**Robot Mask Challenge**

**Description**

In this activity, students are exposed to feedback loops and latency (the delay between command and response) by wearing a blindfold mask containing LED lights and using it as their only source of information while navigating through a complex set of obstacles. Students develop a communication protocol to allow one student (the “controller”) to direct the other (the “robot”) through the obstacles quickly and efficiently, using a code system to communicate instructions with only LED lights.

This activity helps students by:

* Focussing attention on the wide variety of inputs and feedback mechanisms provided by human senses
* Illustrating the challenge of operating in an environment where feedback is limited and subject to latency
* Requiring teamwork and cooperation to accomplish a task
* Giving them practice using the terms and tools needed to construct a simple electronic circuit

## Lesson Outcomes

Students will be able to:

* Describe the types of feedback loops provided by human senses
* Describe the steps in a communication protocol and relate them to human conversations
* Explain the challenges of latency in control loops
* Create a simple electronic circuit
* Use appropriate terminology to describe the components in their electronic circuit

## Assumptions

Students will have basic understanding of the following:

* Use of simple hand tools:
  + Wire strippers
  + Hot glue
  + Soldering iron
* Online video games
* Stripping and soldering wires



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* Relieving strain on wires
* Constructing a mask
* Creating a circuit using an LED, resistor, battery and switch

## Key Terminology

**Anode**: the “positive” side of an electrical component.

**Cathode**: the “negative” side of an electrical component, often marked with a distinguishing feature such as a flat side on LEDs, or a stripe on electrolytic capacitors.

**Communication protocol**: a set of rules for transmitting information.

**Feedback loop**: an iterative process in which an output signal is continually modified in response to the effect of the output signal. An example would be a car’s cruise control system, where the throttle position (the output) is modified based on the vehicle speed (the effect of the output).

**Latency**: the delay between the transmission and reception of a signal.

**LED**: Light Emitting Diode. A device that converts electricity into light when electrons cross a semiconductor P-N junction. The wavelength, or colour, of the light is determined by the energy drop across the P-N junction.

**Loading Zone**: the starting place where the payload will be found. Cyborgs will move the payload from the Loading Zone to the Objective Zone.

**Objective Zone**: the ending place where the payload should successfully end up to score points.

**Payload**: the object or objects that will be moved during the challenge from the loading zone (starting place) to the objective zone (ending place).

**Sensor**: a device that provides information about the environment to a device or robot.

**Solder**: a low melting point alloy for connecting metallic components. Typically used in electronics, plumbing and jewellery.

**Strain relief**: a design feature, component or mechanism intended to transfer stress into a flexible connection in such a way as to reduce fatigue and stress concentration in the connection.

## Estimated Time

Total time 5–8 hours:

1–2 hours of lesson time

3–4 hours of build and testing time 1–2 hours of activity time

## Recommended Number of Students

Two students per mask to a maximum of 20 students, based on *BC Technology Educators' Best Practice Guide.*

**Facilities**

* Any classroom or large area such as a cafeteria or gymnasium
* A multipurpose tech studies shop or lab with access to soldering irons
* Space to navigate with variable hazards for navigation
* Fixed obstacles: workbenches, desks, other permanent or heavy large objects
* Random obstacle: garbage can, chair or other movable solid object

## Tools

* Soldering iron
* Drill press (or suitable hand drill arrangement)
* Whitney punch (if available)
* Wire strippers
* Screwdrivers
* Scissors
* Hot glue guns

## Materials

* LEDs
* Multi-conductor stranded wire
* Batteries and battery packs
* Switches
* Mask-making material (poster-sized card stock, tape)
* Mask-decorating tools (felt pens, glue stick, hot glue, paint)

## Resources

* The “Super Cyborg” Robot Mask Challenge (on page 8)
* Robot Mask Challenge Score Sheet (on page 7)
* Instructions for Building the Control Board (on page 10)
* Mask Examples (on page 15)
* Sensors and Control Loops Discussion Suggestions (on page 17)
* Communication and Control Loops Discussion Suggestions (on page 19)

## Additional Support Materials

“Super Cyborg” Robot Mask Challenge handout

## Procedure

Day 1: Lesson: Introduce activity

Explain the challenge

Demonstrate mask-building procedure

Activities: Put students into teams

Begin mask construction

Day 2: Lesson: Sensors and control loops (see “Resources” for discussion guide) Communication protocols (see “Resources” for discussion guide)

Activities: Complete mask construction and decoration Develop communication protocol

Day 3: Lesson: Building control board

* LEDs – anode and cathode
* Resistors
* Switches
* Batteries – positive and negative
* Strain relief: emphasize its importance to ensure reliable communication

Activities: Build control board

Install LEDs in mask

Connect board and LEDs using proper strain relief

Day 4: Lesson: Review the challenge

Activities: Assist students to complete unfinished masks Practice runs for students with completed masks

Day 5: Lesson: Review sensors, control loops, communication protocols Review challenge rules

Activity: Robot mask competition

Follow-up: Quiz on sensors, feedback loops, communication protocols and mask wiring. Teachers should customize their quiz based on classroom discussion and topics covered.

## Assessment

The evaluation of this lesson is based on the learning outcomes outlined above.

