Overview of building effects

Building your own guitar effects can be a way to get a classic sound without paying a fortune for an original. With the vintage market in its current condition, an original big reputation effect can cost as much as a new guitar.

Building your own effects requires some mental and physical stretching, which is good for us all. To do this well you'll have to:

- learn at least some electronics to understand the effect
- learn some electronic prototyping skills
- learn to so some mechanical operations to put it all together

Major parts inside effects

In almost every guitar effect you examine, you will find the following major subparts or sections:

- circuit board - which contains almost all of the actual works that make the sound modifications; some very early effects were built on terminal strips, but this is very rare. In general, point to point or hand wiring offers no advantage in most effects, no matter what else you're told.
- controls - potentiometers and switches to allow you to shape the sound of the effect; some effects have these mounted right on the circuit board, but most of the vintage effects have them mounted on the enclosure and connected to the circuit board with wires.
- connection jacks - to let signals in and out of the box
- battery or power supply - to provide the electricity that makes it all work
- enclosure - more than just a box to hold everything, the enclosure gives the sturdiness that allows an effect box to be reliable on stage - *very important!*

Steps in building effects

1. Gather all the parts
2. Be sure the parts all fit onto the circuit board and into the enclosure
3. Obtain a circuit board and assemble it
4. Fit the board, controls, jacks, battery, etc. into the enclosure
5. Connect the parts together with wires
6. Do final debug
7. Make it attractive and easy to use

Get your parts together

If you obtained an information package from GEO, this will be fairly simple. The GEO information packages and effect booklets contain:

- a complete schematic of the effect, including wiring to controls, switches and jacks; as well as any changes that may have been made from the original circuit - like true bypass switching, if the original did not do that
- a technical description, telling you something about how the circuits work
- a complete parts list, including possible substitutes for hard-to-find parts where those are possible
- parts stock numbers for recommended suppliers
- estimated purchase prices
- any suggestions or cautions about the circuits or parts in it

If you are building from a schematic, it will be <u>extremely</u> helpful if you use the information above as a guide and write that information down about the effect.

You'll need to have some kind of circuit card to hold the smaller electronic parts. In many cases, you can also (re)make a classic effect on perfboard or stripboard (Vero board) if you prefer, as many of the classics are fairly simple.

GEO offers effects packages that have either toner transfer sheets to make your own printed circuit board, or ready-to-solder circuit boards.

What else do I need besides the parts?

In addition to the parts and some kind of circuit card, to assemble a working unit you'll need:

- 15-30 Watt soldering iron ($8.00 to $20.00)
- needle nose pliers ($3.00 - *$5.00)*
- diagonal cutters ($3.00 - $5.00)
- hookup wire ($1.00 - $3.00 for a small spool)
- solder ($1.00 - $3.00 for several effects worth)
- drill and bits to make mounting holes in the enclosure it goes in ($I 5.00 to
- $50.00 depending primarily on the drill you buy)
- Velcro strips for mounting the board in the box
- Miscellaneous hand tools like screwdrivers, pliers and wrenches for tightening down fasteners.

If you are your own circuit board from the toner pattern, you will also need:

- single sided copper clad board stock 1/4" (6mm) to 1/2" (12mm) bigger in each dimension than the toner pattern (Radio Shack has a printed circuit board kit for about $14 that contains board blanks, drill bit, etchant, touchup pen, and other items mentioned in this list)
- hacksaw for trimming the etched board to finished size
- medium or fine sandpaper for smoothing the edges of the trimmed board
- etchant for etching away the unwanted copper (try Radio Shack)
- etch resist pen or permanent marker (Sharpie is one brand) for touchups
- 0.032" (0.7 mm to 0.8mm) diameter drill bit - carbide is preferred if you are using **a** drill press, but carbide will break in a hand held drill

- Small drill press (the Dremel Moto-Tool drill press is ideal) for drilling holes in the circuit board is highly recommended. (This would be expensive to buy, but it makes drilling much easier; perhaps you can borrow one.)
- Acetone (nail polish remover) for dissolving the etch resist or "0000" steel wool for abrading away the resist once the etching and drilling are done
- pointed punch, ice pick or sharpened nail for dimpling pad centers

Making sure it all fits together

Before you start soldering, it's important to make sure that once you're done soldering, it will all fit inside the box. If you do this first, you will avoid the problem of unsoldering everything and getting a new box. In most cases, you can just place the parts inside the box, looking for how they will all fit when the bottom is screwed on, and determine how it goes together. If you bought the effects package from GEO, the recommended box is certain to have room. In either case, spending extra time on this planning will pay off handsomely in a better looking, better functioning effect later.

