22. Cabinet Art

If you're building your machine's cabinet from scratch, you'll want to decide on what the exterior will look like. This might be a simple flat black paint job, or you might prefer full-color graphics like on a modern real pinball machine.

Real pinball machines have always featured eye-catching cabinet artwork. The motivation was always commercial, of course - the art was there to grab your attention and entice you to drop in a few quarters. But that didn't mean it wasn't also art. Pinball has a recognizable graphics style - actually, several different styles over the decades, but each recognizably "pinball art". It's natural for virtual pin cab builders to want to tap into that by using artwork that would look at home on a real pinball machine.

Reproducing the authentic pinball art style can mean different things, depending on which era you're talking about. Machines built in the 1950s through 1970s tended to use abstract graphics, painted in three or four bold colors with stencils. The stencil artwork continued into the 1980s, but the graphics became more intricate and representational. In the 1990s, the manufacturers started using a multi-color silk-screening process, which allowed for higher-resolution graphics with more detailed designs.

Top left: Gottlieb's Abra Cadabra (1975), with abstract stencil graphics typical of machines built in the 1950s through 70s. Top right: Williams's Space Station (1987), with the more intricate stencil graphics of the 1980s. Bottom: Bally's Theatre of Magic (1995), which used the high-resolution silk-screen graphics typical of the 1990s.

In the 2000s, the remaining manufacturers switched from screen printing to plastic decals. Decals are cheaper to produce, but they also offer more options to the designers, since they can be printed in high resolution and full color. (Silk-screening's palette is limited by the number of color layers used, and has to use half-tone patterns for in-between colors.) The switch to decals opened up even more options for art designers, including full photo-realism.

When to install artwork

I think it's best to paint or install decals after completing the assembly of the wood cabinet, but before installing any of the internal parts (like the PC or TVs), and certainly before installing any of the trim.

I'd wait until after assembly to do any decorating, because that lets you do a final pass with a power sander to even out surfaces, smooth corners, and remove any excess glue. It also eliminates the risk of scratching or marring the artwork during the assembly process.

And I'd paint and/or install decals before installing anything beyond the basic wood box, to keep the cabinet maneuverable and keep all of the surfaces unobstructed. You'll want to be able to flip the cabinet onto different sides while working on paint or decals, so you don't want it weighed down with internal parts. Exterior trim can obviously get in the way of areas where paint or decals will go.

Virtual pin cab design options

As a virtual pin cab builder, you have several good options available. The right option is a matter of taste and budget.

Natural wood style. This isn't common, but some people choose to make their cabs look like a piece of fine furniture or cabinetry, on the basis that it's going to be situated somewhere in their home. If you want this kind of look, you can use a cabinet-grade plywood and a wood stain finish.

Single-color painting. This is another simple, understated look that some people use to make their machine relatively inconspicuous for the home environment (as inconspicuous as a six-foot-tall, five-foot-long, three hundred pound wood box can be, anyway). The most common single-color paint job is a solid flat black.

Stencil graphics. To a lot of people, the electromechanical era (1950s through 1970s) is the Golden Age of pinball, and these machines define what a pinball machine is supposed to look like. To be sure, the EM era's graphical style is unmistakeably distinctive and is iconic of pinball in popular culture. The stencil graphic style that these machines used is also something that you can reproduce on your own, at low cost and without any special equipment. You just need to make a stencil mask out of cardboard and masking tape, and then apply spray paint in as many colors as desired.

Full-color decals. Many pin cab builders want to reproduce the look of machines from the modern era (1990s and onwards). These machines use elaborate designs printed in full color at high resolution. The real machines from the 1990s used high-res screen printing; newer machines almost all use plastic decals to achieve the same look. Happily, professional custom decal printing is readily available for one-off print jobs, and is even relative affordable. This isn't something you can do at home with DIY equipment, since it requires special industrial printers, but there are lots of print shops that have the equipment and can do the job for a reasonable fee. And since the printing is done on what's essentially a giant industrial version of an ink-jet printer, you can print virtually any custom design by preparing the graphics with a PC photo editor program.

Using decals

Most pin cab builders these days opt for decals, since they allow for such unlimited creativity in the artwork.

First-time cabinet builders are sometimes skeptical about decals, thinking that they'll look like cheap stickers. It might reassure you to know that most of the newer real machines now use decals for their artwork, using the same materials that a good print shop would use for your cab decals. If you can find a newer Stern machine to look at, you can get a first-hand look at what kind of finish you can expect. When printed on quality stock and applied properly, you can achieve a finish that's pretty close to the screen printing used in the 1990s machines. Decal printing is actually superior in some ways; you get a wider color gamut and finer dot pitch, and the plastic finish is more resistant to light scratches.

Surface preparation for decals

Before applying decals, you have to do some basic preparation to the plywood surface to ensure good adhesion and a smooth finish.

The key preparation step is to make the wood surface as smooth and clean as possible. The type of decals we use are printed on a heavy vinyl film stock, and when you first look at it, you'll probably think it's thick enough to hide any imperfections in the underlying surface all by itself. But surprisingly, it's not. The adhesive is so strong that the film will exactly conform itself to the surface, so closely that you'll be able to see the wood grain through it. It ends up looking a lot like the graphics are painted directly onto the wood. So you'll want to get the wood surface as smooth as you can before applying the decals.

You'll definitely want to start by sanding. Go over the surface with a power sander in several passes, finishing with a fine-grit finish sandpaper (something in the 400 grit range).

Even after sanding, though, the wood grain will still be visible. Wood has pores that run all the way through (so no amount of sanding can eliminate them). Decals will adhere just fine even with the wood grain still showing, but the appearance will be a little different from the real machines, which have a perfectly smooth finish. If you want to get rid of the wood grain texture, you have to use some kind of wood filler. There are lots of products designed for this; look for the kind of filler that painters use to prepare wood cabinets for painting, such as Aqua Coat or DAP DryDex. Follow the product instructions for the filler you choose. Most wood fillers are designed to be applied in several thin coats, drying between coats, and sanding at the end with a fine-grit sandpaper.

Paint or no paint? Some people prime and/or paint their cabinets before applying decals, and some apply the decals directly to the bare wood. Check with your print shop for their advice on this, since the right approach might depend on the type of print stock they use for your particular decals. My print shop's advice was that it was fine either way (paint or no paint), but I wouldn't assume that's true of every type of decal.

I ended up painting first, with a coat of primer and a coat of black latex enamel. The black layer is nice because it covers up the tiny gaps in the decals around the corners. (My decal artwork has a mostly black field, so the edges of the decals fade into a black under-layer nicely. If your decals have a mostly red field, say, you'd probably want to use a matching red paint instead.)

One drawback of my paint job is that I applied it with a brush, and the brush stroke texture is visible through the decals (just like I was saying earlier about the wood grain). This isn't a major problem - it's not even visible unless you look closely - but it's one of those minor things that bothers me. If I were doing this again, I'd still use a primer coat, but I'd apply it by spraying rather than brushing to get a smoother finish. I'd also skip the black layer *except* at the corners and edges. I'd still want the black background to fill the small decal gaps at the corners, but the rest of the black coat is essentially wasted work and expense, since it's completely covered up by the decals.

Applying decals

Your print shop will give you full instructions, but here's the basic procedure I used:

- Initially, leave the backing in place, and get the decal aligned exactly how you want it on the target surface.
- Once it's lined up correctly, temporarily fix it in place, using clamps or masking tape. Make sure to tape it or clamp it at several places, so that it stays very still.
- Lift one end, making sure that the rest of the decal stays stuck in place, and peel the backing away from the edge for about two or three inches.
- Cut off that first two-to-three inches of backing with scissors or a utility knife. Leave the rest of the backing in place.
- Smooth the decal flat against the surface again - the exposed section will now adhere to the surface. The decal is now serving as its own anchor at this edge.
- Remove the clamps or masking tape.
- Working from the end that's already stuck, lift the decal enough that you can start peeling off the remaining backing.
- Peel off a little bit of backing at a time, and smooth the decal onto the surface as you go. Doing it a couple of inches at a time should ensure that it stays straight so that your original alignment is preserved exactly. Press out any air

bubbles as they form. A squeegee with a felt edge works great for this. (Your print shop might be able to include one if you ask.)

You might read about having to spray a soap solution onto the decal during application, or see videos about that. Hopefully you won't have to do anything like that - that's for older decal material that I hope no one is using any more. Modern decals shouldn't require anything like that; they're self-adhesive, and you just peel and stick. Modern decal stock should also be resistant to air bubbles; it should be porous enough that any trapped air will be able to escape through the pores rather than being permanently stuck under the plastic. Even so, you should try to force out any visible air bubbles as you adhere the film. Use a felt squeegee or similar tool to press bubbles out through the leading edge as you press the decal onto the surface.

Trimming edges

Most print shops will print the decals slightly larger than the final size you want to install, usually about an extra inch on each side. This is intentional; it's to give you a little room for error in the final alignment.

The standard procedure is to align the decals, affix them, then go around the edges with an X-Acto knife to trim the decals to be exactly flush with the edges. This is surprisingly easy; you just let the edge of the wood guide the knife. As long as the knife is sharp, it should make a perfect cut exactly at the edge.

Cutting out holes

When you design and apply the decals, you should simply let them cover the holes in the cabinet for the flipper buttons, front panel buttons, and coin door cutout. After installing, use an X-Acto knife to trace around the edge of each opening. Cut from the **outside**, and let the edge of the opening guide the knife - the same procedure used to trim excess material around the edges.

Finding a printer

My decals were printed by Brad Bowman a/k/a Lucian045 on VP Universe (also reachable at bjbowman045@gmail.com). I highly recommend him. Brad is a serious virtual pinball enthusiast who also happens to run a professional sign printing shop. It's great to work with a printer who knows how pin cabs are set up, because that means he'll be able to picture what you have in mind for any special customizations. The decal stock that Brad uses is also just great: very easy to work with and very durable. I of course can't guarantee that Brad will still be offering print services by the time you read this, but you can always drop him a line to find out.

Other options include VirtuaPin and GameOnGrafix.com. Both offer custom decal printing. VirtuaPin specializes in pin cabs and I think they use similar print stock to what Brad Bowman uses. GameOnGrafix is more oriented towards home-brew video game cabs, but they also provide a template for pinball cabinets, and anyway it's basically the same sort of decal for either type of machine.

You can also try any shop that does commercial sign printing. This is a common commercial service, so you can probably find local vendors in your area, especially if you live near a major city. The type of adhesive plastic material used for pin cab details is also commonly used for commercial signage.

Artwork requirements

Any decal print shop will expect you to provide the artwork in electronic format. The exact format requirements will of course depend on your vendor, but that's just a matter of file format conversion. You should be able to use any photo editor or painting program on your PC to create your graphics and convert them to an acceptable file format.

Decal printing is essentially the same as printing on a home ink-jet printer, so the artwork you provide will have to be prepared at photo-quality resolution. If you're using raster (pixel) graphics, that means you should plan on about 300 dots per inch resolution. Check with your print vendor for more specific guidelines. Yes, a 50" x 30" piece of artwork at 300dpi is a *lot* of pixels; thank goodness we're in the era of 64-bit Windows machines.

Designing your artwork

There are three main options for coming up with your artwork.

Design it yourself. If you're feeling creative and you're good with a graphics editor like Photoshop or Illustrator, you can design your own original artwork.

Opting for a completely original design gives you complete freedom to come up with whatever look appeals to you. But starting with a blank page is also pretty intimidating. Here are some ideas for where to begin:

- If you want to create something in the style of the real machines, start by choosing an era. Go to IPDB and peruse pictures of machines from the era, to get a sense of the prevailing graphic style. If a particular machine's design strikes you as particularly appealing, use that as your starting point.
- Choose a name for your machine. That will automatically plant some ideas about its theme. A lot of pin cab builders name their machines after their favorite movie, TV show, or comic book character, following the long tradition in the real machines of using licensed themes.
- A popular motif is to focus on the virtualness of the machine and/or its ability to run many different games: "Multiball", "Megapin", "Pinball Holodeck", "Pinball Matrix", etc. The most common form this takes in artwork is a collage of clip-art images from real pinball machines, or an array of manufacturer logos.
- If you like space themes, check the NASA, JPL, and Hubble Space Telescope Web sites for some very pretty, high-resolution space images that are in the public domain (meaning you can freely use them without copyright entanglements). I used a Hubble photo of the Carina nebula as the backdrop for my own cab side art; it honestly looks like something a fantasy artist might have created, but it's a photo of a real celestial object. (Admittedly, my "pinball Saturn" and "pinball Jupiter" are added embellishments.)

Commission original custom art. A fellow who goes by "stuzza" on vpforums creates original art on request for forum members, for a fee. A stuzza design is generally a pastiche of pop culture clip art based on a theme you provide. See the long-running thread "Cabinet Artwork I have created" for his contact information and examples of his work. VirtuaPin also offers custom graphic design services for a fee.

Use a pre-made design. Stuzza on vpforums has also released a number of free designs that you can download and use without a commission fee. See the "Cabinet Artwork" thread mentioned above for links.

Reproduce artwork from a real pinball. Some cab builders opt to use the original artwork from their favorite real machine. Be aware that the graphics from commercial machines are copyrighted, so a reputable print shop won't accept an order that reproduces a real machine's artwork without proper clearance from the rights holders, which requires paying a license fee. VirtuaPin sells authorized reproductions of the original art for several popular classic pinball titles. You can also find reproduction artwork for more titles from pinball supply vendors, who sell decals for people restoring old machines.

23. Cabinet Hardware

This section covers the hardware trim on the main cabinet, with details on what all the hardware does and how to install it.

We assume that you've already built the basic plywood cabinet as described in Chapter 21, Cabinet Body, and that you've already painted it and/or applied decals, as described in Chapter 22, Cabinet Art. It's best to finish the artwork before installing any hardware, since some the hardware will get in the way of painting or applying decals once installed.

The sections below are arranged in our recommended order of installation. The order matters in some cases because of dependencies among parts. For example, you should install the side rails before installing the lockbar, since the lockbar's final alignment depends on the side rails being there, and you have to install the glass channels before the side rails because the channels act as spacers and supports for the rails. We've tried to present things in the easiest overall order, to get alignments right the first time and to minimize backtracking.

What to buy

We'll describe the parts needed at each stage as we go, but the full list of hardware parts can be found in Chapter 10, Cabinet Parts List.

Leg brackets

You should attach the leg brackets early in the cabinet build, during the basic wood assembly. The brackets are meant to be permanently installed; they can be left in place with the legs on or off the machine.

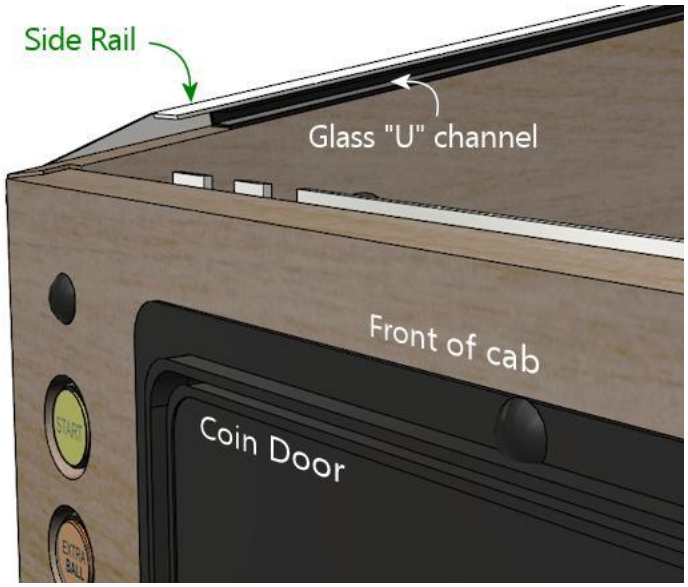
If you followed our plans in Chapter 21, Cabinet Body, you should have already installed the leg bolt brackets on the inside of the cabinet. If you haven't done this already, see the section on Leg brackets in that chapter.

You probably won't want to attach the legs themselves early on, since you'll probably want the cab sitting on the floor or workbench while you install the PC, TVs, and other internal components.

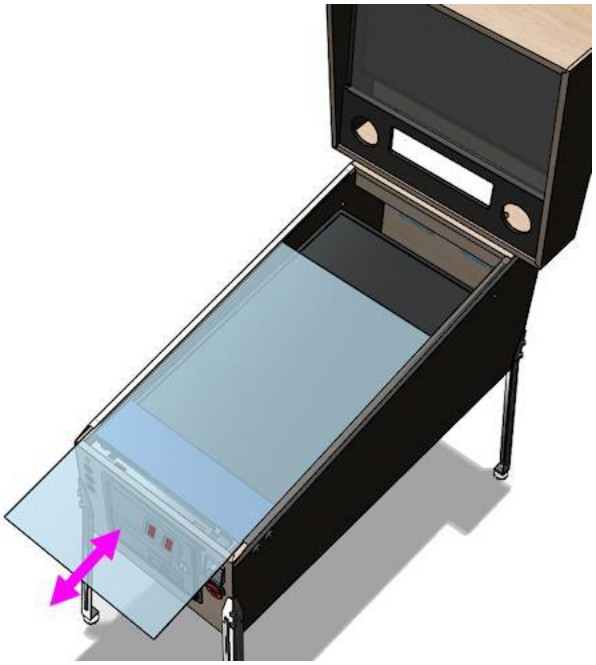
Note that we won't get to the legs themselves until near the end of this chapter, as you'll probably want to keep the cab on the floor or on your workbench while you're installing the PC, TVs, and other internal components.

Glass channels

These are plastic pieces that go under the side rails, to hold the top glass cover in place.



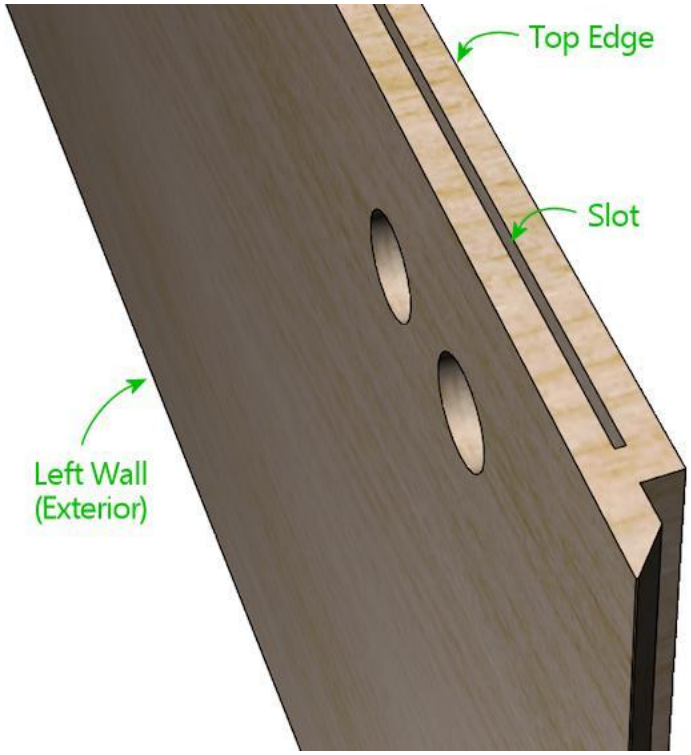
The glass channels aren't visible, so they're not "trim" in the cosmetic sense, but they have two important functional roles. The first is that they let you slide the top glass in and out of the machine at any time, without tools. To remove the glass, you just unlatch and remove the lockbar, then slide the glass out the front. To put the glass back, slide it in the front, and pop the lockbar into place.



The second important functional role of the glass channels is to act as vertical spacers and supports for the metal side rails. All of the side rails made since the 1970s or so are designed to be paired with the glass channels. The geometry of the rails simply takes it for granted that the plastic channels will be there - if they're not, there will be a big gap under the rails, which would make them too weak.

To install the glass channels, the first step is to route a groove along the center top of the side wall. (If you followed our construction plans in Chapter 21, Cabinet Body, you should already have done this.) There's a special router bit for this job, called a slot cutting bit. For this particular slot, you need a slot cutter bit with a 3/32" slot

width and a depth of ⅜" or greater. I used Freude part number 63-106; equivalent bits are available from other brands.



