4-H NATIONAL YOUTH SCIENCE DAY

INCREDIBLE WEARABLES

YOUTH GUIDE

VERSION 2.0

ENGINEER NOTES

ENGINEER NAMES

DATE

www.4-H.org/NYSD

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2017 NYSD YOUTH GUIDE

INTRODUCTION

The 4-H National Youth Science Day (NYSD) connects young people from around the world in an exciting, interactive learning experience in the form of a science, technology, engineering and math (STEM) challenge.

If you've ever wondered how wearable technology like the FitBit or the Apple Watch work, this year's NYSD challenge is for you! Called Incredible Wearables, the challenge will have you and a group of your friends working together as an engineering team to build a functioning health monitor using a small computer and low cost sensors. With the help of volunteers and educators from the nation's 110 land-grant colleges and universities, not only will you build the monitor, but you'll also be able to analyze the information you gather on a computer, tablet or mobile phone. What kinds of careers could you do where a health monitor might help you with your job?

WEARABLE TECHNOLOGIES

Wearable technology refers to electronic fabrics or electronic accessories that can be worn, such as watches, eye glasses, or clothing, that contain electronics and sometimes a small computer. New technologies are being developed in this space all the time, including virtual reality and augmented reality devices, as well as clothing and accessories. Health monitoring is just one area of wearable technologies. By studying STEM subjects, you could learn the knowledge you need to build these technologies as an adult.

Here are just some of the jobs that use wearable technologies:

Field Technician in precision agriculture – A technician drives a robot through corn to detect root rot and bugs so that fields can be treated and corn yields can be increased.

Neural Scientist – A scientist develops wearable technology that helps solve medical problems related to the brain. One example of a technology that has been developed, is a wearable that clips on an infant's ear, which detects brain waves.

Fashion Designer – A designer produces garments that use Light Emitting Diodes (LEDs), sensors and other components to make clothing light up, make sounds, or respond to the environment around the person.

Horse Technician – A technician can use sensors, like tilt sensors, to examine gait problems in horses.

Mobile App Developer – An app developer creates apps for mobile devices that can control sensors, LEDs and a variety of other components on wearables.

Engineers – There are many different types of engineers who develop technology related to wearables, including the sensors, LEDs, microchips, small computers, and programs that control electronic components.

UX Designer for wearable technology – A UX (user experience) designer constructs user interfaces for different wearable technology products.

OVERVIEW

In this challenge, you will build a wearable health monitor using a very small, low cost computer called the ESP8266/The THING, which we sometimes call the 'The THING'. In addition, you will attach a sensor that measures your pulse rate and a sensor that can detect movement.

Health monitoring using a wearable device presents an interesting engineering problem, which is to encourage increased movement through a wearable device that is capable of tracking biological data (pulse rate and movement) and provide feedback on personal health. Like all engineering problems, you will have to work within certain limits, also known as constraints, including:

Size: A wearable health monitor should be small and easy to wear.

Aesthetics: Your design should be somewhat nice to look at, or even trendy!

Available components: Pulse oximeter, tilt sensor, 'The THING', power supply, alligator clips, jumper wires, felt, velcro strip, and AA batteries.

Time: You will have 90 minutes to complete the challenge.

GOALS, OBJECTIVES AND OUTCOMES

In this challenge, you will:

1. Apply the engineering design process;
2. Monitor fitness levels by designing and building a wearable fitness monitor, complete with a programmable Wi-Fi enabled microcontroller (mini-computer) and sensors that will enable you to monitor data on your smartphone, tablet or laptop; and
3. Analyze data to define the best/optimal operational location for the sensors (design refinement/optimization).

IMPORTANT!

If you are using five or more devices at the same time we recommend changing The THING's SSID (wireless network name) before your event.

- The estimated time it will take to change the SSID is 30-60 minutes depending on the number of devices.
- This process will require a USB-A to USB-B micro cable.
- For detailed instructions visit www.4-h.org/NYSD and click the "Guides & Resources" tab.

KIT COMPONENTS

For the challenge, you will work with your team to build one wearable health monitor using the kit you have been given. You will also need a computer or a device like a mobile phone or tablet that is connected to the Internet.

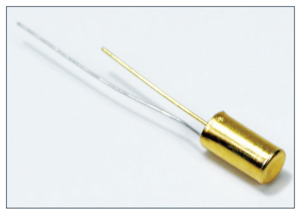
The components of the *Incredible Wearables* kit include three AA batteries, one piece of 12” x 9” felt and a velcro strip to create a wristband, screwdriver, plus the following:

Microprocessor ESP9266 (‘The THING’)

A small computer that also acts as a Wi-Fi router that will “push” sensor data to a website, which can then be viewed online.

