Squishy Circuits as a Tangible Interface

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Abstract

Squishy Circuits is an approach to exploring and learning electronics. This method uses homemade sculpting dough recipes- one that is conductive, and another that is insulating- to replace wires and insulators. Squishy Circuits can be used to model basic circuits, but can also be used as an interface for more advanced microcontroller projects.

Keywords
 tangible interface; play dough; squishy

ACM Classification Keywords
H.5.m. [Information interfaces and presentation (e.g., HCI)]: Miscellaneous;

General Terms
Design, Experimentation

Introduction
Traditionally, students are introduced to electronics using prototyping boards or soldering irons. The Squishy Circuits project attempts to change the way students, particularly young students, are taught by using simple components, such as LEDs, motors, and buzzers, and combining them with homemade sculpting dough [10]. This allows students to sculpt non-

permanent circuits in a playful activity. Two different recipes were developed, one salt based for the conductive dough and one sugar based for the insulating dough [10].

We have used Squishy Circuits with many age groups, from age 3 to adult, and have found most circuit sculptors are engaged in the activity and seem to learn concepts such as short circuits and circuit continuity.
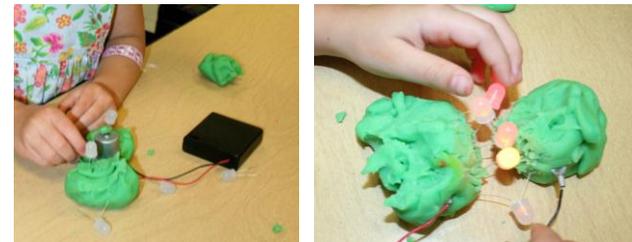
SQUISHY CIRCUITS AS A TEACHING TOOL

Motivation and engagement in science has a high correlation with several factors including lessons that are hands-on and activities that allow individuals to approach the project in their own ways [2, 7, 8, 9]. Squishy Circuits, as a tangible circuit creation technique, provides a medium for allowing such exploration.

Research has shown that the confidence levels in an individual's skills are proven to be increased when positive stimuli are given for success, especially when they are required to think critically [8, 9]. This is why lighting an LED is often the first challenge we present to students. Students must think of how electricity behaves and create a circuit. Success is immediately evident with the LED, or motor, turning on.

Our experiences with Squishy Circuits in the classroom seem to validate these ideas. We have used Squishy Circuits with many age groups, from age 3 to adults, and have found most circuit sculptors are engaged in the activity and successfully learn conceptual electronics, such as short circuits and circuit continuity.

Figure 1 shows students in a preschool classroom (ages 4-5) sculpting circuits. The students were each given a set of Squishy Circuit components, and walked through the creation of a simple LED circuit [3, 4]. They were then given a chance to play with motors, buzzers, and unlimited LEDs to create their own designs. Every child was successful in creating a circuit with, at most, a few minutes of individual attention. The activity was then run with a class of 3-4 year olds with equal success. It should be noted, however, that the younger class preferred motors to LEDs. It is unclear to us whether this was due to the bidirectionality of motors (as opposed to LEDs) or due to their love of spinning things.

Figure 1. Circuits created by pre-school (aged 3-5 years) children.

We are encouraged by what we have seen and are will be doing more research on the effectiveness of Squishy Circuits as a teaching tool in early childhood (pre-school and kindergarten) in the future.

Squishy Interfaces
As Squishy Circuits has developed, we have received emails from teachers who are currently using, or planning on using, squishy circuits in their classroom.

Many secondary school teachers mentioned the desire for more advanced activities, particularly ones that would involve programming and microcontrollers. This can be accomplished by using the resistance of the conductive dough as an input variable, which is made possible by the relationship between the dimensions of the dough's shape and its resistance. To determine this relationship, experiments were conducted in which the dough's resistivity was measured.

Resistivity Testing

The use of the Squishy Circuit dough in tangible interfaces is dependent on being able to reliably characterize its behavior. The easiest way to use conductive dough as a transducer is to take advantage of the fact that resistance is related to geometry:

$$Resistance\,(\Omega) = \frac{Resistivity\,(\rho) \cdot Length(l)}{Area(A)} \, ,$$

where resistivity is a property of the material. If resistivity is stable over time and from batch to batch, manipulation of the dough's shape will change its resistance in known ways. Below, we describe our results in characterizing the resistivity of these doughs.

