Chapter 5

MASTERWORK – SOFT SOUND

Soft Sound is an art-based study on the crossmodal, employing sound, textile, and space as one unified medium. This practice-led material research focuses on the use of sound as a material force, resulting into an audio-haptic surface. This augmented textile, proposes new possibilities to create, and interact with sound. An exploration on the amalgamation of textile and sonic art forms as a spatiotemporal material process, where transdisciplinarity in practice results into powerful moments of reflection, and intrinsically, the medium becomes the message. This project operates on the edge between technical and artistic exploration and focuses on the crossmodal manifestation of sound through matter, recontextualizing textile as a high definition sound source. This modular system enables for a large number of speakers, comparable to a large number of pixels in the visual world, creating a high-resolution vibro-tactile, sonic experience. A practice-based research on intersensory perception, observing the visual and tactile exploration of the vibrational force of sound, as well as the sound of immateriality expressed via the timbre of a textile medium. Soft Sound is a musical instrument, as well as an experimental sound system, investigating the spatial phenomena of wave field synthesis. While working and developing the technology for my masterwork, I was concerned with the indisputable importance of multisensorial experiences, not as a finished rigid art piece or product, but as a process and exercise in liminality. According to Jerome Rothenberg: "The function of art is not to impose a vision or consciousness, but to liberate a similar process in others." I am preoccupied with questions and thoughts dealing with ever speeding pace at which contemporaneity rushes. We are witnessing some of the most significant changes in the shortest amount of time in human memory. Changes in our environments. Changes in our societies. Changes on our bodies. It is imperative for us, in this hectic climate, to construct new myths, and rediscover a new sense of spirituality. A new spirituality that is intrinsically connected to a new materiality.

5.1 Matter / Pattern

Particle physics has radically changed our view of what used to be conceived as matter; a colossal, dull lump of comatose particles. Recent developments in the study of the fundamental forces in the universe, known as the Standard Model, reveal exciting new concepts of the fabric of reality. Ranging from Particle Cosmology with the reproduction of models of the early universe, to the confirmation of the existence of the Higgs-Boson particle, or the attempt to construct a unified description of general relativity and quantum physics, thus creating one consolidated "theory of everything", or "TOE".[99] As these new findings bring new questions, undermining the idea of stable and predictable material substance, hastening a realization that our natural environment is far more complex, unstable, fragile and interactive than earlier models proposed. Soft Sound reflects on the potential of such malleable systems, employing sound as vibrational force[100] on textile structures, thinking about sound, not as an auditive phenomena or mere noise, but as a basic building block in our perception of physical reality.

The use of sound as a material force has been explored in the area of thermoacoustics, the interaction between temperature, density and pressure variations of acoustic waves. Within this field, the research expands from controlling temperature using acoustic drivers to thermoacoustic engines (TAE), devices that convert heat energy into work, however the relevant phenomenon to my research, are the spontaneous oscillations occurring in certain materials when heat is applied; these are known as "Taconis oscillations."[101] These occurrence has been observed for centuries by glass blowers, also often referred to as singing glass. Although many times this sonic event is considered as a purposeless side effect, Georges Frederic Eugene Kastner a french physicist and musician, invented the pyrophone[102] in 1870, also known as the fire/explosion organ. Using the same principle seen in a Rijke tube, turning heat into sound, Kastner tuned glass cylinders by size and organized them musically triggering small controlled sudden explosions in order to make them vibrate. This early inspirational audiovisual musical instrument significant in connection to my masterwork, due to use and focus on its material properties and the mining of the hidden interactions between physics and matter. Another important inspiration in my research of modal vibrational phenomena are cymatics. Robert Hook, english philosopher, architect and polymath, observed in 1680, that by sparkling fine dust on a vibrating glass plate, patterns corresponding nodal lines of vibration would emerge. Experiments on this, the study of Cymatics were later perfected and systematically documented in the book *Discoveries in the Theory of Sound*, by Ernst Chladni in 1787. This raw manifestation of sound in another media, totally independent from the experience of hearing has served as a great tangible direction. By augmenting or amalgamating textiles with soft electronics, I have successfully excited and set these textiles into a vibrational frequency that becomes tangible, fully observable by the naked eye, and clearly audible. This explores a new dimension in the intersection between textile and sound.

When working with the textile medium, the vast amount of possibilities and configurations are breathtaking. During my practice-based research, I have experimented with numerous techniques and materials. The basic premise is to create a soft electromagnetic coil, and attach it to a textile membrane. This textile coil is connected to the driving signal, in order to reproduce sound. The first working prototype in the early stages of this research, was embroidered conductive thread onto canvas. This method, while being the first success, reproduced sound muffled, and at low volume. I continued to experiment with materials under the same technique. During these series of experiments I realized the importance of the materials used for membrane, as well as the important role electric resistance plays on the coil and overall result. Canvas gave way to new tests on membrane materials, as well as new structures. I have experimented with knitting patterns, using conductive yarn, yet these direction and such textile structures, proved to be very much sound absorbent and heavy. Unsatisfied with the overall volume that could be achieved with such techniques, I looked for answers in more traditional musical approaches to sound, such as acoustic musical instruments that use textiles or membranes. Inspired by the tightened skin or plastic over a drum, I replicated a tightly woven textile, using copper wire, over the mouth of a cylindrical body. These resulted in a clear, loud result. The only problem, is that this solution had entirely lost its textile characteristics. It has been a 3 year trial and error process, and while each technique explored during this process has its pros and cons, my aim with Soft Sound is to produce high-fidelity sound via vibrating textiles, hence I had to focus and single out possibilities with this target in aim. By using technical textiles, concentrating on those designed with an ultra tight structure, such as wind proof textiles or water resistant materials, lightweight, yet sturdy, I have been able to yield the most efficiency out of this system, in order to dedicatedly affect the air with the enhanced textile in order to produce high-definition audible sound. To set the textile into vibrational motion, laser cut conductive textile electromagnetic coils are hot-melted onto the membrane textile, which in turn, are connected to an amplifier receiving the driving signal. A permanent magnet is placed close to the electromagnetic coil to allow the mechanical motion in action.

