Ergodynamics of String Feedback

Control interface design for the halldorophone

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ABSTRACT
This paper describes the iterations of signal path routing and mixing control for the halldorophone, an experimental electro-acoustic string instrument intended for music making with string feedback. The paper describes the design thinking behind the cybernetic control structure of the instrument which is informed by long term contact with dedicated users. Specifically, here we discuss the intended "feel" or ergodynamic design of how the electronic control and connectivity options of the instrument are presented on the instrument's electronic interface and the considerations taken to simplify the control schema for new players while not limiting options for expert users. The paper presents a schema of the latest electronics design as a guide for replication of our most recent work.

Author Keywords
NIME, feedback instruments, augmented instruments, feedback musicianship, instrument design, string feedback.

CCS Concepts
• **Applied computing → Sound and music computing**; Performing arts.

1. INTRODUCTION
The halldorophone is a hybrid, electro-acoustic string instrument for working with positive feedback on strings [1]. As such the instrument is based on cybernetic principles, organized around electronically inducing feedback in a coupled system of eight strings allowing for the creation of nonlinear and unwieldy, yet somewhat controllable feedback drones. Halldorophones and related instruments [2] have a growing user group and repertoire [3]. This paper gives an overview of how our notions of control, feedback, cybernetics, and connectivity have matured through user interactions with these instruments in recent years. This paper will therefore focus on the electronic control of the feedback, as opposed to other design strategies for the instrument's overall ergodynamics.

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Figure 1. A halldorophone made in 2021

This paper complements previous publications about the development of the halldorophone [1][3] as it shows the progression of the control and connectivity design through the lifetime of the project (over a decade) which reveals what is specifically relevant to players using this new instrument. Although the instrument has been built in a lab, it's real testing and experimenting has been on the musical stage and in artists' studios. As such this project is somewhat unique in the NIME corpus as it is a sustained, iterative design effort over time, where a luthier hands over fully functioning but varied instances of the instrument to practicing musicians who provide insights that continuously inform further variations on the design. This feedback instrument is built on user feedback! Through the different iterations presented here, the instrument retains a clear identity, despite the explorative variation of the features provided to control its core functionality (string feedback).

1.1 Configuration
The halldorophone is based on the cello in its configuration: upright, four main strings, fretless fingerboard, floating bridge with a contour for bowing. However, it also has four sympathetic strings running below the fingerboard (much like a viola d'amore) which are not directly accessible for bowing or plucking but are only electronically excited to drone.

Each string has a dedicated pickup. In all the various configurations of the electronics interface described in this paper, the player can set the level of each string before passing it to a main mixdown which has a prominently placed volume knob for the master volume. To induce feedback in the instrument, the main mix is sent to an onboard power amp connected to a speaker built into the body of instrument, and this creates a positive feedback loop. The level of the master volume determines how intensively the whole system vibrates and is a very actively used parameter when playing halldorophone (and often delegated to a pedal to free up the hands for other tasks). The signal from each of the pickups can be externally routed for DSP or applying effects (such as guitar pedals), and this has been presented in various ways as discussed below.

2. SHAPING HALLDOROPHONES

2.1 Method

In making the halldorophone, Úlfarsson has been embedded in a living culture of composers and performers who use the instrument, suggest changes and comment on new design developments through use and exploration. This iterative design, based on regular user feedback, is at the heart of the development of the halldorophone.

The instrument has been in development for over a decade, during that period around twelve instruments have been made. In this paper we present a timeline overview of how the electronic control and connectivity in the instrument has evolved, discussing six distinct versions of the instruments and how certain features of those instruments have developed. Although the paper focusses on the electronic cybernetic aspects of the instrument, in this section we present a more general design context.

Each of the instruments presented was, at the time of their completion, presented as a fully functional and ready instrument to dedicated users. We do not consider these performers test subjects in user studies, but rather friends and artistic collaborators who have used these instruments in mature musical projects. In this discussion, we may consider these collaborations user testing, but more truly they have been an informal and organic collaborative process based on affinity and mutual artistic interests.

