# My experiences with back lighted panels on an experimental aircraft.

**Larry Buller**

First off, let me for warn you, I am not an expert at making back lighted engraved panels. Now creating and cutting a metal instrument panel with the Panel Pro is a snap. My desire has always been to make engraving and back lighted just as easy as creating the base panel.

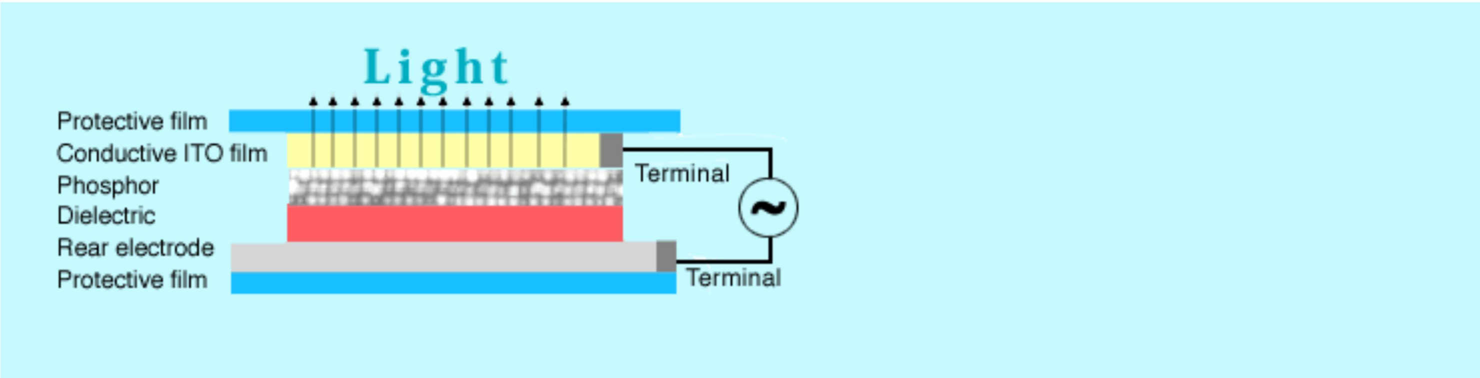
Things to consider when making a back lighted panel:
Lighting sources
light transmission medium
engraving surface.

Lets start this exercise by reviewing lighting sources.
Possible lighting sources are:
Incandescent lamps
Electoluminescent lamps
fiber optics
Light emitting diodes (LED)

Incandescent lamps. These have been available forever and used in many Kin Air and other circuit breaker panels. Advantages are they are commonly available and good light pattern off of the side of the lamp. Disadvantages are Heat, and difficulty in mounting. These lamps have short life and provisions for easy replacement must be made. I am aware of some sockets where the base is mounted to the metal panel base The cap has a clear side and is threaded through the lighted panel. When the lights are on, they shine through the clear cap into the light distribution medium.
I do not have a source for these sockets. Another potential disadvantage is that the drive current over a large number of lamps could be significant.

Electroluminescent lamps (EL). An EL material is one that when connected to an AC voltage source, gives off light. These are available as sheets and wires.
The power source for an EL lamp is an AC voltage typically in the range of 110v. 400 hz frequency will work, but dedicated el power supplies will typically run around 20khz.
EL material is capacitive and the current required is nearly negligible.

Advantages. EL sheet gives a very uniform lighting. The current requirements are very low. Dimming can be achieved with a simple potentiometer.




Since the light output is fairly even, the diffuser layer of your lighted panel can be fairly thin. EL tapes are available in long lengths appropriate for sub panels. The light output is consistent from about .1” of the edges all the way across, so it is easy to accommodate vertical text beside the switches.

Power supply: Requires a high voltage AC. If you have an existing aircraft inverter, you may consider using the high voltage supply. 26Vac will not work.

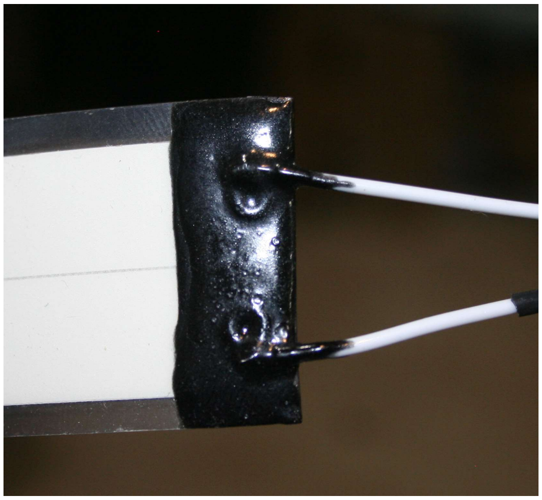
Resist the temptation of cheap EL inverters. They are can be sensitive to the area you are lighting relating to the capacitance. Hooking up an inverter designed for a particular capacitance to a lamp with less capacitance can result in the destruction of the inverter. In addition, cheap inverters can exhibit undesirable electrical noise and interference with other electronics. Aircraft inverters are more tolerant to the small capacitance of el panels, but 400 hz can be coupled to headset wiring if close to the el panel.

