Capacitive Touch

Introduction

It is something we interact with countless times during the day, whether it be on our phone or a public computer, touch screens have revolutionised the way we interact with electronics. But have you ever stopped to question how exactly touch screens work?

Smart phones use a technology based on the capacitors you may have seen in your physics classes. Capacitors in the most basic sense can be thought of as a battery in that they are able to store electrical charge. People sometimes used the analogy of a bucket collecting water where the bucket is the capacitor and the water is the electrical charged being collected. Just like a battery we can recharge a capacitor by connecting it to a power supply and discharge by connecting the capacitor to a LED or small motor.

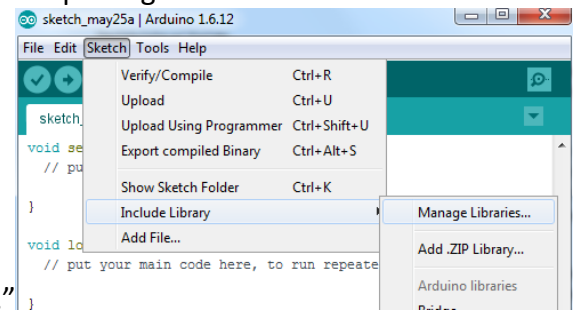
The construction of a capacitor is extremely simple, being just two metallic plates separated by a gap. However importantly, the plates don't have to be metal. They may be any conductive material, for example, your skin perhaps... This is an important point to keep in mind throughout this lesson as it is the reason capacitive touch sensing is possible.
Before we tackle the theory let's demonstrate the concept by building our very own touch sensor.

Demo

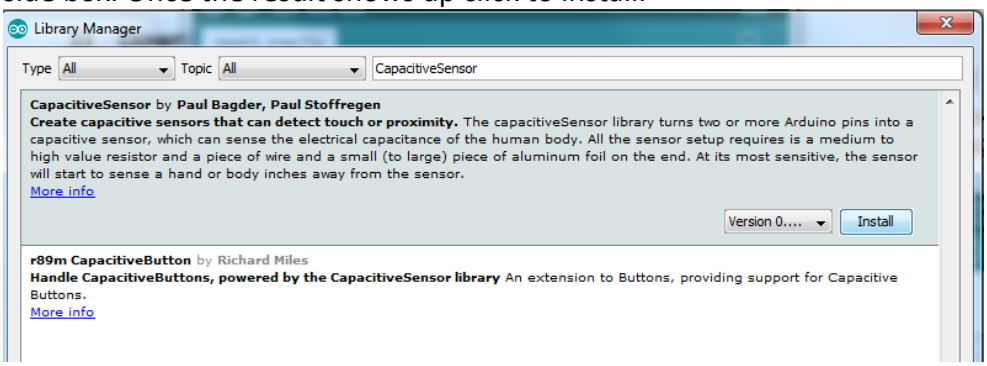
Requirements

- Arduino
- A 1 Mega Ohm resistor (Any value of resistor which is reasonably large should do)
- Metal foil (Such as tin foil)
- Crocodile clips
- Wire

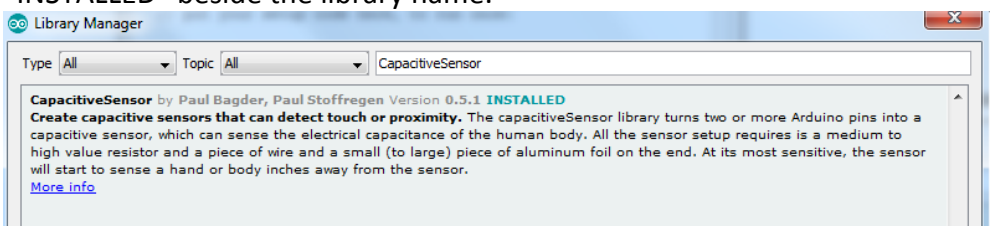
1) **<u>Download required libraries (Teacher to do in advance for younger classes)</u>**
   - **a.** Open the Aruino IDE (The software used to write code for the Arduino)
   - **b.** Using the toolbar at the top navigate to "Sketch>>Include Libraries>>Manage Libraries…"



