Unit

16

Bumper and Limit Switch

In Unit 16: Bumper and Limit Switch, you learn about limit switches, their most common uses in robotics, and how to integrate them successfully into a complete robot design. You document and communicate your decision-making and design process.

The concepts behind bumper and limit switches have countless real-world applications. In STEM Connections, we pose questions regarding a robotic lawnmower. After completing the Think and Build phases, you see how those concepts come into play in the real world.

Unit Objectives

After completing this unit, you will be able to:

- Describe the differences between a bumper switch and a limit switch and list some of their uses.
- Use Cable and Harness to add wiring to the bumper switches using Autodesk® Inventor® Professional.
- Integrate limit switches into a robot to increase functionality.
- Explain the usefulness of limit switches and their applications, and generate ideas as to where limit switches can be used to maximize functionality.

Prerequisites

Related resources for Unit 16: Bumper and Limit Switch are:

- Unit 1: Introduction to VEX and Robotics.
- Unit 2: Introduction to Autodesk® Inventor®.
- Unit 4: Microcontroller and Transmitter Overview.
- Unit 12: Object Manipulation.
- Unit 15: Linkages.

Key Terms and Definitions

The following key terms are used in Unit 16: Bumper and Limit Switch:

Term	Definition
Bumper Switch	In the VEX system, a type of switch that is inside a plastic casing. It can be exposed to impacts without risking damage to the switch itself. For this reason, it is useful in any application in which the trigger can be high impact.
Cable	A premanufactured grouping of wires that is typically wrapped in some sort of insulation or sheath. It is also referred to as a multiconductor cable.
Hard Stop	A point at which a mechanical system cannot go any further because it has hit a fixed limit.
Harness	A harness assembly contains harness objects such as the wires, cables, ribbon cables, and segments that make up a wire harness, and optionally the connectors to which the wires and cables are attached. Multiple harness assemblies can exist within an assembly.
Limit Switch	In the VEX system, a type of switch with a function similar to that of a bumper switch. Unlike the bumper switch, the limit switch has a thin sheet-metal arm as its trigger mechanism, which can be bent into custom shapes for specific applications.
Pins	Points added to electrical parts to indicate where to attach wires.
RefDes	For reference designator, a simple text string such as J12 or R15 that is used to uniquely identify electrical components and component occurrences within the context of a harness design. The RefDes maps the part to the schematic wiring diagram or electrical connectivity data.
Switch	A mechanical device used to make or break connections within an electrical circuit.
Wire	Existing or custom objects in the Cable & Harness Library. Each wire has a wire name, color style, and outer wire diameter. Other optional properties can also be set, along with any custom properties you need.

Required Supplies and Software

The following supplies and software are used Unit 16: Bumper and Limit Switch:

Supplies	Software
VEX Classroom Lab Kit	Autodesk Inventor Professional 2009
The robot built in the Unit 16: Bumper and Limit Switch > Build Phase	
Notebook and pen	

Supplies	Software
Work surface	
Five soda cans	
One calculator	
One stopwatch	
An approximately 6" high stack of textbooks	
3' x 3' of open space	
Small container for loose parts	

Academic Standards

The following national academic standards are supported in Unit 16: Bumper and Limit Switch:

Phase	Standard
Think	**Science (NSES)** *Unifying Concepts and Processes*: Form and Function *Physical Science:* Motions and Forces *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 5.8: The Attributes of Design **Mathematics (NCTM)** *Algebra Standard* Understand patterns, relations, and functions. *Measurement Standard* Understand measurable attributes of objects and the units, systems, and processes of measurement. *Communication* Communicate mathematical thinking coherently and clearly to peers, teachers, and others. *Connections* Recognize and apply mathematics in contexts outside of mathematics.

Phase	Standard
Create	**Science (NSES)** *Unifying Concepts and Processes*: Form and Function *Physical Science:* Motions and Forces *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 5.8: The Attributes of Design 5.9: Engineering Design 6.12: Use and Maintain Technological Products and Systems **Mathematics (NCTM)** *Numbers and Operations* Understand numbers, ways of representing numbers, relationships among numbers, and number systems. *Algebra Standard* Understand patterns, relations, and functions. *Geometry Standard* Use visualization, spatial reasoning, and geometric modeling to solve problems. *Measurement Standard* Understand measurable attributes of objects and the units, systems, and processes of measurement.
Build	**Science (NSES)** *Unifying Concepts and Processes*: Form and Function *Physical Science:* Motions and Forces *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 5.8: The Attributes of Design 5.9: Engineering Design 6.11: Apply the Design Process **Mathematics (NCTM)** *Algebra Standard* Understand patterns, relations, and functions. *Measurement* Understand measurable attributes of objects and the units, systems, and processes of measurement. Apply appropriate techniques, tools, and formulas to determine measurements. *Connections* Recognize and apply mathematics in contexts outside of mathematics. *Problem Solving* Solve problems that arise in mathematics and in other contexts. Apply and adapt a variety of appropriate strategies to solve problems.

Phase	**Standard**
Amaze	**Science (NSES)** *Unifying Concepts and Processes*: Form and Function *Physical Science:* Motions and Forces *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 5.8: The Attributes of Design **Mathematics (NCTM)** *Algebra Standard* Understand patterns, relations, and functions. *Communication* Communicate mathematical thinking coherently and clearly to peers, teachers, and others. *Connections* Recognize and apply mathematics in contexts outside of mathematics. *Measurement* Understand measurable attributes of objects and the units, systems, and processes of measurement. Apply appropriate techniques, tools, and formulas to determine measurements. *Problem Solving* Solve problems that arise in mathematics and in other contexts. Apply and adapt a variety of appropriate strategies to solve problems.

Think Phase

Overview

This phase describes characteristics of linkages. It also describes some common applications for linkages.

Phase Objectives

After completing this phase, you will be able to:

- Describe a switch.
- Describe the differences between a bumper switch and a limit switch.
- List some uses for bumper switches and limit switches.

Prerequisites and Resources

Related phase resources are:

- Unit 4: Microcontroller and Transmitter Overview.
- Unit 12: Object Manipulation.
- Unit 13: Rotating Joints.

Required Supplies and Software

The following supplies are used in this phase:

Supplies
VEX Classroom Lab Kit
Notebook and pen
Work surface

Research and Activity

Switch

A switch is a mechanical device used to make or break connections within an electrical circuit. In robotics, switches can be used by the operator to give the robot commands. Switches can also be placed on the robot to respond to external triggers.

When a switch is triggered, it completes a circuit which sends a signal to the VEX Microcontroller. This signal can be interpreted by the programming in the Microcontroller to trigger some robot action.

The focus in this phase is on the VEX Bumper Switch and VEX Limit Switch and two momentary switches. A momentary switch is one that sends a signal only when it is triggered. When the trigger is removed, it springs back to its natural state and there is no signal.

