University of Art and Industrial Design Linz

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Turntangilism

Enhancing traditional Turntable Setups with Tangible Controls for Digital Sequencing and Live Sampling

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Abstract

This thesis examines how the familiar setup of vinyl DJ turntables can be reimagined by introducing tangible interfaces and digital tools. The goal is to open up new ways of making music while still respecting the traditions and gestures that define vinyl-based DJing.

Influenced by practices such as turntablism, sequencing, and especially live sampling, the project focuses on how physical interaction with sound can be extended rather than replaced.

The outcome of this exploration is the Turntangilism 3000, a modular system that uses small physical tokens, called Tamples (tangible samples), to control sound in playful and tactile ways. The setup connects seamlessly with a standard turntable environment and deliberately avoids screen-based interaction, emphasizing hands-on, non-quantized control. A range of custom-built devices, built around ESP microcontrollers, color and motion sensors, and a Bela audio board, provide the technical backbone for sampling, arranging, and processing audio in real time.

The work is informed by my own background as a DJ, by historical developments in sampling culture, and by research in tangible user interfaces. Alongside documenting the technical development, the thesis discusses the design ideas that shaped the system and reflects on its potential in live performance.

In the end, the Turntangilism 3000 seeks to connect digital and analog approaches, encouraging tangible and playful interaction in a performative context.

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Chapter 1

Introduction

1.1 From Personal DJ Practice to the Turntangilism Concept

As someone who mainly deejays with vinyl, I've often caught myself asking whether a DJ can really be thought of as a musician. Is placing records on a turntable and mixing them slightly comparable to playing an instrument? To me, it feels more like reading the room, sensing the atmosphere, and crafting a coherent playlist in real-time, rather than creating my own unique sounds.

This perspective changes for DJs with a turntablism or hip-hop background. When techniques like scratching come into play, the turntable is no longer just a playback device. It turns into an instrument that can be played expressively and create its own unique sounds.

Turntablism techniques are primarily used in hip-hop, but they don't align particularly well with my style or musical preferences.

But still, the idea of turning the turntable into a musical instrument that works across all kinds of genres was very compelling to me. An instrument I could play in the same context where I usually DJ, mostly bars and clubs.

One feature I particularly miss is (live) sampling, which I use a lot when working in DAWs. Integrating live sampling into a DJ setup would open up new possibilities of musical expression.

All these ideas led me to the following question:
How can a traditional turntable setup be enhanced with digital technologies to integrate new ways of playing music while preserving the original functionality and combining techniques from turntablism, sequencing and live sampling?

1.2 Earlier Works

Before going into details on the related background topics, I want to start by discussing some of my earlier works.

1.2.1 Baby 8 Cubes

A direct predecessor to the Turntangilism 3000 is a tangible step sequencer called Baby 8 Cubes. It features eight quantized steps, each step can play one of four different samples, depending on the rotation of a cube. The cubes light up in different colors, based on the sample they are playing, making it a very intuitive one-track step sequencer.

Originally designed for use in public spaces, such as festivals, the concept later evolved and more features got added.

Eight quantized steps, that sounds a bit boring. But it enables everyone to play it, no musical background needed.

To make it more expressive, the Baby 8 Cubes sequencer includes several features to shape the sound it produces. Tilting it to one side applies a bitcrusher, while tilting it to the other side (away from the performer) applies a delay. The amount of tilt determines the effect parameters. The speed is also tilt-controlled: lifting the left side makes the playhead run downhill and play faster, while lifting the right side slows it down. In addition, a distance sensor is used to temporarily control the volume, the closer the hand comes, the quieter it gets, similar to how a theremin reacts to hand movement.

Figure 1.1: Baby 8 Cubes Step Sequencer

Inspiration

The Baby 8 sequencer is a simple and compact step sequencer often used in DIY electronic music projects. There are both, analog and digital versions. It typically has eight steps (hence the "8" in the name) and is designed to control synthesizers or other sound-generating devices, or even effect parameters, typically through control voltage (CV) and gate signals. One can find many DIY projects, kits, and tutorials online for building a Baby 8 sequencer, for instance on synthdiy[1].

Instead of using knobs or sliders to set pitches or notes, the Baby 8 Cubes uses, as the name suggests, cubes to select the drum sound being played.

A tangible step sequencer for the public space, to be used by children, people without musical education, grandmas. Maybe even an instrument that works well for music therapy.

[1] https://wiki.synthdiy.com/modules/cv-sequencer/baby8/

Implementation

It is based on a Teensy 4.1 and a Teensy audio shield. The audio shield handles sample playback. The Teensy controls the shield, the sensors and the LEDs. The combination of the audio shield and the Audio Library is quite powerful. In this case, it's mainly used to play samples, but it can also synthesize sounds. Additionally, I use it as an effects processor, applying bitcrusher and delay effects, both with dynamic parameter control.

It is a standalone device, additionally it offers multiple connectivity options. Audio can be output either through the headphone jack and line out, or as a class-compliant digital audio interface. MIDI data is transmitted over USB using class-compliant USB-MIDI, enabling integration with other hardware and software setups. It even sends out MIDI clock, allowing it to control other devices, or being the main clock for much more complex setups.

The main part, the cubes, their rotation is detected using Hall effect sensors. Each cube has exactly one magnet on the bottom side, and under each socket sits a PCB with four Hall effect sensors (north, east, south, and west). This makes it relatively easy to robustly detect the cube's rotation. The cube itself can stay very simple: just a plastic shell with a magnet inside. In order to handle 32 inputs, multiplexers have been used.

The tilt detection is done via an accelerometer, mounted at the center of the top plate.

Future Work

The instrument is already functional and has been used in live settings and several jams, but there are many ideas for improvements and extensions.

Form Factor The current version is a bit bulky and heavy. While this works well for workshop situations, it is also a very performative instrumentpeople will notice it on stage and in classrooms, even from a distance. However, it is cumbersome to travel with, and some people might want to play it differently, for example by holding it like an accordion. For these reasons, it would be nice to make it smaller and lighter.

Cube Handling The cube holders need some rework. Ideally, I could use magnets so the cubes would snap into place. Or at least make the walls higher, so the cubes don't fall out easily, when heavily tilted.

Sequencing Velocities The current version allows to sequence pitches well, however there is an opportunity to also sequence velocities. One idea would be to use weights that can be placed on the cubes to indicate loudness. Another option is to somehow set velocities when placing a cube.

Turning It into a Drum Machine Currently, it only plays one sample per step. Cubes could be made configurable, placing up to four magnets on the bottom could enable the playback of different sounds. However, this would compromise the color concept. What color would represent a snare and hi-hat played together? Alternatively, taking inspiration from existing hardware and software sequencers, having four parallel synchronized modules would achieve the same effect and also resolve the color issue mentioned in the previous point.

CV controls Ideally each step would output CV and gate signals, allowing it to control analog synthesizers directly. In combination with a reset CV input, one could shorten the loop length.

Chaining Them Instead of syncing them as explained above, the modules could also be chained, turning them into a 16-step sequencer, or even longer.

System of Tangible Sequencers As already discussed, the cubes in the Baby 8 are actually prisms with a square base. The height does not really matter. Using different polygonal shapes could enable different functionalities. For example, a 12-sided polygon could represent a sequencer that plays 12 different samples per step, making it possible to play a full octave. This could be combined with an octave switch. Multiple such sequencers could be synced to the same clock.

On Stage

The Baby 8 Cubes were performed live at the following events:

- Compost Festival, Linz, 2025 (Baby 8 Cube Boys)
- Out of Control Festival, 2025 (played by Sandra Muciño)

1.2.2 Oramics Beat Machine

(a) Oramics Beat Machine

(b) Daphne Oram's promotional photo, 1966
Source: `https://www.daphneoram.org/oramicsmachine/`

Figure 1.2: Oramics Beat machine and the original Oramics Machine.

The Oramics Beat Machine is a machine-learning-based drum sequencer with hand-drawn drum notations. Each shape represents a different drum sound (e.g. a square maps to a kick drum, a circle to a snare, a horizontal line to a closed hi-hat, etc.).

The speed of the sequence can be changed by pulling the paper strip with the notation faster or slower through the machine. The playback direction can also be changed by pulling the strip in the opposite direction. It can even be changed midway, a feature which is not available in most DAWs.

Inspiration

This concept was inspired by the work of Daphne Oram, especially her Oramics Machine (Manning [2012]). She was a pioneer in the field of electronic music and co-founder of the BBC Radiophonic Workshop. Her innovative approach to sound synthesis and manipulation laid the groundwork for many modern music technologies (Hutton [2003]).

The Oramics Machine was an instrument that allowed users to create sounds by drawing shapes on transparent 35mm film strips. Each strip controls a different parameter. It was possible to sequence pitches, timbres, and dynamics via the drawings on the film (Marshall [2009]). Figure 4.2b shows Daphne Oram's promotional photo from 1966.

Implementation

It used a custom-made openFrameworks app to downscale the webcam feed to a 64x64 grid and send that grid via OSC to Wekinator by Fiebrink and Cook [2010], a machine learning tool that can be trained to run classification algorithms. Wekinator communicates via OSC, making it easy to integrate with other software. It just does the machine learning tasks, not sensing or sound synthesis tasks. Wekinator was trained to recognize different shapes such as horizontal lines, vertical lines, squares, circles, etc. The classification results were again sent via OSC to a Pure Data patch that triggered the drum sounds.

1.2.3 Crank 3000

Crank 3000 is an instrument/controller built for the Klang-/Licht STROM project[2], which was performed at Blaue Nacht in 2022[3], and on numerous other occasions. When not in performance mode, the setup was turned into

[2] https://klanglichtstrom.de
[3] https://www.nuernberg.de/internet/dieblauenacht/

Figure 1.3: Crank 3000: Glump live at Kunstraum Sommerfest, Munich, 2024

an interactive installation open to the public, allowing visitors to experience and control it themselves.

It was operated with a single, simple controller placed at the center of the room. One look and you immediately know what to do: crank it!

In this setup, the crank functioned more like a generator that fed energy into the installation. The longer one cranks, the more energy builds up in the system, the louder the sounds become and the more they move around the space.

An LED strip served as a level meter, visualizing the current energy state.

The main idea is that players must load the system with energy by cranking it, and they need to keep cranking, otherwise the system gradually loses energy. This constraint creates a unique form of interaction that is still highly performative, and from the audience's perspective, both fun and engaging to watch.

Implementation

The setup is based on a home trainer bike with a magnet attached to one of the pedal spokes. A Hall effect sensor detects each time the magnet passes by, similar to the principle of a bicycle speedometer.

A Teensy microcontroller processes the sensor data and outputs both MIDI and OSC messages. It only transmits one parameter, namely the energy level. It is transmitted as a MIDI Control Change message, and when using it in OSC mode, it simply sends the normalized energy value.

There is also a backchannel to configure the controller via OSC or MIDI, for instance to set the increment per rotation, or the decay rate.

The device can be powered either via USB or through PoE, allowing for flexible installation options.

On Stage

Originally built for Klang-/Licht STROM, it has since been used in other performances:

- The End of the Future, Linz, 2023 (Silent Sex)
- Kunstraum Sommerfest, Munich, 2024 (Glump)
- Leicht über Linz, Linz, 2025 (Postdigital Ensemble)

1.2.4 TAW - Tangible Audio Workstation

TAW is a first-semester project I created in 2023 as part of Seminar 1 of the master program, a fictional design exercise. However, it wasn't entirely fictional, since I already had certain technical limitations in mind and planned to eventually build it. Later, I realized that the idea is closely related to the Turntangilism 3000 project.

The concept was to create a one-track tangible audio workstation, where tokens representing audio samples could be placed freely on a surface, and the playhead could be moved manually, forward, backward, and at any speed.

Figure 1.4: TAW - Tangible Audio Workstation with wooden tokens representing audio samples

The wooden blocks in Figure 1.4 represent the tokens, which can be placed on a surface. The red and black acrylic serve as a generative background texture.

This project has never been implemented, but by prototyping and creating mockups, it laid the groundwork for future ideas, including the Turntangilism 3000.

Chapter 2

Background

This chapter provides an overview of the foundational concepts that this work is based on, namely turntablism, sampling, and sequencers. Turntablism, as a form of musical expression through manipulating records on turntables, inspires the interactive and performative aspects of the instrument. Sampling, as a method of capturing and recontextualizing sound, enhances the traditional turntable setup with a new feature people know from the digital production domain. Finally, sequencers, in particular tangible ones, play an important role in bridging the gap between physical interaction and digital sound generation.

2.1 Turntablism

2.1.1 Introduction

Turntablism is the art of manipulating sounds and creating music using turntables and a DJ mixer. This practice involves techniques such as scratching and beat juggling to creatively manipulate and mix pre-recorded sounds. Turntablists, also known as DJ artists or scratch DJs, use the turntable as a musical instrument, producing original compositions and performances that go beyond just playing records. Turntablism is a key element in hip-hop culture, but is also used in various other music genres and styles (Weissenbrunner [2017]).

The term Turntablism was introduced by DJ Babu from the Beat Junkies crew in the mid-1990s. DJ Babu used it to distinguish the art of manipulating records and creating sounds with turntables from the traditional role of DJ, namely playing and mixing music (Smith [2016]).

Turntablism is a highly rhythmic art form that requires hand coordination and a strong sense of rhythm. It does not necessarily require extensive knowledge of music theory, unlike some traditional musical instruments.

It is interesting that the instrument itself was basically created by hacking a music playback device. What began as a creative manipulation of turntables, originally designed for playing recorded music, developed into a unique musical practice. This is in a way similar to how early musical instruments were repurposed from hunting tools, e.g. hunting bows, later functioning as musical bows (Montagu [2007]), telecommunication devices from the war times or everyday objects.

