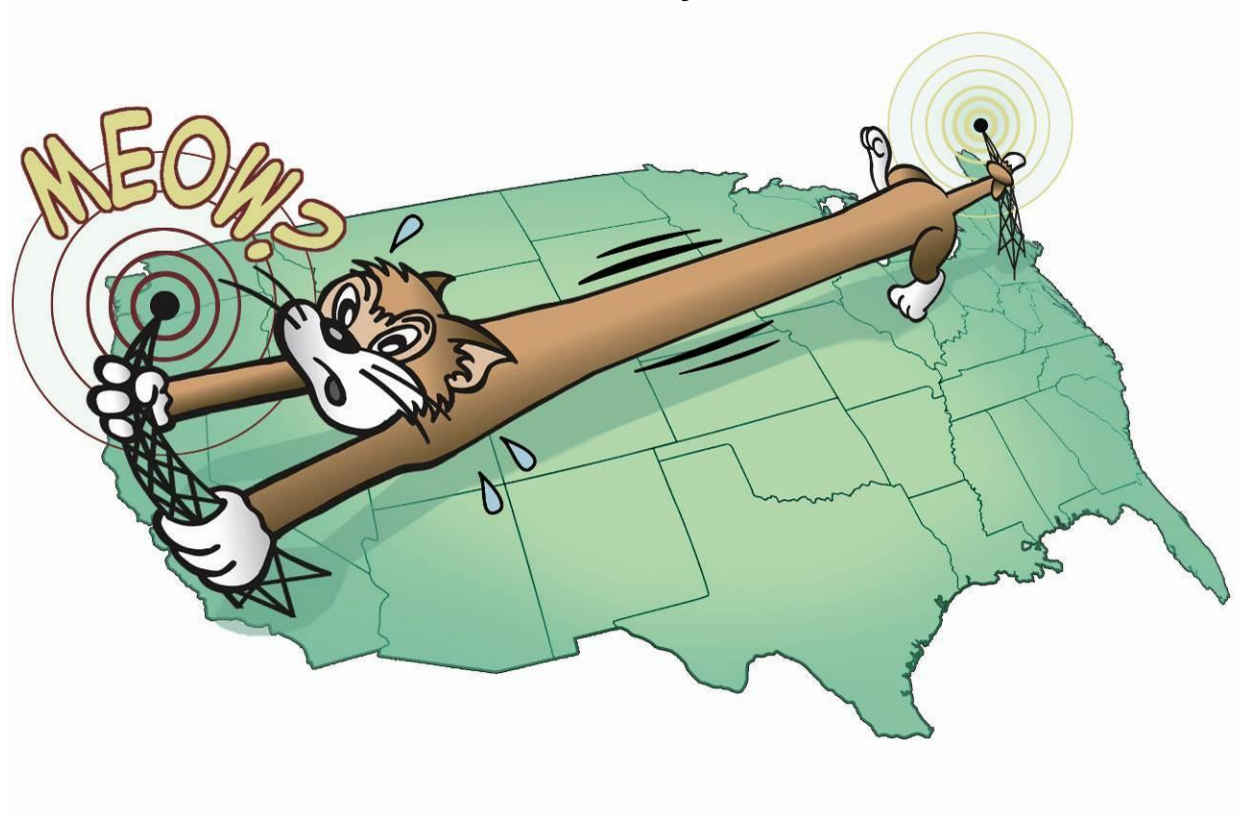


**Wireless Transmission:**

# **Your TV Remote**

**TechXcite: Discover Engineering**

**Pratt School of Engineering  
Duke University and 4-H**



*"The wireless telegraph is very easy to understand, really. Imagine a very large cat with its tail in New York, and while yanking its tail the head is meowing in Los Angeles, except there is no cat."*

Albert Einstein

## Table of Contents

Table of Contents.....	2
Module Overview.....	3
TechXcite Program.....	4
Online Support.....	4
E-mail and Phone Support.....	4
Using this Guide.....	5
Tools Used in the Module.....	6
Activity 1: Sound on a Breadboard.....	8
Activity 2: Amplifying Sound.....	13
Activity 3: IR Music Receiver.....	17
Activity 4: IR Music Transmitter.....	20

### Module Overview

This TechXcite: Discover Engineering module introduces youth to basic sound signals and how they can be transmitted using light. Youth will build a simple circuit using a breadboard and build a circuit that amplifies sound. They will then build a wireless music transmitter and receiver.

**Activity 1:** Youth connect a music player directly to a small speaker.

**Activity 2:** Youth build a circuit to amplify the sound from the music player.

**Activity 3:** Youth build an infrared receiver that turns a light signal into a sound signal and test it using a TV remote control.

**Activity 4:** Finally, youth put the whole project together by building a circuit that converts a sound signal into light. This signal is then picked up by the receiver built in Activity 3 so that students can observe their music transmitted wirelessly.

**Authors:** Gary A. Ybarra, Ph.D., and Paul A. Klenk, Ph.D.

**Editor:** Carla Burgess

**Acknowledgments:** We would like to thank Dr. Martin Brooke, Heather Wake, Xin Cai and Arnak Aleksanyan from Duke University's Department of Electrical and Computer Engineering for contributing to the development of this module. These activities were adapted from the Chaney Electronics, 44 in 1 Deluxe Communications and Opto-Electronics Lab Manual (1997).

**Copyright:** Engineering K-Ph.D. Program, Pratt School of Engineering, Duke University and 4-H.

## ***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 *Techtronics* afterschool engineering program at Rogers-Herr Middle School and Lowes Grove Middle School in Durham, N.C. The *TechXcite: Discover Engineering* curriculum is built on the previous work by creating in-depth engineering learning modules for use in afterschool programs nationwide. The result is 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](mailto:techxcite@duke.edu).

## ***Online Support***

The TechXcite Web site ([techxcite.pratt.duke.edu](http://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](mailto: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 module. 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 includes 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.

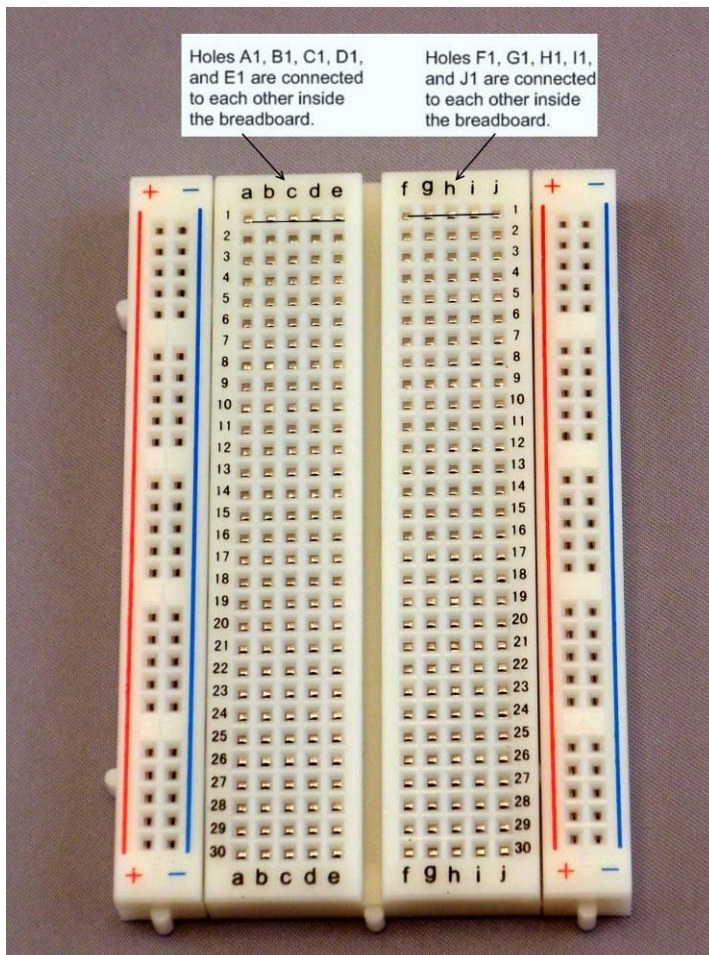
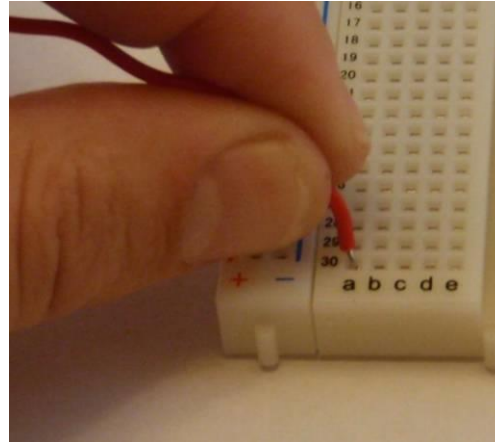
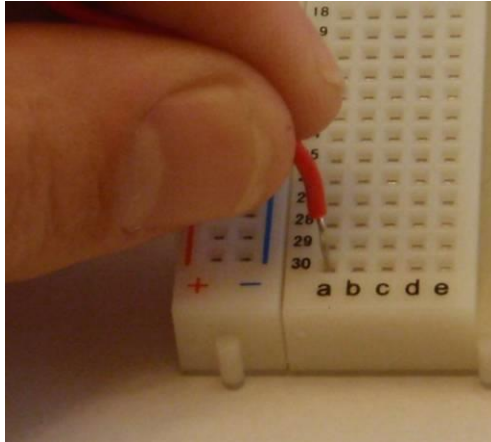
### Assessment

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 1 and are reproduced below. Wires can be inserted into the holes to connect them to the circuit. Insert wires as shown below.



### Breadboard Inner Holes

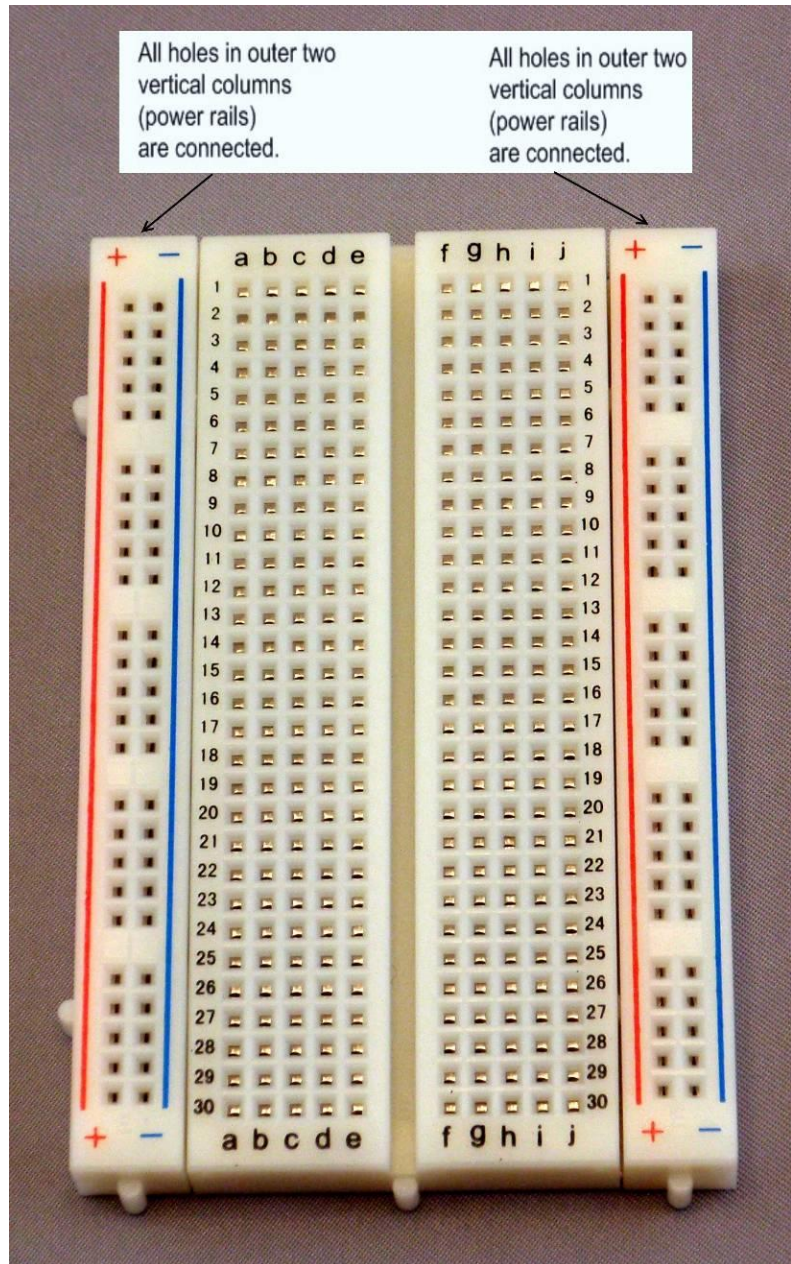
All five holes in a single row are connected inside the breadboard. Opposite halves of the breadboard are not connected.

Examples:

- **A1** is connected to **D1**.
- **A1** is NOT connected to **A2**.
- **E1** is NOT connected to **F1**.

### Breadboard Outer Holes (Power Rails)

All 25 holes in a column of a power rail are connected together inside the breadboard. We will use the blue power rail on the left and the red power rail on the right. We will make the blue power rail negative and the red power rail positive.



