Cutting the top edge at angle as shown results in the best fit. But if you want to keep it simpler, I think it's okay to skip the angle and cut it square, using the shorter **exterior** height. Using a square cut means that the back top edge won't quite align with the top edges of the side walls. But this whole area is covered by the lockbar when the machine is assembled, so it'll only be visible at all when you remove the lockbar to access the interior. The gap won't affect alignments for any of the trim hardware, so it won't have any functional impact.

If you do use the sloping top edge, note that all of the measurements shown in our diagrams and plans are based on the **front** face - the shorter exterior side. Things will be off by ⅛" if you measure with reference to the top edge of the back side, since it's slightly taller. So be sure to do all of your measuring and drilling from the front side.

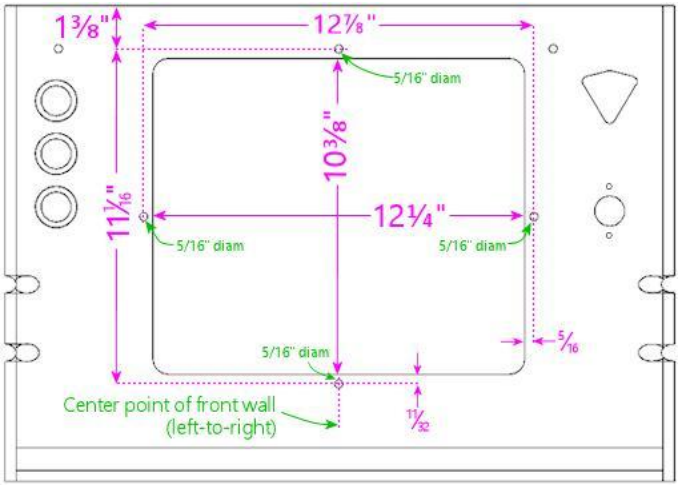
Edge finishes

The original WPC cabinets use a slight chamfer (a 45° bevel) on the outside bottom edge of the front wall, to soften the edge and reduce splintering. This is optional, but it's a little nicer than a sharp square plywood edge. See Edge finishes above.

Coin door cutout

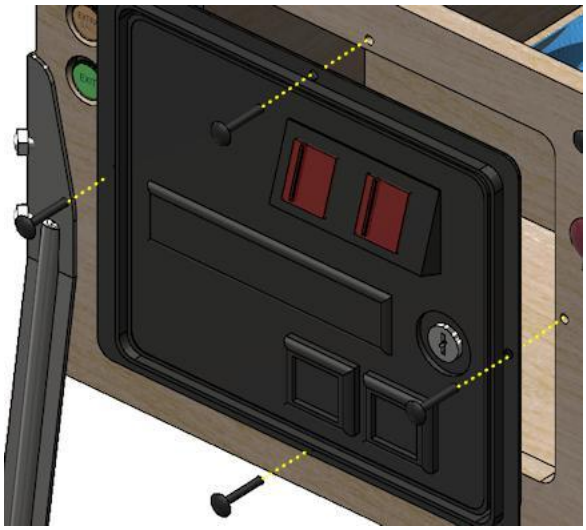
The rectangular cutout in the center of the front wall is for a standard pinball coin door, of the style used on 1990s-2000s machines. All of the doors used by all of the manufacturers from the mid 1980s onward have the same dimensions, so you can use any late-model Williams or Stern parts. SuzoHapp makes a universal replacement door that fits the same cutout. Older doors from before the mid 1980s might have different sizes, so measure your actual hardware first if you're using an older model.

Note! The gaps between the coin door cutout and the four bolt holes around the perimeter are very small (only about 3/16"). Be as precise as you can when measuring, and be careful when drilling.

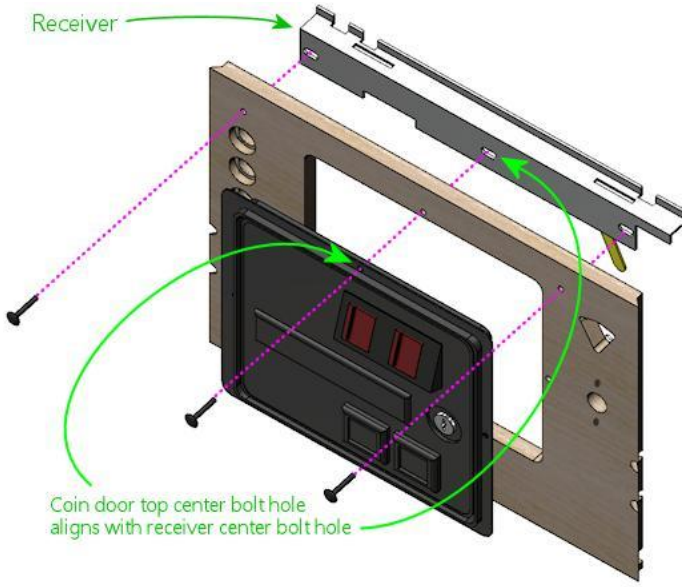


*Coin door cutout and bolt locations, viewed from the **interior** face of the front panel. Important: the measurements referenced to the top edge will be slightly different (about 1/8" less) when measured on the exterior face, because of the angled cut on the top edge. The interior face is about 1/8" taller than the exterior face because of the slant.*

The four 5/16"-diameter drill holes around the perimeter of the coin door cutout are for the carriage bolts that fasten the door to the plywood. Use ¼"-20 x 1½" carriage bolts for these. Mate them to ¼"-20 hex nuts, which go on the inside. The carriage bolts are available in black, which is what the WPC machines use to match the powder black finish of the WPC-style doors. The bolts are also available in stainless steel, chrome-plated steel, and silicon bronze, one of which might look nicer if you have a door with a metallic finish.



The coin door is usually centered left-to-right. If you're using a custom width, simply figure the position so that it's centered horizontally. **Don't** try to center it vertically, though. The vertical position has to align with your lockbar receiver, because the coin door's top center bolt hole has to align with the receiver's center bolt hole, as illustrated below.

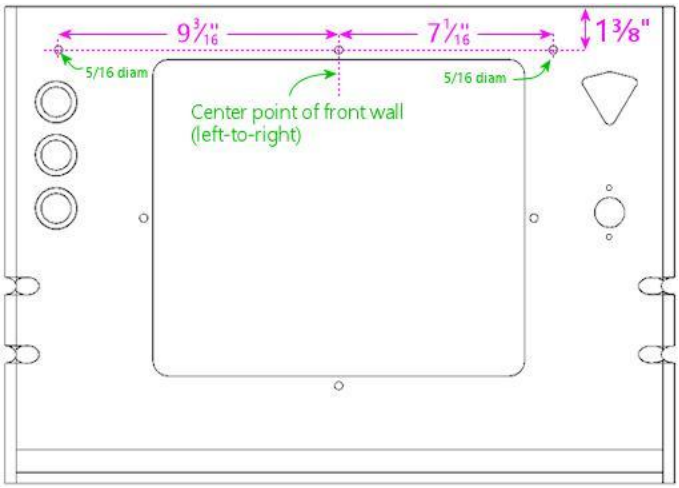


If you're using the standard WPC-era parts (a 1990s coin door and a Williams WPC lockbar receiver), the vertical position shown in our diagrams should align the receiver properly. If you're using different parts, they might have a different design, so you might need to adjust the vertical position to match. See the "dry fit" procedure in the lockbar receiver section below for advice on how to figure the right position for different parts.

If you're not using a coin door at all, you should obviously omit the rectangular cutout, as well as the drill holes around the perimeter. Note that the top center hole is shared by the coin door and lockbar receiver, though, so if you're using a standard lockbar receiver, you'll still need to drill that hole even though you don't need it for the coin door.

Lockbar receiver

The three small drill holes shown at the top of the front wall plan are for the carriage bolts that fasten the lockbar receiver to the front wall. (If you're not sure what the receiver is or what it's for, we'll explain more about it shortly.)



As with the coin door, use the center point of the front wall (left to right) as the horizontal reference point for the center hole.

The receiver has to be positioned vertically so that the lockbar will fit properly when inserted into the receiver. The vertical position of the bolt holes in our plans is specifically for a Williams WPC lockbar receiver, to place it at the right height so that the lockbar will fit properly.

But be warned! Our plans assume that you're using the WPC lockbar receiver, *and* that you're using all of the mating parts, including standard side rails with glass guides. The thickness of the rails and guides is important to the overall positioning.

If any of this is different in your setup - different brand of lockbar, different generation, different side rails, no side rails - then you'll probably need to adjust the position. It's difficult to figure the right position on paper because there are so many factors. It's easier and more reliable to just measure it with a mockup or "dry fit" with all of the parts together. That means that you set up the parts in their assembled positions without actually gluing or fastening anything yet:

- Set up the front and side walls in their assembled positions.
- Set up the side rails with the glass guides, if they'll be part of the final setup.
- Plug the lockbar into the receiver.
- Position the lockbar at the top front where it'll be during normal use. You want the lockbar to sit snugly on top of the side rails when everything is put together, so at this stage it's a good simulation to simply set the lockbar on top of the rails.
- Now hold the receiver's front surface flush against the inside front wall. Make sure the lockbar is still where you want it.
- Mark the positions on the inside of the front wall corresponding to the positions of the three bolt holes in the receiver. (The bolt holes in the receiver are actually little slots, to give you a little wiggle room to make up for measuring errors, so mark the position at the center of each slot.)

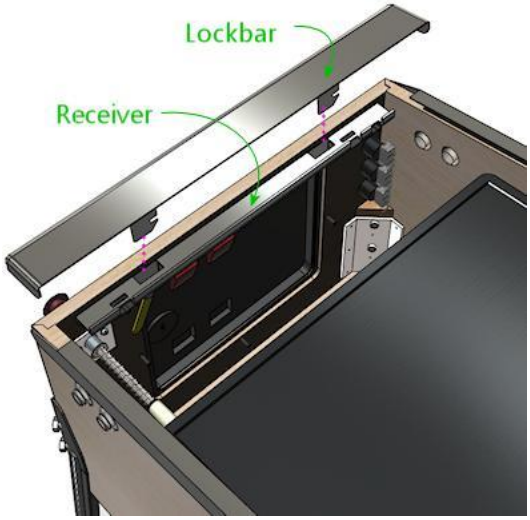
You can now take it all back apart, and drill at the marked positions instead of the ones in the plans.

If you're not using a standard receiver, you can omit the left and right drill holes. The center hole is still needed for the coin door, if you're using one, even if you don't need it for a receiver.

In case you're not already familiar with how all of the pinball trim pieces work, here's a brief overview.

The "lockbar" (also known as the "lockdown bar") is the metal trim piece along the top front edge of the machine. It's so named because it serves to lock the top glass cover in place. It also functions as a trim piece, for the sake of appearance as well as to provide a comfortable place to rest your hands while operating the flipper buttons. Standard lockbars have nice smoothly rounded corners. Try playing a round on a machine with the lockbar removed if you want experience for yourself how unpleasant the plywood edges are as a hand-rest.

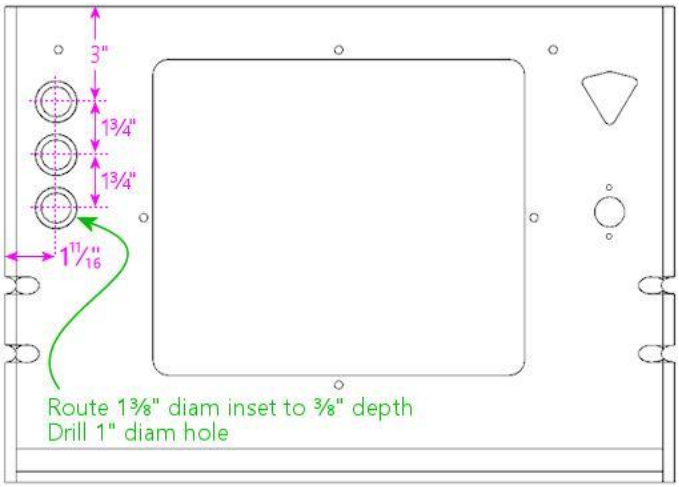
If you're using standard pinball parts, the lockbar mates with a part inside the cabinet called the "receiver". A couple of prongs that stick down out of the lockbar fit into receptacles in the receiver, where there are some spring-loaded latches that grab the prongs and secure the lockbar. A lever on the receiver, which you can reach through the coin door opening, lets you release the latches and free the lockbar. With the lockbar off, you can slide out the glass to access the interior. It's all cleverly designed to let an operator open up the machine quickly and without any tools, while keeping it buttoned up against intrusion by mischief-makers.



The receiver attaches to the inside of the front wall of the cabinet. It's fastened with three carriage bolts. This is what the drill holes at the top of the front wall are for. The center bolt is shared between the coin door and receiver - both parts have holes in this position that align when everything is assembled. This is why the vertical position of the coin door is so important: the coin door aligns with the lockbar receiver, and the receiver has to align with the top of the wall so that the lockbar fits properly.

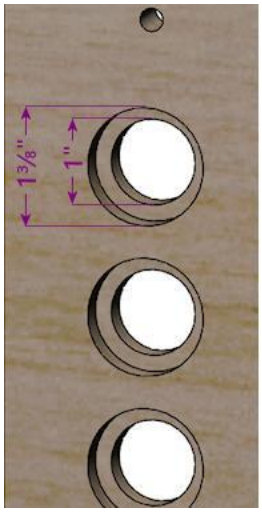
Front panel buttons

The three large circular holes at the top left of the front panel diagram are for buttons that the player uses to start and exit games and otherwise interact with the software. Our plans assume that you're using SuzoHapp small pushbutton (pictured at right), which are the type used for most of the front-panel button on real machines since the 1990s. These are the exact type that most pinball suppliers will sell you if you buy a replacement Start button, Extra Ball button, or generic "pushbutton with lamp assembly". There are other similar buttons available from other companies that you can use as well, but you might need to adjust the drilling dimensions and/or spacing for other models.



Attention: Reproduction cabinet builders: If you're building a cabinet for a real pinball machine, you should adjust the button layout to match the original design of the machine you're reproducing. Take care to line up the button positions with corresponding designs in the artwork, if any.

For the standard pushbuttons, drill the holes in two stages. First, route a 1⅜"-diameter depression on the exterior face to about half the plywood thickness (⅜"). That's the larger circle depicted in each button hole. Then route or drill a 1" hole the rest of the way through, on same center as the routed depression. If you're using a drill, use a 1" hole saw or Forstner bit to do it cleanly. (Don't use a spade bit; spade bits make ragged holes in plywood.) The depression recesses the pushbutton enough that it's flush with the front surface of the cabinet, which makes for a nicely finished look.



Above left: Drilling detail for the button holes, viewed from the exterior face. Route a 1⅜" diameter depression to ⅜" depth (about halfway through the plywood). Drill a 1" diameter hole the rest of the wall through, on the same center, using a router or a drill with a hole saw or Forstner bit. Above right: when installed, the buttons are recessed in the routed depressions, so the button faces are roughly flush with the outer surface of the cabinet.

The routed depression is optional. It's the way that the buttons were mounted on the real 1990s machines, and I think it makes for a clean, finished look. But if you want to keep things simpler, you can skip the routed inset and simply drill a 1" hole straight through. The buttons will jut out by about a quarter inch if you omit the inset, but this won't look "wrong", since the buttons are trimmed to work with this mounting style as well.

Our plans show the positions for three buttons, but you can vary this slightly. As far as software usability goes, the virtual pinball software more or less requires a minimum of two buttons: "Start" and "Exit". The third button in our plans can assigned be any extra function of your choice. See Chapter 34, Cabinet Buttons for recommendations. I think it's a good idea to include *some* third button even if don't have a clear use in mind, just for the sake of flexibility. I assigned my third button as "Extra Ball", since that's used on a lot of real machines from the 1990s. Another useful function is "Coin In" (to simulate inserting a coin), although I prefer implementing that via the coin return buttons on the coin door, since that's a more natural and inconspicuous place for it. In any case, if you change your mind about the button's function later, it's easy to reassign these buttons in software, and relatively easy to relabel them physically.

