Electronics Safety — It's Your Life

by Ronald Reis

I hear it now: "You've got to be kidding, an article on safety? That's a subject for schools. Maybe they also cover it at work, from time-to-time. But I'm an experimenter, a hobbyist, what does safety have to do with me?" Actually, plenty. It's exactly those who have been out of school for some time, or aren't employed in the industry, that are likely to need a safety refresher course the most.

If you're a hobbyist, working in the den, garage, or basement, the electricity pulsing through your projects and equipment could, if not properly contained, kill you. Furthermore, the myriad of toxic and hazardous chemicals you're using to clean, lubricate, and etch circuit boards with are often noxious and corrosive. And then there are the hand and power tools you use to cut, drill, grind, and solder. If mishandled, you're likely to wind up laid up, at home or even in the hospital.

In this article, we'll look at external body parts susceptible to damage; electrocution, the heart of the matter; electricity, the tingle that hurts; avoiding being exposed to toxic and hazardous chemicals; safety hazards caused by the misuse of hand and power tools; and creating a safe working environment. We will do so, for the most part, in a do's and don't's format that will provide you with the specifics needed to stay safe and keep building, testing, and repairing electronic projects and devices.

External Body Parts Susceptible to Damage

The human body is a fragile thing. It is easily cut, bruised, burned, irritated, shocked, and poisoned. External organs associated with our five senses and internal organs vital to our very lives are susceptible to injury, not only in the workplace, but at home in the den, garage, or basement.

Injury to the *eyes* can cause permanent blindness. Small objects, such as clipped component leads and flying solder balls, can stab and burn sensitive parts of the eye. Furthermore, a splash of acid or the spray from a cleaning solvent can, at the very least, irritate; at the worst, it can destroy the entire eye. Even a bright flash of light from a strobe light project, for example, can cause a serious accident. If you are only momentarily blinded, it may be enough to make you susceptible to other forms of injury.

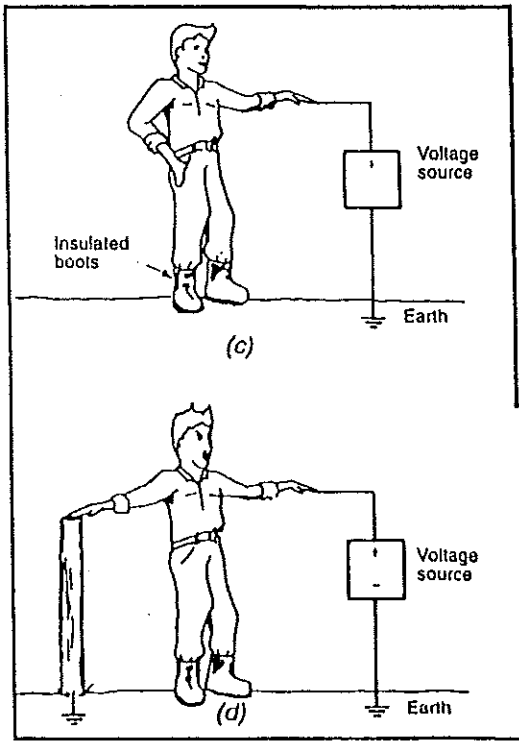
Loud sounds and high-pitched tones can be very irritating to the *ears*. In extreme cases, they may cause temporary or even permanent hearing loss. It isn't just heavy metal rock bands that can produce such noises. Many types of electronic devices can blast forth with ear piercing decibels.

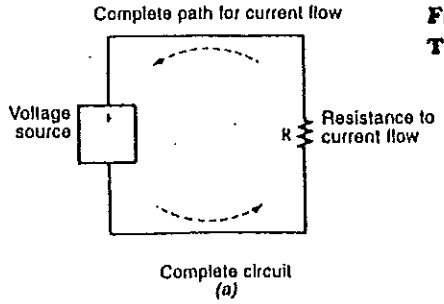
You may not think your *nose* is vulnerable to dangers found in your work area. Yet toxic fumes can be irritating to the membranes lining the nasal passages. More importantly, the nose is one entry leading to the lungs. Damage there can be very serious, as it may affect your ability to breathe properly.

Your mouth, or *throat*, can also be an opening for foreign and hazardous particles. Of course, you wouldn't knowingly put any acid solution or solder wire (which is 40 percent lead) in your mouth. But if etching acid (ammonium persulfate, for example) gets under your fingernails, and you bite your nails, you could be in trouble. The greatest danger, however, lies in using your mouth as a temporary vise to hold small pieces of hardware, tiny transistors, and short strips of wire. Accidental swallowing, or a quick slap on the back from a friend, and presto — it's time to have your stomach pumped.