2.2 Cultural Placement

Musicians are a curious and inventive group of people. Judging by the experience of working with the halldorophone, when presented with something which looks and feels like a proper instrument musicians will fill in the gaps and start inventing a culture for it, equal parts: Deciding what existing styles and practices it may naturally fall into and developing gestures and performance practices specific to what they feel this new instrument invites. This reaction seems to have been intuitive and instinctive to most of the musicians who have engaged with this project. The "friction" of that engagement has pulled the identity of the halldorophone across a few musical styles and cultures, before now mostly attracting musicians from the genres of contemporary classical music, film music and drone metal.

From the perspective of Úlfarsson, a guiding question during this process of finding a place for the halldorophone has been: "what does this instrument want to be?" And sometimes, the more ambitious: "what can it be?" in terms of wider adoption and acceptance. Being guided by these questions follows a humility and open mindedness to who potential collaborators may be and when practically possible offering access to anyone interested.

2.3 The Whole Instrument

"Ergodynamics" is a term proposed by Magnusson [6] signifying the qualities of a musical instrument that go beyond subject-object distinctions and is applied to the experiential (ergonomic, cultural, historical, aesthetic) qualities of the instrument. It can help in the comparison of an instrument to other known instruments of the same or different type.

The term is closely related to "ergomimesis" (from the Greek "ergos" meaning work and "mimesis" meaning simulation or imitation) which brings attention to how instruments and the features they are comprised of carry with them a reference to a performed gesture in the historical stream of musical objects and practices which have come before. The halldorophone applies ergomimesis in that a trained cellist feels comfortable playing the instrument: its interface is quite familiar to them, yet the function of the instrument is not: the halldorophone does not function as a cello, and cellists quickly realize that when they begin to play it. Yet they can play the strings as if it was a cello

In the reflexive process of discovery and prescription described here we suggest that it is the ergodynamics of the halldorophone we are seeking and defining, the term is useful as it suggests a comprehensive perception of the instrument (what other instruments it resembles, but also what is specific to this instrument) as we try to understand its potential through iterations of the design and user studies that range from formal surveys or interviews to casual chat with our instrumentalists.

2.4 Intent

This section is to emphasize that the focus of what has been worked on with the halldorophone has shifted between technical development, identity grooming for cultural placement and, what might best be called, artistic playfulness. Due to the many intersecting threads which form this discreet instrument with an increasingly defined cultural identity, the focus on what to develop at any given time has been somewhat of a moving target dependent on: Resources, visibility of the project, updated insights, and a vague sense of regular mutations as a good evolutionary strategy.

This project began its life as a music making project for Halldór Úlfarsson (who considers himself a rather non-musical person) but as the instrument showed a promise and potential to trained musicians it evolved from that first impetus into more of joke[1] to see if it could pass as a "real" instrument. This game was aimed at Úlfarsson's student friends (of classical composition and musicians more into pop).

As the instrument increasingly "passed", the intent of the work shifted once again, now into more of a design focused project. In the next push the question arose of a suitable identity for the instrument, and it was decided to push it towards that of the baroque strings and the classical western tradition (for familiarity and all the cultural clout residing in that scene).

Also, although there is a probing nature to the work being discussed here, it is also libidinous. There is a desire for this project to succeed by being replicated and evolved by others, hopefully for there to be a thriving genre of string instruments drawing from the traits of the halldorophone. This can be further broken down into more specific goals, such as: growing a user base, encouraging reproduction, supporting a growing repertoire, attempting to create a culture for training and dissemination of performance practices.

2.5 In NIME

Presenting a focus on a single strand of what constitutes the halldorophone (the iterative development of a subsystem) feels a little different to what it felt like to do the work. Working on the halldorophone has often been nonsensical, whimsical, and inefficient but it has always been driven by a desire for an ongoing interaction with musicians who want to engage the project which has been moderately successful.

