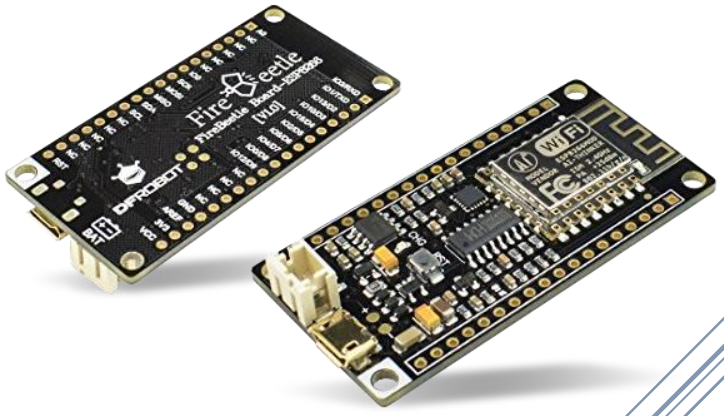
INTERACTIVE SKIN INTERFACE

Smart Tattoo Lab



Wearable Technology Laboratory (BME/CS 479)

Fall 2025 – Lab 3

Materials:

1. Vinyl
2. Copper Tape
3. MPR 121 Breakout Board

Background:

Our goal in this lab is to build a Smart Tattoo that would allow us to control external devices. Imagine, commanding devices from a simple swipe of a tattoo on your arm. The Media Lab at MIT has created DuoSkin as shown in Figure 1. This implementation of the DuoSkin allows the user to control a tablet as a directional pad. In this lab, you will be creating a design similar to the DuoSkin. In order to achieve this goal, we will create a Smart Tattoo embedded with capacitive sensors that could be used for interfacing with external devices. Hence, let's get familiar with capacitive sensors.

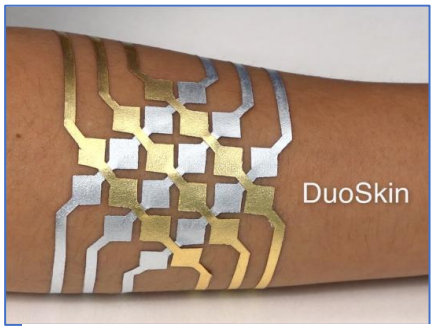


Figure 1: DuoSkin smart tattoo interface created by the MIT Media Lab

Capacitive Sensors

We use capacitive sensors every time we swipe on a touchpad or use a smartphone's screen. Capacitive sensing is based on capacitive coupling, and it can be detected by a medium that has a conductive or dielectric difference from the air. In order to detect the touch events, in this lab, we use the MPR 121 board. When touching a capacitive sensor (electrode), in Figure 2, the total capacitance sensed by the board changes from C_p to $C_p + C_F$, which is attributed to a coupling effect with the conductive finger that acts as ground. The change in capacitance in turn changes the charging and discharging Time Constant detected by the board. When the finger contacts the electrode, the capacitive sensor triggers a change hence detecting the touch event.

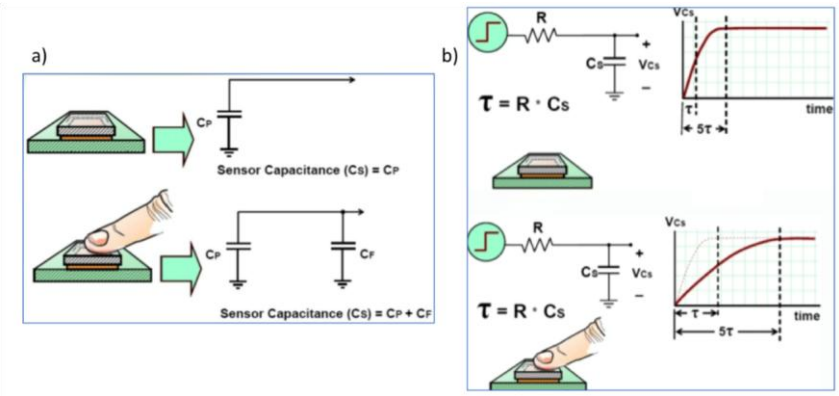


Figure 2: a) The capacitive equivalent of each sensor in the events of touch and no-touch. b) The equivalent RC circuit and time constant associated with the touch and no-touch event.

