Inkstrument: Interactive Musical Instrument with Conductive Ink

Jockey Club Project IDEA Inclusive Digital and Experimental Art

賽馬會科藝共融計劃

Workshop Overview

1

7 Comprehensive Lessons

Each lesson runs 1.5-2 hours, covering conductive ink basics through to building a custom instrument.

2

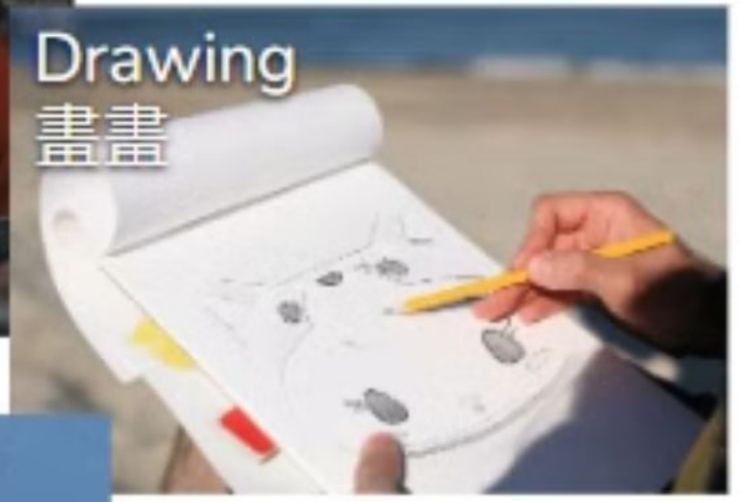
Target Students

Designed for secondary school students, with no prior electronics experience required.

3

Key Learning Outcomes

Conductive ink applications, sound design, Arduino programming, and complete a musical instrument that responds to touch.



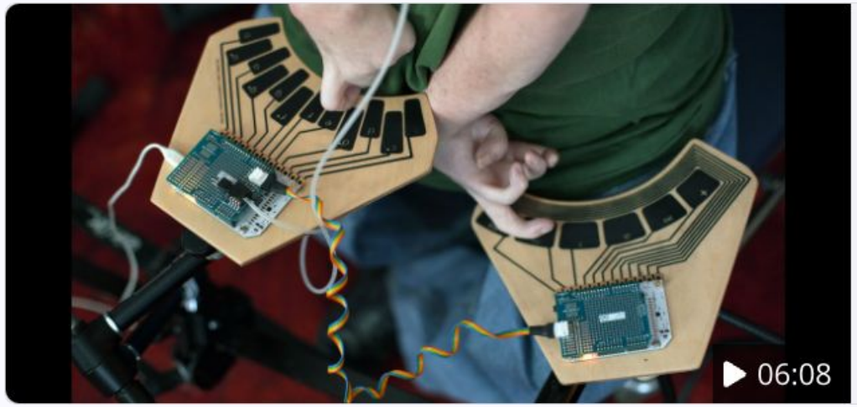
Abstract
抽象

Be Patient
耐性

Observation
觀察力

Curiosity
好奇

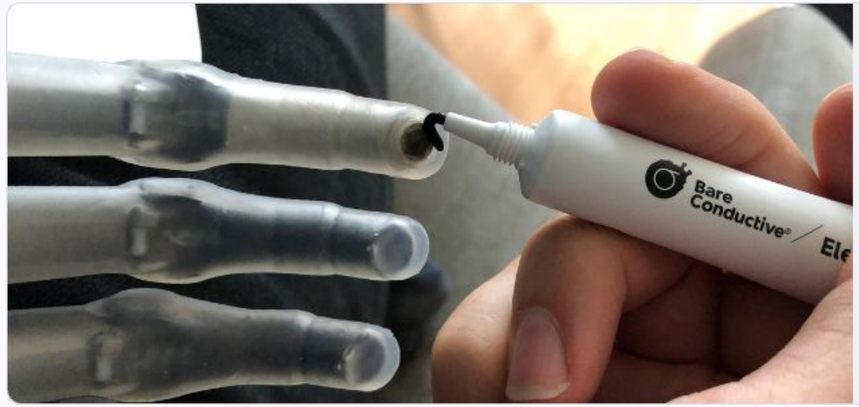
Frustration
沮喪



YouTube

Touch Chord - A Touch Sensitive Breath Controlled Instrument

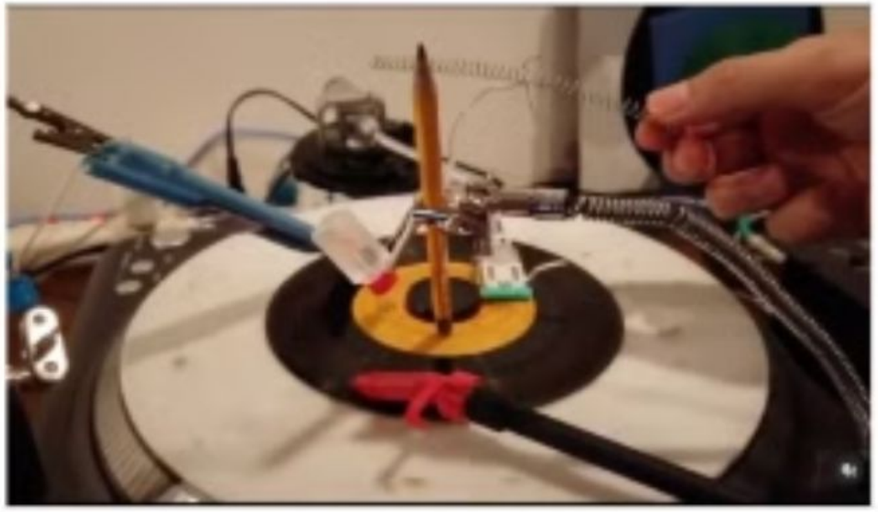
Read the full story: http://bit.ly/1Gg7gQ7 Designer Musician Vahakn Matossian from Human Instruments teams up with Bare Conductive to develop a new musical...



Bare Conductive

Making a Bionic Hand Touchscreen Friendly

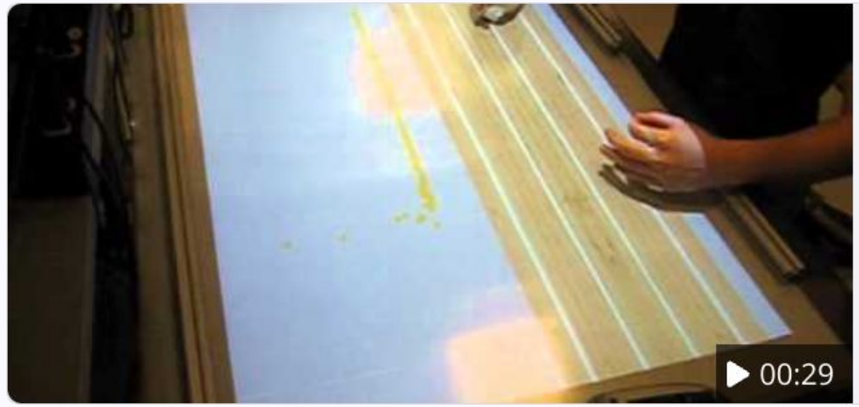
Stephen Lowry shows us how he used Electric Paint to make is bebionic3 bionic hand touch screen friendly, allowing him to use his smart phone and other devices.



YouTube

Demystifying Conducting: The Connection Between Gesture and Musi...

Alan Gilbert, music director of the New York Philharmonic, demonstrates and discusses the role of a conductor. Subscribe to the Times Video newsletter for free...



YouTube

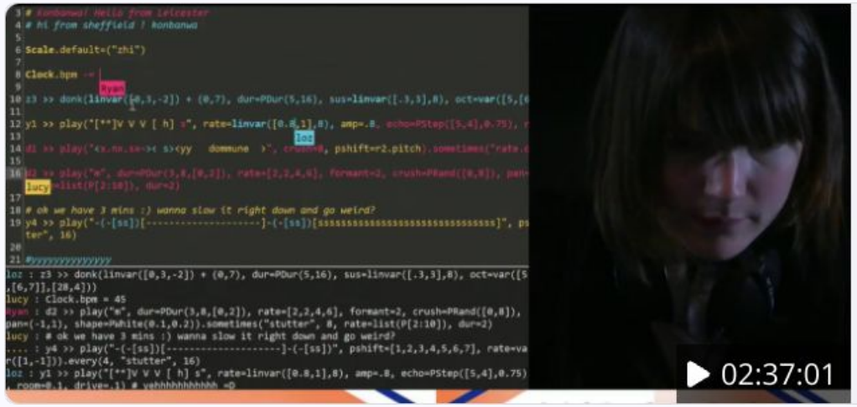
Gesture Based Music

In this demonstration, a ceiling mounted projector displays an image downward onto a partially retro-reflective screen material. This enables a camera, also...

YouTube

Live-Coding – programming masterly music | Juan Romero & Patrick ...

Benoît and the Mandelbrots see the laptop as their main instrument; they are mainly dedicated to live coding, the process of writing software in real time. They...

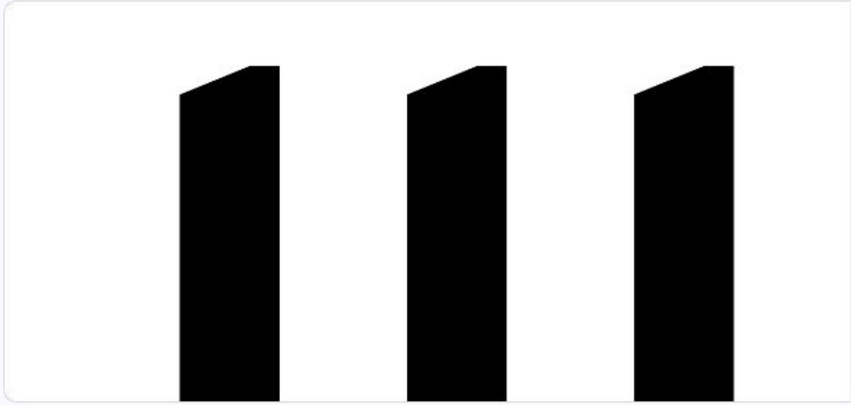


YouTube

DOMMUNE Tokyo - live coding performances - algorave tokyo x yorks...

DOMMUNE - Tokyo x Yorkshire exchange transmission

http://www.dommune.com/reserve/2018/1114/ With thanks to Great Britain...



instrumentinventors.org

Homepage - instrumentinventors.org

iii is an artist run, community platform supporting new interdisciplinary practices linking performance, technology and the human senses

Demo: Adafruit Circuit Playground with Accelerometer

In this demonstration, we'll explore how physical movement translates into sound using the Adafruit Circuit Playground's built-in accelerometer.

What is an Accelerometer?

A sensor that detects changes in velocity and orientation along different axes (X, Y, Z), allowing our instrument to respond to tilting, shaking, and rotation.

Movement-to-Sound Conversion

As we tilt, shake, or rotate the Adafruit board, the accelerometer data directly modifies sound frequency (Hz), creating higher pitches with faster movements and lower pitches with slower movements.

Demo 1 (Processing)

Sound Generation

An oscillator with ADSR envelope (Attack, Decay, Sustain, Release) creates sounds that dynamically respond to movement, demonstrating how electronic instruments produce and shape tones.

Motion Tracking

An accelerometer captures physical movements along X, Y, and Z axes, similar to how our conductive ink sensors will detect touch and pressure.

Visual Feedback

Using Processing IDE to create real-time visualizations of the accelerometer data, showing the connection between movement and sound generation.

Audio Processing

Pure Data (PD) handles the audio signal chain, demonstrating how open-source tools can create sophisticated sound processing systems.

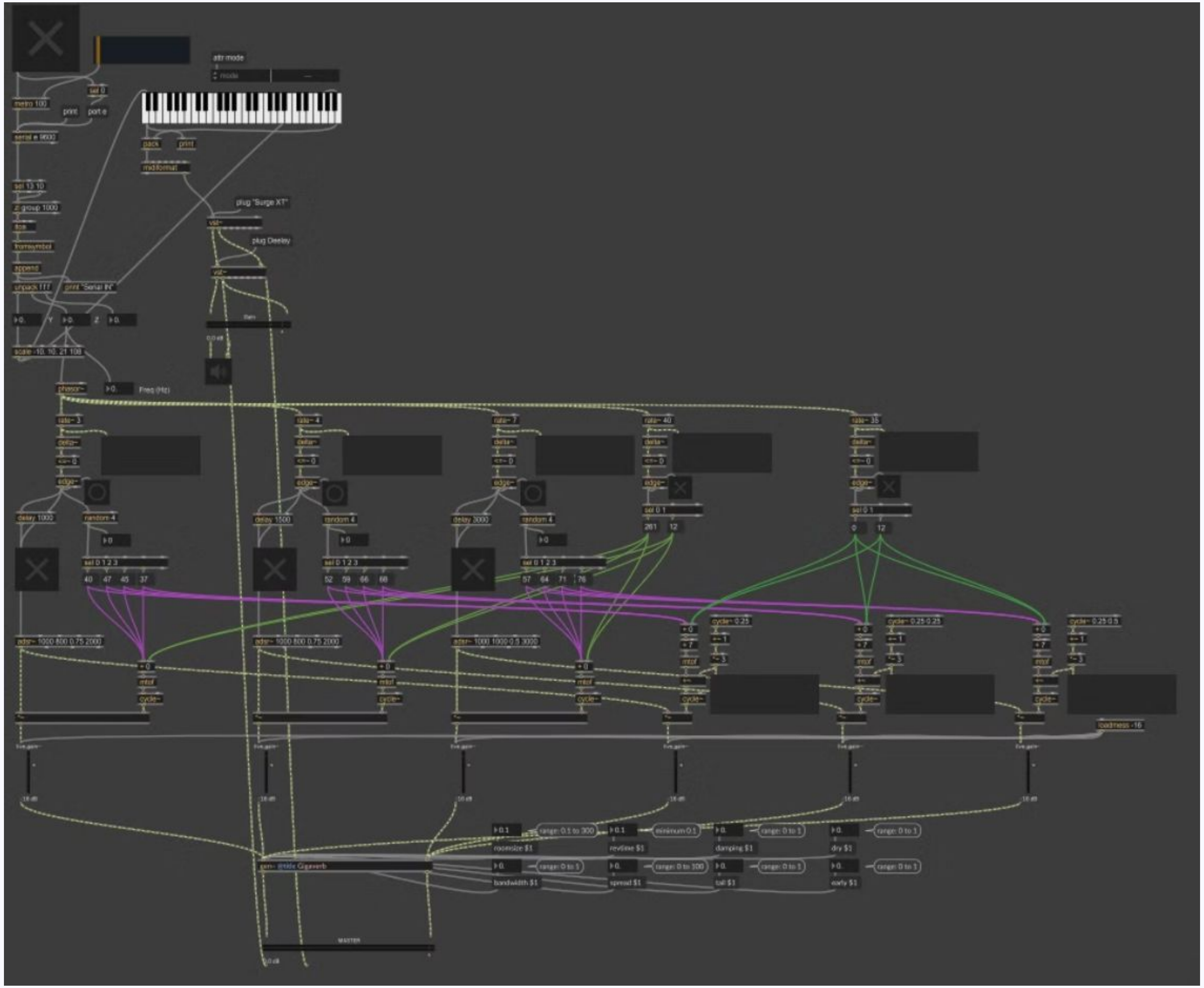

C
C#
D
D#
E
F
F#
G
G#
A
A#
B
PLAY
RESET
Scale: C Pentatonic - C4
No accelerometer connected
DRY
WET
1.00
TIMBRE
0.50
DRY / WET
50% Dry / 50% Wet
97.00
BPM
2.00
OCTAVE
ENVELOPE SETTINGS
5.0E
ATTACK
2.0E
DECAY
0.70
SUSTAIN
3.0E
RELEASE
0.04
PORTAMENTO
REVERB SETTINGS
50.00
REVERB VOLUME
5000.00
REVERB CROSSOVER
ENVELOPE VISUALIZATION
A
S
R

Demo 2 (Max/MSP)

In this demonstration, we'll explore how Max/MSP can transform physical movement into musical parameters.

We're using the powerful free VST synthesizer Surge XT as our sound source, paired with the Deelay effect plugin for time-based audio manipulation. The X-axis movement data (ranging from -10 to 10) is mapped to MIDI notes using the kslider object, which are then sent directly to the Surge XT synthesizer.

Simultaneously, Y-axis movement data feeds into a phasor~ object, creating cyclical patterns that control our note generator. This creates a dynamic relationship between physical gestures and musical output, similar to what we'll achieve with our conductive ink instruments.


attr mode
plug "Surge XT"
plug Deelay
Freq (Hz)
MASTER
roomsize $1
revtime $1
damping $1
dry $1
bandwidth $1
spread $1
tail $1
early $1
loadmess -16

Text vs. Node-Based Creative Coding in the AI Era

As we will develop our conductive ink instruments, we'll use text-based coding (like Arduino) to translate physical inputs into sound.

Text-Based Coding

- Offers precise control through written commands
- Essential for understanding core programming concepts
- Skills remain relevant even as AI tools like GitHub Copilot assist with code generation

Node-Based Programming

- Visual approach that connects functional blocks with "wires"
- Intuitive for sound design and signal processing
- Encourages experimentation and rapid prototyping

Understanding both paradigms gives you versatility in expressing your creative ideas and prepares you to work with both traditional coding and emerging AI-augmented tools.

Lesson 1: Introduction to Conductive Ink

What is it?