Alternative to routing the slot

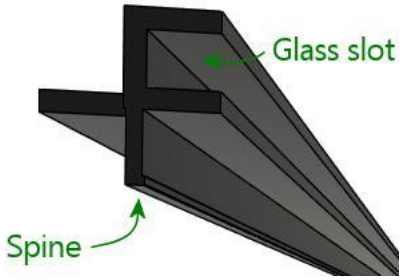
Some virtual cab builders forego routing the slot, because it seems too difficult, or just because they don't want to buy a special tool that they'll only ever use once. But they still want to install the channels. How do you make the spine fit without the slot? You can't, but you *can* chop off the spine to take it out of the picture. The glass channels are a fairly strong plastic, but they are just plastic, so it's possible to remove the spine with a sharp utility knife, a Dremel tool, or something similar. With the spine removed, you can install the channel with staples or glue. You don't have to go overboard with a super-strong attachment, since the metal rail will sit directly on top of the channel, and that by itself will largely keep it from going anyway.

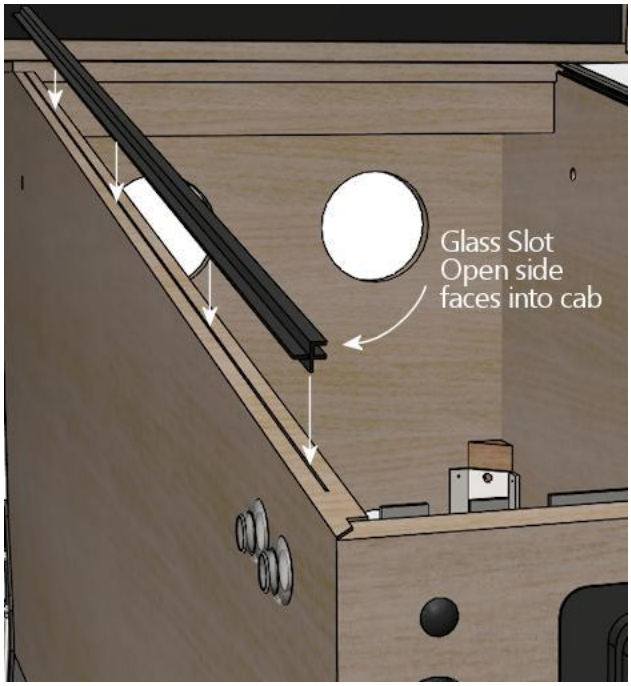
Personally, I don't recommend this approach. I'd install it the "right" way with the slot, since it makes a tidier installation and doesn't risk damaging the plastic piece. Cutting the slot probably seems intimidating if you haven't done that sort of thing before, but the special bit makes it really easy.

Installing the channel

Once the slot is routed, install the plastic channel simply by pressing the "spine" that runs along the bottom of the channel into the plywood slot. **Don't** use any glue or fasteners; the spine will be held in place by friction, and if that's not enough, the side rail on top of it will prevent it from going anywhere.

You should expect the spine to be a tight fit in the slot. You'll need to press it in fairly firmly. Don't force it too aggressively, though - you don't want to split the plywood. If the channel is way too tight, you can always go over the channel with the router bit again to widen it out slightly.





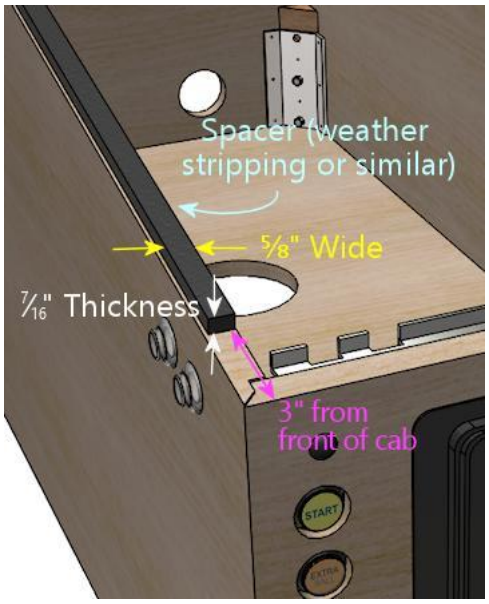
Alternatives to the glass channels

What if you don't want to include the glass channels? Not all virtual pin cab builders do, either because they're not using the cover glass at all, or because they want to install it some other way.

My own recommendation is to use cover glass and use the standard glass channels. That'll look the most authentic and it'll be easier to set up than something improvised. But if you're intent on another approach, you'll still need *something* to serve as spacers under the rails.

If all you need is to fill the space, and you don't care about sliding the glass in and out, you can use any material of the right size. Something like foam tape or rubber weather-stripping material would work. The target size for the spacer is about 7/16" thick, 5/8" wide, and 42" long. Affix your chosen spacer material with glue or double-sided foam tape, starting about 3" from the front of the cab.

Be sure to take the thickness of the adhesive into account when sizing the spacer - the **total** overall thickness (height) of the spacing material should be about 7/16", **including** any adhesive layer. If you're using foam tape that's ¼" thick, for example, the spacer material would only need to be about 3/16" thick.



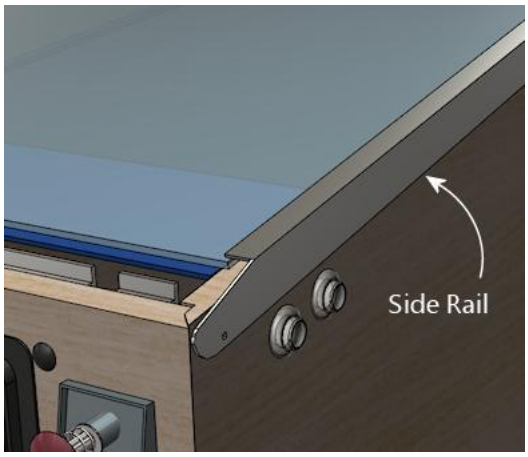
*Improvised spacer material under the side rail. **Only** use this if you're **not** using the normal glass channels! The point is to substitute something that provides the same vertical spacing and support as the glass channels if you're **not** using the actual glass channels.*

If you're using cover glass and want to be able to slide it in and out, I don't think there's any reason to look for alternatives to the standard plastic channels. They're the exact right thing for the job.

Side rails

These are trim pieces that go along the top side edges of the cabinet. On all modern machines, they're made of sheet metal, usually with a stainless steel finish.

(In the very early days of pinball, the side edges were trimmed with wood molding instead of metal, which is the source of the term "wood rail pinballs" that's often used to refer to such machines. If you want to use something like that, it would require custom wood-working; there's no such thing as a "standard" wood side rail, and nothing of the sort that you can buy off-the-shelf, as these haven't been used in real machines for many decades!)



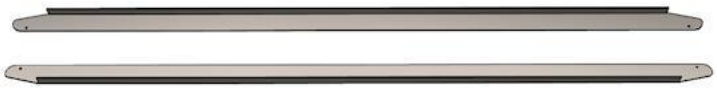
WPC-style side rail. Note that the rail is narrow enough along the side wall that it doesn't reach the flipper buttons. Older side rails (from the 1980s and before)

*extend further down the side and typically **do** cover the flipper buttons, requiring holes in the rails for the flipper buttons.*

The design of the side rails varies by manufacturer and vintage. The illustration above shows the WPC style from the 1990s, which continues to be the standard for everything made since. It's the type I'd recommend if you're buying new parts from a pinball supply vendor. It's the easiest type to find, too, since it's the only type anyone has been using in new machines for the last 30 years or so.

If you're using side rails salvaged from an older (1980s or earlier) machine, they might look different. The big difference with the older designs is that they usually extend further down the side, far enough to cover the flipper buttons. The older rails thus usually have pre-drilled holes for the flipper buttons, so you have to be careful to drill the button holes in the cabinet at the right locations to match the pre-drilled holes in the rails. The WPC design is easier to work with because it doesn't intersect the flipper buttons, so there are no pre-set hole locations dictated by the rails; you just have to make sure that the buttons are placed below the rails.

The WPC-style rails are symmetrical. They don't have "left" and "right" versions because the same rail can be used on either side. Simply flip the rail over to switch sides. Older rails with pre-drilled flipper button holes can't do that trick, for obvious reasons.



Installation

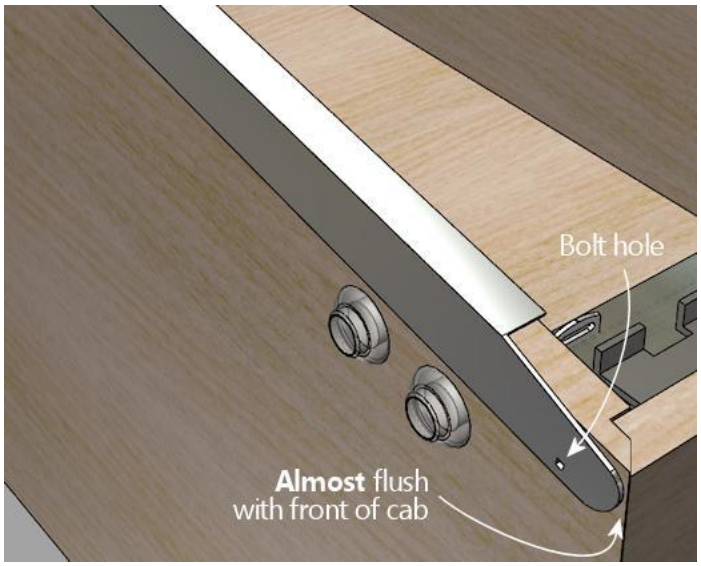
Before installing the side rails, you should first install the plastic channels that hold the top glass (see "Glass channels" above), or some kind of equivalent spacers in place of the channels. Part of the function of the channels is to act as vertical supports for side rails, so you need something in that space, either the channels themselves (recommended) or a similarly sized filler of some kind.

The rails attach to the cabinet with a #8-32 x 1¼" carriage bolt (and matching lock nut) at the front, double-sided foam tape along the side, and a nail or wood screw at the back. (It would be nicer to use another carriage bolt at the back, but that's usually not possible, because the shelf is in the way on the inside. Fortunately for the aesthetics, whatever fastener you use there will be hidden under the backbox hinges.

You can buy the right kind of tape from the pinball vendors (search for "side rail tape"), but there's not really an "official" type of tape that you need. Any good quality double-sided foam tape should work. Use tape that's ¾" wide and about .03" thick. (The original Williams spec called for .032" thickness, but you don't have to match that precisely; I'm sure that was just the spec for the material they actually had in stock at the time.) You'll need about 80" total.

Start by installing the tape on the inside of the metal rail. This goes along the inside side surface - the surface that will face the side wall of the cabinet. **Only** expose the adhesive on the side facing the metal rail at this point - leave the backing in place on the other side.

Next, do a "dry fit" to the cabinet, placing the rail in position, resting it on top of the glass channel. The front of the rail should be **almost** flush with the front wall of the cab. Leave just enough of a margin (1/16" to 1/8") that it doesn't stick out at all, so that it won't snag anyone's clothing.



We're going to assume that you **haven't** drilled the holes for the side rail carriage bolts yet. This is the time to do that. Mark the cabinet positions where the front holes in the rails line up. Only drill for a carriage bolt at the front; at the back, you'll have to use a screw or nail, because a bolt would conflict with the shelf. Remove the rails and drill at the marked positions (straight through) with a 5/32" drill bit.

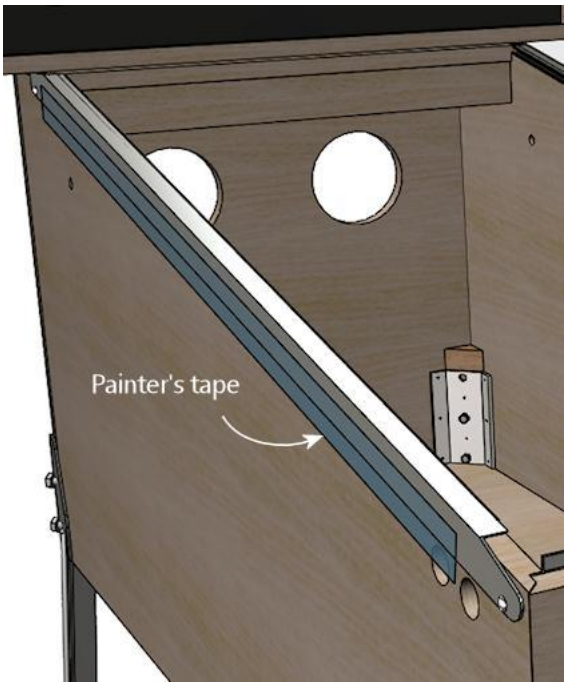
Warning: if a decal is installed over this area, be careful not to damage it. You might want to use an X-acto knife to cut out the area where you need to drill. This area will be covered by the side rail when you're done so it's okay to cut out an area slightly larger than the drill hole.

You're now ready for final installation. There are two ways to proceed from here: you can stick the rail to the cabinet with the foam tape, or you can leave the tape un-sticky for now and only use the front bolt. The first way - using the tape - is the way it's meant to be done for permanent installation. The second way - without sticking the tape yet - is better if you're not ready to commit to the final setup yet (for example, if you might want to touch up the artwork later). The bolt will hold the rail in place well enough for testing and casual play, so there's no hurry to finalize the tape yet.

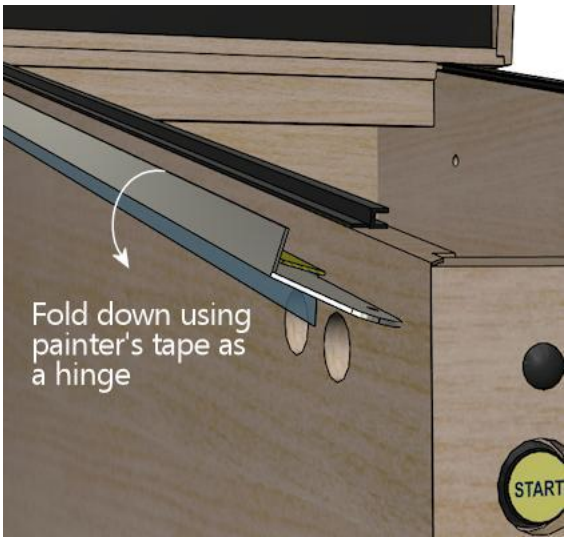
In either case, start by setting the rail in place again and lining it up with the carriage bolt hole you just drilled. Insert the bolt from the outside, and attach the nut on the inside. If you **don't** want to finalize on the tape yet, just tighten the nut, secure the back of the rail with a small wood screw at the back hole, and call it done for now.

If you want to finalize the installation by attaching the double-sided tape, here's the recommended procedure:

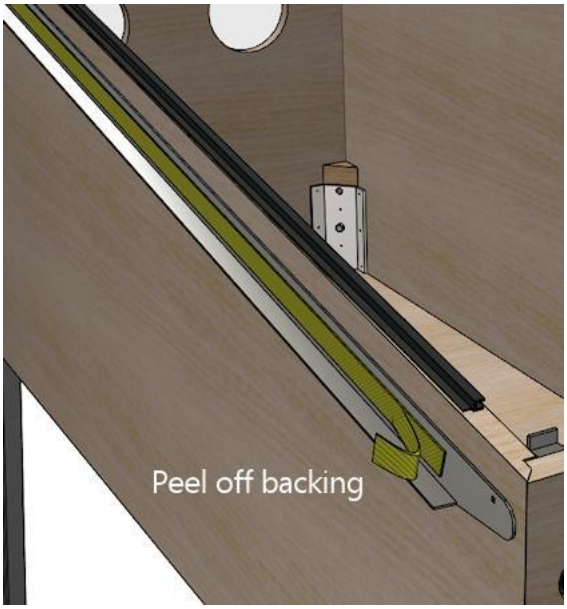
- Start with the side rail bolted on as described above.
- Run a length of wide painter's tape along the bottom edge of the rail, down its whole length, centered on the bottom edge. In other words, half of the width of the tape should be sticking to the side rail itself, and the other half should be sticking to the adjoining side of the cabinet.



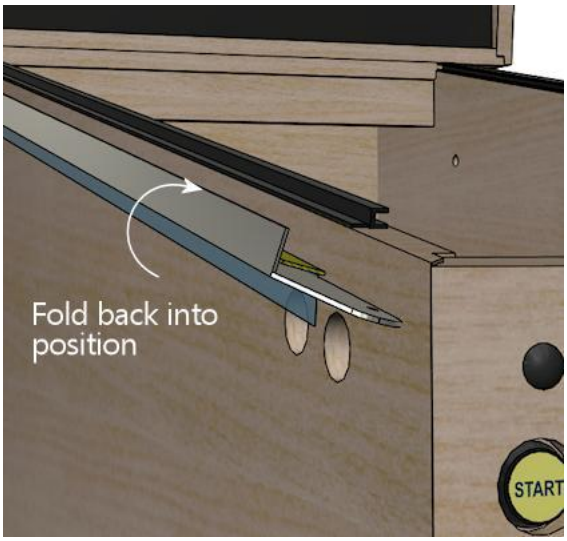
- Remove the bolt.
- Leaving the painter's tape in place, fold the side rail down, using the painter's tape as a "hinge". The rail should now be hanging upside down from the painter's tape, with its inside face (and the double-sticky tape) exposed.



- Remove the adhesive backing from the double-sticky tape.



- Carefully fold the side rail back up and into position, using the painter's tape as a hinge again. This should precisely return it to the original position.

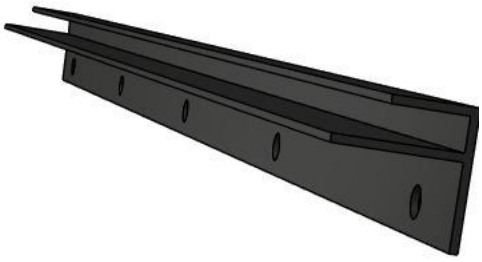


- Press along the side to adhere the double-sticky tape to the cab wall.
- Re-fasten the carriage bolt.
- Install a small nail or wood screw at the back.
- Remove the painter's tape.

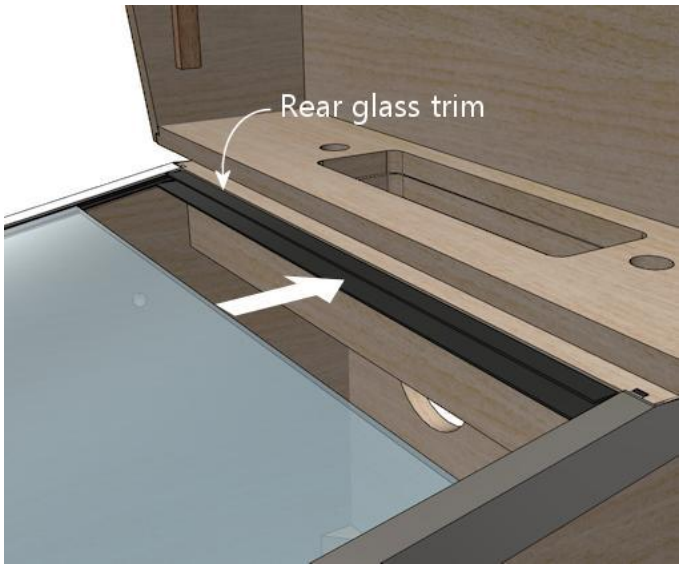
Rear glass trim

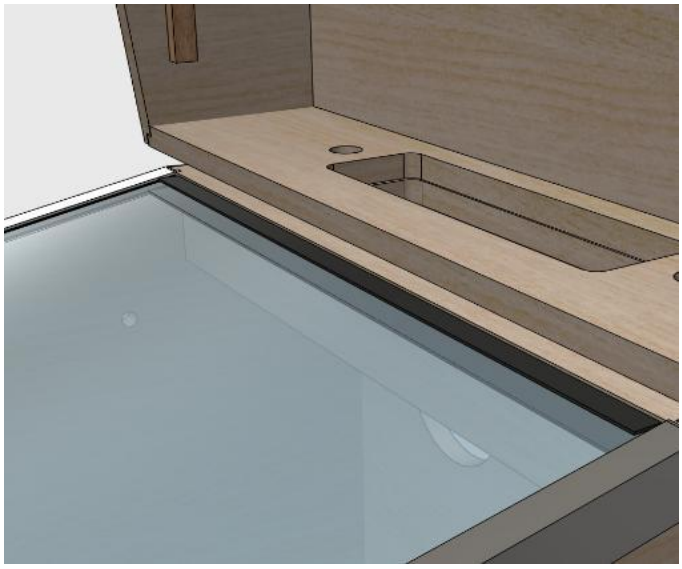
Assuming you're going through this section in order, you've already installed the glass channels that go under the side rails. If not, you should go back and do that before proceeding.

