## Contents at a Glance

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Project: Plotter Bot</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Hacking LEGO I: Connections</td>
<td>51</td>
</tr>
<tr>
<td>4</td>
<td>Project: Remote-Controlled Crane</td>
<td>63</td>
</tr>
<tr>
<td>5</td>
<td>Hacking LEGO II: Alternate Controllers</td>
<td>105</td>
</tr>
<tr>
<td>6</td>
<td>Project: Robot Flower</td>
<td>123</td>
</tr>
<tr>
<td>7</td>
<td>Hacking LEGO III: Create Your Own LEGO Parts</td>
<td>157</td>
</tr>
<tr>
<td>8</td>
<td>Project: Ball Contraption</td>
<td>177</td>
</tr>
<tr>
<td>9</td>
<td>Hacking LEGO IV: Add-on Electronics</td>
<td>239</td>
</tr>
<tr>
<td>10</td>
<td>Project: Flagpole Climber</td>
<td>259</td>
</tr>
</tbody>
</table>

Glossary 303  
Index 307
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td>1 - 2</td>
</tr>
<tr>
<td></td>
<td>Hacking Mindstorms</td>
<td>2 - 6</td>
</tr>
<tr>
<td>2</td>
<td>Project: Plotter Bot</td>
<td>7 - 43</td>
</tr>
<tr>
<td></td>
<td>Parts List</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Building the Plotter Bot</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Program the Plotter Bot</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Moving the Motors</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>A Simple Program</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Resetting the X Axis</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Hacking Opportunities</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
<td>49</td>
</tr>
<tr>
<td>3</td>
<td>Hacking LEGO I: Connections</td>
<td>51 - 62</td>
</tr>
<tr>
<td></td>
<td>Mindstorms Wires Explained</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Inside the Mindstorms Wire</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>Hacking Mindstorms Wires</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Exploring Wireless Options</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>Infrared Sensor and Beacon</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>Bluetooth</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>Hacking Wireless</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
<td>62</td>
</tr>
<tr>
<td>4</td>
<td>Project: Remote-Controlled Crane</td>
<td>63 - 104</td>
</tr>
<tr>
<td></td>
<td>Parts List</td>
<td>64</td>
</tr>
<tr>
<td></td>
<td>Building the Crane</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Programming the Crane</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Controlling the Crane with Infrared</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Using Your Phone's Commander App</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
<td>104</td>
</tr>
<tr>
<td>5</td>
<td>Hacking LEGO II: Alternate Controllers</td>
<td>105 - 120</td>
</tr>
<tr>
<td></td>
<td>Microcontrollers and Microcomputers</td>
<td>106</td>
</tr>
<tr>
<td></td>
<td>Arduino</td>
<td>106</td>
</tr>
<tr>
<td></td>
<td>Raspberry Pi</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>BeagleBone Black</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>But Why?</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>Example Projects</td>
<td>114</td>
</tr>
<tr>
<td></td>
<td>Book Reader</td>
<td>114</td>
</tr>
<tr>
<td></td>
<td>Mini Tank</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>Chocolate Milk Maker</td>
<td>116</td>
</tr>
<tr>
<td></td>
<td>Ball Counting Robot</td>
<td>117</td>
</tr>
<tr>
<td></td>
<td>Rolling Alarm Robot</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td>BeagleBone Black Robot</td>
<td>119</td>
</tr>
<tr>
<td></td>
<td>Programming Environments</td>
<td>120</td>
</tr>
<tr>
<td>Chapter 6</td>
<td>Project: Robot Flower</td>
<td>123</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>Robot Flower Mindstorms Build</td>
<td>124</td>
</tr>
<tr>
<td></td>
<td>Parts List</td>
<td>124</td>
</tr>
<tr>
<td></td>
<td>Steps</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>Program the Robot Flower</td>
<td>146</td>
</tr>
<tr>
<td></td>
<td>Substituting the Arduino</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>Quick and Dirty Arduino</td>
<td>151</td>
</tr>
<tr>
<td></td>
<td>Parts</td>
<td>152</td>
</tr>
<tr>
<td></td>
<td>Steps</td>
<td>153</td>
</tr>
<tr>
<td></td>
<td>Programming the Arduino</td>
<td>154</td>
</tr>
<tr>
<td>Summary</td>
<td>155</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 7</th>
<th>Hacking LEGO III: Create Your Own LEGO Parts</th>
<th>157</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Designing Your Own Parts</td>
<td>158</td>
</tr>
<tr>
<td></td>
<td>Check Your Dimensions</td>
<td>159</td>
</tr>
<tr>
<td></td>
<td>Create the Design File</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>Output and Iterate</td>
<td>161</td>
</tr>
<tr>
<td></td>
<td>Finding Designs</td>
<td>161</td>
</tr>
<tr>
<td></td>
<td>Thingiverse</td>
<td>162</td>
</tr>
<tr>
<td></td>
<td>LDraw</td>
<td>163</td>
</tr>
<tr>
<td></td>
<td>SketchUp Warehouse</td>
<td>163</td>
</tr>
<tr>
<td></td>
<td>Outputting Your Own Parts</td>
<td>164</td>
</tr>
<tr>
<td></td>
<td>CNC Mill</td>
<td>164</td>
</tr>
<tr>
<td></td>
<td>Laser Cutter</td>
<td>167</td>
</tr>
<tr>
<td></td>
<td>3D Printer</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>Tip: Parametric 3D Models</td>
<td>175</td>
</tr>
<tr>
<td>Summary</td>
<td>176</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 8</th>
<th>Project: Ball Contraption</th>
<th>177</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Building the Contraption</td>
<td>178</td>
</tr>
<tr>
<td></td>
<td>Parts List</td>
<td>178</td>
</tr>
<tr>
<td></td>
<td>Steps</td>
<td>179</td>
</tr>
<tr>
<td></td>
<td>Program the Contraption</td>
<td>224</td>
</tr>
<tr>
<td></td>
<td>Creating Your Own Parts</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td>The Baseplate</td>
<td>226</td>
</tr>
<tr>
<td></td>
<td>The Gear</td>
<td>233</td>
</tr>
<tr>
<td>Summary</td>
<td>237</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 9</th>
<th>Hacking LEGO IV: Add-on Electronics</th>
<th>239</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Motors and Wheels</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>Motor Driver</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>Omni-Wheels</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>8-Channel Servo Controller</td>
<td>241</td>
</tr>
</tbody>
</table>
About the Author