Omitting a button is easy. If you only want to include two buttons, simply drill the top two holes at the positions shown, and skip the bottom one.

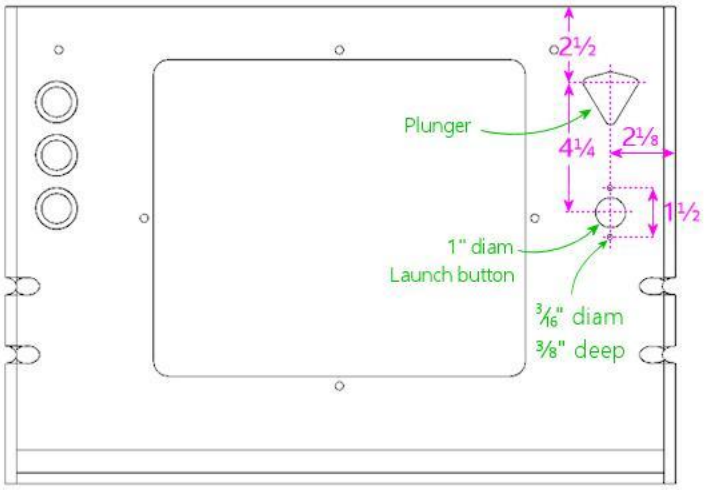
Adding buttons is more difficult, as space is tight. With the three buttons positioned as shown, there's not enough room for a new fourth button at the top, since the lockbar receiver will get in the way, nor at the bottom, where the leg fasteners will conflict. However, you just barely make room if you move the top button up about ½" (that's the limit before it conflicts with the lockbar receiver) and then tighten up the spacing on the other buttons by about ⅛". That will give you just enough room for a fourth button at the bottom.

Plunger and Launch button

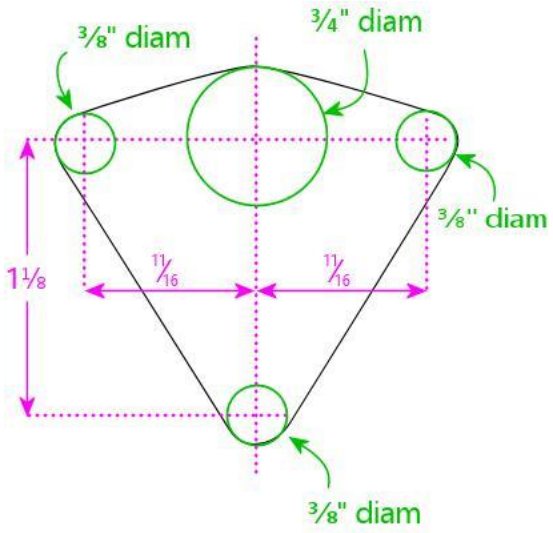
Our plan includes a traditional mechanical plunger, at the standard position used on nearly all real machines, at the upper right corner corner of the front face. We also include a Launch Ball button, situated just below the plunger, to accommodate tables that originally used a button or trigger in place of the traditional plunger.

Be aware that this traditional plunger position doesn't work for everyone! In particular, it can get in the way of the TV if you want to place the TV very close to the front wall. See "Other plunger/Launch button layouts" below for an alternative plan that swaps the positions of the plunger and launch button to make room for the TV. If you haven't thought about the TV conflict issue, see "The dreaded plunger space conflict" in Chapter 29, Playfield TV Mounting and "Positioning the plunger" in Chapter 37, Plunger.

Attention: Reproduction cabinet builders: If you're building a cabinet for a real pinball machine, be aware that the plunger position varies by machine, because it has to align with the shooter lane on the playfield. The position in my diagrams is based on measurements from a couple of WPC machines, but other titles might vary from the ones I sampled. System 11 machines generally need the plunger cutout to be about 1" higher because of the shorter playfield hanger brackets they use. Take measurements from the original cabinet you're replacing, if possible, or ask for help on an owners forum. fr



Drilling positions for plunger and Launch Ball button, with the plunger in the standard position used on real machines, and the Launch button below.



Drilling pattern for the plunger opening. Reference the vertical location from the main plan to the top dotted line. For the standard plunger-on-top configuration, this is 2½" from the top of the panel.

To cut the plunger opening:

- Drill a ¾" hole at the large green circle at top center. It's best to use a router, or a drill with a hole saw bit or Forstner bit. (Don't use a spade bit; they make ragged, chipped holes in plywood.)
- Drill ⅜" holes at the three smaller green circles.
- Use a jigsaw to cut along the perimeter of the shape described by the four holes, shown as the black outline on the diagram.

The illustration at right shows how this looks when assembled.

This arrangement with the plunger on top and a Launch button below is the one I prefer. It has two main virtues. First, it looks like it should, because the plunger is at exactly the standard position used in practically all real machines. Second, it's nice to have the dedicated Launch button for tables that use one, and this placement looks natural. You won't actually find any real tables that have both the plunger and the Launch button, so it's artificial in that strict sense, but it *looks* perfectly normal even

so, because plenty of real machines have some sort of extra control below the plunger (e.g., an Extra Ball button).

Other plunger/Launch button layouts

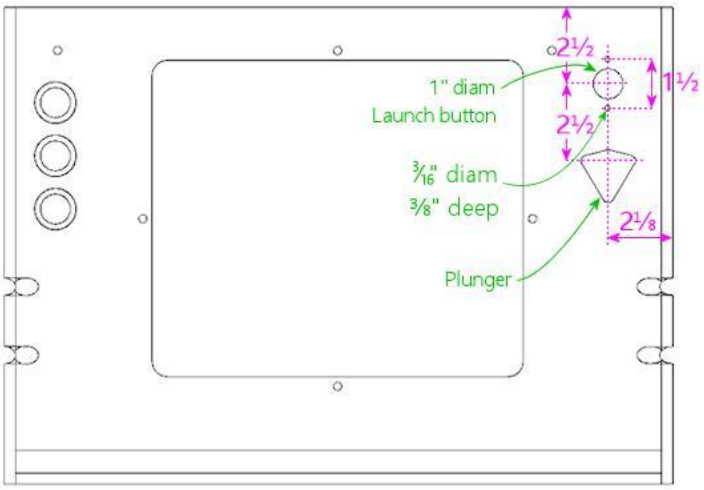
The traditional plunger location shown above doesn't work for everyone, because it can create a space conflict with the TV if you want to position the TV at the very front of the cabinet. Before you drill anything, take a moment to consider if you'd prefer some other setup. Here are the most common options:

- Include only the plunger, with no Launch button. Some people prefer a more authentic setup with just the plunger. This an easy modification: just don't drill the hole for the Launch button.
- Invert the arrangement so that the Launch button goes on top and the plunger goes below. Some people use this arrangement to make room for the TV to fit closer to the front of the cab. To make this change, use the inverted plan below.
- Include only the plunger, but lower it to get it out of the way of the TV, so that the TV can be mounted closer to the front of the cab. To implement this, use the inverted plan below, and skip drilling the hole for the Launch button.
- Include only the Launch button, with no plunger. To do this, use the inverted plan below, but don't cut the plunger opening.

For more advice on choosing among these options, see Chapter 37, Plunger.

Inverted plunger/Launch button

Here's the inverted layout, with the plunger below the Launch button. This places the Launch button at the exact position used on real machines that use this control (which also happens to be the standard plunger position, not surprisingly), so it'll look authentic as far as that goes; of course, the addition of the plunger below the button isn't to be found on any real machines.



Inverted arrangement with the Launch button on top and the plunger on the bottom.

Note that the spacing between the plunger and Launch button is a tiny bit tighter with the inverted layout than with the normal layout (by about an eight of an inch). This is due to space constraints. The plunger can't safely be moved much lower, because the exterior side of the plunger housing will conflict with the front right leg if you do. If you really need to move the plunger even lower than shown (to make room for the TV, for example), you might be able to eke out a few extra 16ths of an inch, but it might be an uncomfortably tight fit. Measure your actual parts carefully before making changes.

Other cutouts

I don't recommend any other controls or ports in the front wall, since this is the most conspicuous part of the machine other than the playfield area, it's already pretty busy with just the standard controls. However, there are a few extra items that some people add here:

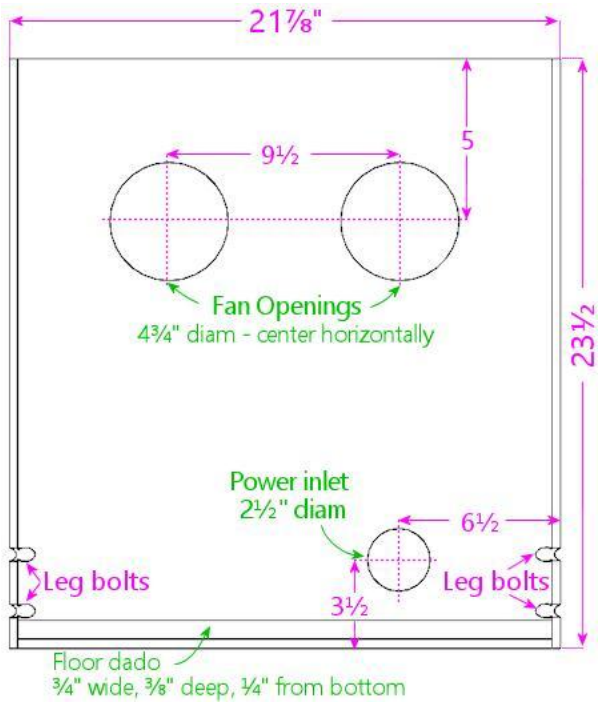
- Volume controls
- Night mode switch
- USB/keyboard/mouse ports

I'd personally avoid the front panel for all of these and place them on the bottom or back of the cab instead, where they'll be less visible.

For volume controls, I'd recommend using doubled-up flipper buttons instead of a separate knob (see my PinVol page for an explanation). But if you really want a separate knob, and you don't want to have to reach under the machine to operate it, one way to make it inconspicuous is to install it in the coin door, by drilling a hole for the knob stem.

Rear wall

After the insane complexity of the front wall, it'll be a welcome relief that its posterior counterpart is rather simple.



Rear wall, viewed from the interior side.

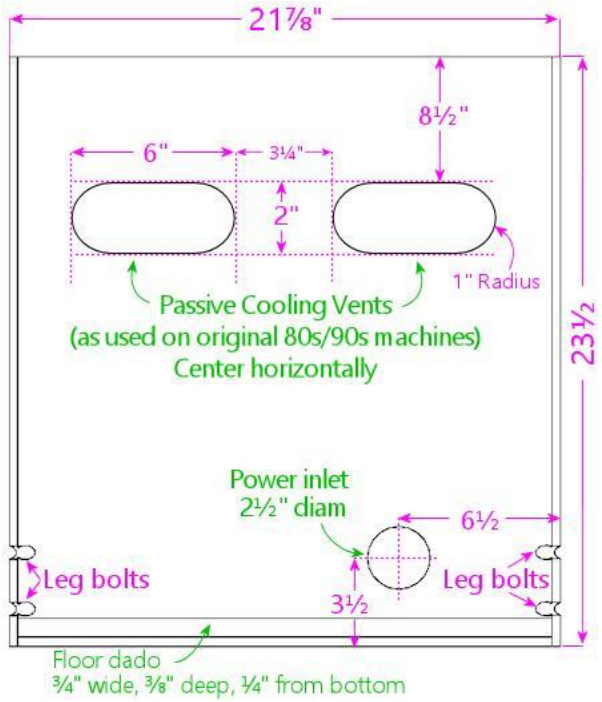
The fan openings are designed to accommodate 120mm PC case fans, mounted just behind the openings (on the inside of the cab) and oriented to blow air out the back. These aren't authentic to the original WPC design (for the original layout, see the diagram below). The WPC machines had smaller, passive vents. Most virtual cab builders want to include fans to actively blow air through the cabinet for cooling, which the larger openings accommodate.

The power inlet opening is there to pass the machine's main power cord through the back, for plugging into a wall outlet. This is the same as the original WPC equipment, which has a C14 power inlet (the same type of power cord connector used on most desktop computers) behind the opening.

The size and placement of the fan openings and power inlet are merely suggestions. Customize them as you see fit. Take care that anything you install on the back wall

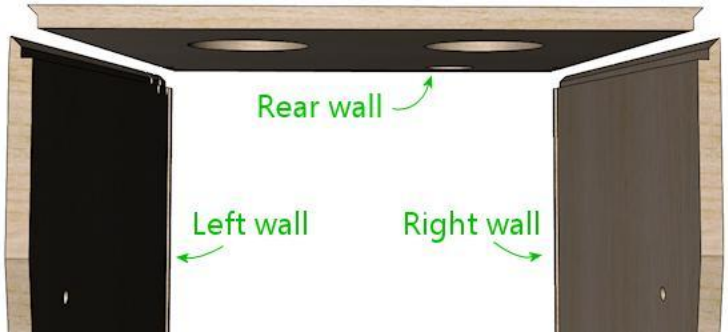
doesn't get in the way of the playfield TV, but that usually isn't a problem, since the back end of the TV is usually well forward of the back wall. The leg notches and floor dado should be implemented as shown, since those do have to align with other parts.

Attention: Reproduction cabinet builders: The circular fan openings shown in the diagram above aren't authentic to the original WPC cabinet design. The Williams cabinets of the 1980s and 90s did have vents in the same area, but they were smaller and were purely passive (no fans). The original layout is shown below.



Original rear wall design used on the real machines, with passive cooling vents instead of fan openings, viewed from the interior side. This is the layout of the Williams cabinets of the 1980s and 1990s. Virtual cab builders usually replace the vent slots with larger circular openings that can accommodate PC case fans, to provide active cooling. Virtual cabs tend to need active cooling in the main cabinet because they typically house a TV and a PC motherboard, both of which can generate a lot of heat.

Most people use the same joinery style for the rear wall as for the front wall, but that's not required. I think a mitered join (such as a mitered rabbet or lock miter) is nice here, since it yields seamless corners, but that isn't as important here as in the front, since the back wall isn't as visible. A simpler join that produces visible seams, such as a rabbet or even a butt join, can be perfectly adequate aesthetically.



Top view of rear section, showing the joinery shapes at the rear corners. This uses the mitered rabbet as described in the side walls section earlier.

The leg bolt notches work exactly like on the front and side panels. Use the same measurements as the **rear** leg notches on the side panels, since those need to align with the ones on the back wall when the cabinet is assembled. See the side wall section above for details.

The floor dado is a routed groove. The floor will slip into this groove when you assemble the cabinet. This is the same as the floor dados on all of the other pieces: route a ¾" wide groove, ⅜" deep (about half the thickness of the plywood), in a straight line ¼" from the bottom of the wall. See the side wall section above for a diagram.

Power inlet

The hole near the lower right of the back wall plan is for the main AC power inlet. On the real machines, this is a 2½" diameter hole positioned as shown. There's nothing special about this location for a virtual cab; move it and/or resize it as needed for your own power supply setup. If you're not sure how you're going to set up the main power supply, you can just follow the generic plan, since it's pretty versatile; the opening is large enough that you could just feed a power strip's cord or an extension cord through it, and it could also accommodate a C14 inlet mounted in the opening. You can drill a hole of this size with a hole saw bit, or using a hand router with a circle jig.

Fan openings

The fan holes in our back wall plan represent a deviation from the real WPC cabinet design, to meet the special needs of the virtual cab. Real pinball machines don't need much cooling for the main cabinet, so the WPC cabs just have a pair of small passive vents at the back. Virtual cabs, in contrast, tend to need active cooling with fans, since the main cab has a big TV and (in most cases) a PC motherboard.

Our plans provide two openings in the rear wall designed for PC case fans. The idea is that you place an exhaust fan (blowing air out of the cabinet) on the inside of each opening. The cabinet floor (which we'll get to next) has another similar opening for an intake fan. This arrangement is designed to work with the natural air flow from the tilt of the monitor: the tilt makes the monitor higher at the back, so warm air will tend to flow towards the back of the cabinet as it rises. The exhaust fans at the back will help remove the hot air and pull cooler outside air into the cabinet from the floor vent.