Humanity has been familiar with metals for about 10 000 years. They have been indispensable in the development of mankind, including its vital connection to electricity. Conductive textiles, or semi-conductive textiles are fabrics that via various methods such as, woven metal strands or impregnation of carbon or metal based powders, can conduct electricity. These have a wide array of uses, from static dissipation in high performance firefighter equipment to EMI shielding on spacecrafts and other speciality purposes lightweight is imperative. I have laser cut spiral shapes from Copper and Nickel (CU+NI) plated conductive textile, to produce flat circular textile electromagnetic coils. Traditionally, such coils are produced by wrapping, hundredths, to maybe thousands of time hard copper wire around a cylindrical shape. These are heavy and hard and completely useless to my design. Instead, after much testing, I have settled for conductive textile spirals of about 8cm in radius, varying the amount of turns depending on the thickness of the path itself. I have deliberately decided to leave such spirals visible in the final result, even though they can be easily concealed. Modern technical society tends to hide all these intricate material processes, behind a flat, smooth surface, making us forget about the alchemy-like wonders of the inner workings of technology. I suggest the relaunch the historic sacral meaning of metals by revealing the raw electromagnetic spirals that make Soft Sound work.

The spiral is one of the most widespread shapes found in the natural world, seen in the form of embryos, horns, whirlpools, hurricanes and galaxies. It is also one of the most ancient symbols used by humankind. Findings of spirals being carved decoratively into objects, have been dated to as far back as 10 000 BC, during the Neolithic period. Examples of the geometric shape can be found in archeological sites around the world, such as the Newgrange entrance slab in Ireland using the Celtic triskelion, three outward spirals symbolizing earth, water and air, all driven by fire, having all four elements united as one life, creative power. Swastikas in Asia and India, which amongst many meanings and depending on its orientation, symbolize the path of the sun. In Latin and Central America, Quetzalcoatl, the Mesoamerican god of the wind, life and knowledge, wears a spirally voluted wind jewel around his neck. This is a conch shell cut at the cross-section, also worn by religious leaders and rulers, potentially symbolizing this recurring pattern that had great importance within these cultures. Even though slight mythological differences exist between the significance and spirals between one culture and the other, it is widely associated as a sacred symbol that represents an evolving path and ever changing processes, many times identified with the vector of time through space, the cyclical evolving journey of life and reincarnation within the pertinent belief systems, or the eternal expansion of creation from its origo. In latin "spiro" means to breath, and probably the first ever musical instrument invented was the conch, a wind instrument also known as a seashell horn or seashell trumpet. Spirals are used to represent shells. The spiral is the path that resolves conflict through a balanced natural unfolding into a harmonious transformation. Spiral processes in nature evoke a mystic journey of awakening.[103]

Even though there are numerous examples on visual representations spirals as of sound on textile, I would like to discuss the approach of the Shipibo-Conibo culture in Peru's Amazon forest. Icaros, according to the Shipibo custom, are songs inspired by the connections with the spirits of the plants and ancestors, written by shamans during visions in elevated states of consciousness. These icaros are used in healing ceremonies, and are also translated into colorful tapestries adorned by these stunning geometrical patterns. These tapestries are not meant or used as musical notation, but rather visually represent the physical vibration of a song, as also found in study of cymatics, as mentioned earlier. When placed side by side, a Shipobo pattern and a Chladni figure, the similarities are stunning. An ancient belief, observed by the Shipobo tribe before proof from modern science existed is that vibrations are foundational components of our universe. Space is probably a loop of loops, just as a piece of material is the web of fibers.

5.2 Technology / Energy

Within this subsection I will expand on the technical processes, methods, mechanics and further findings, encountered during the research and development of the working technology for my masterwork. The practical aim behind Soft Sound is the advanced exploration and recontextualization of textile as an electroacoustic transducer, enabling textiles to convert an electrical audio signal into sound, while adding tactility and physical presence to a sonic experience. The relationship between textile and sound have a history focused rather towards the damping, absorption or diffusion of sound within the study of acoustics, than as an actual sound emitter. Soundproofing, whether it be in professional music studios or striving for architectural silence, is achieved by strategically placing specialized textiles, or acoustic foam, such as sound curtains, acoustic drapes or noise blankets in a space in order to reshape its acoustics.

My master work explores and presents textiles as a viable and exciting new approach on working with sound, not only due to its inherent interactivity possibilities, its intuitive tactility and its deeply rooted tradition and implied meaning in modern civilization, but as an attempt to view textiles as a new medium with plenty of yet unexplored advantages. Textile and sound, both hold substantial roles as building foundations of a complex society, they also have shared elemental concepts such as rhythm, structure or pattern. Concepts that denote our perception of a fabric, being tangible or abstract, taking up space and time. These joint concepts are provocative and moving when creating a textile focused on sonic interactions.

During my successful pursuit to animate textile into the extent of producing audible sound, I have deconstructed a modern-day loudspeaker and stripped it from its rigid components in order to translate this technology onto an entirely flexible, durable textile. In the common dynamic loudspeaker, patented in 1924 by Chester W. Rice and Edward W. Kellogg, a diaphragm or cone is connected to a rigid basket or frame through a suspension attached to the “voice coil” wrapped around a cylinder which contains a permanent magnet. As stated by Faraday's Law of Induction a basic law of electromagnetism that predicts how a magnetic field will interact with an electric circuit to produce an electromotive force (EMF), is the phenomenon we refer to as electromagnetism. According to Faraday: “The induced electromotive force in any closed circuit is equal to the negative of the time rate of change of the magnetic flux enclosed by the circuit”. This means that when applying an alternating current, into a coil, next to a permanent magnet, depending on the state of the coil, this will be physically repelled or attracted by the magnet, at the applied frequency, and in turn creates mechanical force, causing the coil to move back and forth rapidly, pushing the air around it, creating sound waves. Whereas this concept bases the materiality of its enclosure, as well as the solidity, coil type and design, directly proportional to the quality of the sound, Soft Sound translates this constant, into the structure, shape of coil and materiality of the textile membrane. Through an extensive research, I have been able to calibrate an efficient balance between the physical textile sound system and the intended reproduction of sound.

The conversion of a repeated occurrences of an event per unit time, also known as frequency into audible sound is, in its purest form, the manifestation of this frequency into a mechanical motion, pushing the air around it back and forth in order to become sound we perceive via our ear canal. This is elementally the translation of an intangible concept, into a physical, tangible force.

