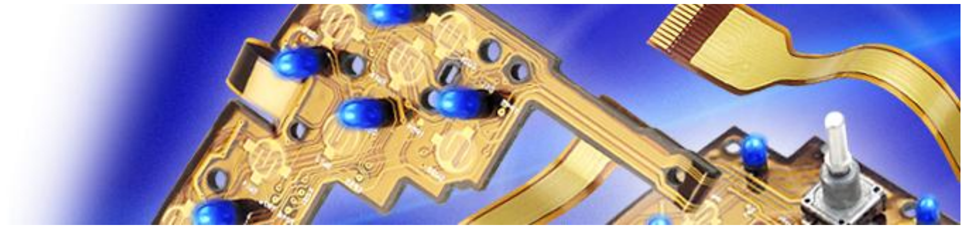

# Polymer Thick Film - Material Performance and Reliability

Just because Polymer Thick Film technology is low cost does not mean that it is low quality. With Parlex, it's just the opposite. Our materials formulated by our Research and Development group are extensively tested for high performance and reliability. Materials have been refined over years of high volume production – the benefit of having manufacturing and material development under the same roof. Batch to batch consistency is ensured via our tightly controlled in-house mixing facility.

This section is intended to give the reader greater appreciation for the reliability of Parlex's Polymer Thick Film circuits by understanding the reliability tests performed on the materials. Unlike the copper based circuitry, there are few industry standard methods and criteria for Polymer Thick Film (PTF) reliability testing. Moreover, few PTF manufacturers perform reliability testing to any significant extent. As a pioneer of PTF technology, Parlex takes reliability very seriously. Our inks and adhesives are subjected to very aggressive accelerated aging tests. They must show virtually no change from their original state - <20% change from initial resistance value is a common criteria.

The tests described in this section have been performed during our material qualification program. Many of these tests are also used as process controls in the material mixing, printing or component assembly operations.

## *Silver Inks*

The test results described below are for Parlex's standard production silver filled ink.

### Print Quality

Parlex inks are formulated to run at fast rates on our high-speed production print presses. This speed advantage translates to a cost advantage over printing inks that are not tuned to high speed printing. Moreover, our inks are formulated for long screen life to eliminate ink waste and unnecessary changeovers due to ink drying. When formulating a new ink, our Research and Development Chemists work with the production printers from conception through final qualification. Circuits are fabricated at normal production printing speeds over the course of a production shift. Samples taken at different time intervals are visually inspected for print quality. Line definition must be good with no pin holes observed on any of the samples. This test is repeated with different ink batches and longer production runs during the scale up phase.

### Resistivity

Parlex inks provide resistivity from 10 to 20mOhms/square/mil. The ink resistivity is determined by measuring the resistance and ink height on a standard 600 square test pattern.

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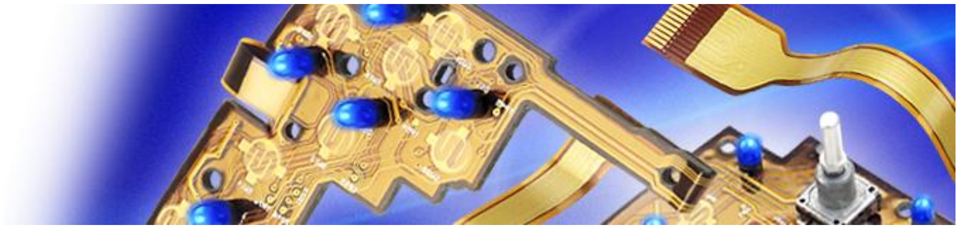

## Adhesion and Abrasion Resistance to Untreated Polyester

Parlex’ printed inks are formulated to provide excellent adhesion to untreated polyester, eliminating the need for expensive print treatments required for inferior inks. Our inks also demonstrate excellent surface hardness – a property vital to a robust membrane switch. The tests described below are used during ink formulation as well as process controls for ink mixing and production printing.