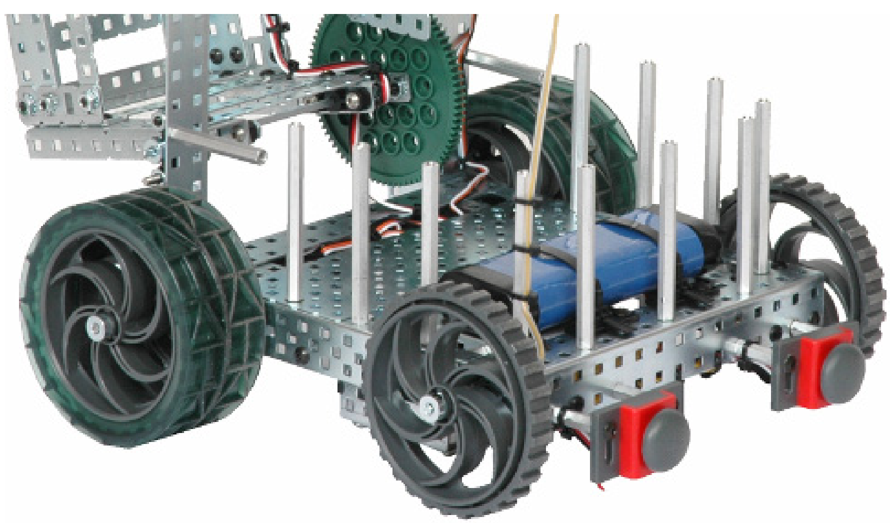
Bumper Switch

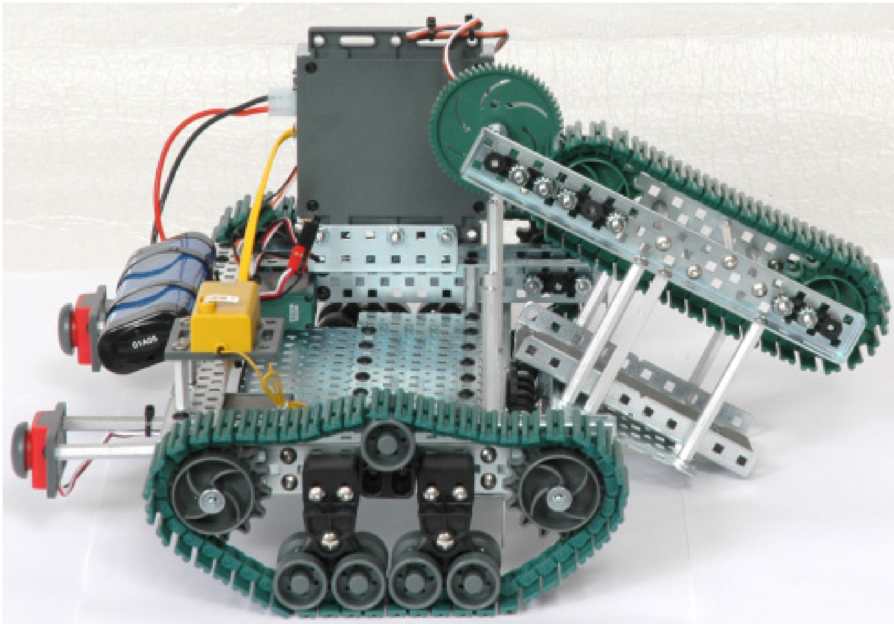
A bumper switch is inside a plastic casing. As its name suggests, it is designed to act as a bumper. It can be exposed to impacts without risking damage to the switch itself. For this reason, it is useful in any application in which the trigger can be high impact.

Bumper Switch 1

One common use of a bumper switch is to signal the robot when it has driven into something. When the bumper switch is triggered, it signals the robot to back up.

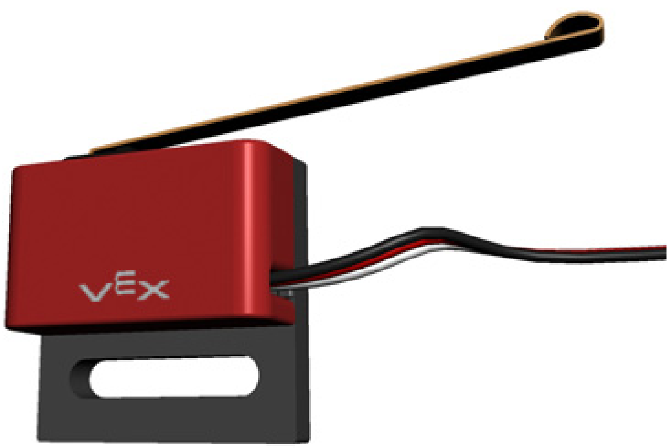
Two robots that use bumper switches are shown here:





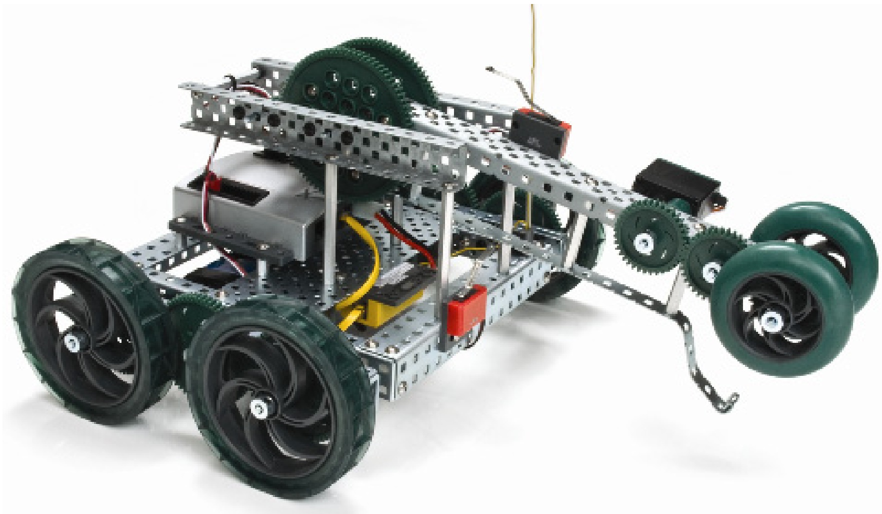
Limit Switch

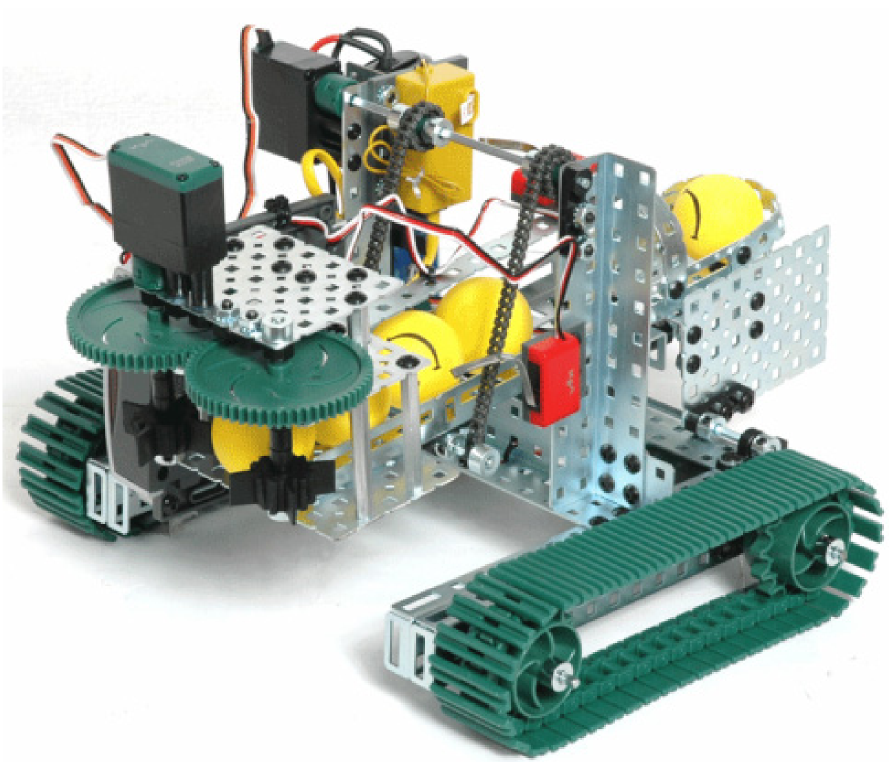
A limit switch has a function similar to that of a bumper switch. Unlike the bumper switch, the limit switch has a thin sheet-metal arm as its trigger mechanism. This switch is not as durable as the bumper switch. In the event of a high impact, the metal arm will bend or break. However, this is also the biggest advantage of the limit switch. The metal arm is designed to be rebent into different shapes. By bending the arm, you can set up the limit switch to fit different applications.



A limit switch is most commonly used to determine when an arm has reached the limit of its travel (hence, the name *limit switch*). Typically, two limit switches are used, one at each end of the arm's travel. When the arm is all the way up, it hits the top limit switch, which signals the Microcontroller not to let the arm rise any farther. When the arm is all the way down, it hits the bottom limit switch, which signals the Microcontroller not to let the arm drop any farther.

Some examples of robots using limit switches are shown here:





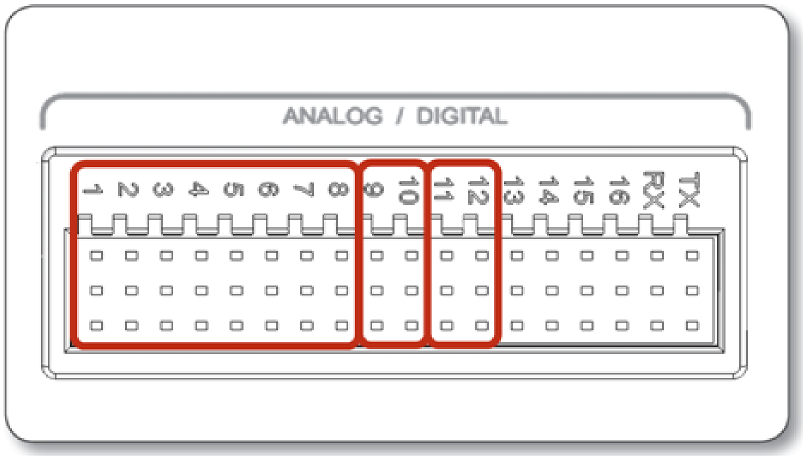
Importance of Limit Switches

Any mechanical system that has a hard stop should have a limit switch. A hard stop is a point at which the mechanical system cannot go any farther because it has hit a fixed limit (for example, an arm has jammed against the chassis and cannot go down any farther). If the mechanical system tries to continue to move after it has hit a hard stop, it will likely cause damage. A limit switch signals the Microcontroller that the mechanical system is at the end of its motion and should be prevented from moving farther. These limit switches keep the system from damaging itself.

Preprogrammed Microcontroller

The VEX Microcontroller comes preprogrammed with several options for using bumper switches and limit switches. Because both these switches have the same functionality, they interface with the Microcontroller in the same way. Remember, both types of switches do the same thing; they just come in different shapes. Either type of switch can be used for any of these functions.

These switches are used with the VEX Microcontroller by plugging them into the Analog/Digital Ports.



A switch has different effects depending on which port it is plugged into. The table shown describes what function each port performs.

Sensor Ports

Port	Category	Behavior
Analog/Digital Port 12	Autonomous Mode Collision Detection Ports	Back up and turn left
Analog/Digital Port 11		Back up and turn right
Analog/Digital Port 10	Collision Emergency Stop Ports	Stop for 2 seconds
Analog/Digital Port 9		Stop for 2 seconds
Analog/Digital Port 8	Limit Switch Behavior	Motor 7 ignores CW
Analog/Digital Port 7		Motor 7 ignores CCW
Analog/Digital Port 6		Motor 6 ignores CW
Analog/Digital Port 5		Motor 6 ignores CCW
Analog/Digital Port 4		Motor 5 ignores CW
Analog/Digital Port 3		Motor 5 ignores CCW
Analog/Digital Port 2		Motor 4 ignores CW
Analog/Digital Port 1		Motor 4 ignores CCW

Preprogrammed Functions

Three different types of preprogrammed functions are available.

The first type is *Autonomous Mode Collision Detection*.
NOTE: For this function to work, Autonomous Mode must be enabled. To enable Autonomous Mode, a jumper must be installed in Analog/Digital Port #13. When Autonomous Mode is enabled, a signal on Port 12 results in the robot's backing up and turning left. A signal on Port 11 results in the robot's backing up and turning right. This functionality is useful for obstacle avoidance.

The second function is *Collision Emergency Stop*. This functionality applies to Port #9 and Port #10. If either of these ports has a switch plugged into it that is triggered, it will shut down the entire robot for two seconds. Once the two-second period is over, the robot will come back to life. This is useful for playing a game of robot tag with bumper switches. Simply mount bumper switches to the back of your robot, and if your opponent touches them, your robot will freeze for two seconds.