Later in this booklet, there is a diagram of my favorite effects box scheme, and the one that I recommend for all beginner-to-intermediate effects builders. With few exceptions, the GEO packages are designed to fit inside this recommended box, the die cast aluminum Hammond 159OBB.

Obtaining a circuit card

As I noted before, you will need some kind of circuit card to hold the smaller electronic parts together. It is possible and reasonable to assemble many classic effects on perfboard or on veroboard., especially the simpler ones. Using a printed circuit card is simpler, once you have a printed circuit board.

GEO offers both ready made PCB’s and toner transfer sheets to make your own. The only difference between the two is that the toner sheets require you to make your own printed circuit board from the iron-on pattern before you can start soldering parts in (it's also cheaper!). In both cases, you get this information booklet and a booklet with information on the specific effect. The toner package makes a circuit board identical to the ready-to-solder board.

Since this booklet was prepared primarily for help with GEO toner sheets or ready-to solder boards, I will concentrate on the toner transfer sheet process. The perfboard and stripboard techniques are well documented elsewhere.

Making a circuit board with a toner transfer sheet is a learned skill. Read through this all, and be prepared to feel your way along if you have never done this before. There is much more to printed circuit technology than I could include here, so I'm not going to write down every possible thing you'll need to make a board, just the important parts about this particular method. There is sufficient information here to allow you to complete a single sided toner transfer board.

If you bought the toner package, you will receive an envelope with a blue plastic sheet, shiny on one side and matte blue with black printed circuit pattern on the other. This is the toner transfer sheet. Since you may be new to this, all packages contain at least two copies of the pattern or one image plus several small "test pattern" toner sheets. This is to allow you at least one false start at making a board if you're new to this. For the packages that contain multiple toner patterns, if you're good, experienced, or lucky you can make a second board, with my complements. If you got the package with the test patterns, try ironing those first, wiping off the pattern with nail polish remover (acetone) after you experiment.

The blue toner sheet is a clear mylar sheet with that blue coating on it that has been individually laser printed with circuit board transfer toner for accuracy. Laser toner can be thought of as hot melt glue with some carbon black mixed. This means that if you heat the stuff, it sticks to whatever it's touching.

To make a circuit board, you clean a circuit board blank so it will chemically etch, put the toner street on the clean copper side with the black pattern side down, and iron with a common household iron. This remelts the toner, which sticks to the copper. When the board and stuck-down toner sheet cool, you peel up the toner sheet. The blue layer sticks to the mylar plastic less well than the toner sticks to the copper, and the circuit pattern remains on the copper. The blue coating over the black pattern also remains on the copper, helping prevent any voids or drop outs.

Toner happens to be an excellent etch resist; all that you have to do then is to etch the uncovered copper away in one of a couple of commonly available etchants, and then drill and trim the board to have a completed circuit board.

Start with a bare board ... make sure that the board blank that you start with is at least 1/8" (3mm) or more larger than the image in all directions; 1/4" (6mm) is recommended. Also make sure that the edges of the blank are smooth and even, not raised or ragged from cutting the blank. You can smooth the edges with an ordinary file or sandpaper if they are raised or rough.

Spend extra effort getting the circuit board clean. To clean the board:

1. Wet the board, leaving some droplets of water beaded up on the surface.
2. Sprinkle Bon Ami cleanser onto the droplets, and work this into a paste with your fingers.

