# Flexible DIY touch–based affordable musical Instrument

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***Abstract*—This paper presents a flexible DIY touch -based musical instrument which mimics the functionality of a piano. The proposed flexible musical instrument utilizes a kapton substrate and consists of IC555 circuitry with a speaker. The copper comb structure acts as a keys of the instrument and when touched with fingers the circuit provides different sounds based on the bias resistance attached to the contact.This musical instrument is conjunction of affordability , DIY and flexible electronics which make it stand compared to the traditional musical instruments.**

***Index Terms*—flexible musical instrument, piano, DIY, Kapton,touch -based ,affordability**

## I. Introduction

There's a growing desire for musical instruments that are not only fun and engaging to play, but also accessible to a wider audience.

Traditional musical instruments can be expensive, require specific skills to build or maintain, and often have a learning curve that discourages beginners. This project seeks to revolutionize that experience. By focusing on affordability, we make music creation available to a wider range of people. The DIY aspect empowers individuals to take ownership of their musical journey, fostering a sense of accomplishment and deeper connection with the instrument. Finally, an emphasis on ease of use ensures that anyone, regardless of prior musical experience, can pick up this instrument and start making beautiful sounds.

This project dives into the world of flexible electronics to develop a touch-based instrument inspired by familiar options like pianos and harmoniums. The key difference here is affordability, DIY construction, and user-friendliness. We're placing this instrument squarely in the category of "personal fabrication," making it achievable for anyone to build and play their own music. This project sits at the intersection of entertainment, consumer applications, and the exciting field of flexible electronics. It's a chance to bring the joy of music creation to a whole new generation, empowering them to express themselves in unique and personal ways.

We envision a musical instrument that breaks down the barriers of cost, complexity, and traditional form factors.

## II. Design and Development

### A. Component identification and material properties

DuPont™ Kapton® polyimide films are an excellent choice for components due to their extreme versatility and thermal performance. These films are known for their ability to maintain mechanical properties under harsh conditions, making them suitable for applications involving high heat and vibration. Kapton® polyimide films have been an industry standard for over 45 years, offering a unique combination of electrical, thermal, chemical, and mechanical properties that can withstand extreme temperatures, vibration, and other demanding environments. Figure 1 shows components used to design the product.

Kapton is a type of polyimide film that is widely used in a variety of applications due to its unique properties. It is a flexible, high-performance material that is resistant to heat, chemicals, and radiation. Kapton has a glass transition temperature (Tg) of approximately 370°C, making it one of the most heat-resistant polymers available. It can withstand continuous exposure to temperatures up to 250°C and short-term exposure to temperatures up to 400°C.

Here we used Kapton polyimide films can be used in conjunction with copper tape, 555 timer (NE555N), resistors, copper wires, capacitors (10 µF, 2nF, 1nF), speakers (8 Ω-2W), and a 5V battery. Each of these components can benefit from the properties of Kapton® polyimide films, ensuring reliable and durable performance even in challenging conditions.

Kapton, a type of polyimide developed by DuPont, is often used as a base material in various applications due to its flexibility and insulating properties. It has a poison ratio of 0.34, which is a measure of the material's resistance to deformation under load. One of the key advantages of Kapton is its high glass transition temperature, which means it can remain stable and maintain its properties even when exposed to high temperatures, up to 400°C.

In the construction you described, Kapton is used as the base material for a comb-like structure made from copper tape. The copper tape serves as the conductive lines, while the keys are formed by the teeth of the comb. To ensure the proper functioning of the device, seven resistors are placed in parallel with the comb structure, with one resistor connected to each


Fig. 1. Component Used to design the musical instrument

key. This configuration allows for the individual monitoring and control of each key, even in the presence of variations in resistance due to factors such as temperature or wear.

## III. Device Development

### A. Comb Structure

The use of a comb structure or fractals in touch-based sensors is a common technique to increase the surface area and improve the sensitivity of the device. The comb structure is particularly useful in this context because it provides a large number of fingers or contact points that can be used to detect a touch event. Even if the finger does not make complete contact with the comb structure, the increased surface area ensures that a tap can still be registered.The use of a comb structure or fractals in touch-based sensors provides a number of benefits, including increased surface area, improved sensitivity, and more accurate touch detection.

