

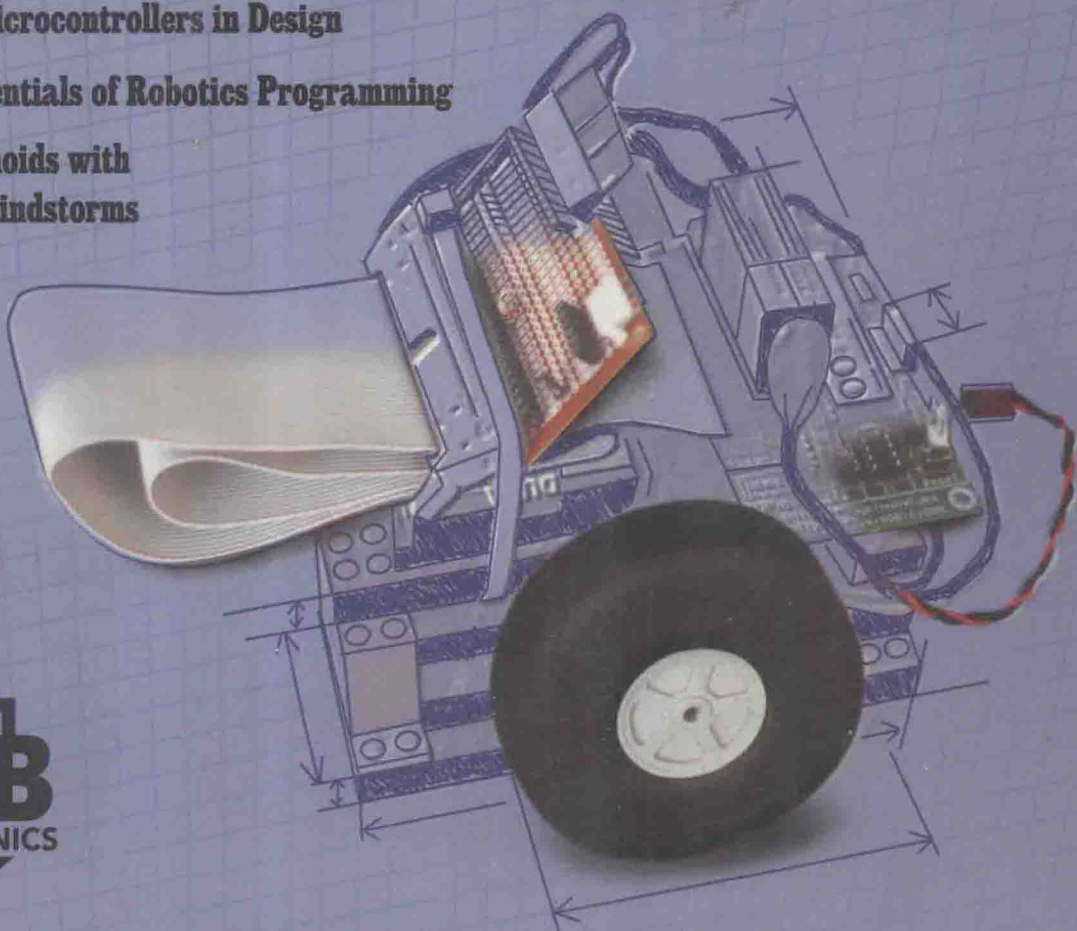
The Robot Builder's Bonanza

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Inexpensive
Robotics
Projects

ALL NEW COVERAGE ON:

- Using Microcontrollers in Design
- The Essentials of Robotics Programming
- Functionoids with
LEGO Mindstorms



TAB
ELECTRONICS

SECOND EDITION

Gordon McComb

THE ROBOT BUILDER'S BONANZA

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This time for my son, Max,
who dreams of robots.

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Only until you've climbed the mountain can you look behind you and see the vast distance that you've covered, and remember those you've met along the way who made your trek a little easier.