3. Rub the paste vigorously over the entire surface of the board, paying special attention to the edges and corners.
4. Rub until the paste turns a blackish-grey color.
5. Rinse under running water, rubbing gently, until the cleanser is all gone. Touch (lie blank only by the edges. Water should run off the surface in a smooth sheet, not bead into droplets, and the color should have a definite pinkish cast. If this is not true, sprinkle on more cleanser and go at it again.
6. Pat the board dry with paper towel. Use clean, dry paper towel to fold the board into until you can get it ironed.

The cleaner the copper surface you start with, the better the etching results!!

Ironing... if you have multiple toner images of the board, cut the images apart, leaving a margin of 1/8" 1/4" (3 to 6mm) of blank blue space around the image on all sides. Center the image up on the copper board blank. Don't try to print the image right up on one edge of the blank. Don't try to make two at once.

Place the copper clad circuit board material on a hard surface to iron on the toner. A soft, padded ironing board is a bad idea. Use a heat proof board or similar object to give a hard surface under the copper clad.

I use my iron set to the lowest heat in the steam range *(but with steam turned off).* The image is still visible through the back of the Press-N-Peel sheet before ironing. As you heat it and it sticks down, the appearance changes, becoming more definite and easier to see through the back of the transfer sheet. There will actually be a tiny but visible depression in the shiny back surface of the toner sheet where the toner has stuck to the copper.

You don't need to press down hard on the iron. The weight of the iron itself should be enough for normal household irons. For tiny travel irons, you'll need to press down gently. Keep the iron moving and try to heat the whole image area evenly. This is not a long process. The ironing process should be less than a minute, sometimes a lot less than a minute. If you iron it too long, the toner spreads and runs on the copper and may cause shorts, and the copper oxidizes to odd colors, although this oxidation has always etched just fine for me.

Once you get what you think is a good ironing, LET IT COOL. Then peel the sheet away. You may have some areas where the toner did not transfer well or the ironing was less than complete. Use an etch resist pen from Radio Shack or an all-surface permanent marker (Sharpie is one brand name) to touch up any missing lines. Use the Check Plot as a guide, remembering that the Check Plot view of the copper traces is how they would appear if you could look through the board from the component side, so the image on the copper blank is the mirror image of the pattern in the Check Plot. You will usually be able to tell easily.

Once you get a good image on the copper, etch it with your favorite etchant, following your own procedures for that. Carefully follow all safety precautions -for the etchant you use. These chemicals are caustic and may cause bums, irritation, and stains. Eye protection is a must.

Finishing the board ... when the etching is done, you have only to drill the board and trim it to size before inserting components and soldering. Drilling boards is, frankly the biggest pain associated with the whole process. The best way to drill is to use something like a Dremel tool in a drill press accessory.

If your ironing and etching were very good, there will be a spot in the center of every pad etched free of copper. A spinning drill bit of about the right size just touched to the pad a little off center will tend to center itself up in the clear spot in the center of the pad if your ironing and etching was perfect. You can actually feel the drill "jump" into the center of the pad. If you didn't get a perfect transfer (I don't, many times!) you can still help the drilling process by making a slight indentation in the center of any pads that don't have a clear spot by pressing a sharp pointed object like a sharpened nail or ice pick into the center of each pad before drilling. This makes a little "crater" so the drill bit will self-center.

This makes it possible to drill freehand, but you'll break a lot of drill bits if you insist on doing it this way - the bits are very thin and fragile. In a drill press, if you hold the board loosely as the bit touches down this will allow the board to move slightly to center the bit in the pad. This is hard to describe, but you'll feel it instantaneously when you drill the first hole correctly. Once the bit is centered, hold the board blank more firmly to drill the hole.

I feet like I have to insert a warning here. Use every caution with the drilling. Even a small power tool can drill through your finger, wind your clothes up into it, or fling the board blank, dust, or powder into places that can be uncomfortable or dangerous for you. *Please be careful. Your safety is your personal responsibility.*

For trimming, you can use a hack saw blade to cut along the edges outside the circuit. The very thin traces along the edges of some boards serves as a trimming guide. You can cut these away when trimming the board or leave them on, makes no difference except in the overall size of the finished board. I usually leave trimming to last, after drilling.

