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!

TIP

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!

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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.

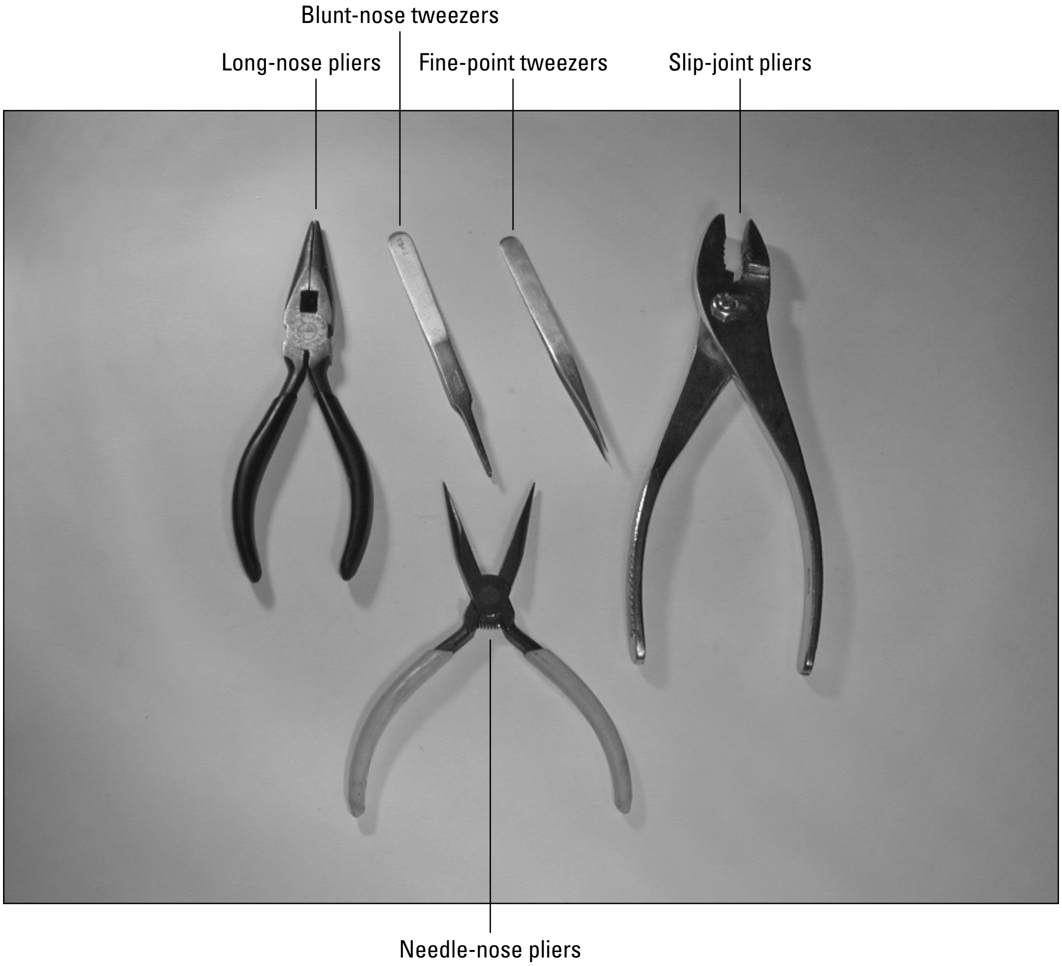


Figure 1-1: This set of pliers and tweezers will grab anything you're likely to encounter in electronics.

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.

