

Using the Touch Screen Controller on the MCF5227x

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The need for graphical user interfaces in industrial and consumer applications is steadily increasing. For instance, LCDs are now on appliances such as washers, dryers, refrigerators, and stoves, allowing enhanced human control. Security and HVAC control systems are other examples of applications that require advanced graphical display interfaces to enable human control of the various system functions. Along with the LCD, the use of touch screens is also increasing. To address this need, Freescale is introducing a family of cost-effective and highly integrated ColdFire microprocessors that feature an integrated LCD controller and an integrated touch screen controller module.

The MCF5227x family of ColdFire microprocessors includes an analog signal processor (ASP) module. The module includes an analog-to-digital converter (ADC) and digital logic to automatically manage the I/O switching and timing required for interfacing to a touch screen. As a touch screen controller, it supports resistive 4-wire, 5-wire, 7-wire, and 8-wire touch screens. When the ASP module is not used as a touch screen controller,

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it can be used as a multi-channel 12-bit general-purpose ADC. Also, if there are channels that aren't used for touch screen functionality, they can be used as general-purpose ADC inputs.

This application note describes how resistive touch screens work and how the ASP module can be used to interface to different types of touch screens. To simplify discussion, this document discusses using the ASP module as a touch screen only. There is no discussion of using the ASP module as a general-purpose ADC or using a mix of touch screen and ADC channels.

1 Touch Screen Overview

There are a number of touch screen technologies available today. Three of the most common touch screen technologies are resistive, capacitive, and surface acoustic wave (SAW). Of these, resistive touch screens are generally the least expensive but also provide good reliability, durability, and accuracy.

Resistive touch screens need only pressure to get a reading. This means that any type of input device can be used to create the touch — finger, stylus, gloved finger, etc. By comparison, capacitive touch screens require a conductive touch device, so they must be used with a finger touch or a special conductive stylus. Surface acoustic wave touch screens rely on the absorption of sound waves to detect a touch so a finger or gloved finger will work. However, a small, hard stylus doesn't work, so SAW touch screens usually require a special soft-tipped stylus.

Resistive touch screens do have some disadvantages. One of the primary disadvantages is that the touch screen uses multiple layers, and the coatings on the layers can reduce light transmission and create some color distortion of the underlying LCD image. The optical quality for resistive touch screens can vary from manufacturer to manufacturer. For applications where resolution and brightness of the display are important, it might be worth the extra investment to purchase a resistive touch screen with better light transmission characteristics, or even move to a different type of touch screen technology.

The ASP module on the MCF5227x supports resistive type touch screens. Modes of operation are available for the commonly used interfaces — 4-wire, 5-wire, 7-wire, and 8-wire. The following sections discuss how the different types of resistive touch screens work, along with their advantages and disadvantages.

1.1 How 4-Wire Resistive Touch Screens Work

A 4-wire touch screen is made from two layers, each with a resistive coating. There is a separation between the two layers. The bottom layer is rigid, but the top one is flexible. Both layers have bus bars placed perpendicular to each other. A voltage is applied to the bus bars on both sides of a layer and the resistive coating creates a voltage gradient across the plane. The basic idea is to create a voltage divider. Detecting the voltage at the division point (the touch point) allows for calculating the relative position of the touch point with respect to the two rails.

To get the coordinates for a single point, two measurements are needed. First a voltage is applied across the x-axis plane, and the contacts for the y-axis plane are allowed to float. The resistive coating on the touch screen creates a voltage gradient across the plane. If the top layer is pressed, it flexes and makes contact with the bottom layer. The y-axis plane now has a voltage equal to the voltage on the x-axis plane at the point of contact. The voltage on the y-axis plane can be measured and used to obtain the x-coordinate. The process is repeated again to get the y-coordinate. This time the voltage is applied across

the y-axis plane and the x-axis plane is allowed to float. Then the x-axis voltage is measured and used to calculate the y-coordinate location.

1.1.1 Example of 4-Wire Touch Screen Measurement

Figure 1 shows an example of how measurements would be taken on a 4-wire touch screen. The first step is to get the x-axis coordinate. To do this X+/XL is biased to 3.3 V, and X-/XR is biased to 0 V. At this point there should be a consistent voltage ramp across the x-axis plane. If the screen is touched in the center, the mid-level voltage of 1.65 V is transferred to the y-axis plane. The Y+/YU and Y-/YD points are floating, so the entire plane should be at 1.65 V. This input voltage is read from the Y+/YU connection and used to determine that the x-axis coordinate of the touch point is at 50% of the screen's width.

