Silicone Technology Corp.

SiTECH Corp. Application Guide

The following Application Guide is an aid in the design and development of silicone keypads and components. Silicone combines excellent feel, reliability and long life in the most rugged environment. Silicone keypads are used in a wide range of applications including medical, industrial, instrumentations and communications equipment.

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Section 1) Liquid Silicone Rubber Molding

1.1 Introduction:

Liquid silicone injection molding or LIM, is a custom injection molding method of liquid silicone rubber (LSR). While normal injection molding typically uses a High Consistency Rubber (HCR) which is also known as gum stock, LIM uses a high viscosity liquid silicone rubber. LSR consists of two parts, an A and a B. Both parts are a liquid, but only one part contains the catalyst which is platinum. LSR is naturally translucent and typically comes in pail kits or drum kits which are 80lbs and 800lbs. LIM is a closed-loop system which means that the raw silicone is sealed, as well as any pigment that may be added. The Part A, and Part B are connected to a dispensing machine that seals the material and uses pressure to pump the material from the original containers into the machine. The pigment which colors the silicone is a silicone based pigment that is connected to the dispensing machine as well. The material and pigment are injected into a water-cooled barrel that keep the material from catalyzing. The material is then injected into a hot mold but the runner gate and sprue are typically smaller due to having a lower viscosity than gum stock. Due to the platinum cure system, Liquid Silicone Rubber cures at a much faster rate than typical gum stock. This allows for frequently lower piece prices than traditional compression molding. The rapid curing also makes LIM the desired choice for high volumes. This can cause an issue for low volume production that requires consistent material purging which can add to the final cost of the product.

1.2 Brands of Materials:

SiTech uses Dow and Momentive brand materials because of their UL listing, six sigma quality rating for consistency and traceability of material batch runs.

DOW CORNING

MOMENTIVE™

1.3 Properties of Silicone Rubber:

TABLE 1: PROPERTIES OF LIQUID SILICONE RUBBER

Physical Properties:

	40 Durometer	50 Durometer	60 Durometer	70 Durometer
UL Flammability Rating:	94HB	94HB	94HB	94HB
Specific Gravity (at 25°C):	1.143	1.140	1.142	1.16
Hardness (Shore A):	44	48.4	59.3	68
Tensile Strength (psi):	1257	1583	1632	1450
Tear (ppi):	191	254	275	274
Compression Set:	25.1	18.3	20.1	57
Elongation (%):	742	645	504	450
Material Color:	Clear	Clear	Clear	Clear
Operating Temperature:	-75 °F to 400 °F (-60 °C to 200 °C)			

Electrical Characteristics:

Contact Resistance:	20 – 200 Ohms
Contact Rating:	30 mA at 12 VDC
Contact Bounce:	<20 mS, typical
Insulation Resistance:	>100 M Ohms at 500 VDC
Dielectric Strength:	500 V/mil

1.4 Advantages of using Liquid Silicone Rubber:

1. Reduced cycle times:

- Keypads and components typically have a cycle time of approximately 30 seconds – 2 minutes depending on the shape, size and complexity of the part.

2. Flash-less tooling:

- Liquid silicone injection molds inject the liquid silicone after the mold has closed. With the utilization of flash rings, venting air tracks, and a well-designed runner system the tooling leaves little to no flash on the final parts.

3. No Pre-Forms Needed:

- Liquid silicone rubber injection molding requires no pre-forms. A pre-form is a basic shape of the end product that is placed into each cavity during compression molding. These pre-forms need to be a surplus of material which insures a total cavity fill of materials. The excess material is pressed between the two molds causing flash around all of the cavities.

4. Production of insert molded components:

- Injection molding silicone rubber allows for the placement of pre-molded clear silicone inserts within the tool. The clear silicone inserts become "over-molded" with the desired color creating a seamless bond between the insert and over-mold. This allows for the blockage of light between keys and eliminates the need for the customer to designing custom light blocking components within the PCB. The clear inserts can also be used for display windows to show components or digital screen behind the silicone keypad. The cross-link bond that over-molding silicone inserts creates, allows for a leak-proof keypad or component.