Creating a system for high-fidelity reproduction of sound has been a fascination for audiophiles since the first phonograph was invented by Thomas Edison in 1877, an incredible yet rudimentary machine that was able to faintly reproduce sound by having a diaphragm attached to a stylus, trace grooves etched into a spinning disc or cylinder. This "talking machine", contemporary to the early attempts of creating an electric loudspeaker by the likes of Graham Bell, Ernst Siemens or the Path'e company, were quite inventive, yet significantly limited by their poor sound quality and the inability to reproduce sound at low volumes. Speech would become muffled, and music would become distorted, rendering these inventions near useless. As mentioned in the beginning of this chapter, it is the Rice and Kellogg patent for the dynamic loudspeaker that models the principles of the high-fidelity loudspeakers we are familiar with today. As technological developments have allowed, since the turn of the last century, advancements in sound systems have become impressively immersive, subtle and detailed. Evolving from mono to the first stereophonic, two channel method of sound reproduction, to multichannel formats such as quadraphonic or 4.0 surround sound. Working on 4 independent channels, or more, are used methods for creating in immersive sonic experience based on the spatial perception of sound. Although these advanced techniques are very effective on exploring a listening event, they remain short for evoking what Pallasmaa calls a "strengthened sense of materiality and hapticity, texture and weight."[104] These systems limit such bodily experience of sound to the lower frequencies and rumble that is perceived by our skin and bones when extremely high volumes of sound are produced. This effect is widely used and exploited in film scores to create tension or in music, mostly electronic music, to force the listener into motion, via low, rhythmical thuds. Pioneers of this approach are Jamaican sound engineers, notorious for creating monumental stacks of dedicated speakers, physically built to faithfully reproduce designated sound frequencies ranges, such as tweeters or super tweeters for higher frequencies noted for their "beem", directional nature, mid-range speakers, woofers and monolithic subwoofers to rattle the ground, the body and the bones, using the omnidirectional constitution of low frequency sound. These complex systems, in order to function at high efficiency, need to be calibrated properly for the respective desired sound, by matching amplifiers, preamplifiers, and all the electronic components involved. Composing an overall electronic signal equilibrium within these network is quite laborious, but when achieved efficiently, the result is astonishing.

For my final artwork, creating an efficient sound system, using experimental interfaces built from textiles, was quite a challenge. Amplifiers, indispensable in all hi-fi reproduction of sound, are electronic devices that take the input audio and increase the power of its signal according to the impedance of the speakers connected. Calibrating and cutting the coils in order to work harmoniously within this system, meant researching the best way to amplify the sound signal, without overheating or burning any of the elements. Experimenting with the various classes, ranging from the typically used for hi-end audio Class-A, Class A-B linear amplifiers, I realized that these, besides requiring a big power supply in order to work properly, also produced a lot of heat on the working textile due to their non PWM amplification. This solution, even if working, meant the soft, flexible lightweight textiles needed to be connected to a heavy duty, sturdy hardware. Another issue was the cost of such amplifiers, per channel. If only dealing with a stereo, 2 system, this could be relatively affordable, but when contemplating a 32 channel modular speaker system, the economic price elevated noticeably. Whilst researching and building my own amplifier, I tested Class D amplifiers, also known as switching amplifiers. These are very efficient amplifiers, as they have a very high power conversion efficiency, meaning in a reduced power waste as heat. Also, can be built into reduced sizes, at a reduced cost. Inspired by previous examples, and as mentioned, I have envisioned Soft Sound as a modular system that opens the possibility for a multichannel, multisensory experience. Fascinating works such as the Philips Pavilion designed for 'Expo58 in Brussels by the intriguing Le Corbusier have a vital influence on my work. This multimedia spectacle created in collaboration with Iannis Xenakis and Edgar Varése is a beautiful example on crossmodal practices celebrating technological progress. As the final outcome of my artistic research, I will present iterations on the working art piece and developed technology exploring the possibilities of multichannel control and the effects of sounds vibrational force exerted by a textile.

5.3 Sound / Perception

Sound as anthropologist Georgina Born states, is "alogogenic"[105] meaning: unrelated to language, non artifact, having no physical existence and nonrepresentational. It is a self referential, aural abstraction. Soft Sound has the intent to broaden this properties of sound, and make it available through a visio-tactile experience. As mentioned earlier, the human ear can perceive from 20 to 20000 Hz, the skin's sensitivity to mechanical vibrations and temporal resolution is smaller with a range of about 1000 Hz where the frequencies around 250 Hz are the most sensitive and with most spatial discrimination. Humans do not just experience sound through the eardrums. When most people are presented with a recording of their own voice, they seem to find it unexpected and weird, even though they have been listening to that voice throughout their life. This is because, when a recording is played back, they will only hear their own voice, and do not experience the vibrations created inside their body and skull when they speak. The art of listening has been an obsession for mankind since the dawn of perception. Humans have been building musical instruments by tightening dried skins over wood, hollowing bird bones. These primitive musical instruments, some dating over 41 000 years of age have overall been agreed as having ritualistic purposes. It is quite interesting to note the fact that these instruments, while depending on their own acoustic body to define timbre, tone and other sonic qualities, were also built and thought for playing in certain contexts and spaces. Acoustic archeologists such as Reznikoff propose, although without conclusive proof, that Palaeolithic cave paintings are directly related with the present resonance within the space. Properties such as placement and amount of painted animals or motifs inside an archeological site, appear to be directly related to the amount of echo counts and other acoustic properties of sound. An astonishing find regarding the importance in the phenomenology of sound.[106]

Soft Sound establishes a link between the textile and the listener, not through an auditory experience only, but by the vibro-tactile properties embedded, as well as the visual feedback this situation creates. The implications within the study of this subjective experience, the intentionality of sound and touch, point towards the unveiling of a very seldom explored dimension of textile interfaces. While it is an essential characteristic in user experience, as well as interaction design, haptic feedback, augments flat, otherwise meaningless experiences, into a physical, memorable event. Take the example of the clicking sound or very mild, stabbed vibration produced by a mobile device while texting. Although more advanced users might decide to turn this feature off, the default settings are set to give out this sonic haptic feedback in order to allow the user to fully grasp and live the action of texting. A temporal guide of what letter has been inputted, and when is it time to type in the next. Same applies to on-phone cameras. Without the emulated shutter sound, short vibration and click, users would not know whether the photo was captured or not. These are examples of rewarding user experiences achieved by synchronizing sound and touch, and are pertinent when considering wearable technology, however I have personally chosen not to work exclusively on the body, as my fascination for material in relation to human reaction, space and sound is stronger.