The next step is to get the y-axis coordinate. This time Y+/YU is biased to 3.3 V, and Y-/YD is biased to 0 V. This creates the consistent voltage ramp across the y-axis plane. The pressure from the touch creates a contact point between the two planes so that the x-axis plane goes to 1.65 V. The input voltage is read from the X+/XL wire and used to determine that the y-axis coordinate of the touch point is at 50% of the screen's height.

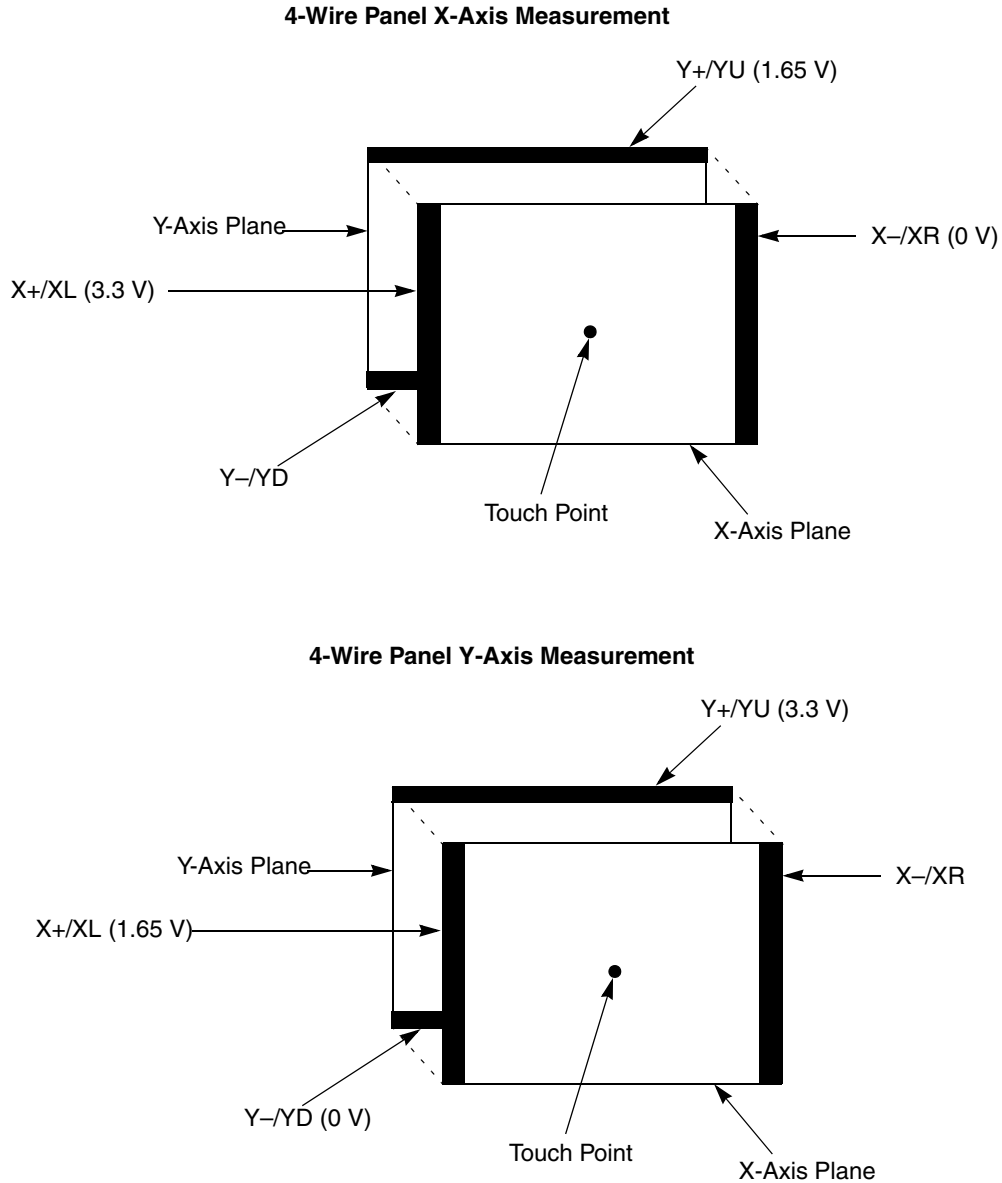


Figure 1. 4-Wire Touch Screen Measurement Example

1.2 How 8-Wire Resistive Touch Screens Work

An 8-wire touch screen is based on the same basic technology as a 4-wire touch screen. Again, four wires are used to provide power at the edges of the touch screen. The extra four wires are used to sense the actual voltage applied at the edges of the touch screen. These sense wires are added to compensate for offset errors. The actual voltage at the bus bars can vary, so adding sense wires at the bars allows for a more accurate determination of the voltage gradient being applied across either of the planes. Because the offset error is taken into account at measurement time, the extra wires also help to reduce the need for calibration of the touch screen. Refer to [Section 4, “Calibration,”](#) for more information.

An 8-wire system is more commonly used for larger touch screens (about twenty centimeters, or eight inches, and up). For a given ADC resolution while making measurements, the accuracy of touch point placement degrades as the screen becomes larger, because the resolution is spread across a bigger distance. Therefore, loss of accuracy due to offset error is a bigger concern. Going to an 8-wire touch screen instead of 4-wire allows for greater measurement accuracy on larger touch screens.

1.3 How 5-Wire and 7-Wire Resistive Touch Screens Work

5-wire touch screens make some improvements on the older 4-wire technology. The construction of the panels are similar, but for a 5-wire touch screen all four bus bars are connected to the lower, non-flexible layer of the screen. The flexible layer is always used as a sense layer to read the voltage connection point to the bottom layer.

The voltage gradients are always applied to the rigid bottom layer. Because the voltage gradient layer does not come into direct contact with the user and does not bend, the durability of the touch screen is higher than a comparable 4-wire touch screen. Touch screen manufacturers will specify a certain number of touches in a single location over the lifetime of the touch screen. When selecting a touch screen to use in an application this value should be taken into account. Specifications will vary from manufacturer to manufacturer, but a 4-wire touch screen might be rated for over 5-10 million touches, and 5-wire touch screens can be found that are rated for over 35 million touches.