The holes shown in the diagram are for 120mm fans (about 4¾" inches diameter). This is a common size for PC case fans, but other sizes are available; some people like to super-size their fans because larger tends to be quieter. Resize the openings for your fans as needed.

There's nothing magical about our placement of the fan openings, so move them as needed. I recommend keeping them relatively high up on the wall to take advantage of the natural flow of rising warm air. The point is to remove the hottest air from the cabinet, and that will tend to move towards the upper portion of the space.

For more on cooling, see Chapter 28, Cooling Fans.

Other rear wall cutouts

Here are some other optional items that you might want to consider, as long as you're drilling holes in this piece. There's no standard placement for any of these, so use whatever location is convenient for your setup.

- Ethernet port. Wired network ports can come in handy even if you're planning to install a Wi-Fi card or powerline Ethernet. The rear of the cabinet adjacent to the power inlet is an excellent place for this. Keystone jacks are useful here. See "External I/O plugs" in Chapter 27, Installing the PC.
- USB ports. It's also good to have some external USB ports, and the back of the cab makes a convenient place for a couple of these. As with Ethernet, you can use Keystone jacks. If you're installing a Keystone jack plate for Ethernet anyway, you can make it a 3-gang or 4-gang plate and populate it with a couple of USB ports while you're at it.
- Keyboard/mouse ports (these are usually just more USB ports). I prefer the floor of the cab near the front, since that's where you'll actually want to use the keyboard and mouse, but the back of the cab will do if you just want a single cluster of ports.

- Openings to pass wires for light strips on the back of the cab (see Chapter 58, Undercab Lighting)

Back rails

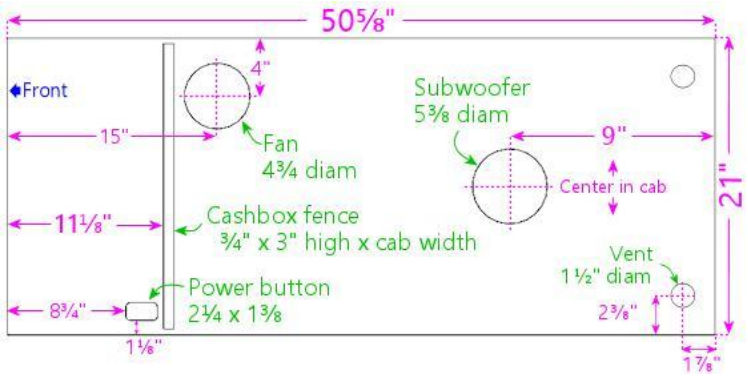
The real WPC cabinets have a pair of wood rails on the back, as illustrated below. Each rail has a pair of hard plastic furniture slider pads attached (the nail-in type, typically 3/4" diameter, white or tan), one at each end. These are designed to let you stand the machine on its back, with the backbox folded. The machine is more compact in this configuration, which can be helpful for moving, shipping, and storage.

These rails are optional. If you want to include them, cut the two strips at the size shown. On the WPC machines, the ends are beveled at about 30°.

Shipping configuration: legs removed, backbox folded down, placed on back. The machine can be strapped to a pallet and boxed or plastic-wrapped. This is good for freight shipping because it has relatively small footprint and it's easy to move with a pallet jack.

Floor

Our plan for the floor of the cab makes some concessions to the special needs of the virtual cab, so its cutouts aren't quite identical to the normal WPC floor design. In particular, we moved the subwoofer from roughly the middle to closer to the rear of the cab, and we added an opening near the front for a PC case fan to actively draw outside air into the cabinet, to supplement the fans at the back that blow hot air out. The power button cutout is also slightly wider than on the WPC machines (1-3/8" in this plan vs. 1-1/8" in the originals), to accommodate an arcade-style pushbutton.



Main cabinet floor, viewed from above.

The joinery for this piece is as simple as can be. Simply cut the edges square. The edges fit into the dados (grooves) in the four walls.

The "cashbox fence" isn't a cutout - it simply marks the location of a short wall installed here on the real machines, mostly to hold the cashbox in place. (The cashbox is a plastic box that sits under the coin slots to collect the booty. It comes in a standard size for Williams machines; you can buy one from a pinball vendor.) If you're not planning to use the standard type of cashbox, you can omit the fence, which will leave more open space for PC parts. However, you'll certainly need *some* sort of container to collect coins, if you're using them; you don't want loose metal discs rolling around your electronics-packed cab interior. The standard cashbox is a convenient solution. But it's also awfully large. On my own cab, I improvised a much more compact coin box using a plastic food container.

If you want to install the fence, it's 3" tall by ¾" thick. Cut the length to match the inside cabinet width. Mount it at the position shown (or whatever position is right for your cashbox, if you use something custom). This isn't a structural element, so it doesn't have to be very strong; you can fasten it with glue and/or nails. Note: the distance shown (11⅛") is from the front of the floor piece, which recesses into the dado in the front wall by about ⅜". If you install this after assembling the rest of the cab, it goes 10¾" from the inside front wall.

The subwoofer opening is shown at the size used in the WPC machines, but the position is further back than in the real machines, where it's closer to the middle (22-1/4" from the back, to be precise). The virtual plan moves it back to create more contiguous floor space for the PC motherboard. I don't think it'll affect the acoustics much (if at all) if you want to move it further back still, for an even bigger stretch of open space.

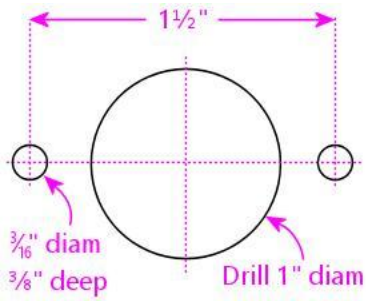
You should consider changing the diameter of the subwoofer cutout to match the speaker you select. The 5-3/8" diameter cutout is based on the 6" speakers used in the WPC machines. Those are small by modern standards; automotive subwoofers are in the 8"-and-up range. If you do use a larger speaker, it'll sound better if the opening is roughly the same size as the speaker aperture.

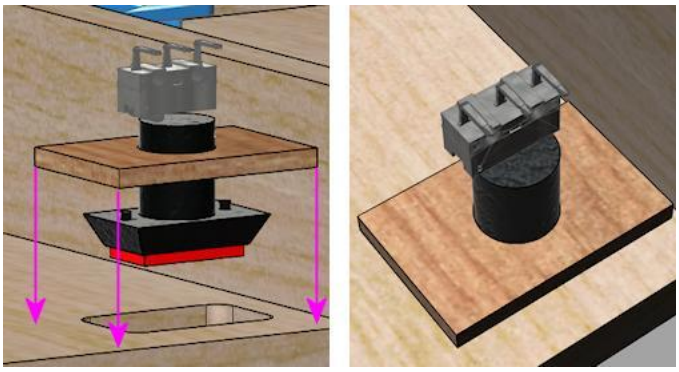
The large fan opening towards the front isn't part of the original WPC design. It's a virtual cabinet add-on for our greater cooling needs. This is meant to be an **intake** fan, with a PC case fan mounted on the interior surface and oriented so that it blows air **into** the cab. This helps draw in cool air from the bottom to replace hot air being blown out by the fans at the back. See Chapter 28, Cooling Fans for more on this subject.

As with the fan openings in the back wall, the position and size shown are only suggestions, and there's nothing special about the exact placement shown, other than that it's generally close to the front of the cabinet to promote front-to-back air flow. The opening is sized for a common 120mm PC case fan. Some people think it's better to use two intakes to match the two vents in the back, so you could add a mirror-image opening on the opposite side (near the power button). But I wouldn't go too overboard on adding fan vents, as they eat into the space available for the PC components and other items, plus too many cutouts will weaken the floor.

The two small (1½" diameter) holes near the back corners are from the the original WPC design, and they're for ventilation. These are redundant in our design with the added opening for the PC intake fan, but I'd keep them anyway for freer air flow. They don't take up much floor space.

The power button opening is shown at the standard position for real machines, which works equally well in a virtual cabinet. The cutout in our plan is slightly wider than in the original WPC design (1-3/8" vs. 1-1/8"), to accommodate more types of buttons. The real machines use a "hard" on/off switch here that controls the AC power to the main transformer, so turning it off is basically the same as unplugging the machine from the wall. On a virtual cab, we usually want a "soft" power button instead, since we're working with a Windows PC, and Windows doesn't like abrupt power loss. Windows wants the power to remain on throughout the shutdown process, so a soft power control is needed. You just need a pushbutton that's wired to the "power button" connector on the PC motherboard. I use one of the common SuzoHapp rectangular arcade-style pushbuttons. This type of switch can be mounted as illustrated below, which recesses it nicely into the opening.





Installing a SuzoHapp rectangular pushbutton (part #D54-0004-5x) in the power button opening. Cut a small piece of plywood (about 2" x 3") to serve as the mounting plate. Drill holes as shown. Mount the button on the plate, then insert the button into the cutout. Attach the mounting plate to the cab floor with a couple of small wood screws.

Cab floor materials

The real WPC machines had particle board floors. I'm usually all for faithful replication of the originals, but this is a detail that I only see as a negative. I'm sure the only reason they used particle board is that it cut a few dollars off the cost. Plywood is lighter and stronger, so I'd stick with that. The problem with particle board is that it tends to sag over time, especially in a big unsupported horizontal span like this. That's been known to happen with older real machines, and I suspect it might be even more likely in a virtual cab, because we tend to install more things on the floor.

Customizing cutouts to accommodate the PC

Before finalizing your floor cutouts, you might want to figure out where you're going to place the PC components, so that you can customize the cutouts to better suit the PC. Some particular things to consider:

- If you're going to install the PC in a full case (such as a desktop case or a mid-tower case), you might need to move the subwoofer opening further back to make room.
- The PC needs good air flow for cooling. The air intake openings should be positioned so that they're close to the PC, and so that they'll be unobstructed. If you're installing the PC in a full case, you should figure out where the case's air intake will end up, and place a floor opening at the same spot, so that the case can draw in outside air directly.

See Chapter 27, Installing the PC for more on planning the placement of the PC components.

Other floor cutouts

Here are some ideas for other cutouts you might want to make in the cab floor, as long as you're working on this piece. These aren't things you'll find in the real machines, and there's no particular standard place to put them in a virtual cab, but you can consider making provisions for them if they look useful for your build.

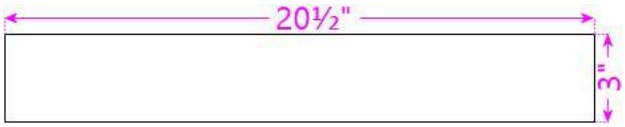
- Keyboard and mouse ports (typically USB). The floor is a good place for ports for input devices that you might want to connect for doing administrative work on the PC, since it's out of sight but within easy reach. I'd pick an area near a front corner, perhaps opposite the power button. Keystone jacks work well for this. See "External I/O plugs" in Chapter 27, Installing the PC.
- Openings for undercab light wiring. If you're going to install light strips on the bottom of the cab for ambient lighting, you'll need a small hole somewhere in the floor for the wiring. A 1" diameter hole somewhere along one of the edges is pretty flexible for this purpose. See Chapter 58, Undercab Lighting.
- Volume buttons or knob. Some people like to put dedicated volume controls somewhere on the cab, and the bottom (somewhere near the front) is a popular choice because it's out of sight but easily reachable. You can use a volume dial here if your amplifier uses one, or an up/down rocker switch. I

installed a rocker switch for this purpose on my own cab, wired through the keyboard encoder to send the Volume Up and Volume Down keyboard commands to Windows. On a new build, I'd probably dispense with the extra switch, and use "shifted" flipper buttons in combination with PinVol.

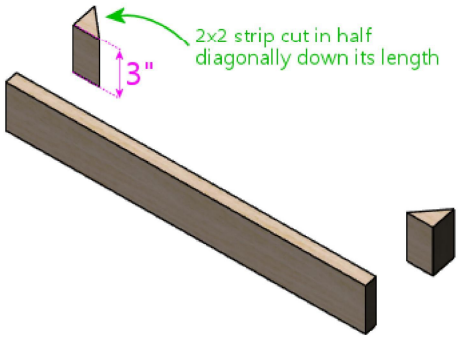
- Other hidden controls, such as an audio mute button or a "night mode" switch (to silence noisier devices for late night use).

The bottom of the cabinet is a good place for controls that you want to keep hidden but accessible. There's an even better place for controls that you want to be *restricted*, not merely hidden: inside the coin door. Controls located there will not only be out of sight during normal play, but won't even be accessible to ordinary users who don't have the key, preventing kids or guests from messing with anything you don't want messed with. It's the same reason the real machines locate the operator menu buttons on the inside of the coin door. See Chapter 40, Coin Door.

Cashbox fence

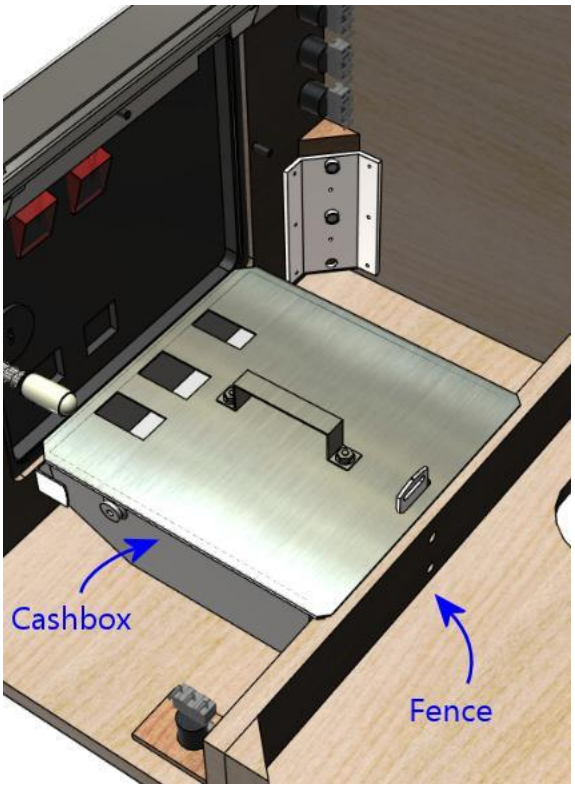


Cashbox fence; attaches to the cabinet floor just behind the cashbox area.

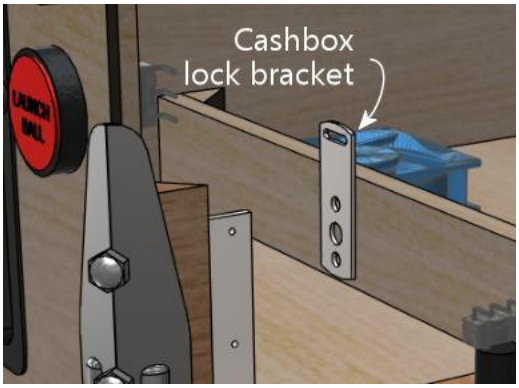


This is a short wall on the floor of the cabinet that delineates the space at the front of the machine where the cashbox goes. On the real machines, it makes a little cubby hole for the cash box and keeps it from sliding around, so that it stays positioned properly under the coin mechanisms.

I don't think most virtual cab builders bother to include a standard cashbox, since the standard model takes up a lot of space that you might prefer to use for PC components and other electronics. You'll probably want to skip the fence if you don't use a cashbox. If you do use the standard type of cashbox, though, the fence is worth including, since it holds the box in place.



Cashbox fence. The metal tab sticking up is the "cashbox lock bracket", which is attached to the fence, and fits through a slot in the cashbox lid. This is designed to hold a padlock for higher security.



Cashbox lock bracket (Williams/Bally part 01-10030 or 1A-3493-1).

