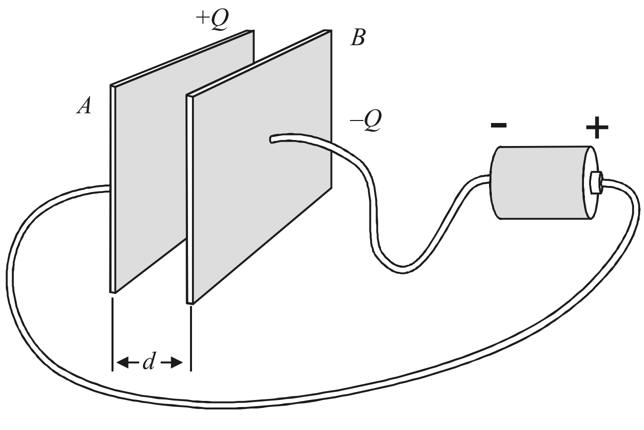
What's a Capacitor?
Building and Using a Capacitor

Semiconductor fabrication is one of the names for the mass production of integrated circuits. Fabrication includes all of the processes that can be done in wafer form. Many integrated circuits now have internal dimensions that are sub-micron in width. To put this in perspective, the human hair is about 100 microns in diameter. In order to produce integrated circuits with predictable yields, everything that comes near the integrated circuits prior to top-surface protective coating must essentially be free of particles and other contaminants. In addition, all of the layers formed during fabrication must be highly controlled in purity and must conform as closely as possible to the surface beneath.

Capacitors are elements in integrated circuits that temporarily store charge. This stored charge is a critical parameter in the operation of memory integrated circuits. A capacitor is a "sandwich" of 3 material layers, two conducting layers with an insulating material separating them. Electrons are supplied to one of the conducting layers from a voltage source. As long as this conducting layer is isolated from the other conducting layer by the insulator, the charge will create an excess negative charge in the wired conducting layer. The second conducting layer is held at *ground* (0 volts) or some very small positive voltage. Since the insulating material, also known as a dielectric, separates the two conductors, there will be a difference in charge between the two conducting plates. This state creates a *binary 1* (ON state) in the *DRAM* (dynamic random access memory) capacitor. When the electrons are removed from the first conductor, creating a state where the two conductors have the same charge, there is no potential (V) and a *binary 0* (OFF state) is created in the DRAM capacitor.



C = KA/d is the equation for capacitance you will be working with in this exercise.

- ***C*** is the capacitance in nanoFarads
- ***A*** is the area of each conducting plates
- ***d*** is the distance between the plates (the thickness of the insulator)
- ***K*** is the dielectric constant for the insulating material

As integrated circuits become smaller and smaller in order for the electronic products they support to perform more complex functions faster and in less space, the design and fabrication of capacitors becomes a major challenge to semiconductor design and process engineers.

PURPOSE

In this activity you will explain concepts of charge storage and explain how a capacitor works. You will also learn how DRAM integrated circuits use capacitors to store memory. You will build a capacitor and measure its capacitance, and you will also consider ways to optimize your capacitor.

GLOSSARY

Capacitance: The property of a circuit element that permits it to store charge. Also the ratio of charge to potential on an electrically charged isolated conductor.

Capacitor: An electric circuit element used to temporarily store charge, consisting of two conducting plates, usually metals, separated and insulated from each other by a dielectric.

Chip (or microchip): An individual integrated circuit built in a tiny, layered rectangle or square on a silicon wafer. There may be as many as hundreds of these chips on a single wafer.

Clean Room: A manufacturing facility where integrated circuits are fabricated. The air inside these rooms is cleaner than a typical surgical operating room.

Conductor: A material that conducts heat, light, sound, or especially electric charge. A conductor allows electricity to freely move from one point on the conductor to another point on the conductor.

Dielectric: A nonconductor of electricity. Dielectric materials do not allow electricity to flow through them. Also called an insulator.

Dynamic Random Access Memory (DRAM): The integrated circuit used for data storage during computation.

Farad: The unit of capacitance in the meter-kilogram-second system that is equal to the capacitance of a capacitor having an equal and opposite charge of 1 coulomb on each plate and a potential difference of 1 volt between plates. This unit was named after Michael Faraday and measures how well a capacitor can store charge.

Insulator: A material that insulates, especially a nonconductor of sound, heat, or electricity. Also called a dielectric.