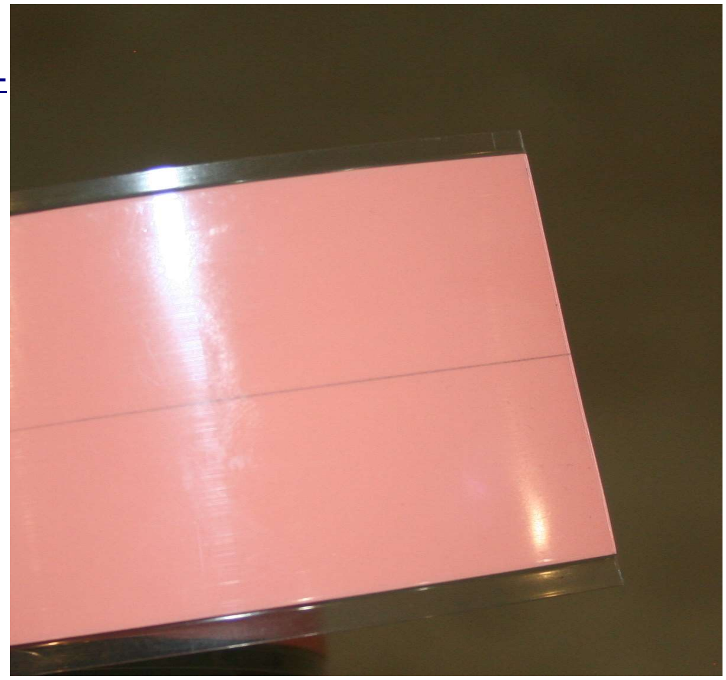
Cutting EL material: You cannot cut EL material with an end mill. Cutting with an end mill will result in the lamp shorted out. It must be cut with blade or scissors. The protective film is fairly tough. AvCAM (the Panel Pro operating software) has provisions for a trailing tip blade cutter. Material mounting on the Panel Pro is a challenge with this. Contact me for more information on the blade cutter. Any cut edges must be protected against shorting to users or the metal panel.

Electrical connection: You cannot solder directly to EL material. EL material reaquires a mechanical connection and the wires can be attached to that. The connectors I have come across have resulted in unacceptable bulk. I have had some success using a simple staple and carefully soldering to that. Even that method requires a pocket in your light distribution medium and the metal panel. Most EL tapes have a protective plastic on both sides but some have the busses accessible along the edges. I have explored the use of conductive glue, however the EL material is lightly attached and comes off along with your wire easily.

If you are considering EL material, be sure to check out the voltage requirements as there are some materials that require around 200vac for the proper light level.

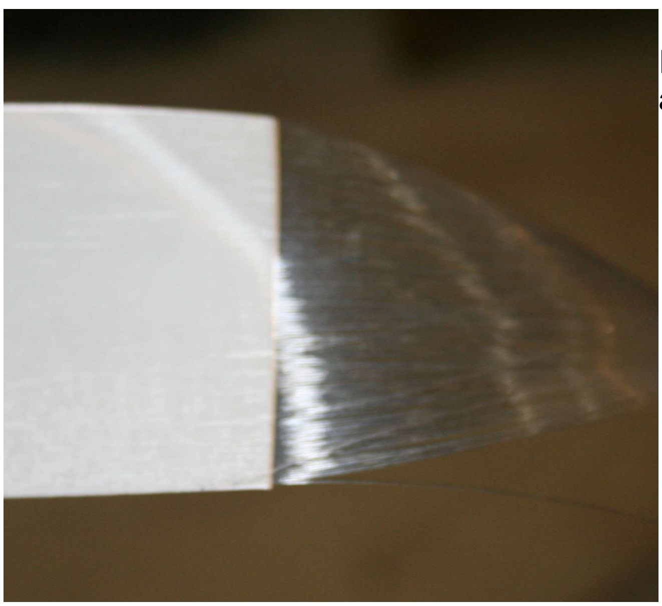
More information on EL material can be found at http://electroluminescence-inc.com/whatisEL.htm