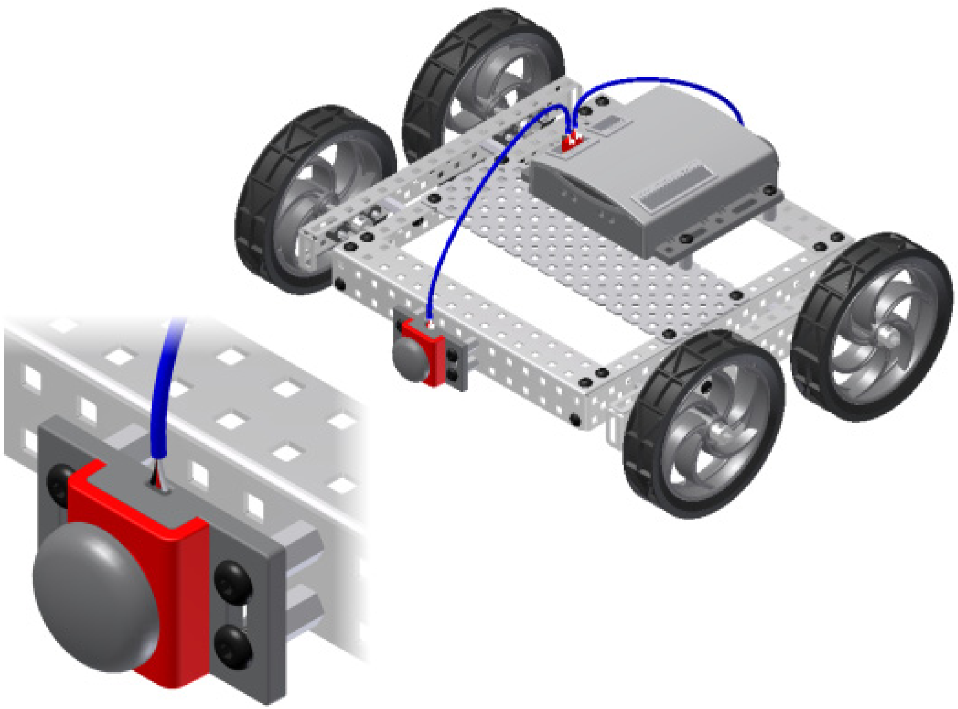
The third and most useful type of preprogrammed behavior applies to Ports 1 through 8. These ports control the limit switch behavior for Motors 4 through 7. Each port controls the direction of a different motor. If a switch triggers Port 1, then Motor 4 will not run in the CCW direction. If a switch triggers Port 2, then Motor 4 will not run in the CW direction. These two ports both control Motor 4. So, if you have an arm being driven by Motor 4, you can put two limit switches on it: one on Port 1 and one on Port 2. The other switches are similarly controlled; refer to the table for more information.

For more information on other preprogrammed functions of the Microcontroller, refer to Unit 4: Microcontroller and Transmitter Overview.

Create Phase

Overview

In this phase, you add wiring to bumper and limit switches. Using Cable and Harness, you model a cable from the bumper and limit switches to the Microcontroller.



Phase Objective

After completing this phase, you will be able to:

- Use Cable and Harness to add wiring to bumper switches.

Prerequisites and Resources

Before starting this phase, you must have:

- A working knowledge of the Windows operating system.
- Completed Unit 1: Introduction to Vex and Robotics > Getting Started with Autodesk Inventor.
- Completed Unit 2: Introduction to Autodesk Inventor > QuickStart for Autodesk Inventor.

Technical Overview

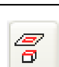
The following Autodesk Inventor tools are used in this phase:

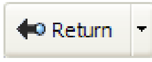
Icon	Name	Description
	**Place Pin**	Creates a connection point for your wires.
	**Create Harness**	Creates a wire harness subassembly. All wiring is contained in this subassembly.
	**Create Wire**	Creates a single wire.
	**Create Segment**	Creates a wiring segment that determines the route for the wires.
	**Automatic Route**	Routes wires through existing segments.

Key Terms and Definitions

Technical Overview

The following Autodesk Inventor tools are used in this phase:

Icon	Name	Description
	**Place Pin**	Used to establish the location and names of individual pins on Autodesk Inventor parts. To define the pins, you select the Place Pin tool, pick a point in the graphics window, and then add a pin name and optional properties.
	**Work Plane**	A construction feature that defines the parametric location of a sketch plane in 3D space. A work plane is useful when no planar face exists to use as a sketch plane, for example, when sketching on curved or toroidal faces. A work plane can be incorporated into dimension and constraint schemes.
	**2D Sketch**	A sketch consists of the sketch plane, a coordinate system, 2D curves, and the dimensions and constraints applied to the curves. A sketch may also incorporate construction geometry or reference geometry. Sketches are used to define feature profiles and paths.
	**Project Geometry**	Projects geometry (model edges, vertices, work axes, work points, or other sketch geometry) onto the active sketch plane as reference geometry.

Icon	Name	Description
	**Return**	Use Return to quit in-place editing and quickly return to the desired environment. The destination depends on which modeling environment you are working in.
	**Work Point**	Work points can be placed or projected onto part faces, linear edges, or onto an arc or a circle. Work points can be constrained to the center points of arcs, circles, and ellipses. In Cable and Harness, they are added to Autodesk Inventor parts to assist in the placement of a segment.
	**Create Harness**	Adds the harness subassembly to an assembly file with the specified name and location and activates the Cable and Harness panel bar. The harness subassembly contains the origin information, a single harness part, and all the cable and harness specific data. The harness part file is created and saved to the location of the parent harness assembly. It has the same name as the harness assembly, with an *.ipt* extension.
	**Create Wire**	Used to create a wire between two pins within a harness assembly. The pins can exist on electrical components (connectors) or splices. The wire that is created is selected from the Cable & Harness Library.
	**Create Segment**	Harness segments represent the possible paths that wires and cable wires may take through the harness assembly. The segments represent a virtual bundle of wires and cables. Each mouse click in the graphics window creates a work point on the segment. Work points are used to manipulate the segment into its desired position and shape.
	**Automatic Route**	Used to route one or more selected unrouted wires or cables or all unrouted wires or cables into segments in the active harness assembly. Routed wires (including cable wires) are ignored.

Definitions

Term	Definition
Cable	A premanufactured grouping of wires that is typically wrapped in some sort of insulation or sheath. It is also referred to as a multiconductor cable.
Harness	A harness assembly contains harness objects such as the wires, cables, ribbon cables, and segments that make up a wire harness and optionally the connectors to which the wires and cables are attached. Multiple harness assemblies can exist within an assembly.
Pins	Points added to electrical parts to indicate where to attach wires.
RefDes	Or reference designator, a simple text string such as J12 or R15 that is used to uniquely identify electrical components and component occurrences within the context of a harness design. The RefDes maps the part to the schematic wiring diagram, or electrical connectivity data.
Wire	Existing or custom objects in the Cable & Harness Library. Each wire has a wire name, color style, and outer wire diameter. Other optional properties can also be set, along with any custom properties you need.

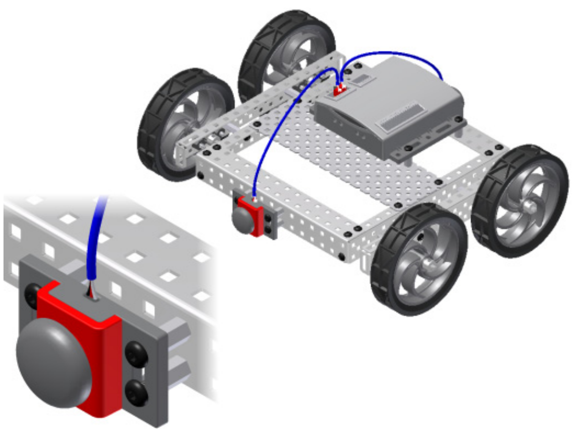
Required Supplies and Software

The following software is used in this phase:

Software
Autodesk Inventor Professional 2009

Exercise: Add Wiring to the Bumper and Limit Switch

In this exercise, you add wiring to the bumper and limit switch. Using Cable and Harness, you model a cable from the bumper and limit switches to the microcontroller.



