National Semiconductor

January 14, 2010

ADC121S101

Single Channel, 0.5 to 1 Msps, 12-Bit A/D Converter

General Description

The ADC121S101 is a low-power, single channel CMOS 12-bit analog-to-digital converter with a high-speed serial interface. Unlike the conventional practice of specifying performance at a single sample rate only, the ADC121S101 is fully specified over a sample rate range of 500 ksps to 1 Msps. The converter is based upon a successive-approximation register architecture with an internal track-and-hold circuit.

The output serial data is straight binary, and is compatible with several standards, such as SPI™, QSPI™, MICROWIRE, and many common DSP serial interfaces.

The ADC121S101 operates with a single supply that can range from +2.7V to +5.25V. Normal power consumption using a +3V or +5V supply is 2.0 mW and 10 mW, respectively. The power-down feature reduces the power consumption to as low as 2.6 µW using a +5V supply.

The ADC121S101 is packaged in 6-lead LLP and SOT-23 packages. Operation over the industrial temperature range of −40°C to +125 °C is guaranteed.

Features

- Specified over a range of sample rates.
- 6-lead LLP and SOT-23 packages
- Variable power management
- Single power supply with 2.7V - 5.25V range
- SPI™/QSPI™/MICROWIRE/DSP compatible

Key Specifications

- DNL +0.5 / −0.3 LSB (typ)
- INL ±0.40 LSB (typ)
- SNR 72.5 dB (typ)
- Power Consumption
- — 3V Supply 2.0 mW (typ)
  — 5V Supply 10 mW (typ)

Applications

- Portable Systems
- Remote Data Acquisition
- Instrumentation and Control Systems

Pin-Compatible Alternatives by Resolution and Speed

All devices are fully pin and function compatible.

Resolution	Specified for Sample Rate Range of:		
	50 to 200 ksps	200 to 500 ksps	500 ksps to 1 Msps
12-bit	ADC121S021	ADC121S051	**ADC121S101**
10-bit	ADC101S021	ADC101S051	ADC101S101
8-bit	ADC081S021	ADC081S051	ADC081S101

Connection Diagram

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Ordering Information

Order Code	Temperature Range	Description	Top Mark
ADC121S101CISD	−40°C to +125 °C	6-Lead LLP Package	X1C
ADC121S101CISDX	−40°C to +125 °C	6-Lead LLP Package, Tape & Reel	X1C
ADC121S101CIMF	−40°C to +125 °C	6-Lead SOT-23 Package	X01C
ADC121S101CIMF	−40°C to +125 °C	6-Lead SOT-23 Package, Tape & Reel	X01C
ADC121S101EVAL		Evaluation Board	

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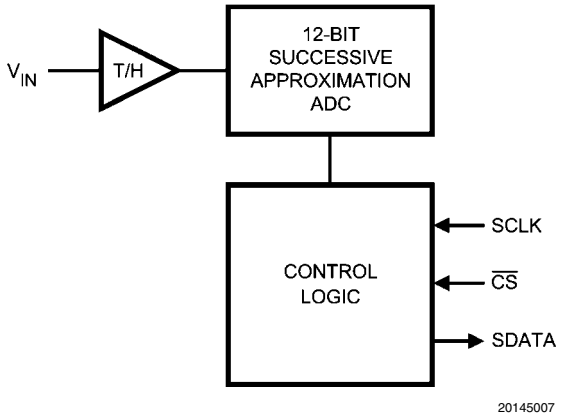
Block Diagram



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Pin Descriptions and Equivalent Circuits

Pin No.	Symbol	Description
ANALOG I/O		
3	V_{IN}	Analog input. This signal can range from 0V to V_A.
DIGITAL I/O		
4	SCLK	Digital clock input. This clock directly controls the conversion and readout processes.
5	SDATA	Digital data output. The output samples are clocked out of this pin on falling edges of the SCLK pin.
6	$\overline{CS}$	Chip select. On the falling edge of $\overline{CS}$, a conversion process begins.
POWER SUPPLY		
1	V_A	Positive supply pin. This pin should be connected to a quiet +2.7V to +5.25V source and bypassed to GND with a 1 µF capacitor and a 0.1 µF monolithic capacitor located within 1 cm of the power pin.
2	GND	The ground return for the supply and signals.
PAD	GND	For package suffix CISD(X) only, it is recommended that the center pad should be connected to ground.

Absolute Maximum Ratings (Note 1, Note 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Analog Supply Voltage V_A	−0.3V to 6.5V
Voltage on Any Digital Pin to GND	−0.3V to 6.5V
Voltage on Any Analog Pin to GND	−0.3V to (V_A +0.3V)
Input Current at Any Pin (Note 3)	±10 mA
Package Input Current (Note 3)	±20 mA
Power Consumption at T_A = 25°C	See (Note 4)
ESD Susceptibility (Note 5)	
Human Body Model	3500V
Machine Model	300V
Junction Temperature	+150°C
Storage Temperature	−65°C to +150°C

Operating Ratings (Note 1, Note 2)

Operating Temperature Range	−40°C ≤ T_A ≤ +125°C
V_A Supply Voltage	+2.7V to +5.25V
Digital Input Pins Voltage Range (regardless of supply voltage)	−0.3V to 5.25V
Analog Input Pins Voltage Range	0V to V_A
Clock Frequency	25 kHz to 20 MHz
Sample Rate	up to 1 Msps

Package Thermal Resistance

Package	θ_{JA}
6-lead LLP	94°C / W
6-lead SOT-23	265°C / W

Soldering process must comply with National Semiconductor's Reflow Temperature Profile specifications. Refer to www.national.com/packaging. (Note 6)

ADC121S101 Converter Electrical Characteristics (Note 7, Note 9)

The following specifications apply for V_A = +2.7V to 5.25V, GND = 0V, f_{SCLK} = 10 MHz to 20 MHz, C_L = 15 pF, f_{SAMPLE} = 500 ksps to 1 Msps, unless otherwise noted. **Boldface limits apply for T_A = -40°C to +85°C**: all other limits T_A = 25°C unless otherwise noted.

Symbol	Parameter	Conditions		Typical	Limits (Note 9)	Units
STATIC CONVERTER CHARACTERISTICS						
	Resolution with No Missing Codes	V_A = +2.7v to +3.6V −40°C ≤ T_A ≤ 125°C			12	Bits
INL	Integral Non-Linearity	−40°C ≤ T_A ≤ +85°C V_A = +2.7V to +3.6V	SOT-23	+0.4	**±1.0**	LSB (max)
				-0.4		LSB (min)
			LLP	+0.4	**+1.0**	LSB (max)
				-0.4	**-1.2**	LSB (min)
		T_A = 125°C V_A = +2.7v to +3.6V	SOT-23		+1.0	LSB (max)
					-1.1	LSB (min)
			LLP		+1.0	LSB (max)
					-1.3	LSB (min)
DNL	Differential Non-Linearity	−40°C ≤ T_A ≤ +85°C V_A = +2.7V to +3.6V		+0.5	**+1.0**	LSB (max)
				−0.3	**-0.9**	LSB (min)
		T_A = 125°C V_A = +2.7v to +3.6V			±1.0	LSB (max)
V_{OFF}	Offset Error	−40°C ≤ T_A ≤ 125°C V_A = +2.7v to +3.6V		±0.1	±1.2	LSB (max)
						LSB (min)
GE	Gain Error	−40°C ≤ T_A ≤ 125°C V_A = +2.7 to +3.6V	SOT-23	±0.20	±1.2	LSB (max)
			LLP	±0.20	±1.5	LSB (max)
DYNAMIC CONVERTER CHARACTERISTICS						
SINAD	Signal-to-Noise Plus Distortion Ratio	V_A = +2.7 to 5.25V −40°C ≤ T_A ≤ 125°C f_{IN} = 100 kHz, −0.02 dBFS		72	70	dB (min)
SNR	Signal-to-Noise Ratio	V_A = +2.7 to 5.25V −40°C ≤ T_A ≤ +85°C f_{IN} = 100 kHz, −0.02 dBFS		72.5	**70.8**	dB (min)
		V_A = +2.7 to 5.25V T_A = +125°C f_{IN} = 100 kHz, −0.02 dBFS			70.6	

