

Panel and Chassis Construction



This document describes methods for panel and chassis construction. Techniques are intended for small shops or home fabrication using simple computer drawing software. While such software is not as detailed as the industry standard CAD products, it is not only sufficient, but far less expensive and less difficult to learn.

Small quantity sheet goods and metal products can be somewhat difficult to locate. Sources are suggested that should help those building prototypes or proof of concept projects.

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Panel Construction

Engineering prototypes and proof of concept models can look nice for very little cost. While professional panels may be necessary for high-end products or significant sales events, most other applications can be accommodated with my simple panel method.

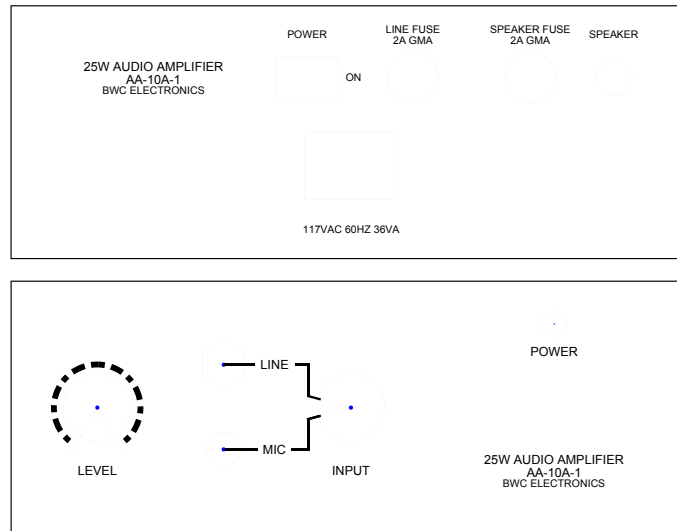


Figure 1. Front and back panel artwork for the AA-10A-1, Audio Amplifier. Note, the blue guidelines and panel outline are not printed. Flags are added at the corners for positioning. The blue centers are printed for drill guides.

Using a simple drawing program (discussed later) an exact 1:1 scale drawing is made for the desired panel, see Figure 1. The outline is replaced with corner flags at printing and the blue guidelines are not printed. These panels are simple, but complex dial calibration, control grouping or other features can easily be added as needed. Some of my other projects use these more complex feature. I use an HP color laser printer which supports color features on my panels. I try to be careful with colors as I am not much of a graphics designer and can conjure up some strange combinations.

To save toner, a pigmented substrate (card stock or photo quality paper) should be used for the back ground color. Then contrasting color text or smaller blocks can be printed as needed. For the most part I use 110 pound card stock that is suitable for laser (toner) printers. I stay away from ink jet papers that may not be suitable for the electrostatic deposition and high temperature fixing of the laser printers.

I next spray the entire artwork with clear lacquer. My panels are small enough that aerosol lacquer is economically feasible - once the cost of cleaning up my big spray rig is considered. Carefully follow the use and safety instructions - especially since lacquer tends to be volatile. I have found some brands of "clear" lacquer have a amber tint after multiple coats dry, so you may need to select a brand that suits you best.

One tedious step of this process is controlling the application of the spray to ensure thin uniform coats are applied without drips or sags. Numerous coats are needed to obtain a hard and durable finish. While this process does not produce a panel as rugged as etched, paint filled or screen printed; it does

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produce a panel as durable as commercial panels on a lot of consumer products and far superior to “rub-on” lettering.

I prepare the aluminum panel (usually 0.063” 5052-H32) by cutting it to size, sanding and treating with a lye bath. Aluminum oxidizes so quickly that it is hard to obtain a pure aluminum surface, but I have found if treated with a lye bath of several minutes, and then washed vigorously under running water, a reasonable surface is obtained for painting or adhesive application.

