

Wireless Transmission:

Wireless Burglar Alarm

TechXcite: Discover Engineering

**Pratt School of Engineering
Duke University**



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Module Overview

In this TechXcite: Discover Engineering module, youth design and build their own wireless alarm system. They use electrical engineering and mechanical engineering concepts to create an alarm system with a sensor to detect an intruder, a transmitter to send the signal, and a receiver to trigger an alarm to warn the user.

Activity 1: Youth experiment with a simple switch that they must fit onto a door (or cabinet or box) to trigger an alarm.

Activity 2: Youth build a transmitter and receiver that send and receive a signal via wires.

Activity 3: Youth modify the wired transmitter and receiver by adding a radiofrequency chip to each that allows the alarm system to operate wirelessly. They explore how an antenna affects transmission range.

Activity 4: Youth put the whole project together to allow the trigger created in Activity 1 to trigger a message they record to warn an intruder.

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TechXcite Program

TechXcite is a partnership between the Pratt School of Engineering at Duke University, the National 4-H Council/4-H Afterschool and North Carolina 4-H.

The program is directed by Drs. Gary Ybarra (PI) and Paul Klenk (Co-PI). Beginning in 2001, they co-created the successful Techtronics afterschool engineering program at Rogers-Herr Middle School and Lowes Grove Middle School in Durham, N.C. The TechXcite: Discover Engineering curriculum is building on this work by creating engineering learning modules in seven theme areas for use in afterschool programs nationwide. Together they have created an engaging, substantive, experiential and inquiry-based curriculum in engineering, technology and applied science for 4-H-supported middle school youth in afterschool programs across the nation. We hope to encourage youth in both rural and urban settings to pursue careers in engineering and technology.

If your program is interested in adopting any of the TechXcite: Discover Engineering learning modules, please contact us at techxcite@duke.edu.

Online Support

The TechXcite Web site (techxcite.pratt.duke.edu) contains additional material to help you implement this module. There are videos to guide you through facilitating the activities with students. You can download copies of the Instructor's Guide and Youth Handouts. You'll also find a list of sources for any materials you'll need. Finally, there are links to additional resources.

E-Mail and Phone Support

If you have questions about any of the material in this curriculum, please do not hesitate to ask. The Duke team is available to support you if you have questions about implementing the modules. Please contact our staff at techxcite@duke.edu. You can also call us anytime by calling the phone number listed on the Contact Us page on our website - <http://techxcite.pratt.duke.edu/contact/index.php>.

Using this guide

The first portion of this handbook is the Instructor's Guide for all of the activities in the module. It includes this introductory section and also the Instructor's Guide for each activity. This introduction contains general information about the TechXcite curriculum, what to expect in each activity's Instructor's guide and background on tools you will be using.

The Instructor's Guide for each activity follows the same format. Below is what you can expect to find in each section. At the beginning, you will find basic information about the activity. This includes:

- Time Required
- Materials
- Group Size – This is the suggested number of students per group.
- Youth Handouts – These will need to be copied.
- Instructor Preparation – This describes what you need to do before the activity and approximately how much time it will take you.
- Learning Objectives
- Vocabulary

Introduction, Procedure and Activity Closure

Three sections form the body of the activity: Introduction, Procedure and Activity Closure. The Introduction and Activity Closure sections are scripted. You may read these sections verbatim to students. Instructions that are not to be read to students, as well as answers to questions, are in brackets/italics. The Procedure section is not scripted. It contains step-by-step instructions for facilitating the activity with a group of students.