The following subsections will dive deeper into the historical context of turntablism and hip-hop culture, including the history of vinyl players, and will be followed by an overview of various techniques and contemporary examples.

2.1.2 Historical Context

Before discussing the historical context of turntablism, I will first provide a brief overview of the history of vinyl players.

Record Players

Figure 2.1: Technics SL 1210 - a classic DJ record player

Source: `https://www.thomann.de/de/technics_sl_1210_mk_7.htm`

As Millard [2005] states, the history of record players dates back to the late 19th century. When Thomas Edison invented the phonograph in 1877, which played sound recorded on a rotating cylinder. Soon after, in the 1880s, Emile Berliner advanced this concept. He developed the gramophone. The gramophone used flat discs instead of cylinders. The early records were typically made from shellac. By the early 20th century, turntables that could play these records became more and more popular. They found their way into homes, making recorded music more accessible.

Vinyl records, as we still know them today, were introduced in the 1940s. The players gained in popularity in the 1950s and 1960s, as the sound quality improved and devices got more affordable. With the rise of rock and roll, jazz, and other genres, vinyl records became a cultural icon. Cassette tapes, later CDs and digital formats challenged vinyl's dominance. Turntables remained a beloved medium for audiophiles and musicians.

By the late 20th century, turntables had found new life in DJ and hip-hop culture, they became instruments for scratching, mixing, and turntablism (Katz [2012]). Vinyl players are still appreciated today, both for their warm sound quality and as nostalgic, collectible items.

History of Turntablism

Early Record Player Experiments

In the 1930s, people started to experiment with turntables, using them as instruments rather than just playback devices. Experimenters explored techniques like speed manipulation, looping, and reversing records to transform recorded sound.

Paul Hindemith, Ernst Toch's "Grammophonmusik" (1920s - 1930s) experimented with manipulating phonograph records in live performances, changing playback speeds and directions to create new sound textures. Toch's Gesprochene Musik (1930) used recorded speech manipulated with turntables (Raz [2014], Katz [2001]).

John Cage's Imaginary Landscape No. 1 (1939) used variable-speed turntables as instruments, manipulating test-tone records to create new sound textures, foreshadowing DJ techniques like pitch control and live mixing (Nyman [1999]).

Schaeffer, the father of musique concrète, experimented with manipulating records by looping grooves, playing them in reverse, and changing playback speeds in this work (De Lautour [2017]).

Techniques used in these early works, can later be found in turntablism culture.

Sound Systems

Sound systems emerged in Jamaica in the late 1940s, revolutionizing the way music was experienced and shared. These mobile setups, consisting of turntables, large speakers, amplifiers, and custom-built equipment, allowed DJs, known as selectors, to play records at street parties for massive crowds. At a time when radios were limited and live bands were expensive, sound systems provided an affordable and electrifying way for people to hear the latest music. Competition between sound system crews fueled innovation, with operators constantly seeking louder, clearer sound and exclusive records. To gain an edge, some DJs would even travel abroad to source rare vinyl, giving their sound system a unique identity.

Figure 2.2: A Jamaican-style sound system, a key element in reggae and dub culture

Source: *https://www.museumofyouthculture.com/sound-system-culture/*

Beyond just playing music, sound systems transformed into a creative platform. DJs developed new techniques like toasting, rhythmic spoken word over instrumentals, which directly influenced the rise of rap in hip-hop. Producers like King Tubby and Lee "Scratch" Perry pioneered dub music by remixing tracks, stripping vocals, adding effects, and reshaping songs in real-time, laying the groundwork for remix culture. As Jamaican migrants brought sound system culture overseas, it left a lasting impact on global music scenes, influencing everything from hip-hop block parties in New York to UK rave culture and electronic dance music (Henriques [2011]).

From Radio Stations to Homes to Discotheques

While sound systems were growing in Jamaica, deejaying was also spreading in other parts of the world. In the early 20th century, radio DJs shaped musical taste by choosing and sequencing records for broadcast. As record players became cheaper, people started building their own collections at home, creating a more personal connection to recorded music. By the 1960s and 1970s, DJs had become central to nightclubs and discothèques, often taking the place of live bands by mixing records to keep people dancing. The rise of disco and later electronic music made the DJ a performer in their own right, paving the way for new, experimental approaches like turntablism.

From Discotheques to Turntablism

Turntablism emerged from DJs pushing the limits of the turntable, though it was not recognized as a discipline until the late 1970s and early 1980s. Radio DJs, reggae sound systems, and disco selectors had long used turntables to mix tracks, but hip-hop DJs in New York were the first to treat the device as a musical instrument.

In the Bronx, DJ Kool Herc pioneered the breakbeat by looping instrumental sections of funk and soul records, a method he called the Merry-Go-Round (Chang [2007]). Grandmaster Flash refined this with his quick mix theory, while Grand Wizzard Theodore introduced scratching, transforming a mistake into an enduring technique. These innovations set the stage for turntablism.

By the 1980s, DJ battles pushed artists to develop new methods such as beat juggling. Crews like the Invisibl Skratch Piklz, X-Ecutioners, and Beat Junkies elevated these practices into an art form. The word turntablism itself was coined in 1995 by DJ Babu to distinguish record manipulation from simply playing tracks.

Smith [2016] describes turntablism as rooted in hip-hop's culture of creativity and resilience. At block parties, DJs remixed familiar songs into something new, using the turntable as both instrument and voice. In this sense, turntablism became a form of empowerment, standing alongside rapping, graffiti, and breakdancing as one of hip-hop's core elements. Over time, it spread into electronic music and experimental sound art, yet it still reflects the capacity of marginalized communities to reclaim and reshape culture on their own terms.

Before turning to specific techniques, it helps to clarify a few key terms that often appear in discussions of DJ culture and turntablism.

MC-ing An MC is the Master of Ceremony, a person who hosts an event, guides the audience through the performance, introduces DJs. Originally the term Master of Ceremonies comes from the Catholic Church, where it referred to the person overseeing proper conduct during liturgical events. In hip-hop, the MC took on a new life. Someone who hypes the crowd, rapping over DJ beats, rhyming, storytelling, battling.

Battle Style Battle style means positioning turntables with their short edge (front side) facing the DJ, allowing for tighter spacing, faster hand movements, and better control for scratching and beat juggling. The mixer sits centered between them in a compact layout.

Club Style Traditional "club style" has the long side facing the DJ.

2.1.3 Techniques in Turntablism

Turntablists usually use a setup consisting of at least two direct-drive turntables and a DJ mixer, with volume controls - mostly cross-fader and channel volume. They use their hands to manipulate the records on the turntables by moving them, and the mixer to rhythmically cut sounds.

Hansen [2002] gives an overview of the basic techniques used in turntablism. Here are some of the most common techniques:

Scratching

Scratching is a technique where the DJ drags the vinyl record back and forth against the needle on a turntable to create rhythmic sounds and effects. It is often used in combination with a crossfader on a DJ mixer to cut sounds in and out.

- **Baby Scratch** is the most basic form of scratching. The DJ moves the record back and forth without using the crossfader. This technique is often used to create simple rhythmic patterns. Many of the more complex techniques build upon the baby scratch.
- **Forward/Backward Scratch** Only the forward motion of a scratch is audible, the backward motion is silent, is cut via the crossfader. Backward scratch is the opposite, only the backward motion is audible.

- **Flare Scratch** The flare scratch is a more advanced technique. One creates a "flaring" effect by quickly cutting the sound in and out while scratching the record.

Beat Juggling

Beat Juggling is a technique where the DJ uses two records, sometimes two copies of the same record, to create new rhythms and patterns by alternating between the two records. Playing a drum break from one record, while rewinding the inaudible record to the beginning of the break, then switching to the other record to play the break again, and so on. This of course is very often combined with scratching techniques to create more complex patterns.

Pitch Shifting

Pitch shifting is used in different ways. One common method is to adjust the pitch/playback speed of a record to match the tempo of another record. This can be used to transition smoothly between the records or blend them together.

The other way is to use pitch shifting as an expressive technique. This involves altering the pitch of a sound in real-time during a performance. One can, for instance use this technique to create gliding or detune effects, similar to a pitchbend on a synthesizer. Modern record players such as the Reloop RP-8000 MK2 allow to use performance pads to change the platter speed in real time[1]. This feature is intended to be used with time-code vinyl and digital tools, but can also be used with regular vinyl records.

[1] https://www.reloop.com/reloop-rp-8000-mk2

2.1.4 Contemporary Practice

Despite its long history and innovation in digital technologies, turntables are still an interesting and fascinating medium today. Here are some contemporary examples of artists and projects that utilize turntables in innovative ways.

Graham Dunning - Mechanical Techno

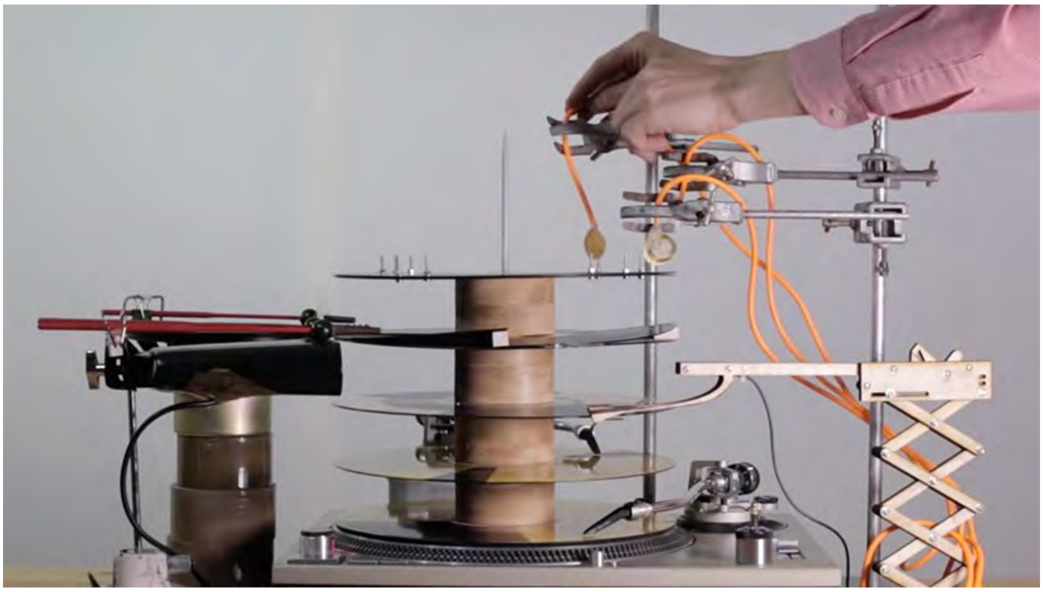


Figure 2.3: Graham Dunning's Mechanical Techno setup

Source: *https://www.designboom.com/technology/graham-dunning-mechanical-techno-turntable-project-11-27-2015/*

According to Dunning [2024], the artist and DJ who used multiple manipulated stacked records on a single turntable to create a complex layered beat. Each record has different grooves cut into it, which produce different sounds when played together. He does not use digital technologies to create or manipulate the sounds, relying solely on the physical properties of the records and turntable. For instance he tapes records, so they would create a stuttering effect when played. Or he would add screws to the record that would hit piezo contact microphones to create a rhythmic clicking sound. Quite a fascinating project that showcases the physicality and mechanical nature of turntables, as well as the power of repetition and looping.

Julia Bünnagel - Sounds like ... Vienna

Figure 2.4: Record Player with a Concrete Record by Julia Bünnagel
Source: *https://www.juliabuennagel.de/en/1616129540*

Julia Bünnagel creates concrete records: moulds of sidewalks and street surfaces in Vienna are cast in concrete to make turntable records of the pavement surfaces. This results in a very noisy, gritty sound when played on a turntable. Playing them on a typical two turntable DJ setup with a mixer, she turns the DJ set "into an urban sound sculpture, an architecture rave" [2]. She played these records in public spaces, using the ambient noise and acoustics of the environment to create a unique soundscape, bringing back the sound of the city to its inhabitants in a new way.

Ronald van der Meijs - Clouds of Knotted Sound

Figure 2.5: Clouds of Knotted Sound installation.
Source: *https://www.ronaldvandermeijs.nl/Clouds-of-Knotted-Sound*

Clouds of Knotted Sound is a sound installation that uses two turntables with a Tibetan singing bowl at the center. The tonearm is equipped with a wooden stick instead of a needle, which would strike the bowl as the record turns. In this way, the tonearm does not read a groove, but rather excites and plays the bowl. There is no mixer and no amplification, the sound is produced acoustically by the bowl itself. Differently tuned bowls or different platter speeds produce different sounds. The interaction between mechanical

[2] `https://www.juliabuennagel.de/en/1616129540`

movement and acoustic resonance defines the unique character of the piece.

