CONTACT MICROPHONE SYSTEM FOR SAXOPHONE

Gating and side-chaining for live electronic extensions

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Live Electronics - saxophone, MA

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TABLE OF CONTENT

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1 INTRODUCTION

1.1 Motivation

Using microphones with acoustic instruments for live electronic extensions on stage can be tricky to control. It is important to use the right kind of microphone for each acoustic instrument to capture the best possible sound of the instrument. The types of microphones that pickup and translate the highest quality of signals are often very sensitive. The microphones that are used in recording studios are really good in sound quality in quiet and controlled rooms but usually not so good for live performances because of their sensitivity. It is a compromise to find the best sounding microphone that is not too sensitive for live performance situations.

The biggest problems in live electronic performances, using microphones with traditional instruments, are unwanted audio feedback[1] and crosstalk[2]. These problems become more prominent the more there are sound sources, that is usually loudspeakers or other instruments, and movement with the microphones on the stage. To avoid these problems special gating[3] and side-chaining[4] systems have been developed since the 1980's. The system makes use of contact microphone with another microphone, and has been adapted for some instruments e.g. flute, voice, piano and strings, but as far as I know, not yet for saxophone. Using the system avoids feedback and crosstalk and enables more accurate envelope following and pitch tracking for live electronic use, when combined with a pitch detection devise[5].

Saxophone hasn't been used in the tradition of live electronic music as long as some other traditional instruments. For example repertoire for saxophone and live electronics is much less in quantity and much younger in age than for flute for example. This might be one of the reasons why the gating system is not yet standardized for saxophone. There are undoubtedly some saxophonists who have tried to solve this problem for themselves, but a research and standardization seem to be missing. While looking for a solution for myself, I was wondering why isn't there more information available about this subject. I found out that not so many traditional instrumentalists are using this type of gating and side-chaining with live electronic extensions, although the fundamental idea has been out there for quite some time already. My questions are: Is it possible to make this type of

1 Mechanistic circular causality. Explained in more detail in the following chapter.
2 Interference in the signal caused by other sound sources. Explained in more detail in the following chapter.
3 Opening and closing a channel.
4 A side-chain input controls gain from main input to output based on the level of the signal at the side-chain input.
5 An algorithm that estimates the pitch of the incoming signal.

gating system for saxophone? What is the best contact microphone to use with saxophone in this particular situation? Can I make the system applicable to my soprano, alto and tenor saxophones and easy to use in my own setup?

1.2 Feedback and crosstalk

Some instruments like electric guitars make use of built-in pickups that literally pick up signals from the guitar string vibrations alone. It is a perfect situation that traditional instrumentalists dream of because unwanted feedback and crosstalk are excluded with pickups. Sometimes contact microphones are used with traditional instruments, but since the sound quality of a pickup is often unacceptable, external microphones are needed. The microphones are attached to the acoustic instruments with clip-ons or placed next to them. Microphones pick up audio signals that are being amplified and played back from the loudspeakers. When an open microphone is on the stage with the PA-system[6], the sound from the loudspeakers might leak into it. If the microphone is picking up the sound coming from the loudspeakers again, the signal is being re-amplified. A loop is created and so the sound becomes louder and louder each loop time until the loudspeakers cannot handle it. It is a serious situation since before the loudspeakers break, the people in the room are most likely deafen. There are ways to stop unwanted feedback when it occurs and before it's too late, but the dream situation is never to come across with it. When the microphone is not built in the instrument it is harder to avoid feedback and crosstalk from other sound sources on stage.

Crosstalk is a situation where unwanted sounds leak into the microphone that is being used. For example in a a band situation drums are often loud and other instruments need amplification to create a good balance within the ensemble. Since the drums are loud, the microphone of the saxophone most likely picks up the drums too, especially on the moments when the saxophonist is not playing. Traditionally it doesn't really matter if that sort of crosstalk occurs. The clean sound of the saxophone can still be amplified through the microphone and the sound engineer will most likely find good levels in the mix to make the sound of the band balanced. The problem of crosstalk becomes prominent while using live electronic extensions. If the saxophonist is using effects (e.g. long reverb and delays) and the drum sounds leak into the saxophone microphone, the music will become unclear. Also analyzing the incoming signal by the pitch detection is challenged when there is unwanted noise in the signal.

6 Public address system, an electronic sound amplification and distribution system.

1.3 The principle of the gating and side-chaining system

The gating and side-chaining system includes two microphones on one instrument: a contact microphone and an external instrument microphone. The contact microphone is placed somewhere in the instrument to pick up signals, where other sounds do not reach the pickup, only the sound from that particular instrument. Contact microphones pick up signals of either solid object vibrations or air pressure fluctuations. The sound quality of contact microphones is often low but in this case that doesn't matter, since the signals from this particular microphone are only to be analyzed and not to be played through the PA-system. Analysis of the contact microphone signals is being side-chained to open or close a gate for the external instrument microphone by following the amplitude of the incoming signal. As illustrated in figure 1, both of the microphones are connected to the gating and side-chaining devise. If the signal of the contact microphone passes the set threshold, the gate opens for the instrument microphone and the signals go through audio processing[7] and amplification to the loudspeakers. In case the material from the contact microphone does not pass the threshold, the instrument microphone is simply not switched on and the possibility for feedback and crosstalk are closed out completely.

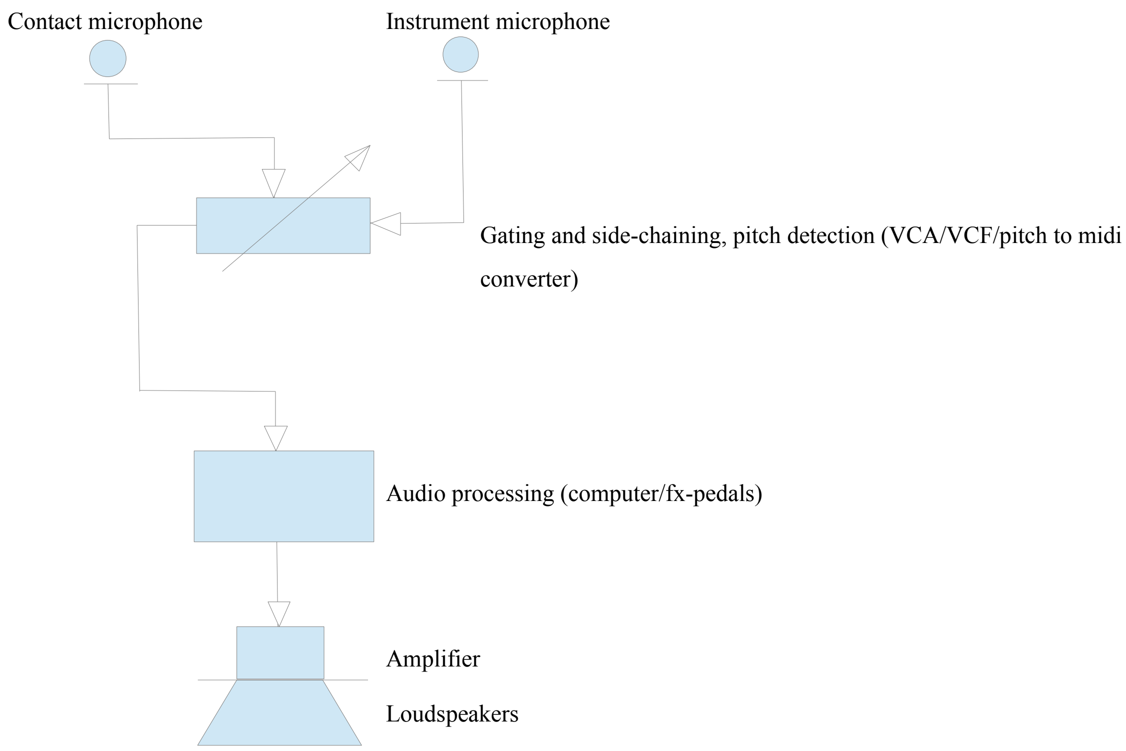

Figure 1

7 Intentional alteration of audio signals through audio effect or effects unit.

It is also possible to use the system with a contact microphone alone. In this case the sound of the contact microphone should be considered to be acceptable for the particular use. This situation could be when the the clean instrument sound is no more audible through heavy audio processing. In that case the signal of the contact microphone is also directed to the gating and side-chaining devise through the other channel instead of the instrument microphone.

1.4 The gadgets from 80's and todays digital solutions

Jos Zwaanenburg[8], developed this gating and side-chaining system with analog gadgets for himself and his colleagues in the Netherlands in the 1980's. Zwaanenburg got his inspiration from the electronic music works of Karlheinz Stockhausen[9] who worked in the NWDR Studio[10] in Cologne in the 1950's. In the studio Stockhausen was able to use voltage controlled amplifiers (VCA)[11] and voltage controlled filters (VCF)[12] to create electronic music. Those days they were still very expensive devises and hard to reach for private users but in the 80's they were already much easier to get. Figure 2 shows a gadget that Zwaanenburg built together with composer Andries de Marez Oyens[13] in 1985. They combined the VCA and VCF together with a Roland CP-40 pitch to midi[14] converter[15] that is seen in it's original casing in figure 3. With this gadget Zwaanenburg could gate the flute mic with a contact microphone and control electronic effects real time with the dynamics of his own flute playing. Pitch to midi converter sending midi out from the gadget enabled him to play synths with his flute. Later on in the 90's Zwaanenburg translated this principle to digital form with Max/MSP[16]. The digital version follows the same principle of analyzing the data coming from the contact microphone but instead of heavy weight analog gadgets, only a laptop and an audio interface is needed. Both versions of the gating principle have been revolutionary inventions but not very widely spread.