<u>Adhesion, ASTM D 3359</u>
A standard test pattern (square block) of silver ink is printed and cured on untreated polyester. A cross hatch (knife blade) is used to cut through the ink. A tape is then placed over the cut area, allowed to stand for 60 seconds and then pulled off. The samples are then examined for any missing pieces of printed ink. All samples must exhibit 100% adhesion.

<u>Abrasion, ASTM D 3363</u>
This method is used to determine the pencil hardness equivalent of the ink. A Paul Gardner test apparatus is used to ensure repeatability of the results. Typically, this test can vary by +/- 1 hardness grade. A minimum hardness of 2H is required. Standard inks measure 3H to 4H.

## Adhesion and Resistivity Over Dielectric

Some product applications require conductive crossover traces. Standard 600 square test samples were printed over Parlex’s dielectrics. Adhesion and resistivity were tested per the methods described above. Adhesion was 100% in all cases. Resistivity was within 10% of the ink-on-polyester value.

## Crease Resistance

This test was used to determine the change in resistance of a conductive ink circuit trace after a crease in both tension and compression. Samples were printed on 0.005 inch (125um) polyester using a standard 600 square serpentine pattern. The samples were folded and a 500g weight was placed at the fold for 60 seconds. Resistance measurements were taken prior to testing and 15 seconds after removal of the 500g weight. The change in resistance was less than 10%. Test samples were visually examined under 30X magnification with no evidence of cracking or delamination.

## Repeated Flex, UL 746E

The purpose of this test was to determine the durability of a conductive ink trace (with and without a cover coat dielectric) when flexed 180 degrees around a 1/8" (3mm) mandrel. The test sample is flexed so that the conductive ink is in tension or compression. The test samples were subjected to 50 cycles. The data is reported as the average percent increase in resistance of the samples. Without dielectric, the resistance increased less than 7%; with dielectric, less than 12%. Test samples were visually examined under 30X magnification with no evidence of cracking or delamination.

## Accelerated Aging Tests

The purpose of this test was to determine the performance of conductive ink when subjected to specific accelerated tests that simulate product aging, shipping and storage environments.

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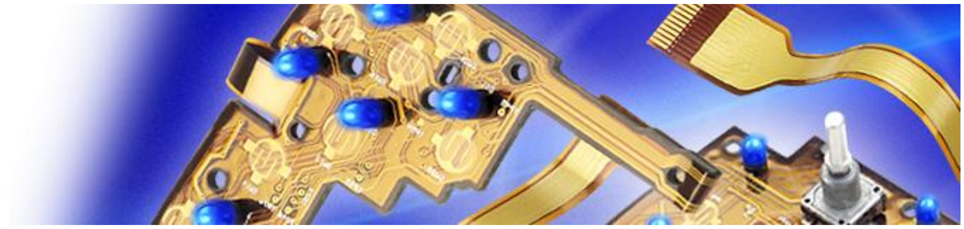


<u>Thermal Shock</u>
Thermal Shock was performed per MIL-STD-1344, Method 1003, 25 cycles, -55C to +85C, 30 minute soak at each extreme, less than a 5 minute transfer time between temperature extremes. This test simulates the thermal excursions that may be seen during shipping or actual usage for some products. 600 square serpentine coupons were used for this test.

<u>High Temperature Aging</u>
The test was performed per MIL-STD-202, Method 108A, +85C for 500 hours, less than 20% humidity. This condition simulates long term application in high temperature storage conditions. 600 square serpentine coupons were used for this test.

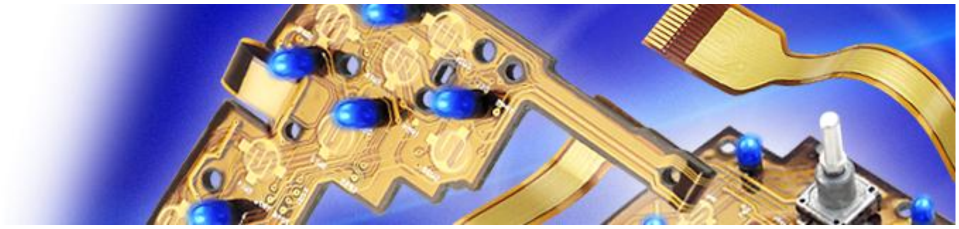
**Accelerated Aging Test Results**

| Test | Conditions | Duration | % Resistance Change From Initial Value |
|---|---|---|---|
| **Thermal Shock** | -55C/+85C, 30 min soak, <5min transfer | 25 cycles | -7% |
| **High Temperature Aging** | +85C | 500 hours | **-5%** |