### Activity 1: Sound on a Breadboard

**Time Required: 45 minutes**

**Group Size: 2**

#### Materials List

##### Each pair needs:

- Speaker from a TechXcite Music Receiver Bag
- Wire with headphone plug from TechXcite Music Transmitter Bag
- Breadboard
- Music player with headphone output —This can be any music player that you can plug headphones into. Encourage students to bring in their iPod, mp3 player or phone with standard headphone output. If you have access to a computer, you may use this for a group. If necessary, use the FM radios provided in the kit to make sure each pair has a player.

##### Youth Handouts:

- "Sound on a Breadboard"

#### Instructor Preparation: (10 minutes)

- Before the program, encourage students to bring in their own music players (see Materials List). They'll have more fun if they get to play their own music during these activities.
- Find and remove the speakers and wires with headphone plugs from the plastic bags in your kits. The speakers are in the Music Receiver Bags and the wires with headphone plugs are either in the Music Transmitter Bags or loose in the kits.

#### Learning Objectives

After this activity, participants should be able to:

- Build a simple circuit using a breadboard.
- Explain that engineers use breadboards to test circuit designs, which allows them to change circuits quickly.
- Explain that music players send sound to headphones or a speaker as an electrical signal.
- Explain that a speaker changes an electrical signal into sound.

#### Vocabulary

Word	Definition
Breadboard	A device used to build and test circuits.
Engineer	Someone who uses math and science as tools to create technology to solve problems that help people or make their lives more fun.



### Introduction

During the next few activities, we are going to explore how your music players transmit sound. On a portable music player such as an iPod or other mp3 player, how do you hear the sound? [*Headphones*]

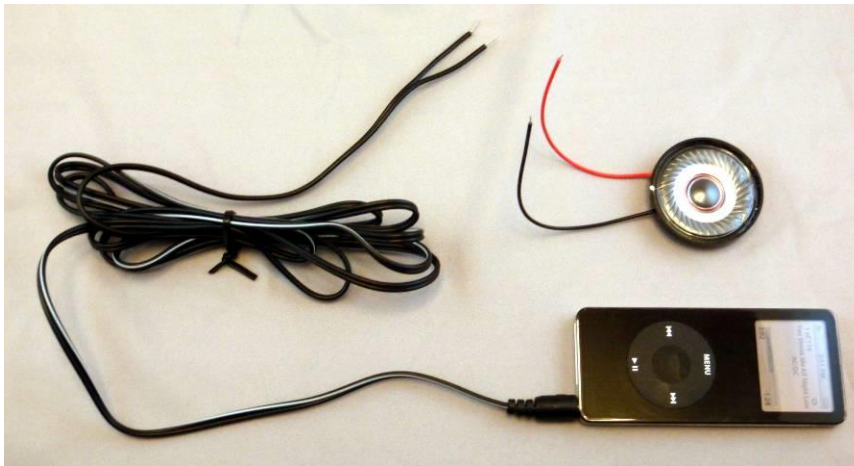
How does the music player transmit sound to headphones? [*Electricity*]

There are mini speakers inside the headphones that convert the electricity into sound. Today we are going to see what happens when we connect that electricity to slightly bigger speakers.

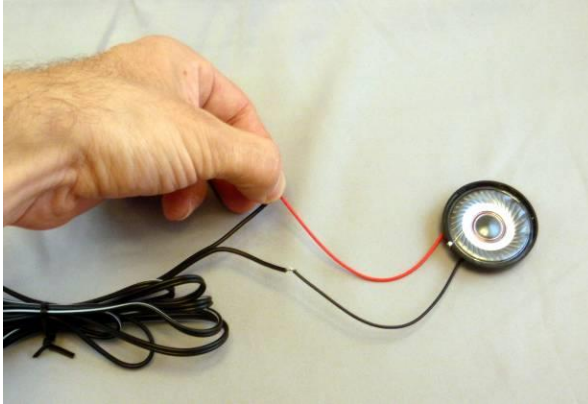
### Procedure

#### Part I: Playing Music Through a Speaker

1. Place students in pairs.
2. Give a handout to each pair of students.
3. Distribute the speakers and wires with attached headphone plugs. Give music players to any students who did not bring their own.

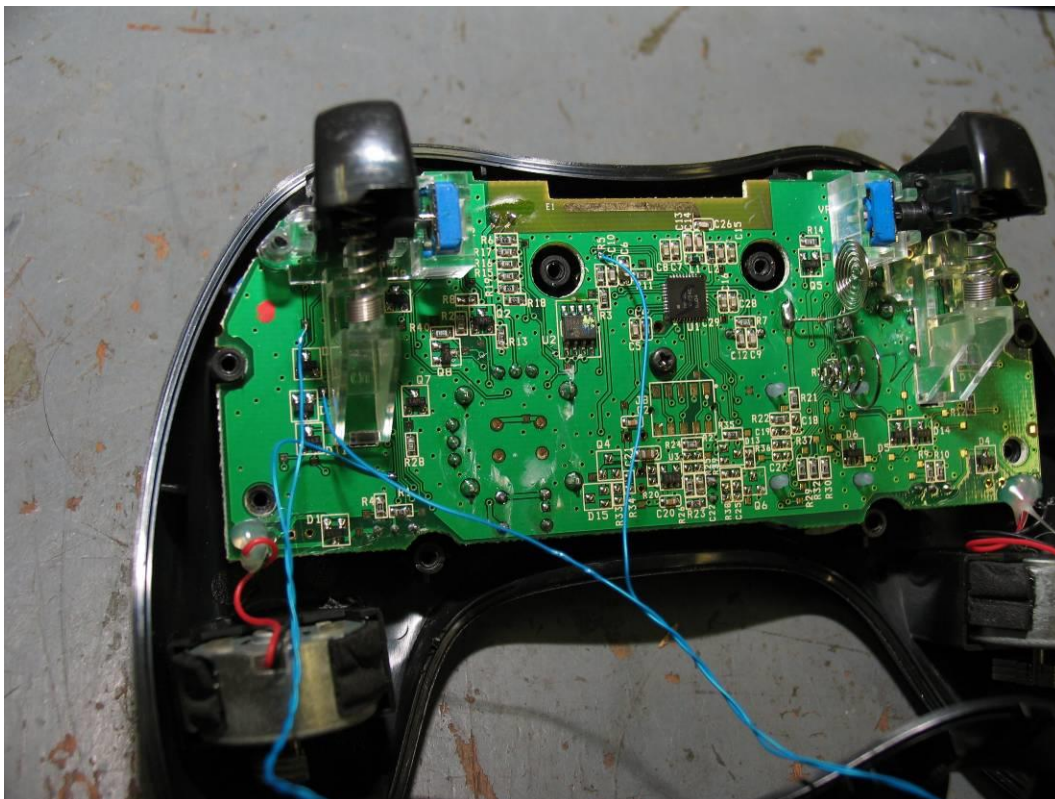


4. Instruct students to be careful with the speakers, as the wires pull off easily.
5. Ask students to see if they can make the music play through the speaker. Allow them to spend some time trying to figure this out on their own. If they have trouble, you may demonstrate as shown on the next page.

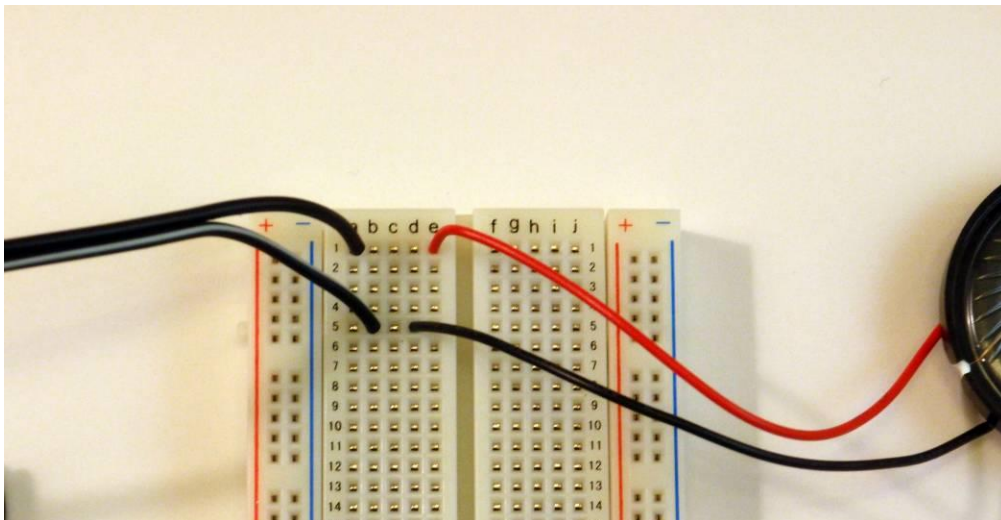


### Part II: Using a Breadboard

6. Give each group a breadboard. The following information is also on the handout, but it is useful to demonstrate Steps 8-13 for students.
7. Explain that electrical engineers use breadboards to test their ideas for circuits before turning them into final versions for things like a phone, computer or music player. Show the picture below or, if you have one, any circuit board from an electrical device. Ask students to raise their hands if they have seen one of these before. Give students a chance to name some devices in which they have seen circuit boards. Explain that on printed circuit boards, electrical wires are permanently connected together. It takes a special tool to remove a wire and put another one in place. On a breadboard, a wire may be removed and another one inserted easily without special equipment.



8. Show students how to insert and remove a wire from a hole in the breadboard.
9. Explain that by using these holes, you can connect a circuit together without having to hold it with your hands. Some of the holes are connected together by wires underneath the breadboard.
10. Show students, using one of the speaker music player circuits, that one of the connections may be made by inserting the two wires you want to connect—one from the speaker and one from the wire connected to the headphone output of the music player—into holes **A1** and **E1**.
11. Explain that this does not mean that all holes in the board are electrically connected together. The board can make many individual connections. In this case, holes **A1** through **E1** are electrically connected together. Have students try this out.
12. Tell students to begin working. They should insert the other two connections in a row to connect them together. Make sure they know the following: Each horizontal row is connected in sets of five. **A1** through **E1** are connected to each other. **F1** through **J1** are connected to each other. There is no connection across the centerline of the board. **E1** is not connected to **F1**. If they're not sure how to make the other connection, have them try **B5** and **D5** since they are in the same row.



13. Next, explain that the vertical sets of holes with red and blue stripes are called power rails. These are connected vertically all the way up and down the board. They are not connected across the board. In other words, the left red power rail is not connected to the right red power rail. These power rails will be used to connect the battery to the circuit in later activities. Ask students, “Will we connect negative or positive to the red rail?” *[Positive is connected to red, while negative is connected to blue.]* If students have had experience with electricity before, they will likely associate red with positive.

14. The activity asks students to explore which holes may be used to connect the music player.
15. Walk around and help students as they work through the activity. If the wires are hard to get into the breadboards, tell them to try bending the short metal end of the wire straight and then carefully inserting it straight into the holes.
16. At the end of the activity, collect the speakers, wires with headphone connections, jumper wires and any music players loaned to students.

### Activity Closure

What did you learn today? *[Give students some time to answer and share their experiences.]*

What is a breadboard used for? *[Give students some time to brainstorm a few answers. [Electrical engineers use breadboards to build and test circuits.]*

Which holes on the breadboard did you use to connect your music player to your speaker? *[Use this time to emphasize which holes are connected on the breadboard.]*

We will be using breadboards more during the rest of this module. Would you like to make the sound coming from the speaker louder?

In the next few activities we will first build a circuit with an amplifier to make the sound louder. Then, we will rebuild the circuit so we can transmit sound wirelessly using light over a short distance from a transmitter to a receiver.

### Assessment

The question “What is a breadboard used for?” in the Activity Closure section is the assessment for this activity. You can also assess whether students learned how to use the breadboards by noticing how much they remember when you start the next activity.



### Activity 2: Amplifying Sound

**Time Required:** 60 minutes

**Group Size:** 2

#### Materials List

##### Each pair needs:

- One TechXcite Music Receiver Bag containing:
  - 3 capacitors (10  $\mu$ F electrolytic)
  - 1 amplifier chip (LM 386 Integrated Circuit)
  - 1 resistor (red, yellow, orange - 24 k $\Omega$ )
  - Speaker
  - Battery snap
  - 1 phototransistor (to be used in Activity 3)
- 9V battery
- Wire with headphone plug from TechXcite Music Transmitter Bag
- Breadboard
- Music player with headphone output —This can be any music player that you can plug headphones into. Encourage students to bring in their iPod, mp3 player or phone with standard headphone output. If you have access to a computer, you may use this for a group. If necessary, use the FM radios provided in the kit to make sure each pair has a player.

##### To share with the class:

- 2" jumper wires (These are provided in a separate bag when the kit is new, but may be put back in the TechXcite Music Receiver Bag when students are done with the module. You should find a bag of them, but if you are not the first to use the kit, there may be some in the TechXcite Music Receiver Bag.)

##### Youth Handouts:

- "Amplifying Sound"

#### Instructor Preparation: (None)

#### Learning Objectives

After this activity, students should be able to:

- Identify the amplifier chip and explain that it increases the electrical signal to make the sound from the speaker louder.
- Identify the polarity of an electrolytic capacitor.