[1] The naming scheme for the halldorophone is inspired by the imaginary instrument of Belgian cartoon character Gaston Lagaffe, the "gaffophone".

As such this work feels a little different than many projects presented in the NIME corpus where there is a focus on what can be measured and thoroughly described, where features are proposed, designed, and evaluated in terms of their usefulness through carefully made user studies.

3. CONTROL AND CONNECTIVITY

Music making for string instruments specifically intended to feedback is music making with a relatively new category of instruments. Deciding the configuration of the control and connectivity interface for the halldorophone is a work in progress informed by the ongoing conversation with musician friends who have played versions of the halldorophone often extensively, over long periods of time.

Organizing connectivity and routing options for the signal flow in the instrument has (mostly) been built into an onboard mixing interface with various grouping, mixing, and routing options for the signal from the pickups to the main mix which comes to a built-in speaker to induce the positive feedback loop. Section 5 of this paper describes the latest version of this interface with a brief overview of previous versions in Section 4.

In this paper we only briefly mention the organization of other control parameters and ergonomics (for the sympathetic strings) where they influence the thinking on the electronics interface.

There is a design decision in effect for the halldorophone to reduce the onboard electronic control to a bare minimum. Mostly this refers to mixing, some versions of the electronics interface have forced the user to rely on external hardware to include certain strings (as discussed in section 4). This reductionist approach when it comes to electronics is an attempt to keep the focus on the string-instrumentness of the halldorophone, with the added function of working with string feedback.

We thoroughly acknowledge that DSP or analog treatment of the signal path in the feedback loop can be fruitful (see for example the work of Eldridge, Kiefer, Overholt, Melbye, Polymeneas-Liontiris) but we do not prescribe strategies for this by building them into the instruments at this point, rather we leave room for the user to make their own decisions about what they want to experiment with by providing routing options in the signal path.

The electronics mixing and connecting interface has been configured a few different ways with the overarching aim of only presenting the most useful parameters prominently while not oversimplifying to the point of sacrificing useful features.

HALLDOROPHONE VERSIONS

3.1 2008

Sympathetic strings	Onboard volume ctrl. nr. of strings	Individually routable strings
None	4	4

The first cello-like halldorophone was made in 2008-9. The basic configuration of this instrument is repeated in later versions although the first instrument only had the four main strings. With an option to route each string for external processing before returning to main mix, which can also be routed for external treatment before the return (to power amp) completing the feedback loop.

It was presented to musician friends and colleagues (composers, cello players, pop musicians) impressions ranged from mildly curious to very interested. A notable theme from the classically trained was to suggest that the instability and volatility of the feedback was a problem with suggestions of improvement along the lines of getting notes to cleanly sustain[2]. The less formally trained gave positive impressions about the unique sound ("drone box" was dropped as a description at some point) and cellist Hildur Guðnadóttir was immediately very interested as it complements her interest electronic music and the cello.

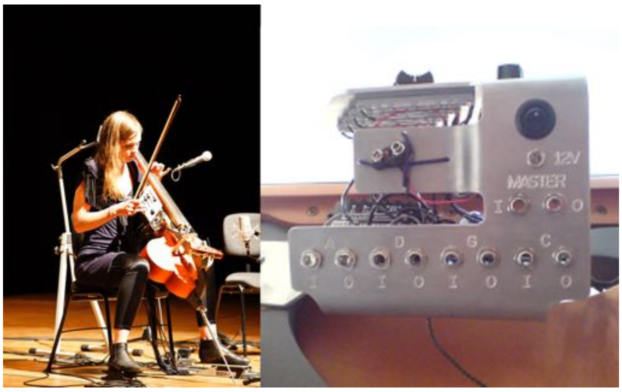

Figure 2. Hildur Guðnadóttir with the first cello-like halldorophone, 2011.