By using sound as a material force, via textiles, a further spatiotemporal process is unveiled. While it is inherent to the sound medium to be inevitably entangled to its spatial-environmental context, Soft Sound focuses on the material agent of the sound source as a focus of this study. This unexpected interaction between textile and electronics, give way to the active process or "poesis" of a textile soundscape, a multisensorial experience. The textile material, its weight and structure used as a membrane is what defines Soft Sounds' distinct timbre. This characteristic is what is also referred to in psychoacoustics as tone color, tone quality, and not surprisingly it is considered the texture attributed to an instrument. Hence we can comfortably conclude that the texture of the textile used as a membrane, will not only be experienced through touch, but this same property will be translated to the sonic characteristics of such. Soft Sounds' textile timbre is intrinsically connected to is materiality. Soft Sound is a textile interface, a modular sound system establishing a direct link between the textile and the listener. The multi channel network requires specialized musical compositions to explore the psychoacoustic phenomena of wave field synthesis. A specialized software was patched using MAX/MSP visual programming software in order to control the flexible array of textile speakers, independently. Envisioned as a microtonal musical instrument, opening the possibilities to use standard tuning based on the standard A=440Hz, the International Standards Organization's recommendations for concert pitch, or to easily switch alternative temperaments, such as the A=432Hz, known as Verdi's A, a beautiful tuning based on Pythagorean harmonic ratios.