After the side glass channels are installed, there's one more part to install for the top glass, which a piece of plastic trim at the back of the machine. This provides a slot for the rear edge of the glass to fit into.



This piece of trim attaches to the "shelf" at the back of the cabinet with a few screws, so it's pretty simple at that level (no wacky new router bits required!). But I found it a bit tricky to get the alignment right when I installed it on my machine.

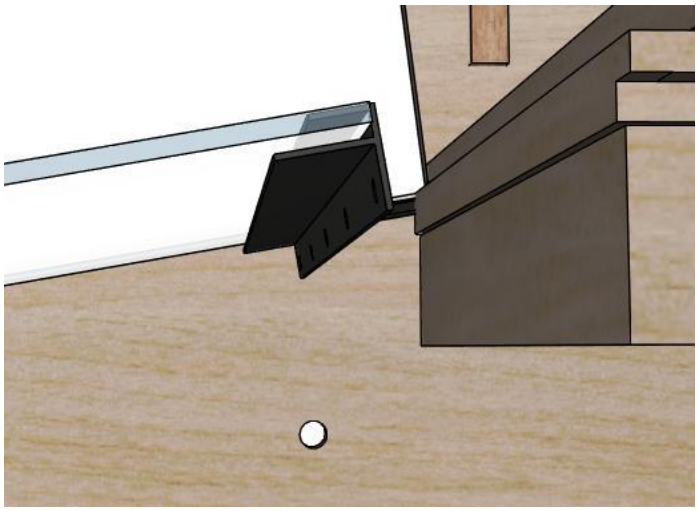




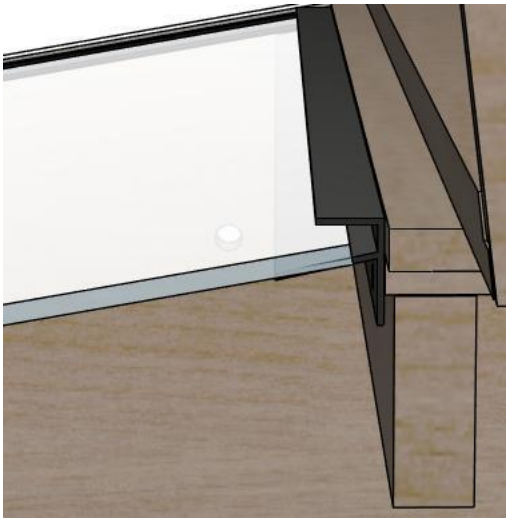
The thing that makes it tricky to install is that the opening in the trim for the glass is just about the same thickness as the glass, so there's not much room for error in aligning it. If the trim isn't aligned perfectly with the glass, the glass will snag on the edges of the trim when you try to slide the glass into place.

The procedure I used was to try to position the trim using the glass itself as a guide. Like I said, I found this a bit difficult in the execution, but I don't have any better ideas.

- Slide the glass into the side channels, almost all the way to the back
- Fit the trim onto the back of the glass, orienting it as shown below

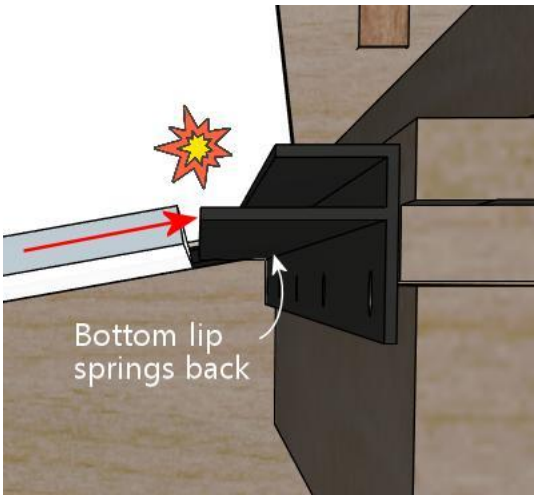


- Slide the glass all the way back, pushing the trim flush against the back shelf



- Mark the position of the trim on the rear wall
- Remove the glass

At this point, the obvious thing to do is to put the trim back at the marked position and screw it into the shelf with some wood screws. That's indeed how I proceeded. The problem I had is that the position we marked above had the glass already in place, and the glass tends to apply a little pressure on the bottom lip that tilts it down slightly. If you install it at exactly this position, the bottom lip of the trim will spring back up without the glass there, so when you try to insert the glass, it'll get hung up there.



I ended up just iterating this a few times with test installs before I found the magic spot. Before you commit to a position, try testing the proposed location with something to hold it in place temporarily, such as masking tape, or a trusty assistant. Slide the glass in and out at the test position. Adjust until you find the spot where the glass will slide in smoothly.

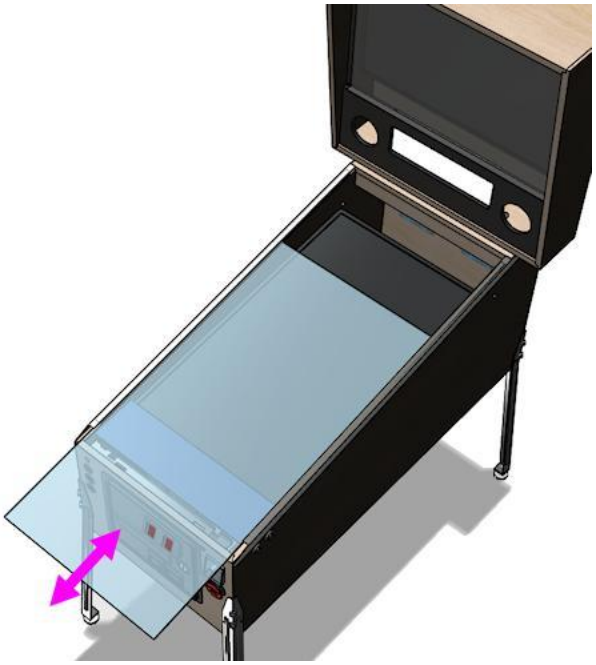
Once you find the right spot, fasten the trim to the rear wall with wood screws. #6 x ¾" should work.

For what it's worth, the install positions on the real machines I've looked at vary from the top of the trim being flush with the top of the shelf, to being as much as ¼" above the shelf. So maybe there's not a mathematically predictable position, as it seems that even the pros resorted to ad hoc alignment.

Lockbar and receiver

The "lockbar" is the metal trim piece at the front top of the cabinet, so named because it serves to lock the glass cover in place. You'll also see it called a "lockdown bar" and a "lock bar" and various other variations on the "locking" theme, since no one seems to be quite sure of its real name. That's worth noting if you're trying to find one on a pinball supplier's web site, because the suppliers can't agree on precisely what it's called, either, even within their own sites. Interestingly, all of these "lock" terms are vernacular; the official that's for it as listed in the Williams parts manuals is the rather vague "front molding assembly".

The lockbar (the name we'll settle on here) serves three main purposes. The first is the "locking" function that's right in the name. The bar serves to lock the top glass in place, by preventing the glass from sliding out the front. If you want to remove the glass, you first have to remove the lockbar. The lockbar itself is secured by some latches inside the machine, which can be engaged and released via a lever you can reach by opening the coin door. So you can't take off the glass without removing the lockbar, which you can't do without opening the coin door, which you can't do without the keys.

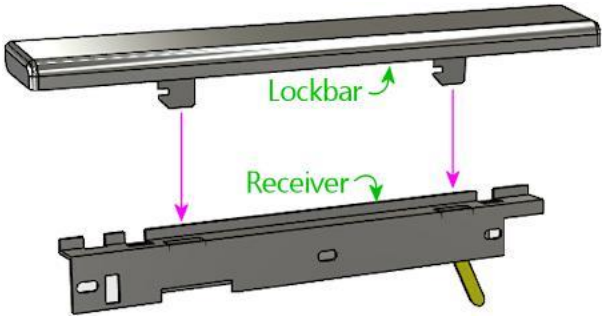


The second function of the lockbar is cosmetic. It serves as decorative trim along the top front edge, as suggested by the official Williams name for the part, "front molding assembly".

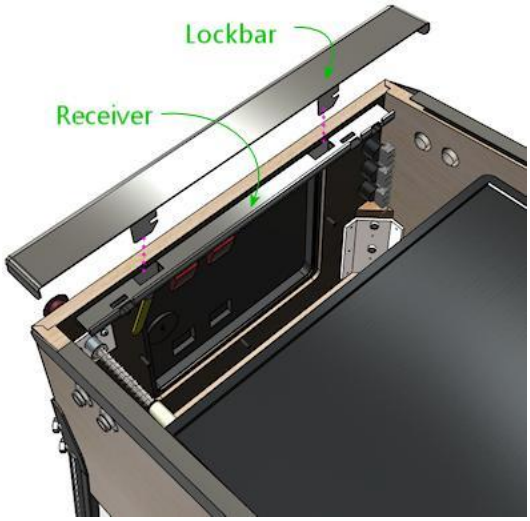
The third function is to provide a comfortable place to rest your hands while playing. The natural hand position while playing is to grip the front corners of the machine with your fingers on the flipper buttons. The lockbar has nice rounded corners right where your palms go. This hand-rest function becomes apparent the first time you try playing a round of pinball on a machine without the lockbar installed - the bare plywood corners can be awfully sharp.

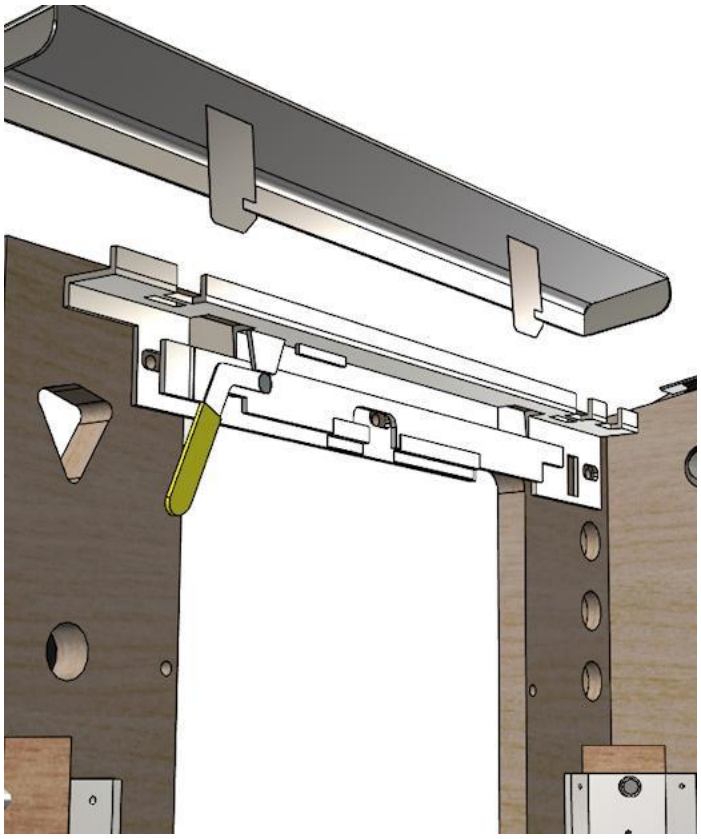
If you're not planning to use a genuine pinball lockbar, you should come up with a substitute that covers all of these key functions, especially the part about providing a comfortable hand-rest.

In the standard setup, the lockbar mates with another part, usually called the *lockbar receiver*. (Although, once again, Williams gives it a less descriptive official name in their parts manuals: "lever guide assembly".) The receiver attaches to the inside of the machine, at the top of the front wall, and isn't visible to players.



The receiver is installed at the top of the front wall, on the interior side:





Fire button

Several Stern machines from the 2000s feature a button on the top of the lockbar, usually labeled "Fire" or something similar. The button typically activates a special feature in the game at certain times, so it's a useful extra control in those games.

You really don't have to replicate this physical button on a virtual cab just to play these games, because Visual Pinball re-creations almost always use the MagnaSave buttons as substitutes for special extra controls like this. (See Appendix 4, Tables with MagnaSave Buttons.) However, the playing experience isn't quite the same when you substitute a different physical button, and one of the huge reasons to build a virtual cab in the first place is to replicate the original playing experience as faithfully as possible. So if you're a big fan of the Stern games that include Fire buttons, it might be worth including one on your cab to better reproduce the original game's feel.

To include a Fire button on a virtual cab, I think the best bet is to buy a Stern lockbar and receiver combo that's specifically designed for the button. A regular lockbar doesn't have a hole drilled for the button. You *might* be able to take a regular lockbar and drill the hole yourself, but I think this would be difficult to do cleanly, as it

requires a largish hole (1⅛" diameter), and you'd have to drill through two metal layers (the outer stainless steel trim piece itself, and the epoxied steel plate inside with the prongs). You'd also have to drill some holes in the lockbar receiver, since the regular receiver will get in the way of the button, and doesn't have the mounting holes for installing the microswitch that goes with the button.

Parts:

- To find a lockbar that can accommodate the button, the search term that seems to work best is "premium lockbar", because Stern typically only includes the extra button as an added feature on the upgraded versions of their games ("premium" or "limited edition"). One example: lockbar for *Star Trek* Premium, Stern part 500-7283-22.
- The receiver that's compatible with a center button is Stern part 500-7237-00
- The button itself is an extra-long (1-3/8") clear flipper button, Stern part 515-7791-00
- Button collar (mounted on top of lockbar), Stern 545-7292-10
- Mounting plate (mounted under lockbar), Stern 545-7291-00
- Palnut (secures button to lockbar), Stern 240-5003-01, Williams/Bally 02-3000
- #8-32 Keps nuts, quantity 2 (secures mounting plate), Stern 240-5104-00

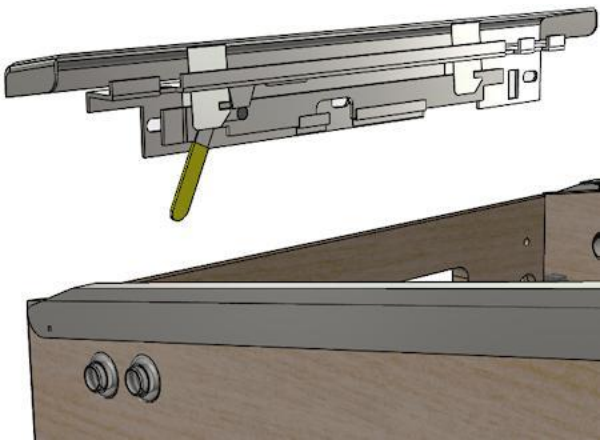
As far as I can tell, there's no such thing as a "generic" lockbar-with-button. They're all made for specific games (*Star Trek*, *Lord of the Rings*, *Game of Thrones*, *AC/DC*, etc), and all of the ones I can find come with powder-coat finishes (not the standard chrome) and special game-specific badges. The game-specific badge in particular would be a big negative for me, in that it would clash with my custom theming, but it's actually a separate part that you could remove and replace with something custom. You'd also almost be forced to use the matching powder-coat finish on the legs and side rails. That might be something you want anyway, as it can look snazzy, but it would increase the cost for those parts. And finally, keep in mind that these lockbars are only available in the standard-body cab width, so these wouldn't be an option if you're building a widebody or custom size.

Feedback request: I'd sure like to know if there are any **generic** lockbar-with-button options (*with* the button hole, in the standard *chrome finish*, and *without* any game-specific badging). Please pass along a pointer if you know of such a product available commercially. Also, if you've personally modified a *regular* lockbar and receiver combo to include a Fire button, I'd like to hear about how you did that and how well it turned out. I'd be thrilled to have detailed conversion plans to add to this section. The options above seem regrettably limiting.

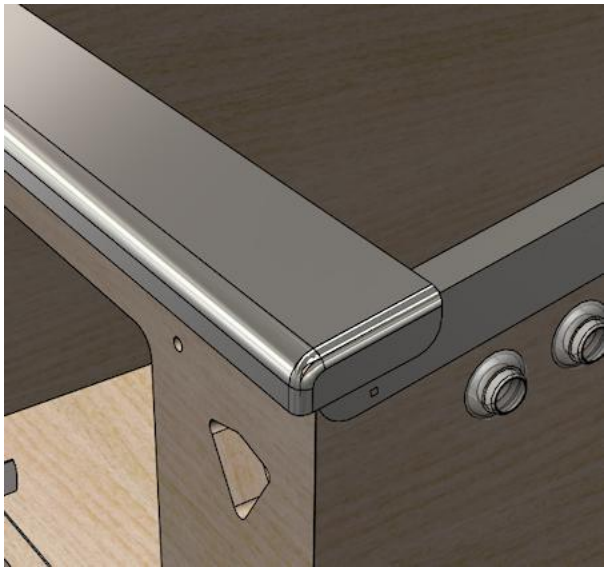
Installing the lockbar receiver

Before you install the lockbar receiver, install the side rails, as described earlier in this section. The lockbar should fit snugly on top of the side rails, so the rails have to be in position before you can fine-tune the lockbar positioning.

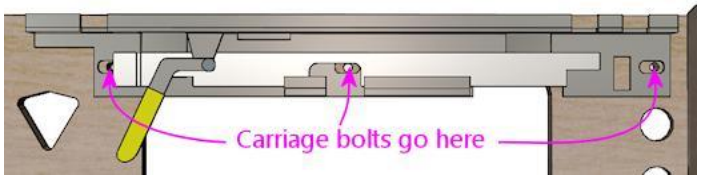
Start by fitting the lockbar into the receiver (with nothing installed in the cab yet).



Put the lockbar/receiver assembly into position. On the inside of the cab, the vertical part of the receiver should be flush with the front wall. On the outside, the lockbar should be resting on the side rails, slightly overlapping their front edges so that there's no gap. The front of the lockbar should overhang the front wall of the cab slightly (by about 1/8" to 3/16").

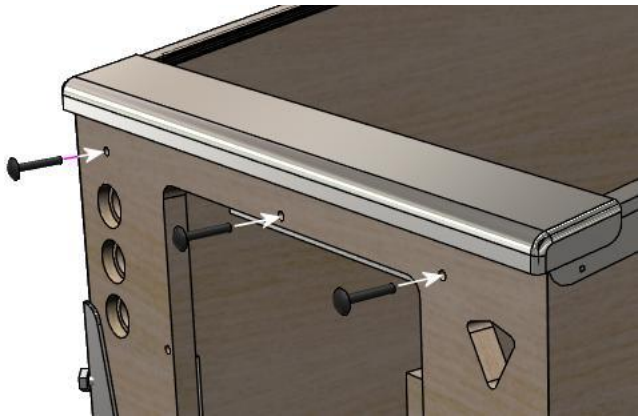


If you haven't already drilled the holes in the front wall for the receiver's three carriage bolts, mark the center positions of the bolt holes in the receiver on the inside wall. The positions of the bolt holes are illustrated below. After marking the locations of the holes, remove the lockbar/receiver assembly and drill them at 5/16" diameter. Put the assembly back in place.



The receiver attaches with three ¼-20 x 1¼" carriage bolts and ¼-20 lock nuts. These are available in silver or black finishes. Most of the real machines use black bolts to make them less conspicuous. I've only been able to find them in black from the pinball supply vendors (Pinball Life, Marco Specialties) - they're not just painted black, but actually have a black oxide finish.

Insert the carriage bolts from the outside of the cabinet:

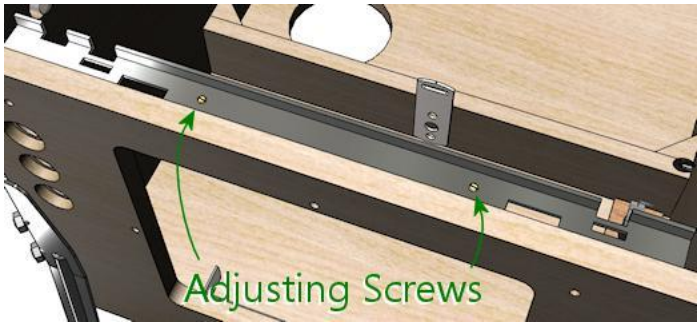


Attach lock nuts on the inside. You might need to pull the lever on the receiver to access one or more of them, since parts of the mechanism can slide in front of the bolt holes. If it's too hard to fit the nuts onto the bolts with the lockbar in place, remove the lockbar for that step. I'd put it back in place before final tightening, though, to make sure things stay properly aligned. The receiver provides a little bit of play in the bolt holes to let you fine-tune the position, and the best way to do that is to use the lockbar itself as the guide.

