RUBBER KEYPAD DESIGN GUIDE

HMI Components Division
Diamond Electronics Limited

Introduction

Thank you for your interest in Rubber Keypad products. This guide has been designed to offer basic information on rubber technology and to provide some basic design constraints assist with the development of your new project.

Conductive Silicone Rubber Keypads were originally developed for the electronics industry as an economical design alternative to discrete switches. 40 years on they are the most widely used form of switch technology mainly due to their reliability, long life and multitude of design opportunities.

Diamond Electronics has been involved in the Design, Development and Supply of Rubber Keypads for over 20 years. We provide design support to OEM's in the UK and now thought Europe and the World. With field sales engineers available throughout the UK we can respond to enquiries with speed and support your in-house design team with Rubber, Membrane, CombiKey, Piezo Electric and Discrete Switch Solutions.

For additional information contact:

Diamond Electronics Ltd – HMI Division
Fourways Technology Park
London Road
Smallwood
Nr. Sandbach
Cheshire
CW11 2US
United Kingdom

Tel: **+44 (0) 1477 500450**
Fax: **+44 (0) 1477 500656**
E-mail **sales@diamondhmi.co.uk**
www **www.diamondhmi.co.uk**

Terminology

Actuation Force	The force required to collapse the web of a rubber switch (identified as Fl on the force/stroke curve).
Air Channel	Air path(s) on the bottom of rubber keypads and switches that allows for air passage (venting) when switch is actuated. Switches must be vented on at least two sides.
Alignment Hole	Through hole in rubber keypad that is used to position keypad in enclosure when overall keypad size exceeds 75 mm in either length or width.
Base	Silicone material that joins all keys on a rubber keypad.
Bezel	The faceplate or cover, typically either plastic or metal, used to secure a keypad to a printed circuit board. The bezel also aligns the keypad during the final assembly and protects keypad-base material from contact with human hands.
Breakdown Voltage	Voltage at which an insulator or dielectric ruptures. Also known as dielectric strength.
Compression Set	The measurement of a material's ability to recover it's original size and shape after compression under prescribed conditions. It is usually expressed as a recovery percentage (fraction) of the compression condition.
Rubber Switch	Mechanical switch made of silicone rubber, with either direct or indirect contact.
Contact	The current-carrying area/surface under each rubber switch (conductive pill or carbon-inked surface) that makes an electrical connection with the electrode on a printed circuit board when the switch is actuated.
Contact Force	The force required to maintain rubber-switch contact closure (F2) force/stroke curve with a printed circuit board.
Contact Rating	The electric power handling capability for rubber contacts under strictly controlled laboratory conditions.
Dual Durometer	Silicone-rubber keypads manufactured using a two-shot moulding process and two-material hardness's.
Electrode	Contact surface/design on a printed circuit board that conducts current when rubber switch is actuated and switch closure occurs.
Key Height	The measured distance from the bottom of a keypad (base) to the top surface of a key.
Legend	Some type of printed graphic (symbol, letter or number) on the top of the key surface.
Life	The number of switch actuations realised before the switch web ruptures or over stresses.
Web	The thin flexible hinge that permits a rubber key to travel, and is responsible for the tactile feel realised.
Negative-Image Graphics	Graphics that allow switch colour or switch masking colour to be seen through top-surface printing on keypad.
Overstroke	Additional travel experienced with a rubber switch after initial switch closure has been realised. Rubber switches with overstroke require a double-cone or double-bell shaped membrane.
Positive-Image Graphics	Single or multi-colour printing on top of key surface.
Return Force	Force created by switch web as it returns the key to a non-actuated position.
Snap Ratio	(F1-F2) divided by F1. The difference between the actuation force (F1) and the contact force (F2) of a switch divided by the actuation force.
Stroke	Distance from the contact surface on a rubber switch to an electrode pattern on a printed circuit board.

Silicone Rubber

Silicone rubber is a synthetic material which has the structure shown in Fig 1.

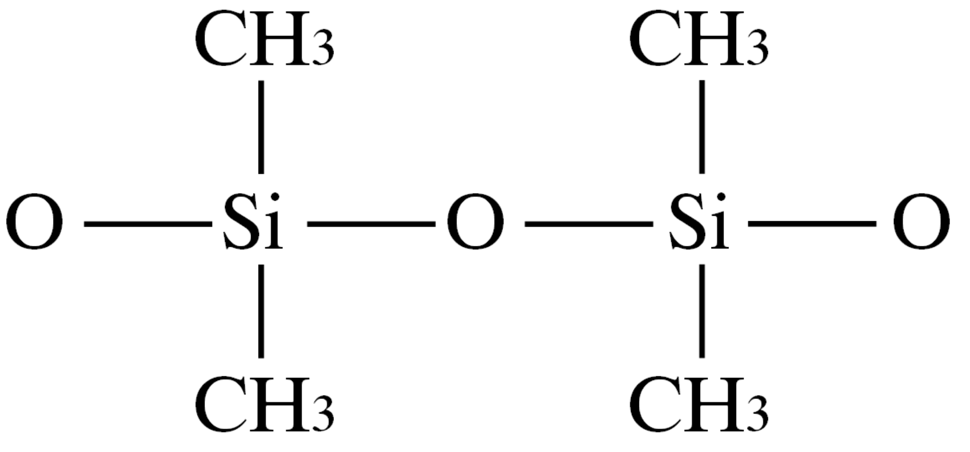


Fig 1 – Structure of silicone rubber

The “Silicone-Oxygen” molecular structure provides characteristics that allow the final material to withstand a wide variety of chemical and mechanical degradation as well as serving as a strong dielectric.