8 The founder and professor of Live Electronics master program at Conservatorium van Amsterdam (CvA).
9 German composer (1928-2007) known for his groundbreaking work in electronic music, aleatory, serial composition and spatialization.
10 The studio for Electronic Music of the West German Radio (Studio für elektronische Musik des Westdeutchen Rundfunks).
11 An electronic amplifier that varies it's gain depending on a control voltage.
12 A filter that can be controlled by means of a control voltage.
13 Dutch composer and electronic instrument designer, founder of Yens&Yens electronic art and design company.
14 Musical Instrument Digital Interface. A digital connection and communication protocol.
15 A devise that can sense the pitch (frequency) of the incoming analog signal and translate it to midi note data.
16 A visual programming language for music and multimedia.

Figure 2

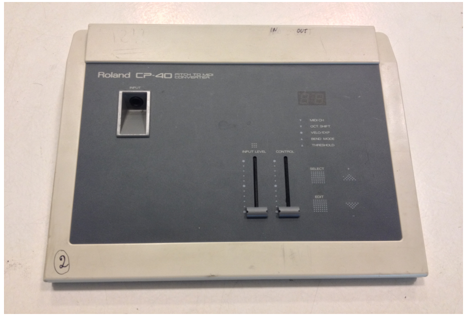

Figure 3

It is possible that other musicians have been busy with solving the same problem for themselves, but not much information is out there nor published about this subject. Live electronic musicians using their traditional instruments have been in such a marginal in general that big companies are not interested to invest in products that would obviously not sell massively. That is why information of the creations already made is hard to find and we have to create and build our own systems for our own private use.

1.5 Goals and purpose

In this work will discuss the practical aspects of existing contact microphone possibilities for saxophone. I will illustrate the problems and possibilities of different contact microphone options and present my own practical research of the possibilities to apply the gating and side chaining idea for the instruments of the saxophone quartet i.e. soprano, alto, tenor and baritone saxophones. I will explain the choices I made to build my own set up and how I can fluently use the contact microphone system in my own practice.

My biggest goal is to make a working gating and side-chaining system for my basic setup, that I can easily use with all my saxophones. The secondary goal is to find out how the system could be applicable for other saxophonists. This is important in case I want to use live electronic extensions with my saxophone quartet or even bigger saxophone ensembles. I also want to present my work to other artist who use electronic extensions with their saxophones and start a discussion about using this type of gating system amongst my colleagues.

2 METHODS

This research is based on a practical problem that needs a practical solution and that is why the methods used are mainly pragmatic. There is not much written information available of contact microphones especially in this sort of use, so this work is based rather on empirical than theoretical research. I am going to present a few pre-existing contact microphones for saxophones, list the limitations regarding my own use of the microphone and describe the wanted functionalities. Based on this information I will test the most suitable contact microphone options by making recordings that I can analyze and compare. The goal is to find a solution for my own setup and based on the test results, I need to order or build the microphones that are most suitable for my use.

2.1 Existing contact microphone possibilities for saxophone

Information about saxophonists using contact microphones is harder to find that I expected. There are some people that use contact microphones for amplification of the saxophone sound, but mostly people find the sound too thin and poor in quality. Some microphone developers use preamplifiers[17] and equalizers[18] with their contact microphones to balance the frequencies in search of better sound. This make-up of the sound quality is enough for some people and they are willing to compromise the sound to have a pick up instead of a good sounding open microphone. Thats why a small market for contact microphones exists, despite the sound quality.
There are two types of contact microphones: one works of fluctuations in air pressure created by the standing wave inside the instrument and the other types sense audio vibrations through contact with solid objects. Here I list a few contact microphones that can be used with saxophone.

2.1.1 Contact microphones based on air fluctuations

Dutch bass clarinetist, John Anderson, had a contact microphone made for him in 1985 by Willem Hienekamp. He used a Sennheiser KE 4-211-2 microphone element inside a metal casing that is placed in a fitting hole drilled on the top part of the bass clarinet mouthpiece. In figure 4 the Hienekamp contact microphone is connected to an alto saxophone mouthpiece. The Hienekamp

17 Electronic amplifier that converts a weak electrical signal into an output signal.
18 A devise that can be used to adjust the balance between the frequencies within an electronic signal.

contact microphone picks up the signals from the airstream inside the instrument and connects to a preamplifier that has a 3,5mm jack output socket. I got a chance to see and test this contact microphone through my research advisor Jos Zwaanenburg, who worked with Anderson in the 80's. According to him it worked perfectly with Anderson's bass clarinet. Zwaanenburg helped me to make some inquiries and found a technician who can make a replica of this microphone for me. If this contact microphone works for my saxophones I can have a replica made by Robert Bosch Geluid for the price of €200,00 a piece.

Figure 4

On the other side of the world Steve Francis, an Australian IT expert and amateur clarinetist, is developing his own pickups for wind musicians as a hobby project. After making electric guitars for a hobby he started to make and sell PiezoBarrel pickups for woodwind instruments because he found out that most musicians cannot technically do that themselves. “It has been a long journey, but my goals remain the same:- To provide wind players with a high quality pickup at a low cost.”[19] The idea of this pickup is based on the same principle. The pickup is in one metal piece that has a piezo component inside and can be connected to amplification through a 3,5mm jack output socket. The pickup is screwed to the mouthpiece that has matching bolt glued in the drilled hole. Similarly to Hienekamps version, the hole is drilled on the top part of the saxophone mouthpiece. The PiezoBarrel Sol in figure 5 is sold by the maker[20] and costs AUD199 (about €138). An already drilled and prepared plastic mouthpiece is sold separately for alto (AUD20 is about €14) and tenor (AUD25 is about €17) saxophones.

19 Stephen Francis, About PiezzoBarrel, http://www.piezobarrel.com/about.htm (accessed January 7, 2017)
20 PiezzoBarrel Prices, http://www.piezobarrel.com/pricelist.htm (accessed January 7, 2017)

Figure 5

A German company Rumberger Sound Products has developed a pickup for clarinets and saxophones, Rumberger K1X, that also uses piezo component transferring differences in air pressure to electric waves. This pickup is advised to place in a hole drilled to the neck of the saxophone, in figure 6, or to the barrel of the clarinet. For most saxophonists the neck part of the saxophone is too valuable to destroy by drilling a hole into it though. A colleague of mine, Josep Garces, who is an engineer, removed the highest f# key of his tenor saxophone and 3D-printed a fitting plug, that is seen in figure 8, for the Rumberger K1X pickup. He also made a fitting cork to block the hole when he is not using the pick up. He has been very satisfied with his creation, since he does not need that key in his playing technique. Rumberger is sold for example by Thomann.de[21] for the price of €349.

Figure 6

Figure 7

Figure 8

21 Musiekhaus Thomann internet shop, https://www.thomann.de/nl/rumberger_k1x_pickup_clarinet.htm?ref=search_prv_6 (accessed January 7, 2017)

2.1.2 Contact microphones based on solid object vibrations

Barcus Berry is an American company that has created contact microphone systems for various instruments over four decades. They have an electret contact microphone that can be used with saxophone clarinet and harmonica. The microphone is in a casing that is to be attached on the bell of the saxophone (figure 9) and it has a 3,5mm jack output socket. The Barcus Berry 5600 comes with an external preamplifier and an equalizer. It is hard to get since there are not many international dealers selling this microphone. In Europe there is for example one dealer in Switzerland[22] that offers the product for a price of CHF495 which is about €462.

Figure 9

A German company Shadow Electronics offers Shadow SH 4001 transducer, in figure 10, for saxophonists and clarinetist. It is a pickup that is made of a piezo component wired to a 6,3mm jack plug with a nice rubber covering. Shadow SH 4001 is to be attached to the reed on the mouthpiece and can be connected to the PA as it is. This pickup is available in many shops, and for example in Thomann.de it costs €39.


Figure 10

22 Legato Music Center, http://www.legatomusiccenter.com/store/barcus-berry-wind-instruments-electret-mic#sthash.VizOhJLT.dpbs (accessed January 7, 2017)

Christian Liljedahl is an artist from Copenhagen creating installations and doing performance art. He has created a balanced piezo microphone that is made from two piezo plates attached to each other (figure11). I heard about this microphone from my colleague Gianluca Elia, who came across with Liljedahl during his studies in Copenhagen. Elia started using the balanced piezo on his tenor saxophone. He attached it to the reed. He combines the microphone with another microphone and creates sonic art with controlled feedback by pointing the microphones to the speakers. Liljedahl gives instructions how to make this microphone, including a connection diagram in figure 12, on his website[23]. It is cheap too, since piezo elements cost €0,60 a piece at Radio Rotor[24] and cable and plug only a few euros, depending on the length of the cable and the type of plug.

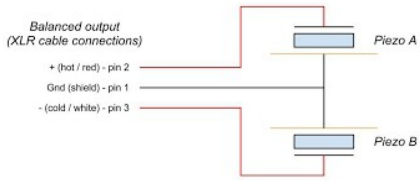

Figure 11

Figure 12

2.2 The limitations and wanted functionality

A contact microphone system that flute players often use is based on the air fluctuations strategy. Barcus Berry has an electret microphone model on market that is to be attached to the cork, inside the flute head joint. It works perfectly since it does not effect the playing and it is isolated from other sounds outside the flute. This strategy does not work instantly with the saxophone, since there is not such a spot to attach the microphone that is in contact with the airstream and does not affect the playing. That is why a hole needs to be created to make the microphone in contact with the air stream, if I want to use this type of contact microphone. The hole needs to be somewhere between the tip of the mouthpiece and the top key holes (excluding the second octave key in the neck) to have a strong air pressure and to cover the whole range of the saxophone. Since I use my

23 Christian Liljedahl, Noice free, balanced piezo microphone, http://christian.liljedahl.dk/guides/noise-free-piezo-microphone (accessed January 7, 2017)
24 Radio Rotor Amsterdam, http://www.rotor.eu/indexzoek.php (accessed January 7, 2017)

saxophones in electronic and acoustic situations I do not want to drill holes in the body or the neck of my saxophones. My saxophones are valuable instruments that I do not want to destroy.
One option could be to remove the top key (f#), like Garces does, and place the microphone there, but this is not an option for me since my playing technique is based on using all my keys. I want to create a system that is applicable for all the common sized saxophones. Removing the key wouldn't work on soprano saxophone since the highest keyhole (g) is too small for the microphone.
That leaves me the mouthpieces to drill. Professional saxophone mouthpieces are not cheap but they are replaceable. If I would drill holes in them, I could still have another set of mouthpieces for acoustic playing. The neck of the saxophone must be placed quite deep inside the mouthpiece for correct tuning. That leaves only a little room for choosing a spot for the microphone hole on the mouthpiece. The reed binder a.k.a. ligature also takes it's space on the mouthpiece, and leaves even less room for drilling. With these limitations it could be an option for this type of contact microphone.