Note that the center bolt is shared with the coin door, so you should leave that out for now if you're going to install a coin door next. I'd still insert the center bolt during the fitting process to make sure the holes are all properly aligned, but don't actually fasten it yet.

Check final alignment by removing the lockbar and then putting it back in place. You should be able to smoothly remove it and re-attach it, and it should still be sitting at the desired position when latched in place again. If it's too tight or too loose, you can loosen the bolts again and tweak the receiver positioning to improve the fit. The receiver has oversized bolt holes to give you a little play to get the position right.

You can also adjust the locking tension slightly via the two brass adjustment screws on the top of the receiver, as illustrated below. Tighten the screws (turn them clockwise) to push down on the latches and increase the tension when the lockbar is installed.



DIY alternatives to real pinball lockbars

Some pin cab builders don't use real lockbars because of the cost, or because they're building an unusual cab design where the standard lockbar doesn't fit the style or the available space.

If size (not price) is the only factor, note that you can buy lockbars in custom widths (made to your specifications) from VirtuaPin.

Fashioning your own metal lockbar seems like a challenging job for a DIYer, short of having access to a well-equipped metal shop. I'm afraid I don't have any workable suggestions here; it's not the sort of thing you can make on a 3D printer, which is the magic answer to almost everything else these days. The closest starting point might be an "L" bar, which you can buy from hardware stores in various metals and

thicknesses - but I'm not sure how you'd mold that to the more complex shape of a standard lockbar with its rounded corners at each side.

If you're going for a furniture look with wood trim all around, it's possible to craft a wood version using fairly ordinary wood-working tools. Here are some vpforums threads that might be helpful:

- Wooden custom lockdown bar
- Alternative for a custom lockdown bar

Another possibility is to use a 3D printer to fabricate a plastic lockbar. Here's a vpforum thread about that, with advice about materials and finishes to make it look like a metal lockbar:

- Alternative for a custom lockdown bar

DIY alternatives to a real lockbar receiver

To save a little money, some virtual cab builders omit the receiver, even while using a real lockbar. The receiver is a purely internal part, so it doesn't serve any cosmetic function, and some pin cab builders find the price (currently about $80) unreasonable for a part with such a simple job. The main thing that makes a standard receiver so expensive is that it has to be rather heavy-duty to fulfill its role as a security lock. For a home machine, you might not be concerned about teenagers trying to pry the thing apart to steal quarters.

One simple solution might be to use Velcro. You'd have to attach some filler material to the bottom of the lockbar to fill the space between the lockbar and the top of the front wall. Once the two areas are in contact, you can simply glue a bunch of Velcro to each side. This would hold the lockbar reasonably well, although obviously not in a truly "locking" way, and it would probably feel a bit wobbly compared with the real ones.

A more elaborate home-made alternative is described here:

> Question about lockdown bars and receivers for mini cabinet (message #5)

Briefly, the idea is to place a pair of toggle latches on the inside front wall of the cabinet, positioned to align with the hooked prongs that stick out of the bottom of the lockbar. To fasten, you reach in through the coin door, hook the latches to the prongs, and engage the latches. To release, you again reach in through the coin door and disengage the latches. The downside is that it would require a fair bit of dexterity to reach the latches through the coin door, since they need to be positioned around the corner on each side. In contrast, the standard receiver can be engaged and disengaged with a lever that's positioned within easy reach.

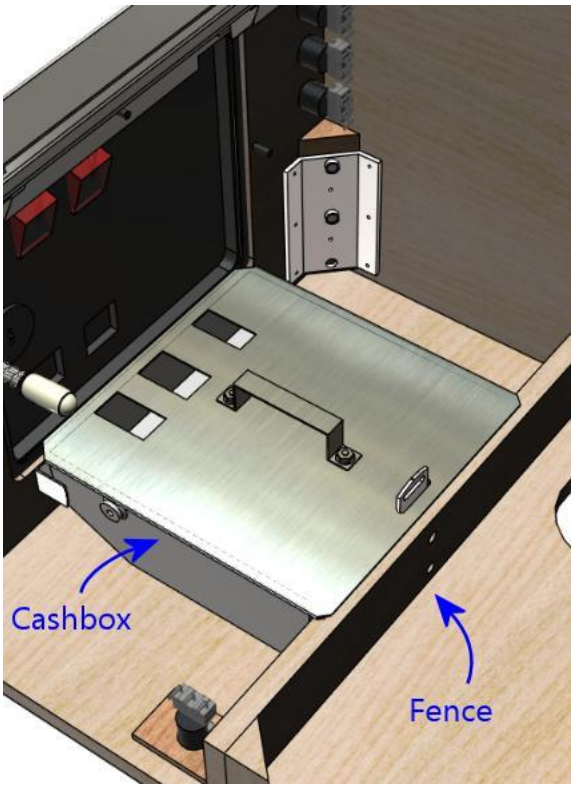
Note that some of the newer Stern machines actually use lockbars with a similar toggle-latch design. Compatible Stern lockbars are equipped with under-carriage latch-hook parts that are specifically designed to be used this way, so you might find it easier to use this approach with a compatible Stern lockbar than with a lockbar designed to fit the standard Williams/Bally receiver. Refer to these parts:

- Stern lockbar, dual luggage latch, 5500-6882-03-00
- Luggage latch, 355-5038-00

Cashbox

If you're planning to drop coins into the coin slots, you'll need something to catch the coins on the other side. You don't want them rolling around loose where they could randomly short out wiring or get wedged in something mechanical.

The real machines' solution is the "cashbox". It's a low-profile plastic box with a metal lid, with slots in the lid that line up with the coin chutes. It sits just inside the coin door. When a coin goes through one of the chutes, it drops straight into the cash box. The cash box is sized to fit through the coin door, so the operator can easily collect the machine's income when making rounds.

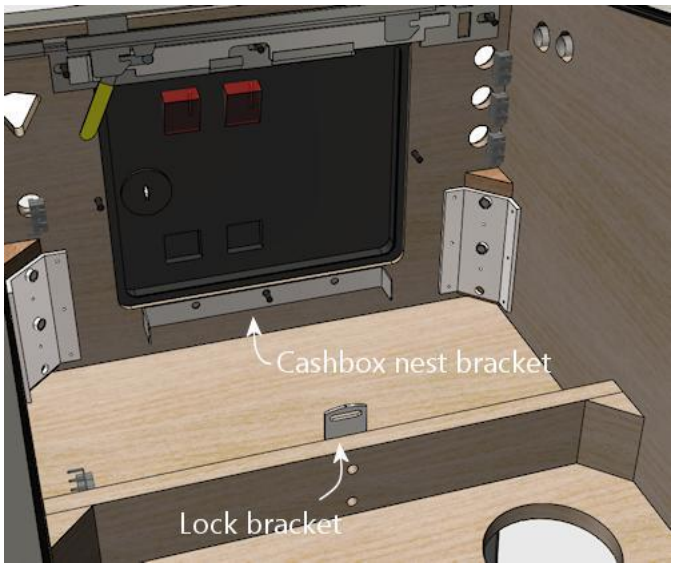


The cashbox has essentially just one design these days, which looks like the illustration above. Older machines used a variety of shapes and sizes, but nearly all pinballs made since the 1990s use the same design that Williams used in the WPC machines. Since it's so close to a standard, it's the one you can buy from pinball vendors. Most of them sell it in two separate pieces: a plastic tray, and a metal lid. They don't separate them just to make your life difficult; it's for modularity, so that the same tray works with lids with different slot patterns for different coin door layouts. The three-slot lid illustrated above is for the typical US coin door configuration. If you have a non-US coin door, you should be able to find a matching cashbox lid at a European pinball parts vendor.

Installation

The cashbox itself doesn't require installation per se; you just pop it into the space at the front of the machine. But you do have to install two brackets to hold it in place, plus a little "fence" or divider wall, called out in the illustration above.

The first bracket goes at the front of the cab, directly under the coin door. This is the "cashbox nest bracket", Williams part 01-6389-01. It prevents the box from sliding back and forth.



The nest bracket has three screw holes. The center one is meant to align with the bottom bolt in the coin door, so that you share the same bolt between the coin door and this bracket. If you haven't already installed the coin door, slip a carriage bolt (¼-20 x 1¼") through the hole from the front of the cab for alignment. (If you've already installed the coin door, just remove the nut from the bottom bolt.) Slip the nest bracket's center hole over the bolt to position the bracket. Make sure it's level, then fasten the two outside holes to the cab's front wall with wood screws (#6 x ¾" should work).

If you've already installed the coin door, reattach the nut on the center bolt. Otherwise just leave that off (and take the bolt back out) for now; you'll install it when you get to the coin door.

The second bracket is the "cashbox lock bracket" (Williams part 01-10030 or 1A-3493-1), which attaches to the fence called out in the earlier illustration. If you followed our plans from Chapter 21, Cabinet Body, you've already installed that. If not, you should go back now and follow the plans in that chapter under "Cashbox fence".

Once both brackets are in place, installing the cashbox is a simple matter of dropping it into the space delineated by the fence, fitting the slot at the back of the cashbox lid over the lock bracket. To remove the cashbox, lift the back edge high enough to clear the lock bracket, and pull the cashbox out. This is all meant to be done through the coin door, since the cashbox is sized to fit through the door.

(If you look more closely at the lock bracket, you'll see that it has a little slot at the top. That's for attaching a padlock, to add an extra layer of security to protect the booty even if someone gets past the coin door. Probably not something you'll need in a home machine.)

DIY cashbox

Apart from cost, the main reason you might want to consider designing your own home-made cashbox substitute is that the real ones are rather large. The standard cashbox is great at its job, but it takes up a whole foot of floor space at the front of the cab, which impinges on space you might want to use for PC parts or feedback devices.

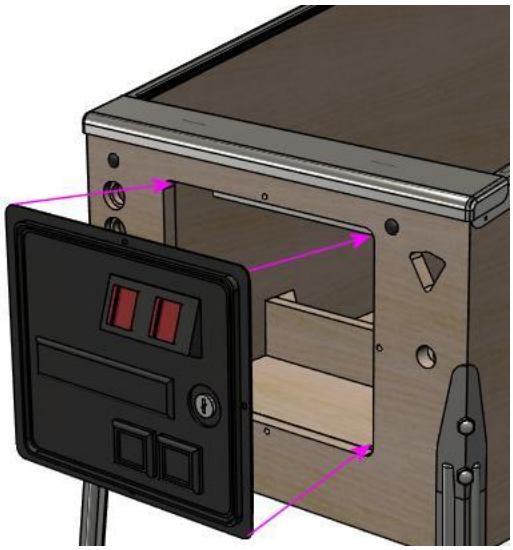
Improvising a home-made cashbox isn't too challenging, since it's just a box with a couple of holes in the lid. You could easily fashion one out of plywood or acrylic. I created one using a plastic food container; I found one with about the right depth, and used an X-acto knife to cut slots in the lid that line up with the coin chutes. I use a bungee cord (connected to a couple of eyelets screwed into the floor) to hold it in place. It's certainly not as elegant as the real cashbox (particularly the bungees pinning it down), but it only takes up about 5" of floor space.

Coin door

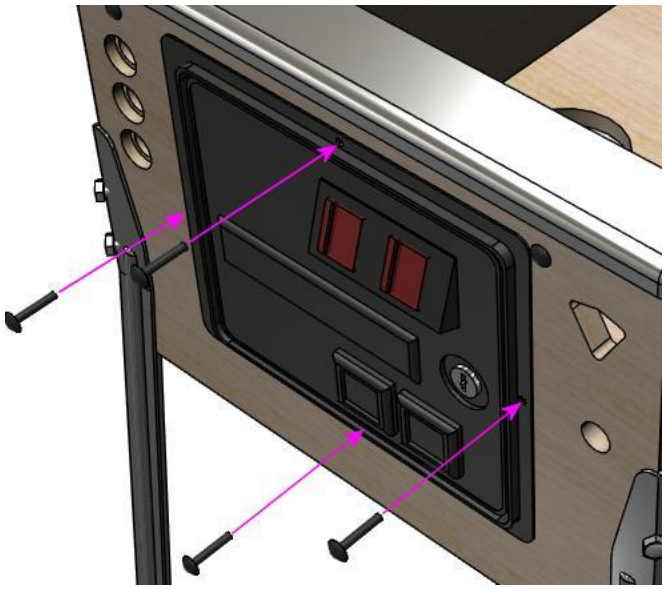
The coin door is a complex enough subsystem that we've devoted a whole chapter to it (Chapter 40, Coin Door). But we'll go over the basic installation process here.

If you're using a standard lockbar-and-receiver combination, it's easier to install the receiver before installing the coin door. Follow the procedure above. The receiver shares its center attachment bolt with the coin door, so you'll need to remove the center bolt in the receiver if it's currently in place.

The standard coin door assembly comes with the door itself and the frame already assembled, so there's not much to installing it. Start with the door closed and locked. Fit it into through the coin door opening in the front wall.



Holding the door in place, insert carriage bolts (¼-20 x 1¼") through the four holes around the perimeter of the door frame. Fasten them on the inside with ¼-20 lock nuts.



The top bolt in the coin door is shared with the lockbar receiver, if you're using one. Thread the bolt through the matching hole in the receiver mechanism, and attach the

lock nut on the interior side of the receiver, so that it secures the receiver as well as the coin door.

If you're installing the full set of cashbox hardware, the bottom bolt in the coin door frame will be shared with the cashbox "nest bracket". Thread the bolt through the matching hole in the nest bracket and attach the lock nut on the interior side of the bracket.

Coin mechs

If you bought a brand new coin door, it probably didn't come with coin "mechs" (mechanisms), the gadgets that sit behind the coin slots to validate inserted coins. You can buy those separately. The mechanical quarter acceptor used in typical US coin doors is an inexpensive add-on (about $10 each). I think it's worth including these in a virtual cab, for the added realism of being able to use real coins. The installation procedure is detailed under "Coin mechs" in Chapter 40, Coin Door.

Custom coin slot inserts

On most types of coin doors, it's possible to replace the illuminated "25¢" signs (known as "inserts") on the coin slots, to show different coin denominations, or better yet, your own custom graphics. See "Custom coin slot inserts" in Chapter 40, Coin Door.

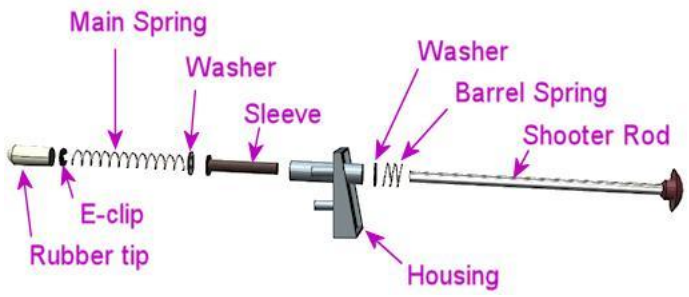
Coin door position switch

On real pinball machines, there's a switch inside the cabinet that detects whether the door is open or closed, just like the light switch in a refrigerator door. You should install the same switch in your virtual cab, because many of the modern ROM-based pinball tables use it to control access to their setup menus.

Full instructions on setting up the physical switch (as well as connecting it to the virtual pinball software) can be found in Chapter 40, Coin Door, under the section "Coin door position switch".

Plunger

If you bought a full plunger assembly, it probably came assembled. If not, or if you bought the separate components, assemble as shown below.

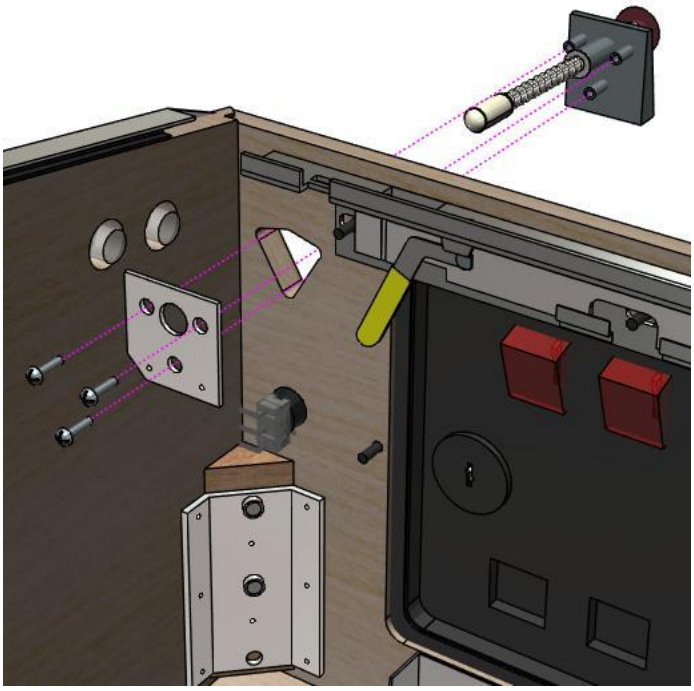


- Slip the barrel spring over the shooter rod and push to the knob end
- Slip the washer over the shooter rod and push down to the barrel spring
- Insert the nylon sleeve into the shooter rod opening in the housing (from the inside of the housing)
- Insert the shooter rod into the opening the housing (from the outside of the housing)
- Slip the other washer onto the shooter rod
- Slip the main spring onto the shooter rod
- Attach the E-clip to the rod. You'll have to hold the spring back while you do this, since the spring will be compressed in its normal position. The E-clip fits into the groove near the end of the rod. Use needle-nosed pliers to snap it into position.

- Fit the rubber tip over the end of the rod. (This is optional in a virtual cab; you probably don't need the tip unless you're using some kind of optical sensor that requires it. Leaving it out will save a little space if you have tight clearance to the TV.)

If you haven't already routed the opening in the front wall for the plunger, see "Plunger and Launch button" in Chapter 21, Cabinet Body.

For installation in the cabinet, you'll need three #10-32 x ⅝" machine screws (¾" length will also work) and a ball shooter mounting plate (Williams/Bally part 01-3535). You can improvise something to replace the mounting plate if you prefer, but the plate makes things a lot easier and only costs about $2.



Fully assemble all of the plunger parts (except for the mounting plate) as described above, then fit the assembly through the triangular opening in the front wall, from the outside. The three prongs in the front of the housing should fit in the obvious way at the corners of the triangular cutout. Align the mounting plate on the inside, fitting the large hole at the center over the shooter rod. The mounting plate should sit flush with the front wall of the cabinet. Screw in the three #10-32 bolts.

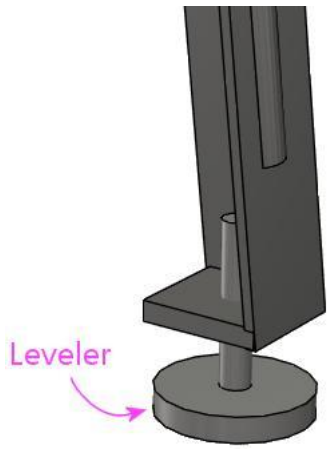
Legs

You'll probably want to leave the legs off for most of the build process. It's easier to install the internal parts (the PC, TVs, buttons, feedback devices, etc) with the machine on the floor or on your workbench. That's why we've saved this for near the end of the hardware chapter. On the other hand, it's easy to attach and detach the legs as needed, so you can always test them for fit.

Assuming the leg brackets are already installed (see above), attaching the legs is pretty easy. You'll need eight bolts (two per leg), ⅜-16 by 2½" or 2¾". The longer length is usually needed if you have leg protectors of some kind. You should buy the bolts from a pinball vendor rather than using generic hardware store parts, as the pinball bolts look nicer; this is a cosmetic item.

The legs on modern machine are all interchangeable front/back/left/right, so you should have a set of four identical legs. (The front and back legs are the same length. The forward tilt of the machine comes from the back legs being attached lower on the cabinet than the front legs.)

If you haven't already attached the "levelers" (the round foot pads) to the legs, do so before installing the legs. These simply screw in to the holes on the bottoms of the legs.