Silicone Rubber possesses the following characteristics:

- Environmental durability with excellent resistance to both heat and low temperature (-55 ~250°C)
- Minimum abrasion and high resistance to SO_2 and oxidisation even in heavy humidity
- Minimum chattering or noise generation due to soft and elastic contact structure.

Features of Silicone Rubber Keypads:

- Multicolour designs easily accommodated
- Design-in of both Tactile and Linear feedback
- Translucent materials available
- Water and contamination proof
- Cost effective

Specific Characteristics

The tables below show data relating to the standard materials used in the manufacture of conductive Silicone Keypads. Additional information on materials with different characteristics to suit specific applications can be obtained by contacting the Diamond HMI Product Support Team.

Characteristics	**Conductor**	**Insulator**
Hardness (Shore A)	65 ± 5	30 ~ 80 ±
Tensile Strength (Kg/cm^2)	60	65 ~ 85
Tear Strength (Kg/cm)	15	10 ~ 15
Compression Set (%)	20	11 ~ 22
Specific Gravity at 25°C	1.18	1.11 ~ 1.18

After 22 Hrs at 175°C

Contact Resistance	<2000 @ 12V dc 30mA
Insulation Resistance	>100m0 @ 250V dc
Max Contact Loading	24V dc 100mA

Strength	20 ~ 25 kv/mm
Constant	26 ~ 35 MHz
Volume Resistance	>2x10^{14} (0^{-cm})

Basic Key Design

INDIVIDUAL KEYS

Key design will vary with the functional and aesthetic requirements of the application. A designer may consider the options detailed in this section which show alternative key styles and the new possibilities for adding legends and backlighting to the design.

The table on page 13 details some traditional applications of Rubber Keymats with outline specifications. These are meant for guidance only but will offer you an insight into the possibilities available to a designer.

Below is a diagram of a basic key structure:

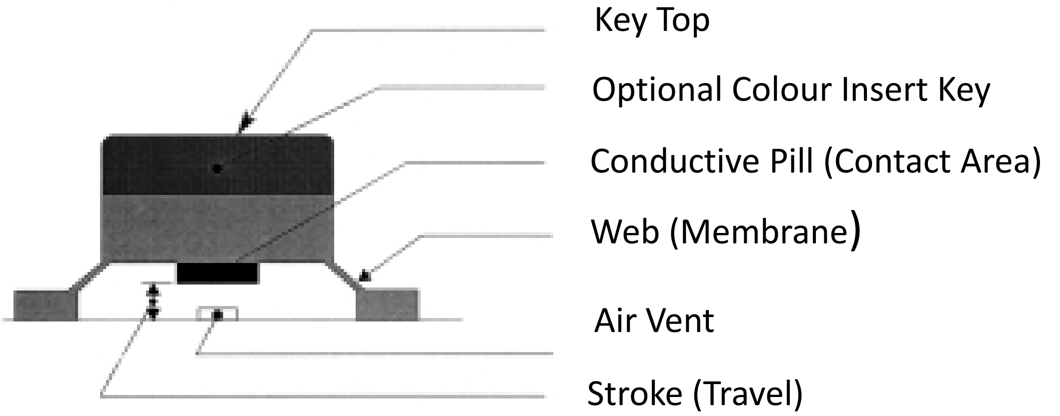


Fig 2 – Basic Key Structure

NEW TECHNOLOGIES

Over recent years advances have been made in many areas of keymat construction. Most recently the area that has been influenced has been improved legend life.

This has been achieved by secondary operations to treat the top surface of the keymat after the printing process:

- P/R Keytops – Clear Plastic Keytops adhered to the keymat base material
- L/C Keytops – Laser Etched Legend
- E/R Keytops – Epoxy Coating deposited on the top surface of the key over printing
- PU / PC / KW Coating – Full coverage of keypad top surface to seal graphics

Design Considerations

SNAP RATIO

The snap ratio of a keypad is directly linked to the tactile feel experienced by the user. Designers should attempt to maintain ratios of around 40-60% only dropping below this if they are prepared to compromise tactile to ensure longer life.

Snap ratio is measured as F1-F2 divided by F1, where F1 is the actuation force and F2 is the contact force. See figure 3.

