GINETTE

DESIGNING AN EXPRESSIVE ELECTRONIC INSTRUMENT BASED ON THE ONDES MARTENOT

Master's Thesis

Petteri Mäkiniemi

Aalto University
School of Arts, Design and Architecture
Media Lab Helsinki
Master's degree programme in Sound in New Media

2020

Aalto University
School of Arts, Design
and Architecture

Aalto University, P.O. BOX 31000, 00076 AALTO
www.aalto.fi

Master of Arts thesis abstract

Author Petteri Mäkiniemi

Title of thesis Ginette: designing an expressive electronic instrument based on the Ondes Martenot

Department Department of Media

Degree programme Master's Degree Programme in Sound in New Media

Year 2020 **Number of pages** 72 **Language** English

Abstract

This thesis introduces the design of the Ginette: a novel, expressive electronic instrument. It is based on one of the earliest electronic instruments, the Ondes Martenot, and develops from the earlier Ginette I designed and built in 2010 and 2011. The thesis presents the background and describes the features of the new design focusing on the player's point of view. The building of the instrument is excluded from the thesis due to the broadness of the project.

Both the first and the new version of the Ginette have a delicate interface consisting of a ribbon and an intensity key for a continuous control of pitch and volume, respectively. The ribbon contains a ring attached to a wire, running on a fingerboard, whereas the intensity key is a pressure-sensitive button. These features, similar to the Ondes Martenot, allow a subtle, gestural control of the sound in the same way as with certain acoustic instruments, such as the cello.

The new design includes additional features not seen in this context before. The key elements consist of polyphony and wider timbral capabilities, while the first Ginette is monophonic and has simpler timbres. The design principle was to preserve the expressivity of the instrument, and apply it also to the new features. In addition to the intensity key, there is a polyphonic keyboard with individual volume control for each key. Together with the ribbon and selectable operating logics, these features enable several playing techniques. There are many options for modifying the timbre; a feature utilizing a fuzz effect circuit creates the expressive tone of the Ginette. It results in an organic sound, reminiscent to brass and string instruments, which gets brighter and more penetrating as the volume increases. Finally, the thesis presents measurements and analyses of the Ginette's timbre played with the fuzz effect.

The results present one way to design an instrument that is based on the Ondes Martenot and to develop it further in terms of polyphony and timbre, yet attempting to maintain the expressivity. Since the building of the instrument is excluded from the thesis, the success of the design will be confirmed only when the new Ginette is finished. However, years of experience in playing the first Ginette and my research on the Ondes Martenot has brought me insight into the design process.

Keywords electronic instrument, Ondes Martenot, expressivity, musical instrument design

Aalto-yliopisto
Taiteiden ja suunnittelun korkeakoulu

Aalto-yliopisto, PL 11000, 00076 AALTO
www.aalto.fi

Taiteen maisterin opinnäytteen tiivistelmä

Tekijä Petteri Mäkiniemi

Työn nimi Ginette: designing an expressive electronic instrument based on the Ondes Martenot

Laitos Median laitos

Koulutusohjelma Sound in New Media

Vuosi 2020 **Sivumäärä** 72 **Kieli** Englanti

Tiivistelmä

Tämä opinnäytetyö käsittelee Ginetten suunnittelutyötä. Ginette on uusi, ilmaisuvoimainen elektroninen soitin, joka perustuu Ondes Martenot'iin, yhteen varhaisimmista sähkösoittimista. Työssä olen jatkokehittänyt aiempaa Ginetteä, jonka suunnittelin ja rakensin vuosina 2010 ja 2011. Opinnäytetyö esittelee uuden soittimen taustan ja kuvailee sen ominaisuudet painottuen soittajan näkökulmaan. Soittimen rakentaminen on rajattu opinnäytetyön ulkopuolelle projektin laajuuden takia.

Sekä ensimmäisessä että uudessa Ginettessä on hienovarainen käyttöliittymä. Äänenkorkeutta hallitaan lankaan kiinnittyvällä sormuksella, joka pingottuu otelaudan yli; äänenvoimakkuuden kontrollointi tapahtuu paineherkällä äänenvoimakkuuskoskettimella. Sekä äänenkorkeus että -voimakkuus ovat portaattomia. Tämä Ondes Martenot'iin perustuva soittotapa hyödyntää soittajan herkkiä eleitä akustisten soitinten tapaan – vertautuen esimerkiksi selloon.

Uudessa Ginettessä on ominaisuuksia, joita ei ole käytetty tässä yhteydessä aiemmin. Keskeisimmät elementit ovat polyfonia ja laajemmat äänenvärimahdollisuudet, ensimmäisen Ginetten ollessa monofoninen ja sointivalikoimaltaan suppeampi. Suunnitteluperiaatteena on säilyttää soittimen ekspressiivisyys, ja hyödyntää sitä myös uusissa ominaisuuksissa. Soittimessa on polyfoninen, äänenvoimakkuusherkkä koskettimisto, joka yhdistettynä sormukseen ja erilaisiin toimintalogiikoihin mahdollistaa useita soittotekniikoita. Soittimen sointia voidaan muokata eri tavoin. Fuzz-efektiin perustuva lohko tuo äänenväriin ilmaisuvoimaa ja luo luonnollisen äänen, joka muistuttaa vaski- ja jousisoittimia, ollen kirkkaampi ja tunkeutuvampi äänenvoimakkuuden kasvaessa. Lopuksi, opinnäytetyö esittelee mittaukset ja analyysit Ginetten sointiväristä yhdessä fuzzin kanssa.

Tulokset esittelevät yhden tavan suunnitella Ondes Martenot'iin perustuva soitin ja jatkokehittää sitä polyfonian ja soinnin suhteen, pyrkien säilyttämään sen ilmaisuvoimaisuus. Koska soittimen rakentaminen on rajattu opinnäytetyön ulkopuolelle, suunnittelutyön onnistuminen varmistuu vasta, kun soitin on valmis. Onnistumista edesauttaa kartuttamani vuosien soittokokemus ensimmäisen Ginetten kanssa ja perehtyneisyyteni Ondes Martenot'iin.

Avainsanat elektroninen soitin, Ondes Martenot, ilmaisuvoimaisuus, soitinsuunnittelu

ACKNOWLEDGEMENTS

Warmest thanks to:

Esa Onttonen for his support as my advisor and all the study projects as my fellow student.
Antti Ikonen for his support as my supervisor and his encouraging presence during my studies.
Ava Grayson for her proofreading, walks and talks, music, and friendship.
Marko Tandefelt for his energetic thesis group meetings.
Thomas Bloch for a memorable day with the Ondes Martenot in sunny Alsace, and Aalto University for a travel grant that made it possible.
Laurent Quartier and Jean Landry for kindly sharing their technical knowledge of the Ondes Martenot.
Ilpo Jauhiainen for being a friend, bandmate, and advocate of art.
Heta Kaisto for her support and care when I was working with the Ginette, and for believing in me in my moments of hesitation.
Jonte Knif for showing how to make audio equipment and instruments properly.
Laura Isoniemi for the encouragement and words of wisdom.
Sikofest and Ari Jaatinen for providing a stage not too high for newcomers.
Tuomas Ahva, Emmi Pennanen, Taneli Luotoniemi, Jouko Koskinen, Jukka Kääriäinen and Hermanni Keko (and many more) for supporting me in my music-related doings.
Seesaw, including Tea Dickman, Guy Dowsett and Aku Rouhe with the guest star J. Camilo Sánchez Carranco, for a tireless team effort and bad jokes when working with the installations. *Great job!*
The people of Media Lab and Aalto Arts for a friendly and cozy atmosphere. I feel normal with you.
My family for lifelong support with everything.
Silja Räty for her academic writing guidance from the opposite side of the kitchen table, for all the encouragement, and also for giving me lovely, occasional reasons to do something other than writing this thesis.

TABLE OF CONTENTS

ABBREVIATIONS

AM	amplitude modulation
CV	control voltage
DC	direct current
DIY	do-it-yourself
FFT	fast Fourier transform
FM	frequency modulation
LDR	light-dependent resistor
LED	light-emitting diode
LFO	low-frequency oscillator
MIDI	musical instrument digital interface
PC	polycarbonate
POM	polyoxymethylene
PWM	pulse-width modulation
USB	universal serial bus
VCA	voltage-controlled amplifier
VCO	voltage-controlled oscillator

LIST OF FIGURES AND TABLES

1 INTRODUCTION

During 2010 and 2011, I designed and built an electronic instrument influenced by the Ondes Martenot. My instrument is called the Ginette. The project was a way for me to combine my expertise in electronics and my passion in music: I had recently graduated as an electronics engineer from University of Oulu, played guitar a lot and made home recordings, and was a music nerd. The Ondes Martenot—an early electronic instrument from France—was familiar to me by the British rock band Radiohead and the French composer Olivier Messiaen. Its haunting tones and extensive glissandi with the humane character greatly fascinated me. I found a website[1] presenting a project of building a synthesizer controller based on the Ondes Martenot, and it encouraged me to make something similar by myself. After many steps of my project the Ginette was finished, and the next step was then to learn to play it since its unusual interface was new to me. It has a ribbon and an intensity key for controlling a pitch and a volume, respectively. The ribbon consists of a ring attached to a wire, running on a fingerboard with both visual and tactile guides for pitch, and the intensity key is a pressure-sensitive button. When I experimented with guitar effect pedals, I found a satisfying method to play solo gigs. The Ginette is a monophonic instrument, so I could play slowly-evolving harmonies by using a delay effect with a long delay time setting. I found that a fuzz pedal at a moderate distortion level modifies the pure sound of the Ginette in a natural and expressive manner, making a character reminiscent of acoustic instruments.

Over years of playing the Ginette, I noticed the restrictions that the pedals had and began to get ideas for a new version I recognized that the tasks I was doing with pedals could be done more freely with the instrument. The new Ginette could be polyphonic, but it should also preserve its expressivity. The timbral capabilities could be more diverse, but a player should focus on playing—in a traditional sense of the word—not on adjusting timbres, as is often the case with synthesizers. My aim is to make a sensitive instrument where gestural nuances can be heard, such as with many acoustic instruments: an electronic instrument, but not a machine.

---

[1] *Ondes Martenot Controller Project* by Dana Countryman, see http://www.danacountryman.com/martenot_project/martenot.html [Accessed September 9, 2020].

I compare this sensitiveness to drawing: with a computer, a perfectly straight line can be drawn, and qualities such as thickness or curvature can be adjusted separately with careful consideration. When using a brush and ink to draw a line with a free hand, such qualities are controlled simultaneously. The hand of a drawer is adjusting many parameters with sensitive gestures, often intuitively and with no analytical or verbal consideration process. The outcome depends on the style and skills of a drawer, as well as the materials used and tools. In addition to a delicate control, a drawer also produces an uncontrolled element: namely, their own touch, a personality. It is like one's own handwriting: it just happens as such, containing an original and recognizable style. If these subtle gestural features are not taken into account in a computer-aided drawing, a result is less human. It is the same with musical instruments. With a synthesizer, knobs can be tweaked carefully to get a perfected sound, but if the instrument lacks a tactile interface, this aforementioned human touch will be absent. Although a modern instrument would be electronic, it can still contain tactility for converting an intimacy of a human gesture into a sound. This is what I am interested in my research of developing the new Ginette.

The new Ginette would be primarily an instrument built for myself and to meet my own needs as a musician. In addition to the new features discussed above, I pay attention to a better feel of the interface, improved reliability and serviceability, good ergonomics, and easy transportability. Moreover, I have plans for a productization since the first Ginette has gained an interest and purchase offers, a design aspect that is also taken into account.

1.1 Scope

Making the new Ginette can be divided in two stages: design and building. This thesis introduces the design concept, whereas the building of it is excluded from the scope of this thesis due to its broadness. These two stages are parallel to some extent, so the design may undergo some changes during the building process. The design is presented from the player's point of view: how the new Ginette would sound, function, and feel as an instrument, and how it is compared to other instruments. The technology (i.e. how all the functions are implemented) is presented only at a general level. The background of the project focuses on the Ondes Martenot and the first version of the Ginette. The Ondes Martenot is introduced extensively, and subsequent instruments continuing its legacy are also reviewed. This is to give a framework of understanding of how the new Ginette is positioned in the continuum, and which features are new in this context. The design and building process of the first Ginette and how I have played it are also introduced comprehensively, since they are the basis for the new design. The first Ginette also acts as the proof of concept.

1.2 Research question

The research question of my thesis is: How can I design a new version of the Ginette, with polyphony and more timbral capabilities, while preserving its expressivity? By expressivity, I am referring to a capability for musical expression, such as varying dynamics, pitch, and timbre. Expressive qualities must also be taken into account when designing the new features.

The first Ginette is a monophonic instrument, so while performing with it I have used a delay effect for layering the sound to make harmonies. The process is rather slow, so changing chord progressions takes time. Instead of including this process of building chords by playing notes one by one into the playing, I began to think of better ways to do it. An instrument with polyphony could be a solution, but it should not lack expressivity. Single voices could be distinct, differing from others in other terms such as pitch.

Using a fuzz pedal with the first Ginette, I have enriched its timbral palette. Not only does this bring a new sound, but the fuzz also varies the timbre in terms of volume, being brighter and more penetrating when playing louder. I found the result satisfying and natural, resembling acoustic instruments. I decided to integrate this feature into the new design alongside the polyphony.

1.3 Structure of the thesis

This thesis is divided into three main stages: the historical background (the Ondes Martenot), the background of my own work (the first Ginette), and the project (designing the new Ginette). Chapter 2 presents the Ondes Martenot: the history, how it is defined as a musical instrument, its repertoire in different genres throughout the history, a detailed technical review, and a review of the instruments and the controllers related to the Ondes Martenot. In Chapter 3, the first Ginette (made in 2010–2011) is presented, including a design and build process, and methods that I have used to play it. Chapter 4 introduces the working portion of the thesis itself: a design of the new Ginette. In this chapter, I will describe my visit to the Ondes Martenot player Thomas Bloch's studio in France, where I took a closer look into his Ondes Martenot. My design process was at an early stage at the time, so the visit had an impact on it. I will then present a categorized construct of the new Ginette. Lastly, in Chapter 5, the conclusions of the project are presented and the topic is discussed further.

2 ONDES MARTENOT

"It's so little known, and yet it's the most expressive electronic instrument ever invented."

—Jonny Greenwood (2004) on the Ondes Martenot in the programme notes for his orchestral piece *smear* for two Ondes Martenots and chamber ensemble of nine players.

Since the Ginette is essentially inspired by the Ondes Martenot, I find it relevant to examine it throughout this chapter. Due to the Ondes Martenot being a rather rare instrument, having evolved significantly over the decades, and the presence of misinformation in written history about it, I find a comprehensive introduction particularly important to include. The main sources I used in the following review are the recent PhD thesis *The Ondes Martenot Network in the Twenty-First Century: The Co-Construction of the Ondes Martenot and its Users* by Dorien Schampaert (2018); Thomas Bloch's sleeve notes for his album *Music for Ondes Martenot* (2004), his website (n.d.), and my visit to his studio in 2017; a book *Technique de l'onde electronique type Martenot, volume. I: Le clavier* by Jeanne Loriod (1987); and a documentary film entitled *Wavemakers* (*Les Chant des Ondes*) directed by Caroline Martel (2012). I excluded one substantial source, a biography *Maurice Martenot, Luthier de l'électronique* by Jean Laurendeau (1st ed: 1990; 2nd ed: 2017), due to the fact that it has no English translation. However, Schampaert (2018) widely refers to Laurendeau's book. In this chapter, the history of the Ondes Martenot is introduced first (section 2.1), including its birth and evolution. It is followed by the definition of the instrument (section 2.2), bringing clarity to what it is and is not. The repertoire composed for the Ondes Martenot is then reviewed (section 2.3), spanning nearly a century of music in many genres. After that, the instrument is examined from the technical point of view (section 2.4), including all of its parts. Finally, other Ondes Martenot-based instruments and controllers are reviewed (section 2.5). A photograph of the Ondes Martenot is presented in Figure 1.

Figure 1. Thomas Bloch's Ondes Martenot (seventh model, built in 1985) with three of its loudspeakers or *diffuseurs*.

2.1 History

The inventor of the Ondes Martenot, Maurice Martenot, was born in 1898 in Paris (Bloch, 2004). He began to study music at a young age, giving his first cello concerts when he was nine years old (ibid.). At the end of World War I, he was enlisted in the military and positioned at a mobile telecommunications unit (Loriod, 1987). Martenot was in charge of sending and receiving messages on a new triode vacuum tube station (Wavemakers, 2012), and while using radios tuned to frequencies close to each other, he noticed a pure sound produced by triode vacuum tubes (Bloch, 2004). This is called 'heterodyning', the principle behind the instrument he would later invent (ibid.). He tried to tame the sound and play melodies by manipulating a frequency by a dial (Wavemakers, 2012). After the war, Maurice Martenot went back to teaching music in Paris (Schampaert, 2018, p. 11) while also beginning to explore these electronic sounds by developing his own electronic instrument in a lab built in an attic (with help from his sister Ginette) (ibid.).

His first instrument was dated circa 1919 and never presented in public (ibid., p. 11). It consisted of "a small box and an antenna," to be played at a distance, "the sound being regulated simply by the movement of the performer's hand in the air (ibid.)." Though no further information exists, there are evident similarities to another electronic instrument from that era called the Theremin (ibid.). Martenot was not aware of this competitor until the early- to mid-1920s, thus making his parallel invention to the Theremin coincidental (ibid., p. 13). Nevertheless, he decided to develop it further to the musical direction before introducing it to an audience (ibid.). The Russian inventor of the Theremin, Lev Termen, or better known under his Westernized name Theremin, had a very similar background to Maurice Martenot, having also been a young cellist and former World War I radio engineer (ibid., p. 12). After spending some years mastering his instrument, Theremin went on to start a world tour in 1927, arriving with it at the Paris Opera before Martenot could premiere his own instrument in his home city (ibid., p. 13). Martenot attended the event, noted how difficult it was to play the instrument, and became convinced of the competence of his own invention (ibid., p. 13).

On 3rd of May, 1928, five months after the presentation by Theremin at Paris Opera, Martenot was ready to introduce his instrument to the public at the very same venue (ibid., p. 15). He played it himself, accompanied on piano by his sister Ginette (Bloch, n.d.). Although the instrument had been under development for several years—and would be developed significantly during the next decades—the concert is considered as the 'birth' of the Ondes Martenot in written history (Schampaert, 2018, p. 15). The concert and a subsequent international tour resulted in an excellent critical acclaim (Bloch, 2004). The French newspaper *Le Figaro* wrote: "this instrument is the most perfected [...] far ahead of the attempts of the Russian professor" (Schampaert, 2018, p. 16). *Deutsche Allgemeine Zeitung* stated: "Theremin is a physician-musician while Martenot is a musician-physician" (Bloch, 2004). This instrument, known as the first official model of the Ondes Martenot, consisted of a control cabinet standing at a distance, and a smaller cabinet on the left side of a player (Schampaert, 2018, p. 13). The control cabinet had a wire with a ring on the end that the player moved towards and away from the cabinet to control the pitch (ibid.). Visual references on a bar placed on the floor helped the performer to locate the correct notes (Loriod, 1987). The smaller cabinet had a volume-controlling button providing pressure sensitivity with a gradual volume scale (Schampaert, 2018, p. 188). The instrument was played in a standing position, moving the ring in the air while pushing the volume button (ibid., pp. 13–14).

In the next few years, many new features were introduced (ibid., pp. 188–191). New models were made to be played in seated position, and the new ring controller was positioned laterally over a dummy keyboard, and later, a functioning, monophonic keyboard (ibid.). The whole keyboard could be moved and wiggled laterally for creating vibrato (ibid.). Transposition buttons, selectable timbres, and a set of resonating loudspeakers were added (ibid.). The Ondes Martenot took its final practical form by the 1940s, although it still underwent some variations (Millar, 2001). The seventh and final model was finished in the early 1970s (Schampaert, 2018, p. 190). Instead of researching new sounds, Maurice Martenot was primarily interested in the expressive and musical potential made possible by electricity (Bloch, 2004). After his death in 1980, Marcel Manière (Martenot's assistant since 1951) continued finishing and repairing instruments until his retirement in 1988 alongside Martenot's son, Jean-Louis Martenot (Bloch, 2004; Schampaert, 2018, pp. 21, 25, 100). However, Manière did not begin to make new instruments (Schampaert, 2018, p. 100). Approximately 370 original Ondes Martenots were manufactured, in addition to several non-professional models (Bloch, 2004). It is not known how many of them are in functioning condition and in use, but an informed, conservative estimation is 60 instruments (Martel, 2013). Since its invention there have been approximately 40 professional Ondes Martenot players, or *ondistes*, with the majority of them located in France, Canada (Quebec), and Japan (ibid.).

2.2 Definition

According to the Hornbostel–Sachs classification[2], the Ondes Martenot is defined as an "electronic instrument" (Musical Instrument Museums Online, 2011, p. 22). In the PhD thesis *The Ondes Martenot Network in the Twenty-First Century: The Co-Construction of the Ondes Martenot and its Users* by Dorien Schampaert (2018, p. 83–85), it is stated that interviewed Ondes Martenot users "overwhelmingly reject" this definition. An "electro-acoustic instrument" is suggested instead by many of them, since the users feel that the subtle playing technique has qualities reminiscent of acoustic instruments. From a technical point of view, the sound of the instrument is generated electrically, and a set of loudspeakers color the sound acoustically (ibid., p. 86).

In a technical sense, the Ondes Martenot can be seen as a synthesizer, providing different timbres generated synthetically (ibid., p. 36). However, the expressive possibilities of the instrument are more extensive than in instruments generally seen as "typical synthesizers" (ibid., p. 37). Jonny Greenwood, a composer and member of Radiohead, describes the keyboard of a synthesizer as switches that are turned on and off, thus lacking the personality of the player in a sound when compared to acoustic instruments or the Ondes Martenot (Wavemakers, 2012). He states that this instrument is all about control with no guessing or random gestures, which "makes the Theremin look like a toy" (Nonesuch Records, 2007).

