Animatronics
Mouth Software Description Document

By: Jim Schrempp and Bob Glicksman; v1.0, 12/8/2025

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https://github.com/TeamPracticalProjects/Animatronics/blob/main/Terms_of_Use_License_and_Disclaimer.pdf

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DOCUMENT OVERVIEW.

This document describes the software (firmware) that runs the Animatronic Head "Mouth" subsystem. This subsystem is described in the document:

https://github.com/TeamPracticalProjects/Animatronics/blob/main/Documents/Animatronic%20Head%20Electronic%20Hardware%20Document.pdf

"MOUTH" SOFTWARE OVERVIEW.

The "Mouth" software runs on a Particle[1] Photon 1 using Particle OS version 3.0.0[2].

The "Mouth" software subscribes to events that are published to the Particle Cloud by the Animatronic "Brain/Eyes" software. Each event causes an audio clip to be selected and played through the DFRobot DFPlayer miniMP3 module and its associated micro SD card. While a clip is being played, the "Mouth" software samples the envelope of the audio clip (every 10 milliseconds, from pin A0) and processes each sample using a digital signal processing chain that includes:

- Number of samples to average (for smoothing); typically set to 1 (no smoothing)
- Optional non-linear scaling of the sample values; typically set to linear.
- Scaling of A/D values based upon maximum and minimum clip amplitude values and mapping to the range of the mouth servo.

The best overall effect for any specific audio clip is determined experimentally using Particle Cloud functions and variables that can be read and set using the Particle Console. The values for each clip on the micro SD card are stored in a separate file in the software. The software uses the values in this file to process each A/D sample into Mouth servo position values.

A backlit push button is provided to mute the mouth temporarily, e.g. when presenting the Head in a demo.

The "Mouth" software supports up to 4 "personalities". Each personality represents a set of audio clips; e.g. different personalities can have different voices and messages for each event published by the "Brain/Eyes" software. Up to 4 audio clips can be associated with each event

[1] Particle.io

[2] This is the latest version of the Particle OS that compiles on a Photon 1 and does not generate errors when compiling the DFRobot DFMini MP3 Player library. This library has several bugs in it. All bugs relate to lack of a return statement in functions that have non-void return values. None of these functions are used by this code. OS 3.0.0 treats these issues as warnings and compiles OK. Later versions of the Particle OS treat them as fatal errors and will not compile the code even though the offending functions are not used.

in each of the 4 personalities. When the “Mouth” software responds to an event, one of the clips associated with that personality and that event is randomly selected and played.

A set of defined constants in the software determines the maximum open and closed positions for the mouth servo. The open and closed positions that give the best visual effect is determined experimentally, as it varies with the face hardware architecture and mouth servo mechanics. Mouth open and closed values can be experimented with using Cloud functions that are available through the Particle Console.

“MOUTH” SOFTWARE FILES.

The source code files for the “Mouth” software are located in this repository, at:

https://github.com/TeamPracticalProjects/Animatronics/tree/main/Software/Photonfirmware/AnimatronicMouthDemo

The following files are located in this folder:

- *lib/DFRobotDFPlayerMini*. This is the library for the DFRobot DFPlayer miniMP3 device.
- *src/MN_Demo_Mouth.ino*. This is the main code for the “Mouth” software.
- *src/TPP_Animatronic_Global.h*. This file defines enumerated event codes for the events that are published by the “Brain/Eyes” software and subscribed to by the “Mouth” software.
- *src/TPP_clipinfo.h.* This file defines the standard C structure (struct) that must be available for each clip that is to be played and processed.
- *src/TPP_clipinfo.cpp.* This file contains the actual values of the standard clip struct for each MP3 clip file that is used by the Head. The values contained in these structs are determined experimentally (using the Particle Console) to provide the best audio volume and best visual mouth movement effect when playing each audio clip.

“MOUTH” SOFTWARE SETTINGS AND CALIBRATION.

Personality Setting and Definition.

Jumper fields A5 and A4 may be used to select one of 4 “personalities” for the “Mouth” software to use. Each personality is a set of audio clips stored on the micro SD card, with up t o 4 clips for each possible event that the “Mouth” software subscribes to. An open pin is a logic 1 and a grounded pin is a logic 0. The “Mouth” software reads these pins and sets the personality to use during setup().