Carsten Nicolai - Bausatz

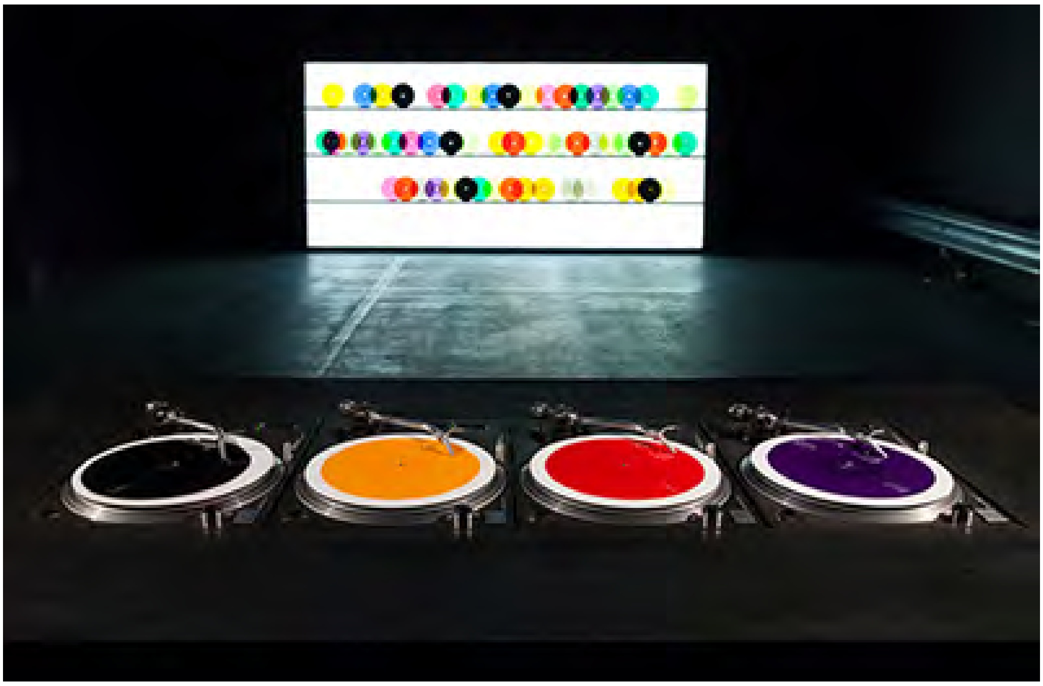


Figure 2.6: Photo of Carsten Nicolai bausatz noto Installation
Source: *https://artfrontgallery.com/en/exhibition/archive/2015_12/511.html*

Bausatz is the German word for assembly kit, and this is exactly what this work is about. It exists as an installation but also as a Vinyl Box set, consisting of 12 colored vinyls. Each vinyl contains 10 loops.

For the installation, tNicolai uses four turntables, but this work also works with a two turntable setup[3]. Listeners can choose any combination of loops, by placing the records on the turntables. The loops are designed to be played together, creating a complex soundscape.

[3] http://carstennicolai.com/?c=works&w=bausatz_noto

2.2 Sampling

2.2.1 Introduction

Sampling in music production refers to the technique of taking a portion or "sample" of an audio recording and reusing it, as it is, or manipulated, as an element in a new composition. The sampled material can be anything from a musical phrase, drum beat, vocal snippet, or field recordings. It is often manipulated through editing, filtering, looping, pitching, and processing through an effects chain to fit into the new musical context.

A processed sample can also be resampled, meaning that the audio signal is recorded again, after effects and manipulations have been applied. This allows producers to create a new sound from the altered audio, simplify complex processing chains, or free up computing resources.

2.2.2 Historical Context

Early Forms of Sampling

Sampling actually began long before computers made it easy. Battier [2007] points out that in the 1940s and 50s, composers like Pierre Schaeffer GRM in Paris started experimenting with musique concrète, recording everyday sounds onto magnetic tape and using them to create new music. They physically cut the tape into pieces, looped or rearranged them, and changed the playback speed to alter pitch and duration. Sometimes they played tapes backward or layered several recordings to build rich, complex textures. These manual techniques laid the groundwork for early sampling, long before digital technology made the process faster and more flexible.

Musique concrète was often performed by playing back the prepared tapes through loudspeakers. Performers could use multiple tape machines at once to mix different sounds live, adjusting playback speed, starting and stopping tapes, or switching between loops in real time. This hands-on approach made each performance unique and allowed for improvisation and experimentation with recorded sounds as musical material.

Other radio stations and studios experimented with these techniques as well, including the BBC Radiophonic Workshop in London, creating sound effects and music for radio and TV shows, e.g. the iconic Doctor Who theme.

The Rise of Digital Sampling

As Harkins [2019] or Exarchos [2019] point out, the real breakthrough came in the late 1970s and early 80s with the arrival of digital samplers like the Fairlight CMI, EMU Emulator, and Akai MPC. For instance the Fairlight CMI, introduced in 1979, was basically the first digital sampler, hence its price was quite high, only allowing big production studies or well established artists to buy it. These machines made it possible to record short sounds and then play them back, change their pitch, loop them, and arrange them easily. This technology was especially important for hip-hop and electronic music, where producers built new songs by reusing parts of other recordings. Sampling helped blend different styles and cultures in new and exciting ways.

As Exarchos [2019] notes, one of the most iconic sampling styles to emerge from this period was boom bap, a subgenre of hip-hop that developed in the late 1980s and early 90s. Known for its hard-hitting drum patterns, typically a deep kick on the downbeat (boom) and a sharp snare on the backbeat (bap). Boom bap relied heavily on sampled drum breaks and melodic fragments from jazz, funk, and soul records. Producers like DJ Premier, Pete Rock, and J Dilla used samplers such as the Akai MPC to chop, loop, and rearrange samples into new rhythmic structures. This approach gave the music a raw, gritty character and showcased the sampler not just as a playback tool, but as a central creative instrument in the studio.

Today, sampling continues to evolve with digital audio workstations. There is a huge amount of online sample libraries, and AI-generated sounds. Contemporary practices will be explored more in detail in the following section.

2.2.3 Sampling in Contemporary Music Production

In contemporary music, sampling is used in many different ways, from studio production to live performance.

Many of the instrument plugins are based on recorded samples. For example, a virtual piano instrument might use high-quality recordings of each key being played at different velocities with different microphones, allowing musicians to play realistic piano sounds using a MIDI keyboard. These sample banks can become quite large, sometimes several gigabytes in size.

Stem separation refers to the process of isolating individual elements (or "stems"), such as vocals, drums, bass, or melody, from a full audio mix. Originally, access to stems required the original multitrack recordings, but advances in machine learning and signal processing have made it possible to extract stems from finished stereo tracks. This technique is especially valuable for sampling, remixing, and live DJing, as it allows artists to isolate specific parts of a song to manipulate or recontextualize them. Tools like Spleeter [4] or LALAL.AI[5] have made stem separation more accessible, opening new creative possibilities in music production and performance. Ableton 12.3 has integrated stem separation directly into its workflow [6]. Stem separation is a feature that is also integrated into DJ software such as Algoriddim DJ Pro [7].

Digital Audio Workstations (DAWs) are software environments used for recording, editing, and producing audio. DAWs like Ableton Live, FL Studio, Logic Pro, and Pro Tools have made sampling more accessible by integrating features such as time-stretching, pitch-shifting, chopping, and triggering samples directly within the interface. These platforms allow producers to work entirely in-the-box, combining recorded sounds, virtual instruments, and effects to create complex compositions without the need for external hardware.

Live Sampling

Live Sampling in today's music performance has been transformed by advances in computing power and specialized tools designed for real-time audio capture and manipulation. Unlike traditional studio sampling, live sampling allows artists, DJs, and performers to record and process sounds on the spot, and integrate them into their performance. Modern DJ mixers and performance controllers often include built-in features for live looping and sample triggering, while software like Ableton Live, Native Instruments' Traktor, and Serato DJ offer integrated live sampling capabilities.

[4] `https://spleeter.online/`
[5] `https://www.lalal.ai/`
[6] `https://www.ableton.com/en/blog/live-12-3-is-coming`
[7] `https://www.algoriddim.com/djay-pro-mac`

Live Looping is a performance technique where musicians record audio snippets in real time and play them back in loops. By adding layers on top, one can build complex textures and arrangements on the fly. Using hardware devices like loop pedals or software tools within digital audio workstations, performers can loop vocals, instruments, beats, or any sound source, building up complete song structures or soundscapes during a live set. This approach encourages improvisation and spontaneity.

2.2.4 Sampling Process

The first step in working with samples is to find an interesting sound. This sound can come from many sources: nature, such as field recordings; playback media like tape, vinyl, or CDs; or even digital libraries. Sometimes, producers start with a clear idea of what they want to create, while other times, they stumble upon a sound that inspires them without knowing exactly where it will lead. Samples are often chosen for their unique characteristics, for example, sounds with clear transients tend to work very well with techniques like granular synthesis, at least according to my personal taste.

Once a sample is selected, the manipulation process begins. This usually starts with cropping the sample, as the initial snippet may not have perfectly set start and end points. Sometimes the sample contains unwanted noise that requires filtering. Pitch manipulation is also very common to help the sample fit harmonically into a composition. Changing the pitch traditionally involves adjusting the playback speed, faster playback raises the pitch, while slower playback lowers it. Additionally, time-stretching allows the length of a sample to be changed without affecting its pitch. However, modern digital audio workstations (DAWs) can alter pitch independently of the sample's length, often using granular synthesis to achieve this effect. Although not perfect, this method provides a flexible and powerful tool for shaping samples to fit the musical context.

After manipulating a sample through cropping, filtering, pitch changes, and time-stretching, producers often use resampling to record the processed sound as a new audio file. This lets them capture the modified sample with all its effects applied, creating a fresh sound that can be further edited or layered. Resampling also helps reduce the processing load during production or performance by consolidating complex effects into a single sample.

2.3 Sequencers

2.3.1 Introduction

A sequencer in music production and live performance is a device or software that records, edits, and plays back sequences of musical events, typically in the form of MIDI data or control voltage. Sequencers allow one to arrange notes, rhythms, and other musical parameters in a specific order over time. These sequences can control synthesizers, drum machines, and other instruments, enabling the creation of complex compositions and performances. Some sequencers also include features for looping, quantization, and automation, making them essential tools in modern music production (Arar and Kapur [2013]).

Since sequencers are often used in combination with drum generators, drum machines were developed, effectively combining a sequencer with a built-in drum generator.

2.3.2 Historical Context

Punch Card Sequencers and Music Automata

Mechanical Music Automata Mechanical music automata are self-playing musical instruments that use mechanical means to produce sound. Michaud [2020] describes in their thesis several types of mechanical music automata, including:

- Musical Clocks
  Musical clocks date back to the 13th century and were some of the earliest examples of automated musical instruments, first being used in churches and clock towers, later also in private homes.
- Music Box (18th century)
  Small self-contained mechanical music automata, often with a cylinder with pins that plucks tuned metal combs. They are still common today as toys and souvenirs.

- Barrel Organ (18th century) Barrel organs use a pinned barrel to trigger notes on pipes, similar to a music box but on a larger scale.
- Player Piano/Pianola (19th century)
  Self-playing pianos that use perforated paper to control the keys. They were used in upper-class domestic settings, as entertainment devices, before radio broadcasting got popular. Also in public venues like bars and cafes, without the need for a live pianist. Self-playing pianos are still around today, though more in the experimental music scene. Icelandic composer Olafur Arnalds uses a self-playing piano in some of his compositions. He uses custom-made MIDI effects that would augment his live piano playing with the self-playing pianos. He collaborated with Spitfire Audio to create a digital instrument based on his self-playing pianos [8].

These early mechanical music automata very often used pinned barrels to encode musical information (Chen et al. [2018]).

Figure 2.7: Punch card music box
Source: https://mitxela.com/projects/musicbox

Punch Cards and Paper Rolls Instead of using pinned barrels or discs, some mechanical music automata used paper cards or rolls with holes to encode musical information. This development not only simplified manufacturing, but also made the systems more flexible, since scores could be produced more easily and even punched by hand. Users were able to create their own musical programs.

The principle of holes in a physical medium to encode information was later used in weaving industry, with the invention of the Jacquard loom in 1801 by Joseph Marie Jacquard (Fernaeus et al. [2012]).

A technology that influenced early computing.

[8]https://www.spitfireaudio.com/olafur-arnalds-stratus

Digital Technology getting accessible in the 80s With digital technology becoming cheaper and more accessible in the late 70s and early 80s, digital sequencers started to become more common in music production, both for live and for studio productions. The introduction of MIDI in 1983 (Rothstein [1995]), which allowed different electronic instruments and devices to communicate with each other, made sequencers even more powerful and flexible to use. Sequencers were everywhere in the 80s, from pop music (e.g. Synthpop, New Wave: Depeche Mode for instance used sequencers extensively) to experimental electronic music.

Sequencers and drum machines shape much of the 80s sounds, they also played an important role in 90s techno and rave culture. Not only were they used in studios, they were also used for live performances, integrating into DJ sets.

Contemporary Examples

Figure 2.8: Robert Henke's CBM 8032 AV setup

Source: `https://aefestival.gr/festival_events/robert-henke-cbm-8032/?lang=en`

Robert Henke - CBM 8032 AV Robert Henke's *CBM 8032 AV*[9] is an example of a live performance setup that integrates sequencing and visual elements. The clue here is the use of the Commodore 64 computer, which was popular in the 1980s. The system uses custom software to control both audio and video in real-time, allowing for a highly synchronized and dynamic performance. One of the five computers is used to sequence his setup. During live performances, Henke often begins by sharing a screen view, him operating his self-programmed tracker (2.3.3).

Memo Akten - Simple Harmonic Series Memo Akten's *Simple Harmonic Series* is a rule-based, generative sequencer. Instead of following a fixed pattern like a traditional step sequencer, the sequences are produced according to physical principles derived from the harmonic series. While it does not use a conventional grid or steps, it can be understood as a form of algorithmic sequencing that explores the intersection of sound, mathematics, and time.

These sequences can be rendered in many different ways, including audio, visuals, or even kinetic outputs, as Akten has explored with moving heads and other physical actuators [10].

[9] https://roberthenke.com/concerts/cbm8032av.html

[10] https://www.memo.tv/works/simple-harmonic-motion-for-light-at-signal-festival-2019/

2.3.3 Sequencer Topologies

Linear Sequencers

Linear sequencers arrange musical events on a timeline, typically from left to right. The playhead moves from start to end, usually at the same speed, triggers events as it passes them, when reaching the end, it either stops or loops from the beginning.