The levelers let you adjust the slope of the machine slightly, and also let you adjust each leg so that all four legs are planted on the floor (to solve the classic wobble problem with a four-legged table on an uneven surface). It's best to screw all of the levelers all the way in initially (so that they're as "retracted" as possible), then adjust as needed once the machine is situated. The levelers can get a little wobbly themselves at their maximum extension, so keep them retracted and only extend as needed.

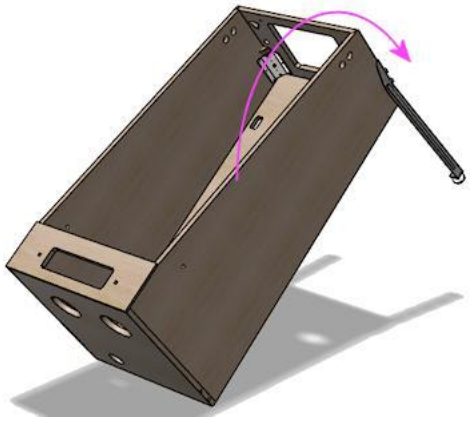
Start by setting the machine on its back. This lets you attach the front legs without any weight on them.

Position each leg at the corner of the cabinet where it goes, aligning the bolt holes in the leg with the bolt holes in the cabinet. If you're using leg protectors, they go between the leg and the cabinet.

Insert the two bolts and thread them into the bracket. There's no need for any nuts or washers, as the brackets themselves are threaded and serve as the fasteners. Use a hex driver or wrench to tighten the bolts. They should be tight enough that the

legs won't wobble, but don't tighten so much that you strip the threads or crush the plywood.

Tip the machine forward until the front legs touch down on the floor, then lift the back of the machine high enough to attach the back legs.



Have an assistant hold the back of the machine up while you install the rear legs, which bolt on just like the front legs. Be sure to have your assistant continue holding the machine off the ground in back until all of the rear bolts are fully tightened.

When the machine is situated at its permanent location, adjust the leg levelers (the foot pads at the bottom) to level the machine, so that all four feet are firmly on the floor without wobble. (On a real machine, you'd also take this opportunity to adjust the leg levelers to fine-tune the cabinet's tilt to level the playfield side-to-side and make its slope match the manufacturer's prescription. But this is superfluous on a virtual cab, where game gravity only exists within the simulation.)

To remove the legs, simply reverse the procedure.

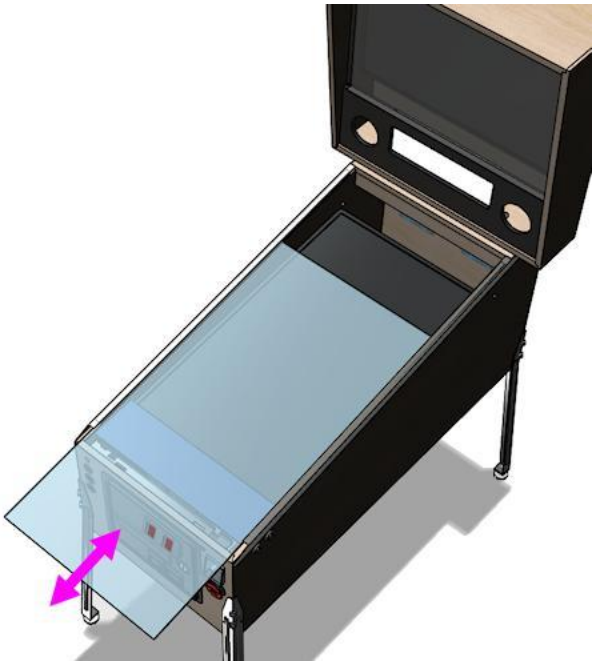
Top glass

If you've set things up as we described above, with the plastic channels for the glass along the side rails and in back, the glass can be easily installed and removed at any time, without tools.

To install the glass, remove the lockbar, and slide the glass through the front of the machine, fitting the edges into the plastic channels under the side rails. Slide it back

until it's nested in the trim at the back. Put the lockbar back in place to keep the glass from sliding back out on its own.

To remove the glass, simply reverse the procedure.



24. Backbox Hardware

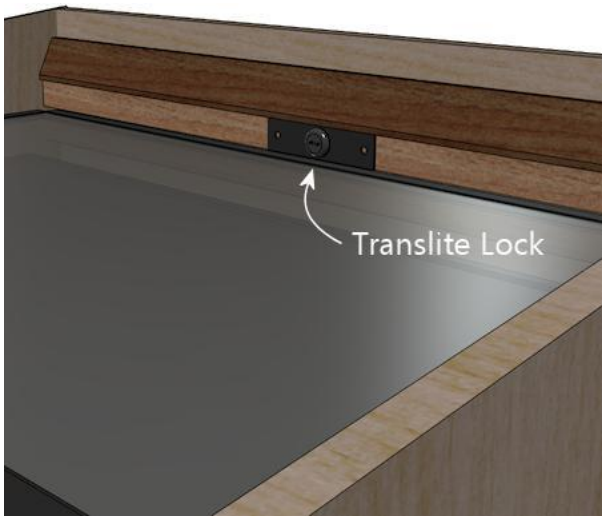
This section continues with the cabinet trim hardware, moving on now to the backbox.

We assume that you've already built the wood shell of the backbox as described in Chapter 21, Cabinet Body, and that you've already painted it and/or applied decals, as described in Chapter 22, Cabinet Art. It's best to finish the artwork before installing any hardware, since some the hardware will get in the way of painting or applying decals once installed.

As with the Chapter 23, Cabinet Hardware chapter, we try to present things in an order you can follow for installation.

Translite lock

The real machines have a keyed lock at the top of the backbox that secures the translite, so that arcade customers can't steal the translite or get into the backbox to mess with the electronics.



The operating principle is pretty simple. In the locked position, a metal tab on the lock sticks into the slot at the top of the backbox trim that the translite fits into. This prevents lifting the translite, which is necessary to remove it.

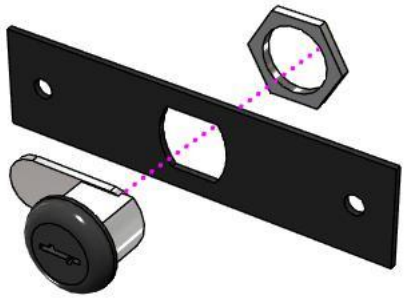
In the unlocked position, the metal tab swings out of the way, letting you lift the translite into the slot, which in turn lets you remove it.

With the lock open, there's enough play that you can remove the translite, as described below. With the lock closed, the tab prevents moving the translite far enough to free it from the top and bottom trim channels, so it's effectively locked in place.

The translite lock is purely for the sake of security - it's there to prevent anyone without the key from removing the glass. The glass won't fall out on its own, though, even if you don't install the lock - it's held in place by the slots it sits in, and you have to intentionally maneuver it out of the slots to remove it. So it's not a functional necessity in a home setting, unless you have obnoxious friends. (The exception is that the glass could conceivably come loose during transport if you give it a bumpy enough ride. A lock does help prevent this by ensuring that the glass can't move out of its slots.)

Installing the translite lock

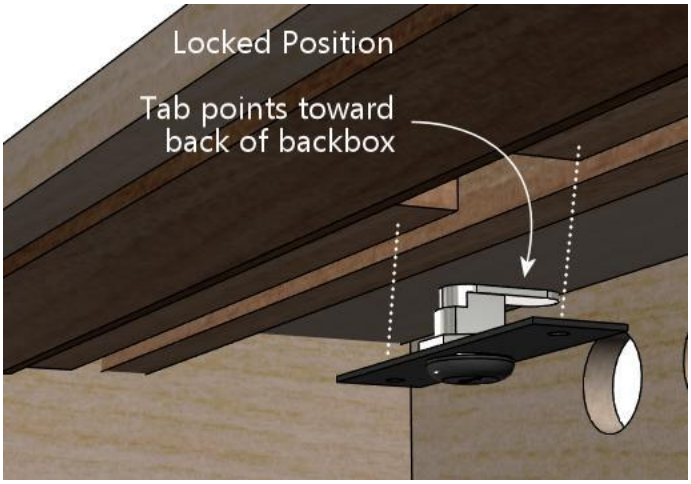
First, assemble the pieces of the lock plate. Slip the lock through the hole in the plate, slip the hex nut over the back of the lock, and tighten the nut.



It should look like this when assembled.

The pinball vendors sell the lock plate assembly as a complete kit, which includes a pair #8-32 machine screws with security Torx heads. There are two reasons you might want to discard these and substitute your own wood screws. The first is that they're the security Torx type, so you need the special security type of Torx driver to use them. "Security screwdriver" is a bit hyperbolic when anyone can go buy one at Home Depot, but it's at least a slight deterrent against mischief simply because most people don't have one lying around. The second reason you might be inclined to discard the special screws is that they're machine screws, not wood screws. They won't attach well to plain wood. They require T-nuts, which must be pre-installed behind the trim, as explained in "Translite lock plate preparation" in Chapter 21, Cabinet Body. If you skipped that step when installing the trim, it's probably too late. Fortunately, wood screws are a pretty decent alternative, especially if you're not concerned about the security aspect of the lock. And if you are concerned about that, you could substitute tamper-resistant wood screws.

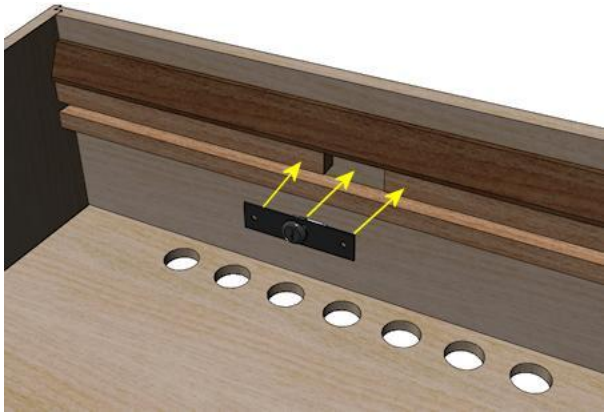
Before installing the lock plate, use a key to check the orientation of the lock. Turn the lock so that it's in the extended position, with the lock tab sticking up perpendicular to the plate. Be sure to install it with the tab facing the **back** of the backbox.



If you did already install T-nuts for the Torx screws, simply put the lock plate in position, and fasten it with the Torx screws.

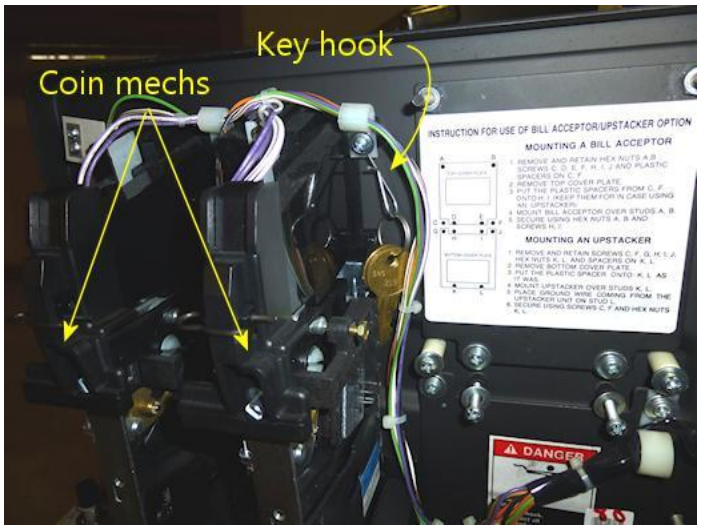
If you didn't install the T-nuts, discard the Torx screws that came with the kit, and substitute a pair of wood screws. I'd go with #6 x ¾". Rounded-head screws will look better, as will black screws if you can find them (if not, you can just paint the heads black after installation if you want).

Line up the lock plate over the gap in the top trim. It should be centered over the gap, which should be the same as centering it side-to-side overall in the backbox. Mark the positions of the screw holes. Remove the plate and drill pilot holes for the #6 screws. Put the lock plate in position again and fasten the screws.



Where to keep the keys

With the real machines, the standard way to keep track of your translite keys is to keep them on a little hook inside the coin door. The WPC and SuzoHapp doors provide a hook specifically for this purpose, located next to the coin mechs.



If you're not installing a standard coin door or can't find the key hook, you might put a little eyelet or hook on the inside wall of the cab somewhere convenient, and hang the keys there.

DIY alternatives

If you don't need the locking function, but your backbox has the gap in the trim where the lock plate goes, I'd simply install a 1" x 4" plate, either metal or a thin piece of wood, painted black. Screw it in with #6 x ¾" wood screws, at holes placed about ⅜" from either edge. Use rounded-head screws, and either use black screws or paint the heads black after installation.

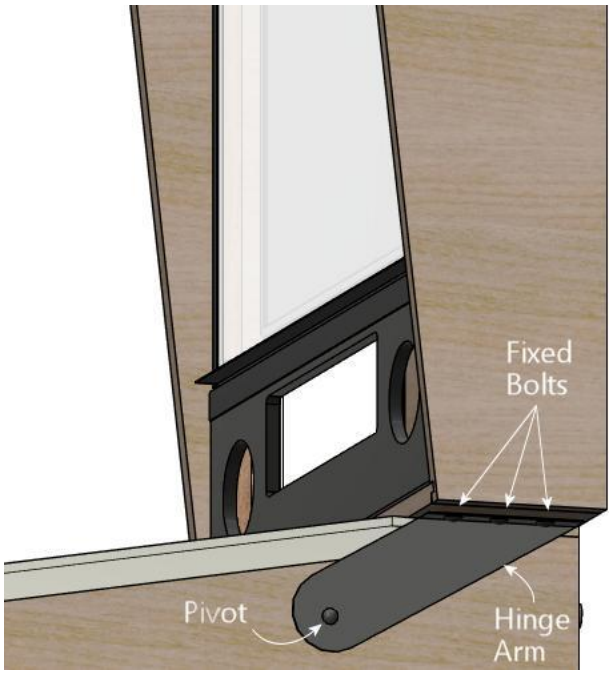
If you haven't yet installed the wood trim where the plate goes, I'd simply run a single piece of wood all the way across rather than replicating the gap in the standard plans.

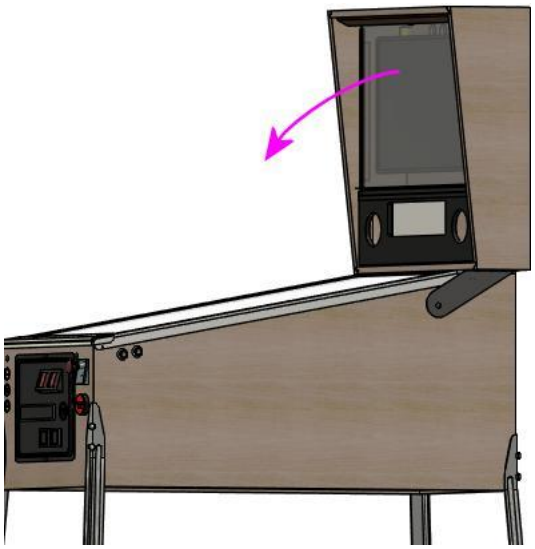
Backbox hinges

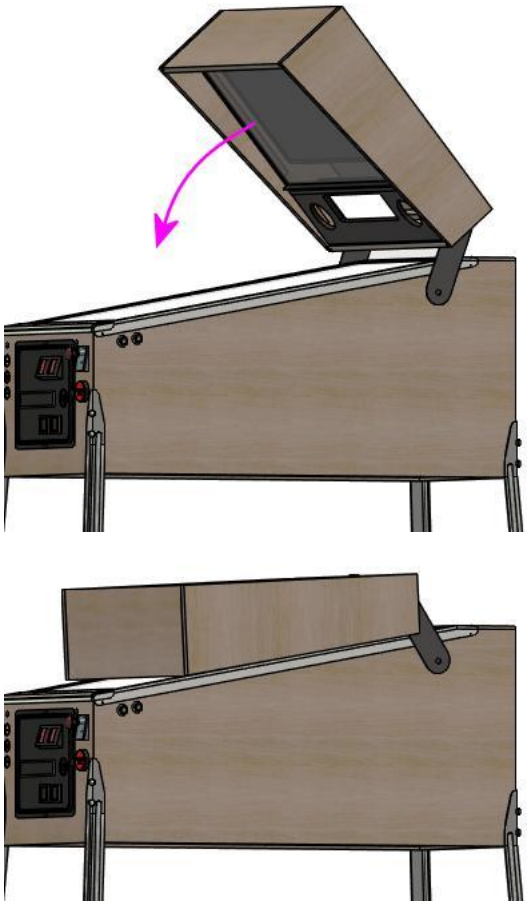
Real pinball machines are designed with a hinge that lets you tilt the backbox forward until it's lying flat on top of the main cabinet. This is an essential feature if you want to transport a pinball machine, as it would be too tall, top-heavy, and fragile with the backbox in the normal position. And you certainly wouldn't want to remove the backbox every time you moved the machine, as that's a major operation that requires disconnecting a lot of wiring, which always creates a risk of breaking something when you reassemble it.

WPC hinges

On the WPC machines, the backbox is attached to the main cabinet with a clever hinge mechanism that uses rotating arms connected to pivots on the sides of the cabinet.


Fixed
Bolts
Pivot
Hinge
Arm





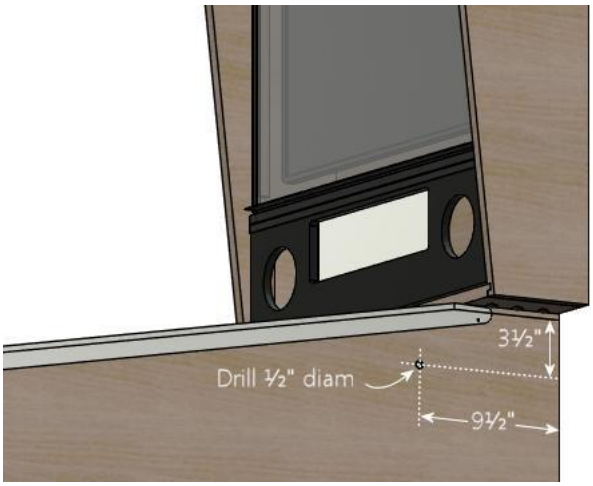
I consider this setup clever, in part because it wouldn't have occurred to me to do it this way, but mostly because it has has some nice functional advantages over the more obvious "door-hinge" approach, where you simply put a regular hinge at the front of the backbox. A door-hinge approach is workable, and in fact it's used on a lot of older pinball machines from before the WPC era - we'll have more on this shortly, since it's a viable alternative if the WPC approach doesn't work for you for some reason. But the WPC system more elegant: it looks nicer, it makes for simpler cabinet geometry, and it's easier to install and to get everything aligned properly. Door-hinge systems can be tricky to get aligned.

So assuming you're building a full-scale cabinet, the WPC approach is all upside. And it's not particularly expensive; the required parts will only set you back about $30.

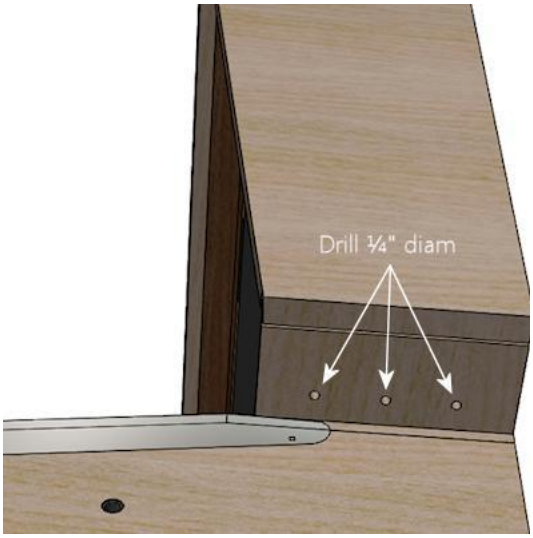
The only reasons I can think of not to use the WPC hinges are (a) that you're building a mini-cabinet that's too small for the standard parts to fit properly, or (b) that you're specifically reproducing a cabinet style from a different era, so you want to use the same hinge system they used. If one of these applies to your build, you can skip down to the "Alternatives" section below for some other ideas.