#### Vocabulary

Word	Definition
Capacitor	A device that stores energy and stabilizes voltage.
Circuit diagram	A plan that electrical engineers use to show how components are connected together.
Resistor	A device that converts electrical energy into heat.
Speaker	A device that turns electricity into sound.
Troubleshooting	The process that an engineer uses when trying to determine why something he/she has built is not working.



### Introduction

In the first activity, you connected a speaker directly to a music player to hear the music. But even at the highest volume, the music was hard to hear. What do you think we need to do to make that sound louder? *[Give students a chance to think about this and answer.]*

Today we are going to make the music louder by using a small circuit called an **amplifier** to increase the electrical signal coming from the music player before it is connected to the speaker. The goal of the circuit is to use this amplifier *[hold up the amplifier chip]* to amplify the electrical signal.

### Procedure

1. Place students in pairs. These can be the same pairs as last time or different pairs.
2. The following rules are helpful when working on projects using small parts. 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 TechXcite Music Transmitter Bags, breadboards, and wires with headphone plugs. Do not give students the battery until they have completed the circuit. This will keep them from connecting it and using the energy in the battery before they need to.
4. Have students reconstruct the circuit they built with the breadboard to make sound play through the speaker. This will be a good review of the previous activity.
5. Give a handout to each pair of students.
6. Ask students which holes are connected. *[Answer: Each horizontal row is connected in sets of five. A1 through A5 are connected to each other. A6 through A10 are connected to each other. There is no connection across the centerline of the board. A5 is not connected to A6. Vertical columns are connected from top to bottom and are called power rails.]*
7. Hold up an amplifier chip for students. Tell them, "Be careful when attaching the amplifier chip to the board. You do not want to bend the pins. Look at the close-up picture of the chip. The chip has 8 pins, as shown in the diagram. Starting at the notch on the top, the pins are numbered counterclockwise. It is important that the chip be oriented with the notch up for this activity."

8. Demonstrate for students where to place the amplifier chip on the breadboard, as described in Step 1 on the handout.
9. Hold up a capacitor for the students. Tell them, "Capacitors store energy. These capacitors have a positive and negative side. That means that you must put the positive and negative sides in the correct holes. The negative side has a stripe down the side. The directions will explain where the negative side with the stripe goes, so pay attention to it."
10. Next, tell students to follow the directions in the handout to build the amplifier circuit. Walk around and help students as they work through the activity.
11. Students must complete the circuit and have you check it before they get a battery. You do not have to catch all mistakes, but looking for a few easy errors can help. Ask the following questions to help them troubleshoot any problems.
  - a. Are there any rows that have only one hole filled out of five? If so, that piece is not connected to anything else, which is a problem.
  - b. Are the battery snap wires correctly connected to the power rails? The red wire should be in the right positive power rail and the black wire should be in the left negative power rail.
  - c. Is the chip oriented correctly with the notch upward?
  - d. Are the capacitors inserted with the positive and negative ends in the correct holes?
  - e. Is the battery dead? Try replacing the battery. You can test it with the multimeter. The voltage should be close to 9V.
  - f. If all else fails, replace the capacitors and amplifier chip, checking the circuit after replacing each of them one-by-one.
  - g. Going through these steps will not ensure that the circuit is perfect, but it will eliminate some initial problems. Give the groups the battery at this point and tell them to test their circuit.
12. If the circuit does not work, disconnect the battery immediately and go through the connections one-by-one with the students to troubleshoot the circuit.
13. Optional: Ask students to tell you what happens with the circuit when you remove the capacitor across pins 1 and 8? [*The sound gets quieter. This is the equivalent of turning the volume down because the amplifier does not amplify as much.*]

### Cleanup

1. Collect the batteries and put them back in the boxes. This will keep the contacts from touching something metal and draining the battery.
2. Ask students to put their completed amplifier circuits with their breadboards back in the plastic bag along with a small piece of paper with their names on it. They will use this circuit in the next activity.

3. Remind the students to put the phototransistor back in the bag also. It was not used in this activity, but they'll use it next time.

### Activity Closure and Assessment

What was your favorite part of putting these circuits together?

How do you think the circuit works? *[Give them a chance to describe how they think the circuit works and then fill in any details for them. The amplifier chip takes the electrical signal from the music player and uses energy from the battery to increase the power of the signal. The amplified signal makes the speaker play louder than it would if the signal came directly from the music player.]*

In the next activity, we will look at ways of sending sound wirelessly using a light signal.

### Activity 3: (Infrared) IR Music Receiver

**Time Required:** 30 minutes

**Group Size:** 2

#### Materials List

##### Each pair needs:

- Amplifier circuit from Activity 2
- 9V Battery
- Phototransistor from TechXcite Music Receiver Bag
- Music player with headphone output —This can be any music player that you can plug headphones into. Encourage students to bring in their iPod, mp3 player or phone with standard headphone output. If you have access to a computer, you may use this for a group. If necessary, use the FM radios provided in the kit to make sure each pair has a player.
- Tape measure

##### To share with the class:

- 2" jumper wires (These are provided in a separate bag when the kit is new, but may be put back in the TechXcite Music Receiver Bag when students are done with the module. You should find a bag of them, but if you are not the first to use the kit, there may be some in the TechXcite Music Receiver Bag.)
- TV Remote(s)

##### Youth Handouts:

- "IR Music Receiver"

#### Instructor Preparation: (5 minutes)

- If you can, borrow a few extra infrared remote controls for TVs, VCRs or other electronic devices. It will be useful to have several when students are testing their circuits.

#### Learning Objectives

After this activity, students should be able to:

- Explain that a phototransistor allows electricity to flow through it based on the amount of light hitting it.
- Explain that infrared light is light that is invisible to the human eye. Other examples are radio waves, ultraviolet light that causes sunburn and X-rays.

#### Vocabulary

Word	Definition
Infrared (IR)	A form of light that the human eye cannot see; invisible light.
Phototransistor	A device that converts light into electricity.

### Introduction

In the first two activities, we took an electrical signal from a music player, turned it into sound and then amplified it. In this activity and the next, we are going to build a wireless music transmitter and receiver. This wireless transmitter uses either visible or infrared (IR) light. Can you think of anything that uses infrared light? [*Possible answers: Many remote controls, TVs, DVD players, some laptops for sending information, the Nintendo Wii, and many other wireless devices that work when they are controlled by a remote.*]

Today we will build the receiver. The circuit will receive an infrared signal. At the end of the day, you will test your circuit to see if it can receive a signal from a TV remote.

### Procedure

1. Place students in pairs.
2. Remind students to be careful with the electrical components in these kits.
3. Distribute materials.
4. Ask students to check their circuits from Activity 2 to make sure they work.
5. Give a handout to each pair of students.
6. Hold up a phototransistor and explain that a phototransistor allows more electricity to flow through it when brighter light hits it. If no light hits the phototransistor, then no electricity flows through it.
7. Next, tell students to follow the directions in the handout to modify their amplifier circuits to receive an infrared (IR) signal. Walk around and help students as they work through the activity. You might suggest that students bend the wires of their phototransistor so that it is pointing along the desk instead of straight up.
8. Students are to test their receivers by pointing a standard infrared TV remote control at the phototransistor. If you have only one or two remotes, make sure that the various student pairs share the remote as they are testing their circuits.

### Activity Closure

Describe the sound that is made when you fired the TV remote at the phototransistor in your IR music receiver circuits. Why do you think it sounds like this? What happens when you press a button on the TV remote and fire it at a TV?

The signal is carried by infrared light, which is invisible to the human eye. The signal is made by turning the invisible infrared light on and off in a regular pattern. The phototransistor senses the light turning on and off and turns the IR energy into electrical energy. A similar receiver in your TV takes the electrical energy and changes the volume or the channel. In this case, the IR receiver uses the electrical energy and amplifies it to drive the speaker to make a sound. We hear the beeping sound produced by that signal.



In the next activity, we will build a transmitter that will transmit music from your music player wirelessly using regular or infrared light.

### Cleanup

1. Collect the batteries and put them back in the boxes. This will keep the contacts from touching something metal and draining the battery.
2. Ask students to put their completed amplifier circuits with their breadboards back in the plastic bag along with a small piece of paper with their names on it. They will use this circuit in the next activity.
3. Remind students to put the phototransistor back in the bag also. It was not used in this activity, but they'll use it next time.

### Assessment

Use the students' answers in Activity Closure to see if they understand how a circuit receives an IR signal from a remote. The important concept here is that the phototransistor converts light energy into electricity. This is also a good time to review the concept of an *amplifier*, which makes the electrical signal stronger by using energy from a battery, and this produces a louder sound out of the speaker.

### Activity 4: IR Music Transmitter

**Time Required: 60 minutes**

**Group Size: 2**

#### Materials List

##### Each pair needs:

- Music Receiver Circuit from Activity 3
- One TechXcite Music Transmitter Bag containing:
  - 5 resistors (brown, black, black - 100  $\Omega$ )
  - Infrared (IR) LED (Light Emitting Diode)
  - Red LED (Light Emitting Diode)
  - Transistor (2N3904)
  - Potentiometer (50 k $\Omega$ )
  - Capacitor (10  $\mu$ F Electrolytic)
  - Wire with headphone plug
  - Battery snap
- 9V battery
- Breadboard
- Music player with headphone output —This can be any music player that you can plug headphones into. Encourage students to bring in their iPod, mp3 player or phone with standard headphone output. If you have access to a computer, you may use this for a group. If necessary, use the FM radios provided in the kit to make sure each pair has a player.

##### To share with the class:

- 2" jumper wires (These are provided in a separate bag when the kit is new, but may be put back in the TechXcite Music Receiver Bag when students are done with the module. You should find a bag of them, but if you are not the first to use the kit, there may be some in the TechXcite Music Receiver Bag.)
- TV Remote(s)

##### Youth Handouts:

- "IR Music Transmitter"

#### Instructor Preparation: (5 minutes)

- If you can, borrow a few extra infrared remote controls for TVs, VCRs or other electronic devices. It will be useful to have several when students are testing their circuits.

#### Learning Objectives

After this activity, students should be able to:

- Explain that light can be used to send a signal.
- Explain that the transmitter circuit takes an electrical signal from the music player and turns it into a light signal.
- Explain that the receiver circuit takes the light signal and converts it to an electrical signal that is then amplified and turned into sound by the speaker.

### Vocabulary

Word	Definition
Light emitting diode	A device that converts electrical energy into light of a single color.
Potentiometer	A variable resistor with three terminals. When the dial is turned the center terminal resistance changes making the volume in radios and TV sets change.
Transistor	An electronic device that amplifies a signal.

### Introduction

In the first two activities, we took an electrical signal from a music player, turned it into sound and then amplified it. Last time, we converted the sound amplifier circuit into an infrared receiver. What did the circuit we built last time do? *[It took an infrared signal from a TV remote control or other type of remote control and turned it into sound.]*

This time, we are going to build a circuit that takes the electrical signal from our music players and changes the brightness of an LED with the sound of the music. The receiver takes this light signal and turns it into sound. You will need your receiver from the last activity to test your circuit.

Have you heard of an LED before? If so, do you know where LEDs are used? *[Wait for students to respond. Examples may include LED brake lights used in cars, hundreds of LEDs are used in traffic lights, and LEDs are used in exit signs at the movies]* This is an LED. *[Hold up an LED.]* LED stands for light emitting diode.

### Procedure

1. Place students in pairs.
2. The following rules are helpful when working on projects using small parts. 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 TechXcite Music Transmitter Bags, breadboards, and wires with headphone plugs. Do not give students the battery until they have completed the circuit and you have had a chance to look at their circuit. This will keep them from connecting it and using the energy in the battery before they actually need to.
4. Give a handout to each pair of students.

5. Hold up the potentiometer and explain that it is a variable resistor. You can change the resistance by turning the knob. There are 3 pins to connect.
6. Hold up the transistor and explain that the transistor is used like the amplifier chip to increase the signal strength. Note that the transistor has 3 pins. It is important that the transistor is inserted correctly so that pins 1, 2 and 3 are in the correct breadboard holes.
7. Next, tell students to follow the directions in the handout to build and test the transmitter. Walk around and help students as they work through the activity.
8. Students must complete the circuit and have you check it before they get a battery. You do not have to catch all the mistakes, but looking for a few easy errors can help. Ask the following questions to help them troubleshoot any problems.
  - a. Are there any rows that have only one hole filled out of five? If so, that piece is not connected to anything else, which is a problem.
  - b. Are the battery snap wires correctly connected to the power rails? The red wire should be in the right positive power rail and the black wire should be in the left negative power rail.
  - c. Is the chip oriented correctly with the notch upward?
  - d. Are the capacitors inserted with the positive and negative ends in the correct breadboard holes?
  - e. Is the battery dead? Try replacing the battery. You can test the battery with the multimeter. The voltage should be near 9V.
  - f. If all else fails, replace the capacitors and amplifier chip, checking the circuit after each of the parts are changed one-by-one.

Going through these steps will not ensure that the circuit is perfect, but it will eliminate some initial problems. Give the groups the battery at this point and tell them to test their circuit.