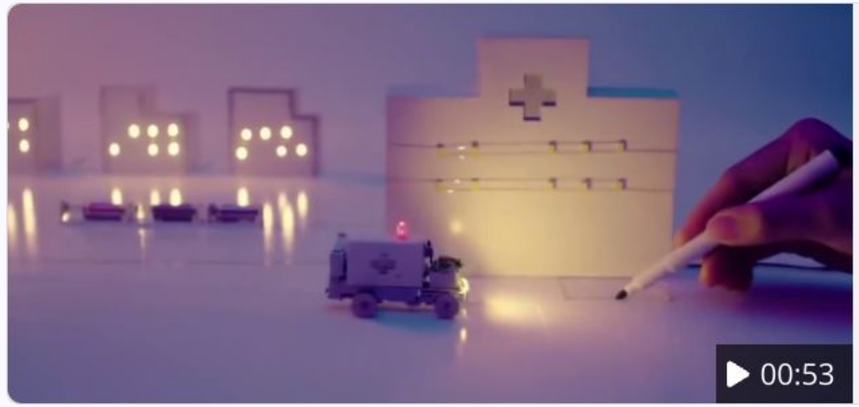
Conductive ink is a special ink that conducts electricity.

How is it used?

It can be used in electronics and art projects.

Lesson Overview

We'll explore its properties and applications.



YouTube

Pen that draws electricity - The AgIC Circuit Marker pen uses conduct...

The AgIC Circuit Marker pen uses conductive ink that allows working electrical circuits to be drawn on pieces of paper. Available on Amazon for only $15!...

Understanding Electrical Conductivity

Conductivity refers to a material's ability to allow the flow of electrical current. Just like water flows through pipes, electricity flows through conductive materials.

Electronic Circuit

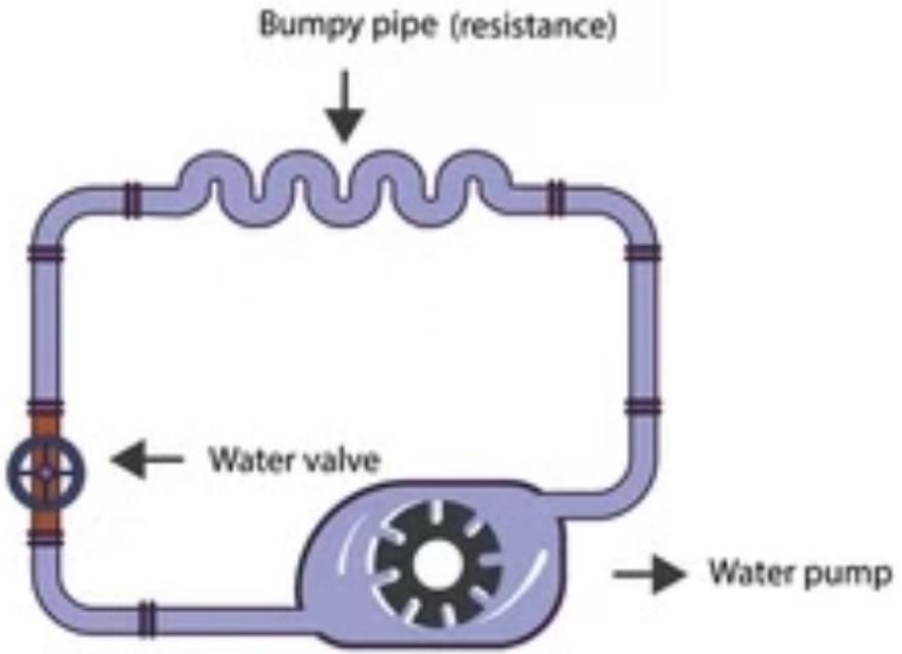
- Electricity flows through conductive wires
- Electrons move from negative to positive
- Resistance restricts electrical flow
- Voltage acts as electrical pressure

Water Pipe System

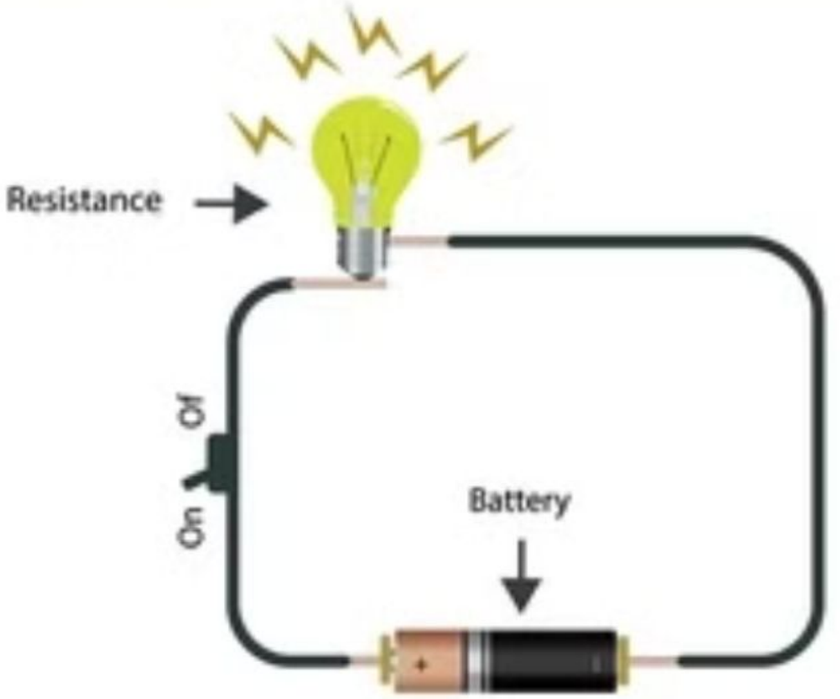
- Water flows through pipes
- Water molecules move from high to low pressure
- Narrow pipes restrict water flow
- Water pressure pushes water forward

When we draw with conductive ink, we're essentially creating flexible "pipes" for electricity to flow through. This allows us to design creative circuits without traditional rigid wiring.

SIMPLE WATER SYSTEM



SIMPLE ELECTRIC CIRCUIT



YouTube

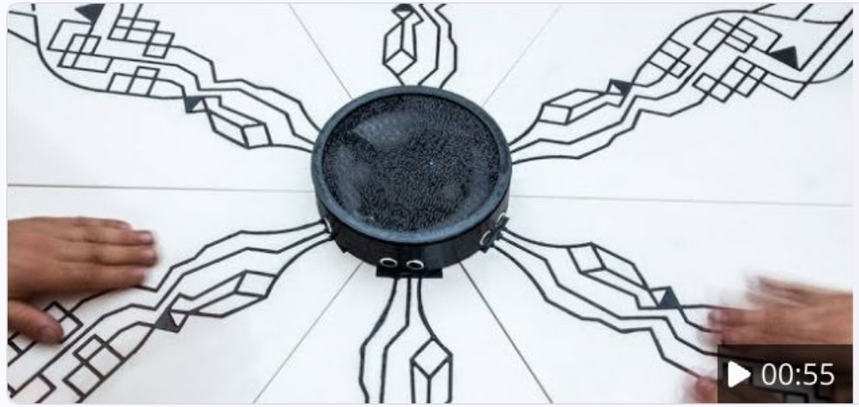
The pen that draws electricity

The AgIC Circuit Marker pen uses conductive ink that allows working electrical circuits to be drawn on pieces of paper. Japanese venture AgIC developed. We test...

YouTube

Electric Paint Lamp Kit

Find out more about the Electric Paint Lamp Kit here:
https://www.bareconductive.com/collections/electric-paint-lamp-kit Transform any...



YouTube

Build Your Own Interactive Sound Table with Electric Pai...

Find out more about Electric Paint here:
https://www.bareconductive.com/collections/electric-paint TACTO is an interactive...

YouTube

Interactive media wall (touch sensor, conductive ink, projection map...

[PLAYDODO] Music Playing Wall : Projection Mapping, Conductive Ink, Interacitve Art Music Playing Wall, a fun Interactive touch wall painted with instruments recognize...

Understanding Resistors in Electronic Circuits

Resistors are fundamental electronic components that limit or restrict the flow of electrical current in a circuit. They provide precise amounts of resistance measured in ohms (Ω).

Resistors in Electronic Circuits

Resistors work by converting electrical energy into heat, thereby reducing current flow.

- Low resistance (e.g., 10Ω) allows more current to flow
- High resistance (e.g., 10,000Ω) significantly restricts current
- Resistors protect sensitive components from excessive current
- They're used to divide voltage and create specific circuit behaviors

Water Pipe System Analogy

The water pipe system provides an excellent way to understand how resistors function:

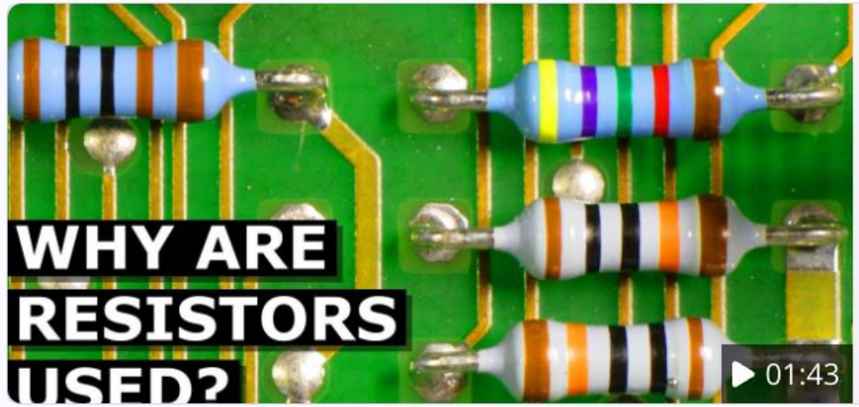
- Wide pipes (low resistance) allow water to flow easily
- Narrow pipes (high resistance) restrict water flow
- Water pressure (voltage) pushes against the restriction
- Flow rate (current) decreases as pipe narrowness increases

Just as we use different pipe sizes to control water flow in specific parts of a plumbing system, we use different resistor values to control electrical current in different parts of a circuit.

YouTube

How Resistor Work - Unravel the Mysteries of How Resistors Work!

In this video, we're going to learn about how resistors work! We'll explore the different types of resistors, how resistors work in circuits, and how to calculate...



YouTube

Why Resistors Are Used In circuits

In this video, we're going to answer the question: Why are resistors used? 👉 👉👉 FREE design software ➡️ https://www.altium.com/asp/the-engineering-mindset/ ...

Why Resistors Are Critical for Our Inkstrument

For our conductive ink musical instrument project, resistors play several essential roles:

Component Protection

Resistors protect our Arduino microcontroller and other sensitive electronic components from receiving excessive current that could damage them when interacting with our conductive ink circuits.

Sound Modulation

By creating voltage dividers with different resistor values, we can generate various tones and control pitch in our Inkstrument, allowing for more expressive musical capabilities.

Touch Sensitivity

When used with conductive ink, resistors help calibrate the sensitivity of the capacitive sensors, ensuring reliable detection of finger touches and gestures on our instrument's surface.

Material list

The following components are required to build our interactive musical instrument:

Core Electronics

- Arduino Uno R3 microcontroller board
- TouchKeyUSB capacitive touch sensor module
- VS1053 module with SD card
- Small speaker with audio jack output
- USB cable

Conductive Materials

- Conductive Ink
- Copper tape
- Assorted resistors (10kΩ, 1kΩ, and 220Ω)
- Clip wires

Lesson 2: Exploring Electronic Instruments

Theremins

Exploring theremins and gesture-based control.

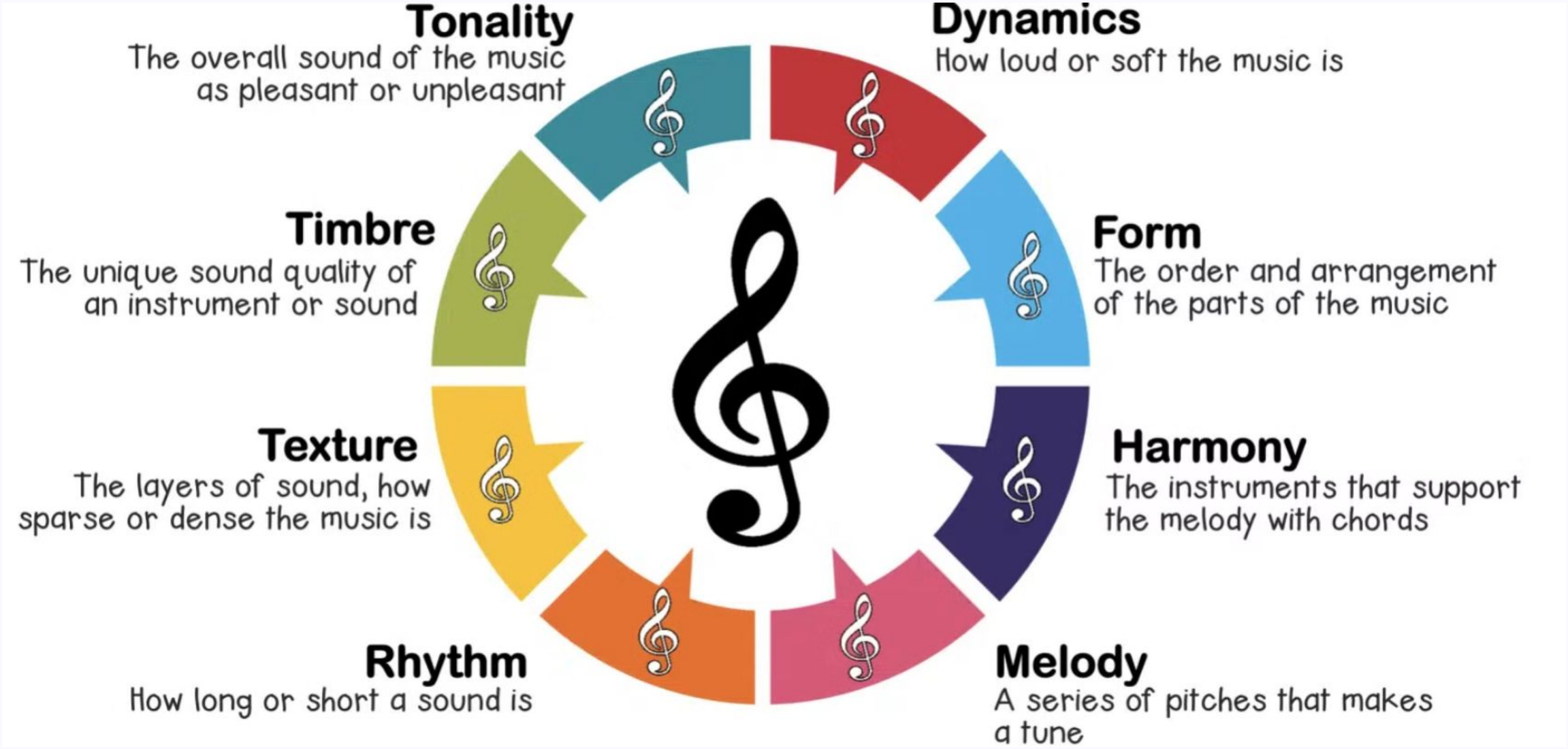
Sound

Understanding electronic sound generation.

YouTube

01 Music Basics - What is Music?

Music theory from the very beginning. If you want to know how to write music, want help revising for exams at school, or just interested in how music works, then this...


Tonality
The overall sound of the music as pleasant or unpleasant
Dynamics
How loud or soft the music is
Timbre
The unique sound quality of an instrument or sound
Form
The order and arrangement of the parts of the music
Texture
The layers of sound, how sparse or dense the music is
Harmony
The instruments that support the melody with chords
Rhythm
How long or short a sound is
Melody
A series of pitches that makes a tune

Core Elements of Music for Electronic Instruments

Rhythm

The pattern of time in music - controls when notes are played and for how long. In electronic instruments, rhythm can be precisely controlled through programming or touch patterns on conductive surfaces.

Melody

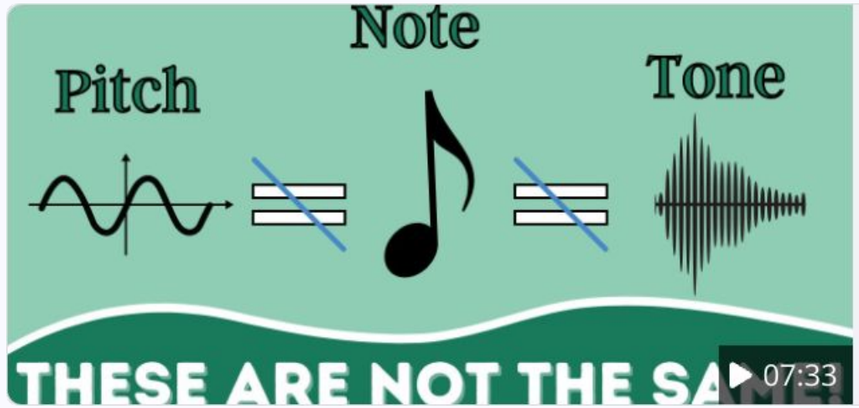
The sequence of notes that form the main recognizable theme. Our Inkstrument will allow different conductive ink patterns to trigger melodic sequences.

Tone/Timbre

The quality and character of sound that distinguishes different instruments. With our Arduino and VS1053 setup, we can manipulate electronic signals to produce various timbres from a single interface.

Dynamics

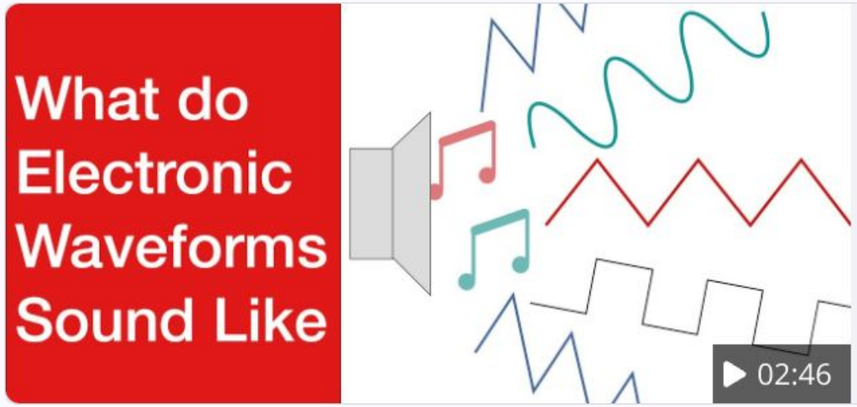
The variation in loudness or softness of notes. Our capacitive touch sensors can detect pressure differences, allowing for dynamic expression in our conductive ink instrument.