Installing the WPC hinges

One of the advantages of the WPC hinge mechanism is that it's easy to set up. If you followed the WPC cabinet plans in Chapter 21, Cabinet Body, you've already drilled the mounting holes in the main cabinet and backbox. To review, the parts get mounted here:



...and here:



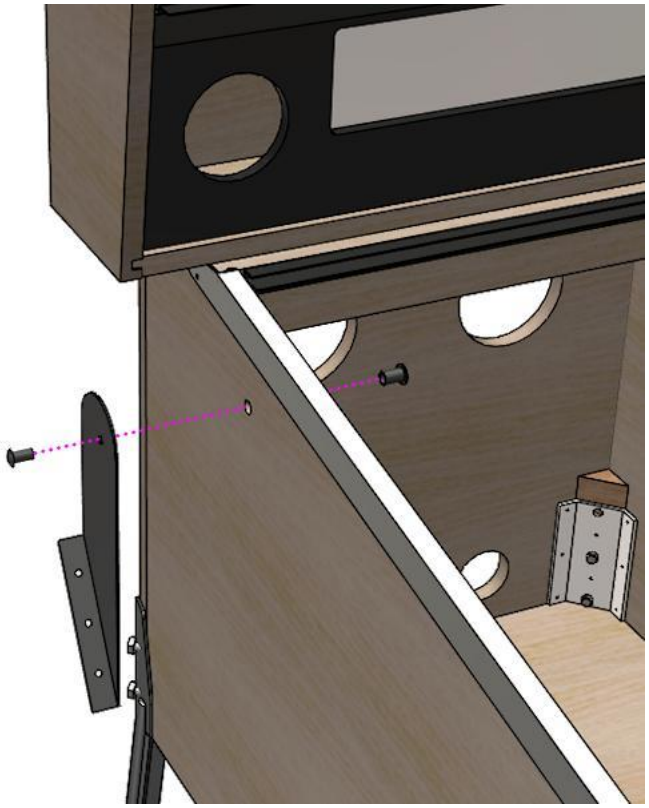
See "Backbox floor" in Chapter 21, Cabinet Body for drilling locations, which depend on your cabinet width. If you haven't already drilled these, an easy way to figure the exact position is to use the hinge arm itself as a drilling template, after attaching it to the main cabinet first. We'll point out the right time to do that in a moment.

You should already have your side rails installed at this point, since the hinges will get in the way of installing them later.

Note that there's a "left" and a "right" hinge arm - they're mirror images. Be sure to install the correct one on each side. They should be oriented with the pivot point pointing towards the front of the cabinet, and the little "wing" that attaches to the backbox pointing away from the cabinet side:

Start with the hinge pivot joint. This uses the ½" diameter hole drilled in the side of the main cabinet:

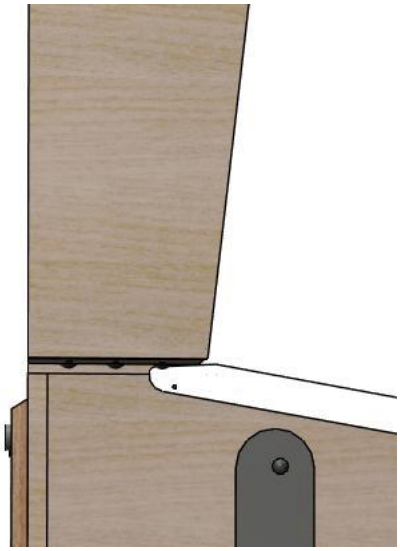
- Fit a ⅜"-16 x ¾" carriage bolt into the squarish opening on the side of the hinge arm. Orient the hinge arm so that it's hanging from the bolt, so that it doesn't swing down into this position on its own and scratch the side of the cab.
- Insert the carriage bolt into the pivot hole in the main cabinet
- From the **inside** of the cabinet, thread the pivot bushing (Williams part 02-4352) by hand onto the end of the carriage bolt
- Use a ¼" hex wrench to tighten the pivot bushing from the inside of the cab



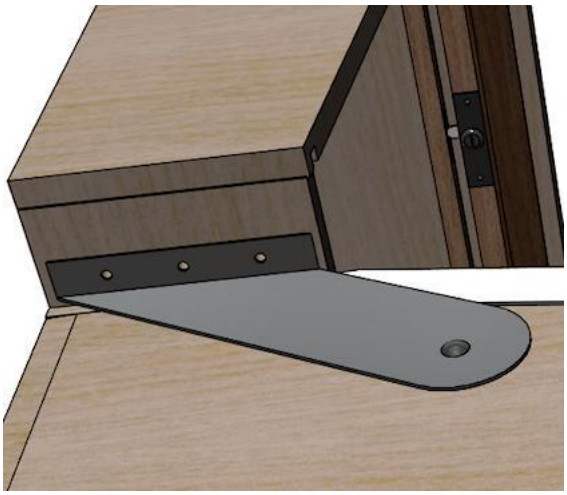
When tightened, this arrangement should leave a little clearance (about 1/8") between the hinge arm and the main cabinet, and you should be able to rotate the hinge arm around the pivot. (It's okay if it's tight.)

Install both hinge arms (left and right) using the procedure above.

Position the backbox on the shelf at the back of the cabinet, centered side to side, with its back flush with the back wall of the main cabinet. (Have an assistant hold the backbox steady while you're working so that you don't accidentally knock it over.)

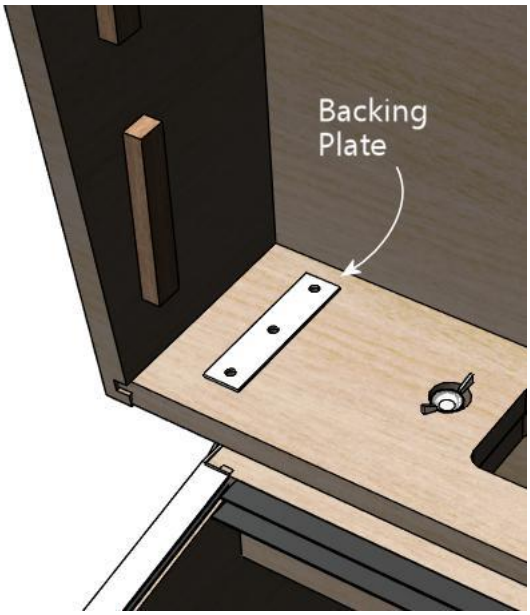


Rotate the hinge arm around the pivot until the side with the three bolt holes meets the bottom side of the backbox. Be careful about rubbing the sides of the cab so that you don't scratch the artwork.

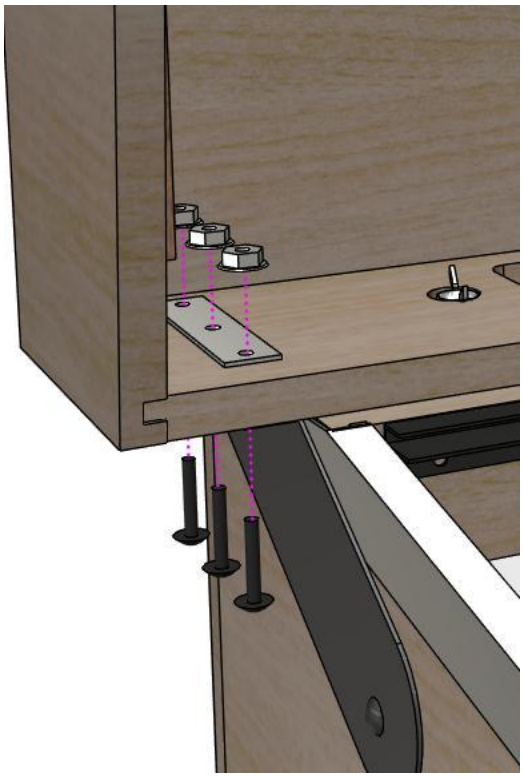


If you haven't already drilled the holes in the backbox floor for attaching the hinge bracket bolts, this is the time! Make sure the hinge arm is flat against the bottom of the backbox, and that it's precisely parallel to the side of the cab. You should be able to see a little gap between the hinge arm and cab across its whole length. The hinge shouldn't be pressing against the cab anywhere, since that could scratch the artwork when you rotate the backbox. Once you have it aligned to your satisfaction, mark the positions of the three bolt holes. Repeat on the other side. Remove the backbox and drill ¼" holes at the marked positions.

On the inside of the backbox, position the backing plate (01-9012) over the bolt holes.



Install three ¼"-20 x 1¼" carriage bolts in each hinge arm, inserting from the bottom side, and through the mounting plate. Fasten each with a ¼"-20 whiz flange locknut. Tighten securely.



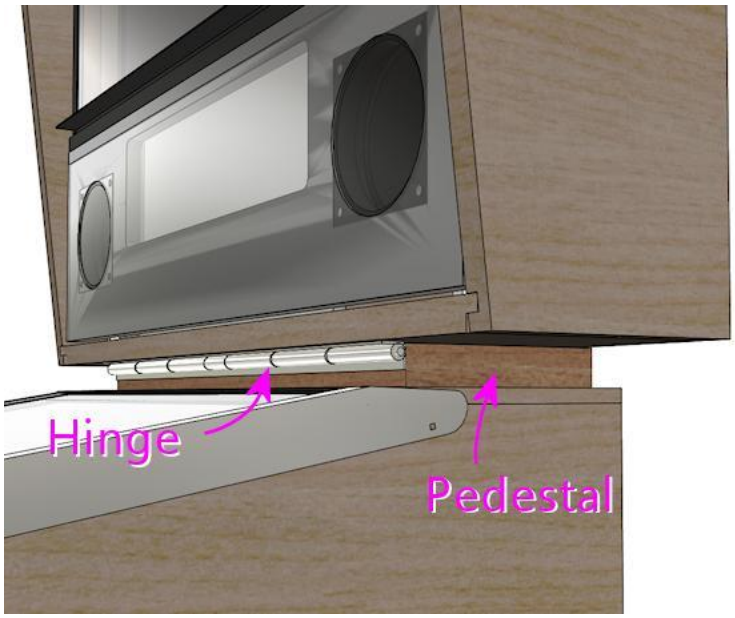
The backbox is now attached! You should be able to freely tilt it forward so that it lies flat against the top of the cab. (It's a good idea to put down some padding when doing this, so that you don't scratch up the side rails or the front edges of the backbox.)

If you ever need to remove the backbox, just take out the carriage bolts attaching the hinge arms to the bottom of the backbox. You can leave the hinge arms themselves attached permanently.

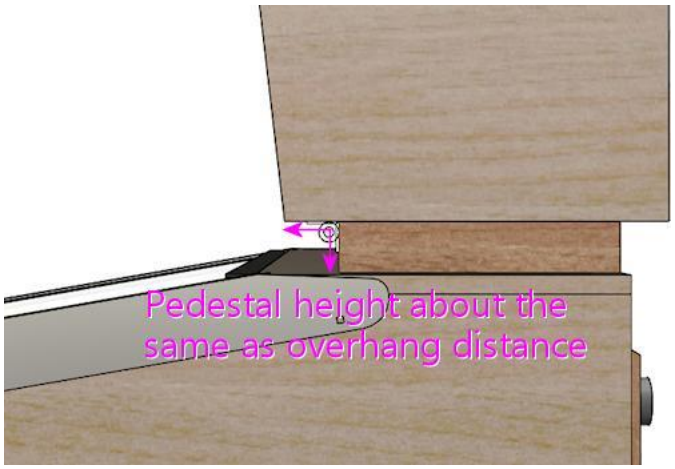
Alternative hinge mechanisms

The WPC hinge mechanism described above has been used on most real machines made from the 1990s to present. But it's not the only type of hinge that the pinball manufacturers used over the years. Most of the earlier machines I've seen use something more like conventional door hinges, attached at the bottom front of the backbox. The backbox folds down forwards onto the cabinet just like in the WPC system, but the pivot point is the door hinge rather than the bolts on the side of the cabinet. The Williams System 11 machines from the 1980s use this approach, as shown below.

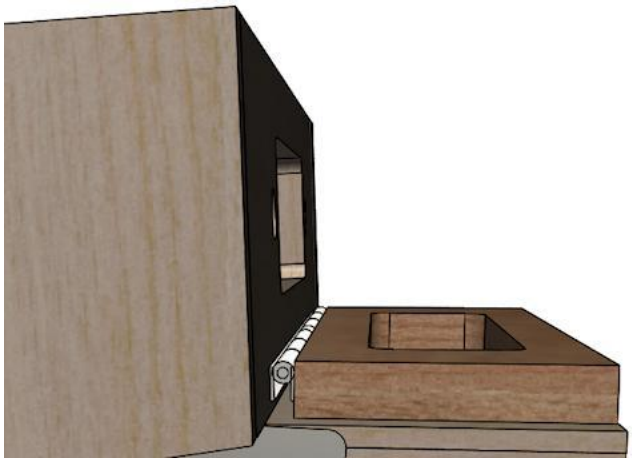
*Williams System 11 backbox mounting (*Space Station*, 1987). This used door hinges at the front of the backbox. Note how the backbox has to be raised slightly above the cabinet on a pedestal, to make space when folded down for the part of the backbox that overhangs the front of the hinge.*



I think the WPC system is nicer in a lot of ways, but the door-hinge system might be a good alternative in cases when the WPC parts won't fit, since they only come in the one size. Mini-cabs in particular might need something like this. If you use the System 11 machines as your model, pay close attention to the way it requires a "pedestal" to raise the backbox about an inch above the main cabinet, to make room for the front overhanging portion of the backbox when it folds down. The standard WPC plans won't work well with a hinge like this, because the backbox sits directly on top of the cabinet in the WPC design. If you want to adapt the WPC plans for this arrangement, you'll have to add the pedestal.



The pedestal has to be at least as high as the distance the backbox projects out in front of the hinge, to make room for that part when the backbox is folded down.



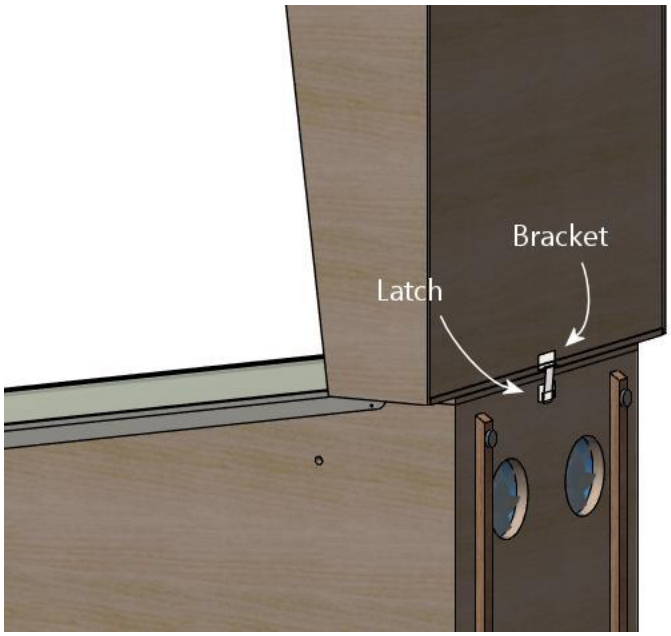
Hinge system with backbox folded down.

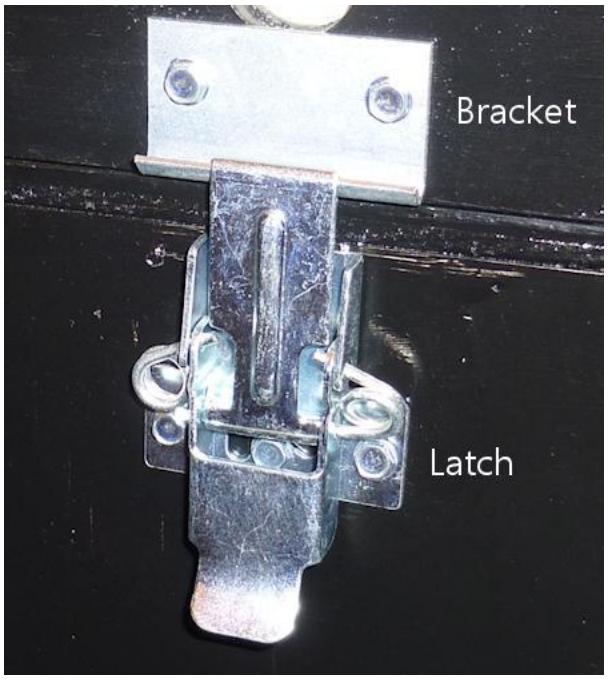
Backbox latch

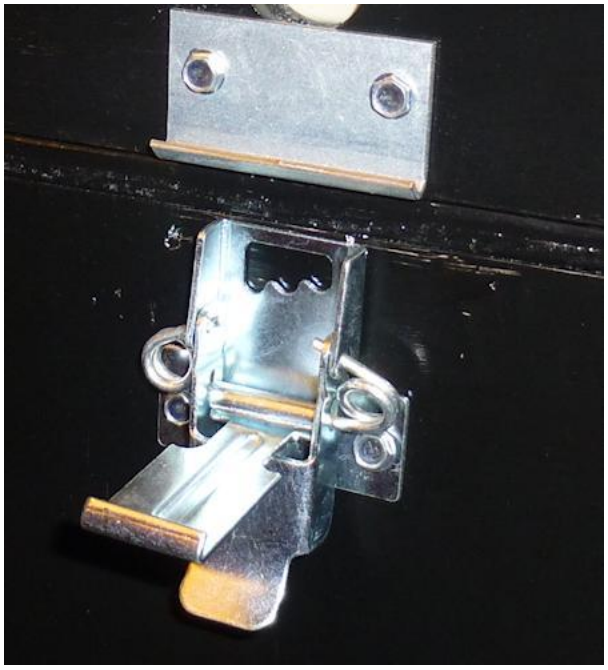
This is a minor bit of hardware that helps when setting up the machine, by temporarily securing the backbox in the upright position, preventing it from falling forward if bumped. The standard part is a simple toggle latch that attaches to the back of the main cabinet, with a mating bracket that attaches to the back of the backbox.

I said "temporarily", because the toggle latch isn't really strong enough to count as a permanent way of securing the backbox. Let me show you the warning that they silkscreen on the back of the real backboxes in big yellow letters:

Their point is that this little toggle latch isn't all that strong; it could fail if the backbox were bumped too hard. The backbox is quite heavy and has a lot of leverage, so you need something a lot stronger to truly secure it. The solution is to install the wing bolts described below. The toggle latch is just meant to be a temporary helper while you're getting the wing bolts in place.







Install this after you've set up the backbox hinges, so that you're working in terms of the actual final alignments.

For fasteners, use any suitable wood screw. On the real machines, they usually use #6 x ¾" sheet metal screws with hex heads. (I know, "sheet metal screw" doesn't sound like the right thing for screwing into wood, but they actually work just fine as self-tapping screws with plywood.)

- Set up the machine with the backbox in the upright position. Have an assistant brace the backbox while you're working so that it doesn't fall forward.
- Attach the bracket (the top piece) first. Align it in the center of the backbox side-to-side, with the bottom edge roughly flush with the bottom of the backbox.

- Figure the position of the latch itself by hanging it from the bracket with the lever pulled partially open, so that there's no tension on the spring, as illustrated below.

- Fasten the bottom bracket at this position. When you close the latch all the way, it should pull the spring tight so that the bracket stays latched.

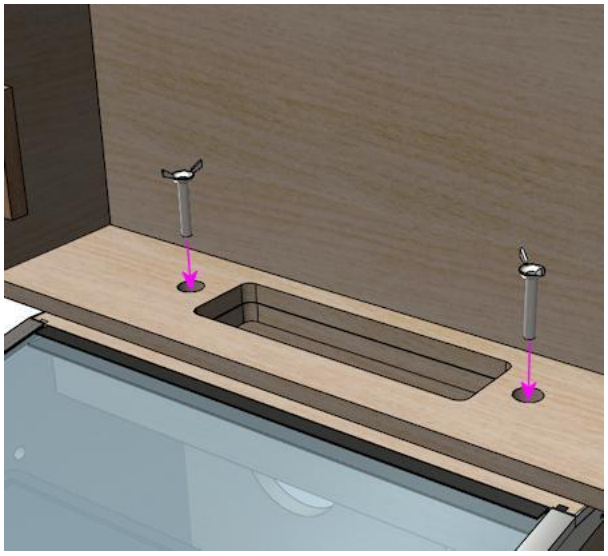
Backbox safety bolts

As the warning placard above points out, the little toggle latch on the back of the backbox is helpful to keep the backbox from flopping over while you're setting up the machine, but it's not strong enough to rely on beyond that. For a deployed machine, you need something stronger, specifically a couple of big bolts installed in the floor of the backbox.

