Harnessing the Power of the Membrane Switch

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Introduction

Consumer tastes are forever changing. Ensuring that your product blends with the decor of modern environments is essential for market success and can define your product's position within a market. First impressions are important and a machine's keypad and control panel design is often an important element in the overall styling package that may influence buyers' decisions.

For many years designers had few options available to them. Often their choices were limited to bulky mechanical switches. This led to designs that were often "industrial" in appearance and severely limited in design scope.

With the trend towards faster product development cycles, and the increasing focus on niche marketing; industry needed a way to easily customise product appearances to different market sectors, and also to find a way to cost effectively manufacture a proliferation of different product lines.

The membrane switch offered a solution. The graphic overlay could be customised to a style consistent with the operational environment, and buttons could be placed in such a way as to facilitate ease of use. Many different product models could use a single PCB, in this way reducing development cycles and stockholding costs.

In the early days membrane switches were often perceived to be unreliable. When correctly designed this could not be further from the truth. Technologies and materials have now developed to the extent where a correctly designed membrane switch is now one of the most reliable switches.

Membrane switches are also well suited to hostile environments. As the switches are completely sealed, the overlay creates a physical barrier between the environment and the switch gear, protecting sensitive equipment from solvents, electrostatic discharge, liquids, and dust. As the membrane switch is a self contained switching unit, there is no need for the PCB to be placed in proximity to the switch (as is the case with an overlay above PCB mounted switches). This can improve security and may help reduce vandalism.

There are now established standards for membrane switch design and manufacture through the international body ASTM. These standards provide a framework to increase membrane switch reliability through the effective use of test methods and practices. Australian and New Zealand designers are fortunate to have several quality membrane switch manufacturers who can guide you to a switch design most appropriate to your needs.

This article will briefly introduce the membrane switch, review some recent developments and offer some useful design considerations to ensure you make the most of these useful devices.

The Simple Switch

In its simplest form a membrane switch comprises two flexible printed circuits, physically separated by a spacer. When the button is pressed, holes in the spacer allow the two circuits to contact completing the circuit. The printed top layer is known as the graphic overlay. It is normally made of clear polyester, and reverse printed to protect the image from wear, solvents, and abrasion. As membrane switches are momentary switches, it may be necessary to introduce a method of electronic latching to replicate the actions of mechanical switches.

There are many variations on this

simple design, and by laminating further layers into the switch, it is possible to add additional features such as snap domes, ESD/RFI shielding films, lighting panels, and embedded surface mount components.

The membrane switch is mounted on a flat enclosure, and a single ribbon cable connects the switch to the PCB through a single slot in the mounting panel. In contrast, an overlay requires cutouts in the enclosure beneath each switch adding to machining costs.

Common Switch Designs

Tactile Domes

The use of metal domes within a switch is popular. Domes are placed within the switch and give positive feedback to the user when they activate a key. Domes are available in many different actuation pressures, and are designed to last between one and three million actuations before failure.

Non Tactile- Soft Touch

In this design there are no tactile devices. Due to its simplicity this is the most reliable switch and they have been known to exceed 10 million actuations before failure. Embossing the overlay may improve tactile feedback to the user. Commonly manufacturers also incorporate an electronic "beep" when a key is pressed to give further feedback.

Polydome

In this design the polyester overlay or top circuit is formed using heat and pressure into a dome shape. This provides a positive tactile feel. By changing variables the "feel" and actuation pressure of the dome can be altered to suit the requirements of the client. As the tactile layer is added as one process, this construction can be cost effective in high quantities despite a reasonably high initial tooling cost. Typical life is around 3-5 million actuations.

PCB Hybrid

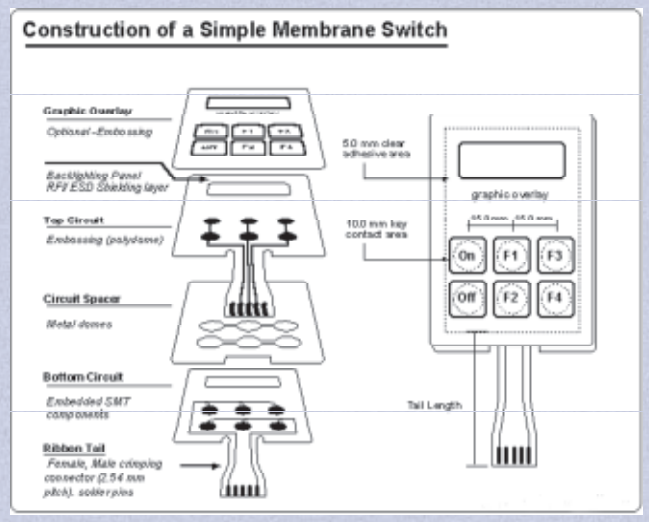
Replacing the bottom circuit with a PCB can be useful when a rigid base is required. The tactile devices and other options can be constructed above the switch in the normal manner. The PCB style switch is also convenient when LEDs or rigid connections are required. PCB switches are typically double sided which allows the possibility of combining the membrane switch and main PCB on the same board.