Prior to teachers using the evaluation grid it is recommended that students perform some form of peer-assessment and self-assessment.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Outcome To Be Assessed** | **6** | **5** | **4** | **3** | **2** | **1** | **0** |
| **Outcome 1** | **Describe the types of feedback loops provided by human senses** | | | | | | | |
| **1.1** | Can describe human feedback loops. |  |  |  |  |  |  |  |
| **Outcome 2** | **Describe the steps in a communication protocol and relate them to human conversations** | | | | | | | |
| **2.1** | Understands and can describe communication protocol. |  |  |  |  |  |  |  |
| **2.2** | Relates protocols to human interaction. |  |  |  |  |  |  |  |
| **Outcome 3** | **Explain the challenges of latency in control loops** | | | | | | | |
| **3.1** | Understands the concept of latency. |  |  |  |  |  |  |  |
| **3.2** | Can describe the issues latency presents in control loops. |  |  |  |  |  |  |  |
| **Outcome 4** | **Create a simple electronic circuit** | | | | | | | |
| **4.1** | Can identify circuit components. |  |  |  |  |  |  |  |
| **4.2** | Can assemble a functional circuit to achieve a goal. |  |  |  |  |  |  |  |
| **Outcome 5** | **Uses appropriate terminology to describe the components in their electronic circuit** | | | | | | | |

### Total Points:

|  |  |  |
| --- | --- | --- |
| 6 | Completed successfully at the exceptional level | Exemplary |
| 5 | Completed successfully at higher than the expected level | Accomplished |
| 4 | Completed successfully to the expected level | Emerging |
| 3 | Attempted successfully at the minimum level | Developing |
| 2 | Attempted - Unsuccessful - Close to Successful | Beginning |
| 1 | Attempted - Unsuccessful | Basic |
| 0 | Not Attempted | N/A |

**Comments:**

**Extension Activities**

Challenge the students to navigate the school using their masks.

Challenge the students to identify robots that use sensors to develop paths and navigate:

* Are self-driving cars “robots”?
* Do “Roombas” learn to navigate?

# Robot Mask Challenge Score Sheet

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | **Penalities** | | | | | |  |  |
| **First Partner** | **Second Partner** | **Base Score**  **# of LEDS2** | **Decoration Style** | **Try**  **#** | **Noise (10)** | **Mask (20)** | **Minor Obstacle (1)** | **Major Obstacle (1)** | **Random Obstacle (1)** | **Accuracy Score** | **Time in Seconds** | **Total Score** |
|  |  |  |  | 1 |  |  |  |  |  |  |  |  |
|  |  |  |  | 2 |  |  |  |  |  |  |  |  |
|  |  |  |  | 3 |  |  |  |  |  |  |  |  |
|  |  |  |  | 1 |  |  |  |  |  |  |  |  |
|  |  |  |  | 2 |  |  |  |  |  |  |  |  |
|  |  |  |  | 3 |  |  |  |  |  |  |  |  |
|  |  |  |  | 1 |  |  |  |  |  |  |  |  |
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|  |  |  |  | 3 |  |  |  |  |  |  |  |  |
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|  |  |  |  | 3 |  |  |  |  |  |  |  |  |

# The “Super Cyborg” Robot Mask Challenge

One partner is the robot, and the other is the controller. Do your job. Do it well. Do it fast. Victory is yours!

### The Challenge

Working together, you and a partner will:

1. Create a “robot mask” that will turn one partner into a human-machine cyborg.
2. Create a “control board” that will allow one partner to control the actions of the cyborg.
3. Create a communication protocol to send information from the controller to the robot.
4. Practise your communication and control systems to complete a task.

### The Rules

1. The mask must completely obscure all visual input from the surroundings.
2. The only communication that the cyborg may receive shall be from the LEDs.
3. The LEDs must be controlled by switches on a control board.
4. The control board must be operated by the controller.
5. The control board must be connected to the mask by a cable.
6. The cable must remain slack at all times when controlling the cyborg.
7. The “payload” will be provided by your teacher. At the beginning of your task the payload will be located in the “loading zone” as defined by your teacher.
8. The start position will be indicated by your teacher with a mark on the floor.
9. At the beginning of the task the cyborg must have a foot in contact with the start location.
10. The “objective zone” will be defined by your teacher.
11. The goal is to move the payload as quickly as possible from the loading zone to the objective zone.
12. Placing the payload close to the objective will improve your score.
13. You may not throw the payload. You must carry it from the loading zone to the objective zone.
14. The “random obstacle” is moved by the teacher between each run. The random obstacle is moved after the cyborg is wearing the mask and is in the start location. Contacting the random obstacle results in a 10-point penalty.

### Self-assessment Scoring

The following are the rules for self-assessment scoring. They can be used alongside the teacher evaluation grid.

The goal is to keep your score as low as possible. The score is calculated as follows:

Total Score = Base Score + Time Score + Accuracy Score + Penalty Score – Decoration Score

The **base score** is the number of LEDs, squared: 1 LED is a base score of 1; 6 LEDs is a base score of 36. Design your communication protocol wisely to use the minimum bandwidth, but beware: limited bandwidth might increase your latency!

