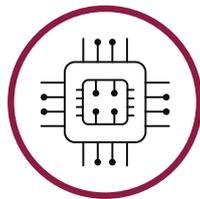
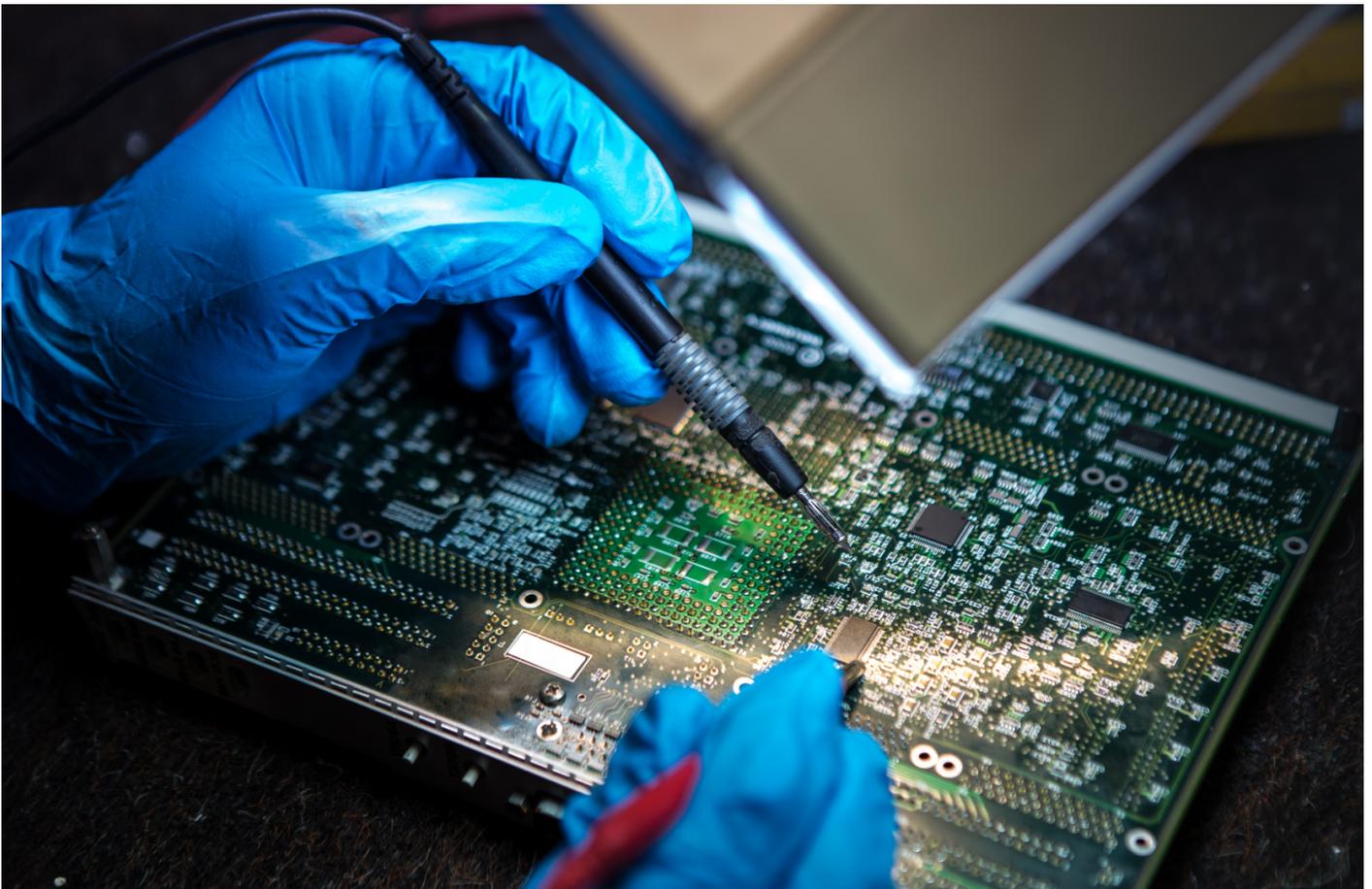




SEMICONDUCTORS

Lesson 3: Fun With Front End Design and Machinery



Facilitator Guide

How to Prepare for This Lesson

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About This Facilitator Guide

This facilitator guide provides instructors with the information needed to guide students through the digital version of Fun With Front End Design and Machinery.