### Activity Closure

*[After most of the student groups have finished writing their descriptions of what the circuit does, but before they clean up, it is important to discuss their answers to the questions. You can use the script below.]*

In what form does the music come out of your music players? *[The music comes out of the player as an electrical signal. The small speakers in your headphones convert those electrical signals into sound.]*

In your handouts, you were asked to describe how the music gets from your music player to the speaker on your receiver circuit. What did you write down? *[You can have one person go through the entire process or after one person has explained the transmission component, you can ask somebody else to continue. Let them say what they think happens all the way through the system. Whether the explanation is correct or incorrect, ask the other students if they agree with it. Then, if it's correct, you can*

*confirm it for them. If there are portions that are correct, confirm those sections for the class and tell them the parts of their explanation that are not quite right. If you're not sure if something they say is correct or incorrect, provide the entire explanation below.*

- 1. The electrical signal from your music player is converted into a visible red or invisible infrared light signal by the LED in the music transmitter circuit. If we wanted to transmit the signal over a longer distance, we would need to use a brighter LED or focus the visible or invisible light using a lens.*
- 2. The light signal hits the phototransistor in the receiver.*
- 3. The phototransistor in the receiver converts this light signal into an electrical signal.*
- 4. Then, the amplifier chip in the music receiver circuit takes this electrical signal and increases its strength using energy from the battery.*
- 5. Finally, this larger electrical signal drives the speaker, which turns electrical energy into sound energy.*

### Cleanup

1. Collect the batteries and put them back in the boxes. This will keep the contacts from touching something metal and draining the battery.
2. Put all of the components that are on the music receiver in the Music Receiver Bags, including the jumper wires. Be careful when removing the amplifier chip not to bend the pins.
3. Put all of the components that are on the music transmitter in the Music Transmitter Bags, including the jumper wires.



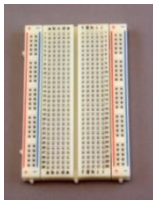
### Assessment

1. Does the student state that the music comes out of the music player as an electrical signal?
2. Does the student state that the LED gets brighter and dimmer to create a light signal that carries the music from the transmitter to the receiver?
3. Does the student state that the phototransistor turns the visible red or invisible infrared light signal into an electrical signal?
4. Does the student state that the amplifier in the receiver takes the electrical signal and makes it stronger so we can hear it when it comes out of the speaker?
5. Does the student recognize that the speaker takes the electrical signal and turns it into sound that we can hear?



### Activity 1: Sound on a Breadboard

#### Parts List:

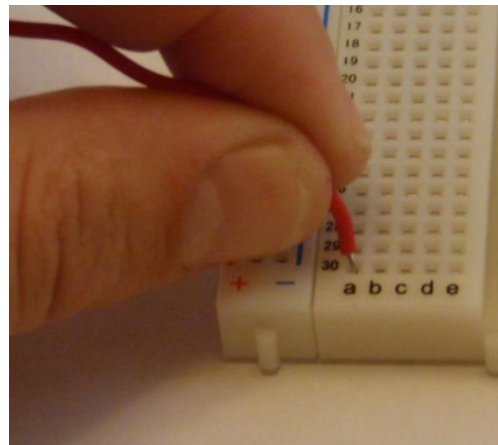
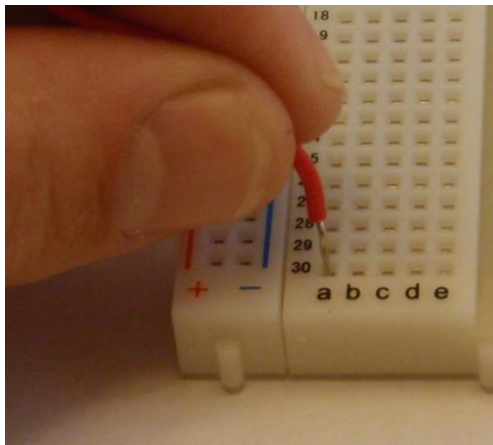
<p>Speaker (Note: Be careful with the wires. They break off easily.)</p> 	<p>Wire with headphone plug</p> 
<p>Music player (MP3 player or radio that uses headphones)</p>	<p>Breadboard</p> 

#### Part I: Playing Music Through a Speaker

**Challenge:** Can you play sound through the speaker using just these three pieces? Hint: You will use the Music player as the source. When you plug in the headphone plug, the music signal is converted to an electrical signal at the two wires on the end of the wire. You will need to connect the wire from the headphone plug to the speaker using the breadboard.

#### Part II: Using a Breadboard

You will build your circuits on a **breadboard**, which electrical engineers use to build and test circuits. Wires can be inserted into the holes to connect them to the circuit. Insert wires as shown below.



# Youth Handouts

## Wireless Transmission: Your TV Remote

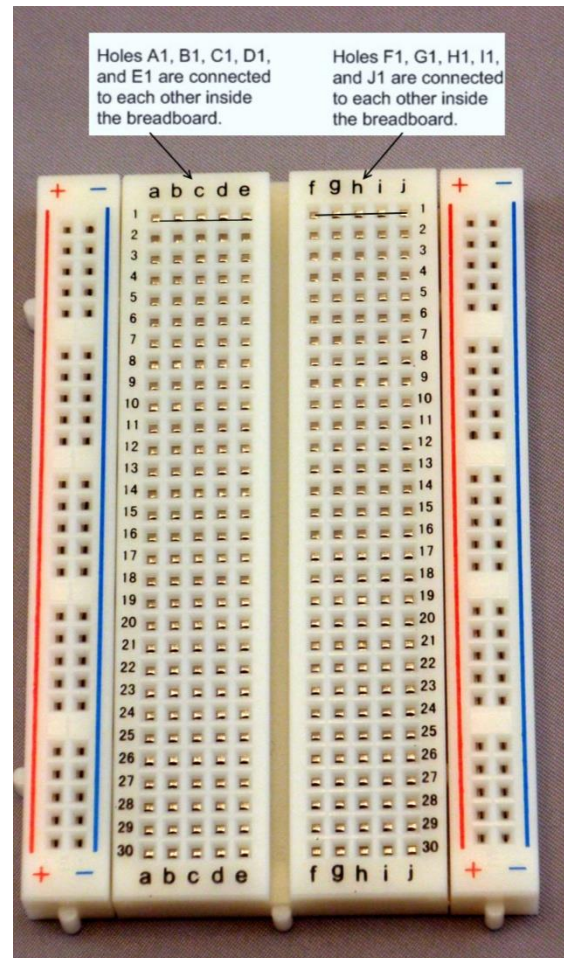
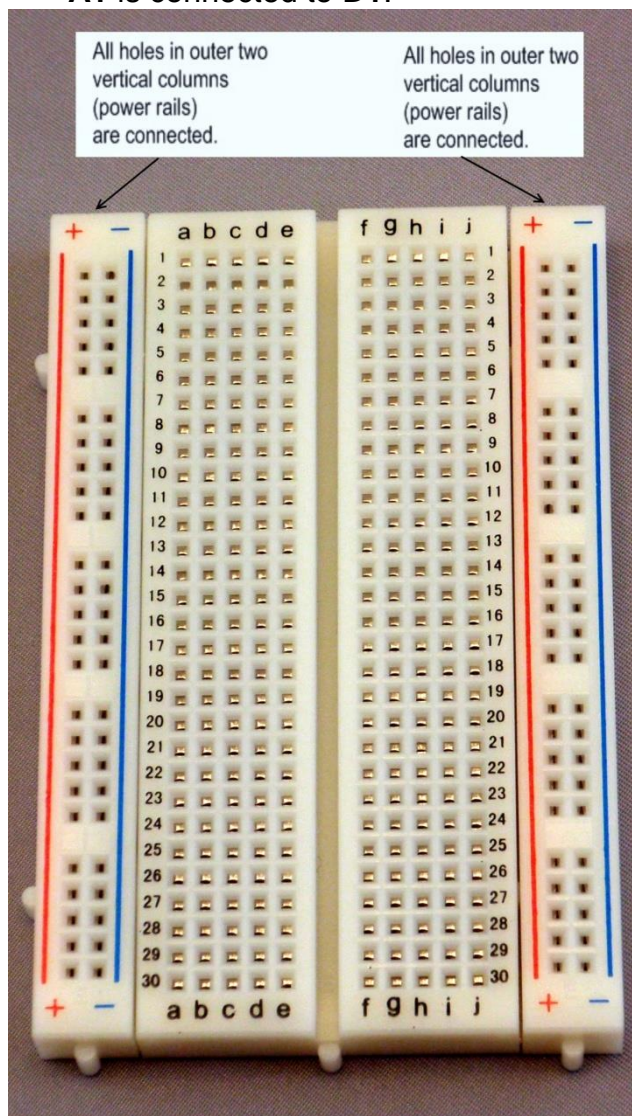
**Challenge:** Can you connect the music player to the speaker using the breadboard? Once you figure this out, try different connections until you are confident which portions of the breadboard are connected and which are not.

### Breadboard Inner Holes

All five holes in a single row are connected inside the breadboard. Opposite halves of the breadboard are not connected.

Examples:

- **A1** is connected to **D1**.



- **A1** is NOT connected to **A2**.
- **E1** is NOT connected to **F1**.

### Breadboard Outer Holes (Power Rails)

All 25 holes in a column of a power rail are connected together inside the breadboard. We will use the blue power rail on the left and the red power rail on the right. We will make the blue power rail negative and the red power rail positive.

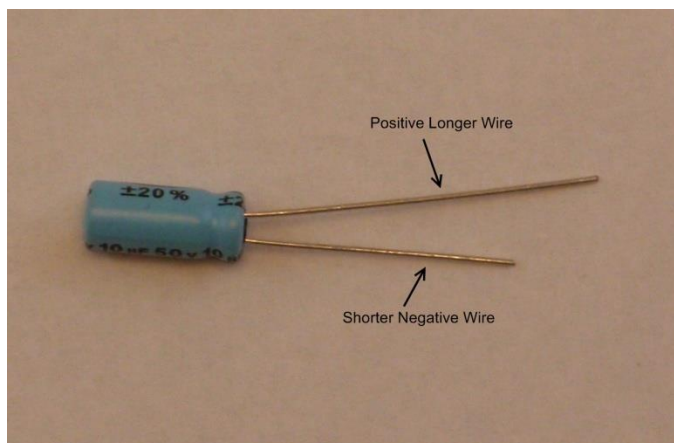
### Activity 2: Amplifying Sound

In this activity, you will build a circuit that uses the energy from a battery to make the sound coming out of the speaker louder. When you finish building this circuit, do not take it apart because you will be using it in Activities 3 and 4.

#### Parts List

- One TechXcite Music Receiver Bag containing:
  - 3 capacitors (10  $\mu$ F electrolytic)
  - 1 phototransistor (to be used in Activity 3)
  - 1 amplifier chip (LM 386 Integrated Circuit)
  - 1 resistor (red, yellow, orange — 24 k $\Omega$ )
  - Speaker
  - Battery snap
- 9V battery
- 2" jumper wires
- Speaker
- Wire with headphone plug
- Music player

A **resistor** converts electrical energy into heat. The colored bands refer to how much resistance each resistor has.

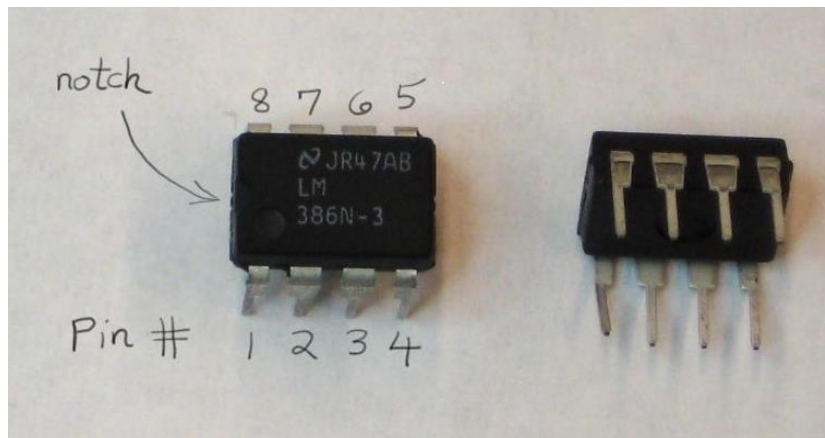


The **capacitors** in this kit have a cylindrical body, as shown in the picture. These capacitors are polarized. This means that there is a positive (+) wire and a negative (–) wire. Look at one of the capacitors closely. Notice that one of the wires is shorter than the other. The shorter wire is negative (–) and the longer wire is positive (+). Also, there is a black band running down the negative side of the capacitor.

When building the circuit, it is important to insert the positive (+) and negative (–) wires of the capacitor into the correct holes.

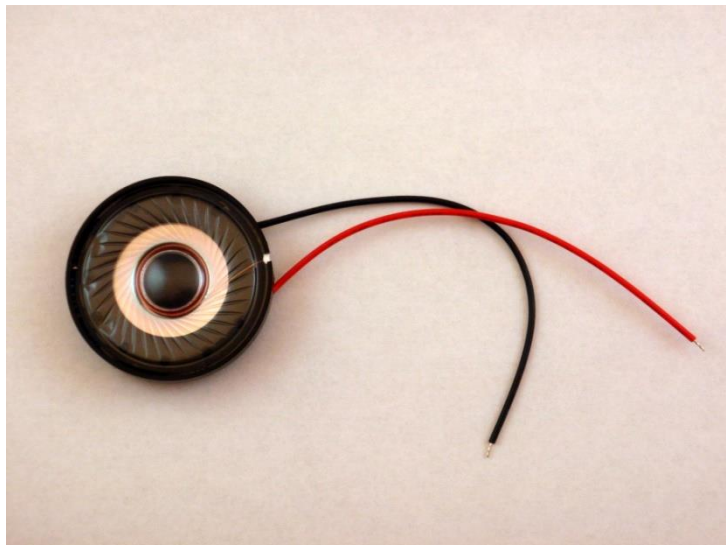


The amplifier chip (labeled LM 386) has 8 pins that connect to the breadboard. Each pin connects to a different part of the circuit.



