DO-IT-YOURSELF

Circuitbuilding FOR DUMMIES®

by H. Ward Silver

Wiley Publishing, Inc.

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About the Author

H. Ward Silver has the experience of a 20-year career as an electrical engineer developing instrumentation and medical electronics. He also spent 8 years in broadcasting, both programming and engineering. In 2000 he turned to teaching and writing as a second career. He is a contributing editor to the American Radio Relay League (ARRL) and author of the popular "Hands-On Radio" column in QST magazine every month. He is the author of the ARRL's Amateur Radio license study guides and numerous other articles. He developed the ARRL's online courses, "Antenna Design and Construction," "Analog Electronics," and "Digital Electronics." Along with his comedic alter-ego, Dr Beldar, Ward is a sought-after speaker and lecturer among "hams." When not in front of a computer screen, you will find Ward working on his mandolin technique and compositions.

Dedication

Circuitbuilding Do-It-Yourself For Dummies is dedicated to the many technical writers whose articles in *QST*, *Popular Electronics, 73, CQ, Scientific American*, among others, inspired me to cut and solder and tinker my way through high school. Getting an amateur radio license on the way, that practical experience led directly to my first career as an electrical engineer. Another dedication is due my students and readers that make my second career as a writer equally enjoyable. If I can do for you what they did for me, I'll be very satisfied, indeed.

Author's Acknowledgments

In the early days of electrical experimentation, before "electronics" was even a word, there was no choice but to build one's own circuits. Back then, circuits were all about motors, lighting, and simple control systems. They were built with hammers, wrenches, screwdrivers, and, yes, soldering irons. Circuitbuilding was a full-body experience!

For a time not so long ago, it seemed that actually building one's own circuits was an activity that would go the way of AC-DC motor and knife switch. Electronic gadgets had become so inexpensive and easy to use, why should anyone bother to build anything more complicated than plugging cables together? The Internet and personal computer took building out of the physical world and into the realms of the network and cyberspace.

That trend has reversed in recent years. People of all ages are rediscovering the thrill and satisfaction of learning-by-doing. They've found that "lifting the hood" is just as much fun for electronics and circuits as developing a Web site or hooking up the latest gadget from the store. Not only just building, but modifying or "hacking" equipment, is providing hours of enjoyment, too!

If you're a budding circuitbuilder, welcome to the party! Join the thousands of ham radio operators, robotics enthusiasts, engineers, inventors, tinkerers, and hobbyists—people just like you. Heat up that soldering iron, turn on the voltmeter, and start building!

—H. Ward Silver

Publisher's Acknowledgments

We're proud of this book; please send us your comments through our online registration form located at www.dummies.com/register/.

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Contents at a Glance

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Introduction

Perhaps you've never built anything electronic, and now you want to. Perhaps you have built something before, but now you want to do something different. Look no further. *Circuitbuilding Do-It-Yourself For Dummies* is the book for both kinds of readers. Primarily, this book is intended to act as an introduction and guide to someone just getting started with electronics and circuits. It covers basic tools and techniques. If you are somewhat experienced with electronics, you'll find the book most useful as a workshop reference for specific kinds of tasks. The latter half of the book focuses on specific how-tos: cables, connectors, measurements, and maintenance.

There are so many circuits and applications of electronics that it is impossible to provide a detailed how-to guide for even a tiny fraction of the different types! The goal of this book is to show you the tools and techniques that circuitbuilders use, common to a wide variety of electronic construction needs.

This book presents basic techniques most useful to beginners. As such, you won't find detailed discussions of advanced topics such as fabricating your own circuit boards or performing reflow soldering at home. Nevertheless, if you become familiar with the techniques in this book, it will be easier for you to move on to more sophisticated techniques. I'll also give you pointers about where to find information on them.

This book is *not* a circuit design course or cookbook. I'll be assuming that you already have a schematic from a book or magazine or maybe you've purchased a kit. This book shows you how to build it, not design it. The list of resources in Appendix A include quite a number of how-to-design books about electronics and even some online courses and tutorials.

