ABSTRACT

Controlling Robots is a detailed and extensive activity in which students create practical robotic devices with a laptop computer. Teachers can use the lesson in its entirety, or just use individual units. The lesson begins with the simple programming of LED lights and progresses from DC motors to advanced stepper motors. The units cover a wide range of topics, such as motors, switches, and relays. *Controlling Robots* requires hands-on participation, and students quickly develop an interest in programming computers, electronics, and robots.

TIES TO CURRICULUM

Controlling Robots incorporates national standards for teaching and learning. This activity develops cognitive reasoning and critical thinking skills as called for in the *National Science Education Standards*, and it also asks students to apply what they have learned by building an independent robotic device. The actvities are challenging, yet students of all levels can succeed.

This project integrates many disciplines in science and math. It fits most neatly into a computer science curriculum, but *Controlling Robots* also teaches math and distance calculations, physics of movement, and basic electronics.

LEARNING OBJECTIVES

Students will be able to

- understand and calculate time, distance, speed, degrees and radians;
- explain how to design, create, and construct a movable robot;
- use LEDs, resistors, transistors, switches, and stepper motors, and explain the basic concepts behind these electronics;
- use a laptop computer to control external devices such as LEDs and motors;
- understand and explain the concepts of binary code; and
- program in QBasic.

TIME REQUIREMENT

Teacher preparation takes about three hours. The time frames for individual units will vary depending on students' skill level.

Task	Time
Unit 1: Controlling LED Lights	3 hours
Unit 2: Controlling DC Motors with the Laptop	2 hours
Unit 3: Constructing the Robot	3 hours
Unit 4: Making the Robot Move	5 hours
Unit 5: Sensor Addition to Your Robot	2½ hours
Unit 6: Using Stepper Motors Instead of DC Motors	4 hours
Unit 7: Creating a Memory of Record of Movement	1½ hours

NUMBER OF LAPTOPS AND GROUP SIZE

Students can work individually in groups, or as a class, and so the number of laptops varies. You don't need state-of-the-art equipment *;* 8086, 286 and 386 laptops are fine.

Criteria are that the laptop:

- can run a programming language such as Basic or QBasic;
- is not too heavy (as some early models are);
- have a working LPT port through which the external device is connected; and
- run on its own battery pack.

Materials on the list below are required for every unit. Individual units have additional materials lists. Each student group needs the materials listed below; increase the amount of materials for more groups. Prepackaged computer tool kits often include most of the supplies on the *Tool Kit* list. Look for the Curtis 42-piece or 56-piece Computer Tool Kits, or the Master Technician 24-piece Computer Repair Kit.

MATERIALS

Computer Equipment

- Laptop computer (see criteria to the left)
- Basic or QBasic program
- 1.8 m DB25M to DB25M printer cable
- 1.8 m FP301H 3M heat shrinking tubing
- DB25M pins (AIM #40-9428M)

Tool Kit

- Soldering iron
- Hi-grade silver solder: .022-42 g
- 12.5 cm nose pliers
- Crimping tool/wire stripper
- 12.5 cm side cutters
- 6.25 mm and 4.69 mm nut drivers
- Phillips screw drivers (sizes #2, #1, #10)
- Standard small screwdrivers, assorted small sizes
- 3 prong part retriever
- Tweezers

General Tools

- Power drill
- 12.5 cm adjustable wrench
- 14 range digital multimeter or 1–8 range analog multitestor
- Small hacksaw
- 15 cm vise grips/locking pliers

Connection Supplies

- Jumper wire kit (assortment of 140 pre-striped wire)
- 7.5 m solid wire, different colors
- 6 volt battery (if rechargeable, include charging unit)
- Two alligator clips
- Double-sided carpet tape
- Assorted self-locking nylon wire ties
- Assorted 6.25 mm matching nuts, bolts and washers

