

## Developing Multipoint Touch Screens and Panels With CPLDs

### Introduction

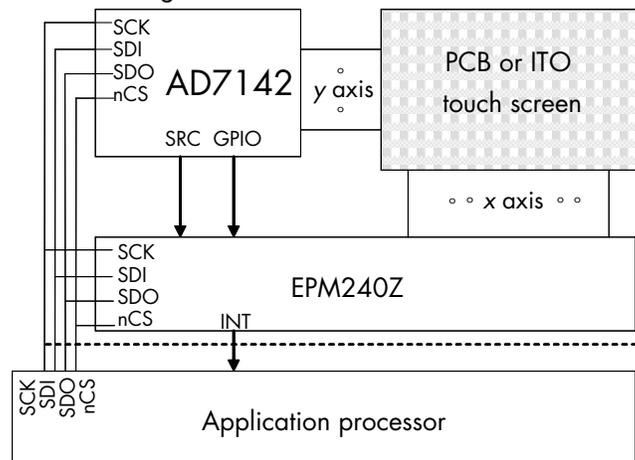
When a certain web-enabled multimedia smartphone hit the market in 2007, it transformed the way that consumers expect to interact with their handheld devices. Especially engaging is the fluid touch-screen interface that allows users to access an array of applications or scroll through web pages with their fingertips. To develop such sophisticated interfaces—without sacrificing time, budget, or power requirements—design with zero-power Altera® MAX® IIZ CPLDs.

Unlike ASSPs or other competitive technologies, MAX IIZ CPLDs deliver high I/O counts, ease of use, low power, and flexibility to support product differentiation. These benefits help simplify and accelerate the process of creating unique handsets, portable media players, and displays, as well as medical, automotive, and industrial applications. Deploy Altera’s new multipoint touch-screen reference design on a MAX IIZ EPM240Z device to move quickly from concept to working product.

### Customize—or Not—and Start Designing

There are two parts of any touch-screen solution: a 2D touch sensor and a computer application that converts sensor data into the user’s intent. The reference design is a complete sensor and data gathering system ready to customize or use as is, with an indium tin oxide (ITO) screen or a simple two-sided PCB used as a multi-touch navigation pad. The 2D multi-touch reference design shown in [Figure 1](#) is based on a MAX IIZ EPM240Z CPLD and an Analog Devices AD7142 integrated capacitance-to-digital converter (CDC) with on-chip environmental calibration and an ITO screen.

Figure 1. Multi-Touch Reference Design



The reference design has a simple data interpretation application that demonstrates and tests the operation of the multi-touch sensor. The AD7142 CDC, which senses the capacitance variation, has only 14 capacitance sensor channels. In this reference design, the MAX IIZ CPLD expands the AD7142 CDC’s ability to handle a two-dimensional ITO film or PCB touch sensor. An application processor accesses the CDC register file of the AD7142 and sets the MAX IIZ CPLD’s control of the SRC signal to the appropriate axes via a SPI or I<sup>2</sup>C bus. The MAX IIZ CPLD also generates an interrupt signal when the touch screen senses a touch after a long pause.

### ITO or PCB Touch-Screen Design

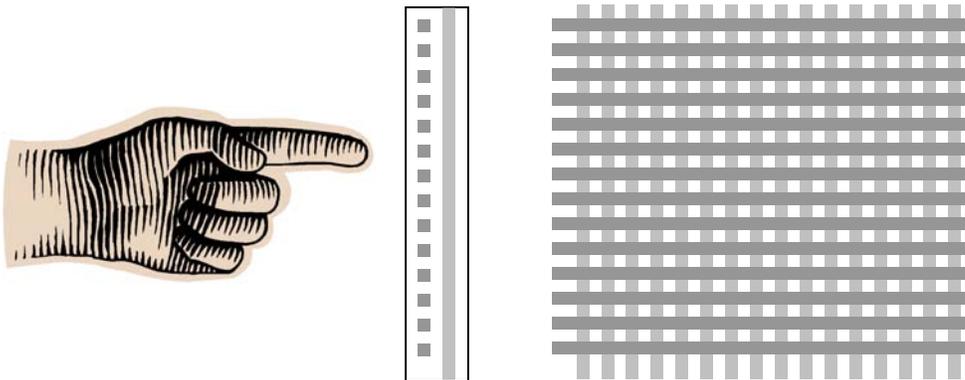
The start of any touch-screen design is the actual touch sensor. Although this reference design focuses on a capacitive ITO touch screen, it also works with a two-sided PCB with horizontal traces on one side and vertical traces on the

other. The ITO touch screen has two transparent layers separated by an insulator, with up to 14 y traces that connect to the AD7142 CDC inputs and 16 x traces connected to the MAX IIZ CPLD. The MAX IIZ CPLD has the ability to add more I/Os for better resolution and large touch areas. The 14x16 design presented works for a screen or pad size up to 16 cm x 14 cm.

The ITO touch sensor has two orthogonal layers, the x and y traces, separated by an insulator. Ideally, the x traces are on the bottom and the y traces connected to the AD7142 inputs are on top, because the CDC is more sensitive to touch events if it monitors the traces closest to the finger. The traces are a loose array with a pitch of 5 mm to 10 mm.