The parts required are a pair of ⅜"-16 x 2" "wing bolts", like the one pictured below. Wing bolts are basically just regular bolts with wing nuts in place of the heads. This lets you turn them by hand, for tool-free installation. (The wing nut at the top isn't a separate part; it's integral, like the hex head on a regular bolt.) The wing nut head also serves as a built-in washer.

You can buy wing bolts in the right size from pinball vendors. You might be able to find them at some hardware stores as well, although they're too obscure for the big-box stores like Home Depot. In a pinch, you could substitute ordinary hex-head bolts of the same size, but note that you'd need to use some kind of giant washers (over 1" outside diameter) in conjunction, because the hex heads by themselves will slip right through the 1" top holes (defeating the purpose).

If you've done the necessary prep work as described in the "Rear shelf" section in Chapter 21, Cabinet Body, installing the bolts is trivial. Just pass them through the holes on either side of the floor opening and thread them into the pre-installed T-nuts. There's no need for washers or other parts. Hand-tighten. You don't have to go beyond hand-tight, since they don't have to hold the backbox up most of the time; gravity takes care of that for the most part. The bolts only kick in if the backbox gets bumped or pushed.



What is a translite?

We're all pinball nerds here, so a quick digression on definitions is in order! There's a bit of a disagreement between virtual pinball people and real pinball people about what "translite" means. So to avoid confusion, I want to make sure we're all clear on what *we* mean by the word.

Throughout this guide, I use the term "translite" to refer to *a clear plastic or glass sheet that you install in front of the main backbox TV*. There's no artwork printed on it (other than perhaps some masking around the edges, to hide the TV bezel), since we want to let the TV handle all of the artwork display. The virtual translite is thus essentially a bit of trim in a virtual cab to disguise the TV-ness of our virtual setup and make it look on the outside more like a real pinball machine.

Okay, so that's how *I* use the term in this guide. It's also how the term is commonly understood in the virtual pin cab community, so that's the way you'll usually see it used on the forums. But technically speaking, it's wrong! At least, it's not what it

means to (most) pinball people when they're talking about the real machines. Technically, in a real pinball context:

- A *translite* is a thin, translucent plastic decal, printed with graphics. There's no glass involved in the translite itself. This plastic decal that they call the translite is then affixed to a clear glass sheet to create a pseudo-backglass. Most modern pinball machines (1990s and later) use this type of assembly in place of a true backglass. It's only a "pseudo" backglass because...
- A *backglass* is a glass sheet with artwork directly painted or silkscreened on the glass. True backglasses were usually used on machines built before about 1990, when the manufacturers switched to the cheaper translite process.

Those are the technical meanings, but even real pinball people often use the words *translite* and *backglass* loosely and interchangeably. They'll often call the translite-plus-glass assembly a translite, or even a backglass. So I think we virtual pinball people can be forgiven for appropriating *translite* to mean kind of the opposite of what it really means, in that we use it to refer to the plain glass sheet without any artwork.

Creating a translite

The basic material for the translite is a clear sheet of either glass or acrylic. If you're using glass, it should be tempered glass. I personally prefer acrylic for the translite because it's so much lighter than glass.

Dimensions for the standard WPC-style translite:

- Thickness: ⅛"
- Size: 18⅞" high x 27" wide

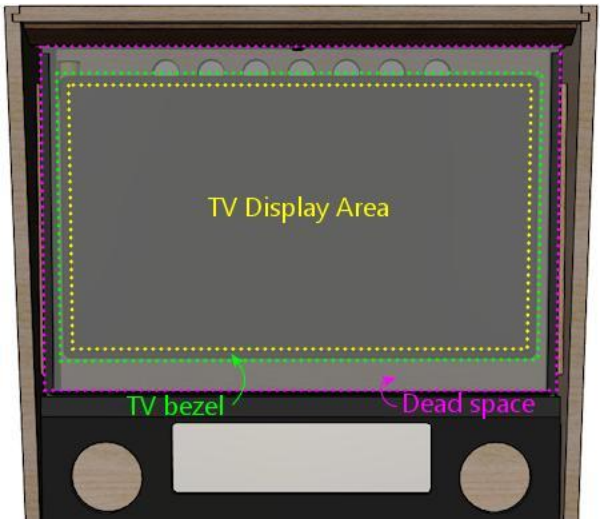
The size obviously depends on your backbox dimensions. The size above is for the standard WPC setup, with the backbox built to the standard dimensions and a standard-sized speaker/DMD panel installed. If you're not using a speaker panel, you'll probably want to increase the height to cover the entire backbox area, so you'd make it about 26½" high if you're using the standard backbox dimensions.

Where to buy: The clear glass or plastic sheet isn't something you can find as a standard pinball part from any vendor. Fortunately, it's easily found as a generic part.

- For glass, you can have a custom glass sheet made by just about any window glass company. Look for local companies that install or repair residential window glass.
- For acrylic, try TAP Plastics or a similar local plastics vendor. You can also buy acrylic in standard sizes at Home Depot and other hardware stores, and cut it to a custom size yourself using a plastic knife. This doesn't tend to make as clean an edge as you'd get from a plastics shop, but that doesn't really matter, since the edges are all covered by trim pieces anyway.

Edge masking

It's nearly impossible to make the backglass TV fill the entire space that's available for the translite in the standard backbox design. Part of the reason is that a TV's viewable screen area never completely spans the full height and breadth of the unit; there's always at least a thin bezel around the edges. The other factor is that the backbox space is much squarer than the 16:9 aspect ratio that's all but universal on current TVs. It's impossible to find a TV that fills the vertical space fully, given the constraint of also fitting in the available width. You can get down to a fraction of an inch of dead space on the sides, but you'll still have more than an inch at the top and bottom in the best case.



Most cab builders want to cover up all of the dead space around the edges of the TV, so that only the live display area of the TV is visible. Understandably, they don't want the insides of the backbox to be visible.

One way that some cab builders deal with this is to create a wood (or similar) cover with a cutout for the TV area.

I don't personally like this look very much, because to my eye, it calls attention what it's meant to hide. I mean that it makes it more even more obvious than it otherwise would be that there's a smaller TV embedded in a bigger backbox space. I also find that it looks too different from the real machines, which creates an impression of home-brew-ness that's at odds with my goal of a realistic appearance.

Given that we're talking about translites, I think you can probably guess that the approach I prefer is to use a clear glass or plastic cover for the whole area. That's exactly what the real machines use, so it looks as close to authentic as you can get, given the inherent differences in what's behind the glass. But that still leaves the problem that you can see into the dead space around the TV, since a clear glass or plastic cover is, after all, clear.

The best solution, in my opinion, is to combine the "cutout" idea from the wood cover with the clear translite, by masking out the edges of the translite. There are two ways to do this:

- The easy way is to paint around the perimeter with black spray paint. Paint on the back side of the panel, so that the front has a uniform glossy sheen - that'll largely eliminate the visibility of the "cutout" that I find objectionable in the wood cover approach. Measure the TV display area size, and use masking tape and paper to cover the cutout area. Paint around the edges.
- The other way is to use printed decals to create the mask. You can have custom decals made for this use just like for the cabinet artwork (see Chapter 22, Cabinet Art). I used this approach for my own cab, because I figured the real machines have artwork here, so I should too.

I used decals printed in the conventional way, to adhere to the front side of the translite. It would have been better to print them in a reverse format, with the adhesive on the graphics side so that they could have been stuck to the back side of the translite. This would have created a more uniform finish on the front, just like why you want to paint on the back if you're using a painted mask.

I really like the way my translite with decals turned out, but for practical purposes you might be better off with a simple black mask. The thing that you might not expect about the decals is that you simply don't see them while playing. The TV display is so much brighter that it completely overwhelms them to the point of utter

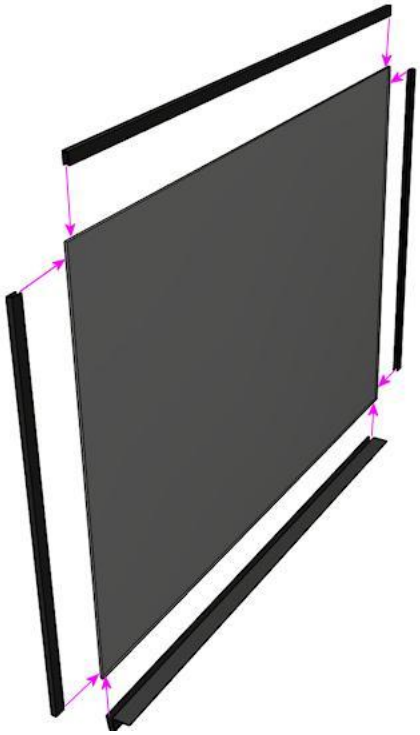
invisibility. Which is exactly what you want, as it turns out: you want it to look like the backbox of the game you're playing, not like a TV embedded in a virtual cab. So that works out great, but my point here is that as far as playing goes, there's no difference between decals and black paint. And when the cab is powered down, the decals arguably create the same visual impression that I said I *don't* like with the wood cutout approach - the way the visible borders call attention to what's missing in the middle. But somehow I don't dislike the look in this flat "2D" version; in person, it actually looks very much like a real translite, even if it would be a rather art-impoverished one on a real machine. Even so, a plain black paint mask would do a better job of hiding the TV cutout when the power's off; it would just like a solid dark sheet. You could easily mistake it for a regular translite with really dark graphics that need some backlighting to come to life.

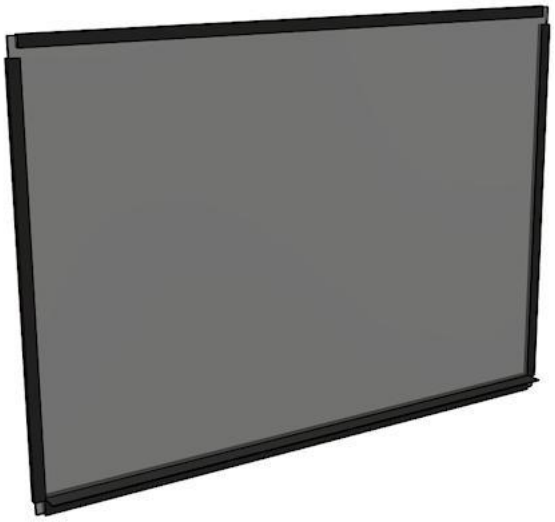
Assembling the trim

The standard WPC translite setup uses four trim pieces around the edges:

- A "lift channel" at the bottom, part 03-8228-1
- A top trim piece, part 03-8228-2
- Two side trim pieces (one for each side edge), Williams/Bally part 03-8228-2

They're all dead simple to install. Each is a plastic piece with a U-shaped channel that the glass/plastic sheet fits into. Just align each piece at the center of its respective edge and press it onto the glass.





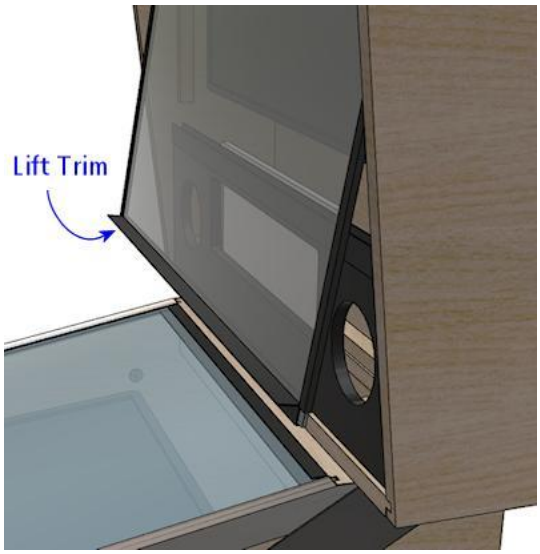
Note that the trim pieces don't cover every millimeter of the edges - there's a little uncovered space at the corners. That's normal.

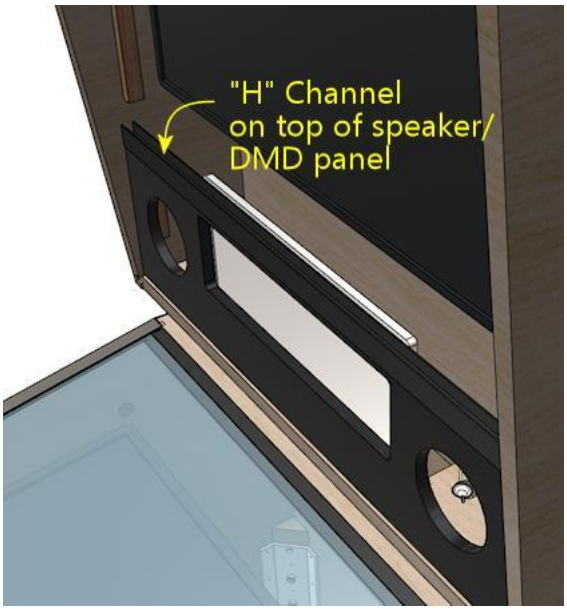
How to install the translite

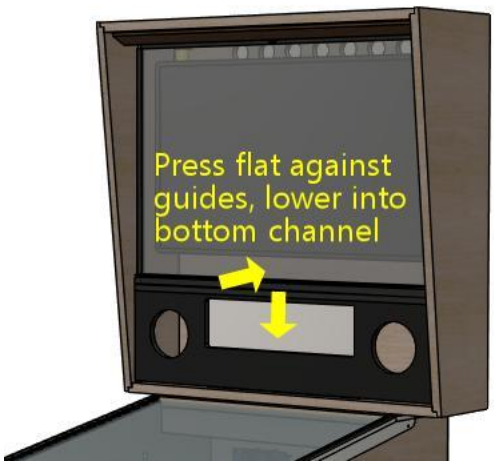
If you installed a translite lock, make sure it's unlocked, with the tab turned "sideways" so that it's not sticking out into the top glass channel. You'll have to use the key to do this. The whole purpose of the lock is that the tab blocks the channel so that the glass can't be removed, but this equally well prevents inserting the glass when the tab is in the "locked" position.

Holding the translite at an angle, lean the top edge against the guides at either side of the backbox, and slide it upwards into the slot at the top.

Lift it high enough into the slot that the bottom edge clears the bottom trim channel. Holding it by the "lift trim" at the bottom, move the bottom edge forwards until the translite is flat against the guides, then lower it into the bottom trim channel until it's seated.





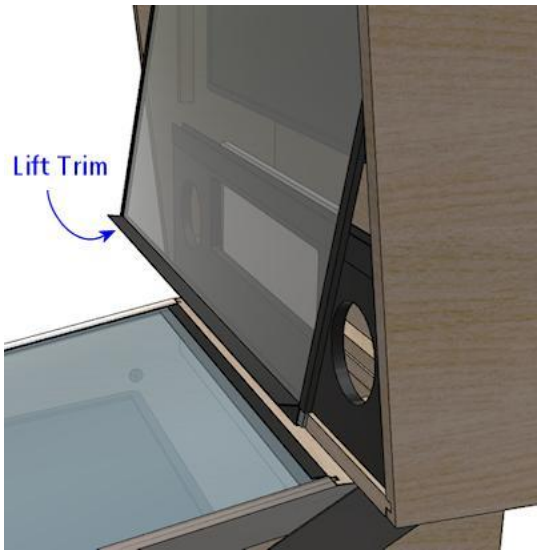


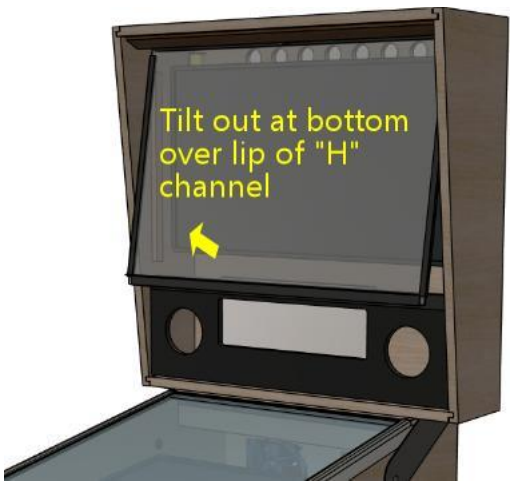
If you installed the translite lock, you can now turn it to the locked position to secure the translite.

How to remove the translite

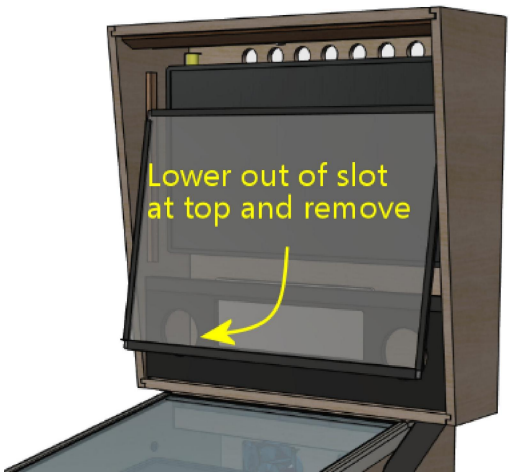
If you installed a translite lock, it must be in the unlocked position before you can remove the translite.

Holding the translite by the "lift trim" at the bottom, slide it upwards until the bottom clears the lip of the bottom trim channel. That lets you tilt the bottom outwards.





Now just lower the translite out of the top slot. It's now entirely free of the backbox trim, so you can remove it.


Lower out of slot
at top and remove

25. Cabinet Grounding

All of the externally exposed metal parts in your pin cab should be "grounded", meaning that the metal parts are all electrically connected to the Earth ground wire in your AC power plug. This includes the leg bolts, side rails, front lockbar, coin door, and plunger housing.

Grounding serves several puproses:

- Safety. If a wire inside the cab carrying voltage ever comes loose, it could come into contact with one of the exposed metal parts, which would create an electric shock risk to anyone using the cab. Grounding all of the metal parts reduces shock risk by shunting any stray voltages directly to ground. It also reduces the chances of a fire or other damage from an electrical mishap, in that a short to ground should quickly trip a fuse or circuit breaker and cut off power at the source, hopefully before anything can get red-hot inside the cab.

  This alone makes grounding a must, since the combination of electricity and exposed metal surfaces creates a real risk to human safety in the absence of proper grounding.

- Static electricity protection. Semiconductors are extremely sensitive to static electricity. You can destroy a computer chip or transistor just by touching it if you have a static charge on your body. The cab itself can accumulate a static charge as well, which can likewise be a threat to the chips inside the cab. Grounding the metal parts in the cab neutralizes any charge on them, and neutralizes the charge on your body when you touch them.

  Grounding the metal parts is a huge convenience any time you're working inside the cab, because it lets you discharge any static on your body simply by touching the side rails or lockbar. That greatly reduces the chance that you'll zap any chips you touch.

- Radio interference shielding. Virtual cabs have computer motherboards and other electronics inside that both generate radio frequencies and can be affected by radio waves in the air. The big metal parts in a cab can act like antennas to transmit and receive this energy. Grounding the metal parts prevents that, and reduces the ability of radio waves to penetrate in or out of the cabinet. This will reduce the chances that your cab will interfere with nearby Wi-Fi networks or garage door openers or cell phones, and it'll help avoid things like picking up local radio stations on your cab speakers.

When to install

Grounding is infrastructure work that should be done early in the build. The best time is after you've assembled the cabinet body and installed the metal trim parts, and before you've started installing the internal components (PC, TV, feedback devices). Running the grounding wire is easier while the cabinet is still mostly empty.

Parts

The ideal type of wire to use for grounding is *flat copper braid*. This is a bare (no insulation) wire bundle with a large number of small wires woven into a wide, flat braid.

Braided wire is great for this because it has high current capacity, and the flat form factor makes it easier to connect to metal parts by providing a large surface for contact. The high current capacity is important because the whole point is to carry the large surge current that would occur if a power supply voltage is ever shorted to ground. The ground wire has to be robust enough that it won't melt before the fuse or circuit breaker trips and cuts off the power at the source.

I'd recommend 1/4" (or larger) tinned copper braid. 20 or 25 feet should be adequate. You can find this at electronics vendors, Amazon, or eBay.

What is Earth ground?