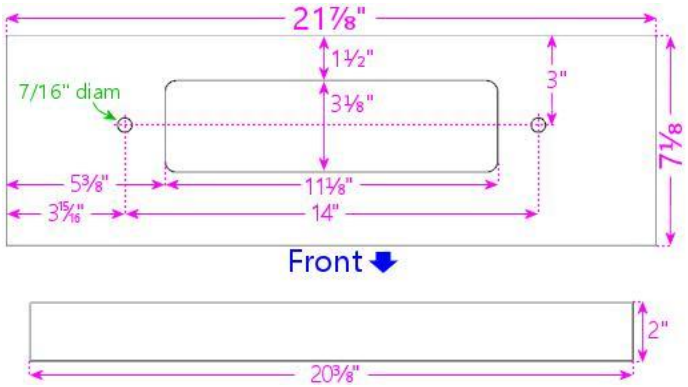
While you're cutting the piece for the fence, also cut two triangular pieces that we'll use to attach the fence to the side walls on the cabinet. Slice a 2x2 strip in half diagonally (at a 45° angle) lengthwise, then cut two pieces, each 3" long. See the illustration above. Note that a nominal "2x2" actually measures 1½" on each side.

The original machines have a metal bracket in the middle, called the cashbox lock bracket (part number 01-10030 or 1A-3493-1), which can be used with a padlock to secure the cashbox. You probably won't feel the need for such strong anti-theft measures on a home-use machine, but if you want to include the bracket anyway for the sake of completeness, attach the bracket to the fence as illustrated below. Do this before installing the fence in the cabinet, since it'll be hard to drill the holes after it's in place.

Cashbox lock bracket. Center the bracket left to right, and make it flush with the bottom of the fence. Attach with two #8 x 7/8" machine screws mated with #8 T-nuts, or with #8 wood screws.

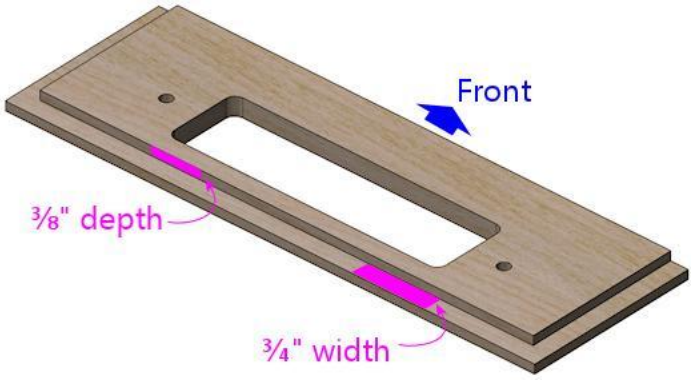
The original WPC machines use two #8 x 7/8" machine screws and #8 T-nuts to secure the bracket; drill 7/32" holes for this setup, using the bracket as a template for the drill locations, and pound in the T-nuts on the back side of the fence. If you want to keep things simpler, use #6 or #8 wood screws instead of the machine screws and T-nuts. That won't be as strong, but it doesn't have to be built like a bank vault for home use.

Rear shelf

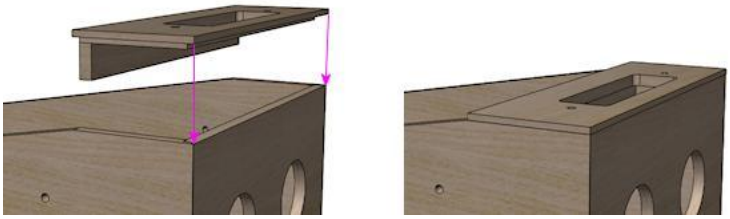


*Rear shelf. The top piece is the flat part of the shelf, viewed from above. This should be the same width as the **outside** width of your cabinet. The bottom piece is the front lip, which attaches below the bottom front edge of the top piece. This should be the same width as the **inside** width of your cabinet.*

How the two shelf pieces fit together. The seam is usually hidden in the finished product, because the rear glass channel (a plastic trim piece that holds the playfield glass) covers roughly the top inch of the front face.



*Routing detail. This view shows the **bottom** side of the shelf. Route out ¾" wide channels on the left, back, and right sides; this should match the thickness of the plywood used for your main cabinet walls. The depth of the channels should be half the thickness of the shelf, so ⅜" if you're using standard ¾" plywood.*

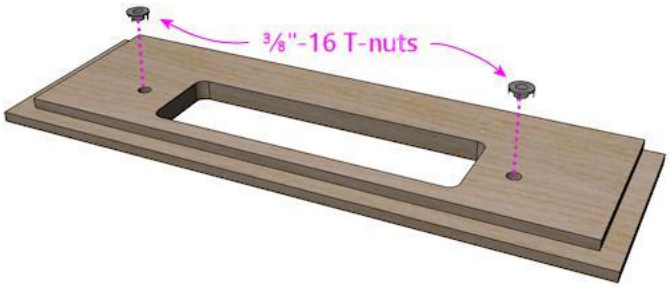


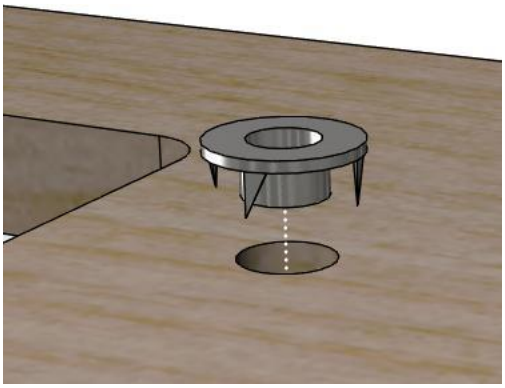
How the shelf fits into the main cabinet.

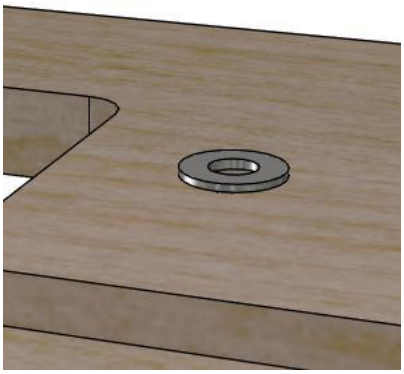
This pair of pieces forms the shelf at the back of the cabinet where the backbox rests. The large opening is for passing cables between the backbox and main body; these match up with corresponding openings in the backbox.

Adjust the width to match your cabinet if you're using a wide-body or custom width. The center opening and bolt holes should be left at the same size (assuming you're using a standard backbox), and should remain centered left-to-right.

The 7/16" holes on either side of the opening are for bolts that secure the backbox in the upright position. Install a ⅜"-16 T-nut on the bottom side of each bolt hole. (T-nuts are threaded bolt sockets, permanently installed in a wood piece. Insert the barrel into the hole as shown and pound it in to secure it.)







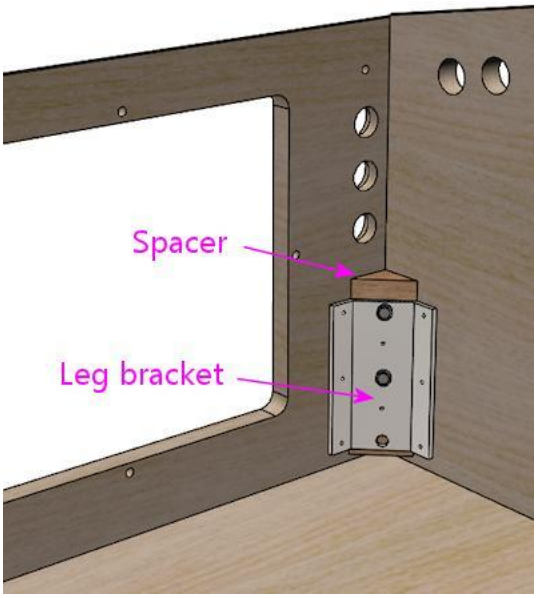
These bolts are an important safety measure, by the way. Don't ignore them. You might think that the latch that conventionally goes on the back of the backbox is enough to secure it. Well, the real pinball machine operator manuals always have a big flashing red warning about that latch, saying that its only purpose is to hold the backbox up while you're screwing in the bolts. The bolts are what *really* hold the backbox up. The latch is a huge safety hazard in that it gives you a false sense of security; the backbox is so heavy that it'll easily rip that latch clean off at the first opportunity. The bolts will truly secure the backbox when properly installed.

The center opening is based on the design in the real machines, which use it to pass through a couple of big cable bundles. This setup works well in most virtual cabs as well, but there's at least one common situation where a larger opening is required: an oversized backbox monitor that needs to recess partially into the cabinet. In this case, expand the opening as needed.

If you customize the cutout shape, remember to make the same changes in the cutouts in the backbox floor. For alignment, use the back edge as the reference point, because the backbox's back wall will be flush with the cabinet's back wall when the backbox is installed and placed upright. For left-to-right alignment, use the center point as the reference; the backbox is wider than the shelf, but it'll be centered horizontally when installed, so the center points will line up.

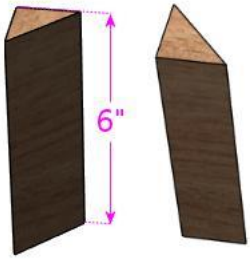
Leg bolt spacers

One last detail. We need some spacers for the brackets used to fasten the legs.

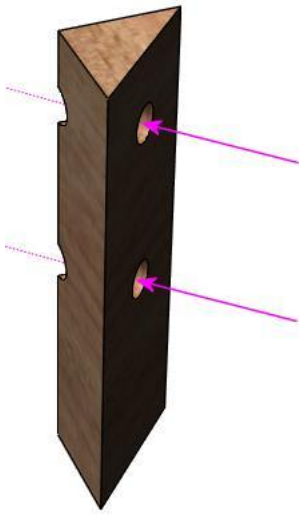


The material required for the leg spacers is a 2x2 wood strip. Select a soft wood such as pine, since that will be less likely to split. Note that what they call a "2x2" at the hardware store is actually 1½" on a side. These typically come in lengths of 6' to 8'.

Cut four 6" lengths of the 2x2. Then slice them in half diagonally (at a 45° angle), lengthwise, to form the triangular wedge shape.

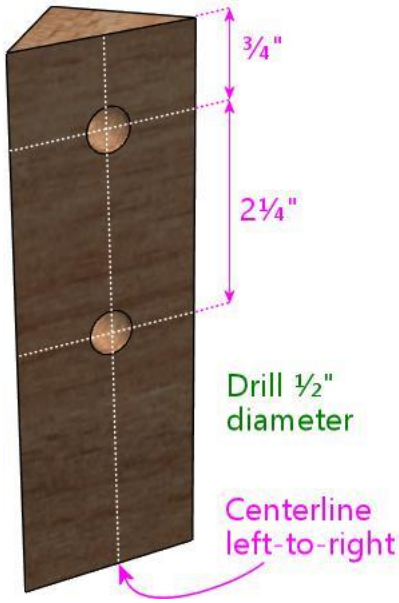


Drill two ½" diameter holes for the leg bolts as shown below. You can also just use your brackets as drilling templates. Drill through the diagonal face (the widest face), on the centerline, square through that face towards the opposite corner.



Drill starting on the diagonal (widest) side, square into that face. The hole should come out on through the opposite corner.

One hole will be near the center (vertically) of the wood piece, and the other will be near the edge. Make four identical copies of this piece.



Backbox

The backbox is (happily) a whole lot simpler than the main cabinet. It doesn't have as many cutouts, and we don't have to get as fancy with the corner joins. The top and bottom surfaces are typically out of view, so we can use joins that leave seams, by hiding the seams on the top and bottom edges where they won't be seen. All of the joins for the backbox can be accomplished with straight router bits.

The backbox is *mostly* built from the same ¾" plywood used in the main cabinet. There's one exception, though: the back wall is made from ½" plywood. The original WPC backboxes had ½" thick back walls, so we're sticking to the same plan to keep the interior dimensions the same.

If you want to substitute ¾" plywood for the back wall, it's fairly easy. You just have to adjust the routed grooves in the other walls where the back wall joins to

accommodate the thicker panel. We'll give you a reminder about that when we get there.

Exploded view of backbox

Corner joins, viewed from the front. This type of join leaves a seam along one face, but we orient the joins to place the seams along the top and bottom , which are normally out of view.

(For purists, I have to confess that my design has a discrepancy from the original WPC design, which is that the joinery at the bottom of the back wall is different. The original WPC back wall simply butts up against the floor, whereas my design uses a rabbet to match the other three sides of the back wall. This is obviously an inconspicuous area - I didn't even notice the deviation until some time after publishing this chapter - and I can't think of any way the difference affects function. The rabbet is perhaps a bit stronger, and works as a glue joint, whereas the original butt join requires nailing. Williams might have used the original butt join simply for manufacturing convenience: it's more forgiving of measurement errors, in that you don't have to get the bottom and back pieces to line up precisely. If you want to modify my plan to reinstate the original design, cut the back wall 3/8" taller, make the floor piece 1/2" less deep, and omit the rabbet at the back of the floor.)

Translite and DMD guides

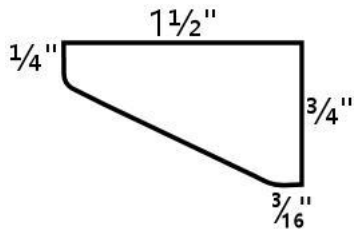
The backbox requires some simple rectangular wood strips that acts as guides to hold the translite and speaker/DMD panels in place.

Quantity	Material	Dimensions
2	½" plywood	4¾" x ¾"
2	½" plywood	15" x ¾"
1	¾" plywood	27⅛" x ¾"
2	¾" plywood	12⅜" x 1"
1	¾" reducer molding **or** nominal 1x2 or 2x2 stock cut to a similar shape (see diagram below)	27⅛" length

The plywood pieces aren't visible to players, so don't worry about making the edges look pretty. They're all hidden behind the backglass or speaker panel when the machine is assembled.

The "reducer molding" shape is a more challenging trim piece that requires an angled cut. And this one *is* visible to players - in fact, its whole purpose is cosmetic - so you'll want to make it look nice.

One way to make the molding piece is to start with a nominal 1x2 strip or 2x2, and cut it lengthwise so that it has this approximate cross-section:

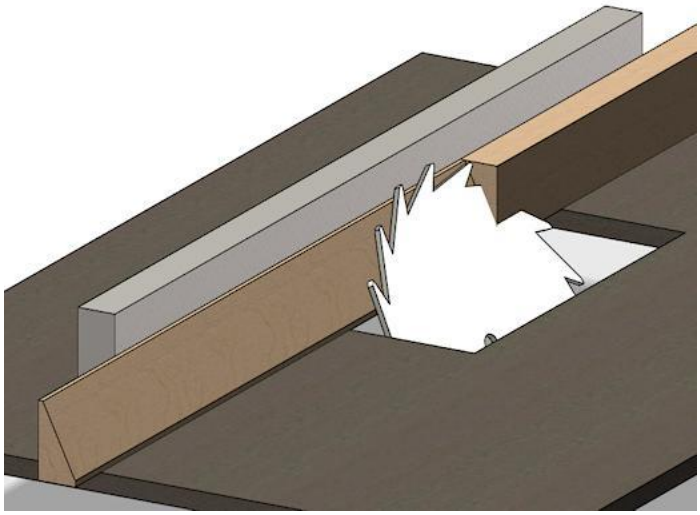


Note that a nominal 1x2 is actually ¾" by 1½", so chopping this profile out of a 1x2 just requires a single diagonal cut. The same goes if you start with a 2x2.

The diagram above is based on the molding used in the original Williams machines, but you don't have to reproduce the shape perfectly, because this piece is purely cosmetic. It's just there to hide the channel that holds the top of the backglass in place, to make the area look nicely finished. The only important thing is to give it a pleasing tapered shape.

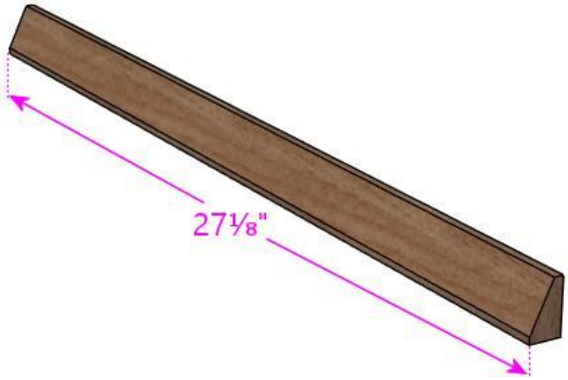
In the diagram above, we show rounded corners, because that's what the trim on the real machines looks like. The rounded corners aren't critical; they're just to make it look more finished. You can just round out the corners a bit by sanding if you like. If you want to get fancy, you can round them out with a suitable router bit.