Hildur Guðnadóttir turned out to be the first dedicated user of this instrument and after a period of use and exploration (around 6 months to begin with) suggested adding sympathetic strings as she found it frustrating how hard it was to keep a sustained drone (suggesting it as a core affordance of the instrument), even just on one string while fretting or bowing another [Guðnadóttir, personal communication, 2009].

3.2 2012

Sympathetic strings	Onboard volume ctrl. nr. of strings	Individually routable strings
4	None	8

This instrument built in 2012 was an experimental platform for prototyping features, it was stripped of all onboard electronics, but the bare components needed to complete the feedback (pickups and speaker/transducer). Practically leaving the player free to (or burdened with) composing their own control interface for working with the feedbacking strings.

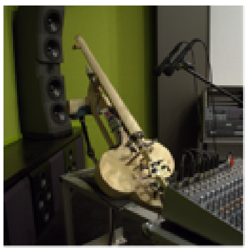

Figure 3. Birch halldorophone at EMS, Stockholm.

This configuration was to see if users preferred their own hardware for signal manipulation. They would need to send the

[2] Something the now discontinued Moog guitar was being made to do around the same time.[8]

pickup signal to an audio interface or mixer and deciding their own way of mixing and control over those mixdowns (pedals made sense) before coming back into the power amp and completing the feedback loop. The exclusion of the mixing console was not favored, it left players with a sense of the instrument being "incomplete" and "brought their attention away from it" [Guðnadóttir, personal communication, 2012].

Figure 4. Sympathetic strings with vibrato levers.

The idea of sympathetic strings is implemented on this instrument with four strings running under the fingerboard, straddling a lower bridge with the tuning machines below it. The sympathetic strings each had a lever for vibrato action accessible by the thumb of the left hand, but this is a clumsy configuration and will not be explored further. Sympathetic are since included in every later halldorophone, and players accept them as a core feature of the instrument.

3.3 2014

Sympathetic strings	Onboard volume ctrl. nr. of strings	Individually routable strings
4	4 (main strings)	4 (sympathetic)

This instrument built in 2014 evolves the inclusion of four sympathetic strings and brings back the console. To reduce options for the player who now had 8 strings to contend with the main strings are "locked in" to the onboard mixer (no routing possible) and the sympathetic strings are each externally routable (IN/OUT per string, in the rows of connectors). The tuning machines for the sympathetic strings are moved up to a position where they suggest live manipulation. The position and orientation of the sympathetic strings suggests that they are not configured to be bowed, plucked or stopped and are intended for drone accompaniment, but with the option of live tuning.

Figure 5. A 2014 halldorophone with sympathetic strings and their tuning machines placed as a live interface.

As the connections are not normalled, leaving them open excludes the string in question from the main mix and feedback loop. To include them in the feedback the player uses external hardware (for example a mixer or volume pedals) to set the signal level and route the strings back into the main mix. Ergonomically, the thinking was to push the user to delegate the sympathetic strings to pedals to create a distinction for control of the two sets of strings: Main strings being hands and sympathetic strings being feet.

This routing organization was described as limiting by experienced users Hildur Guðnadóttir and Guðmundur Steinn Gunnarsson [Guðnadóttir, Gunnarsson personal communication, 2013-2014] as the main strings are essentially locked in and cannot be treated in any way or routed to volume pedal. The options for the sympathetic strings also felt clunky as external hardware is unavoidable.

3.4 2018

Sympathetic strings	Onboard volume ctrl. nr. of strings	Individually routable strings
2	4 (main strings)	2 (sympathetic)

In 2018 two instruments were built, they were very similar except one had a built in Bela for DSP experimentation [7] and will not be discussed here, all references in this section are to the analog version of the two. These instruments now only had two sympathetic strings in an experiment of reducing options to a meaningful minimum. Three IN/OUT connector pairs were presented on the underside of the control panel, one full normalled for the main mix (allowing for treatment of the main mix) and one non-normalled for each of the sympathetic strings. So the sympathetic strings could share a stereo volume pedal with the master mix on a another pedal. And users always prioritized this configuration with a pedal for the master mix for their dominant foot and settled for a flat mix for the sympathetic strings with in a single stereo volume pedal which indicates a clear priorities for the main mix volume (over, say individual sympathetic strings).