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MPR 121 Breakout Board

The MPR121 Breakout board has the capability of sensing 12 individual capacitive sensors, 0 through 11. On the restart, the system recalibrates these sensors, therefore, make sure that you are not touching these sensors when powering up the device.

To connect the MPR121 Breakout board to the FireBeetle board using the I2C protocol, follow these steps:

- Connect the VIN pin to 3.3V
- Connect the GND pin to the Ground
- Connect the SDA pin to the SDA (data line) on the FireBeetle
- Connect the SCL pin to the SCL (clock line) on the FireBeetle

Follow the following link to download the required library and learn from the example codes: https://learn.adafruit.com/adafruit-mpr121-12-key-capacitive-touch-sensor-breakout-tutorial

Device Design:

Our goal is to create a Smart Tattoo that can interact with external devices, such as a computer, to perform various tasks. Examples could include playing a game on the user interface, typing text onto a screen, controlling a slider, or any other creative application your team envisions.

Step I: Initial Smart Tattoo Prototype

We will first create and test a simple version of the Smart Tattoo to familiarize ourselves with the capacitive sensing board. For now, do not attach the tattoo to your skin.

1. For the hardware, start with two base layers of vinyl. Then thread a wire through another two layers of vinyl with holes, and position them onto the base layers. Expose the wires, then place two layers of copper tape on top of the wire. Make sure the vinyl layers are bigger than the copper tape.
2. Cut out four equal-sized keys from the copper tape and arrange them as a directional pad.
3. Connect the wires from the copper tape electrodes directly to the MPR121 board.
4. Write code in Processing that allows you to control a game using four directional arrows.
5. Verify your work with a TA.

Step II – Design Your Version Smart Tattoo

Now that you've learned how to design a smart tattoo and interact with a computer, it's time to brainstorm a cool application!

Design an advanced tattoo that you can wear on your skin to achieve your new goal. Your design should include **at least 10 pads**. You will need two devices for the live demonstration.

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For an added challenge, try incorporating simple electronics, such as diodes, to enhance your Smart Tattoo while ensuring safety. How can you push the boundaries and make your design even more innovative?

The **primary objective** of this lab is to design an advanced user interface and make your Smart Tattoo as creative and functional as possible. While you are required to use Processing (at least for a portion of your UI), you also have the option to explore more advanced software for user interface design, as long as you're willing to teach your team how to use it as well.

Module Requirements:

Your grade for this module will be based on the following criteria:

- **Creativity and Implementation**: **This lab emphasizes creativity, so put your best effort into developing and implementing your idea.**
- **Working Prototypes:** You must deliver two fully functional prototypes by the end of the module.
- **Presentation Quality:** Your presentation should be well-organized, scientifically structured, and include all necessary graphs, visuals, and clear interpretations of your results.
- **Team Knowledge:** All team members must be knowledgeable about the project and able to build the circuit and the accompanying UI.

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Grading Rubric and Evaluation Criteria

Hardware Evaluation Criteria:

- *Does all the hardware work?*
    - *Does each capacitive sensor perform the function it should?*
        - *Are buttons consistently working?*
        - *Are buttons insulated properly so there is no drop in performance when worn on the skin?*
- *Device enclosure*
    - *Is the device packaged sufficiently?*
        - *Additional point for creative packaging*
    - *Are there any exposed wires?*
    - *Are there any shorts in the device or during the presentation of the device?*
    - *Is soldering flush to the board?*
- *Up to two additional points for incorporation of the flex sensor*

User Interface Evaluation Criteria:

- *How does the UI incorporate Processing?*
- *How creative and novel is the UI in its use of the MPR 121 capacitive sensor's readings?*
- *Do all capacitive sensors have distinct functions?*

Data Display Evaluation Criteria:

- *Is the UI intuitive and easy to use/understand?*

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