Cleanup

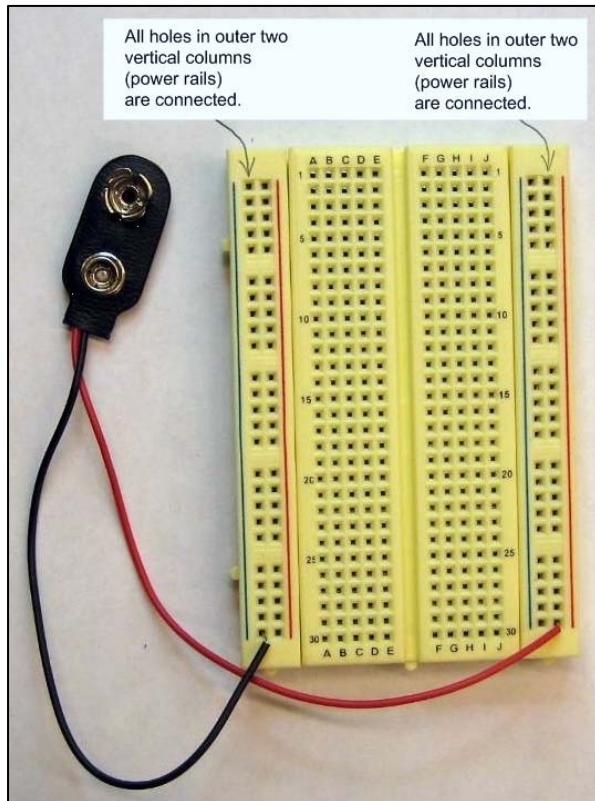
This section appears in activities in which cleaning up in a particular way will help reassemble the kit or prepare for the next activity. Following these instructions will keep the kit in proper order.

Assessment

This section tells you how to assess whether or not students understood the material presented to them in the activity. These assessments are generally based on students' answers to questions asked during the Activity Closure section.

Tools Used in the Module – Electrical Breadboard

Instructions for using the electrical breadboard for creating and testing a circuit are provided in the Youth Handout for Activity 2 and are reproduced below.



All 25 holes in a column of a power rail are connected together inside of the breadboard. There are two power rails on the left side and two power rails on the right side. We will use one power rail on the left and one on the right.

We will make the blue power rail negative and the red power rail positive.

Note: On some breadboards, the red and blue power rails may be the reverse of what you see in this picture. Look closely at your breadboard to see where your red and blue rails are located.

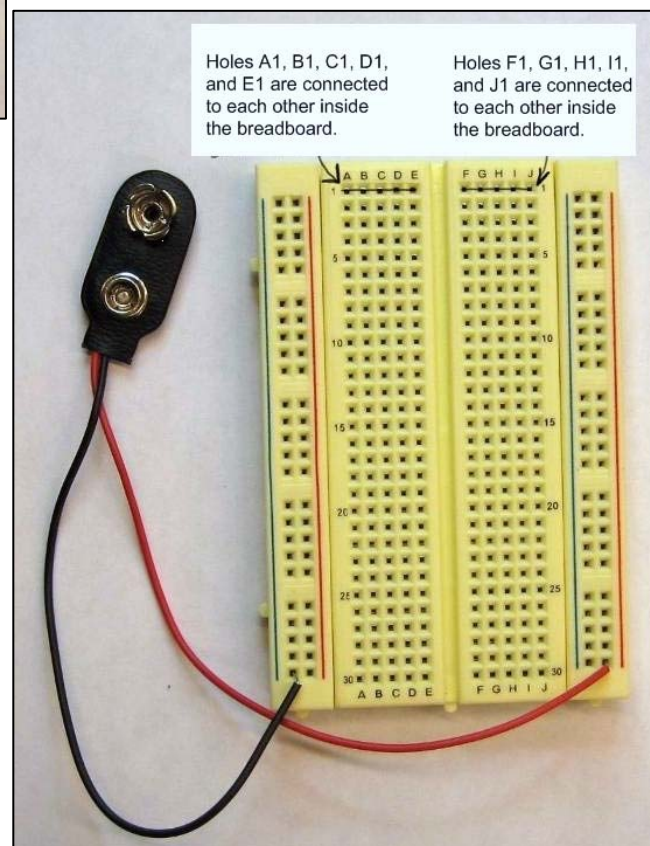
All five holes in one row on one side of the center are connected together inside the breadboard. The five holes on one side of the center are NOT connected to the five holes on the other side.

Examples:

A1 is connected to D1.

A1 is NOT connected to A2.

A1 is NOT connected to F1.



