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Overview

A project enclosure's front panel is akin to a software application's user interface, but for hardware -- it connects the operator with the device's switches, controls, and status lights. A nicely designed panel will inherently familiarize and explain how to use the device, ergonomically match the hands, fingers, and eyes of the operator, and will make your project look professionally made. This tutorial will share design hints and construction techniques for reliable methods to create a colorful front panel.

The first method uses the output of an ink-jet printer with graphics printed on photo paper. The graphics are layered between the enclosure and a clear sheet of polycarbonate or acrylic plastic. The second method replaces the photo paper and clear plastic sheet with a self-adhesive vinyl label (a sticker) obtained from a commercial print shop. Either technique will produce a front panel with a colorful, professional appearance.

The UFO Controller Project

The example for this guide is a project that evolved from a discussion with a local short film producer/screenwriter who needed a miniature UFO model for an upcoming film. The producer had already picked out the scale model, ran a few video tests against a green screen background, and had figured out what collection of Close Encounters lighting animations would be needed. The project that I was tasked to build involves a string of lights for the saucer's outer propulsion ring, an inner ring to represent the portal transporter energy beam, and a set of spotlights to select and mystify potential victims.
Each of the saucer's functions has its own patterns and color combinations, up to four per functional area. Any or all of the sections may operate simultaneously, so independent on-off controls and status indicators were needed. To adjust to the camera's specific light exposure sensitivity and shutter speed, master speed and brightness level controls were included that affect all three saucer lighting functions simultaneously.

**Supplies**

- Washable glue stick
- Blue tack *(Fun-Tak Mounting Putty)*

**Tools**

- Scissors
- Paper cutter
- Sharp hobby knife
- Hand countersink tool
- Automatic or manual center punch
- Power drill or drill press with a variety of drill bits
- A variety of step drill bits (a must for plastics)

As with any project involving power tools and sharp implements, safety is your primary concern. Review tool operational safety instructions before beginning this project. Be careful!

For this project, the drilling was fairly simple since the enclosure was soft ABS plastic and the clear layer was plastic, as well. Drill bits have a tendency to drift away from center of the hole in soft plastics unless you use a drill press. Since we'll be using a hand-held power drill for this build, we'll solve the drifting issue by drilling 1/16-inch pilot holes before drilling to the final hole size.

Small pilot holes are the best way to accurately guide larger drill bits. Be patient -- the components will fit better if the holes are drilled with precision. Take it slow and easy. Carefully center the drill bit before spinning the drill. Use light pressure at a moderate speed and let the drill bit do the work.

A step drill bit works very well with plastics, smoothly cutting a precisely round hole. The trick is knowing when to stop drilling -- when the step drill bit has reached the correct diameter. You will be able to feel it as the drill moves from
Design the Panel

While the film's producer discussed the variety of lighting animations needed for each scene, I sketched a series of front panel arrangements to help draw out the requirements for how the model's lighting would be controlled. Here's the one we settled on.

<table>
<thead>
<tr>
<th>ON</th>
<th>RING</th>
<th>PORTAL</th>
<th>SPOTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The controls of this conceptual drawing were grouped logically by required functions (from left to right): Global Controls, Ring Patterns, Portal Patterns, and Spots Color. Controls were arranged with the most-used controls on the right side of the panel since the operator is right-handed. The power switch was placed away from the other controls to prevent accidental operation.

The Global controls include master brightness and speed for all animations as well as the controller's primary power on/off switch. Each of the other functions have separate on/off switches to allow any combination of the functions to be operated simultaneously (that also created some interesting software challenges). Each function has a variable control knob that selects a pattern or, in the case of the spotlight function, varies the color.
There were no indicator LEDs on the conceptual version of the front panel. It was thought that the switch positions would clearly show the status of each function. That's something that changed during the evolution of the design.

