CRYSTAL SETS TO SIDEBAND

CHAPTER 3

SETTING UP AN ELECTRONICS WORKSHOP

Research and Development as recreation

Building an amateur radio transmitter and receiver from the component level up is true research and development. That's why it's fun. Sure, it's much easier than developing products that have never existed before, but conquering the details will be hard and you'll find it plenty satisfying. When you're done, you can brag about your rig to your ham buddies. These days, if you have a 100% homebuilt station, you'll find you are almost unique among other hams.

We can learn how to do R & D by studying the methods of the master inventors. We Americans would probably nominate Edison as the single most famous inventor in history. Edison is not credited with the invention of radio, but he did develop many of the components used in 20th century radios. Also many of the techniques to build those components were first developed in Edison's laboratory. Edison fabricated the first vacuum tube diode detectors, the loudspeaker and the triode vacuum tube, but he never applied them to radio. Edison is best known for a handful of his most important inventions. However, ***Edison's greatest contribution may have been his <u>methods</u> of inventing.***

Persistence

A reporter asked Edison why he had often succeeded in perfecting inventions, while other experimenters who started down the same path were never able to build a practical device. Edison replied, "Most inventors will have a good idea and try out one or two versions of their concept. When it doesn't work, they declare it hopeless and give up. The difference is, I never give up."

Try everything and keep careful notes

The most well-known story about Edison's persistence was his legendary search for the ideal material to make lightbulb filaments. Edison was asked if he was discouraged by his failure to find a suitable material after trying hundreds of substances. He replied that it hadn't been a failure. He now knew hundreds of materials that didn't work.

The corollary to Edison's method is that it's essential to write everything down in detail. It's not fun writing the details of experiments that failed. But a year later, any researcher can tell you they have had that "deja vu" sensation halfway through an experiment only to find in their notes that they had tried this before. At the moment when you discover "a pearl of wisdom," it seems so profound to you that you believe you will never forget it. Wrong. Unless your memory is much better than mine, months later an old laboratory notebook can be re-read almost as if someone else had written it.

Lots of junk

Edison was asked what a fellow needed to become an inventor. He said, " First you need a large pile of junk. You can't afford the time and money to run down to the store every time you need something. Often the junk pile will supply the parts to try out an idea right away. If you order parts from hundreds of miles away, you may waste weeks just to find out that your idea didn't work."

Subdivide the problem and build for modification

A complex invention like the light bulb, consists of many parts. Light bulbs only look simple. What kind of glass can stand the heat of the filament? What kind of wire has the same coefficient of thermal expansion as that of glass? What kind of filament material is optimum? What should the resistance of the filament be in order to be compatible with the electric power source? How does the resistance change with temperature? What is the trade off between operating life and brightness? How good a vacuum is needed and how can it be produced? Once the air is pumped out of the glass, how can the bulb be sealed? Answers to all of these questions had to be found and tested one at a time before Edison could make a practical light bulb.

Have you seen the movie Gizmo? Gizmo is a collection of film clips of early 20th century inventors showing off their inventions for the first time. The movie is hilarious because again and again, the inventors make the same mistake. They take ideas that are often fundamentally sound, and then they build an entire, polished, handsome prototype without ever testing the pieces. They make the first test run of their airplane, jet boat, etc. in front of a movie camera. In some cases they apparently even called in the press just to be sure the test would be as humiliating as possible.

My favorite relatively recent invention was McCready's human-powered airplane. In 1965 an English sponsor named Cramer offered a $100,000 prize to the first fellow who could fly over a 20 foot obstacle, fly over a half mile course, fly over a second 20 foot obstacle, then turn around and return to fly over the first obstacle again. The plane had to be 100% powered by muscle power. For 20 years many smart people tried to build a pedal-powered plane. Again and again they made the same mistake. They worked for months building beautiful, handcrafted balsa wood airplanes. Then on the first flight the plane would crash and be smashed beyond repair. After two or three attempted flights, the inventors had spent months or years and were out of money and enthusiasm. In contrast, McCready designed his aircraft out of aluminum poles, wire, tape and mylar. He designed his plane to be flown, crashed, repaired and modified. McCready was able to crash and redesign his plane once or twice a day until he got it right. And he made sure there were no cameras around until it was tested and working.