Symbol	Parameter	Conditions	Typical	Limits (*Note 9*)	Units
THD	Total Harmonic Distortion	V_A = +2.7 to 5.25V f_{IN} = 100 kHz, −0.02 dBFS	−80		dB (max)
SFDR	Spurious-Free Dynamic Range	V_A = +2.7 to 5.25V f_{IN} = 100 kHz, −0.02 dBFS	82		dB (min)
ENOB	Effective Number of Bits	V_A = +2.7 to 5.25V f_{IN} = 100 kHz, −0.02 dBFS	11.6	**11.3**	Bits (min)
IMD	Intermodulation Distortion, Second Order Terms	V_A = +5.25V f_a = 103.5 kHz, f_b = 113.5 kHz	−78		dB
	Intermodulation Distortion, Third Order Terms	V_A = +5.25V f_a = 103.5 kHz, f_b = 113.5 kHz	−78		dB
FPBW	-3 dB Full Power Bandwidth	V_A = +5V	11		MHz
		V_A = +3V	8		MHz
ANALOG INPUT CHARACTERISTICS					
V_{IN}	Input Range		0 to V_A		V
I_{DCL}	DC Leakage Current			**±1**	µA (max)
C_{INA}	Input Capacitance	Track Mode	30		pF
		Hold Mode	4		pF
DIGITAL INPUT CHARACTERISTICS					
V_{IH}	Input High Voltage	V_A = +5.25V		**2.4**	V (min)
		V_A = +3.6V		**2.1**	V (min)
V_{IL}	Input Low Voltage	V_A = +5V		**0.8**	V (max)
		V_A = +3V		**0.4**	V (max)
I_{IN}	Input Current	V_{IN} = 0V or V_A	±0.1	**±1**	µA (max)
C_{IND}	Digital Input Capacitance		2	**4**	pF (max)
DIGITAL OUTPUT CHARACTERISTICS					
V_{OH}	Output High Voltage	I_{SOURCE} = 200 µA	V_A − 0.07	**V_A − 0.2**	V (min)
		I_{SOURCE} = 1 mA	V_A − 0.1		V
V_{OL}	Output Low Voltage	I_{SINK} = 200 µA	0.03	**0.4**	V (max)
		I_{SINK} = 1 mA	0.1		V
I_{OZH}, I_{OZL}	TRI-STATE® Leakage Current		±0.1	**±10**	µA (max)
C_{OUT}	TRI-STATE® Output Capacitance		2	**4**	pF (max)
	Output Coding		Straight (Natural) Binary		
POWER SUPPLY CHARACTERISTICS					
V_A	Supply Voltage			**2.7**	V (min)
				5.25	V (max)
I_A	Supply Current, Normal Mode (Operational, $\overline{CS}$ low)	V_A = +5.25V, f_{SAMPLE} = 1 Msps	2.0	**3.2**	mA (max)
		V_A = +3.6V, f_{SAMPLE} = 1 Msps	0.6	**1.5**	mA (max)
	Supply Current, Shutdown ($\overline{CS}$ high)	f_{SCLK} = 0 MHz, V_A = +5V, f_{SAMPLE} = 0 ksps	500		nA
		f_{SCLK} = 20 MHz, V_A = +5V, f_{SAMPLE} = 0 ksps	60		µA

Symbol	Parameter	Conditions	Typical	Limits (*Note 9*)	Units
P_D	Power Consumption, Normal Mode (Operational, $\overline{CS}$ low)	V_A = +5V	10	**16**	mW (max)
		V_A = +3V	2.0	**4.5**	mW (max)
	Power Consumption, Shutdown ($\overline{CS}$ high)	f_{SCLK} = 0 MHz, V_A = +5V f_{SAMPLE} = 0 ksps	2.5		µW
		f_{SCLK} = 20 MHz, V_A = +5V, f_{SAMPLE} = 0 ksps	300		µW
AC ELECTRICAL CHARACTERISTICS					
f_{SCLK}	Clock Frequency	(*Note 8*)		**10**	MHz (min)
				20	MHz (max)
f_S	Sample Rate	(*Note 8*)		**500**	ksps (min)
				1	Msps (max)
DC	SCLK Duty Cycle	f_{SCLK} = 20 MHz	50	**40**	% (min)
				60	% (max)
t_{ACQ}	Minimum Time Required for Acquisition			**350**	ns (max)
t_{QUIET}	(*Note 11*)			**50**	ns (min)
t_{AD}	Aperture Delay		3		ns
t_{AJ}	Aperture Jitter		30		ps

ADC121S101 Timing Specifications

The following specifications apply for V_A = +2.7V to 5.25V, GND = 0V, f_{SCLK} = 10.0 MHz to 20.0 MHz, C_L = 25 pF, f_{SAMPLE} = 500 ksps to 1 Msps, **Boldface limits apply for T_A = -40°C to +85°C**; all other limits T_A = 25°C.

Symbol	Parameter	Conditions	Typical	Limits	Units
t_{CS}	Minimum $\overline{CS}$ Pulse Width			**10**	ns (min)
t_{SU}	$\overline{CS}$ to SCLK Setup Time			**10**	ns (min)
t_{EN}	Delay from $\overline{CS}$ Until SDATA TRI-STATE® Disabled (*Note 12*)			**20**	ns (max)
t_{ACC}	Data Access Time after SCLK Falling Edge (*Note 13*)	V_A = +2.7 to +3.6		**40**	ns (max)
		V_A = +4.75 to +5.25		**20**	ns (max)
t_{CL}	SCLK Low Pulse Width			**0.4 x t_{SCLK}**	ns (min)
t_{CH}	SCLK High Pulse Width			**0.4 x t_{SCLK}**	ns (min)
t_H	SCLK to Data Valid Hold Time	V_A = +2.7V to +3.6V		**7**	ns (min)
		V_A = +4.75V to +5.25V		**5**	ns (min)
t_{DIS}	SCLK Falling Edge to SDATA High Impedance (*Note 14*)	V_A = +2.7V to +3.6V		**25** **6**	ns (max) ns (min)
		V_A = +4.75V to +5.25V		**25** **5**	ns (max) ns (min)
$t_{POWER-UP}$	Power-Up Time from Full Power-Down		1		µs

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

Note 2: All voltages are measured with respect to GND = 0V, unless otherwise specified.

Note 3: When the input voltage at any pin exceeds the power supply (that is, V_{IN} < GND or V_{IN} > V_A), the current at that pin should be limited to 10 mA. The 20 mA maximum package input current rating limits the number of pins that can safely exceed the power supplies with an input current of 10 mA to two. The Absolute Maximum Rating specification does not apply to the V_A pin. The current into the V_A pin is limited by the Analog Supply Voltage specification.

