

OVERDRIVING THE INPUTS TO THE ADS1210, ADS1211, ADS1212, AND ADS1213

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A common situation, yet undesirable condition, is to have the input signal of an A/D converter (such as one of Burr-Brown's delta-sigma converters) overdrive the input stage. A possible question that arises in this situation is "What will the output digital code become if the analog input is overdriven"? The differential analog input range of the ADS1210, ADS1211, ADS1212 and ADS1213 analog-to-digital converters, shown in Figure 1, can be configured to operate in a unipolar or bipolar mode. In the unipolar mode, the input range is generally 5Vp-p. For bipolar operation the input range is generally 10Vp-p. This is true if the PGA (internal Programmable Gain Amplifier) is programmed to be 1, $V_{REF} = 2.5V$, and a system calibration has not been performed. In this discussion, the differential input voltage is defined as $V_{INP} - V_{INM}$, where V_{INP} is defined as the voltage at the non-inverting input (A_{INP} or A_{INXP}) of the differential stage and V_{INM} is defined as the voltage on the inverting input (A_{INM} or A_{INXN}) with relation to ground. Regardless of this definition of the input voltage range of the converter, the actual acceptable input voltage limits of these devices is 0 to 5V (this discussion assumes that $V_{DD} = 5V$ and ground is defined as zero volts).

If either input exceeds these voltage values, the protection circuitry will be enabled. Every pin of these $\Delta\Sigma$ converters are ESD protected with the Burr-Brown's standard ESD protection cells shown in Figure 2. In the event of over voltage stress on the input pins, the ESD devices will forward bias. The product data sheets for these A/D converters recommend that the maximum and minimum limits of 0 to 5V on the inputs to the A/D converter not be exceeded by more than 0.3V. Conversely, the device inputs will also survive input or output currents of $\pm 10mA$, continuous. These restrictions are limited to continuous operation and are exclusive of the situation where electrostatic charge is momentarily injected into or out of these pins. In this instance, the ESD protection diodes are designed to accept these large, short spurts of energy and dissipate the heat quickly. The ADS1210, ADS1211, ADS1212, and ADS1213 have been tested and passed to human body and machine models.

Excluding ESD conditions, the case is examined where the $\Delta\Sigma$ A/D converter is being used under normal conditions (meaning non-ESD conditions) and the input of the device is

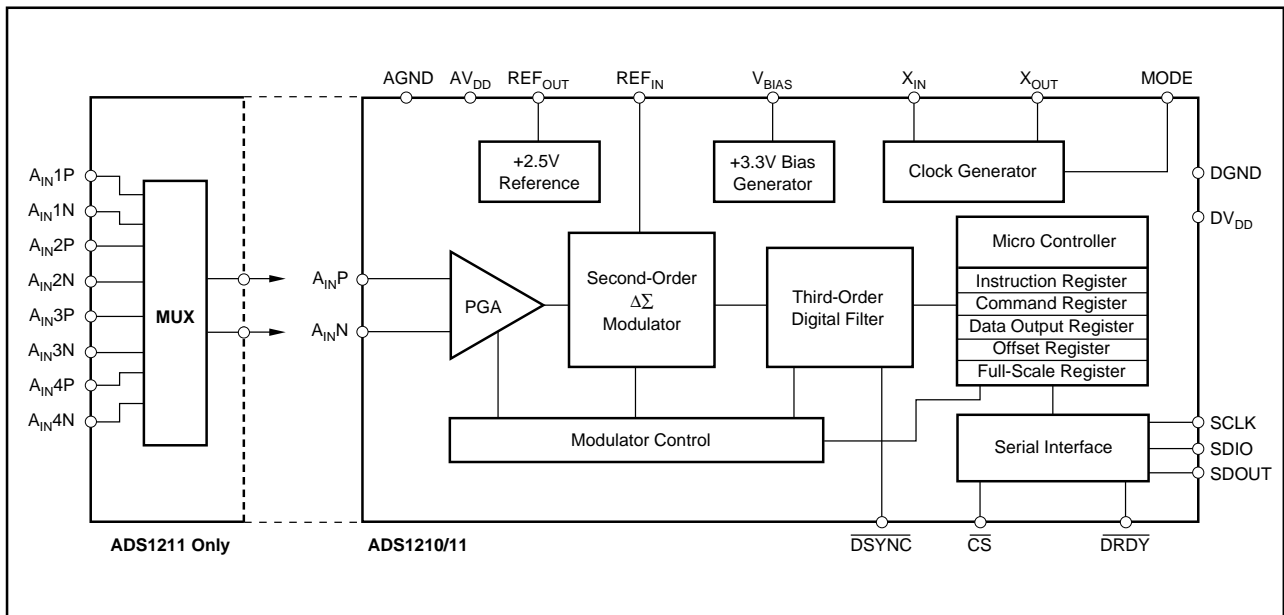


FIGURE 1. The ADS1210 and ADS1212 have one differential input to the device. The ADS1211 and ADS1213 have four differential inputs that are internally multiplexed to the single A/D converter in the chips.