<u>High Temperature / Humidity</u>
This test simulates long term application in high humidity environments. It is run in conjunction with the Poly-Solder® conductive adhesive. Tests were conducted for 1000 hours each at the following conditions: 60C/90%RH, 70C/85RH, 85C/85RH. The junction resistance of components mounted with Poly-Solder ® conductive adhesive was monitored. All samples passed the criteria of less than 20% increase in junction resistance over the 1000 hours. See the Component Attachment Section for further details.

**Pre-Aging Flex Test**
The purpose of this test was to determine the durability of a conductive ink trace (with and without a cover coat dielectric) after being subjected to the thermal shock and high temperature aging tests described above. Following the aging tests, samples were flexed 180 degrees around a 1/8" (3mm) diameter mandrel, both in tension and compression. Test samples were subjected to 50 cycles. The results, expressed as percent increase in resistance, are as follows:

| Condition | Compression | Tension |
|---|---|---|
| **Thermal Shock, no dielectric** | 8% | 11% |
| **Thermal Shock, with dielectric** | 8% | 9% |
| **High Temp Aging, no dielectric** | 4% | 7% |



## *SMT Component Attachment (Poly-Solder® Adhesive and PF200)*

Parlex attaches Surface Mount Technology (SMT) components to flexible circuits using its patented Poly-Solder® Isotropic Conductive Adhesive. After curing of Poly-Solder® Adhesive, the PF200 mechanical strain relief encapsulant is applied to permit extreme circuit flexing without degradation of the component junctions. Poly-Solder® adhesive was specifically formulated to form stable junctions to standard SMT components, even in very humid environments, without special metalization. It is this patented high temperature / humidity performance thatdifferentiates Poly-Solder® adhesive from inferior conductive adhesives. Its reliability has been proven over many years of testing and high volume production. Over 100 million components per year have been attached using Poly-Solder® adhesive.

### Die Shear Strength, MIL-STD-883, Method 2019.5

The adhesion strength is tested by applying a force laterally to a component (that has been mounted with Poly-Solder® adhesive) until it is sheared from the substrate. Both a lab scale / material control test and a production process control test have been established. Both tests are performed without the PF200 mechanical strain relief material applied.

Production Test: A corresponding production process control test uses a chip component (resistor, LED or capacitor) placed into stenciled conductive adhesive pads on polyester. Off-the-shelf components with **standard Pb metalization** are used. Adhesion values correlate to component package size and lead type:

| Package Style | Lead Style | Package Size | Average Adhesion (lbs) |
|---|---|---|---|
| Chip Component | Formed Metalization | 0603 | 5.5 |
| Chip Component | Formed Metalization | 0805 | 7.0 |
| Chip Component | Formed Metalization | 1206 | 8.0 |
| 1206 LED | Gull wing | 1206 | 7.0 |

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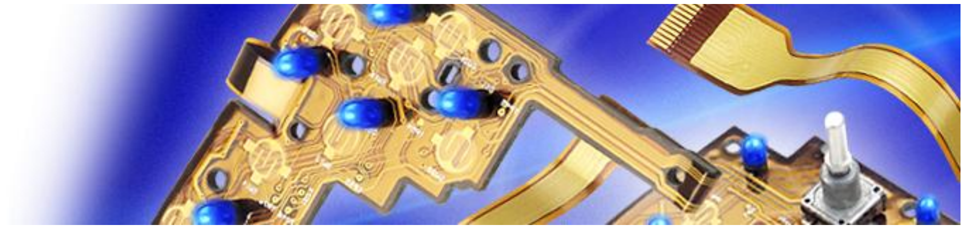