5. Minimal Material Waste:

- Material is only wasted within the sprue and runner system leading to the component or keypad, ad this can be eliminated with the use of a cold runner system. Cold runner systems keep the silicone cool within the runner and sprue to keep the silicone from curing. These systems are typically only used on large quantity orders where the material waste beings to have an effect on the cost.

Section 2) Tactile Response & Key Types:

2.1 Introduction:

When designing a silicone rubber keypad, it is important to consider how you want to apply force to the shorting pad, and how much force is needed. The simplest and most accurate method is by using metal domes. The use of metal domes within your keypad assembly eliminates the need for the use of a diaphragm. However, in some cases, metal domes are not able to be used. This requires the silicone rubber keypad to create the force the customer is looking for. This is where the use of Diaphragms come into play. A Diaphragm is the thin hinged area of a keypad that allows the keypad to move and flex. Diaphragms are also known as Webbing or Webs.

2.2 Diaphragm Design Tips:

- The distance of the edge of a key's diaphragm to the edge of the keypads mat, should be no less than 0.040".
- The distance between two diaphragms should be no less than 0.040".
- The minimum diaphragm height should be no less than 0.020". Diaphragm height is typically greater than or equal to the travel of the keypad.
- The standard diaphragm angle is 45°. Modifying the angle is one way to increase or decrease the force generated by the diaphragm. A lower angle provides less force, while a larger angle increases force.
- The standard thickness of a keypads diaphragm is typically 0.020". Increasing the thickness of the diaphragm increases the force required to get a tactile response.

2.3 Key Types:

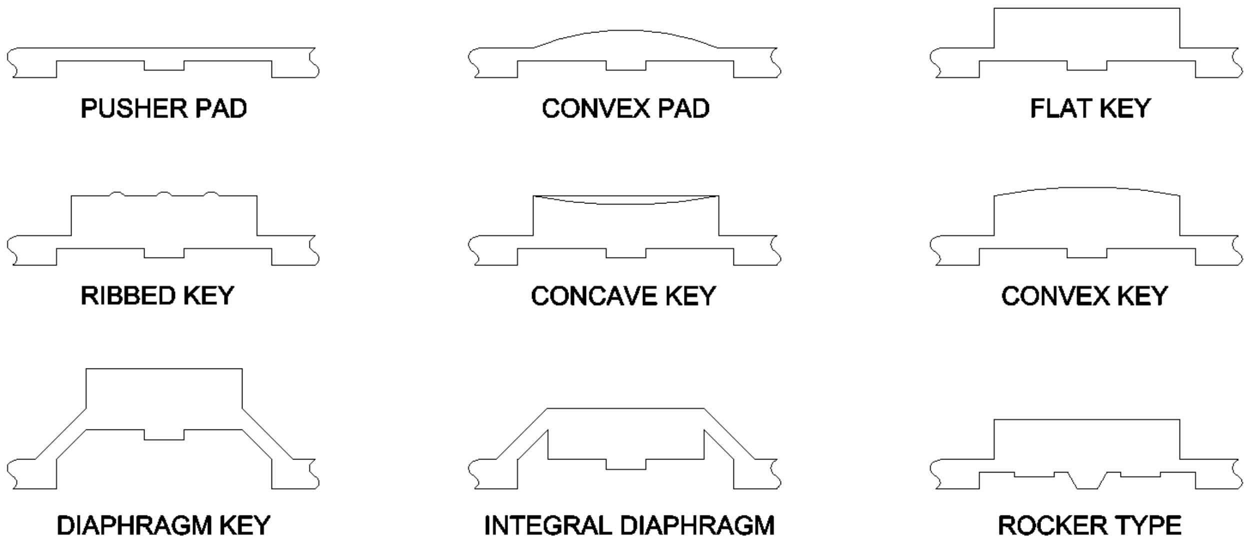
When designing your silicone rubber keypad, there are three main types of keys to consider. First you need to determine whether or not you will be using metal domes, tact switches, or shorting the pad via an electrical source on the silicone key itself. You must then determine whether or not you wish the keypad to be tactile. A good example would be a television remote control versus a microwave oven. Typically the remote control has keys that when pressed, have a "Snap", while most microwave ovens have no snap when a button is pressed.