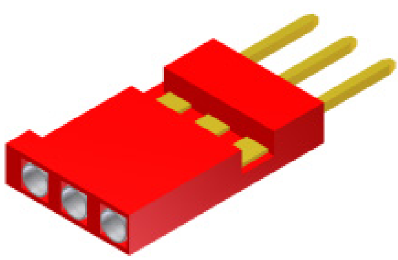
The completed exercise

Create Pins

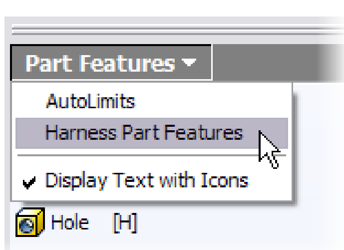
In this section of the exercise, you add pin connections to the part. The pins are added to electrical parts to indicate where to attach wires.

1. Make *IFI_Unit16.ipj* the active project file.

2. Open *Connector_01.ipt*.

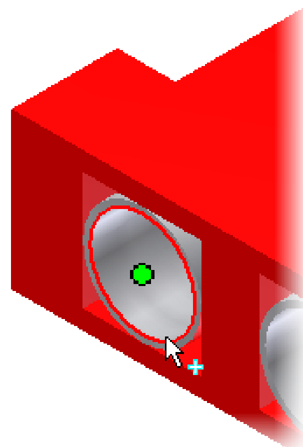


3. Click the arrow beside Part Features. Click Harness Part Features.

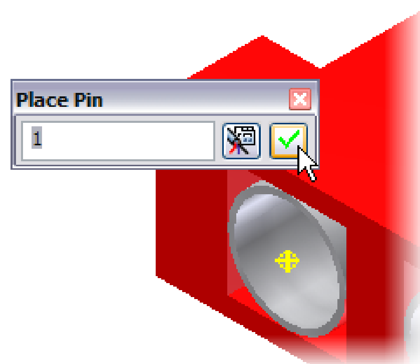


4. Click Place Pin.

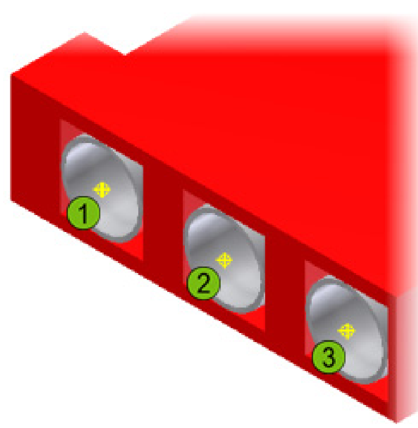
5. Select the edge of the feature as shown.



6. Click the check mark to create the pin.



7. Repeat this workflow to create pins 2 and 3.

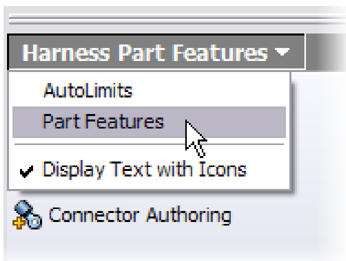


8. Save the file.

Add Work Points

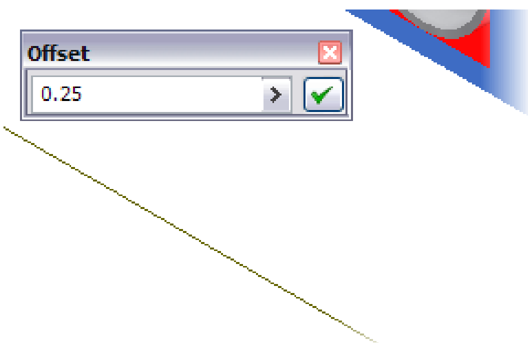
In this section of the exercise, you create two work points. You use the points to ensure that the wire harness is at a right angle to the face of the connector.

1. Click the arrow beside Harness Part Features. Click Part Features.

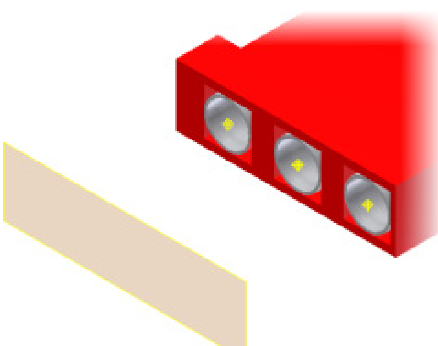


2. Click Work Plane.

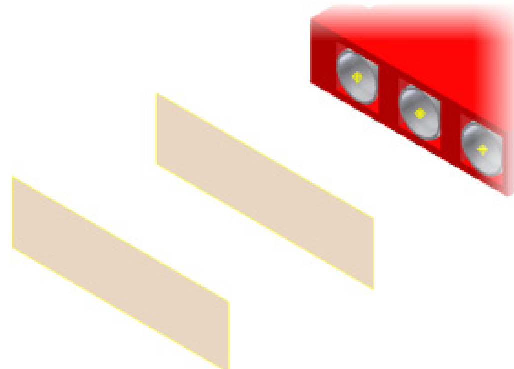
3. Select the end face of the connector and drag away from the connector. In the Offset box, enter **0.25**.



4. Click the check mark to create the work plane.



5. Repeat this workflow to create a work plane **0.5** away from the face of the connector.

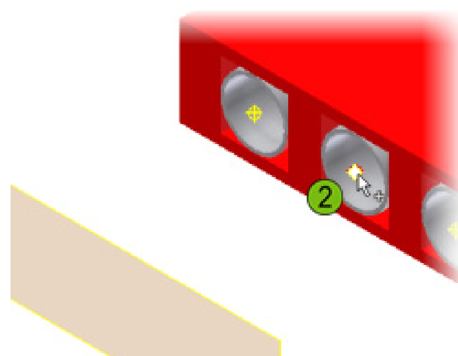


6. Click Sketch.

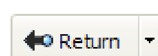
7. Select the first work plane.

8. Click Project Geometry.

9. Click the middle pin (2). The pin is projected onto the sketch.



10. Click Return.

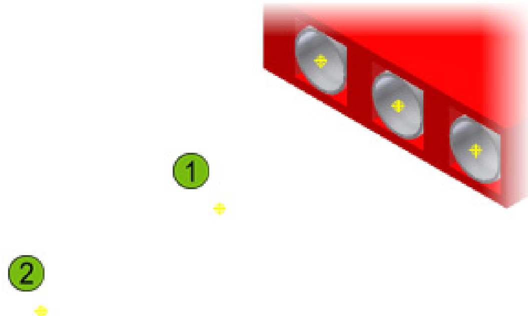


11. Click Work Point.

12. Select the projected point.

13. Repeat this workflow for the second work plane. You should now have two work points.

14. Turn off the visibility of the sketches and work planes.



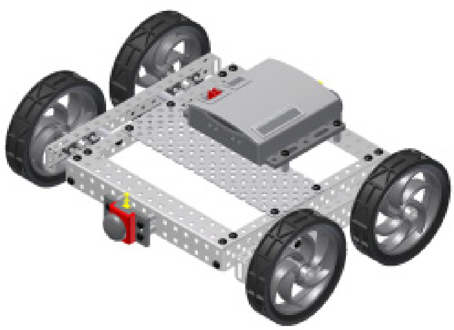
15. Save the file.