Activity 1: Electric Door Trigger

Time Required: 45 minutes

Materials List

Group Size: 2-3

Each group needs:

- Two long wires (about 3' each)
- One short wire (about 6")
- One AA battery
- One lamp holder
- One lamp
- Small sheet of aluminum foil
- An object that will trigger the alarm when breached (such as a door, cabinet, box or other container; the activity script refers to the use of a door. If you choose something else, make the necessary adjustments to the instructions when facilitating the activity with students.)

To share between groups:

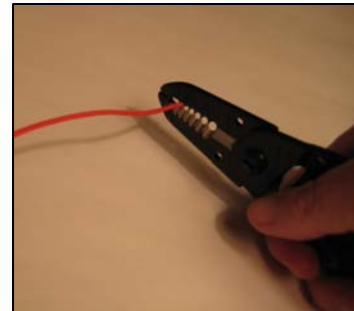
- Clear adhesive tape or electrical tape
- Wire strippers

Youth Handouts (1 per group)

- "Electric Door Trigger"

Instructor Preparation (10-20 minutes)

- Tear off strips of aluminum foil (one 4-inch strip for each group).
- If the wires have not been cut and stripped already, cut two long pieces of wire (about 3') and two short pieces of wire (about 6") per group. Use the wire stripper to remove the insulation from the last 1/2" of wire ends (see picture). You could show students how to do this during the activity if there is extra time.
- Select an object such as a door, cabinet, box or other container that can be rigged with an alarm.



Learning Objectives

After this activity, students should be able to:

- Make a circuit that lights a bulb using a wire and a battery.
- Explain why aluminum foil conducts electricity and demonstrate by building a circuit using an aluminum foil switch.

Vocabulary

Word	Definition
Battery	Source of electrical energy.
Circuit diagram	A plan that electrical engineers use to represent how components are connected together.
Lamp	A device that converts electricity into light.
Short Circuit	A direct connection between the positive and negative battery terminals (to be avoided!).
Switch	A device that turns electricity on or off.
Terminal	Positive or negative end of a device.
Wire	A conductor that carries electric current.

Introduction

Engineers use math and science as tools to design devices to solve problems. Throughout this project, you will be solving problems the same way a real engineer would. Your task will be to design an alarm system that will alert you to an intruder. Such a security system requires a sensor that will detect an intruder, a transmitter to send the signal, and a receiver to trigger a warning sound. Today we will build a trigger that will activate an alarm. In later activities, we will build both a wired and wireless receiver and transmitter to alert you via an LED (light-emitting diode) light. At the end of the project, you will record the sound that the alarm will make to warn the intruder.

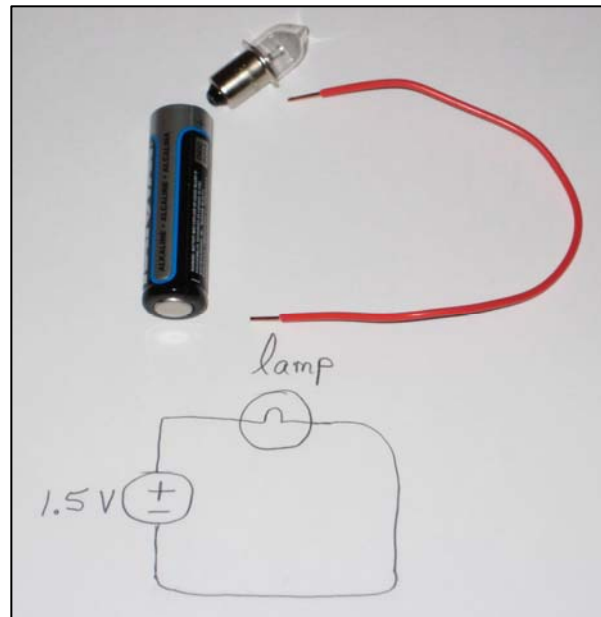
We will start by building the trigger circuit. The simplest electric circuit is a lamp circuit, something we use in our homes every day. You use a switch to turn a lamp on and off. We are going to build a lamp circuit and then make a simple switch out of aluminum foil to turn the lamp on when a door or box is opened.

Procedure

1. Place students in groups of two or three.
2. This activity has three parts. It will be best for students if you hand out only the materials necessary for each part.