Integrated Circuit (IC): An electronic circuit containing as many as millions of microscopic transistors and other devices that work together to perform specific functions. All elements of the circuit are fabricated and interconnected in and on a single chip of semiconducting material, typically silicon. Also called chip or microchip or microcircuit.

Memory: Capacity for storing information.

Micron (or micrometer): One-millionth of a meter (10^{-6} meter); symbol is μ or μm.

nano-Farad (nF): One one-billionth of a Farad; 1 nF = 10^{-9} F.

Semiconductor: A material that can be an electrical conductor or insulator. Silicon is the most common semiconductor used to manufacture integrated circuits.

Silicon: A basic element in the Periodic Table. Sand is the primary source of silicon (Si).

Wafer: A thin slice of silicon, or other semiconductor material, in and on which multiple integrated circuits of the same design are fabricated.

MATERIALS

aluminum foil
spray adhesive
multimeter with capacitance meter capability
memory chip (optional)
plastic shrink wrap
wires with alligator clips
scissors
cotton balls or tissues

PROCEDURE

1. Label *A* and *d* on the capacitor drawing pictured on your student answer page.

2. Obtain 2 sheets of foil that are approximately 18" long. Keep the foil as smooth as possible.

3. Obtain 1 sheet of plastic wrap that is slightly longer than the foil sheets. Keep the wrap as smooth as possible.

4. Decide with your team members how you are going to prevent the two layers of foil from touching each other when the capacitor is complete.

5. Spray the bottom sheet of foil with adhesive and cover it with the plastic wrap. Be sure the wrap overlaps the foil on all sides. Minimize any wrinkles or air bubbles.

6. Spray the top of the plastic wrap with adhesive and cover it with the second sheet of foil. Smooth out any wrinkles or bubbles.

7. Determine the capacitance of your capacitor using the multimeter.
   a. Select the resistance measurement on the multimeter.
   b. Touch the multimeter leads to the plates of the capacitor—one lead to each plate—to determine that the plates are not shorting.
   c. Attach wires to each of the conductor plates with alligator clips.
   d. Measure the capacitance with the capacitance meter and record your capacitance on your student answer page
   e. Report your values to your teacher for the class data table.

8. When the class has completed the class data table, your teacher will lead a discussion about your results and ways to optimize capacitors.

9. Decide with your team members how you will optimize your capacitor.

10. Build your capacitor using the basic processes above but making the optimization you determined in step 9. Use cotton balls or tissues to smooth, flatten or smash any sheet of material to avoid puncturing the sheets.

11. Measure the capacitance of your capacitor as described in step 7.

12. Record your capacitance on your student answer page.

Name ______________________________

Period______________________________

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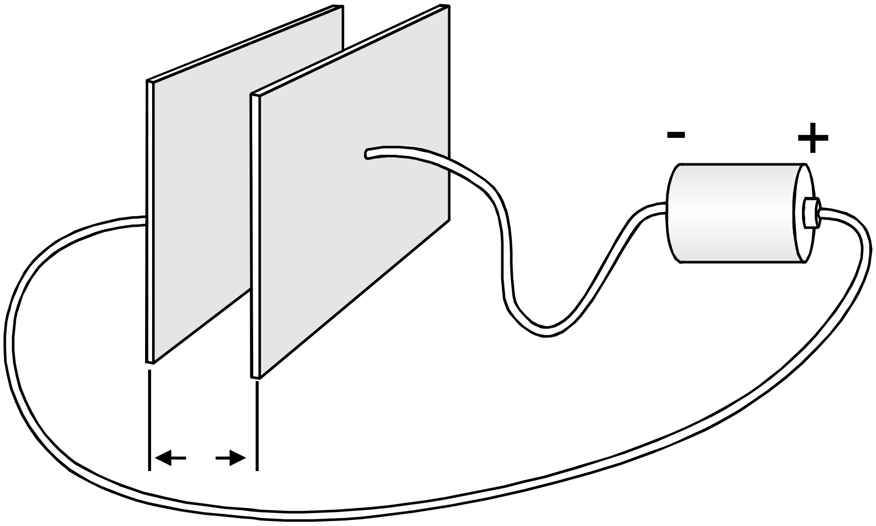

EQUATION

ANALYSIS

Group #	Initial Capacitance	Optimized Capacitance

CONCLUSION QUESTIONS

1. Did the attempt to optimize your capacitor increase the capacitance? If it did not, what happened?

2. If your capacitor exhibited shorting between the conducting plates, what do you think caused it? How would you change your design?

3. What do you think some of the factors are that might limit the choices of materials or physical dimensions for capacitors in integrated circuits?