When drilling and trimming are done, the toner-resist can be removed with fine steel wool or acetone, leaving bright copper to solder to.

Some notes on making the circuit board from toner packages -my layouts are done with extra wide traces (usually 0.030") to deliberately make it easy to get results with toner transfer methods. Press-N-Peel is capable of traces 0.005 to 0.0 10" wide, but you have to be skilled to get good results. I tried to make the layout assuming that the traces needed to be wide and as far apart as possible to make it easier to iron on successfully for a beginner. Nevertheless, these boards are in most cases far smaller than the original effects boards because of better use of the circuit board area and arrangement of the components.

The component pads are 0.062" for IC pads and up to 0.070" or 0.085" in diameter for other components. I try to use the largest pad size that I can and still get the effect on a board that will fit in a normal size box. That necessarily means that some are the 0.062" on IC pads though, and that presents a manual dexterity problem in some cases in drilling the holes. A 0.032" hole in a 0.062" pad leaves only a 0.015" ring of copper, plenty for soldering the component lead, but it does not leave a lot of room for sloppy drilling work.

You should use a drill diameter between 0.028" and 0.032". Any smaller and the component leads are hard to get through the holes, and any larger and you remove a lot of the pad, leaving very little to hold solder and making it hard to drill the holes freehand on the smaller sized pads. If at all possible, use a Dremel or similar tool to drill the holes. The Dremel drill press accessory is ideal for drilling the board, and is highly recommended. You will break far fewer drill bits with a drill press to drill the holes.

If you use a sharpened metal punch to dimple the center of all pads slightly, this will make drilling much easier, as the drill bit will self center very well.

Assembling the circuit board

For most printed circuit boards, it's best to follow a certain order when you put parts into it and solder. First clean the copper side of the board carefully, to ensure that all traces of dirt, oil, bits of resist, etc. are removed. This can be done with "0000" steel wool, acetone (nail polish remover), or scrubbing with a cleanser like Bon Ami. Once it is truly clean, soldering will be much easier. The copper should be bright and shiny, and a pinkish-gold color.

Start by putting in all the resistors first, carefully checking values against the parts placement diagram as you put them in, soldering the leads and clipping off the excess; then all the non-polar capacitors; then the polar capacitors, and finally the semiconductors. This strategy is based on putting the least sensitive and cheapest parts in first, when there are more ways to make mistakes. Not included in the parts list arc sockets for integrated circuits. These are a good idea for most applications, although after you have more experience and skill you may decide not to use them.

Assemble all of the parts and sort them in some order that makes sense to you. I like to put a piece of blank paper on top of a piece of plastic foam, and stick the resistor and capacitor leads through the paper into the foam, then write on the paper what the values of the parts are. It helps me to find them as I go. Your mileage may vary. Pick a way that helps you keep track of what parts are what so that you don't get the wrong value parts in - the board.

I have found that having a block of soft plastic foam on hand is useful so that once the parts are in the board, I can place the foam over the board and turn the board upside down. The foam holds the parts in place while I solder them and then trim the excess lead length off.

When I lay out a board, I try to place all of the resistors and diodes with their leads on 0.4" centers. That way, you can use a lead bender or just a piece of plastic or wood you've cut to the right width as a guide to bending the leads to the right spacing. This is much faster than hand-bending them one at a time

There are jumpers (wires soldered in on top of the board) on some boards. A cut resistor lead will work perfectly for this. Jumpers are used to connect traces where no reasonable path to connect the signals is available on the board, and is used instead of going to a double-sided board, which would be much more difficult to make. Jumpers are clearly indicated in the parts placement diagram. Wherever possible, I make the jumpers be the same 0.4" as the resistors and diodes, so the same lead bender for resistors and diode will bend them perfectly every time.

In terms of soldering technique, be sure your iron is well tinned (covered with a smooth film of melted solder) and clean (by swiping it on a bit of damp cellulose sponge), and hot enough to immediately melt a bit of solder touched to the tip.

Once you're through soldering, and the board is all tested, you will want to go over the bottom of the board with a Q-tip or old toothbrush and common rubbing alcohol to remove the flux residue for a neater appearance. This is not strictly necessary, but produces a much nicer looking board.