Earth ground is pretty much what it sounds like: an electrical connection into the soil. If your house is wired properly, there's a big metal stake driven into the ground somewhere in or around your foundation, and the stake is wired to the "third prong" in all of the AC outlets in your house. In the US, that's the round prong at the bottom of the plug. (In older houses, a buried water pipe might serve in place of a metal stake, and in older houses still, where the old two-prong outlets are installed, you might not have any Earth grounding at all.)

For the purposes of a pin cab, we rely on the house wiring to provide the connection to Earth ground, via that third prong on the AC plug.

How to connect to the Earth ground

One end of your grounding wire needs to connect to the Earth ground in your house wiring. To get there, we can piggy-back on the AC power connection you're using for your PC power supply. That should have a three-conductor power cord, since your PC power supply needs to be grounded.

There are several ways to tap into that ground connection. The best option will depend on your setup and the type of power supply you're using, so look these over and pick the one that works best for you.

Option 1: ATX case

If your PC power supply has a bare metal case, the case itself can serve as the ground connection.

Any ATX power supply with a metal case will have its case connected to Earth ground, for the same safety reasons we need to ground the metal parts on the pin cab. If the case isn't painted, you should be able to get good electrical contact to ground using with the case itself.

It's a good idea to test this with a multimeter, to make sure there's not some kind of coating that insulates the case. With the PSU unplugged from power, and your meter set to resistance (Ohms) mode, measure the resistance between the ground prong on the power supply's AC wall plug (in the US, that's the round bottom prong) and random points on the exterior of the case. It should read close to zero Ohms (you might see a very small resistance on the order of 1 ohm or less). If you get consistent near-zero readings at various random points on the case, the case will make an excellent grounding connection.

To connect the ground braid to the power supply case, you can simply pin the braid under the power supply, pinching the braid between the PSU and the cabinet surface where you're installing it. As long as the PSU is attached tightly to some surface, pinning the braid under it should keep the braid in place and provide a nice solid electrical connection.

Option 2: ATX case screw

If your PC power supply has a painted or lacquered case that prevents the first approach, you might still be able to use the case, by connecting to one of the mounting screw holes - the screw holes intended to be used for mounting the PSU inside a PC tower or desktop case. Even if the case is painted, there's a good chance that the threaded screw holes will be conductive.

You should be able to check this visually. If the threads look metallic, this is probably a good place to connect.

If the visual check looks promising, try the multimeter test. With the PSU unplugged from power, and your meter set to measure resistance (Ohms), test the reading between the ground prong on the PSU's AC wall plug (the bottom round prong, in the US version) and the threads in the screw hole. If you see a reading close to zero Ohms, you have a good place to connect ground.

To use this method of connection, you'll need:

- About 2 feet of 14 gauge (or thicker) wire
- An unpainted metallic #6-32 x ¼" machine screw
- A "ring" terminal that fits around the screw and that fits the wire

To install:

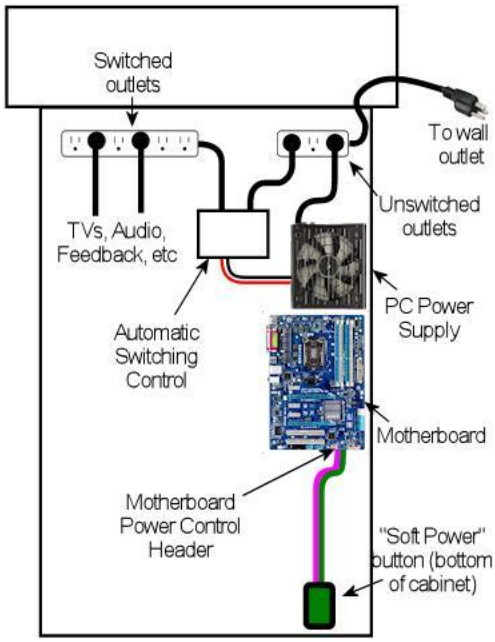
- Cut the wire to about 2 feet
- Attach a ring terminal to each end (by crimping or soldering, according to what kind of ring terminal you're using)
- Slip one of the ring terminals over the screw, and screw it tightly into the case
- Slip the other ring terminal over a wood screw, and then screw it *through the grounding braid* and into the cabinet wall

The last step can wait until you're ready to install the power supply in the cab. The dangling ground wire should serve as enough of a reminder, but put it on your to-do list if you think you might forget! And when you're running the grounding braid around the cabinet, make sure you bring it close enough to the area reserved for the power supply that the ground wire will be able to reach it easily.

Option 3: AC plug

If you can't find a way to make a connection to your ATX power supply, you can connect directly to the power line. I don't recommend this approach unless you have some electronics experience, since it requires cutting into the main AC power wiring. This approach also has the downside that it doesn't make the ground connection as permanent as the others, since it uses a removable plug. Someone down the road might decide to unplug it because they want to use the outlet for something else, without realizing how important it is to leave it in place.

In order for this approach to work, you'll need a setup that follows the basic plan we outlined in Chapter 12, Power Switching. Something like this:



Specifically, you'll need an unswitched power strip that connects directly to the wall outlet. All of the outlets on that power strip will have a connection to Earth ground through the wall outlet plug, so we can get the Earth ground connection we need inside the cab via an unused outlet on the power strip.

The idea here is simple: we need a power cord that *only* has a connection to the ground prong in the outlet. I can suggest three ways to achieve this:

- Buy a "ground plug", such as a "Desco universal ground connection" or "StaticTek banana jack outlet plug ground adapter" (try Amazon or eBay). These are AC plugs with dummy prongs for the two power prongs, and a ground prong that connects to a banana jack or similar connector. They're designed to be used with anti-static wrist straps and mats for doing electronics work. You'll also need a banana plug that fits the jack. Attach a wire (14 gauge or thicker) to the banana plug; plug it in the jack and secure it; and connect the other end of the wire to the braid.

  This approach has the advantage that you can't get the wiring wrong, since the ground plug only has a connection to the one ground prong. The downside is that the banana plug isn't permanently installed, so it could fall out, disconnecting all of the ground connections you went to all this trouble to install. If you go this route, I'd find some way to permanently secure the plug so it can't fall out, perhaps with electrician's tape or heat-shrink tubing.

- Buy a replacement power supply cord (making sure it's the 3-prong type). This has a regular AC outlet plug at one end and three insulated wires (black, white, and green) coming out the other end. The **green** wire is the one that connects to the Earth ground prong. Use wire nuts to cover the white and black wires, which you **don't** want to connect to anything, and secure with electrician's tape. Connect the green wire to the braid.
- Buy a replacement power plug (e.g., Leviton 3W102-E, GE 54301 household plug). This is similar to the above but doesn't have any wires attached - it's *just* the plug, with screw terminals to attach wires. I like this option a little better than using a cord because you don't have to secure any stray wires. Simply connect a 14 gauge (or thicker) wire to the ground screw terminal (which is usually indicated by a green screw, or might simply be labeled "ground" or "Earth"). Leave the other two terminals unconnected. Connect the other end of the wire to the braid.

For all of these options, plug the plug into a free outlet on the unswitched power strip. Connect the ground wire from the plug to your braid with a "ring" terminal: connect the ring terminal to the wire (by crimping or soldering, for example), slip the ring over a wood screw, and drive the screw *through the braid* into the cabinet wall or floor.

Whichever type of ground plug you choose, it would be a good idea to do something to lock the plug into the outlet it's using, so that it doesn't fall out on its own and so that you don't remove it while working on something and forget to put it back. This is the crucial link for all of the grounded metal, so it should always be connected. Wrap a couple of loops of electrician's tape around the plug and the power strip, for example. At the very least, put a big "do not unplug" placard on it.

Option 4: Tap into the power strip

If you're confident that you know what you're doing, there's a better alternative to the approach above: tap directly into the power strip's internal wiring. It's better in that it's not easily undone (unlike the plug-in approach above, where someone could unplug the plug, thinking it's not important). But it's dangerous unless you know exactly what you're doing, since it requires modifying the power strip.

The idea is to connect an additional wire directly to the ground wire in your main unswitched power strip.

- Open up the power strip (by removing its case)
- Identify where the ground wire from the cord connects to the internal wiring
- Connect a length of 14 gauge (or thicker) wire to this point (using whatever technique is appropriate to the way the power strip is constructed: solder the new wire to the existing wire, add it to the existing screw terminal, or whatever else works)

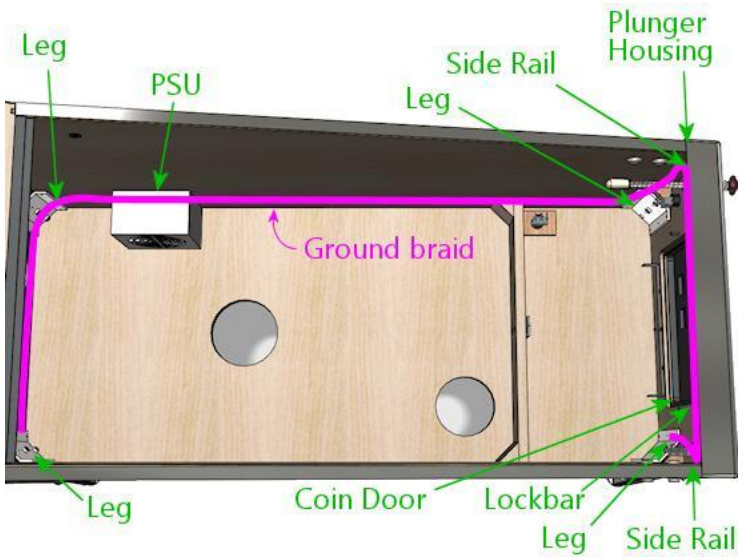
- Find a way to route the new wire out of the power strip's case, perhaps by drilling a hole somewhere for it
- Reassemble the case with the newly added wire routed through to the outside
- Connect a ring terminal to the other end of the wire
- Slip a wood screw through the ring terminal, and drive the screw through the braid into the cabinet wall

How to connect cab parts to the ground braid

The basic technique is to run a single, uninterrupted braid around the perimeter of the cab, bring it into contact with each metal part that needs to be connected.

The reason it's best to use a single run of wire is that it greatly reduces the chance of severing the connection to multiple parts. Consider what might happen if you daisy chained *separate* wire segments from one metal part to the next: suppose the Earth ground connects to A, and A connects to B, and B connects to C. If the connection between A and B gets disconnected for some reason, you lose not only the connection to B, but also the connection to C. With a single braid, in contrast, the only way that could happen is if the braid itself were to break, which is highly unlikely.

Here's a suggested routing:



Use staples to fasten the braid to the cabinet wall every few inches between connections, so that it doesn't flop around.

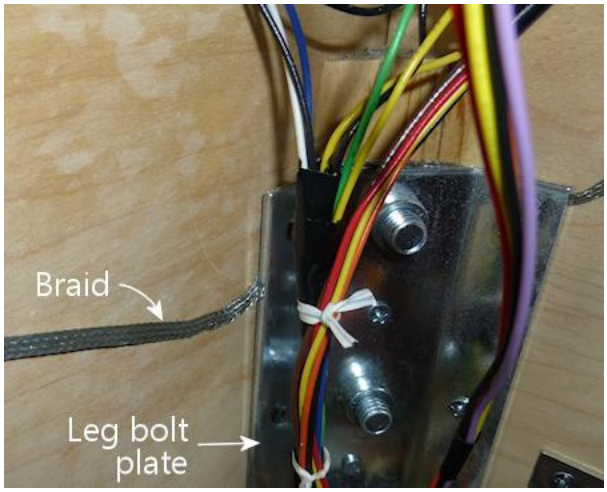
Remember that the ground braid is uninsulated, so you don't want to let it come into contact with exposed terminals on any powered devices. Ideally, you should avoid having any bare wire or exposed terminals (other than the ground braid) in the first place, since they're inherently dangerous. If possible, cover any exposed terminals that are present on devices you install with some kind of insulator, such as heat-shrink tubing, electrical tape, or a plastic cover.

To connect an individual metal item to the braid, all you have to do is bring the braid and the metal into contact.

- For anything that has a large surface that fastens tightly to the cabinet, a great way to accomplish this is to run the braid under that part, sandwiching the braid between the part and the cab. This provides a large contact area, ensuring a good electrical connection, and secures the braid in place mechanically. It also has the virtue of being easy to set up.
- Alternatively, if there's a place where a metallic screw is attached to the item, you can drive the screw through the braid, or pin the braid under a washer held down by the screw.

Legs

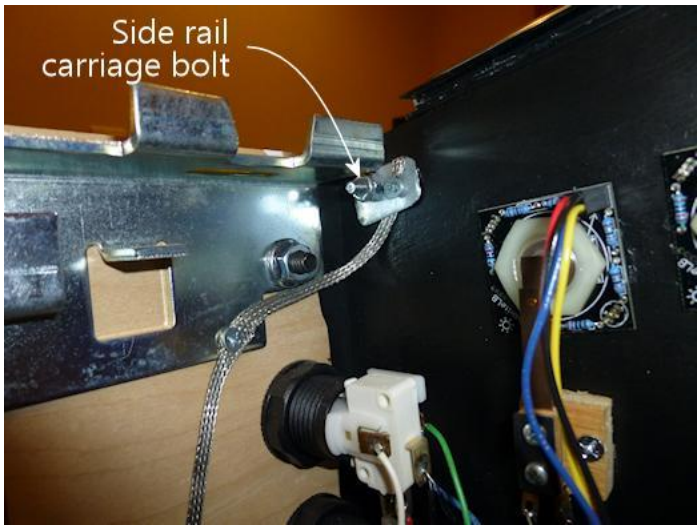
Simply run the ground braid under each leg bolt plate.



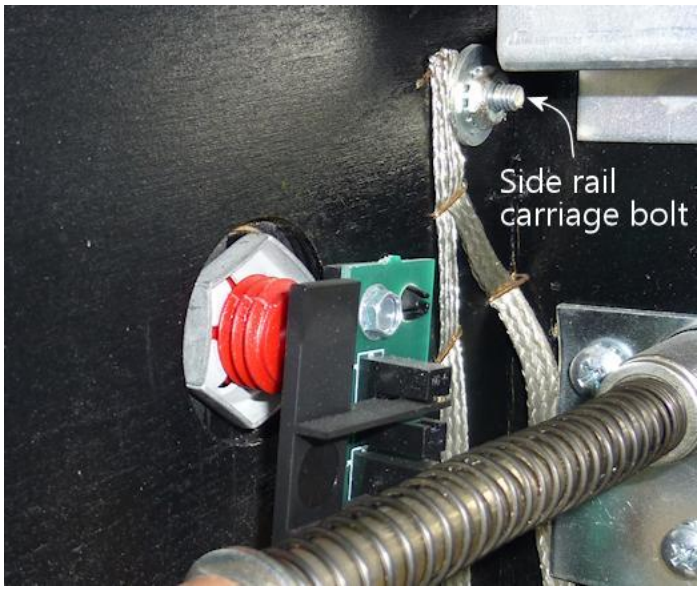
Side rails

The side rails are held on by carriage bolts at the front. Those are metallic, and they're in contact with the rails, so we can ground the rails by grounding the bolts. The bolts don't by themselves offer much surface area to make contact with the ground braid, though, so we have to add something to serve as a connector.

My approach was to use a small metal plate with two holes, one for the bolt itself, and a second for a wood screw. I ran the braid under the plate, and fastened the wood screw through the braid to ensure a solid electrical connection.

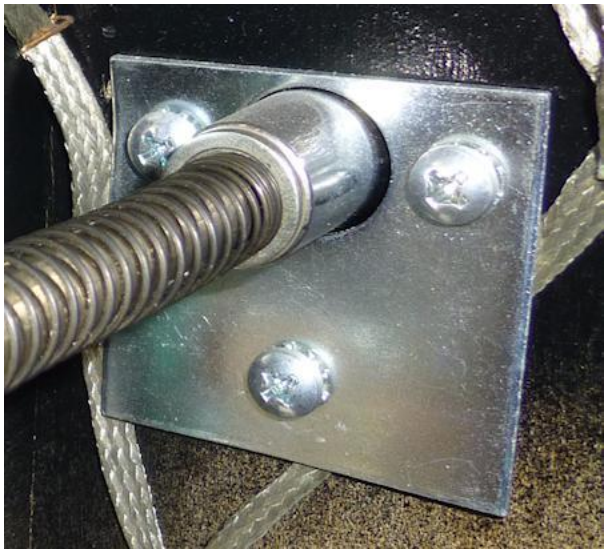


On some of the real machines, they simply pin the braid under a washer.



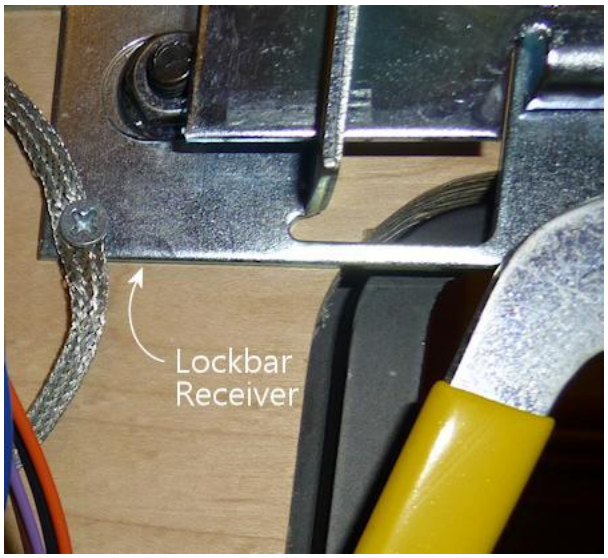
Plunger housing

Run the ground braid under the mounting plate, or fasten it with a wood screw through one of the free holes in the plate.



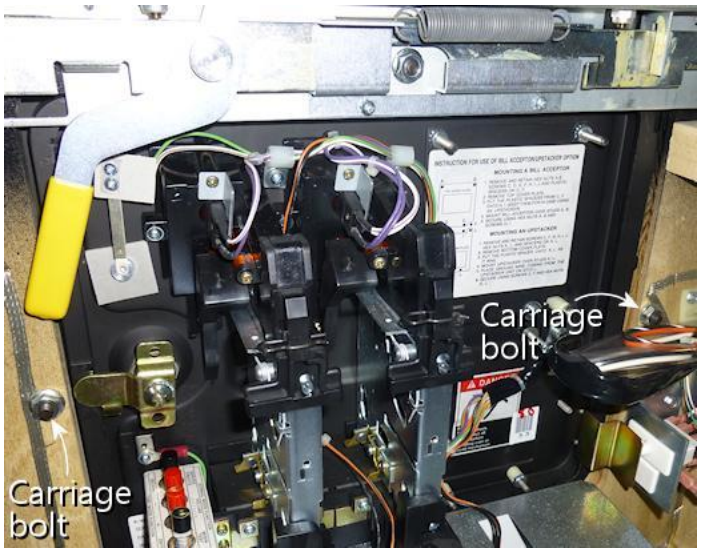
Lockbar

Route the braid under a portion of the lockbar receiver where it attaches to the front wall, or fasten it with a wood screw through one of the free holes in the receiver.



Coin door

You can ground the coin door through the carriage bolts that attach it. (It'll also be grounded indirectly through the lockbar receiver, assuming you've grounded that, since the top coin door bolt also is in contact with the receiver.) Run the ground braid alongside one or two of the carriage bolts on either side of the door, and pin it under a washer.



Backbox

There's not any metal trim in the standard backbox setup, so you might not need to extend the ground wire there. However, the real machines do, because they have some hidden metal pieces that benefit from grounding. In particular, they place a metal grating over the vent holes along the top of the back side of the backbox, primarily to serve as radio frequency shielding. That needs to be grounded to be effective as shielding. They also run the ground braid under the metal backing plates that mate with the carriage bolts that fasten the hinge arms, as safety grounding for the exposed carriage bolt heads. (I guess there actually *is* some metal trim on the backbox, if you count those bolts.)

If you do want to run a ground wire to the backbox, I'd use a separate braid loop in the backbox, and connect it to the braid in the main cabinet via a run of regular hookup wire (14 gauge or thicker). The reason to use hookup wire to bridge the sections is that this portion will need to be long enough to cover the added distance when the backbox is folded down.

Testing

Before declaring the grounding project complete, test that you have a good connection between the metal parts and the ground plug on your main power inlet.

Set your multimeter to resistance (Ohms). With the power unplugged from the cab, measure the resistance between the ground prong on your main AC power plug for the cab and each of the exposed metal parts. It should read close to zero Ohms in each case.