Most linear sequencers are quantized, the timeline is divided into fixed steps, events can only be placed on these steps. This makes it easy to create rhythmic patterns, but also limits the expressiveness of the sequencer. Usually events are either on or off, meaning that a note is either played or not played at a given step. But sequencers can also support additional parameters, such as velocity, length, or even probability.

Examples

Figure 2.9: Moog 960 Sequential Controller

Source: *https://en.wikipedia.org/wiki/Analog_sequencer*

Moog 960 Sequential Controller The Moog 960 Sequential Controller is a classic example of a linear step sequencer, with 8 steps per row and 3 rows (Arar and Kapur [2013]). It features a series of knobs and switches that allow users to program sequences of control voltages. It was released in the early 1970s and has been widely used in electronic music production ever since.

Figure 2.10: Korg SQ-10 Sequencer
Source: https://www.ctrl-mod.com/products/used-korg-sq-10-ec45c96d-47c8-41fe-875c-701301c752a8

Korg SQ-10 The Korg SQ-10 is another example of an early analog step sequencer, released in the late 1970s. The SQ-10 features 8 steps and can be used to control synthesizers such as the Korg MS-20. It has a simple interface with knobs for each step to set the pitch and buttons to control the sequence playback.

Trackers A tracker is a software sequencer that represents musical notes and events in a grid-like format, similar to a spreadsheet. They are text-based and often use hexadecimal notation to represent musical data. In the 1980s and 1990s, trackers were popular on platforms like the Commodore Amiga and early PCs. The early trackers were self contained, using sample based synthesis, later versions could also send MIDI.

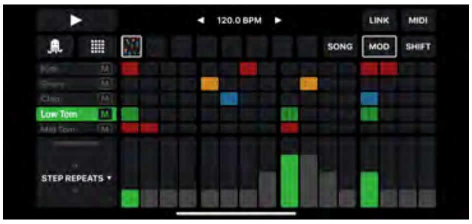


Figure 2.11: Octachron drum Sequencer
Source: *https://www.octachron.de/*

Octachron Octachron is an iOS (drum) sequencer app that features a linear step sequencer interface. It does not generate sound itself, but can send MIDI to other apps or external devices. It includes a variety of mappings for different drum generators and synthesizers. Being a digital app, it offers features that are difficult to implement in analog hardware, such as random pattern generation and organizing sets in layers[11].

Figure 2.12: Arturia Keystep Pro
Source: *https://www.thomann.de/de/arturia_keystep_pro.htm*

Arturia Keystep Pro The Arturia Keystep Pro is, as the name suggests, a keyboard with an integrated step sequencer. It is a very powerful and compact device, that can be used both in the studio and for live performances. It integrates well into digital as well as analog setups, with MIDI, USB, and CV/Gate connectivity. Additionally, it features a built-in arpeggiator and chord mode[12].

There is also a smaller version, the Arturia Keystep, which combines a keyboard with a simpler step sequencer. In addition, the Arturia Beatstep Pro offers a step sequencer with pads instead of keys[13].

[11] https://www.octachron.de/
[12] https://www.arturia.com/products/hybrid-synths/keystep-pro/overview
[13] https://www.arturia.com/products/hybrid-synths/beatstep-pro/overview

Radial Sequencers

Radial or circular sequencers arrange musical events in a circular layout, allowing for a more organic and intuitive approach to loop based sequencing. They can represent different musical parameters, such as pitch, velocity, or duration, using radial patterns. This type of sequencer is often used in live performances and experimental music, as it encourages exploration and improvisation. Radial sequencers can support the creation of polyrhythms and complex time signatures more easily than linear sequencers. In software implementations, concentric rings, each representing a different instrument or sound, can play distinct patterns or run at different speeds.

Radial or circular sequencers are less common than linear sequencers, but they offer unique advantages, such as visualizing the relationships between different musical elements more easily.

A subset of radial sequencers are Euclidian sequencers, which distribute a number of events as evenly as possible over a given number of steps. Suppose one wants to create a beat with 3 hits over 8 steps. A Euclidian algorithm would place the hits as follows: **x . . x . . x .**, where **x** is a hit and **.** is a rest.

Examples

Figure Figure is a software based circular sequencer developed by Propellerhead [14]. It uses a circular representation of musical patterns. Instead of programming them in, users can perform them by touching and dragging on the screen. Users can set loop lengths, and steps per loop, allowing for flexible and interesting rhythmic patterns.

[14] `https://apps.apple.com/us/app/figure-make-music-beats`

Figure 2.13: Lunar Orbiter radial Sequencer

Source: *https://www.perfectcircuit.com/amp-lunar-orbiter.html*

Lunar Orbiter Lunar Orbiter is a radial standalone and Eurorack sequencer by "A Magic Pulsewave". It features a rotating disc on which patterns can be drawn using a stylus. Discs can be swapped, allowing for different patterns to be played back.

A similar concept was used in the Oramics Machine by Daphne Oram, discussed in 1.2.2, where patterns were drawn on film strips, which were then played back by shining light through them onto photo cells. Its design is reminiscent of Orbita, discussed in 2.3.4.

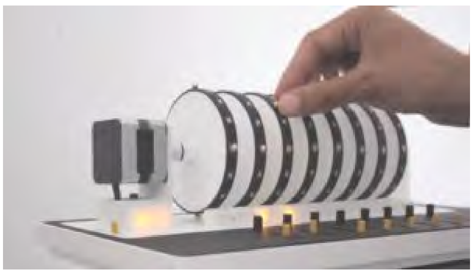


Figure 2.14: XOXX Composer radial Sequencer

Source: *https://mindsparklemag.com/video/xoxx-composer/*

XOXX Composer The *XOXX Composer* is a tangible circular sequencer that would also fit well into the category of tangible sequencers discussed in 2.3.4. The creator of the instrument is Axel Bluhme, a Swedish Designer who also designed the Orbita sequencer[15] discussed in 2.3.4. It uses 8 rotating discs with 16 quantized steps each. Where magnets can be positioned to set the steps. There is a volume and pitch control for each disc in the mixer section of the instrument. All discs are rotated at the same speed, driven by a single stepper motor. [16]

[15] https://hello.axelbluhme.se/

[16] https://leibal.com/products/xoxx-composer/

Generative and other experimental Sequencers

Beyond linear and radial designs, there exists a wide range of more experimental sequencing techniques. Instead of following a fixed path of steps, these systems employ processes such as probability, randomness, or algorithmic rules to determine musical events. Here the underlying topology is no longer a straight line or a closed circle, but a dynamic field of possibilities.

Examples

Mutable Instruments - Marbles Marbles is an Eurorack module that generates streams of events based on controlled randomness. It is quite popular among ambient musicians, often used together with modules like Rings and Clouds. [17]

Ornament and Crime The Ornament and Crime is an open source Teensy based digital Eurorack module that bundles multiple applets in one module. One example of an applet that generates evolving sequences based on probabilities is ENIGMA, a Turing machine-inspired sequencer. ENIGMA is part of the Hemisphere firmware [18].

Figure 2.15: Screenshot of Orca Live Coding Interface

Hundred Rabbits - Orca Hundred Rabbits describe Orca as "a two-dimensional esoteric programming language in which every letter of the alphabet is an operator." It is a live coding environment capable of generating

[17] `https://pichenettes.github.io/mutable-instruments-documentation/modules/marbles/`

[18] `https://github.com/Chysn/O_C-HemisphereSuite/wiki/Enigma`

MIDI or OSC output. With its set of operators, control flow mechanisms, and variables, Orca is a Turing-complete programming language, allowing users to create flexible, evolving, rule-based patterns [19]. One feature that is quite unique to Orca are the moving operators, e.g. the "E" will walk eastwards until it bangs another operator.

Figure 2.16: Tenori-on Instrument.
Source: `https://www.soundonsound.com/reviews/yamaha-tenori`

Toshio Iwai - Tenori-on The Tenori-on is a handheld digital musical instrument featuring a grid of 16x16 (non-pressure-sensitive) LED buttons. It was created by Toshio Iwai and Yu Nishibori and released by Yamaha in 2007.

The Tenori-on can be performed using the different play modes, including "score mode", "random mode", "loop mode" or the "bounce mode". The "score mode" for instance is a regular step sequencer, where the user can input notes via the grid. The "random mode" generates patterns based on a probability distribution. The "loop mode" allows for the repetition of sequences. The "bounce mode" creates sequences that move across the grid in a bouncing pattern, generating interesting rhythms and melodies. (Nishibori and Iwai [2006])

[19] `https://100r.co/site/orca.html`

2.3.4 Tangible Sequencers

A tangible sequencer is a physical musical interface that enables users to compose, arrange, or trigger events over time through direct interaction with physical objects. Often, these systems use tokens, graspable objects that represent musical properties such as notes, rhythms, or instruments. By placing, rotating, or moving around these tokens within a spatial layout (e.g. a grid, circular track), users can define temporal structures in a tactile and visually intuitive way. Tangible sequencers exemplify an embodied approach to musical interaction, making abstract processes like sequencing more accessible, playful, and sometimes even collaborative.

Token-based sequencers offer a unique and expressive approach to musical composition and performance. By using tangible objects to represent musical elements, these systems enable users to physically arrange sequences in space rather than through abstract, screen-based interfaces. Not only can this be more expressive and intuitive, it also makes such systems highly suitable for live performance, where the tangible interactions become part of the performative gesture. This often results in a more playful and improvisational experience, both for the performer and the audience.

Token and Constraints

Ullmer et al. [2005] describe the tokens and constraints model as a foundational framework in the field of tangible user interfaces (TUIs), offering a means of interacting with digital information through spatially organized physical artifacts. In this approach, tokens are discrete, graspable objects that represent digital data or operations, while constraints are physical regions or structures that define and limit how these tokens can be placed and manipulated. The constraints are typically designed to channel user interaction in specific ways, such as restricting movement along a single axis or requiring tokens to align with predefined slots or zones. This physical structuring of interaction allows users to perform complex computational taskssuch as sequencing, filtering, or assigning parameters, through intuitive and embodied actions. Notable implementations include mediaBlocks (Ullmer and Ishii [1999]), which use token movement and placement to manage digital media across devices; DataTiles (Rekimoto et al. [2001]), which enable modular composition of functionality via re-arrangeable physical tiles; and the Tangible Sequencer, which explores temporal control through the spatial arrangement of tokens. Collectively, these systems demonstrate how tangible interaction grounded in the tokens and constraints paradigm can facilitate meaningful, accessible engagement with abstract digital systems.

Examples

Marble Machine The Marble Machine is a mechanical musical instrument created by the Swedish band Wintergatan. It is a hand-cranked wooden machine that uses over 2000 marbles to play music. A system of funnels, gears, and levers guides the marbles to strike various instruments, including percussion elements, a vibraphone and a bass guitar. There is a programmable belt that can be adjusted to change the sequence of notes played by the marbles.

The video went viral on Social Media in 2016, their video on youtube[20] had over 270Mio views (September 2025). The marble machine was built by Martin Molin, a member of Wintergatan, over the course of about 14 months.

The Marble Machine is a fascinating example of a tangible sequencer, it combines physical interaction with musical output in a highly visual way. It does not use any digital components, but it is a purely mechanical system with acoustic sound generation. From a musical perspective, the Marble Machine is more a percussion instrument, as the marbles strike various objects to create sound. However, the programmable belt allows for sequencing and arrangement, making it a unique blend of instrument and sequencer.

Figure 2.17: Marble Machine

Source: screenshot: https://www.youtube.com/watch?v=IvUU8joBb1Q

[20]https://www.youtube.com/watch?v=IvUU8joBb1Q

Figure 2.18: Orbita Sequencer
Source: https://shop.playtronica.com/pages/new-device-orbita

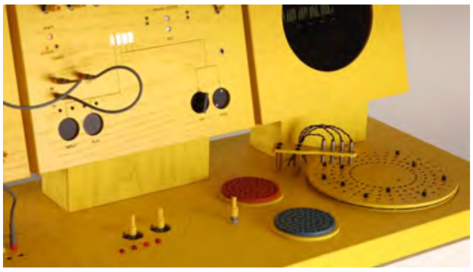
Orbita While most tangible sequencers are DIY projects or research prototypes, Orbita by Playtronica tries to be a commercial product[21].

It is an instrument, a very simple, yet powerful and playful radial tangible sequencer. Orbita outputs MIDI, so it can be used to control any MIDI compatible device, such as synthesizers and drum machines. Its design is actually quite similar to that of a belt-driven record player. Users can place colored tokens on a rotating surface with circular tracks, each color is mapped to a different MIDI note.

Orbita can even be remote controlled via MIDI, allowing for interesting performance possibilities. For example, one could start and stop the rotation of the sequencer or change its speed.

[21]https://shop.playtronica.com/pages/new-device-orbita

(a) Lomond's turntable sequencer
Source: screenshot: https://www.youtube.com/watch?v=XFsiPIX9Cxs



(b) TE-LAB synthesizer.
Source: screenshot: https://www.youtube.com/watch?v=kipx7Ad2z-Q

Figure 2.19: Lomond's turntable sequencer and TE-LAB synthesizer.

Lomond Campbell - DIY turntable eurorack sequencer and TE-LAB Modular Synth The Scottish musician and luthier Lomond Campbell has designed a tangible radial sequencer that can be found on his website [22]. It works similarly as the Tamphall8r (3.2.2). His sequencer consists of two parts, the rotating disc on the turntable, where the user can program the sequence. It inspired other instruments, such as the TE-LAB show in figure 2.19b, a patchable modular synthesizer with a built-in rotating disc with Lomond's sequencer design.

Figure 2.20: Tquencer instrument
Source: https://tamlab.kunstuni-linz.at/projects/tquencer/

Tquencer The Tquencer by Kaltenbrunner and Vetter [2018] is a token-based tangible step sequencer. It differs from most other tangible sequencers in that it supports layers, implemented as interchangeable physical sheets. Layers can be loaded by placing a new sheet with tokens on top of the sequencer.