Part A: Basic Lamp Circuit

3. Give each group a short wire, lamp and battery. They do not need the handouts yet. This portion of the activity could begin casually as students are coming into the classroom.
4. Ask students, "Can you light the lamp using this wire and battery?" Give them a few minutes to try to do this. If necessary, you can demonstrate, using the picture here as your guide.



- Distribute handouts.
- Ask students to look at their AA batteries closely. Tell them that the AA battery is a source of electrical energy. The ends of a battery are called terminals. All batteries have a positive terminal and a negative terminal. The positive terminal is marked with a + sign and has a small, round, metal tip. The negative terminal has a flat metal surface. Ask if they can see the + and - signs on the battery. Make sure everyone is able to find them.
- Tell students that they should never connect the positive and negative ends of a battery to each other directly. This will cause a **short circuit**, which will drain the battery quickly.
- Ask students to inspect their lamps closely. The lamp converts electricity into light. It has two terminals—the metal tip on the bottom of the lamp holder is one terminal, and the lamp holder is the other (see arrows in picture). When the lamp's two terminals are connected to the positive and negative battery terminals, electricity flows in one and out the other.

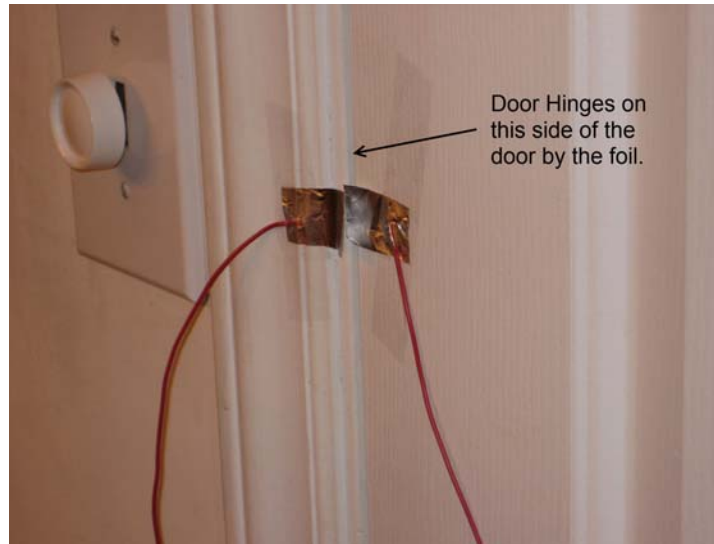


Part B: Aluminum Foil Switch

- Hand out the two long wires and a small piece of aluminum foil to each group.
- Ask students to follow the instructions in Part B to build a switch using the foil.
- Walk around and help students as they work through the activity. If students are not able to make their lamps light up, help them figure out why. Make sure the bottom terminal of the lamp is touching the battery.
- If there is time, let students incorporate a second battery into their circuit. They must connect the positive terminal of one battery to the negative terminal of the second battery. This will make the light twice as bright.

Part C: Engineering Design Challenge — Door Trigger Switch

- Once they have built the circuit with an aluminum foil switch, tell students it is time for them to design their trigger switches. Tell them that as engineers, they must complete the engineering design challenge on the last page of their handout. Assign each pair or group a door, cabinet or box. Encourage them to be creative.
- Walk around and help students as they work through the activity. If students are not able to make their lamps light up, help them figure out why. An example is shown below for your reference.



15. If a group asks to use more aluminum foil, ask them to explain their design to you. You should provide students with extra foil only if they describe a design that requires the extra foil. Encourage their creativity by telling them you're excited to see what they have in mind.
16. If groups finish early, ask them to answer the question on the last page of the handout.
17. At the end of the activity, collect any reusable components (wire, batteries, lamps, lamp holders, unused aluminum foil, etc.).
18. Once most of the groups are finished building their door triggers, bring the class back together to discuss the experience.

Activity Closure

[At the end of every engineering design challenge, ask students the following questions to prompt them to think about which design modifications worked well and which didn't. Their responses will vary.]

1. Which designs worked best and why?
2. Which designs didn't work so well and why?
3. What would you do to improve your designs?