Look closely at the top of the chip. There is a notch on one end. The pin numbers are not written on the chip, but are counted going around the chip, as shown at left.

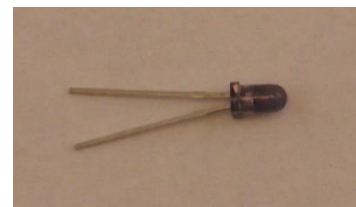
Be careful when you handle the LM 386 to avoid bending the pins.



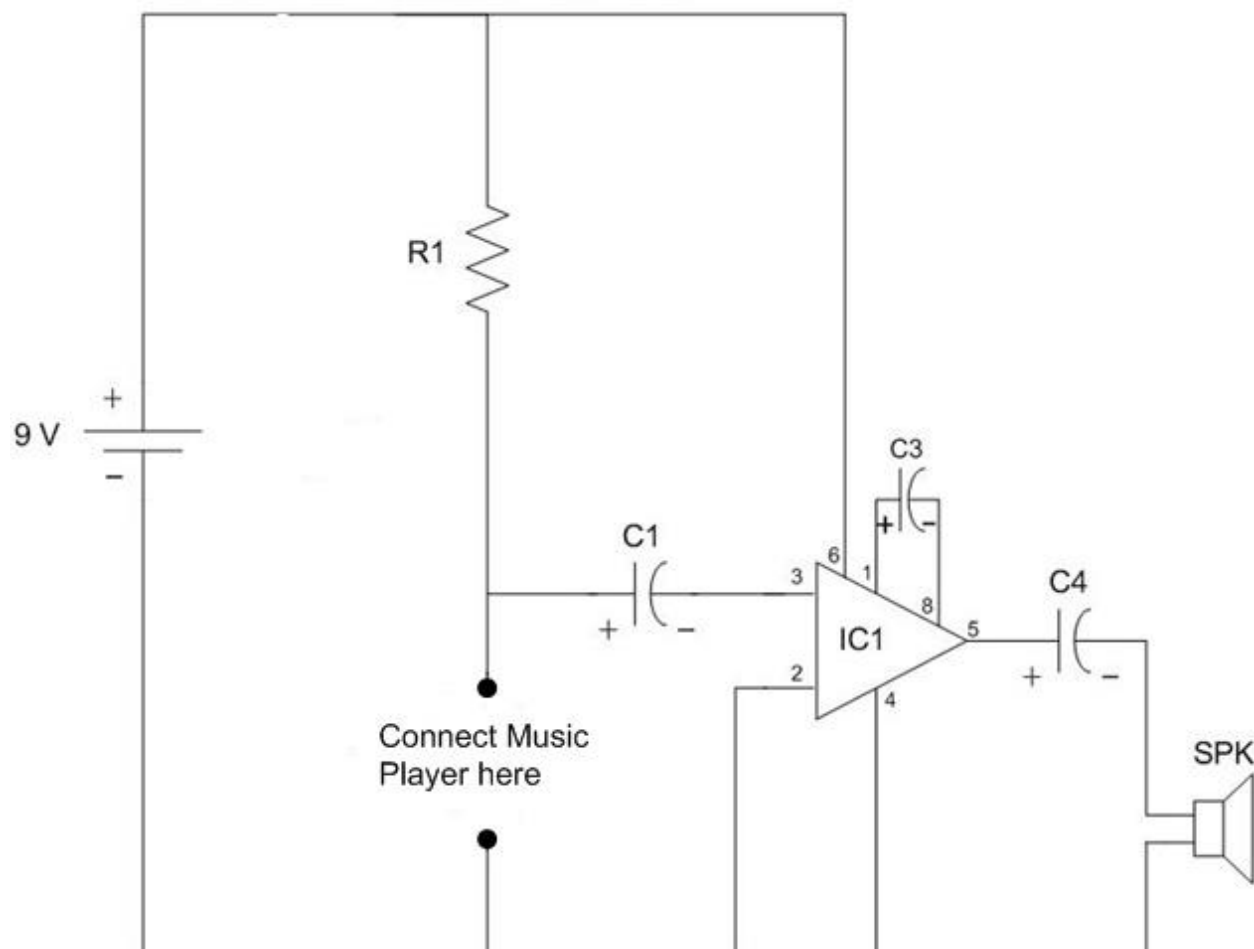
The **speaker** (left) turns electricity into sound.

Be careful when you handle the speaker because the wires break off easily.

The **phototransistor** (right) converts light into electricity. It will not be used until the next activity.



### Sound Amplifier Circuit Diagram



Above is a picture of the amplifier circuit called a **circuit diagram**. A circuit diagram is a plan that electrical engineers use to represent how electrical components are connected together. The music player is connected to the speaker through an amplifier circuit. The lines represent wires and any connections to the breadboard.

The numbers shown by the connections to IC1 are LM 386 pin numbers. For example, pin 6 is connected to the +9V power supply rail, and pin 4 is connected to the negative power rail. All three capacitors (C1, C3, C4) are polarized. This means that you have to be careful when you plug the capacitors into the breadboard to make sure that the positive and negative leads are in the right place.

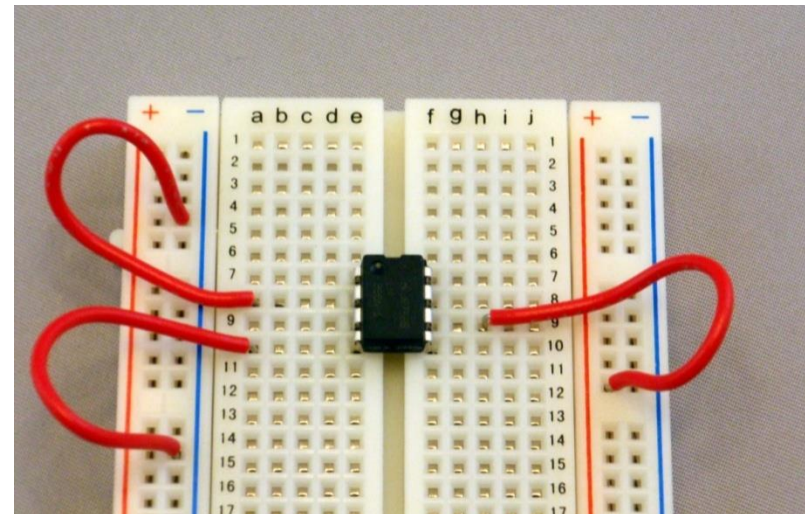
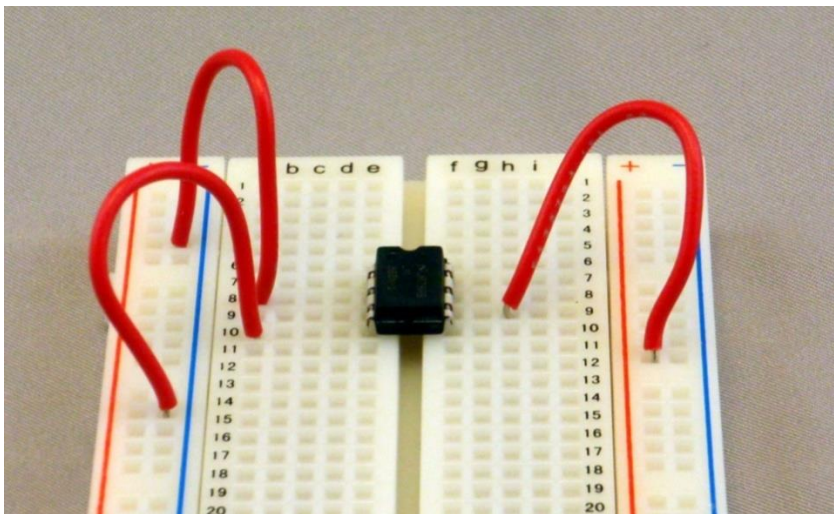
Step-by-step instructions follow, guiding you through the circuit-building process. When you've gone through all the steps, your instructor will give you a 9V battery so you can connect and test your circuit.



# Youth Handouts

## Wireless Transmission: Your TV Remote

Step	Component	Placement Location	Why did I just do that?
1	Amplifier chip	<ul style="list-style-type: none"> <li>Place chip across middle of breadboard as shown below.</li> <li>Notch should face the top of the board.</li> <li>Bottom pins should be in row 10.</li> </ul>	<ul style="list-style-type: none"> <li>The chip needs to split the middle of the board so that each of the 8 pins is connected to a separate row.</li> </ul>
2	2" jumper	<ul style="list-style-type: none"> <li>Connect <b>A8</b> to anywhere on <b>left blue</b> power rail (using a wire called a '2" jumper').</li> </ul>	<ul style="list-style-type: none"> <li>This connects pin 2 of the chip to negative.</li> <li>This provides power to the amplifier.</li> </ul>
3	2" jumper	<ul style="list-style-type: none"> <li>Connect <b>A10</b> to anywhere on <b>left blue</b> power rail (using a wire).</li> </ul>	<ul style="list-style-type: none"> <li>This connects pin 4 of the chip to negative.</li> <li>This provides power to the amplifier.</li> </ul>
4	2" jumper	<ul style="list-style-type: none"> <li>Connect <b>H9</b> to anywhere on <b>right red</b> power rail.</li> </ul>	<ul style="list-style-type: none"> <li>This connects pin 6 of the chip to positive.</li> <li>This provides power to the amplifier.</li> </ul>

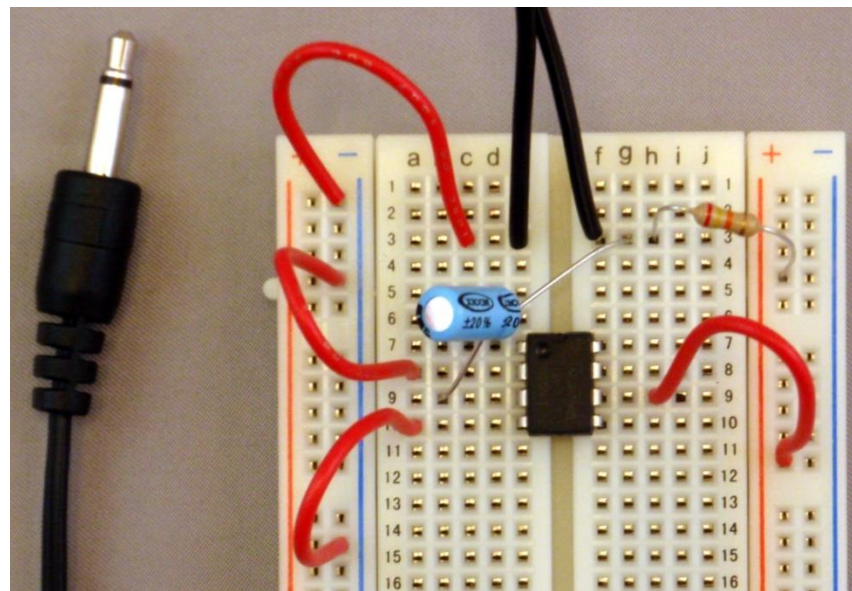


# Youth Handouts

## Wireless Transmission: Your TV Remote

The following instructions refer to the diagram below.