It works with three different types of tokens: event tokens, effect tokens and configuration tokens.

[22]https://www.lomondcampbell.com/turntable

Chapter 3

Instrument

3.1 Design

3.1.1 Guidelines

The development of the system was guided by a set of design rules that defined both conceptual intentions and practical constraints. These guidelines provided a framework for decision making throughout the process, balancing artistic goals with technical feasibility.

1. It is an extension kit, not a standalone instrument.
   It won't work without a record player. The record player can still function without it, and when used together, it preserves the original functionality. This way, the system can combine analog records with the digital capabilities of the Turntangilism 3000.

2. It is modular.
   The system can be expanded at any time, and not all modules need to be used all the time. Modules can be exchanged, developed further, and new modules can be added.

3. No hidden smart features.
   Features such as auto-trimming, auto-pitch or quantization can strip away the natural, organic feel of the performance. The beauty of

turntablism lies in its entirely manual approach to mixing and manipulating sounds. The same principle should apply to the Turntangilism 3000.

4. No screens.
   There should not be a need for visual feedback. The system should be as distraction-less as possible.

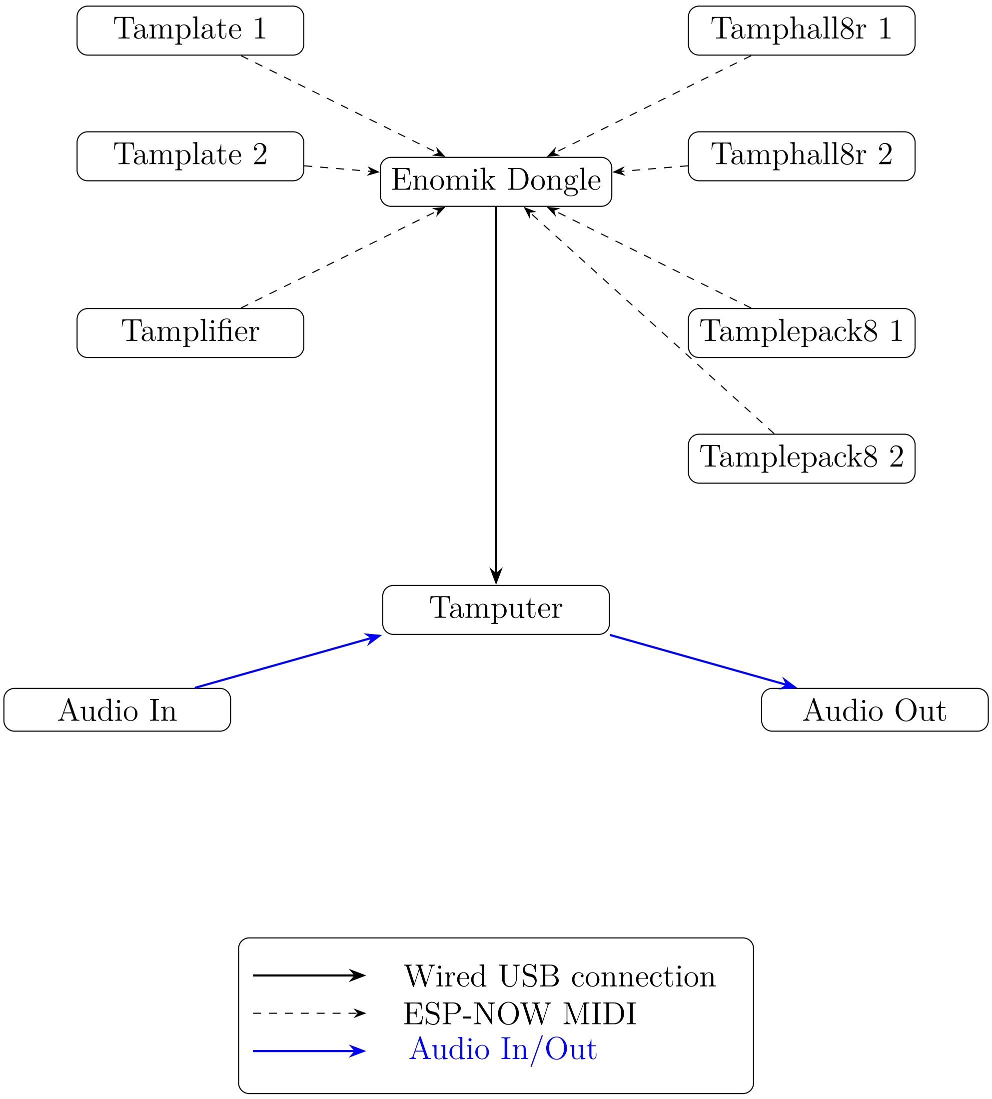
3.1.2 Color Scheme

The color scheme should remain minimal. Ideally, everything is black with a single accent color. Black, like the color of vinyl, is unobtrusive and technically advantageous, since it does not reflect light. A consistent accent color is applied across all instruments to visually unify them. I have picked "maracuja red" as the accent color, as it is a warm and powerful color that contrasts well with black.

3.2 Ecosystem

Having these guidelines and ideas in mind, I designed an ecosystem of tangible musical interfaces that work together to create a flexible and expressive setup for live sampling and sequencing.

The ecosystem consists of the following components:



3.2.1 Infrastructure and Utils

Tample

Tangible sequencers often use physical tokens as a way to interact with and manipulate sound samples in a hands-on, intuitive manner. In my instrument, I've chosen to call these tokens Tamples, a blend of tangible and samples.

Tamples represent physical, touchable units of sound that the performer can load, arrange, and trigger directly. This approach bridges the digital and physical worlds, making the act of sequencing more immediate and playful. By assigning samples to Tamples, the user gains a tactile connection to their sound material, encouraging exploration and creativity beyond traditional screens and knobs.

Importantly, Tamples are not bound to one instrument. The vision is modular and expandable: the same Tample can be used across different devices that support this format. This opens up exciting possibilities for a shared ecosystem of tangible instruments, where Tamples become universal sound carriers, like physical USB drives for music performance.

Tamples do not physically store the sounds themselves; rather, each Tample is linked to a sample within the virtual environment. It is similar to how a wristband at a music festival holds digital payment information or a museum pass tracks collected items: the tangible object acts as a key to virtual content.

Construction Early prototypes of the Tamples were made using manually cut metal rods, with small magnets inserted to enable detection and secure placement. This DIY approach allowed for quick iteration and hands-on testing of dimensions, weight, and feel.

While magnets are lovely and fascinating, they were eventually abandoned in favor of a simplified design. In the current version, Tamples are no longer freestanding and no longer require embedded magnets for detection.

As the design progressed, I transitioned to using standardized industrial parts. Specifically, I sourced 12 x 36 mm metal cylinders, a widely available format in mechanical component catalogs.

(a) Photo of a raw unpainted Tample (b) Photos of 10 painted Tamples

Figure 3.1: Photos of raw and painted Tamples

Each Tample is painted in a distinct color, not only for easy visual identification but also to support the sensor system that detects and differentiates between Tamples.

Tample Detection As mentioned earlier, Tamples are identified based on their color. However, choosing this method involved weighing several alternatives, each with its own strengths and limitations. One option was using slip contacts with different resistance values. Another idea involved RFID or NFC tags, or detecting varying magnetic fields with Hall sensors. While RFID, NFC, or Hall effect sensing can offer highly reliable identification, they may not consistently trigger at the exact same physical position, which is critical for timing-sensitive applications like sequencing. Color sensing, on the other hand, introduces its own challenges for instance, varying ambient lighting conditions can affect detection accuracy. Ultimately, color detection was chosen because it delivered reliable results with the selected sensor. A TCS color sensor was used, which includes two white LEDs to ensure stable lighting during detection. Additionally, color detection solves another important challenge: making Tamples easily distinguishable for both the performer and the audience. I want the instrument to feel transparent and approachable, rather than hiding its workings away.

Colors This opened up a whole new set of challenges. Reliably detecting colors is not as straightforward as it might seem. I chose to work with an RGB color sensor and convert the detected values into the HSV color space, as HSV tends to be much more stable for distinguishing between colors under varying lighting conditions.

Tample detection is a classification problem. I went for a simple, primitive algorithm to check if each component lays within a certain range of values. More advanced algorithms could be used, e.g. k-nearest-neighbors (KNN).

RAL colors RAL colors are a standardized color matching system used primarily in Europe for defining colors in industries like painting, coatings, plastics, and architecture. The RAL system ensures consistency in color reproduction across different materials and manufacturers. Using standardized colors like RAL makes it easier to source paints, having reproduction and extension in mind.

The following colors have been chosen:

Beige (RAL 1001), Traffic red (RAL 3020), Signal yellow (RAL 1003), Sulfur yellow (RAL 1016), Traffic orange (RAL 2009), Heather violet (RAL 4003), Signal violet (RAL 4008), Signal blue (RAL 5005), Turquoise blue (RAL 5018), Yellow green (RAL 6018), Pastel green (RAL 6019), Signal grey (RAL 7004), Granite grey (RAL 7026), Yellow grey (RAL 7034), Signal brown (RAL 8002), Cream (RAL 9001), Light green (RAL 6027), Telemagenta (RAL 4010).

Tamputer

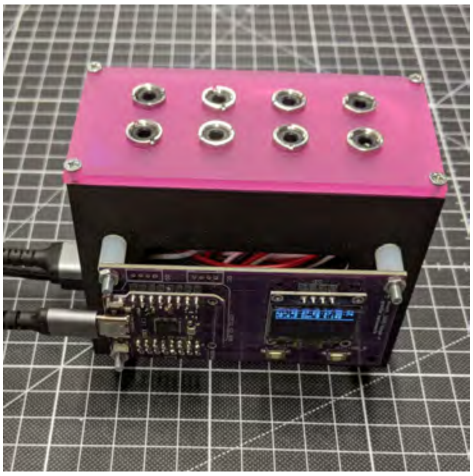


Figure 3.2: Photo of the Tamputer, the central control unit of the Tamputer ecosystem

The Tamputer is the central control unit of the instrument. It manages the entire ecosystem of Tamples, storing all samples, organizing sample banks, and handling playback.

The Tamputer runs on a Bela board with the multichannel extension, making it a truly embedded device. With the multichannel extension, it can handle up to 8 output channels, allowing to output four stereo channels (or 8 mono channels) that can be routed back to a (DJ) mixer for manual mixing. Internally, it runs a Pure Data (Pd) patch that handles recording, sample playback, mapping, and routing.

The Tamputer boots up automatically when powered on, starting all the background services, cleanup scripts and the Pd patch without any user intervention. It does not use Bela's hardware I/O pins, instead it only hosts an Enomik 3000 dongle for wireless communication with the other devices.

For more complex setups or integration into existing live rigs, the Tamputer can easily be swapped out. The same Pure Data patch can be run on any computer with a compatible audio interface, allowing for greater flexibility while preserving the core functionality of the instrument. This can be especially useful in spatial audio environments, where higher channel counts or specific routing requirements may exceed the capabilities of the embedded setup.

Construction The Tamputer is housed in a 3D printed enclosure with an acrylic top panel that holds the board, the TRS sockets for audio in and out, and the Enomik dongle securely in place.

Tamplifier

Figure 3.3: Photo of the Tamplifier, the recording unit of the Turntangilism ecosystem

The Tamplifier is the recording unit of the entire ecosystem. It can record audio samples and assign them to colored tamples.

Pressing a token starts the recording; releasing it stops the recording. This momentary mode was chosen because recording times are expected to be relatively short, and there is no need to perform other actions simultaneously that would require significant affordance.

An alternative interaction would have been a toggle mode, where pressing the token starts the recording and a second press stops it.

By moving the tamples up and down, users can select one of 4 tample banks, numbered from 1 to 4.

Routing The Tamplifier can "tamplify" any audio signal sent to it. In a typical DJ setup, this signal most likely comes from the headphone channel, meaning anything cued to the headphones can be sampled. This could be the left or right deck, a mix of both, or, depending on the mixer, even a microphone or any other device connected to the mixer's line inputs. With a live mixing console, not necessarily a DJ mixer, or even a software mixer, one could use the aux channels to send specific signals to the Tamplifier.

Construction The Tamplifier is constructed from a couple of off-the-shelf components and custom 3D-printed parts. At its heart is a 3D-printed Tampleholder that contains a button below the slot for the Tample, and a color sensor on the side to detect the color of the Tample. The holder sits on top of two slide potentiometers, which serve as sample bank selectors, as well as rails to stabilize the Tampleholder.

Tamplepack8

Figure 3.4: Photo of the Tamplepack8

The Tamplepack8 is a device with 8 slots for inserting Tamples and a slider for selecting the sample bank. The sample bank selector works globally for all 8 slots. The Tamplepack8 provides the following functions:

Assigner The Tamplepack8 allows the user to assign up to 8 Tamples to the 8 rings of the Tamphall8r. This enables the performer to quickly switch between different sets of samples during a performance.

Assignment happens by inserting a Tample into one of the 8 slots, then pressing it down.

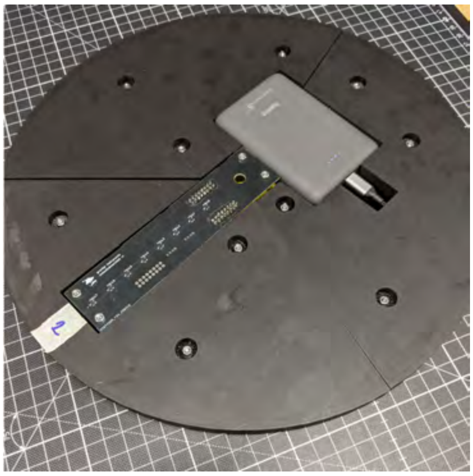
Previewer The Tamplepack8 also allows the user to preview the samples stored on the Bela board. This is particularly useful for quickly checking the content of a Tample without sending it to the master output. Every assignment will trigger a preview, playing the sample to the headphone/preview channel.