Dedication

This book is dedicated to my wife Elise, my kids Arden, Rosemary, and Jack, my mom Barbara, and to all those who strive to make an item or platform work better for them by hacking it!

Acknowledgments

Thanks for the inspiration and assistance (in no particular order) to Miguel Valenzuela, Pete McKenna, Steve Norris, Steven Anderson, MakerBeam, Jude Dornisch, SparkFun Engineering, Adam Wolf, Michael Freiert, Sophi Kravitz, Christina Zhang, Lenore Edman, Rick Kughen, Sean Michael Ragan, John Wilson, Susan Solarz, Akiba, Mark Frauenfelder, Chris Berger, Michael Krumpus, Alex Dyba, Brian Jepson, Becca Steffen, Dave Bryan, Actobotics, Mike Hord, Makeblock, Pat Arneson, Erin Kennedy, Mindsensors, Windell H. Oskay, Johngineer, Matthew Beckler, Riley Harrison, David Lang, Trammell Hudson, Kristina Durivage, AnnMarie Thomas, Pete Prodoehl, Bruce Shapiro, Alex Allmont, John Edgar Park, and Dexter Industries. Apologies to anyone I forgot!
We Want to Hear from You!

As the reader of this book, you are our most important critic and commentator. We value your opinion and want to know what we’re doing right, what we could do better, what areas you’d like to see us publish in, and any other words of wisdom you’re willing to pass our way.

We welcome your comments. You can email or write to let us know what you did or didn’t like about this book—as well as what we can do to make our books better.

*Please note that we cannot help you with technical problems related to the topic of this book.*

When you write, please be sure to include this book’s title and author as well as your name and email address. We will carefully review your comments and share them with the author and editors who worked on the book.