YouTube

The Difference Between Pitch, Note, and Tone

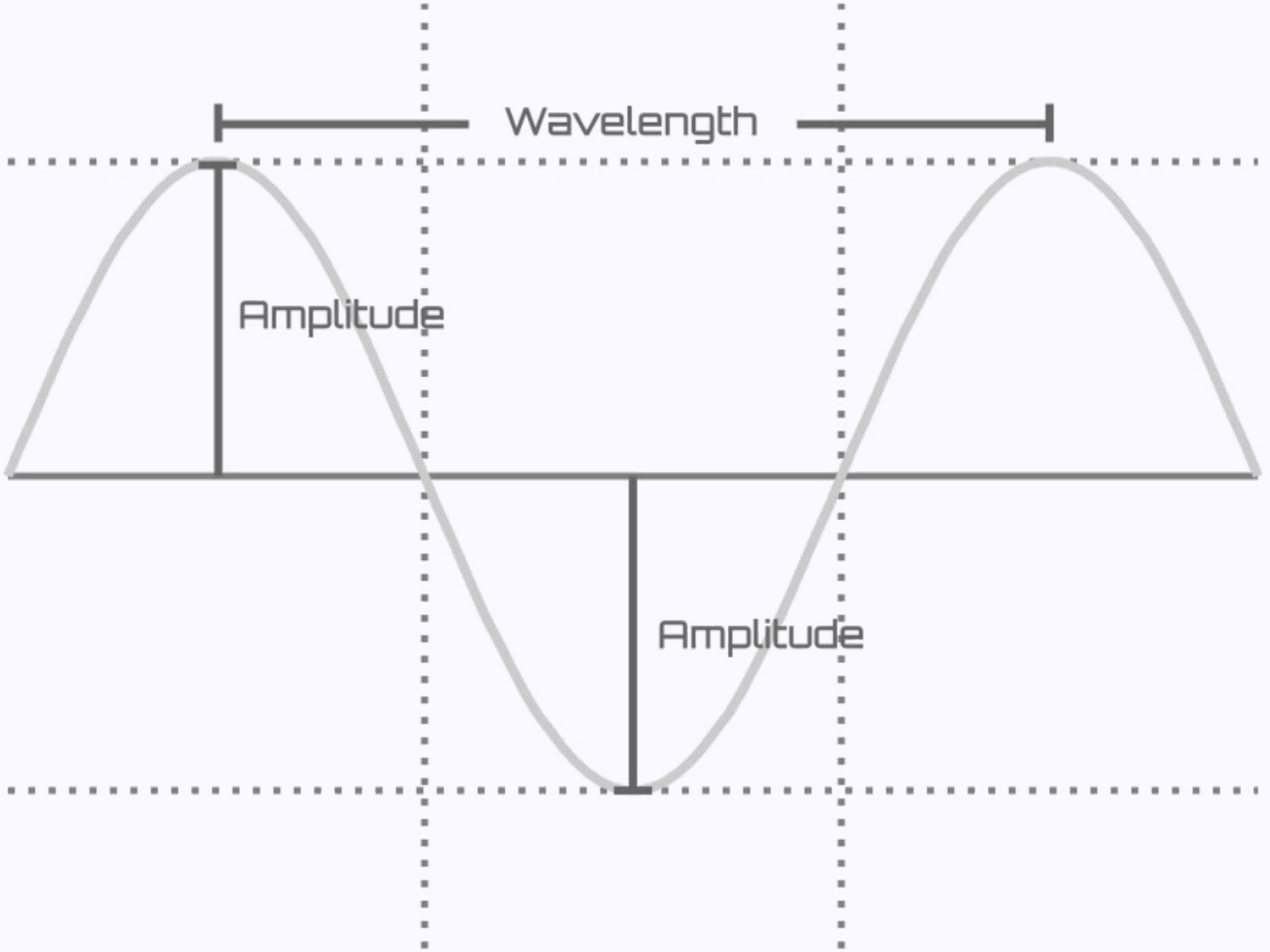
If you'd like to support my channel, consider joining on Patreon: https://shorturl.at/Tw3Mu This is episode 1 of the music fundamentals series!...

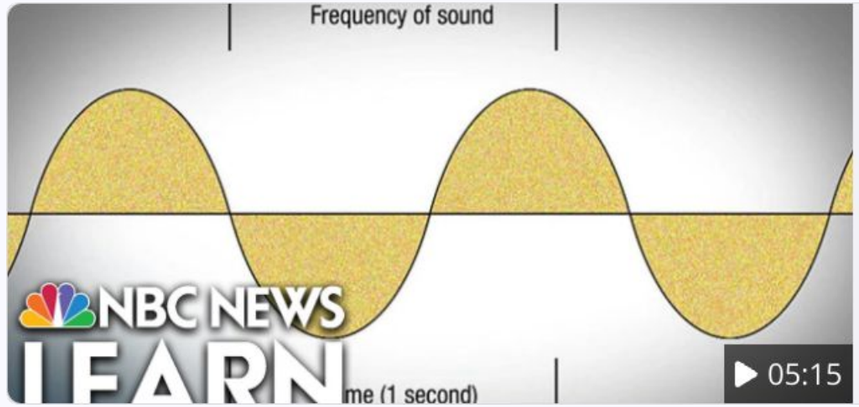


YouTube

What do Electronic Waveforms Sound Like

This video gives you the key information about common waveforms found in electronics and lets you hear what they actually sound like. The waveforms include...

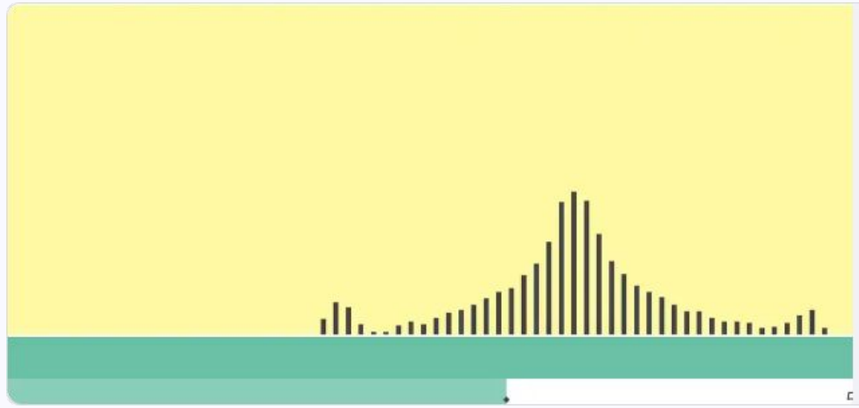

Wavelength
Amplitude
Amplitude



YouTube

Sound Waves

Sound, Sound Waves, Waves, Vibration, Matter, Vibrate, Vibration, Guitar, Singing, Song, Vocal Chord, String, Frequency, Pitch, Energy, Volume, Amplitude



davay42

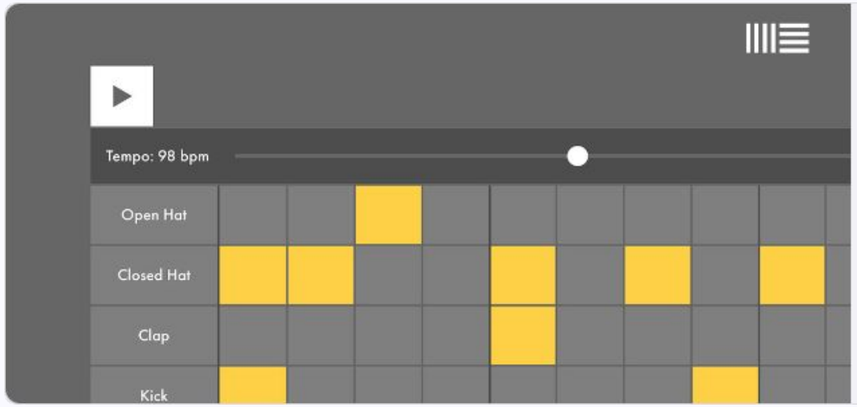
Theremin | Web Synths Collection by Playtronica & Chromatone

Experience the magic of the theremin with this interactive web-app by Femur Design. Harness the power of motion to create ethereal music without physical...

RolandGlobal

Roland50.studio

Emulate the sound of Roland's most famous and influential musical instruments from Yuri Suzuki and Roland.



learningmusic.ableton.com

Get started | Learning Music

Explore the fundamentals of music via Ableton's interactive website. Experiment with beats, melody, harmony, basslines, and song structure in your web browser.

YouTube

Sounds of a Glass Armonica

Composer William Zeitler plays a glass armonica, invented by Benjamin Franklin in 1761. For more on this fascinating story read the full article here on the Toronto...

YouTube

Я сделал Ambient Box на основе EBow | I made an Ambient Box bas...

Взял за основу принцип работы EBow и создал Ambient/Drone Box I took the principle of EBow and created an Ambient/Drone Box based on it

YouTube

KontinuumLAB WORKSHOPS: Recorder MIDI Controller.

In this video tutorial I show you how to make a recorder type MIDI controller from corrugated cardboard and other cheap materials and components. This is one of t...

YouTube

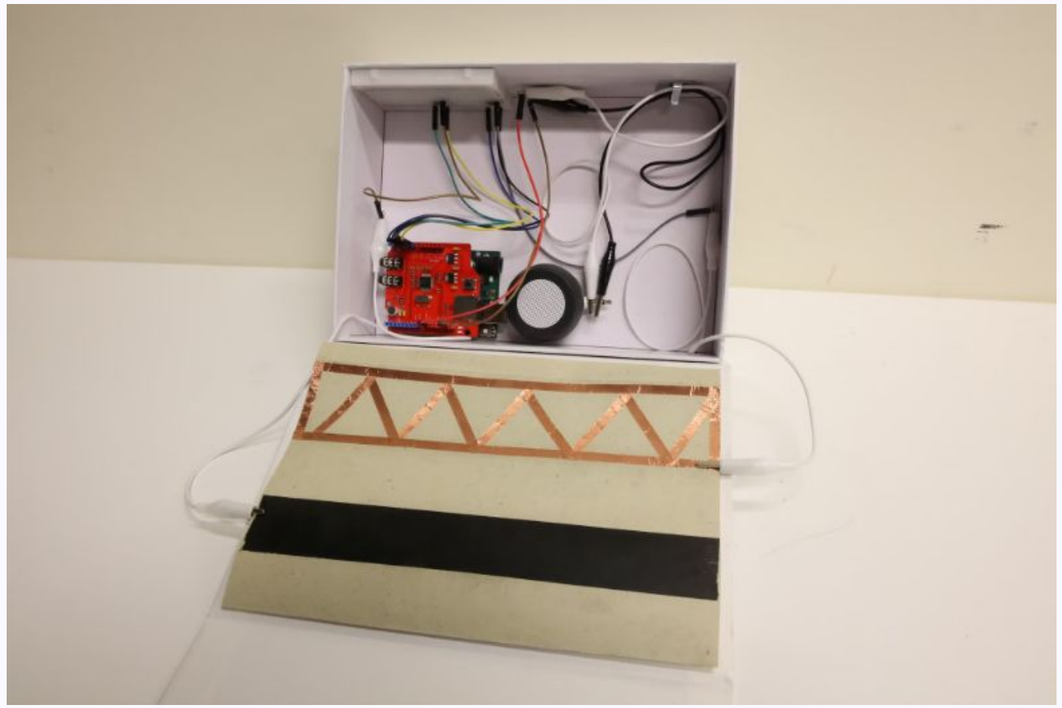
Noise Box 5 - experimental music instrument

Wooden noise box instrument (#5 of my collection). Perfect for film scoring, experimental music, or just improvising with friends. Reverb tank has an output, a...

YouTube

10 Years of the Korg Volca Keys

April 2023 marks ten years since Korg's Volca Keys debuted. Chris Cline revists the popular synth to go over the features and sounds that have made it such a popula...



Lesson 3: Conductive Ink as a Sensor

Sensing

Using conductive materials for touch sensitivity.

Gestures

Recognizing taps, slides, and proximity.

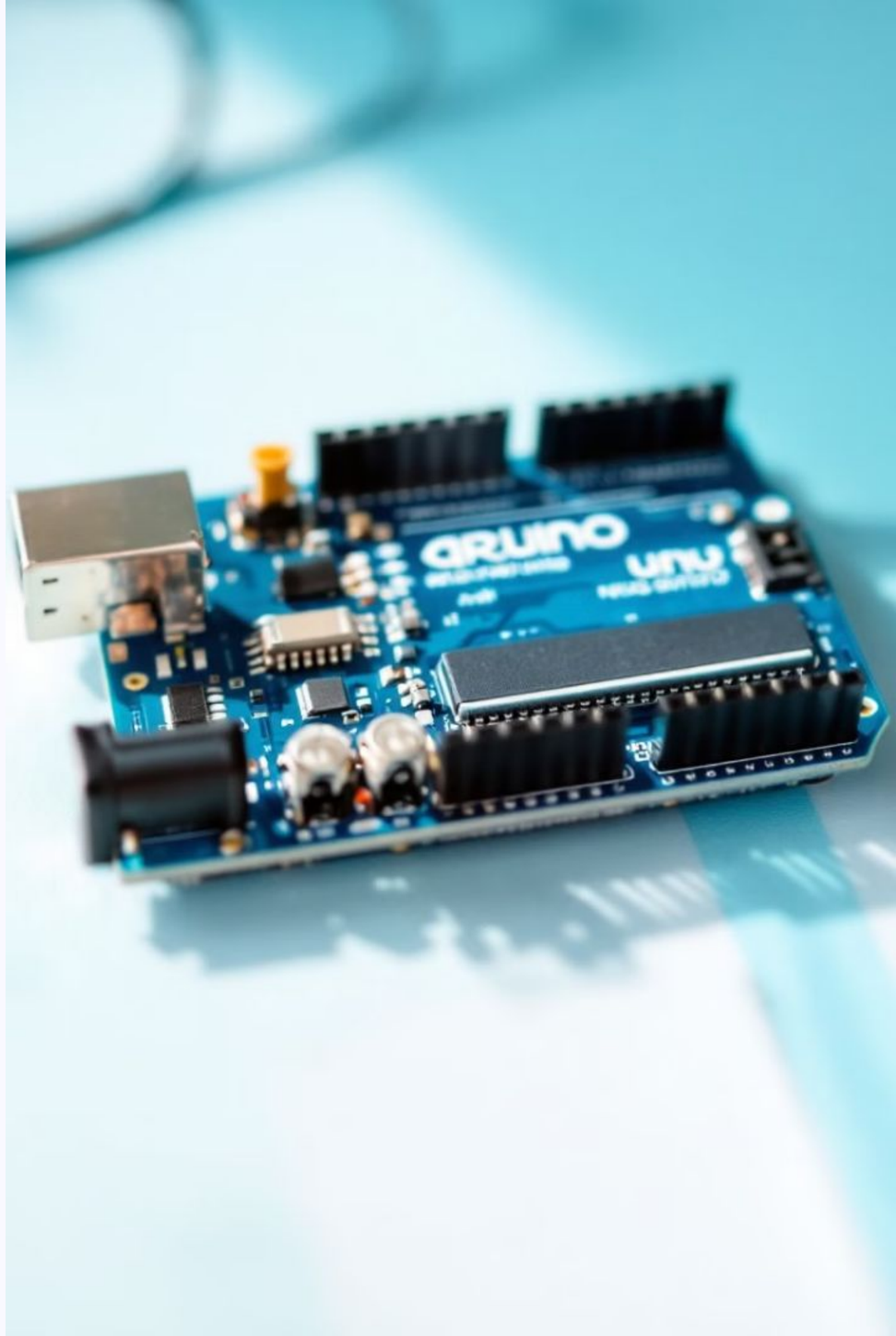
Mapping

Connecting gestures to sound parameters.

Introduction to Arduino

Definition

Arduino is an open-source electronics platform based on easy-to-use hardware and software. It is designed to make the process of creating interactive projects more accessible to artists, designers, hobbyists, and anyone interested in creating interactive objects or environments.