16. Close the file.

Add the Wires

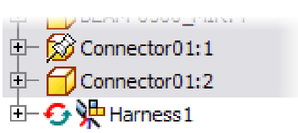
In this section of the exercise, you add the wires between the bumper limit switch and the Microcontroller.

1. Open *Wiring_Assembly.iam*.



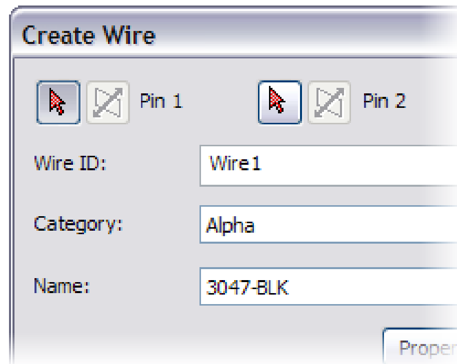
2. Click Create Harness.

3. Click OK. A new harness subassembly is created and listed in the browser.

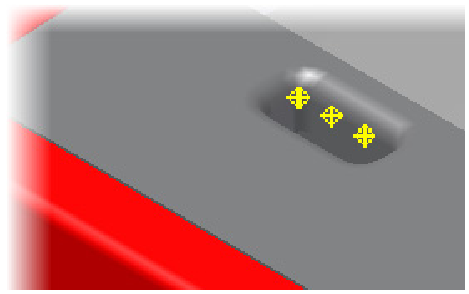


4. Click Create Wire.

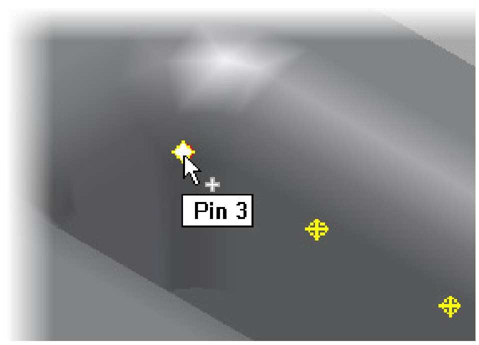
5. In the Create Wire dialog box, select Alpha from the Category list. Select 3047-BLK from the Name list.



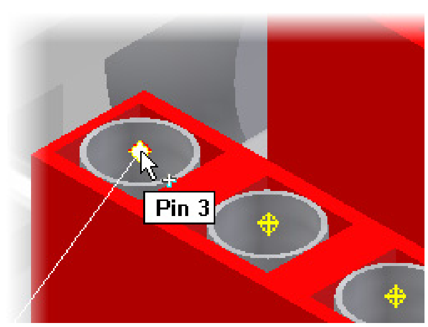
6. Zoom into the top of the bumper switch.



7. Click the pin on the left. It is named Pin 3.



8. Zoom and pan to the Microcontroller. On the connector on the left, click the pin on the left. It is also named Pin 3. Click Apply.



9. In the Create Wire dialog box, select 3047-RED from the Name list.

10. Select the pin in the middle. It is named Pin 2.

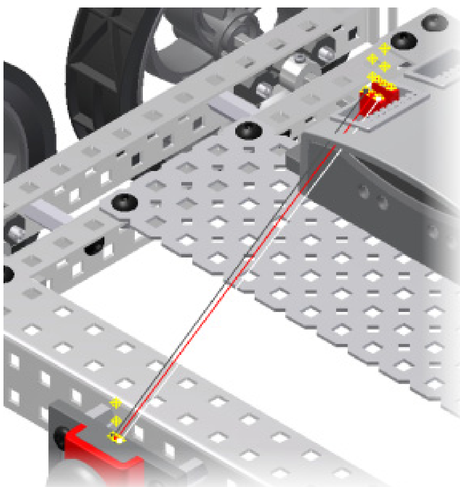
11. Zoom and pan to the bumper switch. Select the pin in the middle. It is named Pin 2. Click Apply.

12. In the Create Wire dialog box, select 3047-WHT from the Name list.

13. Select the pin on the right. It is named Pin 1.

14. Zoom and pan to the Microcontroller. Select the pin on the right. It is also named Pin 1. Click Apply.

The wires are attached to each pin.

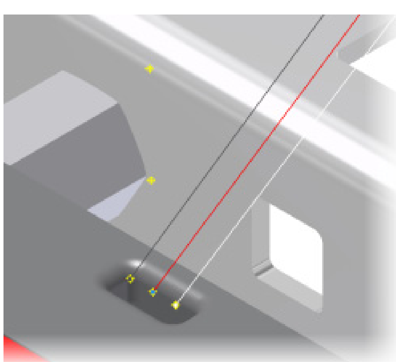


15. Click Cancel.

Create a Segment

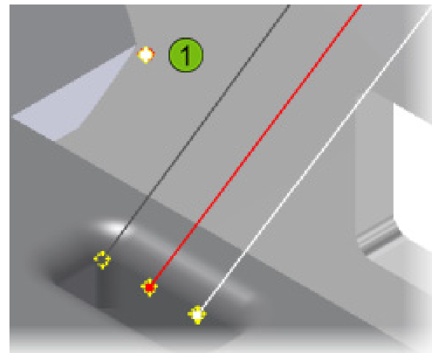
In this section of the exercise, you create a segment for the wires.

1. Zoom into the bumper switch.

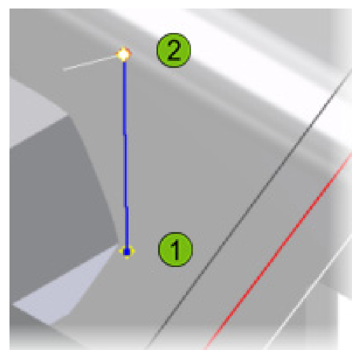


2. Click Create Segment.

3. Select the work point (1) closest to the switch.

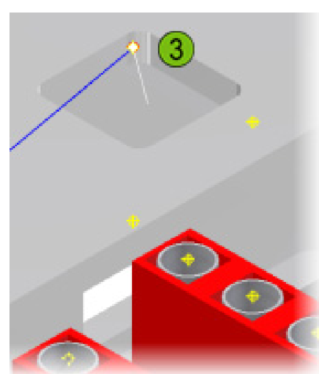


4. Select the next work point (2).

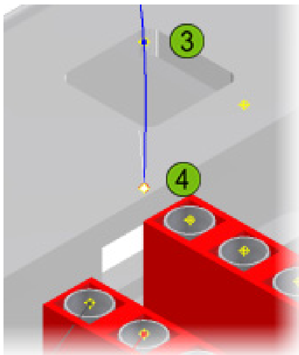


5. Zoom and pan to the connector.

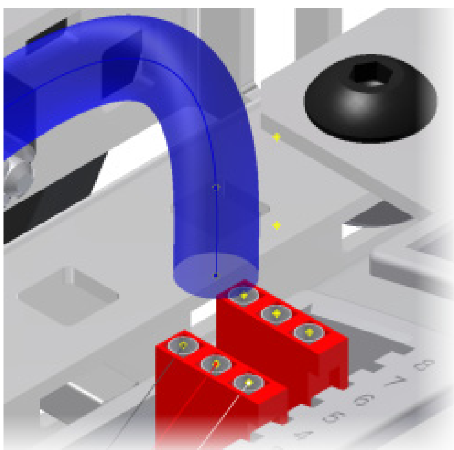
6. Select the work point (3) above the connector.