What You're Not to Read

As you make your way through *Circuitbuilding Do-It-Yourself For Dummies,* feel free to skip around to where your interests and needs take you. You don't have to read each chapter in order. Use the Table of Contents or the Index to find help on a specific topic, such as wiring up a particular cable. The extensive Glossary in the back of the book will help with unfamiliar terms. Sidebars contain material that's interesting but not required reading.

Assumptions About You

The subject of electronics is big and broad and deep, but don't panic! You only need tackle the small steps at first — be comfortable and progress at your own speed. This book doesn't expect you to have an engineering degree or a complete shop. In fact, I deliberately performed all of the tasks myself with the simplest equipment and tools, just to be sure my readers could do them, too!

What I *do* assume about you, however, is that you're curious and motivated to build on the basic skills in *Circuitbuilding Do-It-Yourself For Dummies.* Take a few minutes to investigate the online resources I note throughout the book. You'll also find an extensive list of resources in Appendix A.

Finally, you don't have to run out and buy all of the tools and components shown in the book. I'm sure your local electronics emporium would love it if you did, but take your time! Each task lists the tools and materials needed, and you will be just fine if you acquire them as you need them.

How This Book Is Organized

Circuitbuilding Do-It-Yourself For Dummies is composed of six parts. You'll get started with some electronic construction basics, then move onto specific tasks that show how circuitbuilding is done. From there you can read about techniques that support circuitbuilding like taking measurements and maintenance. A Glossary and the famous Parts of Ten wrap up the book.

Part I: Working Basics for Electronic-ers

This book doesn't neglect the basics — tools and techniques. You may have most of the tools, already! If you don't, this introductory part will help you get the ones you need. Then it's on to simple techniques for working with the materials you'll encounter when building circuits. I'll also help you read and make sense of electronic schematics, the language of circuitbuilders.

Part II: Building Circuits

This part of the book presents several ways of working with electronic components and materials to turn an idea into a living breathing circuit. By learning the basic techniques, you can build even the most complex circuits. Then learn how to install your circuit in a simple enclosure.

Part III: Cables and Connectors

Take a look at the back of any stack of electronic gadgets and what do you find? Cables and connectors! Lots of them! Yet the "how to" of making and repairing cables is rarely presented. That information doesn't get left out of this book! I cover all kinds of cables and connectors so that when your circuit is finally built, you'll be able to make the necessary connections to other equipment, too.

Part IV: Measuring and Testing

You can't see, smell, or touch electricity in your circuits — unless something goes pretty wrong! Testing and evaluating your circuits, then, takes some special electronic eyes and ears. This part of the book shows you how to use basic test instruments as part of the circuitbuilding process and during troubleshooting.

Part V: Maintaining Electronic Equipment

Circuitbuilding isn't just about soldering components together. Once you've built your circuit, what then? This part of the book covers installation and troubleshooting along with information on batteries and dealing with interference and noise. All of these topics are mighty handy out there in the Real World!

Part VI: The Part of Tens

Familiar to all *For Dummies* readers, these are condensed lists of helpful and (hopefully) memorable ideas. In this part, you'll get the top ten secrets of the art of circuitbuilding, as well as indispensable information on circuit first aid and some supplies you should keep handy.

Glossary

As you go through the book, specific technical terms in *italics* will often be found in the Glossary. Keep a bookmark in the glossary and you won't have to *gloss over* a term you don't understand.

Bonus Chapters

The book was so chock-full of critical info, we had to leave a few things out. But have no fear because you can find two bonus chapters on the Web site (`www.dummies.com/go/circuitbuildingdiyfd`) covering resistor and capacitor types.

Conventions and Icons

To make the reading experience as clear and uncluttered as possible, a consistent presentation style is used:

- *Italics* are used to note a new or important term.
- Web site URLs (addresses) use a monospace font.

Additionally you'll see the following icons used as markers for special types of information.

This icon alerts you to a hint that will help you understand a technical or operating topic. These are often referred to as "hints and kinks" by circuitbuilders.