[2] The Hornbostel–Sachs classification categorizes musical instruments based on the sound-producing material (Schampaert, 2018, p. 47).

Greenwood claims that the Ondes Martenot is “the most expressive electronic instrument ever invented” (Greenwood, 2004). The Ondes Martenot player Nadia Ratsimandresy has said that instead of hearing the electricity, you hear the performer (Schampaert, 2018, p. 88). A synthesizer could have a similar timbre as the Ondes Martenot, but when lacking its sensitivity, it is a different instrument (ibid.).

The instrument has been called by several names throughout history (ibid., p. 7). In French, the plural is *les ondes Martenot* and the singular is *l’onde Martenot* (ibid.). Other names are: *les ondes*, *les ondes musicales Martenot*, *le Martenot*, *les ondes musicales*, and *l’onde électronique type Martenot*; and in English: the Ondes Martenot, the Ondes, the Onde, and the Martenot (ibid.). The Ondes Martenot means “Martenot’s waves” in English, referring to its inventor and its electrical sound waves (ibid.). There are other instruments and controllers based on the Ondes Martenot, which are described in section 2.5. Some of these are also called the Ondes Martenot by certain users, though only when they are capable of playing its repertoire (ibid., p. 8).

Despite the Ondes Martenot’s documented premiere having taken place in 1928, it was nevertheless preceded by a decade of development (ibid., p. 33). Additionally, the instrument introduced was not a finished product in its solidified form, but rather the first official model (ibid., pp. 33–34). As mentioned above, the instrument essentially took its final form by the 1940s (Millar, 2001), though Martenot continued to develop the instrument further until his death in 1980 (Bloch, 2004). The instrument was never mass-manufactured, and even instruments from the same period can differ due to Martenot’s new development ideas and players’ wishes (Schampaert, 2018, pp. 84, 256).

In addition to this misleading introduction of the Ondes Martenot with “the year of invention 1928”—including a description of its features not invented yet in that year (ibid., pp. 33–34)—other false information occurs. Some sources (see for example, The Bob Moog Foundation, 2013; Crab, n.d.) suggest that Martenot designed his instrument based on ideas of Theremin. Schampaert (2018, pp. 11–13) disproves this information: Martenot had already built his first instrument around 1919, with resemblances to the Theremin despite his unawareness. She also states that historians often introduce the Ondes Martenot as a historical precursor to synthesizers while omitting its evolution and use in music over the decades (ibid., pp. 35–36). Technology-oriented history timelines could signal that the Ondes Martenot is an ancestor of a synthesizer, perhaps framing later synthesizers as an improvement (ibid.). As stated before, however, although the Ondes Martenot utilizes an advanced sound synthesis in its time, its expressivity is a distinguishing factor (ibid., pp. 36–37).

2.3 Repertoire

The Ondes Martenot has been used in varying music genres throughout its history, and its repertoire includes over one thousand works[3] (Bloch, 2004). In the early days, the Ondes Martenot acted as a classical instrument in orchestras and ensembles (Schampaert, 2018, p. 1). The first composition for the instrument, *Poème Électronique* by Dimitri Levidis, was composed already in 1928, the same year when the instrument was introduced to the public (ibid., pp. 15–16). In the following years, composers such as Arthur Honegger, Darius Milhaud, and André Jolivet also composed for the instrument (ibid., pp. 17–18). The first movement of the *String Quartet* by Maurice Ravel was transcribed for four Ondes Martenots by Ginette Martenot, with approval by Ravel (Whittall, 2009). *Fantaisie* by Bohuslav Martinů and *Ecuatorial* by Edgard Varèse—works composed for the Theremin—are later rewritten for the Ondes Martenot by the composers, due to its better virtuosic capability and tonal control (Bloch, 2004).

The Paris Exposition in 1937 was a notable event for the instrument: an orchestra consisting of eight Ondes Martenots performed classical and popular pieces (Schampaert, 2018, p. 18). *Fête des belles eaux*, a work for six Ondes Martenots, was composed by Olivier Messiaen for the Exposition (Tchamkerten, 2007).[4] In the 1940s, Messiaen wrote more music for the instrument, including two significant orchestral works: *Trois petites Liturgies de la Présence Divine* (1943–1944) and *Turangalîla-Symphonie* (1946–1948) (ibid.). Though gaining great public success, the critics were hostile: Pierre Boulez violently showed his disapproval and declined to conduct these works (ibid.).[5] Serialist composers attempted to reach total control of every parameter of sound, whereas in the case of the Ondes Martenot, the performance relied on interpretation (Madden, 2013, pp. 10–11). The instrument was seen as too expressive, feminine, and human for a new, colder aesthetic (ibid.). As a result, interest in the instrument waned (Schampaert, 2018, p. 20).

A new audience interested in the Ondes Martenot was found in film and television soundtracks, as well as popular music (ibid., p. 23). Maurice Jarre, who studied the Ondes Martenot with Maurice Martenot himself, used it in the Oscar-winning score for the film *Lawrence of Arabia* (1962) (ibid.), and later for *A Passage To India* (1984) and *Mad Max Beyond Thunderdome* (1985) (Millar, 2001). Barry Gray,

[3] The number of works has been stated in 2004. According to Quartier et al. (2015), it is claimed that there are over 1500 works written for the instrument. New music for this instrument is still being composed continuously.

[4] The prerecorded work was played through speakers set on floating stages in the Seine, together with spectacles of water, light, and fireworks (Tchamkerten, 2007). The fourth and the sixth section in the *Fête des belles eaux* later became the fifth section in the *Quatuor pour la fin du Temps* (ibid.).

[5] Pierre Boulez—a renowned French composer, Messiaen's student, and an Ondes Martenot player taught by Maurice Martenot (Schampaert, 2018, p. 19)—described *Trois petites Liturgies* as "brothel music" (Tchamkerten, 2007). In *Turangalîla*, he characterized the Ondes Martenot as "too sentimental, the vibrato unbearable, and the music written for it ugly" (Schampaert, 2018, p. 19). He even renounced performing his own works for the instrument (ibid.).

another student of Martenot, was the composer for many of Gerry Anderson's TV series, and used the instrument not only for music but also for sci-fi sound effects (Schampaert, 2018, p. 23). The instrument was used in both Édith Piaf (Martel, 2013) and Jacquel Brel's songs, including his hit single *Ne Me Quitte Pas* (1959) (Schampaert, 2018, p. 23). In the 1970s, Beau Dommage and Harmonium, two rock bands from Quebec, Canada, used the instrument (ibid.).

The Ondes Martenot was rediscovered by avant-garde composers in the 1970s era of spectralism (or spectral music), Tristan Murail being one of them (ibid., pp. 21–22). This new generation of composers was interested in electronic sounds and timbres and had studied the instrument (ibid.). Schampaert (2018, p. 23) speculates if the Ondes Martenot had even affected the birth of spectralism itself. Olivier Messiaen returned to compose for the instrument after three decades with his opera Saint François d'Assise (premiered in 1983) featuring three Ondes Martenots (Tchamkerten, 2007). Despite the long hiatus, Messiaen did not cease to show his interest in it, instead being highly interested in the new models with new features (ibid.). As a teacher, he regularly introduced the instrument to his class, including his student Murail (ibid.).

Jonny Greenwood played the Ondes Martenot on Radiohead's album *Kid A* (2000) and subsequent albums after obtaining one in the late 1990s (Schampaert, 2018, p. 28). In addition, he has used the instrument in his film scores such as *Bodysong* (ibid., p. 144) and *There Will Be Blood* (Nonesuch Records, 2007), as well as in his orchestral pieces such as smear (premiered in 2004) for two Ondes Martenots and chamber ensemble of nine players (Greenwood, 2004). In addition to playing and composing for the instrument, Greenwood also commissioned Analogue Systems to manufacture an Ondes Martenot-based synthesizer controller called French Connection, released in 2000 (Schampaert, 2018, pp. 1–2) (the controller is described in detail in section 2.5.3). Consequently, Greenwood has brought remarkable visibility to the instrument (ibid.).

In the 21st century, the Ondes Martenot can be heard on many popular music albums such as *Random Access Memories* (2013) by Daft Punk (Switlicki, 2013) and *Ghosteen* (2019) by Nick Cave and The Bad Seeds (The Further, 2020). Damon Albarn, known as the frontman of the band Blur, used the Ondes Martenot in his music for the opera *Monkey: Journey to the West* (2007) (Hickling, 2007). Ryuichi Sakamoto and Alva Noto had the instrument on their soundtrack for the film *The Revenant* (2015) (The Vinyl Factory, 2016). At the time of this writing, Christine Ott has released *Chimères (pour Ondes Martenot)* (2020)—the first album containing only contemporary music for solo Ondes Martenot (NAHAL Recordings, 2020). Ott is an Ondes Martenot teacher in Strasbourg Conservatory, and she has collaborated with many musicians and bands such as Yann Tiersen and Tindersticks (ibid.). In conclusion, despite being a niche instrument, its repertoire spans continuously from 1920s to the present.

2.4 Technical review

In this section I introduce all of the features of the Ondes Martenot. The main focus is on the seventh model that was presented in the 1970s (Schampaert, 2018, p. 191), and the differences to earlier models are introduced in footnotes when they are known. This seventh model was the final version by Martenot, and subsequent instruments called Ondéa and Ondes Musicales Dierstein are near-replicas of this model (ibid.). I had a chance to examine the seventh model of the Ondes Martenot owned by Thomas Bloch. The photos that I took of his instrument, as well as my visit, are introduced in detail in section 4.1.

2.4.1 Intensity key

The intensity key[6] (*touche d'intensité*, *touche d'expression* or *touche*) is a pressure-sensitive button for controlling the volume of the Ondes Martenot (Schampaert, 2018, pp. 34, 86, 188–191, 335). It was inspired by Morse code transmitters that Maurice Martenot became familiar with during the First World War (ibid., pp. 10, 14). The intensity key is located in the drawer (*tiroir*) on the left side of the instrument[7] (see Figure 2). It is compared to a bow of a string instrument—as Martenot was a cellist—or a breath to play a wind instrument (ibid., pp. 10, 86). The total depression of the intensity key is less than an inch[8], having the full range from silence to a loudest possible sound in between (ibid., p. 14). Compared to acoustic instruments, the expressive gesture applied to the intensity key is very small, making the instrument highly sensitive (ibid.). The composer Olivier Messiaen states that the intensity key is the greatest feature of the Ondes Martenot, giving it its sound, intensity, and attack at the same time (Loriod, 1987). Many synthesizers have an envelope generator for controlling the volume by determining its attack time, decay time, sustain level, and release time (Vail, 2014, pp. 151–152). When these are first adjusted by knobs and then triggered by a keyboard, the envelope is essentially repeated the same. The intensity key provides all these parameters intuitively to the fingertip of a player, giving

[6] Several terms are used in different sources, both in French and in English. In this thesis, I use the term "the intensity key" after Quartier et al. (2015).

[7] Apart from the first two models that have the intensity key placed on a separate cabinet on the left side of a player (Schampaert, 2018, pp. 13–14, 188).

[8] An article *Intensity Key of the Ondes Martenot: An Early Mechanical Haptic Device* (Quartier et al., 2015) presents measurements of an intensity key from the seventh model of the Ondes Martenot. The displacement range of the intensity key is about 10 millimeters, and the full dynamic range takes place within about 6.5 millimeters. A picture of a disassembled intensity key reveals that its lever is mounted to a single pivot point and therefore the displacement depends on the measuring position on the key. The measurement is done for a single instrument, and as noted before, there are differences between instruments even from the same period (Schampaert, 2018, p. 256).

freedom for expression. The Ondes Martenot player Suzanne Binet-Audet states that the sensitivity of the intensity key and the touch correspond “very precisely with the unconscious musical intent” (Madden, 2013, p. 6).

Figure 2. The intensity key.

When the intensity key is pressed, a leather pouch filled with powder gets compressed under the key[9] (Schampaert, 2018, p. 17). The pedals of sewing machines at the time of the Ondes Martenot’s invention had a similar mechanism (ibid.). There are electrodes placed on the top and bottom of the pouch, connected to the powder that is a mixture of conducting and insulating material: graphite and mica (ibid.). When the pouch is compressed, a decrease in resistance and an increase in current flow between the electrodes results (Quartier et al., 2015). A ratio of the powder was mixed according to how responsive the player wished the intensity key to be (Schampaert, 2018, p. 17).

[9] Early models have a different structure, consisting of a small piece of frosted glass with a few lines of lead pencil drawn, attached under the intensity key and above a cup of mercury (Schampaert, 2018, p. 14). When depressing the key, the conductivity between the lead and the mercury increases (ibid.).

2.4.2 Ribbon

The pitch of the Ondes Martenot is controlled either by the ribbon (*ruban*) or the keyboard (*clavier*) (Loriod, 1987). The ribbon (see Figure 3) consists of a spring-loaded metal ring (*bague*) (see Figure 4), attached to a wire[10] that runs over a strip in the front of the keyboard (ibid.). The ring is held by the right index finger (ibid.). The strip has tactile guide marks for the fingertip: indentations and studs represent the white and the black keys, respectively, and their positions correspond to the keyboard (ibid.). The ribbon is very light, making all the subtlety of vibrato possible (ibid.). A glissando can be played over the full range of six octaves[11] and landed on a targeted note in one precise movement (ibid.). The Ondes Martenot player Jeanne Loriod (1987) states that the expressivity of the ribbon easily challenges the voice and the violin in terms of finesse.

Figure 3. The ribbon.

[10] The seventh model has a wire, whereas earlier it has a metallized ribbon (Schampaert, 2018, pp. 188–190) moving between several metal plates, forming linear variable capacitors (Huebner, 2011).

[11] The sixth and the seventh model have a six octave range instead of the seven octaves of earlier models (Schampaert, 2018, pp. 189–191). With a lever, the ribbon and the keyboard can be transposed by one octave to reach the seventh octave (ibid.). The range was reduced to achieve a smaller and lighter instrument (ibid., p. 20).

Figure 4. The ring.

The ribbon can be tuned with a dial positioned in the gap between the tactile strip and the keyboard (Loriod, 1987). There are also tuning dials for the bass and the treble, a volume dial, lever switches for an octave selection, and a filter (ibid.) (some of these can be seen in Figure 2 and 3).

The following description is based on my examination of Thomas Bloch's Ondes Martenot. The wire runs inside the instrument and forms a loop guided by pulleys. One of the pulleys is joined to a multi-turn potentiometer, hence the position of the ring corresponds to the position of the potentiometer and consequently the pitch. Another pulley is attached to a spring-loaded lever for tightening the wire. A detailed description of the construction is introduced in section 4.1.

2.4.3 Keyboard

The keyboard has six octaves[12], and the pitch can be transposed by one octave with a lever (Schampaert, 2018, pp. 190–191). The whole keyboard can be moved and wiggled laterally, thereby

[12] Sixth and seventh model has 72 keys from C to B (Schampaert, 2018, pp. 21, 136). Fourth and fifth model has a seven-octave keyboard whereas earlier models have no keyboard (ibid., pp. 188–191).

undulating the pitch up to one semitone (ibid.). A right hand on the keyboard can produce a vibrato with a gesture similar to a cello playing technique (Bloch, 2004). A player therefore has total control of the depth and speed of a vibrato (Semans, n.d.). The inertia of the keyboard has been taken into account in the design for as good response as possible (Loriod, 1987). The thinness of the keys can be seen in Figure 4, which indicates that the keyboard is relatively lightweight.

The keyboard is monophonic and has a low-note priority, so the lowest pressed key determines a played note (Semans, n.d.). The system makes fast trills easy to play, and when using a reverb they can be perceived as chords (ibid.).

In the case of the intensity key being pressed first and a keyboard key then, a clicking sound occurs, referred to as the *claquement* (Schampaert, 2018, p. 24). To avoid this glitch, a player must press the key early and only then control the volume (ibid.). The last generation of the seventh model does not have this issue anymore, and some modified instruments have the *anti-claquement*, a lever for eliminating this click (ibid., pp. 118, 316). However, since there is written music that utilizes the *claquement* the switch is needed for turning it on (ibid., p. 24).

2.4.4 Transposition buttons

Six transposition buttons are placed in the drawer (*tiroir*), on the right side of the intensity key[13] (Bloch, n.d.) (See Figure 2 and 5). When pressed, a played note is transposed instantly (ibid.). The buttons transpose the note a quarter-tone higher and lower, a semitone, a tone, a third and a fifth higher; they can also be used simultaneously to achieve a combination of intervals (ibid.).

Formule is a solo piece for the Ondes Martenot, composed by the Ondes Martenot player Thomas Bloch in 1995 (Bloch, 2004). This virtuosic piece employs the full range of the keyboard together with transposition buttons (ibid.). Bloch himself performed a part of the piece for me during my visit. Using a pedal for controlling the volume, the left hand is free from the intensity key to play transposition buttons only while the right hand is on the keyboard[14]. When the buttons and keys are pressed asynchronously, notes can be played extremely fast. Playing the same passages using only the keyboard would be very difficult, if not impossible.

---

[13] Transposition buttons are included since the second model (Schampaert, 2018, pp. 188–191).

[14] This can be seen on a video documentation on YouTube: *Ondes Martenot /virtuosistic Formule by Thomas Bloch-TV 1999* https://www.youtube.com/watch?v=to1CfKK9qFo [Accessed September 9, 2020]. An excerpt of the sheet music on Thomas Bloch's website presents a notation with transposition buttons: https://www.thomasbloch.net/FormulePage2.jpg [Accessed September 9, 2020].

2.4.5 Pedals

The Ondes Martenot has two foot pedals (see Figure 1): one for controlling a volume in the same manner as the intensity key, and another for controlling a damper filter (*feutré*) (Bloch, 2004). When using the volume pedal, the left hand is free from the intensity key to control other things such as the keyboard or transposition buttons (ibid.). The filter is low-pass with a fixed cutoff frequency (Loriod, 1987), and this is used for creating a muted effect (Bloch, 2004). The pedals have similar powder pouches as the intensity key, though the powder mixture is different for less sensitive behavior (Schampaert, 2018, p. 315).

2.4.6 Timbre

The drawer (or *tiroir*, see Figure 5) contains all the controls for the timbre, as well as the intensity key, transposition buttons, loudspeaker controls, and a switch for selecting between the ribbon and the keyboard (Loriod, 1987). There is a selection of timbres that can be switched on and off individually and thus can be combined (ibid.). All of the timbres are listed and explained in Table 1.

It is said that the *ondes* is the most used and recognizable timbre (Schampaert, 2018, p. 151). It is a sine wave (ibid., p. 335), a pure tone consisting only of the fundamental frequency with no harmonics (Vail, 2014, p. 11). The *octaviant* is a sine wave that is rectified so that the polarity of the negative half of the waveform is inverted (Schampaert, 2018, p. 335). As a result, it is an octave higher with a lot of harmonics (ibid.). Both the *octaviant* and the *petit gambé* have individual volume level sliders (Loriod, 1987). A balance between the *souffle* and all the other tones is adjustable (ibid.). Once the timbre is selected, it does not vary when playing—as opposed to many acoustic instruments—with the exception of the distortion in the output stage at certain configurations (ibid.).

The sound is generated based on transistors[15] and uses heterodyning (Schampaert, 2018, p. 191). It is the principle of two tones at frequencies above the hearing range that generates an audible tone at their difference frequency (ibid., pp. 320–321). The initial waveform used is a triangle wave, and all the timbres are shaped from it, excluding the *souffle* (which is generated by a noise generator) (Loriod, 1987).

[15] All the models before the seventh model are based on vacuum tubes (Schampaert, 2018, pp. 188–190). The tone between the transistor and the tube based models deviates slightly (ibid., p. 191).

Figure 5. The drawer or *tiroir*. The left half has switches for timbres and loudspeakers. Sliders (with numbers from 1 to 5) are volume controls for the *octaviant* (left) and the *petit gambé* (right). Dial wheels are balance adjustments for the loudspeakers (left) and the *souffle* (right). The rightmost switches are the *souffle* (top) and the ribbon/keyboard selector (bottom). The left side of the drawer has a switch for the loudspeaker D4, and a cable connector for the pedals.

Table 1. The timbres of the Ondes Martenot.

Abbrev.	Name	Definition
O	*ondes*	A sine wave
8	*octaviant*	A rectified sine wave with adjustable volume
C	*creux*	A peak-limited triangle wave
G	*gambé*	A square wave
g	*petit gambé*	A square wave with less harmonics with adjustable volume
N	*nasillard*	A pulse wave with a narrow pulse width
S	*souffle*	A white or pink noise with adjustable balance
T	*tutti*	A combination of all tones apart from the *souffle*

Source: Schampaert, 2018, pp. 335–336; Semans, n.d.

2.4.7 Loudspeakers

The Ondes Martenot has four different types of loudspeakers (*diffuseur*) (see Figure 6) that amplify, and—apart from one—also acoustically modify the tone (Schampaert, 2018, p. 187). *Diffuseur principal* (D1) is a traditional loudspeaker with no timbral modification (ibid.). *Résonance* (D2) adds a reverb effect with springs that are mechanically coupled to the speaker cone (Semans, n.d.). *Métallique* (D3) has a gong type of a resonating metal plate where the sound is coupled for producing metallic resonances (Bloch, 2004). *Palme* (D4) has two sets of twelve metal strings, tuned chromatically, which resonate in sympathy when playing (ibid.). All the loudspeakers can be turned on and off, and a balance between *diffuseur principal* and other speakers can be adjusted from the drawer (Loriod, 1987) (see Figure 5).

Figure 6. Loudspeakers. From left to right: *résonance*, *métallique*, *diffuseur principal*, and *palme*.