When silicone keypad assemblies utilize metal domes or tact switches, it is preferred to use the "Pusher Pad" design of silicone keys. This keypad design utilizes what we call a "dead web" which is simply a flat diaphragm. The reason these dead webs are used is to prevent a double click feeling from occurring. The height of the metal dome or tact switch determines the height of the contact surface on the bottom of the key. Typically we here at SiTech recommend a 0.005" of preload onto the dome or switch to minimize the stroke distance of the key and to keep the force profile as close to that of the dome or switch as possible.

If the key itself is to provide the tactile feedback, then an angled diaphragm will be needed. There are many different variations of diaphragms but the general function remains the same. Typically a conductive material is molded into the silicone key which provides the means to short the pad on the circuit.

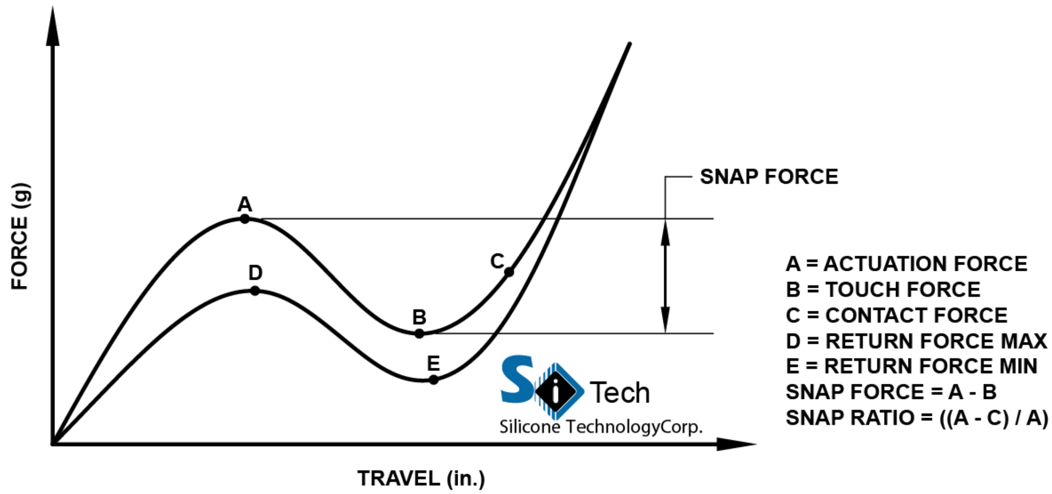
Another type of key design is what we at SiTech call a "Rocker Type". The Rocker type of key is designed to incorporate multiple shorting pads within one key. An example would be if you wanted to have an object move forward and backwards with one key. If you were to press on one side of the key, one of the shorting pads would short, and vice versa. This is made possible by incorporating a pivot feature within the middle of the key. These keys typically do not have a high snap, but can be utilized in the Pusher Pad or Tactile types of keys.

Below are a few of the different types of keys we frequently see here at SiTech:



2.4 Force Curve:

The force curve of a tactile silicone key is made up of a couple different variables. First at the top of the curve you have the actuation force. The actuation force is the force required to collapse the membrane of a silicone key. Next you have the touch force. The touch force is the amount of force required to maintain the closure of the silicone key. With these two forces, you are able to calculate a snap ratio. The formula for determining the snap ratio as followed: (Actuation Force – Touch Force) / Actuation Force. This ratio is what gives the keypad a tactile response or more simply put the snap feeling. The last force to determine is the return force. This is the force created by the keypad's webbing as it returns to its neutral position. These forces are all mostly determined by the design of the webbing. Different variations in the thickness, angle and travel will give different forces across the board.