Figure 6. The two halldorophones built in 2018 were dubbed "The Sisters".

The configuration of this instrument was moderately more successful than the previous design, with less negative comments from users.

Baroque cellist Konstantinos Chinis, who had no experience with previous instruments but played the analog Sister extensively forcefully expressed he would prefer four rather than two sympathetic strings [Chinis, personal communication, 2019]. Further reinforcing the identity of the halldorophone as a drone instrument.

These two instruments were also a study in materials and esthetics. After Hildur Guðnadóttir recorded halldorophone for drone metal band Sunn O))) this look referencing the color and material palette familiar in the doom, drone metal scene (black and exposed metal) was presented to see if it might start to interest metal head. The neck and fingerboard are one solid, cast aluminum piece, this experiment was about esthetics as previously stated but also about simplifying a complicated assembly. The cast aluminum made it easier to include the per-string vibrato levers at the top of the neck seen in figure 5 (detailed discussion of which is outside the scope of this paper, but they may return on future models).

3.5 2021

Sympathetic strings	Onboard volume ctrl. nr. of strings	Individually routable strings
4	4 (main strings)	4 (sympathetic)

From the beginning of 2020, grant funding presented an opportunity to commission a complete, integrated design of the electronics for halldorophone. The opportunity was also used to review material choices for each part of the instrument and commission the work of a luthier (Konstantinos Tsopelas) to refine the design of the soundbox. Three instruments came out of this process in 2021-'22.

Figure 7. The first of the "new" halldorophones.

For these "new" instruments the four sympathetic strings have a single slider on the front panel which sets the level of a flat mixdown of all four strings in the master mix. This sympathetic-mix slider has a prominent place below the main string individual volume sliders and is intended for live use. This flat-mix slider is a compromise (to providing per-string volume control for the sympathetic strings on the main control panel.

The connections side of the panel has a send return for the master mix presented through two, normalled mono ¼" jack connectors. There is also a send return for each of the sympathetic strings presented as a stereo ¼" jack (for space saving purposes, and so requires a stereo Y ¼" jack cable for most routing needs) which is normalled. The return for each sympathetic string comes in before the flat-mix volume slider, meaning that an externally routed and treated signal will still be trimmable in the flat mixdown).

The thinking in this configuration is to provide individual access to some of the strings (sympathetic), allowing for focused DSP manipulation (in a DAW or perhaps some more involved dynamic processing) for treating the signal of individual strings. For simplicity and clutter reduction (of connections) we restricted this to only the sympathetic strings. The choice is a suggestion that involved signal manipulation is a background consideration (accompaniment) while playing the main strings live is still the main feature of this instrument.

This configuration of the controls is still generating comments indicating friction in how users want work with the halldorophone. The flat-mix slider for the sympathetic strings is an improvement to previous models as it allows for them to be included without external hardware but the involved presentation of the routing for the sympathetic strings (Y cable) leads to them being neglected by most users and they mostly rout the master mix to a pedal.

4. CURRENT HALLDOROPHONE

Sympathetic strings	Onboard volume ctrl. nr. of strings	Individually routable strings
4	8	8

Figure 8. The best one yet.

The 2022 configuration of the interface has a central concept of two mix groups which can contain any string and be routed to a send-return. This configuration strongly suggests the use of two pedals, one for each group. We expect the most used configuration of the groups to be for the Main and Sympathetic strings separately. [3]

Besides the routable groups we provide access to the individual signal of every string through an EDAC (a rugged panel connector) for users who want to get specific with individually processing or recording all or any of the strings.