Then there is the *skin*, the outer layer designed to protect the entire body. Destruction of nerve endings as a result of electrical shock, burns from soldering irons and hot components, acid irritations, and, of course, common cuts, bruises, and abrasions can occur in an environment where safety is lax.

Clearly, your entire body is subject to harm. However, there is no cause for alarm, only a healthy concern. Shortly, we'll see how you can eliminate most of these dangers from your work area by taking simple precautions and following commonly





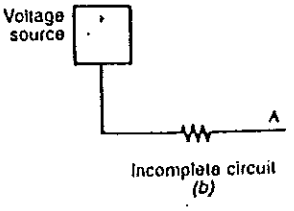


Figure 1
The Human Body and Current Flow

Figure 3
Do's and Don'ts: Working with Electricity

The Do's

- *Do* work with one hand behind your back while testing live circuits. In that way if you complete the path for current flow, at least it won't be through your heart.
- *Do* use an isolation transformer or Variac (autotransformer) while working on AC-powered equipment. These devices isolate the powered equipment from the power source, adding a strong measure of safety.
- *Do* make sure all capacitors (components that store an electrical charge) are discharged before troubleshooting begins. Use an insulated screwdriver to short out capacitor leads.
- *Do* use three-conductor grounded line cords and polarized plugs with AC-operated equipment. Both items reduce the danger from short-circuited chassis.
- *Do* keep your fingers out of live chassis. Test all circuits with a voltmeter or specially designed test lamps.

The Don'ts

- *Don't* install or remove any electronic components while the circuit is connected to a power source. Following this procedure will protect you, as well as the component.
- *Don't* overfuse. Using a fuse with a higher rating than is recommended only defeats the fuse's purpose.
- *Don't* work with wet hands. As noted earlier, if body resistance goes down, current flow goes up. Even sweat can moisten the hands enough to cause excessive current flow.
- *Don't* cut wires carrying electricity. Again, it isn't just the AC line cord that is lethal. Assume all wires carry enough current to harm you.
- *Don't* disconnect electrical devices from the wall outlet by pulling on the line cord; pull the plug handle.

Figure 4
Do's and Don'ts: Working with Toxic and Hazardous Chemicals

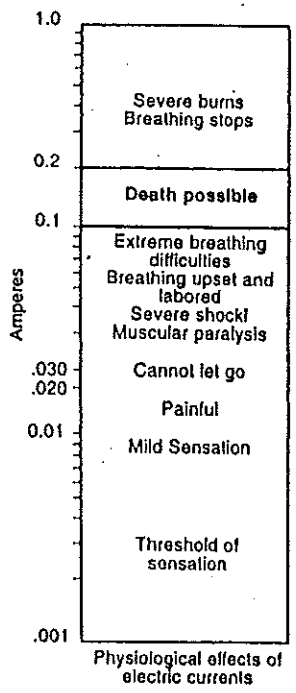
The Do's

- *Do* read the labels on all the chemicals you use. Pay particular attention to printed warnings.
- *Do* work in well-ventilated areas. This is particularly important when using paint and chemical sprays.
- *Do* wear eye protection when working around hazardous chemicals.
- *Do* wear rubber gloves when working with acid solutions. Be sure they are washed or thrown away when work is done.
- *Do* hold printed circuit boards securely with tongs when placing them in or removing them from an acid solution when etching.
- *Do* immediately clean all tools that have come in contact with hazardous chemicals. This will prevent someone from inadvertently touching the toxic substances.

The Don'ts

- *Don't* pour solvents, paints, or acids down the drain. In addition to being a health hazard, in many localities it is illegal.
- *Don't* transfer chemicals to unlabeled containers.
- *Don't* inhale fumes from soldering paste. Such fumes can be harmful to your lungs.
- *Don't* leave any chemicals in open containers where they can be splashed or spilled. Put all unused chemicals safely away, preferably in a locked metal cabinet.
- *Don't* place any chemicals near sparks or open flames. Assume all chemicals are highly combustible.

Figure 2
How much current is enough to kill?



accepted safety practices.

Electrocution — The Heart of the Matter

Protecting external body parts is one thing, preventing damage to various internal organs, particularly the *heart*, is vital. If the heart stops, even for only four to six minutes, death can result. Many factors can cause the heart to stop beating. For purposes of discussion here, **electrocution**, or **electrical shock**, is the most relevant. Let's see just what electrical shock is and how it can destroy the heart.