A default set of clips and personalities is included in this repository. The personalities are:

Bob Personality #1: ground both A4 and A5
Bob Personality #2 (not yet implemented): ground A5, open A4
Jim Personality #1: open A5, ground A4
Jim Personality #2 (not yet implemented): open A5, open A4

The details of each of these “personalities” are defined in:

https://github.com/TeamPracticalProjects/Animatronics/blob/main/Software/Photonfirmware/AnimatronicMouthDemo/src/TPP_clipinfo.cpp

The clips themselves are contained in:

https://github.com/TeamPracticalProjects/Animatronics/tree/main/Data/SDCardMP3Folder

Mouth Mechanism Calibration.

The Mouth mechanism is a single servo that attaches the jaw piece of the Head via a lever arm. The servo positions for the Mouth closed and Mouth wide open are dependent on the mechanical details of this mechanism and on the initial servo position during Head assembly. The Mouth closed servo position (angle) should be set so that the Mouth is almost touching the upper lip (leaving a little room for mechanical bounce). The Mouth open position should be set for the best visual effect – open enough to make all movement easily visible but not open so much that the effect is unrealistic.

The settings for any newly constructed Head must be determined experimentally using the Particle Console. See figure 1 for details:

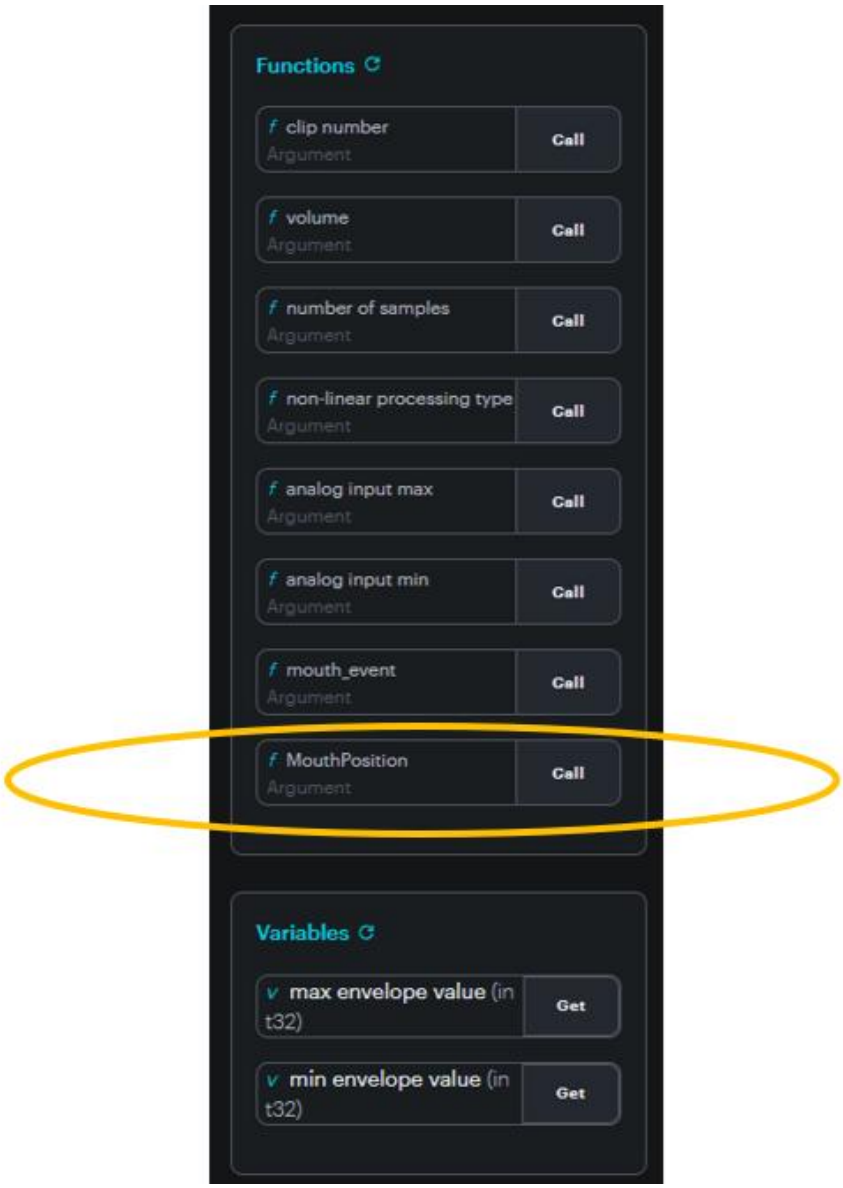

Figure 1. Mouth Position Calibration Control.

The argument for the “Mouth Position” Cloud function, shown in figure 1, is the servo angle. Entering a number in the *Argument* field and clicking on *Call* will cause the Mouth servo to go to that position. The best values for open and closed servo positions should be noted and then entered into the “Mouth” software:

https://github.com/TeamPracticalProjects/Animatronics/blob/main/Software/Photonfirmware/AnimatronicMouthDemo/src/MN_Demo_Mouth.ino

See lines 94 and 95 for these defined constants.

Note that the servo angle change between open and closed of the default values is only about 11 degrees. A larger difference in servo angle makes the open Mouth position too wide and unrealistic in appearance.

The “Mouth” software must be recompiled and flashed to the Mouth Photon 1 after this file is changed.

Clip Processing Value Determination and Setting.

The digital signal processing settings for each clip that is to be played on the Head should be calibrated for the best overall visual effect. The clip calibration data for each clip is defined by a C structure. The definition of this C structure is in:

https://github.com/TeamPracticalProjects/Animatronics/blob/main/Software/Photonfirmware/AnimatronicMouthDemo/src/TPP_clipinfo.h

The actual data for each clip is added to the relevant “personality” in the file:

https://github.com/TeamPracticalProjects/Animatronics/blob/main/Software/Photonfirmware/AnimatronicMouthDemo/src/TPP_clipinfo.cpp

The “Mouth” software must be recompiled and flashed to the Mouth Photon 1 after these files are changed.

The best values to use for any given clip will depend upon the clip playback volume and the actual contents of the audio clip. The best overall effect for each clip is determined experimentally using Particle Cloud functions and variables available through the Particle Console; see figure 2, below.