This icon highlights a new term or concept that you'll need to know about. Be sure to check the book's Glossary, as well.

Whenever I could think of a common problem or "oops," you'll see this icon. Before you become experienced, it's easy to get hung up on some of these little things.

This icon lets you know that there are safety, rules, or performance issues associated with the topic of discussion. Watch for this icon to avoid common gotchas.

These icons remind you of an important idea or fact that you should keep in mind.

Where to Go from Here

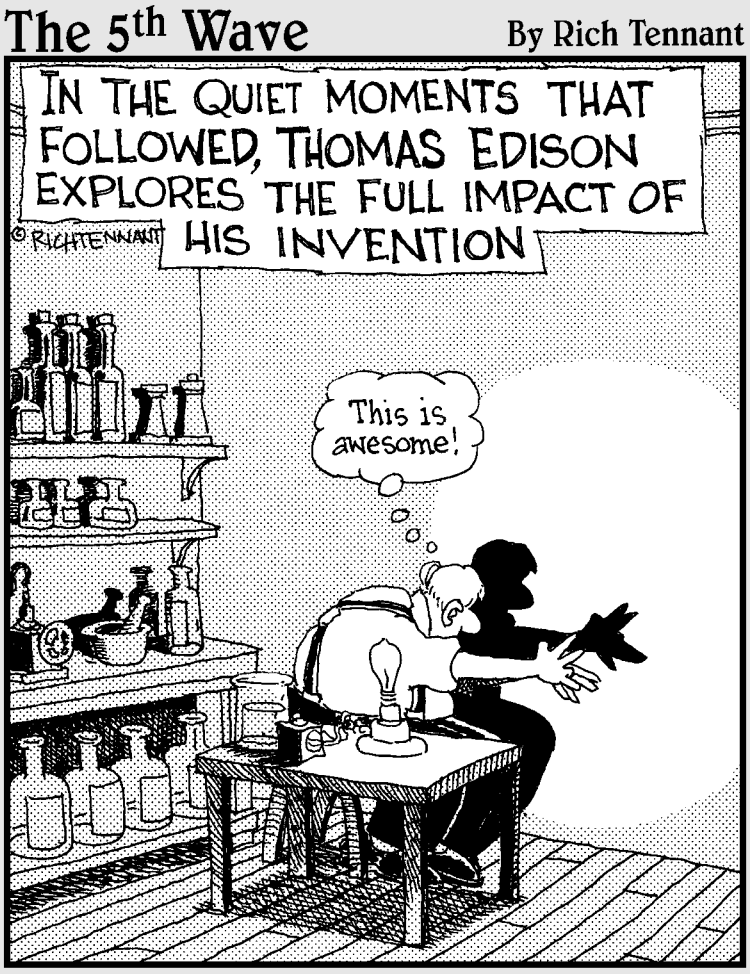
If you are just getting started with electronics, I recommend that you read Parts I and II thoroughly and try a few of the tools and techniques. Building a kit (Chapter 4) is a great way to turn your newfound knowledge into a gadget you can really use — a great confidence builder! Then try a couple of the other techniques before striking out on your own. The tasks in Part III can be performed whenever they arise as you build circuits. Study the techniques in Parts IV and V and give them a try.

If you're more experienced with electronics and want to use this book as a reference and how-to guide, be sure to scan through the book first. I'll bet there are a few sections or tips that might be an "Ah, hah!" for you. The Table of Contents can serve as your reference for workbench use.

Appendix A lists many references and provides some bonus material about electronic components, too. Bookmark the sites you find most interesting or useful and you'll have an instant electronic reference library! The print references listed in Appendix A are those that I've found to have a long useful life — many can be found in used bookstores or online at a fraction of their new cost. Even older texts will provide excellent information about how circuits work.

I couldn't be more pleased to welcome all of you readers to the world of electronics and circuitbuilding. You'll be able to use these tools and techniques for a long time. Learning them launched me into a lifetime of professional electronics that I've found to be both rewarding and enjoyable. I hope it's the same for you!