## High Temperature / Humidity

This test simulates long term application in high humidity environments. In order to monitor the component junction resistance, a daisy chain test vehicle was developed. This circuit incorporated 10 zero ohm resistors connected in series, a daisy chain PLCC44 (50 mil pitch) and a daisy chain QFP80 (25 mil pitch)

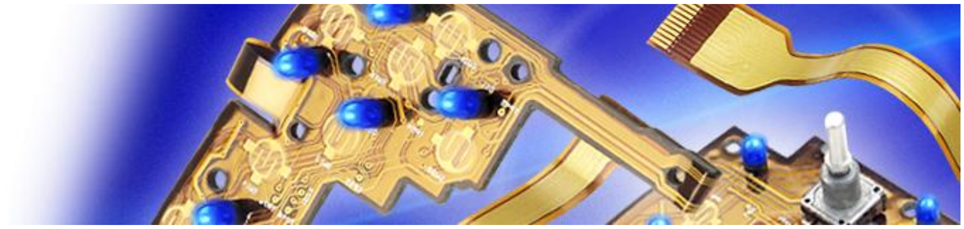
Poly-Solder® adhesive was tested with and without PF200. The test circuit pattern was printed on 5 mil (125um) polyester using Parlex's silver ink. The conductive adhesive was stenciled on the polyester and the SMT components attached. PF200 was applied to half the circuits. The series chain resistance for each component type was monitored during exposure to high temperature and humidity using a four wire measurement technique. The pass/fail criteria was less than 20% increase in junction resistance over 1000 hours exposure. Results are as follows:

| Test Conditions | Without PF200 | With PF200 |
|---|---|---|
| 60C, 90%RH, 1000 hrs | 100% Pass | 100% Pass |
| 75C, 85% RH, 1000 hrs | 100% Pass | 100% Pass |
| 85C, 85%RH, 1000 hrs | 100% Pass | 100% Pass |

Poly-Solder® adhesive was then tested against two commercially available conductive adhesives, without PF 200. Both commercial materials shorted on the QFP80 component due to poor material printability. Poly-Solder® adhesive did not exhibit short circuit conditions as it was developed for fine pitch printing applications. The test circuits were exposed to 85°C, 85% RH. Results were as follows:

| Material | Resistors | PLCC44 | QFP80 |
|---|---|---|---|
| Conductive Adhesive A | Failed <96hrs | Failed<96hrs | N/A (shorted) |
| Conductive Adhesive B | Failed <240hrs | Failed <300hrs | N/A (shorted) |
| Polysolder® | Passed >1000 hrs | Passed >1000hrs | Passed >1000hrs |

Numerous third party studies have also concluded that Poly-Solder® adhesive has much better temperature and humidity performance than other commercially available materials.



**Accelerated Aging with Flexural Stress**

This test simulates the flex stress a circuit may see during handling or end application. The test vehicle was a functional circuit containing two LED's and two resistors, mounted with Poly-Solder® adhesive and encapsulated with PF200 strain relief material. These circuits were wrapped around a 0.5 inch (12.5mm) diameter mandrel to applystress to the component area. Circuits were functionally tested and then subjected to the tests listed below. The circuits were functionally tested after environmental exposure.

| Test | Conditions | Duration | Results |
|---|---|---|---|
| **Thermal Shock** | -50C/+85C, 30 min soak, < 5 min transfer | 25 cycles | 100% Pass |
| **High Temperature & Humidity** | +75C/85%RH | 1000 hours | 100% Pass |
| **Thermal Cycle** | -50C/+85C, 12 hr soak, <30 min transfer | 40cycles hours | 1000% Pass |

## *Dielectric Materials*

**General**

Dielectric materials provide mechanical protection of conductive traces, electrical isolation of adjacent conductors and electrical insulation between conductive layers. While most polymer dielectric can provide some degree of mechanical protection, their isolation and insulation properties are most critical to the long-term reliability of circuits with silver conductive traces, in high temperature/ humidity environments.