Before You Get Started

Before you get started with this lesson, please be sure to do the following:

- Read through the facilitator guide
- Review the Rise lesson
- Prepare any resources needed for the lesson

Using Editable PDFs

Most lessons include using an editable PDF for students to capture responses to questions and other activities.

Guiding language is included in the lesson to help students access and use the editable PDFs where they appear.

Students who will be using Chromebooks will need to use the Print to PDF function to save their editable PDFs to their devices. Here's how to do this:

1. Open the editable PDF and select Ctrl + P.
2. Open the file destination where the file will be saved.
3. Select "Save as PDF."
4. Select "Print." Your document is now "printed" as a PDF file, which will save your work.

PDFs cannot be submitted via the Rise interactives. If you plan to collect these documents for career planning portfolios or grading, you will need to coordinate that with your students.

Unit Overview and Alignment of Learning Targets

This unit contains five lessons, as follows:

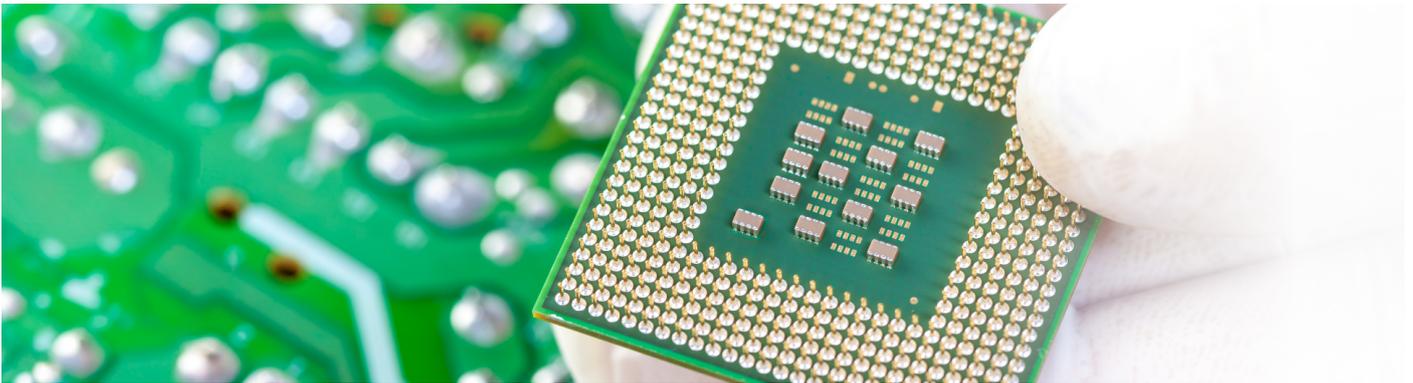
- Lesson 1: Introduction to Semiconductors
- Lesson 2: The Magic of Raw Materials and Design
- Lesson 3: Fun With Front End Design and Machinery
- Lesson 4: A Beginner's Guide to Back End Assembly and Functions
- Lesson 5: The Future of the Semiconductor Industry and My Place in It

For students to get the most value from this unit, please plan on implementing all lessons in this unit in sequential order.

Tracking Completion of Lessons

If you are using SCORM Cloud or Canvas with the lessons in this unit, completion tracking options are available. If you are not using either platform, please determine if and/or how you plan to track the completion of lessons by the students.

Lesson 3: Fun With Front End Design and Machinery



Lesson 3 Components

Pacing

The lesson is designed to extend over multiple class periods to build the background knowledge students need to explore careers and to be able to answer the lesson's guiding question. You may tailor the lesson to meet the needs of the class. If you choose to teach the lesson in its entirety, plan where you will stop after each session. Prepare an appropriate debrief for that class and a way to reengage students in the activities for the next class session.

Materials

This lesson has a cleanroom lab simulation to help students understand the lithography process. During this learning activity in the lesson, the following materials will be required:

- Clear tape (one piece per student)
- Leaves (two per student)
- Scissors (one pair per student)

- Tissues
- Cyanotype paper
- Pens or markers
- Sand, dirt, or beads
- Clear acrylic sheets, glass, or plastic wrap

Be sure to review any Extension Activities that may be suggested at the end of this lesson and consider when and how your students will complete them.