How careful do I have to be with the parts? For semiconductors, you have to know what type of semiconductor you are dealing with. Ordinary bipolar silicon semiconductors are pretty tough. You can often just stuff them in and solder, no particular care beyond what you would do for a resistor or cap. It is possible to overheat/kill silicon transistors and IC's but this hasn't been a problem to me.

Germanium transistors and diodes are a different story. Overheat them with a soldering iron and you WILL damage them. You can turn that hard-won vintage AC128 for your Fuzz Face repro into an ugly-sounding lump of coal by overheating the leads while soldering. If you are not already skilled at soldering (clean parts, medium heat, well tinned iron, fast in and fast out, fast cool), don't try to solder germanium transistors down without holding on to the lead with a pair of needle nosed pliers between the body of the part and the place you're soldering. The pliers soak up some of the beat that's conducted up the lead and keep the transistor chip inside the body from overheating.

CMOS IC's and older MOS devices are static sensitive. The amount of static charge you pick up walking across a carpet in sneakers or other insulating sole shoes will kill them dead when you touch them. You need to have some way of discharging your body before you touch them, like keeping one finger on the screw in the center between the two sockets in a duplex AC outlet. It helps to remove your shoes, working barefoot (I'm not kidding) and wearing only cotton clothes, which don't make static charges like synthetics do. It helps to only work on CMOS when the weather is fairly wet, and NOT when the humidity is low, like with central heat in the winter. If you can zap yourself on doorknobs, you can for sure kill CMOS unless you are careful. One guy I know fired up his shower to get the bathroom nice and steamy and worked in there. Sounds silly, but he didn't kill his parts...

Putting it into a box

To get the best use out of your effect, you need to put it in a sturdy metal box so it's not fragile and always breaking and is shielded from hum.

While there are all kinds of potentially useful boxes you can use, I heavily recommend the Hammond 159OBB as listed in the parts list. This is a die cast aluminum box, so it offers shielding and is mechanically very sturdy. It is easy to drill holes for mounting parts, and does not require any special tools beyond an electric drill. This was not just my choice for pedals - MXR used almost exactly the same box for all their early production, and most of the boutique pedal makers use them as well, for the same reasons I recommend them.

I have included a sketch to show my preferred way to mount effects in this box. Using this sketch as a guide, measure and mark the places in the box to be drilled and drill them out for the controls, switches and jacks that mount on the box. Put each part in place and verify that it fits and does not interfere with other parts. The sketch is only a guide - your effect may have more or less controls and switches. Once all the cutting and drilling have been done, you can either go ahead and mount everything inside the box, but it's probably best to paint and pretty up the box first.

How pretty is this thing going to look? And how important is that to you? You can just leave the box raw, unpainted and hand letter the controls with a permanent marker if you like - the circuit doesn't care, works the same.

On the other hand, you can also make this into something unique and very attractive. For boxes I want to look good, I paint the box after I've drilled the control and jack mounting holes but before I assemble the parts all into the box. Cleat the box carefully with a solvent to remove all dirt, oil, grease, gook, etc. Spray paint it with automotive gray primer, which will air dry in fifteen minutes or so. Then give the thing a top coat of appearance paint. Automotive touch up spray paint is a good, durable, coating, and easy. I spray the box, then bake it in a toaster over (or my kitchen oven!) for about 30 minutes at 120F to 200F This results in a really durable surface.

For a really fancy looking box, find the on line document on swirl painting on the GEO web page, http://www.eden.com/-keen/. I

Once the painting and or lettering are all done and dry, put the controls, jacks and switches into the box a final time and tighten them down.

Don't get your wires crossed...

It's probably easiest to connect a long-enough wire to each pad on the circuit board before you put it into the enclosure. That way you can just stick the board in place and not have to move the board around to solder wires through the holes. I used to use standoffs and screws to mount the circuit boards into the boxes, but sticking velcro to the board and to the box serves the mounting so well that I don't even put mounting holes on the boards any longer. Use velcro it works well.