Electrical shock is the passage of current through the body. Current flows through the human body, as it does anywhere else, when a complete circuit exists. Such a circuit is shown in Figure 1A. A source of voltage and a conducting path (shown in the figure as having a given amount of resistance) are all that is required. Note, however, that the path for current flow must be complete. In Figure 1B no current flows to point A. The reason is that although it has a place to come from (in this case, the battery's negative terminal), it has no place to go (in this case, the battery's positive terminal).

The same is true when the human body is the conducting path. As illustrated in Figure 1C, even though the person is touching the positive terminal of the voltage source, he is in no danger. As long as he is wearing insulated boots, current can find no path through him to the negative, or ground, terminal of the battery. However, if he completes the circuit by, for instance, touching the negative battery terminal with the other hand (possibly through a ground connection), current will indeed flow, as shown in Figure 1D. Just how much current depends on a number of factors.

One way to increase current flow is to reduce circuit resistance. Body resistance may be quite high if skin moisture is low and there are no cuts or abrasions at the point of electrical contact. In such cases, little current will flow and only a mild shock may result. Nonetheless, if any of these factors are reversed, resistance will be lowered and large amounts of current could result. If the path for current flow is through the chest, the heart can receive a lethal dose of current — an electrical shock. The heart will then most likely go into fibrillation (rapid, irregular muscle contraction) and stop beating.

How much current is enough to kill? Although the amount varies widely and especially depends on the organs that current passes through, it is less than you probably think. Figure 2 gives the effects of even mild doses of current. A mere 1 to 20 mA can cause a painful sensation; at 30 mA, breathing may stop; and 100 to 300 mA is enough to cause electrocution. Clearly, even small amounts of unwanted current through the body can be very dangerous to your health.

Electricity: The Tingle that Hurts

There is good news and bad news. The good news is that today's electronic devices, many of which are solid-state and battery powered, are much safer than their predecessors of the vacuum tube era. Instead of circuits with voltages in the hundreds and currents in amperes, we now have equipment operating on 5 to 12 volts DC and drawing currents of less than 50 to 100 mA. The bad news is that many systems, even though employing solid-state circuitry, do not get their power directly from a battery, but rather from the AC line. And any electronic project that is plugged into the wall outlet is a potential death trap.

The problem with AC is twofold. The ordinary wall outlet will supply up to 25 amperes of current, certainly enough under many conditions to kill you. In addition, AC tends to "hang

on." The victim can be prevented from releasing the source of voltage, thus increasing the damage to the body.

But circuits powered from the AC line are not the only problem. A serious shock can be had from many circuits, DC or AC, containing charged capacitors, faulty wiring, or shorted components. Treat every electronic circuit as potentially hazardous. Electricity, though not to be unduly feared, must be respected.

One solution to being safe while working with electricity is to follow some basic "do's and don't's." A list of the more important ones are shown in Figure 3.

There is not much you can do for yourself if severe electrical shock occurs. All the more reason you should avoid working alone whenever possible. At the very least, if you are fiddling around in a garage or basement, make sure someone is in the house and knows what you are doing.

When I am out in the garage alone, I plug in — don't laugh — a line-operated "nursery monitor," the kind used to listen to your baby from another room. The transmitter is in the garage, the receiver, in the house with my wife. If anything happens, chances are she'll hear me yelling.

Exposure to Toxic and Hazardous Chemicals

With toxic and hazardous chemicals, you should be concerned about inhaling vapors, swallowing liquids, acid burns on the skin, contact with the eyes, and the overall danger of fire and explosion. Chemicals such as etching solutions, spray paints, component cleaners, glues, photographic developing solutions, and general household solvents can cause health hazards if improperly used or stored. To minimize risks, follow the do's and don'ts listed in Figure 4.

If an emergency occurs, follow all first-aid directions printed on the label of the chemical you have been using. Read the label before use so that you won't be confused if trouble develops. For example, some instructions tell you to induce vomiting if the substance is swallowed; others tell you not to. Do what the label says and call a physician immediately.

More specifically, in the case of acid burns and eye irritations, wash and flush thoroughly with cold running water. When exposure to vapors has occurred, get yourself outside in the open air.