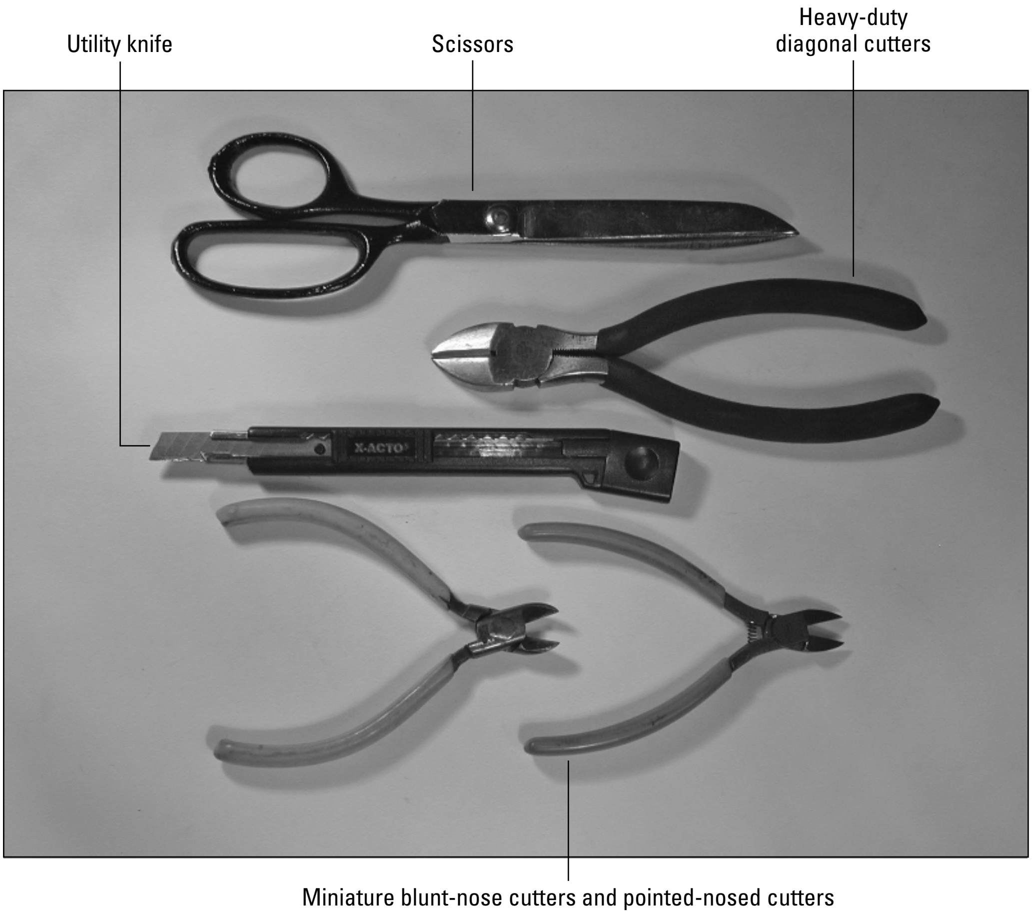


Figure 1-2: The essential cutters and knives.

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.