Now that this book is finally finished, after the many miles of weary travel, I look back to those who helped me turn it into a reality and offer my heartfelt thanks: To the gang on comp.robotics.misc, for the great ideas, wisdom, and support; to Scott Savage, designer of the OOPic; to Frank Manning and Jack Schoof of NetMedia for their help with the BasicX; to Tony Ellis, a real-life "Q" if I ever met one; to Scott Grillo and the editors at McGraw-Hill; to my agents Matt Wagner and Bill Gladstone; and last and certainly not least, to my wife Jennifer.

INTRODUCTION

The word *robot* is commonly defined as a mechanical device capable of performing human tasks, or behaving in a human-like manner. No argument here. The description certainly fits.

But to the robotics experimenter, “robot” has a completely different meaning. A robot is a special brew of motors, solenoids, wires, and assorted electronic odds and ends, a marriage of mechanical and electronic gizmos. Taken together, the parts make a half-living but wholly personable creature that can vacuum the floor, serve drinks, protect the family against intruders and fire, entertain, educate, and lots more. In fact, there’s almost *no limit* to what a well-designed robot can do.

In just about any science, it is the independent experimenter who first establishes the pioneering ideas and technologies. Robert Goddard experimented with liquid-fuel rockets during World War I; his discoveries paved the way for modern-day space-flight. In the mid-1920s, John Logie Baird experimented with sending pictures of objects over the airwaves. His original prototypes, which transmitted nothing more than shadows of images, were a precursor to television and video.

Robotics—like rocketry, television, and countless other technology-based endeavors—started small. But progress in the field of robots has been painfully slow. Robotics is still a cottage industry, even considering the special-purpose automatons now in wide use in automotive manufacturing. What does this mean for the robotics experimenter? There is plenty of room for growth, with a lot of discoveries yet to be made—perhaps more so than in any other high-tech discipline.

Inside Robot Builder’s Bonanza

Robot Builder’s Bonanza, Second Edition takes an educational but fun approach to designing working robots. Its modular projects take you from building basic motorized platforms to giving the machine a brain—and teaching it to walk and talk and obey commands.

If you are interested in mechanics, electronics, or robotics, you’ll find this book a treasure chest of information and ideas on making thinking machines. The projects in *Robot Builder’s Bonanza* include all the necessary information on how to construct the essential building blocks of a personal robot. Suggested alternative approaches, parts lists, and sources of electronic and mechanical components are also provided where appropriate.

Several good books have been written on how to design and build your own robot. But most have been aimed at making just one or two fairly sophisticated automatons, and at a fairly high price. Because of the complexity of the robots detailed in these other books, they require a fairly high level of expertise and pocket money on your part.

Robot Builder's Bonanza is different. Its modular “cookbook” approach offers a mountain of practical, easy to follow, and inexpensive robot experiments. Taken together, the modular projects in *Robot Builder's Bonanza* can be combined to create several different types of highly intelligent and workable robots of all shapes and sizes—rolling robots, walking robots, talking robots, you name it. You can mix and match projects as desired.

About the Second Edition

This book is a completely revised edition of *Robot Builder's Bonanza*, first published in 1987. The first edition of this book has been a perennial bestseller, and is one of the most widely read books ever published on hobby robotics.

This new edition provides timely updates on the latest technology and adds many new projects. In the following pages you'll find updated coverage on exciting technologies such as robotic sensors, robot construction kits, and advanced stepper and DC motor control. Plus, you'll find new information on microcontrollers such as the Basic Stamp, digital compasses, open- and closed-loop feedback mechanisms, new and unique forms of “soft touch” sensors including those using lasers and fiber optics, radio-controlled servo motors, and much, much more.

Book Updates

Periodic updates to *Robot Builder's Bonanza* can be found at <http://www.robot-oid.com>. You'll find new and updated links to Web sites and manufacturer addresses, a robot product and parts finder, tutorials on robot construction, a robot builder's discussion board, and more.