Note 4: The absolute maximum junction temperature ($T_J$max) for this device is 150°C. The maximum allowable power dissipation is dictated by $T_J$max, the junction-to-ambient thermal resistance (θ_{JA}), and the ambient temperature (T_A), and can be calculated using the formula $P_D$max = ($T_J$max – T_A) / θ_{JA}. The values for maximum power dissipation listed above will be reached only when the device is operated in a severe fault condition (e.g. when input or output pins are driven beyond the power supply voltages, or the power supply polarity is reversed). Obviously, such conditions should always be avoided.

Note 5: Human body model is 100 pF capacitor discharged through a 1.5 kΩ resistor. Machine model is 220 pF discharged through zero ohms.

Note 6: Reflow temperature profiles are different for lead-free and non-lead-free packages.

Note 7: Tested limits are guaranteed to National's AOQL (Average Outgoing Quality Level).

Note 8: This is the frequency range over which the electrical performance is guaranteed. The device is functional over a wider range which is specified under Operating Ratings.

Note 9: Data sheet min/max specification limits are guaranteed by design, test, or statistical analysis.

Note 10: This condition is for f_{SCLK} = 20 MHz.

Note 11: Minimum Quiet Time required by bus relinquish and the start of the next conversion.

Note 12: Measured with the timing test circuit shown in Figure 1 and defined as the time taken by the output signal to cross 1.0V.

Note 13: Measured with the timing test circuit shown in Figure 1 and defined as the time taken by the output signal to cross 1.0V or 2.0V.

Note 14: t_{DIS} is derived from the time taken by the outputs to change by 0.5V with the timing test circuit shown in Figure 1. The measured number is then adjusted to remove the effects of charging or discharging the output capacitance. This means that t_{DIS} is the true bus relinquish time, independent of the bus loading.

Timing Diagrams

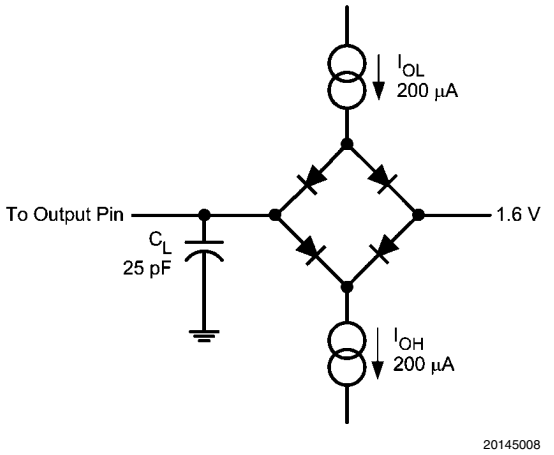


FIGURE 1. Timing Test Circuit

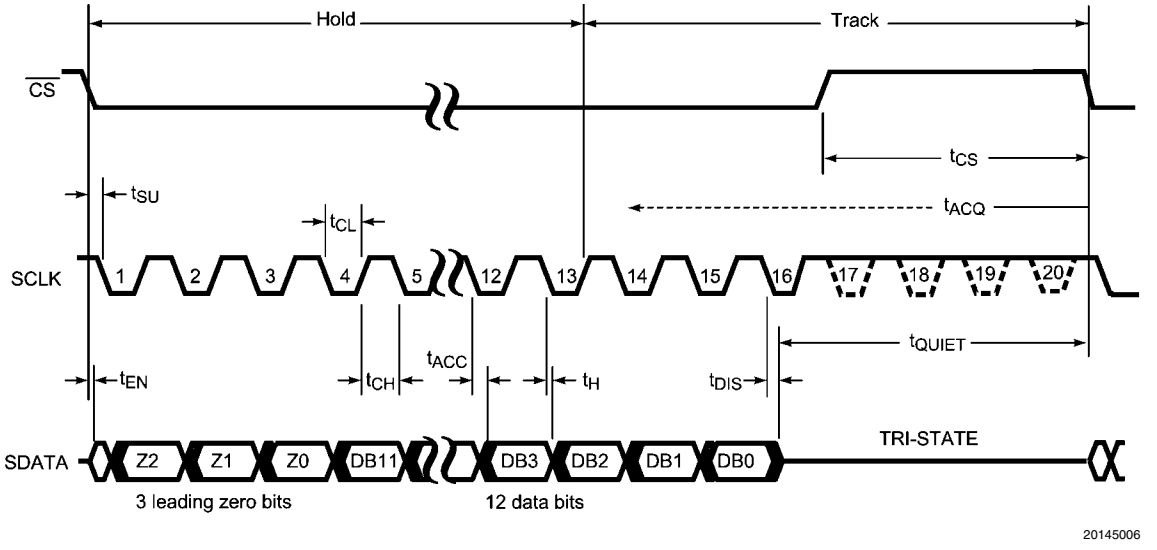


FIGURE 2. ADC121S101 Serial Timing Diagram

Specification Definitions

ACQUISITION TIME is the time required to acquire the input voltage. That is, it is time required for the hold capacitor to charge up to the input voltage. Acquisition time is measured backwards from the falling edge of $\overline{CS}$ when the signal is sampled and the part moves from Track to Hold. The start of the time interval that contains t_{ACQ} is the 13th rising edge of SCLK of the previous conversion when the part moves from hold to track. The user must ensure that the time between the 13th rising edge of SCLK and the falling edge of the next $\overline{CS}$ is not less than t_{ACQ} to meet performance specifications.

APERTURE DELAY is the time after the falling edge of $\overline{CS}$ to when the input signal is acquired or held for conversion.

APERTURE JITTER (APERTURE UNCERTAINTY) is the variation in aperture delay from sample to sample. Aperture jitter manifests itself as noise in the output.

CONVERSION TIME is the time required, after the input voltage is acquired, for the ADC to convert the input voltage to a digital word. This is from the falling edge of $\overline{CS}$ when the input signal is sampled to the 16th falling edge of SCLK when the SDATA output goes into TRI-STATE.

DIFFERENTIAL NON-LINEARITY (DNL) is the measure of the maximum deviation from the ideal step size of 1 LSB.

DUTY CYCLE is the ratio of the time that a repetitive digital waveform is high to the total time of one period. The specification here refers to the SCLK.

EFFECTIVE NUMBER OF BITS (ENOB, or EFFECTIVE BITS) is another method of specifying Signal-to-Noise and Distortion or SINAD. ENOB is defined as (SINAD – 1.76) / 6.02 and says that the converter is equivalent to a perfect ADC of this (ENOB) number of bits.

FULL POWER BANDWIDTH is a measure of the frequency at which the reconstructed output fundamental drops 3 dB below its low frequency value for a full scale input.

GAIN ERROR is the deviation of the last code transition (111...110) to (111...111) from the ideal (V_{REF} – 1.5 LSB), after adjusting for offset error.

INTEGRAL NON-LINEARITY (INL) is a measure of the deviation of each individual code from a line drawn from negative full scale (½ LSB below the first code transition) through positive full scale (½ LSB above the last code transition). The deviation of any given code from this straight line is measured from the center of that code value.

INTERMODULATION DISTORTION (IMD) is the creation of additional spectral components as a result of two sinusoidal frequencies being applied to the ADC input at the same time. It is defined as the ratio of the power in the second and third order intermodulation products to the sum of the power in both of the original frequencies. IMD is usually expressed in dB.