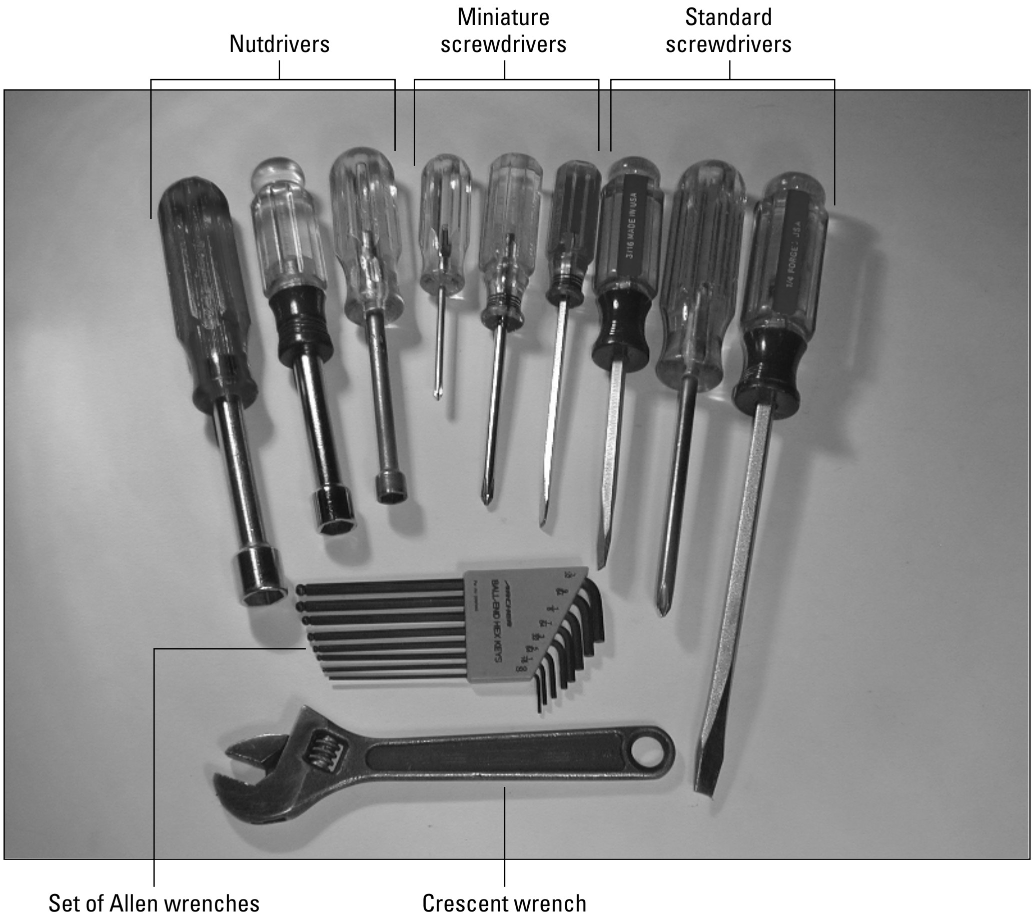


Figure 1-3: An assortment of screwdrivers is complemented by a set of nutdrivers. The miniature Crescent wrench and Allen wrenches round out the collection.

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.acehardware.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`.

It's important to mark a hole's center before drilling to prevent "walking" or wandering by the drill bit before the hole is deep enough to control the drill's position. A *center set punch* is tapped with a hammer, leaving a small dimple that can be placed precisely where the hole is to be drilled. Or you can use a nail, saving a bit of dough at the cost of a tiny bit of precision.

A *scratch awl* is handy for a number of punching and poking tasks. It can do the job of a center set in soft metal, plastic, and other soft materials. It makes holes in all sorts of flexible coverings. In wood, it can make a deep enough hole for a wood screw to be inserted.

A ½" *hand reamer* is used to enlarge a small hole. Using a reamer is often easier than drilling a large hole, especially in brittle plastics. An example showing how a reamer is used can be found in Chapter 5. *Needle files* come in a set including round, half-round, triangular, square, and other cross-sections (see Figure 1-4). They are used to smooth holes or file them into custom shapes.

Figure 1-4: A set of drill bits and simple tools are all that is needed for basic electronic construction.

TIP

The toolkits made by Kronus and Belkin include good, reasonable-quality starter tools. They are available from many electronics and tool retailers, including RadioShack, Sears, CompUSA, and others. You can replace individual tools with higher-quality selections as is convenient.

A somewhat odd, certainly optional, but very handy tool for circuitbuilders is the *nibbling tool*. All holes are not round! You may find that a display needs a rectangular cutout in a panel or that an elongated connector needs a rounded slot. Instead of drilling a lot of holes and then filing away (that works, but it takes a while), the nibbling tool shown at `http://adelnibbler.com/index.html` takes small bites out of sheet metal (and other thin material) in just about any shape you need!

Special electronic tools

As you put your circuitbuilding projects together, you'll find that you need a few specialized tools. You'll need some kind of wire stripper to remove insulation. A number of tools include wire-stripping capability, but they don't work as well (or as conveniently) as a tool made specifically for that purpose. The stripper should have individual positions for different sizes of wire, such as the Kronus 64-2980 available from RadioShack (`www.radioshack.com`). An automatic stripper (Kronus 64-2981) doesn't require pulling on the wire and is bulkier than the plier-like stripper — but it is fun to watch as it works!

Working on circuit boards and small devices is a lot easier if they are held firmly and at a convenient angle. The Panavise 301 vise shown in Figure 1-5 (`www.panaviseonline.com/index.php`) is made specifically for electronic and other detail work. The head of the vise swivels and turns 360 degrees. The *PC board vise head* has extra-wide jaws that can open wide for big boards.