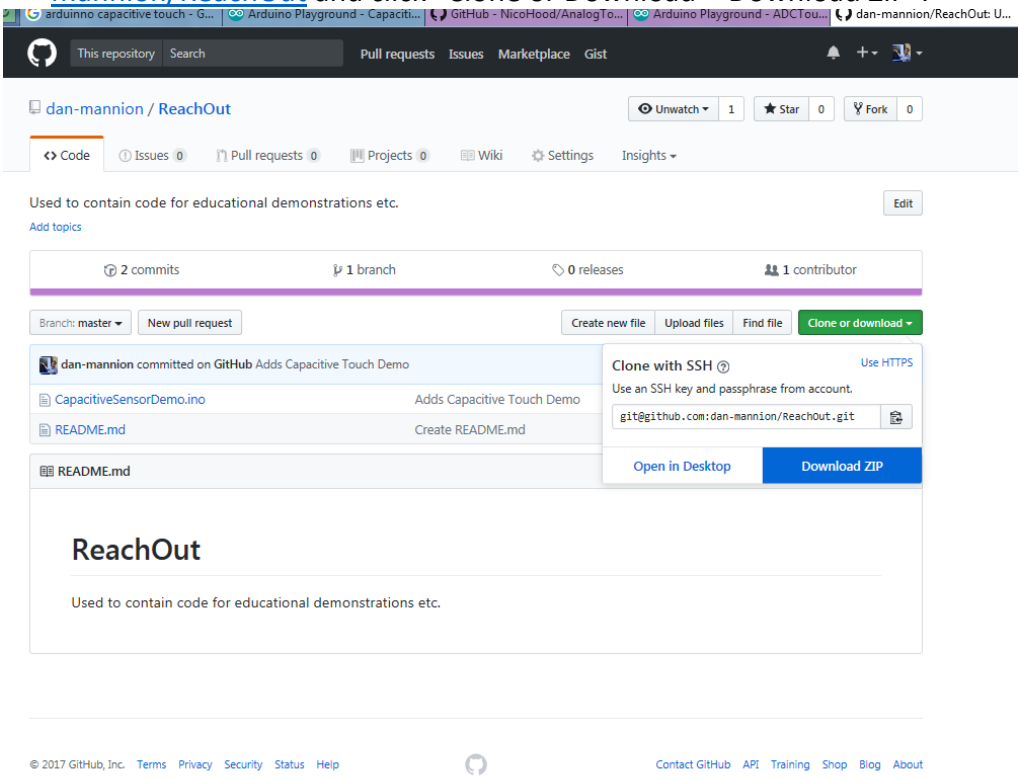
   - **c.** In the window that opens, search for "CapacitiveSensor" in the top right hand side box. Once the result shows up click to install.



   - **d.** If the library is sucesssfuly installed it should now be indicated with a blue "INSTALLED" beside the library name.



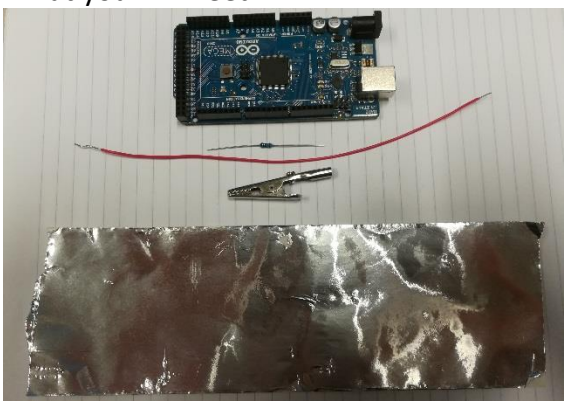
e. Finall we need to download the code that we will upload to our arduino. To do this go to the following website https://github.com/dan-mannion/ReachOut and click “Clone or Download>>Download ZIP”.