Email: feedback@quepublishing.com

Mail: Que Publishing
ATTN: Reader Feedback
800 East 96th Street
Indianapolis, IN 46240 USA

Reader Services

Visit our website and register this book at quepublishing.com/register for convenient access to any updates, downloads, or errata that might be available for this book.
This page intentionally left blank
Hacking LEGO I: Connections

Mindstorms’ components consist of modules linked together. The motors connect to the Intelligent Brick but not directly—they use wires to link the power and data of both modules together. Those linkages are themselves fascinating. This chapter explores what’s up with those Mindstorms wires and demonstrates how to hack them into different configurations. Then, I describe some of the common methods Mindstorms hackers employ to control and connect components without using wires.

Mindstorms Wires Explained

Let’s begin by exploring all the nitty-gritty details of the standard Mindstorms wire. LEGO uses semiproprietary wires in its Mindstorms variants. I call them semiproprietary because they’re just a standard configuration (known in the business as RJ12) but with the tab off to one side, as shown in Figure 3.1. You literally could use RJ12s if those tabs were off-center. Since LEGO has seen fit to do it this way, however, we have to use our creativity to overcome this inconvenience.

First, however, let’s check out what you get in the EV3 set:

- Four—250mm/10-inch
- Two—350mm/13.75-inch
- One—500mm/20-inch

So to recap, the EV3 set includes four short cords, one long cord, and two in the middle. The cords can be swapped end-to-end and can be used with everything from motors to sensors. They’re truly universal in the Mindstorms world, meaning you only have to worry about length when you grab a wire.
CHAPTER 3: Hacking LEGO I: Connections

FIGURE 3.1 Mindstorms cables’ off-center tabs are all that differentiate them from RJ12s.

Not surprisingly, these three sizes aren’t good for everyone, so some established suppliers have come up with different wire sets:

- HiTechnic’s NXT Extended Connector Cable Set (P/M NWS1000) includes six cables, ranging in length from 120mm (4.7-inch) to 900mm (35.4-inch). You can buy the set at hitechnic.com.
- Mindsensors’ Flexi-Cable pack (P/N FLEX-Nx) includes four cables: 200mm, 350mm, and 500mm just like regular LEGO cables. However, Mindsensors’ cables have thinner and more flexible insulation, allowing them to move around and bend more readily than LEGO’s stiffer wires. You can buy the Flexi-Cables at mindsensors.com.

Inside the Mindstorms Wire

So, what’s going on inside that black plastic insulation? It turns out there are six smaller wires inside, as shown in Figure 3.2.
1. The blue wire is the SDA (serial data) wire, one-half of a two-wire data transfer protocol called I^2C. EV3 can transmit sensor data and commands through the I^2C bus.

2. Yellow is the SCL (serial clock) wire, the other half of the protocol.

3. Green is power, typically delivering either 3.3 or 5V from the EV3’s battery pack. You can use this wire to power electronic circuitry and add-on modules.

4. Red is ground. Creating a circuit with the power pin and this ground yields 5V.

5. Black is also ground. A circuit with this ground and the power pin yields 3.3V.

6. White is analog, transmitting analog sensor signals back to the EV3 Intelligent Brick.

Knowing the purpose of each wire helps you hack them, and it never hurts to understand what’s going on under the insulation.

FIGURE 3.2 The Mindstorms wire actually consists of six smaller wires.

Hacking Mindstorms Wires

Not unexpectedly, LEGO hackers have explored the wires and created their own variants to suit the needs of their projects. The following are a sampling of techniques you could employ.

Changing the Length of a Mindstorms Wire

This is an obvious one. How do you change the length of a Mindstorms wire? The following takes you through the steps, with Figure 3.3 guiding you along the process.

1. Make a shorter wire: Cut the plug off one end, making sure to leave yourself a couple of inches of wire, and trim the remaining length down to the size you want. To make a longer wire, cut an end off two wires, so that their combined length equals the size you want.

2. Carefully remove the outer black insulation and pull apart the six inner wires.

3. Solder together each wire to its same-colored mate on the other side. (If you need to polish up your soldering skills, there’s a helpful how-to here: http://mightyohm.com/files/soldercomic/FullSolderComic_EN.pdf.)

4. Insulate the individual wires with heat-shrink tubing, such as SparkFun P/N 9353. Then the combined wires should get a larger piece of tubing to keep them in check.
CHAPTER 3: Hacking LEGO I: Connections

FIGURE 3.3 To alter a Mindstorms wire, just cut it apart and solder it back together.