To make the diagonal cut with a table saw, set the blade at a 25.5° angle to the vertical, and feed the 1x2 or 2x2 stock in length-wise:



An alternative to cutting this shape yourself is to buy a pre-cut wood molding in roughly the same shape. There's a common type of floor trim called a **3/4" reducer molding** that has roughly this same shape and size. A 3/4" reducer molding will typically be a bit deeper than the profile we want, since it'll usually have a lip that sticks out from one side. But it still might be easier to trim off that extra bit than to cut the whole shape yourself.

Once you have a strip in that shape, cut it to a length of 27⅛".



Translite lock plate preparation

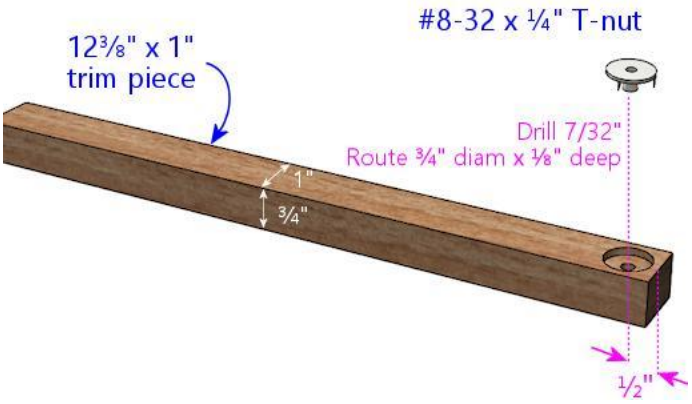
If you're planning to install a translite lock plate, there's some preparation you can do at this stage that will make installing the lock easier and more secure when you get there. If you don't know what the translite lock plate is, you can learn about it in the "Translite lock" section in Chapter 23, Cabinet Hardware. Briefly, it's a keyed lock that you can install at the inside top of the backbox to secure the translite. For a home machine, the security function isn't important, but you might want to include the lock anyway if you're a stickler for realism, since it's there on all of the real machines going back at least to the 1980s.

The translite lock is installed in the front translite guide (described in the section above), which is part of the ceiling of the backbox. The front guide has a gap of about 2 inches in the middle, specifically for the lock.

On the real machines, they install the lock plate with #8-32 security Torx machine screws (the Torx variation with tamper-resistant heads). The important thing to note here is that they're **machine** screws, not wood screws. Machine screws won't self-tap in wood; they need to be fastened with nuts. If you look at the arrangement pictured above, you can see that there's no way to install ordinary hex nuts by hand with this setup, because you'd have to get behind the wood trim somehow - and it's going to be glued in place by the time you're ready to install the screws. So the question is: how do you install a nut in a place you can't reach? The answer is a T-nut. A T-nut is threaded like a hex nut, but it's permanently installed in the wood rather than being screwed on by hand. They're specifically for this type of situation where you need to pre-install a nut someplace you won't be able to reach later.

So, **if** you want it to install it the professional way, the required preparation is to pre-install T-nuts in the 12⅜" x 1" trim pieces:

- Drill a 7/32" hole, 1/2" from one end, centered across the width
- Route a 3/4" recess on the same center, 1/8" deep
- Insert a #8-32 x 1/4" T-nut from the recess side
- Pound it in flush into the recess

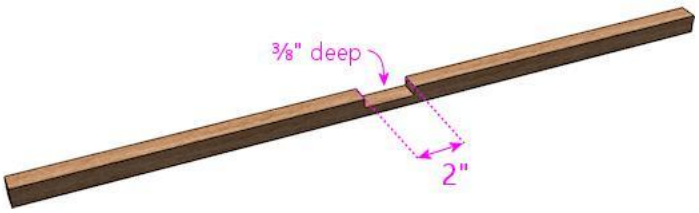


All of this prep work is optional, at two levels. First, it's completely unnecessary if you're not going to install the translite lock. Second, even if you're going to install the lock, there's a simpler alternative: throw out the wacky Torx machine screws that come with the lock plate kit, and use ordinary wood screws instead. Wood screws will happily self-tap straight into the trim, without any other fasteners. So why would anyone (even the pros) bother with the T-nuts? In a word, security. Apart from the tamper-resistance of the security Torx screws, the T-nuts add a lot of strength. It's easy to pry out wood screws; it's almost impossible to pry machine screws out of T-nuts, short of ripping out the whole wood trim piece.

Extra routing for translite lock

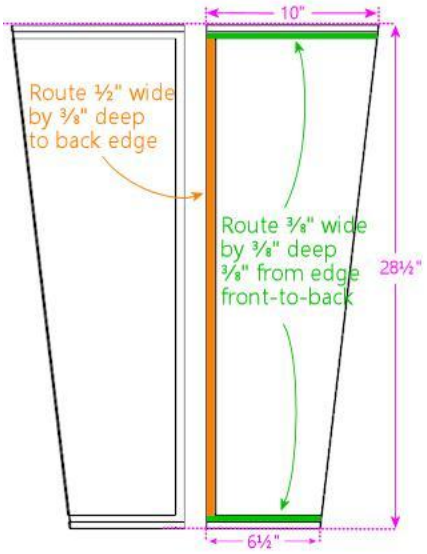
For a good fit, there's a little extra routing you need to do for the translite lock.

In the 27⅛" x ¾" x ¾" piece, route a 2" wide notch in the center of one side, to ⅜" depth.

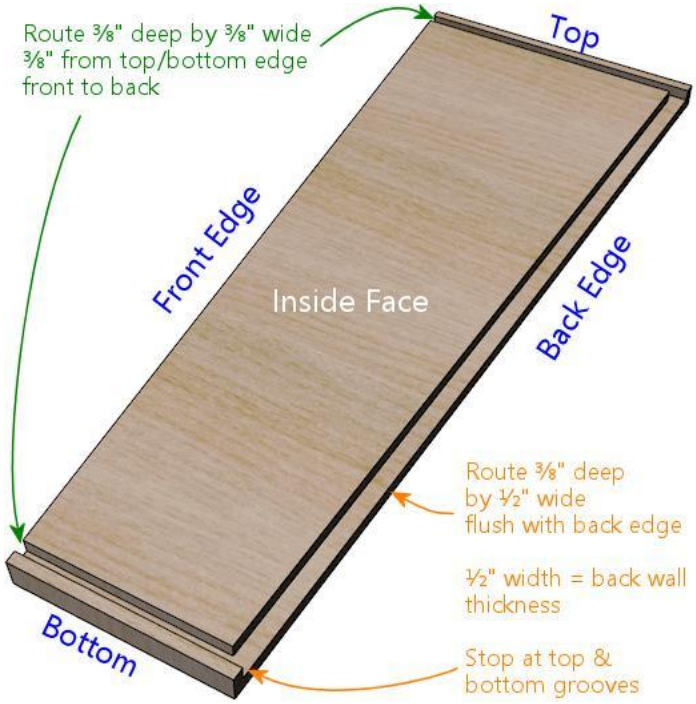


This is necessary to leave room for the lock tab when it's in the "locked" position. The tab is slightly wider than the slot, so it needs this extra room on the other side.

Backbox sides



Backbox left and right sides, shown from the interior side to detail the routed grooves for the joins. These are mirror images of one another. Note that the rear groove's width should equal the thickness of your back wall plywood. Our plans assume you're using ½" plywood for the back wall, so the groove is shown at ½" width.



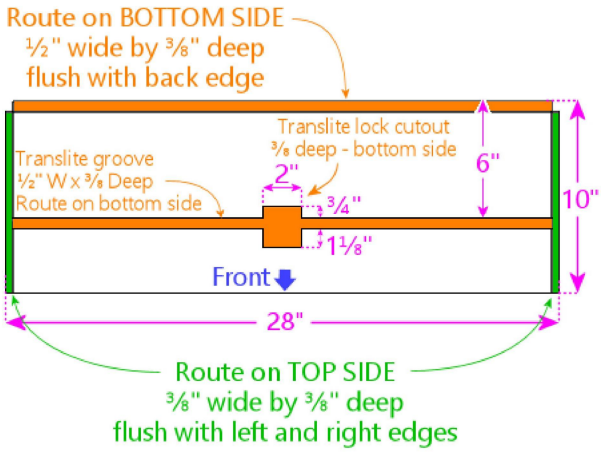
3D view of the routed grooves in the side walls, to clarify the geometry.

The routing at the back edge assumes you're using ½" plywood for the back wall. If you're using a different thickness, simply increase the width of the groove to match the thickness of your back wall.

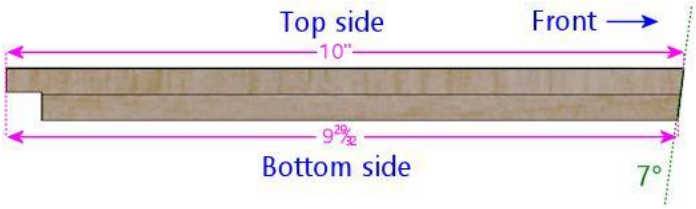
Backbox top

The top of the backbox has a few special features:

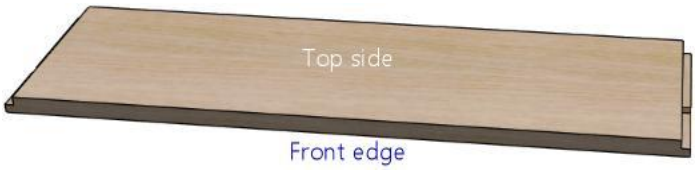
- The front edge should be cut at a 7° angle to match the slope of the front edges of the side walls.
- The side edges are routed on the top side in a rabbet cut, to fit the rabbet grooves in the side walls.
- The back edge is routed on the bottom side in another rabbet cut, to fit the back wall.
- A 1/2" wide, 3/8" deep groove runs across the width of the bottom side of the piece. This matches the plane where the translite fits. The translite doesn't actually sit in this space most of the time, but this groove provides a little extra room to lift the translite into when inserting and removing it. You can omit this if you're not using a standard translite.
- A 2" wide rectangular depression is routed in the middle of the translite groove, on the bottom side of the piece, to accommodate the translite lock. Center this side to side, and refer to the diagram below for the dimensions. This is only needed to make room for the translite lock, so you can omit it if you're not using a lock.



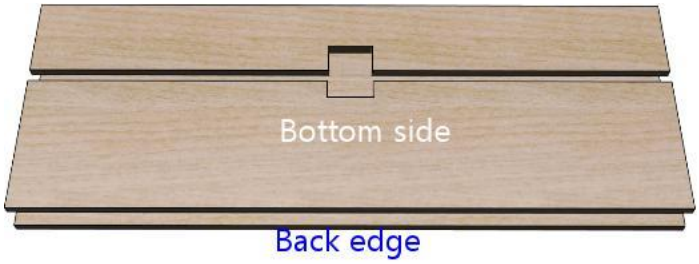
Backbox top piece (roof)



To match the slope of the front sides, the front edge of the top piece should be cut at a 7° angle. This is an edge-on view from the left side.



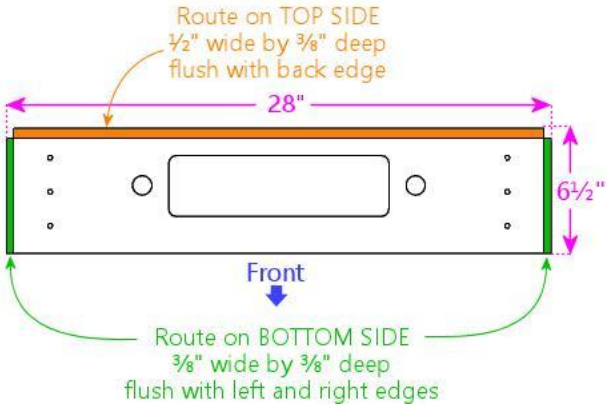
3D view of top piece, viewed from top front, to show routing detail on the top side. The grooves at the wide are ⅜" deep and ⅜" wide, all the way to the outer edges.



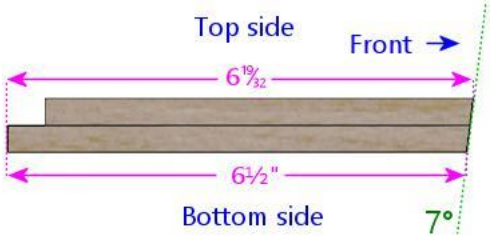
Top piece, bottom side, viewed from the back, to show routing detail on the bottom side.

If you're planning to install any "toppers" (decorations on top of the backbox, such as a rotating beacon, fan, bell, or flashers; see Chapter 42, Backbox Toppers), consider pre-drilling any openings in the roof that will be needed for mounting hardware or wiring.

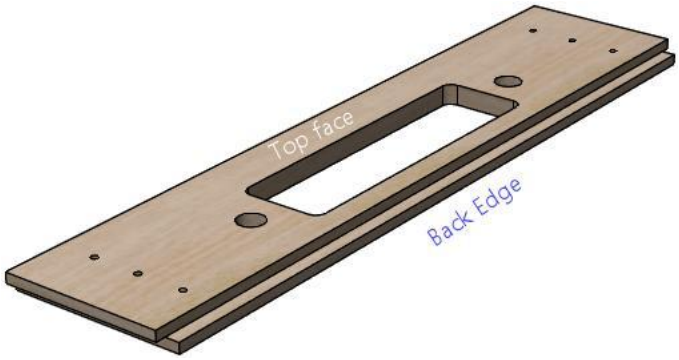
Backbox floor



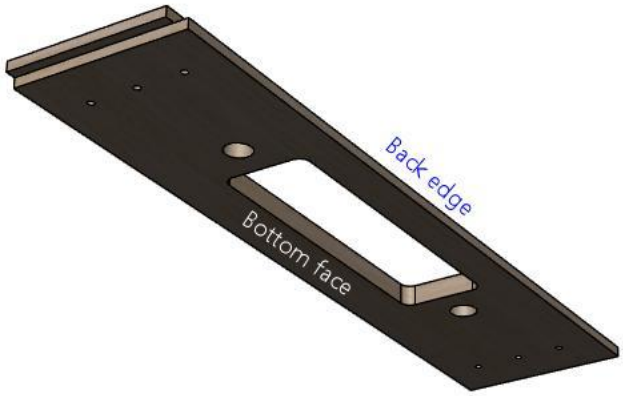
Backbox floor



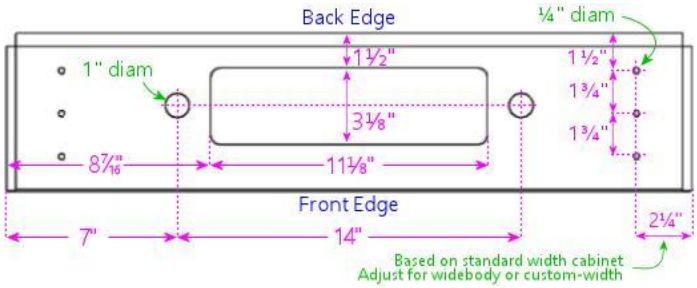
To match the slope of the front walls, cut the front edge at a 7° angle. This is an edge-on view from the left side.



3D view of backbox floor, viewed from back side, to show routing detail. The groove at back is ⅜" deep and ½" wide, flush with the back edge. The ½" width should match the plywood thickness of the back wall.



Backbox floor, bottom side, to show routing detail.



Above: Cutouts in floor of backbox. The rectangular cutout is for passing cables between the backbox and cabinet. The 1"-diameter holes on either side of the cable cutout are for safety bolts that lock the backbox in the upright position. The ¼"-diameter holes along the outer edges (three on each side) are for the WPC-style hinge brackets that attach the backbox to the main cabinet. The hinge bolt positions shown are for a standard-width main cabinet - they need to be adjusted for a wide-body or custom-width cabinet (see below).