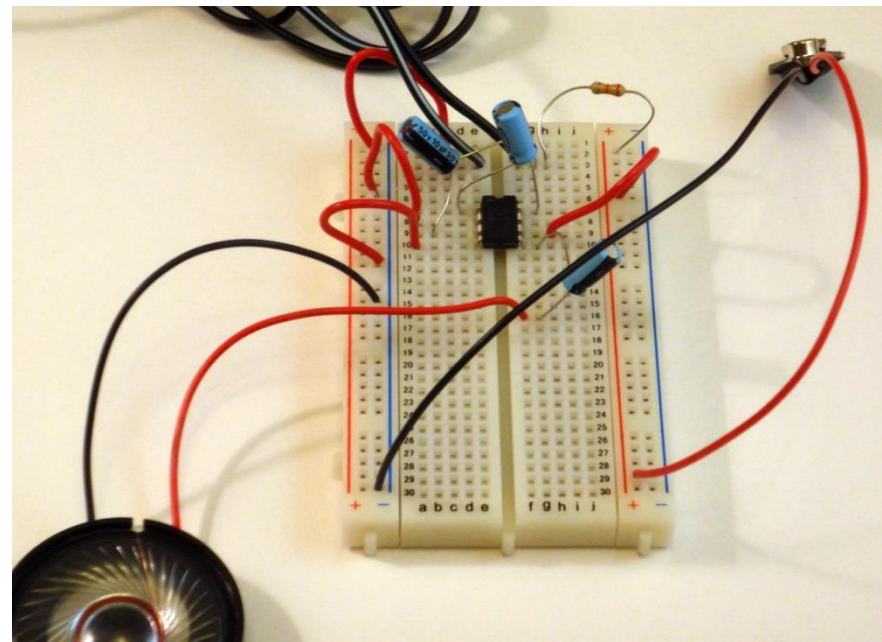
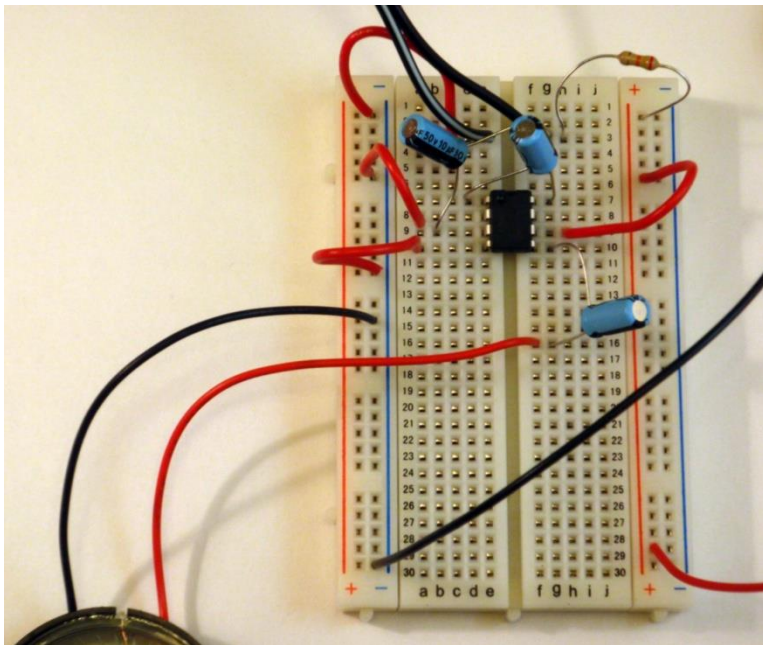
5	Wire with headphone plug	<ul style="list-style-type: none"><li>Connect these two wires to <b>E3</b> and <b>F3</b>.</li></ul>	<ul style="list-style-type: none"><li>This is how the music player connects to the amplifier circuit. The sound signal (as electricity) enters and returns through this pair of wires.</li></ul>
6	2" jumper	<ul style="list-style-type: none"><li>Connect <b>C3</b> to anywhere on <b>left blue</b> power rail.</li></ul>	<ul style="list-style-type: none"><li>These connect the signal to the positive and negative power supply rails.</li></ul>
7	Resistor (R1)	<ul style="list-style-type: none"><li>Connect resistor from <b>H3</b> to anywhere on <b>right red</b> power rail.</li></ul>	
8	Capacitor (C1)	<ul style="list-style-type: none"><li>Insert long wire of capacitor into <b>G3</b> and short wire of capacitor into <b>B9</b>.</li></ul>	<ul style="list-style-type: none"><li>The shorter, negative wire on the side of the capacitor with the stripe connects the weak signal to the input of the amplifier chip.</li><li>The longer wire of the capacitor connects the music player to the capacitor.</li></ul>



# Youth Handouts

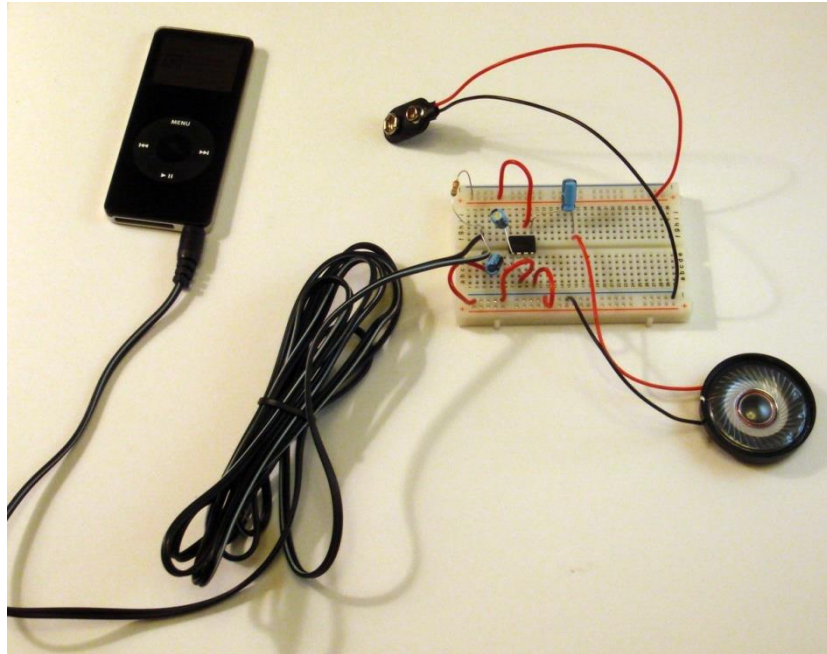
## Wireless Transmission: Your TV Remote

9	Capacitor (C3)	<ul style="list-style-type: none"> <li>Insert long wire of capacitor into <b>D7</b> and short wire of capacitor into <b>G7</b>.</li> <li>Be sure that the wires do not touch other components on the board.</li> </ul>	<ul style="list-style-type: none"> <li>The longer, positive wire connects to pin 1 of the amplifier chip.</li> <li>The shorter, negative wire on the side of the capacitor connects to pin 8 of the amplifier chip.</li> </ul>
10	Capacitor (C4)	<ul style="list-style-type: none"> <li>Insert long wire of capacitor into <b>G10</b> and short wire of capacitor into <b>G16</b>.</li> </ul>	<ul style="list-style-type: none"> <li>This connects the speaker to pin 5 (the output) of the amplifier chip.</li> </ul>
11	Speaker	<ul style="list-style-type: none"> <li>Connect red speaker wire to <b>F16</b> and black speaker wire to <b>left blue</b> power rail.</li> </ul>	<ul style="list-style-type: none"> <li>The speaker changes the electrical signal into sound.</li> </ul>
12	Battery snap	<ul style="list-style-type: none"> <li>Connect red battery snap wire to <b>right red</b> power rail and black battery snap wire to <b>left blue</b> power rail.</li> </ul>	<ul style="list-style-type: none"> <li>This connects the battery to power the circuit.</li> </ul>
13	9V battery	<ul style="list-style-type: none"> <li>Ask your instructor for a 9V battery to connect and test the circuit.</li> </ul>	<ul style="list-style-type: none"> <li>The 9V battery provides power to the amplifier chip, which increases the volume of the sound.</li> </ul>





### Testing the Circuit



To test the circuit, plug the music player in and turn it on. You should hear sound and it should be louder than in the last activity when the music player was connected directly to the speaker. If you do not hear any sound from the speaker, you will need to **troubleshoot** your circuit.

Connect a 9V battery to the battery snap. If your circuit does not work, immediately disconnect one of the battery snap wires from the breadboard. A wiring error has occurred and you don't want to drain the battery!

### Troubleshooting (Go through this process if your circuit fails to operate.)

Troubleshooting is the process of figuring out why a circuit does not work.

- 1) The most common problem is a wiring error. Check to make sure that every wire and component leads are going into the correct holes.
- 2) The second most common error is a polarity mistake. Check the direction of each capacitor to make sure the short negative wire is in the correct hole.

### Storing Your Sound Amplifier Circuit

You will need to store your receiver for use during the next two activities. Disconnect your battery from the breadboard and remove the battery snap. This will maximize the life of your battery. Your instructor will collect the batteries.

### Activity 3: Music Receiver

In this activity, you will build a sound receiver that converts light signals into sound. At the end of the activity, you will test your receiver by pointing a TV remote at the input and hearing the signal that your TV responds to when you press a button on the remote. When you finish building this circuit, do not take it apart because you will be using it in the next activity.

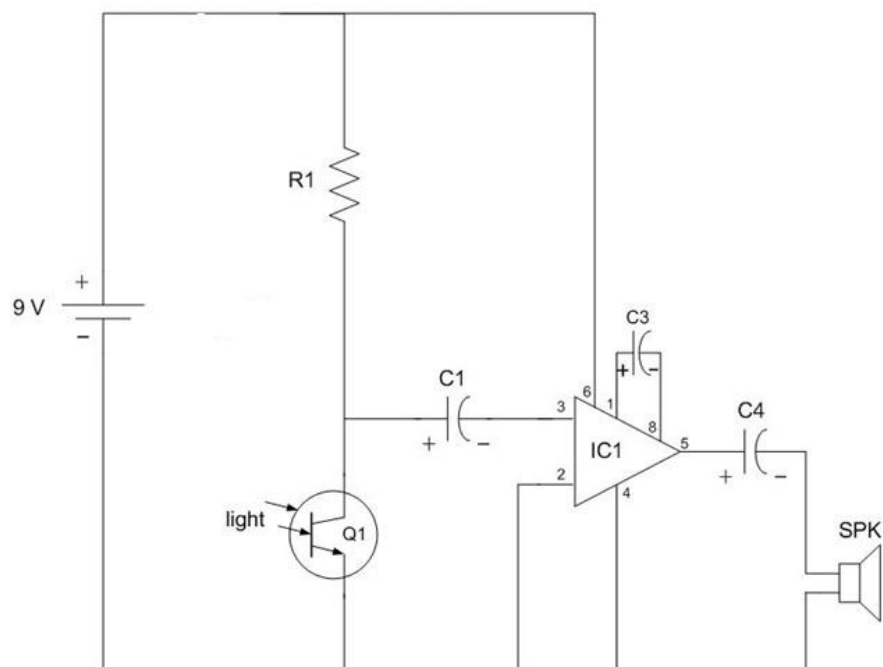
#### Parts List

- Sound amplifier circuit from Activity 2.
- Phototransistor
- 9V battery
- Tape measure



A **phototransistor** converts light into electricity and looks like a small light. The phototransistor has a flat side by one of the wires that indicates positive (+).

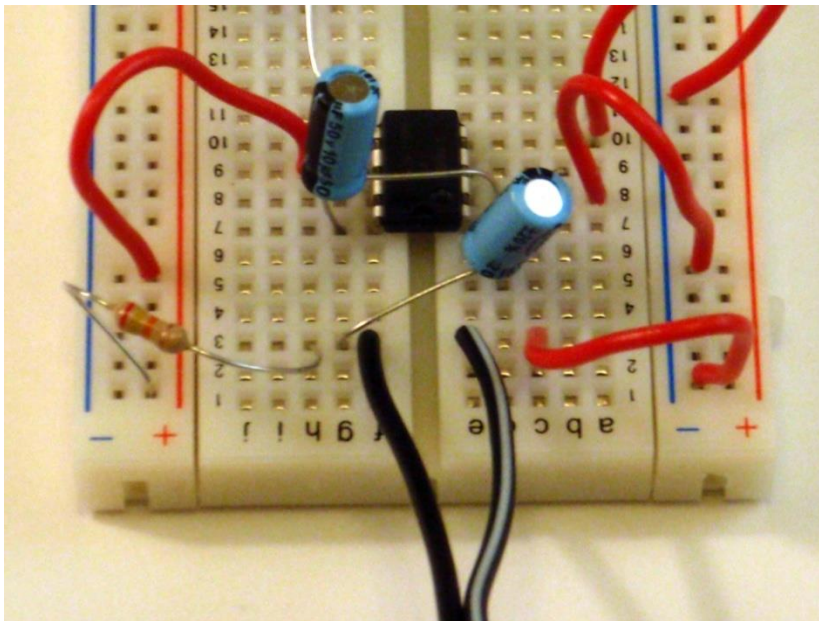
#### Music Receiver Circuit Diagram



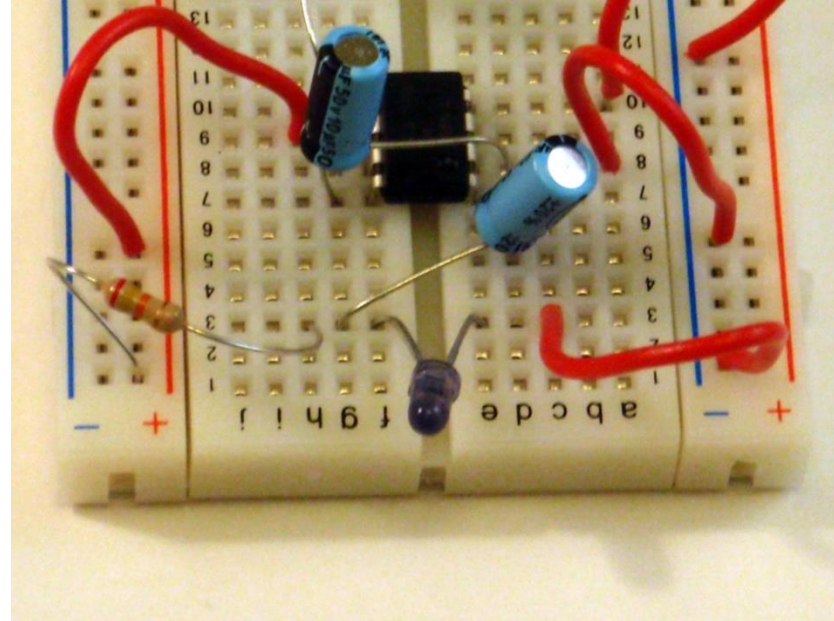
### Converting the Sound Amplifier to a Music Receiver

