Energy
Efficient Solutions
by Freescale

Pad Layout Application Note

INTRODUCTION

Freescale produces a range of Capacitive Touch Sensor Products using three sensing technologies. Each of these technologies will have slightly different response to changes in pad layout. Though, since each technology is measuring capacitance from the electrode to ground, the overall difference will be relatively insignificant. All electrodes follow the basic principle that capacitance increases on a single line as a ground reference is introduced. In this case, the ground reference is your finger.

THEORY

While exact calculations are sometimes difficult, it is always best to minimize stray capacitance and isolate electrodes. Stray capacitance can come from a two sources: trace capacitance and pad capacitance. The isolation will become a factor in very small designs. However, due to the single line methodology of Freescale's touch sensors, the lines are inherently isolated; thus, this is usually not a problem.

Trace Capacitance can be generated in two ways: the traces through ground fill or the trace to ground planes. In the case of a ground fill, the fringe capacitance effect causes the total capacitance to increase, thus reducing the sensitivity of the touch sensor. The fringe effect is shown in Figure 1. In addition, capacitance can be generated between the trace and a ground plane. This effect will be much more significant than fringe capacitance, as there is now much more area exposed to the parallel ground plane. This effect is shown in Figure 2.

Pad Capacitance is affected by the same principles as traces. Both fringe capacitance and ground capacitance will be important. Reducing the trace capacitance and pad capacitance while increasing the touch area for the electrode achieves the best result.
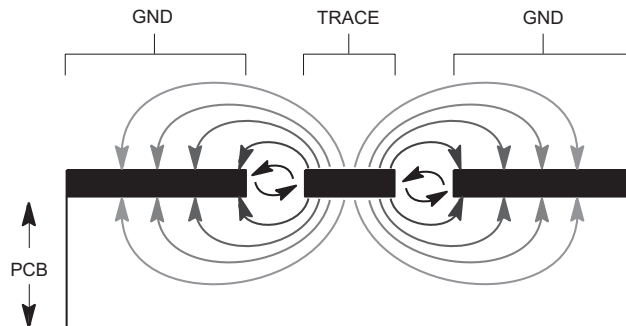

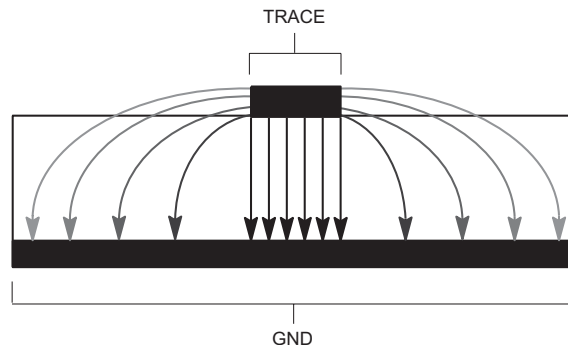**Figure 1. Trace Fringe Capacitance**

Figure 2. Trace Ground Capacitance

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DESIGN CONSTRAINTS FOR CONDUCTIVE PADS

Pad Size / Dielectric Thickness

When using Freescale touch sensors, relatively basic pads are all that is needed. Using square or circular pads should provide the best results. There is a significant relationship between the size of the pad and the thickness of the material that will separate a user's finger from the conductive surface. For very small pads, thin plastics must be used. With large pads, thicker plastic covers are acceptable.

The minimum pad size for Freescale's products is 3 mm by 3 mm when using thin film overlays to about 0.5 mm thickness of acrylic or ABS plastic. The maximum pad size used for touch is about 1.5 mm by 1.5 mm. This thicker pad can be used with plastics of up to 3 mm thickness and still achieve consistent operation.

Minimum Pad Size: 3 mm by 3 mm
Maximum Pad Size: 15 mm by 15 mm
Minimum Dielectric Thickness: Film
Maximum Dielectric Thickness: 3mm

Pad Layout Constraints

Even though electrode design is fairly simple for a single line system, other requirements in a system may have shielding requirements for noisy environments, and this can complicate the design. If shielding is required in an application, it is best to use coplanar ground, as this will have the least influence on the capacitance. The best way to do this is to surround a pad with a ground connected ring. The ring can be the minimum thickness for the production technology, and the space between the ring and the electrode can also be the minimum thickness, as shown in Figure 3.
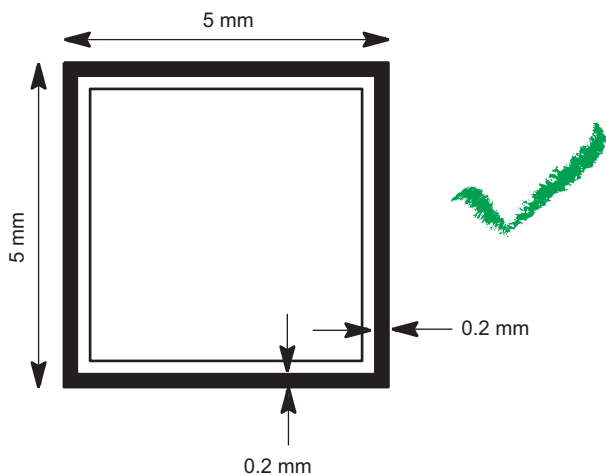

Figure 3. Pad Layout Constraints

Note that a ground plane should not be used to shield the electrode from noise. In some cases this ground plane can actually amplify noise by transmitting this across power on the board.

Figure 4. Ground Plane Usage

Trace Layout Constraints

For traces to electrodes, the total capacitance should be minimized. Thus, the pad width and length should be kept as small as possible. Using <0.20 mm width traces on the electrode lines is recommended. Trace length should be kept as small as possible as well. Although, 1 mm – 20 cm trace lengths should be fine for most applications.