Player "Hack" By routing the preview channel to master output, the performer could even use the Tamplepack8 as a simple sample player. This was not the original intention and clearly steps away from the turntable concept, but it is a nice side effect of the design.

3.2.2 Playback Devices

Similar to vinyl records, which can be played on various turntables, the Turntangilism system includes different playback devices that can be used to interact with. Each of them offers a unique way to manipulate and perform with the Tamples. When not in use, of course the record player can be used a regular turntable to play vinyl records.

Tamphall8r



(a) Tamphall8r rotating part with 8 Hall effect sensors

(b) Tamphall8r static part with 8 rotatable concentric rings

Figure 3.5: Photos of the two parts of the Tamphall8r

The Tamphall8r is a device consisting of two parts:

1. A static part with 8 rotatable concentric rings, each representing a track in the sequencer. Each ring can be rotated independently to set the timing offset for that track (3.5b).
2. A rotating part with 8 Hall effect sensors, each corresponding to one of the rings. As the rotating part spins, the sensors detect the presence of magnets embedded in the tamples placed on the rings (3.5a).

A similar, yet distinct, instrument that I came across while doing research is Orbita by Playtronica. 2.3.4 describes it in more detail. Orbita in my opinion has one downside. performers are interacting with a rotating plate.

The Tamphall8r is a 8-track radial tangible sequencer. All tracks run in parallel, due to one single shared record equipped with sensors. Users can create short sequences by placing magnets on the rings. They even can rotate the rings to set the timing offset for each track, allowing for polyrhythmic patterns to emerge. Each magnet fires a Note-on event, triggering a sample.

The sensor-equipped record is a regular 12" vinyl, allowing users to interact with it in familiar ways, such as scratching or manually changing the pitch. The loop length is rather short, 1.8s on $33\frac{1}{3}$. With some record players one can pitch $\pm 50\%$, which results in 3.6s per evolution.

Implementation Tamphall8r uses Hall effect sensors to detect the presence of magnets. The current implementation cannot sequence velocity or other parameters, only Note-on events. A custom-made PCB ensures that the sensors are properly connected to a microcontroller, which reads the sensor values and sends MIDI messages via ESP-NOW MIDI (3.3.2).

Figure 3.6: Photo of the Tamphall8r rings during CNC milling

Construction The rotating part is built around a standard 12" vinyl record. The rectangular PCB and 3D-printed parts, designed to hold the power bank with cable cutouts, were screwed to a standard 12" vinyl record. The original idea was to manufacture a round 12" PCB, but this turned out to be too expensive. While this would be an elegant solution for mass production, for a one-off prototype/first iteration, it is not worth the cost.

The static part with the rings was CNC milled from an acrylic sheet. First trials were done with laser cutting, engraving the 1mm deep tracks for the rings into the acrylic. While this worked, the result was not very precise, also due to the heat the laser produces, the acrylic bends a bit.

The rings had several requirements:

- They need to be magnetic, so that they can hold small neodymium magnets.
- They need to be thin (0.5mm), to block the magnetic field as little as possible.
- They need to be stiff enough, so that they do not bend when being rotated.

After testing several materials and experimenting with different ways how to cut them, laser-cut spring steel turned out to be the best choice.

The 0.5mm thick rings fit perfectly into the 1mm deep tracks milled into the acrylic base. The rings can be rotated easily, but do not move around on their own. They are secured with 2mm polyamide screws with a big washer on top, preventing the rings from being lifted. Polyamide was chosen because it is non-magnetic.

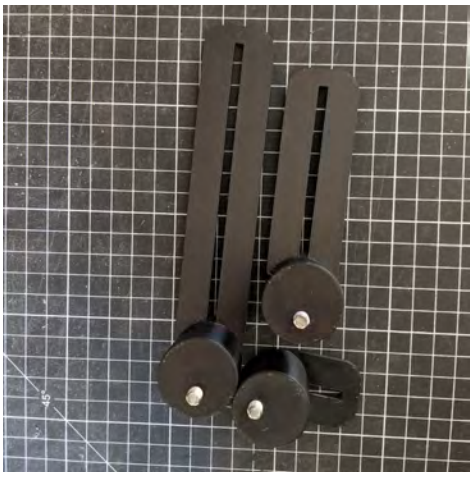


Figure 3.7: Photo of the Tamphall8r stands

The last missing piece was to create stands for the top part, to hold it at the right height above the rotating record - not too high, so that the magnets can still be detected, but also not too low, so it does not touch the record. For this, I used 3D-printed parts, with a 6mm screw, where the acrylic overlay can be mounted on top. It is not necessary to fix them with a nut, the way how it is constructed can hold it securely without. I have made two versions of these stands, one that works well with the case I use for my record player. Another one that can be clamped to a record player without using a case.

Tamplate

Figure 3.8: Photo of the Tamplate

The Tamplate is a 7" device equipped with a gyroscope to detect motion and orientation. It also features a color sensor for detecting colors, as well as a button to trigger samples. This makes the Tamplate a versatile instrument.

Scratcher It can be used as a scratching device: by rotating the Tamplate, one can scratch through a sample. This is particularly compelling, as it corresponds to what most people intuitively expect from a turntable, namely, that rotation determines the playback position within a track.

However, since the processing takes place in the digital domain, entirely new possibilities can be explored. For example, the Tamplate can control a granular synthesis patch, which I currently refer to as the Scratcher. To support longer samples, higher resolution than the standard 7-bit MIDI is required. For this reason, the Tamplate transmits MIDI pitch bend messages.

Panner or tangible Modulator Since the Tamplate transmits its orientation, it can also be used to pan sounds within spatial audio systems, especially in circular or spherical layouts. This is particularly interesting because panning is subject to physical constraints similar to those of a turntable. For instance, sound objects cannot immediately appear on the opposite side. They must be moved there gradually.

Another idea is to use the Tamplate as a tangible modulator. It is sending the rotation value as MIDI CC messages, allowing for expressive control over various parameters in a digital audio workstation or other MIDI-compatible software. For example, one could map the rotation to the filter cutoff frequency, creating a dynamic and interactive sound design tool. Even without any parameter mapping, the raw values themselves produce a sawtooth-shaped

LFO.

And of course, since they can be played like vinyl records, one can scratch them, stop them, change direction, or change their speed, either by hand or by using the pitch fader.

Construction The Tamplate consists of a round 7" PCB equipped with LEDs, push buttons, and connectors for the sensors. It is accompanied by 3D-printed holders for a power bank and the Tample.

The gyroscope was not surface-mounted, as it needs to be positioned exactly at the center of the PCB. Since this central location also contains a hole for the player's spindle, the component was raised using 2.54 mm pins to elevate it above the spindle.

Tamploop

Figure 3.9: Photo of an early prototype of the Tamploop

The Tamploop is still a work in progress.

It is similar to the Tamphall8r (3.2.2), but instead of having 8 Tamples assigned to 8 rings, it has one ring around the platter, where users can freely place Tamples. The Tamploop is a monophonic sequencer, meaning only one sample can be triggered at a time. But it won't cut off the previous sample, so one can create overlapping sounds. As with the other devices, there is no quantization, so the timing of the samples depends entirely on the user's placement of the Tamples.

Users can also interact with it while it is playing, e.g. through changing Tamples or manipulating the rotating platter, for example by scratching or changing the pitch.

It consists of two parts:
The rotating disc on the turntable with sensor and micro-controller and the static ring around the platter. The sensor is mounted on the disc pointing towards the static ring. The static ring is the part where Tamples can be placed.

Current State The Tamploop uses the same electronics, protocol and software implementation as the other devices. The missing part is the physical construction of the static ring around the platter. Mainly how to place the Tamples on the ring, with ideally no external light sources interfering with the color sensors. All the other parts of the ecosystem use the 3D-printed Tample holders, which block external light.

3.2.3 Accessories

Tample Case

Figure 3.10: Photo of the Tample case with all 256 Tamples inside

Tamples are stored in a custom-made case. The case is designed to hold 16x16 Tamples, 16 of each color, for a total of 256.

Originally an old case from a Grundig reel-to-reel tape player, it has been repurposed with custom laser-cut inlays to securely hold the Tamples. One inlay at the bottom keeps them in place, preventing unwanted movement that could damage the painted layer. Another inlay at the top holds them tightly, ensuring they stay secure without any jumping.

The lid of the case can be removed to allow easy access to the Tamples during performances.

This provides both protection and organization, ensuring easy access on stage, while preventing damage during transport.

Tample Crate

Besides the hardware components, a comprehensive ecosystem also includes software tools that enhance the user experience and expand the creative possibilities. One such tool is the Tample Crate, it is an API to provide access to the samples stored on the Bela board.

Sample Management Tool The initial motivation was to introduce a dedicated tool for managing samples. While recording material on the fly serves one purpose, preparing sample banks in advance of a live set, organizing sounds during rehearsals, or archiving recordings for later studio work represents a different set of requirements. Such tasks are not time-critical and do not necessarily need to be executed directly on the device. Instead, they can be facilitated in a more flexible and powerful manner through an external interface. Given that in 2025 laptops and smartphones serve as the primary platforms for most creative workflows, providing a web-based interface for sample management seems to be a very natural evolution.

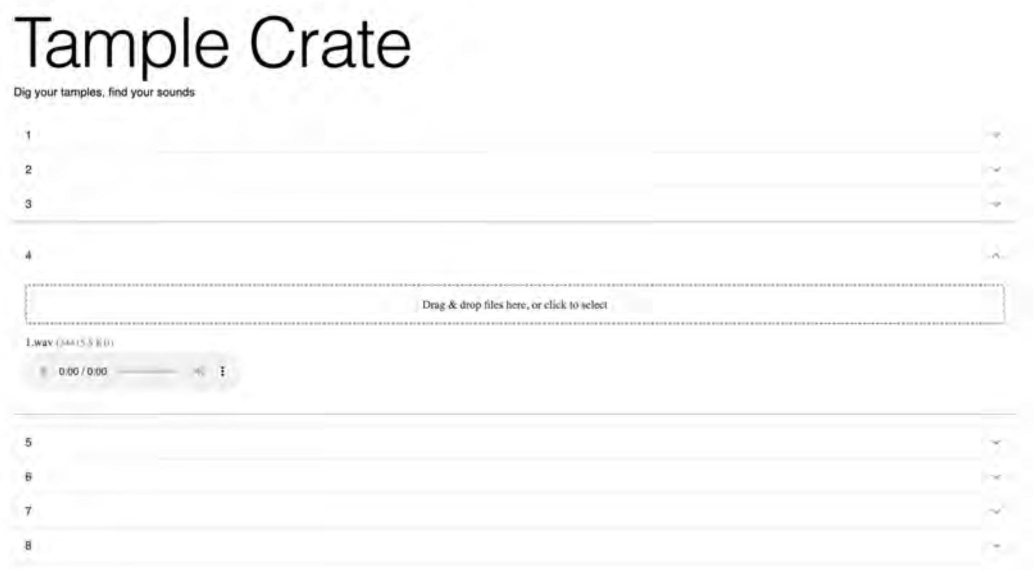


Figure 3.11: Screenshot of Tample Crate Application

Of course this is just a very practical starting point. Another idea that is very interesting to integrate is a cloud synchronization feature.

Digital Instruments An API like Tample Crate could be used to provide the samples to a set of digital instruments, such as custom audio plugins.

3.3 Implementation

3.3.1 Construction

All 3D printed parts were modelled in Onshape[1] and printed on a Bambu Lab 3D printer using PLA filament. 3D printing was the most cost-effective and flexible method for prototyping the custom parts needed for the instrument.

For the cover of the cases I used 3mm acrylic sheets, as they were easy to cut with a laser cutter. Using a laser cutter allowed for precise and clean cuts, which would have been difficult to achieve with hand tools.

For the screws and nuts, I opted for stainless steel or galvanized steel to ensure durability and resistance to corrosion. I mainly used M3 hex socket screws (DIN 912) and M3 hex nuts (DIN 934), as they are widely available, and using the same screws across all parts makes assembly easier.

3.3.2 Electronics - Hardware and Software

Architecture

The central audio server is implemented on a Bela audio board, which is based on a BeagleBone and runs a real-time Linux environment optimized for ultra-low-latency audio processing. Bela's architecture ensures deterministic scheduling, allowing the system to achieve round-trip latencies below 1 ms, a crucial requirement for responsive live performances. In addition to its low latency, Bela is also a relatively affordable solution compared to other multichannel audio platforms (McPherson [2017]).

Bela supports running a variety of environments for audio programming, including Pure Data (Pd), SuperCollider, and custom C++ code. For this project, I chose Pure Data, as I am already quite familiar with it and it is well documented, as well as actively maintained. Pd also provides a highly flexible environment for rapid prototyping, making it easier to experiment with different processing strategies and adapt the system as the design evolved.

The server can be controlled via MIDI. Recorded samples are stored directly

[1] `https://www.onshape.com/`

in the filesystem, which makes it easy to back up files, for example via an SSH connection.

Also, the Bela board runs a web server that provides access via an API for managing files. It is written in Python and designed to work without installing any additional dependencies on the Bela.

Transmission

Since the project comprises multiple hardware components, I went for a multi-controller architecture to manage them effectively. Communication between controllers is handled wirelessly using ESP-NOW, chosen for its low latency and reliability. Not all devices require wireless communication, but because ESP-NOW has proven to be both stable and relatively easy to implement, I decided to use it as the common protocol for all devices.