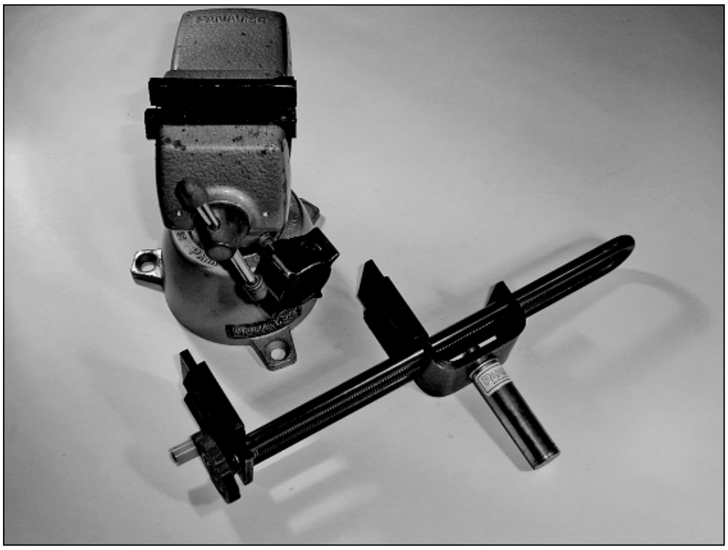


Figure 1-5: The Panavise family of benchtop vises is designed for working with electronics and other small projects.

Some of the tasks later in this book require specific tools that do something unique — for example, the crimping tools used to install connectors (as shown in Part III of this book). Soldering equipment is covered in Chapter 2.

Measuring sticks

A small, metal *mechanic's rule* is a must-have in the electronics toolbox. Most are 6″ long with one side marked in metric units (mm and cm) and the other in English units (inches and fractions of inches). Because it's made of metal, it doubles as a conveniently firm straight-edge for marking or cutting. A short tape measure is also useful.

Stop giving me static!

As you peruse tool catalogs and Web sites, you'll see a number of accessories that dissipate static from people and tools. Why is this important? Well, if you've ever walked across a room and gotten a shock when you touched a doorknob, imagine that same amount of energy applied to a defenseless little transistor or IC! Suddenly, ESD (Electrical Static Discharge) protection starts to make sense!

A thorough introduction to ESD (`www.esda.org/basics/part1.cfm`) is published by the ESD Association, an electronics industry group that researches ESD protection. You can learn all about the different tools and techniques that prevent roasting your electronic components with a spark.

If you live in an area that is very dry on occasion, the best way to add ESD protection to your workspace is a static-dissipating mat and a personal grounding clip. Both of these connect to a safety ground and conduct excess charge away from sensitive electronics.

TIP

A permanent ruler is an option if your workspace allows. Use a yardstick to make permanent markings directly on the work surface. If you have a broken or cut tape measure, tack a length of the tape to the work surface. Being able to measure a cable or wire or other material without having to get out a new tool saves a lot of time!

Optionally, you may want to pick up a set of *calipers* to measure inside and outside widths and diameters, thicknesses, and even depths. Excellent quality calipers are available for a few dollars if you learn to read a vernier scale as instructed at `www.marylandmetrics.com/tech/calipuse.pdf`.

The Solderless Breadboard

One of the keys to learning about electronics is convenience. That is, learning and experimenting and testing should be as easy as possible. One way to make it easy is to use tools and techniques that reduce expense and bother. An excellent example of such a tool is the *solderless breadboard*. Using a breadboard is one of the basic starting points for the design of many types of circuits and projects. Also known as a *plugboard* or *prototyping board*, this miniature workbench allows you to whip up a circuit or try a new design in just minutes!

Using a breadboard

Figure 1-6 shows two examples of breadboards available from electronics parts and tool vendors. You can probably pick one up at your local RadioShack store. Models are available from postage stamp-sizes used for trying small circuits inside equipment all the way to foot-square models on which entire complex circuits can be built. A small one will do just fine as you start out, but it's a good idea to buy one size bigger than you think you need. You'll find yourself quickly outgrowing it, otherwise.