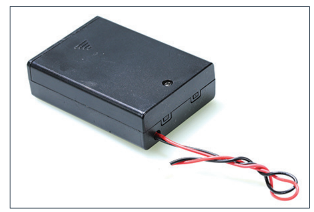
TILT SENSOR

A sensor that measures when something either tilts, speeds up, or slows down.



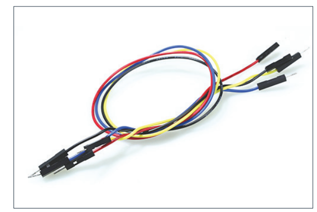
POWER SUPPLY

Batteries and holder to power the ESP8266/ The THING.



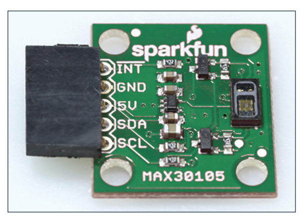
JUMPER WIRES

A short wire with a metal pin on each end used to complete an electrical circuit.



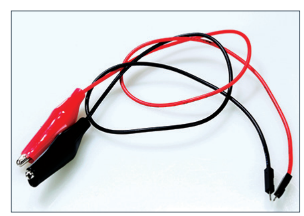
PULSE OXIMETER

A sensor that measure the amount of oxygen in the blood as well as temperature.



ALLIGATOR CLIPS

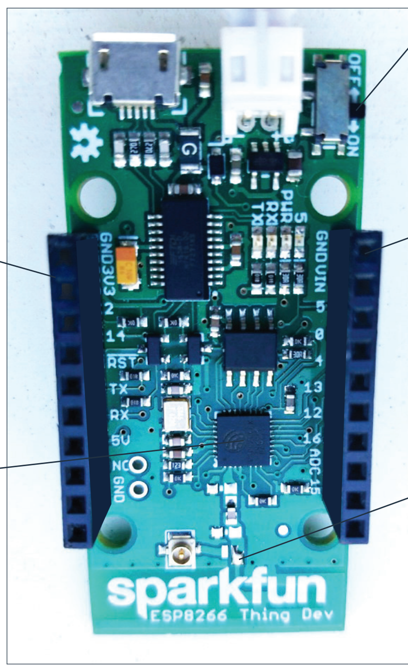
A metal clip with copper wires for making temporary electrical connections.



ABOUT THE THING

The diagram below shows the different components that make up The THING. The THING is a low cost computer, called a microprocessor. It works because the chip collects data and transmits instructions to other parts of the microprocessor. These parts include the female headers. They communicate with the chip through silver lines on The THING. These lines function like an electrical highway, sending information to and from the female headers to the chip.

Look closely on The THING and you will see some numbers or letters next to the female headers. These labels name each separate pin on the female header. In the challenge you will connect the tilt sensor and the pulse oximeter to specific pins on the female headers. The chip knows how to make the sensors work because the pins you connect the sensors to have specific instructions for them written into the chip's code. This allows the chip to know what each pin will do and communicate those instructions to the rest of the microprocessor.



Female Headers: These are the two black bars on the THING that are made up of pins.

Chip: The is the brain of The THING, it executes the instructions written in its programming.

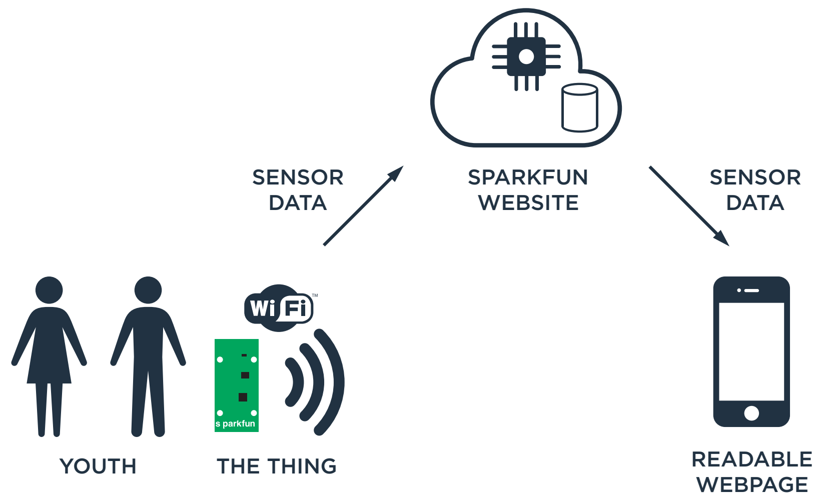
On/Off Switch: This controls the power to and from The THING

Pins: The small holes on the female header. These can either input or output data to external hardware.

Printed Antenna: This transmits the network signal to your computer or other device.

HOW IT WORKS

The THING has built-in Wi-Fi and runs a web server to read data from the tilt sensor and pulse oximeter. The Thing then populates that data as a webpage, but it isn't connected to the web. This type of wireless service is known as a LAN, a Local Area Network.