2.5 Instruments and controllers related to the Ondes Martenot

In this section I review instruments and controllers that are related to the Ondes Martenot. The purpose of the review is to survey what has been done in this field, thus underpinning how the new Ginette is positioned. Although the history of the Ondes Martenot already began a century ago, the legacy still continues. A lot has happened in this scene since I finished the first version of the Ginette in 2011. Some instruments presented here are faithful to the original instrument, which, from the perspective of the classical tradition, can be used for playing music composed for the Ondes Martenot. There are also instruments with new features, omitted features, smaller size, and lower cost, targeted for players outside the classical tradition.

The following review consists of commercial instruments and controllers that all include an Ondes Martenot-based intensity key and ribbon (with a ring). A controller is defined here as a piece of equipment for controlling an external sound source, such as a modular synthesizer, and thus does not produce sound itself. Some of the following instruments are also capable of this type of controlling. The review from sections 2.5.1 to 2.5.6, is in chronological order and includes the following: Ondes Martenot by Jean-Louis Martenot, Ondéa, French Connection, Ondes Musicales by Dierstein, Therevox ET-4, and Ondomo. Other related instruments or controllers that do not fully meet this definition (Ondioline, Persephone, and Touché) are reviewed briefly in section 2.5.7. Software-based instruments and non-commercial, do-it-yourself (DIY) instruments are excluded from this review.

2.5.1 Ondes Martenot by Jean-Louis Martenot

Jean-Louis Martenot, son of inventor Maurice Martenot, began to develop the new version of the Ondes Martenot after his father passed away (Schampaert, 2018, pp. 25, 91). Jean-Louis collaborated with the French Ministry of Cultural Affairs, who demanded that the new instrument must be digital (ibid., p. 25). The instrument is largely based on the seventh model, although the sound differs from the original due to the Hewlett-Packard sound card (ibid., p. 191). There are also changes in the layout, including a significant change in the position of the drawer (ibid., p. 91–92). Professional players have described the sound as "jarring" and "unrefined," and due to the drawer position, certain pieces are impossible to play (ibid.). Although the instrument is legally called the Ondes Martenot, professional players categorically rejected it due to these differences (ibid.). Production lasted a few years in the late 1980s and early 1990s (ibid., pp. 25, 191).

Jonny Greenwood, who has worked extensively with the Ondes Martenot on various Radiohead albums since the late 1990s (Schampaert, 2018, p. 28), is featured in the documentary *Wavemakers* or *Le Chant des Ondes* (2012, 0:48:21–0:54:06). Greenwood is shown presenting the instrument, which is a student model with a four-octave range with the control panel placed on top instead of having the drawer. He uses sliders on the left side of the intensity key for adding a second and third note in major third and major sixth intervals. Then he makes a vibrato and transposes this triad with the ribbon. This instrument has four of these sliders, whereas the full size model has eight of them (Fédération des Enseignements

Artistiques Martenot, n.d.). Unlike the original Ondes Martenot, the model by Jean-Louis Martenot has polyphonic capabilities, although harmonic notes seem to be only preselectable and not actually playable directly via the keyboard interface.

2.5.2 Ondéa

In 1997, the engineer Ambro Oliva began to design a new instrument called the Ondéa (Schampaert, 2018, p. 26). It is a near replica of the seventh model of the Ondes Martenot (ibid., pp. 191–192), and being faithful enough to the original instrument, it is accepted by professional players (ibid., p. 166). In fact, several of them use it as their main instrument (ibid.), partly due to the fact that new instruments were needed by professionals whose original Ondes Martenots become unrepairable (ibid., p. 2). Although the Ondéa does not legally carry the name of the Ondes Martenot, some professional players think of it as the Ondes Martenot since it is capable of playing music written for it (ibid., pp. 142, 166). The manufacturing of the Ondéa was discontinued in 2011 (ibid., p. 2), although a new version came into production in 2016 (ibid., p. 166) by David Kean (Draper, 2020). Along with the original features, the new Ondéa[16] has modernizations such as control voltage (CV) and polyphonic MIDI outputs for using the instrument as a controller, as well as a standard audio output (Schampaert, 2018, pp. 191–192).

2.5.3 French Connection

Analogue Systems, a British synthesizer manufacturer, was commissioned by Jonny Greenwood to make a synthesizer controller based on the Ondes Martenot (Schampaert, 2018, pp. 1–2). It is called the French Connection[17], and was released in 2000 (ibid.). According to the website (Analogue Systems, n.d.), it has a keyboard and a ribbon with a range of four octaves, an intensity key, and a joystick. The CV signals from each of these components—as well as gate and trigger signals from the keyboard—can be connected to a modular synthesizer. The French Connection does not generate sound itself. The intensity key and the joystick with its control signal connectors, knobs, and switches are located on the panel on the left side from the keyboard. The intensity key is much less refined compared to the Ondes Martenot: for instance,

[16] A website for the new Ondéa, see https://www.ondesmartenot.com/ [Accessed October 18, 2020].

[17] A website for the French Connection, see https://www.analoguesystems.co.uk/index.php/keyboards/the-french-connection [Accessed October 18, 2020].

the difference between silence and the quietest note can be heard on the former (Schampaert, 2018, p. 87). The keyboard is lacking the feature for vibrato via lateral motion (ibid.), hence, the French Connection is not accepted as a replacement for the original by professionals despite its approval by synthesizer enthusiasts (ibid., p. 184).

2.5.4 Ondes Musicales by Dierstein

Jean-Loup Dierstein, a repairer of electronic instruments, took the responsibility of maintaining the Ondes Martenots for the Paris conservatory beginning in 2006 (Dierstein, 2020). The work included the manufacturing of new parts for replacing broken and obsolete ones (ibid.). This led Dierstein to make his own version of the Ondes Martenot (ibid.), and since 2011, the Ondes Musicales by Dierstein[18] has been in production (Schampaert, 2018, p. 2). It is a near replica of the seventh model of the Ondes Martenot (ibid., p. 191). Based on the photos (ibid., p. 136; Dierstein, 2020), the appearance is essentially the same. As with the new Ondéa, the Ondes Musicales by Dierstein has CV outputs for using the instrument as a controller in addition to a standard audio output (Schampaert, 2018, p. 191).

2.5.5 Therevox ET-4

The Therevox ET-4, as introduced in its website[19] (Therevox Custom Musical Instruments, n.d.), is an electronic instrument inspired by the Ondes Martenot and early analog synthesizers. It was released in 2012 and is manufactured in Canada. It has a ribbon with a range slightly over three octaves. Under the ribbon, there is a reference keyboard with visual and tactile guides. Whereas the Ondes Martenot has indentations and studs corresponding the white and the black keys, the Therevox has only indentations for all notes. The reference keyboard is replaceable with alternatives, such as ones containing different scales or microtones. Since the Therevox ET-4 has no actual keyboard, the pitch is thus controlled only by the ribbon. There are two intensity keys for controlling two analog oscillators independently. Both oscillators can be tuned separately to certain intervals and can be synced. It also features timbre selection consisting of a sine wave, a rectified sine wave (similar to the *octaviant*), a triangle wave, pulse waves with different pulse widths, and white noise. The instrument has a low-pass filter with adjustable cutoff

[18] A website for the Ondes Musicales by Dierstein, see https://jeanloupdierstein.fr/ [Accessed October 18, 2020].

[19] A website for the Therevox ET-4, see https://therevox.com/ [Accessed October 18, 2020].

frequency, an internal spring reverb, CV outputs for using the instrument as a controller, and an expression pedal for several purposes. All the controls are located on top of the instrument, so it does not have a drawer. There are three submodels, the best equipped also utilizing a MIDI output and effects loop. In June 2020, Therevox implied on Instagram that a new model called ET-5 is under development, although no further details have been revealed at the time of writing (therevox_hq, 2020).

2.5.6 Ondomo

The Ondomo is a compact Ondes Martenot-based instrument released in late 2010s (Schampaert, 2018, p. 192). It is introduced on its website[20] (Ondomo by ASADEN, 2017) as being made in Japan by Naoyuki Omo. The instrument has a laterally-movable four-octave keyboard, a ribbon controller, and an intensity key. All the controls are located in a drawer with a similar layout as the original instrument. All the timbres from the Ondes Martenot (see Chapter 2, section 4.6) are included, apart from the *souffle* (the noise), and the levels of the *octaviant* and the *petit gambé* are similarly adjustable. There is a built-in speaker, a compatible connector for the original loudspeakers or *diffuseurs* (see Chapter 2, section 4.7) with a stereo line out, and their volumes are separately adjustable. It is suggested that *diffuseurs* for the Ondomo will be released later. A register can be changed with octave selectors, expanding the overall range to seven octaves. There are three transposition buttons (called 'gamelan buttons' in the Ondomo) rather than the six that the original Ondes Martenot employs (see Chapter 2, section 4.4). They transpose the pitch upwards by two, four, and seven semitones, and the transposition can be combined by pressing multiple buttons at once. A standard expression pedal can be connected for controlling the volume in the same manner as using the intensity key. The Ondomo is only 64 cm wide and weighs 6 kg, and it has a handle on the front for easy portability.

The professional Ondes Martenot player Nadia Ratsimandresy regards the Ondomo as an Ondes Martenot, with its intensity key having an acceptable sensitivity (Schampaert, 2018, p. 91). In contrast, the *ondiste* Nathalie Forget claims that the drastically smaller size compared to the original would be a problem when playing a classical score (ibid.). Being much cheaper as the Dierstein's instrument or the Ondéa, the Ondomo offers an affordable option for amateurs and students (ibid., pp. 172–173).

[20] A website for the Ondomo, see http://ondomo.net/ [Accessed October 18, 2020].

2.5.7 Others

This section contains brief reviews of two instruments and one controller that are somewhat related to the Ondes Martenot, yet not that evidently as previously introduced ones. In chronological order they are: Ondioline, Persephone, and Touché.

Ondioline

The Ondioline is a French electronic keyboard instrument developed by Georges Jenny (Preston, 2018) and began its development in 1938 (Vail, 2014, p. 10). It was patented in 1941 and produced until 1974 (ibid.). Similar to the Ondes Martenot, it has a laterally-moving keyboard that allows vibrato (ibid.). The keyboard is also pressure-sensitive: after a note is played, its volume and timbre can be varied by pressure applied to the key (ibid.). The Ondioline is a monophonic instrument, and its timbre has several modification options (ibid.). The instrument is rather compact, with a three-octave keyboard that can be transposed to cover eight octaves (ibid.).

Persephone

The Persephone is a fingerboard synthesizer by a French company Eowave. Launched in 2004, its second model (Mark II) made its appearance in 2009 (McNamee, 2009b). The instrument is inspired by early electronic instruments: the Trautonium, the Ondes Martenot, and the Theremin (ibid.). The Persephone contains both a rubberized ribbon controller (used by gliding a finger across it) and an expression key (ibid.). Based on its user's manual (Eowave, n.d.), the ribbon has a linear scale despite having no guides for pitch, and its scale can be set to one, two, five, or ten octaves. Whereas the Persephone Mark I is monophonic, the Mark II is duophonic, so both the lowest and the highest position on the ribbon define the pitch using two oscillators. The ribbon also makes use of pressure-sensitivity: pressure applied to the ribbon controls the velocity or amplitude of the note. The expression key is similar to the intensity key of the Ondes Martenot, since it is used for controlling the volume or the filter.

Touché

The Touché[21] is a controller by a French company Expressive E, released in 2017. According to the company website (Expressive E, n.d.a; n.d.b), the Touché consists solely of a touch plate that recreates a sensation of the intensity key of the Ondes Martenot. The touch plate has four axes of movement that are translated into MIDI, CV, and USB control data, so that both hardware and software synthesizers can be controlled with its usage of four parameters. There is a silicon cylinder under the touch plate for giving a specific feel when pressure is applied to it. The cylinder can be replaced for different responsiveness. Additionally, the lateral stiffness of the mechanism is adjustable with a slider.

[21] A website for the Touché, see https://www.expressivee.com/1-touche [Accessed October 18, 2020].

3 THE FIRST GINETTE

In 2010, I had the urge to build some sort of electronic instrument for myself. By then, I had graduated as an electronics engineer and played guitar for over a decade. I had gathered many instruments, the Stylophone[22] being one of them. I became interested in how it was made and began thinking about how I could hack it. With its tuning screw, a pitch could be swept, and this led me to think that it could be easy to make an alternative pitch control for it. I then found Dana Countryman's *Ondes Martenot Controller Project* website[23], which inspired me a lot. The Ondes Martenot has fascinated me for a long time both due to its use by two of my favorite music influences, British rock band Radiohead and French composer Olivier Messiaen—and because it is a beautiful, unique, and unusual instrument. Dana Countryman's controller includes a ribbon and an intensity key based on the Ondes Martenot. The controller does not produce a sound on its own but it does connect to his modular synthesizer to control the latter's pitch and volume. Since the project was well-documented and Countryman kindly replied to my questions, it really helped me to begin with my own Ondes Martenot-inspired project. At first, I planned to use a hacked Stylophone as a sound source for my instrument, but then I wanted to use a sine wave sound resembling the Ondes Martenot. I decided that my instrument would be a functioning instrument, not simply a controller, therefore I designed the oscillator inside the instrument, unlike Countryman. After searching for information and learning about synthesizer components, I found *Music From Outer Space*: a website[24] of analog synthesizer circuits designed by Ray Wilson. His voltage-controlled oscillator (VCO) design seemed to be ideal for my purpose. My instrument building project began to take shape.

---

[22] The Stylophone is a pocket-sized electronic instrument invented in 1968, and relaunched in 2007 (Dubreq Ltd, n.d.). It is played by touching a metal keyboard with a stylus (ibid.). David Bowie used it on his song *Space Oddity* (1969) (ibid.).

[23] See http://www.danacountryman.com/martenot_project/martenot.html [Accessed September 9, 2020].

[24] See http://musicfromouterspace.com/ [Accessed September 9, 2020].

3.1 Design and building process

In this section, the design and building process of my instrument is introduced. An interface consisting of a ribbon (section 3.1.1) and an intensity key (section 3.1.2) are described. It is followed by a VCO (section 3.1.3) and a body of the instrument including panels (section 3.1.4). Lastly, a background of the name "Ginette" is presented (section 3.1.5).

3.1.1 Ribbon

The ribbon consists of a ring attached to a wire, running on a type of fingerboard consisting of both visual and tactile guides for pitch. The ribbon functions similarly to the one used by the Ondes Martenot (see Chapter 2, section 4.2 for detailed description). A detail of the ribbon can be seen in Figure 7.

Figure 7. A detail of the ribbon.

The fingerboard is made of transparent polycarbonate (PC) sheet. Natural notes (i.e. notes corresponding to the white keys on a piano) have indentations machined into the fingerboard, whereas accidental notes (black piano keys) have bumps made of dome head nails (see Figure 7). This is similar to the Ondes Martenot. Since there is no keyboard in my design, I wanted to emphasize the visual feedback of note positions by painting them in black and white from the underside of the transparent plastic material.

The ring (see Figure 7) is made of silver and fits quite nicely onto my right index finger. The ring could be resized for other players, thus making the instrument personal. The Ondes Martenot has a ring with spring-loaded tightening. I assume that instead of being an adjustable size for everyone, it could be tailored to be a pleasantly snug fit for one player, since Ondes Martenots are built for players based on their wishes (Schampaert, 2018, p. 17).

The range of the ribbon is a compromise between the size of the instrument and the intended playing range. I decided to have a four-octave ribbon, from C to C. The register is selectable with a knob, enabling the full range to be nine octaves. The oscillator has no technical restrictions preventing it from having an even wider range, although it would be difficult or impossible to tune at very high and low frequencies. On the other hand, these extremities could have been useful nevertheless for producing some atonal effects, and a certain amount of detuning could even be compensated for with the continuous pitch ribbon through eventual practice.

The wire runs through four pulleys, forming a loop. Under the fingerboard, on the opposite side from the ring, the wire is attached to an extension spring that tightens the wire. The spring moves along the wire and gives it an elastic feel. One pulley is joined to a multi-turn precision potentiometer. The position of the ring and the potentiometer are matched, translating the resistance and voltage into pitch. The wire rotates the pulley less than half of the latter's circumference , and though at first I was a bit concerned that it would slip, the outcome was better than I had expected. I have noticed only minor deviations in pitch after long and intense playing, and have concluded that it is mostly due to a slightly eccentric joint between the potentiometer and its pulley. As a point of improvement, more friction between the wire and the pulley could correct this, which is a matter I will take into account in the next model.

The VCO has a one-volt-per-octave tracking: when the control voltage increases by one volt, the pitch will increase by one octave. Because of its linear behavior, the potentiometer in the ribbon must have a linear taper. The one-volt-per-octave tracking for the ribbon is easy to implement to be adjustable with a trimmer potentiometer, as well as tuning the ribbon. The linearity of the potentiometer is a critical matter here—the precision potentiometer used in the ribbon has an independent linearity of $\pm 0.25\%$, according to its specification. The independent linearity is defined as a maximum permissible deviation of an output curve from a reference line that is chosen to give as small a deviation as possible (Bourns, n.d., "Linearity"). In other words, an actual value deviates up to ±0.25% from a straight line that represents the ideal pitch in the ribbon. The type of deviation is also an important matter. A wirewound potentiometer gives a quantized output whose resolution depends on winding, whereas non-wirewound elements produce a smoother curve and are considered to have infinite resolution (ibid., "Resolution"). The former may result in an audible discontinuity in pitch when playing glissando or vibrato and may result in an imprecision of pitch if the resolution is not sufficient. When moving the ring from the lowest note to the highest over the span of four octaves, the potentiometer shaft rotates approximately seven and a half turns, while the full range is ten turns. The deviation due to nonlinearity would be relatively smaller if utilizing the whole ten-turn range. To put the full range in use, the pulley diameter should be smaller, but I decided to use a commercially-produced pulley with a certain diameter rather than a custom-made one.

To examine the precision of the ribbon, a maximum pitch deviation can be calculated based on the above-mentioned values. The corresponding distance between the lowest and the highest note on the ribbon (of four octaves, or 48 semitones) is approximately seven and a half turns on the potentiometer. Consequently, the full range of ten turns corresponds to approximately 64 semitones.[25] A change in the resistance of the potentiometer is directly proportional to the control voltage and the resultant pitch (defined chromatically rather than in frequency). Therefore, a maximum deviation of ±0.25% in a range of 64 semitones is ±0.16 semitones, or ±16 cents.[26] Hence, the pitch of a note controlled via the ribbon can deviate up to ±16 cents due to the nonlinearity of the potentiometer.[27] When examining the precision of the ribbon, it is good to remember that the pitch will ultimately be controlled by hand. Intonation must be determined by ear, as when playing fretless string instruments. As discussed in section 4.1, I noticed that Thomas Bloch's Ondes Martenot has a potentiometer connected to the ribbon with the same specified linearity of ±0.25%. The range in that ribbon is slightly wider than in that of Ginette, so I concluded that with these calculations, the theoretical precision of my instrument may in fact be somewhat better. In practice, I have not faced problems due to the potentiometer deviations when playing. In case it would pose an issue sometimes, the note positions in the fingerboard can be placed correctly based on an actual pitch, assuming that the deviations remain the same over time.

[25] 48 semitones / 7.5 turns · 10 turns = 64 semitones

[26] 64 semitones · ±0.0025 = ±0.16 semitones = ±16 cents

[27] If using a smaller pulley to utilize the full range of the potentiometer, then a maximum deviation would be ±12 cents (48 semitones · ±0.0025 = ±0.12 semitones = ±12 cents). In practice, it is slightly more if margins for vibrato for the highest and the lowest notes are taken into account.

3.1.2 Intensity key

The intensity key is attached to a control panel near all the control knobs (see Figure 8). The key is machined from black polyoxymethylene (POM) plastic. The spring-loaded key is joined to a linear position sensor that is in essence a miniature slide potentiometer. At first, the audio signal from the oscillator was fed directly through the potentiometer for controlling the volume, but soon I realized that this was a bad design. A potentiometer is an electromechanical component that has a limited mechanical lifespan, and in the audio context, signs of wear will manifest as crackling noises. Instead, I made a voltage-controlled amplifier (VCA)—also designed by Ray Wilson from *Music From Outer Space*—to control the volume of the audio signal. The audio is fed through the VCA, which is controlled by a control voltage from the above-mentioned potentiometer. The control voltage is low-pass filtered whereby any high frequency crackling is removed. The cutoff frequency of the filter can be fairly low, since changes in volume level are always relatively slow and below audible frequencies.

Figure 8. The intensity key.

3.1.3 Voltage-controlled oscillator

As mentioned earlier, the voltage-controlled oscillator (VCO) I decided to use is from the *Music From Outer Space* website, designed by Ray Wilson. The VCO outputs four different waveforms: a sine wave, a triangle, a saw, and a pulse wave. The sine wave was the main reason for choosing this design, since I felt that it is the most essential sound of the Ondes Martenot. Now, after years of playing, it has indeed been the sound I have used the most. The VCO has trimmers for adjusting the shape of the sine wave. I initially adjusted the shape with the help of an oscilloscope, but later I readjusted it by ear, achieving a more pleasant sound even if it was no longer a pure sine wave. The VCO has a one-volt-per-octave tracking (a voltage increase by one volt resulting in an output pitch increase of one octave), making the ribbon easy to implement in linear scale (as described in section 3.1.1). There are several control voltage inputs whose sums determine the pitch. In addition to the ribbon, the octave switch and a tuning dial also have their own pitch-defining control voltages.

3.1.4 Body and panels

The body of the instrument is made of birch plywood. I chose the material because my brother Teemu happened to have sufficient leftover pieces of it. I wanted the instrument to have a wood grain finish with its natural color visible. I sanded the plywood carefully and applied a light-colored wood wax finish. See the finished instrument in Figure 9.