Cable cutout: The rectangular center cutout is meant to match the corresponding cutout in the "shelf" at back of the main cabinet. If you're customizing the shape of the cutout, remember to make the same changes in both places. To figure the alignment between the two parts, use the back edge as the reference point in both places. When the backbox is installed and placed upright, its back wall will be flush with the back wall of the main cabinet. For left-to-right alignment, use the center point as the reference: the backbox is wider than the shelf, but it will be centered side-to-side when installed, so the center points will line up.

Lock bolts: The 1"-diameter holes on either side of the center cutout are for locking bolts. These should be aligned on the same centers as the corresponding ½" holes in the main cabinet shelf. If you had to move those to accommodate a custom center cutout, move these holes to match. Note that the shelf holes are ½" diameter, whereas the corresponding backbox are 1" diameter. As with the center cutout, the reference point to use for alignment is the centerpoint of the back edge, because that will line up on the shelf and backbox.

Hinge bolts: The ¼" diameter holes near the outer edges (three on either side) are for carriage bolts that attach the WPC-style hinges to the backbox. Drill these only if you're using the WPC-style hinges.

Important! The positions shown are for a standard-width main cabinet. If you're using a wide-body or custom-width cabinet, **or** a custom backbox width, you'll need to refigure the positions. Use this formula:

Inset = (Backbox Width - Cabinet Width - 2⅜") ÷ 2

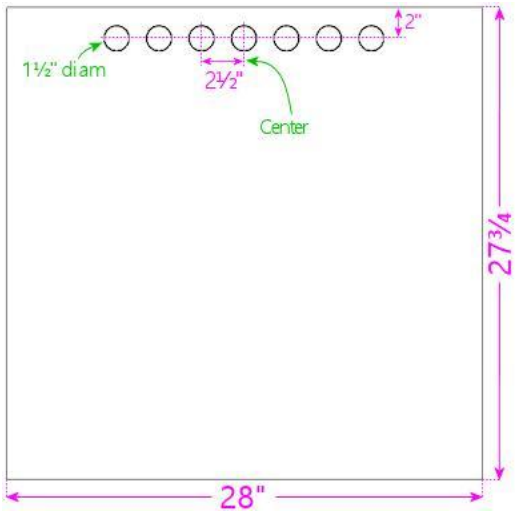
Plug in the **outside** widths of the backbox and cabinet (as they will be when assembled). The result is the inset of the bolt holes from the left and right edges of the floor, so simply substitute this for the measurement shown in our diagram.

If you don't want to take chances on getting the measurements perfect before-hand, you can wait to drill these holes until you've assembled your cabinet and backbox, at which point you can set it up and use the hinges themselves as a drilling template to mark the proper positions. This is getting a little ahead of ourselves, but here's the procedure:

- Make sure the shelf is in place in the cabinet, if you haven't already installed it. No need to glue it yet; just set it in place.
- Attach the hinges to the main cabinet using their pivot bolts. They'll rotate freely, so be careful not to let them scratch anything.
- Put the backbox in position. Center it left-to-right, and align the back wall of the backbox so that it's flush with the back wall of the main cabinet. The front of the shelf will stick out slightly further than the front of the backbox; that's normal. Have an assistant hold it up so that it doesn't fall over from this precarious position - it's heavy enough to be dangerous!
- Rotate the hinges up into position where they'll attach to the backbox. Make sure the contact area is flush with the bottom of the backbox. Mark bolt hole positions.
- Take down the backbox and drill at the marked positions.

Backbox back wall

The back wall of the backbox on the real machines is typically 1/2" plywood. It's a simple rectangular piece, with some holes for passive cooling.



Backbox back wall. The holes near the top are for passive ventilation. Note that the back wall uses ½" plywood rather than the ¾" plywood used for the other walls.

Backbox ventilation

The original WPC backboxes used passive ventilation, via seven 1½"-diameter holes along the top of the back wall. ("Passive" meaning that they didn't use fans to circulate air; they relied on natural air flow driven by hot air expanding and rising.)

Some virtual cab builders add fans to the backbox for extra cooling. If you want to add active cooling, I'd remove the passive vent holes and replace them with one or two larger circular openings for 120mm PC case fans, similarly placed near the top of the back wall. You could also add some intake vents at the bottom, although I don't think that's necessary, as air will be drawn in from the main cabinet through the openings in the backbox floor.

Is active cooling required? From my own experience, the answer seems to be no. My cab uses passive ventilation (the same design shown in the diagrams here), and I haven't had any obvious heating problems. That doesn't necessarily rule out longer-term problems, but at least nothing gets catastrophically hot. If you want a more analytical answer, you can do a rough calculation comparing the heat generated by

the electronics in a real WPC pinball machine's backbox to the heat generated by a TV in a virtual cab backbox (see Chapter 28, Cooling Fans). That calculation comes out about even between the two scenarios, which strengthens the case that passive ventilation is adequate.

On the other hand, there's little downside to adding a fan or two, other than the space they take up and the added noise (which should be minimal if you use a large fan). If you do plan to add a fan, just take into account the space required for the TV, DMD, replay knocker, and any other backbox devices you plan on installing.

Backbox back door

Some virtual cab builders make the back of the backbox into a door rather than a fixed wall.

The plan I'm presenting here uses a fixed back wall, following the original Williams design. On the real machines, most of the main control electronics are mounted on this wall - the CPU board, sound board, power supply board, etc. To access these parts for service, the operator simply removes the translite and accesses the interior from the front side.

The complication for a virtual cab is that we fill most of the backbox with a TV. Some cab builders mount the TV in such a way that it can't be easily removed, in which case you won't be able to access anything behind the TV through the translite side. That's where a back door comes in handy.

I don't have an alternative set of plans to offer using the back door approach, so if you want to go that route, you'll have to improvise something. Other people have built such schemes into their cabs, so you might be able to find ideas by checking build threads on the forums.

I personally prefer the fixed back wall, instead of a door. The main reason is that it makes the backbox a lot stronger if the back is a solid, fixed panel. I also don't like the idea of using a permanent mounting for any of the TVs, since doing so makes it very difficult to repair or upgrade the machine later. I prefer to install all of the TVs (and other major components) in such a way that you can remove them non-destructively when necessary. In the case of the backbox TV, I favor mounting it so that it can be removed through the front of the backbox, preferably without having to disassemble anything. That removes any need for a back door. It also makes it easy to replace the TV, if that should ever become desirable or necessary.

See Chapter 30, Backbox TV Mounting for some ideas about how to mount the TV so that it can be removed.

Toppers

If you're installing some kind of "topper" (a decoration on top of the backbox, such as a beacon, fan, bell, or flashers: see Chapter 42, Backbox Toppers), consider pre-drilling any openings needed for the mounting hardware and wiring.

How to assemble the cabinet

Before you glue everything together more or less irrevocably, it's a good sanity check to do a "dry fit" of the pieces (fitting them together without any glue or nails) to check that everything is the right size and aligns as expected. Check for any dados that are too tight, and use sandpaper or a file to expand them slightly as needed. Check the alignment of the rabbet joins.

Have a good quality wood glue on hand. This will be used at all of the joints. Optionally, you can also use finish nails (perhaps ¾" #18 brads) along the seams, spaced a few inches apart. Nails will add some strength and will serve to hold the joints in place while the glue dries, but the trade-off is that they create a certain amount of risk of splitting wood around the edges. I used nails for my own build, but I don't think they're really necessary. If you're using the joins we suggested (dadoes at the floor seams, and either the mitered rabbet or double rabbet joins at the corners), I think glue alone will be plenty strong.

Another good thing to have on hand is an assistant! The job is easier with two people.

It should be fairly obvious how the pieces fit together, but here's a suggested assembly order.

Pre-assemble the shelf

Install a #6-32 x ⅜ on the bottom side of each bolt hole. (These are there to mate with safety bolts screwed in through the matching holes in the backbox, to secure the backbox in the upright position.)

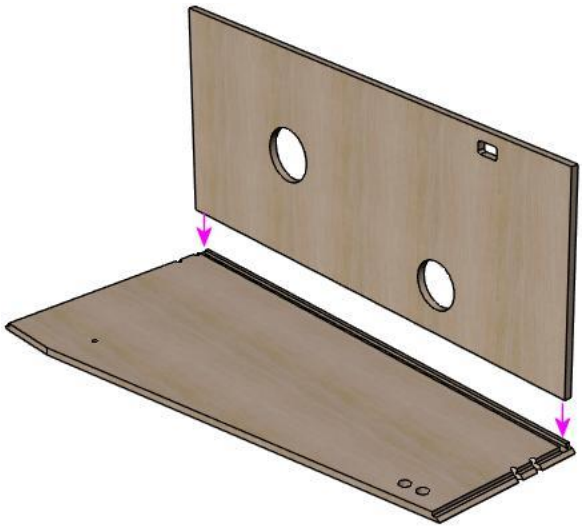
Glue together the two pieces that make up the shelf as illustrated below. The front edge of the lip should be flush with the front edge of the top piece.

Set the assembled shelf aside for the glue to dry, so that it'll be set when we're ready to install it in the cab later on.

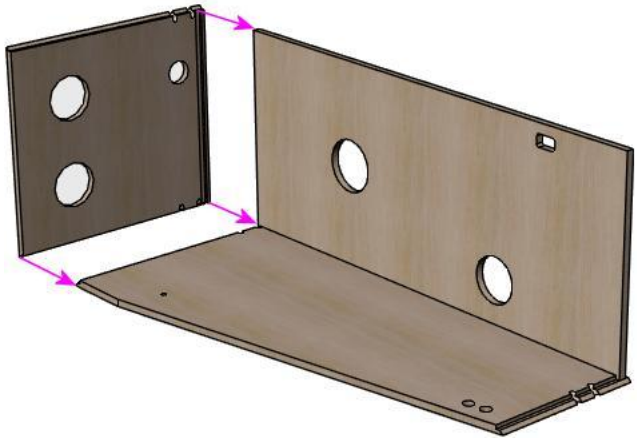
Main cabinet

On to the main cabinet! Start by joining the floor to one of the side walls. Put glue along the inside of the dado (groove) at the bottom of the side wall as illustrated below. Don't use an excess of glue - you just want a single continuous bead down the center of the groove. Insert the floor into the groove. Make sure the front and rear edges are properly aligned and flush, and ensure that it's pressed down all the way into the dado.

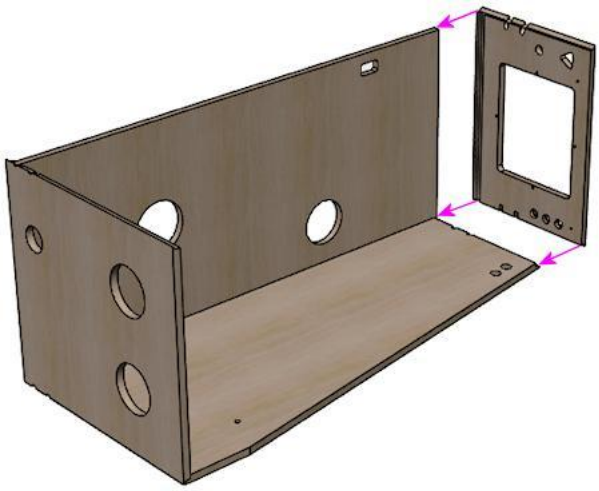
Beware that this arrangement is precarious! The floor piece will want to tip over; the dado isn't strong enough by itself to hold it upright. Keep the floor piece supported so that gravity doesn't stress the joint. It's good to have an assistant to hold things in this position until you get to the next piece.



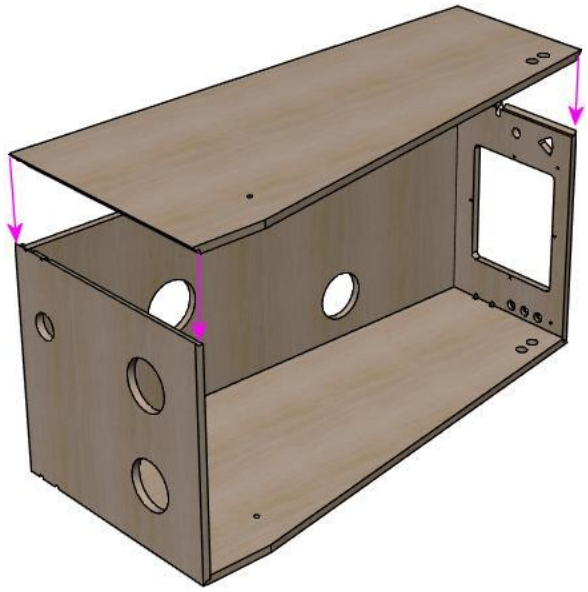
Next, add the back wall. Put glue along the dado and edge of the back wall that we're about to join, as shown below. Again, use continuous bead of glue. Put the back wall piece in place. As before, make sure that the edges are aligned properly and that the floor is pressed all the way into the dado in the back wall.



Now do the same thing with the front wall.



Add the remaining side panel.



Leg brackets

The next step is to install the leg brackets. The brackets will be permanently installed in the cabinet, so this is a one-time step that you won't have to repeat when you want to attach or remove the legs.

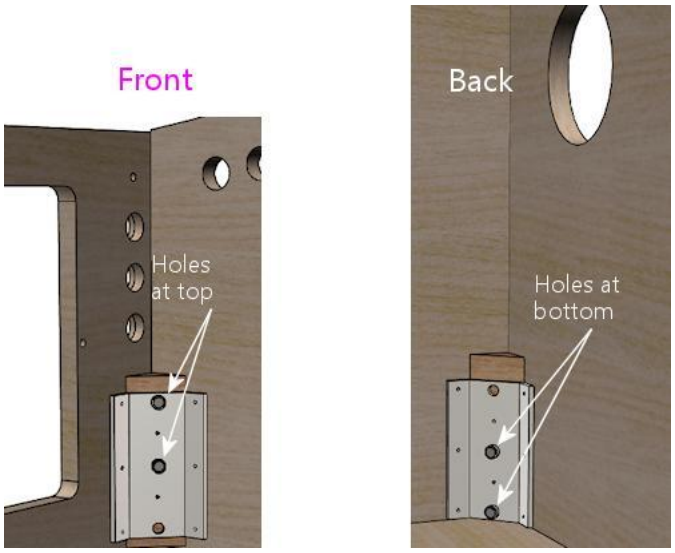
The procedure here assumes you're using the standard brackets used on newer machines, Williams/Bally part 01-11400-1. These brackets have integrated threading for the bolts, so no additional nuts or other fasteners are needed - you just screw the bolts into the brackets.

You'll need four of these brackets. The matching bolts are ⅜"-16, in 2½" or 2¾" lengths. Note that you'll probably want to buy the bolts from a pinball vendor rather than use generic hardware store bolts, for cosmetic reasons: the ones made for pinball machines have nice shiny finishes and rounded heads that look nicer than generic galvanized hex-head bolts. You'll need eight bolts (two per leg). No washers or nuts are needed, as the brackets are threaded and serve as the fasteners.

The recommended brackets have their own threading for the bolts, which lets you attach and detach the legs purely from the exterior of the cabinet. In other words, there's no need to reach inside the cabinet with a wrench to turn a nut or other fastener, since no other fasteners are needed - the bolts screw directly into the threaded holes in the brackets. That's important because it's difficult to reach into the interior corners (especially with a wrench) once all of the equipment inside is installed. So the threaded brackets make things much easier in the long run, but they require some extra work for the initial installation, since you have to align them and fasten them inside the cabinet. That's what the procedure below is intended to accomplish.