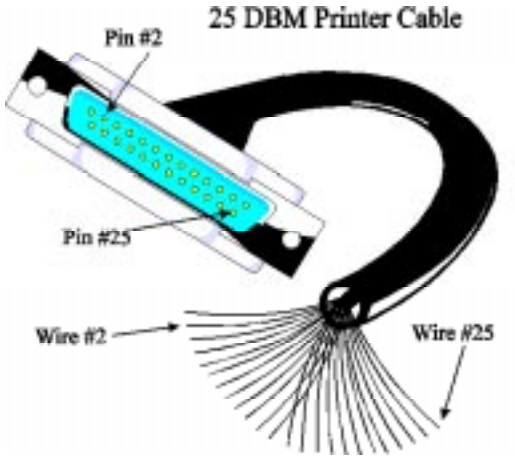
LESSON DESCRIPTION

Modify *Controlling Robots* depending upon the level of the students. You can use units independently or together, but it is important to use each unit as a building block for the following ones. Units 1–4 are the basic activities, and the end of the Unit 4 is a good stopping point. Units 5–7 are more advanced applications. Each unit suggests topics for classroom discussion and lectures. Encourage students to keep a log of their experiments. You might also create word lists of terms and definitions.

Teacher Preparation

It will take some time to find all the computer parts needed for these activities. A good source for this equipment is old computers and printers. You will also need to modify the LPT printer cable for use with the breadboard. Cut the printer cable in half. Strip the cable ends for the wires and solders and solder a DB25M pin to each wire. Cover each with heat shrink tubing to insulate the tubing. This will make 2 LPT connecting cables (see Figure 1).

Figure 1: LPT connecting cable



Teachers should become familiar with connecting the breadboard and all parts of the robot prior to each unit.

LESSON SUGGESTIONS

- Check the address for the LPT port on your laptop—it may be different than H378.
- To give students more experience working with computers and related equipment, recycle parts from discarded computers and printers. These are great sources for DC and stepper motors, LEDs, cases, nuts, bolts, and screws.
- The activities in *Controlling Robots* also are great for science fairs and exhibitions.

Unit 1: Controlling LED Lights

Discussion Topics: electronic circuitry, input/output data, binary code

MATERIALS: UNIT 1

- LEDs (8)
- 2n2222 type transistors (8)
- 2.2 K resistors (8)
- 82 ohm resistors/1 K resistors (8)
- Breadboard socket, 6.25 x 15 cm

Review how a computer sends a signal from an LPT port. Connect the laptop to the breadboard using the LPT end of a printer cable. Use a breadboard or a similar board that allows you to connect resistors, transistors and LEDs (see Figure 2).

Load QBasic onto the computer and enter the program code shown in Figure 3.

Enter a number when the program asks for an input of 1–255. QBasic will then send the number out via the LPT port in binary code and control the LED lights. Students should note the relationship between the number they input and the LED lights: which LEDs go on when certain numbers are input?