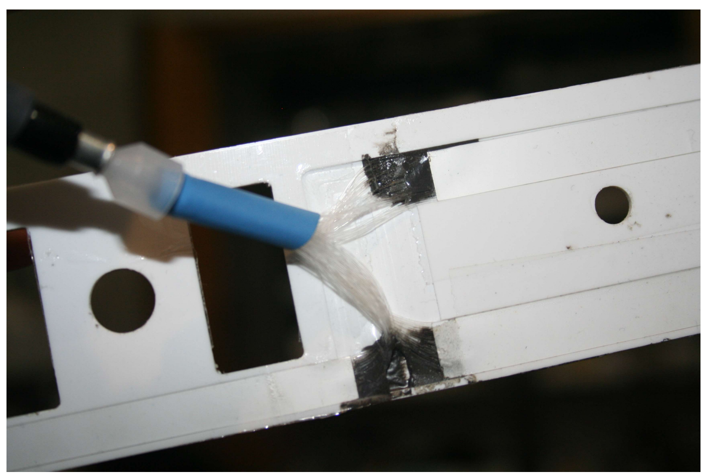


Fiber-optics.

I found what I thought might have some application. http://sptpanel.com/
Superior Panel Technology has some fiberoptic sheets, although I was not able to find them just now on their web site. You may have to call them if you want this product.



It consists of tiny plastic fibers that are adhering to double sided tape. What you



need to do is make a channel behind the lettering. Cut lengthwise along the tape which is about 10" long to make strips that fit behind your lettering. I embedded the fibers into the channel with rtv and secured the fibers as they pull away from the panel with epoxy. The groups of fibers get grouped into a bundle crimped with a metal ferrule. The LED that provides the light, is in a soft plastic cup that is a friction fit on the ferrule. Like the EL lamp, you need to have a large cutout in the panel. It is not easy at all to make any corners with the fiber strips. You cant use heat shrink on the fibers because of the ow melting point of the fibers.

The light output is fairly even.

LEDs:
Leds are now ubiquitous and inexpensive. So how can we use them for back lighting.

My early experiments involved cutting holes in the back of clear acrylic and placing the leds in the holes. One thing to bear in mind is that leds are designed to emit light out the top as opposed to around the sides like an incandescent lamp. Clear acrylic transmits light just fine, but if you place a led directly behind lettering you will have a very bright spot in front of the led and dim beside it. I contacted Johnson plastics to see if they had some translucent plastic to use as a light diffuser. They did not. I had some white HDPE plastic that diffused ok, but polyethylene does not glue well. Then I ran into TAP plastics and hit the jackpot.

http://www.tapplastics.com/product/plastics/plastic_sheets_rolls/acrylic_sheets_color/341
on this page select "sign white 40%, 3/16 thick. This material is used to diffuse the light and provide a more even light distribution. I found that 1/8 (3mm) thick is not thick enough to diffuse the light.

Top layer. For years I have recommended reverse engraved plastics. If you are not back lighting, that is still probably the way to go. Engraving on the back side leaves the front surface smooth and almost impossible to damage. However, in order to see the engraving, it is necessary to paint fill the engraving. Unfortunately white paint is very opaque. We want light to shine through when back lit, but visible during daylight hours.

Reverse engraved plastics work nice on an annunciator where the lettering is not paint filled, but lights up brightly when lit. Annunciators will be the subject of another paper.

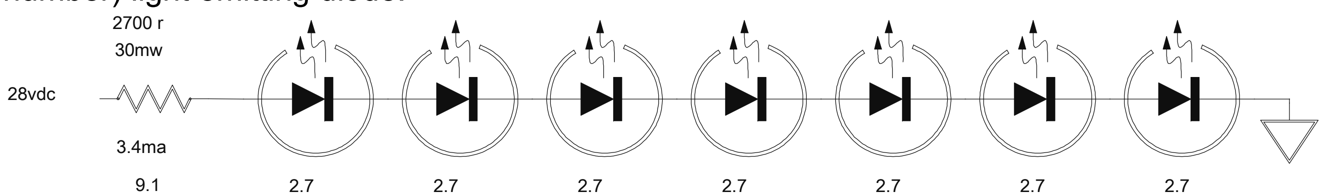
Rowmark has a product part number UG602402 available at Johnson Plastics.
http://www.johnsonplastics.com/catalogsearch/result/?q=ug602402

This is .020 thick plastic, black matte surface with a white background. Light shines through very nicely. You front engrave this .005 deep. The lettering looks spectacular!. A Very visible brilliant white.
HOWEVER, the top surface is attached by a screen printing, is durable except for solvents. Solvents WILL dissolve the top layer. You can get materials with a plastic top layer, but they need to be engraved to about .012 depth. The additional depth is not as attractive from a front engraved perspective.

