Burr-Brown Products from Texas Instruments

ADS8341

16-Bit, 4-Channel Serial Output Sampling ANALOG-TO-DIGITAL CONVERTER

FEATURES

- PIN FOR PIN WITH ADS7841
- SINGLE SUPPLY: 2.7V to 5V
- 4-CHANNEL SINGLE-ENDED OR 2-CHANNEL DIFFERENTIAL INPUT
- UP TO 100kHz CONVERSION RATE
- 86dB SINAD
- SERIAL INTERFACE
- SSOP-16 PACKAGE

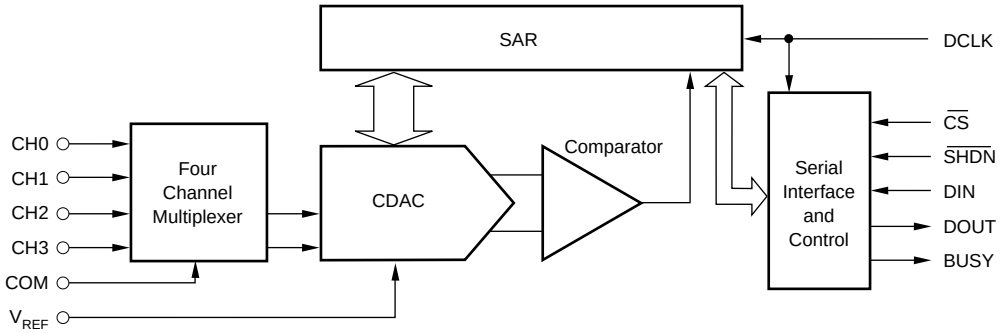
APPLICATIONS

- DATA ACQUISITION
- TEST AND MEASUREMENT
- INDUSTRIAL PROCESS CONTROL
- PERSONAL DIGITAL ASSISTANTS
- BATTERY-POWERED SYSTEMS

DESCRIPTION

The ADS8341 is a 4-channel, 16-bit sampling analog-to-digital converter (ADC) with a synchronous serial interface. Typical power dissipation is 8mW at a 100kHz throughput rate and a +5V supply. The reference voltage (V_{REF}) can be varied between 500mV and V_{CC}, providing a corresponding input voltage range of 0V to V_{REF}. The device includes a shutdown mode which reduces power dissipation to under 15µW. The ADS8341 is guaranteed down to 2.7V operation.

Low power, high speed, and on-board multiplexer make the ADS8341 ideal for battery operated systems such as personal digital assistants, portable multi-channel data loggers, and measurement equipment. The serial interface also provides low-cost isolation for remote data acquisition. The ADS8341 is available in a SSOP-16 package and is guaranteed over the –40°C to +85°C temperature range.



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PDS-1566A Printed in U.S.A. September, 2000

SPECIFICATION: +5V

At T_A = –40°C to +85°C, $+V_{CC}$ = +5V, V_{REF} = +5V, f_{SAMPLE} = 100kHz, and f_{CLK} = 24 • f_{SAMPLE} = 2.4MHz, unless otherwise noted.

PARAMETER	CONDITIONS	ADS8341E, P			ADS8341EB, PB			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
RESOLUTION				**16**			*	**BITS**
ANALOG INPUT								
Full-Scale Input Span	Positive Input - Negative Input	0		V_{REF}	*		*	V
Absolute Input Range	Positive Input	–0.2		$+V_{CC}$ +0.2	*		*	V
	Negative Input	–0.2		+1.25	*		*	V
Capacitance			25			*		pF
Leakage Current			±1			*		µA
SYSTEM PERFORMANCE								
No Missing Codes		14			15			Bits
Integral Linearity Error				±8			±6	LSB
Offset Error				±2			±1	mV
Offset Error Match			1.2	4.0		*	*	LSB(1)
Gain Error				±0.05			±0.024	%
Gain Error Match			1.0	4.0		*	*	LSB
Noise			20			*		µVrms
Power Supply Rejection	+4.75V < V_{CC} < 5.25V		3			*		LSB(1)
SAMPLING DYNAMICS								
Conversion Time				16			*	Clk Cycles
Acquisition Time		4.5			*			Clk Cycles
Throughput Rate				100			*	kHz
Multiplexer Settling Time			500			*		ns
Aperture Delay			30			*		ns
Aperture Jitter			100			*		ps
Internal Clock Frequency	$\overline{SHDN}$ = V_{DD}		2.4			*		MHz
External Clock Frequency		0.024		2.4	*		*	MHz
	Data Transfer Only	0		2.4	*		*	MHz
DYNAMIC CHARACTERISTICS								
Total Harmonic Distortion(2)	V_{IN} = 5Vp-p at 10kHz		–90			*		dB
Signal-to-(Noise + Distortion)	V_{IN} = 5Vp-p at 10kHz		86			*		dB
Spurious Free Dynamic Range	V_{IN} = 5Vp-p at 10kHz		92			*		dB
Channel-to-Channel Isolation	V_{IN} = 5Vp-p at 50kHz		100			*		dB
REFERENCE INPUT								
Range		0.5		$+V_{CC}$	*		*	V
Resistance	DCLK Static		5			*		GΩ
Input Current			40	100		*	*	µA
	f_{SAMPLE} = 12.5kHz		2.5			*		µA
	DCLK Static		0.001	3		*	*	µA
DIGITAL INPUT/OUTPUT								
Logic Family			CMOS			*		
Logic Levels								
V_{IH}	| I_{IH} | ≤ +5µA	3.0		5.5	*		*	V
V_{IL}	| I_{IL} | ≤ +5µA	–0.3		+0.8	*		*	V
V_{OH}	I_{OH} = –250µA	3.5			*			V
V_{OL}	I_{OL} = 250µA			0.4			*	V
Data Format			Straight Binary			*		
POWER SUPPLY REQUIREMENTS								
$+V_{CC}$	Specified Performance	4.75		5.25	*		*	V
Quiescent Current			1.5	2.0			*	mA
	f_{SAMPLE} = 12.5kHz		300			*		µA
	Power-Down Mode(3), $\overline{CS}$ = $+V_{CC}$			3			*	µA
Power Dissipation			7.5	10			*	mW
TEMPERATURE RANGE								
Specified Performance		–40		+85	*		*	°C

* Same specifications as ADS8341E.

NOTES: (1) LSB means Least Significant Bit. With V_{REF} equal to +5.0V, one LSB is 76µV. (2) First five harmonics of the test frequency. (3) Auto power-down mode (PD1 = PD0 = 0) active or $\overline{SHDN}$ = GND.

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SPECIFICATION: +2.7V

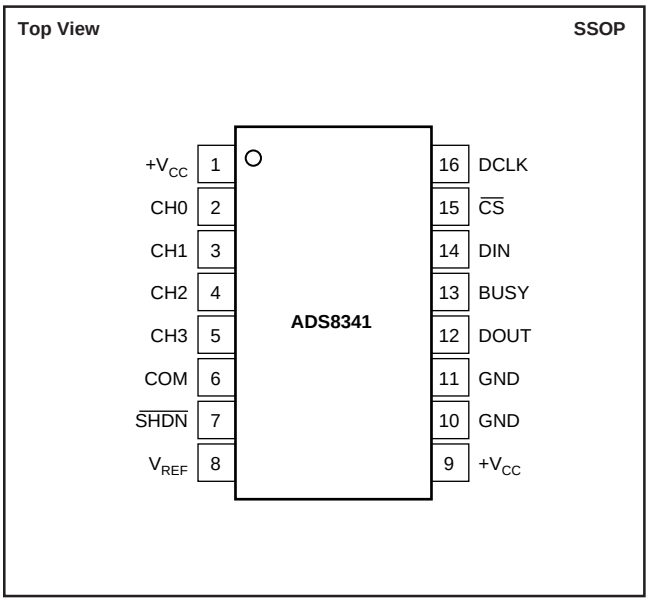
At T_A = –40°C to +85°C, $+V_{CC}$ = +2.7V, V_{REF} = +2.5V, f_{SAMPLE} = 100kHz, and f_{CLK} = 24 • f_{SAMPLE} = 2.4MHz, unless otherwise noted.