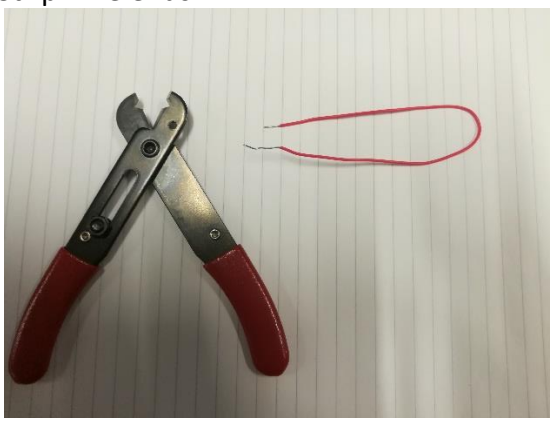
f. Locate where you have downloaded the zip folder. Extract all the files and move the file named “CapacitiveSensorDemo.ino” to a memorable location that all your students are able to access. This contains the code they will need to be uploading to their Arduino.

2) **Build circuit (Student task)**

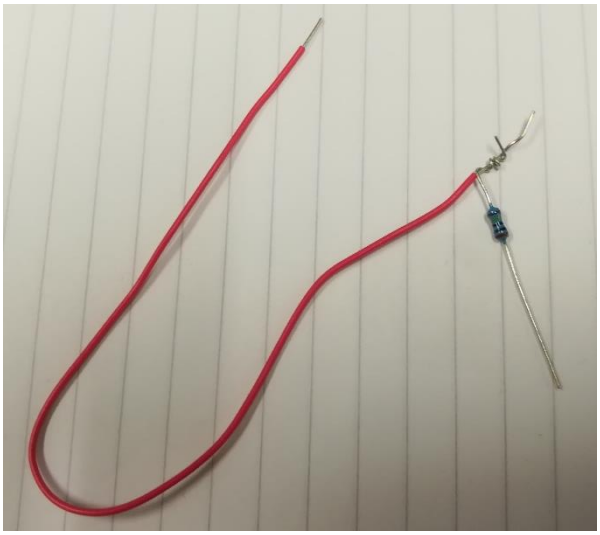
a. What you will need.



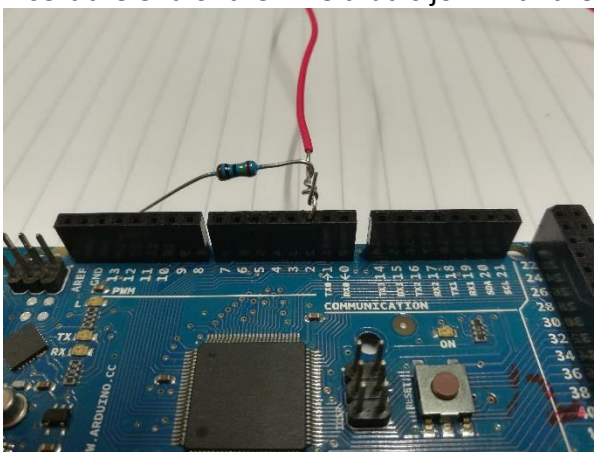
b. Strip wire ends.



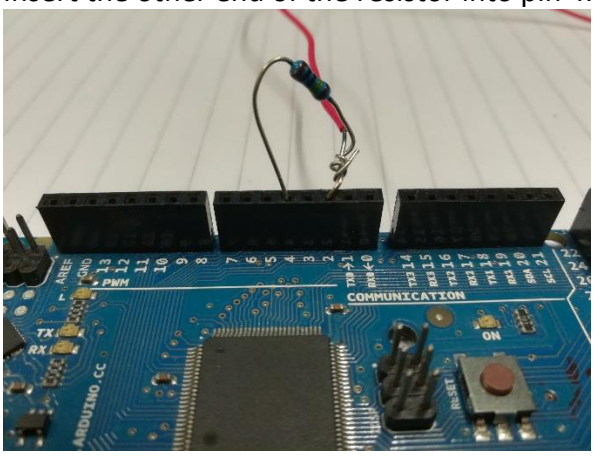
c. Connect one end of wire to resistor.