Part I
Working Basics for Electronic-ers



In this part . . .

Are you ready to roll up your sleeves and get started? Well, the handiest place to begin is a tour of the toolbox and a review of a few techniques that every circuitbuilder must master. The better you are equipped and the more experience you have in building, the better you will be at this craft.

This part begins with a chapter that covers the physical tools that you'll need to create the circuits. Along with the hardware, you'll be introduced to some low-cost, easy-to-use software that makes circuitbuilding (and designing!) much easier.

And what book on electronics would be complete without a discussion of soldering? The second of these chapters introduces you to the fine art of melting solder. There's also some information about how to install your circuits in enclosures and on working with metal and plastics. Finally, get a handle on reading schematic diagrams — your roadmaps to understanding circuits everywhere!

Chapter 1

The Toolbox

Tasks Performed in This Chapter

- Basic tools for electronic construction
- The solderless breadboard
- Keeping a notebook
- Software tools and utilities

To build anything, large or small, using the right tools makes a huge improvement in the quality of the finished product. The right tools will also speed up the process of building, minimize wasted materials, and reduce operator fatigue and stress. Sounds pretty important to have the right tools, doesn't it? You're right! This chapter shows you which, out of the zillions of tools, are the ones to use for building electronic circuits.

Basic Tools for Building Circuits

You'll be pleasantly surprised to find that you don't need a giant set of fancy tools to do excellent work! In fact, you may have most of them already and a couple of additional acquisitions are all that's needed.

Mechanically speaking, you'll need squeezers, cutters, turners, pokers, holders, and hole makers. That's pretty simple, isn't it? Of course, there is an incredible variety of available tools. I'll list the basic items you really need, ways to upgrade them, and some optional tools that are handy but not necessities. Then you go shopping!

Buy the best tools you can afford — always! Then take care of them — always! With care, tools will last a literal lifetime. The author's toolbox has perfectly functional and often-used tools that are 40 years old or more. Avoid bargain-bucket and no-name tools. An all-in-one tool is handy at times, but is no match for a single-purpose tool. Buy from a store with a no-questions-asked return policy that stands behind their tools.

The selection of tools listed in this section has been made with electronics in mind, not robot assembly, plumbing installation, or home wiring. Tools for those jobs are often inappropriate for the smaller scale of electronics. Conversely, electronic tools are often overmatched for beefier work. There is no one-size-fits-all tool selection!

The Klein Company has specialized in tools for electrical and electronic work for decades. They have an excellent selection of tools designed for every possible use at the electronics workbench. Their online catalog (`www.kleintools.com/ToolCatalog/index.html`) is a great reference. Klein is my favorite, but there are many other fine tool companies. Ace Hardware has a comprehensive introduction to many common types of tools on their Web site at `www.acehardware.com`. Click Projects➪Solutions➪Learning Guides to access the directory of informative pages.

Safety and visibility

Before you head off to the hardware store with a big list, be sure that right at the top you include some basic safety equipment — goggles (or safety glasses), workspace ventilation (for soldering smoke or solvent fumes), and first aid. Electronics may sound tame, but the first time you snip a wire and hear the sharp end "ping" off your safety glasses or take them off and find a small solder "splat" right in front of your eye, you'll be glad you had them on!

It sounds trite, but you really do need to be able to see what you're doing! There are two paths to seeing your electronics clearly; lighting and magnification. Your workspace simply has to be brightly lit, preferably from more than one angle to minimize shadows. Inexpensive swing-arm laps with floodlight bulbs are good choices because they can be moved to put light where you need it.

Head-mounted magnifiers are inexpensive and lightweight. The Carson MV-23 dual-power magnifier (`www.carsonoptical.com/Magnifiers/Hands%20Free`) is widely available and provides both x2 and x3 magnification. Swing-arm magnifiers, such as the Alvin ML100 (`www.alvinco.com`), can be positioned in front of your face and provide additional illumination, too. Magnifiers are often found at craft and sewing stores for considerably less cost than at office or technical-supply stores.