Figure 2: Making the wire connections for Unit 1

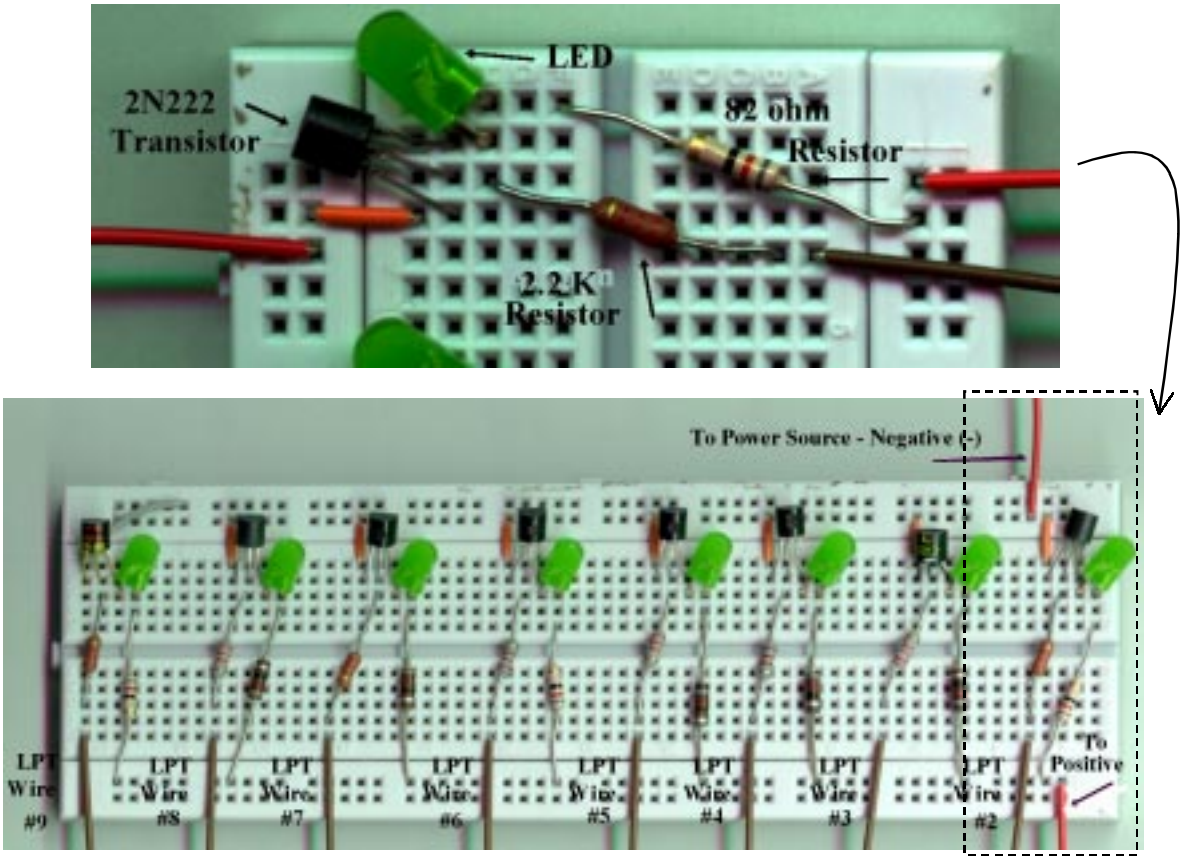


Figure 3: Computer program for Unit 1

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"*** Computer program shows binary output from a computer using the LPT port****
DO
PRINT "Enter a number between 0 and 255. 0 turns off any LEDs."
PRINT "All other numbers will be converted to binary code and"
INPUT "light up LEDs respectively.", x
OUT&H378, x
LOOP
END
```

Students can expand on the program to run patterns in the LEDs. For example, try to program the computer to count to 255 and then repeat the pattern. Create light patterns by programming individual LEDs.

Unit 2: Controlling DC Motors with the Laptop

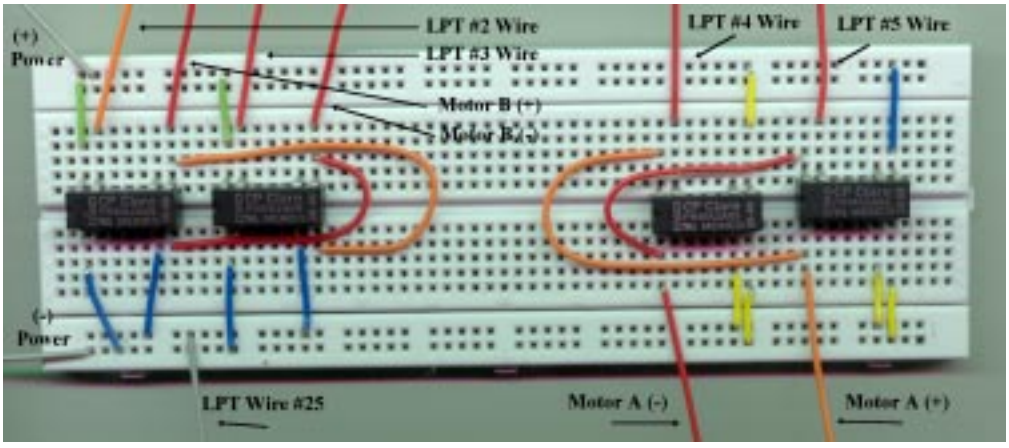
Discussion Topics: AC/DC current, relays

After students learn to control LEDs in Unit 1, replace the LEDs and transistors with relays and small DC powered motors. The two motors represent the right and left sides of a robotic device (see Figure 4).

MATERIALS: UNIT 2

- Breadboard from Unit 1
- 5VDC, 5A, 140 ohms DPST, N.O. DIP Dry Reed Relays, model PRMA2A05 (2)
- 5VDC hobby motors, 8,000 rpm (2)

Figure 4: Making the wire connections for Unit 2



Students control the computer code by using binary code, but now they also specify numbers to control which relays open and close. The relays control the supply power connected to the motors. A sample computer program to control motor movement can be seen in Figure 5.

Figure 5: Computer program for Unit 2

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"*** Computer program shows binary output from a computer using the LPT port ****
DO
CLS
PRINT "1) Forward"
PRINT "2) Backward"
PRINT "3) Right"
PRINT "4) Left"
PRINT "5) Stop"
PRINT "6) Exit"
INPUT "Choose one (1-6)", a
If a=2 THEN OUT &H378, 5
If a=1 THEN OUT &H378, 10
If a=4 THEN OUT &H378, 9
If a=3 THEN OUT &H378, 6
If a=5 THEN OUT &H378, 0
If a=6 THEN END
LOOP
END
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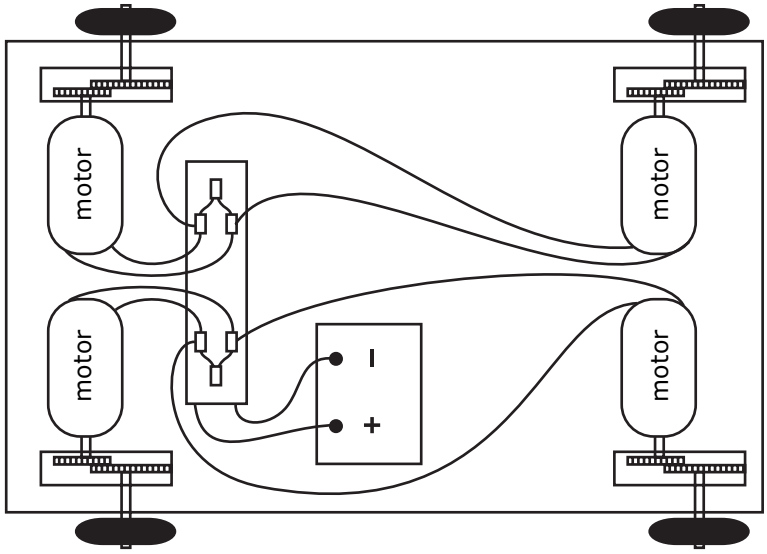
Unit 3: Constructing the Robot

Discussion Topics: design and planning, gear movement, forces and opposing forces, weight displacement

Mount one motor and gear transmission on each of the four corners of a platform. The platform will be the base of the robot. One set of relays will control the two motors on the left side of the robot, and another set of relays will control the other two motors. Mount the batteries and breadboard (already connected to the laptop and motors) to the platform (see Figure 6). Attach four wheels to the platform.