Build for function, not beauty

First and foremost, your equipment should work well. It is natural to feel embarrassed by its crude, homemade appearance. Don't be! Commercial ham equipment has been designed and redesigned several times before you ever see it. Moreover, commercial equipment is packed with custom displays, custom heat sinks, custom cabinets and even unique integrated circuits. You can't compete with that, so don't try. Instead take pride in your crude prototype.

When you see designs for homebuilt equipment in the ARRL handbook or in ham magazines, the equipment is usually quite attractive. But if you read carefully, you will find that the unit in the picture is prototype number five or even number one hundred. You probably don't have time to rebuild your station 5 times just to achieve beauty. Also, if you attempt to duplicate one of those units, you'll find you must use exactly the same parts and circuit board the author did. This means buying a custom circuit board and perhaps a parts kit from some manufacturer. If you try to substitute parts, I can almost guarantee it won't work.

Get smart guys to help you

This piece of wisdom from Edison may be limited in usefulness to the basement ham, but it's still interesting. Edison was the first fellow to industrialize the process of research and development. Once he acquired financial backing, he hired a whole team to work on his projects. He didn't try to do everything himself. The quantity of Edison's inventions can be partly explained by the number of competent guys he had working for him. Edison and his lab were credited with inventions that represent the work of dozens of lifetimes. Even for a guy who works day and night, there are limits on what one fellow can do. If you're a one-man show, it's important to limit yourself to projects you can complete. Be sure to use the library to find previous work in your area. Although real ham homebuilders are rare, homebuilding is the most fun if you can find someone in your area to share your triumphs and problems.

Assume as little as possible

Edison looked for guys who had the right attitude about R & D. Many job applicants have a knack for sounding good in an interview, but turn out to be more glib than useful. One of Edison's tricks was to take potential employees out to lunch. If they put salt and pepper on their food without tasting it first, they were in big trouble with Edison. Edison's selection method is probably extreme, but it does illustrate a cardinal rule of research. ***Never assume anything about the project without good data to back up your starting assumption.***

For example, I had known for twenty years that resistance in series with a transistor emitter was important for the thermal stability of an RF amplifier. However, I believed that any emitter resistance would inevitably reduce the signal output from that stage. In other words, I thought stability and gain were a tradeoff. Recently I took the time to try different values of emitter resistance over the entire range of possibilities. I was amazed to find that maximum output occurred not at zero ohms, but at a certain significant value, 300 ohms in my specific amplifier. When you do experiments like this, write down the details! You'll want them later.

Many inventions are frustrated by assumptions that turn out to be limiting. For example, weapons inventors were limited for centuries by the concept that firearms had to be ignited by flintlocks. When you consider the practical difficulties of inventing a waterproof, rapid-firing, breech-loading flintlock rifle, it's no wonder that firearms were essentially unchanged for 250 years. Millions of lives were probably saved by this fixation on flintlocks! Narrow-mindedness in inventors isn't always bad for society, but it sure restricts innovation.

The genius of trying

Magic happens when you actually sit down at your workbench and try to do something. You may have thought about the problem in spare moments for weeks, but when you actually have the work in front of your face, ideas pop into your head as if by magic. For this reason, many people, like Edison for example, were well known for working non-stop all night. Once you get the momentum going, it can be wasteful to stop. Otherwise you may not remember all the details when you get back to work hours or days later.

I used to work with a patent attorney, Robert E. Harris, who always put everything off until the last minute. I kidded him about his procrastination. He answered me seriously with an explanation that went something like this: "I do it deliberately," Bob said. "I find that in order to write a patent application, I need complete concentration and nothing gives me that intensity like an approaching deadline. In order to write a good patent, I must have all of the prior inventions in my head at the same time. If I just put in just a few hours, by the next day I will have forgotten important details.

"For example, suppose that Jones' claim 14 partially eclipses our proposed claim 12. But the essence of Jones' work was already in place by Smith whose patent has recently expired. Therefore, Jones claim was already invalid and should never have been allowed. And the novel part of our claim 12 now becomes valid because it has no precedent and the old part doesn't interfere with Jones. For that reason, the day before the deadline I go into seclusion and work all night if necessary."