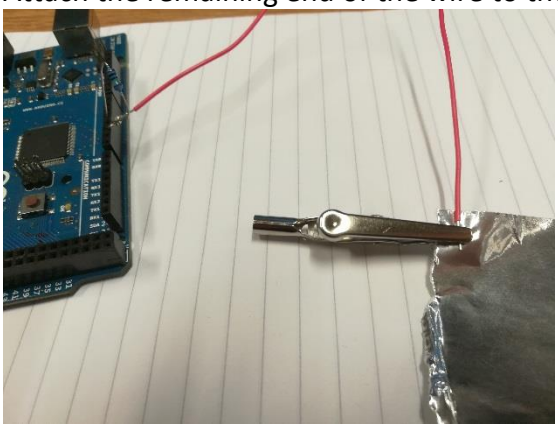
d. Insert the end of the wire that is join with the resistor into pin 2.



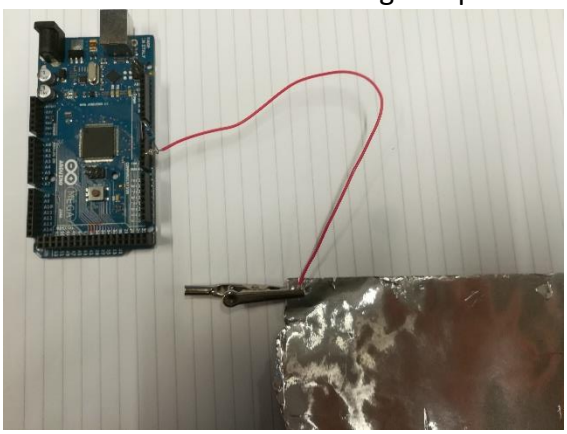
e. Insert the other end of the resistor into pin 4.



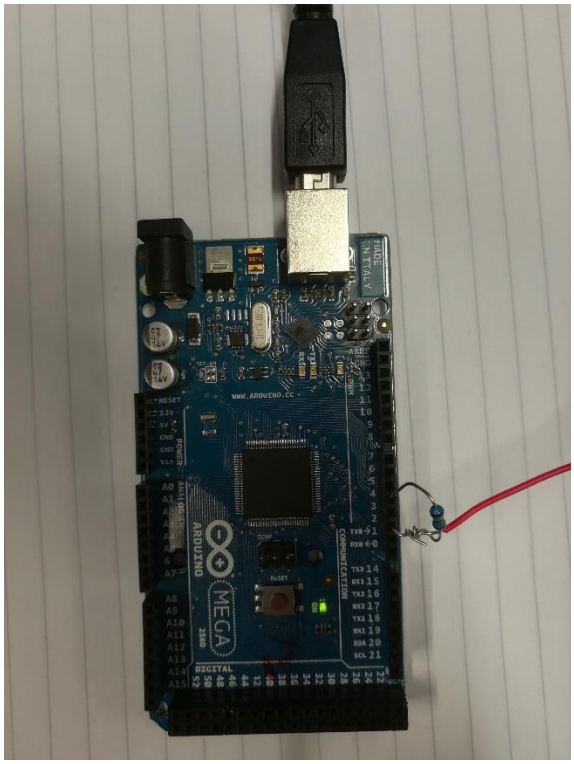
f. Attach the remaining end of the wire to the tin foil using a crocodile clip.



g. You should have the following complete circuit.



h. Finally, plug in the USB to the computer and you are ready to upload the code…

