquely identify the module. It uses the Serial Port Profile to transmit and receive data with the following serial port parameters:

Baud:	9600 bps
Parity:	Even
Data:	8 bits
Stop:	1 bit
Flow:	None

Pairing can be achieved with a PIN code of *1234*.

Signal

The data stream from the AudeoSensor is an 8bit unipolar value which is proportional to the muscle activation, and has a sampling rate of around 800Hz. This data generally corresponds to the RMS value of a differentially amplified biopotential (x1000). The 8bit range corresponds to an input range of 0 – 0.6mV RMS, as shown in the example signal below.



Feedback

The feedback mechanisms built into the AudeoSensor are controlled through a set of commands sent over the Bluetooth interface. In order to synthesize speech, ASCII text may be sent to the AudeoSensor followed by a NULL or CR character. In addition to normal text-to-speech mode, there is also a phonetic mode which allows one to directly control the pronunciation of the speech engine. Once this mode is activated (see the Command Summary), all ASCII text is interpreted as a string of sounds according to the table below. For example, sending the string, "K AX M P YY UW DX ER", would say the word "computer".

Phoneme String	Example	Phoneme String	Example
A	das (Spanish)	N	new
AA	cot	NG	rung
AE	cat	NY	nino (Spanish)
AH	cut	O	no
AW	cow	OW	boat
AX	bottom	OY	boy
AY	bite	P	pop
B	bib	PX	spot
CH	church	R	ring
D	did	RR	tres (Spanish)
DH	either	S	sell
DX	city	SH	shell
E	ser (Spanish)	T	tin
EH	bet	TH	thin
EI	mesa	TX	stick
ER	bird	U	uno (Spanish)
EW	Acteur (French)	UH	book
EY	bake	UW	boot
F	fee	V	valve
G	gag	W	we
H	he	WH	when
I	libro (Spanish)	Y	mayo (Spanish)
IH	bit	YY	you
IX	rabbit	Z	zoo
IY	beet	ZH	vision
J	age	(space)	inter-word pause
K	cute	'	short pause
KX	ski	,	medium pause
L	long	.	long pause
M	me		

In addition to the speech interface, there are many other commands which can be used to modulate the feedback mechanisms of the AudeoSensor. These commands are outlined in the table below, and are generally a combination of raw bytes (shown in black, hexadecimal format) and ASCII text (shown in red).

Command Summary

Command	Parameters	Description
0x00 0x0D	(none)	Play all buffered audio.
0x02	(none)	Switches audio output to the headphone jack.
0x03	(none)	Switches audio output to the speaker.
0x04 ***n***	n = unsigned byte, 0-255	Activate LED/vibration at amplitude *n*. Example: 0x04 FF - Maximum amplitude
0x10	(none)	Pause audio output.
0x12	(none)	Resume audio output.
0x18	(none)	Stop audio output.
0x19	(none)	Skip to next sentence in buffer.
0x1E01 ***n***T	n = 0-15	Enter text-to-speech mode with a delay between words. Example: 0x1E01 3135 54 - Maximum delay between words (= 0x1E01 15T)
0x1E01 D	(none)	Enter phonetic mode.

0x1E01 ***n*S**	n = 0-13	Changes the speaking rate. Example: 0x1E01 3133 53 - Speak at the fastest rate (= 0x1E01 13S)
0x1E01 ***n*O**	n = 0-10	Switch between 11 predefined voices. Example: 0x1E01 304F - Selects the default voice (= 0x1E01 0O)
0x1E01 ***n*A**	n = 0-9	Select the articulation level of the voice. Example: 0x1E01 3541 - Selects the default articulation (= 0x1E01 5A)
0x1E01 ***n*E**	n = 0-9	Select the pitch variation (intonation) of the voice. Example: 0x1E01 3545 - Selects the default intonation (= 0x1E01 5E)
0x1E01 ***n*F**	n = 0-99	Select the overall frequency response (vocal tract formant frequencies) of the voice. Example: 0x1E01 3530 46 - Selects the default frequency response (= 0x1E01 50F)
0x1E01 ***n*P**	n = 0-99	Select the average pitch of the voice. Example: 0x1E01 3530 50 - Selects the default pitch (= 0x1E01 50P)