When you get stuck, do something else for a while

Unfortunately non-stop work often slows to a crawl when you run out of significantly new ideas to try. As long as you keep sitting in front of the problem, you will keep finding little variations to try, but as the hours go by, you will become more and more tired and your ideas will become less and less creative. To escape from this trap, get up from the workbench and do something else. Take a walk, take a shower, go home. When you're not in front of the work, you can't do anything with your hands. Since you've been concentrating so long on the problem, your brain will continue to work on the problem long after you leave the workbench. Because you can no longer try out little, uninspired ideas, your mind must wander farther and you'll find you are thinking seriously about radically new concepts.

For example, when Edison was searching for his light bulb filament material, he was stuck on the idea of using an inert metal filament. An inert metal would not react with oxygen or with residual gasses that might remain in the light bulb. If Edison had been able to use his "try everything" philosophy, he would have eventually tried every known metal. Therefore, he would have eventually tried tungsten and that's what filaments are made of today. But perhaps tungsten wasn't available 120 years ago.

Edison was particularly stuck on platinum as a filament material. Yes, it was expensive, but it seemed to work beautifully and gave a bright yellow-white light for a few hours. Unfortunately, eventually a segment of the platinum wire would become thin and abruptly melt, thereby ruining the bulb. A related problem was that the resistance of platinum was too low. This meant that a long, very thin platinum wire had to be used to make the filament compatible with his 100 volt power source.

Edison and his team realized that, if they could detect the sudden resistance rise of the filament as it started to fail, they could turn down the current and keep the filament intact. In theory, a temperature/ current regulator could allow the bulb to last indefinitely and would make it almost immune to power surges. The team expended a great deal of effort to invent the regulator, but it never worked well enough. Finally while away from work, Edison thought that the whole idea of a metal filament should be reconsidered. From metals he turned to carbon filaments. Carbon was cheap, had an inherently high resistance and it didn't melt. Carbon turned out to be a practical answer he could use and in the end carbonized cotton thread became the filaments in his first commercial bulbs.

Developing your own basement electronics laboratory

Before you can begin building ham equipment you will need some basic tools and materials. Notice that, in addition to books, you will need both heavy-duty tools and light-duty ones. If you use tools that are too fragile, you may ruin the tool. If you use tools that are too heavy, you may ruin your project. The following list is incomplete, but it will get you started.

1. Buy an ARRL Amateur Radio Handbook

An R&D hobbiest can't hire a staff of underlings and consultants, but he can get advice from guys who have done it all before. ***The first investment a new ham should make is The ARRL Handbook for the Radio Amateur.*** These handbooks are as big as a phone book. It is published every year and the latest edition has all you need to understand the breadth of our hobby. It will also give you a good background in basic electrical principles and some detailed descriptions of do-it-yourself construction projects.

The ARRL Handbook , 1986 edition

Yes, the above handbook is way out of date. However, I have two criticisms of modern ARRL handbooks. First, they are so huge, they discourage most people from sitting down and reading them. The second limitation is that modern hams no longer build complex receivers and transmitters. So projects like this are no longer described in detail. In fact, reading my up-to-date handbook I got the impression that building complex transmitters and receivers is impossible for amateurs. That's not true and that's why I'm writing this book.

Other than that, the latest edition handbook is a great reference to own. It covers all the latest exotic technology and you can use in like an encyclopedia. For actual homebuilding I recommend a handbook from the 1980's. During that decade hams were still building good equipment from discrete transistors. Handbooks from the 1970's and earlier usually describe projects that are unnecessarily primitive. The projects in the Handbooks from the 1990's and later usually contain integrated circuits which don't teach you anything about how your project works. The authors of the present day handbook don't seriously expect anyone to build complete stations. You should be able to find a handbook from the 1980's at a ham radio swap fest. Or maybe you can buy one from a ham in your neighborhood who has no interest in homebuilding.

2. A heavy duty, 100 watt soldering gun and a fine pointed small 25 watt pencil or gun

You need both. The big soldering iron is important for soldering antenna wires and heavy work. A fine pencil is essential to solder the leads on fragile components like transistors and integrated circuits.