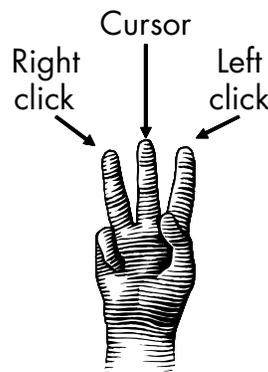
Figure 2 shows a touch-screen cross section on the left and the screen view on the right. In an actual display touch screen, the traces are transparent.

Figure 2. ITO Touch-Screen or PCB Touch-Pad Cross Section (left) and Screen View (right)



The sensor in Figure 2 can be implemented as a computer navigation pad, which eliminates the select pushbuttons required on a normal navigation pad. As shown in Figure 3, the middle finger moves the cursor and the pointer and ring fingers touch the screen to indicate left or right mouse clicks. Eliminating the moving parts makes the capacitance touch screen sensor more durable than pushbuttons and pushbutton switches.

Figure 3. Finger Controls of Switchless Navigation Pad

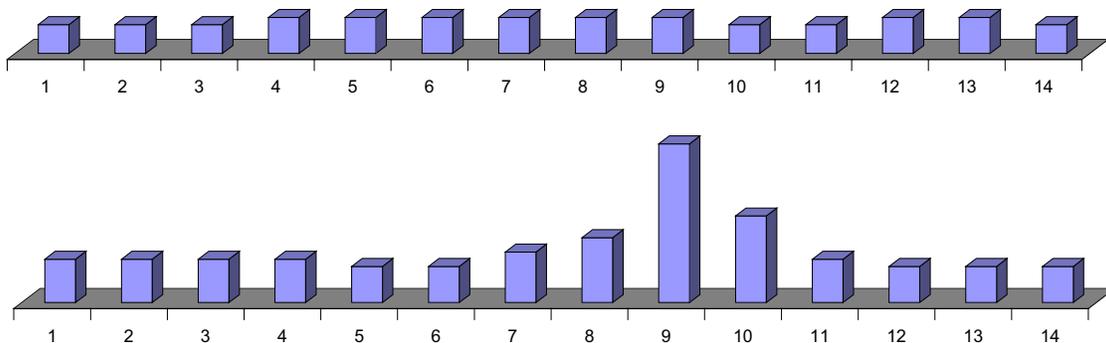


### Analog Devices AD7142 CDC

The AD7142 CDC was not designed to be used as a touch-screen decoder, but it does measure the capacitance and the change in capacitance of a linear array of sensor pads on a PCB. The AD7142 CDC's complex electronics allow it to calibrate to a specific PCB layout and then generate a capacitance measurement for each of 14 sensor inputs to 12 bits of accuracy. These values are accessed by the I<sup>2</sup>C or SPI bus after each measurement cycle. The AD7142 CDC sends a 250-KHz square wave signal on the SRC signal that drives a trace near the sensor pads, then measures the SRC signal strength received. Because the capacitance of the touch pad is proportional to the SRC signal receive strength, the AD7142 CDC detects and quantifies the change in capacitance as a user's finger approaches the touch pad.

The AD7142 CDC makes 14 serially addressable capacitance measurements. In [Figure 4](#), the top chart in shows a representation of the register values under baseline conditions when no finger is near, while the bottom chart shows the register values when a finger is closest to sensor 9. The sensitivity of the AD7142 CDC allows an application processor to use this detailed vector of capacitance values to interpolate that the finger is centered at the 9.3 sensor location, or between sensors 9 and 10. With the 12-bit accuracy of the AD7142 CDC, it is possible to have a very fine measurement of the finger's location with only 14 sensors.

Figure 4. Representative Linear AD7142 CDC Samples



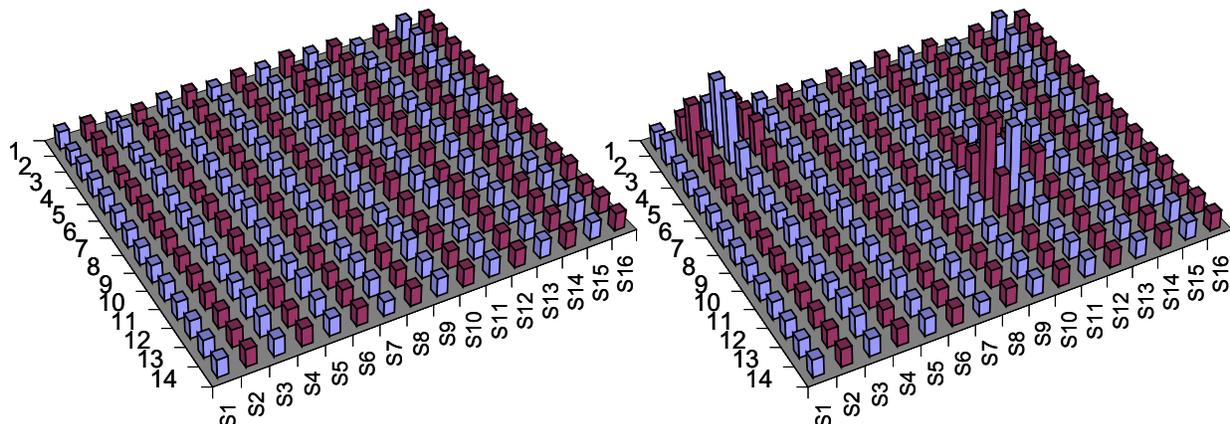
 The [AD7142 CDC documentation](#) supplies more details on operation and calibration features.