A copper tape is placed on a Kapton film base to create a conductive surface for the device. The comb structure is then formed by shaping the copper tape into a series of teeth, which serves to increase the surface area of the conductive material. This design allows for the device to register a tap even if the user's finger does not make complete contact with the comb structure, as the increased surface area provides more opportunities for the finger to make contact with the conductive material. Figure 2 shows the comb structure which we use as a touch button in our design.

To further enhance the device's functionality, a separate resistor is connected in parallel to each tooth of the comb structure. This configuration ensures that the overall resistance of the circuit decreases when a key is pressed, as the resistivity of the human body is higher than that of the copper tape and the resistors. This allows for the accurate detection of a key press, as the change in resistance can be easily measured and interpreted by the device.

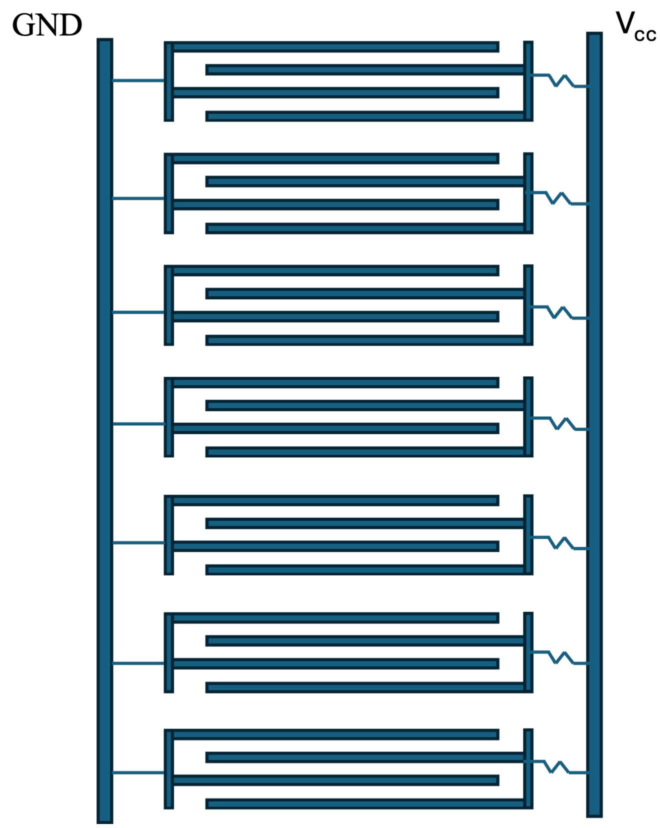


Fig. 2. Comb structure

Each key in the comb structure can be assigned a binary value, with a pressed key representing a bit value of 1 and an unpressed key representing a bit value of 0. This allows for the simple and straightforward encoding of user input, making it easy to interpret and process the data captured by the device.

we also tried maing comb structure on paper with rubbing an pensil, because of conductivity of pencil, but the graphite content is not allowing us to get desired resistance and it was also not long lasting and easy to handle.

### B. Circuit implementation on Kapton film

A circuit is constructed on a Kapton tape substrate using copper tape to create the necessary conductive paths and connections. Various electronic components, including ICs, a speaker, and a battery, are soldered onto the Kapton substrate using the copper tape as a foundation for the solder joints. The voltage required to power the circuit is provided by two batteries connected in series, which increases the overall voltage available to the circuit.

At the heart of the product is a 555 timer circuit, which serves as a free-running multivibrator capable of producing a square wave of varying frequencies. This circuit is a fundamental building block of the device, providing the necessary timing and control functions required for operation. The 555 timer is a versatile and widely-used integrated circuit that can be configured in a variety of ways to perform different