The artwork is now attached to the prepared aluminum panel using a spray adhesive on both the panel and the back of the artwork. Select an adhesive intended for such applications and follow the use and safety instructions carefully. This is the other tedious step of the process, as alignment is critical and the messy adhesive has a tendency to stick before you are ready. I have found it best to work from

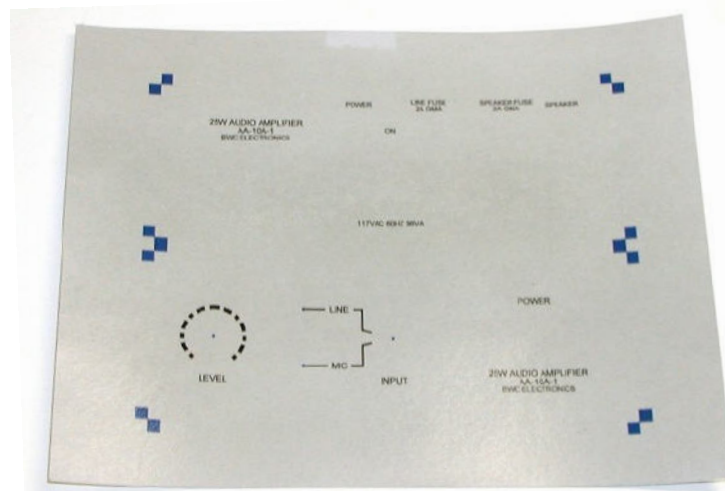


Figure 2. Concentric marking around the “Level” control requires post-application panel drilling. Note the flags mark the panel corners for alignment. The artwork is lacquer coated at this point.

one edge and/or corner and keep the artwork lifted above the remainder of the panel until I work my way across the panel.

If the artwork has highly concentric features around controls or other through-panel items, I will prepare the aluminum as previously described - except I do not drill or punch any holes. Instead I skip to attaching the artwork, as described, and then carefully drill the holes to ensure concentric features. I am amazed how little offset the human eye can detect. Just a slight misalignment jumps out at you and makes an otherwise attractive panel look poor. However, I am so clumsy with my mechanical work that I try to avoid having to drill panels after the artwork is attached. If you look closely at some of my projects you will see tricks I use to avoid highlighting misalignment. Figure 2 is an example of concentric panel features requiring post-application drilling.

I use two methods of sizing the artwork to the panel. Normally I use my metal shear to cut the artwork to size prior to attaching it to the aluminum panel. Sometimes I oversize the artwork trim, then use panel holes or features for alignment and trim the artwork to final size after attachment. You may want to try both to see which you prefer, as they both have advantages and disadvantages. I also have

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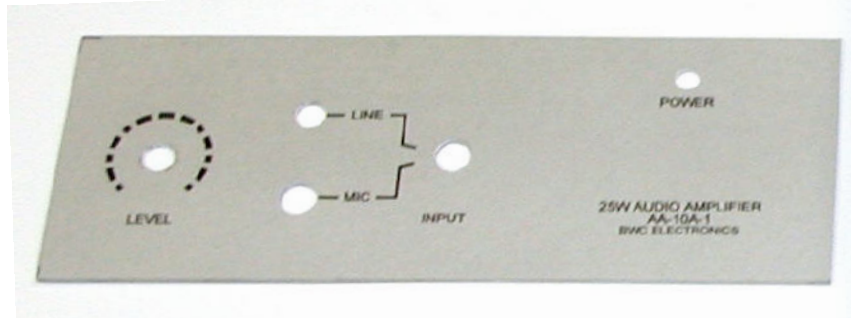


Figure 3. AA-10A-1 laminated front panel. The lacquered artwork was cut to size, attached to the aluminum panel and then drilled.

considered (and will try on a large panel) using a blank aluminum panel, attach the artwork and then trim and drill the completed laminate, however the completed panel will be at risk during the drilling process.