PARAMETER	CONDITIONS	ADS8341E, P			ADS8341EB, PB			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
RESOLUTION				**16**			✻	**BITS**
ANALOG INPUT								
Full-Scale Input Span	Positive Input - Negative Input	0		V_{REF}	✻		✻	V
Absolute Input Range	Positive Input	–0.2		$+V_{CC}$ +0.2	✻		✻	V
	Negative Input	–0.2		+0.2	✻		✻	V
Capacitance			25			✻		pF
Leakage Current			±1			✻		µA
SYSTEM PERFORMANCE								
No Missing Codes		14			15			Bits
Integral Linearity Error				±12			±8	LSB
Offset Error				±1			±0.5	mV
Offset Error Match			1.2	4.0		✻	✻	LSB
Gain Error				±0.05			±0.0024	% of FSR
Gain Error Match			1.0	4.0		✻	✻	LSB
Noise			20			✻		µVrms
Power Supply Rejection	$+2.7 < V_{CC} < +3.3V$		3			✻		LSB[1]
SAMPLING DYNAMICS								
Conversion Time				16			✻	Clk Cycles
Acquisition Time		4.5			✻			Clk Cycles
Throughput Rate				100			✻	kHz
Multiplexer Settling Time			500			✻		ns
Aperture Delay			30			✻		ns
Aperture Jitter			100			✻		ps
Internal Clock Frequency	$\overline{SHDN} = V_{DD}$		2.4			✻		MHz
External Clock Frequency		0.024		2.4	✻		✻	MHz
	When Used with Internal Clock	0.024		2.0	✻		✻	MHz
	Data Transfer Only	0		2.4	✻		✻	MHz
DYNAMIC CHARACTERISTICS								
Total Harmonic Distortion[2]	V_{IN} = 2.5Vp-p at 10kHz		–90			✻		dB
Signal-to-(Noise + Distortion)	V_{IN} = 2.5Vp-p at 10kHz		86			✻		dB
Spurious Free Dynamic Range	V_{IN} = 2.5Vp-p at 10kHz		92			✻		dB
Channel-to-Channel Isolation	V_{IN} = 2.5Vp-p at 50kHz		100			✻		dB
REFERENCE INPUT								
Range		0.5		$+V_{CC}$	✻		✻	V
Resistance	DCLK Static		5			✻		GΩ
Input Current			13	40		✻	✻	µA
	f_{SAMPLE} = 12.5kHz		2.5			✻		µA
	DCLK Static		0.001	3		✻	✻	µA
DIGITAL INPUT/OUTPUT								
Logic Family			CMOS			✻		
Logic Levels								
V_{IH}	$\lvert I_{IH} \rvert \leq +5\mu A$	$+V_{CC}$ • 0.7		5.5	✻		✻	V
V_{IL}	$\lvert I_{IL} \rvert \leq +5\mu A$	–0.3		+0.8	✻		✻	V
V_{OH}	I_{OH} = –250µA	$+V_{CC}$ • 0.8			✻			V
V_{OL}	I_{OL} = 250µA			0.4			✻	V
Data Format			Straight Binary			✻		
POWER SUPPLY REQUIREMENTS								
$+V_{CC}$	Specified Performance	2.7		3.6	✻		✻	V
Quiescent Current			1.2	1.85		✻	✻	mA
	f_{SAMPLE} = 12.5kHz		220					µA
	Power-Down Mode[3], $\overline{CS} = +V_{CC}$			3			✻	µA
Power Dissipation			3.2	5			✻	mW
TEMPERATURE RANGE								
Specified Performance		–40		+85	✻		✻	°C

✻ Same specifications as ADS8341E.

NOTES: (1) LSB means Least Significant Bit. With V_{REF} equal to +5.0V, one LSB is 76µV. (2) First five harmonics of the test frequency. (3) Auto power-down mode (PD1 = PD0 = 0) active or $\overline{SHDN}$ = GND.

PIN CONFIGURATIONS



ABSOLUTE MAXIMUM RATINGS[1]

$+V_{CC}$ to GND	–0.3V to +6V
Analog Inputs to GND	–0.3V to $+V_{CC}$ + 0.3V
Digital Inputs to GND	–0.3V to +6V
Power Dissipation	250mW
Maximum Junction Temperature	+150°C
Operating Temperature Range	–40°C to +85°C
Storage Temperature Range	–65°C to +150°C
Lead Temperature (soldering, 10s)	+300°C

NOTE: (1) Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability.

ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PIN DESCRIPTIONS

PIN	NAME	DESCRIPTION
1	$+V_{CC}$	Power Supply, 2.7V to 5V.
2	CH0	Analog Input Channel 0.
3	CH1	Analog Input Channel 1.
4	CH2	Analog Input Channel 2.
5	CH3	Analog Input Channel 3.
6	COM	Ground Reference for Analog Inputs. Sets zero code voltage in single-ended mode. Connect this pin to ground or ground reference point.
7	$\overline{SHDN}$	Shutdown. When LOW, the device enters a very low power shutdown mode.
8	V_{REF}	Voltage Reference Input. See Specification Table for ranges.
9	$+V_{CC}$	Power Supply, 2.7V to 5V.
10	GND	Ground. Connect to Analog Ground
11	GND	Ground. Connect to Analog Ground.
12	DOUT	Serial Data Output. Data is shifted on the falling edge of DCLK. This output is high impedance when $\overline{CS}$ is HIGH.
13	BUSY	Busy Output. This output is high impedance when $\overline{CS}$ is HIGH.
14	DIN	Serial Data Input. If $\overline{CS}$ is LOW, data is latched on rising edge of DCLK.
15	$\overline{CS}$	Chip Select Input. Controls conversion timing and enables the serial input/output register.
16	DCLK	External Clock Input. This clock runs the SAR conversion process and synchronizes serial data I/O. Maximum input clock frequency equals 2.4MHz to achieve 100kHz sampling rate.

PACKAGE/ORDERING INFORMATION

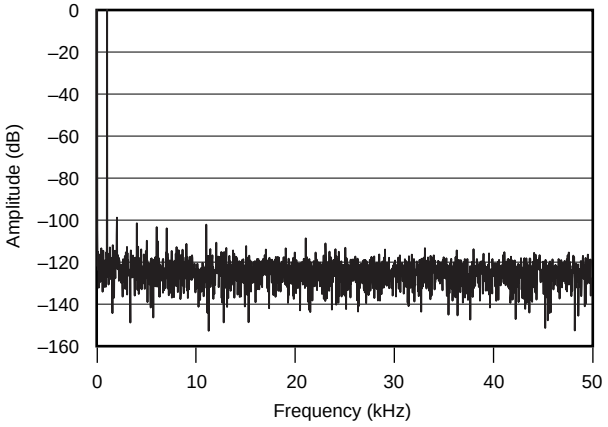
PRODUCT	MAXIMUM INTEGRAL LINEARITY ERROR (LSB)	NO MISSING CODES ERROR (LSB)	SPECIFICATION TEMPERATURE RANGE	PACKAGE	PACKAGE DRAWING NUMBER	ORDERING NUMBER[1]	TRANSPORT MEDIA
ADS8341E	8	14	–40°C to +85°C	SSOP-16	322	ADS8341E	Rails
"	"	"	"	"	"	ADS8341E/2K5	Tape and Reel
ADS8341EB	6	15	–40°C to +85°C	SSOP-16	322	ADS8341EB	Rails
"	"	"	"	"	"	ADS8341EB/2K5	Tape and Reel

NOTES: (1) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /2K5 indicates 2500 devices per reel). Ordering 2500 pieces of "ADS8341E/2K5" will get a single 2500-piece Tape and Reel.