The next step in the process was to determine the physical dimensions of the control panel. Spacing between switches and potentiometers should 1) appear visually balanced, 2) accommodate the operator's fingers, and 3) provide enough room for the knobs, connecting wires, and the component itself.

A grid was drawn over the conceptual drawing to get an idea about physical size. Next, a graphical rendering of the final front panel was made to obtain the producer's approval of the look, feel, and functionality of the controller.
Evolve the Design

The panel design for this project had to change to accommodate an available enclosure and panel size. The overall layout of the final version (on the right) is very similar to the original concept, but the iterations made it smaller, simpler, and more consolidated. The design evolution also introduced a way to incorporate color-coded activity LEDs to make it obvious which function is active.

Once the design is completed, component layout can commence. To do that, we're going to need an accurate drawing so that we can drill the enclosure's front panel for those LEDs, switches, and potentiometers.

Don't be hesitant to rework your design. Pretend to use it to see if it fits your hand and if it accommodates any special operational needs. Ask someone who is unacquainted with your project to describe what the panel is supposed to do. Be open to suggestions.
Produce the Panel Drilling Guide

After the conceptual design is finalized, overlay an accurate grid to determine hole placement and to guide the panel machining process. The drilling guide can be drawn by hand, designed in a CAD tool, Photoshop, or even PowerPoint. Accuracy is important since we'll be applying a label layer that will need to line-up with the enclosure's panel holes.

- Use the drawing tool or method that is most familiar to you and that can print out accurate copies of the guide on paper.
- To speed up the drilling process, list the diameters of each hole on the guide.

Some components employ integrated mechanical index pins or tabs to prevent the components from changing orientation during use. Another benefit of using index pins when fabricating is that the component's mounting nut won't have to be over-tightened to secure the component, avoiding label and panel warping. Both label attachment techniques in this guide will disguise the index pin holes so that they won't show on the finished panel.
Determine Component Placement

It's a good idea to check your panel layout with actual components. In this photo, a drilling guide was placed on the front of the enclosure, then each switch, potentiometer, and LED bezel was positioned to confirm the look and feel as well as the wiring clearances needed for electrical connections. Use a few globs of blue tack to stand up components in their typical operating orientation to complete the visual mock-up.

Many software CAD tools have 3D features to assist in component placement and clearance tests for printed circuit boards and 3D printing. With the addition of a few custom footprints for panel-mounted components, you can use the tool for designing...
front panels. Here's a rendered KiCad example of the panel layout for this project. The underlying 2D model can easily be printed and used as a drilling guide.

Next, let's have a short discussion about the two labeling methods.

**Labeling Methods**

Let's take a break from the design process to talk about methods for applying front panel labels. Although there are many ways to label a panel, this guide will detail the two that have been working well for me given my limited set of hand fabrication tools (no 3D printer, drill press, laser cutter, or milling machine).

Each method attaches the labels through a series of layers that are drilled or machined in a specific way. Let's start with the first technique, the Sandwich.
The sandwich approach consists of three layers, the enclosure base, an ink-jet printed layer, and a clear covering that protects the printed layer from wear and tear. This is the more rugged of the two techniques and is the one that takes longer to prepare.

The enclosure can be almost anything from aluminum or steel to ABS plastic or acrylic. It can be 3D printed or assembled from laser-cut plywood. Your project will dictate the selection of the enclosure material. For the UFO miniature controller, the enclosure material selected was ABS plastic, sized to fit the layout of the front panel (Jameco #18893). The label graphic layer is ink-jet printed on a sheet of high quality photographic paper. A sheet of 1/16-inch transparent acrylic or polycarbonate plastic is used for the clear layer.

Most components, when mounted, will require holes through all three layers. Components with index pins such as potentiometers and toggle switches will require an additional hole in only the enclosure layer. It's not recommended that you clip off or bend the index pin to avoid drilling a hole for it; the index pin will keep the component from changing orientation. Without the index pin, the shaft nut would need to be overtightened to prevent spinning, causing the label graphic and clear layers to warp and distort.