Figure 3 is the AA-10A-1 front panel. The artwork in Figure 2 was cut to size and then attached to the blank aluminum panel. If you look carefully the remnants of a corner flag is visible in the upper left hand corner. Once the wrap around cover is in place this is quite unnoticeable, but this amount of misalignment of a concentric feature could be noticeable. The lacquer coated artwork is water and abrasion resistance, but be careful drilling it. A dull bit can tear the artwork rather than cutting it cleanly. I find that even with sharp drill bits some clean up of drilled holes is required using a very sharp hobby knife. Sharp drill bits will reduce the aluminum burr also. I prefer a sharp knife or sand paper (for non-laminated panels) to remove drill burrs. I do not like to use a larger drill bit as they tend to roll-off the edge of the drilled holes.

The drilled panel attaches to an internal chassis, see Figure 4, using the control bushings and mounting hardware. This method is not always sufficient, but when it is, it allows the panel to have no visible mounting screws. The back panel is mounted to the chassis flanges with four machine screws.

It may be hard to see, but the chassis clearance holes for the panel controls are oversized. Alignment of the controls to the artwork is critical so the panel holes are drilled exact, but the panel needs some adjustment in order to fit squarely into the covers when attached to the chassis. A good sheet metal mechanic may not need this fudge, but I do and it is not obvious in the completed project.

With some projects I clamp the panel to the chassis during construction. I then drill the panel and chassis holes simultaneously for precise panel to chassis fit. However, sometimes it still is advantageous to adjust the panel on the chassis slightly, once the chassis is mounted into the enclosure.

Table 1 and 2 summarize steps for two panel construction processes. While not detailed, the tables provide a guide to the steps required so detailed processes can be developed. Also keep in mind these represent only two of several methods I use for panel construction and as well you may develop others that are more suitable for your situation.

Table 1. Panel construction steps for pre-drilled panel.

1.	Layout panel artwork
2.	Print paper copy (working copy)
3.	Temporarily attach to aluminum panel as layout guide
4.	Drill, punch and cut panel
5.	Remove paper guide, sand, de-burr, and lye bath
6.	Print high quality copy of artwork
7.	Coat with lacquer
8.	Trim to size with shear
9.	Attach to aluminum panel using spray adhesive

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Figure 4. Internal chassis serves to mount the front and back panels, support the circuit board and provide attachment of the clam shell covers by supporting the threaded 0.125" aluminum plates.

Chassis construction

Bud (and other manufacturers) chassis were widely used for vacuum tube projects. Most components of that era were designed for chassis or terminal strip mounting, but with the advent of printed circuit boards the usefulness of these diminished. I find that most of my projects (though not all) need more of a frame than a full chassis.

See Figure 4 as an example where the chassis serves to support the PWB, secure the front and back panels, and connect the covers to the threaded cover plates. This chassis is 0.050" 5052-H32 aluminum formed on a low-end import, combo sheet metal break and shear. While the quality of the bends may be somewhat less than I desire, it actually works pretty well. The shear function, which can handle up to 30" width, is indispensable. Just be careful - I trimmed off a finger tip while shearing paper - wasn't too bad, but cut a small vein that started shooting blood all over making a real mess and requiring an expensive trip to the ER to get it stitched shut.

I use both 0.040" and 0.050" aluminum for the chassis depending upon size, component weight, tendency to twist, and other mechanical considerations. The power transformer in this project caused me to use 0.050" aluminum. The covers, see Figure 5, are made from 0.040" aluminum.

Figure 6 shows the chassis and covers after forming on the sheet metal brake. Note, with this project, I did not drill the plates prior to bending. For more complex drill patterns I drill the aluminum while flat and then do the bending. Also notice the difference in appearance between the mill aluminum in Figure 6 and the lye bathed aluminum in Figure 4.

To avoid the tedious task of marking the aluminum bend and drill locations, I print a working copy of the fab drawing (full size) and use spray adhesive to attach it to the flat aluminum. I then shear, drill, notch and bend using the attached drawing as a guide.

Table 2. Panel construction steps for post-drilled panel.