0x1E01 ***n***R	n = 0-9	Adds a reverberation effect to the voice. Example: 0x1E01 3952 - Maximum reverberation (= 0x1E01 9R)
0x1E01 ***n***V	n = 0-9	Selects the overall volume of the audio output. Example: 0x1E01 35 - Selects the default volume (= 0x1E01 5V)
0x1E01 ***n*****J*****aaaabbbb***	n = 2-59999 (duration in tens of ms) aaaa = 0-9999 (freq. 1 in Hz) bbbb = 0-9999 (freq. 2 in Hz)	Buffers up to two simultaneous audio tones. Note that all four digits of 'a' and 'b' are required. Example: 0x1E01 3130 304A 0033 3500 0034 3400 - Outputs a 350/440Hz tone pair for one second (= 0x1E01 100J03500440)

Application Strategies

Recognition

The most misunderstood of strategies, Recognition with the AudeoSensor is most commonly associated with speech recognition. Here, a person tries to speak a word naturally and that word is then detected from the signal pattern of the AudeoSensor. However, this approach carries some novel challenges in addition to all of the traditional challenges of speech recognition. For example, subvocal (silently spoken) speech is not a natural act. Even though you may think that you are subvocalizing a certain word, you have never had the feedback to tell you otherwise. Additionally, the signal from the AudeoSensor is but a small subset of the many control signals and muscles used to produce actual speech. Add to this the natural variability both between people and within a single person, and the result is a relatively limited application strategy.

Despite these challenges, it is possible to successfully implement small-set recognition of the signals of the

AudeoSensor. Below is a picture of Ambient's demonstration of the “Mind-Controlled Wheelchair” at National Instruments 2007 developers conference. This application managed robust and accurate recognition through a combination of a small, strategically selected command set and simple feature extraction. Three of the commands which were subvocalized in order to control the wheelchair are listed below. It is clear that the duration alone is an excellent signal feature to detect the given command. Additional amplitude-based features made recognition even more reliable, resulting in an impressive demonstration of the technology.

Wheelchair Commands:

"Move Forward"
"Rotate"
"Stop"

Selection

The most common strategy uses the signal to choose between a discrete set of options, such as commands or spoken phrases. This approach requires the user to learn a particular selection method, but once mastered can easily scale to large selection sets. This application strategy is the basis for Ambient Corporation's assistive communication offering, The AudeoBasic. The simplest example chooses between two responses, 'Yes' and 'No'. One of these responses is highlighted, and after a period of time alternates to the other response (a technique known as scanning). The program waits for the signal from the AudeoSensor to go above a certain threshold, after which it speaks the currently selected response. In this way, the AudeoSensor acts as a kind of switch or button. Even with a selection mechanism as simple as this, choosing among thousands of phrases is only a matter of how you structure them.

Transformation

The final strategy directly transforms the signal of the AudeoSensor into a continuous output of some kind. Although this can also require an adjustment period by the user, the continuous and real-time nature of the feedback have the potential to significantly shorten the time required for mastery of the control mechanism. The most obvious example of this is the biofeedback mode included in the AudeoSensor. All of the feedback activates directly in proportion to the strength of the signal on a more-or-less continuous scale. A more complex example is shown below. Here, Ambient Corporation developed a muscle augmentation appliance which used a powerful motor to assist the contraction of the arm. The position of this motor is directly controlled in proportion to the AudeoSensor signal, extending the users natural arm control mechanism to an artificial muscle. From a user perspective, this strategy is best in the sense that it gives them a much richer experience. However, it can be a significant challenge to implement well.