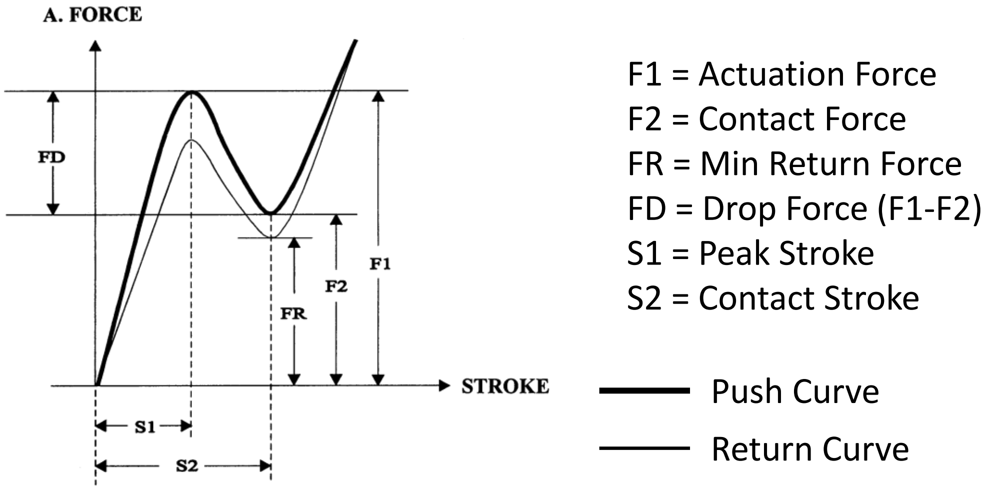


Fig 3 – Snap Ratio

TACTILE FEEDBACK

The membrane shape and size of any rubber keymat can be designed to achieve almost any combination of actuation force and tactile response. Most applications simply require a positive tactile feel with a long life and as such an actuation force of 125 ~ 150g, with an accompanying snap ratio of 40 ~ 60% is a good recommendation.

Variations in tactile response can be achieved with various combinations of contact stroke, actuation force, key shape and material hardness. As a simple rule it should be remembered that the higher the force ,the longer the life but the poorer the tactile response. More specific guidelines are difficult to lay down. However, if a customer specifies key size, actuation force and stroke, Diamond can assist in the membrane design to achieve the required parameters. Always remember to specify higher actuation force for wider or taller keys.

A common problem with rubber keypad design is ensuring that the rocking action that can be a feature of a switch design is minimised. The following suggestions will assist in reducing the problem.

- Keep stroke as near 0.8 mm as possible
- Add stabilising posts on base of key or use multiple contacts per key
- Keep web length to a minimum
- Keep web angle as close to 40°
- Actuation force 80 ~ 150g for keys 10 ~ 15mm high and 150 ~ 175g for keys 15 ~ 25mm high

Return force should also be set at around 30 ~ 35g to ensure that keys do not stick.

SWITCH LIFE

Membrane style and the durometer of the material are the factors that most effect switch life. Using a higher durometer silicone, increasing the actuation force or by increasing the stroke will all decrease life. See fig 4.

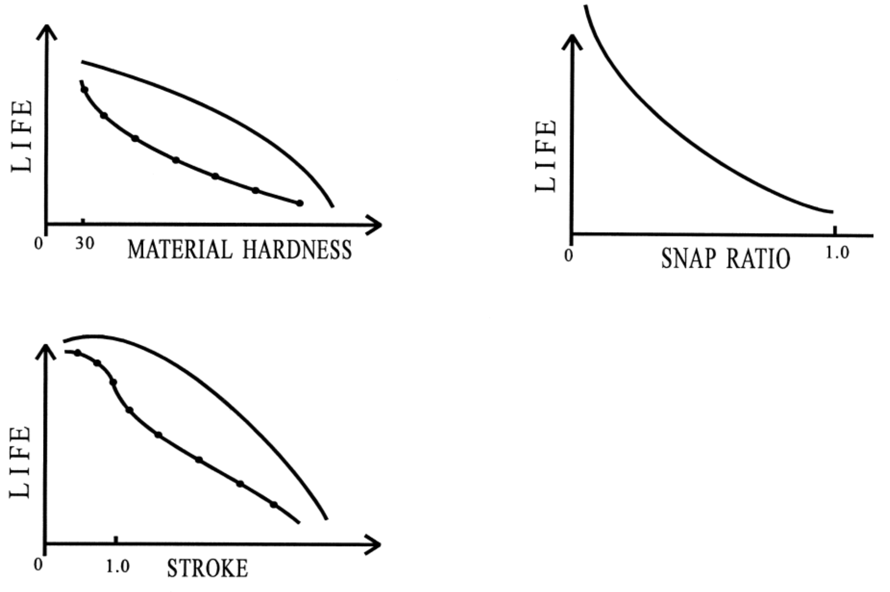


Fig 4 – Switch life

MINIMUM KEY HEIGHT

This can be calculated for any design from:

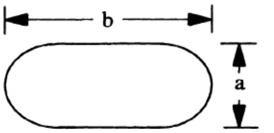
Keypad base thickness + bezel thickness + stroke of key + 0.5mm

CONTACTS

We offer four different types of contact solutions, each with it's own unique characteristics. **Carbon Pills** are most commonly used due to their long life (>10 million ops) and low resistance (<150Ω). The pills are usually circular with diameters ranging from 2.0 ~ 8.0mm and thickness from 0.3 ~ 0.8mm. Oval shaped pills are also available in the sizes shown in fig 5.