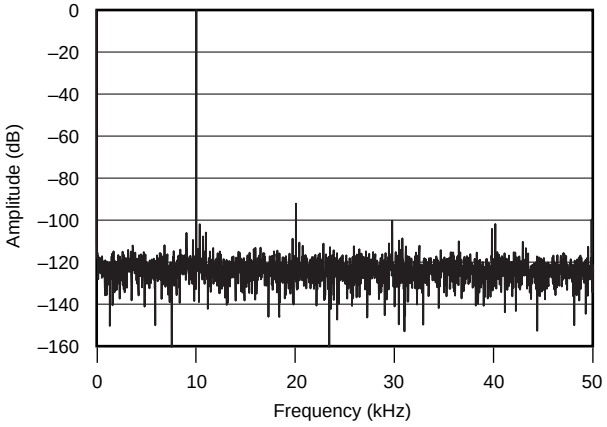
TYPICAL PERFORMANCE CURVES: +5V

At T_A = +25°C, $+V_{CC}$ = +5V, V_{REF} = +5V, f_{SAMPLE} = 100kHz, and f_{CLK} = 24 • f_{SAMPLE} = 2.4MHz, unless otherwise noted.

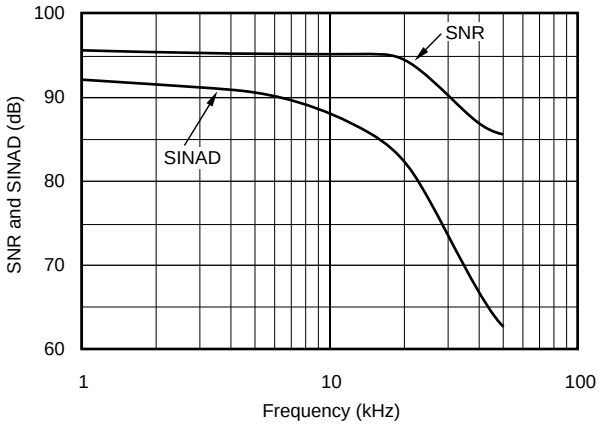
FREQUENCY SPECTRUM
(4096 Point FFT; f_{IN} = 1.001kHz, –0.2dB)



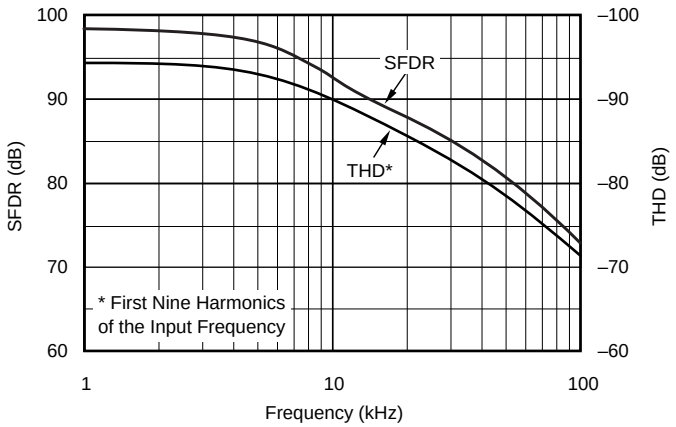
FREQUENCY SPECTRUM
(4096 Point FFT; f_{IN} = 9.985kHz, –0.2dB)



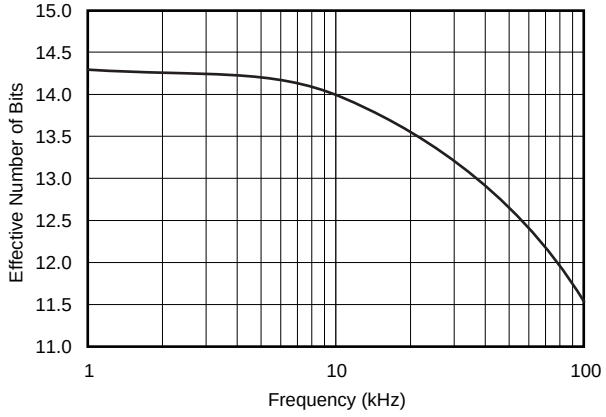
SIGNAL-TO-NOISE RATIO AND
SIGNAL-TO- (NOISE+DISTORTION)
vs INPUT FREQUENCY



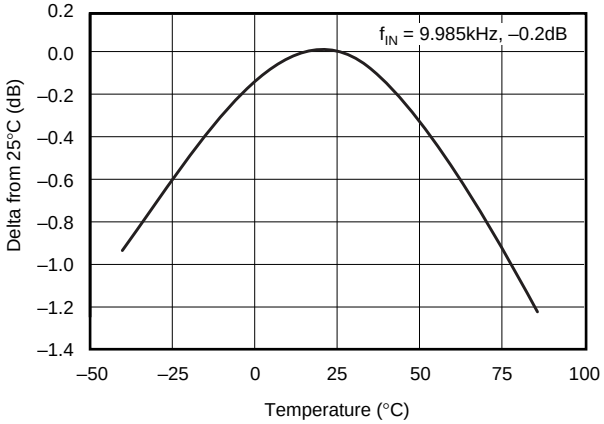
SPURIOUS FREE DYNAMIC RANGE AND
TOTAL HARMONIC DISTORTION
vs INPUT FREQUENCY



EFFECTIVE NUMBER OF BITS
vs INPUT FREQUENCY



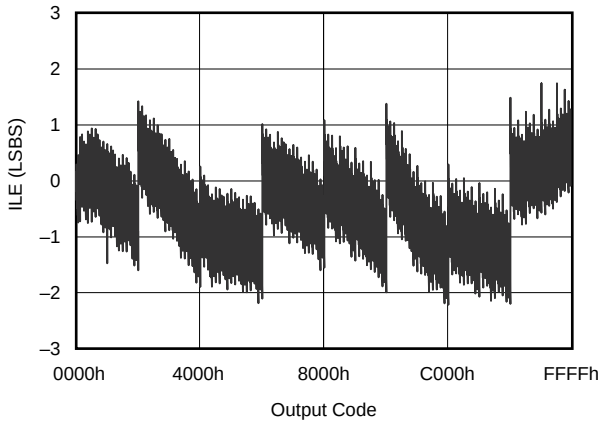
CHANGE IN SIGNAL-TO-(NOISE+DISTORTION)
vs TEMPERATURE



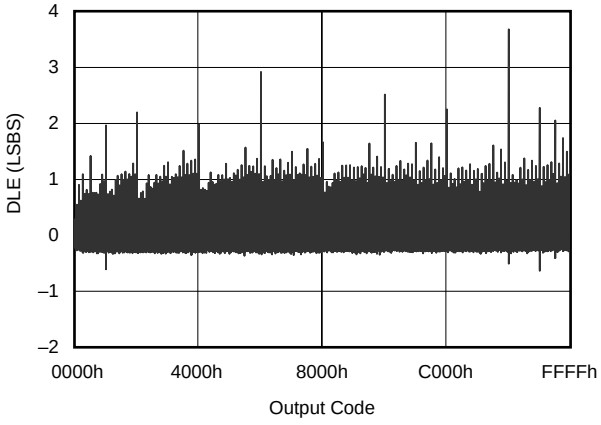
TYPICAL PERFORMANCE CURVES: +5V (Cont.)