MISSING CODES are those output codes that will never appear at the ADC outputs. The ADC121S101 is guaranteed not to have any missing codes.

OFFSET ERROR is the deviation of the first code transition (000...000) to (000...001) from the ideal (i.e. GND + 0.5 LSB).

SIGNAL TO NOISE RATIO (SNR) is the ratio, expressed in dB, of the rms value of the input signal to the rms value of the sum of all other spectral components below one-half the sampling frequency, not including harmonics or d.c.

SIGNAL TO NOISE PLUS DISTORTION (S/N+D or SINAD) Is the ratio, expressed in dB, of the rms value of the input signal to the rms value of all of the other spectral components below half the clock frequency, including harmonics but excluding d.c.

SPURIOUS FREE DYNAMIC RANGE (SFDR) is the difference, expressed in dB, between the desired signal amplitude to the amplitude of the peak spurious spectral component, where a spurious spectral component is any signal present in the output spectrum that is not present at the input and may or may not be a harmonic.

TOTAL HARMONIC DISTORTION (THD) is the ratio, expressed in dB or dBc, of the rms total of the first five harmonic components at the output to the rms level of the input signal frequency as seen at the output. THD is calculated as

$$THD = 20 \cdot \log_{10} \sqrt{\frac{A_{f2}^2 + \ldots + A_{f6}^2}{A_{f1}^2}}$$

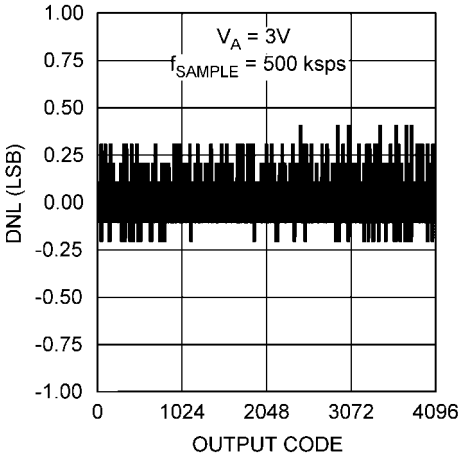
where A_{f1} is the RMS power of the input frequency at the output and A_{f2} through A_{f6} are the RMS power in the first 5 harmonic frequencies.

THROUGHPUT TIME is the minimum time required between the start of two successive conversion. It is the acquisition time plus the conversion time.

Typical Performance Characteristics

T_A = +25°C, f_{SAMPLE} = 500 ksps to 1 Msps, f_{SCLK} = 10 MHz to 20 MHz, f_{IN} = 100 kHz unless otherwise stated.

DNL
f_{SCLK} = 10 MHz



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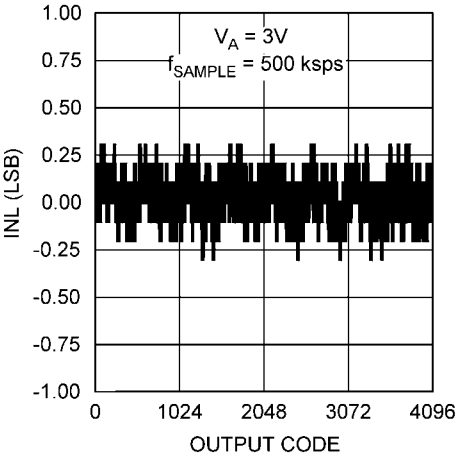
INL
f_{SCLK} = 10 MHz



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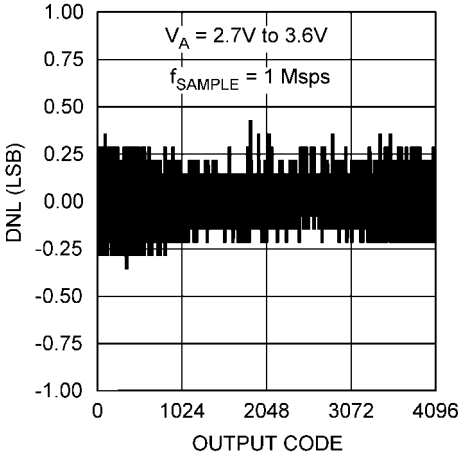
DNL
f_{SCLK} = 20 MHz



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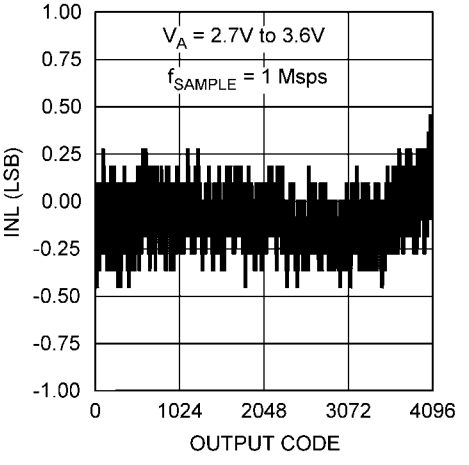
INL
f_{SCLK} = 20 MHz



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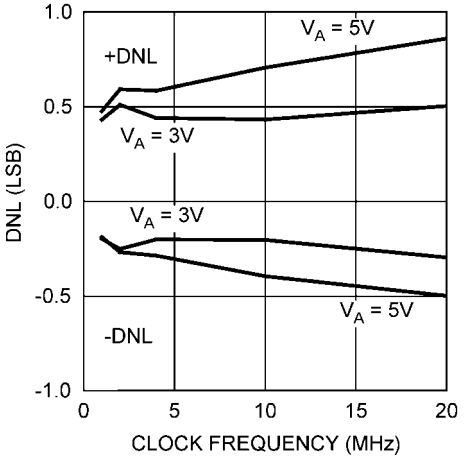
DNL vs. Clock Frequency



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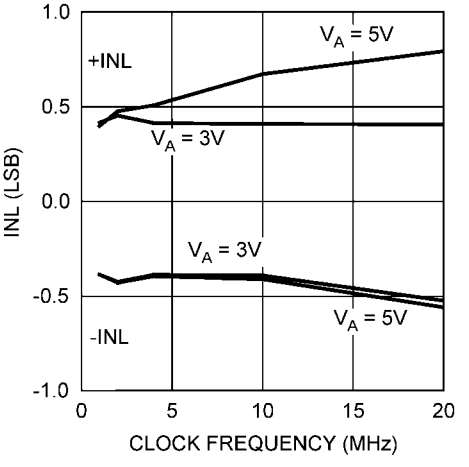
INL vs. Clock Frequency



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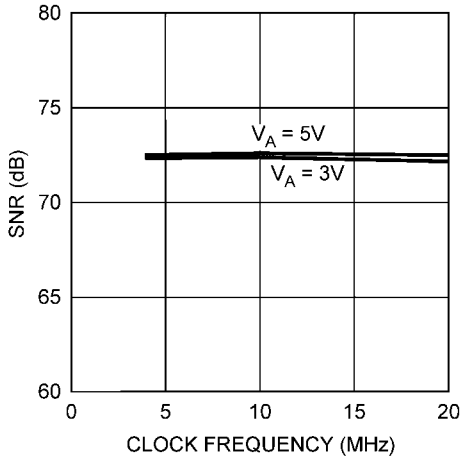
SNR vs. Clock Frequency



