

Feedback Ocarina - a DIY entry-level instrument for feedback musicianship

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Figure 1: Small and large variations of the Feedback Ocarina

Abstract

Audio feedback in its pure form is notoriously difficult to control, yet at the same time it has a lot to offer as one of the simplest methods of creating sound in an expressive, tangible way. In an effort to provide a simple, easily replicable feedback instrument, I'm proposing the Feedback Ocarina - a simple device, combining a 3d-printed variable frequency Helmholtz resonator with an inexpensive microphone cartridge. By opening and closing the finger holes, it's possible to control the feedback frequency, much like with a standard, acoustic ocarina.

Keywords

NIME, feedback, tactile, diy, replicable

1 Introduction

1.1 Motivations

The goal of this research is to provide a blueprint for an easy to make, affordable feedback instrument, which could be used as a means of introduction to feedback musicianship. Nevertheless, with some refinements and dedication, the methods outlined in this paper can be used to create a functional musical instrument for more serious applications.

1.2 Background

Audio feedback is a commonly known phenomenon and, in most cases, it is perceived as an undesired error or nuisance. Nevertheless, it has been explored for artistic purposes since at least the 1960s, most notably by artists such as Jimi Hendrix, Alvin Lucier or Steve Reich. The main attraction behind the feedback utilized as a musical device might be its immediate responsiveness to physical manipulations, as it's inextricably interactive and tangible, offering a direct and satisfying experience to its operator. As observed by Magnusson et al, „(...) *feedback musicianship is not about exercising control but rather about giving it away: about playing »with an instrument« and not »playing on an instrument«.*” [1]



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In the last couple of decades, there were numerous attempts at controlling the musical pitch of the feedback generated with unmodified instruments; Robert Fripp reportedly marked specific spots between his guitar and amplifier, at which feedback settled on specific musical notes [2]. Similarly, Marek Pospieszalski, by using an unaltered tenor saxophone as a means to control the audio feedback between a microphone and a guitar amplifier, set out to create alternate fingerings to play specific notes in such configuration [3].

The interest in musical applications of audio feedback currently seems to experience resurgence, exemplified by a number of feedback-related publications at the NIME conference, as well as research projects such as the Feedback Musicianship Network [4]. In this vein, a number of instruments had been modified or purpose-built in order to explore musical capabilities of audio feedback even further.

Without dwelling on the theoretical principles of the Larsen effect, a simplified assumption can be made that the pitch of the feedback tends to settle on the main resonant frequency of the whole system. Thus, by forcing the resonance into specific frequencies, it should be possible to actually "play the feedback" like a musical instrument.

A number of successful attempts with non-direct feedback had been conducted, such as different approaches to string instrument feedback (i.e. the eBow, Sophtar [5], Halldorophone [6], or Magnetic Resonator Piano [7]), where the string is a direct means of constraining the feedback to a given frequency.

The idea of picking up a simple acoustic system, such as wind instruments' pipe, and utilizing it as a means for direct, "classic" audio feedback, has also been explored in recent years [8] [9] [10] [11]. However, in most cases, additional audio processing has to be incorporated in order to achieve satisfying results. This might be necessary in order to stop the feedback from settling on higher harmonics (i.e. "overblow") as well as to mitigate the influence of the microphone and speaker on the overall resonant frequency of the system [8]. Nevertheless, additional processing also serves as a means to expand the musical and expressive capabilities of the instrument. There is, however, an alternative approach to controlling resonance in wind instruments that, to the best of my knowledge, haven't been applied so far to feedback instruments - the principle of a vessel flute, with a vibrating mass of air, rather than a column, as a resonant body.

2 Basic principle

A vessel flute, or globular flute, is basically a variable frequency Helmholtz resonator with a means for easily attracting the resonance (i.e. a fipple). An air mass, unlike the air column in a pipe of most other wind instruments, has a tendency to vibrate strongly at the fundamental frequency, making it much harder to play overtones (i.e. higher harmonics) [12]. What might be seen as a downside of acoustic wind instruments utilizing the globular/vessel principle, is precisely what makes such construction perfectly suitable for a feedback instrument.

