ANALOG DEVICES

AN-957
APPLICATION NOTE

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Layout Guidelines for the AD7147 and AD7148 CapTouch Controllers

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INTRODUCTION

This application note gives layout guidelines to assist with designing sensors for the AD7147 and AD7148 CapTouch™ controllers, covers sensor construction and PCB stack-up, gives general-purpose layout guidelines, offers guidelines for EMI and ESD sensitive designs, and proposes tips on integrating the sensors into final designs.

The AD7147 and AD7148 are capacitive-to-digital converters (CDCs) for single electrode sensors. The AD7147 is a 13 capacitive input device, while the AD7148 is an 8 input device. The AD7147 is designed for use with capacitance sensors implementing functions such as buttons, scroll bars, wheels, and touch pads. The AD7148 is for use with buttons, scroll bars, and wheels.

SUITABLE MATERIALS FOR SENSOR CONSTRUCTION

Any standard PCB material is suitable for capacitance sensor design, which allows the sensors to be manufactured using industry-standard techniques. Sensor board and trace material examples are shown in Table 1.

Table 1. Materials Suitable for Sensor Manufacturing

Sensor Board	Sensors
FR4 (and Similar)	Copper
Flex (FPC or Polyamide)	Copper
PET (Plastic)	Indium tin oxide (ITO)/silver/carbon
Glass	ITO

SENSOR PCB STACK-UP

The sensors should be on the top layer of the PCB. Each sensor connects to the AD7147 or AD7148 through the CIN input pins. Place an AC_{SHIELD} plane around the sensors and sensor traces on all layers of the PCB.

The stack-up in Table 2 is recommended to ensure there is no cross coupling of noise onto the sensors from other signals routed on the PCB. Use the stack-up in Table 3 only in cases where there is sufficient space available on the PCB to ensure no routing crosses underneath the sensors or sensor traces.

Table 2. Sensor PCB 4-Layer Stack-Up

Layer	Sensors
1 (Top)	Layout sensor electrodes and CIN connection traces; surround by 2 mm of an AC_{SHIELD} plane. Place a ground plane around board edges to protect from ESD.
2	Place an AC_{SHIELD} plane under sensors and sensor traces (mirror AC_{SHIELD} and ground plane from Layer 1); do not place digital routing under sensors or AC_{SHIELD}.
3	Route serial interface and other signals, mirror AC_{SHIELD} and ground plane from Layer 1.
4 (Bottom)	Place the IC, serial interface, and other signal routing here, mirror AC_{SHIELD} and ground plane from Layer 1.

Table 3. Sensor PCB 2-Layer Stack-Up

Layer	Sensors
1 (Top)	Layout sensor electrodes surrounded by 2 mm of an AC_{SHIELD} plane and a ground plane around board edges to protect from ESD.
2	Place the IC, CIN connection traces with 2 mm of an AC_{SHIELD} plane around sensor traces. Place a serial interface, other signal routing, and other components here surrounded by a ground plane extending to board edges (mirror AC_{SHIELD} and ground plane from Layer 1).

LAYOUT GUIDELINES

The following guidelines apply for all sensor layouts:

- Recommended trace width is 0.2 mm.
- Minimum clearance between traces is 0.15 mm.
- Maximum recommended distance between AD7147 or AD7148 and the sensor is 10 cm. Any traces connecting sensors to the C_{IN} inputs of the AD7147 or AD7148 should be shielded using AC_{SHIELD}.
- Place an AC_{SHIELD} plane around the sensors and sensor traces on all of the layers of the PCB. The AC_{SHIELD} plane should be at least 1 mm around the sensors and sensor traces (see Figure 1 through Figure 4 for layout examples).
- Place the ground plane around the serial interface and any other nonsensor area of the PCB. The distance between an AC_{SHIELD} plane and ground plane can be 0.2 mm or 0.4 mm, depending on manufacturing tolerances (see Figure 1 and Figure 2).
- When laying out the AD7147 or AD7148, an AC_{SHIELD} plane should be routed around the CIN traces and pins, while a ground plane should be routed around the serial interface and other digital pins (see Figure 3 and Figure 4).
- The AC_{SHIELD} and ground planes should be mirrored on the subsequent PCB layers.
- Do not route any switching signals directly underneath the sensor electrode or the traces to/from the sensor.
- If there is no space on the sensor PCB to allow routing around the sensors, use an AC_{SHIELD} plane layer directly under the sensor layer. The routing on subsequent layers can be under the sensor area, provided an AC_{SHIELD} plane is in between.
- Floating traces should not be routed next to the sensor traces. Ensure LED traces are not floating by including a 100 nF capacitor to ground on any LED signal.
- The serial interface signals should be routed as far away from the sensors as possible.