3. 60/40 Rosin core solder, fine and coarse sizes

Rosin core solder (60% tin/ 40% lead) is used for joining wires whenever reliable electrical conduction is the primary goal. The rosin flux is built into the wire-like solder, so you never have to apply solder flux. Acid core solder is used for structural purposes. It is not usually recommended for electrical use because the acid continues to corrode the metal for years afterwards. Eventually residual acid may result in a poor electrical connection. However, ***a roll of plumber's acid core solder is nice to have around.*** Sooner or later you will be building an antenna or some other project that forces you to solder copper wires to steel. Since nothing else works, a bit of acid core solder can be a lifesaver.

4. Fine needle nose pliers and diagonal cutters for bending and clipping tiny leads

These should be high quality and your best pairs should be almost small enough to fix watches. In fact, if you use modern "surface mount" electronic components, you will also need fine pointed tweezers to manipulate the parts. ***A cardinal rule about fine tools is NEVER use them on large wires and parts.*** These delicate tools will be ruined instantly if you try to cut steel wire with the small diagonal cutters or use the needle nose pliers as a wrench. A hemostat can be useful for holding small parts in place while you solder. A non-conductive plastic screwdriver is helpful for adjusting trimmer capacitors in situations where the adjustment screw is floating above ground.

The yellow-handled tool in the collection below is a wire stripper for removing plastic insulation from wires. A pocket knife is also nice to have for stripping insulation off the ends of enameled and Teflon insulated wire. These kinds of insulation cannot be removed gracefully with a wire stripper and must be scraped and carved off with a knife blade. A set of tiny jewelers' screwdrivers is also useful.

5. Microscopes & reading glasses

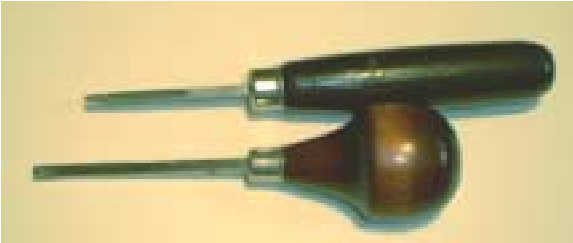
Even if your eyes are much better than mine, you'll need a strong magnifying glass to inspect your solder connections. Often tiny whiskers of solder or bits of thin wire short out connections. Other times a solder joint looks OK from a distance, but under extreme magnification, the piece is not actually making contact with the desired terminal. These problems usually can't be seen with the naked eye and you might spend hours looking for a problem you could have noticed immediately with a glass. I routinely examine each solder connection with my lens before moving on to solder the next component. I use pocket microscopes, a strong magnifying lens and over-the-counter, strong (+3.50) reading glasses for this purpose.

6. Heavy needle nose pliers, heavy-duty diagonal cutters and small wrenches

You will often need large versions of the delicate tools. Use them when appropriate. You will also need a vise, assorted files, a hacksaw, and hole reams for shortening and mounting PC boards and heat sinks.

7. A set of wood carving gouges

"A set of what?" you ask. Wood carving gouges are a kind of delicate wood chisel with a cupped end. I use them for cutting traces on blank printed circuit boards. You will find they work well for making one-of-a-kind prototype printed circuit boards. In my opinion, carving a circuit board is superior to any other method I have seen for homebuilt radio frequency circuit boards. (Other folks prefer the Superglue and disk method described in chapter 6.)



8. An electric drill

An electric drill is used make holes in PC boards and heat sinks.

9. Male Thread taps

Rather than assemble your entire project with machine screws and nuts, you'll find it's often simpler and more professional to tap threads into the aluminum heat sinks and brackets. I find 4-40 and 6-32 threads to be the most useful sizes.

10. A high quality multimeter

Modern digital “multimeters” measure voltage, current and resistance. Fancy ones may also measure frequency, conductance, capacitance, decibels, temperature and other parameters. All multimeters are based on a high input impedance voltmeter. A quality modern meter has an input resistance (impedance) of 10 million ohms. High impedance is needed so that the measurement doesn’t load down the circuit and alter what you are trying to measure. Old-fashioned electro-mechanical meters have impedances as low as a few thousand ohms. A quality meter is also extremely accurate. Measurements of a certain voltage or resistance will be correct to several decimal points. ***Don’t be cheap with this item.*** It is the core of your electronic measurement capability. If you expect to take the meter outdoors to work on the car or up onto the roof to do antenna work, then maybe you should also buy a cheap multimeter you can afford to break.