Using a Breakout Board
Another way to access the inner workings of a Mindstorms wire is to use a breakout board. These are little circuit boards with Mindstorms-compatible plugs on them, allowing you to break out the six inner wires as separate pins.
A couple of variants are floating around; I like the Bricktronics Breakout Board, selling for only $4 from wayneandlayne.com. In Figure 3.4 I demonstrate how to light up an LED, connecting from the power pin to the red ground (5V) with a 470-ohm resistor protecting the LED from too much voltage.

FIGURE 3.4 To access the inner wires individually, use a breakout board.
Breadboard-to-PF Hybrid Wire

PF refers to Power Functions, a mostly compatible motorized set put out by LEGO and marketed alongside Mindstorms. In fact, the beams and other building elements in the EV3 set are identical to the parts sold with PF sets, making the two remarkably compatible. Not completely, however, because there is no way to control PF’s awesome DC motors using your EV3 brick. Two of PF’s four wires are 9V and GND, and the other two control the speed of the motor.

You still need a way to trigger the voltage—the 9V the Power Functions motors are expecting is more than the EV3 brick can handle. In Chapter 5, “Hacking LEGO II: Alternate Microcontrollers,” I show you how to use an Arduino microcontroller that not only can control those great PF motors, but also Mindstorms servos as well.

In the meantime, here’s how to make your own hybrid wire:

1. Cut off one end of a Power Functions extension cable (LEGO P/N 8886). It has a male end and a female end, with the male end looking like a regular 2x2 LEGO brick, and the female end looking like the underside of a similar brick, allowing you to attach them together just like they were regular bricks.

2. Strip the four individual wires on the female end. They consist of Power, Control 1, Control 2, and Ground. Solder each wire to a male header pin (SparkFun P/N 12693) or a Molex plug like you see in Figure 3.5, which you can crimp on yourself, or buy a pigtail such as the SparkFun P/N 9920. Use heat shrink to cover all conductive surfaces.
Exploring Wireless Options

Mindstorms wires are a given—but what about wireless communication? The EV3 kit comes with two ways to communicate wirelessly with your Intelligent Brick.

Infrared Sensor and Beacon

The EV3 set includes a dirt-simple infrared remote (IR) control and receiver that allow you to control two motors on your model, both forward and backward (see Figure 3.6). In addition, you can opt between two channels, so theoretically you could control four motors with two remotes and two receivers. Another option would be to have four motors connected to your robot—for instance, two for propulsion and two to control a robot arm—and you simply switch channels when you want to do one task or the other.
The sensor has one added feature that most IR receivers lack: It can be used as a proximity sensor, beaming out infrared light and sensing as it bounces back. This feature has a short range compared to other proximity sensors (for example, ultrasonic), and can detect proximity only within 50cm to 70cm, or around 2 to 3 inches.

The beacon is what LEGO calls its remote control, and this is not just for fun: One of the projects described in the EV3 set is an IR-homing robot that wanders around until it senses the infrared signal from the beacon and rolls toward it. The controller’s range is only about 2 meters, unfortunately.

**FIGURE 3.6** The infrared sensor and beacon give you simple wireless control of your robot.

**Bluetooth**

Another intriguing option is the EV3 brick’s Bluetooth capabilities. The Intelligent Brick has a Bluetooth chip on-board, allowing it to connect to other EV3 bricks as well as take commands from smartphones using an application called the Commander, which includes preset control configurations for the five sample robots that are part of the EV3 set (see Figure 3.7). You can also create an interface for a custom robot, pulling out sliders and buttons from a library to match what you’re building.

EV3’s Bluetooth capability also allows you to control the Intelligent Brick from your PC or Mac wirelessly, just as if you had it plugged in with a Bluetooth cable.
Finally, one cool aspect of the robot, both in terms of Bluetooth and regular wiring, is you can link up to four EV3 bricks together if you want to build a gloriously complicated robot.

FIGURE 3.7 LEGO’s Bluetooth app allows you to control robots wirelessly.

Hacking Wireless

It almost goes without saying that Mindstorms fans have figured out how to control their robots in ways not officially supported by LEGO. Here are just a few ways to wirelessly control your Mindstorms robot.