Components that are not natively designed for panel mounting such as an LED with wire leads can be mounted by using fabrication accessories such as a bezel. A bezel will help to disguise the mounting hole and will improve the looks of the LED.
The second labeling method consists of just two layers: the enclosure and a vinyl sticker with the printed label graphics. The enclosure layer is machined exactly like the sandwich method. A pre-printed sticker is then aligned with the holes and carefully applied. Status lights can either be mounted with a bezel or placed just under the sticker with a dot of hot glue or blue tack. If the area of the sticker above the LED is a lighter color, the LED's glow will usually shine through.

Since the vinyl sticker layer is soft, it's essential that component index pin holes be used so that shaft mounting nuts will not have to be overtightened to prevent spinning. The uncut sticker layer above the index pin hole will cover and disguise the hole.

This method is easier to align and much faster to prepare than the sandwich method and works well for projects that won't see continuous use. It isn't as glamorous or shiny as the other method due to slight flaws that result from the vinyl printing and coating process, but the colors are vibrant.

Commercial vinyl stickers come in many varieties and finishes. It's recommended that you look for stickers with a clear outer protective layer designed to minimize UV and physical abrasion damage. Tell your sticker vendor that dimensional accuracy is important to you and ask them to minimize the border size to avoid trimming the graphic content during printing. StickerMule (https://adafruit.it/Cwa), who has an
affordable 10 unit minimum order quantity, was the vinyl sticker printing vendor selected for the controller project.

Remind your sticker vendor that dimensional accuracy is essential for your label. Printing and shipping could take a week or two -- plan accordingly.

We will step through the Sandwich panel labeling process next. Many of the techniques for preparing the enclosure layer will apply to the Sticker method, which we will cover in its own chapter.

Make the Sandwich Label

The steps shown here are for the Sandwich labeling technique. Skip to the Use the Sticker Method chapter if you plan to use a vinyl sticker as the label for your project’s front panel.

Prepare and Print the Label Graphic

Prepare the final graphic by removing all but the final drawings and legends. Hole markings are not needed for every control or LED, but some should be included to align the label to the pre-drilled enclosure.

Print the label on high quality glossy photo paper using your ink-jet printer’s highest resolution setting. After printing, compare the component placement and overall size
of the label with the enclosure and clear layer to confirm that the label dimensions are correct.

The next step will seal the printed label's front and back surfaces to protect it from fading and warping. Move to a dust-free environment where the fumes from the spray coating won't be a problem for pets or people.

**Seal the Printed Label**

Select a clear gloss spray that is non-yellowing and that will provide some UV resistance to keep the front panel looking fresh for a long time. The spray coating will also keep moisture from warping and decaying the label’s photo paper foundation. The gloss finish provides a smoother and more uniform layer than a matte finish and looks better when sandwiched under the clear polycarbonate/acrylic layer.
• Place a clean sheet of paper over the printed side of the label to protect it from handling and dust.
• Flip the label and protective sheets over so that the protective sheet is on the bottom next against the benchtop surface. We'll be sealing the back of the label page first.
• Tape the corners of the label page to keep the sheet taut and apply a coat of clear gloss spray to the back side of the label page. Wait until the spray has completely dried, then apply a second coat.
• Remove the tape, flip the pages over, and place the protective sheet under the label page. Secure the label page corners with tape and apply a coat of clear gloss spray over the printed graphics. Work to achieve an even coating.
• Wait until the spray has completely dried, then carefully apply a second coat. Allow the two coats to dry thoroughly before handling.
• Let the coatings cure overnight before cutting the graphic to its final shape.
It's time to drill and machine the enclosure and the clear polycarbonate/acrylic layers for the sandwich. Power tools will soon make an appearance.