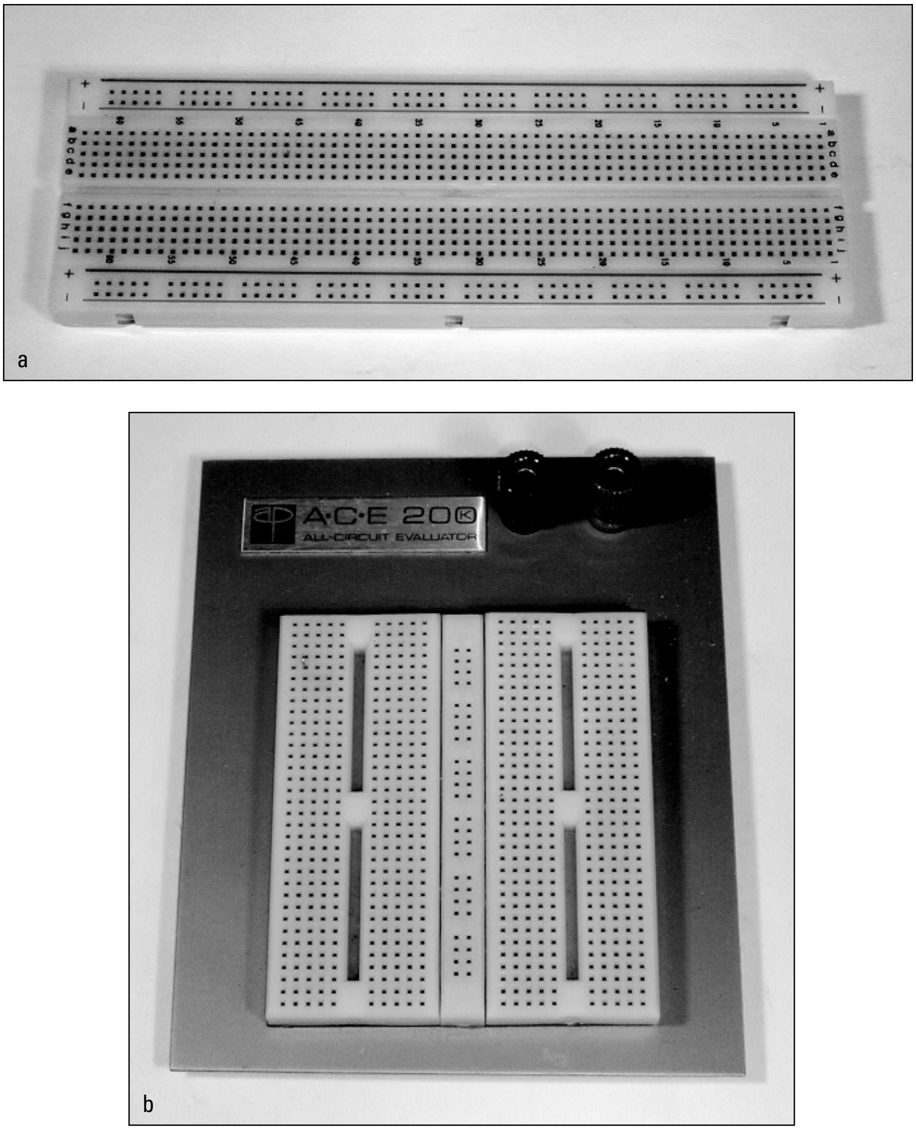


Figure 1-6: Two examples of solderless breadboards available from electronic retailers.

A solderless breadboard consists of plastic strips with small holes into which the leads of electronic components are inserted. (Figure 1-7 is a simplified drawing of a breadboard.) Brass strips under the holes connect each short row of openings together. Any two leads inserted into the same row of holes will be connected together electrically. The plastic body keeps adjacent strips from shorting together.

Up to four leads can be connected together in this way. If more common connections are required, a short piece of wire can be used to connect two (or more) rows together, creating a common electrical contact between all the holes in those rows. The slot between halves of the plastic strip is an insulating gap between the two sides so that integrated circuits with a DIP (Dual In-line Package) can be inserted with one row of pins on each side of the strip.

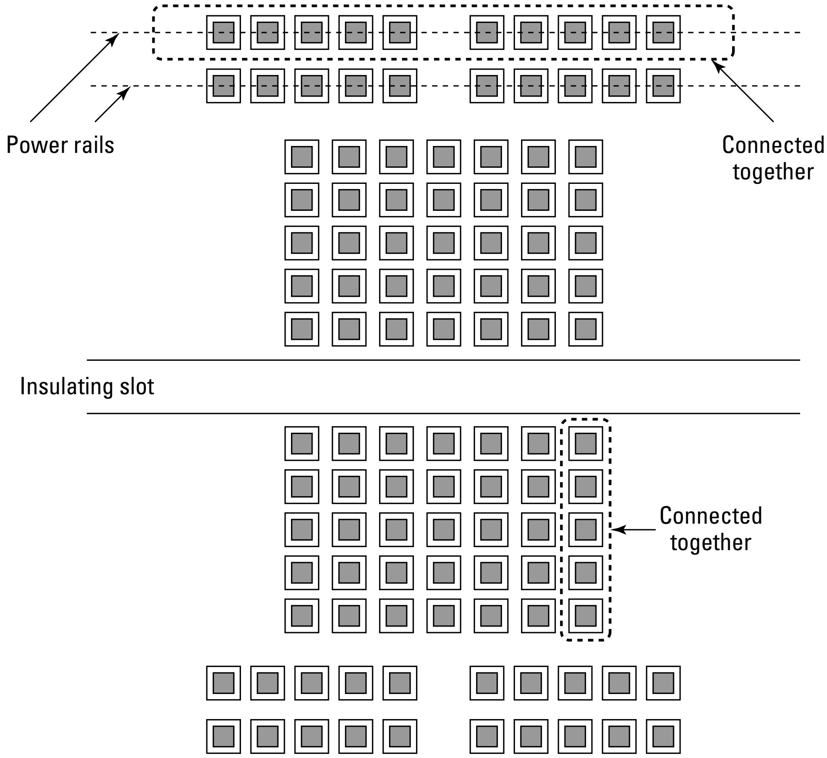
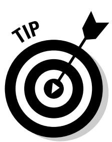