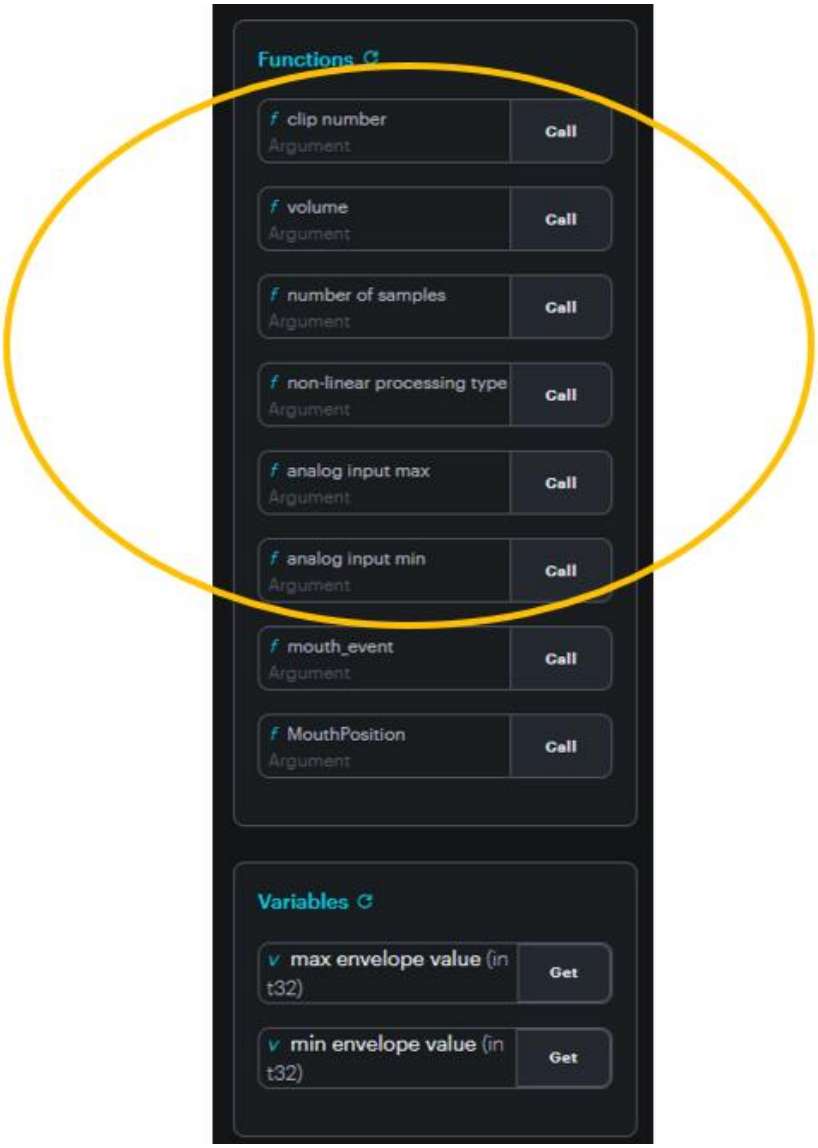

Figure 2. Clip Settings for Clip Calibration Testing.

The “clip number” function *Argument* is the number preceding the clip file’s name, e.g. a clip file named “0110 HelloThere.mp3” can be played by entering “0110” in the “clip number” *Argument* and clicking on *Call*.

Prior to playing a clip, some reasonable defaults should be set into each of the following functions:

- volume: use a number like 23 (max is 30).
- number of samples: use 1 (no sample averaging)
- non-linear processing type: use 1 (linear processing; either 1 or 2)
- analog input max: use 4095 (max is 4095)
- analog input min: use 0 (min is 0)

The *Argument* for each function must be set by clicking on the relevant *Call* button. Once the *Arguments* are set in the software, the functions do not have to be called again for subsequent experiments, unless you want to try changing them.

Note that the playback “volume” setting is most important as it effects the volume of the sound through the loudspeaker as well as the amplitude of the analog signal into the Photon 1 A/D converter. The loudness of the playback sound will depend upon the parameters used when originally recording the clip. See below for tips on proper clip recording.

The “volume” function *Argument* should be set to play the clip using the best audio volume. The default settings for “analog input max” and “analog input min” should be set to the overall max and min of the Photon 1 A/D converter (4095 and 0, respectively). The “clip number” function should then be called to play the clip and assess the sound playback volume. The “volume” function should then be changed in order to achieve the best play back volume. When the best playback volume is achieved, click on “max envelope value” and “min envelope value” (see figure 3) in order to determine the highest and lowest A/D converter values during the last clip playback.

In general, the “min envelope value” should be 0 (or very close to 0). If so, set the “analog input min” to be zero. If this value is not close to 0, then the analog circuitry is noisy – this is a hardware problem that should be corrected.

In general, the “max envelope value” will be somewhere between about 2500 and 4000. This will vary with the clip and the volume setting that is selected. It is important to scale the “analog input max” to be close to 4095 (the A/D converter max) but with a little headroom. This way, the scaling process with move the mouth for the best effect. The value to set for “analog input max” should be slightly higher than the “max envelope value” for this reason. Change “analog input max” and replay the clip to see that the “max envelope value” is now around 4000 (not critical but must be less than 4095).

You may experiment with changing the other parameters to observe the best Mouth effect for that clip. In general, averaging samples or selecting non-linear processing does not make a large visual difference, but improvement over the defaults may be possible. The final effect is, of course, subjective.

Once all of these values are experimentally optimized. The clip information (the arguments to these Cloud functions that produce the best visual effect) should be entered/edited in the file:

https://github.com/TeamPracticalProjects/Animatronics/blob/main/Software/Photonfirmware/AnimatronicMouthDemo/src/TPP_clipinfo.cpp

The “Mouth” software must then be re-compiled and flashed to the Mouth Photon 1.