11. A high quality oscilloscope

The oscilloscope is another foundation of your laboratory. The traces on the screen tell whether your device is working and how well. Without a scope, you are almost blind. Perhaps the most amazing achievement of people like Edwin Armstrong is that they were able to do their work by inferring the function of circuits from secondary measurements. For example, the plate current of an RF amplifier tube dips when resonance is achieved. However, it’s so much easier to just look at the signal with a scope and WATCH the actual sinewave while the circuit is tuned.

A first rate oscilloscope might cost $10,000 brand new. But there are advantages to living in the 21st century. One of them is that 20 year old $10,000 oscilloscopes are all transistorized, still first-rate quality and you can buy a used one for $300 or $400 dollars. The prime consideration is that the scope must have a frequency rating higher than the frequencies you will be working with. For HF ham radio, 50 MHz is enough, but you can find used scopes that will go as high as 1000 MHz.

The oscilloscope is connected to your project by a "***probe***." A probe is a 3 to 6 foot long coaxial cable with a ground wire clip and a little "grabber" at the end that hooks onto the wires carrying the voltage waveforms you want to look at. Probes usually have a 10:1 voltage divider that protects the oscilloscope from high voltages you may be measuring. Not all probes are created equal. ***For high frequency radio work you need a short probe with minimum capacitance***. If you buy a probe, look at the specifications to see what kind of capacitive load you are putting on your circuit.

For example, if your circuit is tuned by a variable capacitor that ranges from 5 to 60 pF capacitance and your probe has 50 pF of capacitance, the probe will totally dominate the circuit tuning. In general, a good RF probe has a short cable and a short ground lead. Of course even 5 pF is a significant load. So when I'm tuning a circuit, I try to tune one stage of an amplifier, while I use the scope to monitor the signal in the following stage. That way, the tuning of the first stage will not be affected by the probe.

12. A frequency counter

As soon as you as you build your first ham transmitter, you will need to prove that your transmitter is operating inside the ham band. Also, we hams are supposed to limit our transmissions to one frequency, not splatter all over the band. By definition, a pure sinewave is a single frequency. My solution is to routinely monitor the frequency and shape of my RF sinewave right at the base of the antenna. If it looks like a good sinewave on the scope, the signal is almost certainly clean.

You can estimate the frequency of the sine wave by using the horizontal marks on the oscilloscope screen to measure how long it takes to complete a complete sine wave. If you count grid squares on the screen, you can measure the frequency of a sinewave to about 10 or 20%. Unfortunately, that isn't nearly good enough. For example, if your transmitter frequency is 7.05 MHz, one complete sine wave will take 0.142 microseconds. You won't be able to read it closely enough be sure it isn't really 0.143 microseconds and just outside the 40 meter band. You really need a frequency counter.

Some sophisticated oscilloscopes have built-in frequency counters to measure the exact frequency of a signal. Almost certainly, you will have to buy a separate frequency counter to tell you exactly where you are to the nearest Hz. You can buy a new, quality counter for $2,000 or more. Or you can get a new, cheap frequency counter for $200. The best bargains are first-rate used frequency counters. You may be able to buy one for under $100.

13. A quality short wave receiver

Aside from using it to hear other hams, a good quality, commercially manufactured shortwave receiver can serve as a laboratory instrument. A modern receiver is so well calibrated that it may be used as a substitute for a frequency counter. Also, it's important to be able to listen to your own signal in a receiver to be sure that it doesn't have subtle defects that may be hard to see on an oscilloscope. Ideally, you should have both a counter and a calibrated receiver.

14. A laboratory power supply

A laboratory power supply allows you to apply voltage to a circuit cautiously. This will usually prevent component damage due to wiring errors or other problems. Meters tell you how much current is being drawn and the voltage applied. This particular old power supply is actually three separate supplies. For example, you might use the 5 volt supply to power a microprocessor, while the other two variable supplies could be set up to deliver + 12 volts and – 12 volts for operational amplifier circuits.

15. An RF frequency generator

This is a tool you will eventually want. But if you have everything above, it isn't essential. The RF frequency generator allows you to inject a sinewave of known amplitude and frequency into an amplifier so that you can align it. When aligning a homebuilt receiver, it is nice to have a known test signal you can listen to any time you want.