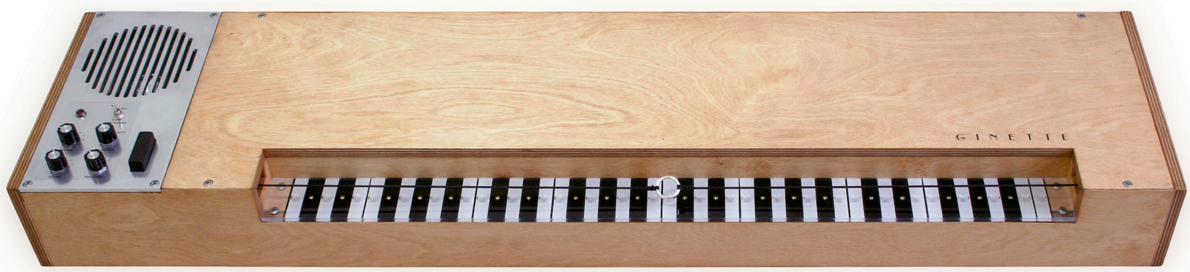


Figure 9. The first Ginette.

A control panel, machined from an aluminum plate, is located on the left side of the instrument (as seen in Figure 9). The panel contains the intensity key, knobs, a toggle switch, an indicator light, and a speaker. The controls are for volume adjustment, octave and waveform selections, as well as for choosing the pitch and volume controls' sources from either the ribbon/intensity key or the external CV signals. I included the option to play the instrument with an external device, such as an Ondes Martenot-style keyboard with a finger vibrato feature (see Chapter 2, section 4.3) that I might build later. Apart from a volume potentiometer, the knobs have rotary switches, which are somewhat disadvantageous with their stiffness and mechanical loudness. I chose knobs with a small diameter for a delicate appearance, but together with the rotary switches, the feel is uncomfortably stiff. When turning knobs, the rotary switches make rather distinct clicks that I find inappropriate for a musical instrument: though the clicks are not in the audio signal, they do occur acoustically. I will pay attention to this issue when selecting switches for the next version of this instrument. I decided to integrate the speaker with an amplifier to the instrument so that it could be played either as a standalone instrument or by using an external sound system. After playing the finished Ginette for some time, I now realize that I do not use the internal speaker at all. The sound quality was not very good, obviously, and I always had a better sound system available anyway.

Another panel consisting of connectors is located on the back of the instrument. There are ¼ inch jacks for an audio output, a speaker input, and external pitch and volume CV inputs. The speaker input makes it possible to insert effects pedals before the internal speaker in the audio signal chain. The back of the instrument also has a connector for mains electricity, including a power switch and a fuse holder, as well as an XLR connector for a supply voltage output. The latter connector provides supply voltage for external devices such as the aforementioned keyboard. It would have been useful to have pitch and volume CV outputs, so the Ginette's interface could also be used for controlling a modular synthesizer, for instance. I will include these outputs in the new Ginette.

3.1.5 Name

The instrument should have a name. I thought that the name should express its musicality, inferring that it is a delicate musical instrument rather than a machine. I preferred a humane name instead of a technical one like some synthesizers have, such as MS-20 by Korg. I read that the sound of the Ondes Martenot has been compared to a female singer[28], so I thought a woman's name could be suitable. I have always liked how B.B. King gave his Gibson guitars names such as *Lucille* (Bienstock, 2015). I also wanted to respect and emphasize the French roots of the instrument. My girlfriend at the time, Heta, who had been reading about the Ondes Martenot—suggested the name *Ginette*, after Ginette Martenot. Ginette was the younger

[28] A popular misconception is that The Star Trek theme is a Ondes Martenot mimicking a woman singing, but it is actually a woman singing (McNamee, 2009a).

sister of the inventor Maurice Martenot, not to mention that she was also the first accomplished *ondiste* (ondes Martenot player) (Tchamkerten, 2007). With this in mind, I thought the name was very befitting, how it looks and sounds, and I also liked its diminutive suffix *-ette*. After all, the Ginette is a smaller instrument than its relative, the Ondes Martenot. After playing many live gigs and introducing the Ginette to the public, I have noticed that the name draws attention. Perhaps it gives a productized and finished association, and maybe it sticks in the mind. People are also curious about where the name comes from. On the other hand, a pronunciation of the French name can be confusing for people of different languages, such as English and Finnish. The case is no easier with the Ondes Martenot, though.

3.2 Playing the Ginette

I finished the Ginette in the spring of 2011. This was the first time I had a chance to play an instrument requiring this kind of technique, so first I had to learn to play it (see the playing position in Figure 10). I had a solid background of playing guitar, as well as keyboards. The feel of the Ginette was intuitive: the ribbon felt like a fretless string instrument. The ribbon caught my attention at first, since I found a vibrato, a glissando and other pitch-related gestures the most prominent characters in such an instrument. It took some time to discover the diverse potential of the intensity key. An envelope, shaped by hand, is also a fundamental part of the nature of this sound. Playing in tune required practice (unlike when playing guitar or piano), although the fingerboard with its tactile feedback helps a lot. Experiments with effects pedals gave me ideas of how to take the sound further and how to play this instrument as a soloist.

Figure 10. The playing position.

3.2.1 Live setup

Over time, I have gathered a set of effects pedals that I find useful with the Ginette. With this setup, I have found an inspiring way to play solo concerts. I have modified an old briefcase into a pedalboard (see Figure 11) that is convenient to carry to venues. In this section, I will describe how I am using these effects pedals.

With the Digitech Hardwire DL-8 Delay/Looper, the longest delay setting (lasting eight seconds) is the basis of my live solo sets. As the Ginette is a monophonic instrument, this delay effect enables me to build harmonic layers. The difference between the delay and the looper is that with delay, a repeated audio signal progressively fades out, while the looper repeats it until the loop is turned off. The rate of fade-out can be adjusted, even during playing. At minimum, an audio signal gets repeated once, and at maximum, the delay acts like a looper. This adjustment makes it possible to control how many layers of played sound are audible at a time and how fast a repeated signal will fade and give way to a new one. The delay is the last pedal in the chain: when adjusting other pedals, the delayed material remains unchanged.

After playing with this setup for some time, I noticed similarities in both the function and resulting aesthetics between my setup and Robert Fripp's *Frippertronics* system[29]. At first, I tended to build soundscapes in the style of ambient music, which consist of many layers of sounds—it is rather easy to achieve pleasant-sounding atmospheres. After a while, however, I began to look for a more subtle and vulnerable expression in which the playing itself is more present. With the delay adjusted to repeat a signal only once, I am able to play a sort of a duet with my past playing. A delayed signal can be locked as a loop, at which time a new signal gets bypassed, allowing me to play a solo melody over the loop. Although this system makes polyphony and a richer sound possible in many ways when playing the Ginette as a solo, it has its restrictions. The practice of making music develops and transforms rather slowly with it.

Figure 11. The briefcase pedalboard. Top row, from left: Digitech Hardwire DL-8 delay and looper, Digitech Polara reverb, and Harley Benton PowerPlant Junior power supply; bottom row, from left: Korg Pitchblack Mini tuner, DIY fuzz, UralTone kit tremolo, and Ibanez Soundtank DL5 delay.

---

[29] Frippertronics, introduced to Robert Fripp by Brian Eno, is the system originally consisting of a pair of Revox tape recorders, with effect pedals and a guitar (Mulhern, 1986). A reel of tape goes from one tape recorder into the other, and an output of the second recorder loops back into the first, creating recirculation for guitar lines (ibid.). The system can be heard on album *(No Pussyfooting)* (1973) by Fripp & Eno, and several subsequent albums featuring Fripp (ibid.).

I built a fuzz pedal for my electric guitar at the same time as I was building the Ginette. The fuzz is based on the Dallas-Arbiter Fuzz Face topology with germanium transistors, a favored component in fuzz pedals (Holmes, Holters and van Walstijn, 2017). Compared to silicon transistors, the sound of fuzz pedals with germanium transistors has a softer clipping character (Bryant, 2007). I once happened to try the fuzz pedal together with the Ginette, and I really liked how it sounded. Instead of the stinging buzz that electric guitars with fuzz effects often give off, the sine wave of the Ginette at a moderate volume resulted in a soft and pleasant tone. The result reminded me of brass and strings. The louder the input sound, the more the distortion, hence a wide dynamic range of the intensity key gives a control to the variance of timbre as well. The behavior of the fuzz is described in detail in section 4.2.6.

For more brutal distorted sounds, I use another delay pedal (Ibanez Soundtank DL5) with the delay time set to 400 ms, placed before the fuzz in the signal chain. With the delay, multiple notes can be audible simultaneously, and when it is input to the fuzz the sound can get rather complex due to an intermodulation distortion by the fuzz (Fumo, 2018). The intermodulation distortion produces additional tones at sum and difference frequencies based on the frequencies of an input signal (Hartmann, 2013, p. 183). The more dissonant the played intervals, the more dissonant the distortion.

Occasionally I use a tremolo pedal, which is the UralTone kit I have built. The tremolo pedal varies the amplitude of a signal in a pulsatile manner. Together with the fuzz (with the tremolo placed before it in the signal chain), it modulates not only the volume but also the timbre. Having a tremolo speed out of sync with the eight-second delay causes the tremolo pulse to be in a different phase within different delay layers and results in an arpeggio-type of texture.

I use a reverb pedal (Digitech Polara) mainly for adding natural reverberation to the sound. I tend to vary the amount of the reverb while playing in order to alternate between a bigger and more intimate sound. The pedal has several reverb modes, and sometimes I use less natural reverbs to color a timbre.

4 DESIGNING THE NEW GINETTE

"*...peut-être qu'après les lampes et les transistors, nos petits-fils du XXIe siècle connaîtront un Huitième et "Super-Onde", plus riche encore que les précédentes...*"

"...perhaps after the radio tube and transistor of today our grandchildren of the 21st century will know an eighth, "Super" Ondes, even richer than its predecessors."

—Olivier Messiaen in May 1982, speculating the future of the Ondes Martenot legacy in the preface of *Technique de l'onde electronique type Martenot, volume. I: Le clavier* by Jeanne Loriod (1987).

My initial idea was to build an electronic instrument as a project for my master's thesis. I thought it could have a new 'interface', and consequently a new expressive method to play it. I was pondering the idea of a keyboard with pressure-sensitive keys, among other things, but eventually I realized that I should go back to improving the Ginette since the first version was successful. I am satisfied with playing it, I have done many solo concerts with it, and there are people who have shown an interest in owning such an instrument. Thus, it felt the most relevant project for me. Instead of attempting to replicate the Ondes Martenot—and with the recently published Ondomo being a faithful realization of it (see section 2.5.6)—I began to think of the needs I have come across during the years of playing the Ginette and started to design the new one based on that. I am aware that new features are always experimental in nature and that their usefulness is only discovered through practice. Hence, I need to build the instrument first so I can find out whether these features would make a good instrument.

The detailed construction of the new Ginette is presented in section 4.2. In the previous section (4.1), I describe my visit to Thomas Bloch's studio where he gave me an initiation to the Ondes Martenot. Designing the new Ginette was still in progress during this visit, so it gave me beneficial insight into my design process.

4.1 Meeting Thomas Bloch

On May 16th, 2017, I had a chance to visit Thomas Bloch's studio in Gueberschwihr, France (see Figure 12). Thomas Bloch is a professional Ondes Martenot player and a teacher of the instrument at the Strasbourg Conservatoire.[30] During this day, he taught me the basics of how to play the Ondes Martenot, let me examine the inside of the instrument, and discussed it with me. Before the visit, I was pondering how the feel of the instrument might be and how it would differ from the Ginette. This was the first time I had had an opportunity to play the Ondes Martenot or anything related besides the Ginette. The Ondes Martenot I played was built posthumously for Bloch in 1985 by Maurice Martenot's assistant Marcel Manière[31] (Bloch, 2004). It is the seventh model, the first of its kind with a transistor-based sound generator instead of vacuum tubes. Bloch told me that he owns another instrument from that era and a third made recently by Jean-Loup Dierstein (see Chapter 2, section 5.4), though those instruments were not present at that time.

Figure 12. Thomas Bloch, myself, and his Ondes Martenot.

[30] In addition, he also plays other rare instruments: glass harmonica and Cristal Baschet.

[31] Marcel Manière finished and repaired Ondes Martenots throughout the 1980s along with Martenot's son, Jean-Louis Martenot (Schampaert, 2018, p. 25), but did not build any subsequent versions of these instruments (ibid., p. 100).

Before playing, I had the misconception that the intensity key would have required much more force in order to play loudly. I had been thinking that there must be a very strong and serious gesture needed for *fortissimo*, but I was surprised at how delicate the feeling actually was. Controlling the intensity was really on a fingertip. At first it felt too difficult to control because of its subtlety, however, it just requires getting accustomed to. And so it should be: it is a delicate instrument, and mastering all the expressivity in such instruments takes time to learn. It is also helpful to remember that the feeling of the intensity key is tailored to each player (Schampaert, 2018, p. 17). Making percussive, short attacks by tapping the intensity key felt natural, intuitive, and very responsive. The feel and the sound was strongly connected. Playing attacks as short and tight with the first Ginette would not be possible. Inspired by all this, I adjusted the response of the Ginette's intensity key to be lighter. The feel improved slightly, but the moving mass should be lighter, so I will take this into account in the new intensity key design. Thomas Bloch kindly removed and opened the *tiroir* (the drawer where the intensity key and controls are placed) to let me look at and photograph it. In Figure 13, the underside of the *tiroir* can be seen. Six blue components in the foreground are the transposition buttons (described in detail in section 2.4.4), two stacked printed circuit boards in the background are under the switches and sliders, and a construction between these two is the intensity key. In the middle of the intensity key, a ball-shaped grey object with a connected yellow wire is a powder-filled leather pouch. The more the key is pressed, the more the pouch will be squeezed, and the louder the sound (a detailed operating principle is described in section 2.4.1). Although the Ondes Martenot has been in production for over half a century when this instrument was built, it is evident that it is handmade when examining the soldering and an overall construct; the Ondes Martenot has never been mass-manufactured (Schampaert, 2018, p. 84).

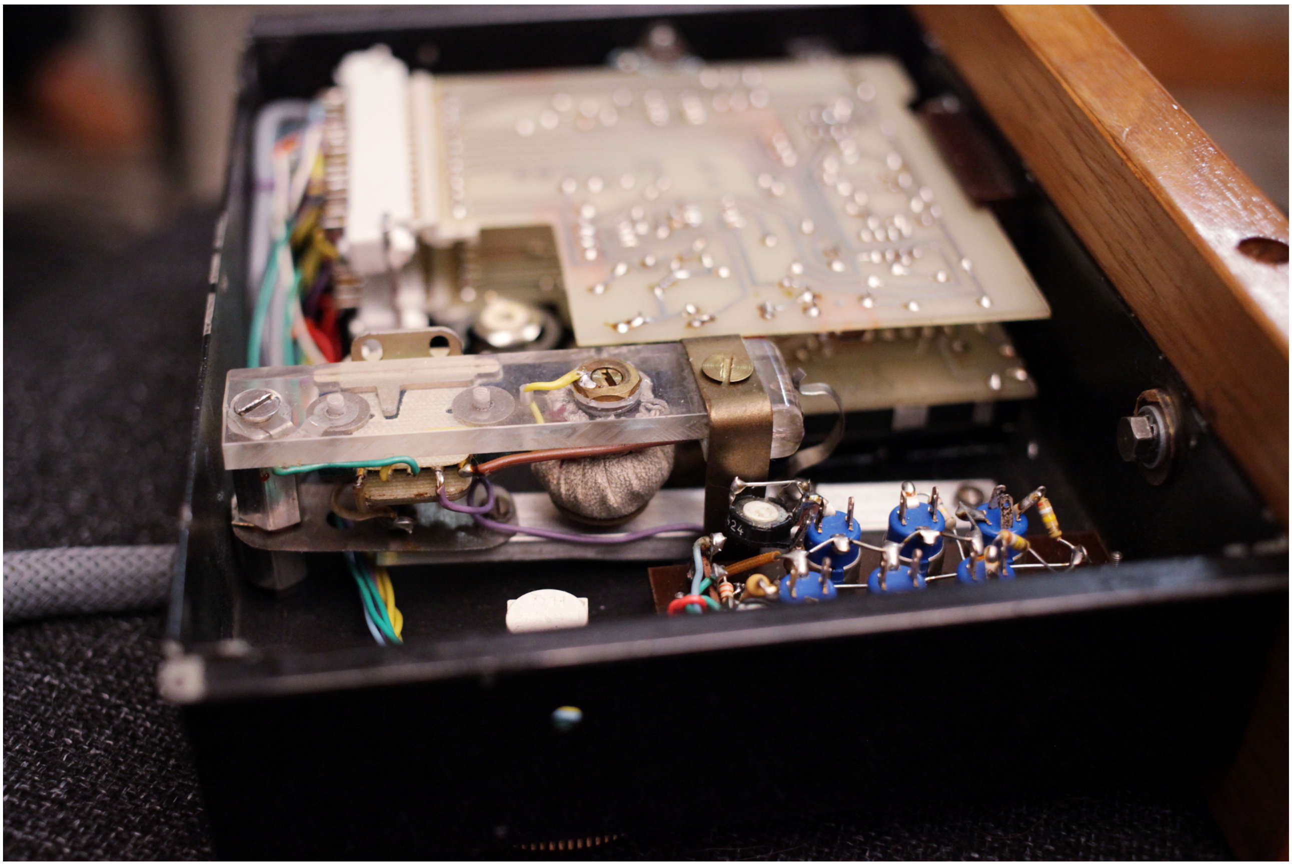


Figure 13. Inside the *tiroir*.

The ribbon felt more rigid to move compared to the Ginette. It was not exceptionally hard to play with it, but I personally found the Ginette's ribbon more comfortable to play. I am not sure if this slightly rigid feeling was intended or if it was a consequence of structure or aging. The ring was a bit loose for my index finger, reminding me again that the Ondes Martenot is an instrument tailored for its player. A central part of the ribbon mechanism can be seen in Figure 14. The picture is from the right-hand side of the instrument, and the keyboard is lifted up to reveal the interior underneath. Three pulleys can be seen: the topmost pulley guides the wire of the ribbon from the tactile 'fingerboard' to inside the instrument, the pulley in the middle is connected to a multi-turn potentiometer that transforms the position of the ring into a resistance, and the rightmost pulley is on a spring-loaded lever for tightening the wire. The pulley with the potentiometer has a threaded groove, and the wire is wound around it multiple times to prevent slippage. When the ring is moved, the wire travels back and forth in the pulley parallel to its shaft, while adjacent pulleys allow the wire's lateral movement. Print on the potentiometer indicates that its linearity is ±0.25%, which is the same as in the first Ginette (this is described in detail in section 3.1.1). Therefore in the six-octave range (or 72 keys to be exact), a maximum deviation in the ribbon is about ± 0.18 semitones or ± 18 cents.[32] If there are margins at both ends of the potentiometer range, the maximum deviation is slightly larger.

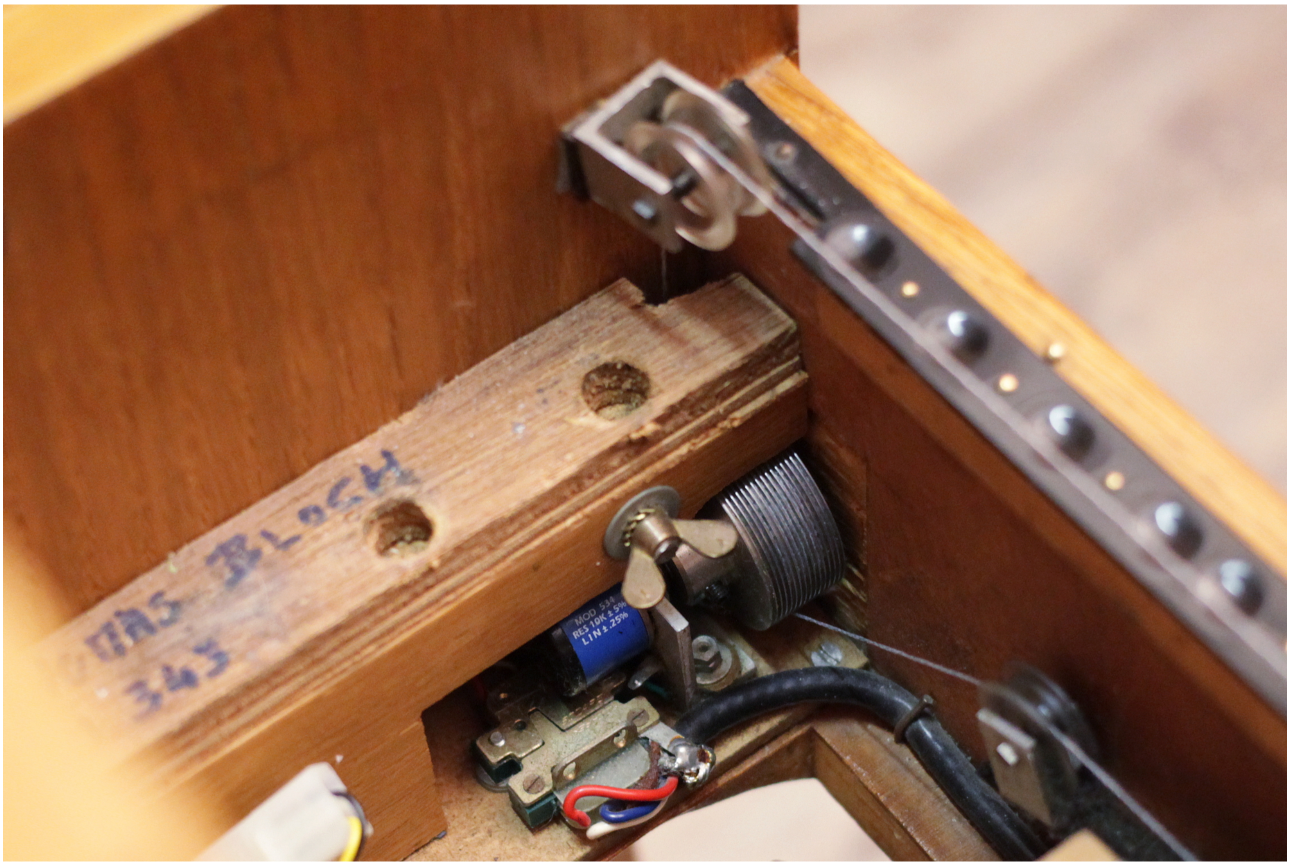


Figure 14. The pulley mechanism of the ribbon.