Section 3) Design Recommendations & Rules:

3.1 Introduction:

When designing a silicone keypad or component it is important to consider how the tooling will be made as well as how the tooling will effect production. There are some industry standards that can help you with your design in regards to these considerations.

- The minimum radius capable of being used is 0.010”.
  - It is not recommended to use anything smaller than 0.020” in deep pockets or cavities.
- Keys that are taller than 0.200” are recommended to have a minimum draft of 1°.
- Keys that are taller than 0.500” are recommended to have a minimum draft of 2°.
- The minimum thickness of a keypad mat should be no less than 0.040” thick
  - Making a keypads mat too thin can have a negative effect on the force profile you are seeking.
- The maximum thickness of a keypad mat should be no more than 0.150” thick.
- Air channel geometry is recommended to be 0.080” – 0.125” wide by 0.010” – 0.013” deep.
- Holes or openings within the silicone part require tear plugs which are removed either by hand or tweezers. This means that the smaller the opening the more difficult it will be to remove the plug. Also the smaller the plug the more chance for residual flash to be left on the part.
- The clearance between a bezel to a key should be no less than 0.012”.

3.2 Backlighting:

Silicone keypads have the capability of being backlit. This is done with the use of LED lighting via a printed circuit board. Typically an LED insert or clear window is insert molded into the keypad to show the light. LED light pipes, windows and displays have a few design recommendations as well:

- The maximum depth of an undercut for a feature window opening is 0.250”.
- The minimum size for an insert molded silicone light pipe is 0.060”.
- The minimum thickness for an insert molded window is 0.030”.
- The minimum height for a molded silicone light pipe is 0.030”.
- The minimum distance needed between the edge of a keypad or opening and a silicone light pipe or window is 0.030”.

3.3 Shrink & Tolerances:

Injection molded silicone components and keypads shrink after the demolding process. The shrink varies between molding temperatures, and material used, but typically a part or keypad can be expected to shrink approximately 2-3% from molded size. Due to the variable shrinkage a silicone part can have, liquid silicone rubber components have a standard tolerance for specific sizes. As shown below in our tolerance chart, our tolerances vary from your standard Class M2 and are more closely represented by the Class M1 tolerances in ISO 3302.

DIMENSION	TOLERANCE +/-
< 0.400	0.004
0.400-0.800	0.006
0.801-1.200	0.008
1.201-1.600	0.010
1.601-2.000	0.012
> 2.000	0.6%

Section 4) Insert Molding:

Here at SiTech we have the capability of molding individual and conjoined silicone inserts into a final silicone molded assembly. This allows us to create unique and custom backlit keypads and components. This method of molding is known as Insert Molding.

SiTech uses insert molding as a process to isolate light sources, and prevent the spread of light to specific areas of a keypad. This method is done utilizing a double-shot process which entails the first shot of molding a silicone insert or window in a clear or translucent material. This insert is then placed into a secondary mold that then injects opaque silicone around the pre-molded insert. The liquid silicone creates a cross-link bond with the pre-molded insert creating a seamless seal. This method of molding allows for the elimination of light bleeding into LED indicators or separate keys that are not supposed to be illuminated. The ability to mold an opaque barrier around a clear insert opens up the possibility to balance light sources by focusing on individual light sources rather than trying to illuminate an entire keypad.

Currently the most popular method of creating a backlit silicone keypad is molding the entire keypad in a clear silicone, coating the outside black, and then lasering the artwork through the black to have the clear or translucent base showing. The major flaw with this method is the inability to block light. Making this an outdated process which leaves it entirely in the customer's hands to deal with light separation. We have found that light can bleed through very small amounts of clear silicone, which can cause enormous headaches when trying to separate and balance light sources.

Insert molding has become the new standard here at SiTech, as this method provides the capability to light individual keys, without light bleeding from one key to the next.