16. A capacitance meter

While not essential, you can use a battery-powered capacitance meter to sort out your junk drawer and give a reliable indication of capacitor size. I find it extremely useful for determining the maximum and minimum set points on trimmer capacitors.

17. Catalogs of electronics parts suppliers

You will need at least 3 or 4 catalogs. I like RF Parts Company, Jameco, Digi-Key, Newark, Mouser and Radio Shack. Hopefully you have a Radio Shack store in your area in case you need some routine part in a hurry.

18. Your very own junk collection

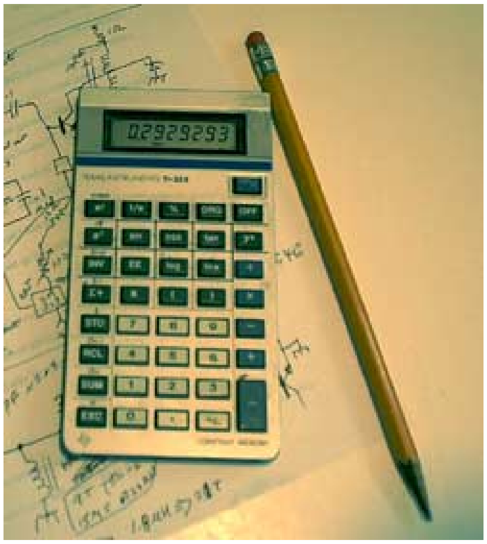
As Edison said, it is important to collect junk parts so that you aren't continually waiting for parts to arrive in the mail. Considering that a capacitor or potentiometer costs a few dollars new, it is easy to spend hundreds of dollars on a project. If you are **not** getting most of your parts from old TVs and ham swap-fests, your project will cost a fortune and will proceed slowly. Never throw away an old radio or computer without first cannibalizing it for useful parts. Organize your parts in bins, parts drawers and labeled boxes so you can find them when you need them. If you can't find a part when you need it, junk is just junk.

19. A laboratory notebook

Your memory isn't half as good as you may think. Write down all your experiments, triumphs and especially your failures. The experiment that doesn't work is just as important as the experiment that did.

20. A simple calculator

You probably already have a calculator that will be adequate for the simple component value calculations you must do. Square roots may be the most complex calculation you'll perform on your way to your first two-way ham radio contact.



When I was in engineering school, the calculator age had not yet arrived. We young engineers swaggered about carrying big sliderules that hung from our belts like swords. We were very cool. When I sat down in class to take a test, I would ceremoniously draw my sliderule from its sheath and check to see that the upper scale was perfectly aligned with the lower scale. If it wasn't lined up perfectly, I used the blade of my pocketknife as a screwdriver to adjust it. For me this ritual was something like a US marine checking out his rifle one more time before hitting the beach.

For you whippersnappers who haven't used sliderules, these antiques do logarithms, calculate trigonometric functions, take squares and square roots and do almost everything you can do on a simple "scientific" calculator. The point of this archaic story is that sliderules don't do decimal points. Therefore, to get the right answer, we had to have a FEEL for the math. We had to be able to estimate the answer so that we would know what order of magnitude it would be and where to put the decimal point. In other words, we had to know what we were doing. The sliderule expanded our skills. It did not replace them.

When calculators came out, engineering students suddenly began to fill their test papers with random numbers. Beginners think that, if they push the buttons, the calculator is doing the thinking for them. Wrong. It turns out that calculators really aren't different from sliderules. The students must estimate the work in their heads so that they will know if they have pushed the right buttons. After the students mastered the ability to estimate, calculators became a boon to engineering.