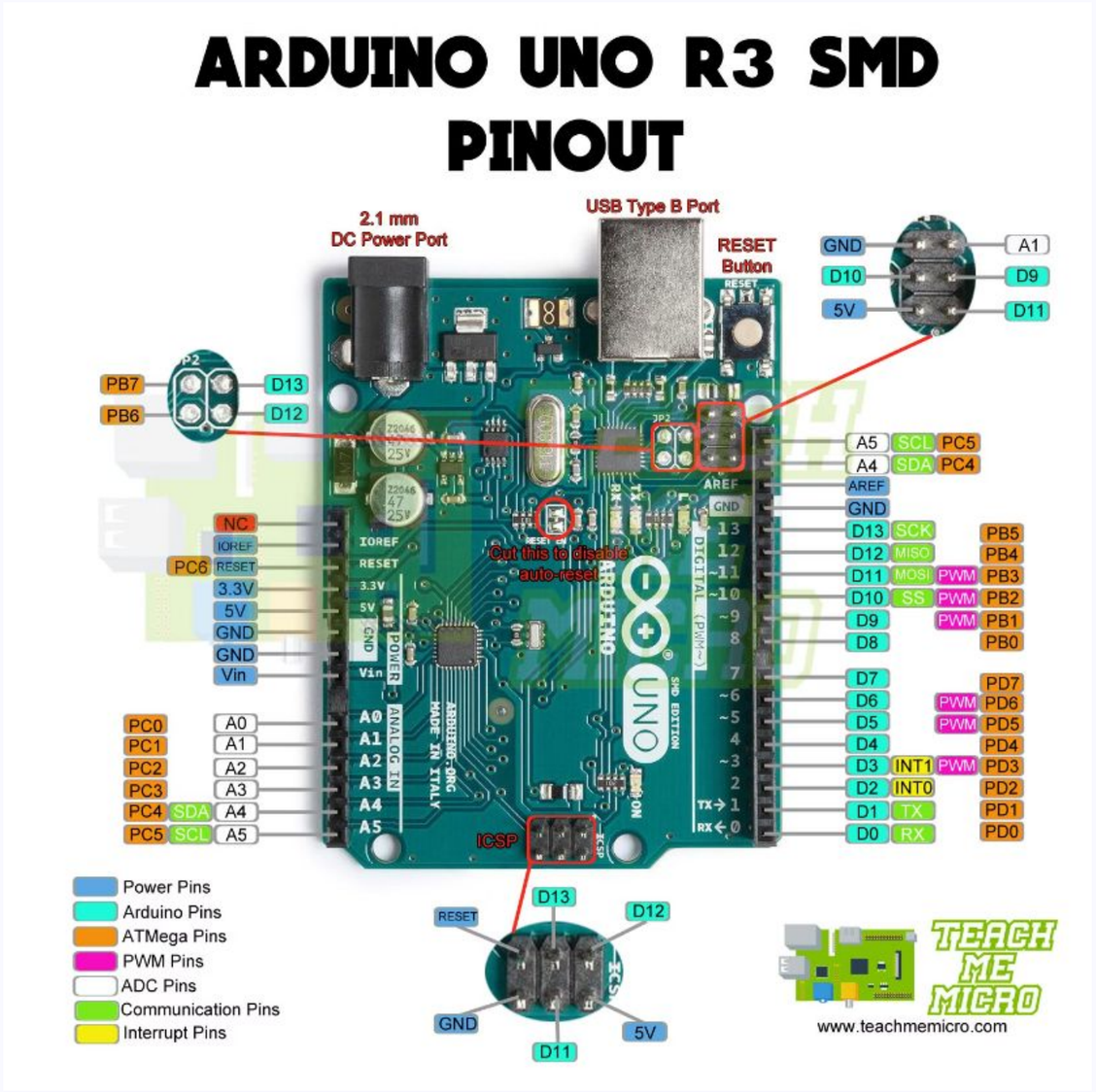


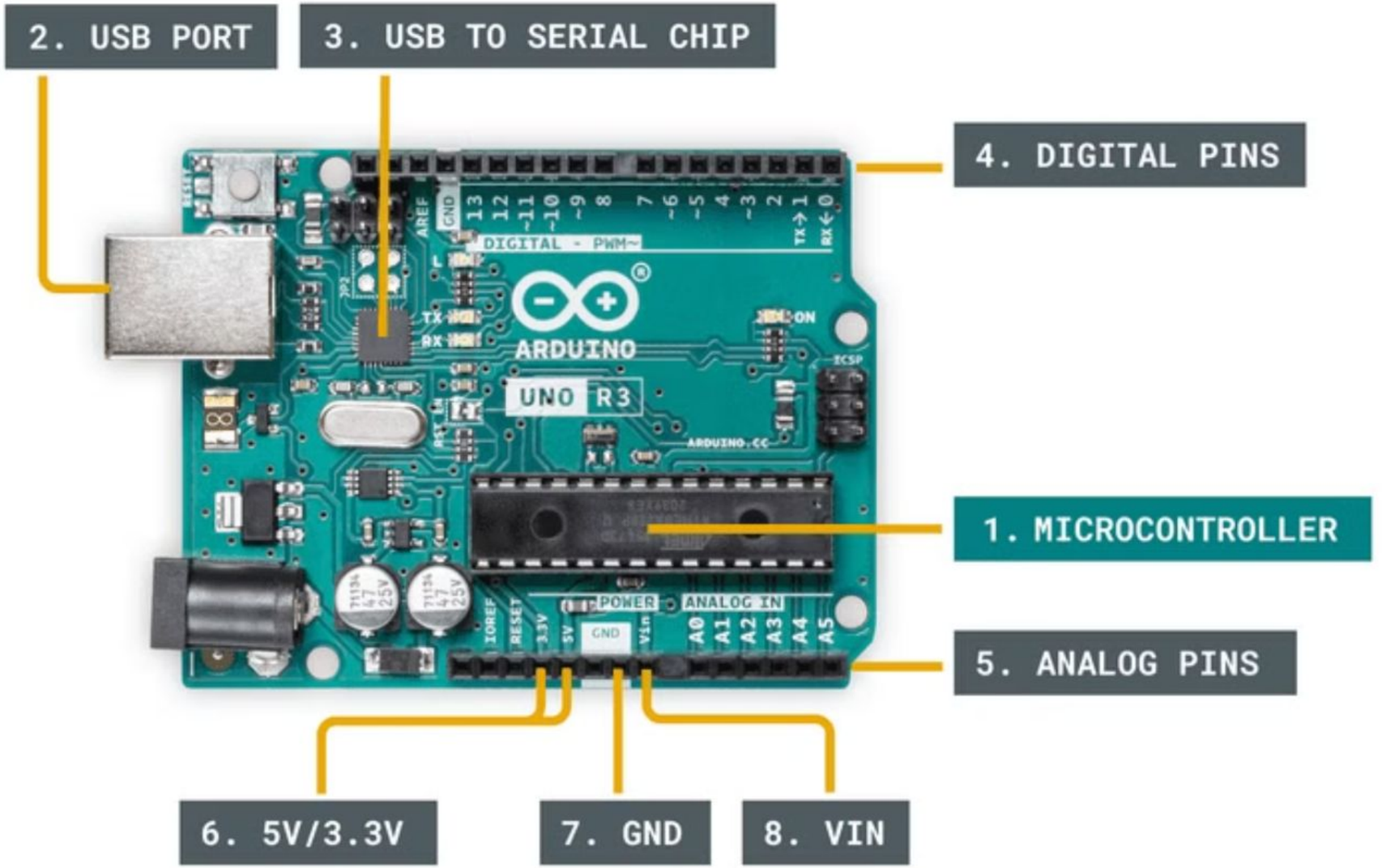
Arduino Uno R3

The Arduino Uno R3 is our microcontroller of choice for the inkstrument project because of its reliability and extensive community support. This board features an ATmega328P microprocessor with:

- 14 digital input/output pins (6 can be used as PWM outputs)
- 6 analog inputs for reading our conductive ink sensors
- USB connection for programming and serial communication

The Uno R3 provides a stable platform for processing sensor data from our conductive ink interfaces.




2. USB PORT
3. USB TO SERIAL CHIP
4. DIGITAL PINS
1. MICROCONTROLLER
5. ANALOG PINS
6. 5V/3.3V
7. GND
8. VIN
ARDUINO
UNO R3
DIGITAL - PWM~
POWER
ANALOG IN
ARDUINO.CC

Serial Communication: Connecting Arduino with Creative Software

Arduino can seamlessly exchange data with creative coding platforms through serial communication protocols (RS-232, SPI, USB, CAN, I2C, and Modbus). This connectivity enables our conductive ink sensors to control sound, visuals, and interactive experiences in software below:

Processing

Create visual responses to touch gestures by sending sensor values from Arduino to Processing sketches using the Serial library.

Processing

Welcome to Processing!

Processing is a flexible software sketchbook and a language for learning how to code. Since 2001,...

TouchDesigner

Build interactive installations by feeding Arduino sensor data through COM ports into TouchDesigner's real-time node-based environment.

Derivative

Derivati...

Derivative is a software company that offers TouchDesigner, a visual development platform.

Max/MSP

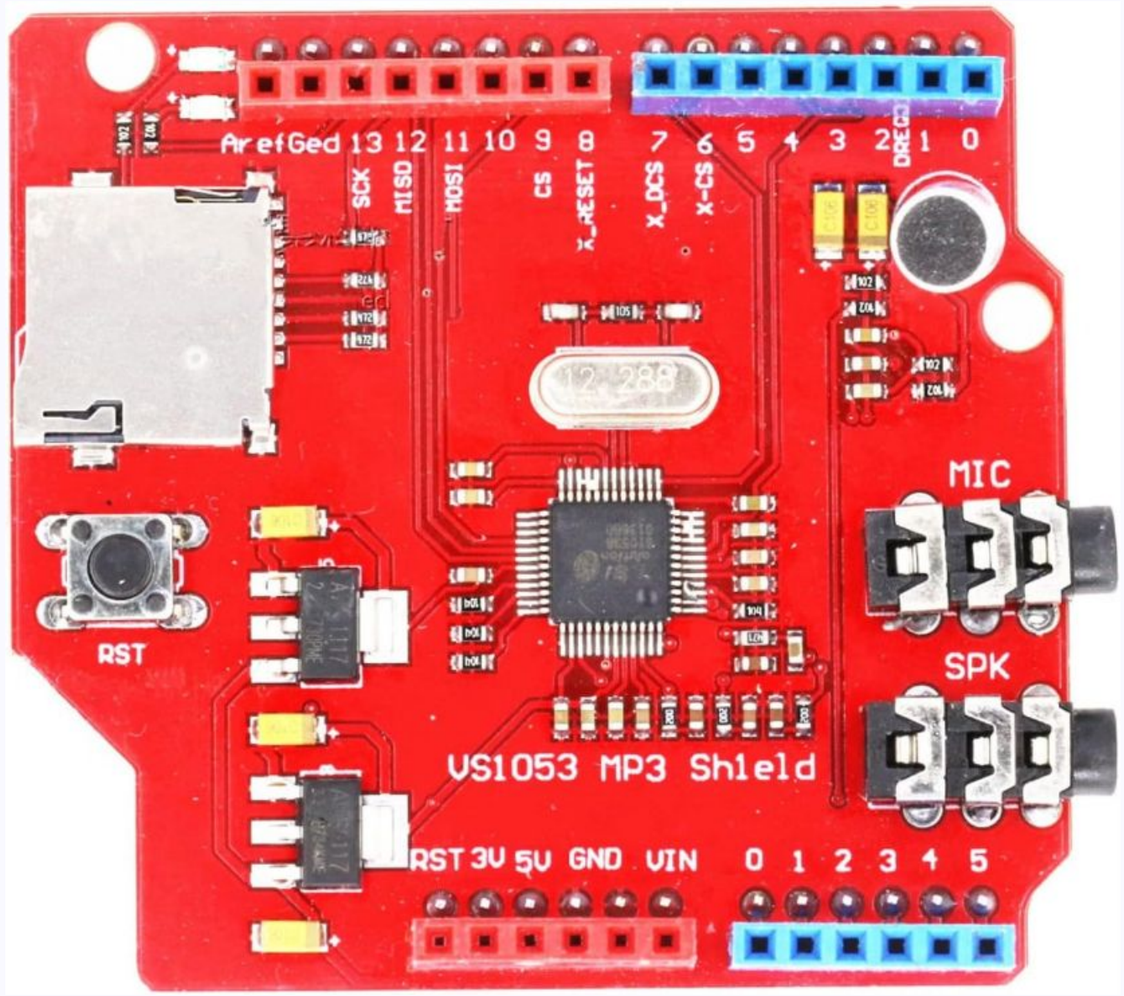
Generate complex sounds and musical compositions by routing conductive ink sensor readings from Arduino into Max/MSP.

cycling74

Cycling '74

Tools for sound, graphics, and interactivity

VS1053 MP3 Shield



The VS1053 audio codec breakout board

The VS1053 is a versatile audio codec that's perfect for creating interactive music with conductive ink instruments.

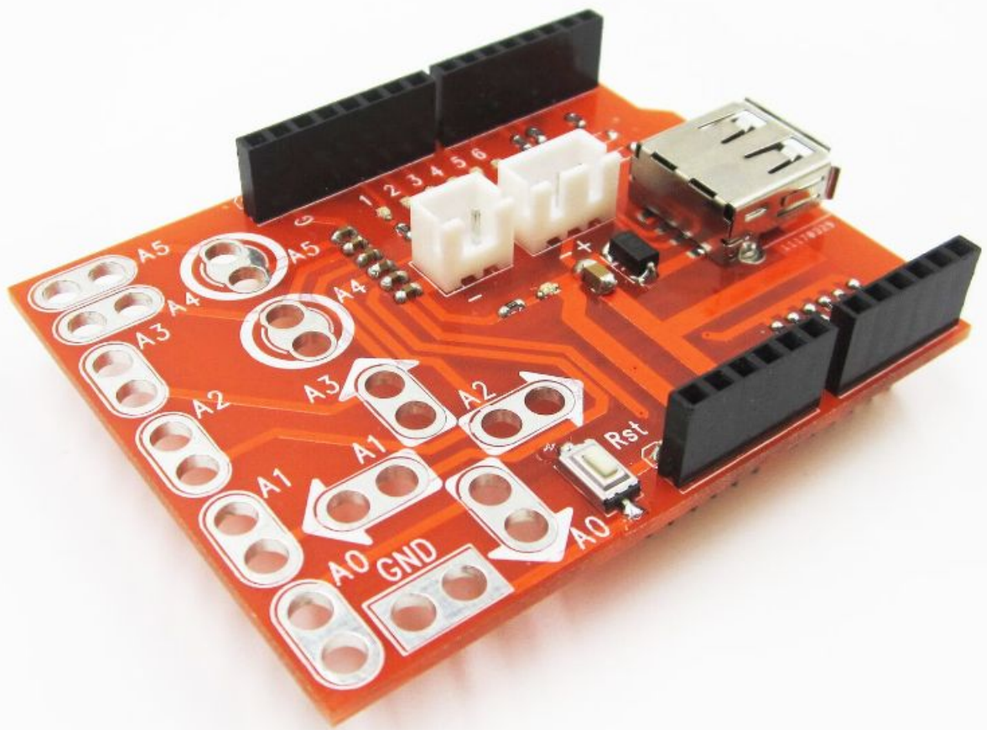
This shield enables Arduino to play MP3, WAV, MIDI, and OGG files, making it ideal for responsive sound installations.

For Inkstrument, the VS1053 translates capacitive touch inputs into dynamic sound output, creating an intuitive musical interface.

With a microSD card slot (up to 32GB), it can store and trigger complex soundscapes based on different touch gestures.

The 3.5mm audio jack and optional speaker terminals deliver high-quality stereo sound with minimal additional components.

Touch key USB



The Touch Key USB shield is an Arduino-compatible expansion board that transforms conductive surfaces into touch-sensitive inputs via capacitive sensing. This shield connects directly to our Arduino Uno R3, providing up to 16 touch-sensitive channels without requiring physical buttons. It's ideal for our conductive ink projects as it can detect touch through paper, plastic, or fabric coated with conductive ink, allowing us to create custom interactive interfaces that trigger sounds or control parameters in our electronic instruments.

Introduction to Theremins

1

History

Invented in 1920 by Russian physicist Léon Theremin, it was one of the earliest electronic instruments.

2

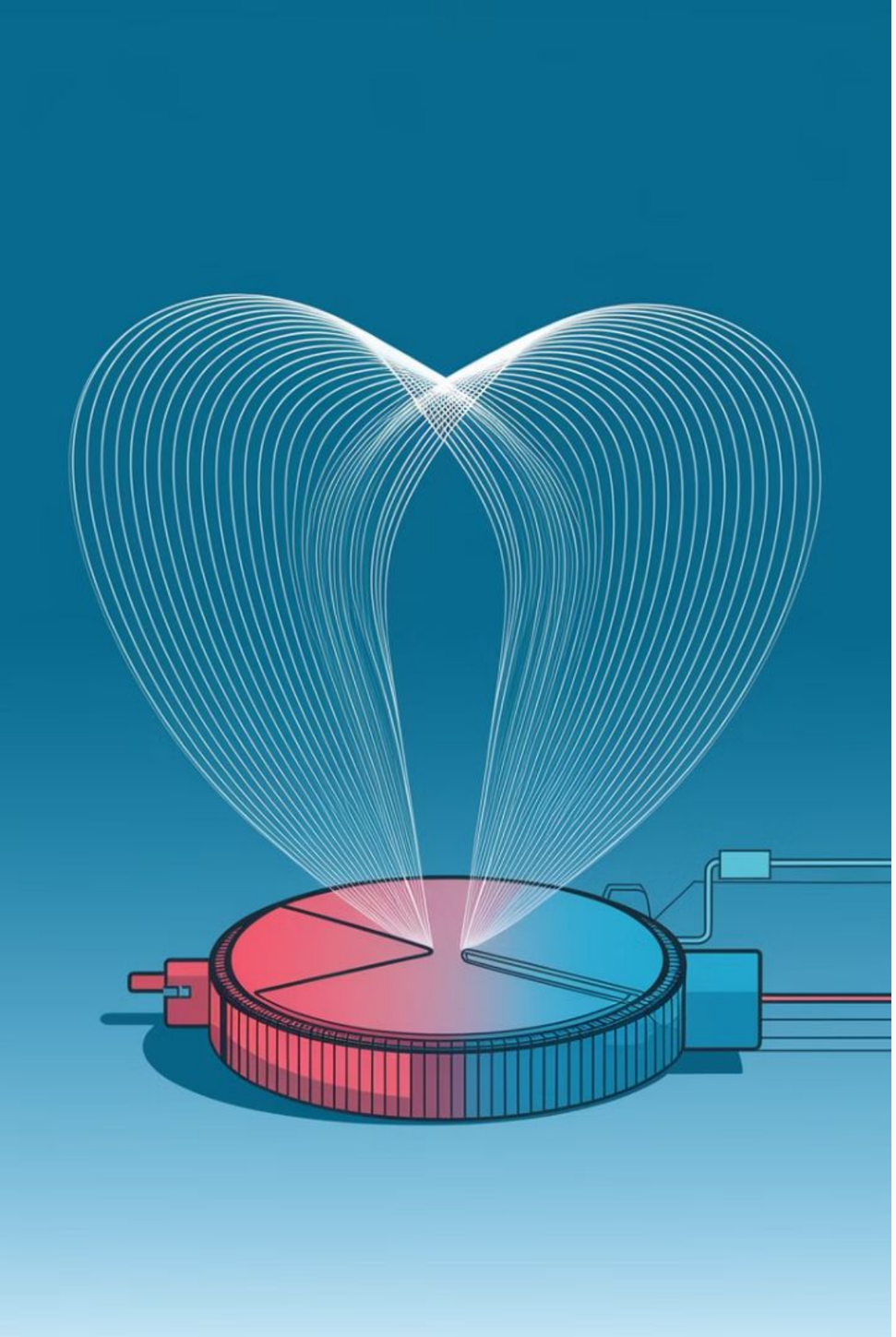
Principle

The theremin is controlled by hand gestures without physical contact, using two antennas that sense the position of the player's hands.