Unlike the more common, pipe-based wind instrument, the overall size of the hole (or a sum of the sizes of a couple of holes), rather than the actual placement of the finger holes, influences the frequency.

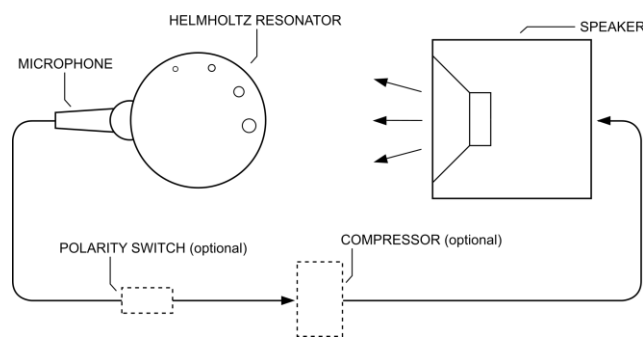


Figure 2: Basic principle of operation of the Feedback Ocarina

Feedback Ocarina follows a basic principle of creating a feedback loop between a microphone and an amplified speaker, with the addition of a spherical chamber with holes, in which the microphone is placed. The chamber acts as a Helmholtz resonator, i.e. effectively as an acoustic bandpass filter, forcing the feedback to occur at (or around) a specific frequency. In practice, additional factors, such as the distance between the microphone and the speaker, or qualities of a specific speaker, also influence the resulting pitch.

3 Technical Description



Figure 3: First prototype of the Feedback Ocarina

The initial, experimental prototype was built "the other way around" - a small battery-powered bluetooth speaker with aux input was built into the Ocarina itself - a cuboid-shaped MDF box with rounded edges. A simple, single board preamplifier and a Shure SM57 microphone completed the circuit. This version already showed promise with regards to straightforward pitch control of the feedback. Initially it seemed more intuitive to have the speaker built into the instrument, making the sound come from the instrument itself, as in an acoustic instrument. Nevertheless, with the microphone attached to the instrument, rather than the speaker, the Ocarina becomes much easier to handle and doesn't necessitate relying on a given type of speaker. This arrangement had been utilized for all subsequent prototypes.

Another set of prototypes was created in three sizes - with 80, 90 and 100 mm diameters - to practically verify the ergonomics and influence of the sphere diameter on the feedback pitch. The main body (the resonator) took a form of a 3d-printed sphere, with wall thickness of

2 mm. The body has six finger holes and two thumb holes. At the second prototype stage, an arbitrarily chosen diameter of 9 mm was used; while it offers extended pitch range, it results in steep pitch jumps, making it difficult to play standard musical scales. This version of the instrument can be seen in action in a short video: <https://vimeo.com/1164311046/55cfa27ac1>

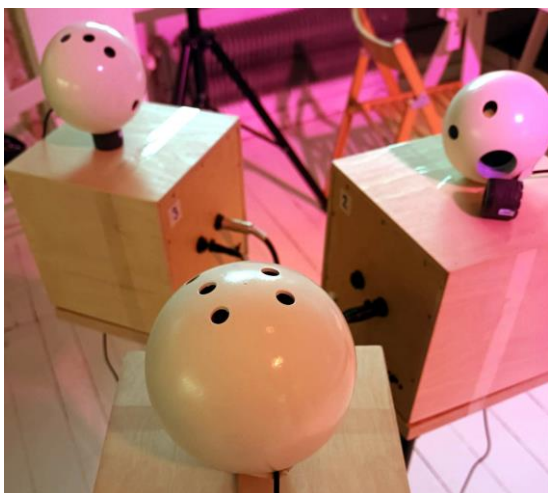


Figure 4: Three sizes of the Ocarina; the cartridge mounting hole visible in the upper right corner

Early tests were conducted using cheap “computer speakers” and a Bluetooth speaker with an aux input. Eventually, simple custom speakers were built for all subsequent tests and performances, with an added feature of a built-in polarity switch.

4 Practical implementation as a DIY instrument

In order to supply a blueprint for a quick and easy build, the following section describes a working prototype, but is by no means exhaustive, as many other variations and further development of the instrument are possible.