Thickness / Diameter	0.3~0.4 mm	0.3~0.4 mm	0.4~0.5 mm	0.4~0.5 mm	0.5~0.8 mm	0.5~0.8 mm
	Texture	Flat	Texture	Flat	Texture	Flat
2.0mm	130	110	120	120	110	75
2.5mm	120	100	120	100	100	80
3.0mm	80	60	70	50	60	50
3.5mm	60	50	50	40	50	40
4.0mm	60	50	40	40	35	30
4.5mm	55	40	40	40	35	30
5.0mm	55	40	40	30	30	30
5.5mm	50	40	30	30	30	30
6.0mm	50	40	30	30	30	30
6.5mm	50	40	30	30	30	30
7.0mm	50	40	30	30	30	30
8.0mm	50	40	30	30	30	30

OVAL SHAPED CONDUCTIVE PILLS (a × b m/m)



1.5 × 5	2 × 5	2.5 × 4	2.5 × 11	3 × 8	4 × 8	4 × 15	5 × 7
2 × 3.5	2 × 6	2.5 × 5	3 × 5	4 × 6	4 × 11	4 × 16	5 × 14
2 × 4.5	2 × 12	2.5 × 6	3 × 5.5	4 × 7	4 × 14	4.5 × 8	6 × 10

Fig 5 – Oval shaped conductive pills

Hard and Soft Gold Pills are available and tend to be specified for Automotive switching applications due to their low resistance and higher current handling capabilities.

Printed Carbon Contacts are available in any shape however thickness is typically 10 ~ 20 microns and resistance around 500 Ω. Care must be exercised with electrical design if specifying this type of contact.

Dipped Carbon Contacts offer a compromise with any shape being available and contact resistance of <3000 Ω.

PRINTED CIRCUIT BOARD DESIGN

Rubber Keymats themselves are very reliable in operation but when considering PCB design, the environment that the keypads are to be used in must be taken into consideration to ensure the complete switching unit remains reliable.

The choice of plating for the board is probably the most important factor.

Gold plating over Nickel is the preferred choice with a recommended layer of 1 micron of Gold over 5 microns of Nickel and 25 microns of Copper to provide a contact resistance of <150 Ω.

When designing shorting pads always attempt to get as many shorting paths as possible to increase switch reliability and ensure that the pad size is never smaller than the carbon pill by a minimum of 1.25 times.

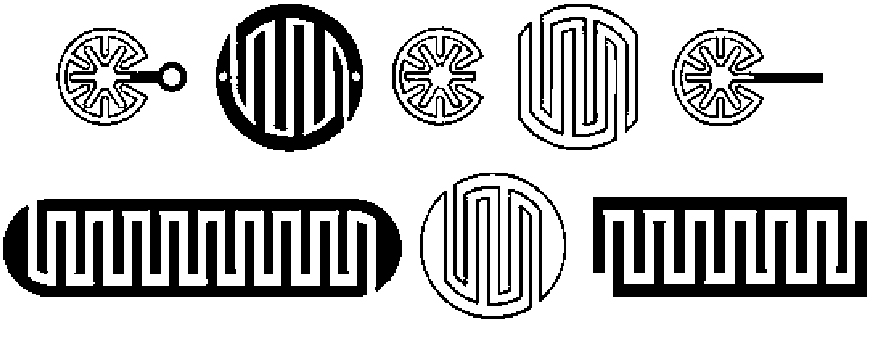


Fig 6 – Examples Of Switch Pad Designs

Dimensional Tolerances

Due to the fact that silicone is a highly elastic material and subject to manufacturing variations in Moulding conditions and material compounding, careful consideration to should be given to the tolerance tables below.

DIMENSION TOLERANCE

Dimension (mm)	General (± mm)	Precise (± mm)
<10	0.1	0.1
10 ~ 19.9	0.15	0.15
20 ~ 29.9	0.2	0.15
30 ~ 49.9	0.3	0.25
>50	0.60%	0.40%