Cutting the diffuser:
The process I use is to make the holes in the diffuser layer large enough to clear mounting nuts, and the holes in the top (engraved) layer big enough to clear switch levers, circuit breaker knobs etc. With the holes large enough to clear the nuts, you will have to provide holes for hold down screws.
After cutting, The back and sides need to be painted so that ight does not leak out the sides. Using a good grade of masking tape, mask the areas by the LEDs so that the light will shine through. Mask the front so that the light can get through to the top engraved layer.

Tape the 2 parts together with 3M 467MP double sided tape available from Johnson Plastics in various widths.  Spray adhesive can be used only with great caution to avoid getting it on the top sheet engraving.  Spray adhesive also has a way of getting on the painted edges of the diffuser making it difficult to get off without also removing the paint.

LEDS and dimming.
The project that was the basis for this paper was a circuit breaker panel for a turbine Lancair.  This is a 28v airplane.  Lets talk about led characteristics.  Leds are wired with the anode to a positive voltage.  They act somewhat like a zener diode.  Essentially no current flows until they reach a point where they start conducting and start emitting light.  Leds need to be powered by a current limited device or have an inline current limiting resistor.  They are rated with a forward voltage, which should be the voltage across the diode when it is conducting.  The diodes also have a specified current.  I settled on the VAOL-3MWY4 (Digikey part number) light emitting diode.



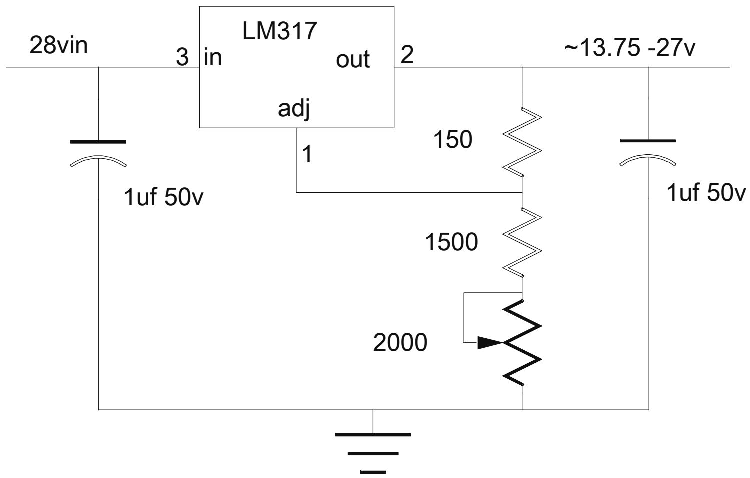

The data sheets do not give a lot of useful information with respect to back lighting.  You may need to do a bit of experimenting to get the desired results.  There is one hard and fast rule.  Never apply a dc voltage without a current limiting resistor!.  The part number led above is listed as a high intensity white led with an average maximum forward current of 30ma.  I have found that 3.5 – 5 ma is about all required.  Bear in mind that the bright white engraving stands out nicely until the cockpit is quite dark.  When it is pitch black out, very little lighting is needed.  Beyond 5 ma there is little difference in the light output.  The math here is a little difficult due to the non linearity of current to light output.  The data sheet shows the forward voltage of 3.2 to 3.4 v.  There is a graph of forward voltage and increases from about 2.7 at around 2ma to 3.7 at 30 ma.  The minimum forward voltage is important because that is the voltage at which the diode will start to conduct.  If you use a different led, you may need to experiment to find this turn on threshold.  On these leds the actual minimum turn on voltage is about 2.5 volts.  The voltage measured above was a typical voltage under normal back lighting conditions.

In the drawing above I have 7 diodes in series.  The circuit breaker panel I was working on had 6 circuit breakers in a row.  The leds were placed in between each breaker on a .75" spacing.  More about that later.  The forward voltages add up to 10.8 volts. The higher the forward voltages in the led string are, the less power will be dissipated by the resistor.  You could put a resistor on each led, but being a basically lazy person, I elected to have as many leds in series as possible.  The resistor in this case is only dissipating 30mw.  Well below even an eighth watt resistor.