3

Demonstration

Let's listen to the unique, ethereal sound of a theremin and see how hand movements affect the pitch and volume.



Capacitive Sensing Basics

1 **How it Works**

Detects changes in electrical capacitance.

2 **Applications**

Touchscreens, proximity sensors, and more.

3 **Sensitivity**

Affected by sensor size and design.

Conductive Ink as a Capacitive Sensor

Advantages

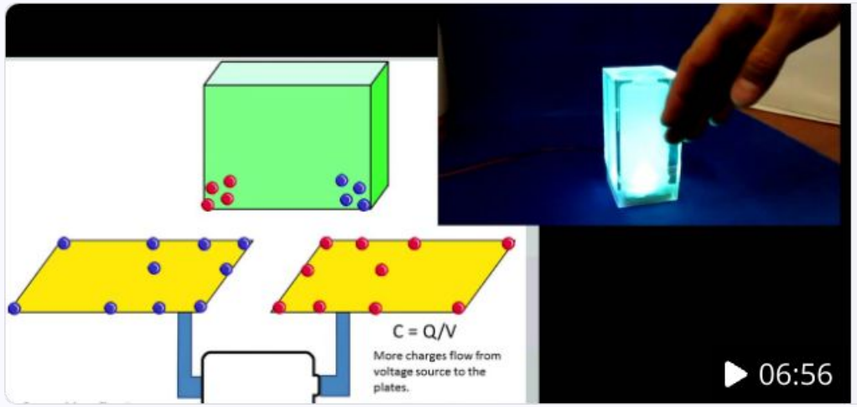
Flexible, printable, and customizable.

Limitations

Lower sensitivity than dedicated sensors.

Design

Creative layout for optimal performance.

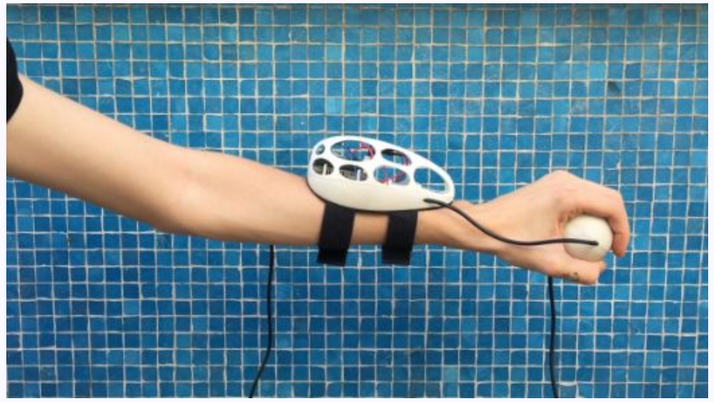


YouTube

Capacitive sensor, Theory, application and design

This video explains the physics behind the surface capacitive sensors, with numerical results supporting the theory. A video for the projected capacitive senso...


Brainstorm
sketch
A/a




LABO

Lesson 4: Introduction to Arduino

What is it?

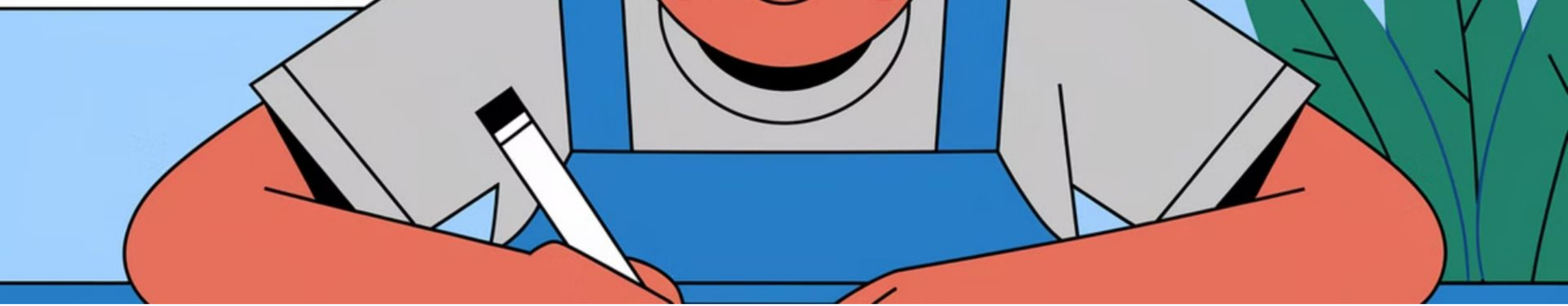
An open-source electronics platform.

Why use it?

Easy to program and interface with sensors.

Lesson Overview

Setting up the Arduino environment.



Hands-on: Creating Simple Sensors

Drawing

Create patterns with conductive ink.

Testing

Measure touch sensitivity with a multimeter.

Connecting

Integrate with electronic components.

Exploring Gesture Recognition

1

Taps

Single touch events for simple actions.

2

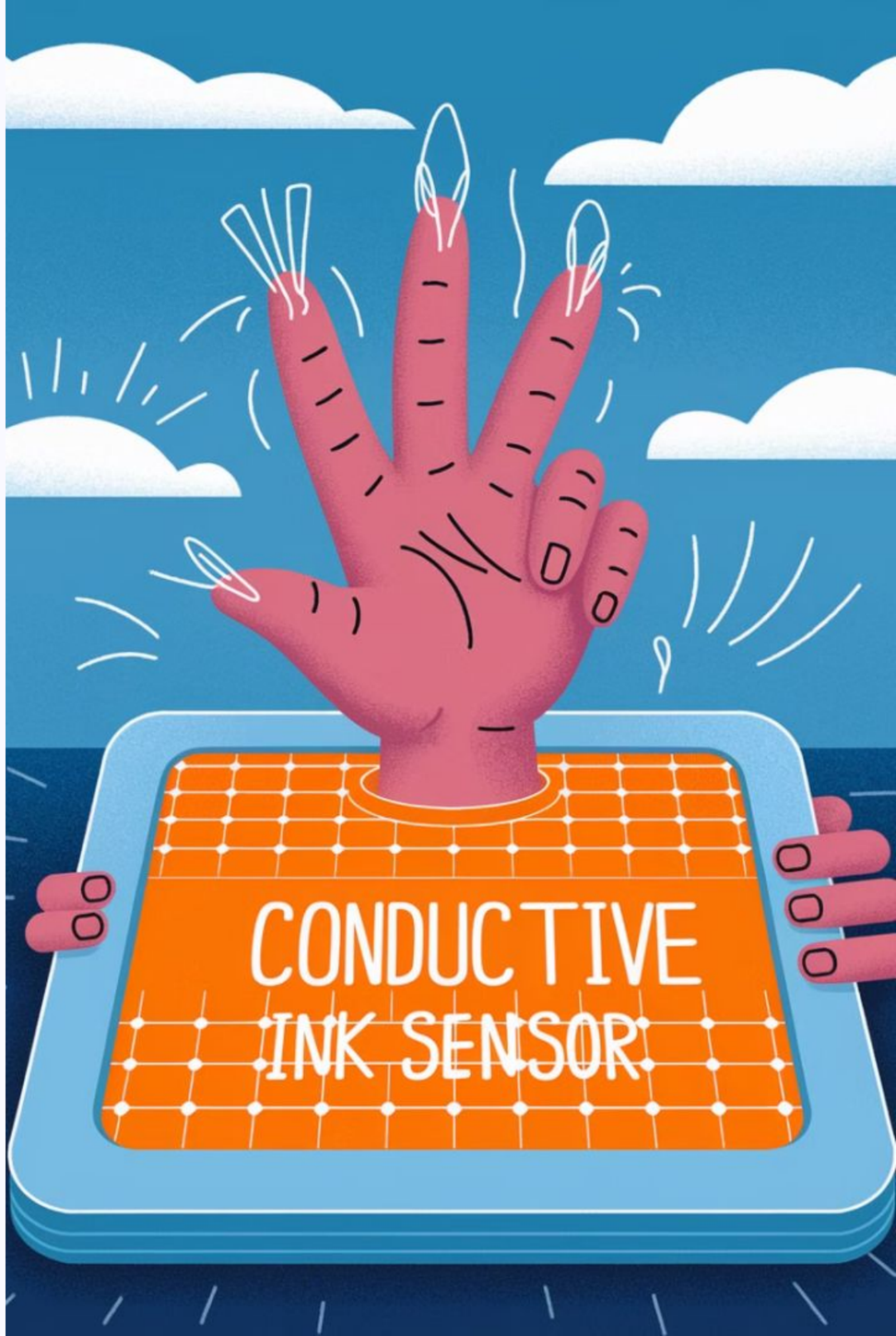
Slides

Continuous motion for parameter control.

3

Proximity

Detecting hand distance for effects.



Concept Development

1 **Brainstorming**

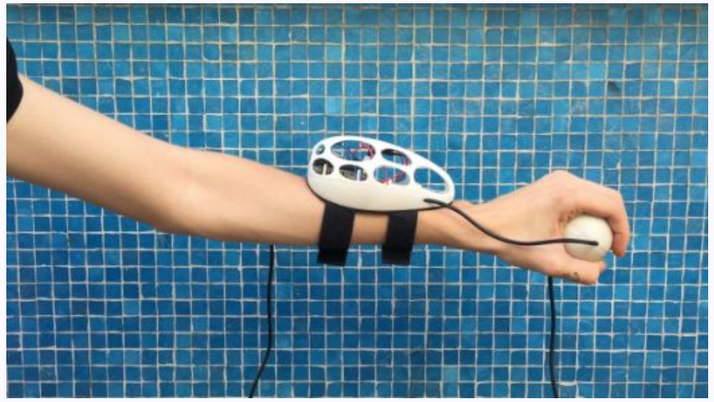
Generate as many ideas as possible.

2 **Sketching**

Visualize your ideas on paper.

3 **Refining**

Choose the best concept for your instrument.

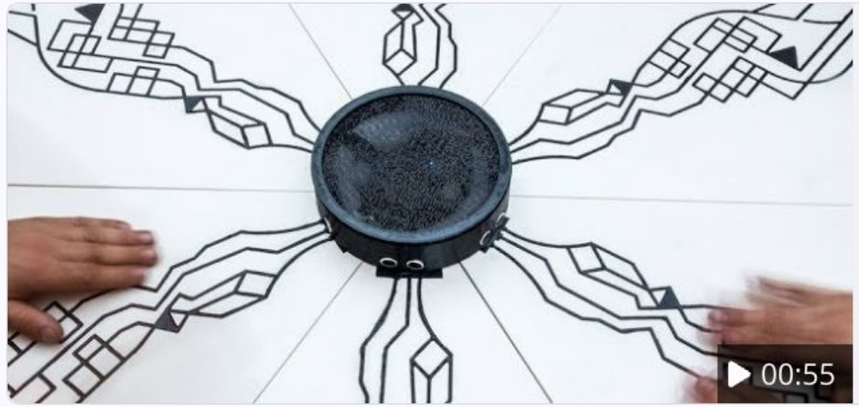



LABO

YouTube

Electric Paint Lamp Kit

Find out more about the Electric Paint Lamp Kit here:
https://www.bareconductive.com/collections/electric-paint-lamp-kit Transform any...



YouTube

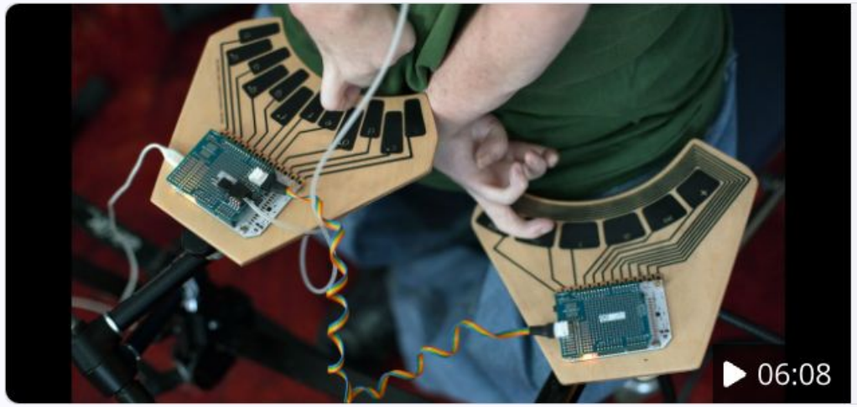
Build Your Own Interactive Sound Table with Electric Pai...

Find out more about Electric Paint here:
https://www.bareconductive.com/collections/electric-paint TACTO is an interactive...

YouTube

Interactive media wall (touch sensor, conductive ink, projection map...

[PLAYDODO] Music Playing Wall : Projection Mapping, Conductive Ink, Interacitve Art Music Playing Wall, a fun Interactive touch wall painted with instruments recognize...



YouTube

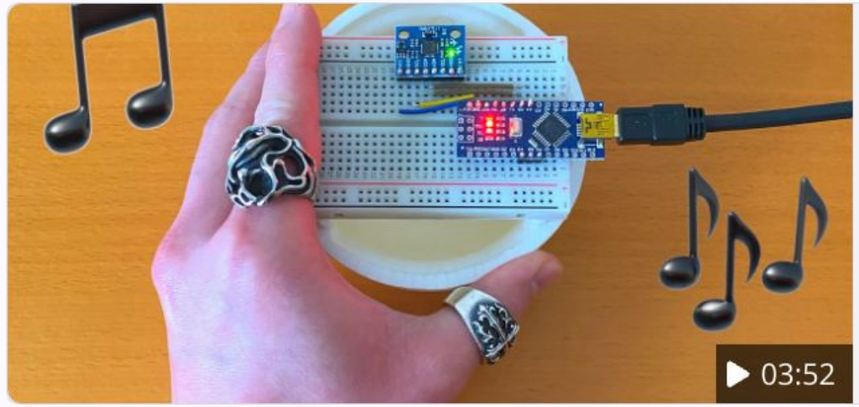
Touch Chord - A Touch Sensitive Breath Controlled Instrument

Read the full story: http://bit.ly/1Gg7gQ7 Designer Musician Vahakn Matossian from Human Instruments teams up with Bare Conductive to develop a new musical...

YouTube

I Built a MIDI THEREMIN! Theremidi - A DIY Arduino MIDI Controller

➡️ Download the files: https://go.musiconerd.com/files-download ➡️ Making Music with Arduino: https://go.musiconerd.com/nerd-musician-pro/ ➡️ Curso Fazendo...

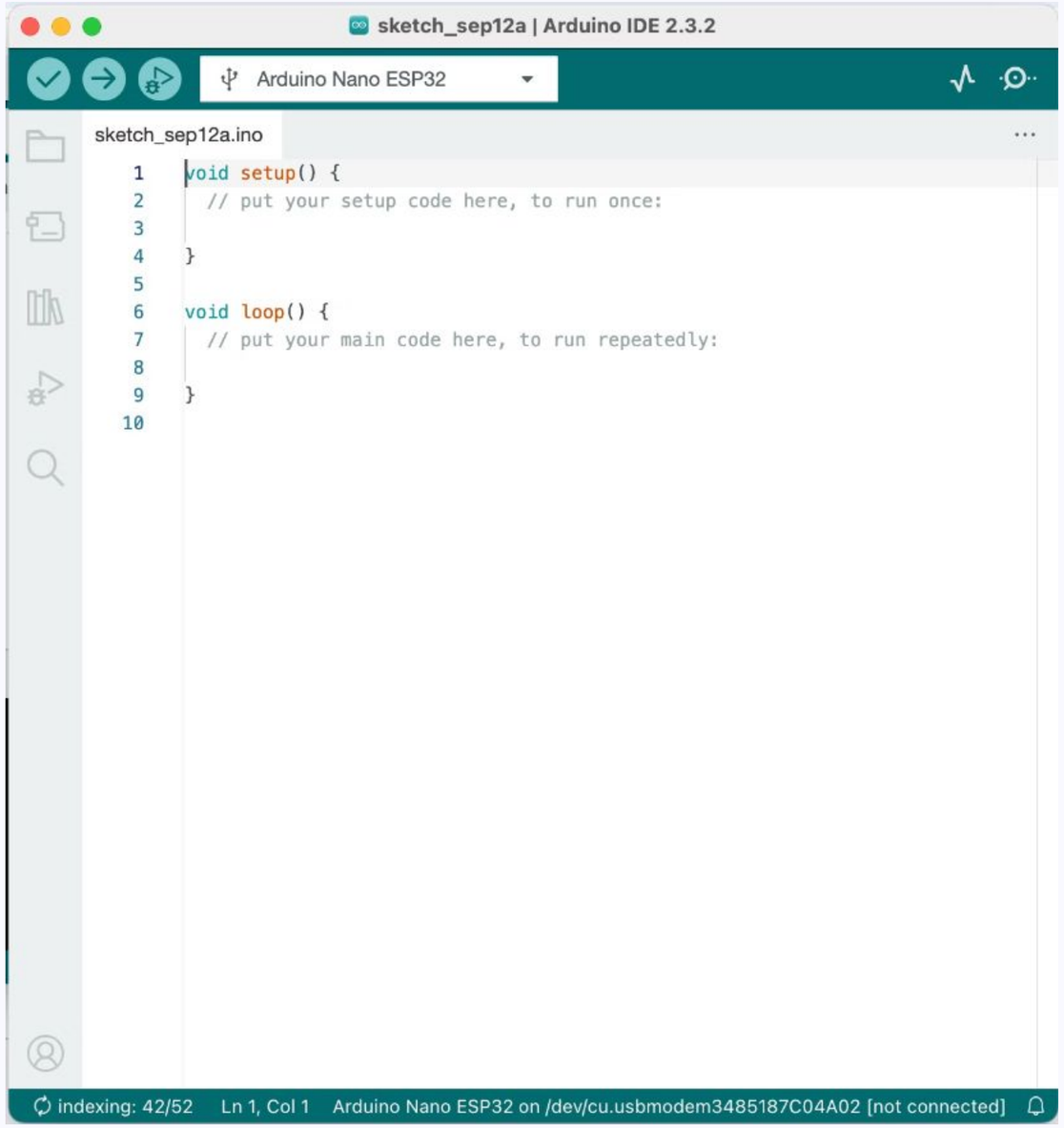


YouTube

Accelerometer Music Controller (Arduino Tutorial)

Let's use accelerometer to control sounds in Pure Data or Max/MSP!! --- To Buy - Arduino Nano https://www.amazon.com/ELEGOO-Arduino-ATmega328P-Without-...