Unpredictability is often regarded as a prominent quality of the feedback instruments. Nevertheless, as the instrument was initially conceived as a proof-of-concept of a low-tech, simple means of controlling the feedback variables, practical implementation described in the following section favors pitch and volume control over unpredictability, thus the use of compressor to restrain sudden jumps in the feedback volume.



Figure 5: Playing the Feedback Ocarina

For the open source, DIY-ready version, a mid-sized (90 mm) Ocarina size was chosen, mostly for the ergonomics. In practice, rather than utilizing an existing microphone, a bare microphone cartridge can be used, as it's significantly less expensive than a proper microphone of similar quality; it's also smaller and lighter, which makes it easier to incorporate into the main Ocarina body. For all prototypes, a Monacor MD-110 cartridge had been used for its relatively wide frequency range. The back portion of the cartridge, presumably shaped to fit as a replacement cartridge for certain microphone bodies, can be removed with a saw without sacrificing the acoustic properties of the component. The 3d files are modeled to fit this specific cartridge, although they could be modified to fit any other cartridge/microphone type.



Figure 6: Original (left) and modified Monacor MD-110 microphone cartridge

The polarity of the speaker driver with regards to the audio input might vary depending on the specific type of powered speaker used. When deliberately inducing the feedback (such as is the case with the Ocarina), reversed polarity of the microphone in relation to the speaker might result in poor response (i.e. limited number of feedback pitches), thus a polarity switch might be necessary. This can be achieved by simply adding a DPDT switch to the circuit (i.e. on the cable between the microphone and audio jack), wired in a way outlined in Figure 7. When the aforementioned microphone cartridge is used, the polarity of the cartridge could also be easily swapped by re-soldering the wires.

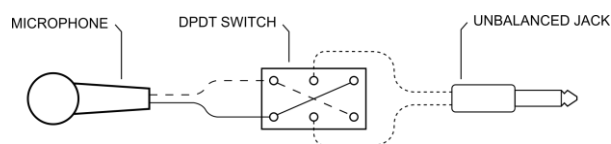


Figure 7: Using a DPDT switch for changing microphone cartridge polarity

As observed by Hopkin [12, p. 71] the effective pitch range of a globular flute resides between two extremes – on one hand, the smaller the hole, the lower the note. However, a hole too small will only produce sound of very low volume. On the other hand, increasing the hole size results in higher pitch, but only to a point in which the hole is too large for the instrument to force the air mass into a specific resonant frequency. This is also true for the feedback

ocarina: with only the smallest fingerhole open (low A note on the fingering chart – **Figure 8**) the volume is much lower and it requires bringing the instrument closer to the speaker for the feedback to occur.

The tone hole sizes were determined by a decidedly non-scientific, hands-on approach, as inspired by Hopkins' remarks [12, p. 83]. The process was as follows: a version of the Ocarina with small, uniform size for all holes (4mm) was printed on a STL printer and the sizes were adjusted with hand tools until satisfactory results were achieved; the holes were then measured with calipers and the 3d model was adjusted according to the measurements.

The resulting tone holes have varying diameters (4 mm – 9 mm) to allow smaller intervals to be played, facilitating melodic pitch control. For instance, **Figure 8** depicts a fingering chart approximating the A-major scale. This variation of the instrument can be seen in the following video: <https://vimeo.com/1164312583/eadb7007e7>

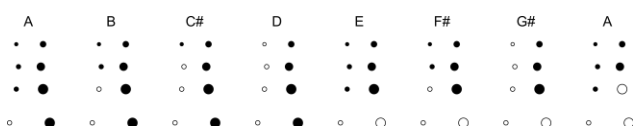


Figure 8: Fingering chart for the A major scale on the second variation of Feedback Ocarina

Additional hole on the back of the body holds the microphone cartridge. 3d models for printing this version of the Ocarina can be downloaded at:

<https://github.com/HybridInstrumentsLab/FeedbackOcarina>



Figure 9: Body of the Ocarina printed in two halves on SLA (left) and FDM printers

For a more refined look and feel, the two halves can be glued together, sanded and finished with a spray paint. If a 3d printer is not available, a functional version of the Feedback Ocarina could be created from ready-made objects, as any thin-walled hollow object with around 0,2 – 0,5 liter volume could be fashioned into the air chamber (i.e. Helmholtz resonator) for the instrument – a plastic or wooden container, or a natural object such as a gourd or even an ostrich egg shell [12].