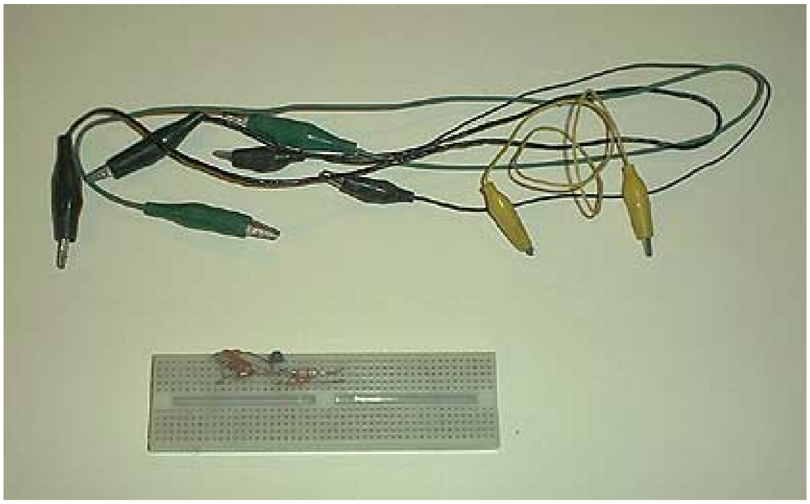
Software for experimenters

I hesitate to mention circuit simulation software. I am a rebel against the modern age of smug engineers who have never soldered a wire. I don't like the trend of increasing specialization and generalized ignorance that is spreading through the technical industry. Spice programs are very much like calculators. They're wonderful if you can estimate what the circuit should do before you activate the simulation. Once you get very far into building ham gear, you will probably get tired to doing everything the hard old way. There are many different simulation programs available that allow you to emulate a circuit on your PC computer before you build a real circuit. Like most modern conveniences, this one is truly marvelous. However, Spice should complement actual circuit testing, not replace it.

I use an old **Electronics Workbench** "Spice" program, but there are probably many newer ones that work as well or better. Mine is a simple program that will not simulate some components, such as crystals or some kinds of circuits like oscillators. I really like it for simulating filters. If I need to build a filter with a certain cut-off frequency, but I don't have the right parts, I can simulate substituting parts and see how critical the values are. Actually, it's so much fun trying out circuits with so little work, that it's almost addictive. Also, other problems in my design become obvious that I had never thought of.

For example, I built a filter for a ham transmitter that was designed to eliminate interference to the neighbors' TV reception. (See chapter 9.) Any transmitter signal has minor "impurities" in its frequency spectrum. This means that it can easily be radiating weak signals on the TV channels. A filter will reduce these harmonics. Before I built my filter, I took the time to model it on the Spice and found that, as I had planned, it severely reduced interference on channels 2, 3 and 4. Above those channels, the attenuation of possible harmonics was not nearly as great. For the upper UHF channels, there was hardly any attenuation. Once I saw the problem, it was easy to add a couple more stages of filtering to insure that *all* TV channels were protected.

Test leads and experimental "socket" circuit boards



Every electronics lab has handfuls of test leads and a few temporary circuit boards. Although I routinely use these, I am hesitant to recommend them. ***ANY ELECTRICAL CONNECTION THAT ISN'T SOLDERED CAN'T BE TRUSTED!*** Yes, it's true that these gizmos often work, but many times I have been led to believe that parts were bad or that circuits didn't work when they actually worked fine.

Let me illustrate: Once when I was in the Air Force I had to wire some explosive squibs on a 1500 pound cargo parachute load. The squibs were supposed to explode and deploy the parachute. I passed the bare, scraped copper wires into two tinned metal eyelets, then wound the wire through the eyelets again and again until the eyelet holes were stuffed with clean, bare wire. Then I wrapped the remainder of the bare copper wires tightly around the outside of the metal eyelets and wrapped the whole thing securely in tape. I thought there is no way that the copper wire wasn't in good contact with eyelets! The huge box fell 3000 feet and crashed into the dirt at a couple hundred miles an hour. The squibs never fired. I checked the firing circuit with my meter and found the proper 3 volts across the squibs. I unwrapped the tape from the eyelets. The squibs exploded as soon as I tugged on the bare wire. After that day I soldered my squib wires and never had another failure.

Pliers for crimping connectors and eyelets

What about the special pliers used to crimp connectors and eyelets? Some metal eyelets and lugs are designed to be installed onto wires using special crimping pliers. Yes, crimped connections can be fairly reliable in the short run. However, in my experience crimped wires pull out easily and, after several years, they often become open circuit. I have seen dozens of failures on old equipment. Personally, when I use eyelets on leads, I always solder them. Eyelets that are screwed down to sheet metal are fairly reliable. However, I always solder the wire onto the eyelet (rather than crimp it) before I screw it down.

In conclusion,

The equipment described above should get you started. Everyone has different ideas about what works best and what is essential. For what it’s worth, the above list pretty well describes my workshop.