

## Configuring the AD7877

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### INTRODUCTION

The AD7877 touch screen controller is a 12-bit successive approximation ADC with a synchronous serial interface and low on resistance switches for driving touch screens. The AD7877 features direct battery measurement on two inputs, temperature and touch-pressure measurement.

The AD7877 has many user-programmable conversion controls, including variable acquisition time, first conversion delay, and averaging. It is ideal for battery-powered systems, such as personal digital assistants, smart phones, and other portable equipment with resistive touch screens.

The AD7877 requires configuration via the on-board registers to fully utilize its features. This application note goes through the configuration process step by step, and explains how to configure the device for your application.

### SINGLE-ENDED OR RATIOMETRIC MEASUREMENT

The main task of any touch screen controller is to take accurate measurements from the touch screen. On the AD7877, there are two measurement methods available: single-ended or ratiometric. The difference between the two methods is in the ADC reference voltage. In single-ended mode, the ADC is referenced to ground and to  $V_{REF}$ . ( $V_{REF}$  can be either the internal reference voltage or an external reference). For the differential measurement, the ADC is referenced to the screen excitation voltage.

The advantage of using the single-ended method is that the touch screen does not need to be powered except during signal acquisition. Signal acquisition takes only a portion of the total conversion time. This method can result in significant power savings in the system, as the screen itself can draw more than 1 mA while powered. This method also has some disadvantages. Voltage drops across the internal switches cause errors in the measurement, as they reduce the apparent excitation voltage across the screen. In addition, this method can only be used when  $V_{CC}$  is close to  $V_{REF}$ , otherwise the ADC is saturated (when  $V_{CC} > V_{REF}$ ), or conversely, the full range of the ADC is not used ( $V_{CC} < V_{REF}$ ). The single-ended method is particularly suited for battery-operated systems where power is at a premium. It is only recommended for applications that use the finger as an input device, and therefore do not need high accuracy measurements.

Using the touch screen excitation voltage as the ADC reference gives a ratiometric measurement of the input signal. This method is more accurate than the single-ended method because voltage drops across the internal switches do not have any effect on the measured results. However, the screen needs to be powered at all times in order to provide the ADC with its reference. For applications such as handwriting recognition, where the measured touch screen position must be accurate, the ratiometric method is recommended.

### AVERAGING

The signals measured from the touch screen can be noisy. To minimize low level noise, the AD7877 can automatically perform averaging on the measured input signals. The AD7877 can be programmed to perform one, four, eight, or sixteen consecutive measurements on the same channel, and write the averaged result to the result register. The more averages the part performs, the longer each measurement takes. When choosing the amount of averaging in the system, the time available for conversions needs to be taken into account. The amount of averaging required will depend on the noise factors in the specific system, but in general, at least four averages are recommended for each measurement.

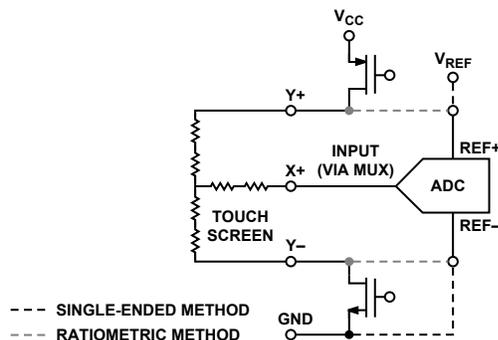


Figure 1. Measurement Methods

## STOPACQ

In most applications, the touch screen is placed directly on top of the LCD. Periodic noise from the display can interfere with the touch screen measurements. As the LCD horizontal lines are written, noise is generated that can be coupled onto the touch screen. This specific type of noise is generally framed by an LCD control signal related to the horizontal refresh phase. HSYNC and Vcom are the two typical control signals found on different types of LCDs. The noise can be framed by the high or low period of these signals, or it may be worse at the signal transitions.

If the user sees periodic noise in the system, an analysis should be performed to determine if the noise is coming from the LCD, and whether there is a control signal available that frames the noise. This control signal should be tied directly to the AD7877 StopAcq pin, provided the signal level is suitable. Even if the control signal does not frame all the noise but frames at least some of it, greater accuracy will be obtained by using the StopAcq feature.

The StopAcq feature can be used with any signal to control the acquisition period of the AD7877. Its recommended use is in prevention of noise pickup from the LCD as described earlier, but that does not preclude its use for other purposes.

## FIRST CONVERSION DELAY

The nature of the touch screen measurement process means that voltages are being switched on and off the touch screen pins in rapid sequence. To get both X and Y positions, voltage needs to be switched across first the X then the Y layer, while the Y+ or X+ input is switched to the ADC. Once the voltages are switched, the input signal will require a settling time before it reaches its true value. Taking a measurement before the signal is settled gives an erroneous result.

The AD7877 can be programmed to add an automatic delay before each touch screen measurement commences. The delay should be long enough to allow the input signal to settle. The AD7877 first conversion delay can be 500 ns, 128  $\mu$ s, 1.024 ms, or 8.19 ms. The user should calculate the settling time of the input signal and then choose a first conversion delay that is at least as long. Note that the choice of first conversion delay will add to the total conversion time. The first conversion delay happens automatically before the first conversion is performed on the AD7877, before each touch screen positional measurement, and after the final conversion in a sequence.