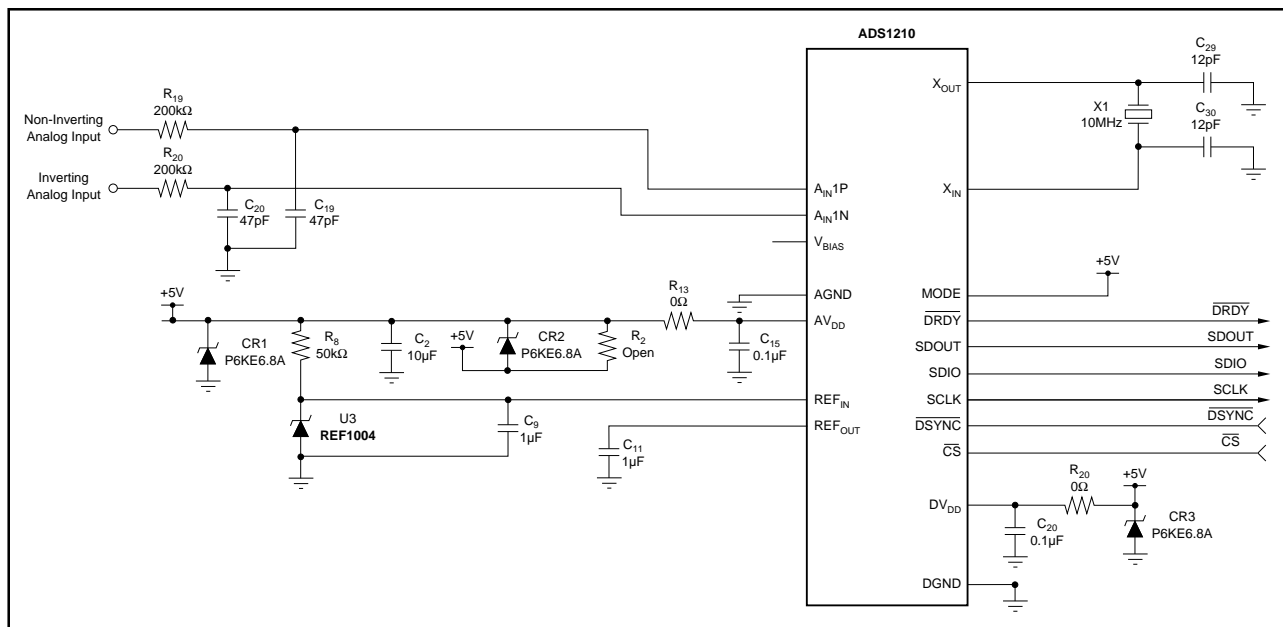


FIGURE 3. This is the recommended input configuration for these $\Delta\Sigma$ A/D converters. The R || C pair that is used at the inputs serves as an anti-aliasing filter. The resistors' secondary purpose is to limit the input current to the device during overvoltage situations.

overdriven by the input signal. In this situation, the internal ESD diodes will start to conduct once the input is below ground by approximately $-0.4V$. The ESD diode will be fully turned on at $0.7V$ below ground and essentially clamp the input to that value. Conversely, the inputs to these A/D converters will also conduct above the power supply voltage at approximately $V_{DD} + 0.4V$ and clamp at $V_{DD} + 0.7V$. If a series resistor (R_{19} or R_{20} as shown in Figure 3) is not included in the circuit signal path, currents from the signal source into or out of the A/D converter's inputs can become very large, very fast and possibly exceed the acceptable $\pm 10mA$ maximum continuous input current.

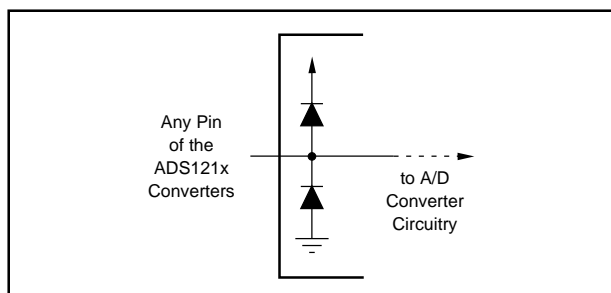


FIGURE 2. All pins on the ADS121x devices have this ESD protection cell to protect the device from static stress.