**Time score** is the time in seconds from when the cyborg’s foot leaves the start position until the cyborg releases the payload and raises both hands above their shoulders to indicate they are finished.

**Accuracy score** is the square of the distance (in centimetres) of the nearest edge of the payload to the objective zone. If the payload covers any or all of the objective zone, the accuracy score is zero.

**Penalty scores** are assessed by the teacher according to the chart below. Penalties may be assessed even for “accidental” or “minor” offenses. It is the team’s job to ensure that they avoid penalties. Teams that intentionally take penalties may be disqualified. If a penalty gives a team an unfair advantage they may be disqualified or required to re-start their run.

|  |  |
| --- | --- |
| **Offense** | **Penalty Points** |
| Making noise, even briefly and unintentionally, or any other attempt to communicate with the cyborg using something other than the LEDs. | 10 |
| Having the mask “slip” or move for any reason such that it allows even the possibility of seeing outside the mask. | 20 |
| Contacting a “fixed obstacle” such as a chair, desk or other obstacle. Minor offenses are unintentional contact where the cyborg backs off immediately. A major offense is where the cyborg follows the obstacle, obtaining position or orientation information. | Minor offense: 1  Major offense: 10 |
| Contacting the random obstacle. This penalty is applied only once. | First offense: 10  Subsequent offenses: 0 |

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| --- | --- | --- |
| Decoration score is: | 0 | For an undecorated mask |
|  | 5 | For a basic mask with simple artwork or decoration |
|  | 10 | For a mask with creative or detailed artwork or decoration |

See Robot Mask Challenge Score Sheet on page 7

**Instructions for Building the Control Board**

The control board is a simple electronic circuit consisting of a number of LEDs, each with a current-limiting resistor and controlled by a pushbutton switch. The power source is typically a 9 V battery. Figure 1 shows the schematic for a control board with four LEDs. Students may choose to use as few or as many LEDs as they feel will be optimal for completing the challenge.

Note that the battery and switches will be located on the control board, while the LEDs and resistors will be located in the mask. This requires a cable to connect the control board to the mask. A typical cable length is roughly 2 m long— enough to allow a reasonable amount of slack in the cable during the competition.

BAT1 9V

Each team will require a cable with one conductor per LED plus one conductor to supply power to the LEDs. For a set- up with four LEDs, a five-conductor cable will be required. It is fine to use a cable with extra conductors and leave some unused.

There are a number of suitable cable types (Figure 2). The preferred cable type is the multi-coloured ribbon cable (sometimes called *rainbow* cable) at the right of the photo, as it is lightweight, flexible and can be easily separated to provide the correct number of conductors for each team.

The wire colours are useful for tracing connections between the control board and the mask.