Section 5) Secondary Processes:

5.1 Screen Printing:

Here at SiTech, all of our positive and reverse graphics are done using screen printing. We use our proprietary silicone inks that create a cross-link bond to the silicone rubber keypads and components during the curing process. This makes a hard-wearing and long lasting graphic that will last the lifetime of your keypad under normal industry circumstances.

Visually aesthetic graphics can have a large influence on how users feel about your product. A well designed keypad enhances not only the appearance of your product, but can also enhance the functionality of it as well. Below are a few recommendations we frequently give to enhance the design of your silicone rubber keypad and the graphics you intend to have applied.

SiTech has the capability to accept graphic designs in the following formats:

- *.ai (Adobe Illustrator)
- *.cdr (Corel Draw)
- *.pdf (Adobe)
- *.dwg (Autocad)
- *.dxf (Autocad)

Graphic Design Considerations:

- Solid colors can be screened up to the edge of a flat keytop.
- On curved keytops, solid colors can be screened up to 0.015" to the tangent point of the outer radius.
- The minimum distance from the edge of a keypads mat to a legend is 0.015".
- The minimum line weight for a legend is 0.010".
- The minimum text height is 0.050".
- The minimum radius of a concave or convex keytop is 0.375".
- The maximum curvature depth for concave keytops with a minimum radius of 0.375" is 0.060".
- The maximum curvature height for convex keytops with a minimum radius of 0.375" is 0.060".

5.2 Embossing & Engraving:

One of the easiest ways to decorate a silicone rubber keypad or component is to add embossing, or engraving to the component, or key's surface. This is done by simply adding the image or text to the mold so it either engraves or embosses the surface of the silicone. One advantage of using this method is that the embossing or engraving will last the lifetime of the keypad. A disadvantage of using this method is the area of the embossment or engraving allows for dirt and debris to easily become trapped. Some limitations for designing this method include a minimum line weight of 0.015". And a maximum height or depth of 0.012".

5.3 Die & Laser Cutting:

SiTech provides the capability of applying a custom adhesive backing to our customer's silicone keypads and components. We have two methods of creating the custom cut-outs of adhesive. The first being die cutting, which is a method that requires a custom tool to be made. Die cutting has a larger initial cost due to the necessity of a custom tool, but is greatly efficient when dealing with larger volume orders. The second method mentioned is Laser cutting. This method uses a laser that cuts the intended design of the adhesive backing out of a larger stock size sheet of adhesive. This method is preferred for smaller quantity orders as a custom tool is not required. This method does take significantly longer to run but allows for a customer to make revision changes to their product without having to modify a die-cutting tool. Laser cutting offers a significant advantage to die cutting by simply altering a computer file with the

5.4 Abrasion Coating:

Si Coat ™ is an abrasion resistant coating system developed by SiTech Corp. for use in silicone rubber applications requiring superior wear protection.

Si Coat ™ is a tough, wear-resistant coating offering an outstanding abrasion resistance for elastomer keypad applications. Under independent lab test using an RCA abrasion wear tester, Si Coat I surpassed by more than 20 times the standard acceptance criteria for the keyboard/keypad industry. Now, you can be sure that the SiTech's rubber keypad will have the same consistent look and feel with no degradation throughout the life expectancy of your product.

When combining Si Coat I ™ with our proprietary screened silicone inks and Liquid Injection Molding, we offer you a unique set of features that will assure the right solution for your product requirements.

Si Coat I offers:

- Tough, wear-resistant coating. Eliminates replacement costs
- Smooth, matte surface finish
- Seamless coating, 100% keypad surface protection
- Coating of irregular shapes
- Can be applied over any graphics/color
- Repel dust
- Homogeneous cross link for permanent bond
- Silicone base for flexibility

When your product needs protection for harsh environments or put in a high usage industrial application, Si Coat I ™ with our silicone keypads is the solution for your product. Proven success in industries such as:

- Military
- Telecommunications
- Medical devices
- Computers
- Laboratory instrumentation
- Point of sales
- Industrial equipment
- Consumer electronics
- Automotive
- Aerospace

The RCA abrasion Wear Test method provides a reference and comparison data for the durability abrasion resistance of printed graphics on rubber and plastic keytops. Accepted standard is a minimum of 35 cycles.