PART I

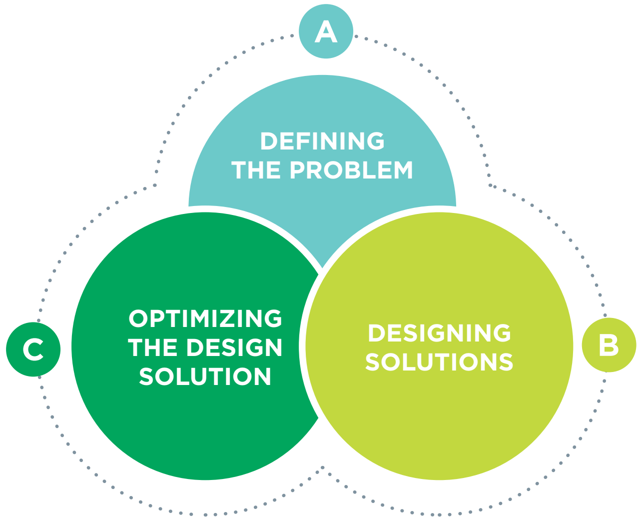
HEALTH LEARNING

CHALLENGE

(10 MINUTES)

ENGINEERING PROBLEM

Health monitoring using a wearable device is an interesting engineering problem. The idea is to connect an instrument that measures signals from your body (biological signals) and converts those signals to data that can then be analyzed. The problem for this challenge is to design a wearable device that tracks biological data (pulse rate and movement) and uses this to provide feedback on the activity level. Remember, your design should be small and not get in the way of the wearer, and of course, you should try to make it look cool!



A **Defining engineering problems** involves stating the problem to be solved as clearly as possible in terms of criteria for success and constraints or limits.

B **Designing solutions to engineering problems** begins with generating a number of possible solutions, then evaluating those solutions to see which ones best meet the criteria and overcome the constraints.

C **Optimizing the design solution** involves a process in which solutions are systematically tested and refined, and the final design is improved by trading off less important features for those that are more important.

STEP 1:

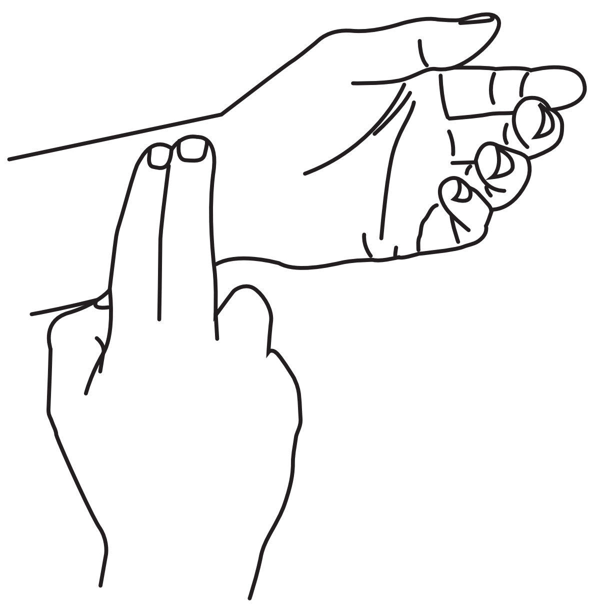
If you recall, the **constraints** for your engineering design problem include: cost, only two sensors, 90 minutes to build, and visually pleasing. Think about your design for the health monitor using the two sensors and small computer (The THING), and sketch it in the space below.

SKETCH DESIGN HERE

STEP 2

The pulse oximeter sensor measures pulse over time. Pulse in this case is the number of times the heart beats per minute. A resting heart rate is the lowest pumping frequency for a person not moving and is usually between 60 and 100 beats per minute. Physical exercise will elevate the heart rate.

By placing two fingers on your wrist, measure and record your resting heart rate for 30 seconds. Multiply your result by two to calculate beats per minute (60 seconds), then record your answers in the chart to the right. For example, engineer 1 has a pulse of 35 beats in 30 seconds; 35 x 2 = 70 (beats per minute). To find the average, add up all the scores and divide by the number of scores, for example, (70 + 75 + 90 + 80) = 315. There are four scores so take 315/4 = 78.75 beats per minute.



ENGINEERS	ENG. 1	ENG. 2	ENG. 3	ENG. 4	GROUP AVERAGE
Pulse					

Have you done all of Part I? Check off each item when you have completed it.