Figure 1-7: Typical organization of breadboard connections. Check the manual or use a voltmeter to see how your contacts are organized.

Most breadboards have areas for point-to-point circuit wiring and areas for distributing power and ground. These are called *rails* and run the length of the breadboard's plastic strips. For analog circuits, these are generally used for positive and negative power supplies, plus a common ground or return to the power supply. Builders of digital circuits that operate from a single voltage find it easier to "double up" and use the extra rail for a duplicate power-supply connection. Breadboards with more than one strip, each with its own set of rails, are easy to use for circuits that have both analog and digital circuitry.

If you are just getting started, you might consider purchasing a breadboard that comes with its own power supplies and possibly even some limited test capabilities, such as the Jameco 1537264 (`www.jameco.com`). More expensive models even have test meters and test signal generators.



While separate power supplies and test equipment might be more flexible and have additional features, the convenience of always having the test equipment connected and ready (remember?) will be appreciated.

Figure 1-8 shows some typical components inserted into the breadboard, ready to be "wired up." While circuits can be easier to build and troubleshoot with all the components laid horizontally, this generally isn't required. Here short pieces of solid wire make the connections from point to point around the circuit. Don't use stranded wire; the strands will move apart and cause hard-to-find short circuits.

What is a breadboard anyway?

Back in the old days, breadboards were literally just that — a wooden board on which loaves of bread were cut. Early electronics experimenters knew that these breadboards didn't conduct electricity (much), wouldn't catch fire (usually), and were cheap (definitely). That made breadboards just the right base for building a circuit — which in that era meant vacuum tubes: relatively high voltages and rather large components. Many a wireless set or amplifier was constructed with sockets and terminal strips screwed to the soft wood of the kitchen breadboard! Although it's unlikely that you'll be slicing any loaves on modern breadboards, the name has stuck. In fact, the term *breadboarding* has come to mean the "roughing out" or "prototype" stage of designing and building electronic devices.

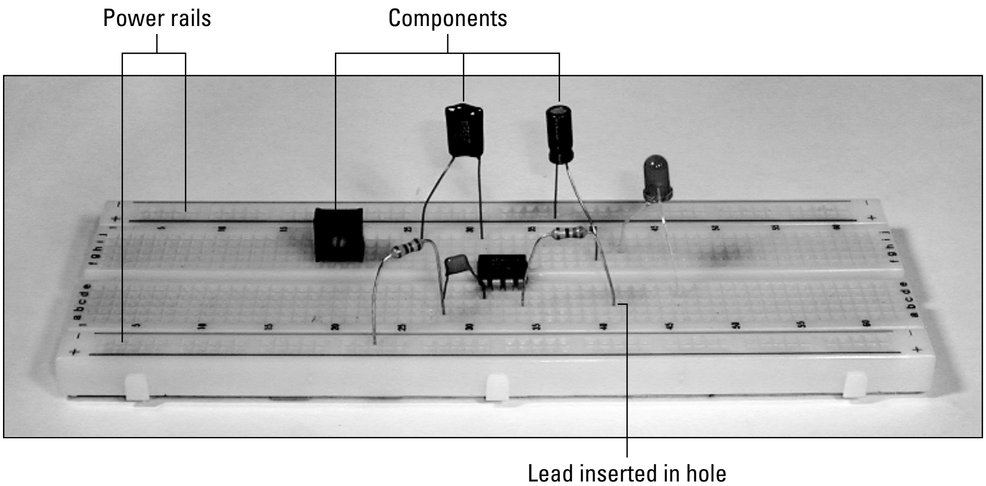


Figure 1-8: Component leads are inserted into the breadboard holes. Strips of contacts under the holes allow other components to be connected at the same point.