At T_A = +25°C, $+V_{CC}$ = +5V, V_{REF} = +5V, f_{SAMPLE} = 100kHz, and f_{CLK} = 24 • f_{SAMPLE} = 2.4MHz, unless otherwise noted.

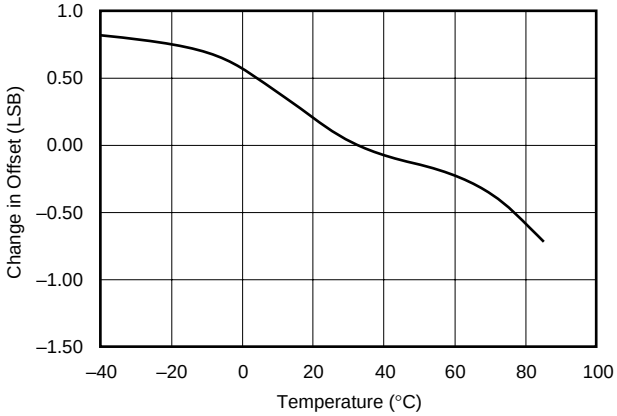
INTEGRAL LINEARITY ERROR vs CODE



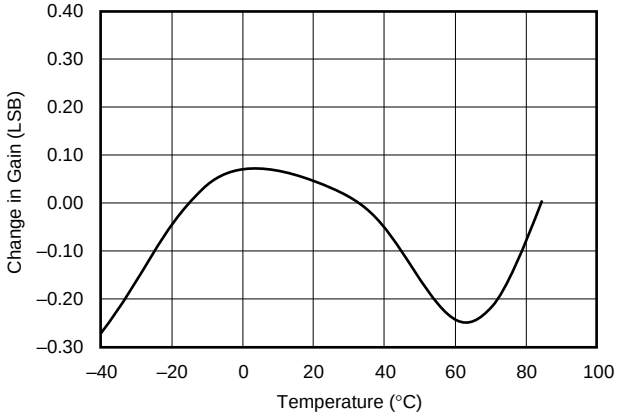
DIFFERENTIAL LINEARITY ERROR vs CODE



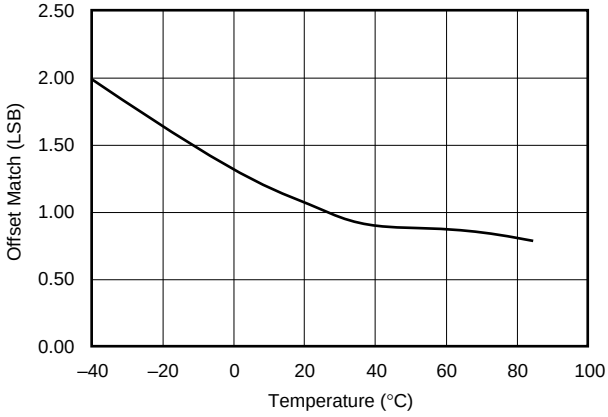
CHANGE IN OFFSET vs TEMPERATURE



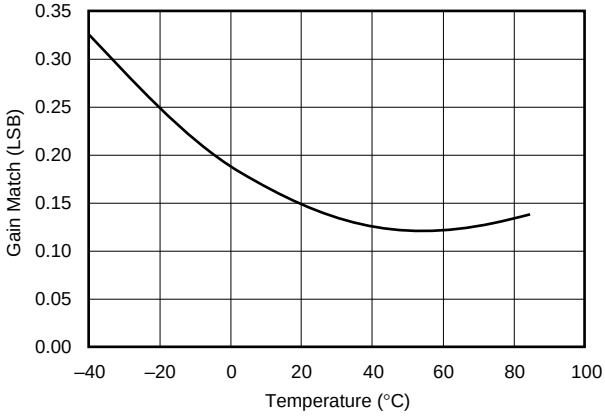
CHANGE IN GAIN vs TEMPERATURE



WORST CASE CHANNEL-TO-CHANNEL OFFSET MATCH vs TEMPERATURE

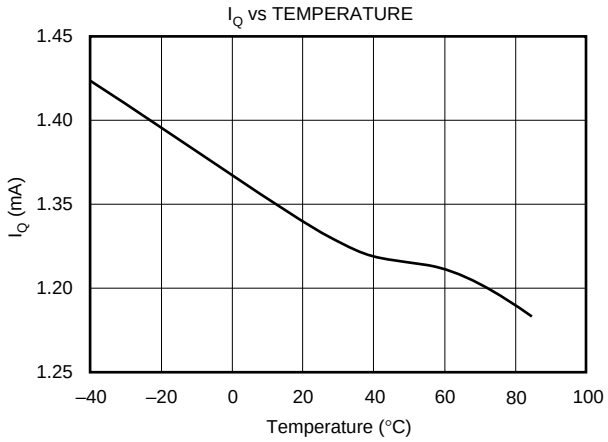


WORST CASE CHANNEL-TO-CHANNEL GAIN MATCH vs TEMPERATURE



TYPICAL PERFORMANCE CURVES: +5V (Cont.)

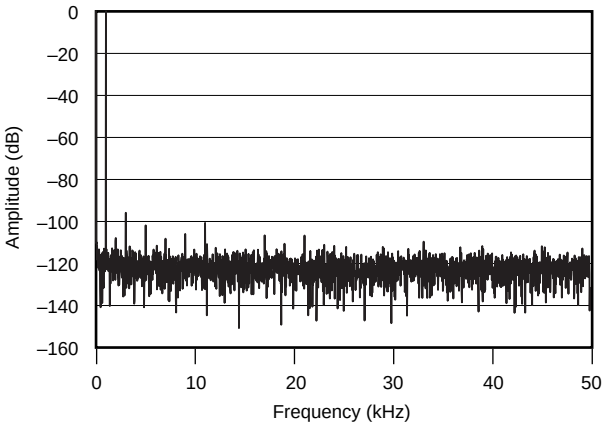
At T_A = +25°C, $+V_{CC}$ = +5V, V_{REF} = +5V, f_{SAMPLE} = 100kHz, and f_{CLK} = 24 • f_{SAMPLE} = 2.4MHz, unless otherwise noted.



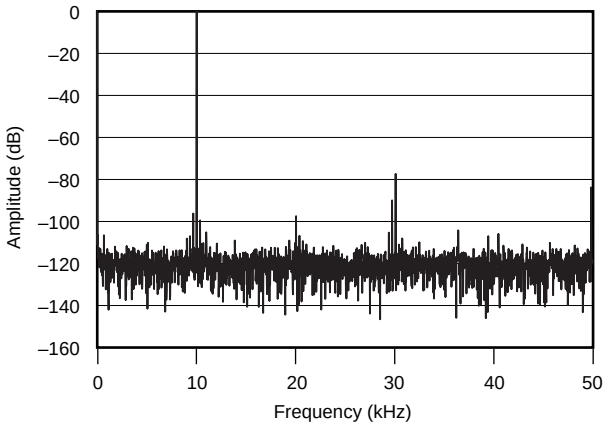
TYPICAL PERFORMANCE CURVES: +2.7V

At T_A = +25°C, $+V_{CC}$ = +2.7V, V_{REF} = +2.5V, f_{SAMPLE} = 100kHz, and f_{CLK} = 24 • f_{SAMPLE} = 2.4MHz, unless otherwise noted.