Similar to the way 8-wire touch screens add sense lines to the 4-wire touch screen standard, 7-wire touch screens add two additional sense lines to the 5-wire interface. One sense line is used to detect offset on one of the x-axis bus bars, and the second is used to detect offset on one of the y-axis bus bars. Again, this helps to increase the accuracy of touch measurements and reduce the need for calibration.

2 Hardware Connections

Table 1 shows the connections that must be used between the MCF5227x and the four different types of touch screens.

Table 1. MCF5227x to Touch Screen Connections

MCF5227x Pin	4-Wire	5-Wire	7-Wire	8-Wire
ADC_IN0	X+/XL ¹	UL	UL _{force}	X _{sense} ¹
ADC_IN1	X-/XR	UR	UR	X _{sense}
ADC_IN2	Y+/YU ¹	LL	LL	Y _{force}
ADC_IN3	Y-/YD	LR	LR _{force}	Y _{force}
ADC_IN4	—	Wiper/Sense ¹	Wiper/Sense ¹	Y _{sense} ¹
ADC_IN5	—	—	UL _{sense}	Y _{sense}
ADC_IN6	—	—	LR _{sense}	X _{force}
ADC_IN7	—	—	—	X _{force}

¹ This pin is used for input channel measurement of the X coordinate, Y coordinate, or both.

3 ASP Initialization

The steps below describe the initialization of the ASP module. They are presented as a numbered list here for simplicity, but there is no need to adhere to this order of operations.

1. Write ASP_CR:
 - Clear the MDIS bit to enable the module (bit is set at reset).
 - Set the TSE bit to enable touch screen mode.
 - Set the TSTYPE field to the appropriate setting for your touch screen.
 - Set the MODE field to 0'b01. In this mode the ASP will process touch screen inputs.
 - Optionally set the PENE, AZE, and/or AUTO bits.
2. Set the clock divider in the ASP_CLKD register. The nominal value for the ASP clock is 2 MHz. For a 160 MHz core clock, an ASP_CLKD value of 0x27 will generate a 2 MHz ASP clock.
3. Write ASP_ICR to enable desired interrupts and set the FIFO watermark level. Freescale recommends enabling the POVIE, PUIE, PDIE, PFLIE, and PFFIE flags to generate interrupts.

4 Calibration

Touch screens can require many types of calibration. Probably the most obvious and necessary calibration is used to correct for differences between LCD coordinate values and the corresponding touch screen coordinates. Because user input is required, this calibration must be done in software.