Machine the Layers

The steps shown here are for the Sandwich labeling technique. Skip to the Use the Sticker Method chapter if you plan to use a vinyl sticker as the label for your project's front panel.
So that the holes will line up, we'll simultaneously drill through the clear and the enclosure layers. After that, the clear layer will be removed leaving the enclosure and its drilling guide. The index pin holes are drilled next. The final machining step is to remove the enclosure's drilling guide.

Let's head out to the workshop bench to do some drilling then to the kitchen sink to remove the enclosure's paper drilling guide.
Attach the Drilling Guides

- Do not remove the protective covering from the clear polycarbonate or acrylic plastic sheet. The protective covering will be removed just prior to mounting the components to the panel.
- Using a washable glue stick, attach one of the two drilling guides to the clear plastic sheet. After the glue dries, trim the clear layer to size using the guide as an outline for cutting the edges. (The photo shows a small desktop saw being used to trim a polycarbonate sheet to size.)
- Attach the second pre-printed drilling guide to the enclosure face using the glue stick. Thoroughly secure the guide, particularly the outer edges. Press down with your fingers to secure the label.
- When the glue dries, place the clear layer directly on top of the enclosure's drilling guide and accurately align the edges. While holding the clear layer, tape it in place with blue painter's tape.
- Don't place tape over any of the hole markings that need to protrude through the clear layer. In this example, the hole markings for component index pins were covered with tape to keep from accidentally drilling through the clear layer.
Drill the Clear and Enclosure Layers

- Use a small, sharp center punch to create an indentation in the exact center of each hole. The indentation will help to guide the pilot drill in the next step. The photo shows the use of an automatic center punch adjusted to a low impact setting, perfect for soft plastics.
- Start by drilling 1/16-inch pilot holes in the center of three or four holes marked on the drilling guide. Choose holes that will help to secure the clear layer to the enclosure. After drilling the pilot holes, enlarge the holes with a 1/8-inch drill bit.
- Insert screws into the those first few holes and attach with nuts. Pro tip: instead of small nuts, secure the screws with long standoffs; they are easier to handle and grip with your fingers.
- After the clear layer is secured with screws, continue drilling 1/16-inch pilot holes. After the remaining pilot holes are drilled, enlarge the holes with a 1/8-inch drill bit.
- Using a step drill bit, drill each of the remaining holes to the size printed on the drilling guide. Gradually remove each screw and drill those holes to the correct size. Pro tip: place some tape around the step drill bit to visually note the desired hole diameter.
- Peel back the blue tape and remove the clear layer. Do not remove the clear layer’s protective film just yet.
- Using the enclosure's drill guide, drill the index pin holes.
• On both sides of the enclosure and clear layers, use a countersink or small file to remove burrs left over from the drilling process. This is an important step since irregularities may show through the label.

• Head to a sink and run lukewarm water over the enclosure drilling guide. The paper will soften and the washable glue will start to dissolve. Remove the paper and rub the remaining glue with your finger until it completely disappears. Dry with a paper towel.

• Check for any remaining burrs around the holes and remove with the countersink or a small file.

With the drilling completed, it's time to attach the label and the components to the enclosure. Our new front panel will be ready soon!

Attach the New Panel

The steps shown here are for the Sandwich labeling technique. Skip to the Use the Sticker Method chapter if you plan to use a vinyl sticker as the label for your project's front panel.
The final part of the process is to assemble the layers of the sandwich. The printed label will be aligned and attached to the enclosure followed closely by the clear layer. Since the holes in the clear layer and enclosure were drilled simultaneously, hole alignment should be a fairly easy process.
• Place a few spots of glue on the enclosure; three or four should be enough to hold the printed label in place during alignment with the component holes.
• Carefully place the label on the enclosure and coarsely align it with the holes.
• Remove the protective film from the clear layer and place it against the printed label. Adjust the alignment of the label and clear layers simultaneously. Once things are lined up, hold the layers tightly against the enclosure during the next step.
• Using a very sharp hobby knife, remove the label paper from a hole near the top or bottom of the panel. Insert the component into the mounting hole and secure with a shaft nut, or in this case, an LED bezel. The installed component will help to maintain the alignment.
• Check the alignment and make any necessary adjustments, then remove the label paper from a hole on the opposite end of the panel. Insert the component for that hole and secure it. The alignment is now locked-in.
• Use the hobby knife to remove the label paper from the remaining holes. Remove any paper pieces and dust from the process then install the remaining components.
You've done it! You now have a durable, colorful, and functional front operating panel for your project. We'll be looking forward to seeing your project's new front panel on the weekly Show and Tell! (https://adafruit.it/Cy6)
Use the Sticker Method