LED1

LED2

LED3

LED4

R1 470R

R2 470R

R3 470R

R4 470R

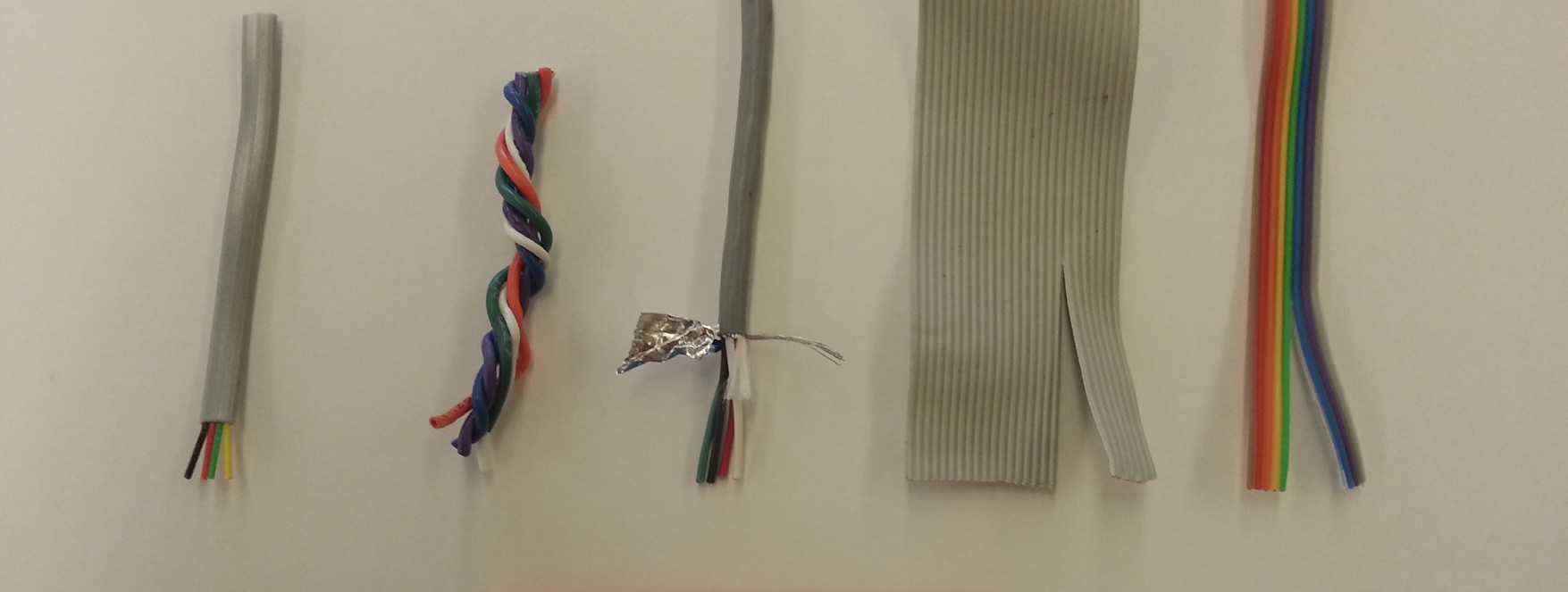
SW1

SW2

SW3

SW4

**Figure 1—**Control board schematic

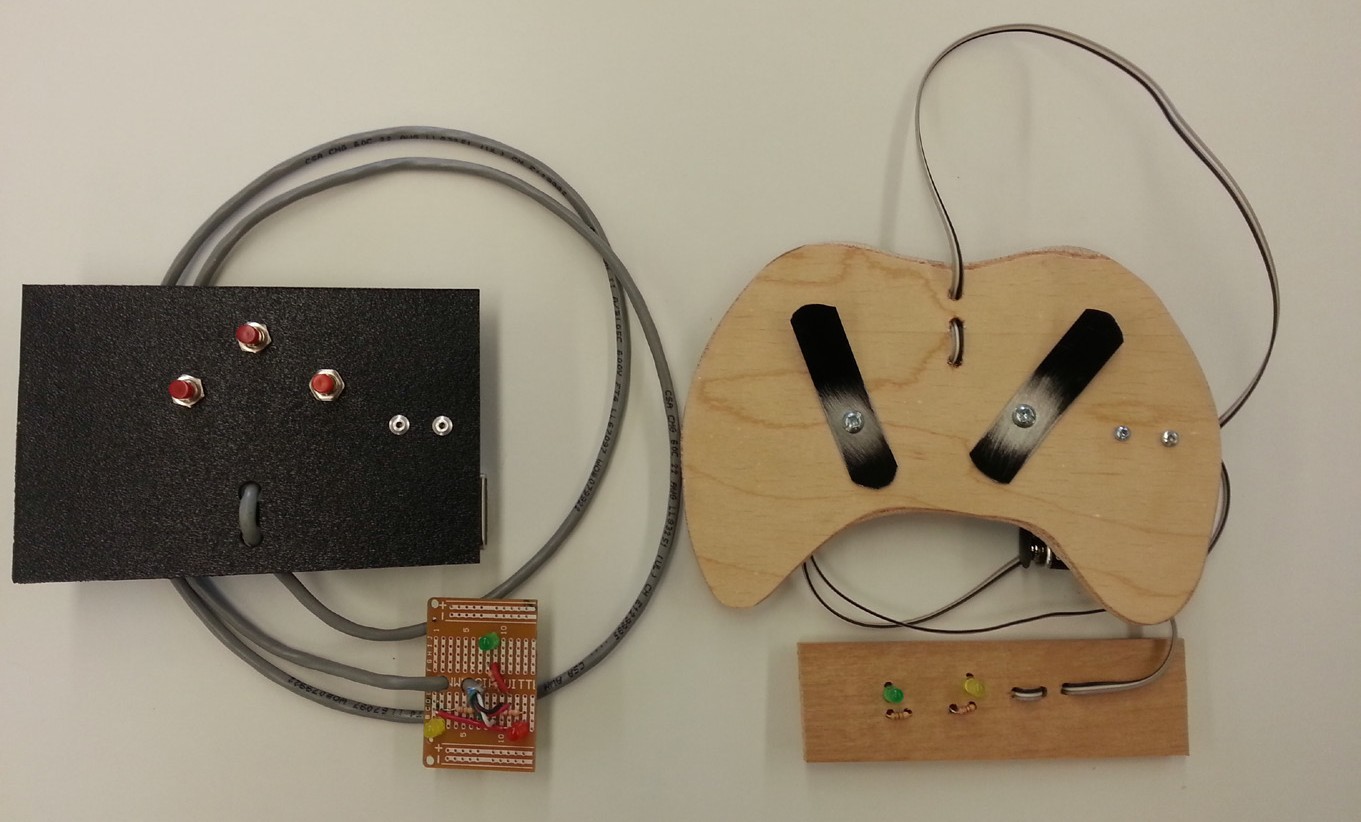


**Figure 2—**Various kinds of multi-conductor stranded wire

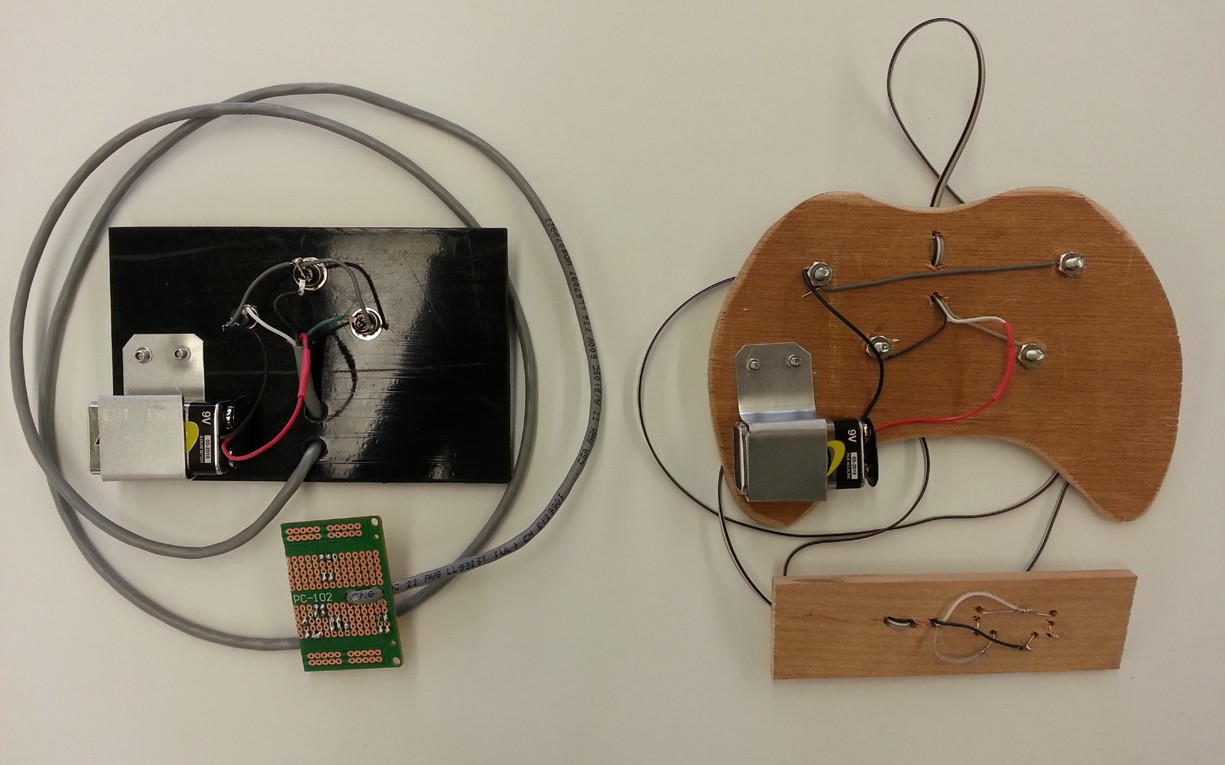
Ideally the cable will be made of stranded wire, as solid-core wire is less flexible and has a tendency to fatigue (break) at inopportune times. Students may notice that solid-core wire is commonly used in stationary or architectural applications, while stranded wire is used in mobile applications subject to flexing or vibration, such as vehicles and machinery.

There are a number of ways to create the control board, depending on the tools and resources available. Two different constructions are shown (Figures 3 and 4), one using ABS plastic, purchased switches (momentary, normally open (“N.O.”) pushbutton switches), and the other a “perfboard” prototyping board to hold the LEDs and resistors in place.