### MAX IIZ CPLD Transforms Linear Sensor Into 2D Sensor

By itself, the AD7142 CDC measures the capacitance of 14 sensors with respect to a single SRC trace. Adding the MAX IIZ CPLD allows multiple SRC traces by taking the SRC square wave signal from the AD7142 CDC and, under the control of a serial interface, selectively drives one of the touch-screen vertical  $x$  traces. It is then possible for the AD7142 CDC to take a capacitance measurement localized to the region or axis of the active vertical trace. The large number of I/Os available in the MAX IIZ (up to 54 I/Os possible in the 5x5 mm package or 116 I/Os in the 7x7 mm package), along with the high resolution of capacitance-to-digital measurements of the AD7142, enable the potential for this solution to address very large touch screens and pads.

[Figure 5](#) represents the results of a 2D capacitance measurement made with the combination of an AD7142 CDC and a MAX IIZ CPLD, and shows 16 traces or 16 divisions of the  $x$ -axis. On the left is a baseline capacitance measurement, while the right is the possible result of two fingers touching the sensor. The charts show blue and red rows of samples determined by which SRC trace is active.

Figure 5. Representative 2D Array of Capacitance-to-Digital Samples: Baseline (left) and Touched (right)



Using a serial interface, the application processor sets the MAX IIZ CPLD to drive the S1 column of the sensor with the SRC signal, and reads the 14 capacitance values from the AD7142 CDC. The application processor then signals the MAX IIZ CPLD to move the SRC to the next vertical trace and take another 14 capacitance measurements, repeating until the application processor has all 244 (14x16) capacitance measurements representing the 2D area of the touch sensor. The process of gathering all the data takes about 375 ms using the I<sup>2</sup>C bus and about 300 ms using the SPI bus. (Lower resolution CDC samples reduce the sample period.) The application processor then processes the raw data to determine the user's intent.

### **Saving Power, Time, and Processing**

The MAX IIZ CPLD and the AD7142 CDC touch-screen decode reference design is very power efficient, typically requiring 1.5 mA at normal full-speed and -resolution operation. However, three additional levels of efficiency are possible. The first level of power savings is obtained by the application processor reducing the sample rate, sampling a subset of the horizontal and vertical traces, and/or using the accuracy of the AD7142 CDC to interpolate touches between active traces. The next level of power savings requires a user to touch the center of the screen to wake the device. This limits the application processor to sampling only one horizontal and one vertical trace.

The lowest power level possible puts the application processor and the AD7142 CDC in power-down mode. With an external 32-KHz clock and a once-per-second sample rate, the typical MAX IIZ CPLD standby current is as low as 50  $\mu$ A. When the MAX IIZ CPLD's power-efficient capacitance detection system senses when the screen is touched, it wakes the processor using an interrupt signal. Once awake, the system reads the touch location with more accuracy.

### **Conclusion**

The single-point touch screen and pad is no longer a novel way to interface with electronic systems and is almost expected by users. Single-point touch-screen solutions are readily available, so to get a consumer product noticed, a two-touch or multiple-point touch screen or pad is required. Multi-touch options are very limited, but the Altera MAX IIZ CPLD makes a flexible multi-touch user interface possible using existing components.

## Further Information

- New Zero-Power MAX IIZ CPLD: Minimize Power, Space and Cost:  
[www.altera.com/maxiiz](http://www.altera.com/maxiiz)
- Contact an Altera local FAE or sales representative:  
[www.altera.com/corporate/contact/con-index.html](http://www.altera.com/corporate/contact/con-index.html)
- Purchase a MAX IIZ touch-screen development kit:  
[www.altera.com/buy/buy-index.html](http://www.altera.com/buy/buy-index.html)
- For standard multipoint-capable capacitive touch screens, contact:  
[www.NKKsmartswitch.com](http://www.NKKsmartswitch.com)
- Analog's AD7142 CDC documentation:  
[www.analog.com/static/imported-files/data\\_sheets/AD7142.pdf](http://www.analog.com/static/imported-files/data_sheets/AD7142.pdf)
- Literature: MAX II Devices:  
[www.altera.com/literature/lit-max2.jsp](http://www.altera.com/literature/lit-max2.jsp)
  - *Reduce Total System Cost in Portable Applications Using Zero-Power CPLDs:*  
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  - *Controlling Analog Output From a Digital CPLD Using PWM:*  
[www.altera.com/literature/wp/wp-01085-analog-output-digital-cpld-pwm.pdf](http://www.altera.com/literature/wp/wp-01085-analog-output-digital-cpld-pwm.pdf)

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