ESP-NOW MIDI Library and Enomik 3000 Kit As a small side project, I isolated the communication code into a library, available on github[2]. It is also accessible via the Arduino Library Manager. The library provides the same interface as the standard MIDI library, making it largely a drop-in replacement. However, instead of transmitting MIDI messages via traditional methods, it sends MIDI packets over ESP-NOW. The receiver then converts these packets back into standard MIDI messages.

ESP-NOW MIDI supports common MIDI message types, such as Note On, Note Off, Control Change, Pitch Bend, Program Change, and even Clock synchronization. System Exclusive (SysEx) messagesused for sending arbitrary data, and MIDI MPE (MIDI Polyphonic Expression) are not yet supported. Nonetheless, the library has proven to be easy to use and quite efficient.

The receiver functions as a class-compliant MIDI device, making it straightforward to use on the host side, including in DAWs and prototyping environments. Since it adheres to the class-compliant MIDI standard, it can be used in any DAW or patching environment that supports MIDI, such as Pure Data or Max. It even works in browsers, on mobile devices, and on embedded platforms like Raspberry Pi or the Bela audio board.

The library uses ESP-NOW under the hood, a well-maintained protocol de-

[2] `https://github.com/thomasgeissl/esp-now-midi`

signed for ESP microcontrollers. ESP-NOW is a wireless communication protocol developed by Espressif Systems [3]. , the makers of the ESP32 and ESP8266. It enables multiple ESP devices to communicate directly with each other without requiring Wi-Fi or a router.

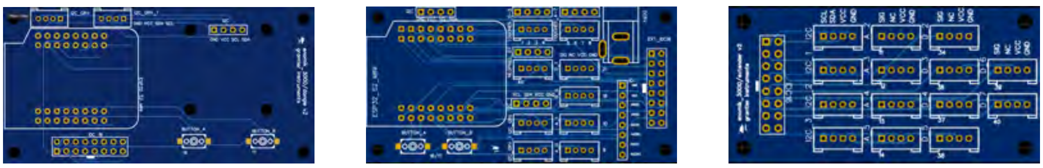
Designed for low latency and low power consumption, ESP-NOW is well suited for transmitting musical data, such as MIDI messages. Each packet can carry up to 250 bytes, which is more than sufficient for standard MIDI message types (Pasic et al. [2021]).

Labib et al. [2021] describe using ESP-NOW in an apiary monitoring system with ESP8266 and ESP32 modules, achieving efficient star topology communication and low power operation.

ESP-NOW uses Wi-Fi frames for communication but bypasses the TCP/IP stack, operating instead on the MAC layer. At the time of writing, there are still relatively few libraries that build on top of ESP-NOW, making this implementation somewhat unique. Since the library is open source, it has already started to be adopted by others in their own projects.

Accompanying this library, I have built a DIY-style kit called Enomik 3000, short for ESP-NOW MIDI Kit. It consists of three main components:

- A **dongle**, which connects to a laptop or embedded device and acts as the receiver.
- A **client board**, designed to interface with sensors and actuators.
- An optional **extender**, which adds additional I/O in case the client requires more connections.



(a) Dongle (b) Client (c) Extender

Figure 3.12: The enomik3000 components: dongle, client, and extender

[3]`https://docs.espressif.com/projects/esp-idf/en/stable/esp32/api-reference/network/esp_now.html`

I chose to use Grove connectors because they are mechanically stable, giving me confidence that cables won't come loose during a performance. They also integrate seamlessly with Grove sensors by Seeed Studio, which I use in many of my projects. This makes it easier to build complete kits that include a selection of sensors and actuators right out of the box.

Additionally, the client board also can be used with standard 2.54mm headers, making it compatible with a wide range of sensors and actuators available in the maker community. All pins are clearly labeled on the PCB. This makes it easy to connect components without needing to refer to a schematic.

Future Work

The library is still under active development, with plans to add more features and improvements. One feature I have already started working on is configurable client, without the of coding and recompiling the firmware. This would allow users to configure the client board via MIDI SysEx messages from a custom-made web app. Users could select which pins are used for which purpose, e.g. setting a pin as input for a button, potentiometer, or sensor, or as output for an LED or motor. Configuring CC/note mappings as well as input ranges and scaling would also be possible. This would make the library and the Enomik 3000 kit more accessible to users who are not comfortable with coding or using the Arduino IDE/Circuit Python.

Another feature that is missing in the library is support for Circuit Python. Circuit Python is a popular platform for beginners and educators, and adding support for it would make the library more accessible to a wider audience.

MIDI Specification

All communication is managed through MIDI messages transmitted over ESP-NOW. The use of a standardized protocol such as MIDI not only streamlines development and debugging but also ensures straightforward integration with existing systems.

Sample Recording The sampling process is controlled via MIDI messages, specifically using Control Change (CC) messages.

- **channel**: sample bank selection, e.g. channel 1 selects sample bank 1, channel 2 selects sample bank 2, etc.
- **controller**: sample selection, e.g. controller 1 selects sample 1, controller 2 selects sample 2, etc.
- **value**: starts or stops recording, e.g. value $>$ 0 starts recording, value $==$ 0 stops recording

Sample Playback The playback is controlled via MIDI messages, specifically using "Note on" messages. There are two modes of operation, one with specified sample bank and sample, the other with specifying a slot and using the assignment table to determine which sample and bank to use.

Direct Sample Playback only takes effect when the note value is less than or equal to 64.

- **channel**: sample bank selection, e.g. CC 1 selects sample bank 1, CC 2 selects sample bank 2, etc.
- **note**: sample selection, e.g. note 1 selects sample 1, note 2 selects sample 2, etc.
- **velocity**: volume control, e.g. velocity 127 plays the sample at full volume, velocity 0 mutes the sample

Sample Playback via Assignment Table is activated when the note value is greater than 64.

- **channel**: specifies which instrument is being played, e.g. channel 1 maps the instrument with ID 1
- **note**: sample bank selection from assignment table
- **velocity**: volume control, e.g. velocity 127 plays the sample at full volume, velocity 0 mutes the sample
- **program**: a program change message can be sent prior to the note message to select the sample bank for that instrument

Sample Assignment MIDI control change messages are used to map which sample is triggered. As instruments only operate on one sample bank at a time, the mapping is done per instrument.

- **channel**: specifies which instrument is being mapped, e.g. channel 1 maps the instrument with ID 1
- **controller**: specifies which slot is being mapped
- **value**: specifies which sample is being mapped to the slot

Code

The source code for the MIDI devices, the Pd patch, and the scripts that run on the Bela board are all available on GitHub[4].

[4] `https://github.com/grantler-instruments/turntangilism3000`

Sensing

To simplify development and with potential future reproduction in mind, the same components were used across all devices.

The following sensors are utilized:

- Button
- Slide Potentiometer
- Color Sensor (TCS34725)
- Gyroscope (MPU6050)

Color sensor and button are used in combination to create the Tample holder, used in the Tamplifier, Tamplate, Tamplepack8. The TCS34725 is a color sensor that can be controlled via I2C in 400kHz mode, allowing for fast and reliable color detection. Also, the breakout version I have used includes white LEDs, which provide consistent lighting conditions for the color detection.

For the slide potentiometer, a simple linear slide potentiometer with a 100mm travel distance is used. I have chosen one on a breakout board with mounting holes, making it easy to integrate into the 3D printed enclosures. Only devices that work with variable sample banks (Tamplepack8, Tamplifier) use the slide potentiometer to select between banks.

The MPU6050 is motion sensor that combines a 3-axis gyroscope and a 3-axis accelerometer. It is only used for the Tamplate, where it detects the rotation of the 7". The firmware of the Tamplate only uses the gyroscope data to detect the rotation angle, while the accelerometer data is ignored. The MPU6050 sensor is also controlled via I2C in 400kHz mode. I have programmed a small calibration routine that allows the user to calibrate the sensor's zero position. The sensor is not as accurate as a dedicated rotary encoder, or for instance a BNO055 sensor, but it works well enough for the purpose of detecting rotation on only one axis.

3.3.3 Sound Generation

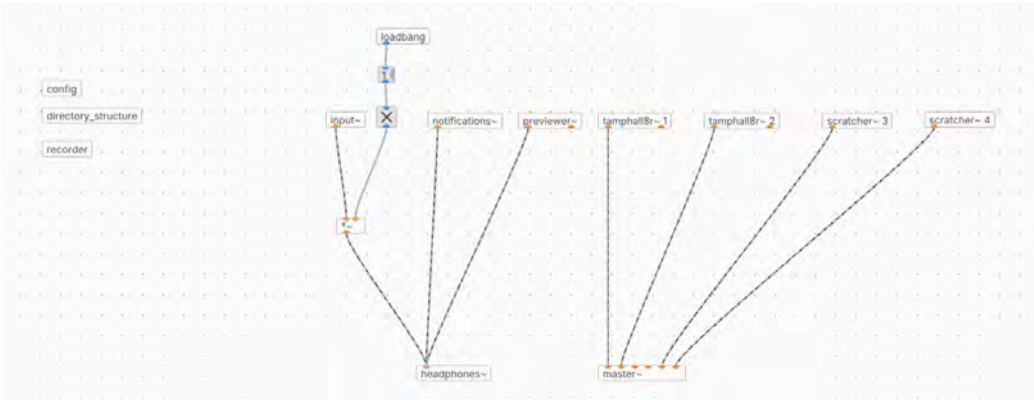


Figure 3.13: Screenshot of Pd patch

The sound generation in the Turntangilism 3000 is realized purely in Pure Data (Pd) running on Bela Audio board (Moro et al. [2016]). It operates on a sample basis. This approach is essential because the instrument is designed around live sampling, allowing recorded material to be immediately integrated into performance.

The patch is relatively simple. It contains subpatches for the recorder and each instrument, which handle sample playback, as well as utility subpatches for setting up the directory structure.

In principle, sound could also be generated through synthesis methods. This ensures that the instrument remains tightly connected to its central idea of transforming recorded material into a playable and manipulable medium.

Each instrument can play up to 24 voices, utilizing PD's clone object. Samples are read from the filesystem upon triggering, which helps keep memory usage low and simplifies the implementation. This approach represents a trade-off: while loading samples directly into memory would slightly reduce latency, it would also increase memory consumption and complicate the system.

Samples are stored in directories named after their respective sample banks. Each sample is numbered according to its color mapping; for example, 1/1.wav corresponds to the first sample (traffic red) in the first bank.

Chapter 4

Artistic Practice

With the instruments now playable, it is time to bring them onto the stage. The upcoming performances are not only a chance to hear them in action but also to explore their musical and expressive possibilities in a live context. On stage, improvisation, audience interaction, and the physicality of performance reveal new dimensions of the instrument, moments that cannot be fully anticipated in the studio.

Before moving into this live setting, however, I will first outline some ideas of how the instrument can be used.

4.1 Musical Possibilities

Turntablism has developed its own ways of using record players as musical instruments. The same applies to Turntangilism: I have certain ideas in mind about how I would use the system, but it is a system designed to be explored and hacked.

They can be used as standalone setups or in hybrid constellations that combine elements from different sources and styles. In the following section, I will elaborate on my ideas for how the instrument can be used.

4.1.1 Sample Source

At the core of the instrument lies the idea of sampling. The flexibility of the setup makes it possible to record sounds from a wide variety of sources. In a typical DJ context, the most immediate option is to use a DJ mixer, where individual channels can be routed into the sampler. For instance, the headphone cue can act as a discreet sampling bus, allowing sounds to be captured without sending them to the main output. Alternatively, an auxiliary send or a dedicated output channel can be used for this purpose.

This means that essentially any signal that can be isolated within the mixer can become a potential sample: records, digital tracks, external instruments, microphones, or even effects returns. In setups that do not rely on DJ mixers, a traditional studio or live sound mixer can serve the same function, as long as there is a way to split or route a signal into the sampler. This opens up the possibility of integrating the instrument into very different performance environments, from club setups to live bands, experimental electronics, or installations.

Vinyl Records

Probably the most straightforward way is to route what is playing on a record player into the Tamplifier. For example, if you come across a breakbeat section, an isolated drum hit, or even an a cappella vocal sample, scratch sounds, any of these can be captured and assigned to a Tample.

Dubplates Dubplates are custom cut vinyls. They often contain unreleased music and are usually produced in much smaller quantities. Dubplates are therefore cut, and not pressed (Rietveld [2012]).

They can be used to have self produced content on a vinyl, e.g. own tracks, or stems of a song. having the isolated vocals on a dubplate can be very useful for live remixing. Or having one-shots on a dubplate helps to sample isolated drum hits, which is very useful for creating clean drum beats.

Prepared Records Prepared records are vinyl records that have been altered in some way to create new sounds. For instance, one could stick small objects like pieces of tape onto the record surface, Or the record could be physically modified, e.g. scratching the surface, cutting holes into it.

Noise Pickup and the Record Player as a Resonator

A slightly more experimental approach is to use the needle to pick up noises. Simply touching the needle produces raw sounds that can be captured and used as material. Another option is to place the needle on a record without playing any music and amplify the signal, effectively turning the record player into a resonating body that can be sampled. It can be used to generate textures, hums, and percussive artifacts that differ from conventional musical sources.

External Instruments

Since the system deals with audio sources, it does not really matter where they come from or how they are eventually played back. This means that almost anything can serve as input: guitars, synthesizers, or acoustic instruments picked up with a microphone. Staying within the hip-hop territory, it can also be interesting to connect a mic and capture beatbox sounds, vocal samples, or spontaneous phrases. All of these can be turned into playable material on the fly.

Another possibility is to use the sampled sounds as a backing track, creating a foundation over which the performer can play an instrument, rap, or sing. In this way, the system supports both the spontaneous capture of sounds and their use as structured accompaniment, allowing for flexible combinations of live performance and pre-arranged elements.