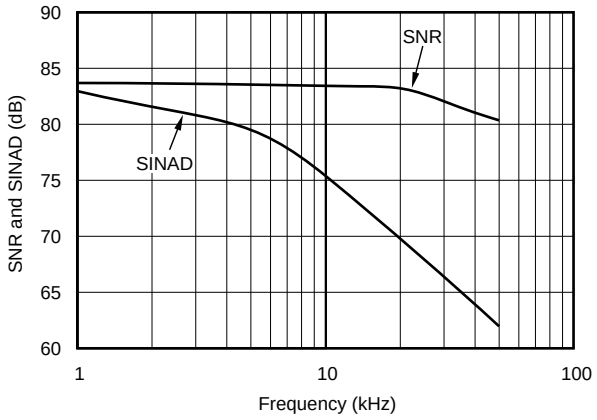
FREQUENCY SPECTRUM
(4096 Point FFT; f_{IN} = 1.001kHz, –0.2dB)



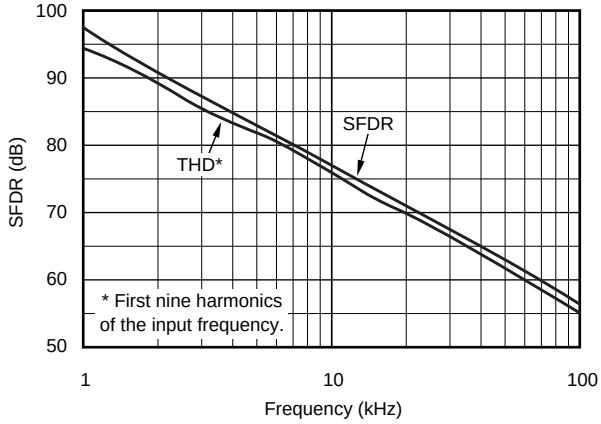
FREQUENCY SPECTRUM
(4096 Point FFT; f_{IN} = 9.985kHz, –0.2dB)



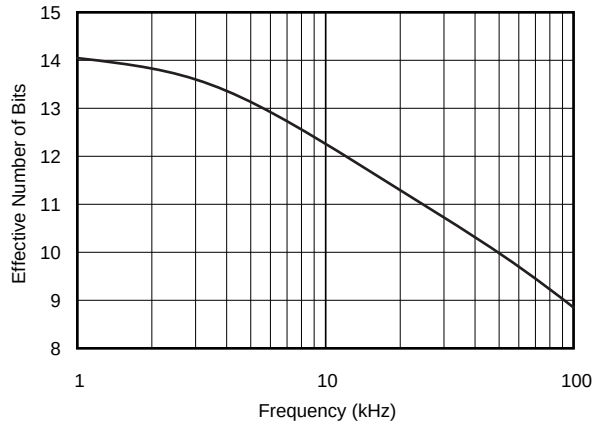
SIGNAL-TO-NOISE RATIO AND
SIGNAL-TO- (NOISE+DISTORTION)
vs INPUT FREQUENCY



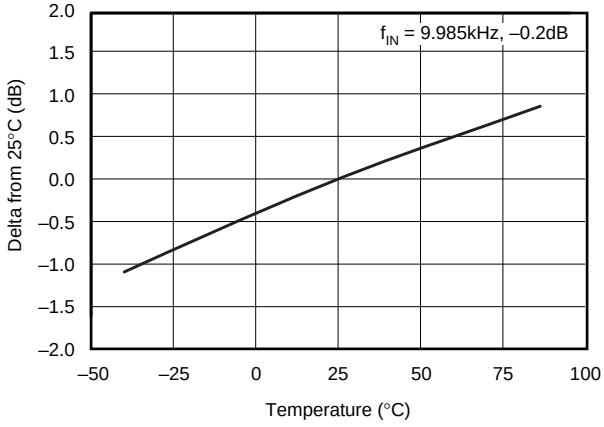
SPURIOUS FREE DYNAMIC RANGE AND
TOTAL HARMONIC DISTORTION
vs INPUT FREQUENCY



EFFECTIVE NUMBER OF BITS
vs INPUT FREQUENCY



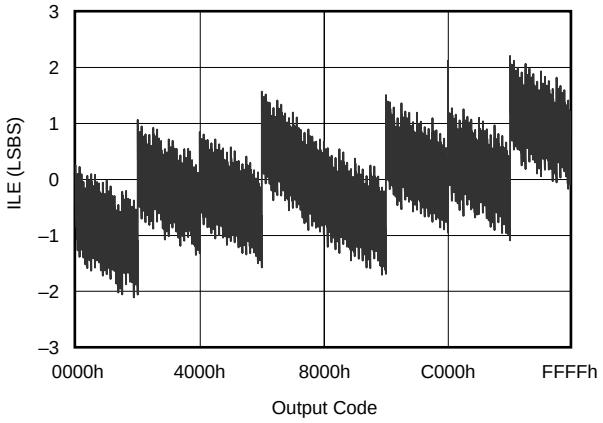
CHANGE IN SIGNAL-TO-(NOISE+DISTORTION)
vs TEMPERATURE



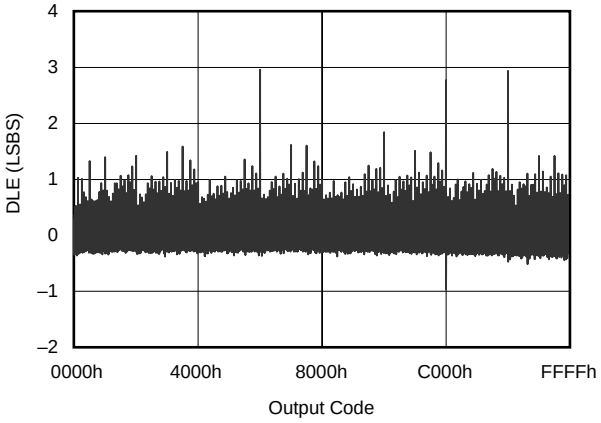
TYPICAL PERFORMANCE CURVES: +2.7V (Cont.)

At T_A = +25°C, $+V_{CC}$ = +2.7V, V_{REF} = +2.5V, f_{SAMPLE} = 100kHz, and f_{CLK} = 24 • f_{SAMPLE} = 2.4MHz, unless otherwise noted.

