THE DEFINITIVE GUIDE TO

MEMBRANE SWITCH DESIGN

JN WHITE®
PRECISION ANSWERS

PRIME LABELS | GRAPHIC OVERLAYS
MEMBRANE TECHNOLOGY

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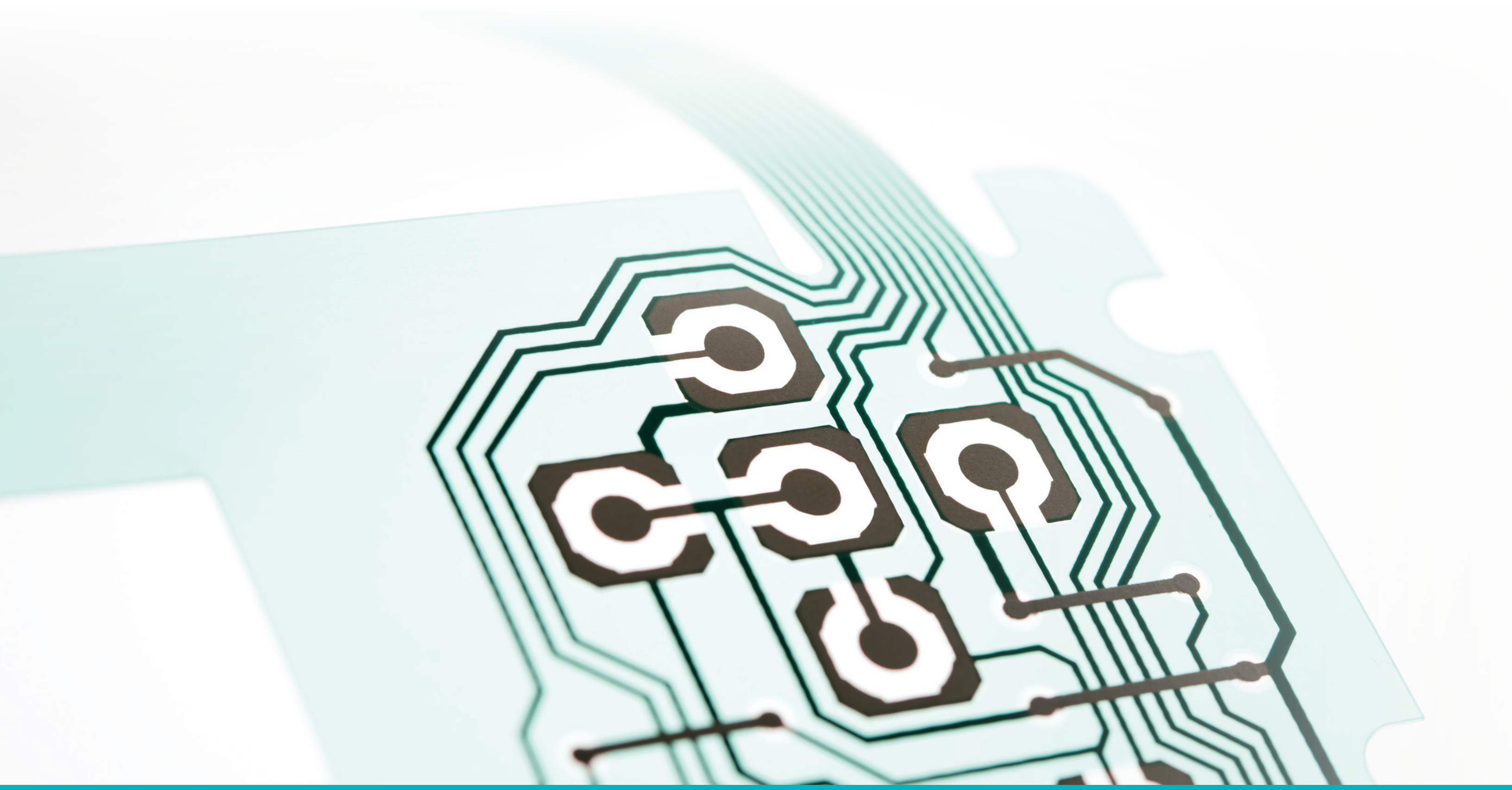


INTRODUCTION

We've developed this Membrane Switch Design Guide to outline the essential areas you as an engineer need to specify so that your membrane switch manufacturer can design and develop an assembly that meets your exact objectives.

We will start with different functional aspects of the user interface itself, and then conclude with general recommendations for tolerances and limits you should be aware of. All of these factors will contribute to the design choices made for each layer of the membrane switch assembly (see Figure 1).

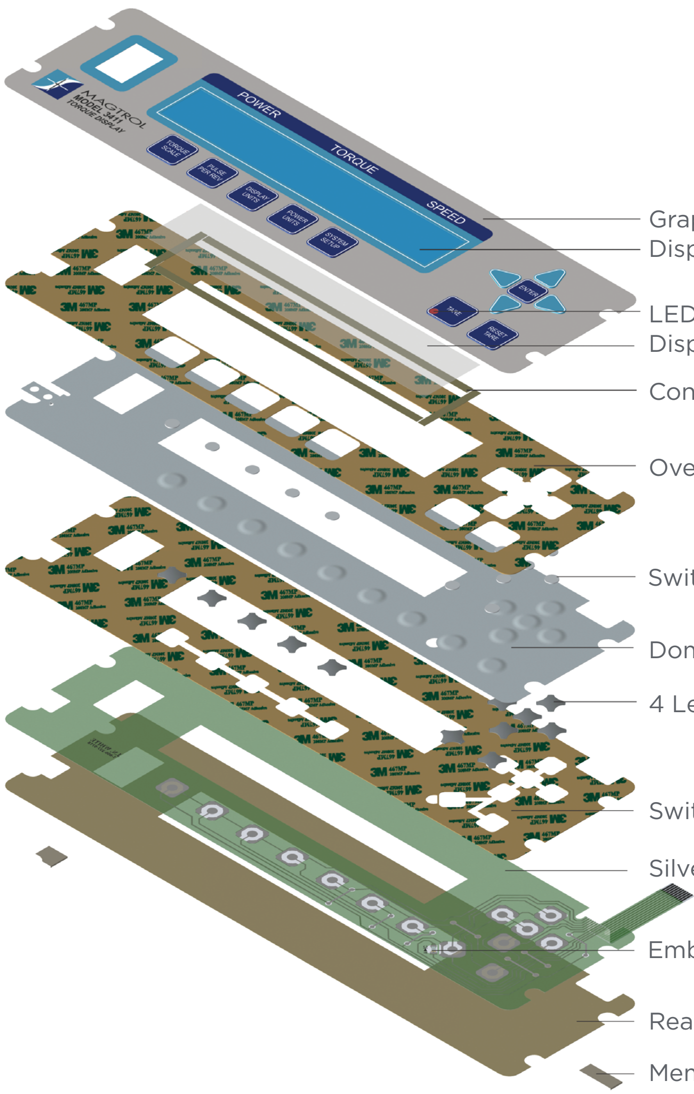


Figure 1. Exploded View of a Typical Membrane Switch

WHAT TYPE(S) OF TACTILE FEEDBACK ARE REQUIRED?

Your answer(s) to this question address the "feeling" that accompanies the activation of individual membrane switch buttons. These decisions will dictate many of the structural choices made by the manufacturer. Elements that come into play include the following:

GRAPHIC OVERLAYS

If no feedback is required, the design decision relies solely on the material that forms the outer layer of the user interface.

While the two most widely used materials for graphic overlays are polycarbonate and polyester, JN White™ always recommends polyester for membrane switch applications. Polyester is more durable, more chemically resistant, and can successfully withstand more than one million key actuations.

Polyester is a clear material available in a variety of finishes and textures, including a range of gloss and matte finishes.

For good tactile feedback, choose an overlay thickness between .006" (.152mm) and .008" (0.203mm). These thickness ranges will offer the durability to meet your requirements, with the sensitivity to provide a quality tactile effect.

BUTTON DOMES

Tactile membrane switches incorporate a metal dome or a polydome into the membrane assembly to achieve a desired tactile (and sometimes audible) response.

By using different materials and sizes for these domes, you can vary the actuation force required to activate the switch.

An additional adhesive layer, called the dome retainer, is placed just under the graphic overlay to hold the dome in place. This is often integrated with shielding properties to provide additional electrical functionality.

Stainless steel metal domes come in a variety of shapes and sizes. Actuation forces range between 180 to 700 grams, with 340 grams being the most common. Metal domes are nickel-, silver-, or gold-plated. The selected plating depends on the conductivity requirements of the switch, chosen based on electrical resistance.

Softer and quieter than metal domes, plastic polydomes are thermo-formed from a layer of polyester that's been screen printed with a silver "shorting" pad. This allows you to create multiple buttons across a single panel, and it is a very cost-effective technique for high-volume switches (after the cost of the initial tooling).

SILICONE-RUBBER KEYPADS

Silicone-rubber keypads are ideal for industrial environments, where a bold look and a more rugged, robust interface is required.

Silicone-rubber keypads can be custom-molded in different shapes, patterns, and colors to support user-friendly backlighting options.

WHAT TYPE(S) OF TACTILE FEEDBACK ARE REQUIRED? *(continued)*

EMBOSSING

By providing raised tactile elements, embossed features can dramatically enhance the look and functionality of the graphic overlay.

There are three basic styles of embossing: pillow, dome, and rim.

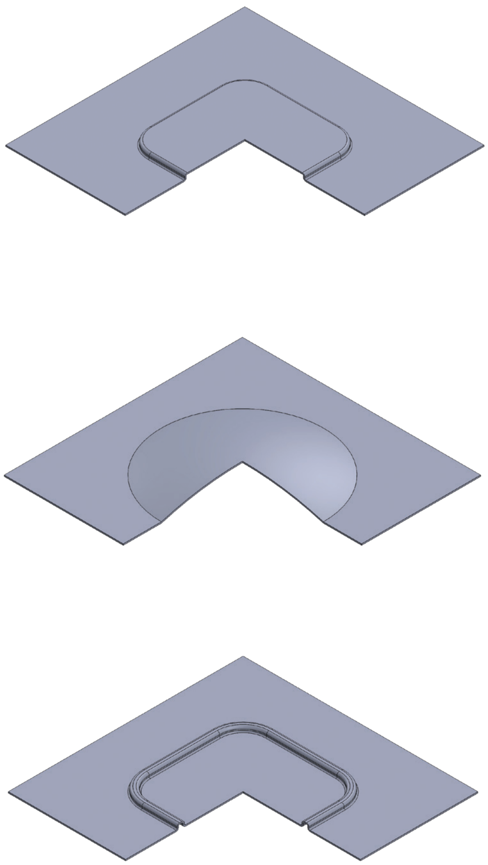


Figure 2. Pillow, Dome, and Rim Embossing

There are two ways to emboss an overlay. The first method is with male and female magnesium dies. This method is fine for most applications but there are height limitations: embossing height is usually 2.5 times the material thickness, the minimum width of a rim emboss is 0.050” (1.27mm), the distance between embossed features should be .100” (2.54mm) and the minimum inside radius should be .020” (.508mm).

Thermoforming is the second method and has more design flexibility, but higher tooling costs. It is ideal for complex shapes, including multi-level designs and logo details.

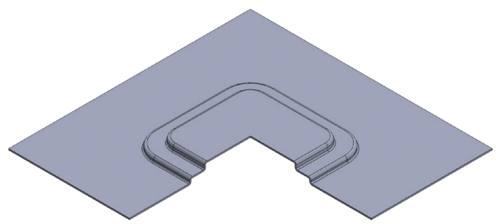


Figure 3. Multi-Level Embossing

HOW MANY BUTTONS ARE REQUIRED?

This fundamental question will dictate key design decisions related to the underlying circuitry of your membrane switch. Elements to consider include the following:

ELECTRICAL LAYOUT

A variety of factors come into play as you choose how to handle the contact points in your membrane switch design.

First of all, how many contact points (or buttons) are required? Once you determine this, you can determine what type of pinout will be used.

Both common bus and X-Y matrix designs can be supported (see Figure 4). The X-Y matrix schematic is more compact, and also lends itself to a more compact connector with fewer pins.

As for electrical properties, contacts are typically rated to carry no more than 100mA for standard circuit traces with a .039" (1mm) width. Closed loop resistance is typically less than 100 ohms, and the power rating should be kept below 1.0 watts.

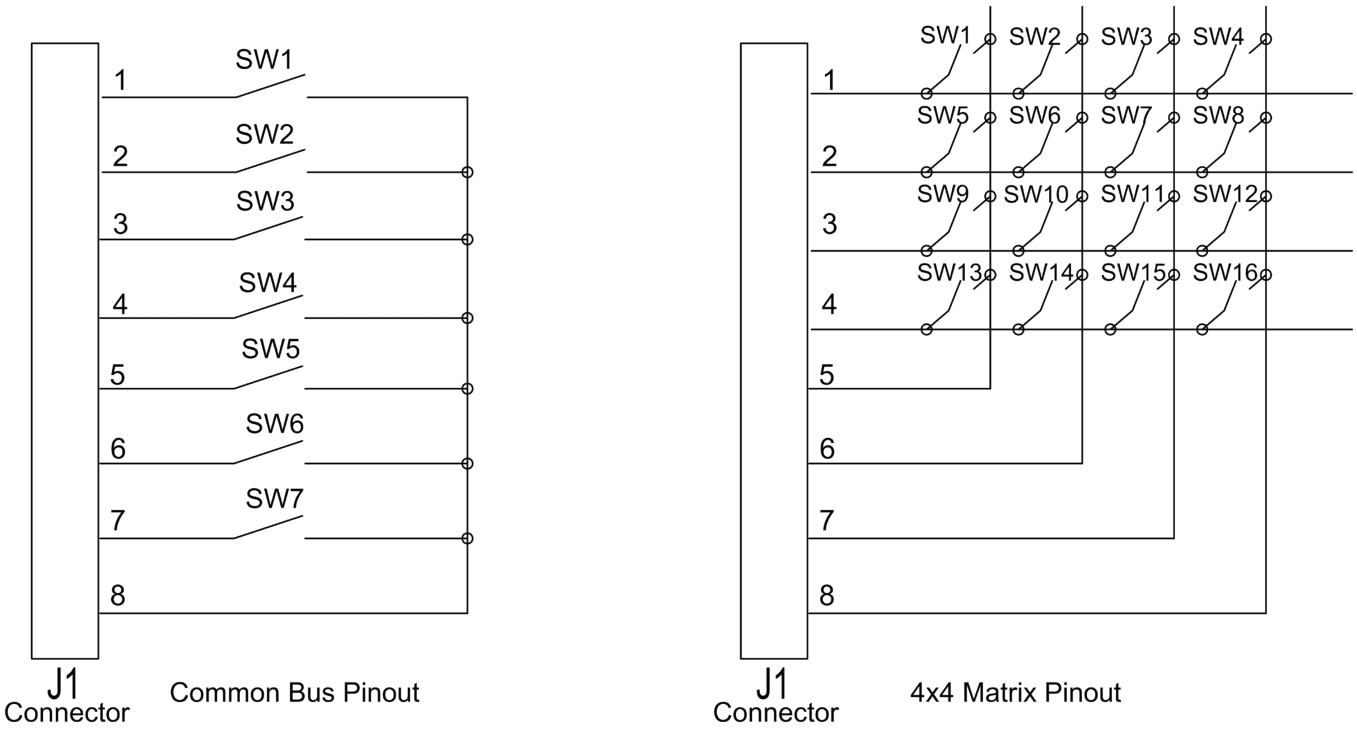


Figure 4. Common Bus and X-Y Matrix Pinouts

HOW MANY BUTTONS ARE REQUIRED? *(continued)*

TERMINATION METHOD

There are a few different options and considerations for terminating the electrical circuitry of the membrane switch.

The first consideration is tail length, as well as the location of the tail exit. This is largely determined by the design of the overall product, and how the membrane switch will be integrated into this design.

The next consideration is the design of the tail itself. If there's room and a non-complex path for the tail, a ribbon cable of screen-printed silver is a simple, cost-effective approach. For compact designs requiring bending and creasing of the ribbon cable, etched copper flex over polyimide is the smarter option.

Once these choices have been made, you need to determine how this circuitry will be physically connected to the printed circuit board. The simplest option is a solder tab, which is stitched onto tail and directly soldered to a printed circuit board.

If you choose to incorporate a connector, standard connectors interface to .025" (.635mm) square posts on .100" (2.54mm) centers. Latching and non-latching options are available. Alternatively, ribbon cables can be designed to slide into board mounted connectors. LIF and ZIF connectors are available with .049" (1.25mm), .039" (1mm), and .019" (.5mm) trace spacing. Minimum pitch for silver screen-printed traces has typically been .039" (1mm), but there are some advanced printers currently achieving .5mm. While these smaller pitched traces are typically produced on etched copper flex circuits, or PCBa's, if resistance is not a major concern then silver circuits can be a very economical solutions.

STATIC SHIELDING

When specifying electronics in a membrane switch, shielding is key area that needs to be addressed.

If the product is going into an environment where there is a high risk of a static charge being applied by the user when pressing the buttons, and/or that charge is likely to exceed the 1000 volts / .001" (.025mm) thickness absorption property of the overlay material, then electrostatic discharge (ESD) shielding is likely required.

Different techniques can be used to dissipate a static charge. First is with a screen-printed grid pattern of conductive silver ink, which can be grounded to a trace on the interface panel and then routed to a ground plane on the product.

Second is the use of full conductive laminates, tapes and foils inside the product. These provide a higher level of dissipative properties, but they can also be more expensive. The absorptive properties of the outer materials are an important factor in determining whether this technique should be used.

WHAT TYPE(S) OF VISUAL FEEDBACK ARE REQUIRED?

This question addresses how different lighting options and displays can be incorporated into the membrane switch to improve the user experience. Several options are available for consideration:

LEDS

Light emitting diodes are highly reliable light sources with low power requirements and a wide range of colors and intensities. Typically, side-firing LEDs are placed around the buttons of the switch assembly. To create a smoother visual appearance from these single-point light sources, additional diffusing layers can be incorporated into the membrane switch assembly.

EL LAMPS

Solid-state electroluminescent lamps produce light by charging phosphors with AC/DC current. They are highly efficient and provide an extremely even appearance. In membrane switch assemblies, EL lamps are typically implemented as a panel just beneath the graphic overlay. EL lamps do require an alternating current source, so they are not appropriate for all applications.

FIBER OPTICS

By shining an LED through optical fibers, you can illuminate very specific parts of a membrane switch. This precision, combined with the low cost and low temperatures associated with fiber optics, make this a preferred technique for many applications. However, there can be a bulky pigtail. To overcome this physical limitation, many designers will specify woven, fiber optic pads. These can be expensive, but they deliver a compact, low-power, highly controlled backlighting result. "A" or layers could have an impact on switch actuation force. Fiber optic layer .010" (0.254mm) thickness over the metal domes will preload more than standard thin dome retainer layers .003" (0.076mm) thickness. The result is the switch is more "silent" (less tactile feedback, less "click").

LGL

Light Guide Layer technology features a light-diffusing plastic material to evenly backlight broad areas with LED sources. LGL is more cost-effective than woven fiber optic pads. However, more LEDs are required to achieve the same backlighting effect, so while LGL can be a very good choice for high-volume, low-cost applications, this approach does require more components. Manufacturing automation can become a critical deciding factor when implementing LGL technology.

LENSES & DISPLAYS

If displays need to be incorporated into the membrane switch, you need to specify appropriate materials for the cutout in the graphic overlay. For example, LCD Displays typically require transparent materials, while brighter LED displays allow for darker materials. In all cases, coatings can be applied to add additional functional properties, such as anti-reflective.

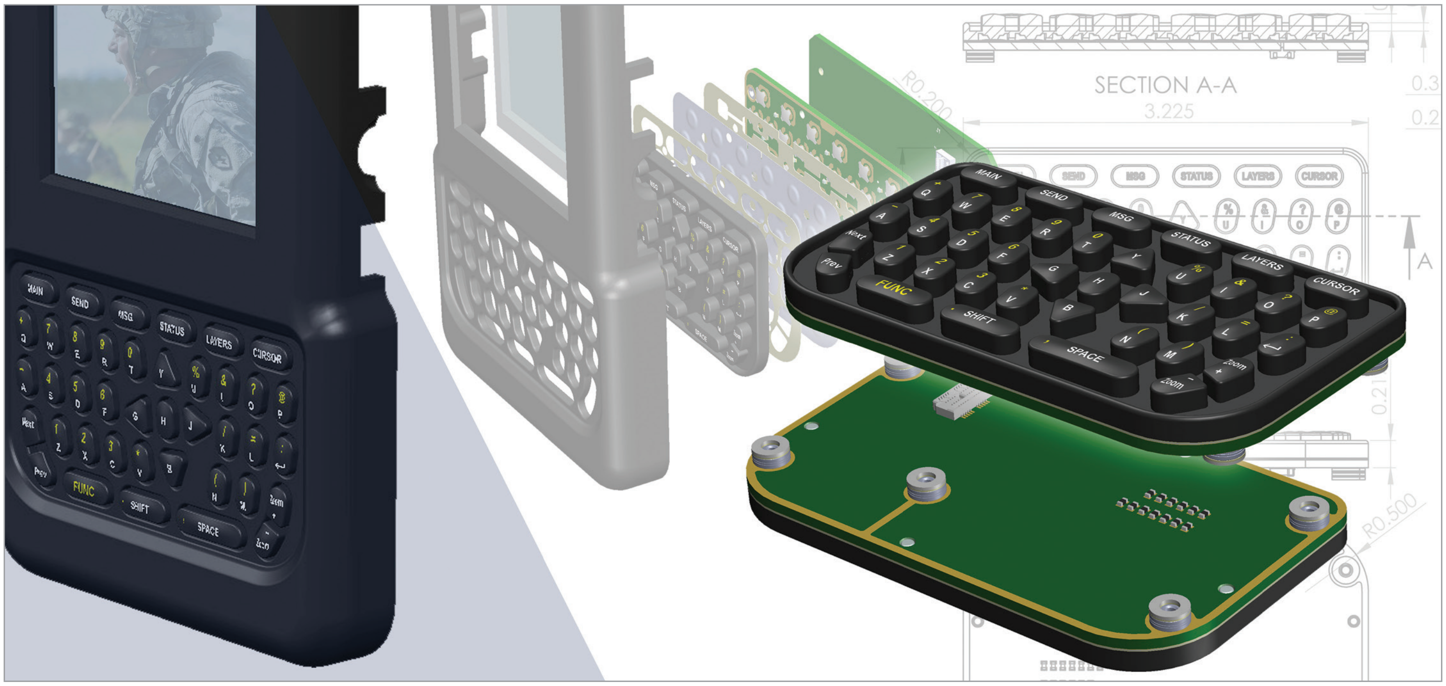
ARE PCB / PCBA'S REQUIRED?

Printed circuit boards (PCBs) and printed circuit board assemblies (PCBAs) are often incorporated into switch designs with complex user interfaces requiring higher-density, more miniaturized components.

While standard membrane switches feature a tail that plugs into a motherboard, PCBA-based switches provide another platform for electronics. These secondary boards can be used to offload a portion of your product's electronics, with the top layers used for the interface and the bottom layers reserved for the product. Conversely, the PCBA in the switch could house all necessary electronics, eliminating the need for a motherboard altogether.

Printed circuit board assemblies (PCBAs) can be single or multiple layers (up to 16 layers typical). The typical base material for PCBAs is FR-4, CEM-1 or CEM-4. A wide range of thicknesses is available, ranging from .016" (.406mm) to .125" (3.175mm). Typical standard thicknesses are .032" (0.812mm) and 0.062" (1.574mm). For final keypad thickness take in consideration PCB tolerances are +/- 10% of this nominal thickness. Depending on the materials and thicknesses selected, PCBAs can help provide back panel support, in addition to providing a base structure for components and circuitry.

The minimum trace width for gold is .003" (.076mm), and for hot air solder leveling is .006" (.152mm). Plating thickness is dependent on the material, and it can range from 1 micron to 25 microns. Plating options include tin, carbon, nickel or gold.



WHAT ENVIRONMENTAL AND DURABILITY FACTORS NEED TO BE CONSIDERED?

This question helps to clarify elements of the membrane switch beyond core functionality, including how the switch needs to be incorporated into the overall product. Considerations include the following:

OVERLAY MATERIALS

The choice of overlay material will have a significant impact on the long-term durability and reliability of the interface.

As mentioned previously, polyester is highly recommended for membrane switch applications. Polyester is chemically resistant, dimensionally stable, and has inherent dielectric properties.

Specialty materials, inks, and coatings are also available to accommodate unique applications (for instance, antimicrobial materials for medical environments).

ENVIRONMENTAL SEALING

By their very design, membrane switches are able to resist moderate exposure to moisture and spills.

To ensure environmental integrity, a distance of min. 0.150” (3.81mm) should be maintained between any circuiting in the keypad and the outer edge of the switch assembly, as well as between a keypad edge and the tail exit point.

For applications where additional moisture resistance is required, pressure-sensitive seals and gaskets should be incorporated into the design.

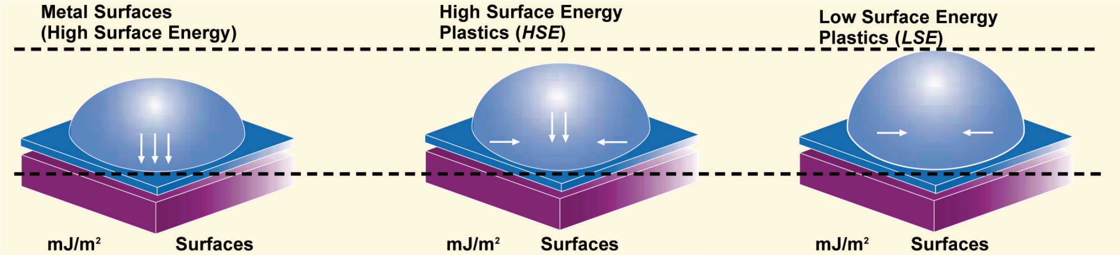
Additionally, silicone rubber keypads allow you to completely seal a product from moisture, dust, and other environmental conditions, and they can also provide a level of vibration resistance.

BACKER ADHESIVES

A wide variety of adhesives are available to bond the membrane switch to a substrate. However, there is no single adhesive choice that will work the best for all applications.

One of the key elements is to understand is the surface energy of the underlying material. High surface energy materials (like an unwaxed car) are very easy to adhere to. For low surface energy materials (like a highly waxed car), special adhesives with flow agents are typically required for a proper bond. See Figure 5 for a summary of the surface energy (in mJ/m2) of some popular substrates.

Other factors to consider when selecting an adhesive technique include whether the surface is textured or smooth, flat or curved, and painted or unfinished.



mJ/m²	Surfaces
1103	Copper
840	Aluminum
753	Zinc
526	Tin
458	Lead
700-1100	Stainless Steel
250-500	Glass Porcelain

mJ/m²	Surfaces
50	Kapton® Industrial Film
47	Phenolic
46	Nylon
45	Alkyd Enamel
43	Polyester
43	Epoxy Paint
43	Polyurethane Paint
42	ABS
42	Polycarbonate
39	PVC Rigid
38	Noryl® Resin
38	Acrylic

mJ/m²	Surfaces
37	PVA
36	Polystyrene
36	Acetal
33	EVA
31	Polyethylene
29	Polypropylene
28	Tedlar® Polyvinyl Fluoride Film
18	Teflon® Fluoropolymer
*	Powder Coated Paints

Figure 5. 3M Surface Energy Chart (For reference only)

HOW DO YOU WANT TO INCORPORATE GRAPHICS AND BRANDING?

This question addresses the final visual choices related to the membrane switch. These include aesthetic details to support brand and product objectives, as well as directional communications to support functionality.

GRAPHIC DESIGN

While digitally printed graphic overlays can generally accommodate most any design, darker backgrounds with lighter, positive text generally provide greater legibility and wear quality.

Digitally printed overlays also allow you to replicate photographic backgrounds, so you have a virtually unlimited range of patterns and images that you can specify.

To maximize legibility and visual impact, remain aware of how colors work together, as well as how these color and material choices will integrate with selected backlighting options.

COLOR REQUIREMENTS

Since components are often provided by different suppliers, color specification and matching are critical parts of the design process.

Colors are typically specified as a CMYK mix, a Federal Standard 595 code, or a Pantone® (PMS) number. Many manufacturers can also match to a physical color swatch, or even to another component on the product (bezel, outer shell, etc.).

Depending on the importance of color consistency in your application, you'll also want to specify whether color is managed via calibrated light booths or digital colorimeters.

HOW SHOULD I SUPPLY ARTWORK?

This question addresses the delivery of final reference materials required by the manufacturer to produce the membrane switch.

ENGINEERING DRAWINGS

Engineering drawings should clearly delineate all physical characteristics and dimensions, including copy and color breaks (.DXF or .DWG are the most common electronic file choices for mechanical design features).

DESIGN ARTWORK

For logos, symbols, and other design elements, scalable vector artwork (EPS, AI, etc.) provides better resolution than image files (JPG, TIFF, etc.).

3D MODELS

3D files are becoming more standard within the industry, and allow OEMs and their suppliers to dramatically streamline the design and production process (.STP are the current file types of choice).

BASIC RECOMMENDATIONS AND TOLERANCES

CUT-OUT SPECIFICATIONS

A=0.063" MIN. THRU-HOLE DIA
B=0.063" MIN. GAP BETWEEN THRU-HOLES
C=0.063" MIN. GAP BETWEEN CUT OUTS AND EDGE
D=0.100" MIN. GAP BETWEEN BUTTONS
E=0.031" MIN. RADIUS INSIDE CUT-OUTS AND OUTSIDE CORNERS
F=0.063" MIN. SLOT CUT-OUT WIDTH
G=0.050" MIN. SPACE BETWEEN CIRCUIT TRACES AND EDGES

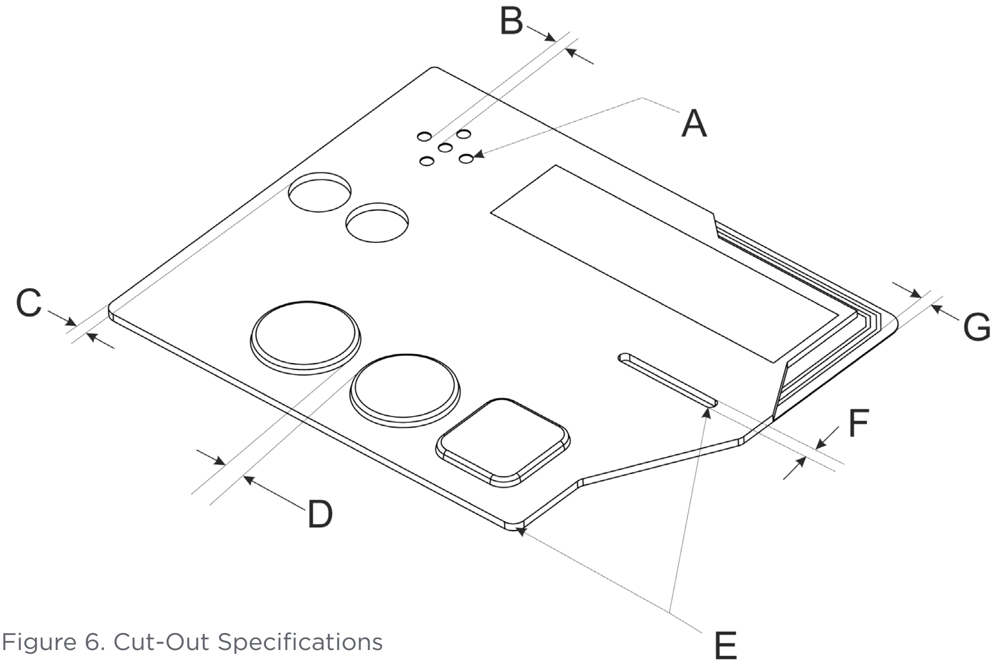


Figure 6. Cut-Out Specifications

KEYPAD & CIRCUITRY TOLERANCES

Keypads circuitry should be a minimum of .150" (3.81mm) from the edge of the switch panel. Allow at least .125" (3.175mm) between keypads or printed circuitry to the edge of a window.

Circuitry tolerances should be +/-.015" (.381mm).

TOOLING

The standard tooling for membrane switches are steel rule dies. Steel rule dies normally achieve a tolerance of +/-.010 (.254mm) when cutting material up to .025" (.635mm) in thickness.

For thicker materials, hard tooling (male/female punch dies) is more common. This technique can achieve a tolerance of +/- .002" (.05mm). However, cost is significantly greater than steel rule dies.

Membrane switch layers can also be digitally cut to a tolerance of +/-.005"(.127mm) or less. Digital cutting does not require tooling charges but typically increases the piece price. Digital cutting options include laser and plotter cutting.

GETTING STARTED

To help you address all of these various issues, your selected membrane switch manufacturer should be able to offer expert design and engineering advice. If you can answer this quick set of questions, it will give them a good starting point to begin this process:

1. What is the industry or application of the final product (e.g., medical, consumer electronics, etc.)?
2. What type of environment will the product be used in (e.g., outdoor conditions, in the home, etc.)?
3. What are the general dimensions of the user interface?
4. How many buttons in the user interface?
5. Is tactile or audible feedback important? Are you looking at clickable buttons, embossing, or both?
6. Is visual feedback important? How would you like lighting to improve usability?
7. Is there a display?
8. What type of circuit (matrix or common) will be used? What is the pin quantity?
9. What is the maximum resistance?
10. Are you aware of any specific shielding requirements?
11. Will a PCB be integrated into the membrane switch?
12. How would you like to terminate the ribbon cable connection (e.g., ZIFF, male pin connector, etc.)?
13. What is the desired center-to-center pitch of the pin connector?
14. Where will the tail be exiting the switch and connecting to the product?
15. How long does the tail need to be?
16. What type of surface will the membrane switch be adhered to?
17. Are there unique decorative or aesthetic requirements?

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