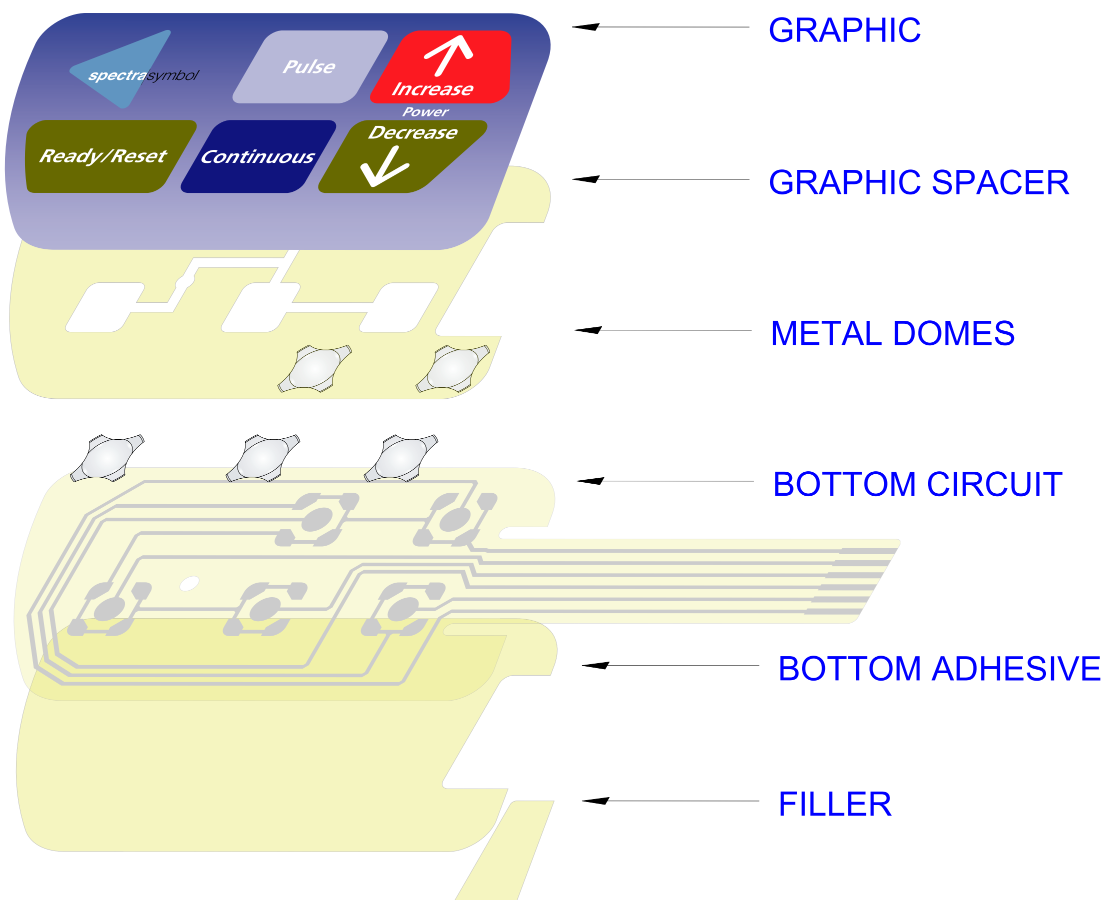
Membrane Switch Design Guide

Spectra Symbol Corp.

Introduction:

This Design Guide includes much information necessary to successfully produce a high-quality, high performance Membrane Switch. However, for complete understanding of the technology, we suggest conferencing with any of our design engineer group. They are available to answer any questions you may have when designing and producing Membrane Switches.



Design Guide Categories:

Flexible Top Circuit
Rigid Bottom Circuit
½ Switch
PCboard
Separate Layer
Conductivity
Silver
Carbon
Plating
Spacers
- **Die-Cut Spacers**
- **Dielectric Dot Patterns**

I/O Means/Tail
- **Single**
- **Double Overlap**
- **Side by side**

Connectors
- **Berg Clinch**
- **ZIF (Zero Insertion Force)**
- **Solder tabs (Nicomatic or AMP)**
- **Male/Female Connectors (Nicomatic or AMP)**

Venting
- **Internal Venting**
- **External Venting**

Dielectric
Overlays
Tactile
- **Polydome**
- **Stainless Steel Domes**

Shielding
- **ESD**
- **Foil shielding**

Backlighting
- **Fiberoptics**
- **LEDs**

Membrane tolerances
PCB
Tail Design
Emboss
Adhesive Layers
- **Overlay Adhesive**
- **Bottom Adhesive**
- **ESD/RFI spacer Adhesives**
- **Coverlay and Bottom Coverlay**

Flexible Top Circuit

The upper layer of the switch is called the "Top Circuit". The top circuit uses electrical conductors to make the switch circuit on its internal surface. This layer must be able to flex to make contact with the rigid surface and be able to return to its original position, which avoids shorts. Polyester is used for the top circuit for the following reason:

- **Longevity of the switch.**
- **Memory of the material.**
- **Processing (curing temperatures of conductive inks).**

Rigid Bottom Circuit

The base layer or bottom circuit of a membrane switch can be made from a thin plastic film or a more rigid composite depending upon the application. The exposed surface of this layer serves as an insulator while the internal surface carries electrical conductors as a portion of the switch. The name is derived from the basis that it will not flex once applied.

½ Switch

This construction places shorting pads, which completes the circuit when pressed, on the top circuit. Another option may use domes, which completes the circuit when pressed, on interdigitated circuits. The overlay must also be able to handle the chemical resistance requirements of the application. It also should be able to comply with construction options related to the ½ switch.

PC BOARD

In this construction a Printed Circuit Board (PCB) is used as the bottom circuit. This construction gives designers the capability to incorporate electronics in the switch. It also provides mounting that other constructions cannot. The PCB is a laminate by which copper is chemically etched to form a desired circuit pattern. The PCB is available in various thicknesses. Typical thickness include .020, .03125, .0625 and .09375.

SEPARATE LAYER

In the separate layer system, the top circuit is printed separate from the bottom circuit. By means in assembly, the top circuit matches switch patterns printed on the bottom circuit.

Conductivity

The switch requires an electrical path and contact points to be functional. By using a polymer thick film, we selectively print the path and contact points. The conductive ink we have chosen in the membrane switch market is solvent based. The solvent is used as a flow agent in order to print the silver or carbon. Once printed the ink must be heat cured to remove the solvent. As the solvent evaporates, the printed image shrinks. This causes the silver or carbon flakes to be pressed together which gives a desirable resistance reading.

Silver

Silver conductive inks are the most desirable because the resistance is low and the oxide is conductive. Membrane switch contacts made of polymer thick film are usually rated to carry no more than 100 ma @ 24 VDC. Desirable resistance of less than 200 ohms.

Carbon

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. Another reason is to protect the tail from damage from repeated use in ZIF connectors.

Plating

Plating is associated with PCB construction. When the PCB is chemically etched, it removes unwanted copper. This copper will oxidize unless it is plated. There are three types of metal which can be plated into copper that have acceptable results. They are Tin/Lead, Nickel, and Gold.

- **Tin/Lead** **Lowest cost and highest resistance.**
- **Nickel*** **Medium cost and medium resistance.**
- **Gold*** **Highest cost and lowest resistance.**

***Domes should have some plating to eliminate the problems associated with dissimilar metals.**

Spacers

For a membrane switch to function, space between the top and bottom circuit must exist. The space eliminates shorts. The size and depth of the space is critical in providing a switch that feels good. A switch with a

space that is too thin will result in high sensitivity. A switch with a spacer that is too thick will be very hard to actuate. Add tactile feedback to this and the difficulty increases.

Die Cut Spacers

Many membrane switch manufactures use a die cut spacer between 7-10 mils to provide that necessary space. This system works well with non-tactile switches. However, for tactile switches this system will not allow switch closure at the snap point of the dome.

Dot Patterns

When the key size is too large for die cut spacers and spacer rings, printed dot patterns of dielectric are a proven solution. The height of the dielectric will provide the space and allow sufficient actuation area.

I/O Means/Tail

In all applications of membrane switches, there must be electronics to interpret switch closure. The connection between switch and electronics is called the "I/O MEANS" or tail. The tail can vary in number, length, exit point, and type. All variations are determined by the layout of mating electrical connectors and the keyboard mounting within the product.

The number of tails can be as few as one and as many as prudent. Obviously the fewer the number, the lower the cost. The length of tail also has a similar cost effect.   The shorter length would equate to less wasted material. The exit point can have a cost factor.
The type of tail reflects the interconnection technique. Three basic options apply: A) Single; B) Double Overlap; and C) Side by Side.

Single

This type of tail exits only from the rigid bottom circuit. With this system, any of the connector options will apply. Single tails are a valid option for all types of construction with the exception of Separate Layer in most cases.

Double Overlap

The Double Overlap option fits well with the separate layer construction. By design the Flexible Top Circuit and the Rigid Bottom Circuit exit at the same point. By doing so both tails can be cut with the same die. Saving labor and die cost, it is clear that this kind of tail is preferred. With this system, any of the connector options will apply, except for ZIF.

Side By Side

The Side by Side tail uses multiple single tails, exiting at alternative locations. With this system, any of the connector options will apply.

Connectors

The connectors are the interconnection device between the I/O Means/Tail and the electronics. The connectors are classified into two categories: 1) solderless and 2) solderable.

The solderless connector can normally be used on any type of circuit. This system applies an insulation piercing connection on the tail that is housed for mail or female interface with the electronics. Although solderless techniques may appear to be more expensive because the initial cost of the connector, they lend themselves to automated assembly.

The solderable connector can normally be used on any type of circuit. By using either solder tabs or a ZIF connector, the tail can have termination that is solderable.

Berg Clinchers

This is a solderless connector system manufactured by Du Pont. This system applies an insulation piercing connection on the tail that is housed for mail or female interface with the electronics. Unlike the Nicomatic or Amp connector systems, the clincher is fully housed and need only be crimped in place.

Features

- **1-row: 2 through 34 positions**
- **The clinching portion of the contact forms a gas-tight crimp to prevent contamination of the contact.**
- **Mates with 0.64mm (0.025) square or round pins on 2.54mm (0.100) centers.**
- **Finish plating – Gold or Tin/Lead**
- **Maximum thickness of cable – 0.013 in. including insulation**

ZIF (Zero Insertion Force)

This is a solderable connector system. The tail is printed and die cut the same as if Clincher were to be used. However, the insulation is not pierced. The exposed conductive ink on the end of the tail is ramped to contact points on the circuit. Unlike the solder tabs, this devise has a housing which has through-mount, solder-to-board connectors.

Features:

- 1-row: 4 through 20 positions
- Right-angle and straight connector configurations
- Centers .100”, .050”, and/or .039”
- Maximum thickness of cable – 0.012 in. in contact area.

Solder Tabs

This is a solderable connector system. The tail is printed and die cut the same as if Clincher were to be used. This system applies an insulation piercing connection on the tail which is able to provide enough heat dissipation, during soldering, to prevent damage to the printed conductive. Solder tabs do not use a housing.

Features:

- Mass terminated to flat, flexible circuits by individual conductors.
- The clinching portion of the contact forms a gas-tight crimp to prevent contamination of the contact.
- Finish plating – Tin/Lead
- Maximum thickness of cable – 0.015 in. including insulation
- Recommended hole size for solder tabs - .031 - .035 dia.
- Multiple-Crimp contact design. Four crimping tines on each contact are used to penetrate the cable insulation and conductor, assuring optimum electrical and mechanical reliability.

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 a robust connection.

Venting

Environmental sealing of membrane switches represents an advantage over traditional mechanical switches and is strongly recommended. A sealed membrane switch offers increased protection from environmental contaminants such as dirt, moisture, and electrostatic discharge.

With an environmentally sealed keyboard, a laminate acrylic adhesive is used on each side of the spacer layer. However, environmental sealing traps the air in the switch cutouts of the spacer layer, meaning that the problem of equalizing this trapped air must be addressed. In order for the switch to close properly, air within a switch cavity must be displaced, equalizing the internal pressure.

Internal Venting

Sealed keyboards require venting for both flat and tactile membrane constructions. Narrow channels between key location cutouts are cut in the spacer layer, permitting air from one key location to move elsewhere when that key is pressed. In this type of venting, the air channels never exit to the outside of the keyboard, preventing the risk of contamination since the keyboard remains sealed. However, extreme atmospheric changes can produce internal pressure that impedes switch performance and may damage the keyboard. When hostile environments render external venting unacceptable, venting through the mounting surface will be required.

This can be accomplished by running vent channels to interior finish cut cutouts. LCD's; LED's; tail exits; and via's in printed circuit boards are examples of location possibilities. When those options are unavailable, consulting with the client to locate holes in the mounting surface should be attempted in the early stages of design.

External Venting

Because external venting increases the risk of contamination, it is only recommended when the keyboard will be exposed to rapid or extreme atmospheric pressure fluctuations and will not generally come in contact with a hostile environment. Certain types of keyboard constructions can accommodate external venting.

As in internal venting, narrow channels that have been cut into the spacer layer connect each key location. These channels then exit through the sides. This design allows pressure within the switch cavities to be equalized with the surrounding atmosphere, thus allowing switch closure at any atmospheric pressure.

External venting increases the chance of environmental contamination. In particular, an electrostatic discharge may enter the external vent channel, follow the conductive circuitry, and damage sensitive internal components.

Dielectrics

Dielectrics are nonconductors of electricity. Dielectrics, in membrane switches are an insulation and/or protection coating for printed circuitry. This is accomplished by selective placing of self-adhesive polyester or selective overprinting dielectric ink. The insulative property is measured by the materials dielectric strength or its nonconductive ability. The dielectric also provides prevention of sulfur attach and silver migration.

Overlays

In contrast to the layers of the switch which carry circuitry and are selected primarily for their electrical properties, the faceplate or graphic layer is chosen based upon its durability, clarity, printability, texture and, in some cases, formability. The two primary materials in use today are polyester film and polycarbonate film. Both plastic films are generally second surface screen printed, thus avoiding the need for protective coating.

Tactile

Tactile switches require some type of tactile device referred to as a dome. The number of sizes, shapes, actuation forces, and manufactures of domes are vast. In an effort to standardize our switches, we have tested the domes up to a million cycles, we have been able to acquire domes which provide clients with a highly reliable tactile switch. If for some reason our list of domes will not fit a need, testing must be done in order to approve the design. This testing must show less than a 10% change in the actuation and release forces after 1 million cycles.

Tactile switches can either be Coupled or Decoupled. Coupled meaning that the tactile device uses its conductive properties to complete the circuit. Coupled usage is best illustrated by a ½ switch with tactile. In this construction the dome sets on the rigid layer. Decoupled meaning that the tactile device uses its mechanical properties to complete the circuit and need not be conductive. Decoupled usage is best illustrated by a separate layer switch with tactile. In this construction the dome sets on the flexible layer of the switch.

Poly-Dome

This is a process where either the top circuit of the overlay is thermoformed to create a dome. The advantages in this process are that polydomes are not destructive to the substrate and labor involvement is less.

Stainless Steel Domes

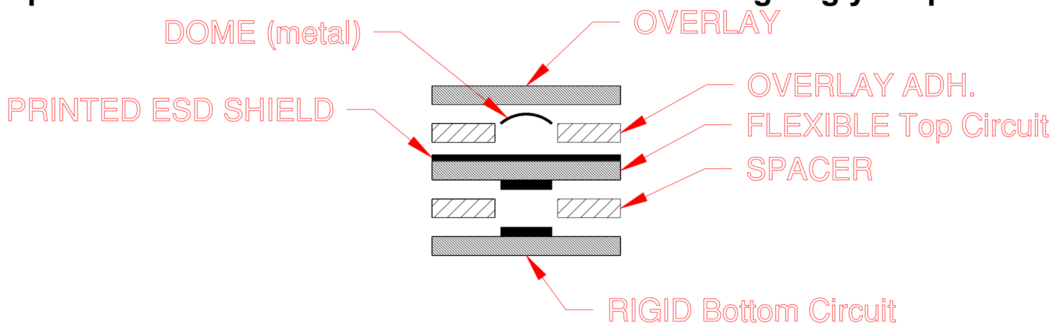
Metal domes can be placed above the top circuit (separate layer or bifold) to actuate the switch as a tactile only device. Metal domes can also be placed between the top and bottom circuit or above the pad on a single layer switch to actuate the switch as a conductive tactile device. Careful modeling must be used to insure contact on the snap of the dome.

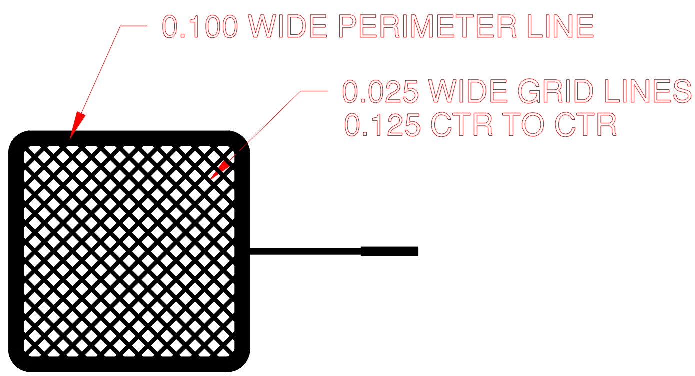
Shielding

Electrostatic Discharge (ESD) – Transfer of high potential electrical charge between objects by contact or through the air. ESD from humans to electronic apparatus may damage or destroy circuit components. Friction between dissimilar insulating materials produces this electrical charge. For instance, walking on a rug and then touching a grounded object produces and transmits such a charge.

The usual voltage accumulation average 10-15 KV, although it may reach as high as 50 KV under ideal condition. Low relative humidity, dissimilar materials with high friction, and large dry body surface area all result in voltage accumulation.

ESD protection should be a consideration when designing your product.



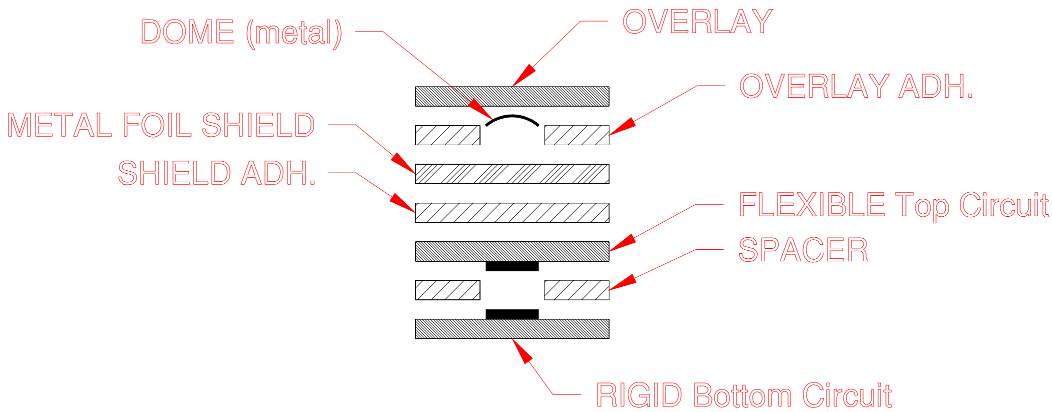


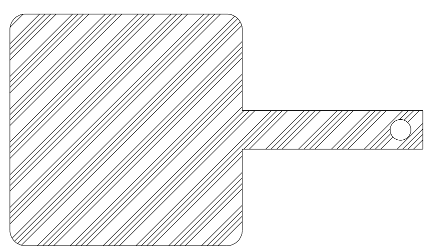
Printed shielding silver placed on the first surface of the flexible layer.

Active ESD protection consists of providing a grounded, conductive sheet between the graphic layer and the switch circuitry assuring safe dissipation of any discharge tat penetrates the former. The ground plane may also prevent transfer of high voltage to keyboard circuits by capacitive

coupling. The shield can either be made of metal foil or printed conductive ink. If printed the shield can be terminated to the circuit tail.

Radio Frequency Interference (RFI) – Emitted high and low frequency radio waves from computing devices. It is these waves that make computer terminals and peripherals, as well as digital telephones susceptible to interference. RFI emissions must be below levels prescribed by the Federal Communication commission (FCC).





Foil Shielding

Metal foil can be used on all keyboard constructions. Aluminum foil laminated to polyester may be used for ESD and/or RFI preventative. The foil will need a separate tail for the ground connection.

Backlighting

Backlighting is a means of lighting selective graphics from behind the overlay. In some cases this can be provided by LED's either placed behind the mounted surface or on the rigid bottom circuit. When it becomes necessary to make the overlay visible in a dark environment, Fiber Optic lighting becomes the backlighting of choice.

Fiber Optics is a light-emitted panel woven from plastic optical fibers. The thin, flat panel is Heat and EMI free. Fiber Optics provide superior

brightness, longer life, significant design flexibility, and less power when compared to EL backlighting. EL backlighting also requires an AC inverter that must be implemented in the package design. Although EL many times can be less expensive.

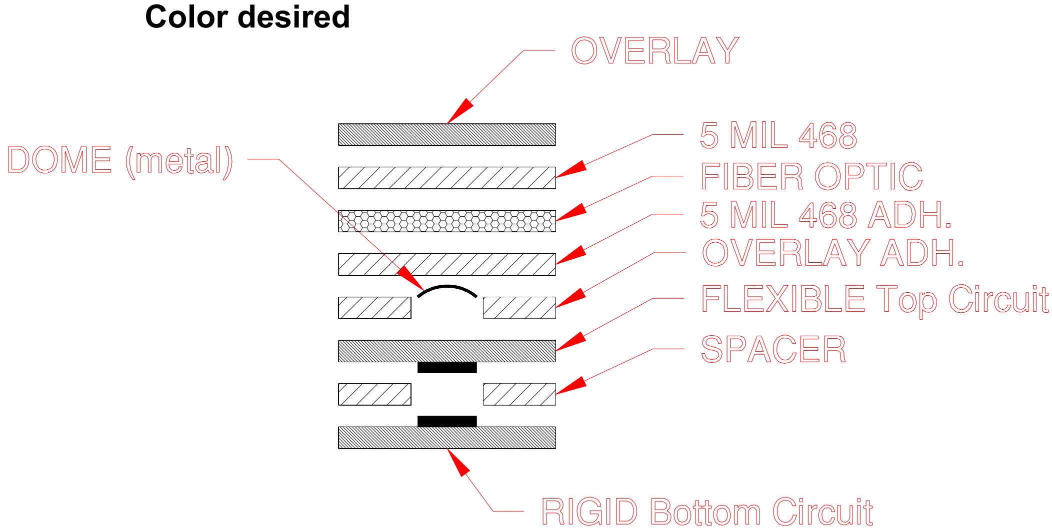
Fiber Optics

The thinness and flexibility of the fiber optics allow it to be sandwiched between tactile dome/overlay and membrane switch. Typically fiber optics add 2 ounces of actuation pressure.

Fiber optic panels may have one or several layers. Depending on the light source, two layers connected to the same light source can create almost twice the brightness of a single layer. 3 or 4 layer backlighting panels are not uncommon. It also makes the illuminated surface more uniform. Panels are made with a reflective backing to increase brightness on the top.

Standard light sources: 1) LED's. 2) incandescents.
Standard power requirement: 30mA to 3A, 2 to 12 volts.
Ordering information

- **Width**
- **Length**
- **Maximum Thickness**
- **Number of Cables**
- **Cable length**
- **Light source type**
- **Light source output**
- **Light source power**
- **Color desired**



LED’s

This is a target lighting system of a small circle in a key cap or background of a keypad. By lighting an LED (Light Emitting Diode) under a small clear or translucently colored window in the overlay. The most common function of the LED light is to indicate which of a number of functions or lock keys is currently active. When a single key invokes the active function, it is preferable to place the LED within the invoking key’s touch area. However, target lights must be placed in the touch area where the LED will not interfere with the mechanical operation of the switch.

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

Emboss

Embossing is used to enhance the visual and tactile definition of keys. Several types of embossing are available including; Rim (sometimes called Ring or Perimeter), Full (sometimes called Pillow or Plateau), and Spherical as in thermoformed polydomes.

Polyester embossing is created by heating the overlay material and pressing it between a specially photoetched male/female die. Polycarbonate can be embossed without heat.

Photoetching produces the exact embossing detail necessary while providing for material clearances in the die. This process allows for very accurate tooling.

Tail Design

Before the tail of the membrane keypad is designed, it is necessary to select and specify the termination. The length of the tail is determined by the layout of mating electrical connectors and the keyboard mounting within the product. Tails, for the membrane switches, can exit at the perimeter or interior.

Adhesive Layers

Most if not all membrane switches and overlays have pressure sensitive adhesives for:

A) Adhering parts to enclosures.
B) Laminating layers in switches.

C) Laminating overlay to switch.
D) Holding domes in place.

Bottom Adhesive

2 mil 467 (3M) used for flat smooth mounting surface contact.
5 mil 468 (3M) for textured mounting surface.

Spacer Adhesive

Spacer adhesive are used on all switches. The purpose is to laminate the flexible layer to the rigid layer. Thickness and size of cutouts directly affect actuation pressure of switches and vary depending on construction.

In Conclusion

Completing the loop of knowledge requires fine-tuning and collaboration with Spectra Symbol's corps of design engineers. Feel free to contact us via phone or email.

Sincerely,

The Spectra Symbol Team.