XBee

A common hobbyist and professional wireless specification is called Zigbee, and XBee is a brand of wireless modules built to that spec. Dexter Industries (dexterindustries.com) sells a
Mindstorms-compatible XBee breakout called the NXTBee, though I’m not sure whether it’s compatible with EV3 yet. Another technique is to ditch the EV3 brick altogether and use an Arduino: Check out the cool LEGO bracer shown in Figure 3.8. It has an Arduino, battery pack, XBee, and Wii nunchuk, allowing me to operate a robot with a wearable controller. SparkFun sells XBee radios (P/N 8665) as well as its own flavor of breakout board.

Radio Control

Normal radio control (RC) technology doesn’t mesh well with Mindstorms, but it can be made to work. RC flight electronics consist (in their most basic configuration) of a radio, shown in Figure 3.9, as well as a receiver. The receiver interprets the data from the transmitter and triggers pins that tell the motors what to do. Not surprisingly, those same pins can trigger Arduino actions or could be used to bump Mindstorms touch sensors with a servo.
PlayStation Controller
Mindsensors.com and a couple of other places sell a wireless controller that consists of a PlayStation 2 (PS2) interface card that plugs into the EV3 Intelligent Brick—onto which a wired PS2 controller may connect (see Figure 3.10). Mindsensors also sells a 2.4Ghz wireless PS2 controller and a matching dongle that plugs into that interface card, allowing you to wirelessly control your robot.
Mindsensors’ PS2 adapter lets you control your model with a game controller.

Wi-Fi Dongle in EV3

There is no native Wi-Fi capability in EV3 bricks, but you can add it with a USB dongle, such as the NetGear WNA1100 shown in Figure 3.11. As a matter of fact, the WNA1100 is currently the only wireless dongle that the EV3 works with out of the box. It may be that other models can be made to work with the EV3, but so far just this one works.
BrickPi and a Wi-Fi Module

Here's another example of a Wi-Fi add-on module allowing wireless communication of a Mindstorms robot. The BrickPi shield allows you to control Mindstorms by doing away with the EV3 brick and using a Raspberry Pi minicomputer, with the BrickPi mounted on top (see Figure 3.12). A Wi-Fi module from Adafruit (P/N 814) provides connectivity, though the Pi’s built-in Ethernet port is always an option.

Summary

This chapter is all about connections: hacking Mindstorms wires and playing around with wireless options such as infrared, radio control, and Wi-Fi. In Chapter 4, “Project: Remote-Controlled Crane,” you put this knowledge to good use, making a rolling crane that responds to a variety of wireless control methods.
This page intentionally left blank
Index

Symbols

3D printers, 170-174
5x3 bricks, 157-158
8-channel servo controller, 241
80/20 interface, 173

A

absolute IMU-ACG (accelerometer), 250-251
accelerometers, 250-251
alternatives to EV3. See controllers
aluminum bricks, 166-167
Arduino
  Ball Counting Robot project, 117-118
  Bricktronics shield, 107-108
  components of, 106-107
  Mini Tank project, 115-116
  resources for information, 151-152
Robot Flower project, 150-155
  building instructions, 153
  parts list, 152
  programming instructions, 154-155
Arduino-to-LEGO interface pieces, 169

B

backlights, 239
Ball Contraption project, 177
  building instructions, 179-223
  creating bricks, 225
    baseplate, 226-232
    gear, 233-237
  parts list, 178-179
  programming instructions, 224-225
Ball Counting Robot project, 117-118
  baseplate, creating (Ball
  Contraption project), 226-232
BeagleBone Black (BBB)
  components of, 110-111
  EVB cape, 112
  Gyro Boy project, 119-120
  beams, curved, 161-162
  black wires, 53
  blue wires, 53
  Bluetooth controls
    explained, 57-58
    Remote-Controlled Crane
    project, 98-103
  Book Reader project, 114-115
  breadboard-to-PF hybrid wires, 55-56
breakout boards, 54
BrickPi
  installing, 292-294, 297-301
  mounting plates, 169-170
  shield, 62, 110
    Book Reader project, 114-115
bricks, creating, 157-158
Ball Contraption project, 225
  baseplate, 226-232
  gear, 233-237
designing parts, 158
dimensions, 159
output and iteration stages, 161
software for design files, 160
finding designs, 161-164
parametric 3D models, 175
tools for output, 164
  3D printers, 170-174
  CNC mills, 164-167
  laser cutters, 167-170
Brickstuff
  light strands, 245
  proximity sensor, 247-248
Bricktronics, 240
  shield, 3, 107-108
    Mini Tank project, 115-116
Budel, Tristram, 166-167