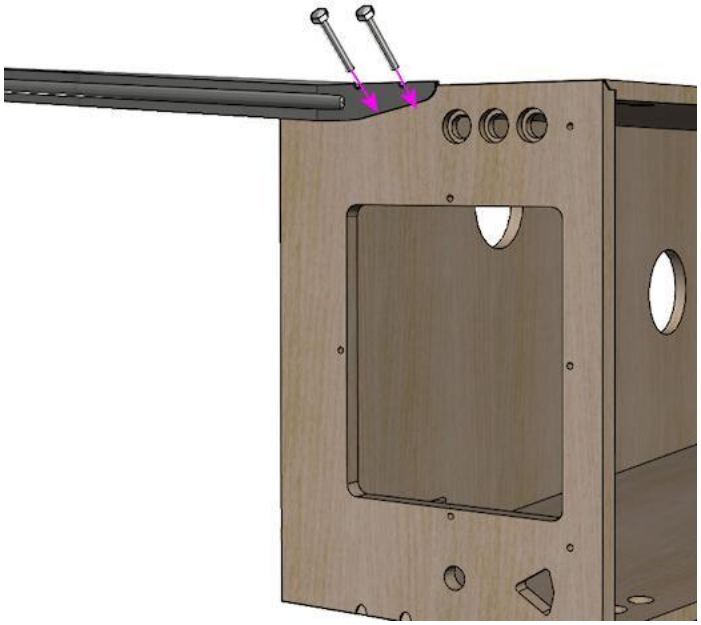
All four legs are interchangeable - there's no such thing as a "front leg" or a "back leg" or a "right leg" or a "left leg". You should simply have four identical parts for the legs. The same is true of the metal leg brackets.

Before we begin, it's worth noting how the positioning of the leg bolts relative to the floor of the cabinet affects how the brackets and spacers are installed. The bolt holes are higher up on the wall in front, lower in back, to give the cabinet a slight forward tilt when it's set up. (The legs themselves are all the same length, so we get the tilt by mounting the legs at different heights.) Because of this asymmetry, we can flip the brackets upside down in front to keep them lower on the wall.



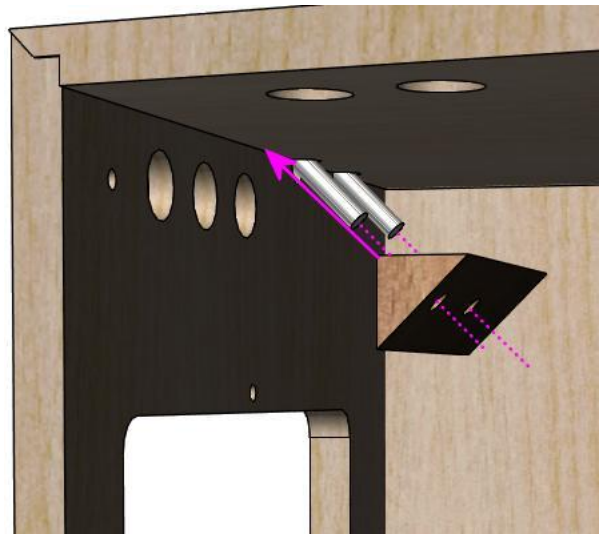
We'll start with a dry fit (no glue) to make sure everything fits, before we finalize the install. The bolt holes tend to be tight, which is good in that you don't want a lot of play or wobble when the legs are attached. But the bolt holes in the wood can be so tight initially that the leg bolts just won't fit. We need to make sure that the bolts will fit properly.

With the cabinet on its side, place the leg in position, and insert the bolts through the leg holes and into the cabinet. If the fit is too tight to get them through by hand, use a round file to ream out the holes enough to get them to fit.



The point of using the legs for this step is just to make sure that the spacing of the bolt holes in the legs matches the spacing in the cabinet. We're not actually attaching the legs permanently yet; we're only attaching the brackets at this point. The legs can be easily attached and detached at any time once the brackets are installed.

Once the bolts fit comfortably, slip the triangular wood space piece over the bolts.



Now attach the metal leg bolt bracket. Screw in the bolts to make sure everything still fits.

If anything is wrong with the fit, go back and use a round file to open up the holes in the cabinet walls and/or the spacers as needed. (Obviously, don't attempt to modify the legs themselves or the metal bolt bracket! We consider those to be the source of truth here - they're the reference points we're trying to match with the wood parts.)

Once you're satisfied with the fit, take the bracket off and remove the spacer. We're now ready to install this all permanently.

Keep the legs and bolts in place, since we still want them there as the reference point for final alignment.

Apply glue to the sides of the spacer that face the cabinet walls. (Those are the narrower sides. Don't glue the wider side that faces the bracket.) Use a thin layer of glue covering the whole face. Avoid the area around the bolt holes to avoid too much glue oozing in there.

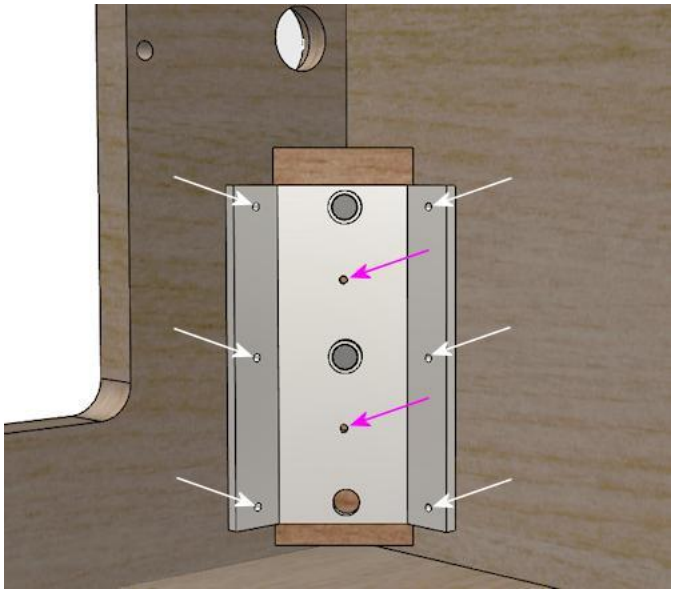
Put the spacer back in place. Press it against the cabinet walls to attach the glue.

Reattach the bracket and screw the bolts into it. Screw them in all the way this time so that the leg is firmly attached. Don't over-tighten.

Use **#8 x 5/8" wood screws** to attach the metal bracket to the cabinet walls and to the spacer. The standard plates have holes for three screws on each side and two more in the middle to attach to the spacer. Don't leave out any screws; we want the bracket attachment to be very sturdy, so we want to distribute the load over as many screws as possible. Tighten the screws but be careful not to over-tighten and strip the wood.

Note: some people recommend #10 x 3/4" screws for greater strength. I've seen this advice from people who were fixing split corners on their newer Stern machines, and upgrading to the Williams leg brackets in the process. (Stern is apparently using cheaper leg brackets lately that don't provide any corner bracing at all.) Williams used mere #8 screws with these brackets, and I don't think split corners have been a problem on those machines even after 30 years in service, so I suspect that upgrading to #10 screws is a bit of overkill with the beefy brackets. But I can't see the added strength doing any harm. The one potential problem is that 3/4" screws could potentially poke through the 3/4" plywood, so check before screwing them in that they're not too long for your actual plywood stock. You don't want a dimple or a sharp point sticking out through your artwork. The bracket itself adds enough extra spacing that this shouldn't be a problem, but nominal 3/4" plywood is almost always

a little less than 3/4" thick, so I'd check to make sure. If it looks like it's going to be close, you can add a washer or two to each screw for some extra padding.



Use #8 x 5/8" wood screws to fasten the leg bracket to the cabinet and spacer at the locations shown (arrows). You can substitute #10 x 3/4" wood screws for greater strength if desired, but check them against your plywood stock to make sure they won't poke through the other side.

Once the wood screws are all in place, unscrew the main leg bolts and remove the leg.

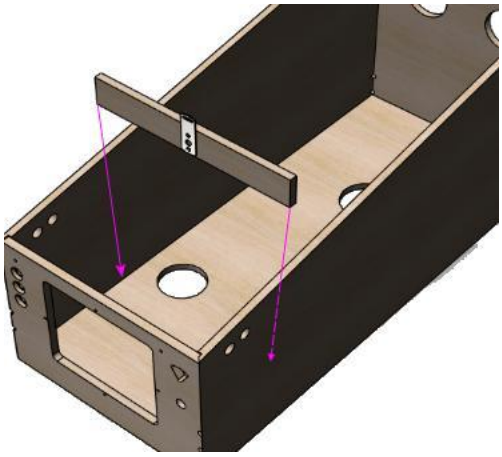
Repeat this process for each corner until all four leg brackets are attached.

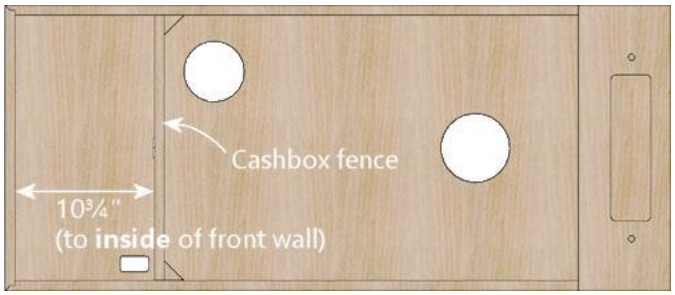
Cashbox fence

If you decided to include the fence that delineates the cashbox area, this is a good time to install it. Flip the cabinet upright for this step.

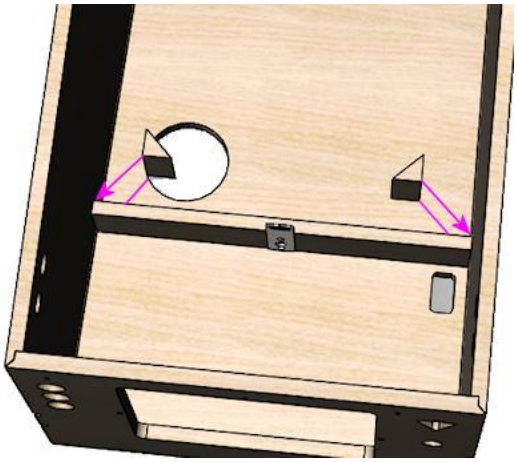
Figure the desired position for the fence. Assuming you're using the standard type of cashbox, the front surface of the fence should be 10¾" back from the inside of the front cabinet wall. If you have your cashbox on hand, you can try placing it to ensure a good fit - there should be about 1/2" of play front-to-back.

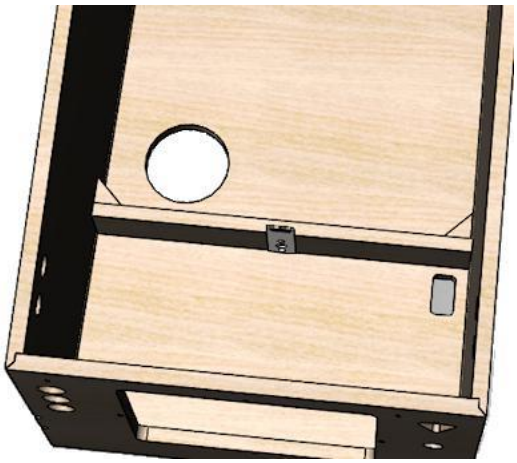
Without using any glue yet, set the fence in place at the desired position.





Apply glue to the two square sides of the 3"-tall triangular pieces that you cut along with the fence. Making sure to keep the fence at the desired position, press the triangular pieces into place on the rear side of the fence at each side, to fasten the wall to the two sides of the cab.





Back rails

If you want to include the back rails, attach them to the back of the cabinet, oriented vertically, near the edges. The exact positioning isn't particularly important, as long as the rails form a stable base for standing the machine on its back, so make any adjustments needed to keep clear of your fan vents and other openings in the back wall.

Attach these to the back with glue and finish nails (1¼" #18 brads should work). Nail down the centerline, with a nail every 4" or so.

If desired, affix hard plastic furniture slider pads near the ends. The exact type isn't important; the ones Williams used in the 1980s and 1990s were typically the nail-in type, hard plastic, 3/4" diameter, white or tan.

Shelf

At this point, you can install the shelf that you assembled back at the start of the build process. We saved this for last (in particular, until after the leg brackets were in place), because the shelf gets in the way when you're trying to work around the back wall. For exactly this reason, you might want actually want to skip the shelf for now, and come back to it later, after you've had a chance to install the internal items that you may plan to attach to the back wall:

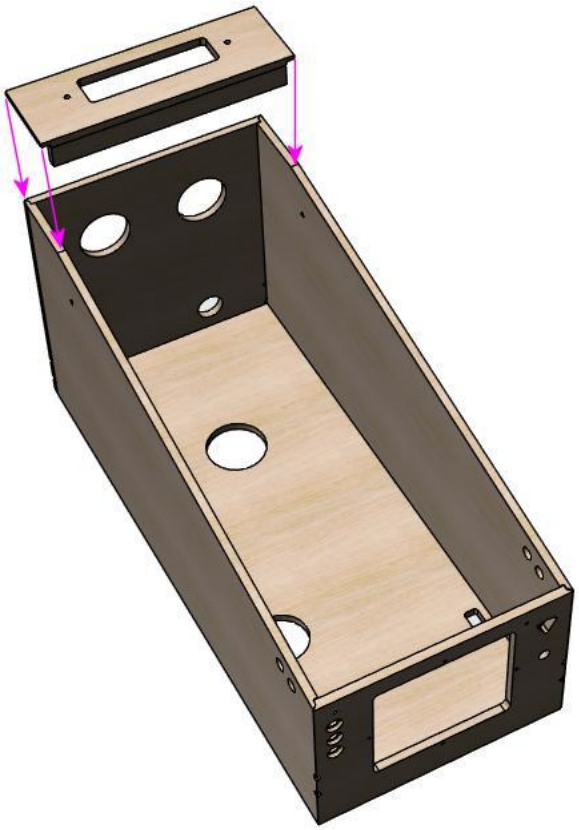
- Fans
- Power inlet
- Power strips
- Ethernet port
- USB ports

If you want to hold off installing the shelf for now, you can just set it aside and make a mental note to come back here when you're ready.

If you haven't already done so, install ⅜"-16 T-nuts in the holes on either side of the central rectangular opening, on the **bottom** side of the board. These mate with the wing bolts that are meant to be attached through matching holes in the floor of backbox. The bolts are an important safety measure to secure the backbox in the upright position while deployed.

Once you are ready to install the shelf, start by flipping the cabinet upright.

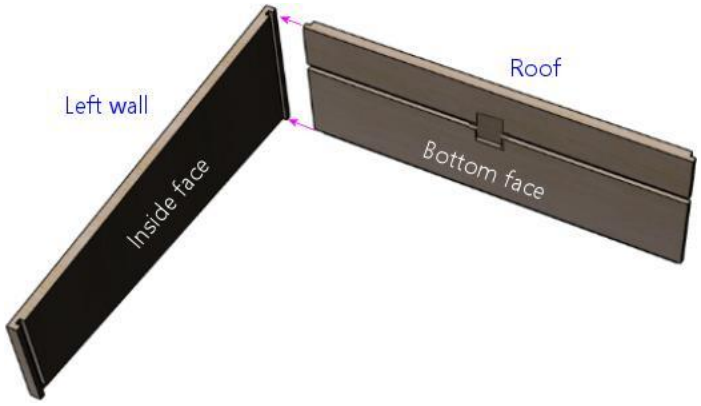
Run glue around the edges of the shelf where it joins the main cabinet (as shown below), and set it in place.

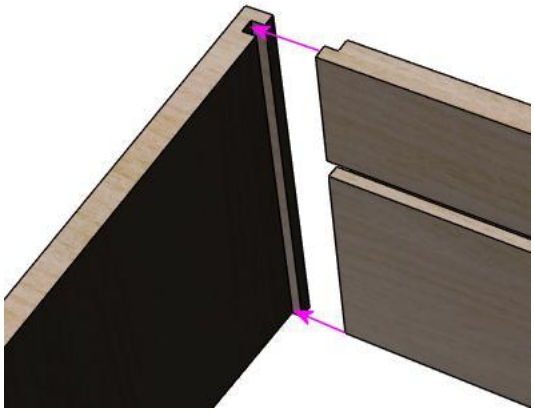


If the top of the shelf sticks out at all from the side or back walls, use a power sander to remove excess material until it's flush with the adjoining wall.