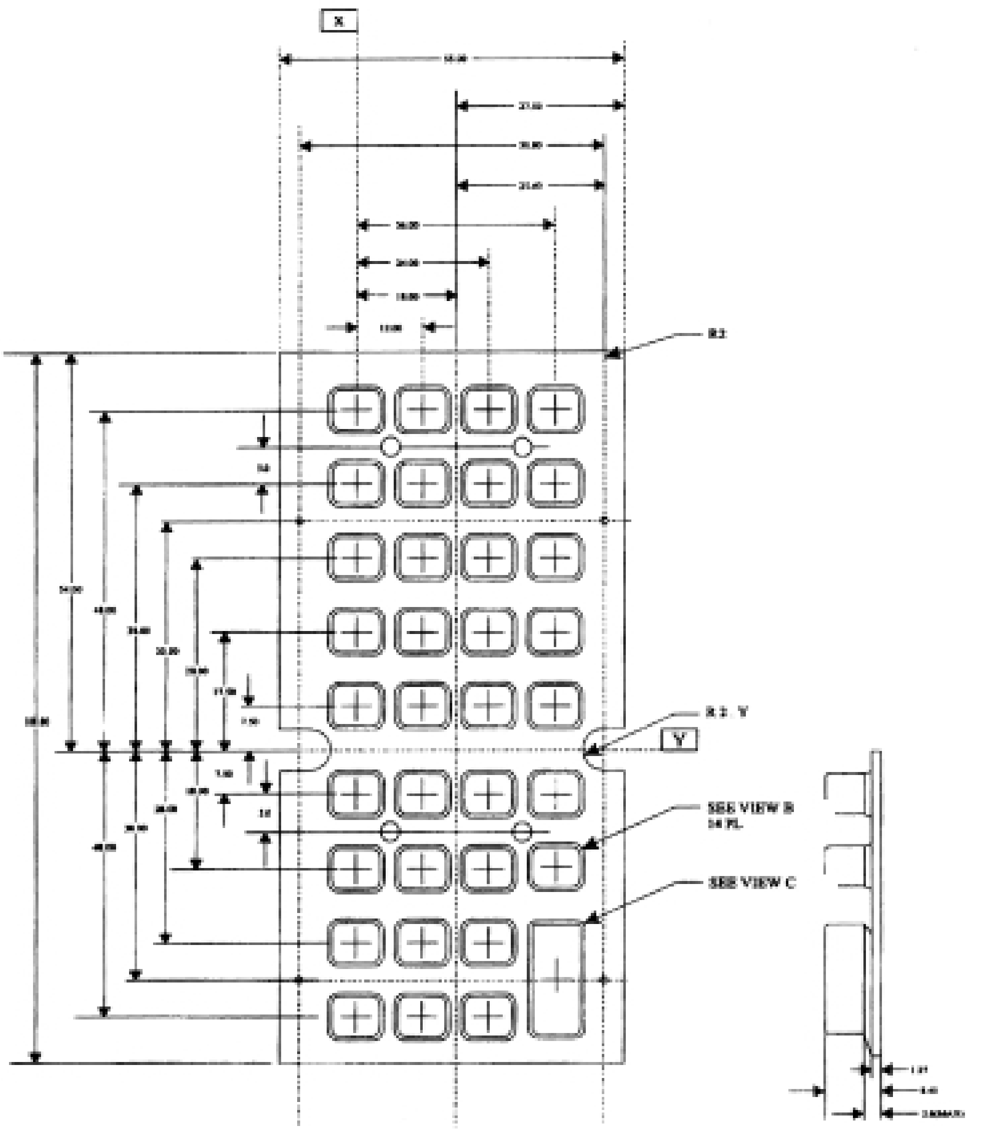
ACTUATION FORCE

Design Force (g)	General (± g)	Precise (± g)
40 ~ 59	15	10
60 ~ 79	20	15
80 ~ 99	25	20
100 ~ 150	30	25
>150	25%	20%

Mechanical Drawings

A sample mechanical drawing is shown below. To assist our designers please ensure that the following information is included in the drawing:

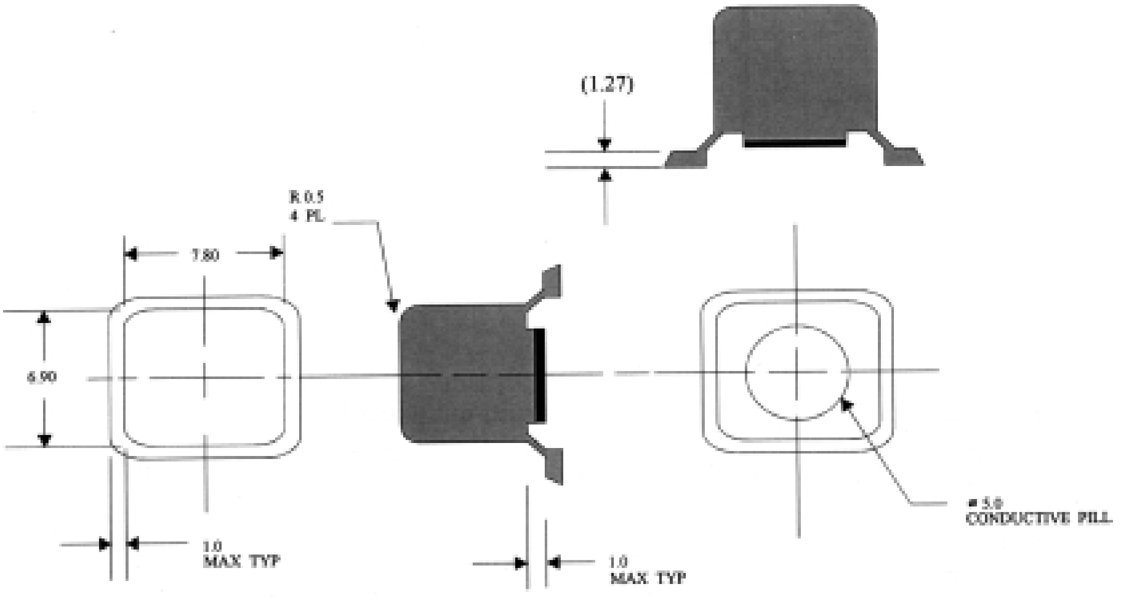
- Overall Keypad Size
- Base Thickness
- Keytop Outside Dimensions
- Overall Key Heights
- Contact Size
- Mounting Hole Details
- Pull Through Details
- Dimensions
- Keypad / Button Colours
- Stroke / Travel
- Actuation Force
- Snap Ratio
- Electrical Specs
- Material Specs Inc Surface Coating
- Graphic Colour
- Printing Artwork