Guiding Questions

The guiding question is intended to provide a focal point for each lesson. This lesson's guiding questions are as follows:

- How does a slice of pure silicon transform into a finished wafer, which becomes a semiconductor you can find in a device you use every day?



Lesson Overview

This lesson will explore the front end design process. We will define the steps of making a semiconductor and then perform our own lithography in a clean room lab simulation. Finally, we will learn how transistors work.



Vocabulary in This Lesson: Flip Card Activity

The flip card activity is designed to familiarize students with key vocabulary terms and definitions for this lesson. These vocabulary words are bolded throughout the lesson. Students must flip each card to proceed with the lesson.

Wafer:

A thin and round sheet cut from an ingot made from a material used in creating semiconductors (like silicon or gallium). Imagine slicing a sausage into rounds. The sausage is the ingot, and the wafer is the rounds.

Doping:

The act of introducing impurities to a semiconductor device in order to produce the desired electrical behavior. Like adding baking powder to a cake turns flour and sugar into a cake, adding impurities to silicon makes it a semiconductor.

N-Type:

A negative-type semiconductor is doped with impurities that add free electrons. N-type semiconductors are like friends who have extra cookies to give away. The electrons, like the cookies, can be passed to a device that has none.

P-Type:

A positive-type semiconductor is one in which the doped materials leave electron “holes,” yielding a positive charge in the semiconductor. Positive-type semiconductors are like the friends who would like an extra cookie and are ready to be connected to their N-type friends who have cookies to give away.

Photolithography:

The process by which light is projected through a blueprint or mask to create a pattern on a given surface. Photolithography is like creating a pattern on paper through a stencil; instead of a pencil or paint, it uses concentrated light.

Etching:

After the wafer gets a coating, the semiconductor design is laid on top. During the etching process, excess coating is removed to leave only the design behind. Etching can be done in many ways and is like when you scratch a design into a piece of wood.

**Learning Targets**

By the end of this lesson, students will be able to do the following:

- Explore the basic steps of front end design in semiconductor manufacturing
- Identify the purpose of the silicon wafer
- Recognize the significance of clean room environments to prevent contamination
- Explain the concept of doping and its effect on material conductivity
- Summarize the steps in front end design

Semiconductor Front End Design

In this section, students will be introduced to how a semiconductor transforms from a wafer to a finished device through a YouTube [video](#). The graphic character, Sami, will introduce the topic to students.

You can also share the following additional resources with the students.

Additional Resources

- Front end design and manufacturing and back end assembly explained in

detail in this resource: https://www.st.com/resource/en/application_note/cd00003986-introduction-to-semiconductor-technology-stmicroelectronics.pdf

The Steps in Making A Semiconductor

In this section, students will review the essential steps involved in manufacturing a semiconductor in a factory, along with the materials and machinery required for the process. The information is presented in a Rise course component called a process block, where students can navigate through the steps or sections by selecting the arrows on the left or right side.

You can also share the following additional resources with the students.

Additional Resources

- Deposition:
 - [Types of machines used in silicon deposition](#)
 - [Applied Materials page on deposition technologies](#)
- Photoresist:
 - [A helpful slideshow showing all the different techniques, and the technologies used](#)

- Lithography:

ASML is a company that produces lithography machines. Their resources are some of the best for finding information on lithography and the manufacturing process:

- [An ASML page on the six crucial steps of making a microchip](#)
- [The ASML manufacturing process](#)
- [Intel shows the inside of a sub fab and shows the ASML machine](#)
- [Intel shows inside one of its ASML lithography machines](#)

Instruction

Select one of the resources—the ASML page on the six steps of making a microchip or the TEL page on how semiconductors are made—and review it with the students as a supplement to this material, providing an opportunity to see the actual equipment used.

Clean Rooms

In this section, students will watch a YouTube [video](#) that explains why cleanrooms are essential to the semiconductor design process.

You can also share the following additional resources with the students.

Additional Resources

- [Getting suited up for a clean room](#)
- [A tour of a real clean room](#)

Let's Find Out Why We Need Clean Rooms!

In this section, students will explore a clean room lab simulation to understand how the lithography process works. The information is presented in a Rise course component called a process block, where students can navigate through the steps or sections by selecting the arrows on the left or right side.