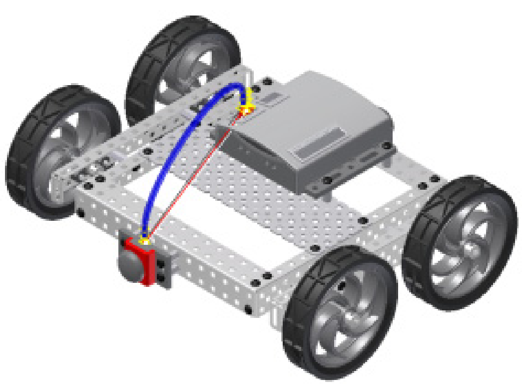
7. Select the work point (4) closest to the connector.



8. Right-click in the graphics window. Click Finish.



9. On the ViewCube, click Home.

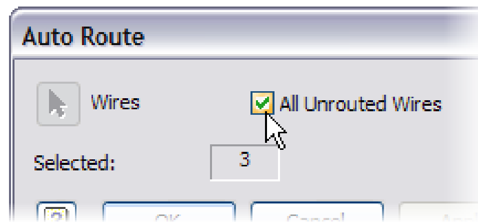


Route the Wires

In this section of the exercise, you route the wires through the segment. Single wires can be routed, or all wires can be routed using the Automatic Route tool.

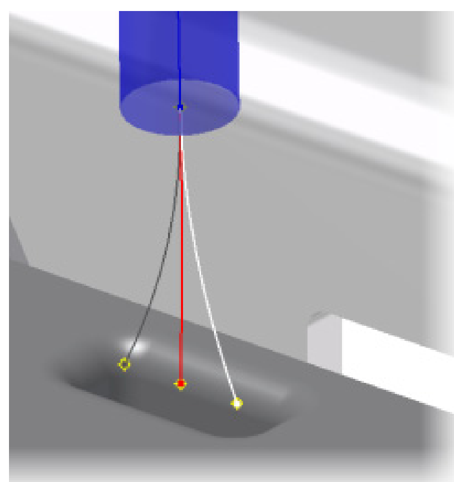
1. Click Automatic Route.

2. Select All Unrouted Wires.

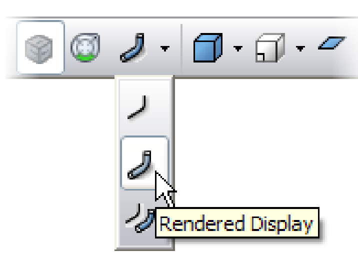


3. Click OK. The three wires are routed through the segment. The segment is resized to match the three wires.

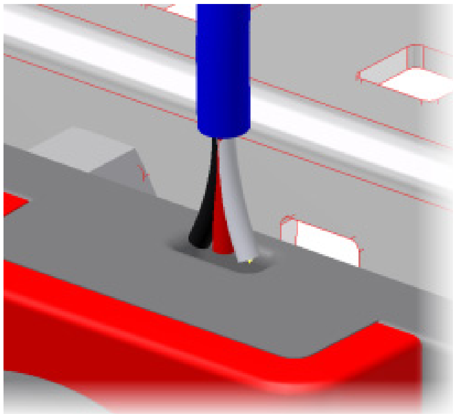
4. Zoom into the top of the bumper switch. The wires are displayed as centerlines.



5. On the Standard toolbar, click Rendered Display.



6. Click Return.



Add a Second Segment

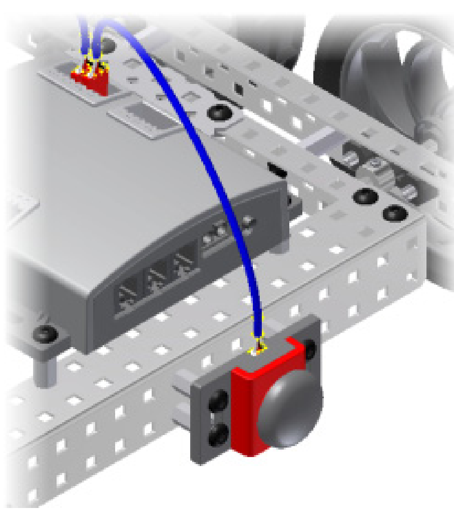
In this section of the exercise, you add a second segment.

1. Click Create Harness.

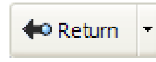
2. Click OK. A second harness subassembly is created and listed in the browser.

3. On the ViewCube, click the top right corner.

4. Using the workflow from the previous sections, add a second segment between the bumper switch and the connector.



5. Click Return.



6. On the ViewCube, click Home.

7. Click Save.

8. Close the file.

Build Phase

Overview

In this phase, you add limit switches to the robot from Unit 15: Linkages, to restrict the motion of your linkage.

Phase Objective

After completing this phase, you will be able to:

- Integrate limit switches into a robot to increase functionality.

Prerequisites and Resources

Before starting this phase, you must have:

- Completed Unit 16: Bumper and Limit Switch > Think Phase.

Related phase resources are:

- Unit 1: Introduction to VEX and Robotics.
- Unit 4: Microcontroller and Transmitter Overview.
- Unit 12: Object Manipulation.
- Unit 13: Rotating Joints.
- Unit 15: Linkages.

Required Supplies and Software

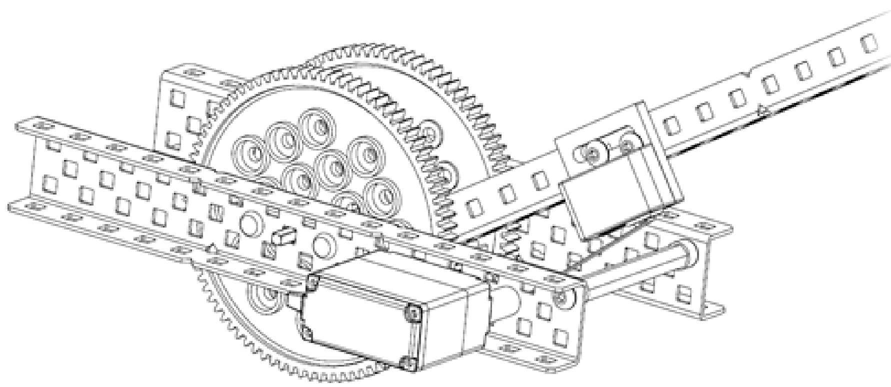
The following supplies are used in this phase:

Supplies
VEX Classroom Lab Kit
The robot built in the Unit 15: Linkages > Build Phase
Notebook and pen
Work surface
Small storage container for loose parts
An approximately 6″ high stack of textbooks
Measuring tape
Optional: Autodesk Inventor Professional 2009

Activity

In this activity, you add limit switches to your robot to restrict the motion of your linkage. The challenge in the Amaze Phase will be to place five soda cans on a stack of textbooks as quickly as possible. Properly placed limit switches enable you to perform this task much faster.