- ☐ **1. Sketched the design of your health monitoring device.**
- ☐ **2. Measured and recorded the resting heart rate of each person in the group.**
- ☐ **3. Calculated the group average of the resting heart rates and recorded it.**

PART II

DEVICE LEARNING

CHALLENGE

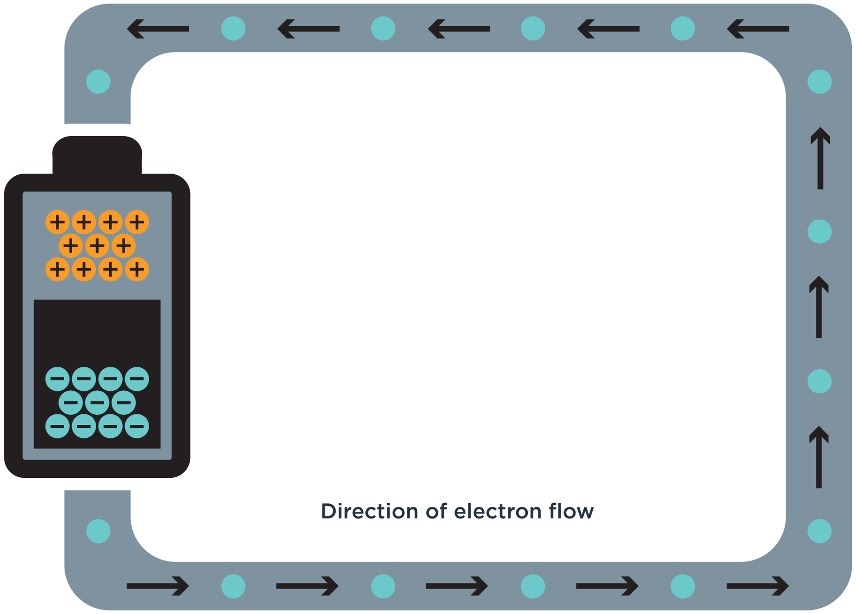
(10 MINUTES)

A BASIC CIRCUIT

In order for electricity to do any work, it needs to be able to move. It's kind of like a blown-up balloon; if you pinch it off, there is air in there that could do something if it's released, but it won't actually do anything until you let it out.

Electricity wants to flow from a higher voltage to a lower voltage. This is exactly like the balloon: the pressurized air in the balloon wants to flow from inside of the balloon (higher pressure) to outside of the balloon (lower pressure). If you create a conductive path between a higher voltage and a lower voltage, electricity will flow along that path. If you insert a useful component into that path like an LED, the flowing electricity will do some work for you, like lighting up that LED. (Please note that if you put nothing in that path to 'resist' the flow of electricity, it will flow very fast and cause the system to heat up and be damaged.)

So, where do you find a higher voltage and a lower voltage? Here's something really useful to know: **every source of electricity has two sides.** You can see this on batteries, which have metal caps on both ends. In batteries, these sides, called **terminals**, are named **positive (+)**, and **negative (-)**. If we connect the positive side of a voltage source through something that does some work, such as an LED, and back to the negative side of the voltage source, electricity, or current, will flow.

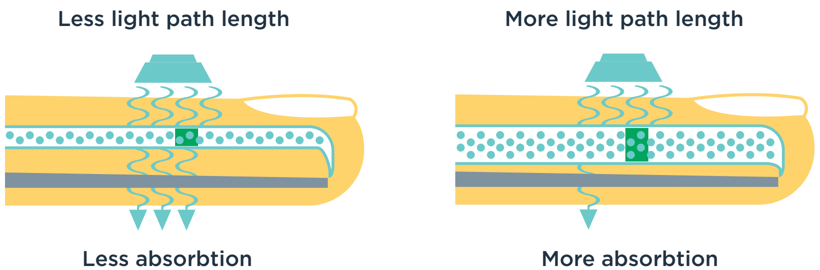


A simple circuit with electrons moving through the conductive material.

CAUTION – this will short circuit a battery causing heat and potentially a fire!

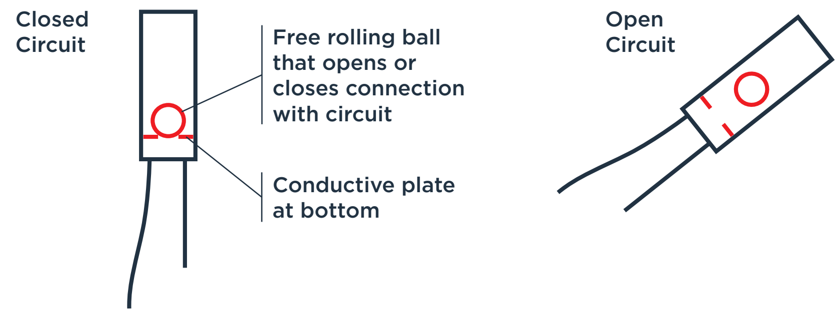
THE PULSE OXIMETER

A pulse oximeter measures the amount of light that travels through an artery (tubes in the body that carry blood from the heart). The amount of light received by the light sensor depends on the amount of blood the light has to pass through, as well as the amount of oxygen in the blood. Since the artery expands each time the heart pumps, the light signal decreases and the pulse can be detected as a change in the sensor's signal.