High temperature and humidity with an electrical bias has become a generally accepted standard for product life and reliability growth testing. Failure mechanisms, such as corrosion and ion mobility, can be triggered by the effects of these conditions. This testing was used by our research chemists to develop (and make improvements) to PF114 "hydrophobic" dielectric for telecommunication and appliance applications.

### Insulation Resistance Testing

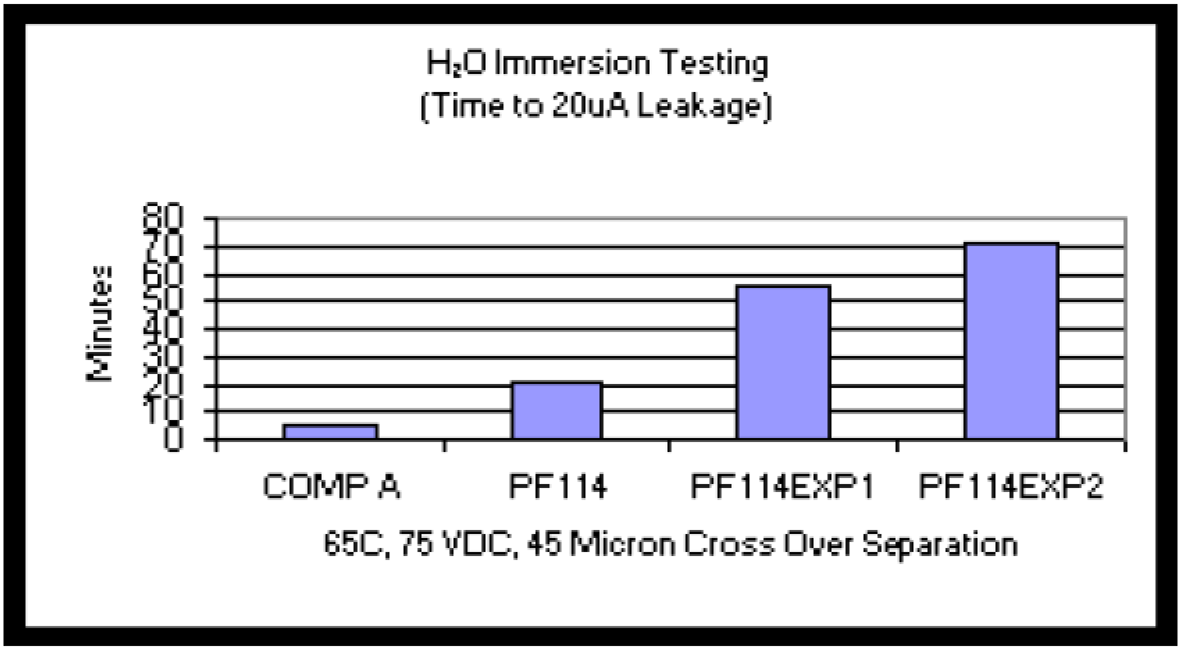
**Case 1** – Sample circuits were produced with Parlex PF012 silver and PF114 dielectric inks, and with similar materials from a commercial manufacturer. The separation between conductors on the samples was .015" at their closest point. The circuits were sent to an independent lab to perform 70ºC and 85% RH 1000 hour testing with a 10 VDC bias between adjacent conductors. A leakage current of >20µA was considered a failure.
Circuits with the commercial dielectric coating exhibited a steady increase of leakage current until exceeding the 20µA limit at 400 hours. The circuits exhibited severe discoloration with evidence of electromigration (dendritic growth.)

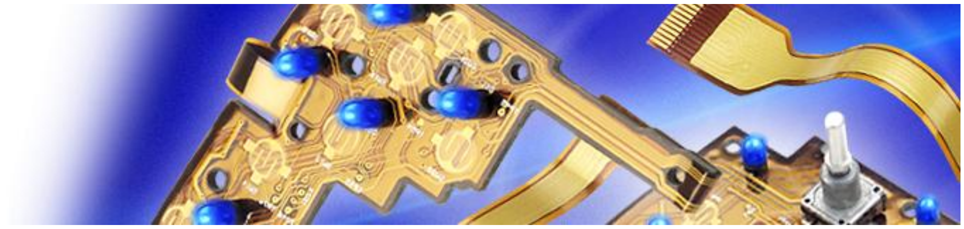
The circuits manufactured with Parlex materials continued to 1000 hours with a minimal increase of leakage current. When removed from the environmental chamber the circuits showed little discoloration and no evidence of electromigration.