1. Measure the exact height of your stack of textbooks.
2. Review the Think Phase of Unit 16 and the Sensors section of the Inventor's Guide for VEX limit switch behavior.
3. In your notebook, brainstorm locations and implementations of where you will place your limit switches. An example of a limit switch mounted to an arm is shown in the following image.



When deciding where to place your limit switches, you need to consider many factors, some of which include:

- What range of motion needs to be limited?
- Where does the arm need to be stopped?
- How many limit switches are needed?
- What space is there to mount the switch?
- Will special mounting points need to be added?
- How can the switch be mounted to avoid running directly into it?

Work as professionals in the engineering and design fields by leveraging the power of Autodesk Inventor to explore potential solutions through the creation and testing of digital prototypes.

NOTE: Come to class prepared to build and test your best ideas! Team members can download a free version of Autodesk Inventor Professional to use at home by joining the Autodesk Student Engineering and Design Community today at *http://www.autodesk.com/edcommunity*.

4. Based on your criteria, choose a design and start building!
5. Once your limit switches are mounted, hook them up to a Microcontroller and test that they function as planned. Make modifications as needed.
6. Move on to the Amaze Phase and get ready for your upcoming challenge!

Amaze Phase

Overview

In this phase, you test the new functionality of your robot by attempting to place five soda cans on a platform as quickly as possible.

Phase Objectives

After completing this phase, you will be able to:

- Explain the usefulness of limit switches and their applications.
- Generate ideas as to where limit switches can be used to maximize functionality.

Prerequisites and Resources

Before starting this phase, you must have:

- Completed the Unit 16: Bumper and Limit Switch > Think Phase.
- Completed the Unit 16: Bumper and Limit Switch > Build Phase.
- An assembled robot from Unit 15: Linkages that consists of a linkage from Unit 14: Accumulator Design > Build Phase attached to the gripper from Unit 12: Object Manipulation > Build Phase that is attached to a drivetrain of your choice.

Related phase resources are:

- Unit 1: Introduction to VEX and Robotics.
- Unit 4: Microcontroller and Transmitter Overview.
- Unit 12: Object Manipulation.
- Unit 13: Rotating Joints.
- Unit 15: Linkages.

Required Supplies and Software

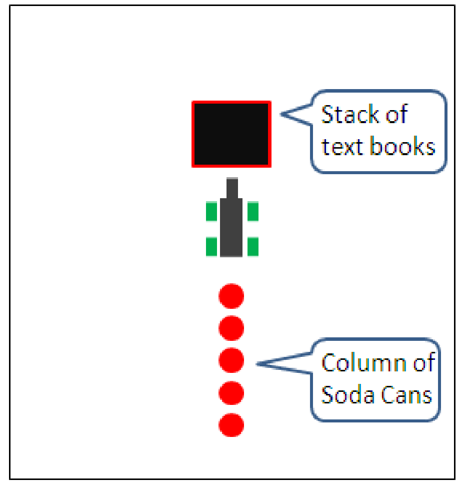
The following supplies are used in this phase:

Supplies
VEX Classroom Lab Kit
The robot built in the Unit 16: Bumper and LImit Switch > Build Phase
Notebook and pen
Work surface
Five soda cans
One calculator
One stopwatch
An approximately 6” high stack of textbooks
3’ x 3’ of open space

Evaluation

Challenge

In this challenge, you test the new functionality of your robot by attempting to place five soda cans on a platform as quickly as possible.

Instructions	Figure 1
1. Place the stack of textbooks on the ground. 2. Place your robot behind the textbooks. 3. Place a column of five soda cans behind your robot. See Figure 1. 4. To begin this challenge, you can compare the performance with and without limit switches. Unplug your limit switches. 5. Using your robot, place the five cans on top of the stack of textbooks as quickly as possible. Start timing once the first can is grabbed, and stop timing when the last can is placed on the stack. Record this time in your engineering notebook. 6. Repeat this task five times, recording your time for each trial. 7. Plug your limit switches back in. 8. Repeat the same task as earlier, except now use the functionality of the limit switches. Perform the task five times, recording your time for each trial.	

Engineering Notebook

Calculate the average time to complete the task with and without limit switches.

- Which time was faster? Why do you think this is?
- Limit switches are used in many different applications. Think back to all the robots you have built in the past units. How can you improve them with limit switches?
- List some real-world applications of limit switches.

Presentation

Present your design to the class. Explain how you were able to integrate the switches into your design and the effects they had on your robot. Talk about the criteria you used to decide on your implementation.

STEM Connections

Background

You are given the opportunity to develop a robot that safely takes care of mowing any size lawn. A critical aspect of the design is to maximize maneuverability and to ensure that the mower never endangers anyone and cannot cause property damage or inflict damage in itself.

Science

1. Bumper and limit switches act by turning on or off electrical current. Knowing this, what materials would be used at the connection points where current is turned on or off?
2. When electrical conductivity is involved, why is the selection of materials important? What provisions do you need to make in order to prevent the electrical current from being accidentally switched on or off?
3. The outer casing of a bumper switch is made out of plastic; the bumper pad is made from an elastomer or rubber. Why are these materials used for this application?
4. Because a lawnmower is used outdoors, what are some of the characteristics you want in the materials that are used for the bumper switch housing?

Technology

1. As the robotic mower does its job, you want to make sure that it corrects its movement if it runs into something. How can you use bumper switches to accomplish this? Where do you mount the switches?
2. In order to turn the mower 90 degrees, you incorporate a skid steering system (wheels on one side turn forward; wheels on the opposing side turn in the opposite direction). How can you use bumper switches to control this action?
3. Similarly, after completing a row, you want the mower to move over and continue cutting in the opposite direction. How can you use bumper switches to control this action?

Engineering

One of the biggest safety hazards associated with a lawn mower involves hand injury from a blade that starts spinning when a person tries to clean out the undercarriage of the mower.

1. How can you use limit switches to absolutely prevent this type of injury? How can you make sure that the limit switches always return to their original operating position in order to maintain absolute safety?
2. How do you prevent the effects of the environment (water, mud, accumulated grass) from impacting the performance of the limit switches?

Math

The robotic lawn mower moves at a speed of two feet per second. As it moves forward, the diameter of the blade enables the machine to cut a section of grass that is 18 inches wide. The mower is going to be used on a rectangular area of lawn measuring 110 feet long x 45 feet deep. The mower starts out in one corner and runs the full horizontal length of 110 feet. When the mower reaches the end of one row, a bumper switch comes in contact with a border that runs the entire depth of the lawn (45 feet) on both ends. Upon contact, it takes six seconds for the mower to maneuver into position for mowing back in the opposite direction. When it starts mowing in the reverse direction, the mower overlaps the first cut section by four inches and then cuts another section that is 14 inches wide. It repeats this pattern until the whole lawn is mowed.

Based upon this information and assuming no obstructions exist, how long will it take for the robotic mower to cut the entire lawn? If you have two identical robotic mowers and you start each of them in opposite corners at the exact same time, how long will it take for them to meet if one mower is set to mow at a speed of two feet per second and the other mows at a rate of three feet per second. At these rates, where inside the 110-foot x 45-foot rectangle will the two mowers meet (noted as x and y coordinates) to the nearest feet?