Building instructions
- Ball Contraption project, 179-223
- Flagpole Climber project, 262-287
- Plotter Bot project, 9-43
- Raspberry Pi and BrickPi installation, 294-298
- Remote-Controlled Crane project, 65-92
- Robot Flower project, 125-146
- Arduino version, 153

C programming language, RobotC, 121

Cables. See wires
- Cailliau, Robert, 159
- Cameras, Pixy, 248-249
- Cape, 111
- Cartesian coordinates, 43-44
- Changing wire length, 53-54
- Chocolate Milk Maker project, 116-117
- Chronodot, 113-114
- CNC (computer-numerically controlled) mills, 164-167
- Commander app, 57
- Remote-Controlled Crane project, 98-103

Connections
- Wireless
  - Bluetooth controls, 57-58
  - BrickPi shield, 62
  - IR (infrared) controls, 56-57
  - PlayStation controllers, 60-61
  - RC (radio control) technology, 59-60

- Wi-Fi dongles, 61
- XBee modules, 58-59
- Wires
  - Breadboard-to-PF hybrid wires, 55-56
  - Breakout boards, 54
  - Changing length of, 53-54
  - Components of, 52-53
  - Length of, 51-52
- Controllers, 105
- Arduino
  - Bricktronics shield, 107-108
  - Components of, 106-107
  - Resources for information, 151-152
  - Robot Flower project, 150-155
  - Ball Counting Robot project, 117-118
  - BeagleBone Black components of, 110-111
  - EVB cape, 112
  - Book Reader project, 114-115
  - Chocolate Milk Maker project, 116-117
  - Gyro Boy project, 119-120
  - Mini Tank project, 115-116
  - PlayStation controller interface, 257
  - Programming environments, 120
    - Lejos, 121
    - Monobrick, 121
    - RobotC, 121
  - Raspberry Pi, 291
  - BrickPi shield, 110
    - Components of, 108-109
    - Installing, 292-294, 297-301
    - Instructional overview, 292

- Reasons for using EV3 alternatives, 112-114
- Relay Drivers, 256
- Rolling Alarm Robot project, 118-119
- sBrick, 256-257
- XBee modules, 258
- Crane project. See Remote-Controlled Crane project
- Creative Robotics, Hub-ee wheels, 242
- Curved beams, 161-162
- Customizable Technic Hub, 175

D

- Designing bricks, 158
  - Dimensions, 159
  - Finding designs, 161-164
  - Output and iteration stages, 161
  - Parametric 3D models, 175
  - Software for design files, 160
  - Tools for output, 164
  - 3D printers, 170-174
  - CNC mills, 164-167
  - Laser cutters, 167-170

- Dexter Industries
  - BrickPi installation, 292
  - dGPS, 246-247
  - dLights, 244-245
  - dPressure, 251
  - NXTBee, 58
  - Thermal infrared sensor, 252
  - XBee modules, 258
  - dGPS sensor, 246-247
  - Dimensions, designing bricks, 159
  - dLights, 244-245
dPressure sensor, 251
drawing pens. See Plotter Bot project

E
ecosystems for hardware and code, 113
Education set. See LEGO Education
education usage, 113
EV3, alternatives to. See controllers
EV8 cape, 112
Gyro Boy project, 119-120

F
finding brick designs, 161-164
Flagpole Climber project, 259-260
building instructions, 262-287
installing ultrasonic sensor, 289
parts list, 260-261
programming instructions, 288
programming ultrasonic sensor, 290-291
Raspberry Pi and BrickPi installation, 292-301
troubleshooting, 301
Flexi-Cables, 52
Flower project. See Robot Flower project

G
gear, creating (Ball Contraption project), 233-237
GoPro camera mount, 171-172
green wires, 53
Grove Sensor Adapter, 246
Gyro Boy project, 119-120