Lesson 5: Arduino Libraries for Sound



Arduino IDE (Integrated Development Environment)

Software application that provides everything needed to write, compile, and upload code to Arduino boards.

- Features code editor with syntax highlighting
- Includes compiler that converts your code into machine language
- Provides serial monitor for debugging as we discussed
- Manages libraries for expanded functionality

Why Are Creative Coding Skills Still Important in the AI Era?

Understanding Fundamentals

AI can generate code, but understanding core principles of circuits, sensors, and programming enables you to customize instruments beyond templates and troubleshoot unexpected errors in your conductive ink projects.

Creative Problem-Solving

When building novel musical instruments like the Inkstrument, you'll encounter unique challenges that aren't in existing codebases or AI training data, requiring original solutions and adaptations.

Physical Computing Integration

Merging code with hardware like Arduino requires hands-on knowledge of how digital signals interact with analog materials like conductive ink, something AI assistance cannot fully replace.

Artistic Expression

Creative coding allows for unique artistic decisions in how gestures translate to sound, giving your instrument a signature character that generic AI-generated code cannot capture.

Balancing Fundamentals with Augmented Intelligence Tools for Creative

Students achieve better outcomes in conductive ink projects when they understand electronic fundamentals while leveraging AI programming assistance.

Troubleshooting Capability

Understanding circuit basics allows students to diagnose issues in their Inkstrument projects that AI might not recognize, especially when working with novel conductive materials.

Customization Beyond Templates

Knowledge of Arduino programming principles enables students to modify AI-generated code specifically for unique gesture-based sound control that commercial tools don't support.

Material-Digital Integration

Grasping how conductive ink interacts with sensors allows students to create distinctive instruments while using AI to accelerate repetitive coding tasks.

Basic Arduino Programming

1

Structure

Sketches consist of setup() and loop().

2

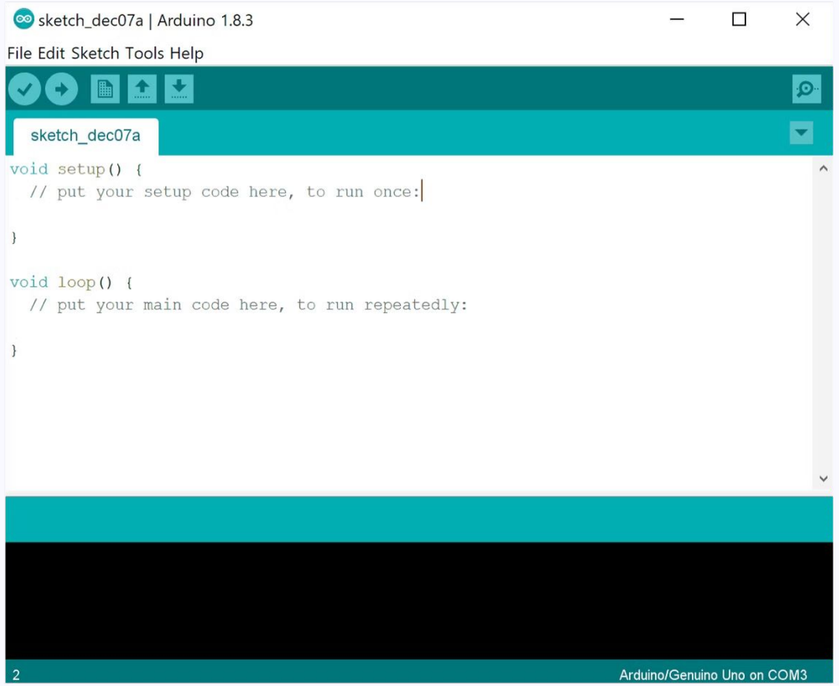
Setup

Initializes variables and pins.

3

Loop

Repeatedly executes the main code.



Arduino's void setup() and void loop()

void setup()

Runs once when your Arduino powers on or resets.

- Initialize pin modes with pinMode(pin, INPUT/OUTPUT)
- Start serial communication with Serial.begin(9600)
- Set initial values for variables

```
void setup() {
  pinMode(13, OUTPUT);  // LED pin
  Serial.begin(9600);   // Start serial monitor
  digitalWrite(13, LOW); // Initial state
}
```

void loop()

Runs continuously after setup() completes.

- Contains your main program logic
- Reads sensors and controls outputs
- Executes repeatedly until power off

```
void loop() {
  digitalWrite(13, HIGH); // Turn LED on
  delay(1000);            // Wait 1 second
  digitalWrite(13, LOW);  // Turn LED off
  delay(1000);            // Wait 1 second
}
```

Hands-on: Blinking LED

Connect LED

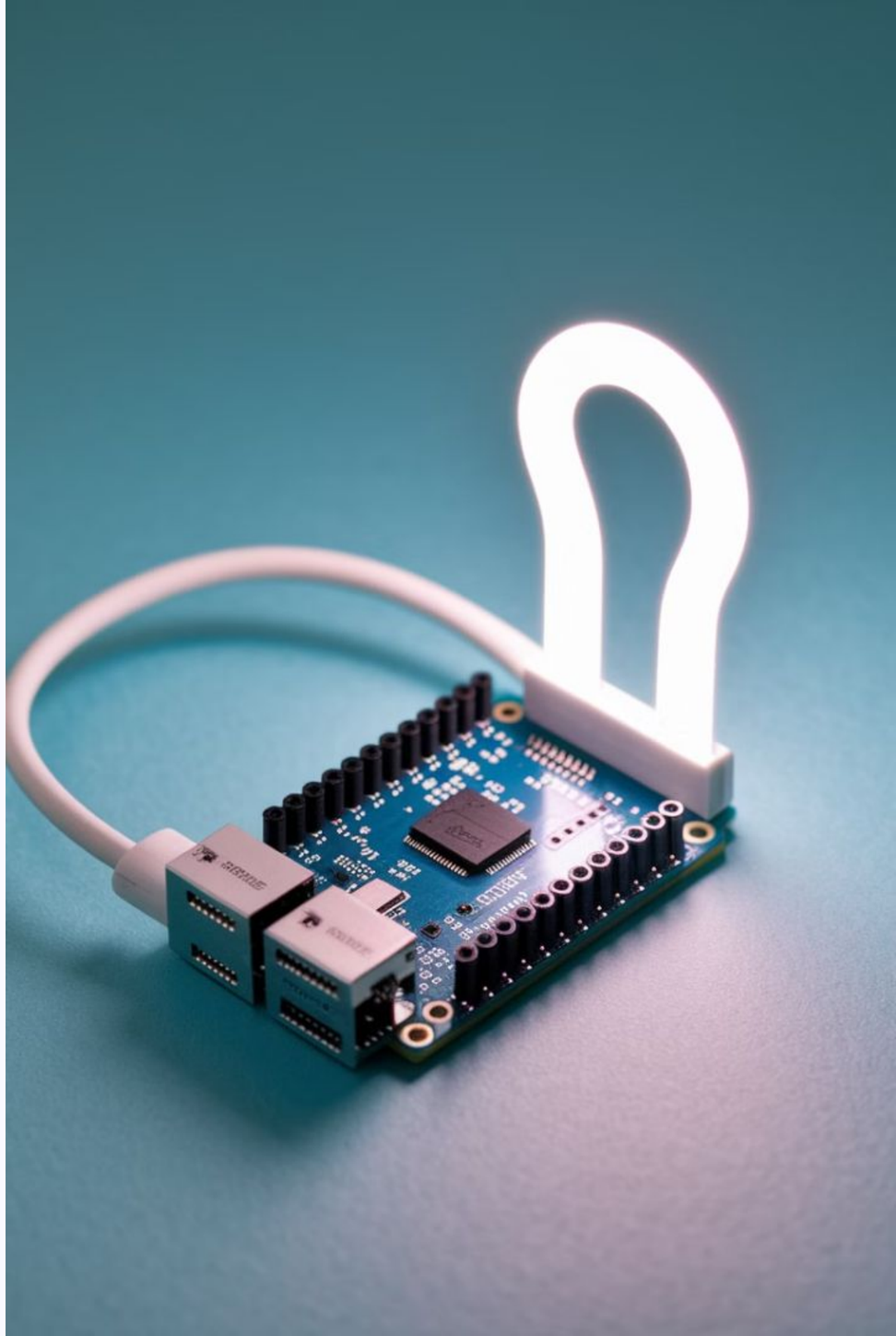
Wire an LED to an Arduino pin.

Write Code

Create a sketch to blink the LED.

Upload

Send the code to the Arduino board.



Blink

```
void setup() {
  // initialize digital pin LED_BUILTIN as an output.
  pinMode(LED_BUILTIN, OUTPUT);
}


// the loop function runs over and over again forever
void loop() {
  digitalWrite(LED_BUILTIN, HIGH);  // turn the LED on (HIGH is the voltage level)
  delay(1000);                      // wait for a second
  digitalWrite(LED_BUILTIN, LOW);   // turn the LED off by making the voltage LOW
  delay(1000);                      // wait for a second
}
```

What is Serial Monitor in Arduino?

A debugging tool that allows communication between Arduino and computer.

Purpose

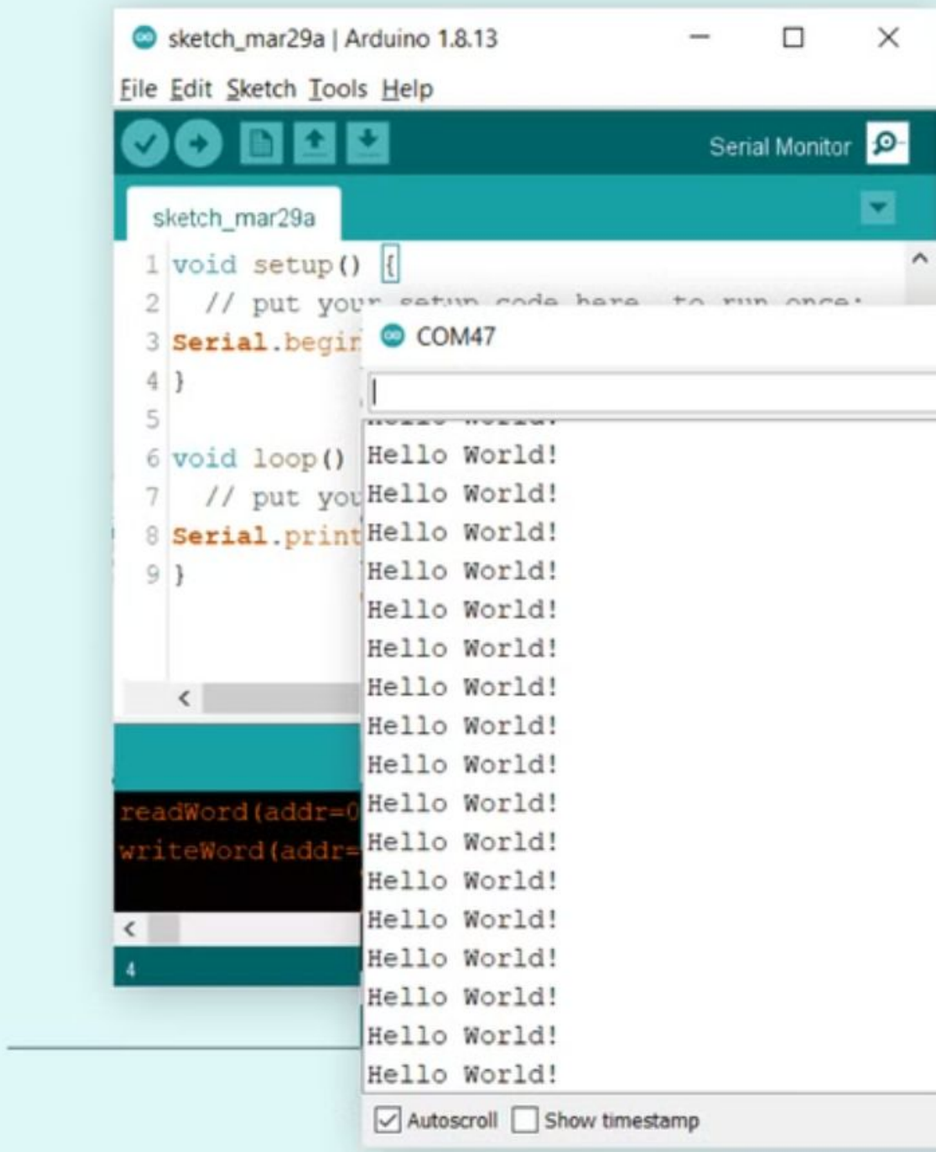
Displays data sent from Arduino to your computer, essential for troubleshooting and monitoring sensor values.

Usage

Accessed from Arduino IDE by clicking the magnifying glass icon or using Ctrl+Shift+M.

Configuration

Must match baud rate in code (e.g., Serial.begin(9600)) to properly display data.



Introduction to Arduino Libraries

1 **What Are They?**

Collections of pre-written code.

2 **Why Use Them?**

Simplify complex tasks and save time.

3 **Finding Them**

Available online and through the Arduino IDE.

What are Programming Library?

Reusable Code Packages

Collections of pre-written code that perform specific functions, saving developers from "reinventing the wheel" for common tasks like reading sensors or generating sounds.

Arduino Library Structure

Arduino libraries typically consist of C++ header (.h) and implementation (.cpp) files, organized to provide easy-to-use functions for interacting with hardware components.

Sound-Related Libraries

For our Inkstrument project, we'll use audio libraries like Tone (basic sounds), Mozzi (advanced synthesis), and VS1053 (MP3 playback) to create interactive musical experiences.

Installing Libraries

Arduino libraries can be installed through the Library Manager in the IDE, downloaded from GitHub repositories, or created from scratch for custom functionality.

Arduino Libraries we use

Tone Library

Generates square wave tones on any Arduino pin, essential for creating musical notes in our Inkstrument project. Provides functions like tone() and noTone() for controlling pitch output.

Capacitive Sensor Library

Enables Arduino to detect touch through conductive materials. This library is critical for transforming our conductive ink drawings into interactive touch sensors that respond to human contact.

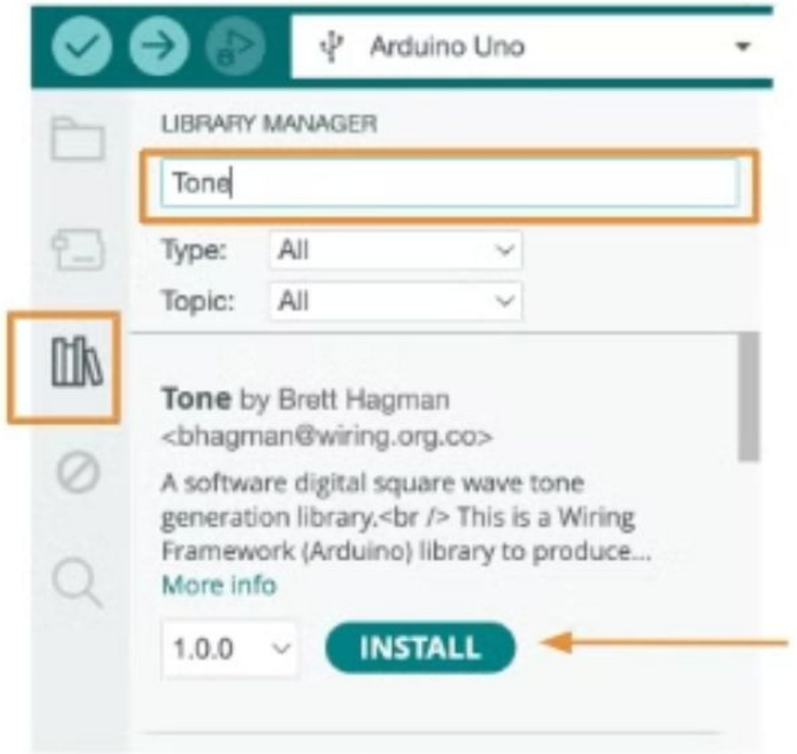
SFEMP3Shield Library

Interfaces with the VS1053 MP3 decoder chip to play audio files stored on an SD card. Allows our Inkstrument to produce high-quality sounds beyond simple tones.