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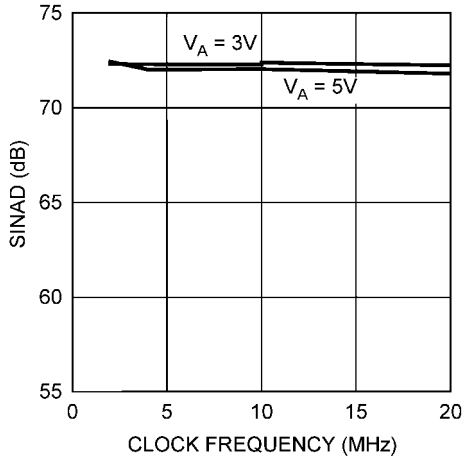
SINAD vs. Clock Frequency



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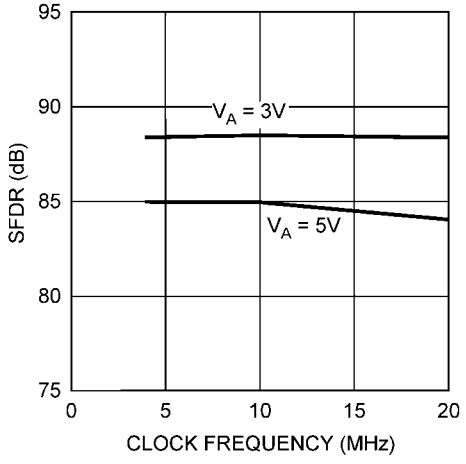
SFDR vs. Clock Frequency



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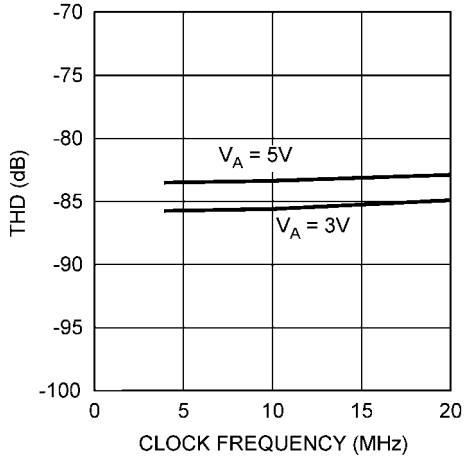
THD vs. Clock Frequency



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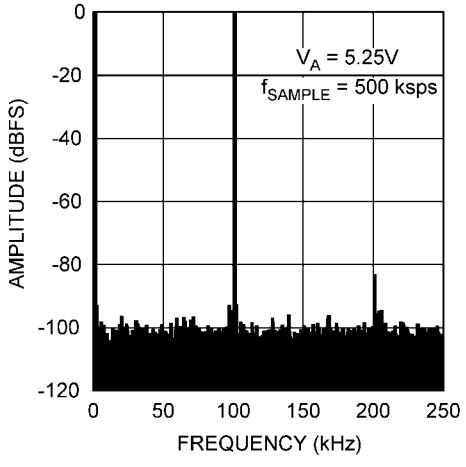
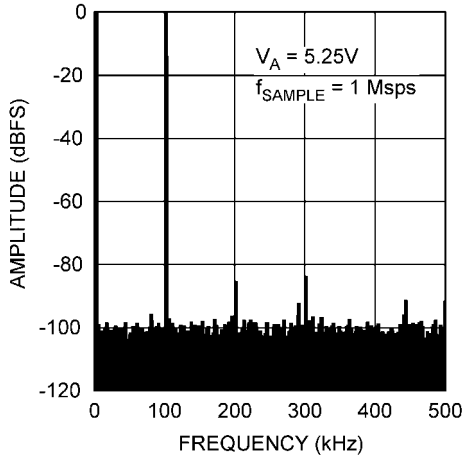
Spectral Response, V_A = 5.25V
f_{SCLK} = 10 MHz



20145069

Spectral Response, V_A = 5.25V
f_{SCLK} = 20 MHz



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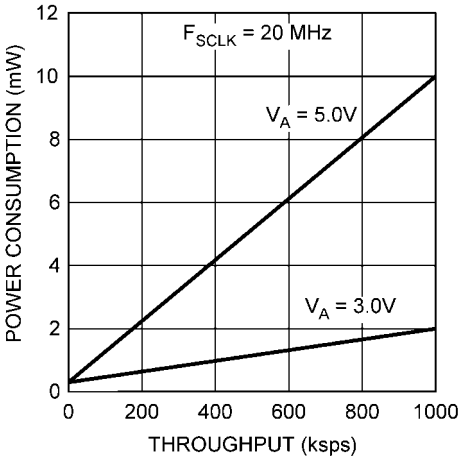
Power Consumption vs. Throughput, f_{SCLK} = 20 MHz



20145055

Applications Information

1.0 ADC121S101 OPERATION

The ADC121S101 is a successive-approximation analog-to-digital converter designed around a charge-redistribution digital-to-analog converter core. Simplified schematics of the ADC121S101 in both track and hold modes are shown in *Figure 3* and *Figure 4*, respectively. In *Figure 3*, the device is in track mode: switch SW1 connects the sampling capacitor to the input, and SW2 balances the comparator inputs. The device is in this state until $\overline{CS}$ is brought low, at which point the device moves to hold mode.

Figure 4 shows the device in hold mode: switch SW1 connects the sampling capacitor to ground, maintaining the sampled voltage, and switch SW2 unbalances the comparator. The control logic then instructs the charge-redistribution DAC to add or subtract fixed amounts of charge from the sampling capacitor until the comparator is balanced. When the comparator is balanced, the digital word supplied to the DAC is the digital representation of the analog input voltage. The device moves from hold mode to track mode on the 13th rising edge of SCLK.

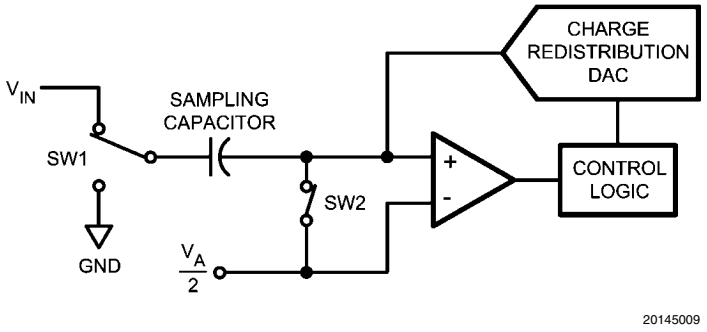


FIGURE 3. ADC121S101 in Track Mode

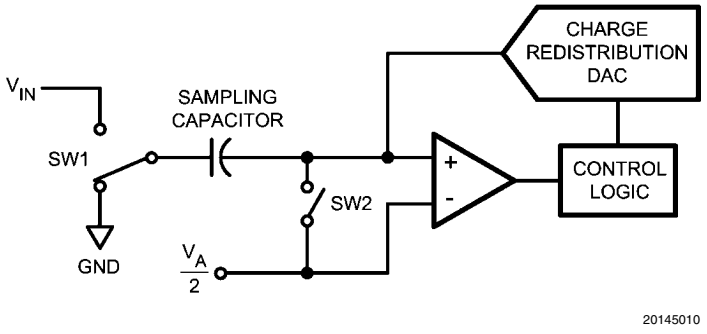


FIGURE 4. ADC121S101 in Hold Mode

2.0 USING THE ADC121S101

The serial interface timing diagram for the ADC is shown in *Figure 2*. $\overline{CS}$ is chip select, which initiates conversions on the ADC and frames the serial data transfers. SCLK (serial clock) controls both the conversion process and the timing of serial data. SDATA is the serial data out pin, where a conversion result is found as a serial data stream.