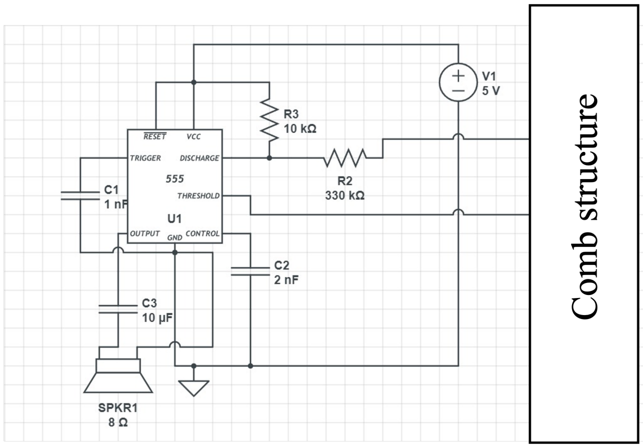


Fig. 3. Circuit on Simulator

functions, making it an ideal choice for this type of application. The ability to generate a square wave of different frequencies is particularly useful in this context, as it allows for the precise control of the device's operation and the generation of the necessary signals for communication and control. Figure 3 shows circuit architecture which we have designed from LTSPICE.

The use of the 555 timer IC in a musical instrument provides a number of benefits, including low cost, high reliability, and ease of use. Additionally, the 555 timer is a versatile and widely-used integrated circuit, making it an ideal choice for a wide range of electronic projects and applications. Whether you're a seasoned musician or a beginner just starting out, a 555 timer-based musical instrument is a fun and exciting way to explore the world of electronic music and sound.

### C. *Circuit working Principle*

The operation of the device requires the use of three fingertips, which are used to interact with the conductive elements of the circuit. The Trigger Pin (Pin-2) of the 555 timer IC is connected to a point in the circuit that is sensitive to changes in voltage. If the voltage at this point drops below 1/3rd of the supply voltage, the Trigger Pin will detect this change and turn ON the output of the 555 timer IC [5].

Similarly, the Threshold Pin (Pin-6) of the 555 timer IC is connected to a point in the circuit that is sensitive to changes in voltage in the opposite direction. If the voltage at this point rises above 2/3rds of the supply voltage, the Threshold Pin will detect this change and turn OFF the output of the 555 timer IC [1].

The Discharge Pin (Pin-7) of the 555 timer IC serves a special function in the circuit. Whenever the output of the 555 timer IC is in the OFF state, the Discharge Pin is automatically connected to ground (0V), providing a path for current to flow and discharge any capacitors that may be present in the circuit. This is an important feature of the 555 timer IC, as it helps to ensure the stability and reliability of the circuit by preventing the buildup of excess voltage and current [2].

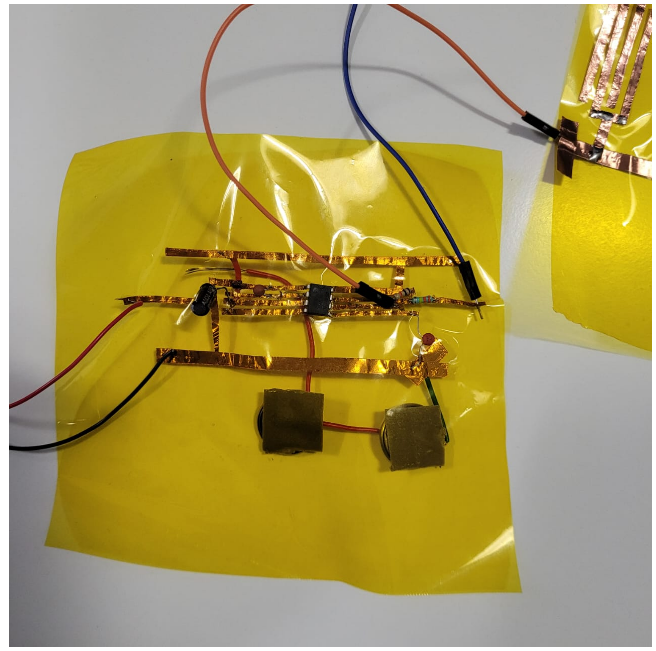

Fig. 4. Circuit on Kapton film

The reset pin (Pin 4) is employed to reset the internal Flip-flop that manages the output state (Pin 3). It functions on an active-low basis and is typically tied to a logic "1" level when inactive to avoid unintended resetting of the output.The purpose of the control pin is to level out any fluctuation in the supply voltage. Figure 4 shows circuit on kapton as finalize structure.