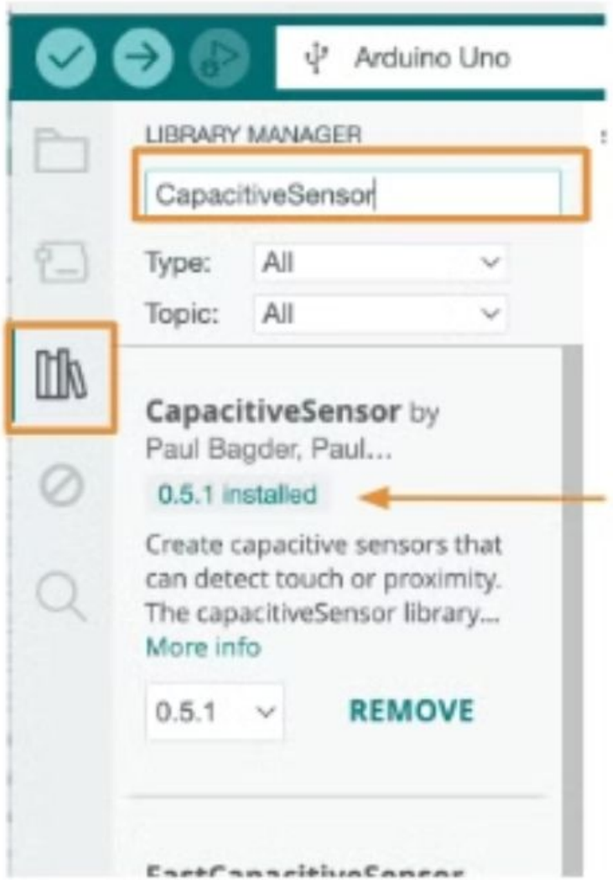
SdFat Library

Provides efficient and robust access to SD cards in FAT16 or FAT32 format. Essential for storing and retrieving sound samples and configuration files for our instrument.

Installing Library

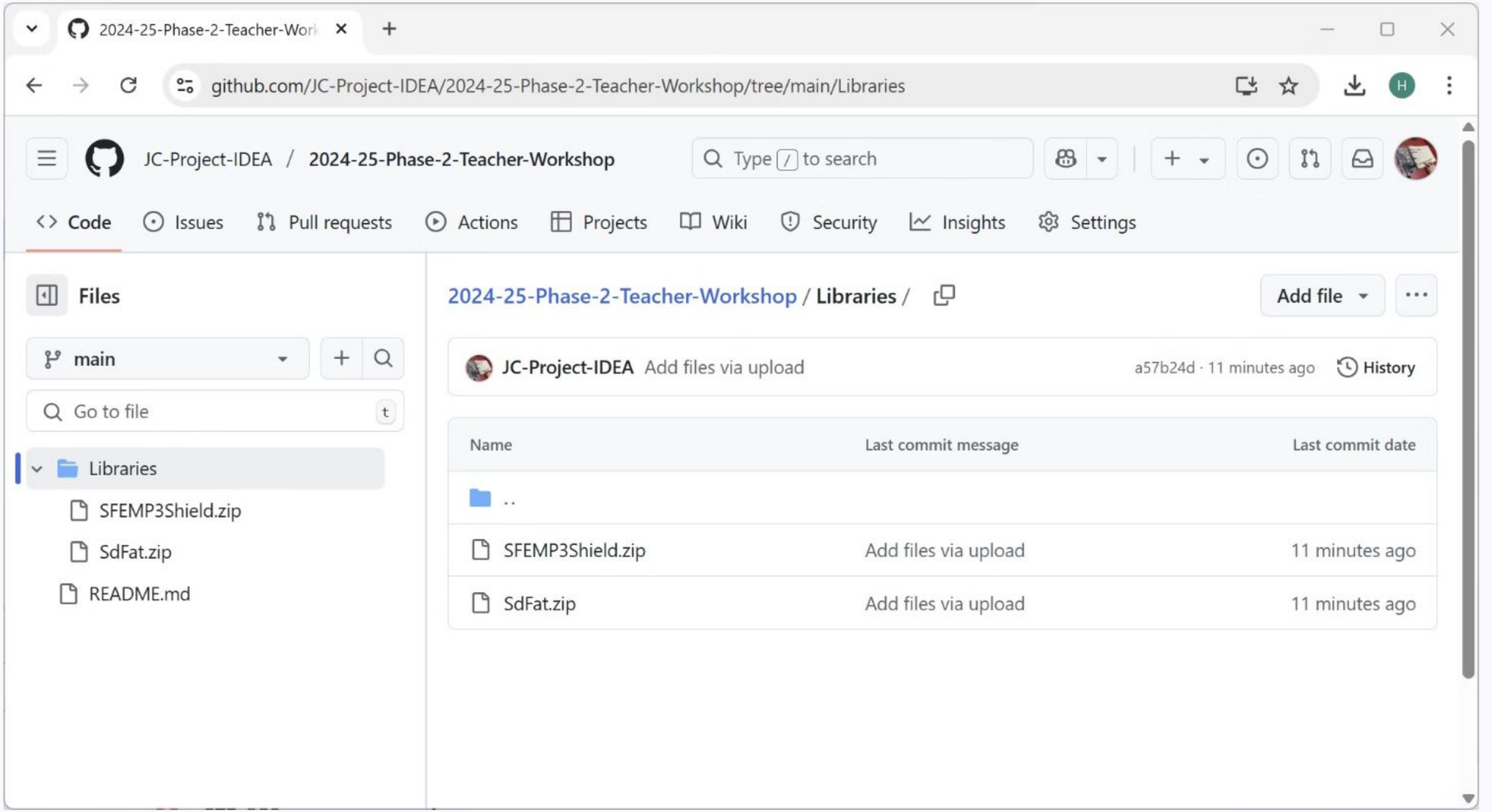


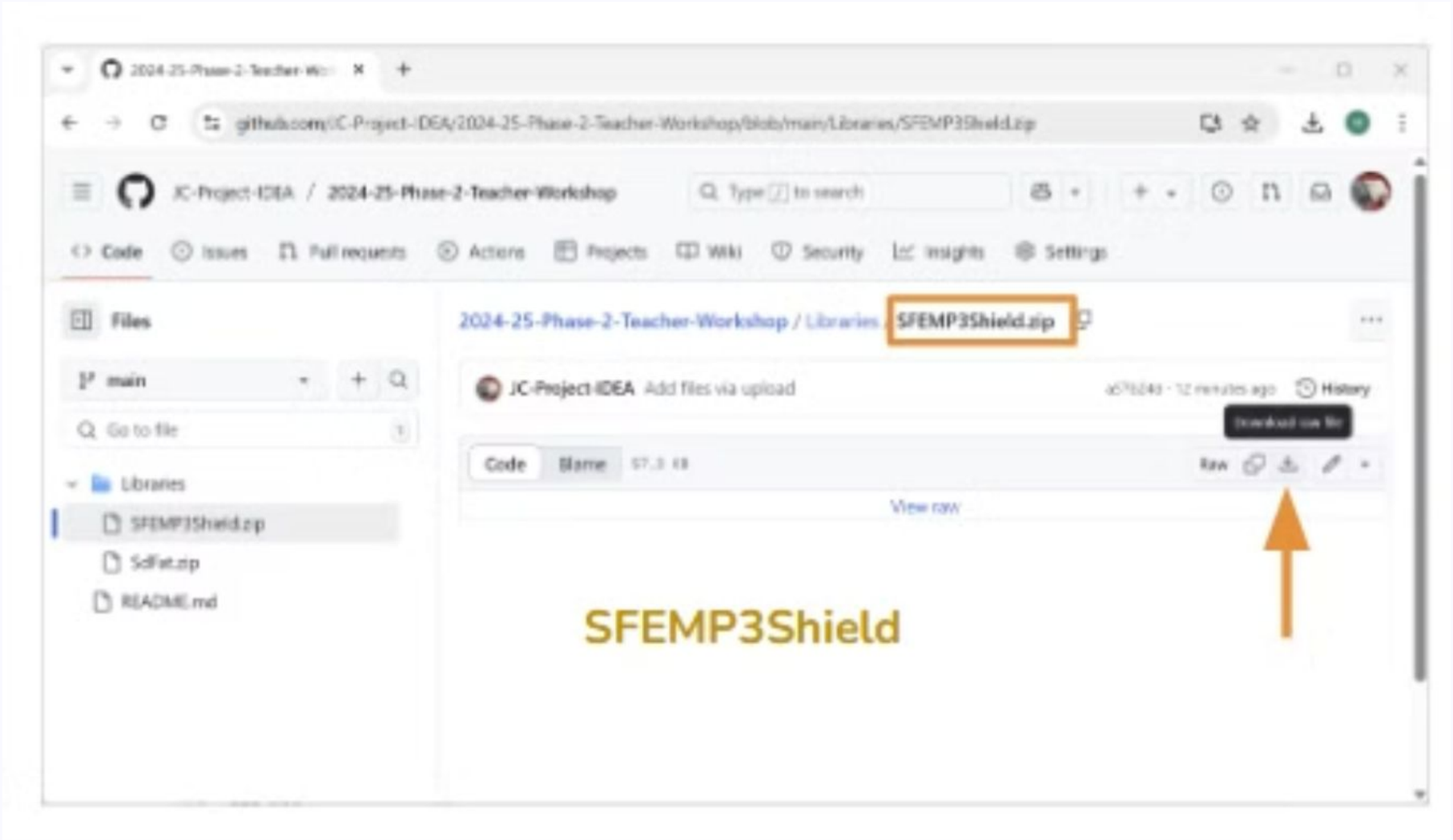
Tone



Capacitive Sensor

https://tinyurl.com/JCIDEA-Teacher-2425P2




JC-Project-IDEA / 2024-25-Phase-2-Teacher-Workshop
Code
Issues
Pull requests
Actions
Projects
Wiki
Security
Insights
Settings
Files
main
Go to file
Libraries
SFEMP3Shield.zip
SdFat.zip
README.md
2024-25-Phase-2-Teacher-Workshop / Libraries / SFEMP3Shield.zip
JC-Project-IDEA Add files via upload
History
Code
Blame
Raw
View raw
SFEMP3Shield

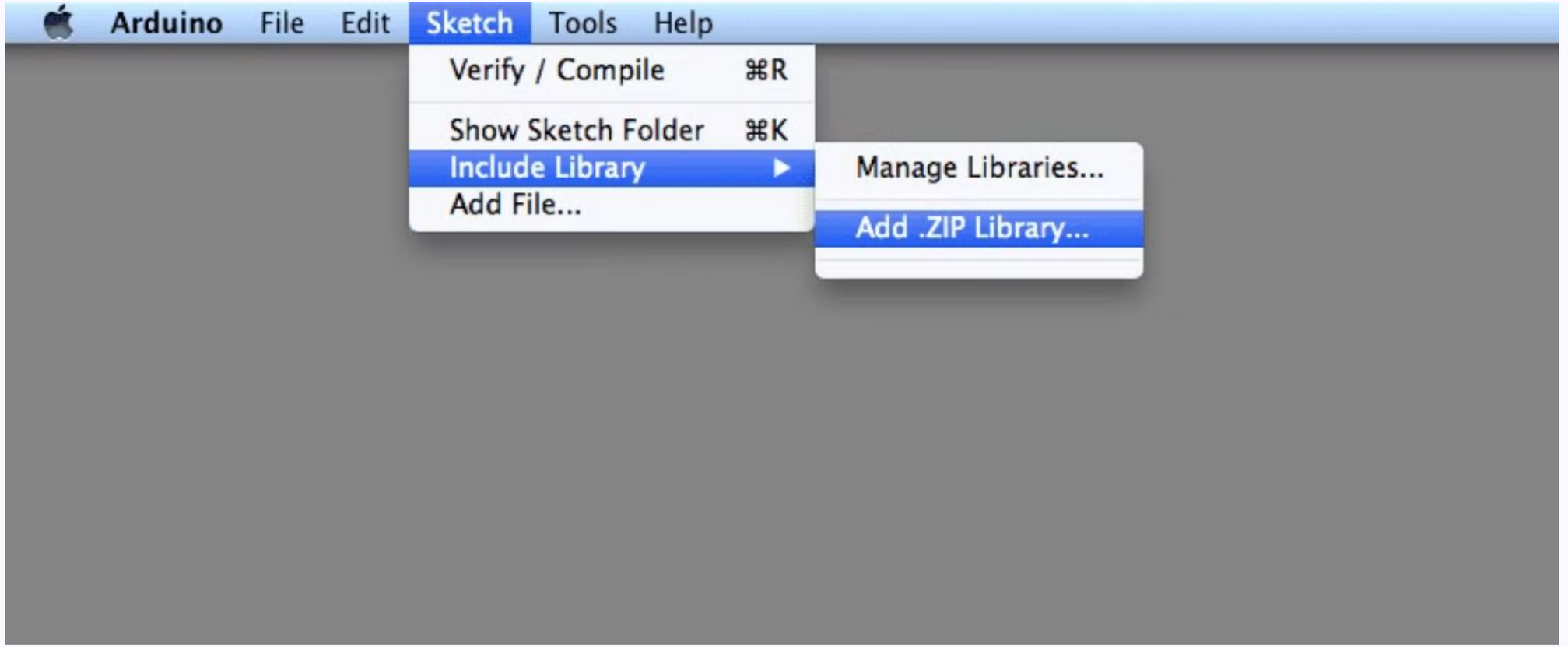
Download two compressed files (.zip) to your desktop

Visit **https://tinyurl.com/JCIDEA-Teacher-2425P2** to access the required library files for our Inkstrument project.

Download the **Capacitive_Sensor_Library.zip** containing the necessary code for touch detection with conductive ink

Download the **SFEMP3Shield_Library.zip** for interfacing with the VS1053 MP3 decoder chip

These libraries must be properly installed in your Arduino IDE before we begin building our conductive ink instrument. We'll cover the installation process in the next step.


Arduino
File
Edit
Sketch
Tools
Help
Verify / Compile ⌘R
Show Sketch Folder ⌘K
Include Library
Add File...
Manage Libraries...
Add .ZIP Library...


docs.arduino.cc

Arduino Programming Fundamentals

Building our Inkstrument requires understanding key programming concepts in Arduino:

Variables & Data Types

Declaring variables with appropriate types (int, float, boolean) to store sensor readings from our conductive ink interfaces

Global Variables

Using global variables accessible across the entire program to manage state for our touch sensors and sound playback features

Library Imports

Including external .h library files for specialized functions like the Capacitive Sensor and SFEMP3Shield libraries we downloaded for touch detection and audio playback

These programming fundamentals will allow us to transform physical touch interactions with conductive ink into musical expression through our Arduino controller.

touch_to_play_mp3

```
// Include necessary libraries for SD card, utility functions, and MP3 player shield.
#include <SdFat.h>
#include <SdFatUtil.h>
#include <SFE_MPHAT_Shield.h>

// Create instances of the SdFat (SD card) and SFEMP3Shield (MP3 player) classes.
SdFat sd;
SFEMP3Shield MP3player;

// Variables to store analog readings from pins A0 to A5.
int InData0 = 0; // Analog reading from pin A0
int InData1 = 0; // Analog reading from pin A1
int InData2 = 0; // Analog reading from pin A2
int InData3 = 0; // Analog reading from pin A3
int InData4 = 0; // Analog reading from pin A4
int InData5 = 0; // Analog reading from pin A5
int InData0 = 0;

// Sensitivity threshold for detecting touch inputs.
int TouchSensitivity = 280;
```

.h C++ library in Arduino

Header (.h) files in Arduino are C++ libraries that contain pre-written code, function definitions, and variable declarations that extend Arduino's functionality.

For our Inkstrument project, we're using two critical libraries:

The **CapacitiveSensor library** (.h) that enables our Arduino to detect touch through conductive ink patterns
The **SFEMP3Shield library** (.h) that provides functions for playing audio files from the VS1053 MP3 decoder

touch_to_play_mp3

```
void setup() {
    // Initialize serial communication at 115200 baud rate for debugging purposes.
    Serial.begin(115200);

    // Initialize the SD card using pin 9 as the chip select pin (CS).
    // If the SD card fails to initialize, halt the program and display an error.
    if (!sd.begin(9, SPI_HALF_SPEED)) sd.initErrorHalt();

    // Change directory to the root folder ("/") on the SD card.
    // If the directory change fails, halt the program and display an error.
    if (!sd.chdir("/")) sd.errorHalt("sd.chdir(\"/\")");

    // Initialize the MP3 player and set the volume level to maximum (10, 10).
    MP3player.begin();
    MP3player.setVolume(10, 10);

    // Configure pins A0 to A5 as input pins to read analog values for touch sensing.
    for (int i = A0; i <= A5; i++) {
        pinMode(i, INPUT);
    }

    // Disable Timer0 overflow interrupt to avoid conflicts with other operations.
```

Serial.begin 115200 vs 9600 ?

Serial communication in Arduino requires setting a baud rate - the speed at which data is transmitted between the Arduino and your computer.

115200 baud

- Faster data transmission (12x faster than 9600)
- Better for high-volume data like sensor readings
- Ideal for our Inkstrument's real-time responsiveness
- What we use in our touch_to_play_mp3 code

9600 baud

- Arduino's traditional default rate
- More stable for basic projects
- Sufficient for simple debugging
- Slower, but compatible with older hardware

MP3player.begin() & MP3player.setVolume()

MP3player.begin()

Initializes the VS1053 MP3 decoder shield to prepare it for audio playback. This function:

- Sets up communication between Arduino and the VS1053 chip
- Configures internal settings for optimal audio performance
- Must be called before any other MP3player functions

MP3player.setVolume(10, 10)

Adjusts the output volume level of both left and right audio channels:

- Parameters represent left and right channel volumes
- Range: 0 (maximum) to 255 (mute)
- Our setting (10, 10) provides loud, balanced stereo output
- Can be adjusted during runtime to create volume effects

touch_to_play_mp3

```
void loop() {
    // Read analog values from pins A0 to A5 and invert them (higher values mean touch detected).
    InData0 = 1024 - analogRead(A0); // Invert A0 reading
    InData1 = 1024 - analogRead(A1); // Invert A1 reading
    InData2 = 1024 - analogRead(A2); // Invert A2 reading
    InData3 = 1024 - analogRead(A3); // Invert A3 reading
    InData4 = 1024 - analogRead(A4); // Invert A4 reading
    InData5 = 1024 - analogRead(A5); // Invert A5 reading


    ...
}
```

What is analogRead()?