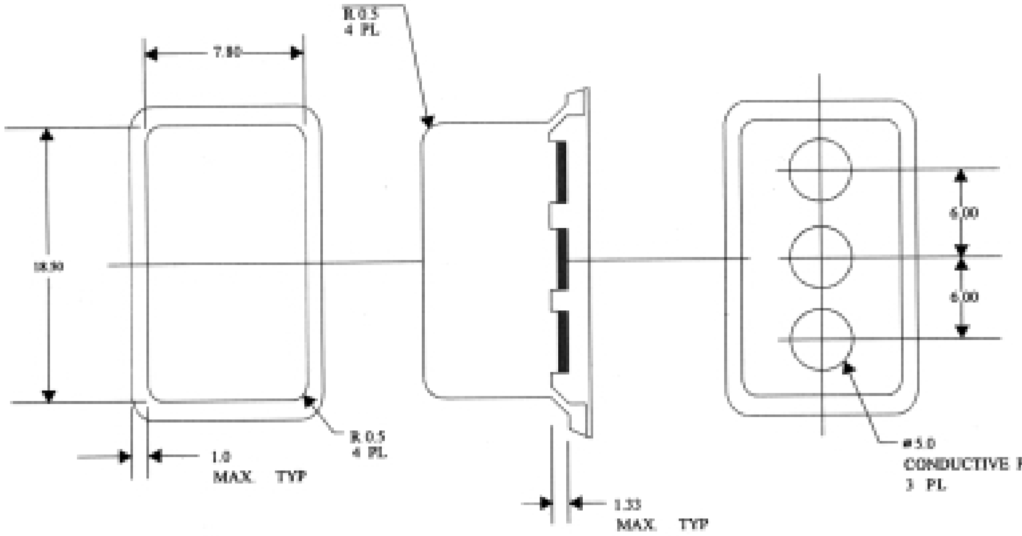
We can work with most common 3D file formats such as .IGES, .SLDPRT, .STP as well as .DWG and .DXF. We prefer artwork in .AI, .CDR or .EPS format but can use .PDF if quality is high enough

The views below are referenced on the drawing on the previous page, i.e. views A and B. These should also be included with any mechanical specification presented.

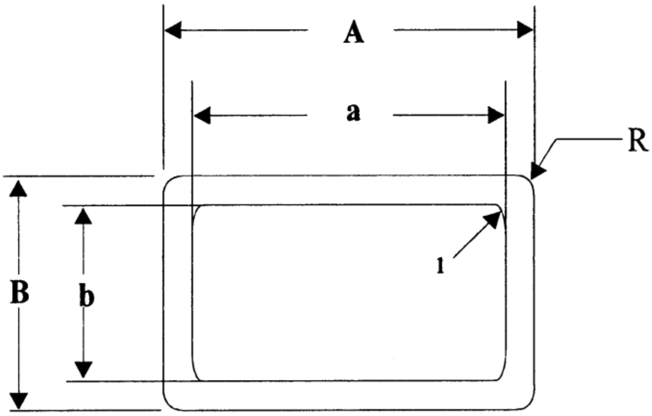
Diagrams below show in more detail tolerances when designing keymat and plastic assembly



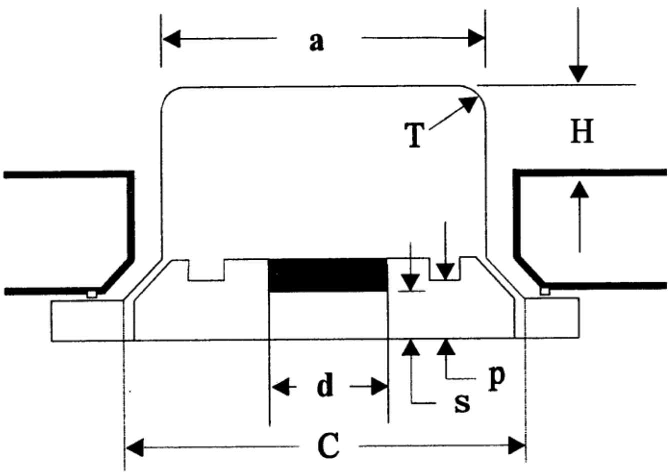
View A



View B



A & B = Plastic Case Dimensions
a & b = Rubber Dimensions
A – a = ≥ 0.4 mm
B – b = ≥ 0.3 mm



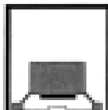
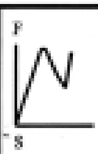
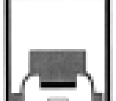
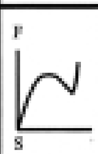
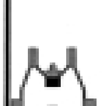
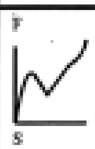
H = Height Of Key Above Plastic
S = Stroke Of Key
P = Stroke Of Stop Bar
H – S = ≥ 1.0 mm
A – d = ≥ 1.5 mm
P – S = ≥ 0.15 mm