The sound quality in timber or color of the signal is not important, since the contact microphone is not going to be used for amplification of the saxophone sound. In other words I do not need to get a good saxophone sound from the contact microphone. There are two parameters of sound that are more important while choosing a contact microphone for this particular gating purpose. I need a contact microphone that gives me the most accurate pitch information and amplitude response.

To be able to use pitch-tracking devises the signal needs to be reliable on pitch information. Some patches use score following techniques that analyze the pitch of the incoming signal and changes from a cue to another by using that information. For example Scherzinger's Shadowed for soprano saxophone and interactive Max patch[25] uses pitch detection and score-following[26] technique in such a clever way that 48 cues are being executed during the piece without pressing a pedal or changing presets manually. If the pitch information is not reliable the patch and the piece would not work.
The contact microphone has to be able to response well to the amplitude changes while I play. Amplitude analysis is extremely important for the gating of the good sounding microphone. There is a threshold that prevents unwanted noise to be amplified by not letting the signals of the amplified microphone through. When the signals go over the threshold the sound is being amplified. If the information of the amplitude is not accurate and reliable through the whole range of the saxophone, the system will not work.

25 Nicolas Scherzinger: Shadowed (2006) for solo soprano saxophone and interactive computer (MaxMSP), ScherziMusic, http://www.scherzimusic.com/works-shadowed.html (accessed November 18, 2016)
26 Process of automatically listening to a live music performance and tracking the position in the score.

The contact microphone needs to be easy to setup and reliable on use. It needs to stay in place throughout the performances without problems. It also needs to be affordable to buy or build. I might need four copies of it in case I need to use all four saxophones in the same concert or if I want to use them with my saxophone quartet.

2.3 Testing two types of contact microphones

I chose to test two contact microphones, one of each type. My first choice was to test the Hienekamp microphone because it had worked so well on the bass clarinet and because I had the opportunity to test it. Since the PiezoBarrel is based on the same idea, I thought to test the one that I had on hand. Otherwise I would have had to buy BiezoBarrel, or tickets to Australia, to be able to test it, so that was out of the options. The Rumberger K1X is not really an option for me, since I do not want to drill holes in my saxophone necks nor take out any keys from my saxophones. I couldn't think of other options for the placement of it than mouthpiece and in that case it would do the same job as the Hienekamp microphone.
My second choice was to test the piezo on the reed since the other solid object transducer, Barkus Berry 5600, is too expensive for my budget and too hard to get for testing purposes. The Shadow SH 4001 transducer is simply made of one piezo element, a mono cable and a jack plug so I thought that it is easy to make a similar microphone as a DIY-project[27] by myself. For testing I borrowed one of the self-made piezo pickups from my colleague Tatiana Rosa, who has used them as body percussion triggers.

2.3.1 The Hienekamp contact microphone

To be able to test the Hienekamp microphone with my saxophone I had to drill a hole in my saxophone mouthpiece to place the microphone in it. I chose to do the testing first with alto saxophone, since it is in the middle in range and size of the four most commonly used saxophones. Since soprano is much smaller and shaped straight as opposed to the other saxophones, I wanted to test it also with the soprano.
I drilled a hole into an old alto saxophone mouthpiece and to a cheap plastic soprano mouthpiece (figure 13) since I didn't want to destroy my good mouthpieces for testing. I drilled the hole on the

27 Do it yourself.

top part of the alto saxophone mouthpiece with the assistance of my advisor Zwaanenburg. With soprano mouthpiece the hole had to be drilled to the side of the mouthpiece since the ligature was taking too much space on the top part of this small mouthpiece. The drilling happened in two parts. First we drilled a small hole going through to the chamber of the mouthpiece to make contact with the airstream. Then we drilled the part where the contact microphone was placed, this had to be measured very carefully, since the hole had to be closed to be airtight with the contact microphone. The casing of the microphone should not go through to the chamber of the mouthpiece either, since in that case it would have a negative effect to the air column inside the saxophone, and through that to the sound and intonation. Close-ups of the the Hienekamp microphone placings are shown in figure 14 with alto mouthpiece and with soprano mouthpiece in figure 15.

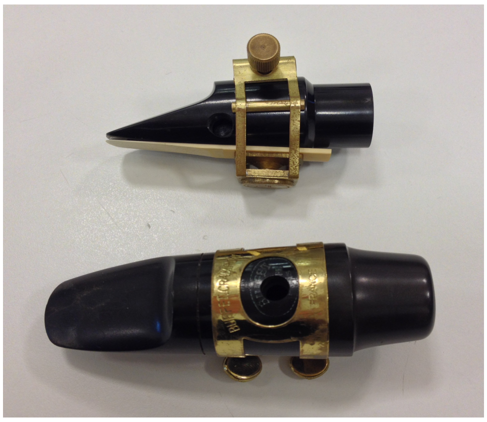

Figure 13

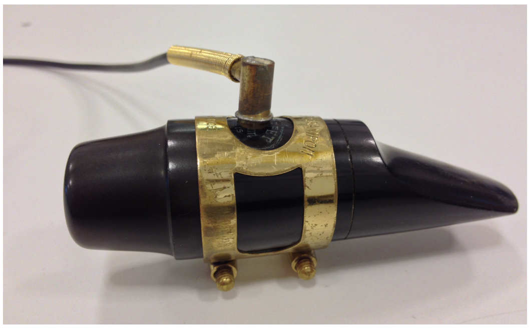

Figure 14

Figure 15

The quality of the mouthpieces themselves was obviously not the professional level that I am used to play with, but good enough for testing purposes. To find out if the drilled hole made a difference to playing the instrument itself, I had two similar soprano mouthpieces: one with the hole and the microphone placed in it and one untouched. Playing the soprano saxophone with these mouthpieces did not have a noticeable difference with each other feeling or sound wise, so in this part this system passed the test.

First tests seemed to give promising results. The contact microphone seemed to pick up signals nicely while I was playing. When I was making noise next to the microphone but not playing it, signals were not going through, which is a very important aspect. The gating and side chaining seemed to work too. In the altissimo register the signal seemed to get weaker, so more accurate testing had to be done.

2.3.2 The piezo pickup

With the piezo pickup not much preparations needed to be done. I just attached the piezo to the mouthpiece, with a couple of rubber bands to make it stable, the metal side of the piezo next to the middle part of the reed where the ligature ends. Figure 16 shows piezo attached to the alto mouthpiece and in figure 17 the piezo is attached to the soprano mouthpiece.

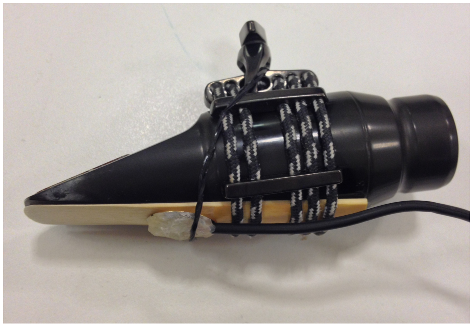

Figure 16

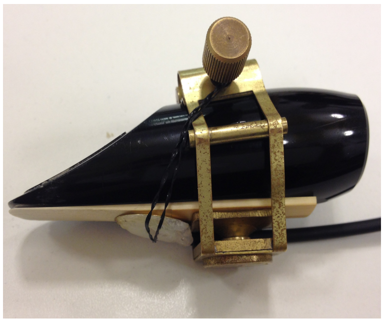

Figure 17

I was doubting if the soprano reed is too short for the piezo, but as shown in figure 18 there is still some room between my lip and the piezo, and no need to adjust my normal embouchure.

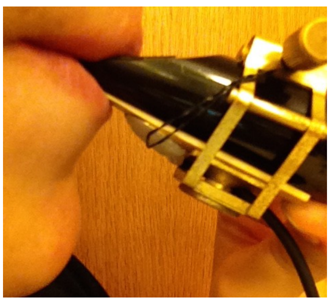

Figure 18

Signals were coming through very nicely in the whole range of alto and soprano saxophones with the piezo pickup. The disadvantage is that the key noise of the saxophone was quite prominent.

When I connected the microphone straight to the mixer, I could hear every touch on the saxophone though the loudspeakers, mostly in low frequencies. On the other hand this microphone is never going to be sent to the loudspeakers so I don't necessarily have to be worried about that. Loud noises and even screaming next to the piezo was not picked up in the test, only a little when the reed was really close to my mouth and started vibrating with the vibrations of my voice. The early stage of the piezo testing seemed promising: good enough isolation, signals throughout the whole range and it seemed to have nice response to amplitude changes. The disadvantage was the key noise.

2.4 Making recordings for accurate testing

To have material to analyze, I did the next round of testing by recording alto and soprano saxophones with both variations of the contact microphone.
First I used three microphones simultaneously for making recordings to compare: a DPA d:vote 4099 saxophone clip-on microphone on the bell of the saxophone, a Shure SM58 dynamic microphone in front of the saxophone and the Hienekamp contact microphone on the mouthpiece, as shown in the figure 19 with alto and in figure 20 with soprano.