What You Will Learn

In the more than three dozen chapters in this book you will learn about a sweeping variety of technologies, all aimed at helping you learn robot design, construction, and application. You'll learn about:

- *Robot-building fundamentals*. How a robot is put together using commonly available parts such as plastic, wood, and aluminum.
- *Locomotion engineering*. How motors, gears, wheels, and legs are used to propel your robot over the ground.
- *Constructing robotic arms and hands*. How to use mechanical linkages to grasp and pick up objects.

- *Sensor design.* How sensors are used to detect objects, measure distance, and navigate open space.
- *Adding sound capabilities.* Giving your robot creation the power of voice and sound effects so that it can talk to you, and you can talk back.
- *Remote control.* How to operate and “train” your robot using wired and wireless remote control.
- *Computer control.* How to use and program a computer or microcontroller for operating a robot.

...plus much more.

How to Use This Book

Robot Builder's Bonanza is divided into six main sections. Each section covers a major component of the common personal or hobby (as opposed to commercial or industrial) robot. The sections are as follows:

- *Robot Basics.* What you need to get started; setting up shop; how and where to buy robot parts.
- *Robot Construction.* Robots made of plastic, wood, and metal; working with common metal stock; converting toys into robots; using LEGO parts to create robots; using the LEGO Mindstorms Robotics Invention System.
- *Power, Motors, and Locomotion.* Using batteries; powering the robot; working with DC, stepper, and servo motors; gear trains; walking robot systems; special robot locomotion systems.
- *Practical Robotics Projects.* Over a half-dozen step-by-step projects for building wheels and legged robot platforms; arm systems; gripper design.
- *Computers and Electronic Control.* “Smart” electronics; robot control via a computer or microcontroller; infrared remote control; radio links.
- *Sensors and Navigation.* Speech synthesis and recognition; sound detection; robot eyes; smoke, flame, and heat detection; collision detection and avoidance; ultrasonic and infrared ranging; infrared beacon systems; track guidance navigation.

Many chapters present one or more projects that you can duplicate for your own robot creations. Whenever practical, I designed the components as discrete building blocks, so that you can combine the blocks in just about any configuration you desire. The robot you create will be uniquely yours, and yours alone.

I prefer to think of *Robot Builder's Bonanza* not as a textbook on how to build robots but as a *treasure map*. The trails and paths provided between these covers lead you on your way to building one or more complete and fully functional robots. You decide how you want your robots to appear and what you want your robots to do.

Expertise You Need

Robot Builder's Bonanza doesn't contain a lot of hard-to-decipher formulas, unrealistic assumptions about your level of electronic or mechanical expertise, or complex designs that only a seasoned professional can tackle. This book was written so that just about anyone can enjoy the thrill and excitement of building a robot. Most of the projects can be duplicated without expensive lab equipment, precision tools, or specialized materials, and at a cost that won't contribute to the national debt!

If you have some experience in electronics, mechanics, or robot building in general, you can skip around and read only those chapters that provide the information you're looking for. Like the robot designs presented, the chapters are very much stand-alone modules. This allows you to pick and choose, using your time to its best advantage.

However, if you're new to robot building, and the varied disciplines that go into it, you should take a more pedestrian approach and read as much of the book as possible. In this way, you'll get a thorough understanding of how robots tick. When you finish with the book, you'll know the kind of robot(s) you'll want to make, and how you'll make them.

Conventions Used in This Book

You need little advance information before you can jump head first into this book, but you should take note of a few conventions I've used in the description of electronic parts, and the schematic diagrams for the electronic circuits.

TTL integrated circuits are referenced by their standard 74XX number. The common "LS" or "HC" identifier is assumed. I built most of the circuits using LS or HC TTL chips, but unless otherwise indicated, the projects should work with the other TTL families. However, if you use a type of TTL chip other than LS or HC, you should consider current consumption, fanout, and other design criteria. These may affect the operation or performance of the circuit.