The other control board uses offcuts of wood and plywood along with screws and manufactured switches (Figure 5). The switches may be manufactured of any reasonably flexible sheet metal. In this case they use the metal strapping that is used to secure stacks of lumber. This strapping can usually be obtained for free from a local lumber supply store. (Note that the paint on the strapping must be sanded off in order to ensure an electrical connection with the screws.)



**Figure 3—**Two styles of control board - front



**Figure 4—**Two styles of control board - back



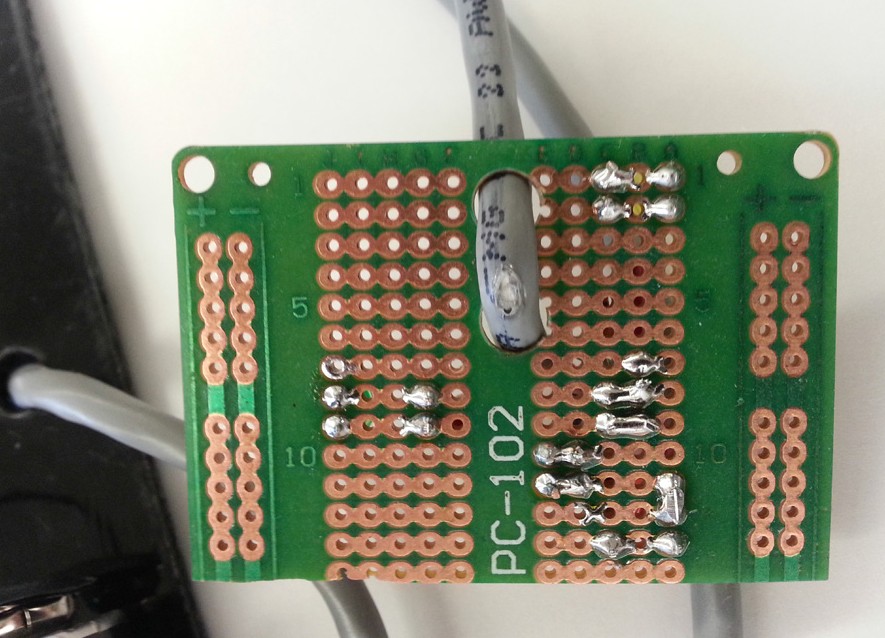
**Figure 5—**Control board with custom-built switches

Note the strain relief provided by weaving the cable through holes drilled or punched in the control board. While there are many ways to provide strain relief, it is essential for reliable robot operation. Cables that lack strain relief will pull on the electrical connections, causing them to fail.