Figure 19


Figure 20

I wanted to compare the signal levels of the three microphones so I adjusted the levels to match in an overall line-check. I recorded the whole range of alto saxophone, from low Bb going all the way to the second G of the altissimo register[28], which makes almost four octaves. I did the recording in the same medium loud dynamic (mf/f) to be able to compare the differences through the ranges. I repeated the test with soprano saxophone, from low Bb to the first altissimo A which is almost three octaves. In the next test I replaced the Hienekamp microphone with the piezo pickup and the drilled test mouthpieces with my own mouthpieces. I went through the same steps with this setup.

28 The uppermost range of the saxophone. Tones are based on harmonics and are produced by overblowing.

3 TEST RESULTS

3.1 Analysis of the recordings

3.1.1 Signal and amplitude response

The screen shots of the Ableton Live[29] sets of my test recordings, in figures 21-24 show the signal and amplitude response of the different microphones with alto and soprano saxophones quite clearly. Figure 21 shows the results of the Hienekamp contact microphone with alto saxophone and figure 22 shows the results of the same microphone with soprano saxophone. Figure 23 shows the results of the piezo pickup with alto saxophone and figure 24 the same microphone with soprano saxophone. Each of these screenshots show three tracks of samples, that have been recorded simultaneously. On top are the recordings with the DPA d:vote 4099, underneath it with the Shure SM58 and last the contact microphone in question. The recorded samples are each a long note, covering the whole normal range of the saxophone in question and adding a few altissimo notes to the end. The notes are all played in medium loud dynamic and samples organized chromatically from lowest note (Bb,)[30] to the altissimo register (up to G''') in left to right order. All samples of the same vertical line are recorded simultaneously with the three microphones.

The recording test with the Hienekamp contact microphone on alto saxophone shows what I already predicted. The signal in the normal register is very stable, much more so than the signal of the DPA and Shure microphones. The natural unevenness of register and resistance changes are not present in the Hienekamp samples as much as in the open microphone samples. The signal gets slightly weaker in the end of the normal range of the alto saxophone (f#'') and suddenly much weaker further in the altissimo register (a''). On the other hand the DPA and Shure microphones are picking up even louder amplitudes in this range, which makes sense because the nature of the top tones is more piercing. On the soprano recording with the same microphone the results are even more alarming. The signal gets weak already in the middle register (a) and soon disappears almost completely.

29 A software music sequencer and digital audio workstation.
30 Octave differences are marked from low to high: Bb, – Bb – Bb' – Bb'' – Bb''' .