5.5 *Chemical Coating:*

One of the chemical coating systems that we have developed at SiTech is called Si Coat II. It eliminates these problems. Si Coat II protects the custom silicone rubber keypads from many different types of chemicals, including petroleum-based chemicals and those containing chlorine, lipids and oxidants. Items like bleach, sulfuric acid and hydrogen peroxide will not damage the surface, helping the product live up to its design. Si Coat II is a relatively inexpensive coating offering a cost-effective solution to extended= product life. The coating is silicone based, so it creates a homogeneous bond with the silicone rubber. This is a permanent cross-link bond that increases the flexibility and resilience of the keypad, and leaves a 100% seamless finish for excellent wear protection.

Si Coat II has had proven success in industries such as:

- Medical devices
- Machine/Tools
- Laboratory instrumentation
- Industrial equipment
- Point of sales
- Consumer electronics
- Automotive
- Telecommunications
- Military
- Aerospace

Si Coat II offers excellent protection against:

- Petroleum based products such as:
  - Hydrolic oil
  - MEK
  - VMP Naphtha
  - Acetone
  - Motor Oil
  - WD40
- Oxidizing and Chlorinated solvents such as:
  - Bleach
  - Nitric Acids
  - Phosphoric Acids
  - Sodium Hydroxide
  - Sulfuric Acid
  - Hydrogen Peroxide
- Lipids:
  - Body fat

Silicone Technology Corp.

5.6 Conductive Coating:

SiCoat V ™ is a proprietary conductive silicone based coating developed by SiTech for use in silicone keypad applications.

Si Coat V ™ is an outstanding wear resistant conductive coating offering a homogeneous cross link bond to SiTech's silicone keypad products. Under independent laboratory testing, conductive pads with Si Coat V ™ surpassed more than one million actuation cycles with negligible increase in resistivity. Elaborate conductive pads and shapes and other desirable features can be economically produced to provide unique, application specific keypads.

Si Coat V ™ complements our proprietary screened silicone inks, abrasion resistant and chemical resistant coatings, adhesive primer and liquid injection molding process offering you a complete set of features to meet your product requirements.

SiTech's state of the art process, combination of technology and quality provide unique, application specific keypads solutions from a competitive domestic manufacturer of silicone rubber products.

Si Coat V ™ offers:

- Low cost design solution
- More than one million actuation cycles
- Low contact resistance
- Homogeneous cross link for permanent bond
- Design flexibility for different conductive pad shapes and uneven surfaces
- E.M.I. shielding
- No flaking, chipping

5.7 Bonding Coating:

Si Prime™ is a coating system specifically designed for bonding silicone rubber to a variety of different surfaces with common acrylic adhesives used in the membrane switch industry.

Si Prime™ offers the best solution to the intrinsic problem of bonding rubber to polyester switches for far less cost than mechanical means. A thin coating of Si Prime™ is added to the underside of a Silastikey silicone rubber array.

This coating serves as a bonding barrier between the silicone surface and an acrylic adhesive. When used in conjunction with any 3M™ 350 series Hi holding acrylic adhesive, Si Prime™ offers an outstanding high bond strength for elastomer keypad applications. Under independent lab test using ASTM standard D-3330, Si Prime™ out performed by more than two times the bonding capabilities of other silicone/acrylic adhesives.