The battery mount is made by bending an offcut of sheet metal to clip the battery in place. This prevents strain in the wiring between the battery and control board and allows batteries to be shared between teams or easily returned at the end of class. The batteries are one of the more expensive components in this project.

Electrical connections to the switches are made by soldering wires in place. Connections on the wooden board are made by wrapping the wire around the screw, then tightening the nut. This makes it easier to adjust the wiring should the students make a mistake.

For mounting the LEDs inside the mask it makes sense to build a board to hold the LEDs and resistors. This ensures that the cable can be strain relieved at the robot end and allows the LEDs to be tested before being installed in the mask. Again there are a number of options for constructing the LED mounting board, including perfboard (Figures 6 and 7) and a custom-built equivalent made of offcuts (Figures 8 and 9).



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|  |  |  |
| **Figure 6—**Perfboard - front |  | **Figure 7—**Perfboard - back |

|  |  |  |
| --- | --- | --- |
|  |  |  |
| **Figure 8—**Wood LED mount - front |  | **Figure 9—**Wood LED mount - back |

Building and testing the LEDs and control board before installing them in the mask also allows a team of two students to work in parallel: one can be working on the controls while the other works on building or decorating the mask.

Once the control board and mask are completed they can be joined together by inserting the LEDs into the mask (Figures 10 and 11) and holding them in place with tape or hot glue. Note that additional strain relief between the cable and the mask may need to be provided, usually by taping the cable securely to the mask.

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|  |  |  |
| **Figure 10—**Wood board in cardboard mask |  | **Figure 11—**Perfboard in cardstock mask |

The students may now don their masks and practise their communication protocol.



### Troubleshooting

If there are problems, try the following:

1. Check the LED polarity. The anode, or positive side, is the rounded side of a standard 5 mm LED and should be connected to the positive side of the battery. The cathode, or negative side of the LED, should have a flattened side and should connect (via a resistor and switch) to the negative side of the battery.
2. Check the battery with a voltmeter. A 9 V battery should be delivering at least 8 V.
3. Use a voltmeter to check the voltage across the LED and resistor when the switch is pressed “on.” If you see a voltage drop across the LED and resistor but the LED does not turn on,

it is possible that the LED has been burned out. This happens when an LED is connected to a power supply without a current-limiting resistor. Replace the LED. If you do NOT see a voltage drop, then investigate for a problem with the wiring or switch.

### Using Different Batteries

There is no requirement to use a 9 V battery. Any battery or battery pack between 3 V to 12 V should work fine.

### Using Different Resistors

Just about any resistor between 300 ohms and 2000 ohms should work okay. Ideally your resistor is chosen to work with your battery voltage and LED “forward voltage drop” to deliver 5–20 mA of current through each LED. For most LEDs the forward voltage drop is roughly 2 V. For blue or white LEDs the voltage drop is closer to 3 V. To determine the resistor value, use the following formula and select something that you have in stock that is close to this value:

(Battery Voltage – Forward Voltage Drop) × 100 = Resistor Value

It is necessary to use one resistor per LED to ensure equal current to each LED. If the circuit shares one resistor across all the LEDs, then all the LEDs will dim whenever more than one LED is turned on.