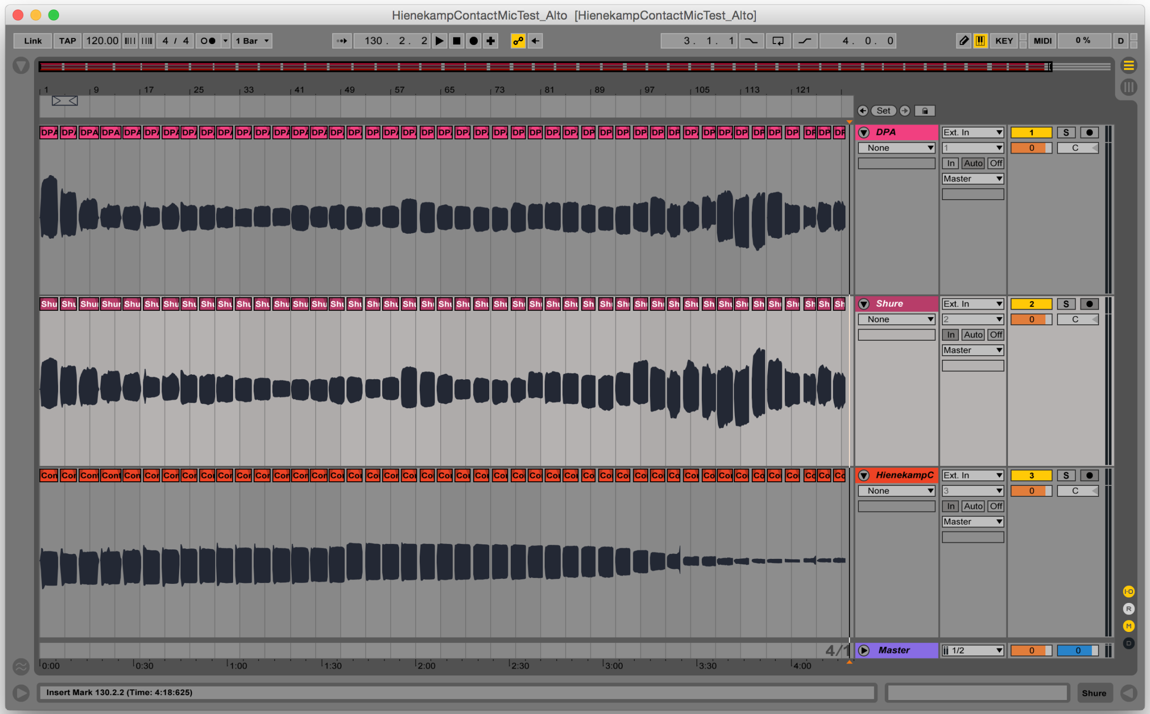

Figure 21

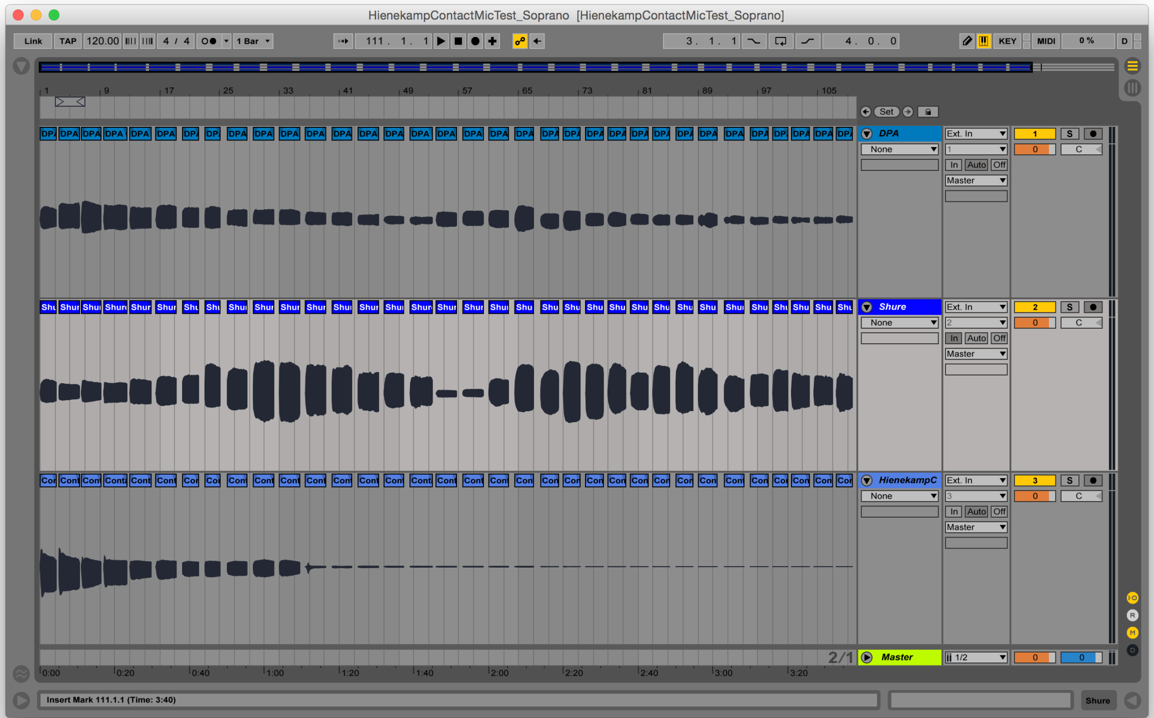

Figure 22

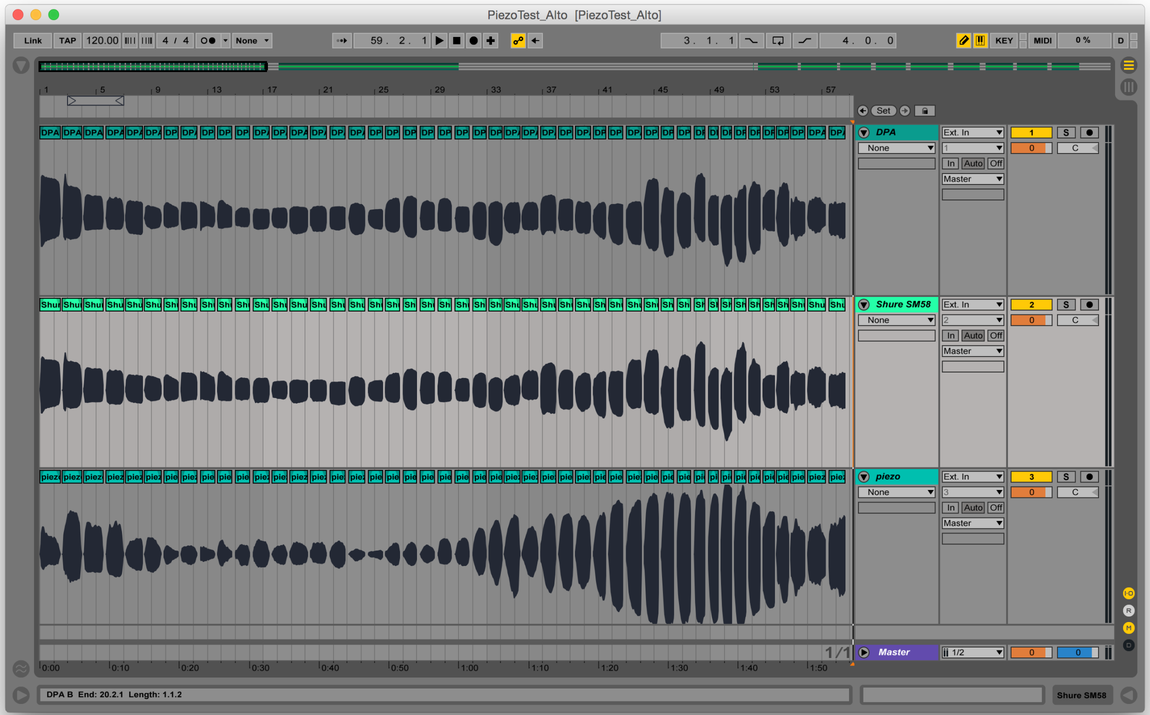

Figure 23

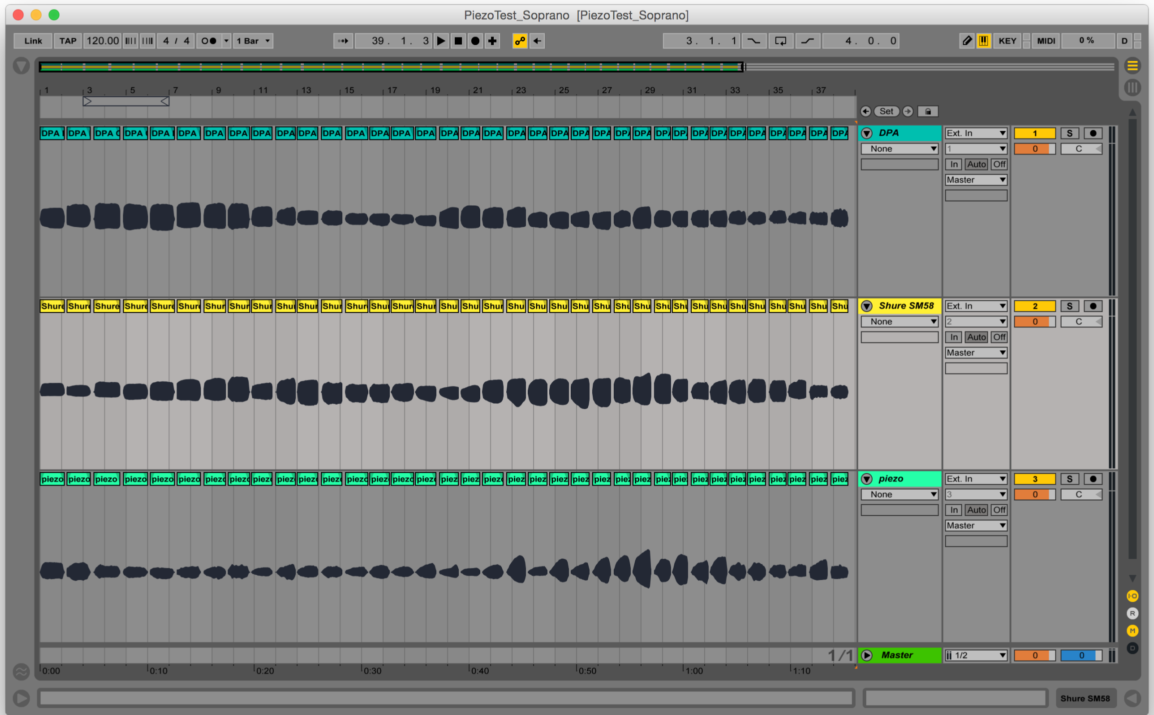

Figure 24

I discussed this phenomenon with my teachers Jos Zwaanenburg, Jorrit Tamminga and Arjan van Asselt, who all found it peculiar. My guess is that it must be a problem with the acoustics of the saxophone and how the sound waves move inside the tube. I tried to find answers by looking a bit deeper into saxophone acoustics, but could not find one. I would need to consult a physician, who has knowledge of saxophone and acoustics to get an answer to this question. In this research I am looking for a practical solution, so finding out why it is not working does not help me any further for now.

The tests with the piezo pickup figures 23 and 24, show more promising results. The signals are picked up throughout the whole range of both the soprano and the alto saxophones. The amplitude changes are more or less the same if compared to the open microphones. There are some differences that are caused by the placing of the microphone. The piezo picks up the vibrations of the reed, so the natural resistance changes of the different ranges of saxophone are shown more than on the samples of the open microphones. Also the way of playing affects the reed vibrations. Different choices of colors are partly produced on the reed and so detected much more obviously on piezo than with the other microphones.
One alarming thing that came up is that the piezo is also picking up more key noise of the saxophone. Every touch on the saxophone makes a noise that the piezo picks up, mostly in quite low frequencies. This fact is quite obvious because this contact microphone is picking up all solid vibrations on the saxophone. It might not be a big problem in the end though. The signal of the piezo is not going to be made audible through the sound system, so only the key noises that the other microphone picks up are played through the loudspeakers.

To have better proof that the piezo signal really follows the the amplitude of my playing, I made another recording similarly with the three microphones, but now playing with different dynamics and extended techniques. I also tested the isolation of the microphone with noise outside the saxophone. I used randomly different techniques, such as slap tongue, open slap, mouth ram, flutterzunge, growl, altissimo tones, vibrato, sub tones and multi-phonics to get an overview how the piezo reacts to those.
In figure 25 the first and second recorded samples show the response to extended techniques and the dynamic changes of my playing with sustained playing to short notes. The first sample is recorded with alto saxophone and second with soprano saxophone. The three microphones follow more or less the same amplitude changes and the extended techniques are shown in similar shapes. It is very useful and relieving to know that the response of the piezo is accurate and reliable with all the

extended techniques that I use so frequently.

The third sample shows the isolation of the piezo while I spoke and screamed next to the saxophone. If the saxophone and more accurately the reed starts to vibrate with the noise coming from outside, then there is going to be some leakage of that noise to the signal. The threshold of the gating is to be set high enough to avoid most of the noise. That will probably fix the problem and stop the noise from activating the other microphone.

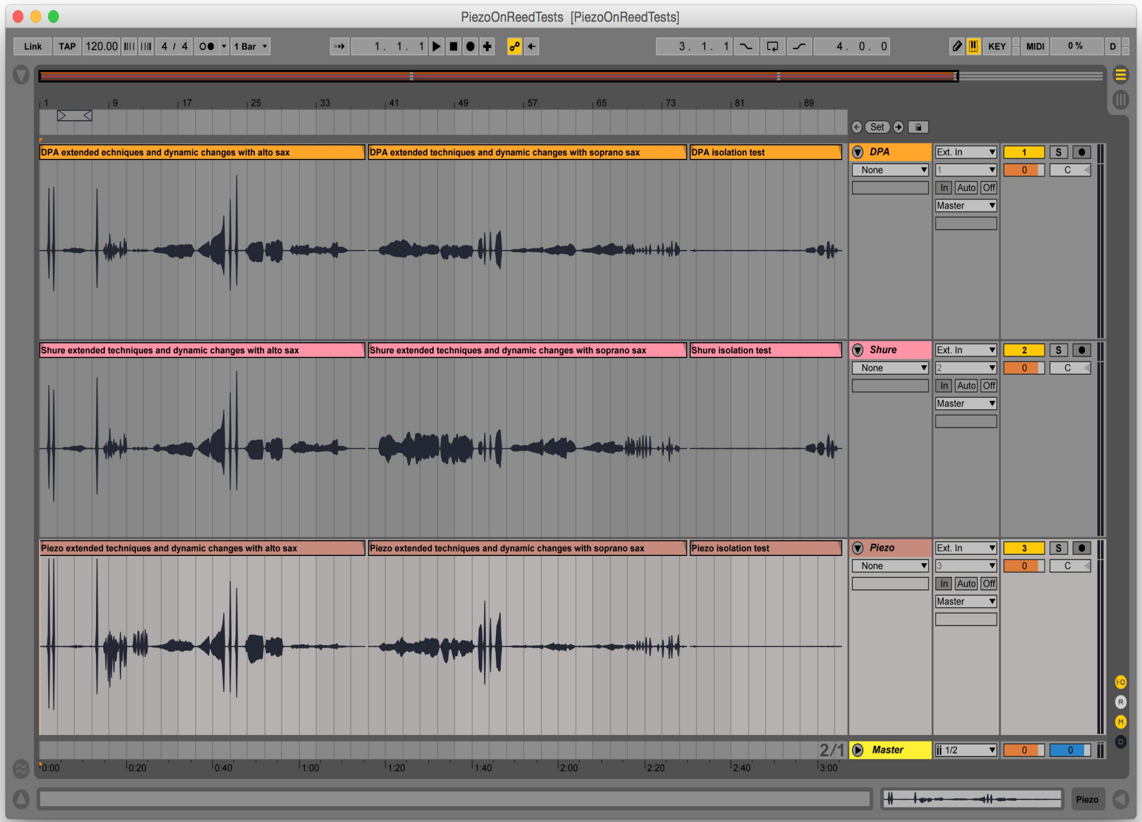

Figure 25

3.1.2 Pitch accuracy

To test if the microphone signal is giving accurate information about the pitch I built a test patch on Max/MSP as shown in figure 26. I wanted to know if the pitch detection devise that I use will recognize the pitches of the recorded samples. I made a list of the saxophone range in midi notes and checked if all my samples matched with the expected note. I ran all the samples of the different contact microphones I recored with Ableton Live with this patch.