Basic operation of the ADC begins with $\overline{CS}$ going low, which initiates a conversion process and data transfer. Subsequent rising and falling edges of SCLK will be labelled with reference to the falling edge of $\overline{CS}$; for example, "the third falling edge of SCLK" shall refer to the third falling edge of SCLK after $\overline{CS}$ goes low.

At the fall of $\overline{CS}$, the SDATA pin comes out of TRI-STATE, and the converter moves from track mode to hold mode. The input signal is sampled and held for conversion on the falling edge of $\overline{CS}$. The converter moves from hold mode to track mode on the 13th rising edge of SCLK (see *Figure 2*). It is at this point that the interval for the t_{ACQ} specification begins. In the worst case, 350ns must pass between the 13th rising edge and the next falling edge of SCLK. The SDATA pin will be placed back into TRI-STATE after the 16th falling edge of SCLK, or at the rising edge of $\overline{CS}$, whichever occurs first. After a conversion is completed, the quiet time t_{QUIET} must be satisfied before bringing $\overline{CS}$ low again to begin another conversion.

Sixteen SCLK cycles are required to read a complete sample from the ADC. The sample bits (including leading zeroes) are clocked out on falling edges of SCLK, and are intended to be clocked in by a receiver on subsequent falling edges of SCLK. The ADC will produce three leading zero bits on SDATA, followed by twelve data bits, most significant first.

If $\overline{CS}$ goes low before the rising edge of SCLK, an additional (fourth) zero bit may be captured by the next falling edge of SCLK.

2.1 Determining Throughput

Throughput depends on the frequency of SCLK and how much time is allowed to elapse between the end of one conversion and the start of another. At the maximum specified

SCLK frequency, the maximum guaranteed throughput is obtained by using a 20 SCLK frame. As shown in *Figure 2*, the minimum allowed time between $\overline{CS}$ falling edges is determined by 1) 12.5 SCLKs for Hold mode, 2) the larger of two quantities: either the minimum required time for Track mode (t_{ACQ}) or 2.5 SCLKs to finish reading the result and 3) 0, 1/2 or 1 SCLK padding to ensure an even number of SCLK cycles so there is a falling SCLK edge when $\overline{CS}$ next falls.

For example, at the fastest rate for this family of parts, SCLK is 20MHz and 2.5 SCLKs are 125ns, so the minimum time between $\overline{CS}$ falling edges is calculated by

12.5*50ns + 350ns + 0.5*50ns = 1000ns

(12.5 SCLKs + t_{ACQ} + 1/2 SCLK) which corresponds to a maximum throughput of 1MSPS. At the slowest rate for this family, SCLK is 1MHz. Using a 20 cycle conversion frame as shown in *Figure 2* yields a 20µs time between $\overline{CS}$ falling edges for a throughput of 50KSPS.

It is possible, however, to use fewer than 20 clock cycles provided the timing parameters are met. With a 1MHz SCLK, there are 2500ns in 2.5 SCLK cycles, which is greater than t_{ACQ}. After the last data bit has come out, the clock will need one full cycle to return to a falling edge. Thus the total time between falling edges of $\overline{CS}$ is 12.5*1µs +2.5*1µs +1*1µs=16µs which is a throughput of 62.5KSPS.

3.0 ADC TRANSFER FUNCTION

The output format of the ADC is straight binary. Code transitions occur midway between successive integer LSB values. The LSB width for the ADC is V_A/4096. The ideal transfer characteristic is shown in *Figure 5*. The transition from an output code of 0000 0000 0000 to a code of 0000 0000 0001 is at 1/2 LSB, or a voltage of V_A/8192. Other code transitions occur at steps of one LSB.

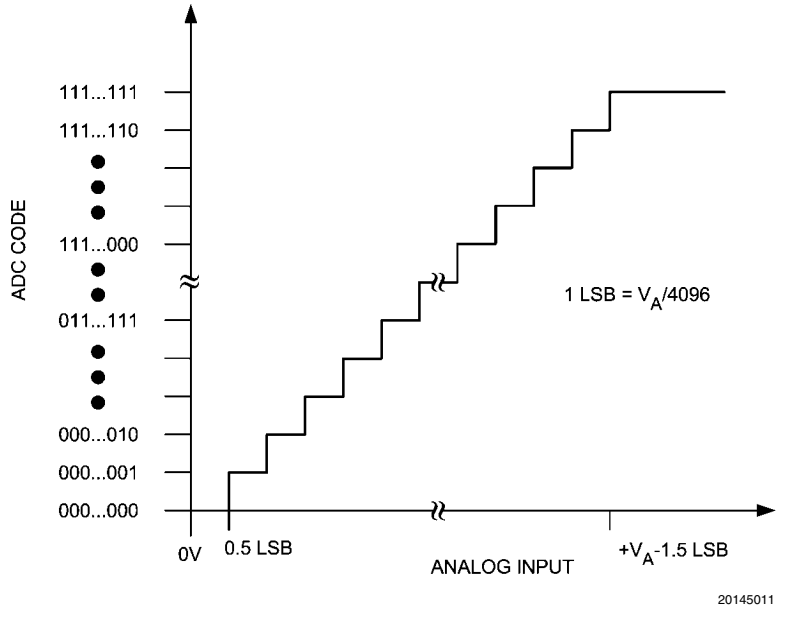


FIGURE 5. Ideal Transfer Characteristic

4.0 TYPICAL APPLICATION CIRCUIT

A typical application of the ADC is shown in *Figure 6*. Power is provided in this example by the National Semiconductor LP2950 low-dropout voltage regulator, available in a variety of fixed and adjustable output voltages. The power supply pin is bypassed with a capacitor network located close to the ADC. Because the reference for the ADC is the supply voltage, any noise on the supply will degrade device noise performance. To keep noise off the supply, use a dedicated linear regulator for this device, or provide sufficient decoupling from other circuitry to keep noise off the ADC supply pin. Because of the ADC's low power requirements, it is also possible to use a precision reference as a power supply to maximize performance. The three-wire interface is shown connected to a microprocessor or DSP.

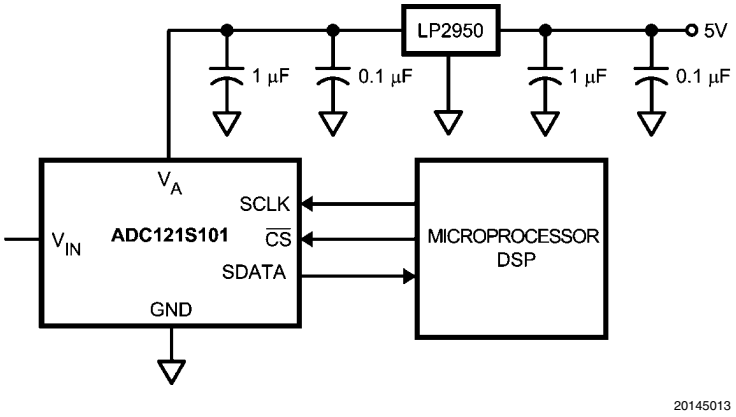


FIGURE 6. Typical Application Circuit

5.0 ANALOG INPUTS

An equivalent circuit for the ADC's input is shown in *Figure 7*. Diodes D1 and D2 provide ESD protection for the analog inputs. At no time should the analog input go beyond (V_A + 300 mV) or (GND – 300 mV), as these ESD diodes will begin conducting, which could result in erratic operation. For this reason, the ESD diodes should not be used to clamp the input signal.