Once the board is placed, run the wires to the right places as noted in the wiring diagram included with the info package, cutting to length where needed. Finish up by running any wires that don't connect to the board. There should only be a few- the wires from input/output jacks to bypass switches are the most common ones.

Oh, great! I got this thing all put together and it doesn't work (welcome to debugging!)

OK, it's all wired up - and it failed the acid test. No worry - you can make it work. Here's where the electronics comes in.

The most common reasons effects don't work - in order, by my experience - are:

1. No power - battery voltage is not reaching the circuit. Measure the voltage *on the circuit board*, and on IC's directly on the chips. No voltage? No mystery why it doesn't work then. Trace it all the way back to the battery.
2. Bad soldering - cold solder joints, too much solder blobbed onto the joints and not really stuck to anything, little solder blobs and strings shorting things together.
3. Wires go the wrong places - check it (again!). I still hash this up and I've been building stuff for 25 years. Electrons are sticklers for accuracy.
4. Wrong, part, or parts put in the wrong places - like wires; check it again. I'm forever getting a 4.7K resistor (yellow/ violet/ red) for a 47K resistor (yellow/ violet/ orange) because I'm slightly red-green colorblind.
5. Polarized parts put in the wrong, way - check the parts orientation diagram. Transistor pinout varies, so check the pinout of the devices you get. Electrolytic caps often look like a short if the voltage is reversed.
6. Bad parts - yes, in my experience, this is the least likely thing to be wrong. Not that you can't kill germanium by bad soldering or CMOS with static electricity, but normal resistors, caps, and transistors are highly likely to be good.

If it's really, truly wired up correctly and the parts are in the right places, do some simple tests with no signal through the effect:

- Many of the effects schematics have "typical" voltages on them. This is intended as a debugging aid. If the DC voltages aren't reasonably close to these values (+/- half to one volt), something is wrong with the DC biasing setup of at least one stage. Check the values of the parts, and the bottom of the board for solder shorts, cold joints, and opens.
- For NPN transistors used as amplifiers, with no signal, the collector is the most positive voltage, usually by at least a couple of volts; the base is somewhat lower and the emitter is invariably 0.5 to 0.7V (0.2 to 0.3 in germanium) lower than the base. If this is not true, something is fouled up about the biasing on that stage.
- For PNP transistors used as amplifiers, with no signal, the collector is the most negative voltage, usually by at least a couple of volts; the base is somewhat higher and the emitter is invariably 0.5 to 0.7V (0.2 to 0.3 in germanium) higher than the base. If this is not true, something is fouled up about the biasing on that stage.
- For bipolar (NPN/PNP) transistors, if the collector/base, collector emitter or base/emitter are exactly the same voltage, either there is a circuit board short or the device is internally shorted and dead.
- To check a bipolar transistor, read the collector voltage; short the base to the emitter with a clip lead. The collector voltage should go up except for cases where the collector is tied to the + power supply. In that case, the emitter will go down significantly.
- Measure the power voltages of IC's directly at the pins of the IC
- Opamps used as linear amplifiers must have the negative input and the positive input at the same voltage +/- a few millivolts of the positive input. If this is not true, the opamp is dead or the circuit board is fouled up some way (not true if it's used as a comparator!)
- Opamp positive and negative inputs and output pins should usually all be between +2 and +7 volts DC with respect to ground in single battery systems for linear amplifier opamps, not including some special “rail-to-rail” opamps, comparator use and some precision rectifiers.

Supplier Addresses

Mouser Electronics
1 1433 Woodside Ave 2401 Highway 287 N. 12
Emery Ave
Mansfield TX 76063 Santee CA 92071
Randolf NJ 07869

370 Tomkins Court Sales and Service 1-800-
34-MOUSER (800-346-6873)
Gilroy CA 95020 $5 handling **f@** under
$20

Digi-Kcy **Stewart-MacDonald**
Guitar Shop Supply
701 Brooks Ave. South (DPDT stomp switches)
Thief River Falls MN 21 N. Shafer St.
56701-0677 Box 900
1-800-DIGI-KEY Athens OH 45701
No minimum order, 1-800-848-2273
$5 handling fee under $25.1