As figure 26 shows, the alto saxophone test with the Hienekamp contact microphone gives quite accurate pitch information until reaching the high register. Then some of the notes are semitone higher than expected. The same phenomenon is shown in the soprano test with the same microphone, shown in figure 27. The reason for the results of semitone higher midi note on some of the notes is most likely that the recorded samples are out of tune. The quality of the mouthpieces I used for testing is very low and playing with them in tune is nearly impossible. I did the tests with these mouthpieces to get an overview if this contact microphone system works. I did not want to drill holes in expensive mouthpieces before knowing if the system works at all. After seeing these results I can say that the pitch information is accurate with the Hienekamp microphone on both alto and soprano saxophones.

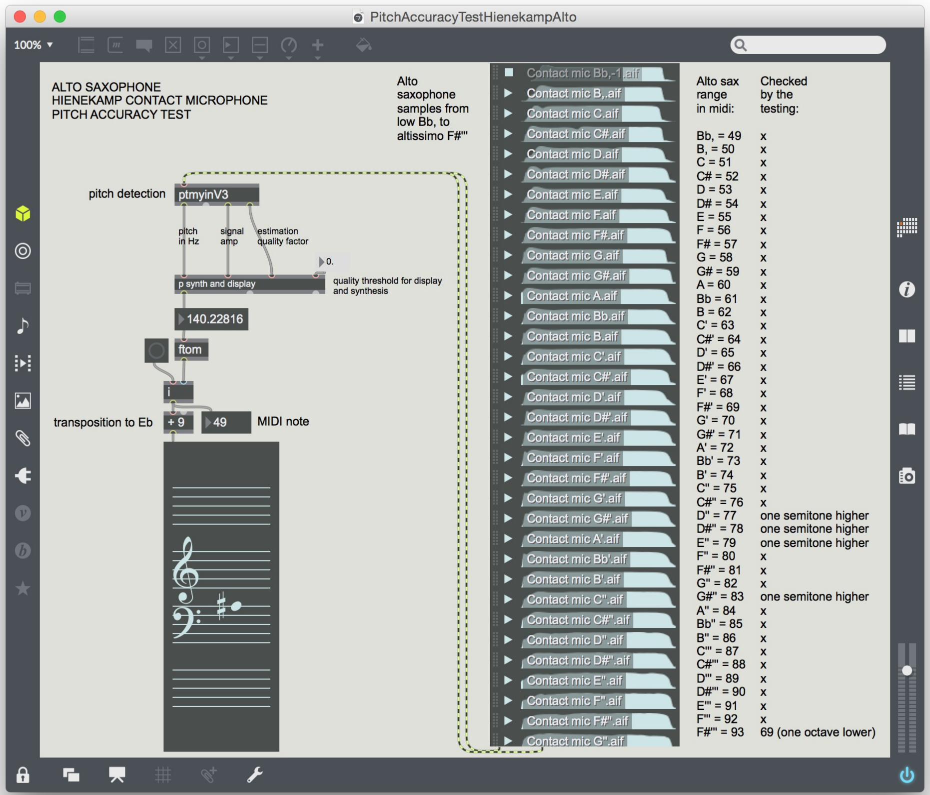

Figure 26

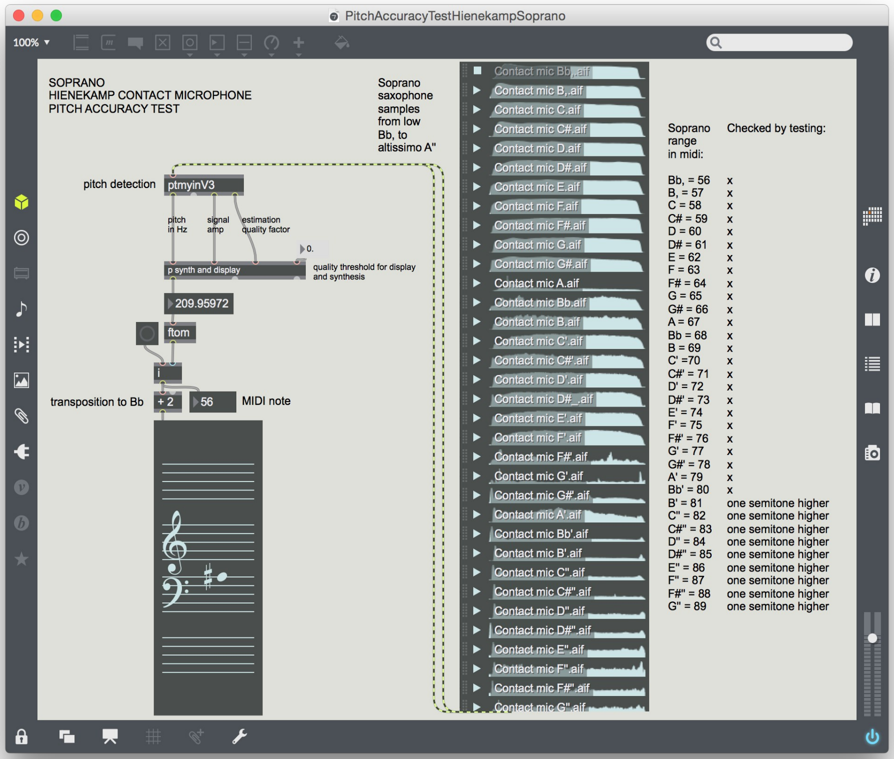

Figure 27

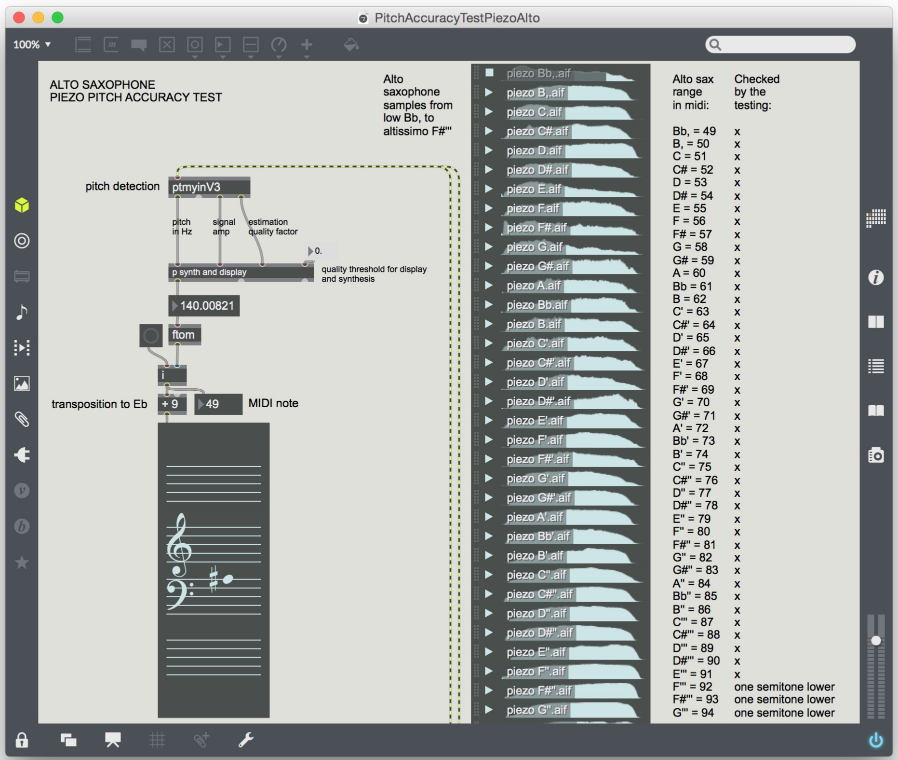

Figure 28

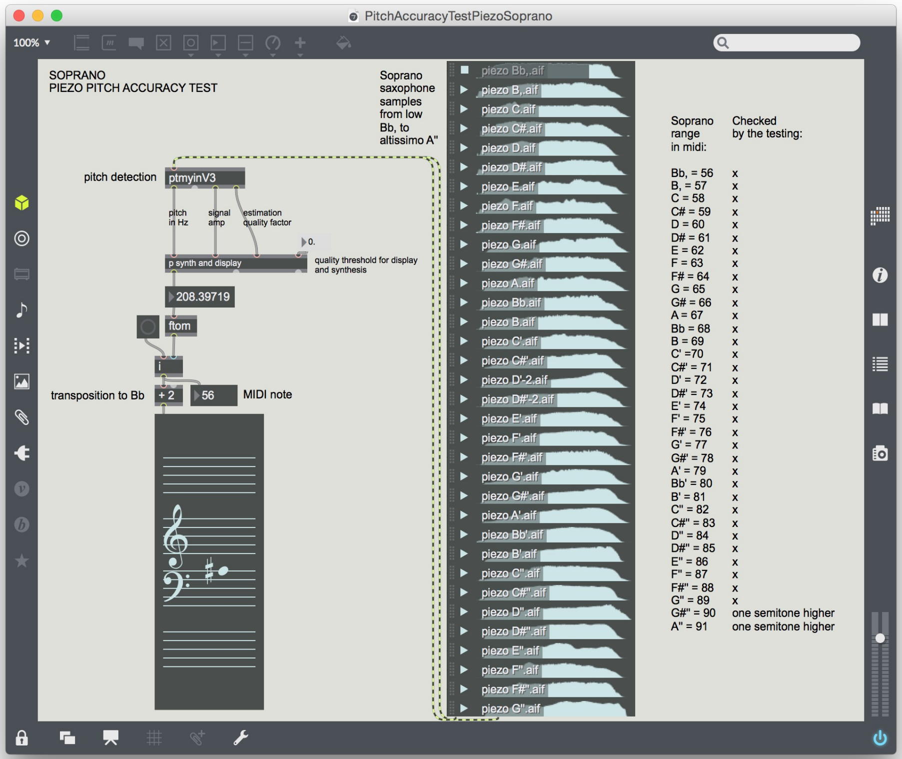

Figure 29

The results of the pitch accuracy tests with the piezo pickup are more consistent. Only the very high altissimo notes (F''', F#''' and G''') of alto saxophone samples are out of tune as seen in figure 28. In the soprano test, in figure 29, the first notes of altissimo register (G#'' and A'') are out of tune.