Figure 6: Platform with wheels and motors

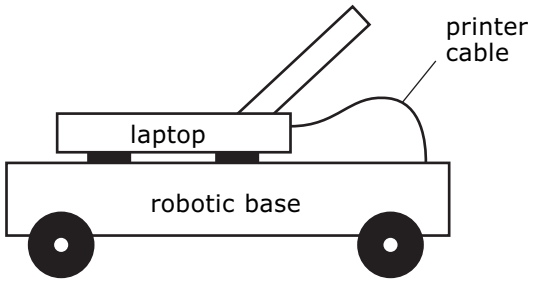


MATERIALS: UNIT 3

- Hobby gear transmissions (4)
- 5VDC hobby motors (4)
- 4VDC, 5A, 140 ohms DPST, N.O. DIP Dry Reed Relays
- 10 cm diameter wheels (4)
- Platform (e.g., base from a stripped computer)
- 6 volt battery (two batteries connected by parallel circuitry will last longer)
- 15 cm VELCRO® strips (3)

Secure the laptop with VELCRO® strips attached to the bottom of the laptop and the robot platform (see Figure 7).

Figure 7: Laptop mounted on platform



MATERIALS: UNIT 4

- Robot constructed in Unit 3
- Tape measure
- Stopwatch
- Calculator

Unit 4: Making the Robot Move

Discussion Topics: distance calculations, velocity and stopping time, traction, turning radius, forces and movement

MATERIALS: UNIT 5

- Robot constructed in Unit 3
- Sub-min SPDT reed switches with roller ends, 5g operating force (4)

Once students have constructed the robot and all the motors work, they can develop a program that will allow the robot to move down the hallway. Depending upon the location, students can program the motors to stop turning after a certain time; reverse direction to bring the robot back up to its original position; or even move around objects by programming the motors to turn in opposite directions.

Unit 5: Sensor Addition to Your Robot

Discussion Topics: forces and movement, velocity and stopping time, cause and effect responses

Once students have programmed the robot to move up and down a hallway, add simple reed switches to the robot that will trigger the robot to stop or change direction when it comes in contact with obstacles. Students should connect switches to the breadboard. Reed switches should be mounted at the front, back and sides of the robot. Students will then need to modify the computer program controling the robot, so that the robot reverses direction when either the front or back switches makes contact with an obstacle. Instead of just sending a signal out, students must also program the signal input. LPT pins/wires #18–25 work well for receiving signal input through the LPT port.

MATERIALS: UNIT 6

- Breadboards (2)
- 4" diameter wheels (4)
- Platform (e.g., base from a stripped computer)
- 6" VELCRO® strips (3)

And Either

- Identical 12 volt Mistumi Stepper motors (M68SP-1) 33 ohm 1.8 deg/step—no gear transmissions (4)