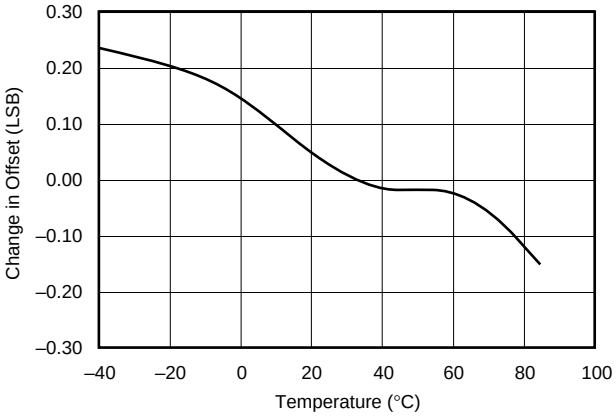
INTEGRAL LINEARITY ERROR vs CODE



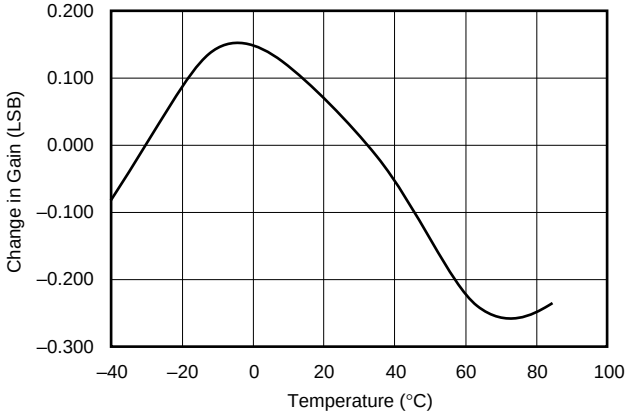
DIFFERENTIAL LINEARITY ERROR vs CODE



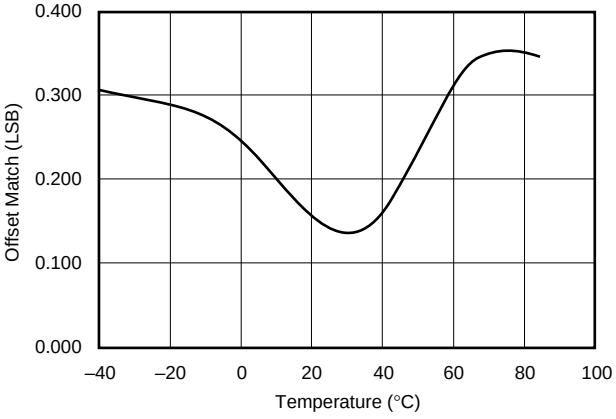
CHANGE IN OFFSET vs TEMPERATURE



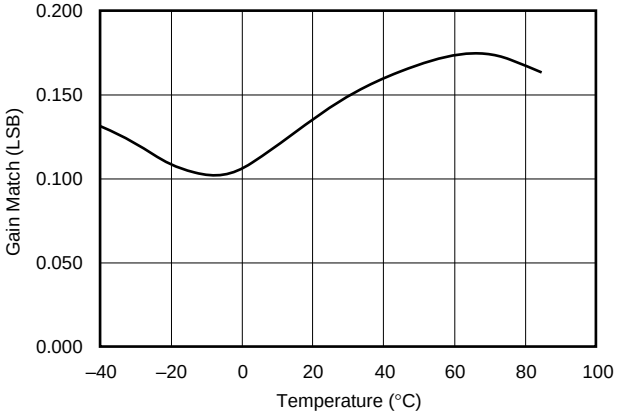
CHANGE IN GAIN vs TEMPERATURE



WORST CASE CHANNEL-TO-CHANNEL OFFSET MATCH vs TEMPERATURE



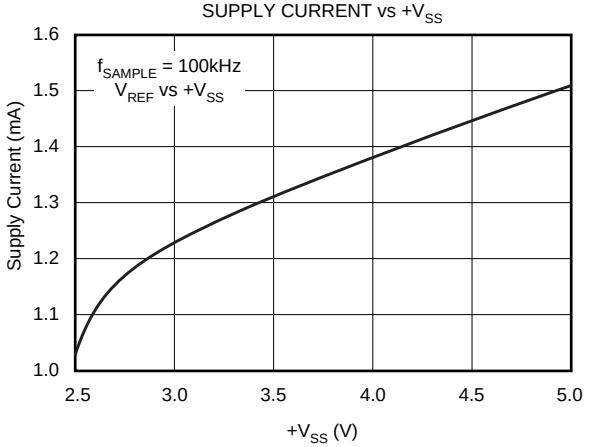
WORST CASE CHANNEL-TO-CHANNEL GAIN MATCH vs TEMPERATURE



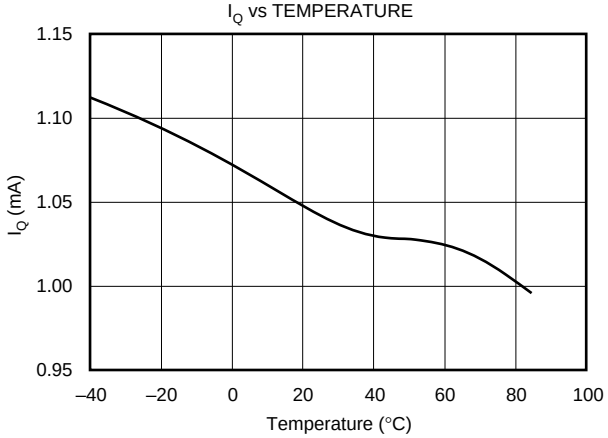
TYPICAL PERFORMANCE CURVES: +2.7V (Cont.)

At T_A = +25°C, $+V_{CC}$ = +2.7V, V_{REF} = +2.5V, f_{SAMPLE} = 100kHz, and f_{CLK} = 24 • f_{SAMPLE} = 2.4MHz, unless otherwise noted.

SUPPLY CURRENT vs $+V_{SS}$



I_Q vs TEMPERATURE



THEORY OF OPERATION

The ADS8341 is a classic successive approximation register (SAR) analog-to-digital (A/D) converter. The architecture is based on capacitive redistribution which inherently includes a sample/hold function. The converter is fabricated on a 0.6µm CMOS process.

The basic operation of the ADS8341 is shown in Figure 1. The device requires an external reference and an external clock. It operates from a single supply of 2.7V to 5.25V. The external reference can be any voltage between 500mV and $+V_{CC}$. The value of the reference voltage directly sets the input range of the converter. The average reference input current depends on the conversion rate of the ADS8341.

The analog input to the converter is differential and is provided via a four-channel multiplexer. The input can be provided in reference to a voltage on the COM pin (which is generally ground) or differentially by using two of the four input channels (CH0 - CH3). The particular configuration is selectable via the digital interface.

ANALOG INPUT

Figure 2 shows a block diagram of the input multiplexer on the ADS8341. The differential input of the converter is derived from one of the four inputs in reference to the COM pin or two of the four inputs. Table I and Table II show the relationship between the A2, A1, A0, and SGL/$\overline{\text{DIF}}$ control bits and the configuration of the analog multiplexer. The control bits are provided serially via the DIN pin, see the Digital Interface section of this data sheet for more details.

When the converter enters the hold mode, the voltage difference between the +IN and –IN inputs (see Figure 2) is captured on the internal capacitor array. The voltage on the –IN input is limited between –0.2V and 1.25V, allowing the input to reject small signals which are common to both the +IN and –IN input. The +IN input has a range of –0.2V to $+V_{CC}$ + 0.2V.

The input current on the analog inputs depends on the conversion rate of the device. During the sample period, the source must charge the internal sampling capacitor (typically 25pF). After the capacitor has been fully charged, there is no further input current. The rate of charge transfer from the analog source to the converter is a function of conversion rate.

A2	A1	A0	CH0	CH1	CH2	CH3	COM
0	0	1	+IN				–IN
1	0	1		+IN			–IN
0	1	0			+IN		–IN
1	1	0				+IN	–IN

TABLE I. Single-Ended Channel Selection (SGL/$\overline{\text{DIF}}$ HIGH).

A2	A1	A0	CH0	CH1	CH2	CH3	COM
0	0	1	+IN	–IN			
1	0	1	–IN	+IN			
0	1	0			+IN	–IN	
1	1	0			–IN	+IN	

TABLE II. Differential Channel Control (SGL/$\overline{\text{DIF}}$ LOW).

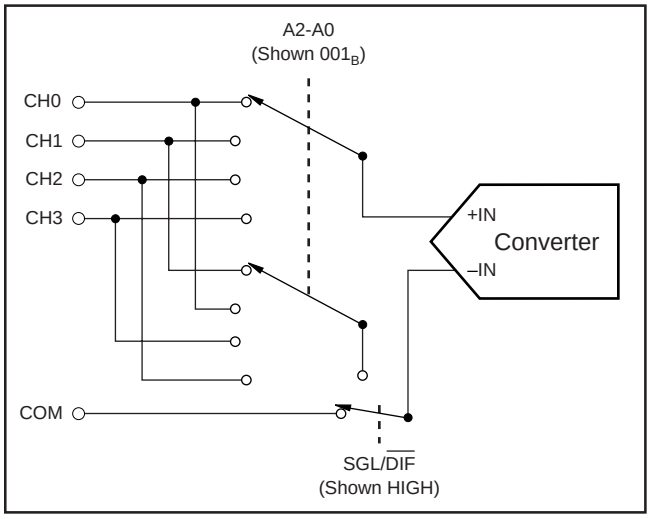


FIGURE 2. Simplified Diagram of the Analog Input.