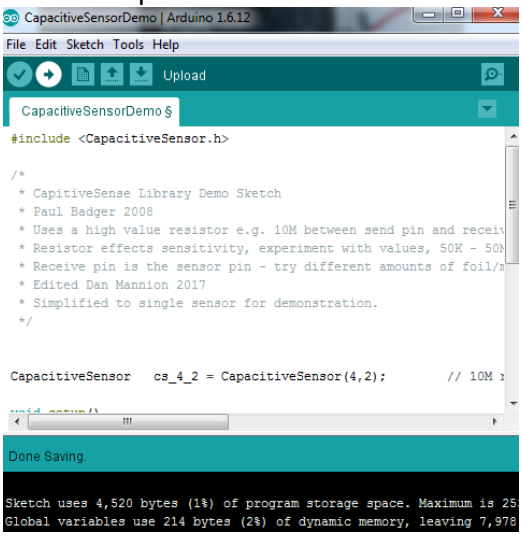


3) **Upload code and observe (Student task)**

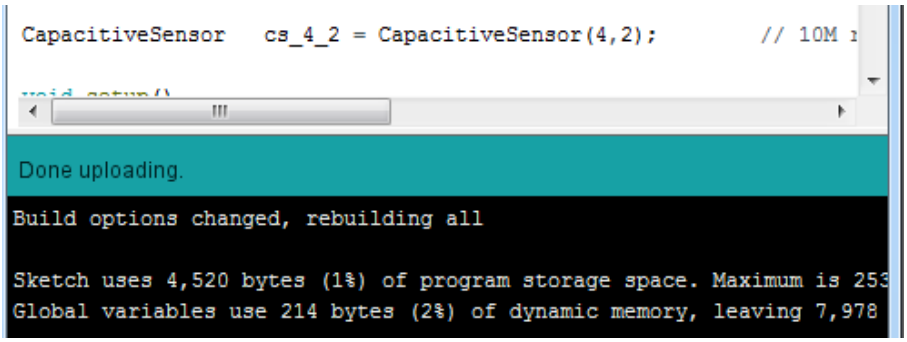
a. Open the Arduino IDE (The software you use to write and upload code to the Arduino).

b. Navigate to “File>>Open…” to open the code for the capacitive sensor which is titled “CapacitiveTouchDemo.ino” and should have been saved to your PC in earlier steps.

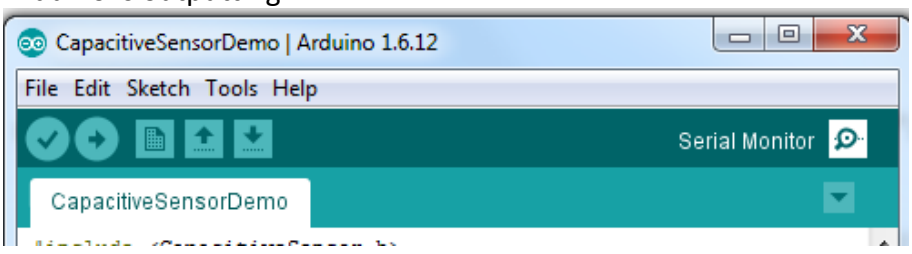
c. Click the upload button which is the arrow pointing to the right.



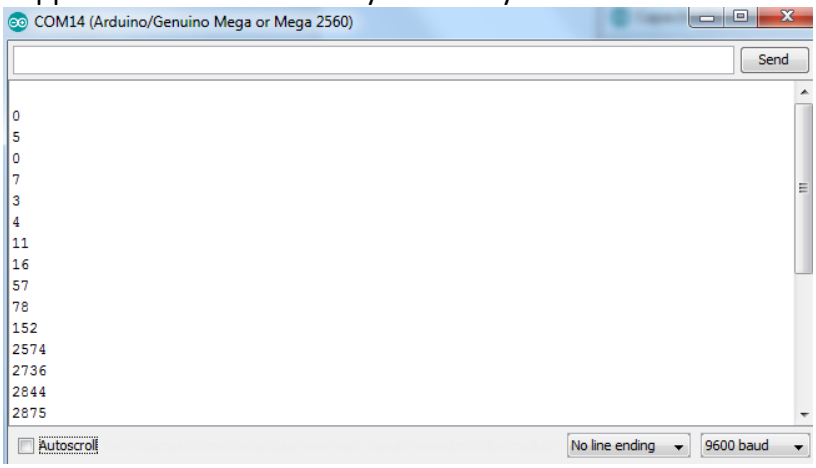
d. If the code uploads correctly it should say “Done uploading” in the blue banner at the bottom of the screen.



e. Once uploaded, we then open the Serial monitor by clicking the magnifying glass in the top right hand corner. This allows us to see what information the Arduino is outputting.



f. A window will pop up and with numbers rolling down the screen. Watch what happens to the numbers as you move your hand closer to the metal foil…



The Theory

We now tackle the theory that explains why this happens. First we have to acknowledge that the metal foil is essentially a capacitor. This may seem strange because we said earlier that a capacitor requires two conductive plates but we only have one... So where is the second? Surprisingly the second plate is actually the earth, the ground you are standing on.