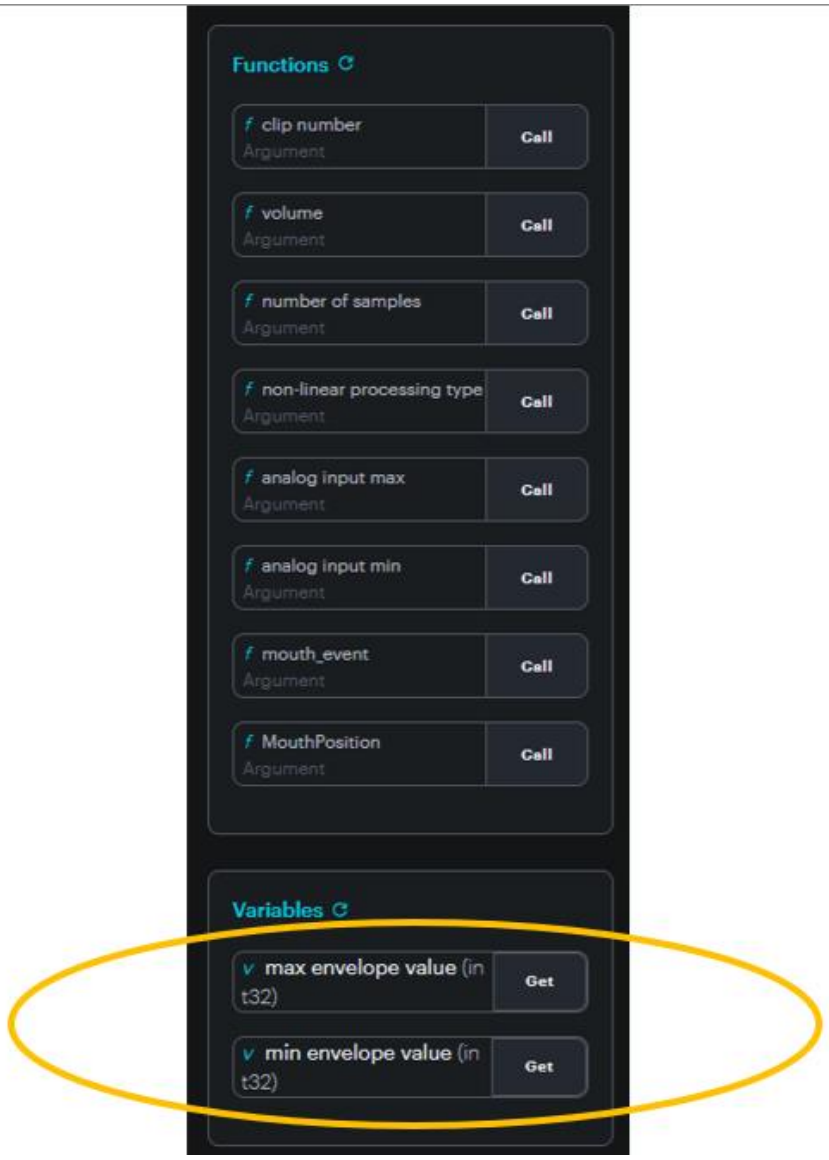

Figure 3. Max/Min A/D Values for a Clip.

Clip Testing.

The overall process of triggering the “Mouth” software from a Particle event and playing the clip with appropriate Mouth movement can be tested using the Particle Console; see figure 4, below.