Breadboard materials

In keeping with the theme of convenience, breadboards hardly need any special materials to use! You'll need some test equipment to power and measure your circuits, certainly, but aside from the components themselves, little is needed. Here is a list of things you'll need:

- **Insulated jumpers (20- to 24-gauge solid, insulated wire in various colors):** It doesn't have to be *tinned* (coated with solder); bare copper is fine. A good source of suitable wire is scrap lengths of 4-conductor telephone wiring cable using for wiring the wall jacks (*not* the flat cable used to connect phones and wall sockets).

- **Bare jumpers (20- to 24-gauge solid bare wire):** This is used to connect adjacent rows of contacts, to create connection points for external equipment, or make leads for items that don't have suitable leads for insertion into the breadboard sockets. Save the clipped-off pieces of component leads to create a bountiful supply!
- **Leaded components:** It's very difficult, if not impossible, to use surface-mount technology (SMT) components with a breadboard. Make the task easier by purchasing and stocking only *leaded* components.

That's it! No special tools other than needle-nose pliers and a small pair of wire cutters are needed. You may also want to augment your eyesight by purchasing a pair of head-mounted magnifier glasses from a local craft store for a few dollars.

Limitations of breadboards

The breadboard sounds like a perfect way to build circuits, doesn't it? There are limits, however — and you should keep them in mind.

Current and voltage limits

The small contacts in a breadboard mean that they can only handle so much current before they are damaged by heating. Check the manufacturer's specification on how much current is safe. Higher currents can also melt the plastic strips. High voltage is often a problem, too, since the plastic insulation is only so thick. Arcing can also damage a breadboard. Whether from excessive voltage or current, damaged breadboard contacts can't be used reliably — and can't be repaired. A good rule of thumb is to limit breadboards to circuits that use a maximum of 100 mA and 50 V. If your circuit uses higher currents and voltages, it's a good idea to change your building methods or construct a separate circuit that only makes low-current connections to the breadboard circuit.

Frequency limit

The convenience of having lots of contacts and connections made of small wires has a drawback in poor performance for high-frequency signals. At high frequencies, the wires start to look like small inductors, upsetting circuit performance. Further, the many rows of closely spaced contacts act like small capacitors. Both the inductors and capacitors affect circuit performance in unpredictable ways. It's also harder to create a good, solid ground connection for a circuit of any complexity that's built on a breadboard. Another good general rule is to limit your circuit's highest frequencies to about 500 kHz. For digital circuits, the clock-speed limit is 1 MHz. Above those frequencies, your circuit won't be behaving the same way it will in a final version built with better techniques.

Contact wear-out

If you are a frequent builder, you'll probably start wearing out the breadboard's contacts. For example, some of the contacts will loosen, weakening their grip on a lead or wire. This is hard to detect — and can lead to intermittent problems that are difficult to assess and fix. If a contact has been overheated or has an oversized wire stuffed into it, its grip on smaller wires is relaxed. The connection points at one end of a power rail are particularly prone to this problem. Since you can't repair those contacts, it's best to mark which ones are bad and not use them again.

Your Notebook

The most important tool isn't one that lives in your toolbox, it's the one between your ears! The sharpening and lubricating for this tool comes from a notebook. Almost any old notebook will do — even one with cartoon characters on the cover. While a notebook filled with graph paper is the best, regular old lined or blank paper is fine. The important thing is to have a handy place to write down information as you work on projects.

Your notebook can be a record for design ideas, construction and installation notes, test results, project ideas — anything that you think goes in the notebook *should* go in the notebook. Believe me, you'll be a believer when you can go back into a years-old notebook and quickly find just the right circuit or look up the color code of a control cable you installed way back when!

TIP

Make a habit of opening the notebook before you even start work!

Software Tools

Can software be a tool for building electronics? Sure it can! If you can draw it on paper or calculate it, there is a software tool to help with the job. The only thing software can't do (yet) is fire up the iron and melt solder on that PC board. That's still your job, but by using the appropriate software, what you build will be finished faster and work more like what you expected.