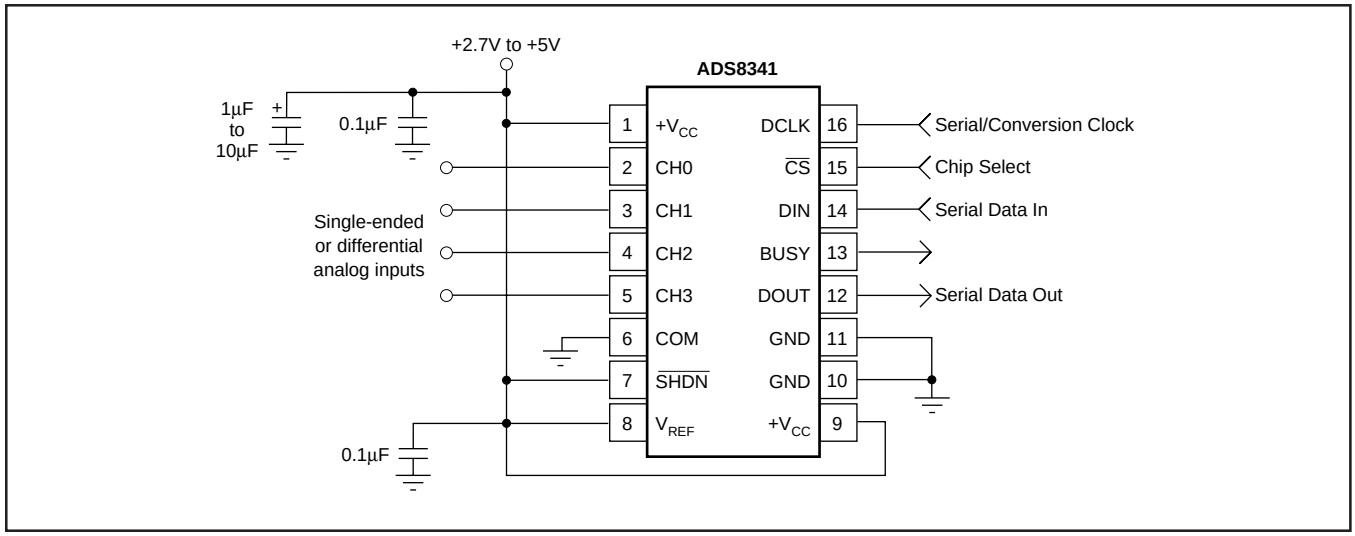


FIGURE 1. Basic Operation of the ADS8341.

REFERENCE INPUT

The external reference sets the analog input range. The ADS8341 will operate with a reference in the range of 500mV to $+V_{CC}$. Keep in mind that the analog input is the difference between the +IN input and the –IN input as shown in Figure 2. For example, in the single-ended mode, a 1.25V reference, and with the COM pin grounded, the selected input channel (CH0 - CH3) will properly digitize a signal in the range of 0V to 1.25V. If the COM pin is connected to 0.5V, the input range on the selected channel is 0.5V to 1.75V.

There are several critical items concerning the reference input and its wide voltage range. As the reference voltage is reduced, the analog voltage weight of each digital output code is also reduced. This is often referred to as the LSB (least significant bit) size and is equal to the reference voltage divided by 65, 536. Any offset or gain error inherent in the A/D converter will appear to increase, in terms of LSB size, as the reference voltage is reduced. For example, if the offset of a given converter is 2 LSBs with a 2.5V reference, then it will typically be 10 LSBs with a 0.5V reference. In each case, the actual offset of the device is the same, 76µV.

Likewise, the noise or uncertainty of the digitized output will increase with lower LSB size. With a reference voltage of 500mV, the LSB size is 7.6µV. This level is below the internal noise of the device. As a result, the digital output code will not be stable and vary around a mean value by a number of LSBs. The distribution of output codes will be gaussian and the noise can be reduced by simply averaging consecutive conversion results or applying a digital filter.

With a lower reference voltage, care should be taken to provide a clean layout including adequate bypassing, a clean (low noise, low ripple) power supply, a low-noise reference, and a low-noise input signal. Because the LSB size is lower, the converter will also be more sensitive to nearby digital signals and electromagnetic interference.

The voltage into the V_{REF} input is not buffered and directly drives the capacitor digital-to-analog converter (CDAC) portion of the ADS8341. Typically, the input current is 13µA with a 2.5V reference. This value will vary by microamps depending on the result of the conversion. The reference current diminishes directly with both conversion rate and reference voltage. As the current from the reference is drawn on each bit decision, clocking the converter more quickly during a given conversion period will not reduce overall current drain from the reference.

DIGITAL INTERFACE

Figure 3 shows the typical operation of the ADS8341's digital interface. This diagram assumes that the source of the digital signals is a microcontroller or digital signal processor with a basic serial interface (note that the digital inputs are over-voltage tolerant up to 5.5V, regardless of $+V_{CC}$). Each communication between the processor and the converter consists of eight clock cycles. One complete conversion can be accomplished with three serial communications, for a total of 24 clock cycles on the DCLK input.

The first eight cycles are used to provide the control byte via the DIN pin. When the converter has enough information about the following conversion to set the input multiplexer appropriately, it enters the acquisition (sample) mode. After three more clock cycles, the control byte is complete and the converter enters the conversion mode. At this point, the input sample/hold goes into the hold mode. The next sixteen clock cycles accomplish the actual analog-to-digital conversion.

Control Byte

Also shown in Figure 3 is the placement and order of the control bits within the control byte. Tables III and IV give detailed information about these bits. The first bit, the 'S' bit, must always be HIGH and indicates the start of the control byte. The ADS8341 will ignore inputs on the DIN pin until the start bit is detected. The next three bits (A2 - A0) select the active input channel or channels of the input multiplexer (see Tables I and II and Figure 2).

Bit 7 (MSB)	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0 (LSB)
S	A2	A1	A0	—	SGL/$\overline{\text{DIF}}$	PD1	PD0

TABLE III. Order of the Control Bits in the Control Byte.

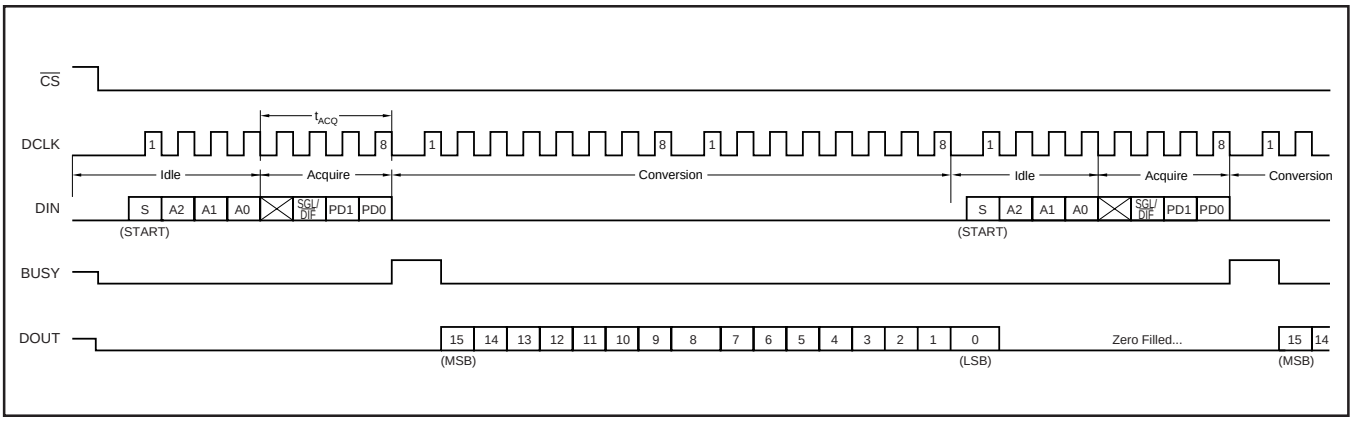


FIGURE 3. Conversion Timing, 24-Clocks per Conversion, 8-Bit Bus Interface. No DCLK delay required with dedicated serial port.