In addition, calibration to compensate for temperature variation, cable length, noise, and offset error might be needed. The MCF5227x ASP module includes hardware to assist in calibration for noise and other environmental factors that might influence the ADC readings from the touch screen.

4.1 Positional Calibration

Positional calibration, as its name indicates, is used to correct for positioning of the touch screen in relation to an LCD. The coordinates of the touch screen will not directly correlate to the coordinates on the display. To perform positional calibration, a series of points is displayed on the LCD and the user is prompted to touch them in sequence. After a set of LCD point coordinates and the corresponding touch screen coordinates are obtained, then calculations can be performed to correct for any misalignment or scaling errors.

Because the position of the touch screen in relation to the LCD will be constant in almost all cases, positional calibration needs to be performed only once. If the calibration information is saved to flash or other nonvolatile memory, then calibration can be part of factory testing. If the data is not saved, then positional calibration must be performed during system bring-up.

Carlos E. Vidales has written an article available on embedded.com titled “How to Calibrate Touch Screens.” This article includes a detailed description of how positional calibration can be done using only three points. The article also includes a link to source code files. Freescale uses this source code to perform positional calibration in our example touch screen projects. For more information on positional calibration and how to correct for misalignment and scaling errors between the LCD and touch screen, please refer to that article.

4.2 Auto-Zero

The ASP module on the MCF5227x includes an auto-zero mode that can be used to determine the offset error for each touch screen measurement. If auto-zero is enabled (ASP_CR[AZE] is set), then the ASP will measure what should be the zero point for the x-coordinate (AZE) before taking the actual x-coordinate measurement. A measurement of what should be the zero point for the y-coordinate (AZY) is taken before measuring the actual y-coordinate. These auto-zero values reflect the instantaneous noise and offset error around the time the coordinate measurements are made. These auto-zero values can then be subtracted from the respective coordinate measurements in software to obtain a more accurate reading.

This is similar to the offset data obtained by the sense lines when using a 7-wire or 8-wire touch screen. The difference in this case is that software needs to subtract the auto-zero values from the coordinates, whereas if sense lines are used in 7-wire and 8-wire modes the offset is automatically subtracted by the ASP module.

Because auto-zero mode is designed to help correct for instantaneous error, after auto-zero mode is enabled, then auto-zero measurements are taken for every pair of coordinate measurements. So, unlike positional calibration, which needs to be performed only once, auto-zero calibration is performed any time a measurement is taken. This adds some additional delay to the measurement time, and extra code is needed to subtract the auto-zero value from the respective coordinate value. Not all applications will require auto-zero calibration. Because 7-wire and 8-wire touch screens have auto-zero calibration built-in, these types of touch screens will not require auto-zero measurements. Auto-zero also has limited usefulness in a system that has a small touch screen, a short cable, and is running at room temperature.

4.3 MCF5227x Calibration Assist

The final type of calibration helps to compensate for drift over temperature in the characteristics of the ADC within the ASP module. The MCF5227x provides a calibration assist mode, designed to collect measurements from the ADC, which can be tracked over time to quantify drift.

Unlike auto-zero mode, the calibration assist mode is a special mode of operation for the ASP. This means that calibration data is not obtained at the same time as regular coordinate data. The following are the steps required to use calibration assist mode:

1. After the ASP module has been initialized, set ASP_CR[CALA] to enable calibration assist mode. ASP_CR[AUTO] must also be set.
2. Set ASP_CR[ASPE] to start calibration conversions.
3. Wait for the pen FIFO watermark flag to set (ASP_SR[PFLF]).
4. Save off calibration number.
5. Clear ASP_CR[ASPE, CALA] to stop conversions and exit calibration assist mode.

The calibration must be performed once at startup, and the resulting values saved off. Calibration must be performed again at regular intervals. The new calibration values must be compared to the old ones to determine a percentage of drift over the interval. The percent change can be applied to sample data after the auto-zero values, if any, are subtracted, to compensate for the effect of temperature drift on the ADC circuit.

Because the goal of the calibration assist mode is to correct for temperature change, the time interval between the collection of calibration samples should be varied, based on the temperature volatility in the system and the amount of accuracy needed for the size of the touch screen. Not all applications will require this calibration. For systems that run at a fairly constant temperature and/or use a small touch screen, the calibration assist procedure might not be needed at all.