Prepare the Sticker Graphic

Prepare the final graphic by removing all but the final drawings and legends. Hole markings are not needed for every control or LED, but some should be included to align the label to the pre-drilled enclosure.

Create a high-resolution actual-size file of the final graphic in the format specified by your vinyl label printing vendor. When you order, request dimensional accuracy and a minimum border size.

Attach the Drilling Guide

- Attach a pre-printed drilling guide to the enclosure face using a glue stick. Align and thoroughly secure the guide, particularly the outer edges. Press the guide in place with your fingers.
Drill the Enclosure Layer

- Use a small, sharp center punch to create an indentation in the exact center of each hole. The indentation will help to guide the pilot drill.

- Drill a pilot hole for each of the component mounting and index pin holes using a 1/16-inch drill bit. After drilling the pilot holes, enlarge the holes with a 1/8-inch drill bit.

- Using a step drill bit, drill each of the holes to the size printed on the drilling guide. Pro tip: place some tape around the step drill bit to visually note the desired hole diameter.

- Use a countersink or small file to remove burrs left over from the drilling process. This is an important step since irregularities may show through the label.
• Head to a sink and run lukewarm water over the enclosure drilling guide. The paper will soften and the washable glue will start to dissolve. Remove the paper and rub the remaining glue with your finger until it completely disappears. Dry with a paper towel.
• Check for any remaining burrs around the holes and remove with the countersink or a small file.

With the drilling completed, it's time to attach the vinyl label and the components to the enclosure. The new front panel will be ready soon!

Attach the Label
• After verifying that the label size and hole placements are correct, remove the sticker's backing sheet. Carefully align the sticker so that the component mounting holes line up with label.
• Once aligned, apply pressure to the center of the label with your fingers and gradually work out towards the edges.
• Double check the alignment before continuing to the next step. Remove and reposition the label if necessary.
• Using a very sharp hobby knife, cut away the label covering each component mounting hole. A clean edge on the inside of the hole will help the component seat properly.
Install the Components

- Mount and secure the components.
  Apply a washer between the shaft nut and the vinyl label to keep from damaging the label.

You now have a nifty new front panel!
We'll be looking forward to seeing your project's new front panel on the weekly Show and Tell show! (https://adafruit.it/Cy6)

Do not remove the label from index pin holes. The label will cover them so that they won't show.

If you are planning to project the light from behind the label as was done with the UFO controller, do not remove the label from LED mounting holes.
Other Examples

These panel design and making techniques evolved over the past few years, driven by the need to provide a useful hardware interface and to protect the internal circuitry. More importantly, the projects provided an outlet for refining my fabrication skills, learning new skills, and the stress-reducing therapeutic benefit of working mostly with hand tools.

Here is a sampling of projects from the past two years that may help to illustrate my continuing journey to discover the front panel fabrication holy grail.
GuitarView

The label on this guitar pedal was ink-jet printed on regular paper and decoupaged to the pedal case with three coats of brush-on polyurethane finish. The 3mm LEDs were mounted in plastic bezels.

A custom PCB was used for the internal circuitry. A custom panel drilling guide for the LEDs was included with the circuitry PCB order. The epoxy-fiberglass drilling guide made accurate drilling a breeze. (The guide survived many projects and is still in use today.)

Although the quality was excellent, decoupage was a slow process requiring four to six hours of waiting between coats. I needed to find a faster method.