Please note that this activity gives students a hands-on opportunity to personally engage in the lithography process. Without it, students miss the chance to participate and explore the various steps involved.

Guide the students through the following steps of the activity.

Step 1: How Dirty Is the Average Classroom?

Provide each student with a piece of clear tape. Instruct them to stick the tape to the surface of their desk and then pull it up and hold it up to a light source. Guide them to count how many pieces of dust and dirt they can see on the tape.

Next, have the students clean their desks with a tissue and repeat the process. Encourage them to observe if their desk became cleaner after wiping.

Step 2: Trimming the Leaves

Distribute two leaves to each student. Ask them to use scissors to cut thin pieces from the leaves, possibly creating a pattern. Ensure both leaves look similar. Explain that they are creating a “mask,” a stencil that will transfer a pattern onto cyanotype paper to mimic the semiconductor process.

Step 3: Placing Leaves on the Cyanotype Paper

Instruct students to cut their cyanotype paper in half and write their names on the bottom of each half. They should then place one leaf on each half of the paper, ensuring to use the colored side.

On one half, guide students to sprinkle sand, dirt, or beads over the leaf. Then, have them place the papers in the sun under a piece of clear acrylic, glass, or plastic wrap. Explain that this step simulates the lithography process, where the sun exposes the special coating on the paper to transfer the pattern created by the leaf onto the paper.

Step 4: Exploring Results

Once the paper has developed in the sun, instruct students to remove their leaves and rinse the paper. Explain that this rinsing step is similar to the etching step in the semiconductor process, where the developer is removed to reveal the pattern. Guide students to observe the image of the leaf and pattern on each half of the cyanotype paper.

Materials

Here's a list of materials needed for the activity:

- Clear tape (one piece per student)
- Leaves (two per student)
- Scissors (one pair per student)
- Tissues
- Cyanotype paper
- Pens or markers
- Sand, dirt, or beads
- Clear acrylic sheets, glass, or plastic wrap

Instructions (for Modifying the Activity)

This activity can be modified by using standard paper to create negative stencils that mimic the shapes of leaves, or by using actual leaves, along with dirt and paint. If using leaves, students should follow Step 2 as written; otherwise, they can create stencils from paper. In Step 3, instead of placing their paper under the sun, students will paint over their stencils. After allowing the paint to partially dry, they will remove the stencil. Step 4 will involve simply removing the leaf to reveal the pattern on the paper, with no need to wash it.

Let's Think About It

In this section, students will reflect on what they have learned and use the editable PDF to respond to the following questions:

- Did the amount of dust from your desk that you captured on the tape surprise you? Why?
- What happened to the leaf print when you covered it with another material?

How do you think this might impact a semiconductor being manufactured?

- After performing this activity, is there a part of the front end design process that you would like to know more about?

Making A Semiconductor ---> Designing A Semiconductor ---> Creating A Transistor

In this section, students will watch a YouTube [video](#) that demonstrates how a transistor works.



Let's Talk About It

In this section, students will begin by answering the following questions independently. They will then pair up to discuss their responses with a partner. Facilitate the discussion, providing guidance and support throughout the activity.

- What would be more fun, designing or using the machines that we discussed today?
- How did the tape activity change your feelings on how we perceive the word “clean”?
- Was there anything about the operation of transistors or doping that surprised you?

Thinking About Your Future

Students will see the following statement in Rise: In this lesson, you explored the front end design and machinery used in creating semiconductors.

Before moving on to the next lesson, take some time to reflect on these questions:

- Was there any part of the process that seemed interesting to you?
- Which part of the photolithography leaf activity was the most fun?
- Could you see yourself working on any part of the process? Which part?

Career Pathways

Share the following with your students: It's never too soon to start exploring future career options!

Students can access the resources at this link: [PipelineAZ](#)

Lesson Completion

At the end of the lesson, students will see the following message in Rise:

In future lessons, you will learn about different aspects of the semiconductor industry. Topics will include back end design and packaging, the manufacturing process of semiconductors, and the future of semiconductors.