[Below are some questions that are specific to this activity.]

Would any of you like to explain how your door trigger switch works?

[Encourage a few of them to show their switches to the group.]

How might you improve your door trigger switch?

[Let them think about it, and wait for one or two answers. Possible responses: Make it stronger. If they no one mentions strength, you could ask if anyone thinks the trigger would work 100 times or 1,000 times or ask if it would ever break. Another way they might think to improve the trigger would be to make it less visible to an intruder. Or they

might say they would use better materials. In this case, ask “What materials would be better and why?” They should recognize that any materials that connect the circuit must be able to conduct electricity.]

Describe how the lamp circuit works.

[They should acknowledge that electrical energy from the battery flows through the wire, and the bulb converts the electricity into light.]

How does a switch work?

[They should be able to explain that a switch turns the light on or off depending on whether the two pieces of aluminum foil are touching each other.]

Assessment

Assess students' comprehension based on their description in Activity Closure of how the lamp circuit works. If they have understood the material, they should respond that a lamp converts electricity into light. You might ask them to solidify the concept in writing or through a diagram.

Activity 2: Wired Communication

Time Required: 45 minutes

Materials List

Group Size: 2-3

Each group needs:

- Two long wires (about 3', from Activity 1)
- Transmitter Bag
 - Encoder chip with gold dot (R-8PE Encoder integrated circuit)
 - 2 switches
 - 2 resistors (100 k Ω - brown black yellow)
 - 4 jumper wires (2")
 - Battery pack for three AA batteries
 - Breadboard
- Receiver Bag
 - Decoder chip with silver dot (R-8PD Decoder integrated circuit)
 - 2 LEDs
 - 3 jumper wires (2")
 - Battery pack for three AA batteries
 - Breadboard
- 2 long wires (about 3' each)
- 6 AA batteries

To share between groups:

- Tape measure

Youth Handouts (1 per group)

- "Wired Communication"

Instructor Preparation (10 minutes)

- Organize the materials by laying out the transmitter and receiver bags, long wires, batteries and tape measure on a table.
- Check each transmitter bag to make sure it contains an encoder chip with a gold dot.
- Check each receiver bag to make sure it contains a decoder chip with a silver dot.



Note: The encoder and decoder chips look nearly identical, but the encoder chip has a gold dot and the decoder chip has a silver dot.

Learning Objectives

After this activity, students should be able to:

- Explain the purpose of the encoder and decoder chips in communication.
- Explain wired communication and its advantages and limitations.

Vocabulary

Word	Definition
Breadboard (prototyping board)	A device used to build and test circuits.
Decoder	A device that receives a signal and recovers the message that was sent.
Encoder	A device that converts a message into a signal suitable to transmit.

Introduction

Last time we met, you built a trigger circuit for an alarm system. The circuit turned on a light bulb to alert you to an intruder. Today we're going to figure out how to transmit that information to a remote location. We will explore how this can be accomplished using wires.

Can you think of examples of systems that transmit information using wires?

[Allow students some time to think about this and provide some answers.]

Wired communication systems are very common. They are used in applications such as telephones, Internet connections and cable televisions. We will be building a simple wired transmitter and receiver that will allow us to control lights on the receiver by using switches on the transmitter. As you know from last time, these switches can be as simple as two pieces of aluminum foil.

Procedure

1. Place students in groups of two or three.
2. Give students these instructions:
 - a. These kits contain many small parts. Be careful not to lose any.
 - b. Work with your partners while not disturbing other groups.
 - c. Be careful not to disturb the components of other groups.
 - d. Do not knock another group's table.
 - e. Do not touch battery leads together.
3. Distribute handouts and ask students to read over the descriptions of the parts and their uses.
4. Distribute all electronic components except the battery pack (give students the battery pack after they have completed their transmitter and receivers).
5. Tell students to begin building their circuits, following the instructions on the handout. Walk around and help students as they work through the activity. Help students check to make sure their circuits are built correctly. If the transmitter/receiver pair doesn't appear to work correctly, ask students to disconnect the battery pack from the breadboard and go through the troubleshooting steps in the handout.