The capacitor C1 in *Figure 7* has a typical value of 4 pF, and is mainly the package pin capacitance. Resistor R1 is the on resistance of the track / hold switch, and is typically 500Ω. Capacitor C2 is the ADC sampling capacitor and is typically 26 pF. The ADC will deliver best performance when driven by a low-impedance source to eliminate distortion caused by the charging of the sampling capacitance. This is especially important when using the ADC to sample AC signals. Also important when sampling dynamic signals is an anti-aliasing filter.

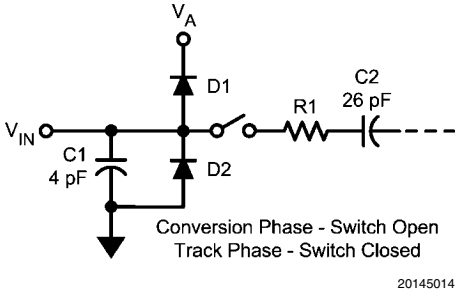


FIGURE 7. Equivalent Input Circuit

6.0 DIGITAL INPUTS AND OUTPUTS

The ADC digital inputs (SCLK and $\overline{CS}$) are not limited by the same maximum ratings as the analog inputs. The digital input pins are instead limited to +5.25V with respect to GND, regardless of V_A, the supply voltage. This allows the ADC to be interfaced with a wide range of logic levels, independent of the supply voltage.

7.0 MODES OF OPERATION

The ADC has two possible modes of operation: normal mode, and shutdown mode. The ADC enters normal mode (and a conversion process is begun) when $\overline{CS}$ is pulled low. The device will enter shutdown mode if $\overline{CS}$ is pulled high before the tenth falling edge of SCLK after $\overline{CS}$ is pulled low, or will stay in normal mode if $\overline{CS}$ remains low. Once in shutdown mode, the device will stay there until $\overline{CS}$ is brought low again. By varying the ratio of time spent in the normal and shutdown modes, a system may trade-off throughput for power consumption, with a sample rate as low as zero.

7.1 Normal Mode

The fastest possible throughput is obtained by leaving the ADC in normal mode at all times, so there are no power-up delays. To keep the device in normal mode continuously, $\overline{CS}$ must be kept low until after the 10th falling edge of SCLK after the start of a conversion (remember that a conversion is initiated by bringing $\overline{CS}$ low).

If $\overline{CS}$ is brought high after the 10th falling edge, but before the 16th falling edge, the device will remain in normal mode, but the current conversion will be aborted, and SDATA will return to TRI-STATE (truncating the output word).

Sixteen SCLK cycles are required to read all of a conversion word from the device. After sixteen SCLK cycles have elapsed, $\overline{CS}$ may be idled either high or low until the next conversion. If $\overline{CS}$ is idled low, it must be brought high again before the start of the next conversion, which begins when $\overline{CS}$ is again brought low.

After sixteen SCLK cycles, SDATA returns to TRI-STATE. Another conversion may be started, after t_{QUIET} has elapsed, by bringing $\overline{CS}$ low again.

7.2 Shutdown Mode

Shutdown mode is appropriate for applications that either do not sample continuously, or it is acceptable to trade throughput for power consumption. When the ADC is in shutdown mode, all of the analog circuitry is turned off.

To enter shutdown mode, a conversion must be interrupted by bringing $\overline{CS}$ high anytime between the second and tenth falling edges of SCLK, as shown in *Figure 8*. Once $\overline{CS}$ has been brought high in this manner, the device will enter shutdown mode; the current conversion will be aborted and SDATA will enter TRI-STATE. If $\overline{CS}$ is brought high before the second falling edge of SCLK, the device will not change mode; this is to avoid accidentally changing mode as a result of noise on the $\overline{CS}$ line.

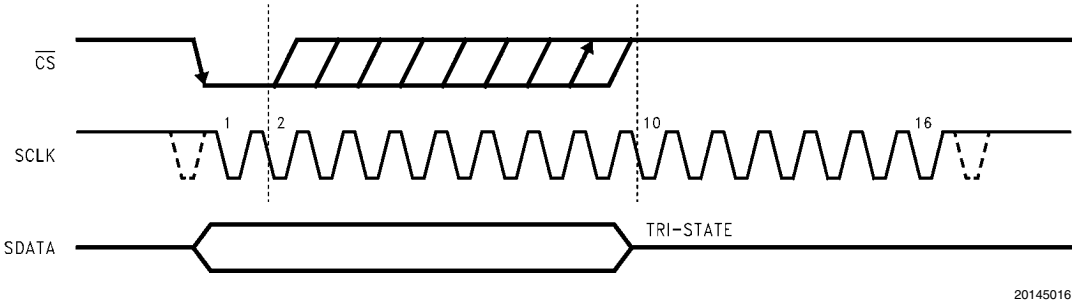


FIGURE 8. Entering Shutdown Mode

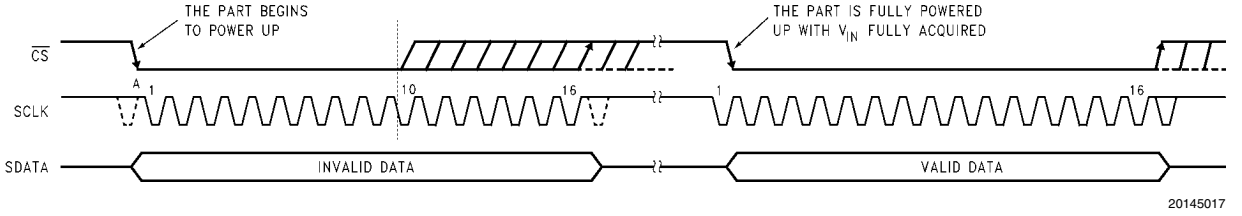


FIGURE 9. Entering Normal Mode

To exit shutdown mode, bring $\overline{CS}$ back low. Upon bringing $\overline{CS}$ low, the ADC will begin powering up (power-up time is specified in the Timing Specifications table). This power-up delay results in the first conversion result being unusable. The second conversion performed after power-up, however, is valid, as shown in *Figure 9*.

If $\overline{CS}$ is brought back high before the 10th falling edge of SCLK, the device will return to shutdown mode. This is done to avoid accidentally entering normal mode as a result of noise on the $\overline{CS}$ line. To exit shutdown mode and remain in normal mode, $\overline{CS}$ must be kept low until after the 10th falling edge of SCLK. The ADC will be fully powered-up after 16 SCLK cycles.

8.0 POWER MANAGEMENT

The ADC takes time to power-up, either after first applying V_A, or after returning to normal mode from shutdown mode. This corresponds to one "dummy" conversion for any SCLK frequency within the specifications in this document. After this first dummy conversion, the ADC will perform conversions properly. Note that the t_{QUIET} time must still be included between the first dummy conversion and the second valid conversion.

When the V_A supply is first applied, the ADC may power up in either of the two modes: normal or shutdown. As such, one dummy conversion should be performed after start-up, as described in the previous paragraph. The part may then be placed into either normal mode or the shutdown mode, as described in Sections 7.1 and 7.2.