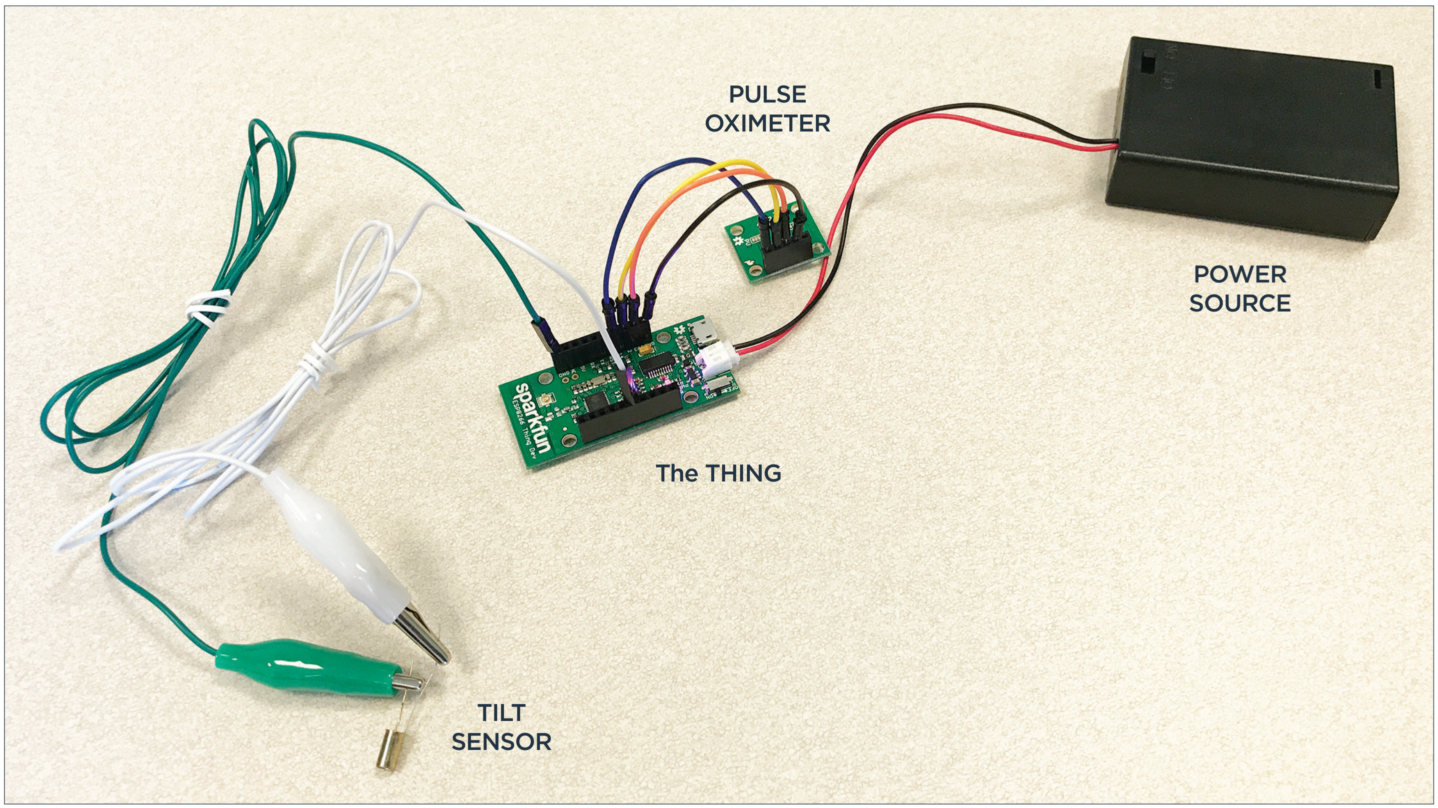
THE TILT SENSOR

The tilt sensor uses a small metal ball that moves when the sensor is tilted. There is a conductive plate at the bottom of the tilt sensor, so when the ball makes contact with the plate, it closes the circuit.



OVERVIEW OF THE ASSEMBLED COMPONENTS

The diagram below provides an overview of the connections between the sensors, the ESP8266 computer (The THING) and the power source. The components are connected using jumper wires and alligator clips as per the diagram below. You will find kit building instructions on page 17.