TimeBox Controller

This was the first attempt at the sandwich technique and was used to perfect the process. The photographic paper label was printed on an ink-jet printer, protected with two layers of glossy clear spray coating, then installed under a 1/16-inch thick clear acrylic (Plexiglas) layer. The mounting shafts of the pushbuttons and the potentiometers held the clear layer in place without glue or additional screws.

The project was an interpretation of a time machine controller for a local film. It produced the sound effects of time travel using an Adafruit sound FX board (https://adafruit.it/e82) and stereo amplifier (https://adafruit.it/Cy7).
Workshop Corrosion Monitor
When the remodeled workshop was christened, this was used to monitor and predict corrosion conditions in the unheated shop. The main unit and the remote used twin Adafruit Feather M0 RFM69 (https://adafruit.it/wid) boards to calculate dew point and comfort levels, transmitting the data to the small battery-powered remote unit.

The challenge of this project was to incorporate a large, rectangular opening into the panel. The custom display bezel was made using Plastruct (https://adafruit.it/Cwm) architectural extrusions. The clear panel was made from a 1/16-inch clear acrylic sheet. The clear layer was attached to the enclosure with four knurled hex screws.

SMA-2020 Monitor
The controls on this 20 watt stereo audio monitor amplifier (https://adafruit.it/Cy8) didn't span the entire guitar pedal enclosure so the front panel was sized to accommodate only two controls and the text labeling.

The connector panel on the rear of the enclosure (not shown in this photo) also had a sandwich label to indicate which connector did what.

SMA-0303 Monitor
Since the controls of this small stereo audio amplifier (https://adafruit.it/Cy7) weren't part of the front panel, it provided the freedom to experiment with a more graphical approach to the label.

For the first time, a 1/16-inch clear polycarbonate sheet was used for the clear layer of a sandwich panel label. Polycarbonate isn't as brittle as acrylic, preventing breakouts when drilling holes near a cut edge.
FXM-8 Effects Mixer
The challenge with this project was to incorporate a removable sound effects legend card. The photo paper layer was trimmed away where the legend was to live, creating a nice thin gap between the enclosure and the clear polycarbonate layer to insert the legend card.

The rear panel connectors received the same sandwich label treatment as the front panel.

This project was used to play pre-recorded sound effects for my band's live musical performances. The mixer portion allowed relative adjustment of sound effect loudness with that of the attached keyboard so that only one stereo wire had to run to the PA system.

Snowman Holiday Lighting Controllers
The repeatability of the drilling guide technique came in handy for making six NeoPixel strip animated lighting controllers. Prepainted metal guitar stomp pedal enclosures (one-half size) were used (Hammond-DigiKey (https://adafru.it/Cwn)).

There's an Adafruit Trinket M0 (https://adafru.it/zya) running CircuitPython (https://adafru.it/BeW) inside each of those boxes.
RetroMon USB Power Meter
This front panel was inspired by 1960's era test equipment. LED pilot lamps and switches similar to those of the period were selected to keep with the retro look. Illumination for the analog panel meter ([https://adafru.it/Cy9](https://adafru.it/Cy9)) was provided by four white LEDs filtered through Kapton tape. The Plastruct bezel technique perfected earlier was used in this project, augmented by a graphic black frame that was part of the ink-jet printed label.

The project was designed to isolate incoming USB power while passing the data signals needed for attached microprocessor boards. An internal battery provides power to the load while being trickle-charged by the USB input.

Eurorack Modular Lunchbox Synthesizer
The colorful Crunchable Synth and blue Ice power distribution modules were the first attempt at using the Sticker label technique. This project also helped to perfect the method for hiding LED indicators behind a vinyl sticker label. The foundational panel material for this project was 1/16-inch acrylic plastic although other plastics or metal would work as well.

Yes, that's an AdaBot lunchbox ([https://adafru.it/Cya](https://adafru.it/Cya)) used as an enclosure.