6. Bring the class back together once most of students have completed their circuits.

Activity Closure

What was the hardest part of putting the circuit together and why?

[Give students time to answer.]

You now have a transmitter and receiver that are connected by two wires. Imagine that at home, there is a similar transmitter in the kitchen that is connected by long wires to a receiver with two LEDs in your bedroom. You could use the switches in the kitchen to turn the two LEDs in the bedroom on and off. Imagine that someone in the kitchen wanted to send you a message in the bedroom using the system. You could develop a code for communicating. How many unique messages would it be possible to send between the receiver and transmitter? Describe how this system might work.

[There are a number of correct answers. For example, there are four combinations of the two LEDs (on-on, off-off, on-off, off-on). Students may also realize that they can convey more than four different messages by turning one or both lights on and off, similar to Morse code. In this manner, they could transmit any number of messages.]

Give me some examples of what messages you might transmit using this kind of system.

[Give several students a chance to answer.]

Next time, you will modify your transmitter and receiver to send the signal without wires.

Cleanup

1. At the end of the activity, ask students to keep the circuits assembled.
2. Ask students to disconnect the batteries and have someone collect them. The batteries go back in the boxes to keep the contacts from touching metal (this will prevent a short circuit that could cause the batteries to lose their energy).
3. Ask students to disconnect the transmitter from the receiver and put the two circuits in the two bags the components came in. These will be used in the next activity.
4. Collect the circuits from students.

Assessment

You can determine whether students understood the material by evaluating their examples of the types of messages they might transmit. Make sure they have chosen messages that can be conducted from one fixed location to another, rather than from a fixed location to a cell phone or something else that is mobile. (They will be doing that in the next activity). When asked, students should also be able to explain that the purpose of the encoder and decoder chips is to allow multiple messages (two LEDs on or off) to be sent over two wires.

Activity 3: RF Wireless Communication

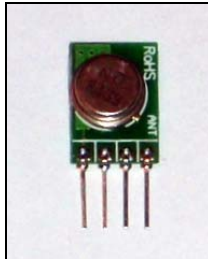
Time Required: 45 minutes

Materials List

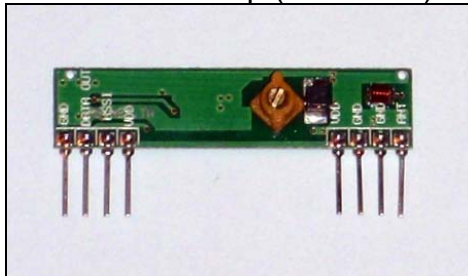
Group Size: 2-3

Each group needs:

- Working transmitter and receiver circuits from Activity 2
- 1 RF transmitter chip (TWS-434A)



- 1 RF receiver chip (RWS-434)



- Jumper wires (2")

To share between groups:

- Tape measure

Youth Handouts

- "Wireless Communication"

Instructor Preparation (10 minutes)

- Lay out the transmitter and receiver circuits students built in Activity 2.

Learning Objectives

After this activity, students should be able to:

- Explain that a radio frequency (RF) link can replace a wired link.
- Explain that an antenna extends the range of a radio frequency (RF) link.
- Discuss advantages and disadvantages of wireless versus wired communication systems.

Vocabulary

Word	Definition
Antenna	A device used to improve RF communication by radiating or capturing radio waves.
RF (radio frequency)	A type of invisible light often used to transmit information wirelessly.

Introduction

Last time we met, you built a wired communication system using a transmitter circuit and receiver circuit that were connected using two wires. This communication system allowed you to turn two LEDs on and off independently. Today we are going to make a wireless connection between the transmitter and receiver.

What devices can you think of that use radio waves to transmit information?

[Radios might be the most common example they provide. Other wireless systems that use radio waves include systems for laptops, Bluetooth, keyless car entry, cell phones and radio-controlled (RC) cars.]

You use many kinds of devices that transmit wireless signals using radio waves. Radio waves are known as radio frequencies or RF. Before we begin building RF wireless transmitters and receivers, let's talk briefly about a radio that would be in a car.

Where is the transmitter for an FM radio station?

[The transmitter is at the radio station.]

How many radios can receive the RF signal from the radio station at the same time?