The metal foil and the ground you are standing on form a capacitor.

This metal foil-ground capacitor can, like all capacitors, store charge. The amount of charge it can store is called its capacitance. Capacitors that can store a lot of charge are said to have a high capacitance whereas capacitors which can store only a little amount of charge have a low capacitance. Fortunately, the Arduino is able to measure the capacitance of the capacitor. The numbers you saw on the screen relate to the capacitance of the metal foil changing as you moved your hand closer to the foil.

The metal foil-ground capacitor has a capacitance which the Arduino can measure.

But how does this help us detect when we are near to the metal foil? The capacitance of the metal foil is a complex thing to calculate however in the simplest of cases it is given by the following equation.

$$Capacitance = \frac{Area \times \varepsilon}{Distance}$$

Where $Area$ is the area of the two metal plates and $Distance$ is the distance between the two plates. If you have studied physics you may have seen this before. The ε symbol refers

to a constant describing the permittivity of the material between the two plates. Do not worry about this we do not need to understand it.

So, if we saw the Arduino was reporting a change in capacitance as we moved our hand closer to the metal foil we must have either been changing the area of the foil OR the distance between the plate and the earth. The area of the foil is obviously not changing so it must be the distance between the foil and the ground. While you are standing on the earth you essentially become part of the conductive plate that is the ground so it is easy to see that as you move your hand (which is essentially part of the ground) closer to the metal foil the distance is reduced which leads to an increase in capacitance.

Moving closer to the metal foil changes its capacitance which the Arduino is able to measure.

Application to smart phones

In our example the Arduino could only detect changes in how close you were to the metal foil. It isn't able to sense the difference between you touching the centre of the foil or the edge. However, touch screens are much more advanced than this being able to detect both position of fingers and certain gestures. I would encourage you to stop reading here and use this an exercise to discuss in groups how this technology is modified to work in such touch screens.
The secret to their operation is to use a large grid of metallic contacts. Each contact alone acts almost identically to the sensor you have made today. i.e. they can only detect how close your finger is. However, if you have a grid of many of these at different locations on the screen it is possible to locate where exactly your finger is as well as how many fingers are pressed and how your finger moves across the screen.
In recent years another application of capacitive touch sensing has emerged in mobile phones and that is in fingerprint scanners. Higher end phones available today allow for fingerprint scanners to unlock phones. These use an incredibly tiny array of capacitive sensors to detect the ridges in your fingerprints.

So there you have it, you have been able to demonstrate the concept of capacitive touch - the technology that allows touch screens on smart phones and fingerprint scanning - with only an Arduino and some tin foil.

Further practical work

We will now take a closer look at the code. The following work can be done without prior knowledge of coding on the Arduino platform however it is aimed at those who have had some previous experience and therefore does not go through basics in detail. That said, the task is modifying a single value so should be accessible for even those who have never coded before.
You will have noticed when you touch the metal foil the following LED turns on. (NOTE this may not be true for everyone but carry on because we will get it working if not.) There are a number of LEDs on the board we are interested in the one highlighted with the red rectangle below.

On closer inspection of the code we see a variable named threshold defined to a particular number. In the picture adjacent this has been set to 500. An interesting task is to vary the value of this variable to try to discover what changing the number of this does. HINT: Observe the LED as you bring your hand closer to the foil. Repeat this for multiple values of threshold.

How to change the value? That is as simple as changing the line in the adjacent picture to something like:

const int threshold = 100;

This would set the value to 100. Do this for multiple values. How does this affect the behaviour of the LED?