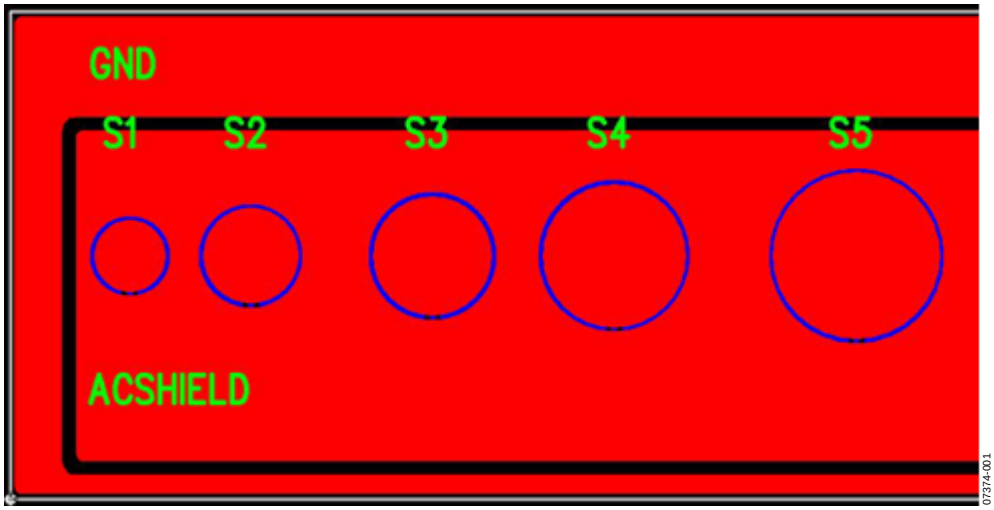

Figure 1. Sensor Layout Example, Top Layer

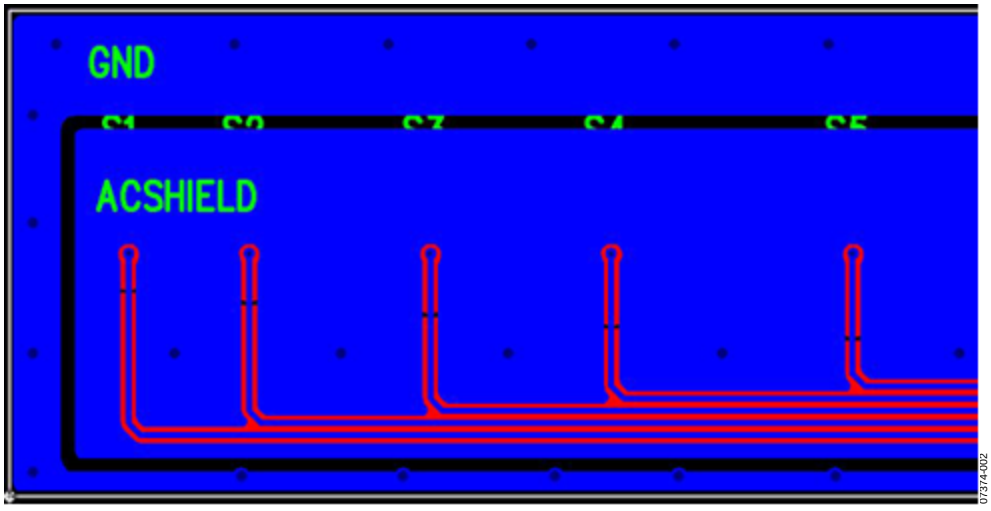

Figure 2. Sensor Layout Example, Bottom Layer

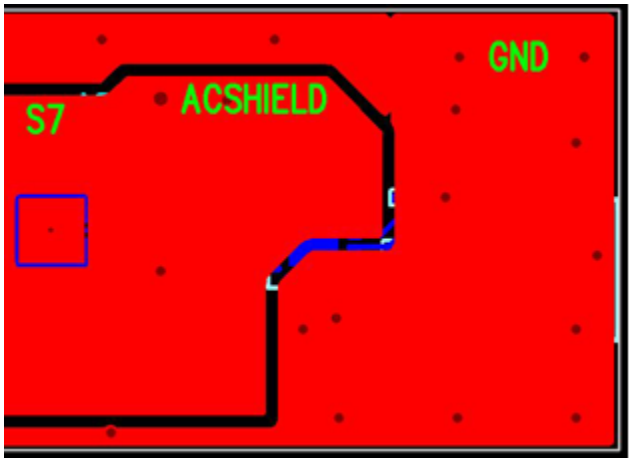

Figure 3. AD7147 or AD7148 Layout Example, Top Layer

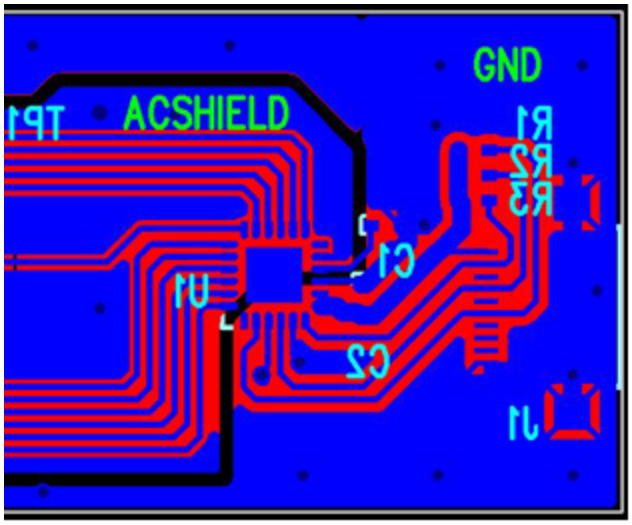

Figure 4. AD7147 or AD7148 Layout Example, Bottom Layer

LEDS AND OTHER COMPONENTS

LEDs and other components may be placed on the same PCB as the sensor. For LEDs, the parasitic capacitance from the LED control trace to the sensor trace may increase or decrease, due to changes in the capacitance of the LED when it is switched on or off. To ensure this does not interfere with the sensor operation, a 100 nF capacitor to ground should be placed on the LED trace.

Other components placed on the sensor PCB may have floating traces, that is, traces that are not always driven to V_{CC} or GND. To ensure these floating traces do not interfere with the sensors, a 100 nF capacitor to ground should be placed on any floating trace.

EMI AND ESD SENSITIVE DESIGNS

For designs where EMI is a concern, keep the trace lengths from the sensor to the AD7147 or AD7148 to minimum lengths. If the traces are shorter than the wavelength of the EMI signal, then noise will not be coupled onto the sensors.

Protection devices can be used to prevent EMI/ESD from affecting the sensors. For example, a Semtech RClamp3304P or similar part can be used to protect the C_{IN} inputs of the AD7147. This part is recommended because it has very low junction capacitance (<1 pF), so it does not load the sensor capacitance. This part should also be used to protect the AC_{SHIELD} pin.

An On Semiconductor® ESD9X3.3ST5G-D diode or similar part should be placed on the V_{CC} and V_{DRIVE} supplies to protect them from high transient spikes during an ESD pulse. The junction capacitance of this diode is too high to be used on the CIN pins so it should only be used on the supply pins.

In addition to using ESD protection devices, it is recommended to place an AC_{SHIELD} plane 2 mm in width around the sensors and sensor routing to the AD7147 or AD7148. A ground plane should be placed outside of this area extending to the board outline. This ensures the ESD pulse finds the path of least resistance to ground rather than onto the AC_{SHIELD} or C_{IN} traces. The example layouts in Figure 1 through Figure 4 show where to place the ground and AC_{SHIELD} planes on the sensor PCB.

PLACING THE AD7147 OR AD7148 ON A DIFFERENT PCB THAN THE SENSORS

The AD7147 or AD7148 does not need to be placed on the same PCB as the sensors. This allows the AD7147 or AD7148 to be placed, for example, on a motherboard, while the sensors are placed close to the user input surface of the device.

The traces to the sensors from the IC must be carefully shielded to prevent noise from interfering with them. The AC_{SHIELD} output from the AD7147 or AD7148 should be routed around the sensor traces, as shown in Figure 5.