Circuit Specialists, Inc. 1-800-528-1417
220 S. Country Club Dr. #2 Internet: www.cir.com
Mesa AZ 85210-1248

Reference Material

About Components

Wires - This is the most basic "component', but it deserves some attention. For building effects, the voltages and currents are small enough not to need special wires in most cases. Wires are sized in "gauges", with the gauge number getting larger as the Wire gets smaller. For building effects, you want insulated (no bare wires, please!) hookup wire, of about # 22 to #26. Much larger wires are likely to be too big and stiff to fit well in the cramped confines of a pedal, and much smaller wires will be too hard to strip and solder well. Get stranded, not solid hookup wire. Stranded wire is composed of many smaller bare wires in a bundle. This makes the resulting larger composite wire much more flexible.

Resistors - next to wire, the most mundane parts. The resistors you'll use in effects are most likely to be 1/4 Watt carbon film resistors. These are about 0.1" (2.54mm) diameter, 0.3" (7.66mm) length cylinders with **a** wire lead sticking out the axis of the cylinder. These are tough, cheap, easily available parts. Resistors are measured in "ohms"; one ohm is the resistance that causes a voltage of one volt to appear when one ampere of current flows through it. That is a large current for effects, so most of the resistances in effects are measured in kilo-ohms (Kohms), which is one thousand ohms or one volt per milli-ampere, or in megohms (Mohms) which is one million ohms or one volt per micro-ampere.

There's a lot of myth grown up around carbon composition resistors. Do carbon composition resistors really give you a "brown sound" or "vintage sound"?
Sadly, probably not. There ARE differences in how carbon composition resistors pass audio frequencies from how carbon film or metal film resistors do this, but it's only under rare circumstances that you can hear any differences – except for the prominent hiss you get from carbon comp's. Go with carbon film for low cost, metal film for stable, quiet performance, and carbon comp only if you believe in elves or Maxwell's Demon.

Capacitors - unlike resistors, capacitors come in a bewildering array of shapes and sizes. All capacitors are internally composed of two conductive plates separated by a very thin insulator or "dielectric". This insulator blocks DC voltages but allows AC voltages to go through. The bigger the surface area of the plates and the thinner the dielectric, the bigger the rated capacitance.

Capacitance is measured in farads, which is one coulomb per volt, coulomb being a measure of charge. You can think of a coulomb as being a huge number of electrons gathered together in one place. A farad is a very large amount of capacitance, so the capacitors in effects are measured in microfarads (abbreviated as uF, one millionth of a farad), nano-farads (abbreviated Nf, one thousandth of a microfarad), and picofarads (abbreviated pF, one millionth of a microfarad).

Capacitors of 20uF on down through pF are usually used for coupling a signal from section to section while blocking a DC voltage, or for tone and frequency response shaping. Capacitors of 100uF on up are usually used for filtering DC voltage by "shorting" AC voltages to ground.

The dielectric that is used in a capacitor determines many of the capacitor's characteristics. In effects building, you'll find plastic (mylar, polyester, polypropylene, polyethylene, polystyrene, etc.) capacitors from about 1nF up to 0.47uF values; ceramic capacitors from 10pF up to 0.47 or 1.0 uF, and electrolytic (aluminum or tantalum) capacitors from about 0. I uF up to thousands of microfarads. The electrolytic capacitors are polarized, meaning that they should always have one side of the capacitor more positive than the other. Aluminum and tantalum capacitors are both polarized, and on schematics, parts placement diagrams, and on the capacitor itself, the positive or negative terminal will be marked so you can put them in the right way 'round. For other capacitors, polarity does not matter, the work equally well both ways.

Inductors - Where capacitors store energy in an electric field, inductors store energy in a magnetic field. They do (his by enhancing the magnetic field that forms naturally around any conductor with current flowing in it. Inductors are coils of wire, sometimes with iron, ferrite, or other special materials inside the coil. The unit of inductance is the I henry. Inductors are relatively heavy and expensive for the amount of energy they store, so engineers look for ways not to use them. The only common inductor in effects is the one in a wah-wah pedal, a 0.511 or 500 millihenry inductor. You won't seem many inductors in effects.