Step	Component	Placement Location	Why did I just do that?
1	Wire with headphone plug	<ul style="list-style-type: none"> <li>Remove these two wires from <b>E3</b> and <b>F3</b>. (See picture, below left.)</li> </ul>	<ul style="list-style-type: none"> <li>This is where the electrical sound signal entered the circuit.</li> </ul>
2	Phototransistor	<ul style="list-style-type: none"> <li>Connect the phototransistor to <b>E3</b> and <b>F3</b> with wire coming out of the flat side in <b>F3</b>. (See picture, below right.) Bend the phototransistor down so that it points along the table.</li> </ul>	<ul style="list-style-type: none"> <li>Now the light signal is received by the phototransistor and converted into an electrical signal.</li> </ul>

Before Step 1



After Step 2

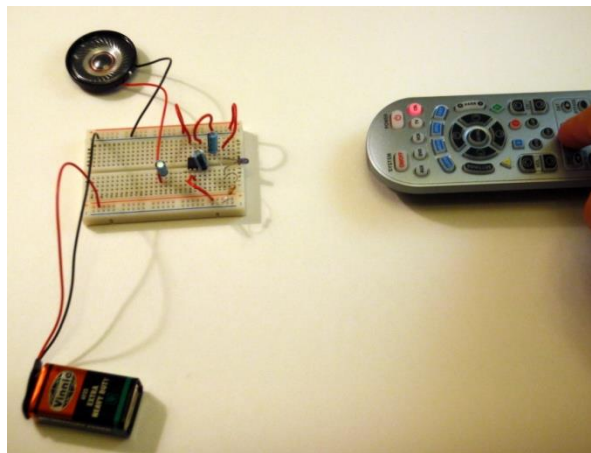




### Exploring the Music Receiver Circuit

**Infrared** (IR) light is invisible. You cannot see the IR light that is emitted from the TV remote. But you know that the TV remote is emitting IR light because when you fire it at the sound receiver, you can hear the signal coming out of the speaker.

**Exploration 1:** Take turns with your partner firing the TV remote at the phototransistor from different distances and angles. What happens if you put something (like a piece of paper) between the remote and phototransistor? Discuss with your partner what you observe and what you think causes the system to respond the way it does. What is the purpose of the phototransistor in the circuit?



Write down what you observe and possible explanations below:

**Exploration 2:** Work with your partner to use the tape measure to determine the farthest distance the TV remote can be fired and still trigger a sound in the sound receiver. Compare your results with other teams' results. Discuss why your results are different.

What is the farthest distance the TV remote can be fired and still trigger a sound in the sound receiver? Explain how you would change the system to increase the trigger distance.

Answer:

### Storing Your Music Receiver

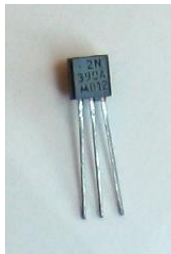
You will need to store your music receiver for use during the next activity. Disconnect your battery from the breadboard and remove the battery snap. This will maximize the life of your battery. Your instructor will collect the batteries.

### Activity 4: Infrared Music Transmitter

In this activity, you will build an infrared (IR) music transmitter. The signal from any music player can be “jacked in” to the input of the transmitter.

#### Parts List

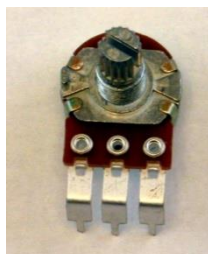
- Music Receiver Circuit from Activity 3
- One TechXcite Music Transmitter Bag containing:
  - 5 resistors (brown, black, black — 100  $\Omega$ )
  - IR LED (Light Emitting Diode)
  - Red LED (Light Emitting Diode)
  - Transistor (2N3904)
  - Potentiometer (50 k $\Omega$  variable resistor)
  - Capacitor (47  $\mu$ F Electrolytic)
  - Wire with headphone plug
  - Battery snap
- 9V battery
- Breadboard
- 2” jumper wires



The **transistor** has a black body with a flat front and three leads coming out of the bottom.



The headphone plug is a standard 1/8-inch mini plug that fits most portable music players. The other end of the cable has two wires that can be inserted into a breadboard.

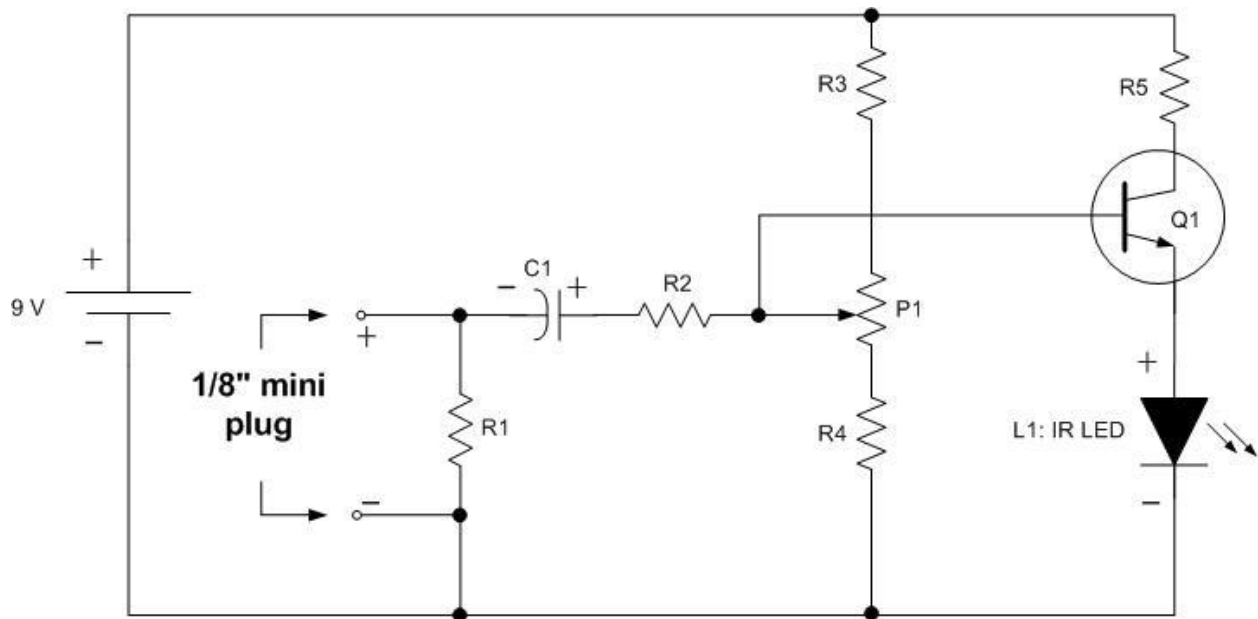


The 50 k $\Omega$  **potentiometer** (variable resistor) has a rotatable dial and three metal connections. Rotating the dial changes the resistance between the center lead and the leads on the outside. A potentiometer allows you to rotate a dial to control the electricity through it.



A **light emitting diode**, or **LED**, converts electrical energy into light of a single color. It has two metal wires. The longer lead is positive (+) and the shorter lead is negative (-).

### Music Transmitter Circuit Diagram

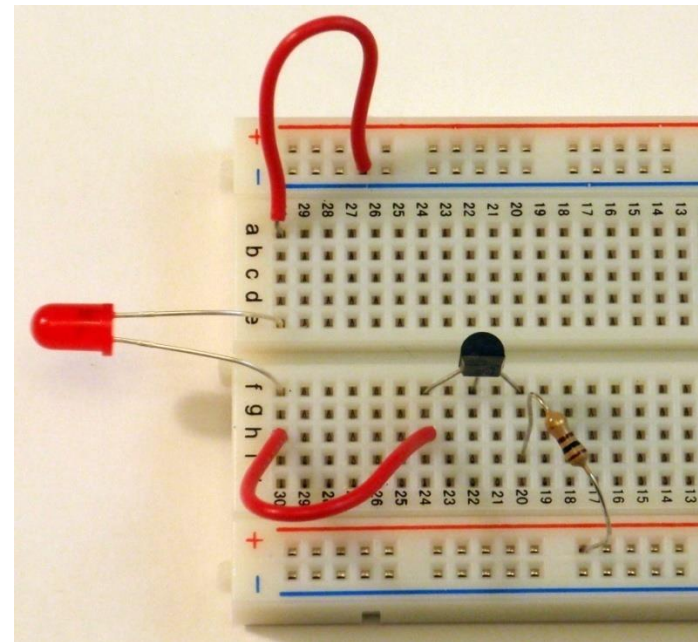
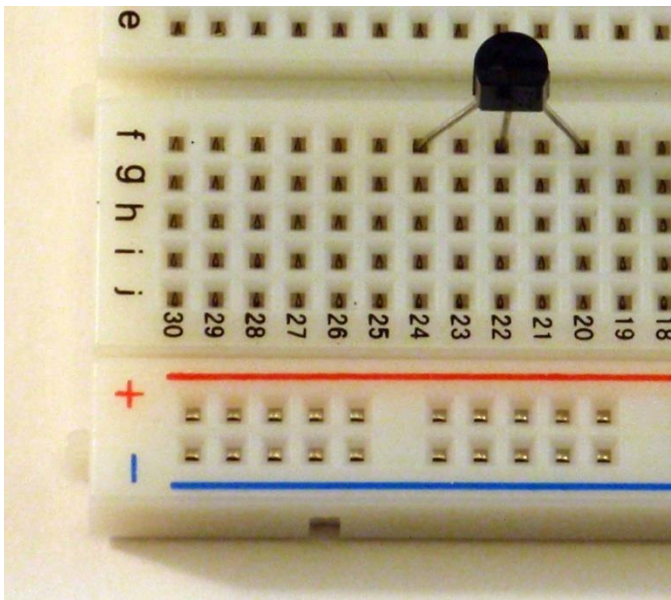


Note: The black dots emphasize that a physical connection is made. The wire that goes from the middle pin on the potentiometer (P1) to the middle pin on the transistor (Q1) does **not** connect to the wire between R3 and P1, even though the wires cross, because there is **no black dot at the cross point**.

Step-by-step instructions are on the next page. As you build the circuit on your breadboard, you can refer back to the circuit diagram to relate the schematic drawing to your breadboard circuit. When you've gone through all the steps, your instructor will give you a 9V battery so you can connect and test your circuit.

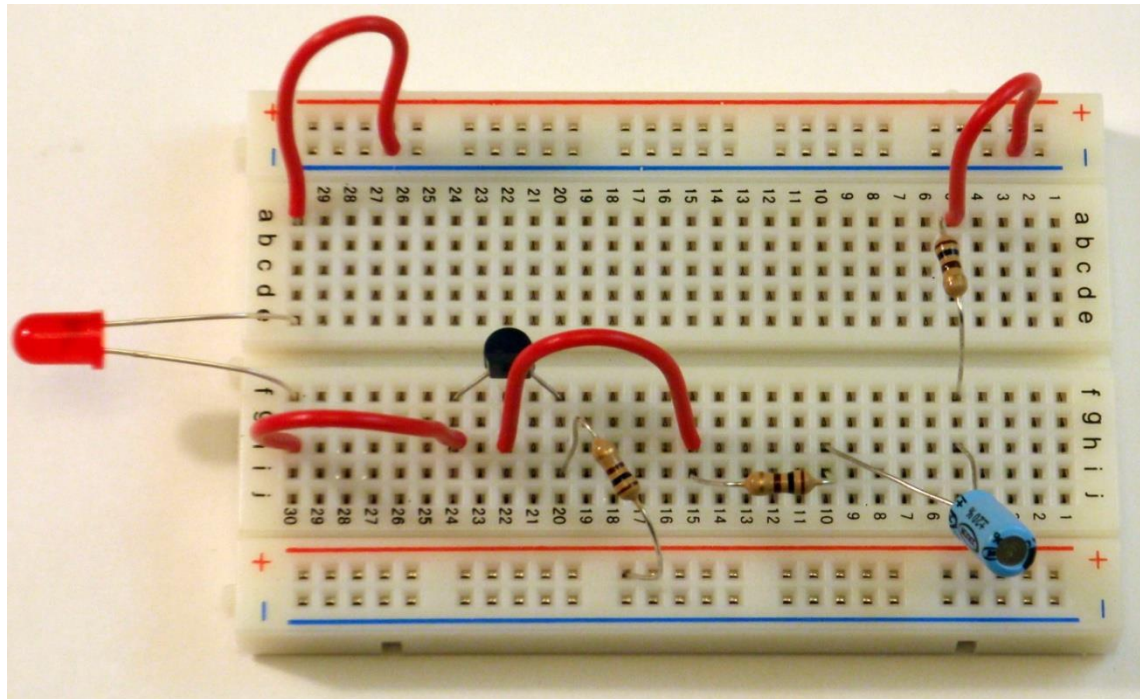
### Building the IR Music Transmitter Circuit