Trace Width: <0.20 mm
Trace Length: 1 mm to 200 mm

Note that if ground planes are used in a system, the capacitance generated from a trace will be greatly increased. Thus, with ground planes, the maximum length should be 40 mm instead of 200 mm.

When routing traces on a board for capacitive sensors, one of the goals must be to reduce the effect that one electrode will have on another. To reduce the coupling effect of electrodes, traces should never be routed under other electrodes. However, it is no problem for traces to cross.
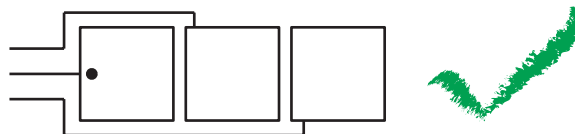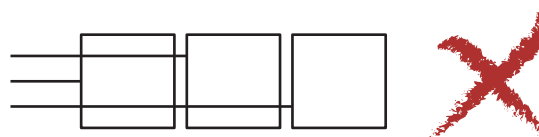

Figure 5. Correct Electrode Tracing

Figure 6. Incorrect Electrode Tracing

Neighboring Buttons

In most designs, buttons are placed very close together. When using Freescale's touch sensors the single line methodology provides a great deal of electrode independence, allowing electrodes to be placed in very close proximity. Two buttons do not need to be separated by any more than simple trace widths, but it is recommended that the ground ring is used in this case. The minimum edge to edge distance between two pads is going to be equal to three times the minimum tolerance for the manufacturing system, as shown in Figure 7.

Figure 7. Neighboring Electrodes

DESIGN CONSTRAINTS FOR RESISTIVE FILMS

When using Indium Tin Oxide (ITO) film, the design must chance slightly, though all of the basic principles still apply. The two primary differences between resistive film and conductive pads are the resistive nature and the single layer design requirement.

Resistive Traces

Resistive Traces can cause problems depending on the total resistance of the trace. Different ITO films will have varying resistance. A higher resistance will increase the transitivity of the film. The unit for the resistance of a film is Ohms per square. The total resistance of a trace can be calculated by dividing the length by the width (to obtain the number of squares) and multiplying the result by the Ohms/sq. In the case that a trace is 105 mm and 0.15 mm thick, the number of squares would be 700. If the resistance per square is 50 Ohms, the total resistance of the trace would be 35 kOhm.

Each of Freescale's devices will respond differently to high resistance traces, but all can tolerate even moderately high resistances.

E-field (PN: MC33941) – The E-field device family can tolerate resistances of up to 2 MΩ with no significant change in the output or setup.

Software (PN: MPR084) – The software device family can tolerate resistances of up to 100 kΩ but will require settings to
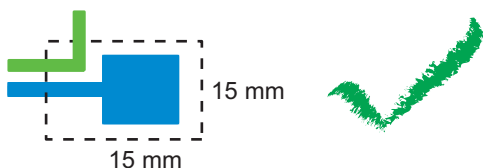
be changed. The electrode measurement mechanism on the software based devices charges through an external resistor to the IC. Thus, this resistance may also have to be calibrated for the different trace resistance values.

ASIC State Machine (PN: MPR031) – The state machine family can tolerate resistances of up to 1 MΩ but may require settings to be changed. These devices will not be as sensitive to trace resistance variation, and their performance will not be decreased. Some register settings on the device may need to be slightly adjusted to compensate for the high resistance. Even larger resistances of up to 5 MΩ may also work with these devices. However, depending on the pad, capacitance may be outside the standard operating range.

Due to the total resistance restrictions, it may be necessary at times to make the traces to the touch pads wider. When doing this, ensure that the space over an electrode where a user would touch the film cannot be covered in a way that a touch is detected. The best way to do this is to keep the area under a finger for a trace less than 20% of the area where a touch pad is. In most cases, it can be assumed that a person's finger is approximately 15 mm by 15 mm area. Thus, if a 15x15 mm square is placed anywhere on a trace, the total area should be 1/5 of the area for a pad. This is shown in Figure 8 and Figure 9.
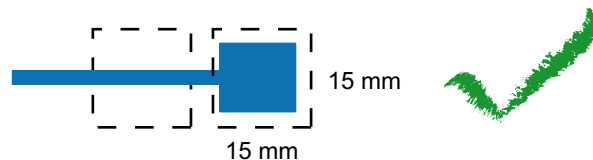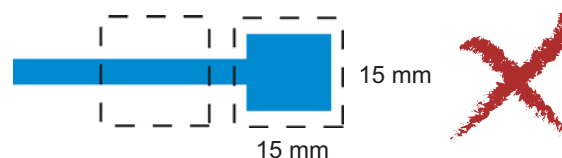

Figure 8. Trace Width Correct

Figure 9. Trace Width Incorrect

Single Layer Design

Apply the same rule as above. When one pad is being touched, a user's finger should not cover 20% of the area of another pad by having a trace too near to a pad. If this is done, it could result in a false touch. This principle is shown in Figure 10 and Figure 11 below.

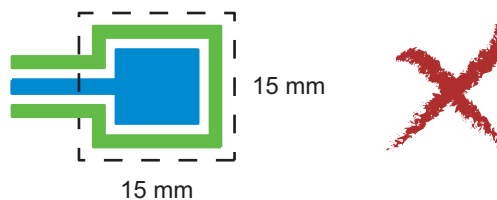**Figure 10. Second Electrode Trace Correct**

Figure 11. Second Electrode Trace Incorrect

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