There are far too many programs to try or even list, so only a few are mentioned here. More software is available all the time. If you do an Internet search for *"free electronic design software"* you'll be directed to Web sites such as the University of Nebraska's Electrical Engineering Shop page (`eeshop.unl.edu/cad.html`) or Technology Systems (`www.tech-systems-labs.com/freesoftware.htm`). They list many, many programs for you to try. Experiment and choose the ones you like!

Schematic and PC board layout

The actual term for the software with which you draw schematics is *schematic capture.* Software you can use to lay out your own circuit boards is *PCB layout.* The following packages listed here include both functions. While professional packages can cost thousands of dollars, there are some capable packages available for free or at very low cost. Free versions are usually limited in how many *pins* (meaning IC pins) can be used — and the designs may not be used for commercial purposes. For a beginner in circuitbuilding, these versions are just fine! Here are a few:

- **Easy PC** (`www.numberone.com`)
- **Dip Trace** (`www.diptrace.com`)
- **Eagle** (`www.cadsoft.de`; click Freeware)
- **Designworks Lite** (`www.capilano.com/dwlite.html`)

There are also low-cost PC board fabricators that provide schematic-capture and layout software (Express PCB, www.expresspcb.com) but they are usually proprietary packages that don't let you interface to other fabrication services. Nevertheless, this might not be a problem if such a package suits your purposes.

If you are familiar with PowerPoint software and only want to draw schematics that look good without any advanced features, a free package of schematic symbols developed by the author is available from the American Radio Relay League's Technical Information Service at www.arrl.org/tis/info/HTML/Hands-On-Radio.

Electronic simulators

The power of the PC is really put to work in electronic circuit *simulators* that can predict how your circuit will work. With a simulator, it is possible to do almost all your developmental work at the computer — and only turn on the soldering iron for the final version. To be sure, there are many subtle factors in circuit design that a computer doesn't know about or can't handle well, but these are well beyond what a beginning circuitbuilder worries about.

Simulators are powerful programs; they have a steep learning curve when you get beyond simple simulations. Nevertheless, there's no time like the present to try them out! These two packages are evaluation versions of professional-level circuit simulators:

- **Micro Cap** (www.spectrum-soft.com/index.shtm)
- **Intusoft ICAP** (www.intusoft.com)

The Linear Technology software, LTSPICE, is a capable version of the public-domain circuit-simulator program, SPICE. It's completely free from www.linear.com/designtools/software/index.jsp and also includes a switching power-supply design package.

Mechanical drawing software

It's also important to be able to make accurate drawings of panel layouts and other mechanical parts that are part of your project. Software that does mechanical drawings is called *CAD* for Computer-Aided Drafting. There are many inexpensive or free software packages (enter "cad drawing freeware" into an Internet search engine) for the downloading. Here are some general purpose drawing packages to try:

- **Vector Engineer** (www.vectorengineer.com)
- **CadSted** (www.cadstd.com)

There are also software packages for specialized drawing applications:

- **Scale** (http://stiftsbogtrykkeriet.dk/~mcs/Scale.html) is a Web application to design meter scales and control dials. You enter the data for your scale and it sends you a graphic file you can edit or print.

- **Dial and Panel** (http://hfradio.org/wb8rcr) are simple programs to make dial scales and design front panels.
- **Gpaper** (http://pharm.kuleuven.be/pharbio/gpaper.htm) draws any kind of graph paper you can think of!

Utilities and calculators

Literally thousands of utility software packages are available on the Internet. If you need one for a specific purpose, just type the purpose plus "design utility" into an Internet search engine — for example, "555 timer design utility" or "555 timer design calculator" — and dozens of programs and Web sites pop up. Caveat emptor (or, in this case, browser), of course; you don't know the pedigree of these programs. There is also a nice listing of electronic calculator programs at 101science.com/Radio.htm#Calculators.

As you collect the URLs for online calculators, set up a folder in your browser's Favorites list specifically for calculators. That way they'll always be easy to find.

You don't have to download every calculator individually as there are some very nice packaged sets. Here are two of my favorites, both free:

- **Hamcalc** (www.cq-amateur-radio.com/HamCalcem.html) has dozens of routines for all sorts of electronic design tasks.
- **Convert** (http://joshmadison.com/software/convert) is a terrific little utility that I leave on my PC desktop for whenever I have to convert a value between units of measure — say, barrels to pecks. Seriously, this is one of those tools that occasionally saves a whole lot of time.