The chart in Fig. I-1 details the conventions used in the schematic diagrams. Note that nonconnected wires are shown by a direct cross or lines, or a broken line. Connected wires are shown by the connecting dot.

Details on the specific parts used in the circuits are provided in the parts list tables that accompany the schematic. Refer to the parts list for information on resistor and capacitor type, tolerance, and wattage or voltage rating.

In all full circuit schematics, the parts are referenced by component type and number.

- IC# means an integrated circuit (IC).
- R# means a resistor or potentiometer (variable resistor).
- C# means a capacitor.

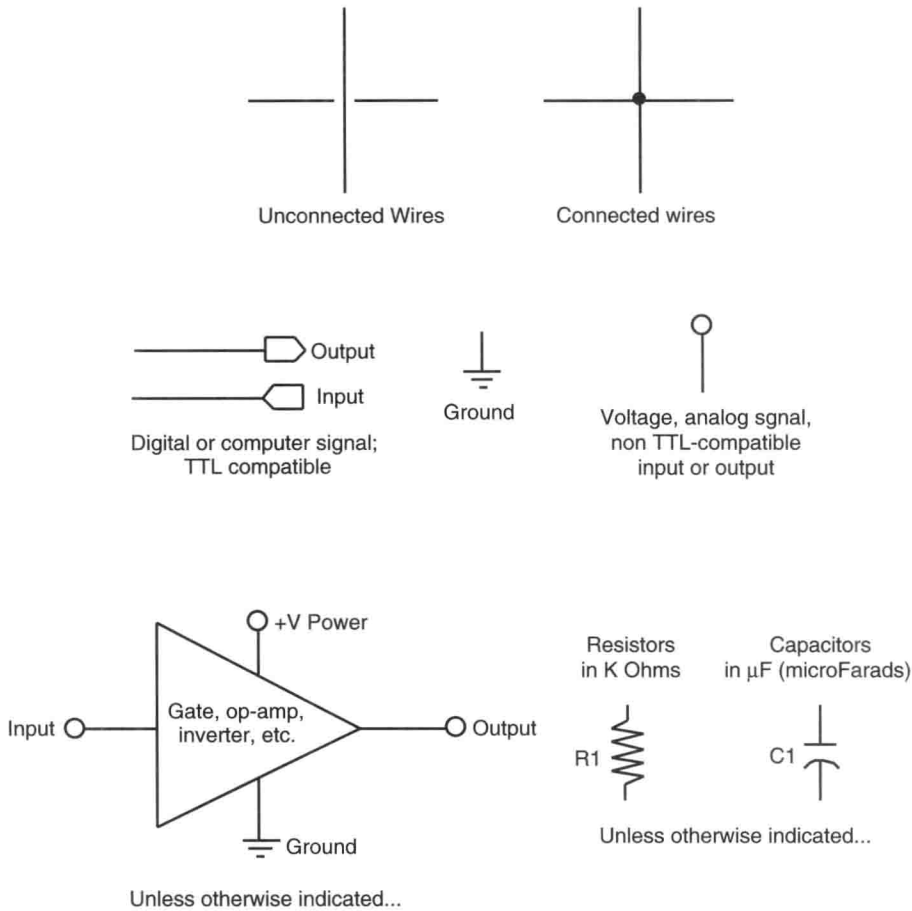


FIGURE I.1 Schematic diagram conventions used in this book.

- *D#* means a diode, a zener diode, and, sometimes a light-sensitive photodiode.
- *Q#* means a transistor and, sometimes, a light-sensitive phototransistor.
- *LED#* means a light-emitting diode (most any visible LED will do unless the parts list specifically calls for an infrared or other special purpose LED).
- *XTAL#* means a crystal or ceramic resonator.
- Finally, *S#* means a switch; *RL#* means a relay; *SPKR#*, a speaker; *TR#*, a transducer (usually ultrasonic); and *MIC#*, a microphone.