In this way, the 555 timer IC serves as a key component in the operation of the device, providing the necessary timing and control functions required for accurate and reliable operation.

When the power supply is first turned on, the capacitor (C1) in the circuit is in a discharged state, and as a result, the voltage at Pin-2 of the 555 timer IC is 0V. Since this voltage is less than 1/3rd of the supply voltage, the output of the 555 timer IC is turned ON. At the same time, Pin-7 of the 555 timer IC is internally disconnected from 0V, allowing the capacitor to begin charging via the resistors R1 and R2.

As the capacitor charges, the voltage across it increases. Once the voltage across the capacitor reaches 2/3rds of the supply voltage, Pin-6 of the 555 timer IC senses this change and turns OFF the output. Simultaneously, Pin-7 of the 555 timer IC is reconnected internally to 0V, providing a path for the capacitor to discharge via resistor R1.

Once the voltage across the capacitor falls below 1/3rd of the supply voltage, Pin-2 of the 555 timer IC detects this change and turns ON the output once again, initiating the next cycle of operation. This sequence of events repeats continuously, with the capacitor charging and discharging via the resistors R1 and R2 and the output of the 555 timer IC turning ON and OFF in response to the changing voltage across the capacitor. This creates a square wave signal that can be used for a variety of purposes, such as timing, control,

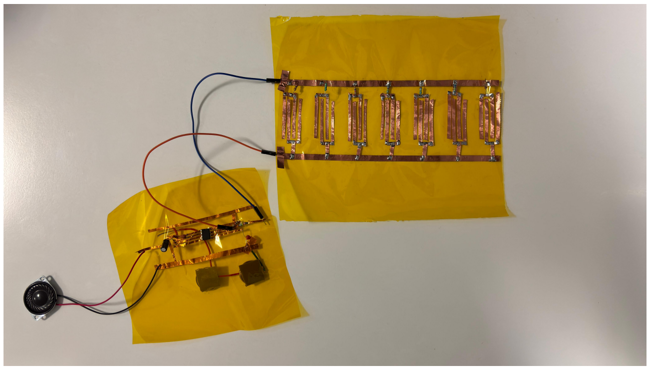

Fig. 5. Final product

and communication.

The 555 timer circuit is connected to a speaker or other audio output device, which converts the electrical signal into sound. By using a combination of buttons, switches, or other input devices, the user can manipulate the frequency of the square wave and create a variety of musical patterns and sequences. By adjusting the values of the resistors and capacitors in the circuit, the frequency of the square wave can be precisely controlled, allowing for the generation of a wide range of musical notes and tones. The frequency of the output tones can be fine-tuned by calculating the precise values of resistors.

In the musical instrument circuit, the 555 timer IC is connected to a capacitor (C1) and two resistors (R1 and R2) to form a RC network. The values of these components determine the frequency of the square wave generated by the 555 timer IC. When a button is pressed, the circuit is triggered, and the 555 timer IC starts oscillating, generating a square wave of a specific frequency. This frequency determines the pitch of the sound produced by the speaker.

## IV. Mathematical Justification

The formula

$$frequency(f) = \frac{1.44}{(R1 + 2R4)C1} \tag{1}$$

defines the resonant frequency of a circuit. This frequency is where the impedance of the circuit becomes purely resistive, indicating the point of natural oscillation with minimal opposition.

The formula computes the time constant of the circuit, indicating the rate at which the circuit's response to changes in voltage or current occurs. The reciprocal of this time constant, scaled by a constant factor of $1.44$, yields the resonant frequency. In essence, the formula offers a method to determine the resonant frequency based on the circuit's resistance and capacitance values, essential for understanding and designing circuits in electronics and electrical engineering contexts.

## V. Final Product

Our final product is a fully-fledged working model of flexible, rollable, do-it-yourself (DIY) and touch based affordable musical instrument which can play different sound while touching the comb structure. Figure 5 shows our final product which only have a comb structure and multi-vibrator circuit on kapton thin film. The circuit also include speaker and 5V battery. the conductivity and soldering is purely based on copper tape. it is important to note that the back side of copper tape is not conductive.

The beep is purely dependent upon resistance we placed on the comb structure. we also observe that when we touch two comb pads at a time we get different sound than touching them at a time.

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