H
hacking suggestions
Plotter Bot project, 49
wireless controls
BrickPi shield, 62
PlayStation controllers, 60-61
RC (radio control) technology, 59-60
Wi-Fi dongles, 61
XBee wireless modules, 58-59
wires
breadboard-to-PF hybrid wires, 55-56
breakout boards, 54
changing length of, 53-54
HiTechnic NXT Extended Connector Cable Set, 52
Hub-ee wheels, 242

I
infrared (IR) controls
Remote-Controlled Crane project, 98
sensors and beacons, 56-57
Inkscape, 160
installing
BrickPi, 292-301
Raspberry Pi, 292-301
ultrasonic sensor (Flagpole Climber project), 289
interface pieces
80/20 interface, 173
Arduino-to-LEGO pieces, 169
PlayStation controller interface, 257
Universal Connector Kit, 172
IR (infrared) controls. See infrared (IR) controls
iteration stage (designing bricks), 161

J-L
Janssen, Jorg, 157
Java, Lejos programming environment, 121
Klann linkage, 165-166
laser cutters, 167-170
LazerStorm mounting plates, 168
LDRAW, 163
LEGO bricks. See bricks, creating
LEGO Education, 252
NXT temperature sensor, 253-254
pneumatics add-on set, 252-253
Lejos, 121
length of wires
changing, 53-54
standard lengths, 51-52
libraries, 107
lighting
backlights, 239
Brickstuff light strands, 245
NXT light sensor, 253
RGB LED modules, 244-245
linear actuators, 242-243
Linux, 112

M
Makeblock building set, 4
Makeblock Constructor, 170
McFarlan, Stuart, 169
mechanum (omni) wheels, 174, 240-241
Medwin, Steve, 161-162, 175
Meno, Joe, 239
microcomputers. See controllers
Mindsensors
  8-channel servo controller, 241
  absolute IMU-ACG (accelerometer), 250
Flexi-Cables, 52
Grove Sensor Adapter, 246
mux (multiplexer), 249
Pixy camera, 248
PlayStation controller interface, 257
relay driver, 256
servo-actuated pneumatic valve, 243
Mini Tank project, 115-116
Monobrick, 121
Motor Driver, 240
motors
  8-channel servo controller, 241
  Hub-ee wheels, 242
  linear actuators, 242-243
Motor Driver, 240
moving (Plotter Bot project), 44-47
pneumatics add-on set, 253
servo-actuated pneumatic valves, 243-244
stepper motors, 7
mounting plates
BrickPi, 169-170
LazerStorm, 168
moving motors (Plotter Bot project), 44-47
mux (multiplexer), 249-250
N
t attached Pads, 7
NetGear WNA1100 dongle, 61
NXT, 252
light sensor, 253
sound sensor, 254
temperature sensor, 253-254
ultrasonic sensor, 255
Flagpole Climber project, 289-291
NXT Extended Connector Cable Set, 52
NXTBee, 59
omni wheels, 174, 240-241
output stage (designing bricks), 161
outputting bricks, tools for, 164
  3D printers, 170-174
  CNC mills, 164-167
  laser cutters, 167-170
P-Q
parametric 3D models, 175
parts, creating. See bricks, creating
parts list
  Ball Contraption project, 178-179
  Flagpole Climber project, 260-261
  Plotter Bot project, 8-9
  Raspberry Pi and BrickPi installation, 294
  Remote-Controlled Crane project, 64
  Robot Flower project, 124-125
  Arduino version, 152
pens, drawing. See Plotter Bot project
PF (Power Functions), breadboard-to-PF hybrid wires, 55-56
Pi. See Raspberry Pi
Pixy camera, 248-249
PlayStation controllers, 60-61
interface for, 257
Plotter Bot project, 7
building instructions, 9-43
parts list, 8-9
programming instructions, 43-44
hacking suggestions, 49
motor movement, 44-47
resetting X axis, 47-48
pneumatics
dPressure sensor, 251
LEGO add-on set, 252-253
servo-actuated pneumatic valves,
243-244
printers, 3D, 170-174
programming environments, 120
Lejos, 121
Monobrick, 121
RobotC, 121
programming instructions
  Ball Contraption project, 224-225
  Flagpole Climber project, 288
  ultrasonic sensor, 290-291
  Plotter Bot project, 43-44
  hacking suggestions, 49
  motor movement, 44-47
  resetting X axis, 47-48
  Raspberry Pi and BrickPi installation, 298-301
Remote-Controlled Crane project, 93-98
Robot Flower project, 146-149
Arduino version, 154-155