Resistivity Testing of Conductive Dough

Four independent batches of dough were made following the published recipe [10]. While the recipe does not specify the exact quantity of flour needed, to reduce variability 1.25 cups of flour was used for each batch. Samples of the dough were then inserted into the testing apparatus, a 0.5 inch PVC tube. Through the tube, four tin-copper wire electrodes were inserted, with the centermost electrodes placed one inch apart. A current source was attached to the outer two

electrodes, while a voltmeter was attached to the centermost electrodes. This setup is shown in Figure 2.
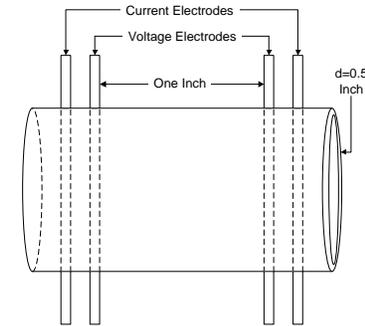
Figure 2. Test fixture used for resistivity testing of conductive dough.

Using this four-wire measurement technique, or Kelvin measurement, all effects due to wire resistance and electrochemical reactions are negated [5], resulting in the resistance of the conductive dough sample, measured in ohms.

The test was automated using LabVIEW [6] measuring voltage at currents from 1 to 50 mA in 1mA steps. Transient effects were filtered by waiting 750 ms after each step in current before making a measurement. The resulting data had a strong linear correlation (r^2=99.8-100%), indicating a resistivity independent of current. The data presented in this paper was collected at 50mA.

Fifteen samples of the first batch were measured to determine stability of resistivity readings within a batch. Then 5 samples of each of the remaining batches were measured. The results of our tests on

multiple samples of multiple batches are shown in Table 1. The uncertainties given are ± 2 standard deviations of the mean.

Batch	Number of Trials	Resistivity Ω-inches
1	15	10.33±0.08
2	5	9.96±0.12
3	5	9.04±0.13
4	5	10.03±0.09
Average		9.8±1.1

Table 1. Resistivity results for the conductive dough.

Samples within a single batch vary in resistivity by less than 2%. While batch to batch variability is greater than intra-batch variability, we still find a reproducibility of approximately 11%.

APPLICATIONS
Our data has shown that the dough has a relatively stable resistivity which allows us to characterize its behavior, and to use it in more advanced projects. This can be accomplished in microprocessor circuits by using conductive dough as part of a voltage divider between the dough and a known resistor. When the user manipulates the dough, the resistance changes and the resulting voltage over the dough is measured. This variable voltage input is passed through equations, derived from the resistivity data, and an output task is performed.
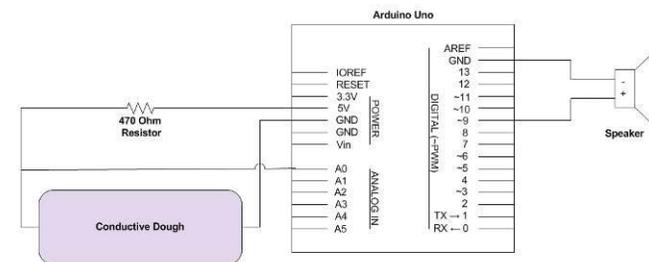
Squishy Sound
For this project, Squishy Sound (described in Figures 3 and 4), we have used an Arduino UNO board [1]. The microprocessor reads the voltage across the conductive dough via an analog input, and converts that value into a tone frequency. This frequency is emitted through an external buzzer or speaker. When the user manipulates the dough, by stretching or squeezing it, the buzzer changes frequencies in real time. The pitch is higher if the resistance is higher and lower if the resistance is lowered.
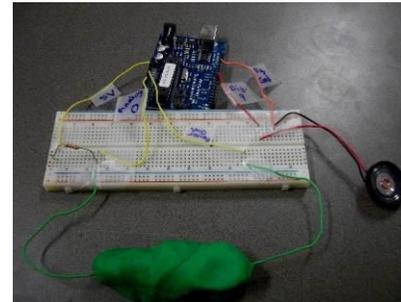