With the keyboard, producing vibrato felt lightweight and intuitive. The instrument is built so that the whole keyboard with six octaves moves laterally (see detailed description in section 2.4.3). When a key is pressed with a finger, vibrato can be made by wiggling the keyboard with the finger. I concluded the keyboard must be rather lightweight, considering the lightness of movement and how delicate it looks. I found a vibrato gesture similar as when playing with the ribbon.

This Ondes Martenot includes two foot pedals, as seen in Figure 1. One is for controlling the volume in the same manner as with the intensity key: potentially releasing the left hand for other uses, such as controlling the transposition buttons and the keyboard. The other pedal is for controlling a filter. This filter is a low-pass type with no resonance, so instead of typical synthesizer filters that color the timbre, it reminded me of the tone knob of an electric guitar that dampens high frequencies. The pedals look dissimilar to the instrument itself, with presumably plastic casing and industrial manufacturing. However,

[32] 71 semitones $\cdot \pm 0.0025 = \pm 0.1775$ semitones $= \pm 17.75$ cents

Bloch mentioned that it has similar handmade powder-filled leather pouches as the intensity key. Controlling the volume with a foot obviously was not that delicate compared to an index finger, but the freedom it brings to the left hand was something I found very useful. Inspired by the experience, I decided to add foot pedals to my new design.

4.2 Construction

Like the first Ginette, the new version consists of the ribbon and the intensity key, which are fundamental parts of the instrument. The ribbon is a wire with a ring attached, running on a fingerboard that has both visual and tactile guides for pitch. The intensity key is a pressure-sensitive button that provides a delicate and expressive volume control. In addition, I have designed more features allowing polyphony and a wider timbral palette. The needs and the ideas for the new design have arisen from the restrictions of the first Ginette and the live setup I am using, as well as the Ondes Martenot itself.

New features are introduced here shortly and described in detail in the following sections of this chapter. Besides the intensity key, the new design has a keyboard of 20 keys, whereby a single key has a similar operating principle to the intensity key (see section 4.2.1). Up to four voices can be played simultaneously with it. There are selectable operating logics called 'modes' for the keyboard (section 4.2.4): for instance, playing a solo melody accompanied with chords is possible. There are two foot pedals for intensity and modulation controls (Chapter 4, section 2.3). The timbre can be mixed from different waveforms and noises (section 4.2.5). An audio signal from one oscillator can be routed to other oscillators for oscillator syncing and frequency modulation (FM). Every voice has its own low-frequency oscillator (LFO) for an individual tremolo and vibrato (section 4.2.2), and its own fuzz effect circuit for shaping the timbre (section 4.2.6). Fuzz is a type of distortion usually used with electric guitars, although I have also found it useful with the Ginette. The principle of the ribbon does not fundamentally differ from the first Ginette (as described in Chapter 3, section 1.1), so it will not be described in this chapter. The intensity key has refinements in its response and reliability similar to the keyboard (see 4.2.1.2), but otherwise the principle is the same as before (as described in Chapter 3, section 1.2). Thus, the intensity key also has no separate description in this chapter. In addition to these new features, the new Ginette is designed to be more reliable and easier to service, as I plan to manufacture it for sale. A sketch of the new Ginette is presented in Figure 15.

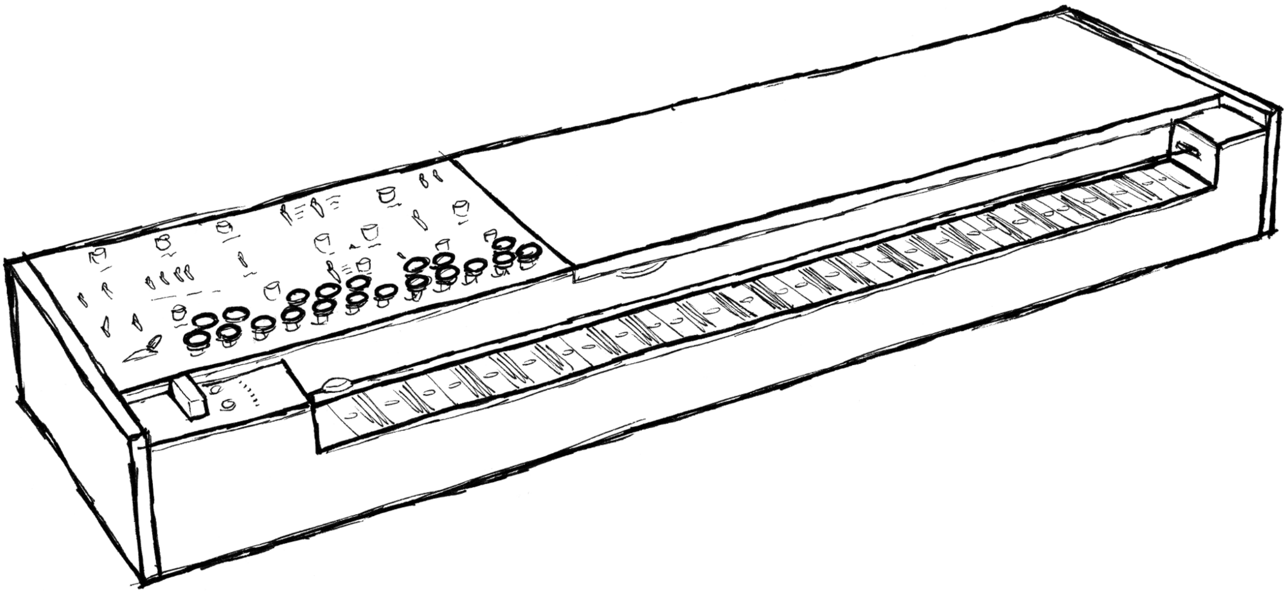


Figure 15. A sketch of the new Ginette.

Based on my design principles, the new instrument must be able to be played like the first Ginette, regardless of the new features. This familiar way of playing has to be ergonomically accessible Therefore, both the keyboard and the intensity key are included, and they are both available at all times with no interruption of a switch selection. The new features must include the ability to show a player's character and not sound mechanical. My goal is not to expand the Ginette to be a synthesizer (in a traditional sense). Rather, my aim is to develop an instrument through which a subtlety of musicianship can be brought out even more.

4.2.1 Keyboard

The key element in my briefcase pedalboard is the delay effect that I have used for creating fading loops (as described in Chapter 3, section 2.1). Since the first Ginette is a monophonic instrument, I find the looping essential because it makes harmony possible. The looping system is also restrictive because it is a slow process to build a loop and then change it. This led me to think of how I could play chords without looping in real time while still preserving the organic and expressive nature in the sound of the Ginette. I had the idea of including several intensity keys and arranging them like the keyboard layout. Each key would produce a sound a semitone apart from adjacent keys—much like a keyboard—but the ribbon could also define the pitch. Therefore, the lowest key on the keyboard could play a note defined by the ribbon, and the second key could play a note one semitone higher, et cetera. When the left hand on the keyboard plays a chord, the right hand on the ribbon can slide the whole chord to another key, vibrate it, and make other pitch-related gestures. A barre chord on a guitar can be used as an analogy for this system: a certain fingering creates a certain chord and voicing, and it can be transposed by the hand position when playing the guitar as by the ribbon with the Ginette.

In addition to the keyboard, there would be a separate intensity key like the first Ginette has, so the playing technique can be altered between these two. The keyboard also brings a new technique in monophonic playing, when a note change can be more rapid and has a different character. A sketch of the keyboard and the intensity key layout can be seen in Figure 16.

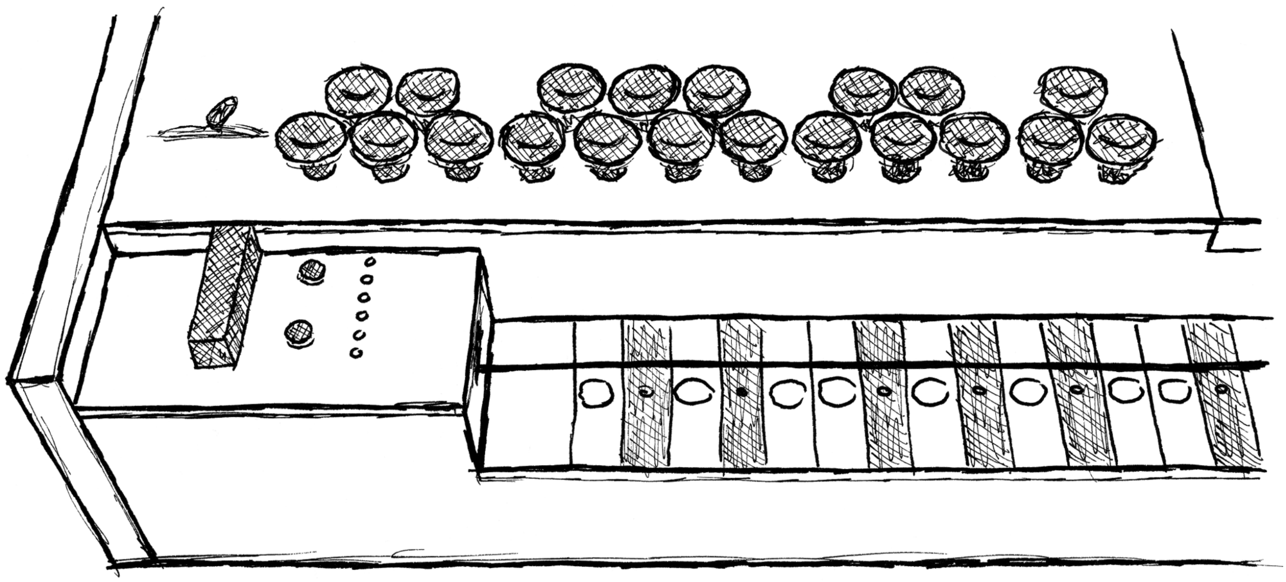


Figure 16. A sketch of the keyboard and the intensity key layout.

The keys are accordion buttons arranged in the same configuration as a keyboard. I also considered an accordion-style button layout that provides wider range from one hand position, but I chose the keyboard layout since it is more familiar to me.

The amplitude of a chord's notes can be controlled separately by the pressure of the keys. I presume that it is easier to control the dynamics if the physical response is tense enough. When I play the Ginette, my left index finger is pressing the intensity key while the other fingers act as a support against the panel. When playing multiple notes with the keyboard, a hand can not be supported in the same, therefore, I think that it could be more ergonomic to lean on the keys themselves. I designed the keyboard structure so that the spring tension of the keys is adjustable for finding a satisfying feel.

Like the first Ginette, the new one will produce an audio signal using analog circuits. Since VCOs are monophonic, several of them are needed for polyphony. There will need to be a compromise between the number of voices and the technical complexity of the instrument. I concluded that a four-voice polyphony would be an adequate solution. It is harmonically satisfying enough, yet not too complicated to build. The number of keys in the keyboard is another design question. When a chord voicing is formed with the keyboard and transposed with the ribbon, a large keyboard range is not necessary. Likewise, a similar compromise is required. I made the decision of the range to span 20 keys (i.e. an octave plus a perfect fifth).

The instrument has a main octave selector for changing the overall register, and there is also another octave selector dedicated for the keyboard. When the selector is in the middle position, the lowest key of the keyboard produces the same note as the intensity key. The register can be switched one octave up and down from there, affecting the keyboard only and omitting the intensity key. This feature is useful when playing chords and a melody simultaneously using certain modes (see Chapter 4, section 2.4).

4.2.1.1 Voice allocation

Having 20 keys and four oscillators requires a logic unit called the voice allocation (Reid, 2001). When pressing a key, a selected tone from oscillator 1 is heard. When pressing a second key, another tone from oscillator 2 is audible. If the first key is released, oscillator 1 goes silent while oscillator 2 remains active. It would not be appropriate that the tone played by the second key would switch quickly from oscillator 2 to oscillator 1, because the change would likely cause an audible click. At first, a single key would be first pressed while oscillator 1 is active, but now another single key is pressed and oscillator 2 is active instead. Hence, both the current situation and the previous matter in this logic. All 16 possible states and their directed connections are presented in a flowchart in Figure 17. In four-digit sequences, each digit represents the state of a corresponding oscillator. When a digit is '0' the oscillator is mute, and when it is '1' the oscillator is active. Thus the sequence '1010' indicates that oscillators 1 and 3 are active whereas the other two are silent. Red and green arrows represent the direction between the states when a key is pressed and released, respectively.

At first I planned to implement the voice allocation with integrated circuit logic chips and other electronic components, but I abandoned this purist idea quickly after realizing its complexity, deciding to implement it instead with a programmable microcontroller and analog multiplexers. In this construction, the audio signal remains analog throughout the signal path—an important design principle in this context—and only the route control signals are mainly digital. Because the voice allocation logic is programmable, it also allows alternative logic with both the existing architecture and with minor component additions. These other control logics (called modes) are described in detail in Chapter 4, section 2.4.

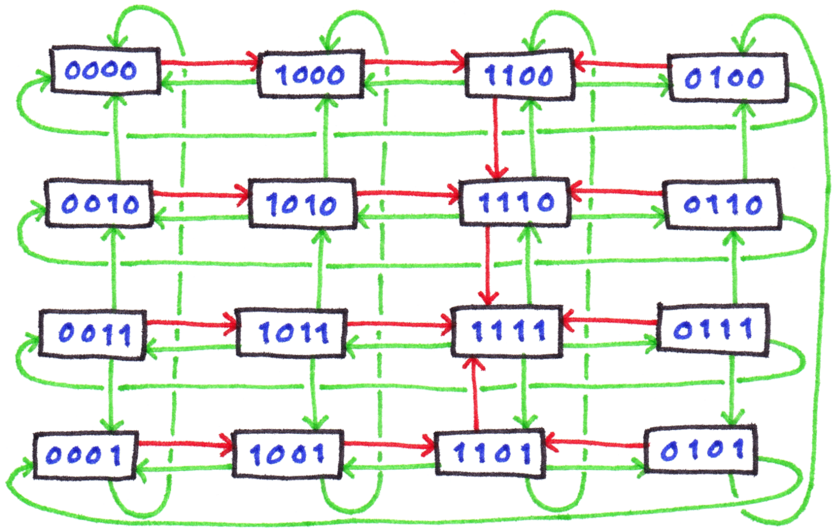


Figure 17. Voice allocation flowchart.

When a key is pressed, the voice allocation will feed a pitch CV signal to the VCO and a volume CV signal to the VCA (which controls the volume of the audio signal from the VCO). The pitch CV is based on the one-volt-per-octave standard. The standard tuning system for the keyboard is equal temperament[33], whereby octaves are divided into twelve equal steps (Vail, 2014, p. 44). Consequently, the pitch increases by a semitone when the pitch CV increases by 1/12 volts. The oscillators sum all the CV signals and define the pitches accordingly so the ribbon, the keyboard, the octave switch, the tuning wheel, and other devices will modulate these pitches. The volume CV defines the audio signal volume. The deeper a key is pressed, the higher the voltage and the louder the sound.

4.2.1.2 Response

An article *Intensity Key of the Ondes Martenot: An Early Mechanical Haptic Device* (Quartier et al., 2015) presents the research of the intensity key of the Ondes Martenot in terms of "the force with which the musician presses on the key, the depression of the key, and the resulting sound." The intensity key of the Ondes Martenot is introduced in Chapter 2, section 4.1. The measurements of the audio signal amplitude and force applied to the intensity key—both related to the displacement of the intensity key—show how

[33] Other tuning systems would be possible to accomplish by changing values in the resistor array, but it must be noted that the ribbon transposes the keyboard, and thus it is an unequally-divided tuning system.

these three variables are non-linearly interrelated in the context of the instrument under testing (see Figure 18). However, there are differences in individual instruments due to players' desired specifications, including the feel of the intensity key (Schampaert, 2018, p. 17). Some players prefer a direct response in the sound when pressing the key lightly, while others favor more control at low volumes (ibid.). My goal was not to achieve a faithful copy of the Ondes Martenot's intensity key, but rather to understand the behavior and reason behind the original design before making a suitable design for my own needs.

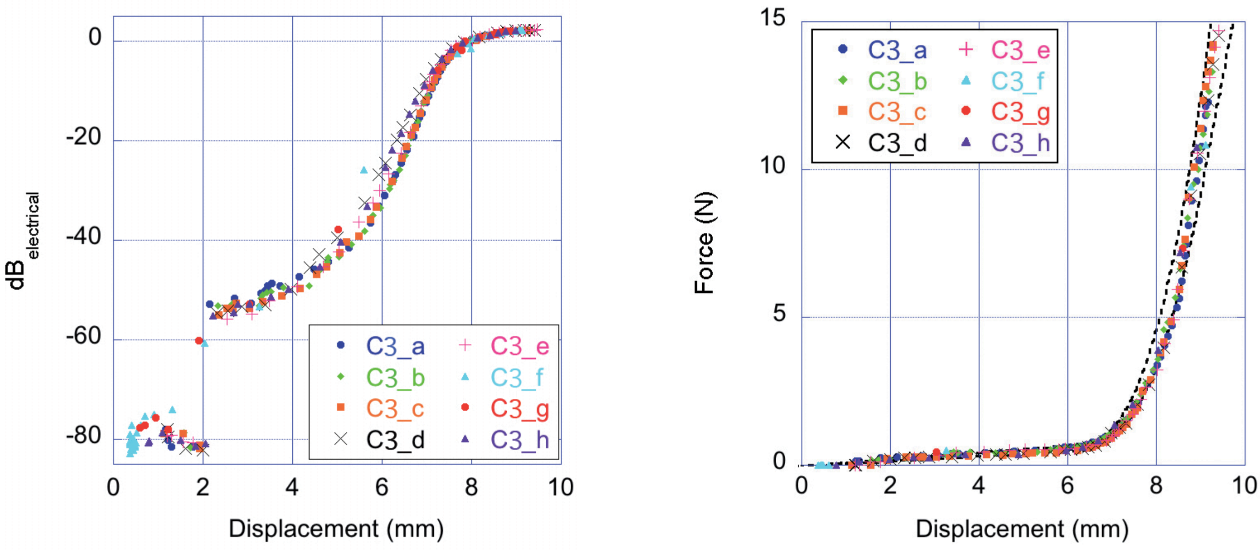


Figure 18. Measured variation of the audio signal amplitude according to the displacement of the Ondes Martenot's intensity key (left diagram) and its measured mechanical response (right diagram). (Quartier et al., 2015, used with permission)

Instead of using position sensors similar to the first Ginette or trying to implement powder-filled leather pouches (as in the Ondes Martenot), I plan to use a structure consisting of an LED, a photoresistor (a light-dependent resistor or an LDR), and a mechanical shutter between them. A moving shutter, fixed to a key, controls the amount of light from the LED to LDR and thereby modifies the resistance, further voltage, and resultant volume of a sound. An advantage in this structure compared to aforementioned ones is the lack of mechanical wear in the electrical components. This design solution will likely result in a more serviceable and less problematic outcome as the instrument ages. Another advantage in the shutter design is that a relationship between the displacement of a key and volume of a tone can be adjusted by the shape of a shutter (once the variation of a resistance of an LDR according to the amount of light is known).

Since the shutter itself will not cause any mechanical response, a relationship between the applied force and the displacement of a key can be implemented and fine-tuned separately. The measured mechanical response (Figure 18, right diagram) can be simplified with a rough approximation of two linear parts:

when displacing the key for the first 7 mm, the curve is roughly linear from 0 N to 0.5 N of force. For the last 3 mm of displacement, the curve can be seen as linear again from 0.5 N to 15 N. This could be implemented with two linear springs or elastic materials, from which the tenser takes effect when displacing the key for 7 mm.

As I mentioned in section 4.2.1, there could be more tension in the keyboard than in the intensity key: as in, the springs in the keyboard could be more tense while the other structure remains the same. This will be the starting point when prototyping, but as stated, I will allow my design to differ from the original if need be, since it is not my aim to copy the first version faithfully.

4.2.2 Low-frequency oscillators

A low-frequency oscillator (LFO) is the component in a synthesizer that produces an oscillation typically below the threshold of audible frequency, and it is used for modulating selected parameters such as the amplitude and frequency of an audio signal, among other things (Shepard, 2013, p. 122). Musical terms for amplitude modulation (AM) and frequency modulation (FM) are tremolo and vibrato, respectively. I decided to add an LFO for all four voices in my design, based on my presumption that controlling the pitch of the four voices only by the ribbon might result in the impression that all the voices are bound together and therefore perceived as a single sound. I assume that adding an individual vibrato to each voice would add a richness and orchestral quality to the sound. If thinking of a sustained chord played by a string orchestra, all the players produce slightly different vibrato. On the other hand, an LFO generates a clean, repetitive cycle that can be perceived as the sound of a machine rather than a player. With my main design principle in mind—creating an instrument that allows the conveyance of a player's distinct gestures rather than a mechanistic sound—I am aware of the possible contradiction in my choice to use LFOs. The finished instrument ultimately will prove how this feature is eventually perceived.