Diodes - Diodes are the simplest semiconductors that are used in electronics. 'They act as a one way valve, letting current flow only one way. Diodes are rated in the amount of toward current they can conduct safely and in the amount of reverse voltage they can withstand before breaking down. Most diodes in effects are about the same size as 1/4 Watt resistors. The direction that a diode allows current to now is front the end with the arrow on the schematic symbol (the anode), towards (lie end indicated by the bar (the cathode). Diodes are, of course, polarized, like all semiconductors, and only work correctly if they're installed the right way round. Do be careful soldering in germanium diodes – they can be damaged by heat, just like the transistors.

Some diodes arc designed to break down at a specified voltage. These diodes are called zener diodes; they serve as voltage references since the voltage across them stays the same over a wide range of current.

Transistors - Transistors were the first solid state components that could amplify. Technical improvements since the First transistors in the 1940's have produced a bewildering array of transistor types. There are bipolar transistors, which is what most people think of when you say "transistor". These come in NPN and PNP types, a letter indicating the polarity of each lead. The relative "goodness" or ratings of bipolar transistors is based on three things –

(a) how much voltage it can withstand without breaking down; this is usually not a problem with any effects you'll see, as most effects use only nine volt batteries as a power source; most transistors withstand 25 or more volts

(b) how much current it can conduct, again not likely to be a problem in effects, and

(c) how much current gain it has. This does make a difference in many cases. Bipolar transistors come in two polarities, NPN and PNP. and made of one of two materials, silicon or germanium. Most of the transistors used in effects will be NPN silicon. occasionally you will use PNP bipolar transistors, and even more rarely germanium transistors of either polarity. The biggest exception to that is of course, the Fuzz Face, which is made from PNP germanium transistors.

Other types you may run into are Field Effect Transistors or FETs. These work by having the voltage on one pin control the amount of current flowing through the other two. FETs are available in N-channel and P-channel varieties, analogous to the NPN and PNP bipolars. These will occur sparingly in effects. There are also MOSFETS, FETs made with Metal Oxide Semiconductors, and Power MOSFETs or just Power FETS. These don't occur very often in effects.

Transistors are polarized, and also have many different arrangements of the three terminals, so you have to check the pinout diagram for the actual ones you have to be sure to install them correctly.

Integratcd Circuits - IC's are the special purpose stars of electronics. IC's contain inside them transistors, resistors, capacitors, even inductors. They are special purpose, in that they contain a whole circuit that does some function. IC's arc polarized, and the package will have a notch or dimple indicating which end is which.

Color Codes

Resistors are color coded for value, rather than having the values printed on them. The key to the color code is that the first two color bands represent the numbers in the value, and the third band represents the multiplier, or number of zeros to add after the numbers. The code is

Black 1 so a [brown-black-red] resistor is I K, a
Brown 2 [yellow-violet-orange] resistor is 47K,
Red 3 [red- red- green I is 2.2M
Orange 4 and so on.
Yellow 5
Green 6
Blue 7
Violet 8
Gray 9
White 0

A fourth band may or may not be present. This is an indicator of the tolerance of the resistor. No band indicates a +/- 20% tolerance resistor, which used to be the standard back in the "golden age" of tubes. A silver band indicates a 10% part, which was the standard for most of the classic effects. Today, almost all resistors have a gold band, which indicates a +/- 5% part. There are resistors with five and six bands, which are uncommon. These indicate 1% tolerance parts, sometimes rated for temperature variation. You won't need to deal with these. Five percent tolerance parts are fine for effects - and MUCH cheaper.

Reading Schematics

It would be difficult and tiresome to make detailed artistic drawings of circuits to show how to reproduce them; in addition, such drawings would contain a lot of details about things that don't matter to how the circuit works. Engineers have developed a stylized way of drawing just the things that matter about a circuit the schematic diagram. The schematic shows components not in any physical arrangement, but how they are connected electronically.

Below are some sketches of schematic diagram symbols and the packages they represent that you might find.