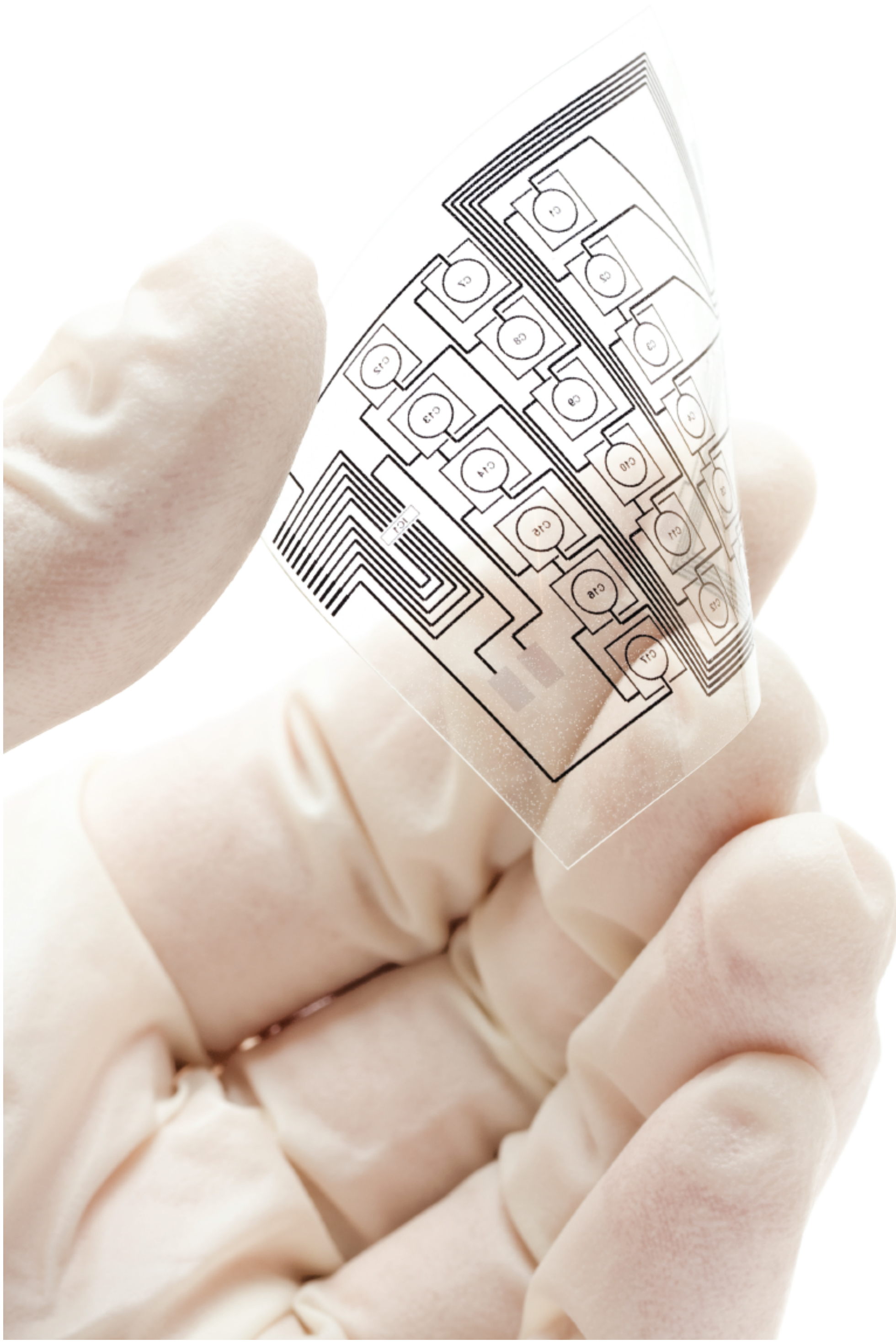
Membrane Switch Design Guide



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Introduction:

Membrane Switch technology is a highly reliable front panel solution. Where environmental concerns are an issue, the sealed technology of the overlay make the membrane switch technology an excellent solution.

The effort between the design engineers and the membrane switch vendor is critical. This design guide is an excellent tool for communicating the requirements of our customers and General Label. General Label's engineers are equipped to help you design a switch that will meet all of your requirements.

Overlay Material:

The two most common materials used are polyester and polycarbonate. These materials are available in a variety of finishes. These begins as a clear material with the graphics usually printed on the reverse side (sub-surface printing) of the product. Selective textures are printed on the front side (top-surface printing) of the product to allow for clear LED/LCD windows.

Polycarbonate is commonly used because it's easy to print on, die cut and emboss, making it cost-effective. The disadvantage of polycarbonate is that it begins to show signs of wear sooner that other materials. While polycarbonate is still used for certain applications, the life cycle data shows that it begins to wear as early as 40,000 cycles. Polyester shows no signs of wear at 100,000 cycles. Polyester is a material with a superior life cycle and chemical resistance properties.

Both polyester and polycarbonate are available with a variety of textures and hardcoats. Keep in mind, glossy materials are highly susceptible to scratching, and should be hardcoated for protection.

Common Materials / Ratings:

Material	Recommended for Outdoor Use	Material	Hardcoated	Finish	Embossable	U.L. Rating	Textureable	Thickness
Melinex 561	No	Polyester	No	Gloss	Yes	No Rating	Yes	.003" - .010"
Autotex2-V	No	Polyester	Yes	Velvet	Yes	94HB*	Yes	.006" - .010"
Autotex2-V-UV	Yes	Polyester	Yes	Velvet	Yes	94HB*	Yes	.006" - .010"
Autoflex EBG	No	Polyester	Yes	Gloss	Yes	94HB*	Yes	.005" - .010"
Autoflex EBA	No	Polyester	Yes	Matte	Yes	94HB*	Yes	.005" - .010"
Autotex XE	Yes	Polyester	Yes	Velvet	Yes	94VTM-2	Yes	.008"
8010 Lexan	No	Polycarbonate	No	Gloss	Yes	94VTM-2	Yes	.007" - .030"
8B35 Lexan	No	Polycarbonate	No	Velvet	Yes	94VTM-2	Yes	.005" - .020"
HP-92 Lexan	No	Polycarbonate	Yes	Gloss	No	94HB	Yes	.007" - .030"
HP-40 Lexan	No	Polycarbonate	Yes	Matte	No	94HB	Yes	.007" - .030"
HP-12 Lexan	No	Polycarbonate	Yes	Matte	No	94HB	Yes	.007" - .030"
FR-60 Lexan	No	Polycarbonate	No	Gloss	Yes	94-V0	No	.010" - .040"
FR-65 Lexan	No	Polycarbonate	No	Velvet	Yes	94-V0	No	.010" - .020"
Makrofol EPC	Yes	Tedlar/Polycarbonate	No	Velvet	Yes	94-VTM-0	No	.010" - .030"
Marnot XL	No	Polycarbonate or Polyester	Yes	Various	Yes	94-V2	Yes	.007" - .030"

*UL Rating is recorded on the base material.

Adhesive / Spacer Material: 3M

General Label incorporates 3M™ materials into the majority of their products. Membrane Switches are produced by laminating various layers of material together. Spacer layers for circuit separation are produced using a polyester layer sandwiched in between two adhesive layers. When specifying an adhesive, it is necessary to specify the adhesive used in the spacer layer, as well as the one which adheres the membrane switch to the component housing.

In most cases, flexible membrane switches are finished with 3M™ 467MP on the backside. This is an excellent adhesive for bonding to smooth metal and high surface energy plastic surfaces. For rougher surfaces, 3M™ 468MP adhesive is recommended. Some surfaces such as powder coated surfaces have lower surface energy. There are specific adhesives that are more appropriate for low surface energy applications. Contact a General Label sales engineer for any questions regarding your application.

Premask:

Graphic Overlays and Membrane Switch Graphic Layers, which have windows for LED/LCD readouts, can be easily scratched during processing, handling or assembly. It is recommended to use a premask material for protection, which has a low tack adhesive. This material will protect windows and is easily removed before applying it to the product housing.

Artwork / Drawings:

Most customers supply an electronic file in .ai (Adobe Illustrator) form or other vector graphics program. General Label does offer design services, if requested. All files should specify type styles, colors, and indicate sizes and locations of all graphics. It is recommended to outline all fonts, and to supply a pdf file in addition to the native file.

We accept DXF or DWG files for mechanical drawings. It is also recommended to supply a pdf file of the drawing. Proofs of all artwork will be sent to our customers for their approval.

Colors:

It is possible to specify colors by providing a reference from either the “PMS” (Pantone Matching System) or any other color matching system. Samples of colors to match can also be provided in many forms. For example: existing labels, plastic housings, color chips or painted metal work.

If you have an overlay being digitally printed, General Label can supply a sample for your approval. Keep in mind, printing PMS colors on a digital press can come out completely different compared to the actual PMS color. If you need an exact PMS color, screen printing may be the best solution.

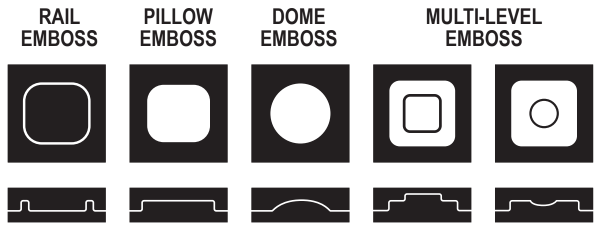
Ultraviolet Hardcoats:

The most durable hardcoats are those that are cured by exposure to ultraviolet light. These coatings are called UV hard-coats. Hardcoats can added to many of the materials by screen printing in selective areas, thus creating coatings for windows and enhancing graphics. Many overlay materials come with a hardcoat on them.

Embossing:

In many applications it is desirable to emboss or hydroform the keys of a switch. “Pillow Embossing” is used to describe keys that are raised and flat on the top. “Rail Embossing” is used to describe raising only the border of a key. Embossing is typically two-dimensional and .010” high.

Hydroforming is used to obtain an emboss 2-3 times the material thickness. Three-dimensional dies can also be built. Overlays can be formed with domes in them to provide a tactile feedback. Hydroforming tools are significantly more expensive than embossing tools.



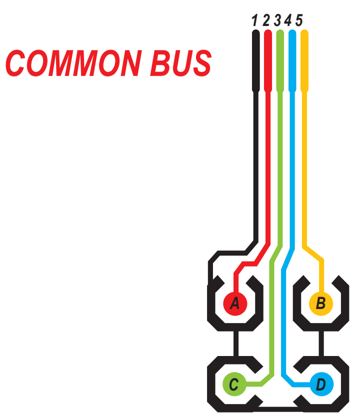
Pinouts:

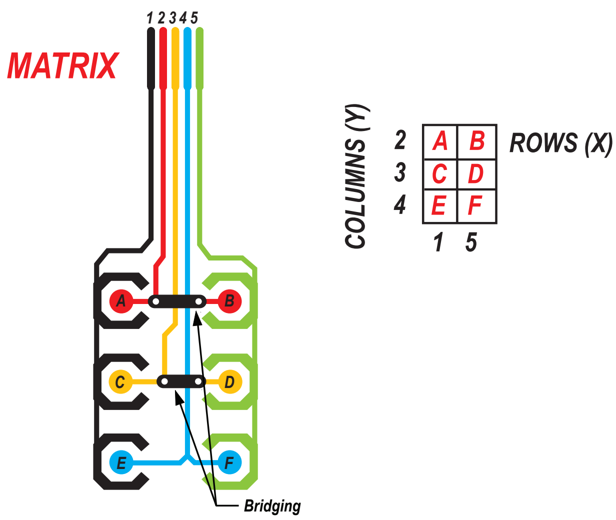
It’s more cost effective and simpler if we layout the schematic or pinout of a circuit. If the pinout is specified by the customer, we can work with you, but this may take extra time and money.

Membrane switches can be designed using either a common bus or a matrix layout.

Common Bus: Mapping the traces for this layout uses one common lead (ground) for all switch locations. Each switch has a single isolated trace that completes the circuit with the common trace. The advantage of this is that only one print is required for a complete trace. This disadvantage is the need for a larger number of leads, connectors and switch size.

Matrix: Mapping the traces for this layout uses leads that run in both the “X” (rows) and “Y” (columns) direction. The advantage of this is that less leads are required to produce a greater number of connections. The disadvantage is the need for multiple prints to produce the trace.





Typical Mechanical / Electrical Specifications:

The following are a guide based on General Label typical membrane switch panels. *Actual specifications for a given customer part design will vary*.

Mechanical / Environmental

	Non-Tactile	Tactile Metal Dome	Tactile Polydome	Notes
Key Travel	.005" - .020" .13 - .5 mm	015" - .040" .38 – 1.0 mm	015" - .040" .38 – 1.0 mm	(1) GL 50397 / ASTM F2592
Operating Force	80 – 340 g 3 – 12 oz	110 – 1700 g 4 – 60 oz	110 – 600 g 4 – 21 oz	(1,2) GL 50397 / ASTM F2592
Actuation Life	> 1M cycles Up to 5M+	> 1M cycles Up to 5M	> 1M cycles	(3) GL 50393 / ASTM F1578
Operating Temp	-30 to 70°C -22 to 158°F	-30 to 70°C -22 to 158°F	-20 to 50°C -4 to 122°F	(4)
Storage Temp	-40 to 70°C -40 to 158°F	-40 to 70°C -40 to 158°F		(4) < 50% RH;
Humidity	12 – 90% RH	12 – 90% RH	12 – 90% RH	(4) Non condensing
Minimum Tail Bend Radius	0.063" (1.6 mm) - 25 cycles min at 20°C			GL 50399 / ASTM F1683

- Key travel and operating force ranges are representative of typical designs. Other values are available. Metal domes typically range from 6mm to 20mm diameter.
- For non-tactile, Operating force is minimum to achieve for stable minimum resistance; For tactile, force is Fmax, the force to "snap" the dome. Fc (force to stable contact resistance) typically exceeds Fmax.
- (2) Life testing at 20°C, < 50% RH, 4mA, < 11V DC; May be substantially different over voltage, current, and temperature/humidity range. Life depends on domes, embossing, materials, etc. Contact General Label for more information. Polydomes exhibit substantial changes in tactile curves over life test.
- Depends on materials used. For high humidity or wide temperature range applications, contact General Label

Electrical

	Non-Tactile	Tactile Metal Dome	Tactile Polydome	Notes
Maximum Current Rating	100 mA max	100 mA max	100 mA max	(1,2) GL Method / ASTM F1681
Maximum Operating Voltage	30 VDC max	30 VDC max	30 VDC max	(1,2) GL Method
Maximum Operating Power	1 W max	1 W max	1 W max	(1,2) GL Method
Typical Operating Current	1 to 30 mA	1 to 30 mA	1 to 30 mA	(2)

Typical Operating Voltage	**3 to 12 VDC**	**3 to 12 VDC**	**3 to 12 VDC**	**(2)**
Closed Circuit Resistance	< 100 ohms typ.	< 100 ohms typ.	< 100 ohms typ.	GL 50395 / ASTM F1680
Insulation Resistance	> 20 Meg	> 20 Meg	> 20 Meg	(4) GL 50394 / ASTM F1689 > 100 Meg typical
Contact Bounce	< 10 mS	< 15 mS	< 15 mS	(3) GL 50396 / ASTM F1681; Most designs < 5 mS
Capacitance	< 30 pF	< 30 pF	< 30 pF	(5) GL 50401 / ASTM F1663
Dielectric Withstand Voltage	> 500VDC	> 500VDC	> 500VDC	(4)

(1) Resistive circuit, 20°C. De-rate above 25°C. Some self-heating will occur at higher power operation especially for some designs and this should be taken into account.

(2) Resistive circuit, 20°C –Operation at higher operating voltage > 12V or current > 5 mA may shorten operating life and may lead to increased resistance.

(3) Measured from 0.9V to 3.0V at 5.0V test voltage. Contact bounce is typically less than 5 mS for most designs. Contact bounce is measured with a 5/8" silicone probe actuated in a quick smooth action and on-axis.

(4) Conductor to conductor typical minimum on new panel at room temperature and dry air. Surface to pin is typically much higher. Dielectric withstand voltage is highly dependent on materials and circuit layout. NOTE: General Label Membrane switches are NOT intended as an electrical safety isolation barrier. Circuits with cross-overs may have lower withstand voltage.

(5) Capacitance measured at 10 KHz with un-mounted switch panel. Mounting on a metal panel may increase capacitance significantly.

LED Electrical

	Red	Green	Yellow	Blue/ White	Notes
Typical LED Operating Current	1 to 20 mA DC; < 20 to 100 mA pulsed (10% duty cycle)				25°C; Contact GL for actual LED specs and ratings.
Typical LED Forward Voltage	1.8 to 2.4 Volts	1.9 to 2.4 Volts	2.0 to 2.4 Volts	2.75 to 4.3 Volts	20 mA @ 25°C; very dependent on temperature.
Wavelength (example)	624 nm	573 nm	589 nm	470 nm	(White is broad spectrum)
Style	SMD Low profile type, Side or Top fired. Bi-color (R/G, R/Y, Y/G) and orange also available. Contact General Label for details or other requirements.				

All above specifications are representative of a typical design and are not guaranteed for a particular design. Each design is unique and thus may have different specifications. All specifications apply only at standard room temperature (20°C / 68°F) unless otherwise noted. **Contact General Label for more information or with specific requirements.**

Circuit Inks:

The membrane switch requires an electrical path and contact points to be functional. A screen printed silver-filled epoxy ink is typically used in printing membrane switches. Silver is the most desirable because the resistance is low and the oxide is conductive. Carbon inks can be used as a substitute for silver when the client's specifications allow for higher resistance. More often the carbon ink is used as an overprint of silver to reduce the chance of silver migration and sulfur attach.

Resistance of Printed Inks

The resistance of traces and printed patterns is determined by ink used, trace length, width, and thickness of the printed layeLonger, thinner traces have higher resistance than shorter, thicker traces.

Resistance of conductive inks are typically specified in "ohms per square per mil," where mils is the printed ink layer thickness. The resistance of a trace is:

R = L/W x ohms/sq/mil,

Where: L is length of the trace
W is width, and
ohms/sq/mil is the resistance of a square element printed at a layer thickness OF 122 mil of printed ink.

For example, if a silver ink is about 40 milohms per square at a typical printed layer thickness, a 4" trace of width 0.1" silver would have a total resistance of 4/(.1) x .040 or 1.6 ohms.

For example, if a carbon ink is about 120 ohms per square at a typical printed layer thickness, a 4" trace of width 0.1" carbon would have a total resistance of 4/(.1) x 120 or 4800 ohms.

Carbon can be overprinted on silver to provide protection against silver migration and to increase durability. The overall trace resistance is controlled by the silver since the silver and carbon are in parallel. The contact resistance of an overprint of carbon ink will be higher .

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Silver Migration (Electro-migration)

Silver migration can occur when a dc voltage is applied across nearby printed silver traces in the presence of an electrolyte, such as water (moisture). Under these conditions silver "dendrites" can grow between the traces leading to a short Silver migration can be mitigated by:

1) Increasing the minimum spacing between traces or features with a DC voltage between them (> 30 mil min) and avoiding sharp points which concentrate the electric field (increasing the likelihood of migration);
2) Overprinting the silver traces where they are near each other with dielectric or carbon ink;
3) Designing vents and openings such that moisture is away from the silver traces. Especially important is avoiding moisture "traps" which can allow water to accumulate between and over silver traces. Liquid water accelerates migration by a factor of about 10,000.
4) If the other mitigations cannot be used, breaks between traces (such as slits or barriers) can block the migration path.
5) Use a lower DC voltage. Higher voltage accelerates migration.

ESD/RFI/EMI Shielding:

Many options are available for shielding membrane switches. Either carbon or silver can be printed over the top of the circuit to act as a shield or aluminum foil can be used. Carbon shields are less expensive than silver. A printed grid pattern is normally used to reduce cost and can be terminated to the circuit tail. Aluminum foil material is the most conductive shield available. However, it adds layers to the membrane switch construction. The foil will need a separate tail for ground connection.

Design of the shield on a membrane switch depends greatly on what performance is required for a given design. In general, EMI shielding works by two mechanisms: reflection and absorption.

Shielding, grounding, and EMI control in general is very complex and specialized, but a few basic principles can help as a guide:

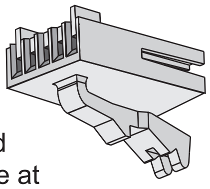
For a reflective shield to be most effective, its termination is very important. The ideal termination would be good electrical contact around the perimeter of the shield. Since this is often not practical, multiple wide, short tabs is the next best option. If only a single termination point is available, that tab should be not more than 3 times a long as it is wide. In general, the lower the resistance (ohms per square) of the shield, the greater its effectiveness.

In some cases, ESD only shields can still be effective even if higher resistance (such as with a printed carbon shield). Shields of this type will prevent a charge build-up but will offer little EMI or coupled ESD protection.

Tail Exit Point:

Flexible membrane switches are connected by means of a flexible tail that is cut from the circuit material. The tail cannot exit under or within .125" of the active keypad.

Interconnect:



The tail that exits a membrane switch usually has single row traces on .100" (2.54mm) centers. This tail can be connected to a circuit board with many different single row connectors designed for flex circuits or can be designed to interface with a ZIF (Zero Insertion Force) connector. Here at General Label, we can crimp Nicomatic, AMP and Berg connectors onto flex circuits.

The AMP system is a two component system. The contacts are specified separately from the housing. One critical consideration is the insulation displacement characteristics of the AMP system. It the design uses dual tails or insulation over the entire contact are, we recommend the AMP connector system.

The lowest cost interconnect is the ZIF connector. AMP and Molex both offer ZIF connectors. When using a ZIF connector the membrane switch is designed with exposed contacts on the end of the tail. The customer then inserts the tail into the ZIF connector. ZIF connectors are readily available with locking mechanisms in 1mm center versions. When using a ZIF connector you should specify either the specific connector, or the requirements for the connector. ZIF connectors must be on the circuit side.

Male/Female Connectors: The most common approach to thin-film connections is through using Nicomatic or AMP male pins and female pins. Both are used extensively to interface to Control Boards, energy sources, wires and housings. The male is similar to the solder tab, but made to connect instead of to solder. The female has three or four sides, and provides robust connection.

Backlighting:

• Light Emitting Diodes (LEDs)

Typically used for indicator lights, they are low-cost, come in a variety of colors, thin profile options and excellent for outdoor environments.

• Thin Film Light Guide - Full and discrete

A thin film that directs light from LEDs for areas that need to be backlit while still providing an excellent tactile feel. Our design and engineering team will provide the best solution to avoid light leaks and hot spots.

• EL Lighting (Electroluminescent)

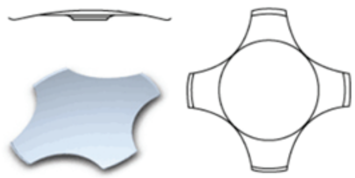
EL llighting consumes very little power and will begin to lose its brightness after reaching its half life. It's a good choice for applications where the light is not left on for long periods of time. They do have a thin profile and provide uniform lighting.

Benefits:

• Cost-effective lighting solutions
• Low power consumption
• Less heat
• Safety
• Replaces more expensive, older technology such as EL and Fiber Optics
• Sleek design
• Thin profile

Tactile / Non-Tactile:

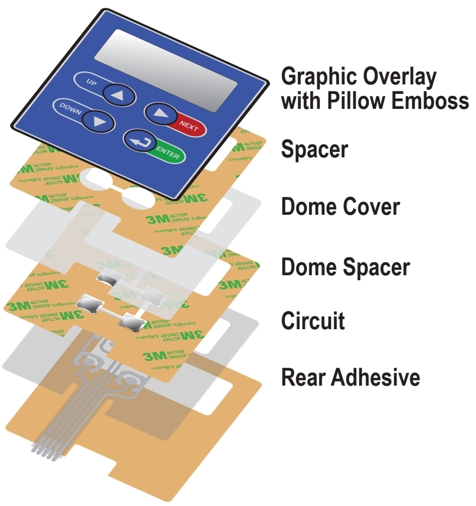
TACTILE:
In order to provide a tactile feedback, stainless steel or polyester. The number of sizes, shapes, actuation forces, and manufacturers of domes are vast. General Label can assist you in choosing the dome that is suitable for your application and one that meets your print specifications.



Stainless Steel - Many prefer the feel of stainless steel domes. They also have lower initial tooling costs. Stainless steel domes are momentary switch contacts that, when used in conjunction with a printed circuit board, flex circuit, or membrane, become normally-open tactile switches. They function the following way: The metal domes are placed on the printed circuit board by means of pressure-sensitive adhesive tape. In their relaxed state, the metal domes rest on the outer rim of the primary pathway. When pushed, the domes collapse and make contact with the secondary pathway, thereby closing the circuit. Many different shapes and actuation forces are available in order to fit your specific application.

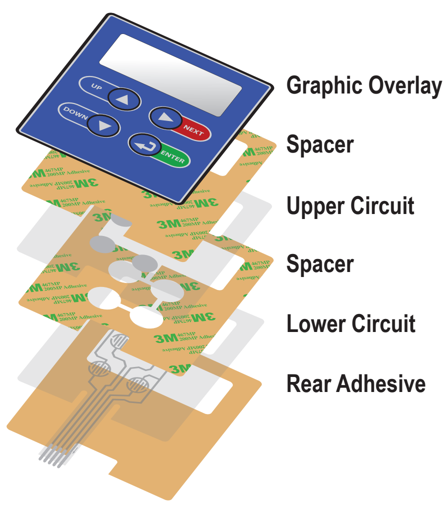
Polyester (Poly-Domes)- Poly domes are usually formed into the top circuit of the membrane. Initially, poly domes require expensive tooling costs. As volumes increase, poly domes become more cost effective, because they're not as labor intensive. Poly domes can relax and lose their tactile feel at elevated temperatures. Poly domes are not recommended for applications that will experience temperatures above 50°C (122°F).

Typical Circuit Build (Tactile w/metal domes)



NON-TACTILE:
The non-tactile switch is more reliable and has a longer life cycle, but requires separate feedback to the operator such as a beep, light or a change in the visual display. A PCB integrated construction offers an efficient design for most non-tactile keypad programs regardless of the key density. In addition to offering more trace routing capability the PCB can incorporate passive and active components, plus act as a rigid backer.

Typical Circuit Build (Non-tactile)



LEDs: (Light Emitting Diode)

A *light-emitting diode (LED)* is a semiconductor diode that emits narrow-spectrum light when electrically biased in the forward direction of the p-n junction, as in the common LED circuit. This effect is a form of electroluminescence.

It is common to include small surface mounted LEDs into membrane switches. A standard membrane switch is normally not thick enough to accommodate the package size of a surface mounted LED. The overlay may need to be embossed or extra filler layers need to be added to the switch construction.

It is very important for the engineering group to receive drawings showing how the LED's interface with the electronics. This should be in the form of a schematic. Items to note are the electrical specifications of LED's and resistors.

General Label utilizes automated pick-and-place equipment that allows for both precise and efficient placement of components.

Inspection:

General Label will follow customer driven inspection criteria, if available. If one is not available, General Label will use its own standard for inspecting membrane switches.

Prototypes:

A prototype is a cost-effective method for testing and executing your design with a minimum investment in tooling and development time. Normally, there are many changes in size, colors, materials and dimensions to provide the most efficient design possible. General Label can produce a prototype with little or no tooling which provides significant savings.

Die Cutting:

Steel Rule: Steel rule dies are normally used to fabricate the various layers for a membrane switch, especially when ordering larger quantities. Standard tolerances are +-.015". Tolerances of +-.010" can be held on critical dimensions, such as cutouts or the perimeter.

Laser Cutting: Various layers of the membrane can be cut using laser technology in which tighter tolerances can be held. Laser tolerance is +-.005". For low volume applications, laser cutting is recommended since there is no tooling cost.

Membrane Switches Terms

Abrasion Resistance – The degree to which a membrane switch is able to withstand surface wear.

Actuation – This is the action of working a switch apparatus.

Actuation Force – The pressure necessary for collapsing the walls of the dome on a polyester, rubber or metal keypad.

Adhesion – The molecular attraction of one material to another. The strength of the bond is determined by the surface energy in each material.

Backing / Rear Adhesive – An adhesive applied to the back of a membrane switch for mounting purposes.

Breakdown Voltage – The minimum voltage at which the insulation between two conductors begins to fail.

Carbon Graphite Inks – The type of ink that consists of prepared suspensions of carbon black and is frequently printed over silver circuitry to diminish the potential of migration of silver. These are also used for lessening costs when the conductivity of a metal base system is not necessary.

Conductivity – A material's ability to allow electrons to flow.

Cross-Over – A conductor intersection insulated by dielectric material.

Dead Front – A cosmetic feature of a graphic overlay in which a button is only visible when backlit.

Dielectric – An insulating or non-conducting medium.

Dielectric Inks – Used for printing protective patterns on conductive printing to isolate selected regions from electrical contact with other conductors. This is used for cross-overs and tail insulation on membrane switches.

Dome Cover – An adhesive layer made to hold metal domes in the keyswitch.

El Lamp – A slender device that illuminates large areas, typically used in LCD membrane switch backlighting and control panels.

Embedded LED – Procedure of integrating a surface mount LED into a membrane switch assembly.

Emboss – A way to supply a raised characteristic to accentuate key surfaces through mechanical and thermoforming of graphical features. This also permits an embedding of a surface mount of an LED inside the switch.

Graphic Keypad – Control keypads that use graphics for button functions for navigation on machines or process operations. Typical graphics include arrows or symbols indicative of a machine process or operation.

Internally Vented – Switch openings connected to one another to seal the switch from moisture and other contaminants.

Key Height – A measure of the distance from the highest point of a key to the base of the keypad.

Light Emitting Diode (LED) – Embedded in membrane switch layers to illuminate the button.

Moisture Resistance – A material's ability to resist the absorption of water from the air or during complete submersion.

Overlay – The decorative front layer of a membrane switch or control panel.

Pillow Emboss – Creating a raised surface in the graphic overlay over the key area.

Pinout – The schematic that describes the circuit output requirements for membrane switches.

Pressure-Sensitive – Adhesive materials that bond after pressure without needing heat or solvents.

Rail Emboss – Produces a raised ridge circling the key area.

Silver Inks – Finely-milled particles of silver suspended in various resin systems that produce conductive patterns on rigid and flexible substrates. This is a typical conductor material for membrane switches.

Spacer – A membrane switch adhesive layer that separates circuit layers to supply keyswitch openings, permitting the contact of conductors when depressed.