The analogRead() function is an Arduino command that reads the value from a specified analog pin, converting voltage (0-5V) into integer values (0-1023).

Reading sensor inputs

In our Inkstrument project, we use analogRead() to measure the conductive ink sensor values from pins A0-A5.

Value interpretation

Higher values (closer to 1023) indicate greater conductivity or touch intensity, which we invert (1024 - analogRead()) to make touch detection more intuitive.

Touch sensitivity threshold

We compare these analog readings against our TouchSensitivity value (280) to determine when a conductive ink pad is being touched.

This function is essential for converting the analog electrical signals from our conductive ink sensors into digital values our Arduino can use to trigger sounds.

Why 1024 - analogRead()?

In our Inkstrument project, we use the formula **1024 - analogRead()** to invert the sensor readings from our conductive ink touch pads. This inversion serves three critical purposes:

Intuitive Touch Response

Without inversion, a stronger touch would produce a lower value (closer to 0) because our conductive ink creates a path to ground when touched. By inverting with 1024 - analogRead(), higher values (closer to 1024) now represent stronger touches.

This inversion technique is a common practice in capacitive and resistive touch sensing applications, allowing for more reliable touch detection in our conductive ink musical interface.

touch_to_play_mp3

```
void loop() {
    ...
    // Check which pin has been touched based on the sensitivity threshold.
    // Play the corresponding MP3 track if a touch is detected.
    if (InData0 >= TouchSensitivity) {
        MP3player.playTrack(0); // Play track 0 if A0 is touched
    } else if (InData1 >= TouchSensitivity) {
        MP3player.playTrack(1); // Play track 1 if A1 is touched
    } else if (InData2 >= TouchSensitivity) {
        MP3player.playTrack(2); // Play track 2 if A2 is touched
    } else if (InData3 >= TouchSensitivity) {
        MP3player.playTrack(3); // Play track 3 if A3 is touched
    } else if (InData4 >= TouchSensitivity) {
        MP3player.playTrack(4); // Play track 4 if A4 is touched
    } else if (InData5 >= TouchSensitivity) {
        MP3player.playTrack(5); // Play track 5 if A5 is touched
    } else {
        MP3player.stopTrack(); // Stop playback if no touch is detected
    }
    ...
```

Conditionals if(){}else{}

Conditional statements are crucial for our Inkstrument's interactivity. They allow the Arduino to make decisions based on sensor input values.

```
if (InData0 >= TouchSensitivity) {
    MP3player.playTrack(0);  // Play first sound if touched
} else if (InData1 >= TouchSensitivity) {
    MP3player.playTrack(1);  // Play second sound if touched
} else {
    MP3player.stopTrack();   // Otherwise stop all sounds
}
```

Each if/else branch creates a unique interactive possibility, allowing us to map different gestures or touch points to distinct musical outputs.

touch_to_play_mp3

```
void loop() {
    ...
    ...
    // Print the current state of the MP3 player and analog readings to the serial monitor.
    Serial.print(MP3player.isPlaying()); // Print whether the MP3 player is currently playing
    Serial.print(" ");
    Serial.print(InData0); // Print inverted value of A0
    Serial.print(" ");
    Serial.print(InData1); // Print inverted value of A1
    Serial.print(" ");
    Serial.print(InData2); // Print inverted value of A2
    Serial.print(" ");
    Serial.print(InData3); // Print inverted value of A3
    Serial.print(" ");
    Serial.print(InData4); // Print inverted value of A4
    Serial.print(" ");
    Serial.println(InData5); // Print inverted value of A5 followed by a newline


    // Add a delay to prevent rapid polling of the touch pins.
    delay(100);
```

Serial.print()

Serial.print() is essential for debugging our Inkstrument. It sends data from Arduino to your computer, allowing you to observe sensor readings in real-time.

```
// Output touch sensor values to Serial Monitor
Serial.print(InData0);  // First ink sensor reading
Serial.print(" ");      // Add space between values
Serial.print(InData1);  // Second ink sensor reading
Serial.println(InData2); // Add newline after last value
```

When designing your Inkstrument, use Serial.print() to:

- Calibrate touch sensitivity thresholds
- Verify that your conductive ink paths are functioning
- Debug issues when sounds aren't triggering as expected

Open the Serial Monitor (Tools → Serial Monitor) with baud rate set to 9600 to view the output.

Lesson 6 & 7: Building and Programming Inkstrument

Concept

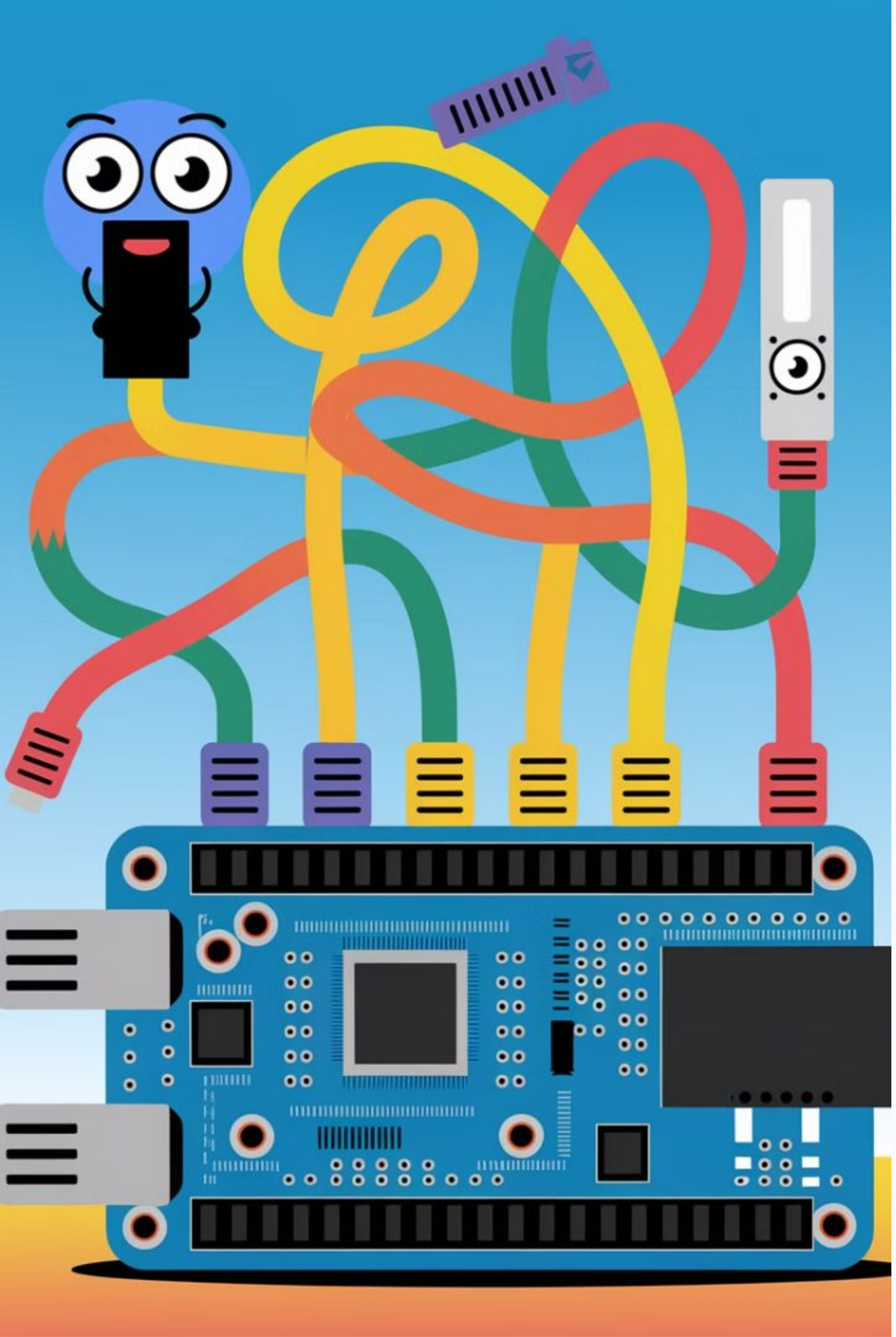
Brainstorming interactive music ideas.

Materials

Selecting the right conductive ink.

Prototyping

Creating a paper prototype for testing.



Wiring the Arduino

1

Connections

Connecting sensors to Arduino pins correctly.

2

Power

Ensuring stable power supply for the instrument.

3

Testing

Verifying all connections before programming.

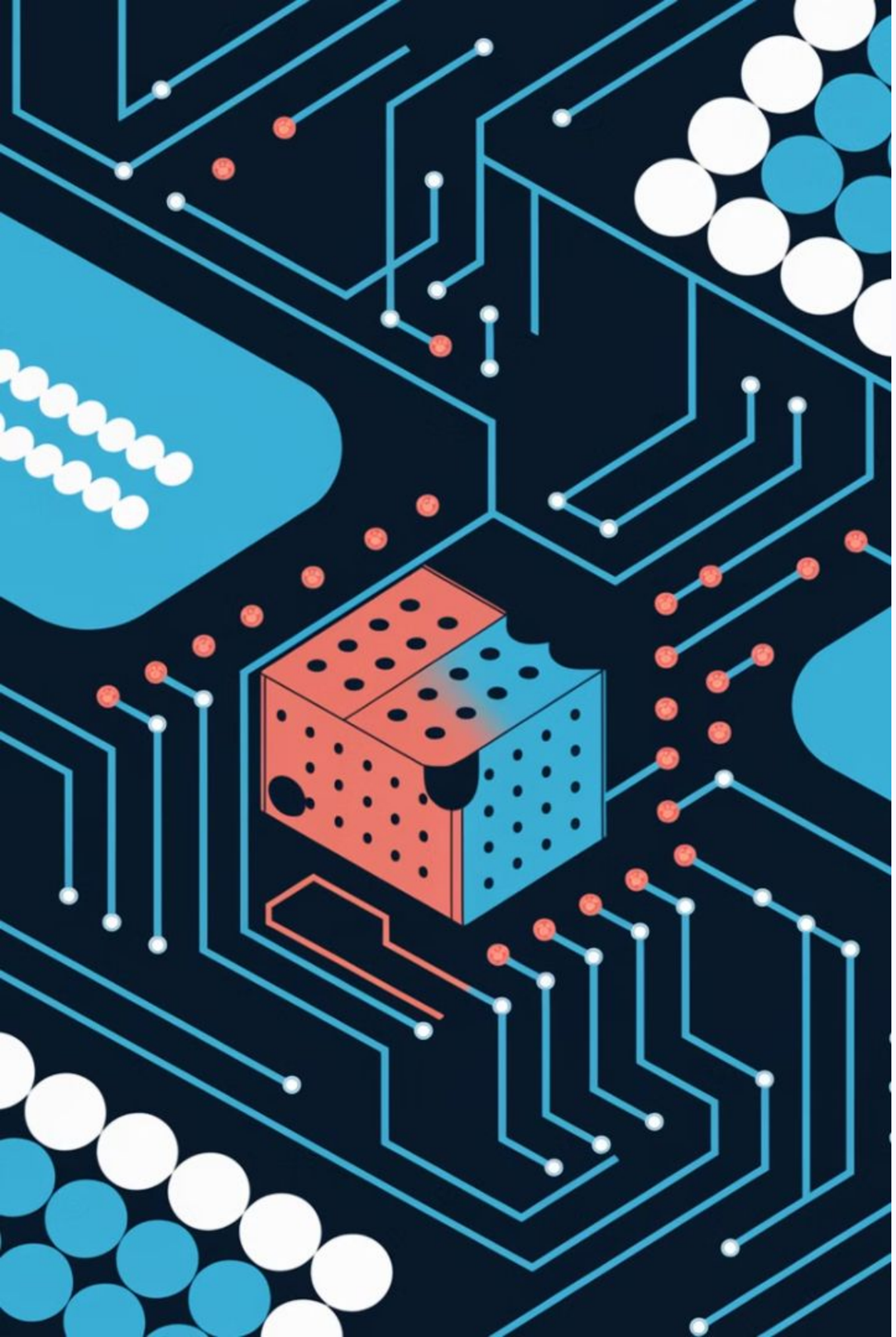
Materials Selection

Conductive Ink

Choose ink with good conductivity and flexibility.

Components

Gather necessary electronic components.



Circuit Design

1

Layout

Plan the conductive ink patterns carefully.

2

Integration

Connect to Arduino pins for sensing.

3

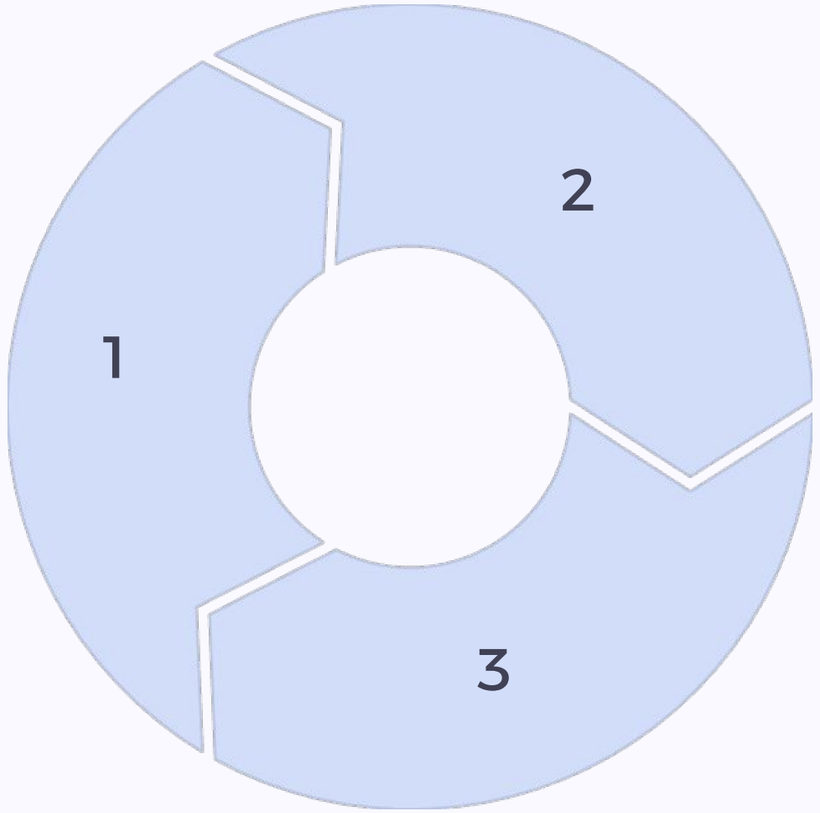
Testing

Ensure all connections are working properly.

Sound Design

Parameters

Choose synth parameters to control.



Mapping

Link gestures to sound variations.

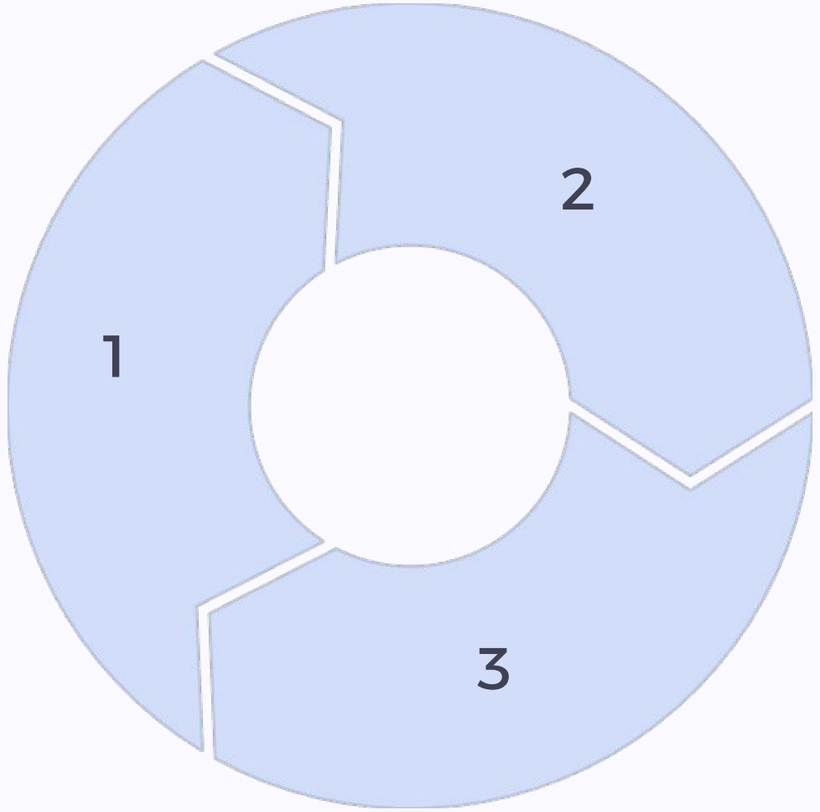
Experimentation

Fine-tune the sound for desired effects.

Programming Inkstrument

Main Sketch

Writing the Arduino code to control the instrument.



Recognition

Implementing code.

Optimization

Tuning the code for responsiveness.

Testing and Debugging

Systematic

Test each function thoroughly.

Common

Identify typical issues and their solutions.

Refinement

Fine-tune for optimal performance.

Project Showcase and Reflection

Thank You and Q&A