5 ASP Interrupt Flowchart

Figure 2 shows a flowchart for a typical ASP interrupt handler that collects touch screen coordinates. This basic flow works if ASP_CR[MODE] is set to 0'b01. In this mode the ASP will sample touch screen inputs only (no sampling of general-purpose inputs). This flow will work in either single-scan mode or automatic mode.

NOTE

The order in which the interrupt flags are checked in the interrupt handler is important. If a different order is used, then software might not operate correctly.

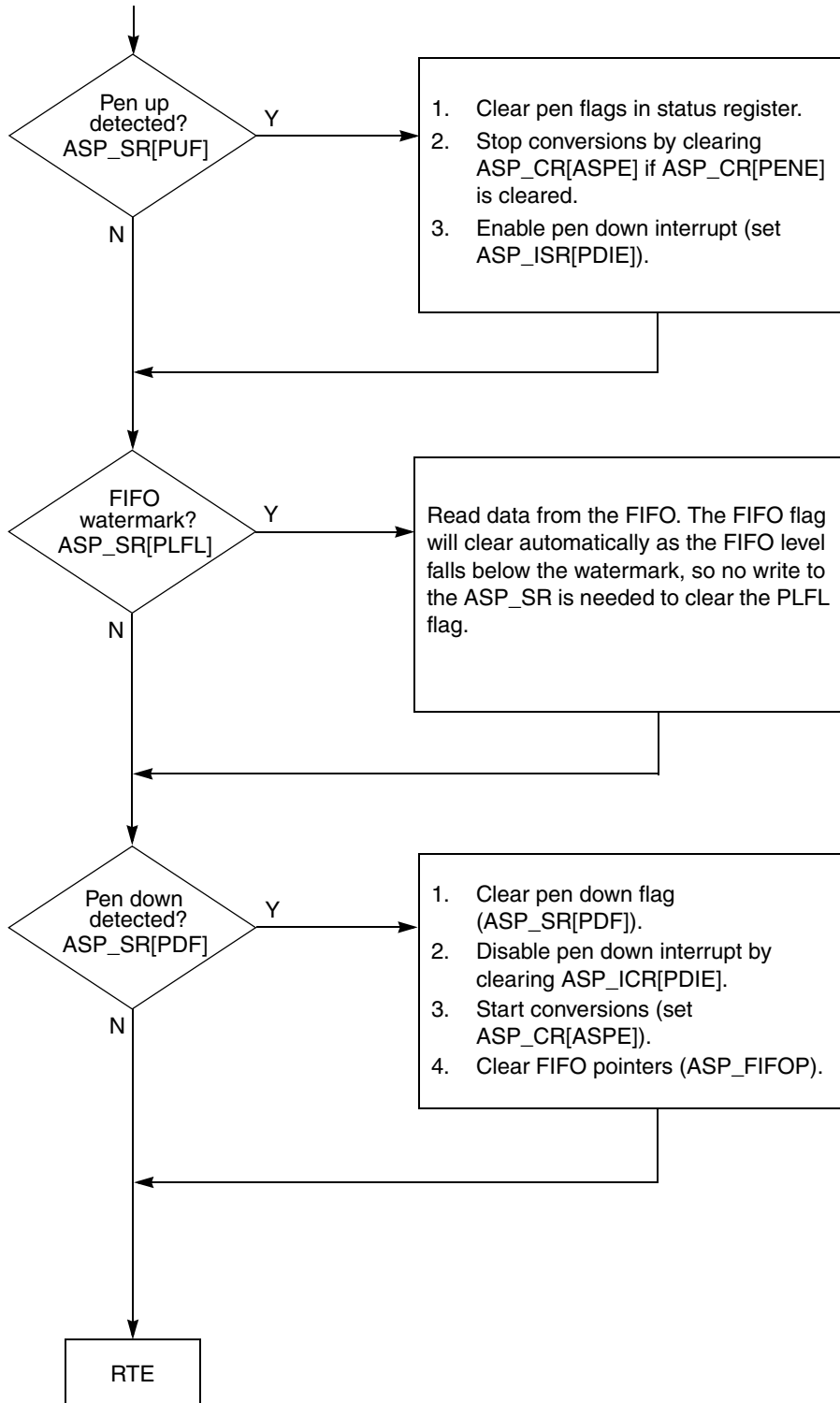


Figure 2. Typical ASP Interrupt Handler Flow Chart

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