PART III

BUILD

STEP 1: CONNECT THE POWER

1. Check that the power switch on The THING is in the "off" position.

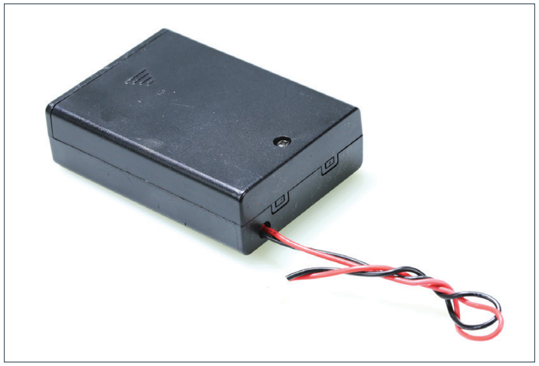
2. Open the power supply with the supplied screwdriver and insert three AA batteries.

3. Connect the power supply to The THING.

4. Turn on the power supply by sliding the power switch to the 'On' position.

5. Turn on The THING by sliding the small switch to the 'On' position. You will see a light appear on The THING.

*Note: Both the Power Supply and The THING must be turned on for the device to function.



STEP 2: GET CONNECTED

One of the great things about The THING is that it has the ability to act like a webserver, meaning that if you connect to it through a standard browser on your device (laptop or mobile device), it will display a webpage.

To connect one THING to one device:

1. On your device, open the Wi-Fi connections and select the 'Incredible Wearables' network. If your device does not connect the first time wait 30 seconds and try again Sometimes it may take multiple tries to connect.

2. Once connected, open an internet browser and enter 192.168.4.1 into the address search bar.

When running more than one THING at the same time, follow steps on page 18.

IMPORTANT!

If you are using five or more devices at the same time we recommend changing The THING's SSID (wireless network name) before your event.

- The estimated time it will take to change the SSID is 30-60 minutes depending on the number of devices.
- This process will require a USB-A to USB-B micro cable.
- For detailed instructions visit www.4-h.org/NYSD and click the "Guides & Resources" tab.

To connect 2-4 THINGs to multiple devices:

Each THING can broadcast its SSID (the name of its wireless network) as either Incredible Wearables, or Incredible Wearables 1-3. When operating more than one THING at the same time they must each have a unique SSID. In this step you will be using jumper wires to connect pins on each THING, so that each THING connects to a separate network.

Tip: Label each THING with its SSID so you can keep track of them.

1. Make sure all things are turned off.

2. Use the jumper wires to set each THING with a unique SSID. These wires will stay connected throughout the challenge.

    THING 1: Connect pin 16 to pin 0 and connect pin 13 to pin GND. THING 1 will now connect to the network 'Incredible Wearables1'

    THING 2: Connect pin 16 to pin 0 and connect pin 12 to pin GND. THING 2 will now connect to the network "Incredible Wearables2'.

    THING 3: Connect pin 16 to pin GND. THING 3 will now connect to the network 'Incredible Wearables3'.

    THING 4: Connect pin 16 to pin 0. THING 4 will now connect to the network 'Incredible Wearables'.

3. Turn your THINGs on.

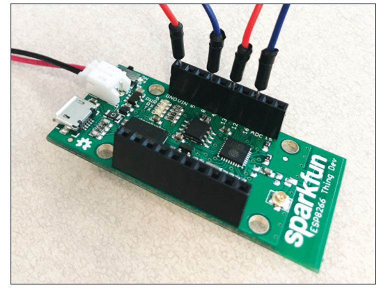
4. On your device, open the Wi-Fi connections and select one of your networks. If your device does not connect the first time wait 30 seconds and try again. Sometimes it may take multiple tries to connect.

5. Once connected, open an internet browser and enter 192.168.4.1 into the address search bar.

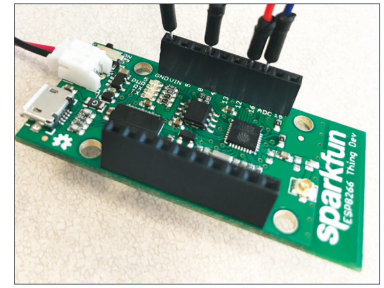
6. Repeat steps 4 and 5 for each THING that had its network changed.

To connect 5+ THINGs to multiple devices:

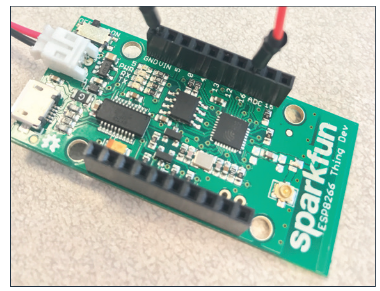
Connecting more than 5 devices will require a USB-A to USB-B micro cable and will take 30-60 minutes. Make sure you do this before your planned 4-H NYSD event. For detailed instructions visit www.4-h.org/NYSD and click the "Guides & Resources" tab.