In order to constrain the dynamics within reasonable limits, a stompbox-type Behringer CS400 compressor (an inexpensive clone of a classic Boss CS-3) had been incorporated into the feedback loop. The compressor introduces enough amplification so that the microphone preamplifier is not necessary, and the instrument can be used directly with an active speaker with unbalanced line or headphone level input,

even such as the classic obsolete "computer speakers". Therefore, a simplest possible diy-version can be assembled of a makeshift "vessel", a pair of obsolete computer speakers and only two inexpensive components - the stompbox and microphone cartridge (although any dynamic microphone could be used as well).

5 Results and discussion

The varying fingerhole sizes on the second variation of the Ocarina were meant to facilitate playing actual musical scales. In practice, as is the case with many other feedback instruments, the pitch doesn't depend solely on the resonant frequency of the body alone, but is also influenced by the distance between the microphone and the speaker and the inclusion of the microphone cartridge into the resonator.

In theory, the resonant frequency of a Helmholtz resonator could be calculated using a common formula. Nevertheless, the formula implies that a number of parameters (such as the "neck" length or end correction) should be taken into account, that do not easily apply to a modified version of Helmholtz resonator, such as the Ocarina. Nevertheless I've decided to conduct practical tests of how the actual resonant frequency of a given Ocarina variation corresponds to the feedback frequency.

First test was conducted with white noise played through the speaker, and the microphone cartridge embedded in the ocarina recording the filtered signal with 1, 2, 3, 4 and 5 tone holes opened. As the tone holes of the "tuned/open source" version of the Ocarina have smaller diameter and didn't produce clear resonance with the white noise applied, an earlier prototype with uniformly-sized 9 mm holes was used for the tests. Spectrum analysis of the resulting recording showed that peak frequencies in these conditions were 291 Hz, 391 Hz, 467 Hz, 531 Hz and 592 Hz, as shown in **Figure 10**.

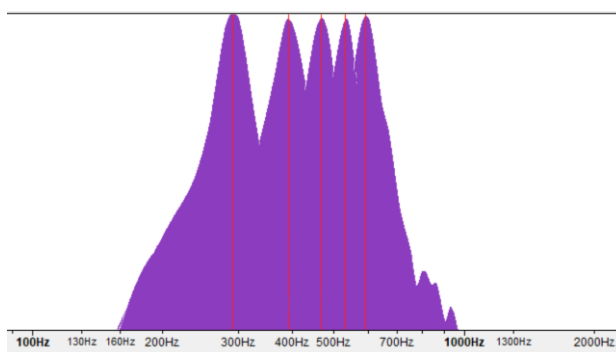


Figure 10: Superimposed spectrograms of the white noise captured by a microphone cartridge of the M-sized ocarina with 10mm tone holes for 1-5 open holes;

The second test also involved gradual opening of the same five tone holes, this time however the ocarina was in the default feedback mode. The peak frequencies for the second test were 297 Hz, 401 Hz, 468 Hz, 523 Hz and 587 Hz, respectively.

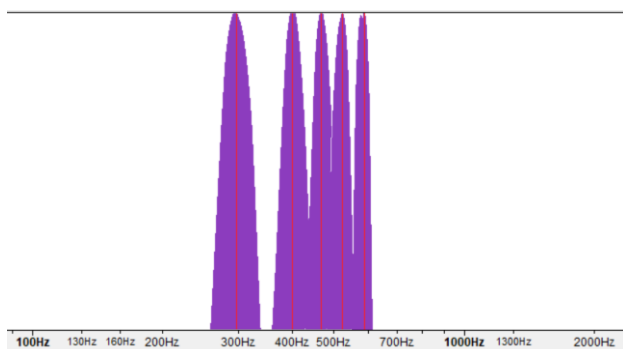


Figure 11: Superimposed spectrograms of the feedback frequencies of the M-sized ocarina with 10mm tone holes for 1-5 open holes;

A third test was conducted by adopting the ocarina as a classic Helmholtz resonator, by bringing the large hole (the microphone hole) to the ear and alternately listening to white noise and a sinusoid with a frequency gradually adjusted to match the white noise resonance through the ocarina. Additional 3d-printed nozzle was added for convenience (it didn't noticeably influence the perceived resonance frequencies).