Pliers and tweezers

In the "squeezer" category are *pliers* and *tweezers*. The largest electronic thing you are likely to have to grab with pliers is a half-inch nut; the smallest will be tiny set screws. Pliers and tweezers that fit things in that range are good to have in your toolkit. Figure 1-1 shows a few examples of the pliers and tweezers that I use a lot.

The most common type of pliers are *slip-joint pliers* (8″) which have jaws that can be adjusted to grip large or small things. A small pair of *locking pliers* (6″) (optional) — also known as Vise-Grips™, come in very handy when working with connectors and can be used as an impromptu clamp or vise.

Needle-nose pliers (a generic term that covers many different styles of pliers) with serrated jaws are a necessity. You'll need a heavy pair of combination long-nose pliers (8″–9″, with or without a side cutter) for bending and holding. Smaller needle-nose pliers (5″–6″) will be used for positioning and holding delicate components. Additional pliers with extra-fine jaws (or bent-nose pliers) are nice to have in the toolbox, but not required.

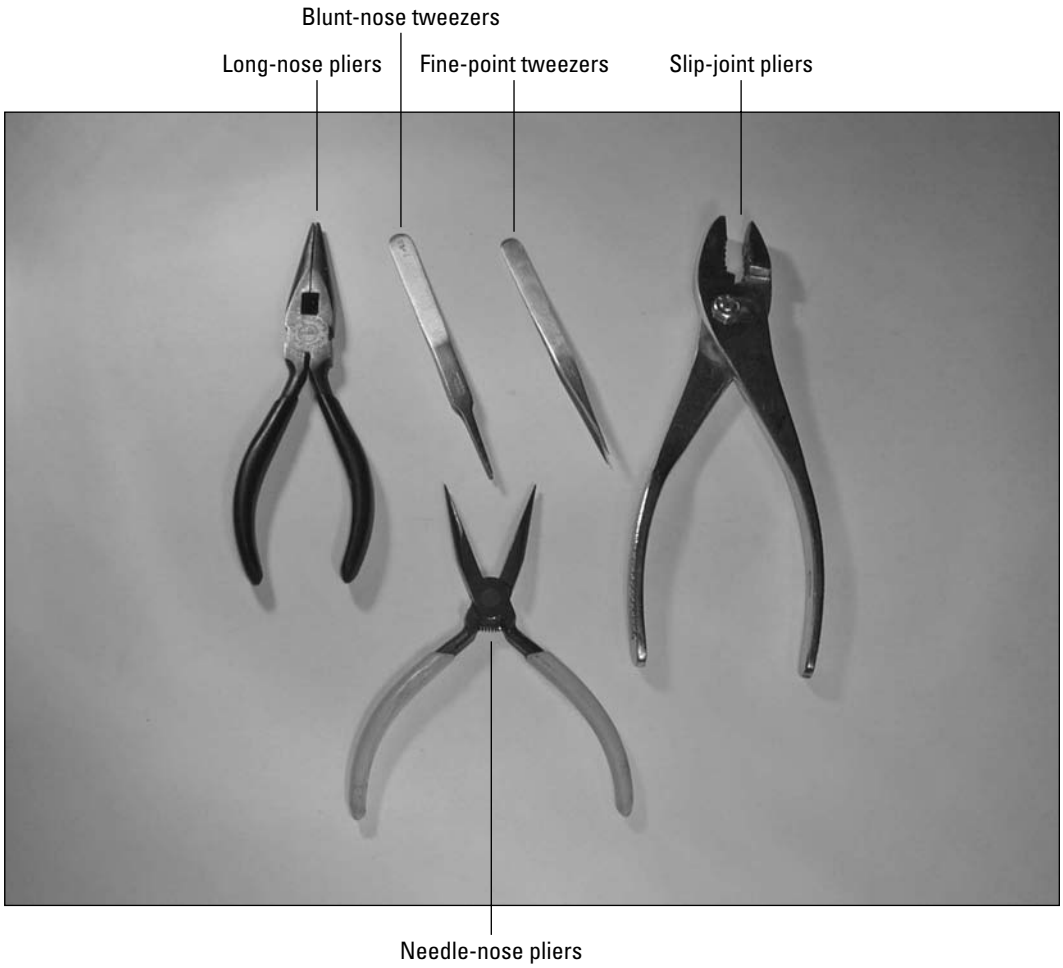


Figure 1-1: This set of pliers and tweezers will grab anything you're likely to encounter in electronics.