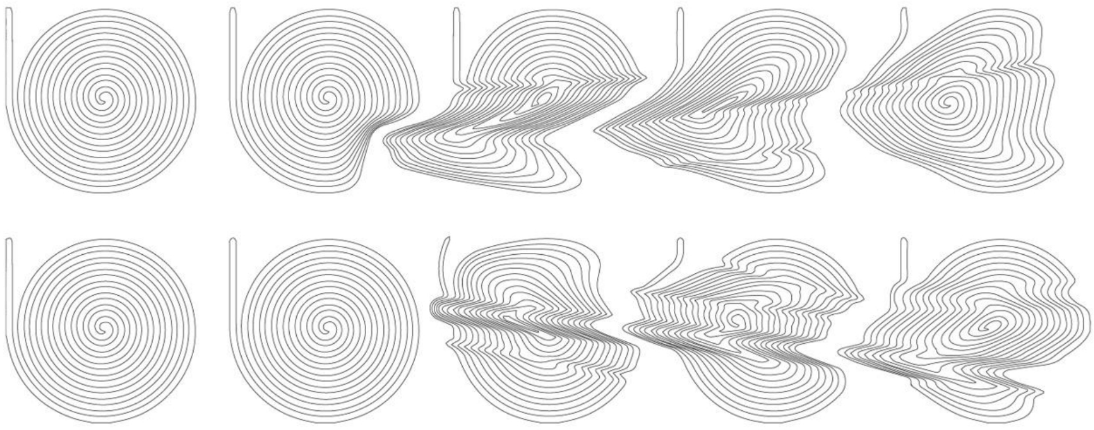


Figure 12: Spiral coil variations for laser cut

Fifure 13: Soft speaker vibration test

Figure 14: Laser cut copper coil on transparent textile

Figure 15: Sof speakers series experiment on one textile

Figure 16: Soft speaker shape experiment on technical textile

Figure 17: Soft speaker shape experiment on technical textile

Figure 18: Stereo soft speaker testing at WeMake makerspace, Milan

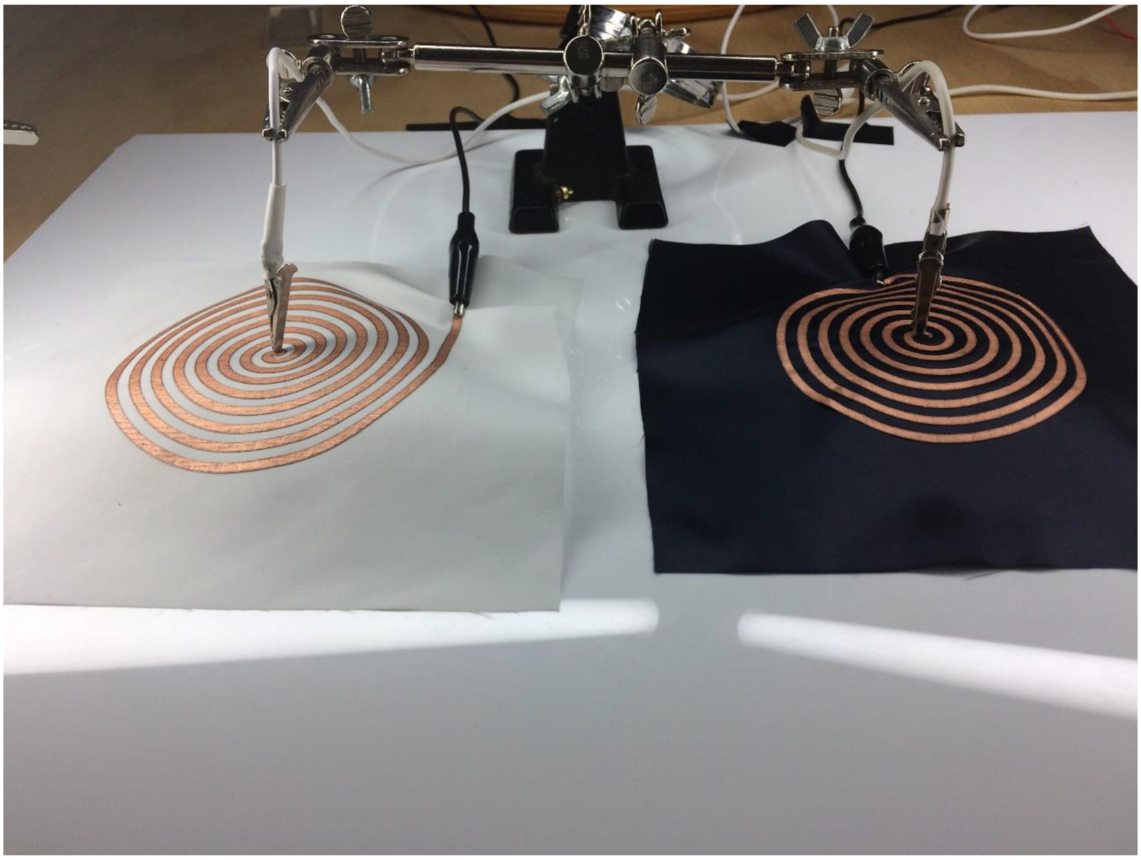


Figure 19: Stereo soft speaker testing at WeMake makerspace, Milan

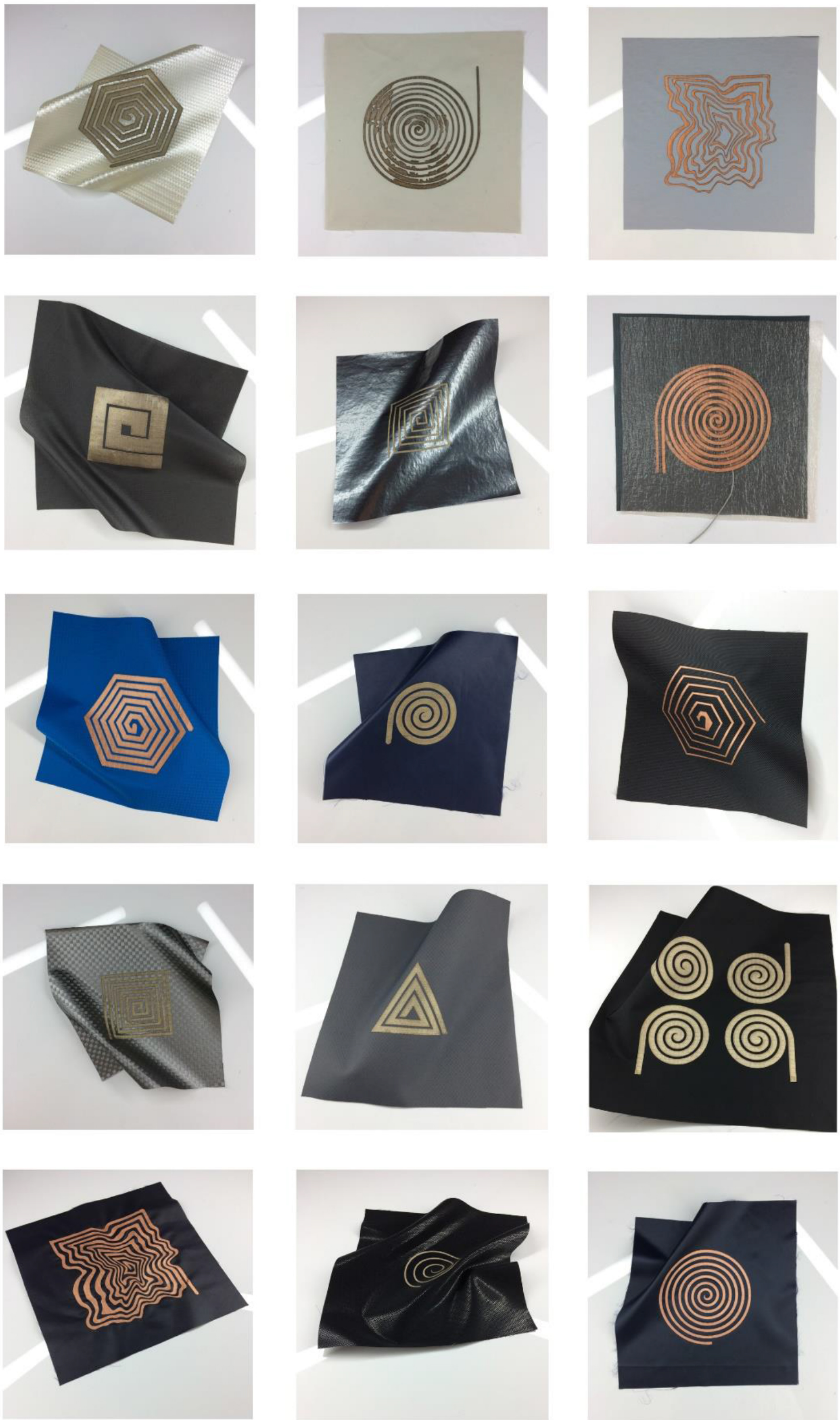


Figure 20: Soft speakers on various textiles, calculated coils in different forms

Production / Vision

Soft Sound is the result of a long research process spanning over three years. The first experiments were done under the Talent Program scholarship in Kitchen Budapest. The aim at this early stage was to get a working prototype: A textile that would emit sound. This was achieved, and as part of an early vision, these working, yet not as sophisticated and efficient textile speakers were embedded onto clothing. The concept behind *Soundwear* (Chapter 2.3) was to create a wearable to replace the usage of headphones. The user would have a one channel speaker embedded onto its clothing, in order to listen to music, as well as feeling it. The main challenge with this early stage, was producing a proper coil. Also, amplification proved to be important, and very hard to pinpoint the sweet spot between the amplifier and electromagnetic textile coil. During this early stage, most of the material tests where across textile structures and media, including knitted, hand woven, felted textiles, screen printing, as well as testing on neoprene and soft shell. The latter ones chosen due to their sturdiness and heat resistance.

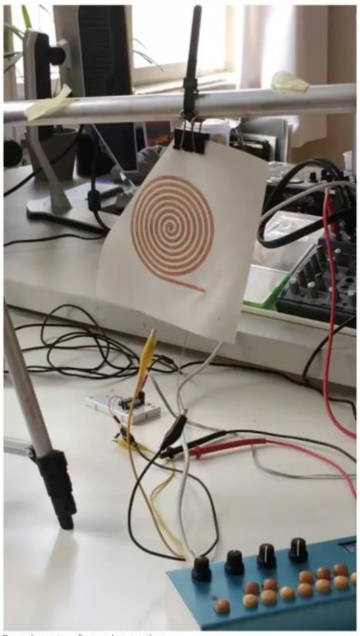
During continued research, thin copper sheets were tested to be very efficient for creating a flat coil or spiral. These sheets, also failed to be as flexible and would break or crack with simple bending. It was also complicated and time consuming to hand cut the desired shape. During this stage, the second iteration of Soft Sound, the research was done at WeMake in Milan, under a 3 months scholarship. WeMake is the leading maker space in Milan, with access to a wide range of machinery. This proved to be very useful as I could test and prototype quickly, dismissing failures and building on successes. During this time, I also investigated and found a very low resistance conductive textile to replace the thin, brittle copper sheets. Originally I tried to vinyl cut the coil, yet soon found laser cutting to be the ultimate solution. Laser cutting is very precise, but textiles are very flammable, hence easily burnt or charred. A high power laser cutting machine is needed to cut such textiles precisely, at a high speed to ensure clean edges. This technique also allowed me to cut the exact same coil many time, in order to test the difference in sound quality when experimenting with new materials for membranes.

It is part of the EJTECH work process, to document stages of successful attempts and development. This work in progress has been exhibited in Japan, USA and Europe. It has also gained recognition by the media and has been registered in the CreativeApplications.net, as well as added to the library of MaterialConexion Flagship in New York. Numerous companies have contacted EJTECH in order to purchase this textile or service, that in my vision, besides being a material research art object and practical study on the crossmodal, is a technology that due to the previously mentioned, can be seamlessly applied to interior design, such as sounding curtains, or space dividers working as a sonic display, these being in large scale such as an airport or any other public space, to the private home of an audiophile. Soft Sound could be applied for interiors of automotive design, as well as on wearable tech and fashion tech as an augmentation to everyday interactions. This technology as a product has the advantages of lightweight, foldable textile structures, with the enhancement of multichannel sound.