Here the control panel has eight sliders to control the volume of each string, now more horizontally oriented (looking at the instrument upright) for better visual confirmation of the setting from the players perspective (and as it turns out, slightly better ergonomic feel). The sliders are now shorter than previously as a space saving consideration.

The sliders are arranged in two groups, the upper one (towards top of neck) for the main strings and the lower for the sympathetic strings. Each string also has a three-position switch to assign it to a mix-group A, B or A&B. There are also two volume knobs on the control panel for the master volume of each mix-group.

Through-holes on the panel give access to ten trimmers (adjustable with screwdriver). These trimmers have become a much-loved feature, allowing for a max setting for the volume of each string before the "live" sliders, they have become especially needed since we are now supplying 100w max power for the speaker which gives us all the headroom we may want but is overkill for most strings, but some strings need more

[3] This mixer configuration was originally designed for a version of the halldorophone with two speakers in the body where each group is delegated to a send-return and one of the two speakers. But seemed so clear and promising we decided to implement it for the "basic" halldorophone. The two-speaker instrument is excluded from the current discussion for clarity as it is still being evaluated and will be documented elsewhere later.

encouragement to get them to feedback and now there is more than enough headroom to get them going.

5. ELECTRONIC DESIGN

This section describes the latest version of the electronic design of the instrument. Previous versions have been cobbled together from a variety of systems and subsystems with mostly the same block diagram underlying the system at any given moment.

In the past four years there has been an opportunity to develop an integrated, optimized system for the instrument (by Moraitis). The leading design consideration has been to reduce noise in the system and provide enough power for the player to drive the feedback as fast as they can ever want.[4] The sections below give an overview of the electronics design, sometimes along with practical notes on connections and components which we have found important.

The electronic system consists of five subsystems:

- Pickups
- Power Handling
- Preamp / Control board
- Power Amp
- Speakers

5.1 Pickups

The instrument uses eight electromagnetic Cycfi Nu single-string pickups that are used to capture the vibrations (sound) of each string. These pickups were chosen for their clean sound, small detection field (allowing for good string separation) and low signal-to-noise-ratio.

5.2 Power Supply and Power Handling

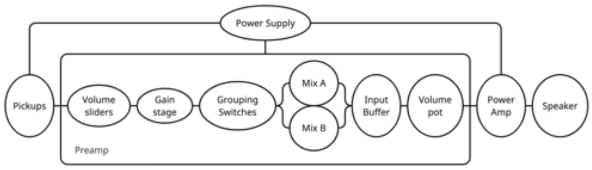

Figure 9. Power overview.

The power supply is a toroid transformer rated to receive either 220- or 110-Volts AC (Europe, USA) and outputs ±24V at 150W. There is an IEC C144 connector[5] for the input power (from grid) and a Neutrik powerCon5[6] for the output power to the instrument (we like the powercon as it is a rugged connector which latches in its socket). There is a footswitch on the power supply to turn the power supply ON/OFF and there are fuses (electrical circuit breakers) for both input and output rails to protect the onboard hardware from spikes in current.

There is a full bridge rectifier which drops the ±24V AC down to ±15V DC for powering the op amps (TL074) and there is a further drop down from the +15V DC down to + 9V DC for powering the internal buffer on the pickups.

5.3 Preamp / Control Circuit

The pickups are physically connected to the PCB via screw terminals (solder connections have proven difficult when servicing the instruments). Immediately the signal from each pickup is treated by a 100kOhm slider (the volume sliders) and then sent to an inverting op amp that amplifies its signal from 1x to 10x (with the trimmer which is accessible by screwdriver from the top of the panel).