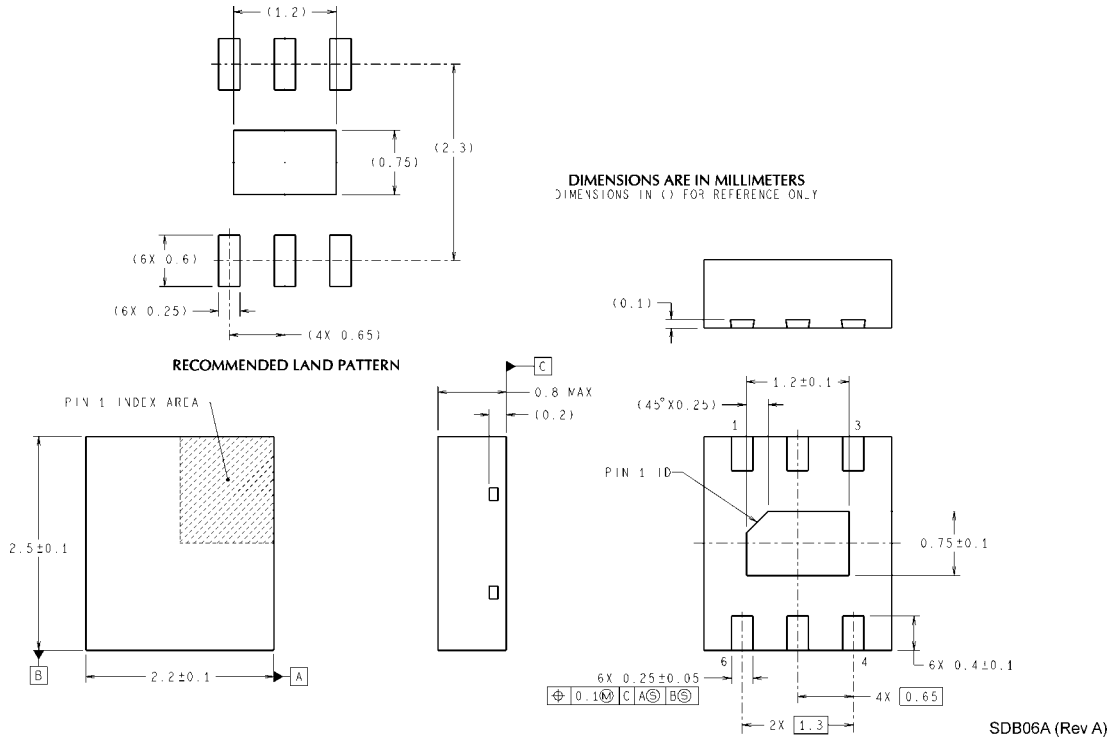
When the ADC is operated continuously in normal mode, the maximum throughput is f_{SCLK} / 20 at the maximum specified f_{SCLK}. Throughput may be traded for power consumption by running f_{SCLK} at its maximum specified rate and performing fewer conversions per unit time, raising the ADC $\overline{CS}$ line after the 10th and before the 15th fall of SCLK of each conversion. A plot of typical power consumption versus throughput is shown in the Typical Performance Curves section. To calculate the power consumption for a given throughput, multiply the fraction of time spent in the normal mode by the normal mode power consumption and add the fraction of time spent in shutdown mode multiplied by the shutdown mode power consumption. Note that the curve of power consumption vs. throughput is essentially linear. This is because the power consumption in the shutdown mode is so small that it can be ignored for all practical purposes.

9.0 POWER SUPPLY NOISE CONSIDERATIONS

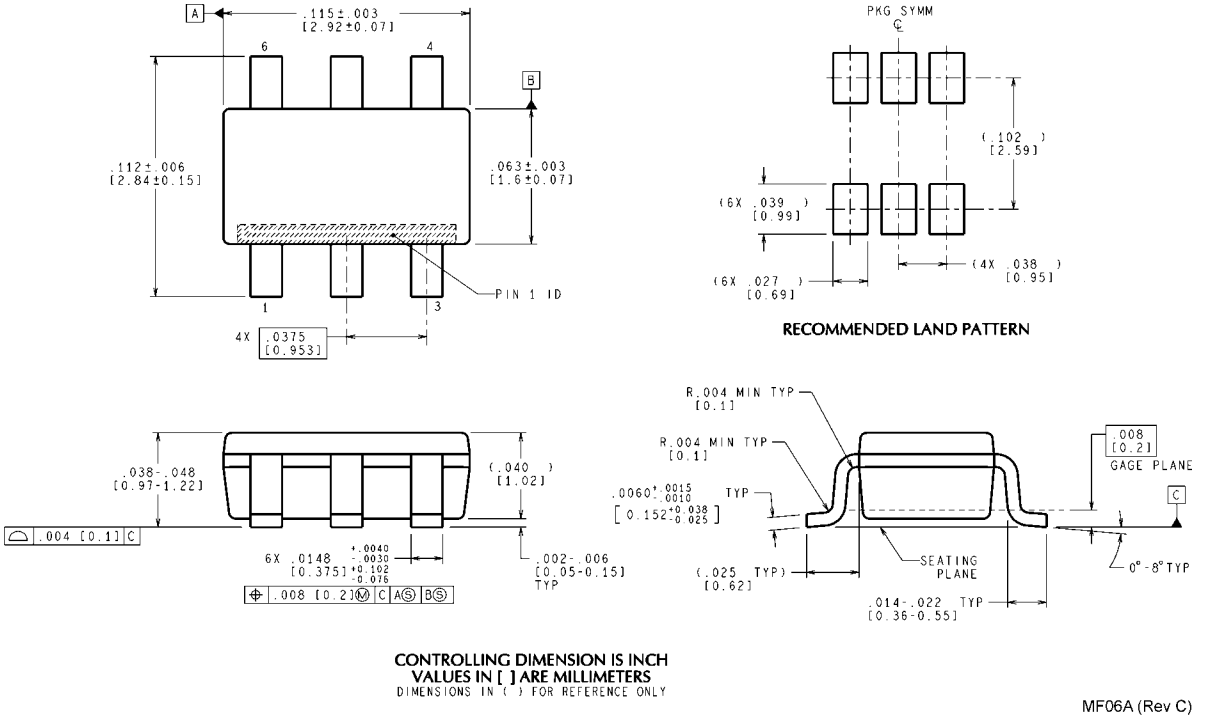
The charging of any output load capacitance requires current from the power supply, V_A. The current pulses required from the supply to charge the output capacitance will cause voltage variations on the supply. If these variations are large enough, they could degrade SNR and SINAD performance of the ADC. Furthermore, discharging the output capacitance when the digital output goes from a logic high to a logic low will dump current into the die substrate, which is resistive. Load discharge currents will cause "ground bounce" noise in the substrate that will degrade noise performance if that current is large enough. The larger the output capacitance, the more current flows through the die substrate and the greater is the noise coupled into the analog channel, degrading noise performance.

To keep noise out of the power supply, keep the output load capacitance as small as practical. It is good practice to use a 100 Ω series resistor at the ADC output, located as close to the ADC output pin as practical. This will limit the charge and discharge current of the output capacitance and improve noise performance.

Physical Dimensions inches (millimeters) unless otherwise noted



6-Lead LLP
Order Number ADC121S101CISD or ADC121S101CISDX
NS Package Number SDB06A



6-Lead SOT-23
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NS Package Number MF06A

Notes

Notes

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