Figure 12: Body of the Ocarina with the additional 3d-printed nozzle

The results of such test are obviously inaccurate, as they rely heavily on the subjective perception of the resonant frequency, prone to obvious mistakes and bias. Nevertheless, the test brought similar results to the first two (297 Hz, 402 Hz, 466 Hz, 545 Hz and 592 Hz for 1 to 5 open tone holes). This would suggest that the resonant frequencies of the Ocarina are indeed the strongest factor defining the feedback frequencies.

It has to be noted that the tests were conducted using a purpose-built simple one-way cabinet with a single 4" speaker and a built-in phase switch. When testing the ocarina with two different two-way speakers with bass-reflex ports (KRK Rokit 5 active near field monitors and Sony HCD-MX500i home stereo speakers), the resulting pitch was consistent with the original measurements only up to the fifth note (~580 Hz), where the feedback frequency tended to stall, regardless of the number of open fingerholes, up to a point of a sudden jump in frequency. This might be due to the influence of the resonant frequencies of the bass ports; however, testing the Ocarina with a number of various types of speakers is a necessary future step to

determine the pitch consistency for a given set of tone hole sizes over different speaker types.

Moreover, other factors (such as positioning the speaker on a large, flat surface or next to a wall) also influence the pitch. Therefore, merely controlling the resonant frequency of the Helmholtz resonator doesn't guarantee consistency of the musical pitch played with the Ocarina. Nevertheless the ability to alter the tuning by moving the instrument in respect to the speaker could be also seen as an advantage, allowing for glissandi, note bends and vibrato. The effect of the distance from the speaker on the ocarina pitch was measured for one and two open fingerholes: for one fingerhole, the pitch at a 40 cm distance was 290 Hz, at 10 cm – 197 Hz (0.41 semitone), for two fingerholes, the frequencies were 380 and 394 Hz (0.62 semitone).

With the shell thickness of 2mm (such as in case of the 3d models used for the prototypes) the body is rigid enough so that the specific material used (PLA or resin) doesn't affect the sound parameters. Nevertheless, while not verified in practice, very thin, non-rigid walls (i.e. plastic bottle walls) could affect the pitch by lowering it, in a similar fashion as the low wall rigidity affects the pitch of wind instruments [12, pp. 126-127] [13, pp. 527-528]

Without the compressor, the volume and consequently the feedback onset differ from note to note, therefore requiring more practice and careful handling. Nevertheless, for more expressive and adventurous playing, various types of more "extreme" amplification, including guitar amplifiers, could be applied. The simplicity of the design invites further experimentation from more experienced feedback musicianship practitioners.

Three Feedback Ocarinas have been used for a performance of my short composition *Aeroklang*. [14] The instrument had been also used for an improvised performance alongside Klaus Gendrung and Emil Schult: <https://vimeo.com/1164151007/927edc351a>

6 Conclusion

Possible future work on improving the performance of Feedback Ocarina might include incorporating a volume pedal or an on/off switch and a means of securing the instrument in a fixed distance from the speaker, although, while it might improve the pitch consistency, it could impair the expressiveness of the instrument. Further tests with regard to theoretical calculations of the resonant frequency should be conducted, as well as tests with a wider array of speaker types.

More importantly, though, it is my hope that the research outlined in this paper serves as a proof-of-concept for the instrument, which could be built quite easily with limited resources, and, as such, serve as an introduction to feedback musicianship or instrument making in general.

Ethical Standards

Three instances of the Feedback Ocarina had been used for the performance of the composition "*Aeroklang*", performed in 2023 the by a group of high-school children. The performers and their legal guardians gave consent to their participation in the performance. The instrument has also been introduced to the students at the Feliks

Nowowiejski Academy of Music in Bydgoszcz, Poland at the "Electroacoustic Improvisation" classes. None of the aforementioned performers or students took part in the actual research.

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