Resampling

Another very powerful technique is to resample the output of the instrument itself. This means that whatever is being played through the main output can be captured and fed back into the sampler. Let’s say tamplified drum parts of a song are rearranged and being played back can be stored onto another Tample. That then can be used again as any other Tample.

4.1.2 Composition and Performance

Now that the material dimension of the instrument has been addressed, the next question concerns how these materials can be organized and deployed in a performance context.

Pure Turntangilism

This approach uses no live sounds from records at all, relying solely on tamplified sounds. Sounds are generated and manipulated via the Tamphall8r and Tamplate, allowing the performer to explore rhythm, texture, and timbre in a purely electronic context.

Using two turntables that play different or even the same sequences, the performer can create complex polyrhythms and interlocking patterns. One example could be to have one turntable play a steady drum beat while the other introduces syncopated rhythms or melodic fragments. Another one could be to play the same sequence on both turntables but at different speeds, creating a phasing effect that evolves over time (Schwarz [1980]).

Hybrid DJ Setups

Hybrid setups combine traditional DJing with tamplified elements. One side of the setup plays pre-recorded tracks, while the other side triggers and manipulates tamplified sounds. For example, additional drum beats can be layered over an (a cappella) track, or ambient textures can be added to enrich the sonic landscape. The turntable is particularly effective for rhythmic elements, as it naturally loops material and allows for tempo adjustments. However, tamplified sounds are not limited to rhythm, they can also function as textures or underlying material, supporting spoken word, vocals, or other live performance elements.

As mentioned in 4.1.1, the setup can also be integrated into live band contexts, where tamplified sounds complement traditional instruments. Sequenced tamplified sounds can provide a rhythmic foundation, while live instruments contribute melodic and harmonic content. Alternatively, the live band can lead, and the tamplified sounds can add effects, textures, or rhythmic accents. Samples can be manually triggered by cueing the Tamphall8r and releasing at the right moment, allowing for one-shots in a manner similar to MPC trigger pads. Sequenced beats can also be beat-matched to a live band, creating a tight interplay between pre-arranged and improvised elements.

4.1.3 Live vs. Studio

The instrument is designed for live performance, but it can also be used in a studio setting. It is designed to work with the Tample system, but it can also be used as a standalone setup. In the studio, the performer has more time to prepare and arrange material, allowing for more complex compositions. Especially the Tamphall8r can be used to create complex rhythmical patterns. In the studio, one can record MIDI directly from the Tamphall8r into a DAW, allowing for further editing and arrangement.

Working in the studio often becomes a process of trial and error, focused on discovering interesting patterns. Many times, it is these small accidents that lead to unexpected and inspiring results.

4.2 On Stage

4.2.1 Gig: Sonic Saturday

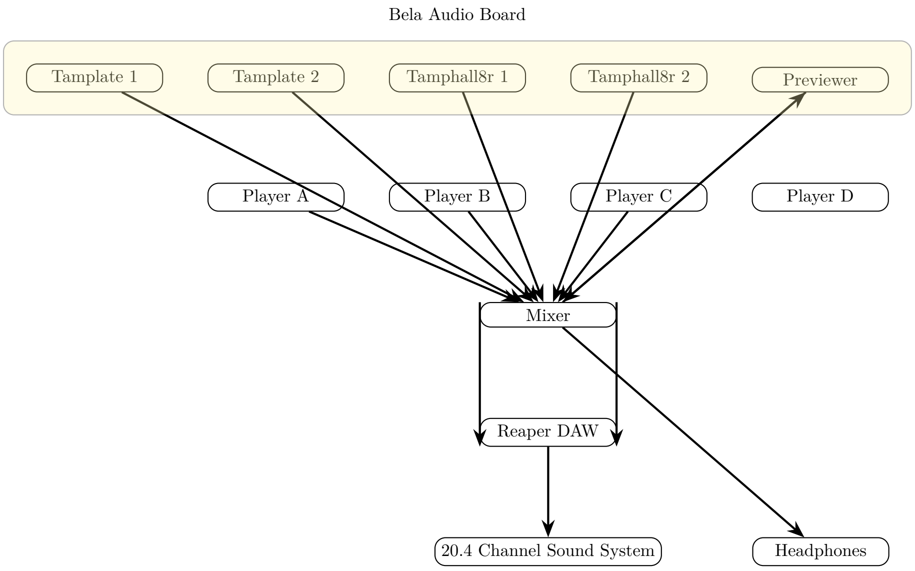
I performed the Turntangilism 3000 instruments at the Sonic Saturday event at Sonic Lab at Anton Bruckner Privat Universität Linz, during ARS Electronica 2025[1].

Setup

I played a hybrid DJ setup, using four record players, the Turntangilism 3000 instruments, a mixer and the 20.4 spatial audio system at Sonic Lab. The setup was as follows:

[1] https://ars.electronica.art/panic/en/

Figure 4.1: Photo of Setup at Sonic Saturday Concert at ARS Electronic 2025



Where the left channel was routed to a channel with a fixed panning. It was sent to all speakers, with slightly higher volumes at the front. The right channel was routed to a channel with dynamic panning, where the rotation of the Tamplate (3.2.2) was mapped to the azimuth of the panner.

The control the spatial audio system at the venue, I used the venue's computer and a reaper[2] session, using the IEM plugin suite [3]. In order to achieve to control the reaper set, I have added a second Enomik 3000 dongle to the setup, which was connected via USB to the venue's computer.

The fourth turntable was not connected to the mixer, but instead it was used to play the Tamplate.

Performance

I played a 20 minutes improvised set, using different vinyl records as source material. Ranging from typical sample material such as film sounds records, or relaxation exercise vinyls, and contemporary avant-garde minimalist music, such as Group 180, to more experimental records such as noise music or field recordings. I started with an ambient soundscape, using the tamplified sounds as textures via the Tamplate in scratch/granular mode, slowly building up the energy and introducing more rhythmic elements via the Tamphall8r. Then adding rhythmic sounds from analog vinyls, panning them via the Tamplate in position mode, and layering more complex rhythms via the Tamphall8r. Ending the set with distorted noisy sounds captured from the record player needle itself, touching it with the fingers and scratching it on the vinyl surface.

4.2.2 Gig: Favoritbar

Since the Turntangilism 3000 is designed to be used in different contexts, I also played it in a more traditional DJ setup at Favoritbar in Munich, Germany on September 22nd. Using the venue's DJ mixer (Allen Heath Xone 43C), their two Technics SL-1210 record players and two additional record players I brought myself. As well as my Turntangilism 3000 instruments. For that gig I have adapted the Pd patch slightly, to output to three stereo channels (Tamphall8r 1, Tamphall8r 2 and both Tamplates combined), which were then routed to three channels on the mixer. The fourth stereo output of the Bela board was used for previewing via headphones, also the cue channel of the mixer was routed directly to the headphones. This small change was needed, as the mixer does not provide auxiliary outputs.

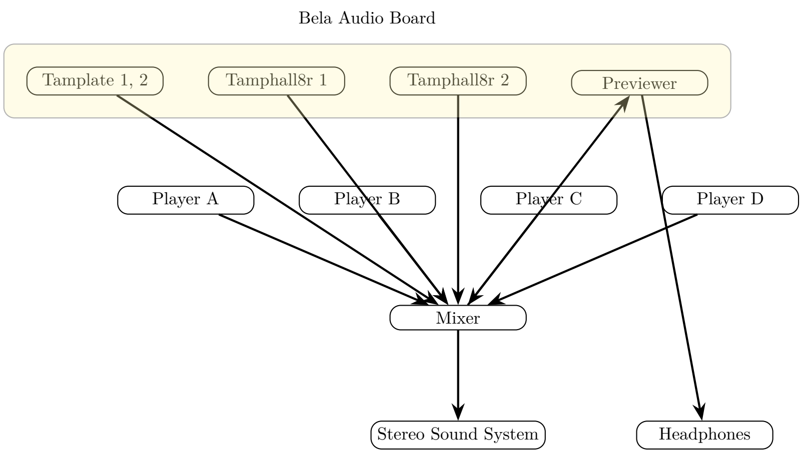
[2] `https://www.reaper.fm/`
[3] `https://plugins.iem.at/`

(a) Setup at Favoritbar

(b) Me performing at Favoritbar

Figure 4.2: Photos from the gig at Favoritbar, Munich

Setup



Performance

On that evening, I first gave a little introduction talk to the audience about the instrument and its background. Then I played a 30-minute improvised set. Starting with demonstrating the individual parts of the setup, first starting to play spoken word samples, capturing these with the Tamplifier, use them in combination with the Tamplepack8 and the Tamphall8r to create a rhythmical piece. Later playing more ambient vinyls mixed with granular textures from the Tamplate. Ending the set with captured noises, sequenced on the two Tamphall8rs, allowing for a smooth transition to the next act: Lucas Abela - an experimental harsh noise musician who plays cut glass with his mouth.

Chapter 5

Conclusion

5.1 Summary of Findings

In this thesis, I have presented the backgrounds, design and implementation of the Turntangilism 3000, a tangible musical interface that extends traditional turntables into expressive instruments for live sampling and sequencing. As well as its potential for musical expression. By integrating token-based tangible interaction with established DJ hardware, the Turntangilism 3000 offers a novel approach to music creation that is screenless and emphasizes physicality.

The current implementation demonstrates both the potential and the technical feasibility of this approach. At the same time, several aspects emerged that highlight the need for practice and personal adaptation. It is easy to understand how the system works, but achieving precise timing requires training. Since the samples are not labeled, each performer must develop their own strategies for working with the colored tokens. For example, assigning bass sounds to darker tokens, or organizing material across different sample banks. Coming from a DJ background, I am used to pre-listening to samples/records before using them.

There was absolutely no need for visual feedback. It is extremely satisfying to work without a screen. The design itself did not require one, and the preview features were more than sufficient. Moreover, having a stable system that never crashed removed the need to constantly double-check the state on a screen.

On a technical note, the chosen hardware platform, Bela, proved to be a solid choice. The same applies to the overall architecture and communication protocol. Having one central unit that runs the audio engine and receives MIDI wirelessly from all other devices has proven to be a stable and flexible solution that is also easily extendable.

5.2 Future Work

Due to time and budget constraints, the current setup is necessarily limited. Nevertheless, there are opportunities for several improvements.

5.2.1 Ecosystem

Manipulation of Tamples

One limitation of the current system is that recorded samples cannot be manipulated after recording, unless resampled, e.g. in order to change start and end points. This could be addressed by adding more modes to the Tamplate, to allow for editing functions like trimming, looping, or reversing samples. Its buttons could be used to activate manipulation mode, and the rotation could adjust start and end points, change the pitch or dial in volume envelopes, or other parameters.

Tamphall8r Improvements

Velocities and Effects Currently, it is not possible to store velocity information, which would be a useful feature for a sequencer. This could potentially be implemented on a per-Tample basis, which makes sense for cases where Tamples act as interaction tokens or triggers. However, it does not make sense for instruments such as the Tamphall8r.

On a per-Tample basis, one approach could be to use magnetic inserts that are then read by Hall effect sensors. RFID might also work, while it is usually not very precise, it could be sufficient since it would not be used for triggering.

Things become more complex when the instrument is not triggered via the Tamples, as with the Tamphall8r.

Additionally, it would be desirable to control effects through the tangible interface. F or example, rings around the tokens could correspond to different effects.

Currently each sensor record has a hard-coded ID. The ID is used to make it work together with the Tamplepack8. Ideally there could be another paring mechanism, e.g. placing the record first on the Tamplepack8 before placing it on the turntable. RFID could do the job. There are many other ways to do this.

Presets/Swappable Rings A feature I initially planned was the ability to remove and replace rings. For example, one could remove an entire ring, effectively muting a track, such as all hi-hats, or replace a hi-hat track with a different one. This feature would be useful for creating more complex structures without having to build everything from scratch.

Tamplate Improvements

Since the capacitive touch pins of the ESP32 are already exposed to connectors, they could be used to enable more interaction possibilities. For example effects such as distortion could be activated by touching the Tamplate or a specific area on it.

Other Instruments and Effects

Tamploop as discussed in 3.2.2, it would be a nice addition to the ecosystem. It is similar to the Tamphall8r, but it is monophonic and not limited to 8 samples only. By its design it is easier to understand, especially for first-time users or people in the audience.

Effects would be a nice feature to have as well, e.g. the Tamplate could be used to control effects parameters, the rotation could be mapped to filter cutoff, or reverb amount, etc. Loop- or sequence-based music often gets boring after a while, the Tamphall8r therefore allows to manipulate sequences on the fly, e.g. through playhead manipulation by moving the sensor record or by changing the pattern. But also effects could help to create more variation and interest.

5.2.2 Standalone

Some parts of the system could be made standalone. For example, the Tamphall8r could operate independently of the ecosystem and would not require a record player. A stepper motor could be used to spin the sensor board. Another promising approach would be to record the motion of the disc when rotated manually and then replay that motion. In this way, the system additionally functions as a motion sequencer.

5.2.3 Product Development

The instrument has been shown to function reliably and to be enjoyable to play. There was quite positive feedback, people wanting to try it themselves. A natural next step could be to investigate how the concept could be refined and developed into a product suitable for broader use. This would involve not only technical optimization, but also considerations of usability, ergonomics, and accessibility for a wider range of performers.

5.3 Final Thoughts

It feels wrong to end the thesis with the business part, as the project is more than just a business opportunity. Accordingly, I would like to share some closing thoughts.

In the very first place Turntangilism 3000 is a project that works very well with my artistic practice. An instrument I will integrate into my DJ sets, an instrument I will use in my performances, in solo projects, and band projects as well. Turning it into a product is not necessarily the main motivation. But something that would allow others to use it, to explore it, to make music with it. The concept and the resulting instrument are quite unique, joyful, and I believe they have the potential to inspire new ways of making music.

Keep spinning!

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