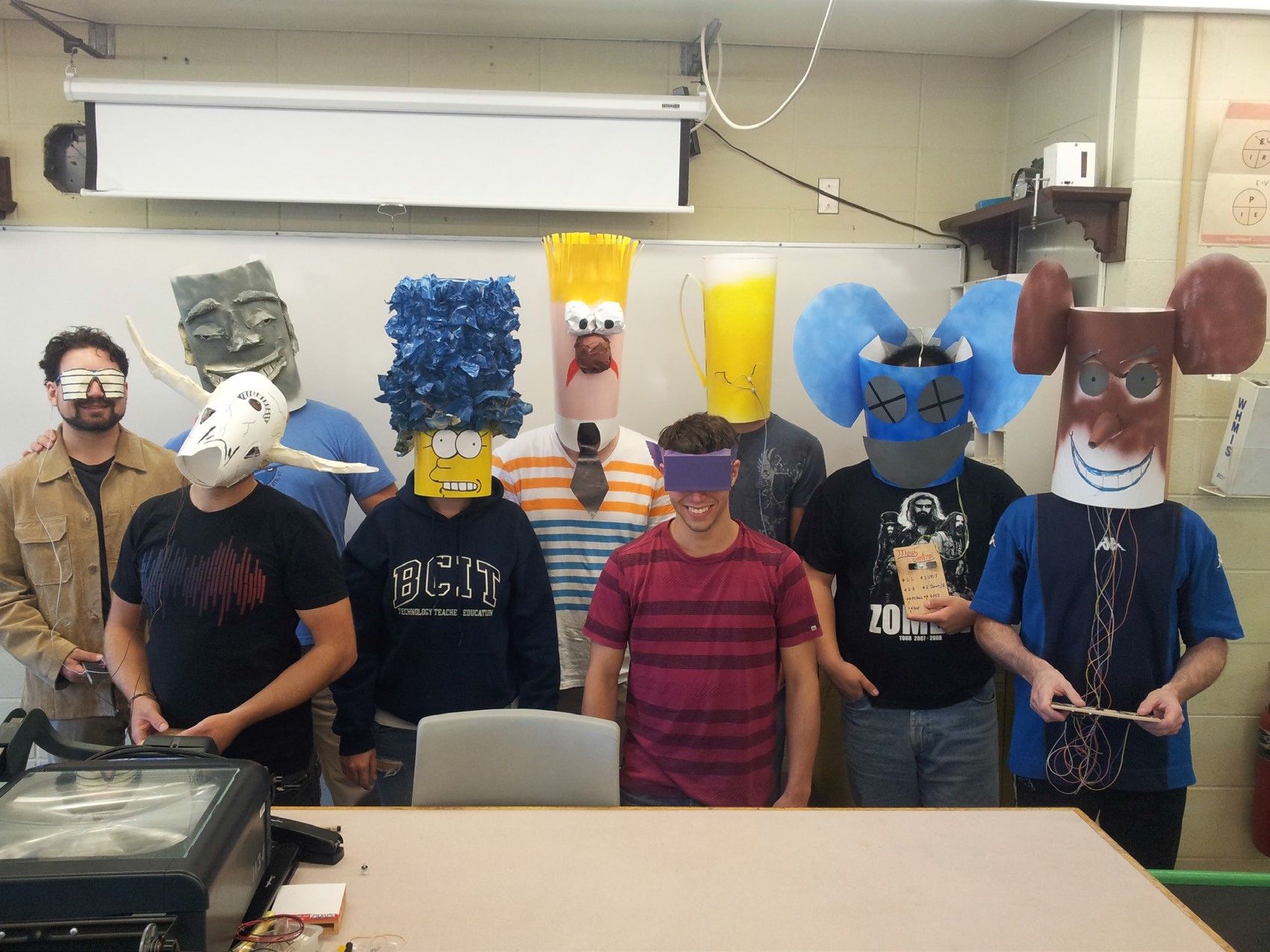
## Mask Examples

The most basic mask consists of a cylinder of cardstock, taped to fit securely over the cyborg’s head with the LEDs mounted on the inside so they are visible to the robot. Graphics can be added to the exterior for personalization, depending on the time available and the creativity

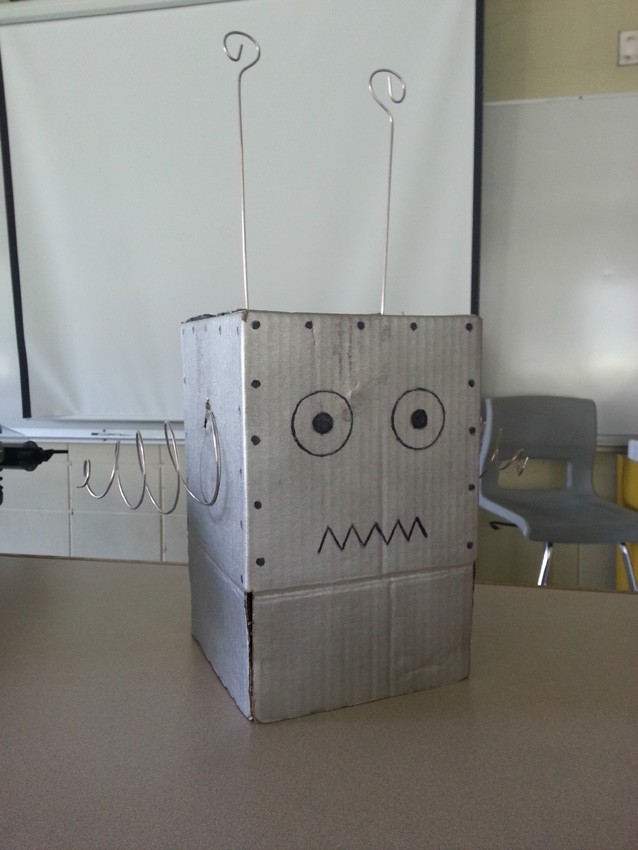
of the students. Figures 12, 13 and 14 give some idea of the wide range of design options available. Note, however, that it does take additional time and resources to design and create unique masks.



**Figure 12—**The BCIT TTED Class of 2012 shows off their robot masks



**Figure 13—**The BCIT TTED Class of 2013 shows off their robot masks



**Figure 14—**A robot mask created from a cardboard box

## Sensors and Control Loops Discussion Suggestions

### Human Senses

Ask students to describe what human senses they use to control their body:

#### How do they know where they are?

* Sight: References known objects or locations. Provides distance information to objects.
* Touch: In a dark room they can follow a wall. They stop when they hit an object.

#### How do they plan a path?

* Sight: Identify goal and obstacles; plan shortest, safest route.
* Memory: What path worked best last time?
* Learning: What path worked best for the other people who tried to navigate this path?