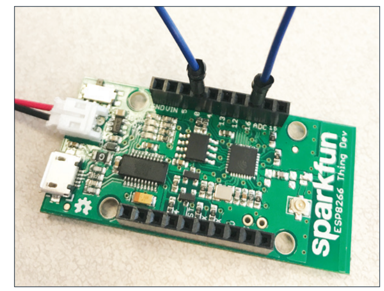
THING 1



THING 2



THING 3



THING 4

TROUBLESHOOTING

If you are experiencing trouble connecting to the Incredible Wearables Network. Please try:

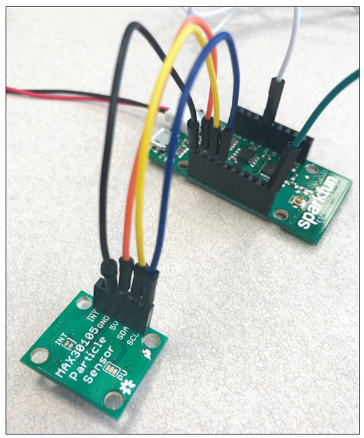
- Opening your device's network connections and disconnect from any other wireless networks by selecting 'forget network'.
- Find the on/off switch on The THING. When your device is trying to connect to the Incredible Wearables network turn The THING off and then immediately back on again.
- For detailed troubleshooting instructions visit **www.4-h.org/NYSD** and click the "Guides & Resources" tab.

STEP 3: CONNECT THE PULSE OXIMETER

In this step, you will use jumper wires to connect the pins on the pulse oximeter to The THING.

1. Turn off the THING
2. Use the chart below to make the proper connections between the pulse oximeter and The THING

Pulse Oximeter Pin	The THING Pin
5V	3v3
GND	GND
SDA	2
SCL	14



Pulse Oximeter connection to The THING

STEP 4: TILT SENSOR

In this step, you will connect the tilt sensor to the THING using alligator clips.

1. Connect the longer leg of the tilt sensor to pin 4 on The THING
2. Connect the shorter leg of the tilt sensor to GND on The THING.

STEP 5: TESTING

1. Power on the THING. A blue light on the THING indicates that the Tilt Sensor is working. As you move the tilt sensor a blue light will turn off and on as the sensor's circuit opens and closes.. A red light will be lit on the pulse oximeter to indicate it is working.
2. Finally, place the pulse oximeter on one of your team member's index fingers. Have the textured side of oximeter against the surface your finger. On the pulse oximeter, the side opposite the pins will be against your finger.
3. Refresh your browser displaying the incredible wearables data at 192.168.4.1. Scroll down to the bottom of the page to see your most recent data.

Have you done all of Part III? Check off each item when you have completed it.

- [ ] **1. Connected the power source to The THING.**
- [ ] **2. Connected The THING to the "Incredible Wearables" network**
- [ ] **3. Opened the webpage 192.168.4.1 in your internet browser and viewed the Incredible Wearables page.**
- [ ] **4. Connected the pulse oximeter to The THING using jumper wires.**
- [ ] **5. Connected the tilt sensor to The THING using alligator clips.**
- [ ] **6. Placed the pulse oximeter on one of your team member's fingers and made sure it is recording data.**
- [ ] **7. Moved the tilt sensor back and forth to make sure that the data are being displayed on your device.**

PART IV

DATA COLLECTION

CHALLENGE

In this part of the challenge, you will complete the build of your team's health monitor and then begin to collect data for the group for both resting pulse and active pulse. Each team member will collect information for each condition and then calculate an average for the entire team. Next, your team will look at optimizing the health monitor by placing the tilt sensor on the arm, elbow, wrist or hand.

STEP 1

It's now time for you to design a way for the health monitor to be wearable using the space to the right to sketch your design. Keep in mind that the final product should be both wearable and visually pleasing. Your pulse oximeter should be placed on the index finger. Design your monitor so that the tilt switch is located on your wrist for this part of the challenge.

What is the engineering problem?

____

____

List the constraints:

____

____

SKETCH YOUR DESIGN
(Also sketch your connections between The THING, the sensors and your power supply.)

STEP 2

In this step, place the pulse oximeter on a team members' index finger and the tilt sensor on their wrist. Record their resting heart rate and the number of steps taken for one minute. Obtain an average resting pulse and the average number of steps taken.

ENGINEERS	ENG. 1	ENG. 2	ENG. 3	ENG. 4	GROUP AVERAGE
Resting Pulse					
Rate of Movement					

STEP 3

Now repeat step two but now have each one of your team members jog in place for one minute and record your answers below. Repeat for all team members.

ENGINEERS	ENG. 1	ENG. 2	ENG. 3	ENG. 4	GROUP AVERAGE
Active Pulse					
Rate of Movement					

STEP 4

Place the pulse oximeter on a team member's index finger. Open the web page (IP address 192.168.4.1) on your device and record their resting pulse rate for one minute, and count the number of steps from the tilt sensor. Once all the data have been collected for each team member, obtain an average resting pulse for the entire team (sum all scores/number of scores).