Because the input stage of these $\Delta\Sigma$ converters is differential, there are several possible input overdrive scenarios that can be evaluated. The first scenario is where the inverting input of the device is grounded and the non-inverting input

is exercised with a triangle wave that is centered around ground (Figures 4 and 5). This illustration will clearly demonstrate the action of the ESD diode and set the scene for the remainder of the discussion. The second configuration examined is where the inverting input is once again grounded and a bipolar input signal is applied to the non-inverting input, however, the A/D converter is programmed to operate in the unipolar mode instead of the previous configuration where the device was programmed to operate in the bipolar mode (Figure 6). Finally, the behavior of the device in an over drive condition is examined with both inputs tied together (Figure 7).

The test configuration for the data presented in this application note is shown in Figure 3. Although the ADS1211 is used as the test device for this evaluation, the data presented would hold true for all four products (ADS1210, ADS1211, ADS1212, and ADS1213). Several cases are examined in this application note in an attempt to anticipate as many conditions on the input of the A/D converter as possible. In all instances, the clock to the converter is 10MHz and the converter's output data rate is $5120\mu s/sample$.

In Figure 4, the ADS1211 is configured to operate in the bipolar mode. In this case the inverting input of the differential input stage of the converter (A_{IN1N}) is grounded with the input signal applied to the non-inverting input, A_{IN1P} . This input signal is a 1Hz, 2Vp-p triangle wave with no offset. The ADS command register is 01000010-00100000-00000000-01100100 which implies that the device is configured in the bipolar mode, $PGA = 1$, channel input = 1, and turbo mode = 1. There is a 200 Ω resistor in series with the input in conjunction with a 47pF capacitor. The R || C pair is primarily used as an anti-aliasing filter designed at 1.7MHz. The resistor's secondary purpose of this R || C pair serves as

a current limit resistor. As the input voltage crosses zero volts and the ESD protection diodes start to conduct, the 200Ω resistor provides a voltage drop between the signal source and the input of the converter. As long as the input signal is restricted to not exceed 2.7 volts below ground or above the supply, the current sourced or sunk by the input pins of the A/D converter will not exceed 10mA.

As shown in Figure 4, the digital output follows the input signal well below ground. At first glance of this wave form it appears as if the “bipolar mode” is not operating correctly. By definition the difference between the inputs of the A/D converter ($V_{INP} - V_{INM}$) should be represented with the appropriate digital word at the output of the converter. As shown in this example the differentiating action of the input stage of the A/D converter starts to break down when one of the inputs exceeds the absolute limits of that respective pin. In this case, A_{IN1P} has been driven below ground by the input signal. Again, the analog input signal is a symmetric triangle wave centered around ground (with no offset) and there is a 200Ω resistor at the input. The difference between the analog inputs of the A/D converter is recorded digitally, until the A_{IN1P} input breaks down and the ESD protection diode starts to conduct. When the ESD protection network finally clamps the A_{IN1P} pin the digital output of the converter becomes +full-scale. The approximate input current in this condition is equal to $(V_{IN} - 0.7V)/R_{IN}$ or 1.5mA.

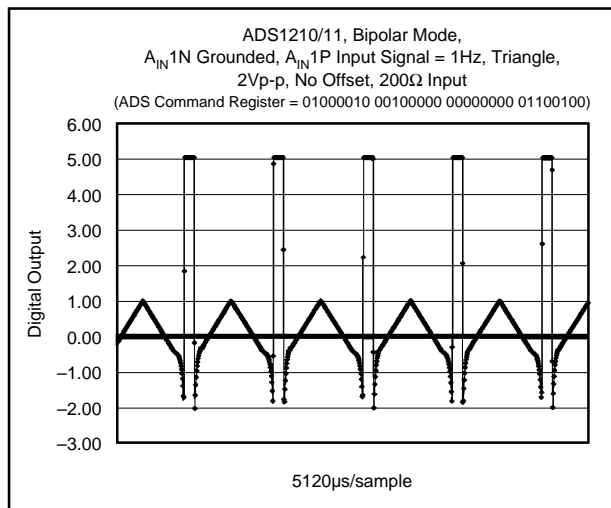


FIGURE 4. With the inverting input of the ADS1210 grounded, a triangle wave of 2Vp-p is presented, through a 200Ω resistor to the non-inverting input of the converter. The digital output on the y-axis has been calculated to decimal to represent the equivalent analog input.

A close look at this phenomena is shown in Figure 5. The external input resistor, R_{19} , plays a very big role in the operation of this error condition. As R_{19} is increased, it will have a larger voltage drop across it for the same amount of current that is conducting through the ESD protection devices. A larger resistor will prevent the device from folding back. In contrast the source impedance of the input signal also affects the normal operation and accuracy of the device.

During normal operation a portion of the signal can be lost across this external impedance.

If the A/D converter is configured to operate in the unipolar mode, the resulting digital output of a sine wave with the same magnitude as the previous triangle wave is shown in Figure 6. The data shown in Figure 6 does not imply that the input pin (A_{IN1P}) voltage does not go below ground. On the contrary, the digital conversion of the signal is not capable of providing a negative digital number that represents a negative difference between the inputs.