Si Prime offers:

- Field proven (More than million units and different applications)
- Highest silicone rubber to surface bonding

- Bonding strength increase with time
- Excellent resistance to slippage or flagging
- Operating temperature tested to -40°C to 85°C
- High humidity resistance
- Good solvent resistance
- Shelf life two years +

Section 6) Keypad Assembly:

Here at SiTech our facility offers an added value service by supporting the ever growing request from our customers for keypad assembly. Be it simply applying adhesive prior to shipment, to the full keypad, bezel, & PCB assembly, we can assembly it all. We install printed circuit boards, metal or polyester domes, or membrane circuits on your custom keypads. In addition, all assembled components are tested to ensure proper functionality and performance. Utilizing this added value service can minimize your sub-assembly time to create a seamless assembly of components.

SiTech offers a number of glass options that can be bonded to the custom silicone keypads as well. We utilize special silicone rubber based adhesives to insure a permanent bond, and that the glass is held firmly in place. Our assembling process for windows includes the use of EFD precision dispensers to dispense the silicone adhesive evenly to create a lasting bond between the window and rubber.

One of the assembling processes that we specialize in is custom adhesives. We recommend a silicone / acrylic adhesive for bonding the silicone keypad to the PCB or membrane switch, but we also offer our proprietary Si Prime, which once applied allows acrylic adhesive to bond to the silicone rubber. We also utilize custom lasered and die cut adhesive for our silicone keypads, and metal dome assemblies.

Below are some design recommendations and considerations for Silicone Keypad Assembly:

- Pull tabs or Spigots are used to help keep the silicone keypad attached to the PCB.
    - A correctly tolerance straight pull tab will act just as well as an undercut pull tab and help reduce tooling costs and product loss.
- Wrap around keypads are designed with an undercut to hold the board in place. Tooling can be difficult, but due to the elasticity of silicone rubber it is possible to old undercuts into your keypads. This method easily allows for the silicone keypad to be installed onto the PCB.

Sealing features that help seal against dust and liquids as well as gases. These can be accomplished by simply creating a rub that surrounds the mat of the keypad that seals against the front bezel. This will eliminate any dirt or dust, as well as most liquids from entering the electronic component area of the product.

Section 7) Terminology

Actuation Force: The force required to collapse the web of a rubber keypad in conjunction with polydome, metal dome, mechanical switch or rubber only.

Air Channel: Air path(s) on the bottom of rubber keypads that allows for air passage when rubber is depressed.

Alignment Hole: Through hole in rubber keypad that is used to position keypad in enclosure.

Base Matte: Silicone sheet material that joins all keys on a rubber keypad. Also known as mat.

Bezel: The faceplate or cover, typically plastic or metal, used to secure a keypad to a printed circuit board or switch.

Bosses: Small posts used for positive alignment of rubber keypad in bezels or assemblies.

Compression Set: The measurement of a material's ability to recover its original size and shape after compression under prescribed conditions.

Conductive Rubber: Silicone keypad impregnated/coated with conductive material.

Color Matching: The visual and electronic analysis of a mixed silicone rubber material compared to a supplied color sample.

Diaphragm / Web: The thin hinged area that permits a rubber key to flex.

Durometer: A measurement range of hardness for silicone rubber.

Key Height: The measured distance from the bottom of a keypad (base matte) to the top surface of a key.

Legend: Printed graphic (symbol, letter or number) on the top of the rubber surface.

Life: The number of actuations realized before the rubber diaphragm/web ruptures.

Reversed-Out Graphics: Graphics that allow rubber color or masking color to be seen through top surface printing on keypad.

Positive-image Graphics: Single or multi-color printing on top of key surface.

Stroke / Travel: Distance from the contact surface of a rubber part to a surface.

Swell: The increase in volume of rubber when in contact with petrochemicals for a determined period.

Tactile Feel: The response of rubber while depressing. For tactile rubber keypads, it is a critical function of the diaphragm web geometry.

Tear Strength: The tear strength is a measure of the resistance of rubber to tear forces. The tear strength is calculated by dividing the maximum force load by the thickness of the rubber.

Wear or abrasion resistance: The resistance of a particular ink or coating to manual wearing. The testing process is usually a Norman tester with the number of cycles legends can perform before wear is noticeable.