#### How do they place an object precisely?

* Sight: They can see where they are putting it in reference to other objects.
* Touch: They can feel other objects and place the object in relation to those objects.
* Proprioception: They can feel the position of their body, limbs and digits.

#### How do they receive feedback on their progress?

* Sight: They can see how they are progressing.
* Hearing: They can hear people yelling “Stop” or “Go Left”—low latency communication!

### Robot Sensors

What sensors do robots have to control their “body”?

#### How do they know where they are?

Sight: Visual sensing is a big challenge for robots.

Simple “sight” sensors include:

* Rangefinders: can identify the distance to an object.
* Infrared
* Ultrasonic
* Laser: Colour sensors can identify colours at short range. Object sensors can identify the presence or absence of an object.

Complex “sight” sensors include:

* Video cameras: image processing is a real challenge: How does a robot know what a “table” looks like?
* LIDAR: scanning laser beams develop a 3D “point cloud” view of surroundings.
* Structured light imaging: Xbox Kinect sensors.

Touch: Robots are good at simple touch sensing but poor at complex sensing.

* Mechanical switches: “Limit switches” are very common and reliable.
* Pressure sensors: Can detect how hard something is being touched.
* Texture sensors: Robots have real difficulty identifying rough, wet or fuzzy surfaces.

Triangulation: Sensing their location relative to known objects

* GPS: measures the distance to orbiting satellites.
* Other radio transmitters with known locations can also be used.
* Cell phone towers and Wi-Fi hotspots can be used.

Dead reckoning: Measuring distance travelled from a known point.

* Stepper motors used in CNC machines and 3D printers move a very precise distance.
* Encoders measure how far a wheel has turned.
* Accelerometers measure how fast a robot is moving.
* Gyros track whether a robot is turning.

#### How do they plan a path? This is a big challenge for autonomous robots and self-driving vehicles.

Sight: Robots can use visual sensors to identify objects. How do they recognize what the objects or obstacles are?

Memory: Can they relate the objects they sense to a map? Learning: Can they create their own map of an unknown area?

#### How do they place an object precisely?

Sight: Optical sensors can provide precise location relative to known markings. Touch: Switches and object sensors can place an object precisely.

Proprioception: Encoders and potentiometers can detect the position of joints and slides.

#### How do they receive feedback on their progress?

Sight: Optical sensors can measure final products for quality control.

Electrical current sensors: Can detect when motors are stalled, jammed or stuck. Human oversight: “Kill” switches and safety interlocks prevent serious damage.

## Communication Protocol Discussion Suggestions

### Human Communication

#### What are human communication protocols?

How do you initiate a conversation?

How does someone know you are talking to THEM?

How do you know the other person is ready to communicate? How do you check to ensure the other person heard you?

How do you check to make sure they understood you?

How do you avoid “cross-talk” (having more than one person talk at once)? Is security an issue?

How do you make sure no one else intercepts your communication? How do you terminate a conversation?

Do different cultures or language groups have different protocols?

### Robot Communication

Robot communication protocols have to do many of the same things as human protocols. Each protocol has its own rules for initiating, terminating and confirming communications. These are some common protocols used in computer and robotic communications:

* TCP/IP (Transmission Control Protocol / Internet Protocol)
* RS-232 is a serial data communication protocol.
* USB is a higher speed serial data communication protocol.
* CAN is a communication protocol used in cars and robots.
* I2C is a communication protocol used between microchips.

#### Latency and feedback

No message is transmitted instantaneously; even computers have delays.

In an online computer game “ping time” is the time it takes for a message to get from the player’s computer to the host computer and back. Slow pings are no fun.

Have you ever heard a delay when calling overseas on a phone or Skype? Fibre optic cables handle most data and have a low latency. Vancouver to Hong Kong is about 170 ms; Vancouver to Calgary is only about 13 ms. Satellites have longer delays because the signals have to travel further. Minimum latency for a geostationary satellite signal is 240 ms. Latency is a big deal when controlling space probes. It can take over half an hour for a signal to go to Mars and back!

Latency is a big deal in feedback loops. A feedback loop senses an event, then sends a command to adjust for the event. If the temperature goes up, a thermostat will turn off the heater. If a car goes downhill, cruise control will cut back the engine power. If your “robot” is about to walk into a desk, the “controller” will send a “stop” command.

Low latency is important for feedback loops. It allows the robot to move faster and position things more precisely. How does a high ping time affect your feedback loop when gaming? What is the feedback for your “robot” and “controller”? What controls the latency for your robot?

## Design a Communication Protocol

You will design a communication protocol for your robot mask. It will be specific to you and your partner.

You will need to consider the following:

* What data do you need to communicate?
* How many LEDs will you need to communicate the data? Fewer LEDs means less work to wire, but it’s more difficult to learn the protocol!
  + Is it possible to create a communication protocol using just one LED?
  + Would it be a good idea to create a protocol using just one LED?
* How will you know that the message has been received?
* How will you know that the correct message has been received?

Write down your communication protocol and practise it by having the “controller” describe the LED pattern verbally and the “robot” respond.

Submit your communication protocol to your teacher for assessment.