- 12VDC, 5A, SPST, N.O. DIP Dry Reed Relays (8)

Or

- Identical 3-5 volt Stepper motors, Miniangle Steppers, 3.4 volt, 2.1 a 1.8 deg/step —no gear transmissions (4)
- 5VDC, 5A, 140 ohms DPST, N.O. DIP Dry Reed Relays, model PRMA2A05 (4)
- 6 volt battery (two batteries connected by parallel circuitry will last longer)

Unit 6: Using Stepper Motors Instead of DC Motors

Discussion Topics: motor armatures and initialization, resistance, degrees and radians

Students should first determine the order in which wires get a current, so that the stepper motor will work properly. By using a multimeter and finding common resistance (ground) and a battery, students can deduce the pattern that turns the motor. Each stepper may have different colored wires, but the initialization pattern may be the same.

Once they have the four steppers working, students can connect these to the breadboards to replace the DC motors. Students can then work on controlling the robot speed and get the wheels turning in stepper degrees.

Unit 7: Creating a Memory or Record of Movement

Students program the computer to write and save all the movements and data to a text file. Later, students can print out the file for analysis.

ASSESSMENT

You can assess student success with a formal evaluation based on written tests and with oral explanations of what the students have accomplished. In both of these evaluations, include questions about how specific parts of the robot work. Questions should focus on cause-and-effect results, problems that arose, and the skills and techniques used to solve those problems.

REFERENCES

Tatchell (1983) suggested computer-controlled LEDs and robots. This activity updates LPT connections and diagrams.

Books

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Gilbertson, Roger G. *Muscle Wires Project Book*. California: Mondotronics, 1994.

Mueller, Scott. *Upgrading and Repairing PCs, Second Edition*. Indiana: Que Corp, 1992.

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Rosch, Winn L. *The Winn L. Rosch Hardware Bible*. New York: Brady Publishing, 1992.

Tatchell, Judy. *Practical Things to do with a Microcomputer*. London: Usborne Publishing Ltd., 1983.

Web sites

Hobby Electronic Robot Control Course: http://werple.net.au/~tonymerc/

Stepper Motor Technical Information: http://www.eio.com/stprtech.htm

Uses for Older Computer Technology: http://www.cfsl.mb.ca/cfsl/best_p/