[There is no limit to the number of radios that can receive the signal at one time.]

What is your favorite radio station?

[Many of them will name a number on the dial. Explain this number is the frequency of the radio station in MHz (megahertz). For example, the station 106.1 is 106.1 MHz.]

What would happen if there were two radio stations near each other that transmitted at 106.1 MHz?

[There would be interference, and the radios tuned to this frequency would pick up both stations at the same time.]

Now let's begin converting our wired communication system into a wireless system. Once it is wireless, we can monitor our trigger alarm system using the LEDs without wires.

Procedure

1. Place students back in the same groups of two or three from Activity 2.
2. Give students these instructions:
 - a. These kits contain many small parts. Be careful not to lose any.
 - b. Work with your partners while not disturbing other groups.
 - c. Be careful not to disturb the components of other groups.
 - d. Do not knock another group's table.
 - e. Do not touch battery leads together.

3. Distribute handouts and electronic components.
4. Ask students to building their circuits, following instructions on the handout. Walk around and help students as they modify first the receiver circuit and then the transmitter circuit. Help students check to make sure their circuits are built correctly. If the transmitter/receiver pair doesn't appear to work correctly, ask students to disconnect the battery pack from the breadboard and help them follow the troubleshooting steps in the handout.
5. Make sure all students have a chance to test their receivers and transmitters. It is important for the class to use only one transmitter at a time. Once students begin finishing the transmitter circuits, have one group at a time test its transmitter circuit. If more than one transmitter circuit is used at a time, the signals will cross. Since all of the receivers will work with each transmitter, the entire class can test their receivers while one group is testing its transmitter.
6. Bring the class back together once most of students have completed their circuits.

Activity Closure

What are some things you can do with your wireless transmitter and receiver circuits that you couldn't do with your wired circuits?"

[Possible answers: The circuits transmit over a longer distance; you don't have to navigate physical obstacles that would block installation of wires between the transmitter and receiver; with the wireless system, you can move the receiver around without tripping anyone on the wires.]

How far was the wireless signal able to transmit? What was the effect of the antenna?

[Give students time to answer based on their tests. Without the antenna, the signal could be transmitted only the distance across the classroom. With the antenna, the signal could travel the distance down a hallway.]

What might be some advantages of the wired system you built compared to the wireless one you built today?"

[Possible answers: the wired system is less expensive and more reliable; the wired system is more secure because other transmitters can't receive the signal.]

Cleanup

1. At the end of the activity, ask students to keep the circuits assembled.
2. Ask students to disconnect the batteries and have someone collect them. The batteries go back in the boxes to keep the contacts from touching metal (this will prevent a short circuit that could cause the batteries to lose their energy).
3. Ask students to put the two circuits in the two bags their components came in. These will be used in the next activity.
4. Collect the circuits from students.

Assessment

Ask students to describe how the circuits they built today are different from the ones they built last time. They should say that the wires have been replaced with RF (radio frequency) transmitter and receiver chips. The range of these chips can be extended with antennas.

Activity 4: Sounding the Alarm

Time Required: 45 minutes

Materials List

Group Size: 2-3

Each group needs:

- Aluminum foil trigger (from Activity 1)
- RF transmitter circuit on breadboard (from Activity 3)
- RF receiver circuit on breadboard (from Activity 3)
- Sound recording module
- Two 2" jumper wires
- 4 wires with alligator clips

To share between groups:

- Clear adhesive tape
- Wire strippers (for prepping extra wires, if needed)
- Additional aluminum foil
- Additional long wires

Youth Handouts (1 per group)

- "Sounding the Alarm"

Instructor Preparation (25 minutes)

- Check the voice recording modules to make sure they are blank or that they don't contain any inappropriate messages. If one has an inappropriate message, you can erase it by recording a blank message.
- Take out each of the transmitters and receivers built by students in Activity 3.

Learning Objectives

After this activity, students should be able to:

- Explain why they have attached a sound module to their alarm system.
- Explain that the sound-recording module records sound on a chip on the circuit board.
- Define an engineering problem with specifications and constraints.