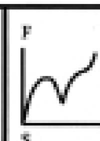
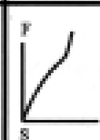
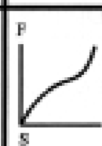
C = Width Of Web Base Typically 2.0 mm More Than “a”

R = Minimum Radius For Side Edges Of Key Is 0.2 mm

T = Minimum Radius For Top Edges Of Key Is 0.2 mm

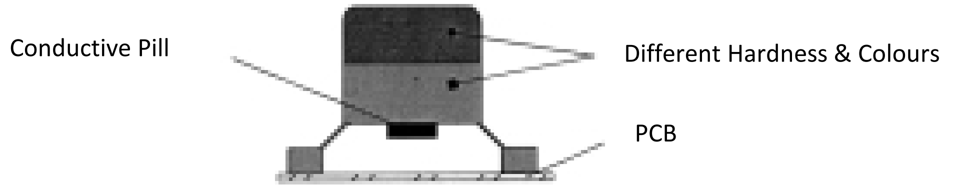
CONDITIONS FOR THE DESIGN OF A RUBBER KEY

		Force Range	30 – 400 grams
		Stroke Range	0.5 – 3.0 mm
		Life Cycle (x 10^3)	500 – 2,000
		Typical Uses	Calculator, Telephone, Remote Control, Toys, Office Machine ...
		Force Range	20 – 200 grams
		Stroke Range	0.5 – 3.0 mm
		Life Cycle (x 10^3)	1000 – 5,000
		Typical Uses	Calculator, Telephone, Remote Control, Toys, Office Machine ...
		Force Range	30 – 90 grams
		Stroke Range	2.0 – 4.0 mm
		Life Cycle (x 10^3)	5,000 – 30,000
		Typical Uses	Computer, Typewriter ...

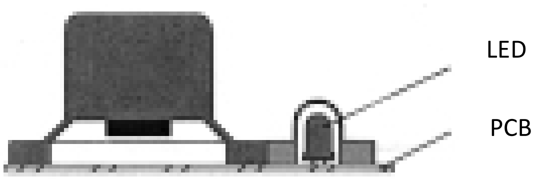
		Force Range	30 – 250 grams
		Stroke Range	1.2 – 4.0 mm
		Life Cycle (x 10^3)	1,000 – 20,000
		Typical Uses	Computer, Typewriter, Calculator ...
		Force Range	10 – 200 grams
		Stroke Range	0.3 – 1.0 mm
		Life Cycle (x 10^3)	1,000 – 50,000
		Typical Uses	Typewriter, Office Machine, Calculator, Toys ...
		Force Range	10 – 100 grams
		Stroke Range	Depends
		Life Cycle (x 10^3)	1,000 – 50,000
		Typical Uses	Typewriter, Office Machine, Calculator, Toys ...

SPECIAL DESIGNS FOR RUBBER KEYS

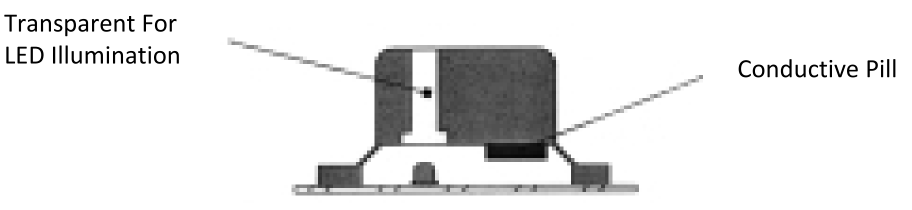
1. Different shore hardness and colour in the basic keypad and key



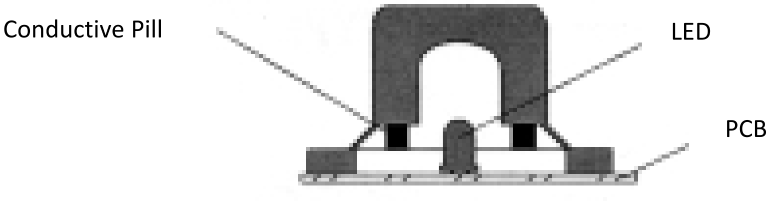
2. Construction idea for application on LED