I decided to use LFOs for modulating amplitude and frequency. A pulse-width modulation (PWM) would also be easily implemented with the VCOs, but I discarded the idea because I felt that it does not belong in my design. From an engineering point of view, it would make sense to add a feature if it can be realized with existing components, but usability can suffer from an irrelevant feature or give an unwanted character to the instrument. On the control panel (see the sketch of LFO controls in Figure 19), I am using the titles 'tremolo' and 'vibrato' instead of 'amplitude modulation' and 'frequency modulation' ('AM' and 'FM') because I prefer the musical terms more than technical ones. I want the Ginette to signal that it is a musical instrument, not a machine; made for musicians, not engineers.

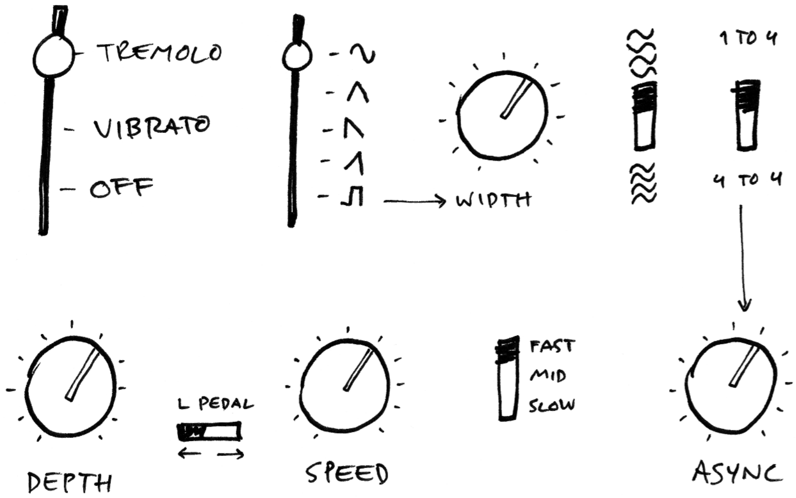


Figure 19. A sketch of the modulation controls in the control panel.

Five different waveforms from the LFOs can be selected: a sine wave, a triangle, both ascending and descending sawtooth, and a pulse wave with adjustable pulse width. The depth and speed of the modulation signal is adjustable, and each of them can be modified separately by the left foot pedal. When controlling the depth via the pedal, the depth level is adjusted by the knob when the pedal is fully depressed, and the depth is '0' (as in, there is no modulation) when the pedal is up. When controlling the speed, pedaling increases the speed level up to double from the adjusted value. The use of the pedal for controlling the LFOs adds the expressivity that will likely ameliorate the machine-like sound I mentioned previously. As an option for using individual LFOs for each voice, one common LFO is selectable in order for all tremolos or vibratos to be in sync. Two of the modulation signals can be inverted, so that when the volume or a pitch of two voices are ascending the other two are descending. For example, when playing four notes in tremolo mode with a sine wave: two notes crossfade with the other two, creating a soft, arpeggio-like texture. When using individual LFOs, they are at the same speed by default although the phase of the modulation is arbitrary. The relative speed of the LFOs is adjustable by an 'async' knob. When the async is set to minimum, all the LFOs will be at the same speed; at its maximum, the highest speed is double of the lowest, and the two middle ones will be distributed evenly in between.

4.2.3 Pedals

Whereas the first Ginette has no foot pedals, I have decided to include them in the new design. As with the Ondes Martenot, a pedal has the same function as the intensity key: the deeper the pedal is pressed, the louder the sound. It would free the left hand for adjusting the controls and controlling the keyboard of the Ginette with no interrupts in playing. The possibility to control both the keyboard and the pedal simultaneously allows several methods of playing the instrument. They are described in detail in the following section (4.2.4). In addition to this pedal, which is controlled by the right foot, I will include another pedal on the left for controlling the depth and the speed of the LFOs (described in the previous section), as well as the volume of the voices when using certain modes.

4.2.4 Modes

Since the operating logic of the keyboard is programmable with the microcontroller, it allows alternative functions that I find useful to implement. I call them modes. This can be seen as a feature creep, wherein new features over the basic function are added during the design process (Wysocki, 2009, pp. 14–15). Regardless, I find this a worthwhile feature since it requires little additional hardware and yields a lot of potential. If some of the modes are not useful or new ones will be needed, they can be revised for the future models or even reprogrammed in this model. I have come up with five different modes, named A, B, C, D and E.

In mode A, the instrument functions in four-voice polyphony with individual volume control. Mode B has individual speed or depth control for LFOs instead of the volume control; the volume is operated by the left pedal. Mode C and D are for playing melody lines and chords separately but simultaneously. In mode C, a chord can be played with the keyboard only, while a monophonic melody line is played with the ribbon and the right pedal. In mode D, a chord can be selected with the keyboard and is stored to the memory, its volume being controlled by the left pedal. The left hand is free for operating the intensity key between chord selections. Mode E has a monophonic function, allowing up to four voices in unison. The ribbon and the intensity key act in the same manner as with the first Ginette in all modes with the exception of mode B, while the use of the keyboard and the left pedal with different modes adds new possibilities. In this way, a familiar and fundamental playing technique is accessible without being impeded by the new features. The detailed operating principles of all modes is outlined below.

Mode A

This function was the starting point for my design. Up to four voices can be played on the keyboard. The volume of each voice is controlled individually by force applied to the keys. Note intervals correspond to the pressed keys, but the overall pitch is defined by the ribbon. The lowest key in the keyboard would produce a pitch corresponding to the ribbon (unless a different register is selected by the octave switch of the keyboard). Optionally, the intensity key or the right pedal can be used instead of the keyboard. They function in the same way as the lowest key on the keyboard. The logic allows also the simultaneous use of the keyboard and the right pedal (or the intensity key, although this is probably not a very ergonomic technique). The left pedal is for controlling either the speed or the depth of the LFOs; the parameter to be controlled can be selected with the slide switch on the control panel.

Mode B

In this mode, depressions of the keys define either the speed or the depth of the LFOs instead of the volumes of the voices (as in mode A). The left pedal is for controlling the overall volume of the selected voices: in other words, the volume is uniform for all voices..

Mode C

Monophonic melody lines and accompanying harmonies can be played simultaneously in this mode. One voice is controlled by both the ribbon and intensity key or right pedal; up to three other voices are controlled by the keyboard. Thus, the left hand plays a chord while controlling the volume of the individual voices in the chord with the keyboard. A melody line is played with the right hand on the ribbon and the right foot on the pedal, or with the intensity key instead of the pedal (if the left hand is free). The LFOs can be used only for the three-voice chords. The idea is to play melody lines with hand-gestured vibrato in the same manner as with the first Ginette. In addition, chords or other further voices can be played with the vibrato or tremolo produced by the LFOs. Similar to mode A, the speed or the depth of the LFOs is controlled by the left pedal.

Mode D

This is another mode for playing a single melody and accompanying harmony at the same time. The difference between this mode and mode C is the memory in the keyboard: when one to three notes are selected on the keyboard, they are stored in the memory. The left pedal controls the overall volume of these notes, which are not audible until the pedal is pressed. When the chord is made audible and a new chord is selected, it will be stored. Until the pedal is released, the new chord will be activated and can be heard after the pedal is pressed again. In other words, chord changes are made with the left pedal by decreasing and then increasing the volume. The left hand is required only to choose the next chord, otherwise it can operate the intensity key for playing a melody line. The LFOs can be used only for three-voice chords as with mode C.

Mode E

The instrument functions in a monophonic manner. It is played with the ribbon and intensity key or right pedal; the keyboard is used for transposing the pitch in a manner similar to the transposition buttons of the Ondes Martenot (see Chapter 2, section 4.4). When a key of the keyboard is pressed, the pitch is transposed up the interval between the lowest key and the pressed key. When the lowest key is pressed, no transposition will occur; when pressing the key a semitone higher, the pitch is transposed a semitone up. If multiple keys are pressed, these intervals will be summed. For instance, a key a major third and a key a fifth from the lowest key are pressed, the pitch will be transposed up by a major seventh. The maximum transposition is limited to an octave and a fifth (which is also the range of the keyboard). Up to four voices can be selected from the control panel (see a sketch of the mode controls in Figure 20). These voices can be selected to be configured either in perfect unison or in octaves. The voices can be also detuned: the level of detuning is adjustable between 'in tune' to 'a semitone apart from each other' (i.e. a chromatic tone cluster). The left pedal and the LFOs function similarly to mode A.

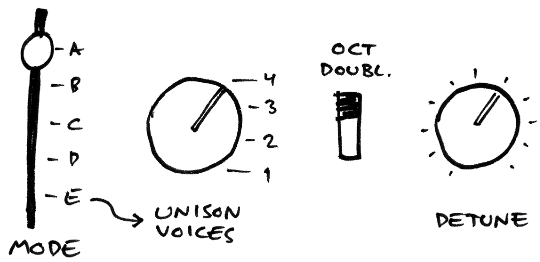


Figure 20. A sketch of the mode controls in the control panel.

In summary, CV signal routings from all the interface parts (the ribbon, the intensity key and the right pedal, the keyboard, and the left pedal) to the circuit components (VCOs, VCAs, and LFOs) in all modes are presented in Table 2.

Table 2. CV signal routings in all modes.

	The ribbon	The intensity key and the right pedal	The keyboard		The left pedal
			Pitch	Volume	
Mode A	VCO1–4	VCA1–4	VCO1–4	VCA1–4	LFO1–4 (speed/depth)
Mode B	VCO1–4	LFO1–4 (speed/depth)	VCO1–4	LFO1–4 (speed/depth)	VCA1–4
Mode C	VCO1	VCA1	VCO2–4	VCA2–4	LFO2–4 (speed/depth)
Mode D	VCO1	VCA1	VCO2–4	n/a	VCA2–4
Mode E	VCO1–4	VCA1–4	VCO1–4	n/a	LFO1–4 (speed/depth)

4.2.5 Timbre

The VCO used in the first Ginette outputs four different waveforms: a sine wave, a triangle, a sawtooth, and a square wave (see Chapter 3, section 1.3). For the new design, I added a fifth waveform: a rectified sine wave, similar to the *octaviant* in the Ondes Martenot (see Chapter 2, section 4.6). The rectification inverts the negative half of the sine wave, after which the DC offset is removed by filtering. As a result, the period of the signal is half of the original signal, and thus the frequency is doubled and the resulting pitch is one octave higher (in addition to a different quality in a timbre).

The new Ginette will consist of four identical VCOs whose waveforms are selected and adjusted with common controls. Throughout the years of playing the first Ginette, I have found the sine wave to be the most useful waveform, used either on its own or with a fuzz effects pedal. In my opinion, it has a natural character reminiscent of an acoustic instrument. The expressive interface, which has a fundamental impact on the sound, goes well with the sine wave because of their similar delicate nature. With the

Ondes Martenot, the *ondes* is said to be the most common timbre used (Schampaert, 2018, p. 140). Additionally, I perceive it as "the sound of the Ondes Martenot." I therefore decided to emphasize the role of the sine wave over the other waveforms in designing the timbral control. In the control panel, there are three knobs for adjusting the levels of the three sounds: the sine wave, a combined waveform, and a noise (see a sketch of the timbral controls in Figure 21). The second sound consists of the four remaining waveforms, which are selectable with individual on-off switches, resulting as a sum. The noise is produced in the noise generator and has three timbral options: white, pink, and red noise. The individually-summable waveforms and the noise are inspired by the Ondes Martenot, although the control logic and some of the timbres in my design differ from its precursor. The new design allows a much wider variety of timbres in comparison to the first Ginette. The sine wave can be combined with a slight amount of other tone to achieve a different, delicate, yet presumably still natural-sounding timbre.

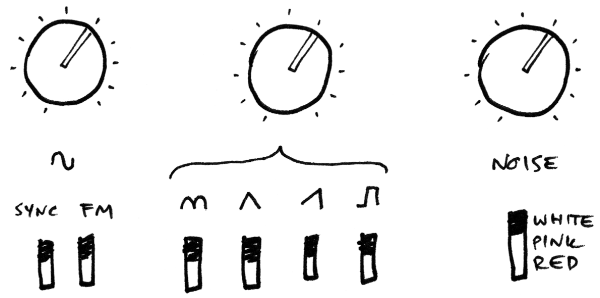


Figure 21. A sketch of the timbre controls in the control panel.

With the timbral controls, there are switches for an oscillator sync and an FM. The sync[34] forces the slave oscillators to restart when the master oscillator restarts (Shepard, 2013, p. 70). Hence, the period of the slave oscillators—and the resulting frequency—is determined by the master oscillator, while timbres of the slave oscillators depend on their initial frequency. The FM functions similarly to vibrato produced by LFO, with the difference being that the modulating frequency is within audible range, producing modified timbres (depending on both the modulating frequency and its amplitude). When using the sync, oscillator 1 acts as the master oscillator and the remaining three oscillators are the slave oscillators; when using the FM, oscillator 1 functions as the modulator oscillator and the remaining oscillators as carriers (ibid., pp. 70, 72). In modes C and D (see Chapter 4, section 2.4), the pitch and the volume of oscillator 1 is controlled with the ribbon and the intensity key, while other oscillators are controlled separately with the keyboard. These modes lend a particular amount of potential for expressive control to both the sync and the FM functions.

[34] Hard sync, in this case.

4.2.6 Fuzz

A long time ago when playing the Ginette, I experimented with connecting different guitar effects pedals to it. I had a self-built fuzz pedal that I found interesting. The fuzz produces a buzzing, stinging kind of distortion intended for an electric guitar. With the Ginette's sine wave at moderate signal level, the resulting sound was soft and pleasant: brass-like in lower registers and string-like in the higher. The amount of distortion depends on the input signal level, and since the Ginette has a wide dynamic range due to its intensity key, the timbre varies when playing: a quality reminiscent of acoustic instruments. It is well known that timbres in most acoustic instruments vary alongside amplitude for instance, the spectral envelope curves of a trumpet indicate that higher harmonics increase more than lower ones when its loudness is increased (Luce, 1975). In other words, the timbre of the trumpet is brighter at higher volumes despite the pitch remaining the same. Furthermore, it is claimed in the article *Influence of pitch, loudness, and timbre on the perception of instrument dynamics* (Fabiani and Friberg, 2011) that both the timbre and a loudness of a trumpet have a nearly equal role in the perception of dynamics, based on an analysis of listening experience. The timbre of the Ginette with no effects are the same at all loudness levels, whereas the fuzz adds another dimension to the dynamics, thereby enriching expressivity.

The fuzz pedal became a fundamental part of my usage of the Ginette, so I decided to integrate it in the new design. Each of the four voices must have its own fuzz circuit in order to achieve the same pleasant sound, otherwise the result is chaotically distorted. Fuzz pedals produce an intermodulation distortion that transforms multiple tones in dissonant intervals into unintelligible sound (Fumo, 2018). The intermodulation distortion is described as follows: when two sine tones (in frequencies f_1 and f_2) are input to a nonlinear system, intermodulation causes summation tones (in frequencies $m f_2 + n f_1$, where m and n are integers) and difference tones (in frequencies $m f_2 - n f_1$) (Hartmann, 2013, p. 183). I find this brutal-sounding effect also useful for some occasions. Instead of routing the voices through individual fuzz circuits, they can optionally be summed together first and then fed into a single fuzz. This is selectable in the control panel (see the sketch of the fuzz controls in Figure 22). The input signal level can be adjusted for desirable distortion, and an output signal level adjustment is for matching the loudness between dry and distorted signals. It is therefore convenient to just switch the fuzz on and off while playing with no further adjustments.

Figure 22. A sketch of the fuzz controls in the control panel.

The fuzz pedal I am using is based on the Dallas-Arbiter Fuzz Face topology with germanium transistors. Silicon transistors have replaced germanium ones in most areas of electronics, but vintage germanium transistors have remained popular in fuzz effects (Holmes, Holters and van Walstijn, 2017). The later Dallas-Arbiter Fuzz Face pedals are equipped with silicon transistors, resulting in a more harsh and aggressive clipping compared to the softer clipping characteristic of the earlier germanium transistor-based models (Bryant, 2007). I perceived the same difference when I tested a silicon transistor-based fuzz with the Ginette. I found the behavior of the fuzz with germanium transistors much more natural and pleasant. A disadvantage of the germanium transistors is their temperature instability: it can change the tone of a fuzz pedal or even prevent it from functioning (MI Audio Pty Ltd, n.d.). I have noticed some variation in tone, but there have not been any major problems. Adjusting the input signal level has always resulted in a satisfying tone. Nevertheless, using four fuzz effects and attempting to get them to produce a similar tone can be challenging; it is important to find a well-matched set of transistors and having them placed in the same thermal surroundings. It will be shown in practice if this is enough or further measures will be needed. On the other hand, a certain instability in tone may be charming when a player has to let go of total control and adapt to the sound and behavior of the instrument.

Many synthesizers are based on subtractive synthesis: which uses a filter to remove selected frequencies from a complex waveform that is rich in overtones (Shepard, 2013, p. 114). The method I am using here acts in the opposite way: there is a simple waveform, such as a sine wave, to which overtones are added by the fuzz. It is different from additive synthesis, however, which adds multiple sine waves together to create a complex waveform (Reid, 2000).

4.2.6.1 Behavior of the fuzz in terms of input volume

I recorded the first Ginette with the fuzz effects pedal to examine their behavior together. I split the audio signal with an ABY pedal, with one signal going straight to the left channel of an audio interface (i.e. clean) and the other signal going first through the fuzz effects pedal and then to the right channel. I made a test recording with the fuzz switched off to ensure that both channels resulted in an equal recording. A tuner was used to get an accurate pitch for the recording, placed before the ABY pedal in the signal chain. The setup is presented in Figure 23. I used Audacity audio editor and recorder software for recording and analyzing the audio signal. The waveform from the Ginette is the sine wave in all recordings. See the appendix for listening to the audio recordings described below.

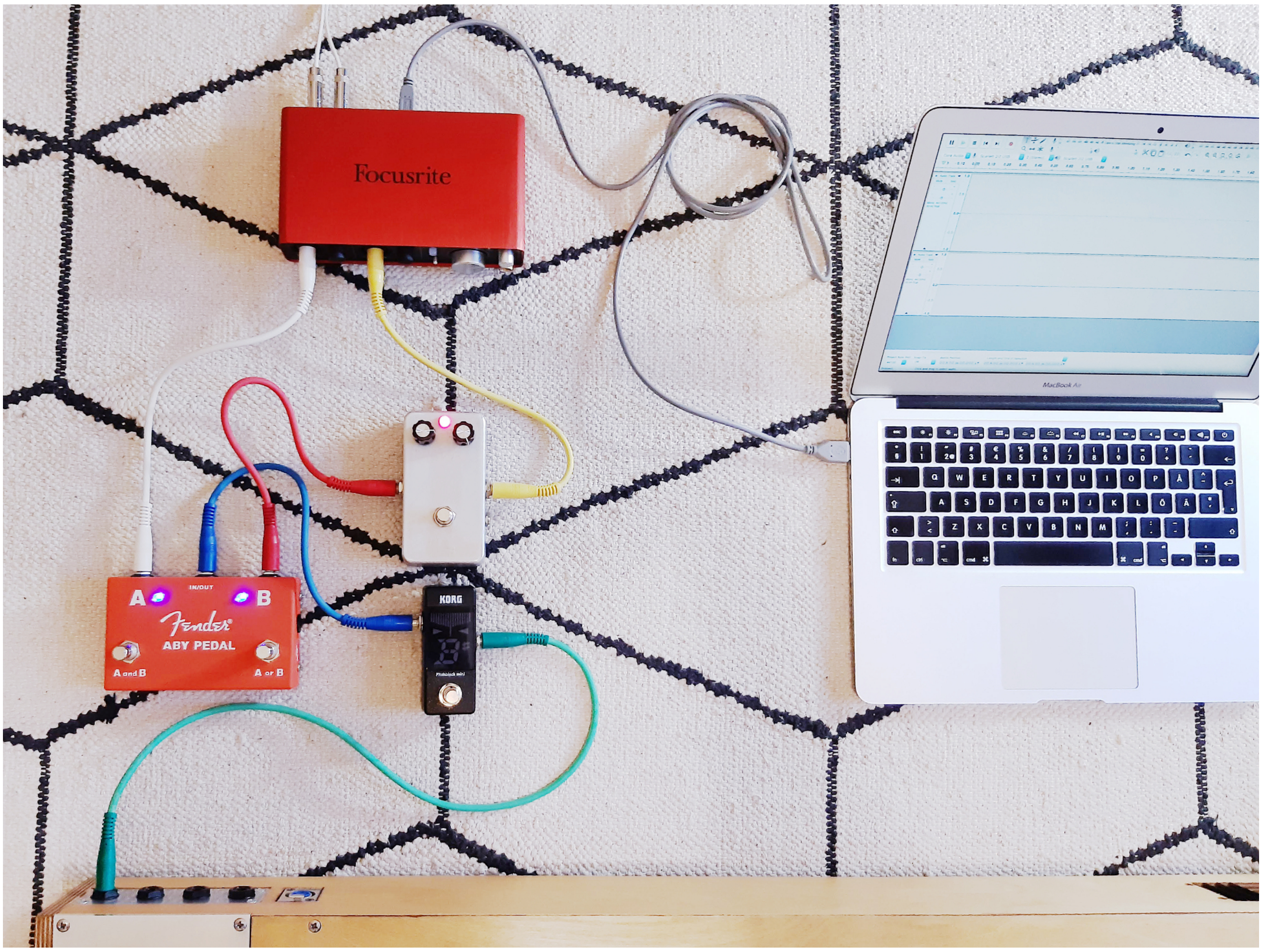


Figure 23. The setup for recording the Ginette with and without the fuzz effects pedal.