I made the testing having mostly the amplitude measurement in mind. I did not pay extra attention on the tuning while recording the samples. This is a mistake I realize now, I should have monitored my tuning while recording, especially in the altissimo register, that is not in my everyday practice at the moment. Despite the tuning of the samples, the results are giving me enough information about the pitch accuracy of the microphones. Both microphones give accurate pitch information with both saxophones. The mouthpieces used for testing with Hienekamp microphone are causing problems with intonation, but the microphone does work in a trustworthy manner.

With my own mouthpieces the tuning works better because I know them well and there is more flexibility for me to adjust the pitch by ear. One thing to keep in mind is that midi notes use the tuning of A = 440Hz. The modern saxophones are built to work best in tuning A = 442Hz, which is the most common tuning of orchestral instruments at current time period and my whole training is based on that. Playing in tuning A = 440Hz is perfectly possible but needs a little more attention.

3.2 Comparison of the tested microphones

As I found out in my test results, the Hienekamp contact microphone is not applicable for the purposes I need it for. In principle the quality of the signal is very good, without any noise. The problem of the signal getting too weak in the high register is so significant that it makes it impossible to use this microphone for gating and side-chaining purposes in my practice. The piezo pickup is more noisy in terms of picking up key noise, but is reliably picking up signals throughout the whole range of the saxophone. Both microphones detect the played pitch accurately, which is an essential quality.

If it would have been possible to use the Hienekamp contact microphone type, it would have become quite expensive for me. I would have had to buy four copies of the microphone, to be able to use it with my saxophone quartet, and an extra professional quality mouthpiece for each of the four saxophones, to drill the holes into. Together it would have cost me around 1600€ excluding the drilling and testing costs. The piezo is easy to make by myself and costs are low because the components are rather inexpensive. I don't need extra mouthpieces to use it and it is very easy and fast to set up.

3.3 Performance stage testing

In my first test performance[31] with using the gating of the piezo pickup and DPA I played Shadowed by Nicholas Scherzinger. The piece was composed in 2006 and in ten years the patch had become a little outdated in terms of the use of pitch detection devise. I modified the patch to make use of the gbr.yin pitch detection devise that works with my system, and added my gating patch to it as well. The pitch detection and score-follower worked like a dream and I was very pleased how my performance went (audio example a1).
During the preparations of this performance, one thing turned out to be a bigger problem: the key noise of the saxophone is picked up quite much louder by the piezo than I realized. When that happens the other microphone amplitude will be turned up at those moments. It means that the key noise is being played louder through the loudspeakers. It became more clearly audible while playing the piece with the effects. Luckily the most loud and irritating frequencies of the key noise are much lower than the saxophone range and can be cut off with a high pass filter. I added a high pass filter

31 Live Electronics block concert at CvA, Amsterdam BlueNote, October 14, 2016.

in my patch and the key noise was gone.

My second test performance[32] with the gating system was with the tenor saxophone in a band of electric guitar, tenor and baritone saxophones, synthesizer, electric bass and drums as shown in figure 30[33]. I didn't have any effects on my saxophone but I wanted to use the gating of the two microphones, since the band was very loud. The performance went well and I had no problems with feedback or crosstalk. I was also free to move on stage as I wanted without any fear of compromising the amplification of my sound. My tenor saxophone was audible throughout the performance unlike the Baritone saxophone that had only a SM57 on a stand next to it. It was impossible to pump up the volume of the baritone saxophone because the drums were so loud next to it (audio example a2). With these experiences I became very happy with the results of my research. Now I have a working system that makes a huge difference to my practice as a saxophonist and live electronic music artist.

Figure 30

32 Karnatic Festival concert at CvA, Amsterdam BlueNote, November 29, 2016. Matteo Nicolin: Escape from Chatusra Island (2016)

33 Screenshot of a YouTube video from the Karnatic Festival concert https://www.youtube.com/watch?v=KlP0rT008Oo (accessed February 25, 2017)

4 IMPLEMENTATION – MY SETUP

4.1 The final setup

This master program has given me the ability to make educated choices when building my own setup for live electronic performance. My final setup for now, in figure 31, consists of the gating and side-chaining of the self made piezo pickup and DPA d:vote 4099 microphone that are connected to my MOTU mk3 audio interface through Shure BLX188/CVL dual wireless system. I use MacBook Pro computer with Max/MSP and Ableton Live as my main softwares for performance. I have a Keith McMillen Softstep 2 foot pedal as my midi controlling devise, that I can use effortlessly with my feet while playing saxophone.
Next to this I can of course use different gadgets for different projects, for example Arduino with different sensors, but this is the main setup that I always carry with me. It's well thought, reliable and I can easily work with it. On stage it is almost unnoticeable because of the wireless microphones and the small amount of gear. The gating system, the result of this research, makes my setup complete.

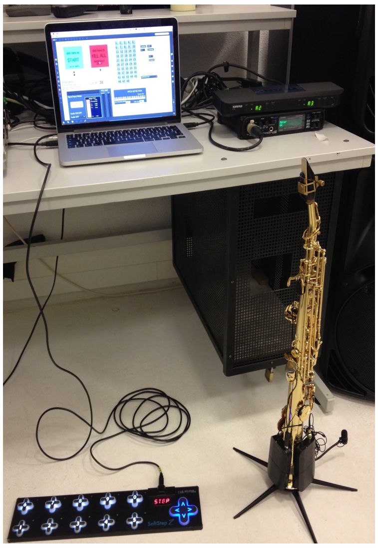

Figure 31

4.2 Building a piezo microphone

I can build my own piezo pickups at home as shown in figure 32. All I need is piezo elements, either mono or stereo cable, solder, soldering iron, hot glue gun and the kind of plugs I want to use.

For testing I used piezo with jack female plug that I could easily connect with a mono jack cable to my audio interface and the mixer. The performance stage testing I did with AKG wireless sets that I borrowed from school so I had to make a piezo with TA3F connector for that. The Shure wireless sets, that I recently bought to complete my own setup, work with TA4F connection. In figure 33 is my self made piezo pickup with TA4F connector. I used a mono cable, soldering the tip to pin3 and shield to pin1 and on the other end signal to the crystal of the piezo and the shield to the metal on the side. All it still lacks is the hot glue that covers the piezo protecting the soldered connections on the piezo element. I pieced the connector together and added the hot glue on the piezo plate after taking this picture to be able to show the connections better. To make a piezo pickup like this doesn't take long time but needs to be carefully done with steady hands.

Figure 32

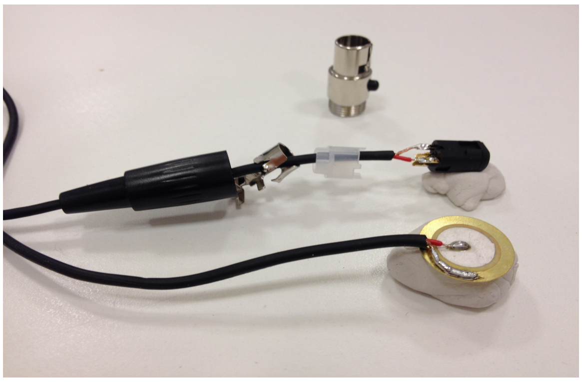

Figure 33

4.3 Gating and side-chaining with Max/MSP and Ableton Live

With Max/MSP I use a patch (figure 34) that I made based on the Jos Zwaanenburg gating system. Because I am using Max7 with Yosemite operating system, most of the old pitch detection devises are not working or are unreliably crashing after an unknown time. I made use of the gbr.yin pitch detection devise (figure 35) in my patch and so far it has worked perfectly. I added a high pass filter[34] to block the low frequency key noise of the saxophone and I made presets for each different size saxophone that I use, so I can set it up very fast.

With Ableton Live I use the gating and side-chaining devise of Ableton. As seen in the figure 36, I have my piezo pickup on the first track of which audio is not enabled but only used for sends. The DPA track has Gate Audio Effect on it. The Gate is side-chained with the piezo track that it is taking the the audio from. With the EQ I can get rid of the key noise of the saxophone and with the

34 An electronic filter that passes frequencies higher than the set cutoff frequency.

Threshold and Return knobs I can set the sensitivity and threshold for the gating. With Attack, Hold and Release knobs I can smoothen the envelope of the audio coming out of the gate. By adding another EQ I make sure that all the key noise is cut off. I can then create different tracks for variable combinations of audio effects for my saxophone by taking the audio from the DPA track to them as the sound source. By activating and deactivating the tracks and devises I want to use at certain points of the performance I can easily jump from a chain of effects to another. I can also just use the dry sound of the saxophone with the gating, by sending the DPA track straight to the master. I could also use my own Max patch with Ableton Live by transforming it to a Max for Live[35] patch. So far the gating tool of Ableton Live has worked for me perfectly fine, so it has not been necessary yet.