Figure 3. A sound-producing circuit which uses conductive dough to control pitch.
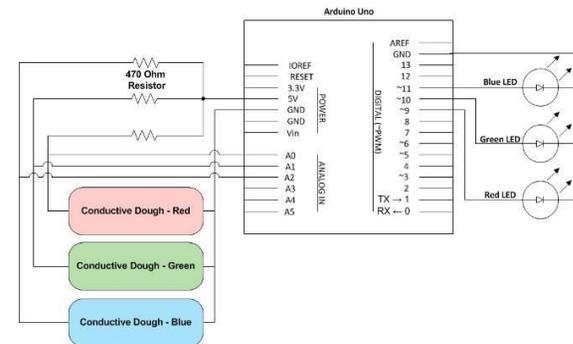

Figure 4. Schematic for the Squishy Sound circuit.

Squishy Red-Green-Blue (RGB) Controller

Another project that can be done with Squishy Circuits and a microprocessor is the Squishy RGB LED Controller, shown in Figures 5 and 6. In the same manner as Squishy Sound, three separate pieces of conductive dough can be utilized as input devices which control the brightness of a cluster of three different LEDs, one each of red, green, and blue. In essence, this creates a large pixel which mixes the three lights into different colors based on their individual intensities. For example, if the dough inputs are manipulated to have a low resistance, all three LEDs will be brightly lit and create a white light. However, if the resistance of the dough for the green LED is increased, the red and blue LEDs will be more brightly lit and the resulting color takes on a purple hue. This project works best in combination with a semi-translucent diffuser to help mix the colors.
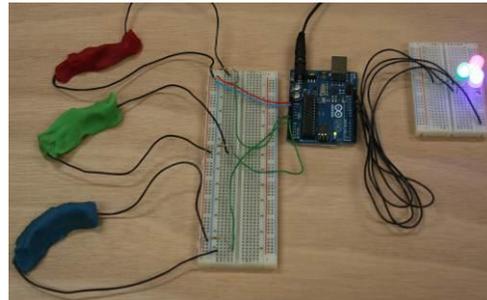

Figure 5. A squishy interface for RGB LEDs.

Figure 6. Schematic for the Squishy RGB Controller circuit.

Squishy Variable Blinker

An additional project that can be done with Squishy Circuits involves two LEDs which alternate on and off in succession. Changing the shape of the conductive dough changes the speed in which the LEDs blink, from completely off on an open circuit, to a speed faster than the human eye can detect, making both LEDs appear constantly on.
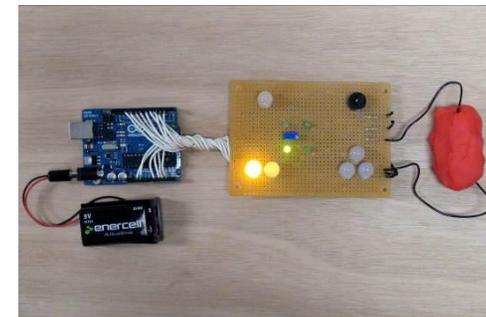
Figure 7. A project that controls two LED lights. (note that this particular board also includes Squishy Sound, Squishy RGB LED and a single LED brightness).
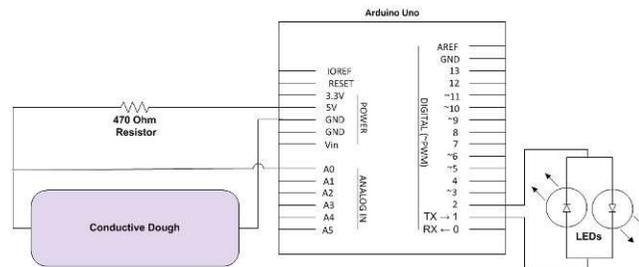
Figure 8. The Squishy Variable Blinker Schematic

Future Work

The use of conductive play dough as an input mechanism opens a new opportunities for design. Components that can create variable inputs exist, such as potentiometers, but a tactile aspect is added with Squishy Circuits.

Future work will expand further upon this concept and will generate additional tangible projects that utilize Squishy Circuits as an input. Additionally, work is being done to create and assess curricular materials based on these interfaces. Finally, as the longevity of these devices is limited by environmental influences, methods to allow long-term use are being explored.

Acknowledgements

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