1.	Layout panel artwork
2.	Cut aluminum panel to size, sand and lye bath
3.	Print high quality copy of artwork
4.	Coat with lacquer
5.	Attach to aluminum panel using spray adhesive
6.	Drill and punch panel
7.	Clean up drilled holes

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I have used a variety of enclosure designs for different projects, but the clam-shell design shown here simplifies the sheet metal work and produces a good looking finished project. The top and bottom covers are identical, except holes drilled in the bottom cover for the feet. The front and back panels



Figure 5. Top and bottom covers after finish paint is applied.

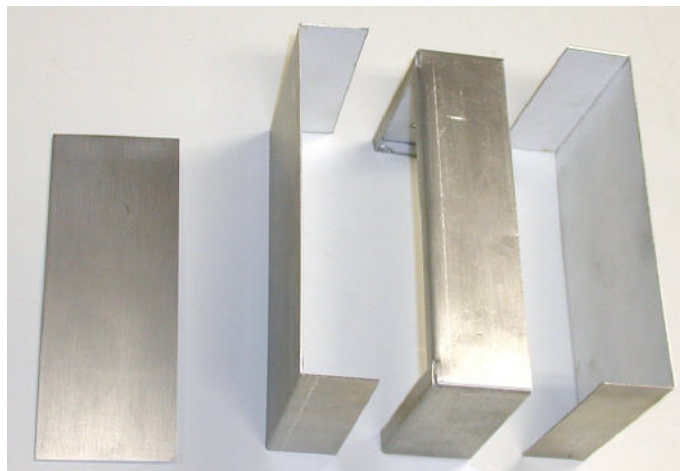


Figure 6. Panels cut to size. Chassis and covers formed and ready for drilling and sanding.

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Figure 7. Chassis and cover without the front and rear panels.



Figure 8. Parts kited and ready for assembly.



Figure 9. Front view of completed project.

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are just flat 0.063" plates of identical size. The chassis provides all of the internal mechanical support and the two identical 0.125" aluminum plates are threaded for the cover screws.

For the AA-10A-1 one of the cover screw plates also provides heat sink for the output transistors. The 0.125" aluminum spreads the heat effectively to the top and bottom covers providing better thermal cooling than one might think. See Figure 10 for measured thermal curve of the 8" x 4" x 3" enclosure (W x D x H) with a 0.125" thick 2" x 4" plate.

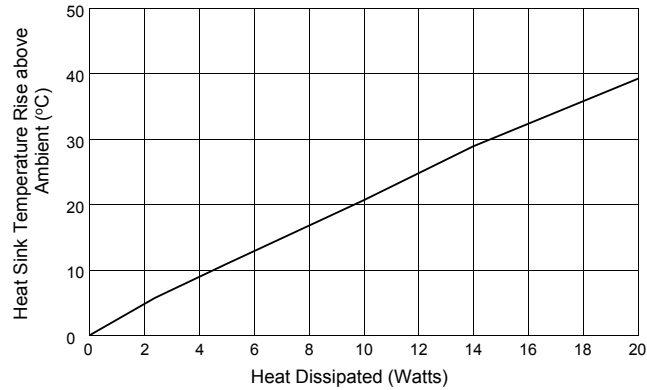


Figure 10. Enclosure thermal performance plotted as temperature rise vs power dissipation.

Figure 7 shows how the top and bottom covers attach to the threaded screw plates. Notice the chassis is positioned 0.375" above the bottom cover. The printed circuit board will mount to the chassis bottom flange. This view shows the oversized panel mounting holes that allow front panel alignment to the chassis/covers. The covers are primed and finish coated with an aerosol textured, multicolor paint. The normal assembly procedure is to attach the printed circuit board, the front and back panels, insert the screw plates, then the bottom cover and finally the top cover.

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Material sources

I buy aluminum sheets 48" x 120" from Trident Metals of Richardson, Texas. Trident like most distributors normally sell wholesale to metal fab shops and are not set up to handle individual sales, but if your order meets their minimum and is for in-stock material they may sell to you. Beware the minimum dollar amount may be considerable so this option is only good for significant material purchases.