One situation that will come up is that you may not be able to use the same number of leds in each string.  You will naturally use a larger resistor on the lower count strings, however the forward voltage will be reached much sooner resulting in the lower count string lighting up sooner than the higher count string.  This could be significant in very low light situations.  One thing you can do to mitigate this is to put a zener diode in series to make up the voltage difference.  Or you can use shorter strings or a resistor by each led.

Don’t even try to match incandescent lighting with a common dimming voltage.

LED dimmer.




The led string above consumed 30mw of power. 8 strings therefor will consume 240 mw or less than ¼ watt! It would be tempting to use a simple potentiometer to control the current. I like to use the LM317 regulator. They are cheap, readily available and almost bulletproof. If the output is shorted the current is automatically limited. It is also thermally protected. At 1/4W, little heat sinking is needed. Note that the tab needs to be isolated from ground. I use a thermal pad and plastic screws.

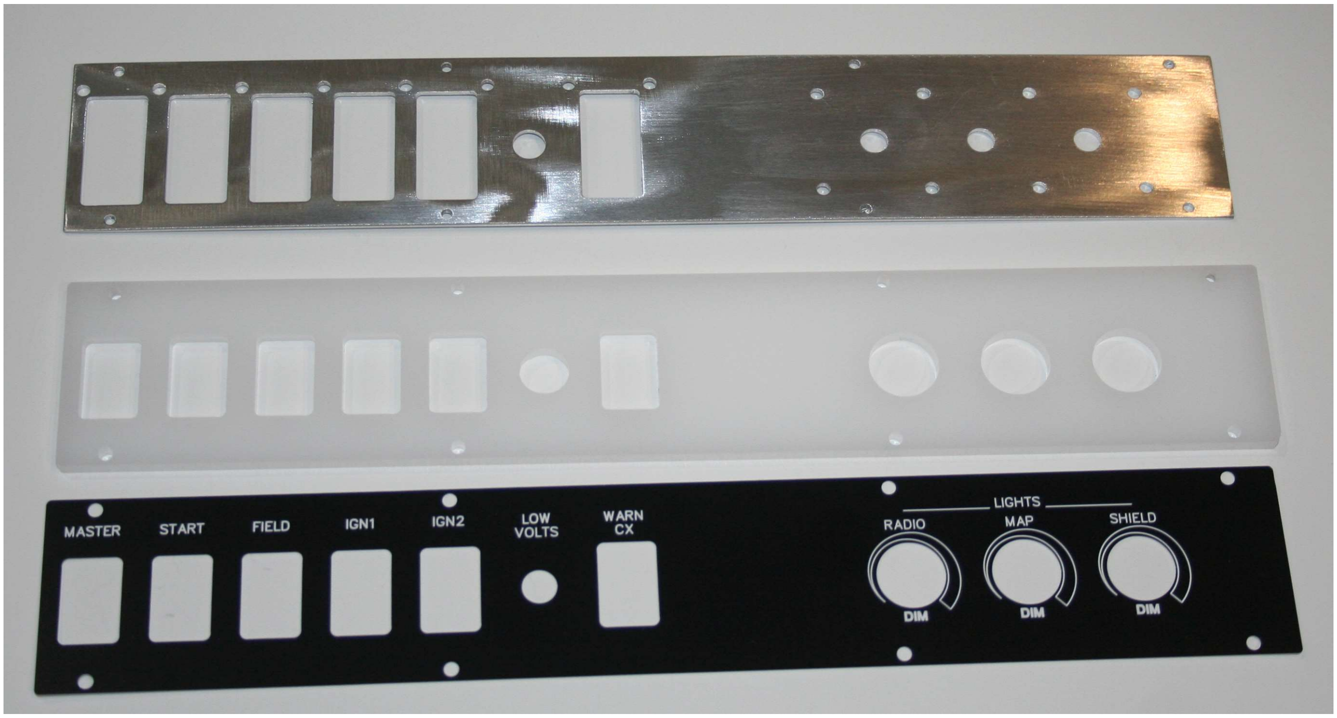
The voltage in this example goes from 13.75 to approximately 27Vdc. At a 2.7v per led turn on, that adds up to 18.9v, so any voltage below that will result in the leds off. There are numerous LM317 resistor calculators available on line. The goal is to have the minimum voltage low enough so the leds do not turn on, and the high end high enough to provide the desired max light without losing Potentiometer travel.

If you use a 0 to maximum voltage control scheme, you will lose about ½ of your pot travel and then have a very sensitive region between proper light level and blinding.