In Figure 24, a crescendo in A_2 (110 Hz) is presented in a spectrogram both as a dry signal (upper image) and a signal with the fuzz (lower image). The maximum amplitudes of both signals are normalized to an equal level. A linear frequency scale is used from 0 Hz to 8 kHz in the y-axis. The maximum volume of the signal fed to the fuzz is adjusted in order to obtain a desired pleasantness of timbre. The colors in the spectrogram represent gain: white is the highest gain, followed by red, magenta, blue, and grey. It can be seen that the ratio of the harmonic partials remains the same in the dry signal, while the higher overtones will be emphasized at a high volume when using the fuzz. The dry signal—a direct output from the Ginette—is not a pure sine wave, since it contains overtones (as can be seen in the spectrogram). As described in section 3.1.3, the VCO could produce a purer sine wave, but after the adjustment aided by an oscilloscope, I decided to adjust it again by ear to give it a timbre that sounded better to me.

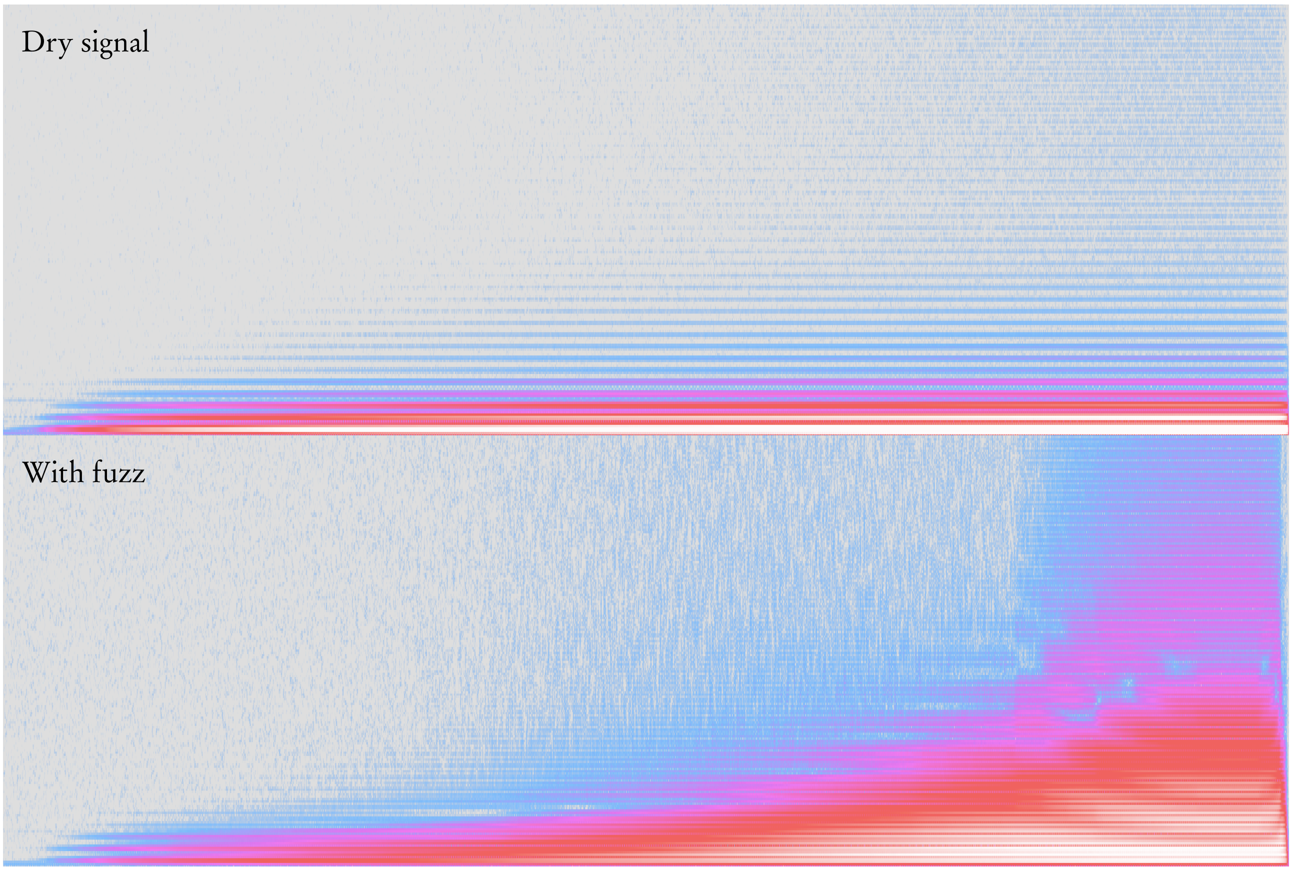
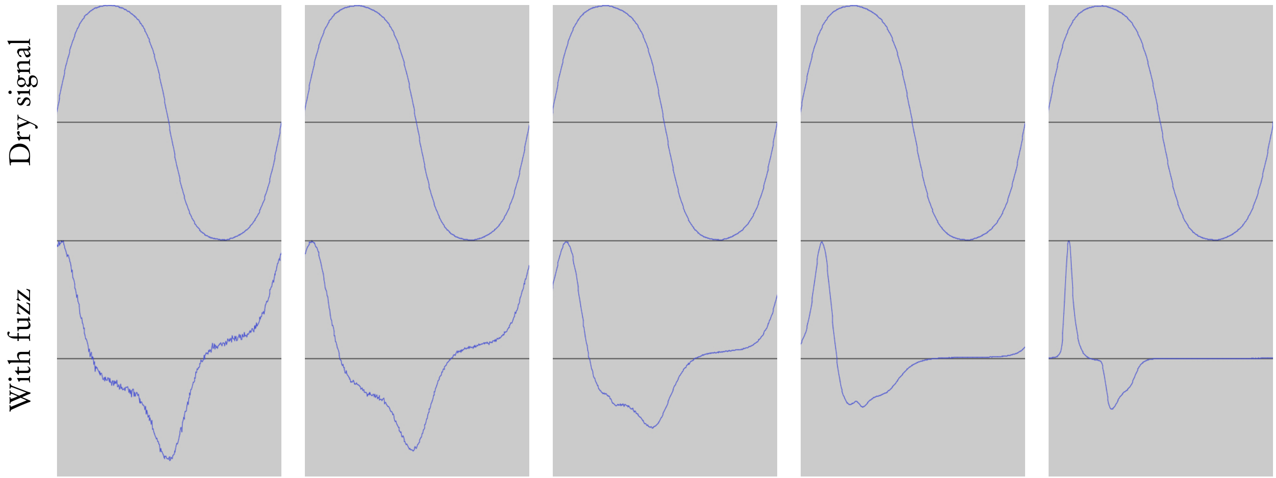


Figure 24. The spectrogram of a crescendo of a dry signal and a signal with the fuzz effects pedal in A_2 (110 Hz). Duration: approximately 12 s. Frequency scale: 0–8 kHz, linear. Window type: Hann; window size: 1 024.

Figure 25 presents peak-normalized waveforms of the dry signal and the same signal with the fuzz at different input signal levels. A relative decibel unit "dBr" is used for comparing the input signal levels together. Figure 25 (e) represents the waveforms from the loudest point of the audio signal presented in Figure 24; the other waveforms are from the same audio signal at lower signal input levels in 6 dB increments. It can be concluded that the waveform of the dry signal—and thus its timbre—remains constant in different signal levels, whereas the waveform of the signal with the fuzz transforms notably. The higher the input signal level, the sharper and the more asymmetric the waveform output from the fuzz will be. A background noise caused by the fuzz can be prominently seen in Figure 25 (a), where it is amplified the most due to normalization. In practice, however, I have not found the level of noise disturbing.



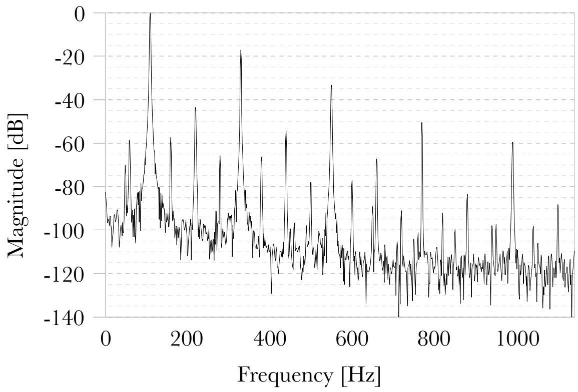
(a) -24 dBr (b) -18 dBr (c) -12 dBr (d) -6 dBr (e) 0 dBr

Figure 25. Peak-normalized waveforms in different input signal levels of a dry signal and the same signal with the fuzz effects pedal in A_2 (110 Hz).

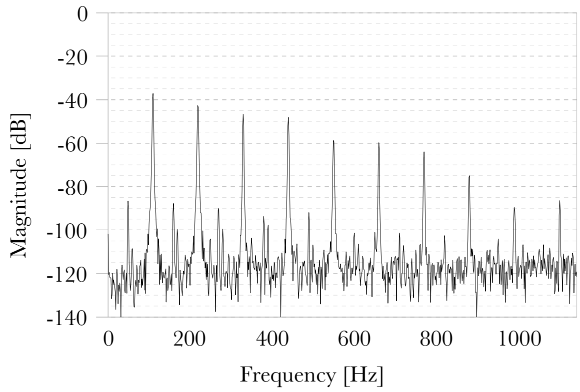
Spectra corresponding to certain points in the audio signal analyzed above are presented in Figure 26. In the spectrum of the dry signal presented in Figure 26 (a), the highest peak is the fundamental frequency (110 Hz, 0 dB), followed by odd harmonics in descending magnitudes, and even harmonics at a less prominent level (also descending).

On both sides of the fundamental frequency, peaks occur at approximately -60 dB and recur in the same manner with the harmonic partials. The peaks occur due to an intermodulation distortion with the audio signal and a ground noise of 50 Hz and are therefore 50 Hz lower and higher than the harmonics of the audio signal. Although these unwanted partials are at a relatively low level, the fuzz can emphasize them, as seen in Figure 26 (d). With this in mind, I will attempt to eliminate the effect of ground noise as much as possible by using better electromagnetic shielding and power supply design in the new Ginette.

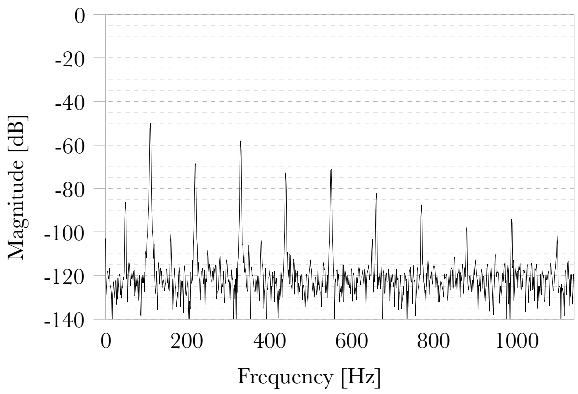
In the spectra of the signal with the fuzz—presented in Figure 26 (b), (c) and (d)—a transformation of magnitude ratios of the harmonics (and the resultant timbre) can be seen. With the input level of -24 dBr, the odd harmonics are mainly at a higher level than the even harmonics, although the difference is not as notable as with the input signal. The higher the input signal level, the more constant are magnitudes of the harmonics and the more the distinction between odd and even harmonics diminishes.



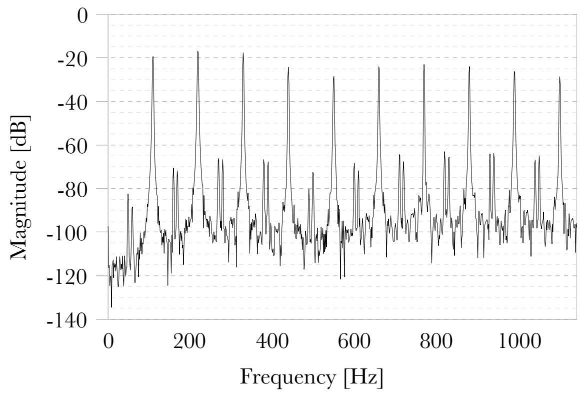
(a) A dry signal at 0 dBr.



(c) A signal with the fuzz with an input level at -12 dBr.



(b) A signal with the fuzz with an input level at -24 dBr.

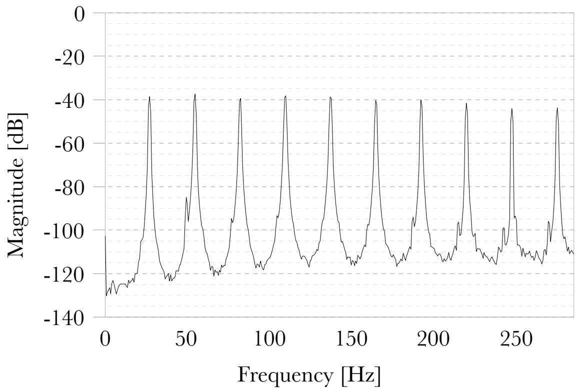


(d) A signal with the fuzz with an input level at 0 dBr.

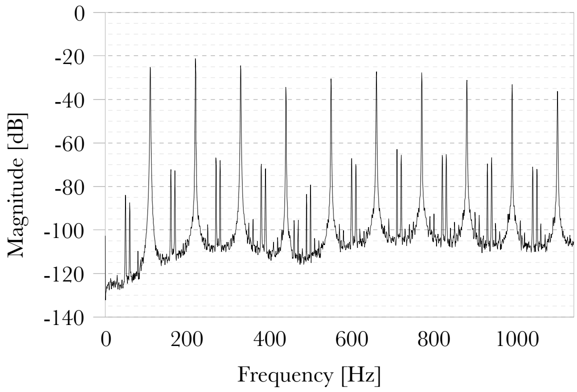
Figure 26. Spectra of a dry signal at 0 dBr, and a signal with the fuzz effects pedal in different input signal levels, in A_2 (110 Hz). Window type: Hann; window size: 32 768.

4.2.6.2 Behavior of the fuzz in terms of pitch

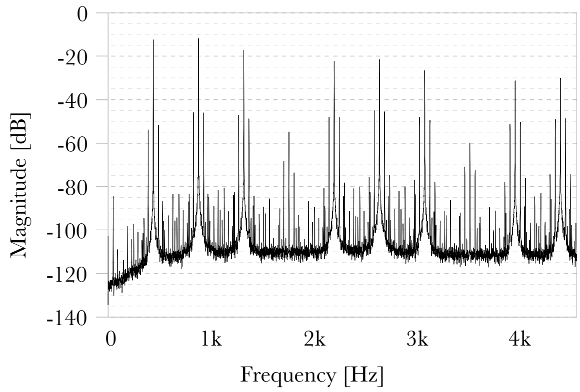
In addition to the level of the signal fed to the fuzz, the frequency of the signal can also affect the timbre. Figure 27 presents the spectra of signals in four frequencies (A_0, A_2, A_4 and A_6) all played at the same volume. The frequency scales are set to represent the first ten harmonics for comparison of the harmonics ratio. The constant signal level in the measurement procedure was realized by placing a weight on the intensity key to keep it pressed down. The input signal level varied within 0.15 dB at these frequencies due to a behavior of the VCO, and it was approximately 1.4 dB lower than the loudest point of the audio (0 dBr) presented in Figures 24–26.



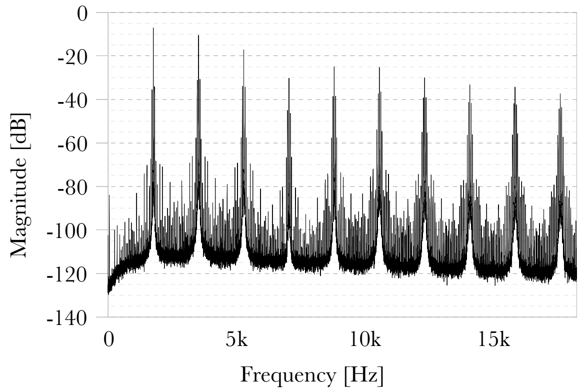
(a) A signal with the fuzz in A_0 (27.5 Hz).



(b) A signal with the fuzz in A_2 (110 Hz).



(c) A signal with the fuzz in A_4 (440 Hz).



(d) A signal with the fuzz in A_6 (1 760 Hz).

Figure 27. Spectra of the signals with the fuzz effects pedal in different frequencies. Window type: Hann; window size: 65 536.

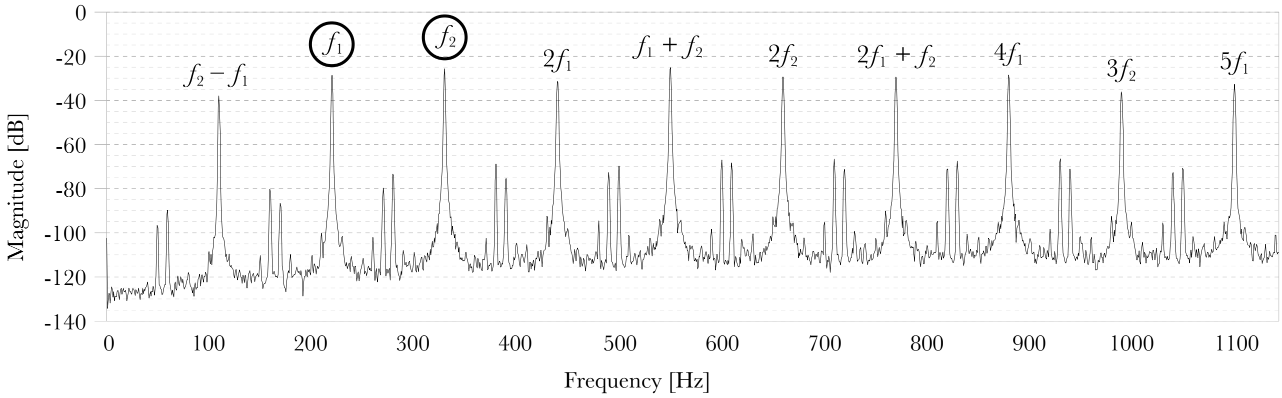
The spectra indicate a frequency-dependent timbral variance. In A_0 (27.5 Hz), all of the first ten harmonics are within 7 dB. It is worth noting that the signal level is lower here compared to the higher notes. In A_2 (110 Hz), more variance between levels of harmonics occurs. The second harmonic has the highest magnitude, whereas there is a clear notch at the fourth harmonic. Compared to the spectrum presented in Figure 26 (d) (where the input signal level is approximately 1.4 dB higher), a similar notch occurs, but at the fifth harmonic. This implies the correlation between the position of the notch and the input signal level. In A_4 (440 Hz), significant notches occur at the fourth and the eighth harmonics. In A_6 (1760 Hz), the spectrum has some similarities with A_2, although the first harmonics are now more prominent. The intermodulation distortion of the audio signal and ground noise is more notable at higher frequencies, as seen in the spectra.

4.2.6.3 Behavior of the fuzz in terms of two notes

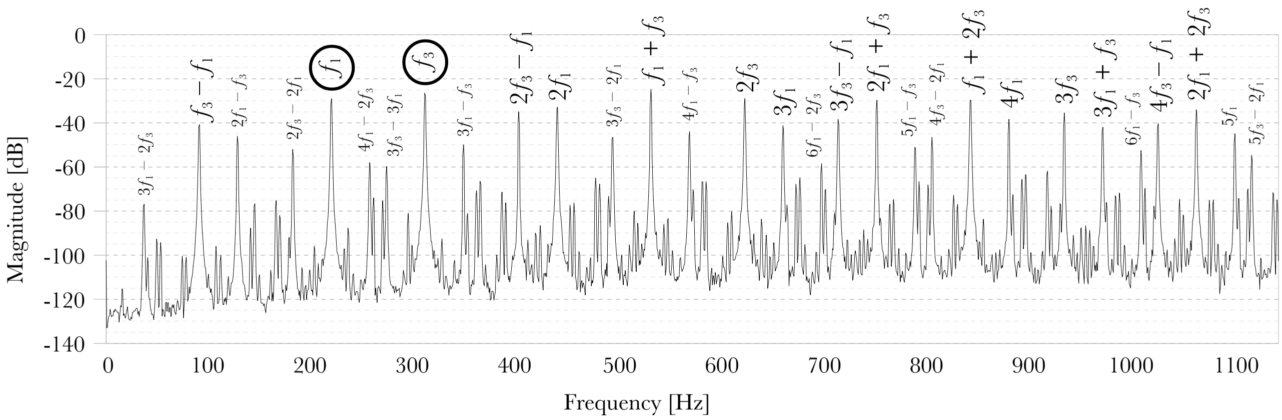
Lastly, I examined the behavior of two notes at certain intervals fed simultaneously to the fuzz. I changed the recording setup (Figure 23) so to include a looper pedal before the ABY pedal in the audio signal chain. With the looper I was able to create looping recordings using two notes. Both of the notes were played at the same volume by placing a weight on the intensity key and changing only the pitch. The overall volume was adjusted so that the resulting distortion was at a moderate level, determined by ear. Figure 28 shows the spectra of two notes: a perfect fifth (a) and a diminished fifth/tritone (b) input to the fuzz. More precisely, the perfect fifth is a just interval with a frequency ratio of 3:2, consisting of notes A_3 (220 Hz) and E_4 (330 Hz); the diminished fifth is in an equal temperament and has a ratio of $2^{6/12}$:1, consisting of the notes A_3 (220 Hz) and Eb_4 (~311 Hz). I chose these intervals to emphasize the consonant and dissonant effects of the fuzz. In the spectra, the peaks at fundamental frequencies of the played notes are named as f_1, f_2 and f_3, while other peaks are at sum and difference frequencies with various multiples (named accordingly) due to the intermodulation distortion described in section 4.2.6.

The spectrum of the perfect fifth (a) represents how these sums and differences are distributed evenly: a lowest notable peak is at $f_2 - f_1$, which is 110 Hz, an octave below f_1; $2f_1$ is an octave above f_1 at 440 Hz; and a sum $f_1 + f_2$ is 550 Hz, a ratio of 5:2 with f_1. The frequencies of the peaks suggest that they are harmonic partials of the lowest peak at 110 Hz. This is due to the interval ratio: both f_1 and f_2 are multiples of 110 Hz, so their sums and differences with any multiples are also multiples of 110 Hz. In other words, it can be concluded that the played notes, A_3 and E_4, are the second and third harmonic of A_2 (the resulting note). Furthermore, A_3 and $C\#_4$ at a frequency ratio of 5:4 are the fourth and the fifth harmonic of A_1, which is the audible outcome to the same extent based on my finding.