Appendix

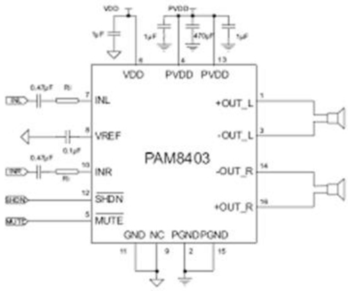
Experiment: thermochromic textile speaker test

Experiment: laser cut test on woven conductive textile

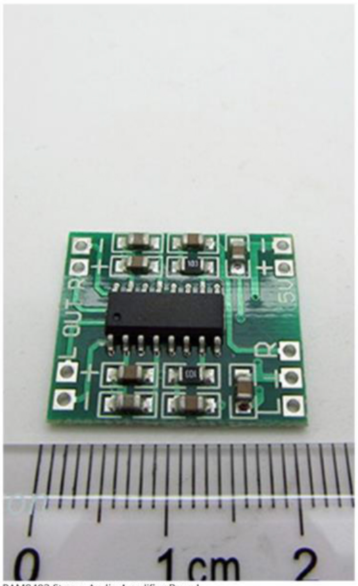


Experiment: soft speaker testing

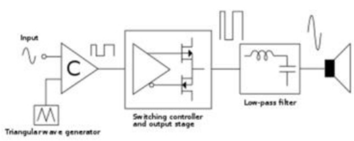
Experiment: laser cutting copper textile