**Case 2** – A manufacturer of appliances subjected flex circuits manufactured by Parlex to the following temperature/ humidity sequence for a total of 1000 hours with a 20VDC bias:

| TEMP. | HUMIDITY | SOAK |
|---|---|---|
| +70 ° C | 50% RH | 2 HOURS |
| +45 ° C | 98% RH | 2 HOURS |
| +85 ° C | 85% RH | 2 HOURS |
| +25 ° C | 35% RH | 2 HOURS |

All test samples passed functionality requirements at the conclusion of the accelerated testing. Some water residue was present on the samples, but no dendritic growth was evident.

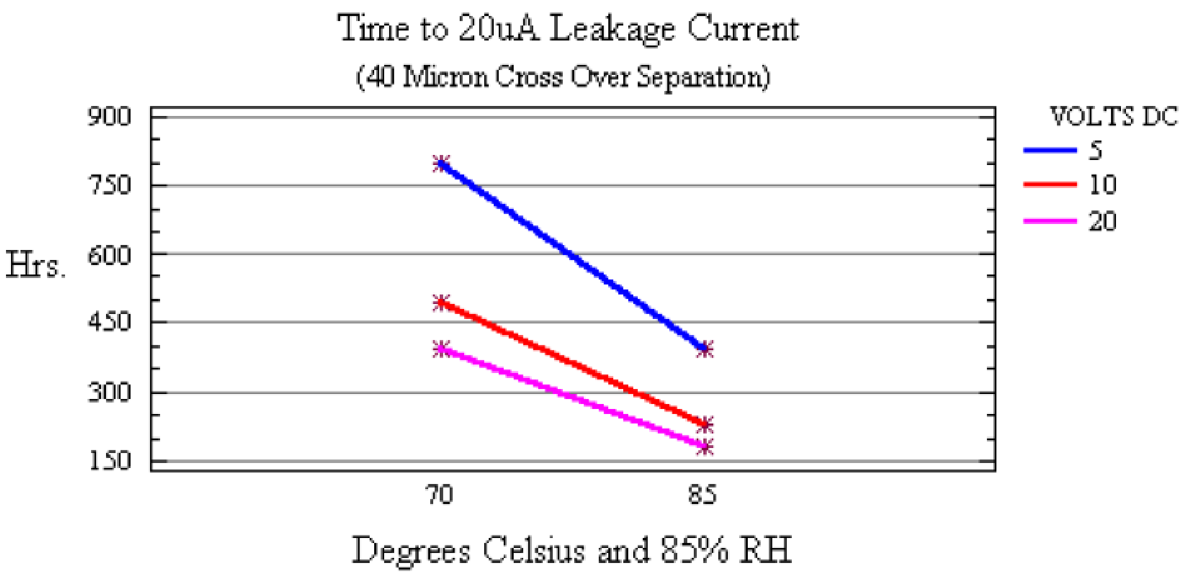


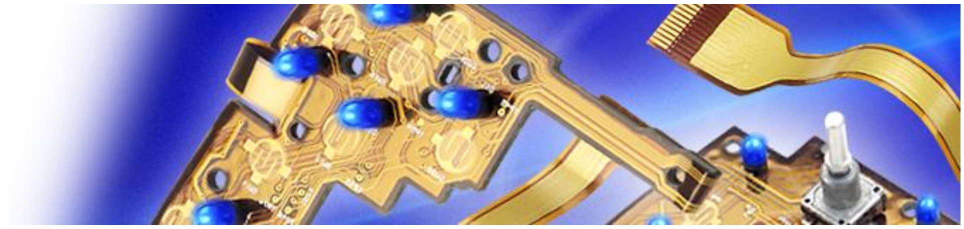


## Isolation Resistance Testing

The following graph shows the results of high temperature immersion testing of a commercially available dielectric material vs. the standard PF114 dielectric in production today, and improved versions of PF114 that will be released into production this year. Each test sample contained 400 cross over points. This extreme test (developed by PFC) allowed our chemists to quickly determine the effect of formula modifications.