Vocabulary

Word	Definition
Decoder	A device that receives a signal and recovers the message that was sent.
Encoder	A device that converts a message into a signal suitable to transmit.
Prototype	An original, full-scale and usually working model of a new product or new version of an existing product. Engineers use prototypes to test new devices prior to mass-producing them.
RF (radio frequency)	A type of invisible light often used to transmit information wirelessly.

Introduction

Over the past few sessions, we've built an alarm system you could use in a number of locations. It transmitted information using a radio frequency transmitter and receiver. How far apart were the radio frequency transmitter and receiver able to communicate with each other?

[Prompt them to think about their experiments with the transmitter and receiver during the last session. They will have found that without the antenna wire attached, the signal could be transmitted only the distance across the classroom. With the antenna, the signal could travel about the distance down a hallway.]

When you listen to the radio in a car, where is the receiver and where is the transmitter? How far apart are they?

[In this case, the transmitter is at the radio station and the receiver is in the car, which could be miles away from the station.]

The radio signals in your car are the same types of signals we're using with our transmitter. The difference is that the radio station has a much more powerful transmitter, so your car can receive the signal from much farther away. As you work on your alarm system today, you could imagine that your transmitter has more power so that you could receive the signal farther away. For instance, you could be at school and be able to receive a signal that warned you of an intruder at home.

Today you are going to design an alarm system the way an engineer would. You must appropriately define the problem you are trying to solve and specify any performance requirements your design must have. You will then build a prototype to demonstrate and test your design.

It is OK if there are performance requirements that you identify as necessary for the alarm but that the prototype cannot meet. You need only describe what you would do to meet those requirements. For instance, you might need the alarm trigger to be invisible to the intruder. The aluminum foil on the prototype might be big and easy for an intruder to see, but you could explain that the actual contacts will be much smaller and that the metal will be embedded in part of the door and the floor.

After defining the problem you're trying to solve with an alarm system, you'll use the materials provided to put together a prototype alarm system to demonstrate your solution for the class.

Procedure

1. Demonstrate to students how to use the recording module by recording your voice on one of them. Press and hold down the record button until you hear the beep. Then start speaking. You will have 10 seconds of recording time.
2. Distribute materials and handouts. Instruct students to determine the design problem they will solve and describe it in the space provided on the handout.

Also tell them to decide their design specifications and constraints and describe them in the second box on the handout. *[Examples of aspects they might want to consider: How will the transmitter and receiver be housed? Is the transmitter outside? Will it get wet? Could it be kicked or stepped on? Who might be breaking in? Will this person scare easily? How big should the receiver be? Does it need to be pocket-sized?]*

3. Tell them to begin working, following the instructions on the handout.
4. While they are working on the activity, walk around and make sure that each group has defined a particular problem. Help them be as specific as an engineer would be when outlining the specifications. For example:
 - a. If students specify that the receiver must be shockproof, ask them to be more specific. For example, they may intend that no electric shock be produced if the receiver is dropped or if something is dropped on it.
 - b. If they specify that the receiver must fit in a pocket, ask them to provide dimensions of such a pocket.
5. Many students will finish recording relatively quickly. Ensure that students use two different triggers to connect the sound card. One should be for the transmitter and one should be for the sound alarm. They could also have two alarms, one for each switch on the transmitter. The first might be a silent alarm. Students can use these components to design the system.
6. When everyone's alarm systems are ready, work with groups separately so that only one transmitter is being used at a time.
7. Bring the class back together once most of students have completed their projects.

Activity Closure

[At the end of every engineering design challenge, ask students the following questions to prompt them to think about which design modifications worked well and which didn't. Their responses will vary.]

1. Which designs worked best and why?
2. Which designs didn't work so well and why?
3. What would you do to improve your designs?

[Below are some questions that are specific to this activity.]

Let's take turns describing your design problems and solutions.

[Give different groups a chance to share.]

What did you learn from building the prototype that you would incorporate into the final design? What other ideas might you incorporate into a final design to meet your specifications?

[Encourage them to be specific.]

Assessment

Evaluate students' design problems. They need to be specific problems but should not lend themselves to a single solution. Also, their designs should meet the specifications they described.