Tweezers are absolutely necessary when working with surface-mount devices (see Chapter 4) and small mechanical assemblies. They should be made of stainless steel; you'll need a pair with a blunt nose and a pair with pointed tips. Do not use regular bathroom or cosmetic tweezers — they're not really designed for electronics jobs.

Cutters and knives

Two pairs of wire cutters will suffice. For heavy wire, coaxial, and data cable, you'll need a pair of heavy-duty *diagonal cutters* (6″) like those in Figure 1-2. Get a pair with comfortable handles so that when you squeeze really hard you won't hurt your hand. For small wires, such as component leads, a 5″ pair of flush-cutting, pointed-nose or blunt-nose cutters is appropriate.

As you use your cutters day in and day out, they'll naturally lose their fine edge — although they may still cut wire just fine. For trimming very small wires, such as coaxial cable braid, you'll want a pair of very sharp cutters. It's a good idea to have one pair of "everyday" cutters and another pair used only for fine jobs — a miniature pair of pointed-nose cutters is good — and make sure those stay sharp.

A sharp knife is a must. For electronics-size jobs, a *utility knife* with a retractable segmented blade is a good choice. As the tip or edge dulls, you snap off the knife blade segment to expose new, sharp cutting edges.

Heavy scissors are used frequently and can even cut the lighter thicknesses of printed-circuit (PC) board. They will also be used to cut lighter gauges of sheet metal, such as aluminum and brass.