The following graph shows the effects of both temperature and voltage acceleration factors on polymer thick film materials using 400 cross point test samples. These data were helpful in predicting long-term product reliability, and provided a base line for materials improvement.





# TACTILE POLYESTER DOME

**Description:**
A tactile polyester dome is produced by thermoforming a pre-printed polyester sheet into an array of domes with a specific shape and set of operating characteristics. In collapsing the dome with an actuator, a crisp tactile response is achieved, which indicates continuity has been established.
.

**Applications:**
- Cell phone: Used in conjunction with a silicone rubber keypad to provide switch shorting. Can mate to a flexible multi-layer circuit or a PCB.
- Appliance panel: Used in conjunction with graphic overlay mated to a multi-layer flexible circuit.
- Replacement for elastomeric pad with carbon shorting pads. Domes may be actuated directly by a plastic actuator that is integral with a molded keycap.

**Presentation Options:**
- Individualized; attached to a flex circuit or as a dome sheet with release liner.
- Reel or fanfold; Dome layer only may be supplied in continuous web with or without tractor feed for use in automated assembly line.

## *DESIGN CONSIDERATIONS*

- Clearance for dome
- Actuator size
- Desired Peak Force (Fmax) and Tactile Feel (Tactile Ratio)

**Tactile ratio** is the snap or tactility of the dome when depressed and is computed using the following formula:

$$(F_{max} - F_{min})/F_{max}$$

**Peak Force** ($F_{max}$) is the maximum gram force measured at the point of dome snap. $F_{min}$ is the point past dome snap at which the printed contact area on the inside of the apex of the dome contacts the shorting pad on the circuit. Figure 1 depicts graphically the relationship between force and travel and the $F_{max}$ and $F_{min}$ points.

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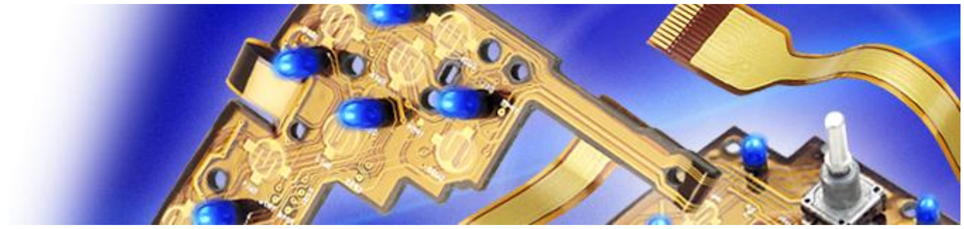