projects
Ball Contraption, 177
building instructions, 179-223
creating bricks, 225-237
parts list, 178-179
programming instructions, 224-225
Ball Counting Robot, 117-118
Book Reader, 114-115
Chocolate Milk Maker, 116-117
Flagpole Climber, 259-260
building instructions, 262-287
installing ultrasonic sensor, 289
parts list, 260-261
programming instructions, 288
programming ultrasonic sensor, 290-291
Raspberry Pi and BrickPi installation, 292-301
troubleshooting, 301
Gyro Boy, 119-120
Mini Tank, 115-116
Plotter Bot, 7
building instructions, 9-43
hacking suggestions, 49
parts list, 8-9
programming instructions, 43-48
Remote-Controlled Crane, 63

Bluetooth controls, 98-103
building instructions, 65-92
infrared (IR) controls, 98
parts list, 64
programming instructions, 93-98
resetting
X axis, 47-48
Y axis, 47
resources for information about Arduino, 151-152
RGB LED modules, 244-245
RJ12 cables, 51
RJ25 cables, 117-118
Robot Flower project, 123
Arduino controller, 150-155
building instructions, 125-146
parts list, 124-125
programming instructions, 146-149
Rolling Alarm Robot, 118-119
proximity sensor, 247-248
radio control (RC) technology, 59-60
Raspberry Pi, 291
Book Reader project, 114-115
BrickPi shield, 110
components of, 108-109
installing, 292-301
instructional overview, 292
Rolling Alarm Robot project, 118-119
RC (radio control) technology, 59-60
red wires, 53
relay drivers, 256
Remote-Controlled Crane project, 63
Bluetooth controls, 98-103
building instructions, 65-92
infrared (IR) controls, 98
parts list, 64
programming instructions, 93-98
sBrick control system, 256-257
sensors
absolute IMU-ACG (accelerometer), 250-251
dGPS, 246-247
dPressure, 251
Grove Sensor Adapter, 246
mux (multiplexer), 249-250
NXT light sensor, 253
NXT sound sensor, 254
NXT temperature sensor, 253-254
NXT ultrasonic sensor, 255
Flagpole Climber project, 289-291
sensors

Pixy camera, 248-249
proximity sensor, 247-248
thermal infrared sensor, 252
servo mounting block, 173-174
servo-actuated pneumatic valves, 243-244
servos, 8-channel controller, 241
SketchUp, 160, 163-164
software, designing bricks, 160
soldering how-to information, 53
sound sensor (NXT), 254
SparkFun BrickPi installation, 292
Steele, Shawn, 173
stepper motors, 7

T

temperature sensor (NXT), 253-254
thermal infrared sensor, 252
Thingiverse, 157, 162
troubleshooting Flagpole Climber project, 301

U-V

ultrasonic sensor (NXT), 255
Flagpole Climber project, 289-291
Universal Connector Kit, 172

W

Warehouse (SketchUp), 163
Weller, Mark, 165
wheels
Hub-ee wheels, 242
mechanum (omni) wheels, 174, 240-241
white wires, 53
Wi-Fi dongles, 61

wireless controls. See also
Remote-Controlled Crane project
Bluetooth controls
explained, 57-58
Remote-Controlled Crane project, 98-103
BrickPi shield, 62
IR (infrared) controls
Remote-Controlled Crane project, 98
sensors and beacons, 56-57
PlayStation controllers, 60-61
RC (radio control) technology, 59-60
Wi-Fi dongles, 61
XBee modules, 58-59, 258
wires
breadboard-to-PF hybrid wires, 55-56
breakout boards, 54
changing length of, 53-54
components of, 52-53
length of, 51-52
WNA1100 dongle, 61

X-Z

X axis, 43-44
resetting, 47-48
XBee modules, 58-59, 258
Y axis, 43-44
resetting, 47
yellow wires, 53
Zigbee wireless specification, 58