New Developments in Membrane Switch Design

Backlighting

For many applications both function and indication backlighting is an important consideration. Often this can be achieved with LEDs mounted on the PCB. This can be satisfactory but requires compromises in PCB design and location, while also requiring cutouts in the enclosure for the light to pass through. Often it is not possible to light a key, given that the opaque circuit pads are directly under the pad. The result is a compromise at best.

Electroluminescent backlighting provides a solution. Less than 0.15 mm thickness, EL lighting panels are created using a printed process. A combination of chemicals is printed to the design required, and are laminated under the overlay. This allows the keys to be fully illuminated.



Electroluminescent lighting is generally powered by an AC power source, meaning that an inverter is required. Inverters can be supplied by many component suppliers however their output is often unsuitable for optimum EL lighting. An output range of 120 VAC @ 400-800Hz is recommended. Your membrane switch manufacturer will be able to recommend or supply a suitable inverter. EL lamps do have a definite life cycle, which depends on the configuration of the inverter to the lamp.

Alternatively, woven fibre optic sheet can be used. A woven fibre optic sheet is laminated under the overlay. Woven fibre optic sheet is most suitable for small keypads, particularly those without the cutouts necessary for LCDs etc. Woven fibre has the advantage that the light source is usually LED and can be changed on failure or chosen to suit the light intensity and colour required.

Function Indication

Typically LEDs are used for function illumination. LEDs are often placed on a PCB directly below the membrane switch. This can cause some constraints on both PCB positioning (directly below the membrane switch) or require that the PCB is bigger than may absolutely necessary. Embedding the LEDs within the membrane switch is a useful alternative. The LEDs are typically surface mounted on a separate circuit to the membrane switch, however low profile LEDs may be mounted on the same layer as the bottom circuit.

Electroluminescent lighting is being examined by same manufacturers as a means of providing function illumination. As the "LEDs" can be printed in the position required this reduces both the cost of LEDs and their mounting.

ESD/RFI Shielding

As requirements for RFI shielding have become more rigorous, the membrane switch has come under scrutiny as an area of RFI compliance. There are several ways RFI can be reduced. The easiest is by printing an earthed silver grid above the top circuit within the switch. For more positive control, a specialist conductive layer is laminated within the switch which is then earthed through a separate connection. Shielding through clear LCD windows is often a problem, however the addition of a clear, earthed conductive layer allows this problem to be avoided.

Cost Effective Prototyping

High initial setup and tooling costs used to make membrane switches an expensive proposition for small quantities. The industrial lasers used by many manufacturers these days can considerably reduce tooling costs. Digital printing technologies are improving, and will soon be adequate for most prototyping and market testing purposes.

Designing for Reliability

Constructed correctly, a membrane switch is an exceptionally reliable device. However, a reliable design requires an in-depth understanding of membrane switch characteristics. Each manufacturer has their own specifications but in a general sense the following are useful guidelines.

Environment

Always give your manufacturer a full description of the environment in which the switch will be used. This is

important to ensure a reliable design. For example the high temperatures experienced within motor vehicles demands careful consideration of air track design. Heat can cause pressures within the switch to increase forcing air out into the environment through the surrounding adhesive. When the pressure subsides, a vacuum may be formed pulling the switch contacts together. High humidity or wet environments require more adhesive area, and consideration of the tail exit point. There are many other environmental considerations.

Button Positioning and Size

Try to allow at least 10 mm of clear area between the edge of the panel, and the centre of a button. This allows for strong adhesive bond and reduces the ingress of water. As a guideline, try to allow 15 mm between button centres — this is a good size for reliability and ease of use.