3. Square key top design with LED window

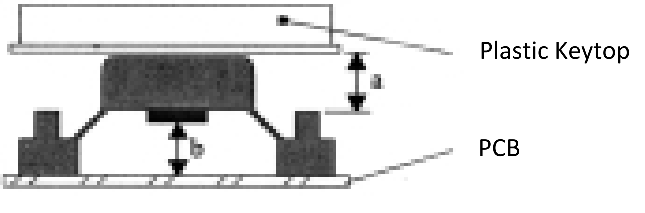


4. Illuminated Key

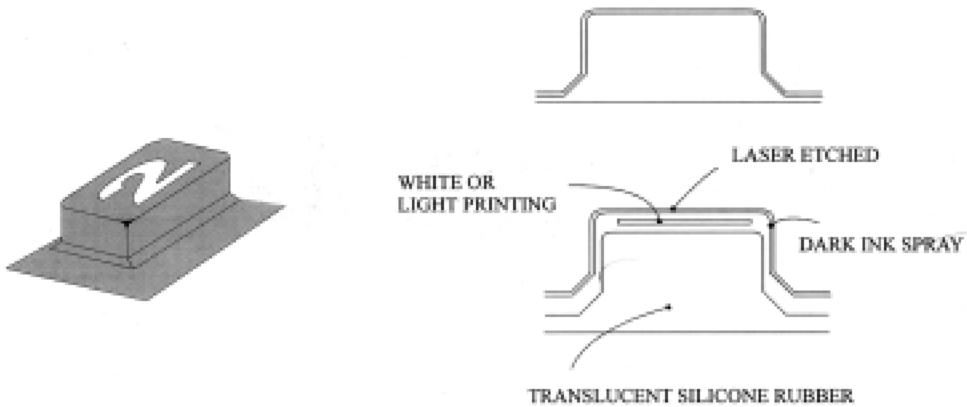


5. Control of stroke distance

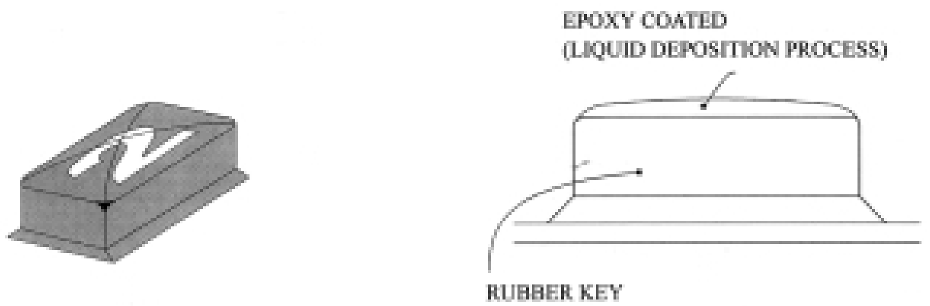
$a - b = \geq 0.2$ mm



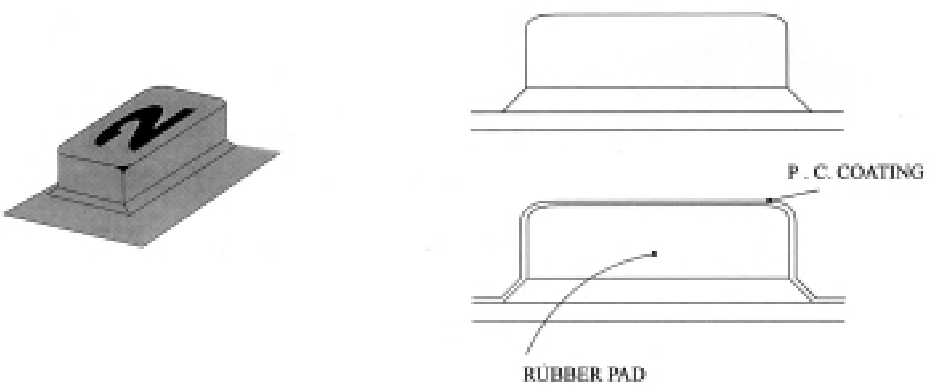
LASER-ETCHED LEGENDS (L/C Keytops)



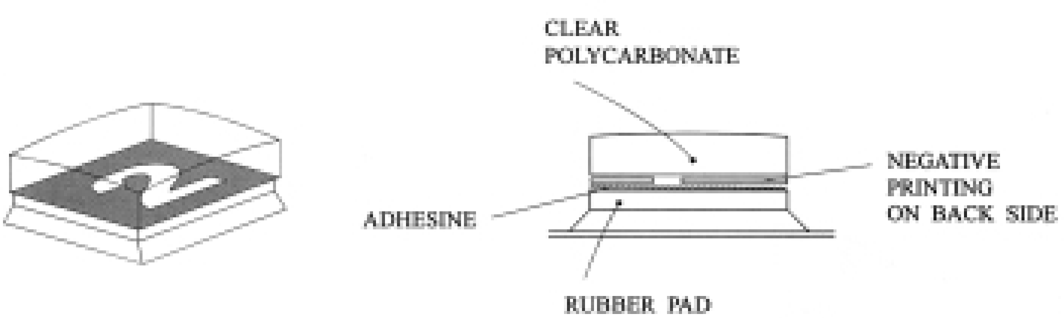
EPOXY COATED KEYTOPS (E/R Keytops, Matte or Gloss)



PC / PU / KW COATING



CLEAR PLASTIC KEYTOPS



To further assist our customers understand and specify a suitable key action Diamond HMI has produced a **Rubber Keypad Design Tool** which has examples of many combinations of Key Travel, Tactile Response and Shore Hardness's including examples of Membrane and Rubber combinations used in our CombiKey products.

[Click Here To order Your FREE Design Tool Keypad Sample]

Click On The 3D Image Below Enable Interactive Content