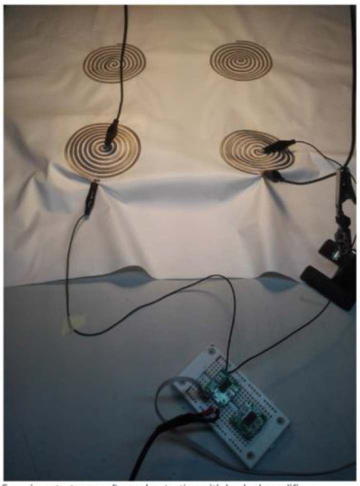


Experiment: testing waveforms in Ableton Live

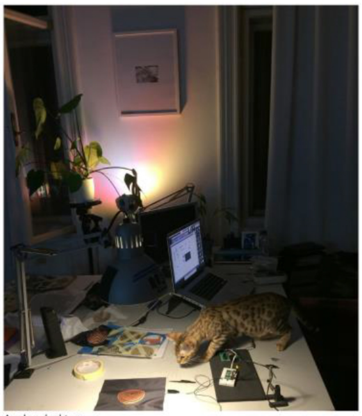


PAM8403 Stereo Audio Amplifier Board

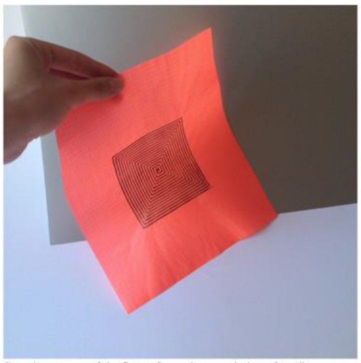


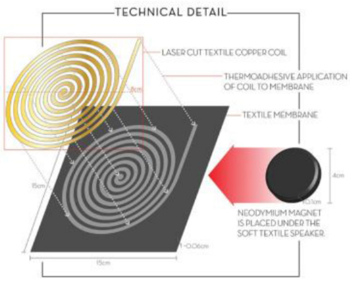

Experiment: stereo soft speaker testing with hacked amplifiers


Experiment: laser cut nonwoven copper textile


Analog desktop

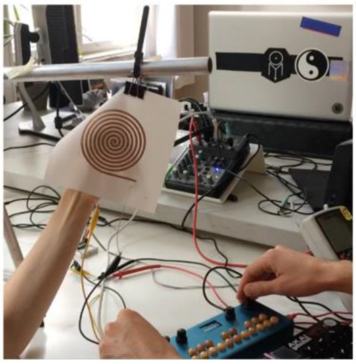

Testing frequencies

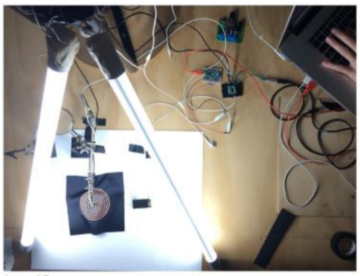

Experiment: one of the first soft speaker on windproof textile

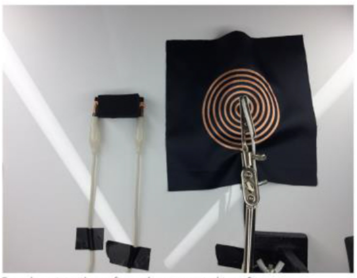


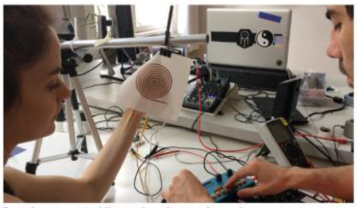
Technical details

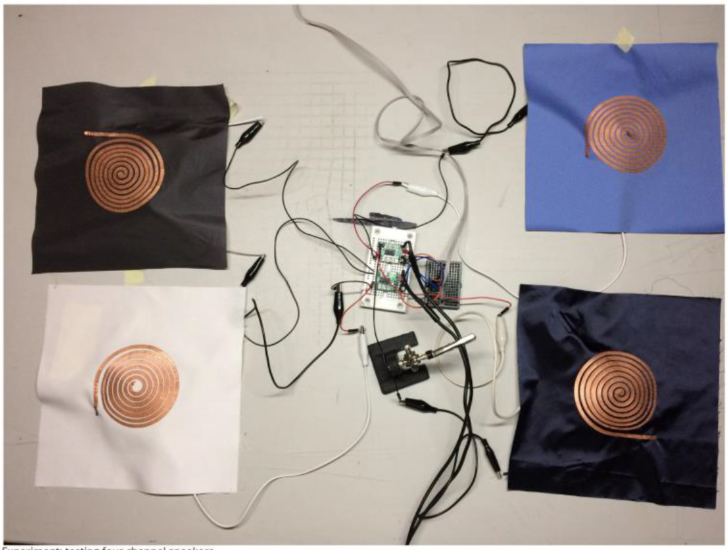

Types of conductive textiles

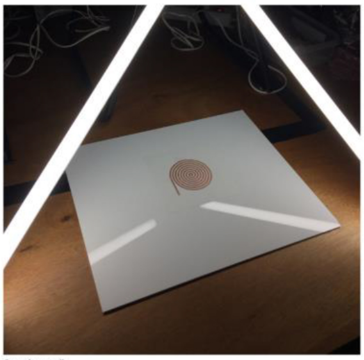


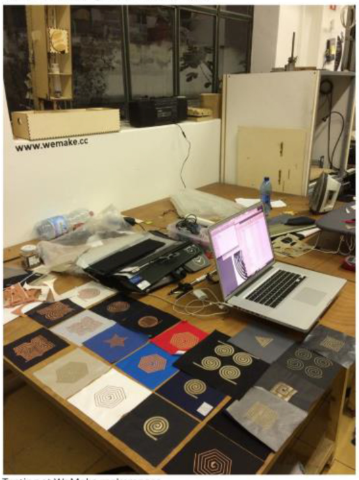

Assembling


Experiment: testing soft speaker connected to soft sensor

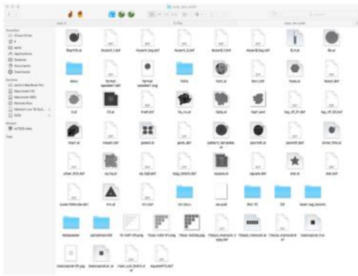

Experiment: assembling and testing a soft speaker


Experiment: testing four channel speakers


Speaker coil

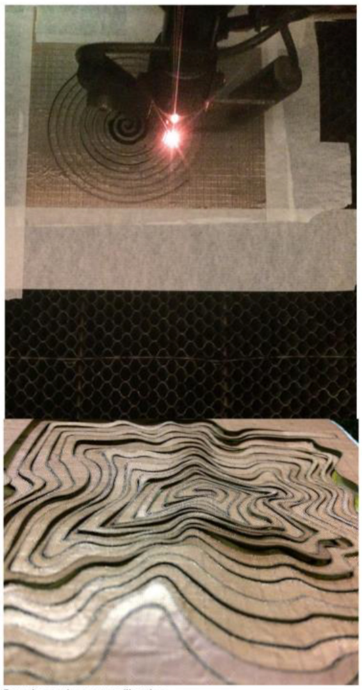


Testing at WeMake makerspace

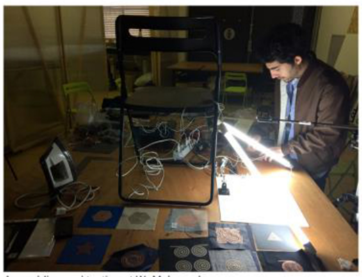

Digital desktop

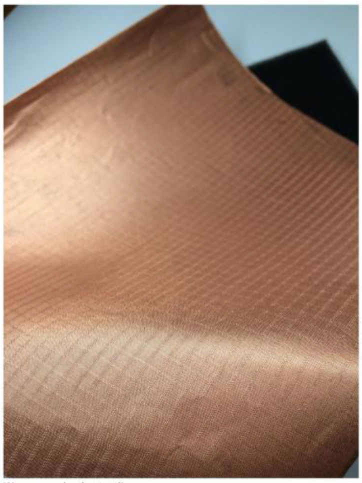

Laser cut coil on transparent textile


Experiment: embroidered soft speaker on technical textile


Experiment: laser cut calibration