Backbox

Assembling the backbox is much like assembling the main cabinet. Start with the top and one of the side walls. Apply a bead of glue to the groove on the side piece, then fit the top piece into the groove.

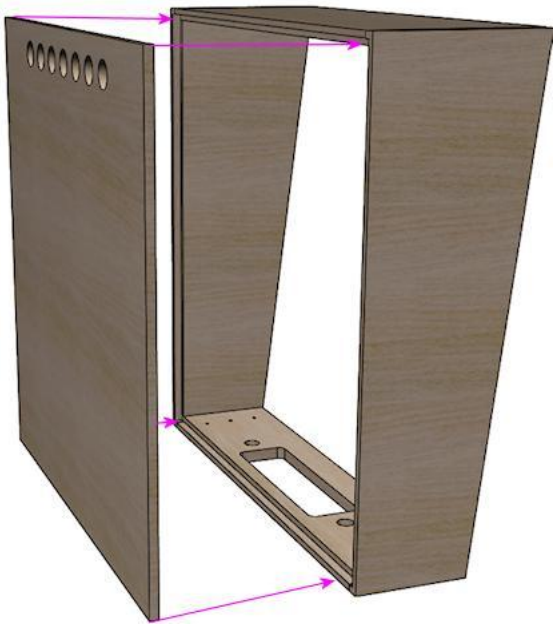




Attach the floor.

Add the remaining side wall.

The back wall should now fit into the grooves along the back edges of all four walls. Apply glue around the grooves, and put the back wall into place. It should fit so that it's flush with the edges of the walls.



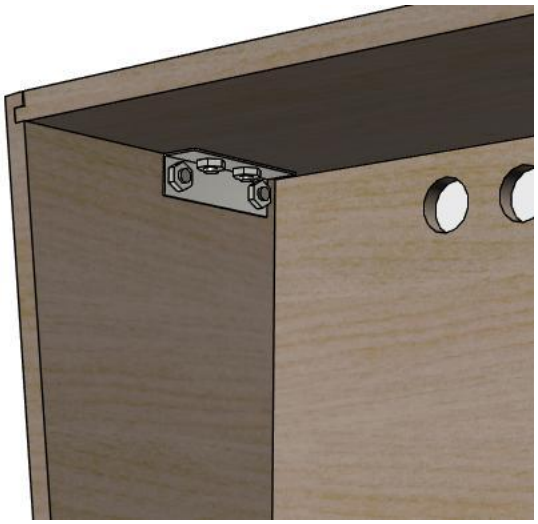
The back should be flush with the back edges of the adjoining walls when installed.

In addition to the glue, you can add some finish nails to strengthen the back wall. Use small finish nails, such as 1" #18 brads. Drive them in from the back of the back wall, around the perimeter, set in about 3/16" from the edges. Space them every few inches; four or five nails on each side should be sufficient.

Corner bracing

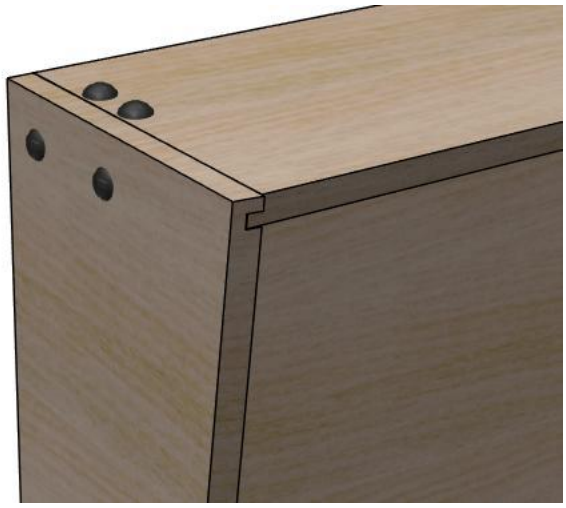
The original WPC backboxes had steel braces at the corners to strengthen the joints. The glued corner joints are actually pretty sturdy all by themselves, if you construct them using the rabbeted design described above, but apparently Williams deemed it necessary to add some heavy reinforcement. I'm sure that came out of long experience with commercial operators who banged the machines up with rough handling and then complained when they broke.

In my opinion, you shouldn't need any corner braces for a machine in home use. The glued corners should be plenty strong. But if you'd like to reproduce the original construction faithfully, or you just don't trust the glue joints, here are the details for the Williams design. The Williams part number for the braces is #01-9167, and they're fastened to the backbox walls with ¼"-20 x 1-¼" carriage bolts (black finish, 4320-01123-20B) and ¼"-20 flange nuts (4420-01141-00). You'll need four of the braces and sixteen each of the carriage bolts and flange nuts. Place one brace at each corner, more or less all the way back against the back wall, and use the holes in the brace as a drilling template to drill holes for the carriage bolts. Insert the carriage bolts with the heads on the outside, and fasten with the flange nuts on the inside.



WPC backbox brace, Williams part #01-9167, installed at the upper corner. The real WPC-era machines used one bracket like this at each corner. If you want to go this route, use the brace as a drilling template to drill ¼" holes for the bolts, and fasten the brackets with ¼"-20 x 1¼" carriage bolts (on the outside) mated with ¼"-20 flange nuts (on the inside).

The Williams corner bracing is about as strong as you can get. You'd have to rip the wood apart before those bolts would come out. The downside is the bolts are visible on the outside of the backbox. (Not *too* visible, though; the WPC machines use black bolts that tend to disappear into the artwork unless you're looking closely.)



How the carriage bolts look on the outside. They have smooth rounded heads (with no screwdriver slots), and come in silver and black finishes.

If you don't care about using the exact original parts, but you still want some kind of corner reinforcement, you might consider using generic steel 1" corner braces instead. You can buy these at any hardware store. Use ¾"-long wood screws to attach them, in a size that fits the holes in the corner braces you buy (#6 screws will usually work). Use two or three braces per corner. Keep them within 5" of the back wall, so that they won't be visible when the translite is in place. This setup won't be as strong as the Williams brackets and carriage bolts, but it provides some reinforcement, and it doesn't require any externally visible fasteners.

Alternative reinforcement using generic hardware-store corner braces, fastened with wood screws. Be sure to keep the braces behind the translite plane (5" from the back wall), so that they're not visible.

Translite/DMD guides

The WPC backbox has some little wood blocks along the walls that act as guides for the translite and DMD/speaker panel. These might or might not be interesting to you for your virtual cab, because a virtual backbox is a little different from a real one. Specifically, our backbox uses a TV in place of the normal translite, and in some cases a single TV replaces both the translite and DMD panel.

But it's not a simple matter of TV *or* translite. You might actually still want something similar to a translite, to mask out the bezel around the perimeter of the TV. There are two common ways to handle this:

- Create a custom wood cover for the TV area, with a cutout for the TV.
- Use a glass or plexiglass translate in front of the TV. Optionally, you can use paint of decals around the perimeter of the plexi to mask out the dead space beyond the edges of the TV display.

Both serve the same function, of hiding the TV's bezel so that you only see the screen, but I very much prefer the second option. The first option calls way too much attention to the virtual-ness of the cab. The second makes it look like a real pinball machine.

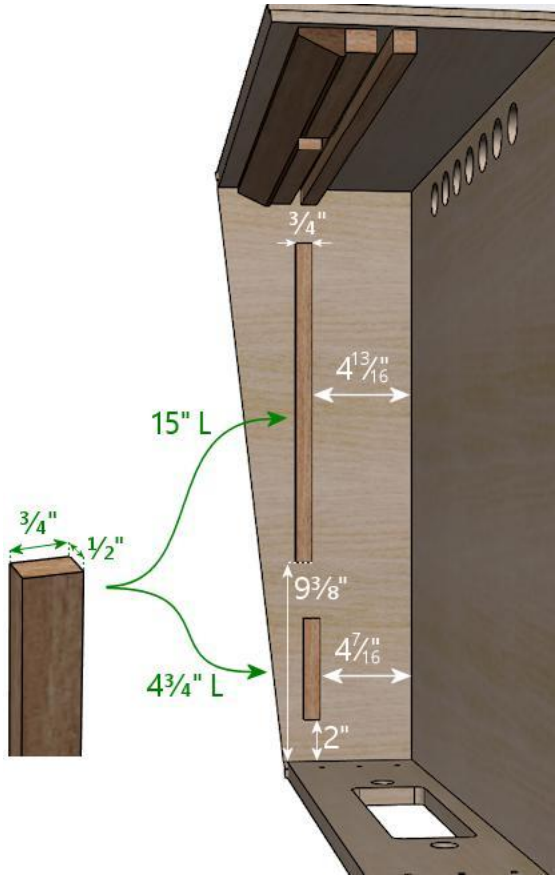
(There's a third, less common option. Some people route grooves into the side of the backbox exactly deep enough to contain the TV's bezels. This requires an extremely thin bezel, and requires that you use a custom backbox size chosen to perfectly match the TV, so it's not compatible with the standard plans.)

If you're planning to use a custom wood cover instead of a translite, you can skip this section, as your custom cover won't need the guides that hold the conventional parts in place.

Before proceeding with installing these, there are some cases where some of the guides should *not* be installed:

- If you're not using a standard speaker/DMD panel, don't install the lower guides (the ones at the bottom of the side walls) until you've worked out whether or not you need them. These are designed for the pre-WPC-95 style of speaker panel only, and might not work if you're using a home-brew design of your own.
- If you're using a WPC-95 speaker panel - the type that's made out of a single piece of molded black plastic - don't install the lower guides. The lower guides are only for the older pre-WPC-95 speaker panel. If you're using a standard panel type but you're not sure whether it's WPC-95 or pre-, consult Chapter 31, Speaker/DMD Panel for help.
- If you haven't finalized your backbox TV install plan yet, don't install the upper side wall guides. Those get in the way of some TV installation methods. See Chapter 30, Backbox TV Mounting for more.

Assuming that you're using the standard translite and the early 1990s style of speaker/DMD panel, here's a cutaway view showing the placement of the guides on the sides of the cabinet. Note that the right side wall isn't shown in this view, but (as you would probably expect) has the same two guide pieces shown on the left wall, at the same positions in mirror image.

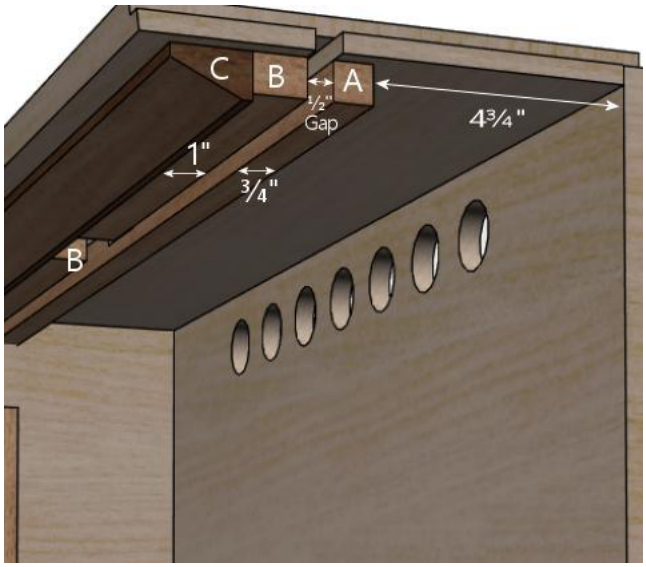


*Guides for the translite and speaker/DMD panel on side walls. The distances shown are to the inside surfaces of the back wall and floor in the assembled backbox. Note that some backbox TV installation designs work better **without** the 15" upper pieces, so you might want to defer installing these until you've finalized your backbox TV plan. Also note that the lower pieces are only used for the "original" style of speaker/DMD panel, **not** the WPC-95 molded plastic type.*

The top piece is 15" x ¾" x ½", and the bottom is 4¾" x ¾" x ½". Orient them so that the ¾"-wide face is against the side wall. Both pieces run parallel to the rear wall.

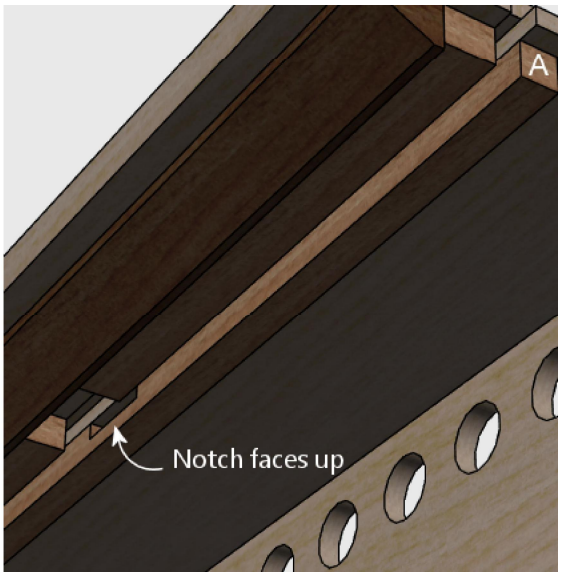
There's nothing sophisticated about the installation of these on the real machines - they're just glued and nailed. You should do the same thing. Apply a little glue on the back of each piece and nail it into place with finish nails (I'd suggest 1" #18 brads). Use one nail about every 4" down the length of each strip, centered in the strip.

Here are the guides on the inside of the backbox "roof":

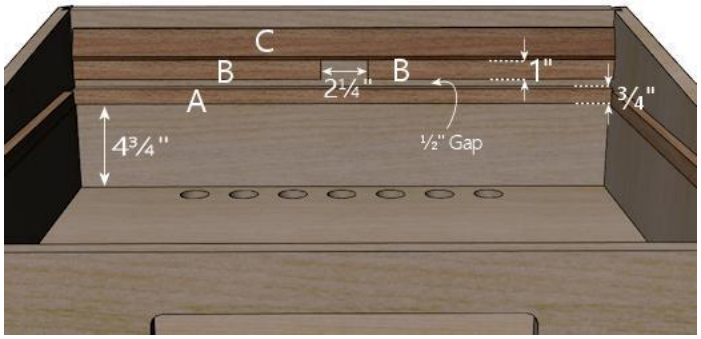


Cutaway side view of the top guides. The pieces labeled "A", "B", and "C" are detailed below.

Note how the "A" and "B" pieces align with the translite groove in the ceiling.



Note that piece "A" should be installed with the notch facing the ceiling of the cab.



Top guides, viewed from below.

All three pieces run parallel to the rear wall.

- "A" is 27⅛" x ¾" x ¾". It should fill roughly the full width of the backbox interior; simply center it left-to-right relative to any leftover space. Install it with the routed notch for the translite lock (if you included that) facing up, towards the ceiling of the cab.
- "B" (quantity 2) are each 12⅜" x 1" x ¾". Leave a ½" gap front-to-back between these pieces and the "A" piece, and leave a 2¼" gap left-to-right between the two "A" pieces.

  Important! If you installed T-nuts for the translite lock plate, see below.

- "C" is the wedge-shaped trim piece we described earlier. Orient it as illustrated in the side cutaway view above. Install it abutting the "B" pieces, without any gap.

Aligning the T-nuts in the "B" pieces: If you installed the T-nuts for the translite lock plate as described earlier, you should make sure they're correctly aligned for your lock plate when you install the "B" pieces. Use this procedure:

- Lay out the pieces at the install location as described above, but don't glue anything yet.
- Orient the pieces so that the T-nuts are on the side that will be glued to the ceiling of the backbox.
- Grab your lock plate and its Torx screws. You don't need to assemble the rest of the parts yet, but it's also okay if you've already done so.

- Put the lock into position. Make any adjustments to the positions of the "B" pieces to match up the screw holes in the lock plate with the pre-drilled holes in the "B" pieces.
- Fasten the lock plate by screwing in and tightening the screws.
- With the lock plate installed, glue and nail the trim pieces into position.
- Remove the lock plate.

This will ensure that the "B" pieces end up perfectly aligned with the lock plate. If you install the pieces separately, very slight variations in the measurements could leave the T-nuts so misaligned that you wouldn't be able to fasten the screws.