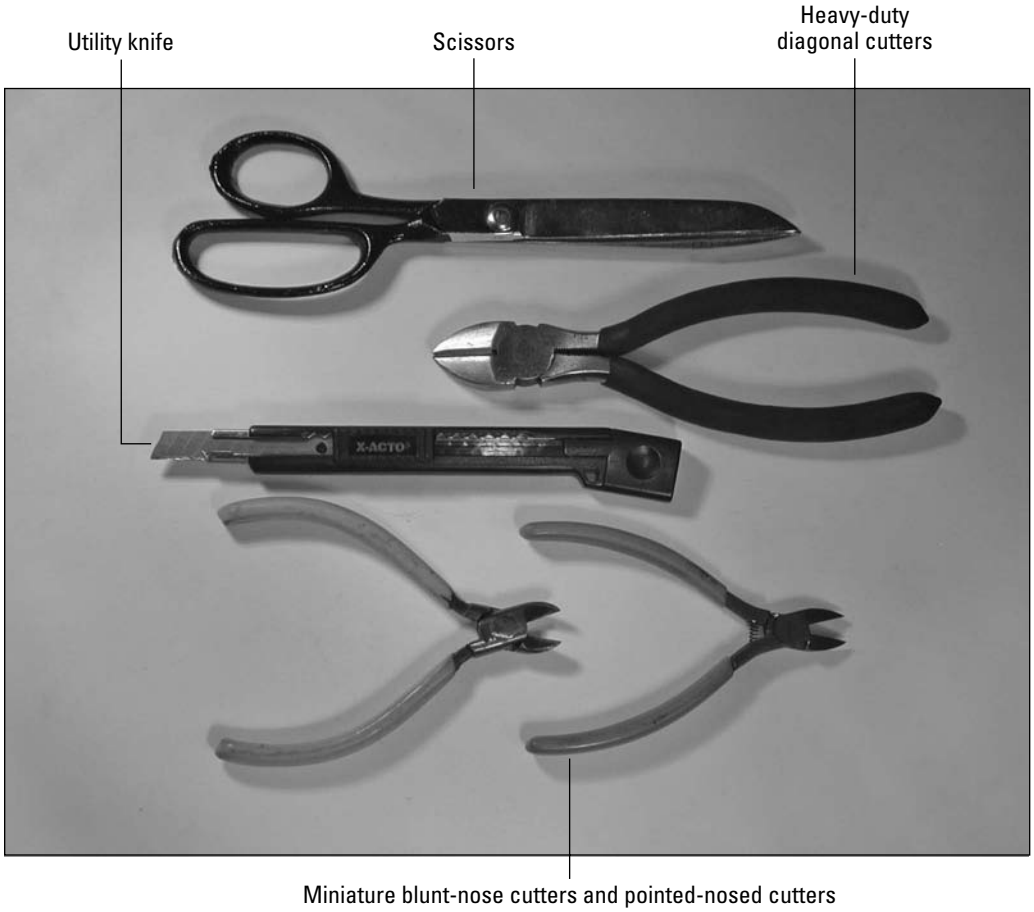


Figure 1-2: The essential cutters and knives.

Screwdrivers and wrenches

Your toolbox should include both Phillips and flat-blade screwdrivers in sizes #0, #1, and #2. An optional long-shaft (8″ or longer) screwdriver is useful for getting at long cabinet-mounting screws in recessed locations. The many different types of screwdriver blades are explained and illustrated at `www.acehardware.com/sm-learn-about-screwdrivers--bg-1266832.html`.

A miniature flat-blade screwdriver with a 3/32″ blade will come in very handy as a general-purpose poker, pusher, and stirrer. It is particularly useful for mixing and applying epoxy! (Just don't let epoxy harden on the blade.)

Jeweler screwdrivers are handy, but not required. You'll use them mostly for attaching knobs to control shafts. If you do buy a set, make sure the shafts don't slip in their handles and that the blades are of good-quality steel. A lot of torque is applied to jeweler's screwdrivers; it's easy to twist off a blade or ruin an irreplaceable miniature screw if the blade isn't tough enough.

Obtain a set of *nutdrivers* for nuts from 1/4″ through 1/2″. These fit the nuts for screw sizes from #4 through 5/16″. The larger nutdrivers also fit switch- and control-mounting nuts. They will tighten the nuts without scratching a front panel and can be used on congested panels where a regular wrench can't be used.

Another optional tool is a miniature *Crescent® wrench* smaller than 6 inches long. Most mechanical fasteners used in electronics are too small for wrenches, but enough are large enough for the Crescent wrench to be a welcome sight in the toolbox.

A set of *Allen wrenches* is optional, but when you really need them (mostly for set screws), they have no substitutes. If you have a choice of buying a set of individual wrenches or a set mounted on a handle, the individual tools are somewhat easier to use (and lose). In addition, the ball-end wrenches can be used at an angle to the screw — which is sometimes necessary in tight quarters. Figure 1-3 shows several examples of screwdrivers, nutdrivers, and wrenches.

It is common for adjustable devices to come with an Allen wrench that fits their mounting set screws. When you're done installing the device, put the wrench in a locking plastic bag and label it with a permanent marker. You'll be able to find it much easier when the adjustment or mounting has to be redone later.

Drills and drill bits

To build electronic stuff, you'll need a small electric drill. A cordless model makes working on a car (or in the field) much easier, but cordless is not required. A 3/8″ chuck is big enough for electronic needs. A *hand drill* can be used on plastics, but is not recommended for general use. If you plan on installing your circuit in cabinets or project boxes with knobs or switches — especially with front panels that need to look good — invest in a small bench-mount *drill press*. It gives you dramatically improved ease of use and finished quality compared to what you get with a hand-held drill.