Experiment: coil design


Assembling and testing at WeMake makerspace


Woven conductive textile

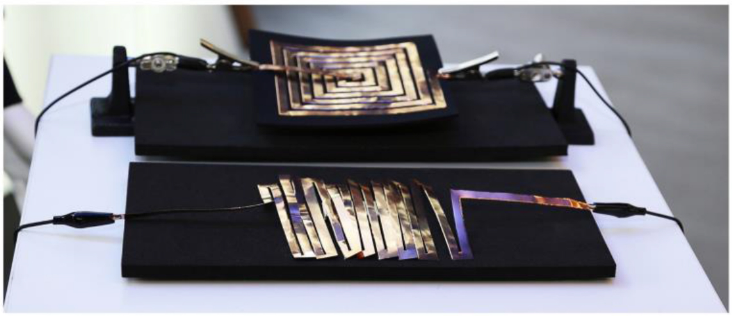

Experiment: woven speaker

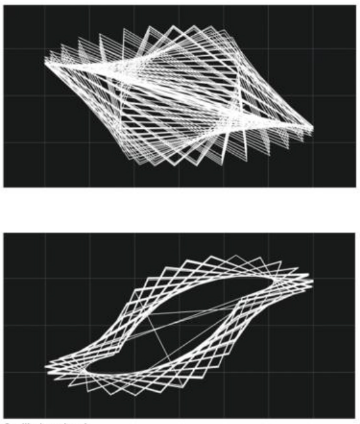

Experiment: liquified speaker test

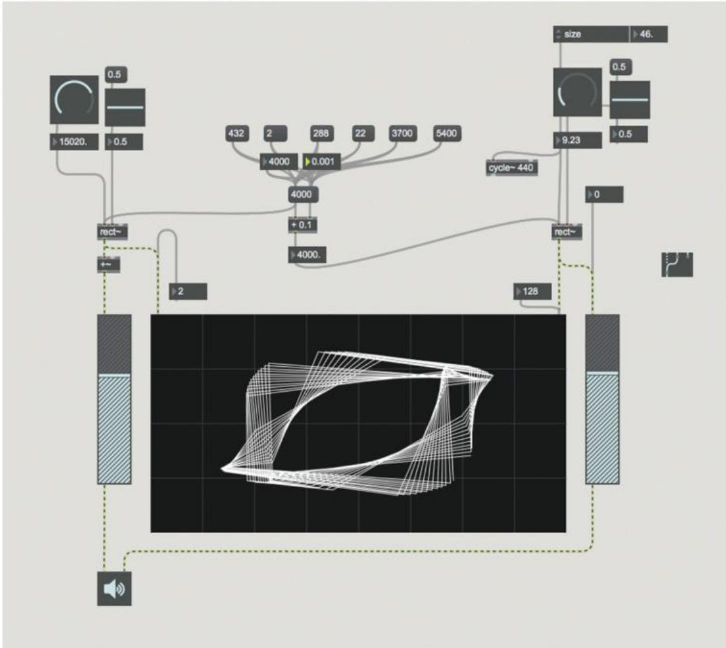

Soundwear


Kozma scholarship exhibition

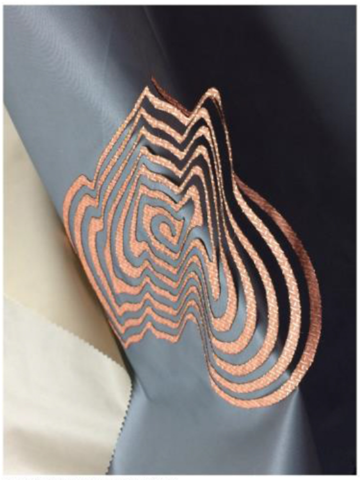

Experiment: speaker connection test


Early soft speakers with copper foil on neoprene


Oscillation visuals



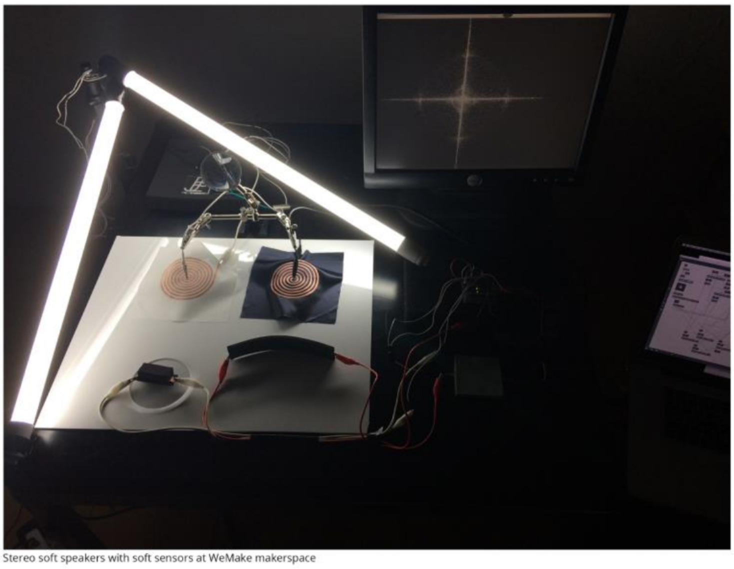
MAX/MSP patch


Experiment: soft speaker variation

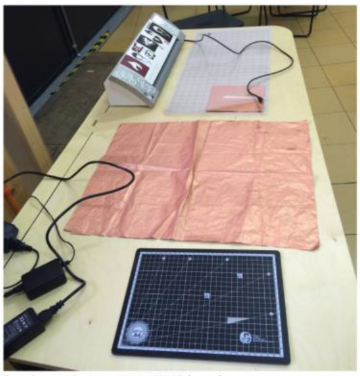

Experiment: laser cut calibration test


Stereo soft speakers

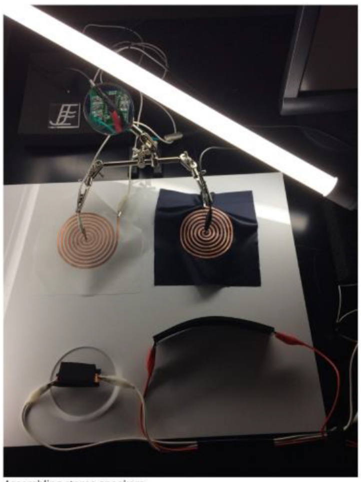

Soft speaker series at Kozma exhibition

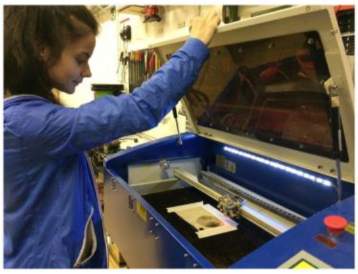

Stereo soft speakers with soft sensors at WeMake makerspace


Experiment: embroidered speaker on technical textile

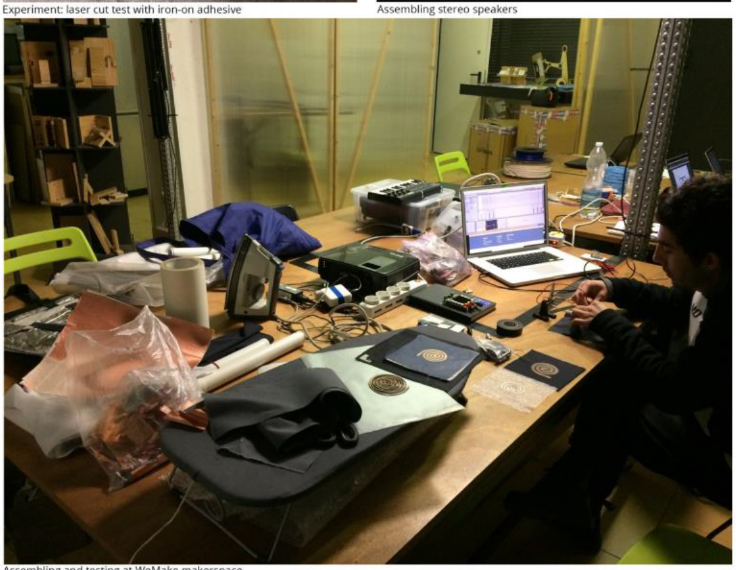

Experiment: plotter cut test at WeMake makerspace

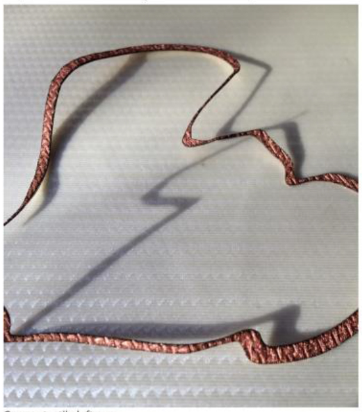

Experiment: laser cut test with iron-on adhesive

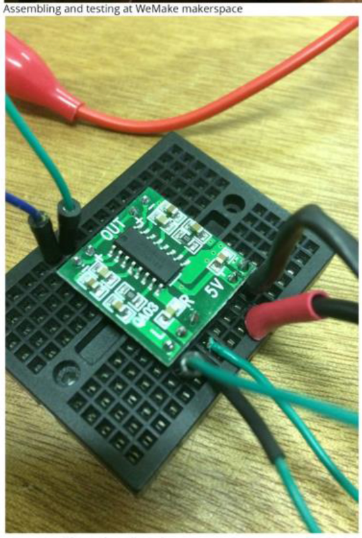

Assembling stereo speakers




Experiment: laser cut testing at WeMake makerspace


Assembling and testing at WeMake makerspace


Copper textile leftover



Stereo amplifier on breadboard


Soft speaker shape variations