Each pickup signal is then routed to the single pole of SP3T topology switch. The single pole of the SP3T switches gets the signal and the 3 throws send the signal to the different mixes (Group A or B, or A&B). On each throw a pulldown at 10MOhm resistor is added to prevent any DC offset when switching the grouping of each pickup. From the grouping, all the inputs get mixed on two inverting op amps, one for each mix-group, with gain 1 (no amplification) and each output is sent to the ¼" jacks normalled connections on the bottom of the panel. From the input jacks the signal is sent to another op amp set in an inverting topology, also with a gain of 1. An AC coupling capacitor is added at the input to prevent any DC offset and a trimmer to adjust the input level. Then at the output there is a potentiometer (100kOhm) to control the (Master) volume before sending the signal to the power amplifier.

5.4 Power Amplifier

The power amp is a class AB amplifier based on the TDA7293 chip, rated at 100W, which drives the speaker (or speakers[7]). The input side of the amps is fed by the mixed output from the preamp board and the output side of the amp drives the built in speaker.

The use of an AB amplifier was chosen based on their extensive use in guitar amp cabinets which have characteristics we want to mimic, in terms of response and power. Also, after extensive experimentation with D class amplifiers, we have found that it is hard to get consistently manufactured units making them hard to design around. The AB topology is suited to the instrument as it can output the power we desire, and we like the sound of it.

5.5 Speakers

For the latest version of the system, we use 4", 8-ohm speakers, rated for nominal power handling (DIN) of 150w with a midrange (or mid low) response curve.

We have used a variety of brands with these (or close to these) specifications. There has been no comprehensive comparison of different speakers and how their specific qualities beyond power and range affect the sound and feel of the instrument. The heuristic is that mid or mid-low response is good, and that more than 50 watts of power is enough for our needs.

6. DISCUSSION

The latest configuration of the control and connectivity panel on the halldorophone is a distillation of insights gained from musicians who have worked intimately with previous versions of the instrument in their music making for longer periods of time (minimum one year). We consider this method of understanding the halldorophone, through our friends and collaborators' music making to be a strong tool to shape the ergodynamics of the instrument. The key ingredients to the work described here are time and care, as the musicians who give their attention to the halldorophone do so because they care for what it does for them and we in turn care about their music. Under these conditions, over time musicians will inevitably have thoughts and feelings about how the instrument is lacking and how, perhaps, it can be better.

[4] No halldorophone player has ever asked for less power so the line has been taken to provide so much overhead that a player will always trim down from the maximum available.

[5] https://en.wikipedia.org/wiki/IEC_60320

[6] https://www.neutrik.com/en/products/audio/powercon

[7] As previously mentioned we have developed a version with two speaker drivers in the body, which is currently being tested.

Much of the electronic control design work described in this paper is about juggling the placement, presentation and prominence of the same core parameters until users feel ergonomic friction is reduced. The halldorophone user interface has two roughly separate categories of parameters: “setup” and “live”. The latest design choices for the electronics interface have increased options in both categories, these choices are contributed here in replicable detail.

7. CONCLUSIONS

The latest schemata of the halldorophone electronic control and connectivity organization, derived through a sophisticated, user supported iteration design process for over a decade is contributed in replicable detail in this paper. In this latest version of the instrument, which has at points in its development been described as overwhelmingly complex, now allows players to preconfigure the system to leverage the amount of complexity they want to deal with when playing live. The presented example of shaping the ergodynamics of the electronic control schema an inherently complex, cybernetic instrument through the long term, informal but extensive conversation with its users gives valuable anecdotal information about instrument making with contemporary materials.

8. ETHICAL STANDARDS

The halldorophone has, throughout its development been supported by various public funding bodies for arts and academic research, these include: The Icelandic Technology Development Fund, which is currently funding development, Arts Council England (ACE), Kultturkontakt Nord (KKN) and others. Due to this generous, public support we aspire to adhere to Open Science principles regarding knowledge gained in the development of the instrument and aim to publish regularly.

The halldorophone is available as a product, upon agreement by commission from Halldór Úlfarsson and sold through his company Dorophone EHF. (registered in Iceland).

All interviewees have verbally consented to being cited.

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