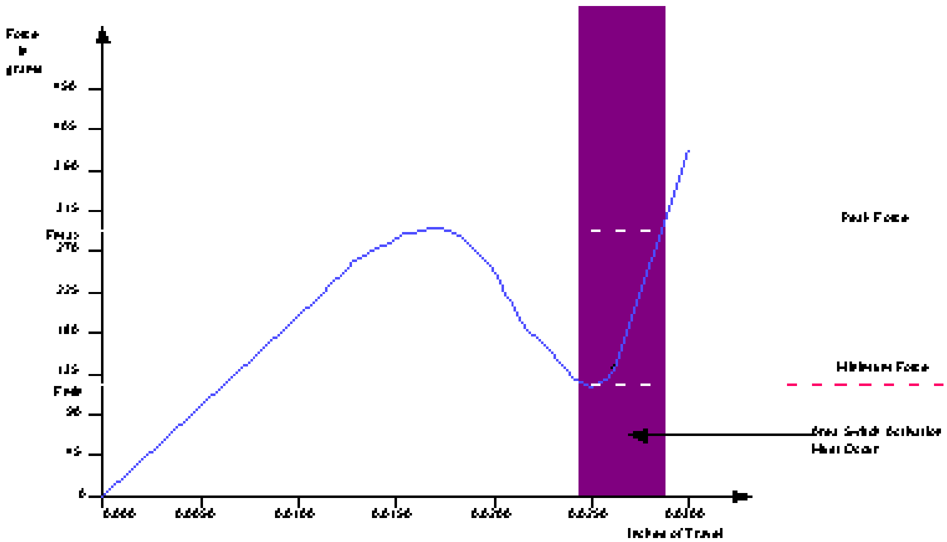


Figure 1: Dome Force / Travel

### DOME FEATURES AND SPECIFICATIONS

| | |
|---|---|
| Environmental | |
| Storage Temperature: | -40°C to 100°C, 120 hours |
| Humidity Range: | 10% to 85% |
| Temperature Shock: | -40°C to 85°C, 32 cycle @ 30 minute interval dwells |
| Accelerated Aging: | 85°C/85% relative humidity for 120 hours |
| Dome Construction | See Figure 2 for typical dome detail |
| Actuator: | Typically specified by customer based on keypad size<br>Hard plastic or silicone rubber<br>Size: typically ½ dome diameter |
| Dome Layer: | .004" or .005" polyester (PET)<br>Clear PET preferred, white PET available for reflectance<br>Thickness of PET will affect peak force and dome height |
| Spacer Layer: | .002" acrylic adhesive on either side of a .001"-.004" PET support liner. Thickness of spacer will affect tactile feel and dome height |
| Bottom Circuit: (if required): | .004" or .005" PET circuit with inter-digitated fingers |
| Dome venting: | Domes may be vented internally if more than 4 domes in series or externally via a hole in dome layer or channel to perimeter through spacer layer |

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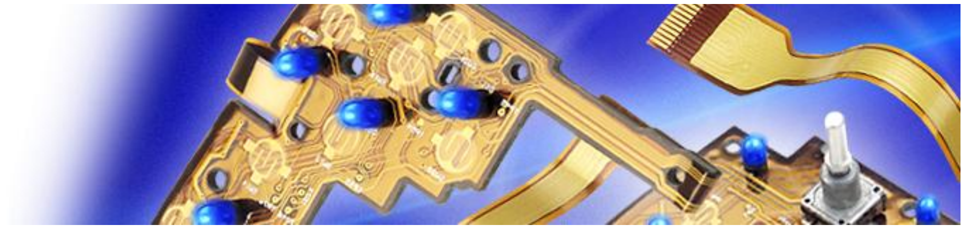

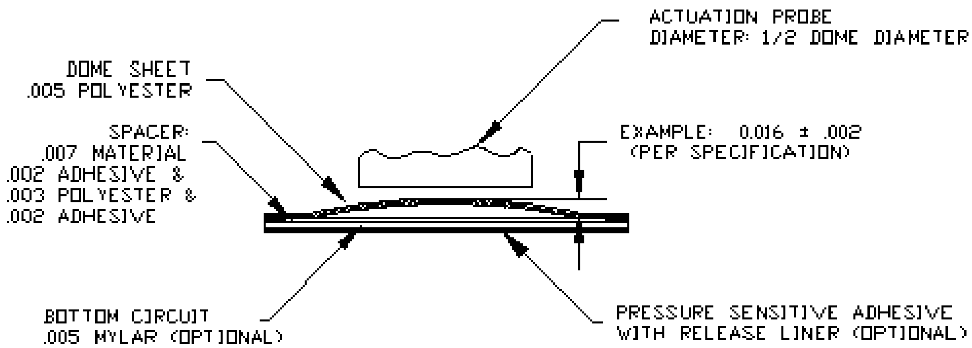


Figure 2: Dome Construction Detail

| Dome characteristics | |
|---|---|
| Peak Force: | 150 to 300 grams, +/-25%, Application dependent |
| Tactile Ratio: | .30 to .65, Application dependent |
| Displacement: | .023 to .034<br>Smaller dome, less displacement<br>Lower peak force or tactile ratio, less displacement |
| Dome diameter: | .187 to .375 inches, application dependent |
| Number of actuations at 25°C | 1,000,000 |

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