Mechanical considerations:

One consideration shared with the use of T1 incandescent grain of wheat lamps is mounting challenges.

The lamps need to mount in the base instrument panel. The technique I used in this uncertified application was to make 1/8” holes in the panel. Place the leds from the rear so that the tip of the led is flush with the front panel. These leds have a fairly narrow beam. The farther you can mount them from the lighted panel, the more even the light distribution will be. I fastened the leds in the panel using hot melt glue. If painting is not an issue, rtv could have been used as well. One nice thing with hot glue is that if you need to change something, heating with a heat gun quickly softens the glue so you can remove leds.



The picture above represents the base panel, the diffuser, the top layer.
I want to add back lighting to an existing design. In this case, I don't want to cut a new panel so I have to work with the constraints of the existing design. The existing switches are a CK brand, and are kind of difficult to remove. I could have pocketed the diffuser layer so that the switches stay snapped into the base panel. Instead what I did was to get a slightly smaller switch that would snap into the top and diffuser. I could then remove the 8 440 screws that I plan to secure the dimmer with and the switches will com with it. I did however leave the existing dimmers attached to the panel. The smaller switches also gives me a bit of working room for the leds.

Since I used the Panel Pro to do all the cutting, I made a metal piece that to use as a jig to drill the 440 mounting holes and the holes for the leds. The switch holes are the same as the original so we can clamp this to the existing panel and get the registration right. This works out for us because the original holes are a bit larger than the new switches (also snap in) and do not compress the new switch snap lugs. The jig is cut with a 3/32 end mill so the holes are close to the required size or a bit under size for accurate match drilling. I intend to tap the base panel 440 which requires a .089 tap drill. I will have to use a 3/32 drill to mark the centers, then finish up with the tap drill. The leds are 3mm (.118) so I made those holes .120 and will drill those straight through.

Diffuser layer. I used 4.5mm (sold as 3/16) 40% sign plastic from TAP plastics. The 40% relates to the amount of light that passes through. They have some sampler packs that let you see the difference between 20%, 40% and 60%. 40% works for me. I am not entirely sure if the 40% lets 40% of the light through or blocks 40% of the light. Either way the 40% works good.

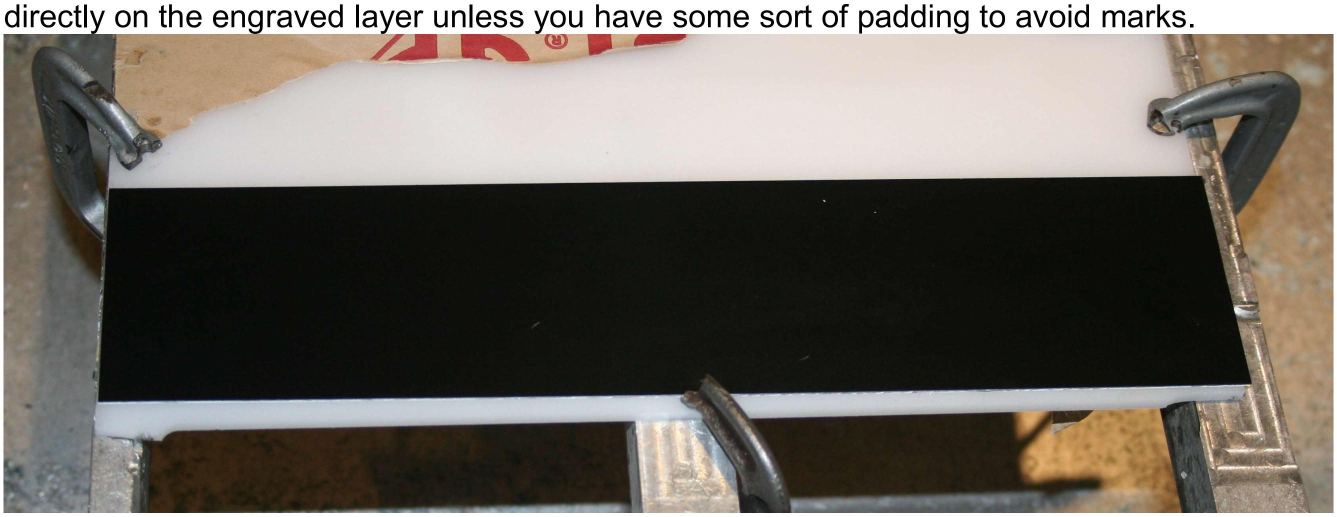
You can consider a couple of strategies. Cut the pieces individually and glue them together or glue the diffuser and top layer and cut them as a unit.