Extension Activity



Materials

- Crayola-type acrylic paint (Other brands can work, but they need to be easily scratched when painted on surfaces and have a chalkboard feel when dry; they can be purchased in bulk from [Crayola Acrylic Paint on Amazon](#).)
- Packaging tape (a six-pack can be purchased on Amazon for under \$15 [here](#)); instead of packing tape, cardboard or cardstock can be laminated, vinyl stickers can be used, or metallic cardboard can be purchased and cut up into blocks
- Cardboard (or cardstock or metallic cardboard; see note above)
- Toothpicks (They can be purchased in bulk from Amazon in a pack of 2,000 under \$6.00 [here](#).)
- Stencils (Any stencils will do, but a 25-pack kit can be purchased from Amazon [here](#).)
- Hair dryer
- Large soft bristle paint brushes (Twelve packs of soft bristle 1-in. paint brushes are \$14 on Amazon [here](#); other brushes of the same type are good, but the bristles need to be soft.)
- Paper plates or plastic paint dishes or cups to hold paint for students



Prep Before the Lesson

1. Cut up cardboard (or cardstock or metallic cardboard) into 6 × 4 cards.
2. Ready the paint brushes.



Vocabulary

1. **Photolithography:** The process by which light is projected through a blueprint or mask to create a pattern on a given surface. Photolithography is like creating a pattern on paper through a stencil, only instead of a pencil or paint, it uses concentrated light.

2. **Etching:** The process of selectively removing material from a thin film on a surface. Etching can be done in many ways and is like when you scratch a design into a piece of wood.
3. **Deposition:** To coat a surface with a material, typically a liquid.
4. **Wafer:** A thin and round sheet cut from an ingot made from a material used in creating semiconductors (like silicon or gallium). Imagine slicing a sausage into rounds. The sausage is the ingot, and the wafer is the rounds.



Questions to Ask Before the Activity

1. How do you think that semiconductor materials are deposited onto a surface?
2. Do you think that we do the same process for anything else?



Procedure

1. Explain to students that semiconductors are built layer by layer through the deposition of different materials onto the semiconductor wafer. Tell students that they are going to be creating their own “semiconductor wafer” in the form of a scratchboard. They will be depositing layers of paint on top of a prepared wafer.
2. (If students have laminated cardstock or metallic cardboard, skip this step.) Explain to students that they will now be preparing their wafer to receive deposited materials. They will be putting tape on their cardboard to create a smooth surface, but a real wafer will be ground and polished to obtain a smooth surface to work with. Have students cover the surface of their cardboard with a layer of packing tape or vinyl. Their cardboard should now be smooth to the touch.
3. Next, hand out one color of paint to each student. Using different colors for each layer can give a cool effect to the final scratchboard.
4. Explain to students that they will now be depositing paint the way that a semiconductor fab deposits various materials onto the semiconductor wafer. Have students paint a layer of paint on top of their smooth surface. Make sure that the paint is thick enough.
5. To speed up the drying process, use a hair dryer on high to dry the boards or place the boards pinned down in front of a fan.
6. After the first layer is dried, add a second and then a third layer following Steps 3–5. Use different colors for each layer.
7. Once the boards are dried and hard to touch, have students place a stencil over their boards. Explain that this is like the photolithography mask that is used by

semiconductor fabs. This mask allows them to transfer a pattern to their wafer.

8. Hand out toothpicks to each student and have them scratch the pattern onto their scratchboard. Explain that they are performing the etching process by removing excess material from their board to reveal the other layers of material underneath.
9. Clean up the workspace and put away materials.



Questions to Ask After the Activity

1. How time consuming was it to deposit and cure each layer of your “semiconductor”?
2. Which part of the activity did you find fun? Was there anything that sparked your interest?
3. How hard was it to etch your design with a toothpick? This is the same as mechanical etching. Do you think there was a better way to etch the material? If so, what?



Thinking About Your Future

Many people are involved in the front end design process for semiconductors. Chemists and chemical engineers help design materials deposited on the surface of a semiconductor wafer. Electrical and Computer Engineers design the semiconductor circuits that are etched onto the wafer. Mechanical Engineers design the mechanical parts of the machinery that make each semiconductor wafer. Electrical and Robotics Engineers design the control systems that allow the machinery to work. Technicians make sure that the machines work the way they are supposed to and check that the final product meets the quality specifications. There are many different jobs involved in the front end design process of semiconductors. Which one interests you?