The physical size of the hole between the two circuit layers (the spacer) has important effects on reliability and actuation pressure. While the printed "button" can be any size, generally there are limits on the physical key contact area. Around 10 mm is usually acceptable. Key contact areas larger than this require careful consideration and you should consult your manufacturer.

Tail Exit Point

Except in PCB switches, it can be difficult to take a tail out from the centre of a group of buttons. As the tail may place an upward pressure on the switch, it is not advisable to take the tail out less than 5 mm from the edge of the switch. This allows an acceptable amount of adhesive around the edge to hold the overlay in position.

Handling

Always operate a switch on a flat surface. While often it is tempting to press the buttons while holding the switch in your hand, this may cause domes and SMT components to be dislodged from their positions.

Circuit Crossovers

While advances in dielectric technology have made circuit crossovers exceptionally reliable, it is often cheaper to construct a switch without crossovers as a correctly manufactured circuit crossover can add two or more additional print runs.

Track Width

While individual manufacturers have their own parameters, most will be reluctant to print conductive traces less than 0.5 mm or less than 1.5 mm centre to centre.

Connector Style

The most common connector style is a 0.1" (2.54mm) pitch female clincher connector. Male connectors, solder pins, and flat tails for ziff style connectors can also be accommodated by most manufacturers.

Materials

Traditionally membrane switch overlays were made of polycarbonate. Unfortunately polycarbonate cracks after extended use. Polycarbonate has been largely superseded by the more durable polyester for membrane switch applications. A matt finish is most popular, gloss finishes tend to be difficult to see in brightly lit areas and quickly show fingerprints and grease.

Enclosures

The membrane switch must be mounted on a flat surface. It is desirable to place the switch within a recess as this makes it more difficult to remove. If it is not possible to recess the switch, ask to have the corners of the switch rounded. This enhances the appearance, and reduces the possibility of clothing etc, catching on the edges.

Colours and Appearance

Experts at manufacturing and electronic design often feel out of their depth when it comes to choosing colours and designs. Ideally, consult a graphic or industrial designer with knowledge of your market and product positioning. If this is not within your budget, your manufacturer can often help. Having viewed many different designs, they can often advise what "looks good" and have the art facilities and experience to develop a few concepts for you.

In general, consider the environment in which you will be operating. Lighter colours will get dirty in dirty environments, strong bright colours may be overpowering in domestic environments. Contrast between colours is important: for readability ensure that text etc, contrasts with the background. Avoid too many different text styles — it makes for a "busy" appearance. Text should be readable but not too big. A mixture of upper and lower case is often more easily read than all uppercase. Do not try to match the colour of the enclosure. Even if it is possible to match the colours, the different surface finishes will often lead to a perceived difference between the colours.

Working With Your Manufacturer

Try to choose a manufacturer with a proven track record. Despite appearances membrane switches are complex and many things must be considered in their design. Taking the cheapest option is often false economy as most manufacturers work to a "no short cuts" policy and substantially different prices may indicate a misunderstanding of your requirements or a design compromise.

Always involve the manufacturer at the earliest possible stage in the development cycle. This allows the manufacturer to share ideas and advise of constraints that may affect your application.

As most manufacturers' charges are in relation to the time involved, it is in your interests to make the design and manufacturing process as painless as possible. Using the guidelines above, try to prepare a workable layout for the overlay. If you are in a position to supply this in a vector graphics format (for instance Corel Draw, Freehand, or Illustrator) you may reduce your art costs. Try to sketch your circuit track layout — if you require a specific matrix this can save the manufacturer much time. Multiplexing a switch is generally less expensive than using a common ground as fewer tracks are required leading to a smaller connector.

Try to provide the manufacturer with samples of the colours you require, ideally go to a local printer and select colours from their PMS book. A PMS book is a standard colour book used by all manufacturers. The fewer colours you choose the cheaper the overall cost. Manufacturers may have their own colours — using these saves the expense of colour matching.

Always insist on a laser printed proof of the overlay graphics and switch layout before manufacture. If colour matching is critical (for instance for corporate logos) ask for a colour match of the colour on your chosen material. While this may be charged for, colours are affected by many variables in the manufacturing process, and the matt surface of the polyester can cause a perceived change in colour. Always compare colours in natural light. A digitally printed colour proof is not always reliable due to issues of calibration and varying manufacturing processes.

While I have touched on many different aspects of switch design, you should find your transition to a membrane switch a painless experience. Soon you will be enjoying the very real flexibility and cost savings that membrane switches enjoy over other forms of user interfaces.

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