I have seen Internet business that claim to sell small lots of aluminum, but have not tried any of them. I did find a local sheet metal shop that is willing to sell some small quantities of aluminum. Roofing companies may also be source as well as the local scrap metal yard. I get most of my 0.125" and larger aluminum from Jennings in Longview, Texas. They sell it per pound as scrap and it is much cheaper than trying to buy from a distributor, but of course you are limited to what is on hand at any given time.

I buy most of my hardware from MSC Industrial Supply, which also is an industrial supplier. However, MSC has a nice web site and accepts Internet orders. I have had good results dealing with them and using their products. Mouser and Newark are my next two stops for hardware.

I have not seen much selection of sheet metal or hardware products at the home improvement stores and only slightly better at hardware stores. Both are expensive for what they do have, but can be a good choice for low quantity purchases.

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Drawing software

Sun Microsystems offers a **free** product suite that includes programs similar to the high-priced MS Office products. Included are equivalents for; Word, Excel, Power Point plus a Data Base and Draw program. These are available from www.download-free.com/Open-Office . I have used “Impress” (Power Point) extensively and it works excellent. I also have used “Writer”, which publishes to PDF directly, with good results. I have not used the others extensively but suspect they too will perform well and recommend Open Office to anyone with limited budget.

I started using Serif’s Drawplus in 1999. I have purchased two or three of the newer versions and guess I am stuck with it now, as I have become quite accustomed to it. It is a fairly inexpensive program and does about all I know how to do. The mechanical drawings, schematics and panels for my articles and projects are done using it.

Serif is not without their quirks, but for the most part they are better to deal with than Microsoft. I have not researched drawing programs but there must be any number of good ones available at reasonable cost. There is no need to buy AutoCAD Lite or other high dollar programs for the methods described in this document. However, if AutoCAD is being learned for school credit or employment, the techniques described here can provide some actual finished projects and practice at the same time.

I took drafting in 1962 and engineering graphics in college some years latter. I was a dyed in the wool tee square and template guy. I still do not care much for the computer age, but I have to admit I am now converted to computer graphics. I designed my 1500 Ft² shop using Drawplus and a wide format printer. The ability to scale dimensions, do layers and easily make changes enabled me to design the trusses, framing, electrical and plumbing.

Once a drawing program is selected, the techniques described in this document can be adapted to that specific software. Some of the newer versions allow the user to make custom galleries where objects can be created and easily re-used. With my older version I just copy my custom graphics from one file to the next and store them off the page. Either way, once a set of graphics is developed it makes new drawings easy and new objects can be added any time. The next time the graphics are copied forward they are included in the custom gallery.

I also use a Serif desk top publisher “PagePlus 10”. I bought several versions with the newest being PagePlus X4. I went with it because it can open PDF files for editing, but never really used it enough to become comfortable with it, so depend on the older version.

Serif does not seem to do a very good job of recognizing and managing files created with other versions of their same programs. This hampers my conversion to the newer versions as well. But for the price and few other quirks I think it is good software. DrawPlus files copy into PagePlus 10 easily and can be sized to fit the document. Both versions export work in PDF file format just fine.

I suspect some calibration will be required once a program and printer are selected. I find most ink-jet printers are quite accurate across the carriage but slightly off in the paper feed direction, but I do mean slightly (less than 1%). None the less, if drawings are used to create actual parts I try to adjust for this when I print - not in the drawing itself, because if another printer is used it may be different. My Laser printer seems to have very little error in either direction.

I see printed circuit board manufacturers offering free layout software. I have only briefly tried one, not near enough to make a judgment on it, but stick to my DrawPlus even for this task. I know some of the “real” design software has schematic capture and auto-routing, as well as other features

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required in serious designs. But a part of the satisfaction that I receive from my projects is a nice looking schematic. I have yet to see a schematic capture program that produces a schematic that I find attractive.

Far Circuits manufacturers my boards using a negative of the artwork I generate. I like his boards and my schematics, but those more practical than I might want to try the real stuff. I should note, I do NOT do microprocessor or complex digital designs - I think they would be awkward to do with my process.