CONDITION 1
Placement of the tilt sensor on: ______________________________

ENGINEERS	ENG. 1	ENG. 2	ENG. 3	ENG. 4	GROUP AVERAGE
Resting Pulse					
Rate of Movement					
Active Pulse					
Rate of Movement					

CONDITION 2
Placement of the tilt sensor on: ____________________

ENGINEERS	ENG. 1	ENG. 2	ENG. 3	ENG. 4	GROUP AVERAGE
Resting Pulse					
Rate of Movement					
Active Pulse					
Rate of Movement					

Have you done all of part four? Check off each item when you have completed it.

- ☐ **Sketched a design for making your health monitor wearable.**
- ☐ **Reflected on your current iteration.**
- ☐ **Placed the pulse oximeter on each team member's finger and recorded their resting pulse rate for one minute.**
- ☐ **Calculated an average resting pulse rate for the entire team.**
- ☐ **Had each team member jog in place for one minute while wearing the pulse oximeter on their finger and recorded the answers in the chart.**
- ☐ **Totaled an average active pulse rate for your team.**
- ☐ **Placed the tilt sensor on two places besides the wrist for each team member and recorded the pulse and movement data.**
- ☐ **Answered the questions in Step 5 using the group averages.**

STEP 5

Share your group data (but not individual data) regarding the average resting pulse, average active pulse, movement rate and the location of the tilt sensor. How does it compare to the manual method of recording a pulse at the beginning of the challenge? What are the advantages of using a health monitor as opposed to using your fingers to measure a pulse?

Engineering journal entry: You just finished building a wearable technology. What kinds of jobs would use these skills?

____

____

____

PART V

COOL DOWN

CHALLENGE

(10 MINUTES)

SHARING & PROCESSING

In this challenge you acted as part of an engineering team, following the steps of the engineering design process to build and optimize a wearable health monitor. The monitor provides time-series data concerning pulse rate which can be used to determine the relative fitness of the wearer.

Now, as a team, reflect on and share your learning experience through the Incredible Wearables Challenge. Feel free to record your answers on the following **'Engineer Notes'** pages before sharing with the group.

SHARE

SHARE WHAT YOU DID. WHAT DID YOU LEARN?

- How could youth and adults use the information your device gathers to make decisions that could improve their health?
- What could you improve about your device to help youth and adults be more active?

PROCESS

PROCESS WHAT'S IMPORTANT. WHAT WAS IMPORTANT TO LEARN?

- How did planning your design on paper prior to building the health monitor help you with design issues?
- How did learning how the sensors worked help you identify where to place the sensors in your design?

GENERALIZE

GENERALIZE TO YOUR LIFE. HOW WILL IT HELP YOU IN EVERYDAY LIFE?

- What is the benefit of knowing your pulse rate and monitoring your health?

APPLY

APPLY WHAT YOU HAVE LEARNED. HOW WILL IT APPLY TO OTHER SITUATIONS?

- What careers would use the skills learned in this activity?

ENGINEER NOTES

ENGINEER NAMES

DATE

INCREDIBLE WEARABLES

www.4-H.org/NYSD

JOBS IN WEARABLE TECHNOLOGY

- Wearable Technology Electronics Engineer
- Technology Software Developer
- Electrical Engineer, Wearable Devices and Accessories
- Product Manager – Partnerships and Platform
- Wearable Technology in Healthcare
- Digital Marketing
- Software Executive Technology Public Relations
- UX Designer for Wearable Technology
- Associate Director, R&D Informatics Wearable Technology
- Software Developer
- Data Scientist
- Research Coordinator
- Marketing Digital Web Developer
- Artificial Intelligence Engineer
- Software Engineer
- Computer Vision Engineer
- Sensor Innovation (IoT) – Market Research Analyst
- Biomechanical Engineer
- Wearable Technology Developer
- Wearable Computing and Electronic Textiles
- Quality Assurance Automation Engineer
- Hardware Engineer: Board Design
- Mobile App Developer
- Fashion Designer
- Neural Scientist
- Field Technician
- Precision Agriculture Researcher

GOING FURTHER

The health monitor is a great stepping stone to other DIY electronic projects. You may choose to continue to optimize your current health monitor - either aesthetically or by investigating other sensors that could be added to The THING. Additional resources are available at **Sparkfun.com/NYSD2017**.

If you would like to know more about what exciting careers involve wearable technologies, please visit**www.4-H.org/NYSD** and do the career activity.

THANK YOU!

Special thanks to **SparkFun Electronics** for supporting the development of the *Incredible Wearables* challenge.

INCREDIBLE WEARABLES

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