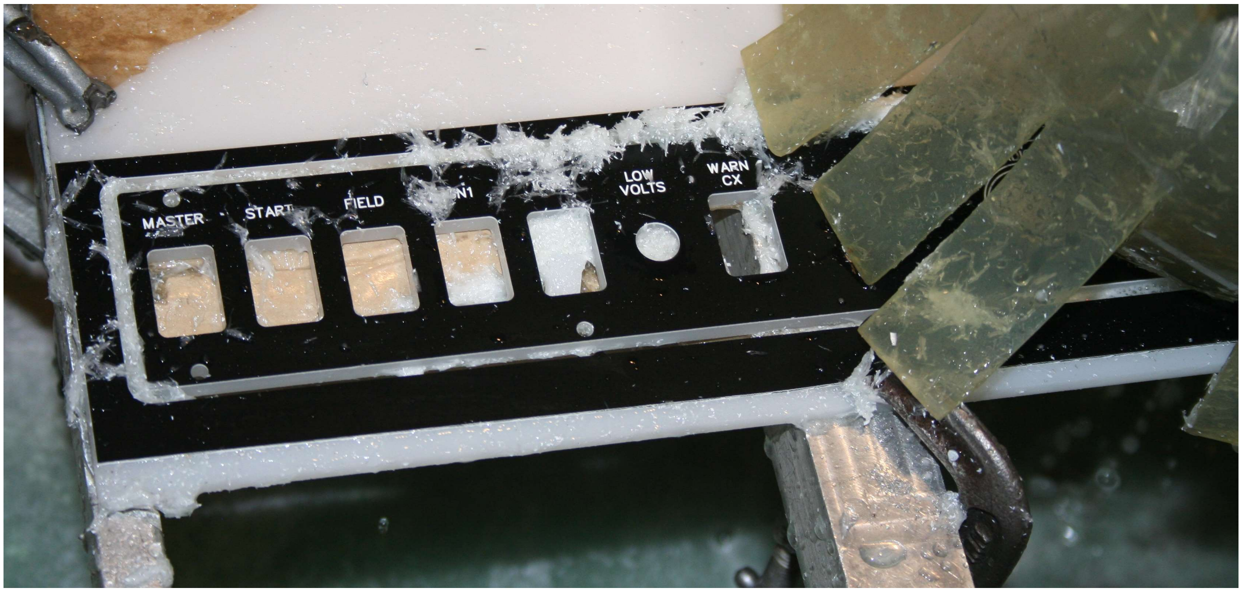
It is difficult to get the 2 pieces exactly registered.
My preferred sequence :
Glue the top layer to the diffuser
do the engraving
cut the holes and outside as the top layer dictates.
Flip the piece around.
Align it so it is straight,
cut the counterbores from the back.
It is difficult to exactly align the piece so you may want to make the counterbores a bit bigger than required.
Paint the counterbores and edges.

The data sheets for the switches I used list a maximum panel thickness of .2”. I cut the diffuser from the back side and included a cut out area to provide a thinner area to snap into. I mad the dimmer openings .625 to clear potentiometer nuts. This also has the effect of making the knobs stick out a bit less.

Top engraved layer: I made the square switch holes to the exact size for mounting from the front. The round Knobs are .625 long x .5” diameter. They are not always perfectly centered on the shaft so I allow a bit so they don’t drag on the side if they are not perfect. After engraving, make sure you rinse the parts with clean water and dry so that you don’t have water spots.

This depicts the engraved layer glued to the 40% sign plastic diffuser layer. Do not clamp directly on the engraved layer unless you have some sort of padding to avoid marks.