Step	Component	Placement Location	Why did I just do that?
1	Transistor	<ul style="list-style-type: none"> <li>With flat side of transistor facing you, insert left wire into <b>F24</b>, middle lead into <b>F22</b> and right wire into <b>F20</b>.</li> </ul>	<ul style="list-style-type: none"> <li>The direction of the transistor is important, which is why the flat side is facing you.</li> <li>This will amplify the signal for the LED.</li> </ul>
2	Resistor (brown, black, brown)	<ul style="list-style-type: none"> <li>Connect resistor to <b>I20</b> and <b>bottom red</b> power rail.</li> </ul>	<ul style="list-style-type: none"> <li>This connects the resistor between the right lead of the transistor and the bottom positive red power supply rail.</li> </ul>
3	2" jumper	<ul style="list-style-type: none"> <li>Connect to <b>H24</b> and to <b>H30</b>.</li> </ul>	<ul style="list-style-type: none"> <li>This will connect to the LED.</li> </ul>
4	Red LED	<ul style="list-style-type: none"> <li>Connect longer wire (+) to <b>F30</b> and shorter wire (-) to <b>E30</b>.</li> </ul>	<ul style="list-style-type: none"> <li>This converts the electrical signal to a light signal.</li> </ul>
5	2" jumper	<ul style="list-style-type: none"> <li>Connect to <b>A30</b> and to <b>top blue</b> power rail.</li> </ul>	<ul style="list-style-type: none"> <li>This connects the LED to the negative.</li> </ul>

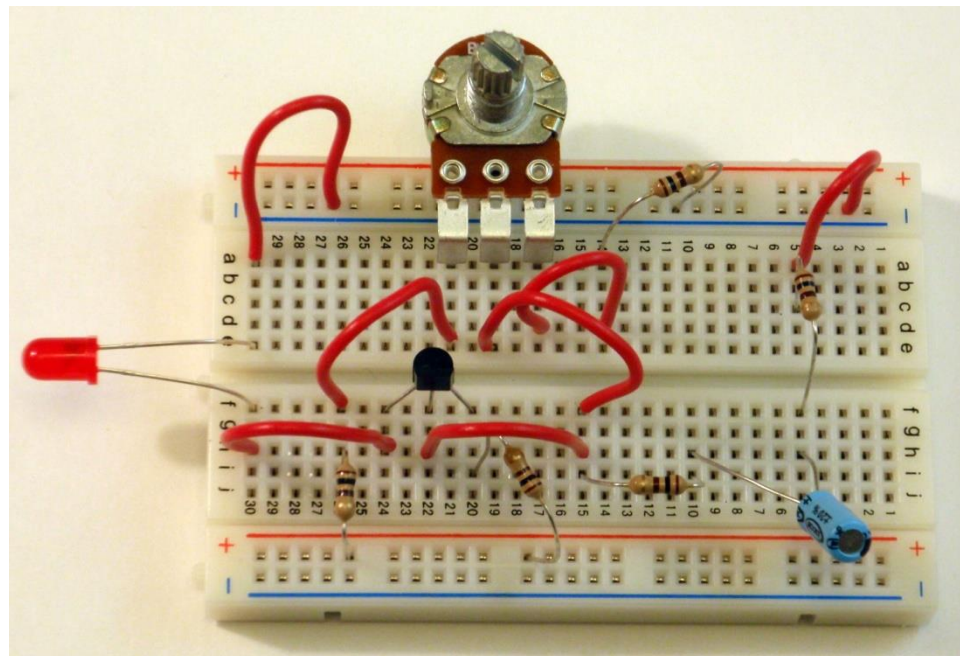




Step	Component	Placement Location	Why did I just do that?
6	2" jumper	<ul style="list-style-type: none"> <li>Connect to <b>H22</b> and to <b>H15</b>.</li> </ul>	<ul style="list-style-type: none"> <li>These components connect the signal to the middle pin of the transistor and to the negative blue power rail.</li> </ul>
7	2" jumper	<ul style="list-style-type: none"> <li>Connect to <b>A5</b> and to <b>top blue</b> power rail.</li> </ul>	
8	Resistor (brown, black, brown)	<ul style="list-style-type: none"> <li>Connect to <b>G15</b> and to <b>G10</b>.</li> </ul>	
9	Capacitor	<ul style="list-style-type: none"> <li>Connect short negative lead to <b>H5</b> and long positive lead to <b>H10</b>.</li> </ul>	
10	Resistor (brown, black, brown)	<ul style="list-style-type: none"> <li>Connect to <b>F5</b> and to <b>C5</b>.</li> </ul>	

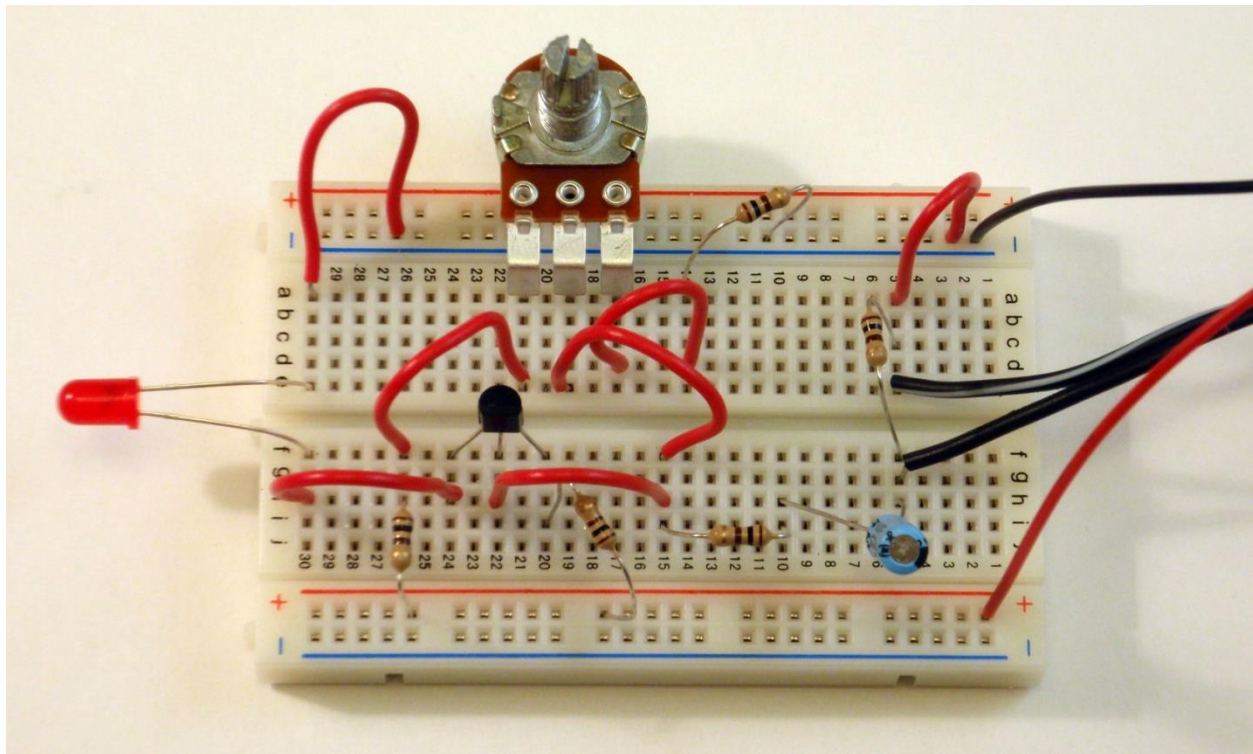


Step	Component	Placement Location	Why did I just do that?
11	Potentiometer	<ul style="list-style-type: none"> <li>Insert potentiometer's metal tabs into <b>A21</b>, <b>A19</b> and <b>A17</b>.</li> </ul>	<ul style="list-style-type: none"> <li>The potentiometer is a variable resistor and turning it varies the amplification of the transistor.</li> </ul>
12	Resistor (brown, black, brown)	<ul style="list-style-type: none"> <li>Connect resistor between <b>J26</b> and <b>bottom red</b> power rail.</li> </ul>	<ul style="list-style-type: none"> <li>This connects the potentiometer to the red positive power rail.</li> </ul>
13	2" jumper	<ul style="list-style-type: none"> <li>Connect to <b>F26</b> and to <b>E21</b>.</li> </ul>	
14	2" jumper	<ul style="list-style-type: none"> <li>Connect to <b>F15</b> and to <b>E19</b>.</li> </ul>	<ul style="list-style-type: none"> <li>This connects the middle pin of the potentiometer to the middle pin of the transistor.</li> </ul>
15	2" jumper	<ul style="list-style-type: none"> <li>Connect to <b>D17</b> and to <b>D14</b>.</li> </ul>	<ul style="list-style-type: none"> <li>This connects the potentiometer to the blue negative power rail.</li> </ul>
16	Resistor (brown, black, brown)	<ul style="list-style-type: none"> <li>Connect to <b>A14</b> and to <b>top blue</b> power rail.</li> </ul>	





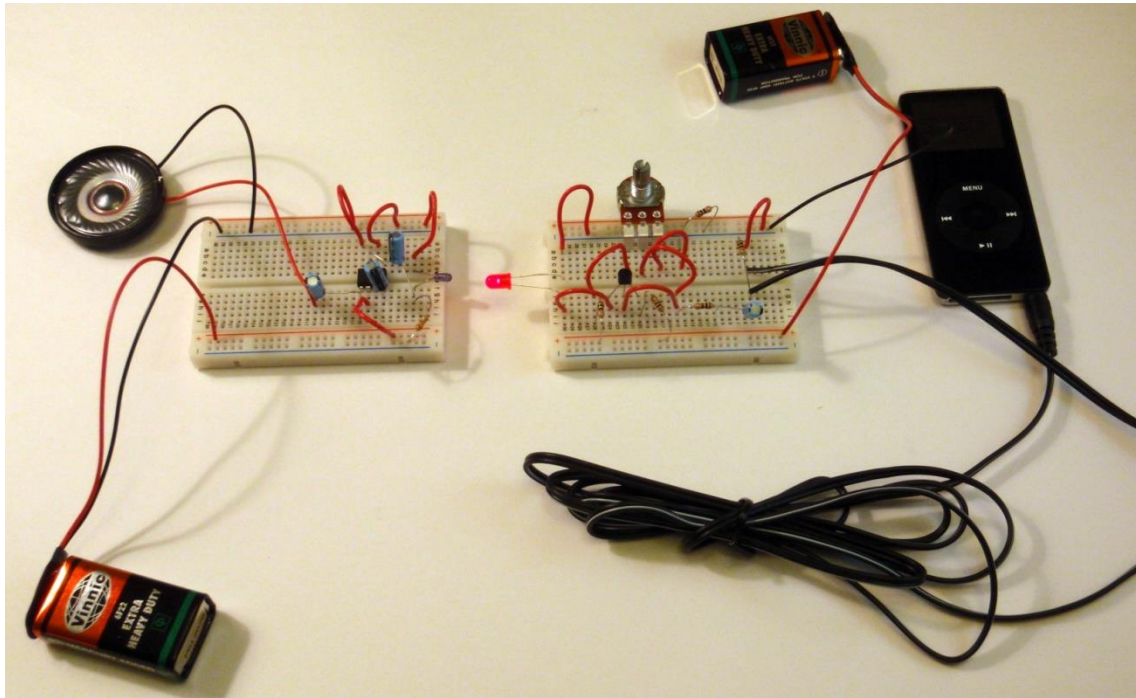
Step	Component	Placement Location	Why did I just do that?
17	Wire with headphone plug	<ul style="list-style-type: none"> <li>Connect these two wires to <b>G5</b> and <b>E5</b>.</li> </ul>	<ul style="list-style-type: none"> <li>This is how the music player is connected to the circuit. The sound signal enters through this wire.</li> </ul>
18	Battery snap	<ul style="list-style-type: none"> <li>Connect the red battery snap wire to <b>right red</b> power rail and the black battery snap wire to <b>left blue</b> power rail.</li> </ul>	<ul style="list-style-type: none"> <li>This connects the battery to power the circuit.</li> </ul>
19	9V battery	<ul style="list-style-type: none"> <li>Ask your instructor for a 9V battery to connect and test the circuit.</li> </ul>	<ul style="list-style-type: none"> <li>The 9V battery provides power for the circuit.</li> <li>The transistor uses this to amplify the electrical signal to increase the brightness of the LED.</li> </ul>



### Test the Circuit

To test the circuit, aim the red LED at the phototransistor of the music receiver that you built in the last activity. Position the music transmitter so that the LED is  $\frac{1}{2}$  inch from the phototransistor.

Get a portable music player from your instructor or use one of your own, such as an iPod. Listen to it through headphones and make sure it is producing loud and clear music or speech.



Connect the music player to your IR music transmitter by connecting the earphone plug to the headphone jack of your music player. Turn up the volume on your music player. Rotate the stem of the potentiometer on your transmitter circuit. The red LED should be on. You should hear music coming out of the speaker in the receiver. If you do not hear any sound from the speaker, you will need to troubleshoot your IR music transmitter-receiver system.

If your circuit does not work, immediately disconnect one of the battery snap leads from the breadboard of both the transmitter **AND** the receiver. A wiring error has occurred and you don't want to drain the batteries!

### Now try infrared.

Try using the clear infrared (IR) LED instead of the red LED.

### System Operation, Exploration and Description

Twist the potentiometer stem in the music transmitter circuit until the sound from the speaker is as clear as possible.

1) Explain how the music goes from the music player to the speaker. Try to address as many of the electronic components as possible.

Answer:

2) What do you think rotating the stem of the potentiometer in the transmitter does?

Answer: