WILSON HURD
Our Innovation, Your Solution

Membrane Switch Design Guidelines

Membrane switches offer a unique set of advantages for a variety of applications. With a completely sealed design, they are the perfect solution for any harsh environment with a minimal risk of failure due to breakage of moving parts. Their low cost and reliable performance make membrane switches a popular choice when it comes to dependable **user-interface** solutions.

Because every membrane switch we create is designed custom for your unique application, certain specifications are required for each design. This set of design guidelines was created to assist you with the design and creation of your custom membrane switch. Our highly skilled engineering team will carefully review your requirements to assist in designing the optimum switch for your application.

Things to Consider when Designing your Membrane Switch:

1. **Environmental conditions** *(indoor/outdoor, harsh environments, sunlight, etc.)*
2. **Mechanical requirements** *(tactile feedback, actuations, etc.)*
3. **Electrical requirements** *(layout, resistance, shielding, etc.)*
4. **Appearance** *(embossing, color matching, selective texture, etc.)*
5. **Certifications** *(ISO, U.L., etc.)*

Membrane Switch Construction:

A membrane switch consists of three main sections: the **overlay**, **switch**, and **backer**. The overlay displays your graphics and can also include **windows**, **embossing**, **coatings**, **adhesives**, and **selective texturing**. A switch generally consists of a **top circuit**, a **spacer**, and a **bottom circuit**. The backer is the final part of your membrane switch, and commonly includes

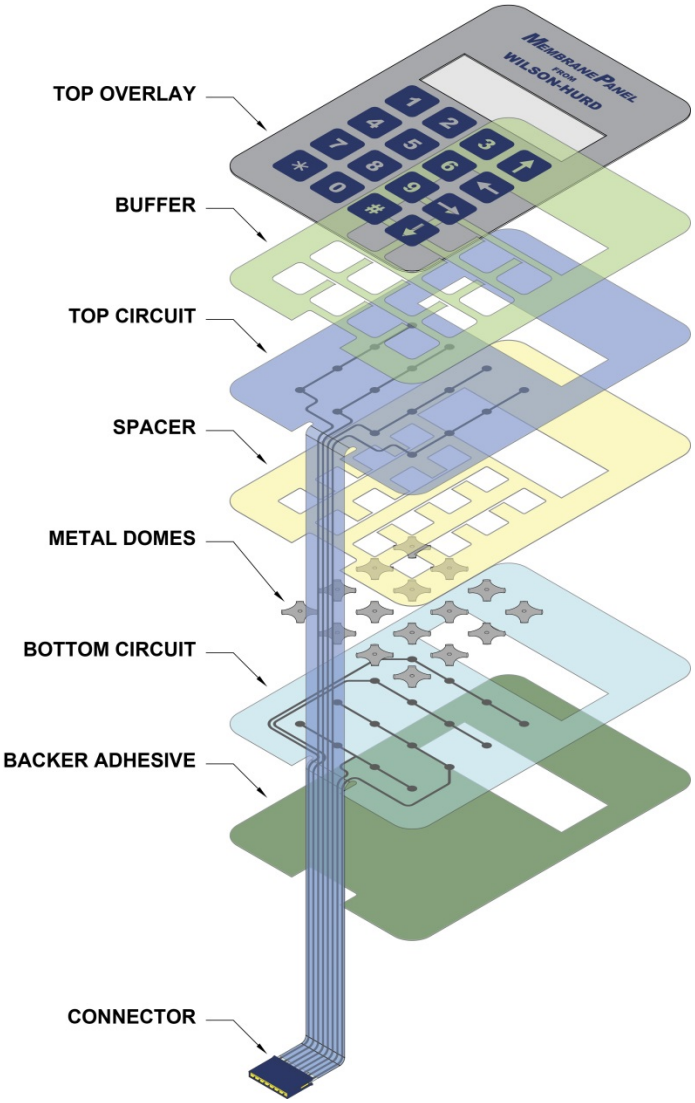


Figure 1 - Example of a common membrane switch build

an adhesive that must bond to your specific substrate. Other layers can be incorporated into your membrane switch based on your project's specific needs including shields, or buffers and domes such as in **Figure 1** above.

Overlay Materials: The overlay is the outermost layer, and will establish the design and feel of your membrane switch. Many overlay materials are available including **polyester**, **polycarbonate**, and blended materials. Polyester materials are utilized more frequently than others due to improved readability, flexibility, and chemical resistance.

Polyester can come in thicknesses up to .010". Polycarbonate materials are best used for overlays without switches, or with switches with limited movement due to limitations in flexibility and chemical resistance, however it does provide improved readability, vivid colors, and dimensional stability when embossing. Polycarbonate and polyester blends combine the best of both materials for specific applications, however generally they are not as cost-effective as polyester or polycarbonate overlays. Refer to **Table 1** for a helpful guide on the materials offered and their specifications.

Color Matching: Wilson-Hurd most commonly uses the **Pantone Matching System** or **CMYK color model** to match custom colors. We can match to a specified or provided color. If you wish to submit a sample, we prefer that it be 2 x 2" in size.

Artwork: Please visit the Resources section on Wilson-Hurd's website to submit artwork, or simply visit the link below.

www.wilsonhurd.com/submit-artwork

We accept the following types of artwork (listed in order of preference):

- AutoCAD (2D)*
- Solidworks (3D)*
- IGES (3D)
- STEP (3D)
- DXF (2D)
- Gerber (PCB) – include dimensional of your part in one of the other formats
- Adobe Illustrator (Graphics) – include dimensions of your part
- PDF (Graphics or Dimensional Support) – with embedded fonts (Graphics)
- Postscript (Graphics) – with embedded fonts

**Most preferred forms of artwork*

Table 1 - Wilson-Hurd Membrane Switch Overlay Material Guide

Material	Base Film	Finish	Thickness	U.L. Rating	Recommended for Outdoor Use (Sunlight)	Hard-coated	Enhancements:		Resistance to:	
							Embossing	Selective Texture	Industrial Chemicals	Household Cleaners
Autotex F	Polyester	Fine	.006-.010"	94HB*	No	Yes	Yes	N/A	Good	Good
Autotex V	Polyester	Velvet	.006-.010"	94HB*	No	Yes	Yes	N/A	Good	Good
Autoflex EBG	Polyester	Gloss	.005-.010"	94HB*	No	Yes	Yes	Yes	Good	Good
Autoflex EBA	Polyester	Matte	.005-.010"	94HB*	No	Yes	Yes	Yes	Good	Good
Autotex XE	Polyester	Velvet	.008-.010"	94VTM-2	Yes	Yes	Yes	N/A	Good	Good
Marnot XL	Polycarbonate or Polyester	Various	.007-.030"	94-V2	No	Yes	Yes	Yes	Good	Good
8010 Lexan	Polycarbonate	Gloss	.007-.030"	94VTM-2	No	No	Yes	Yes	Poor	Fair
8B35 Lexan	Polycarbonate	Velvet	.005-.020"	94VTM-2	No	No	Yes	N/A	Poor	Fair
HP-92W Lexan	Polycarbonate	Gloss	.007-.030"	94HB	Yes	Yes	No	Yes	Fair	Good
HP-40 Lexan	Polycarbonate	Matte	.007-.030"	94HB	No	Yes	No	Yes	Fair	Good
HP-12 Lexan	Polycarbonate	Matte	.007-.030"	94HB	No	Yes	No	Yes	Fair	Good
FR-60 Lexan	Polycarbonate	Gloss	.010-.040"	94-V0	No	No	Yes	No	Poor	Fair
FR-65 Lexan	Polycarbonate	Velvet	.010-.020"	94-V0	No	No	Yes	No	Poor	Fair

Ultraviolet Hard-coats: Polycarbonates and polyesters themselves may not hold up well to weather and ultraviolet light without enhancements. Using an ultraviolet hard-coat on these materials increases their durability, enhances their appearance, and protects it from the environment. Some coatings are available from the manufacturer themselves, or from Wilson-Hurd.

Embossing: Embossing is a physical change to the shape of a normally flat overlay film. Types of embossing include:

- **Pad** (pillow, plateau)
- **Dome** (spherical, machined)
- **Rim** (rail, ridge, ring, perimeter)

Polycarbonate material produces very crisp embossing; however it is not preferred for switches due to its limited flexing properties. Polyester material has increased flexibility which makes it a good choice for embossing with switches. Heat stamping or forming is required to emboss polyester overlays.

Laser Cutting: Laser cutting is a form of cutting that utilizes a CO2 laser as a cost-effective alternative to steel rule die cutting. Cutting with a laser can also provide improved precision, since the laser beam is narrow and cuts all the way through the material, dropping out all internal cuts.

Tooling: Two tooling techniques are generally used when producing a custom membrane switch, steel rule die and hard tools. **Steel rule die** tooling consists of cutting blades (rules) embedded in a wooden base and surrounded by rubber cushions. Outside shapes and interior holes can then be die cut in a single stroke. Steel rule die tooling has a tolerance of ±0.10”, and lasts approximately 25,000 strikes before needing to be replaced. **Hard tools** (Class A Tools) perform the same process; however they are made out of harder steel and consist of both male and female tools, which results in a tighter tolerance of ±0.005” and an extended tool life that lasts millions of strikes before replacement.

Connectors: When selecting a connector for your membrane switch, a number of factors should be considered including cost, reliability, performance, design, environment, as well as any anticipated insertions and extractions. Mechanical specifications for most interface **terminations** are standard. Consequently, circuit construction techniques can be designed for compatibility with specific types of interface termination methods. The typical membrane switch, for instance, consists of one or two **flex tails**. As a result, only certain types of interface terminations are possible. There are two main types of connectors, single row/crimp and ZIF (Zero Insertion Force).

Single Row/Crimp Type connectors provide a gas-tight termination interface between a flex tail and connector. In this method the membrane switch is supplied with a flex tail of a specific length. Crimped to the flex tail(s) are male or female pins with or without housing. The cost of this interface depends on its contact plating material (tin/lead or gold) and the number of pins required. The Berg Clincher 65801 is a commonly used connector of this type and is available in either receptacle or pin type construction. Other common manufacturers are Nicomatic, Tyco, Molex, and Taiwan.

A **Zero Insertion Force (ZIF) connector** requires very little force for insertion. Common manufacturers include Molex, Hirose, and Tyco.

ESD/RFI Shielding: An ESD, or **Electrostatic Discharge**, is the transfer of a high potential electrical charge between objects by contact or through the air. ESD from humans to an electronic apparatus may damage or destroy circuit components. To prevent this, we can provide **ESD shielding**, which generally consists of printing a carbon silver grid or the use of aluminum foil to protect the switch. RFI, or **Radio Frequency Interference**, is high

frequency radio waves that can affect how the user-interface operates. **RFI shielding** can be applied to the membrane switch to protect it from interference; however it must surround the entire switch to be effective.

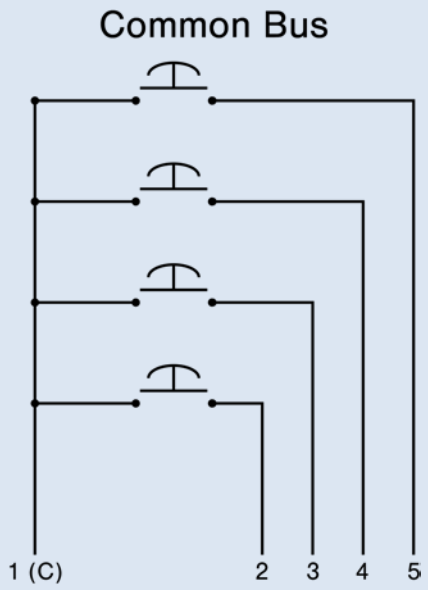
Venting: When a **keypad** is depressed, air pressure within the switch cavity increases. In order for the switch to close properly, air within a switch cavity must be displaced, equalizing the internal pressure. This is usually only a problem in switches that are environmentally sealed. There are two standard venting methods that can solve this issue:

Internal Venting: Narrow channels between key location cutouts are cut into the spacer layer, permitting the air from one location to move elsewhere when that key is pressed. Note, however, that these air channels never exit to the outside of the membrane switch, preventing the risk of contamination since the switch remains sealed.

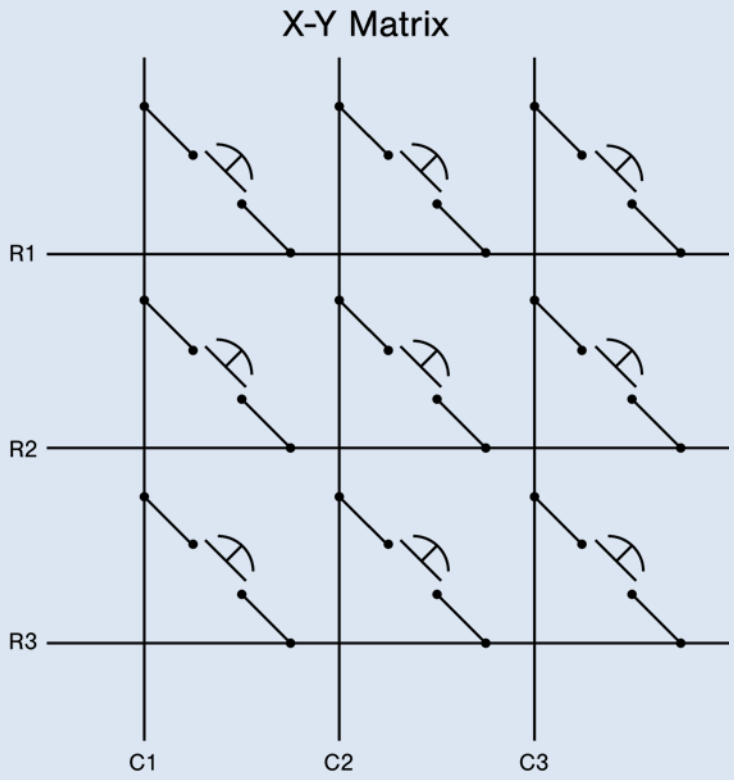
External Venting: As in internal venting, narrow channels that have been cut into the spacer layer connect each key location. These channels then exit through the sides, rear, or internal cut-outs of the membrane switch. This design allows pressure within the switch cavities to be equalized with the surrounding atmosphere, thus allowing switch closure at any atmospheric pressure. Because external venting increases the risk of contamination, it is only

Electrical Layout

To help us design your membrane switch, it is recommended that you provide us with a **pinout** and/or schematic for a **common bus** or **X-Y matrix** layout similar to the examples below.



4 keys with a 5 pin connector



9 keys with a 6 pin connector

recommended when the membrane switch is exposed to rapid or extreme atmospheric pressure fluctuation and will generally not come into contact with a harsh environment.

Circuit Types: There are three main types of circuits that can be included in your switch:

- **Printed Circuit:** An electrical circuit manufactured using standard printing or screen-printing methods along with conductive inks.
- **Flexible Printed Circuit (FPC):** An etched circuit using Kapton polyimide film as a **substrate**. The end result is a thinner, higher density, and more flexible printed circuit.
- **Rigid Membrane Switch:** A membrane switch that is constructed with a rigid lower PCB circuit.

Domes: Wilson-Hurd provides both metal and poly domes. A dome is a mechanical apparatus that provides mechanical-type feedback and closes the circuit when pressed. **Metal domes** are made of stainless steel or a composition of metals that are used to obtain a specific **tactile feedback**. **Poly domes** are made using embossed polyester. Domes are considered an integral part of most circuits. They can vary in size from 6mm up to 22mm, with forces of 100 grams up to 24 ounces.

Windows: The type of window you choose for your membrane switch depends on the type of display you plan on using. **LCD displays** need clear windows. Anti-glare is okay for LCD displays within .125", however gloss is required for distances greater than .125". **VFDs** are a bit more forgiving and may accept a matte finish if the user will be close to the window. **Segment LED displays** require even less clarity. A velvet texture can be acceptable if the display is close (<.040"). Matte or fine textures should work okay at an increased distance (.040"-.062"), but gloss or anti-glare should be used for greater distances (>.062"). **Discrete LED displays** work well under velvet textures.

Backlighting Options: We offer **LEDs**, **electro-luminescence**, **fiber optics**, and **light guide film** for backlighting options.

Backer Adhesive Selection:

100 MP Acrylic: Highest performing 3M **PSA** with resistance to solvents and up to 500°F.

200MP High Performance Acrylic: Excellent resistance to solvents and up to 400°F.

220 Industrial Acrylic: Good chemical resistance and shear strength. Resists up to 350°F.

300MP High Strength Acrylic: Bonds LSE plastics and resists heat up to 250°F.

Moisture Resistant Designs: It is highly recommended that the assembly be environmentally sealed in order to protect it against humidity, dirt, and liquid spills. **Environmental sealing** is achieved by applying an acrylic adhesive to both sides of the spacer layer. Any exposed contacts should also be coated with **carbon** to avoid damage from condensation. In particularly harsh environments additional precautions should be taken, including a **perimeter seal** which places a barrier in-between the switch and the perimeter of the part.

Technical Details:

Mechanical Specifications:

Type	Specification
Actuation Force	4-16 oz.
Switch Travel	.007" to .035"
Overall Thickness	Varies by materials used in design
Size Tolerance	Typically .010"
Tooling	Steel rule dies & hard tools, as well as laser-cutting for prototypes
Number of Actuations	Up to 3 million actuations, depending on design

Standard Environmental Specifications:

Type	Specification
Humidity	0 to 98%, no condensation
Operating Temperature	-28.9°C (-20°F) to 70°C (+158.0°F)
Storage Temperature	-40°C (-40°F) to 70°C (+158.0°F)
Salt Fog	5% salt solution, 48 hours

Standard Electrical Specifications:

Type	Specification
Contact Material	Silver, carbon, gold, or nickel
Voltage	30 volts DC
Rated Current/Voltage	20mA@30 volts DC resistive load
Contact Bounce	Less than 20 milliseconds
Maximum Switch Power	1 watt
Contact Resistance	Less than 100 ohms (closed loop)
Dielectric Strength	5000V max on polyester material ≥ .0005”
Termination	Customer choice
Breakdown Voltage to Ground	1000 volts DC
Open Circuit Resistance	10^6 ohms
Capacitance	20 picofarads
Design Configuration	XY matrix, common bus, or custom

GLOSSARY

Actuation: The process that causes a switch to change position, i.e. to open or close.

Actuation Force: The minimum force required to electrically close a switch contact.

Actuator: A formed or molded protrusion to make contact with the center of a switch location, improving tactile feedback.

Adhesives: Substances applied to the surfaces of materials within the different layers of a membrane switch that binds them together and resists separation.

Backer: A rigid substrate or subpanel to which the back surface of a membrane switch is attached.

Backlighting: Illumination originating from within or behind the switch panel which outlines or accents specific areas. Typical lights are LEDs, fiber optics, electro-luminescence, and light guide film.

Bezel: A molded, routed or die cut frame mounted on the face or perimeter of a keyboard.

Bounce Contact: The momentary (and decreasing) rebounds occurring between two contact surfaces suddenly thrust together before they attain firm closure. Bounce is measured as a time interval required for reaching firm closure after initial closure.

Bounce Operator: The vibration or vacillating of applied force made by an individual’s finger when actuating a mechanical/membrane switch.

Capacitance: The property exhibited by two conductors separated by a dielectric, whereby an electric charge becomes stored between the conductors.

Carbon: A non-metallic element that conducts electricity.

Circuit: The main functioning component of a membrane switch.

CMYK Color Model: Also known as process color and four color, it is a color model used in color printing utilizing the four inks cyan, magenta, yellow, and key (black).

Color Matching: The physical creation of a color in the range of one-dimensional hues.

Common Bus: An encoding output that consists of one circuit lead for all switch locations or group of switches.

Connector: A device that provides electrical connection.

Contact Bounce: The time required for an electrical contact to be stable after closure.

Contact Rating: The maximum volts, amps, and watts electrically passed through a switch.

Current (A or I) Unit, Amp: The flow of electricity, i.e., the characteristic drift movement of carriers such as ions, electrons, or holes. I=E/R

Debossing: Similar to embossing, except the area is lowered in relation to the substrate.

Debounce: An electronic circuit designed for eliminating bounce by latching on to the initial contact and holding it until all bouncing has ceased.

Die Cut: To make an opening by means of a sharp edged steel knife, set in a holding tool.

Dielectric: A material which is a nonconductor of electricity (insulator).

Discrete LED Display: An electronic flat panel display that utilizes discrete light-emitting diodes.

Domes – Metal: Stainless steel or composition of metals that are used to obtain a specific tactile feedback.

Domes – Polyester: An embossed polyester which is to provide tactile feedback to the user.

Electrical Actuation: Switch actuation produced by various electrical phenomena. In most cases, the switching action involves a change in state rather than a mechanical operation.

Electro-luminescent Lighting (EL): Light produced by charged phosphorous.

Electromagnetic Interference (EMI): Electromagnetic force generally produced by electrical motors in operation.

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.

Embossing: A shallow profile extending above the surface of an overlay selectively formed under heat and/or pressure with a die, i.e., rim (raised border), pad (raised keys), and raised lettering. Achieved by using a steel rule die. Material is forced upward a max. of .006” to .010” from the substrate, thus creating a raised image.

Environmental Shielding: The application of an acrylic adhesive to both sides of the spacer layer in a membrane switch, to prevent damage caused by moisture.

ESD Shielding: A method to protect the switch from electro-static discharge.

Etched Circuit: A plastic film/metal foil laminate from which the metal has been selectively chemically removed to produce the desired electrical circuit. Copper foil and polyester (MYLAR) film are common components for etched circuits.

Feedback: The mechanism by which the operator senses that a switch has been activated; audio, visual, or tactile.

Fiber Optic: Extruded materials, such as certain plastic filaments, which provide paths for light.

Flexible Printed Circuit (FPC): A printed circuit using Kapton polyimide film as a substrate.

Flexible Tail: The termination exit which is an integral part of a flexible circuit in all flexible membrane switches.

Graphic Overlay: The outer visible layer of the membrane switch. The layer on which the graphics are printed.

Hard-Coating: A coating applied to the surface making it impervious to particular chemicals and at the same time adding scratch resistance.

Hard Tools (Class A Tooling): Tooling made out of steel which results in a tighter tolerance and extended tooling life compared to steel rule die tooling.

Impedance (Resistance): The total opposition offered by a circuit or device to the flow of alternating current.

Insulation Resistance: The alternating current resistance between two electrical conductors or two systems of conductors, separated by an insulating material.

Keypad: The electrically conductive contact area on the inner surface of the upper membrane (shorting pad).

Laser Cutting: A form of cutting that utilizes a CO2 laser.

LCD: Liquid Crystal Display

LED: Light-Emitting Diode

LED Display: A flat panel lighting or video display which utilizes light-emitting diodes.

Light Guide Film: A more recently developed backlighting technology that uses LEDs to create a solid film of light.

Membrane Switch: An electronic switch that consists of printed circuits and acts as a user-interface, allowing the communication of commands from users to electronic devices and machinery.

Momentary Contact: When the actuator returns from its operating position to its free position after an actuating force is removed.

Operating Force: The force required to transfer the switch from one position to another.

Operating Life: The useful life of a switch typically terminated by outright failure or by reaching pre-designated end-of-life criteria.

Pantone Matching System (PMS): An ink color designation system commonly used in a variety of industries, including printing as well as the manufacturing of paint, fabric, and plastics.

Perimeter Seal: A type of environmental sealing used on membrane switches exposed to harsh environments that places a barrier in-between the switch and the perimeter of the part.

Pinout: Determining the sequence of output signals to be delivered at the end of the circuit tail.

Polycarbonate: A plastic material often used for overlays due to its excellent clarity, stability, printing, and die cutting characteristics.

Polyester: A plastic material often used for overlays, also known as polyethylene terephthalate (PET).

Pressure Sensitive Adhesive (PSA): An adhesive that is activated by pressure.

Printed Circuit: An electrical circuit manufactured using standard printing or screen-printing methods along with conductive inks.

Radio Frequency Interference (RFI): High frequency radio waves.

Resistance: Opposition that a material or electrical circuit offers to the flow of electric current. It is the property of a circuit that transforms electrical energy into heat energy as it opposes the flow of current.

Resistance Units – Ohms: The common unit of electrical resistance. One ohm is equal to one volt per amp.

RFI Shielding: A method to protect the switch from radio frequency interference.

Rigid Membrane Switch: A membrane switch with a rigid lower PCB circuit.

Sealed Membrane Switch: A switch or switch panel where the internal circuitry and contacts are completely sealed from outside elements.

Segment LED Display: A type of electronic display using LEDs to light segments that make up decimal numerals.

Selective Adhesive: Adhesive applied to selected portions of a part.

Selective Texture: A surface coating to texture selective areas on a graphic overlay.

Shielding: A method used to protect the switch from interference or static discharge.

Short to Ground: A switch configuration where one side of the switch is a common ground or bus.

Single Row/Crimp Type Connector: Provides a gas-tight termination interface between a flex tail and a connector.

Snap Action: A contact actuating mechanism that produces a high velocity transfer of the movable contact from one extreme position to the other.

Solvent Activated Adhesive: An adhesive that requires the application of a solvent to energize its holding properties.

Spacer: An insulated non-conductive substrate with openings at switch locations to separate the upper and lower circuit layers.

Steel Rule Die: Used to fabricate plastics and adhesives to their final configuration. Outside shapes and interior holes are die cut in a single stroke. The die consists of cutting blades (rules) embedded in a wooden base and surrounded by rubber cushions.

Substrate: A layer of film in a laminate. In flexible circuitry, the plastic film to which the electrically conductive materials is laminated or screen-printed.

Switch: The electronic layer of a membrane switch consisting typically of a top circuit, a spacer, and a bottom circuit.

Tactile Feedback: Operator perception through their sense of touch that switch actuation has taken place.

Tactile Feel: The snap action feel of a domed switch.

Tail: The portion of the flexible circuit outside the keypad area, used to connect the electrical leads from the switch assembly to the main unit. Contains an integral electrical connector or provisions for a connector.

Termination: The means to electrically connect the contact switches of a membrane switch.

Texturing: Changing the surface characteristics of a substrate.

Travel: The downward movement of a key or the distance between the upper and lower contacts.

U.L. Rating: A rating issued to specific materials from Underwriters Laboratories, a safety and certification company.

Ultraviolet Curing: A system which employs ultraviolet radiation to complete the curing process of hard-coats.

User-Interface: A device used so that two or more independent systems can meet and act on or communicate with one another.

Vacuum Fluorescent Display (VFD): A display that emits a very bright light with high contrast.

Venting: An air channel cut in a spacer layer connecting groups of switch locations for air pressure equalization during switch closure.

Voltage (V or E): Electromotive force, or difference of potential; E=IR, where I is current and R is resistance.

Windows: Portions of the membrane switch overlay material that do not have color printed on them. Hard-coats and textures can be applied to these areas as well.

Working Voltage: Maximum recommended voltage for continuous operation of a connector.

X-Y Matrix: An encoding method to arrange switch groups in particular rows and columns.

ZIF Connector: Zero Insertion Force connector.