Safety Hazards Caused by the Misuse of Hand Tools

Hand tools, those held in the hand and not powered by electricity, can be more dangerous than power tools. Why? Because they are used more often and we tend to dismiss their risk. Do not be deceived. A slip of a hacksaw blade or the launching of a loose hammerhead can maim you — or someone else — for life. Whether it's a puncture from a file tang, a gash from a saw blade, or a slit from a knife, hand tools can do plenty of damage. To avoid the obvious dangers, consider the list of do's and don'ts in Figure 5.

Injury from hand tools usually results in a cut or burn. What specific action to take when a laceration occurs depends on its severity. In all cases, clean the wound, apply direct pressure, and elevate the injured body part. With regard to burns, flush the affected area with cold water (do not apply ice directly) and cover with a clean cloth. Now seek medical aid.

Figure 5
Do's and Don'ts: Working with Hand Tools

The Do's

- *Do* keep hands free of dirt, grease, or oil when using hand tools.
- *Do* keep hand tools sharp. A dull tool is more dangerous than a sharp one because with a dull tool you tend to apply more pressure, increasing the likelihood of slippage.
- *Do* cut away from your body, not toward it.
- *Do* secure all small pieces of work in a vise or with appropriate clamps.
- *Do* put sharp tools away when not in use. Leaving knives, awls, and punches lying around for someone to lean on is extremely dangerous.

The Don'ts

- *Don't* carry hand tools in your pocket; they may injure you or someone else.
- *Don't* use a file without a handle. An exposed file tang can easily puncture your hand or wrist.
- *Don't* run your hands over the edges of sheet metal. Such edges are sharp and can cause severe cuts.

Safety Hazards Caused by the Misuse of Power Tools

Power tools — those that use electricity — can burn, cut, scrape, and even hit you with flying objects. Because most of them plug directly into the wall outlet, they can also give you a nasty electrical shock. Injuries from power tools occur by long hair or unsuitable clothing getting caught in a revolving machine, by small objects flying out of a drill press vise, by guards or safety devices being removed, or by a hot soldering iron being left where someone can lean against it. To prevent such injuries, follow the do's and don'ts shown in Figure 6.

Injuries resulting from misuse of power tools are similar to those occurring with hand tools, so the first-aid procedures are essentially the same. The accident itself, however, may be more severe. Get help immediately, then follow the appropriate first-aid measures.

A Safe Working Environment

Following the do's and avoiding the don'ts presented here will do much to keep you safe while working in your chosen hobby. Yet, more than anything else, establishing a good, clean, well lit working environment is the key to safety success.

Try to locate a workbench in an area that will provide a minimum of distractions. Such a location will increase the likelihood that the bench will be used only for its intended purpose: electronic project building and circuit testing and repair.

The workbench should remain relatively clean. The dirt and mess associated with normal mechanical assembly (such as would occur when working on your car, for example) is incompatible with modern electronics fabrication and repair.

Your workbench should be bathed in direct and indirect light. You might not think this lighting is necessary, but when you are working with tiny circuits and minute letters and numbers printed on small components, you will need all the brightness you can muster. A drafting lamp can provide a concentrated direct beam of light.

An even better choice is a swivel lamp with an illuminated magnifier. Such lamps are particularly useful when you are inspecting or assembling printed circuit boards.

That should do it. Enjoy your electronics experimenting, building, and repairing. And stay safe. NV

Figure 6
Do's and Don'ts: Working with Power Tools

The Do's

- *Do* turn on and off all power tools yourself. Do not allow others to do it for you.
- *Do* make sure all objects being drilled or cut are securely fastened. Small objects, and especially sheet metal, should be held in a vise, clamp, or suitable gripping tool such as pliers or vise grips.
- *Do* see to it that all implements and adjusting tools are removed from your work area.
- *Do* remove the chuck key from a drill press before turning on the machine. A flying chuck key is a frequent cause of injury.
- *Do* ease up on the drill pressure as you break through the work. This will reduce the possibility of the material "grabbing."
- *Do* grasp a soldering iron only by the handle. Don't reach for a falling soldering iron — let it fall.
- *Do* return a soldering iron to its holder. It should be in either one of two places: your hand or in the holder.

The Don'ts

- *Don't* ever leave power tools unattended. If the tool is on, stay with it until it is off — and until all parts have stopped moving.
- *Don't* wear clothing or accessories (jewelry) that can get tangled in revolving machine parts.
- *Don't* stand in the direct "throw" of any machine. Don't line yourself up with a revolving saw blade or spinning grinding wheel.
- *Don't* remove guards or safety devices from power tools. They have been installed for a good reason; keep them in place.
- *Don't* test a soldering iron with your hand. Assume all soldering irons are hot. Test them by attempting to melt a piece of solder.