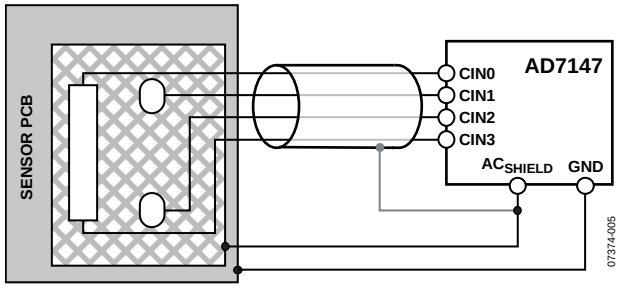

Figure 5. AC_{SHIELD} Used to Shield CIN Connections

COMMON LAYOUT ERRORS

Noise Due To Signal Cross-Over

Noise from the digital interface, or from other switching signals, can couple onto the sensors. This noise may be due to poor layout. Do not route the serial interface, or other digital switching signals under, or directly parallel, to the sensors or sensor traces.

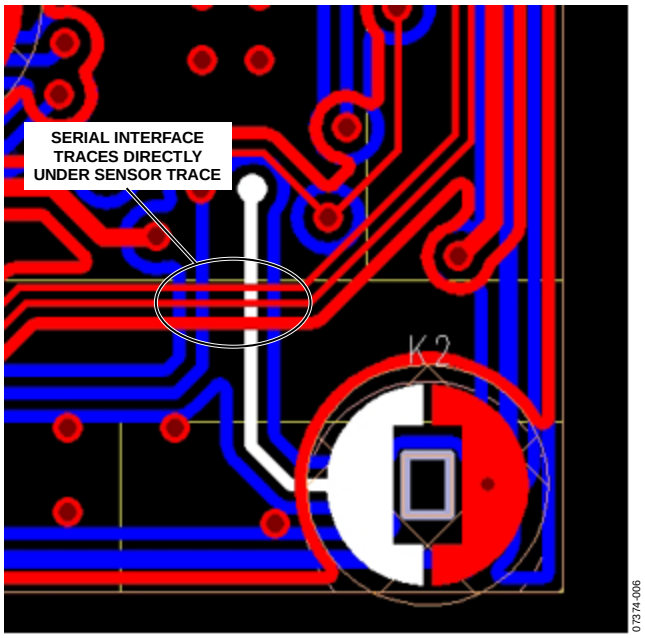

Figure 6. Example of Poor Layout

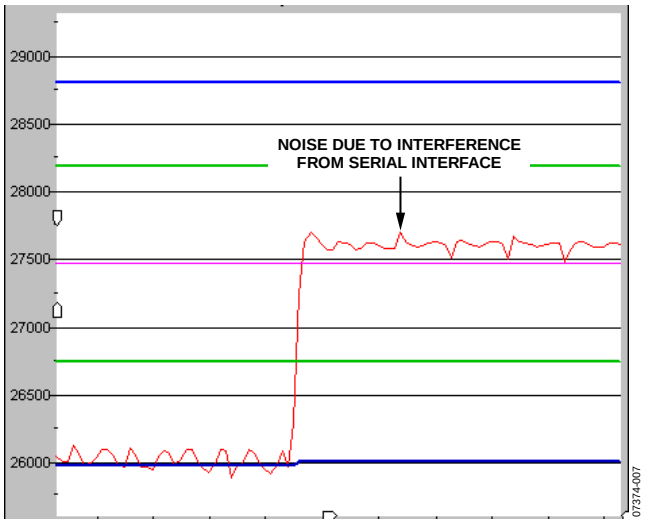

Figure 7. Noisy Sensor Due to Poor Layout

SENSOR INTEGRATION

It is highly recommended that there be no air gap between the sensor PCB and the end product's cover. Air gaps significantly reduce the strength of the electric field and its ability to capacitively couple from the sensor electrode through the covering material dielectric to the touch surface. This results in a poor sensor response, which may affect the reliability and robustness of the sensor operation.

The sensor PCB should be attached to the underside of the end product's covering material. 3M™ Adhesive Transfer Tape 467MP (double-sided tape) is recommended. The sensors operate correctly underneath a covering layer up to a maximum of 5 mm thick. Recommended thickness is 1 mm to 2 mm. The sensors do not work if covered by metal.

For devices with a metal chassis, the metal keep out requirement is 0.2 mm around the sensor area. Any metal within 5 cm of the sensor PCB must be grounded. Floating metal close to the sensors interferes with their operation. There should also be a keep-out area at the rear of the PCB where the AD7147 or AD7148 is mounted. The keep out area should be sufficient to ensure there is no pressure on the IC, and that the tracks on the PCB are not shorted together.

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