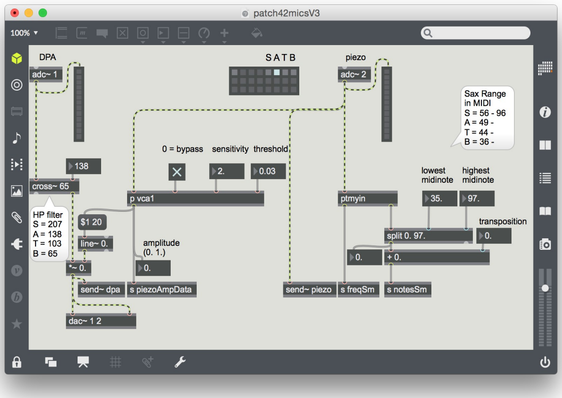

Figure 34

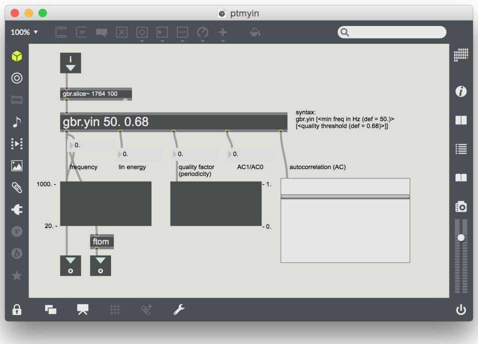

Figure 35

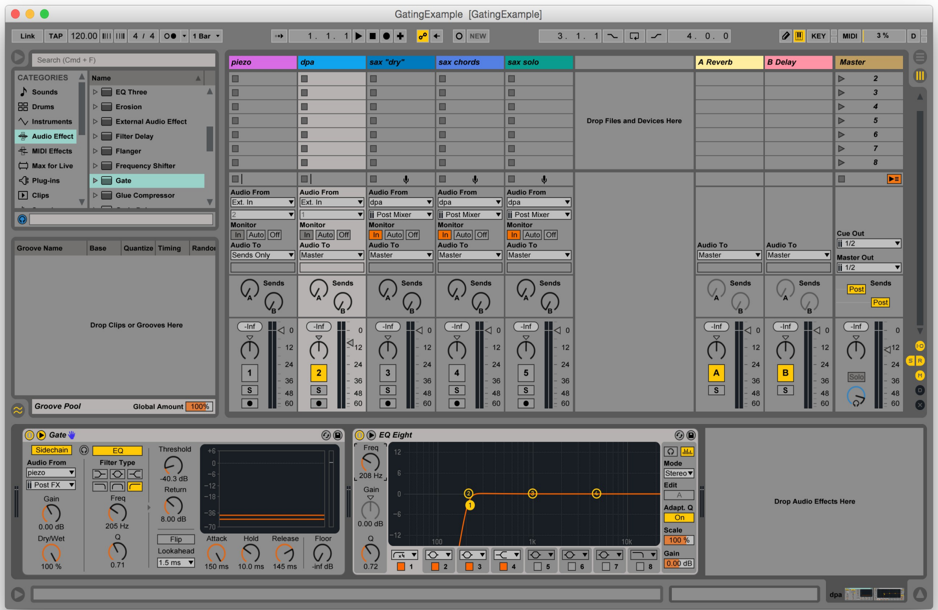

Figure 36

35 Visual programming environment that enables to use Max patches within Ableton Live.

5 CONCLUSION

During this research project I have met my goal to find a contact microphone for my saxophones that makes me able to use the gating system of Zwaanenburg. The answer to my question was closer than I thought. I didn't have to invest loads of money for new microphones and mouthpieces like I thought in the beginning of the project. I had the Hienekamp contact microphone as my starting point and since I was worried of the costs of this research I went through a process of applying for grants to cover the costs of this project. I did not get any funding but luckily I found the competition for the Hienekamp microphone in the piezo pickup, that turned out to be the answer I was looking for. The piezo pickup is a straightforward working tool and I am extremely happy to have found such an inexpensive contact microphone that works for me and that I can make myself.

The piezo pickup is a tool for my own set up but also effortlessly applicable for other saxophonists. In fact a colleague of mine, Ray DeSimone, immediately adopted my way of using the piezo pickup for his practice as tenor saxophonist. We made a piezo pickup for him together and now he is using it with live electronic extensions. I think this could be a very easily approachable technique for all saxophonists who use live electronic extensions.

The next step for this research is to compare the differences between using a mono or a stereo cable. A mono cable might turn into an antenna and pickup unwanted noise very easily if it is long enough. My cables are 40-60cm long, so I did not experience any problem with that so far. Mono cable is smaller and the visual reasons are why I preferred to use it. Next I need to find out if it would make a difference to use a shielded stereo cable instead.
I am also curious to test if the balanced piezo would work better instead of an unbalanced one that I am using now. Christian Liljedahl made the balanced piezo originally for under water use to have a noiseless microphone that works in water. My colleague, Gianluca Elia, uses the balanced piezo with his saxophone and in his set up to create feedback and sonic art but I am more interested if it would have some advantages for gating purposes as well.

During this project I learned a lot about microphones and how they work. I think it is great to have this experience of personally building my own setup and having an hands-on approach to find a tool for myself. It relates closely to the knowledge I have built-up during my studies in the Live Electronics master program at CvA. It has also given me confidence to think outside the box and added to my creativity to design and build digital and analog tools for my own purposes.

BIBLIOGRAPHY

Literature:

Jos Zwaanenburg – Live Electronics, Standardization and Tradition. (first published in Dutch in the *Dutch Journal of Music Theory*, volume 11, number 2, May 2006, the English translation completed August 20th 2007)

Internet:

https://en.wikipedia.org/wiki/Feedback – last checked 18-11-2016

https://en.wikipedia.org/wiki/Karlheinz_Stockhausen – last checked 19-1-2017

https://en.wikipedia.org/wiki/Studio_for_Electronic_Music_(WDR) – last checked 19-1-2017

https://www.yens-yens.nl/about/ – last checked 19-1-2017

https://en.wikipedia.org/wiki/Variable-gain_amplifier – last checked 19-1-2017

https://en.wikipedia.org/wiki/Voltage-controlled_filter – last checked 19-1-2017

http://www.polynominal.com/roland-cp-40/ – last checked 19-1-2017

http://ftm.ircam.fr/index.php/Main_Page – last checked 19-1-2017

https://en.wikipedia.org/wiki/IRCAM – last checked 19-1-2017

https://en.wikipedia.org/wiki/Max_(software) – last checked 19-1-2017

http://www.piezobarrel.com – last checked 7-1-2017

https://cafesaxophone.com/threads/piezo-barrel-mouthpiece-pick-up.16747/ - last checked 7-1-2017

http://www.xe.com/currencyconverter/convert/?Amount=199&From=AUD&To=EUR – last checked 7-1-2017

http://www.rumberger-soundproducts.de – last checked 7-1-2017

https://howarthoflondon.wordpress.com/2013/03/21/k1x-rumberger-telex-pickup-fitting-to-your-instrument-at-howarth-of-london/ - last checked 7-1-2017

https://www.thomann.de/nl/rumberger_k1x_pickup_clarinet.htm?ref=search_prv_6 – last checked 7-1-2017

http://barcusberry.com/product.cfm?ProductID=8 – last checked 7-1-2017

http://www.legatomusiccenter.com/store/barcus-berry-wind-instruments-electret-mic#sthash.VizOhJLT.dpbs – last check 7-1-2017

http://www.embag.ch/downloads/barcusberrycatalogue.pdf – last checked 7-1-2017

http://www.xe.com/currencyconverter/convert/?Amount=495&From=CHF&To=EUR – last checked 7-1-2017

https://cafesaxophone.com/threads/wtb-under-reed-pick-up.7220/ - last checked 7-1-2017

http://www.shadow-electronics.com/viewpro.html?id=176&search=1 – last checked 7-1-2017
https://www.thomann.de/nl/shadow_sh4001_tonabnehmer.htm – last checked 7-1-2017
http://christian.liljedahl.dk/guides/noise-free-piezo-microphone – last checked 7-1-2017
http://www.distrelec.nl/nl/microphone-element-sennheiser-ke-211/p/13010100?q=sennheiser+ke+4-211-2&page=1&origPageSize=50&simi=89.52 – last checked 9-1-2017
http://shure.custhelp.com/app/answers/detail/a_id/2057/~/wa302-wiring-diagram – last checked 9-1-2017

Music:
Nicolas Scherzinger – Shadowed (2006) for solo soprano saxophone and computer (MaxMSP) http://www.scherzimusic.com/works-shadowed.html – last checked 18-11-2016
Matteo Nicolin – Escape from Chatusra Island (2016) https://www.youtube.com/watch?v=KlP0rT008Oo – last checked 25-2-2017

APPENDIX

List of figures

23 Ableton Live set of the recording test: alto sax with DPA d:vote 4099, Shure SM58 and the piezo pickup.

24 Ableton Live set of the recording test: soprano sax with DPA d:vote 4099, Shure SM58 and the piezo pickup.

25 Ableton Live set of the recording test: different dynamics and extended techniques with DPA d:vote 4099, Shure SM58 and the piezo pickup, piezo isolation test

26 Pitch accuracy test with recorded samples of alto sax with Hienekamp contact microphone, test patch Max/MSP.

27 Pitch accuracy test with recorded samples of soprano sax with Hienekamp contact microphone, test patch Max/MSP.

28 Pitch accuracy test with recorded samples of alto sax with piezo pick up, test patch Max/MSP.

29 Pitch accuracy test with sample of soprano sax with Hienekamp contact microphone, test patch Max/MSP.

30 Performance of Matteo Nicolin's Escape from Chatushra Island in Amsterdam Blue Note on the 29th of November 2016. Using the gating system with tenor saxophone.

31 My current setup.

32 Building a piezo pickup by myself at home.

33 Soldered connections with piezo pickup and TA4F connector.

34 My gating and side-chaining patch for two microphones with presets for the different saxophones.

35 The gbr.yin pitch detection devise.

36 Ableton Live set to show how the gating is done in an easy and effective manner.

List of audio examples

a1 Nicolas Scherzinger: Shadowed (2006) for solo soprano saxophone and computer (MaxMSP), Nanna Ikonen – soprano saxophone, Live Electronics block concert at CvA, Amsterdam BlueNote, October 14, 2016.

a2 Matteo Nicolin: Escape from Chatusra Island (2016), Matteo Nicolin – electric guitar; Nanna Ikonen – tenor sax; Mafalda Oliveira – baritone sax; Sander Notenbaert – keyboard; Andre Lourenco – electric bass; Alex Brajkovic – drums, Karnatic Festival concert at CvA, Amsterdam BlueNote, November 29, 2016.