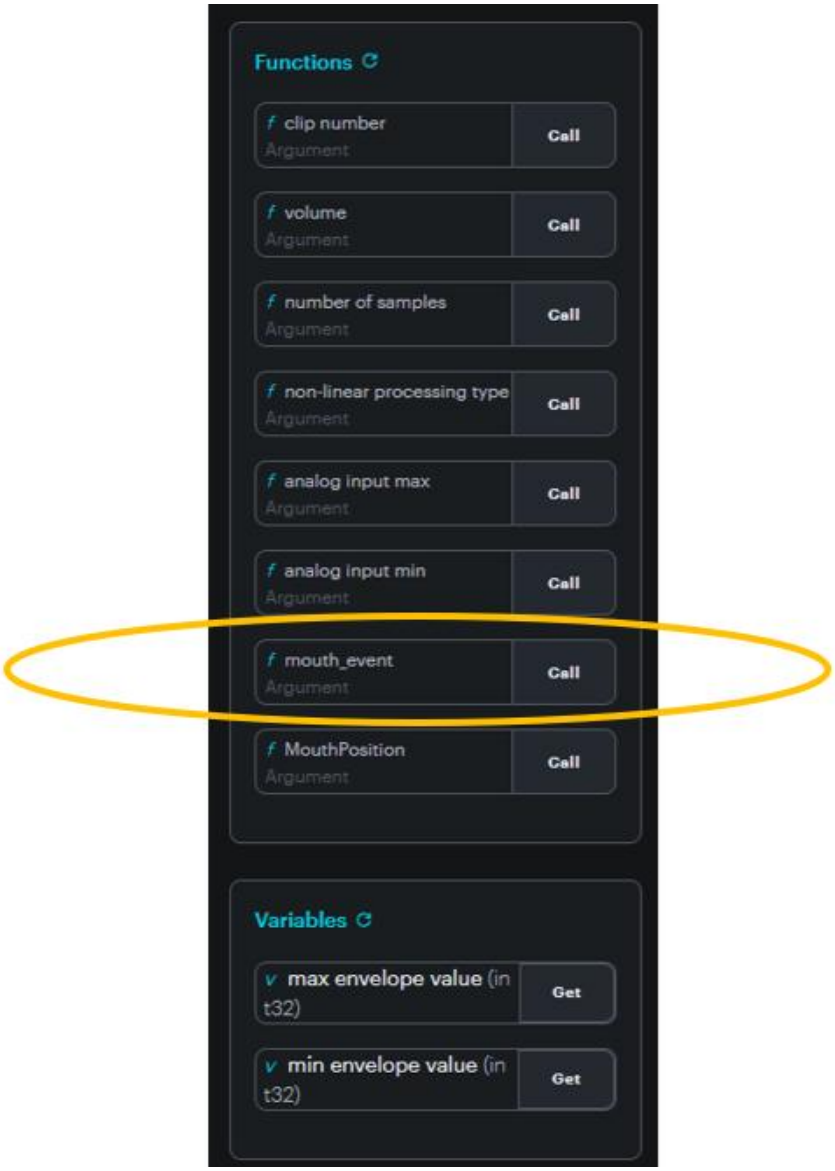

Figure 4. Testing an Event.

The *Argument* to the “mouth_event” function is the event number. Event definitions are in the file:

https://github.com/TeamPracticalProjects/Animatronics/blob/main/Software/Photonfirmware/AnimatronicMouthDemo/src/TPP_Animatronic_Global.h

TIPS ON RECORDING AUDIO CLIPS.

Audio clips for the Animatronic Head may be recorded in your own voice using any voice recording app on your computer or smartphone. Alternatively, synthesized voice clips may be created using on-line text-to-speech services. The recoded clip volume and the enunciation of the words are very important in achieving the best visual effect of the Mouth. This section contains some tips to use when recording your own clips.

All recorded clips should be stored in mp3 format. Online format converters can be used to convert other formats to mp3.

Clip Volume.

Voice clips should be recorded so that the playback volume through the loudspeaker is satisfactory with a “volume” function setting less than 25. The max setting is 30, so this leaves a little room for making the sound louder if necessary.

If a clip created using a voice recording app is too soft, try recording it again speaking louder or speaking closer to the recording microphone. Otherwise, you might use an audio processing app (e.g. *Audicity*) to adjust the clip volume. Just be sure that the volume isn’t made so high as to saturate the audio.

Enunciation.

Believe it or not, how you enunciate a voice clip makes a big difference in the visual effect of the Mouth. Be sure to enunciate clearly. In fact, consciously move your jaw when speaking, in accordance with the enunciation of the text. The recorded voice clip may not sound any different but the Mouth jaw movement will present significantly better than if you do not exaggerate your jaw movement when recording.