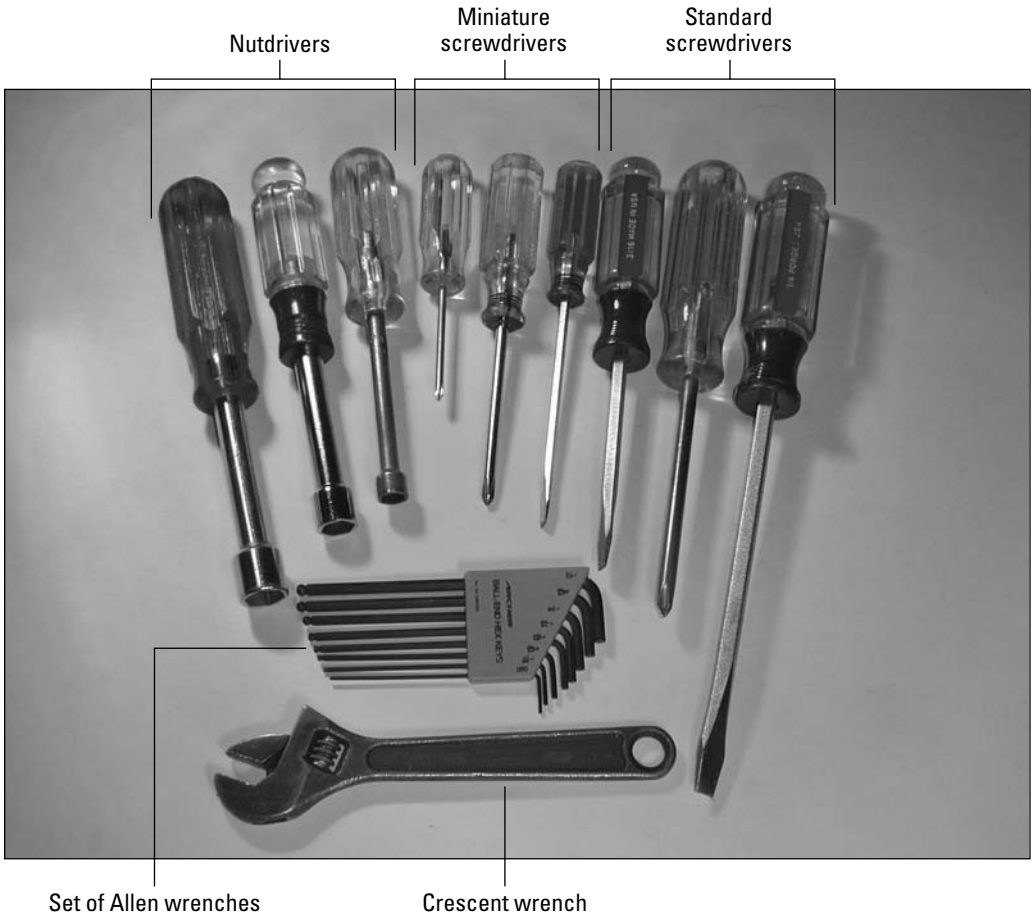


Figure 1-3: An assortment of screwdrivers is complemented by a set of nutdrivers. The miniature Crescent wrench and Allen wrenches round out the collection.

For delicate jobs, enlarging small holes, or just cleaning out a pre-drilled hole, a replacement drill chuck can make a fine hand-held holder for a drill bit. The machined metal chuck fits well in the hand and works like a handle for the bit; its size allows reasonable control of the bit.

You'll need an assortment of *drill bits* from 1/16″ to 3/8″. It's not necessary to have dozens of sizes and standard *twist bits* will suffice. A complete discussion of drill bit types and applications is available on the Ace Hardware Web site (`www.ace hardware.com`). Add an optional *countersink* bit to your collection of drilling tools to smooth the edges of holes.

While drilling small panels and enclosures, you should use a *vise*. For temporary and portable use, purchase a small *machinist's vise* or a small bench vise that clamps to the work surface. Trying to hold the material being drilled by hand often results in damage to your enclosure or panel — and if the material is seized by the drill bit, you can be injured. Examples of both can be viewed at `www.lexic.us/definition-of/machinist's_vise`.