Figure 2 graphically illustrates the effect of the first conversion delay on the accuracy of the touch screen results. The correct first conversion delay value for the particular touch screen used in this experiment is 1.024 ms. The samples taken from the touch screen using this value are in green and clearly show that all points on the touch screen can be measured correctly. Plenty of samples are gathered all over the screen.

If the first conversion delay is set too small, then the range of values read from the screen is severely limited. In this case, the signal has not had time to settle, so the input value is being measured while the signal is still ramping up to its true value. As illustrated by the red samples, vast areas of the screen will never register as being touched.

If the first conversion delay is too large, then not enough samples are measured to gain sufficient information from the screen. The black samples illustrate this. While positions from the full screen area can be measured, the time between samples is too great. If the touched position was to move quickly, not enough samples would be taken to track these changes. Applications such as writing on the screen would be impossible with too large a first conversion delay.

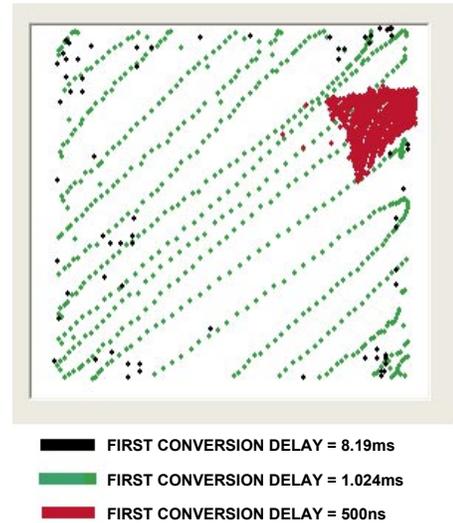


Figure 2. Effect of First Conversion Delay on Touch Screen Results

## ACQUISITION TIME

The AD7877 has sample-and-hold circuitry to control acquisition of the input signal. One of the most common errors made when integrating a touch screen into an application is miscalculation of the acquisition time required to capture the input signal correctly. The acquisition time depends on a number of factors, including the source impedance and capacitance of the input signal, and the input RC of the controller itself.

The addition of a low-pass filter to the touch screen pins has a large effect on the acquisition time. While a filter can help reduce noise, it also increases the acquisition time required to successfully measure the input signal. The user must remember to add any resistances or capacitances from these filters to their acquisition time calculation. For the AD7877, the following equation can be used to get a rough idea of the acquisition time required for an input signal for 12-bit accuracy.

$$t_{\text{ACQ}} \sim (R_{\text{IN}} + 100 \Omega) \times (C_{\text{IN}} + 30 \text{ pF}) \times 10$$

where:

$R_{\text{IN}}$  is the source impedance.

100  $\Omega$  is the input impedance of the AD7877.

$C_{\text{IN}}$  is the input capacitance of the source.

30 pF is the input capacitance of the AD7877.

The AD7877 allows the user to choose from acquisition times of 2  $\mu\text{s}$ , 4  $\mu\text{s}$ , 8  $\mu\text{s}$ , or 16  $\mu\text{s}$  by writing to an on-chip register. The user calculates the required acquisition time for the circuit, and picks the most suitable acquisition time from the options available on the AD7877.

## USING THE SEQUENCER AND TIMER

To minimize host intervention when the AD7877 is running, the part has an on-board sequencer and timer. These can be programmed by the user to ensure the AD7877 performs conversions automatically at set intervals, or when the screen is touched. The sequencer is used to choose which conversions occur in the sequence. This allows the AD7877 to run in a standalone mode, where the only host intervention required after setup is to read the result registers. The on-chip timer does not have to be used, but it can be set to expire every 512  $\mu\text{s}$ , 1.024 ms, or 8.19 ms.

There are two sequence registers on the AD7877. One of the sequence registers contains the conversion sequence for use when the screen is touched, known as master mode. The second sequence register contains the conversion sequence for use in slave mode. Each bit in the registers corresponds to a conversion on one of the AD7877's input channels. To add a conversion to the sequence, the corresponding bit in the sequence register is set. To remove the conversion from the sequence, the bit is cleared.

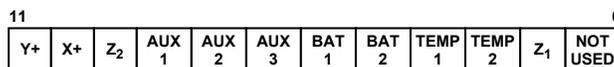


Figure 3. Sequence Register Bits

To trigger a conversion sequence every time the screen is touched, the AD7877 should be put into master mode by setting Bit 0 and Bit 1 of Control Register 1 to Control Register 11'b. Once the sequence of conversions is finished and the results are in the registers, the  $\overline{\text{DAV}}$  interrupt will signal to the host that new data is available. The sequence of conversions in the master mode sequence register will be repeated automatically every time the screen is touched. If the screen remains touched for a long time, for example, if someone is writing on the screen, then the timer can be used to trigger the sequence. However, when the screen is not being touched, the timer cannot trigger the conversion sequence. Master mode is useful for a number of applications. It can automatically gather positional data while a user writes on the screen. It requires little host intervention, as the AD7877 will only interrupt the host once new data is written to the registers when the screen is touched.

There is a second sequence register on the AD7877 for use in slave mode. The AD7877 can be placed into slave mode by setting Bit 0 and Bit 1 of the control register to 10'b. The conversion sequence in the slave mode sequence register is performed once when the part is put into slave mode. The sequence is repeated automatically when a timer event occurs, irrespective of whether the screen is touched or not. If the timer is not set, then the user needs to write to Control Register 1 again to trigger the slave mode sequence.