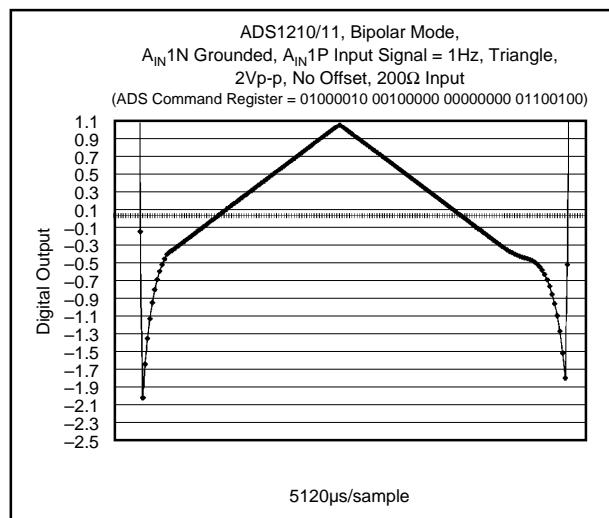


FIGURE 5. A close up of Figure 4 gives a better picture of the non-linearities that occur when the non-inverting input of the converter zero volts.

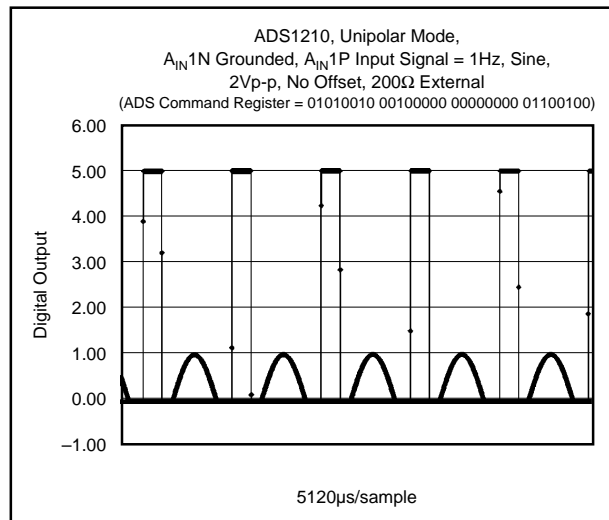


FIGURE 6. The ADS1210 is configured in the unipolar mode instead of the bipolar mode (as it was in Figure 4). The same hardware set-up is used, where the inverting input of the device is grounded and the non-inverting input is exercised. In this case, sine wave instead of a triangle wave is used for the input signal

Finally, both inputs of the converter are connected together and a sine wave that is symmetric about ground is applied to these inputs (Figure 7). Since there is no difference between the input pins, A_{IN1P} and A_{IN1N} , the digital output representation is zero. When the inputs go below ground they eventually cause the A/D converter to produce a full-scale output.

The best of all worlds is to not overdrive the input of these A/D converters beyond their absolute maximum or minimum limits. An alternative to increasing the input resistors, R_{19} and R_{20} , is to decrease the input range of the device by programming an internal gain or performing a system calibration that adds a gain and offset adjustment to every conversion. In both of these instances, the inputs can exceed the programmed input range without exceeding their absolute maximum (positive supply) and minimum (ground) voltage limitations. An added benefit of using one of these two methods is that linearity is not compromised by the conduction of the ESD protection network.

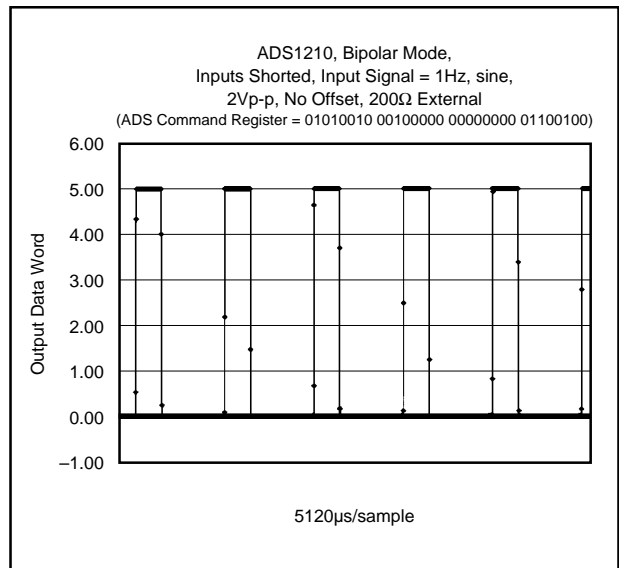


FIGURE 7. A sine wave is applied to both resistors at the input of the ADS1210. The converter is configured in the bipolar mode for this figure, however, there is no difference in performance between the bipolar mode and unipolar mode for this configuration.

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