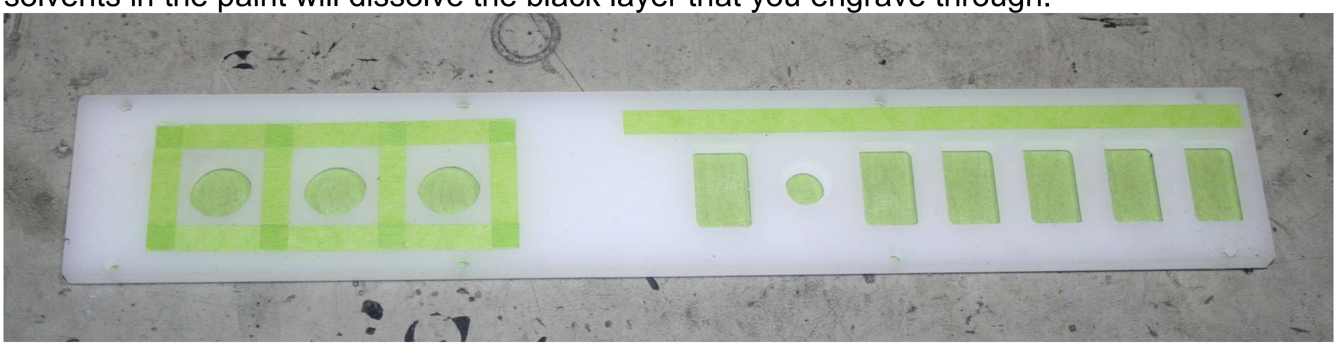


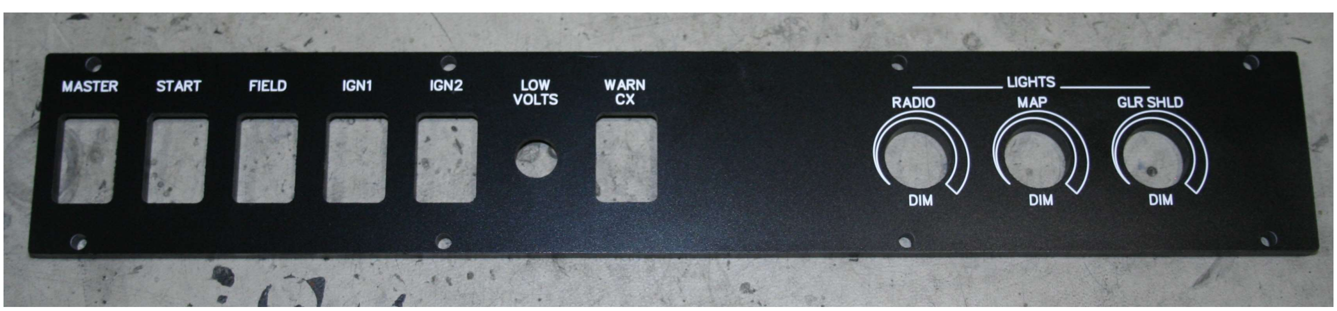



Cutting the panel out after doing the engraving. Yup, I am cutting through the bars, just not very deep.

This is the back view after the counter bores have been cut. These are holes that are larger than the holes in the front, but not cut all the way through.

The back needs to be masked where the Leds are to pass the light through. The edges and cutouts need to be painted so light does not escape around the edges. The front has to be VERY carefully masked so that paint does not leak around the edges or counter bores. The solvents in the paint will dissolve the black layer that you engrave through.






We have a winner. The alignment is great, the engraving is great, the paint is good.

So you ask “why can’t we just paint the diffuser and engrave through the paint?  You can.  A couple things to consider. Will the engraving be the brilliant white of the Rowmark product? Probably not.  How consistent is your paint thickness?

The counter bores will need to be painted after the holes are cut, so you will need to clamp the panel down and align it to do the engraving.  There is always the risk of mis-alignment, as well as the risk of damage by clamping on a finished surface.

Refer back to the statement at the beginning.  I am no expert at engraving.  My purpose here is to give you some ideas and tools in making your own back lighted panels.

Wit a bit of patience and thought you can have beautiful lighted panels.

Engraving material sources:
http://www.johnsonplastics.com/?gclid=CMvo_KKR4dQCFY-KswodnXIl_g

| pn | description |
|---|---|
| 311101 | plastic, reverse eng, reverse matte clear, 1/32 |
| 312401 | plastic, Rowmark reverse engraving, matte, black, 1/32 |
| 322402 | Plastic, engraving, Rowmark, ultramatte front, 1/16, black/white |
| CM101 | acrylic, engraving, clear black matte |
| T467MP12 | 12” x 60 yd .002” adhesive transfer tape. |
| T467mp2 | 2” x 60 yd .002” adhesive transfer tape. |
| ADATAPE | the above tapes applied by Johnson Plastics |

The engraving stock full sheet is 24” x 48”  It can be purchased in quarters.  Johnson plastic can also apply the adhesive transfer tape for a nominal fee about $3.73 per quarter sheet. We advise use of the coolant while engraving which could be a problem with the paper adhesive backing, so it may be a good idea to apply the tape after engraving.

Diffuser material:

https://www.tapplastics.com/

4.5mm-Acry-sign white-40  Acrylic, 4.5mm, white sign white, 40%
you may need to call them to order this.  This is our own part number.