In the spectrum of the tritone (b), more peaks occur compared to the perfect fifth (a). The peaks (named accordingly) can be found, as well as numerous additional ones. Since the ratio of the fundamental frequencies does not consist of integers, the peaks are not distributed harmonically, which results in a dissonant and harsh sound. All of these sums and differences also occur within the spectrum of the perfect fifth. However, they overlap with each other: for instance, $2f_2 - f_1$ and $2f_1$ result in the same frequency of 440 Hz.



(a) A_3 (220 Hz) and E_4 (330 Hz)



(b) A_3 (220 Hz) and Eb_4 (~ 311 Hz)

Figure 28. Spectra of two notes in different intervals input to the fuzz effects pedal. Window type: Hann; window size: 65 536.

The tuning system used for the keyboard (see the mention of equal temperament in section 4.2.1.1) is a relevant question when playing simultaneous notes through a single fuzz circuit. A formation of sum and difference frequencies in the fuzz emphasize an interval impurity. For instance, the same frequency results in $2f_2 - f_1$ and $2f_1$, whereby the frequencies are a ratio of 3:2, as mentioned above. When using equal temperament ($f_1 = 220$ Hz, $f_2 \approx 329.6$ Hz), these frequencies differ slightly ($2f_2 - f_1 \approx 439.3$ Hz, $2f_1 = 440$ Hz), and this causes a beat frequency. A similar deviation appears throughout the frequency scale, resulting in dissonance.

In addition to its unwanted nature, this dissonance can be used for making brutal distorted sounds. Playing three or four notes would create more complex timbres, especially with individual vibrato. With a lower input volume, a more subtle distortion occurs, which can be controlled further by adjusting the volumes of separate notes with the keyboard.

4.2.6.4 Summary of the measurements

The purpose of the performed measurements was to examine and demonstrate the general behavior of the fuzz together with the Ginette. The measurements proved that the timbre does in fact vary due to the loudness level and pitch. When increasing the loudness level of the input signal, higher harmonics increase more than lower ones, resulting in a brighter sound. As discussed earlier in this chapter, many acoustic instruments such as the trumpet have a similar behavior. In the case of feeding multiple notes into the fuzz, the intermodulation distortion occurs and the harshness of the resultant sound depends on the interval of the notes. It is known that the tone of a fuzz with germanium transistors can vary due to temperature changes, thus this instability must be taken into account when interpreting the results. Exactly the same measurement situation may not be replicated, so instead of measuring absolute values, a causality between the measurements should be noted.

The measured audio signals are recorded using a MacBook Air with Focusrite Scarlett 2i2 audio interface and Audacity audio editor and recorder software (version 2.2.2). The recorded audio has a sampling rate of 44.1 kHz. The recording setup is presented in section 4.2.6.1, as well as in section 4.2.6.3 with the addition of a looper. I listened to the recordings carefully to ensure they sound the same as when played. Figures 24 and 25 present a recording in a spectrogram and waveforms; both are screenshots from Audacity. Figures 26–28 presents spectra whose numerical values are exported from Audacity and plotted with OpenOffice Calc spreadsheet software for better viewing and comparison.

The spectrogram and spectra use the fast Fourier transform (FFT) for displaying the frequency information, based on the Audacity manual (2020, "Spectrogram View", "Plot Spectrum"). I used the Hann window type since it was suitable for viewing the information I was interested in. The larger the window size the more accurate the frequency resolution, though it also requires more samples and consequently averages the result over a longer time span. In the spectrogram there was the need to compromise between the frequency resolution and the time resolution, so although the window size is rather small (1 024) it is still sufficient for demonstrating general behavior. With the spectra I was able to use larger window sizes. When analyzing the recordings presented in sections 4.2.6.2 and 4.2.6.3, I used the maximum window size value of 65 536 for the spectra to obtain the most accurate frequency resolution. The analyzed audio contained constant sounds with no variance in volume or timbre. For the recorded crescendo presented in section 4.2.6.1, the window size for the spectra was smaller (32 768) in order to keep the analyzed period of time short enough; since the volume was increasing in the recording and the analyzed samples therefore contain variance, the result is averaged from the whole sample. The length of analyzed samples is calculated by dividing the window size by the sample rate: in this case it was

32 768 / 44 100 Hz $\approx$ 0.74 s. The length of the whole recording was approximately 12 s, so the samples were relatively short with reasonable variance for mutual comparison.

5 CONCLUSIONS AND DISCUSSION

In this thesis, I attempted to answer the research question: how can a new version of the Ginette be designed, with polyphony and more timbral capabilities, while still preserving its expressivity? Since the Ginette owes much of its background to the Ondes Martenot, I examined and discussed the latter instrument in Chapter 2. I explained its significance and positions in the field of music throughout its lengthy history. I reviewed the technical features of both the Ondes Martenot and subsequent instruments and controllers based on it. The review laid out what has been done in this context, thus indicating an originality of certain features in my new design. In addition to the historical background, I presented the background of my own work—the first Ginette—in Chapter 3. It contains an introduction of the design and building process, as well as how I have used the instrument for making music. In Chapter 4, I described my visit to the studio of Thomas Bloch and my examination of his Ondes Martenot from the perspective of both a player and engineer. This visit happened while the design of the new Ginette was at an early stage, hence substantially impacting my design process. This description in Chapter 4 is followed by the in-depth presentation of the design of the new Ginette. Due to the detailed and broad scope of this project, the thesis has focused only on the design of the new version of Ginette while excluding the actual implementation. However, designing and building are parallel stages to some extent, so the need for a certain redesign may occur during the building process.

The main reason for making the new version of the Ginette is due to the limitations of the original. I began to imagine how I could expand its musical possibilities, and this led me to begin the design process. The new Ginette would primarily be an instrument for myself to meet my needs as a musician, but I am taking into consideration building them for sale. My aim was to develop the Ginette further without having to compromise in its expressivity, and applying this principle to its new features. The central new features consist of polyphony and wider capabilities in timbre. The polyphony can contain up to four voices. There is a keyboard consisting of 20 keys functioning similarly as the intensity key: the deeper a key is pressed, the louder the sound. This principle allows individual volume control for each voice. There are multiple logic options (called modes) for controlling polyphony, allowing different playing methods using the keyboard, the intensity key, the ribbon, and the pedals. When controlling the volume of a voice the timbre can also be varied concurrently. A circuitry based on a fuzz pedal distorts the signal in terms of an input volume, resulting in a tone that is brighter and more penetrating when played louder. The behavior brings a natural expressivity to the instrument's timbre, resembling that of an acoustic instrument. For instance, a trumpet played very softly in close proximity and loudly at a distance may produce equally discernible volume, but will contain a very different tone color and expression. Hence, the feature brings another dimension to expressivity. I claim that the features presented above result in a new expressivity that has not been heard in the context of the Ondes Martenot before.

When considering the undertaking of creating a new version of the Ginette, the most relevant and important questions are: does this design work pragmatically as an instrument? Do all the features justify themselves in practice? Will it be ergonomic to play? At the time of writing this thesis, when the new Ginette is not yet finished, I can only make predictions about how it would work. The only way to find solid answers is to put it into practice. Although the new features are designed to meet my needs as a player, they can be used in a multitude of combinations. In addition to possible failures, serendipitous discoveries may also happen if the combinations result in useful playing techniques or sounds that I would not have foreseen during the design process.

I have been asked to explain what the Ginette is on several occasions, and I have found this question rather difficult to answer. It is often assumed that it is a synthesizer, so I correct this by emphasizing that an electronic instrument is a better description, although this vague term is not very good either. Synthesizers can be associated with sound synthesis, which are different methods for controlled sound shaping, often with automated processes. The main focus of the Ginette lies in its expressive playing technique, which is in essence the opposite of automation. I always find the relation to the Ondes Martenot important to mention. Having the ribbon and the intensity key—even if the moving keyboard is omitted—describes and classifies the Ginette well. I often notice that the Ondes Martenot is not well known, and when I am describing it, the first association is usually the Theremin. This can frame it historically, but I think the key difference between them is the touch. The Theremin is played with no touch, whereas the Ondes Martenot is all about touch, utilizing human gestures with precision. With the Ginette, I attempt to preserve this principle while developing it further.

Once when I was talking about the new Ginette and its new interface that I am developing, I was asked if it will be easy to play, if that was the point for further development. I replied that it is about expressivity, and that it is simply different to play. An ever-growing selection of synthesizers and music softwares are more accessible and affordable than before, and fine motor skills are not necessary for making impressive music. Making music is getting easier and thus more democratic, which can be seen as a positive thing. However, I do not necessarily think that every new instrument should be easy to play: difficulty for its own sake is certainly not purposeful, but instruments utilizing fine motor skills require a learning that takes time. I feel that a sound produced by the subtle gestures of the hands or the mouth of a player can be very intimate. In addition to expressive control, a player may also convey an unintentional, personal touch. A machine can imitate a human and be more skilled, but it is always less human. Electricity and new technologies can be utilized for making automated instruments, but they can also be used for developing expressivity in instruments, and I believe that there is a lot of potential yet to be found.

Many synthesizers and software-based virtual instruments are played with a standard keyboard. Although they have a myriad of controllable sounds, the keyboard interaction remains the same. The integral part of the sound of the Ondes Martenot comes from its interface and the way it is played. In addition to being sensitive, it is also a unique system requiring a playing technique that differs from others. The interface is applicable to musical techniques that are difficult to achieve, if possible at all, with some other instruments. When making music for any instrument, its capabilities set the limits and thus affect the way the music can evolve.

Therefore, I find it important that the new Ginette is played with the original technique. Rather than its tone color, I am interested in how the sound can be controlled and how it behaves. Are there new musical territories to be found where no other instrument can enter? The next step in my project is to build the Ginette. After it is finished, we will hear.

REFERENCES

Analogue Systems. N.d. *The French Connection.* [online] Available at: < https://analoguesystems.co.uk/index.php/keyboards/the-french-connection > [Accessed September 30, 2020].

Audacity. 2020. *Audacity 2.4.2 Manual.* [online] Available at: < https://manual.audacityteam.org/ > [Accessed September 23, 2020].

Bienstock, R. 2015. The Legacy of Lucille: The Surprising Story Behind B.B. King's Guitar. *Rolling Stone,* [online] May 15. Available at: < https://www.rollingstone.com/music/music-news/the-legacy-of-lucille-the-surprising-story-behind-b-b-kings-guitar-63896/ > [Accessed August 5, 2020].

Bloch, T. 2004. The ondes Martenot. In: *Music for ondes Martenot.* [sleeve notes] Naxos. Available at: < https://www.chandos.net/chanimages/Booklets/NA5779.pdf > [Accessed September 9, 2020].

——. N.d. *The ondes Martenot in brief...* [online] Available at: < https://www.thomasbloch.net/en_ondes-martenot.html > [Accessed May 3, 2020].

The Bob Moog Foundation. 2013. *macProVideo Blog Series Part One: The Synthesis of Synthesis.* [online] Available at: < https://moogfoundation.org/macpro-video-blog-series-the-synthesis-of-synthesis/ > [Accessed October 24, 2020].

Bourns. N.d. *Basic Potentiometer Theory. Bourns University.* [online] Available at: < https://partnership.bourns.com/bu/bu_basic_pots.shtml > [Accessed October 21, 2020].

Bryant, P. 2007. *Arbiter Fuzz Face. Fuzz Central.* [online] Available at: < https://fuzzcentral.ssguitar.com/fuzzface.php > [Accessed August 5, 2020].

Crab, S. N.d. *The 'Ondes-Martenot' Maurice Martenot, France, 1928. 120 Years of Electronic Music.* [online] Available at: < https://120years.net/the-ondes-martenotmaurice-martenotfrance1928/ > [Accessed October 13, 2020].

Dierstein, J.-L. 2020. *Jean-Loup Dierstein & Les Ondes Martenot.* [online] Available at: < https://jeanloupdierstein.fr/ > [Accessed August 5, 2020].

Draper, C. 2020. *Ondes Martenot.* [online] Available at: < https://www.charliedraper.co.uk/ondes-martenot > [Accessed October 22, 2020].

Dubreq Ltd. N.d. *Stylophone history.* [online] Available at: < https://dubreq.com/history/ > [Accessed September 22, 2020].

Eowave. N.d. *Persephone Mark II. Analogue Duophonic Fingerboard Synthesizer. User's Manual.* [online] Available at: < http://www.eowave.com/downloads/persephone2manual.pdf > [Accessed September 30, 2020].

Expressive E. N.d.a. *The origin of Osmose.* [online] Available at: < https://www.expressivee.com/osmose-story-14 > [Accessed September 30, 2020].

——. N.d.b. *Touché.* [online] Available at: < https://www.expressivee.com/1-touche > [Accessed September 30, 2020].

Fabiani, M. and Friberg, A. 2011. Influence of pitch, loudness, and timbre on the perception of instrument dynamics. *The Journal of the Acoustical Society of America*, 130(4).

Fédération des Enseignements Artistiques Martenot. N.d. *Le Martenot de Concert.* [online] Available at: < https://federation-martenot.fr/Le-Martenot-de-concert/ > [Accessed October 18, 2020].

Fumo, D. 2018. What are the different types of distortion? | Basic Pro Audio Concepts. *Reverb*, [online] June 1. Available at: < https://reverb.com/news/what-are-the-different-types-of-distortion-basic-pro-audio-concepts > [Accessed August 5, 2020].

The Further. 2020. Augustin Viard, the hidden seed on Nick Cave's "Ghosteen" ! *The Further.* [online] May 6. Available at: < http://the-further.com/augustin-viard-the-hidden-seed-on-nick-caves-ghosteen > [Accessed September 11, 2020].

Greenwood, J. 2004. smear. Programme Notes. *Faber Music*, [online] Available at: < https://www.fabermusic.com/repertoire/smear-47 > [Accessed August 5, 2020].

Hartmann, W. M. 2013. *Principles of Musical Acoustics.* New York: Springer.

Hickling, A. 2007. Monkey: Journey to the West. *The Guardian*, [online] June 29. Available at: < https://www.theguardian.com/music/2007/jun/29/classicalmusicandopera.manchesterfestival2007 > [Accessed September 11, 2020].

Holmes, B., Holters, M. and van Walstijn, M. 2017. Comparison of Germanium Bipolar Junction Transistor Models for Real-Time Circuit Simulation. Conference paper. In: *Proceedings of the 20th International Conference on Digital Audio Effects (DAFx-17).* Edinburgh, United Kingdom, September 5–9, 2017.

Huebner, S. 2011. Input Devices. *Huebner Informationselektronik,* [blog] February 19. Available at: < http://huebnerie.de/2011/02/input-devices/ > [Accessed September 20, 2020].

Loriod, J. 1987. *Technique de l'onde electronique type Martenot, volume. I: Le clavier.* Paris: Alphonse Leduc.

Luce, D. A. 1975. Dynamic spectrum changes of orchestral instruments. *Journal of the Audio Engineering Society*, vol. 23, no. 7, pp. 565–568.

Madden, D. 2013. Advocating Sonic Restoration: Les Ondes Martenot in Practice. *Wi: Journal of Mobile Culture.* [online] Available at: < http://wi.mobilities.ca/media/wi_07_01_2013_madden.pdf > [Accessed October 9, 2020].

Martel, C. 2013. The Ondes Martenot is Making New Waves. *Musicworks*, [online]. Available at: < https://www.musicworks.ca/featured-article/featured-article/ondes-martenot-making-new-waves > [Accessed September 9, 2020].

McNamee, D. 2009a. Hey, what's that sound: Ondes martenot. *The Guardian*, [online] October 12. Available at: < https://www.theguardian.com/music/2009/oct/12/ondes-martenot > [Accessed August 5, 2020].

——. 2009b. Hey, what's that sound: The Persephone. *The Guardian*, [online] June 15. Available at: < https://www.theguardian.com/music/2009/jun/15/whats-that-sound-persephone > [Accessed September 30, 2020].

MI Audio Pty Ltd. N.d. *Neo Fuzz. Owner's Manual.* [online] Available at: < http://miaudio.com/wordpress/wp-content/uploads/2014/01/NeoFuzzManual.pdf > [Accessed August 5, 2020].

Millar, C. 2001. Jeanne Loriod: The leading player - and tireless champion - of a unique instrument. *The Guardian,* [online] September 6. Available at: < https://www.theguardian.com/news/2001/sep/06/guardianobituaries > [Accessed August 5, 2020].

Mulhern, T. 1986. On the Discipline of Craft & Art. An interview with Robert Fripp. *Guitar Player.* [online] Available at: < http://www.mulhern.com/articles/fripp_sb_1986gp.htm > [Accessed August 5, 2020].

Musical Instrument Museums Online. 2011. *Revision of the Hornbostel-Sachs Classification of Musical Instruments by the MIMO Consortium.* [online] Available at: < http://mimo-international.com/documents/Hornbostel%20Sachs.pdf > [Accessed October 19, 2020].

NAHAL Recordings. 2020. *Christine Ott. Chimères (pour Ondes Martenot).* [online] Available at: < http://www.nahalrecordings.net/nahal008/ > [Accessed September 14, 2020].

Nonesuch Records. 2007. *Nonesuch Journal Exclusive: An Interview with Jonny Greenwood*. [online] Available at: < https://www.nonesuch.com/journal/nonesuch-journal-exclusive-an-interview-with-jonny-greenwood > [Accessed September 9, 2020].

Ondomo by ASADEN. 2017. *Ondomo.* [online] Available at: < http://ondomo.net/ > [Accessed September 30, 2020].

Preston, S. 2018. Gotye Makes His Return with an Ondioline. Sorry, a What? *Broadsheet Media*, [online] January 12. Available at: < https://www.broadsheet.com.au/sydney/entertainment/article/gotye-makes-his-return-ondioline-what > [Accessed September 30, 2020].

Quartier, L., Meurisse, T., Colmars, J., Frelat, J. and Vaiedelich, S. 2015. Intensity Key of the Ondes Martenot: An Early Mechanical Haptic Device. *Acta Acustica united with Acustica*, vol. 101, pp. 421–428.

Reid, G. 2000. Synth Secrets: An Introduction To Additive Synthesis. *Sound On Sound*. [online] Available at: < https://www.soundonsound.com/techniques/introduction-additive-synthesis > [Accessed September 23, 2020].

——. 2001. Synth Secrets: From Polyphony To Digital Synths. *Sound On Sound*. [online] Available at: < https://www.soundonsound.com/techniques/polyphony-digital-synths > [Accessed September 16, 2020].

Schampaert, D. 2018. *The Ondes Martenot Network in the Twenty-First Century: The Co-Construction of the Ondes Martenot and its Users.* PhD. University of Leeds. Available at: < http://etheses.whiterose.ac.uk/24298/1/PhD%20Thesis%20by%20Dorien%20Schampaert.pdf > [Accessed September 9, 2020].

SEMANS, J. N.d. *A (very) brief history of the ondes Martenot.* [online] Available at: < https://www.joshsemans.com/about-the-ondes-martenot > [Accessed August 5, 2020].

SHEPARD, B. K. 2013. *Refining Sound: A Practical Guide to Synthesis and Synthesizers.* New York: Oxford University Press.

SWITLICKI, L. 2013. Album Review: Daft Punk - Random Access Memories. *EARMILK Media INC*, [online] May 21. Available at: < https://earmilk.com/album-reviews/145021/daft-punk/random-access-memories/ > [Accessed September 11, 2020].

TCHAMKERTEN, J. 2007. From Fête des belles eaux to Saint François d'Assise: the evolution of the writing for the Ondes Martenot in the music of Olivier Messiaen. In: C. Dingle and N. Simeone, eds. 2007. *Olivier Messiaen: Music, Art and Literature.* Aldershot: Ashgate Publishing Limited. Pp. 63–78.

THEREVOX CUSTOM MUSICAL INSTRUMENTS. N.d. *Therevox Custom Musical Instruments.* [online] Available at: < https://therevox.com/ > [Accessed August 5, 2020].

THEREVOX_HQ. 2020. *I can't show you the ET-5 yet, but I can show you some of the jigs that I am making.* [Instagram] June 22. Available at: < https://www.instagram.com/p/CBv-MB3h7GC/ > [Accessed August 5, 2020].

VAIL, M. 2014. *The Synthesizer: A Comprehensive Guide to Understanding, Programming, Playing, and Recording the Ultimate Electronic Music Instrument.* New York: Oxford University Press.

THE VINYL FACTORY. 2016. Scoring The Revenant – An interview with Ryuichi Sakamoto and Alva Noto. *The Vinyl Factory,* [online] February 23. Available at: < https://thevinylfactory.com/features/the-revenant-ryuichi-sakamoto-alva-noto-interview/ > [Accessed October 12, 2020].

WAVEMAKERS. 2012. [film]. Directed by Caroline Martel. Canada: Productions Artifact and the National Film Board of Canada.

WHITTALL, A. 2009. Messiaen Fête des belles eaux. Metallic mysteries from Montreal – rare music for multiple ondes martenots. *Gramophone.* [online] Available at: < https://www.gramophone.co.uk/review/messiaen-f%C3%AAte-des-belles-eaux > [Accessed September 9, 2020].

WYSOCKI, R. K. 2009. *Effective Project Management: Traditional, Agile, Extreme.* 5th ed. Indianapolis: Wiley Publishing, Inc.

APPENDIX

A video documentation demonstrating the first version of the Ginette and presenting audio recordings examined in section 4.2.6 can be found online at: https://petterimakiniemi.wordpress.com/thesis/