Enough talk. Turn the page and begin the journey. The treasure awaits you.

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ROBOT BASICS

THE ROBOT EXPERIMENTER

There he sits, as he's done countless long nights before, alone and deserted in a dank and musty basement. With each strike of his ball-peen hammer comes an ear-shattering bong and an echo that seems to ring forever. Slowly, his creation takes shape and form—it first started as an unrecognizable blob of metal and plastic, then it was transformed into an eerie silhouette, then...

Brilliant and talented, but perhaps a bit crazed, he is before his time: a social outcast, a misfit who belongs neither to science nor fiction. He is the robot experimenter, and all he wants to do is make a mechanical creature that serves drinks at parties and wakes him up in the morning.

Okay, maybe this is a rather dark view of the present-day hobby robotics experimenter. But though you may find a dash of the melodramatic in it, the picture is not entirely unrealistic. It's a view held by many outsiders to the robot-building craft. It's a view that's over 100 years old, from the time when the prospects of building a human-like machine first came within technology's grasp. It's a view that will continue for another 100 years, perhaps beyond.

Like it or not, if you're a robot experimenter, you are an oddball, an egghead, and—yes, let's get it all out—a little on the *weird* side!

As a robot experimenter, you're not unlike Victor Frankenstein, the old-world doctor from Mary Wollstonecraft Shelley's immortal 1818 horror-thriller. Instead of robbing graves in the still of night, you "rob" electronic stores, flea markets, surplus outlets, and other specialty shops in your unrelenting quest—your *thirst*—for all kinds and sizes of motors, batteries, gears,

wires, switches, and other odds and ends. Like Dr. Frankenstein, you galvanize life from these “dead” parts.

If you have yet to build your first robot, you’re in for a wonderful experience. Watching your creation scoot around the floor or table can be exhilarating. Those around you may not immediately share your excitement, but you know that you’ve built something—however humble—with your own hands and ingenuity.

If you’re one of the lucky few who has already assembled a working robot, then you know of the excitement I refer to. You know how thrilling it is to see your robot obey your commands, as if it were a trusted dog. You know the time and effort that went into constructing your mechanical marvel, and although others may not always appreciate it (especially when it marks up the kitchen floor with its rubber tires) you are satisfied with the accomplishment and look forward to the next challenge.

And yet if you have built a robot, you also know of the heartache and frustration inherent in the process. You know that not every design works and that even a simple engineering flaw can cost weeks of work, not to mention ruined parts. This book will help you—beginner and experienced robot maker alike—get the most out of your robotics hobby.

The Building-block Approach

One of the best ways to experiment with—and learn about—hobby robots is to construct individual robot components, then combine the completed modules to make a finished, fully functional machine. For maximum flexibility, these modules should be interchangeable whenever possible. You should be able to choose locomotion system “A” to work with appendage system “B,” and operate the mixture with control system “C”—or any variation thereof.

The robots you create are made from building blocks, so making changes and updates is relatively simple and straightforward. When designed and constructed properly, the building blocks, as shown in diagram form in Fig. 1.1, may be shared among a variety of robots. It’s not unusual to reuse parts as you experiment with new robot designs.

Most of the building-block designs presented in the following chapters are complete, working subsystems. Some operate without ever being attached to a robot or control computer. The way you interface the modules is up to you and will require some forethought and attention on your part (I’m not doing *all* the work, you know!). Feel free to experiment with each subsystem, altering it and improving upon it as you see fit. When it works the way you want, incorporate it into your robot, or save it for a future project.

Basic Skills

What skills do you need as a robot experimenter? Certainly, if you are already well versed in electronics and mechanical design, you are on your way to becoming a robot experimenter *extraordinaire*. But an intimate knowledge of electronics and mechanical design is not absolutely necessary.