Schematic drawings

I made my schematic symbols in proportion to the templates used at Rockwell/Collins. We had very good draftsman that were border-line artist. They would produce a beautiful schematic, ready for publication, from a hand scratched mess that had been through the rigors of prototype build and multiple changes. I liked well drawn schematics before going to work for Collins, but when I saw my designs converted to these near-work-of-arts I was convinced someday I would find a way to produce equally good schematics. Since my drafting skills never approached these draftsman's I had to cheat using computer graphics. All the more reason I detest today's poor schematics - they can be done nicely.

I would suggest anyone wanting to produce their own schematic symbols find a schematic that meets their expectations and scan it into an image file. Then using the insert picture file feature, place it in a drawing where elements can be designed scaled to the ones in the image. I scaled mine to the old "D" size drawing (22" x 34") expecting to reduce the schematic to "B" size (11" x 17") but found I ended up scaling to many different sizes depending upon the publication. My suggestion now is that the scanned-in schematic be enlarged enough, before the drawing elements are produced so the finished schematic will be reduced before printing or publishing. This reduces glitches or slight miss-alignments in the drawing from being objectionable in the finished schematic.

A lot of care should go into creating the symbols. They will be re-used many times over making the effort well spent. I re-did mine several times before getting them to their present state. I do not know any substitute for practice, so some re-dos may just be part of the process. Here is a reason to use the same software for all drawing applications, all practice helps with all the applications. With dedicated tools, the practice on one may not help much using the other, although those working in the industry probably have to just deal with this.

No special scaling requirements are required for schematics, other than the previous mention. However, for mechanical and printed circuit boards scaling becomes critical.

Printed circuit board drawings

I created my own printed circuit board elements using the old Rockwell/Collins standards as a guide. Current industry standards are more area efficient than these rules, but for the photo reversal process from full size printer output, I would not recommend such small features. However, Far Circuits produced a good MSOP8 (0.0165" pads spaced 0.0256" apart) adapter board for me using this process.

Most, if not all, printed circuit board elements are available on-line now, so I suggest only the ones needed be created and then add to them as projects are done. Be sure you know what your printed circuit manufacturer needs, 1:1, 2:1, 4:1 scaling and view from the etched side or reverse side.

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I use several layers for a printed circuit board;

1. board profile,
2. layer one copper,
3. layer two copper,
4. components,
5. legend,
6. drill data.

Far Circuits does not require separate drill data. If drilled holes are scaled to pad size he is able to produce a drill tape without specific hole sizes.

I make component locator drawings by copying the completed layers to another file. I then open it and change the foil from black to light gray so the component outlines will show better. Another benefit of the modern computer age, component profiles are also on-line, so no need to make tedious measurements.

Thermal test data

Thermal test of the 0.125" plate mounted in the enclosure was performed using a single TO-220 NPN power transistor. Table 3 tabulates the results with the chassis in place, but no printed circuit board installed. Natural convection cooling provides approximately 2.0 °C/W thermal resistance from the center point of the 0.125" plate and ambient temperature. Not bad considering the cost of extruded heat sinks. These data were used to create Figure 7.

Table 3. Thermal test data for AA-10A-1 heat sink and enclosure.

T _a = +27.9 °C NPN TO-220 biased with 1.00 A constant current, I _{BE} adjusted for V _{CE} to produce desired dissipation.						
Time	Heat Sink Temp (°C)	P _D (Watts)	V _{CE} (Volts)	I _{CE} (Amps)	ΔT (°C)	θ _{SA} (°C/W)
9:45	30.2	1.00	1.00	1.00	2.3	2.3
10:45	38.5	5.00	5.00	1.00	10.6	2.1
11:44	48.3	10.0	9.99	1.00	20.4	2.0
1:02	57.6	15.1	15.1	1.00	29.7	1.96
2:57	66.9	20.2	20.2	1.00	39.0	1.93
Average θ _{SA} from 5W to 20W is 2.0 °C/W natural convection.						