BIT	NAME	DESCRIPTION
7	S	Start Bit. Control byte starts with first HIGH bit on DIN.
6 - 4	A2 - A0	Channel Select Bits. Along with the SGL/DIF bit, these bits control the setting of the multiplexer input as detailed in Tables I and II.
2	SGL/$\overline{\text{DIF}}$	Single-Ended/Differential Select Bit. Along with bits A2 - A0, this bit controls the setting of the multiplexer input as detailed in Tables I and II.
1 - 0	PD1 - PD0	Power-Down Mode Select Bits. See Table V for details.

TABLE IV. Descriptions of the Control Bits within the Control Byte.

The SGL/$\overline{\text{DIF}}$ bit controls the multiplexer input mode: either single-ended (HIGH) or differential (LOW). In single-ended mode, the selected input channel is referenced to the COM pin. In differential mode, the two selected inputs provide a differential input. See Tables I and II and Figure 2 for more information. The last two bits (PD1 - PD0) select the power-down mode as shown in Table V. If both inputs are HIGH, the device is always powered up. If both inputs are LOW, the device enters a power-down mode between conversions. When a new conversion is initiated, the device will resume normal operation instantly—no delay is needed to allow the device to power up and the very first conversion will be valid.

Clock Modes

The ADS8341 can be used with an external serial clock or an internal clock to perform the successive-approximation conversion. In both clock modes, the external clock shifts data in and out of the device. Internal clock mode is selected when PD1 is LOW and PD0 is HIGH.

PD1	PD0	Description
0	0	Power-down between conversions. When each conversion is finished, the converter enters a low power mode. At the start of the next conversion, the device instantly powers up to full power. There is no need for additional delays to assure full operation and the very first conversion is valid.
0	1	Internal clock mode.
1	0	Reserved for future use.
1	1	No power-down between conversions, device always powered.

TABLE V. Power-Down Selection.

External Clock Mode

In external clock mode, the external clock not only shifts data in and out of the ADS8341, it also controls the A/D conversion steps. BUSY will go HIGH for one clock period after the last bit of the control byte is shifted in. Successive-approximation bit decisions are made and appear at DOUT on each of the next 16 SCLK falling edges (Figure 3). Figure 4 shows the BUSY timing in external clock mode.

Since one clock cycle of the serial clock is consumed with BUSY going high (while the MSB decision is being made), 16 additional clocks must be given to clock out all 16 bits of data; thus, one conversion takes a minimum of 25 clock cycles to fully read the data. Since most microprocessors communicate in 8-bit transfers, this means that an additional transfer must be made to capture the LSB.

There are two ways of handling this requirement. One is shown in Figure 3, where the beginning of the next control byte appears at the same time the LSB is being clocked out of the ADS8341. This method allows for maximum throughput and 24 clock cycles per conversion.

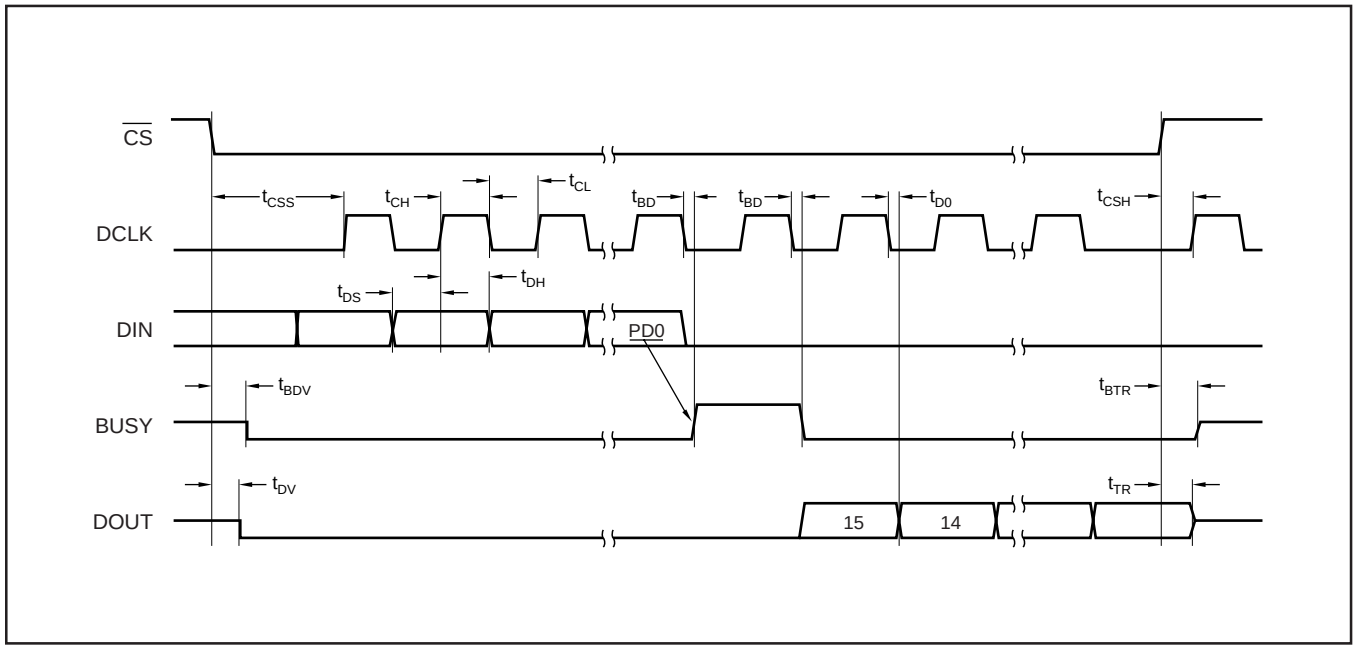


FIGURE 4. Detailed Timing Diagram.

The other method is shown in Figure 5, which uses 32 clock cycles per conversion; the last seven clock cycles simply shift out zeros on the DOUT line. BUSY and DOUT go into a high-impedance state when $\overline{CS}$ goes high; after the next $\overline{CS}$ falling edge, BUSY will go LOW.

Internal Clock Mode

In internal clock mode, the ADS8341 generates its own conversion clock internally. This relieves the microprocessor from having to generate the SAR conversion clock and allows the conversion result to be read back at the processor's convenience, at any clock rate from 0MHz to 2.0MHz. BUSY goes LOW at the start of conversion and then returns HIGH when the conversion is complete. During the conversion, BUSY will remain LOW for a maximum of 8µs. Also, during the conversion, SCLK should remain LOW to achieve the best noise performance. The conversion result is stored in an internal register; the data may be clocked out of this register any time after the conversion is complete.

If $\overline{CS}$ is LOW when BUSY goes LOW following a conversion, the next falling edge of the external serial clock will write out the MSB on the DOUT line. The remaining bits (D14-D0) will be clocked out on each successive clock cycle following the MSB. If $\overline{CS}$ is HIGH when BUSY goes LOW then the DOUT line will remain in tri-state until $\overline{CS}$ goes LOW (Figure 6). $\overline{CS}$ does not need to remain LOW once a conversion has started. Note that BUSY is not tri-stated when $\overline{CS}$ goes HIGH in internal clock mode.

Data can be shifted in and out of the ADS8341 at clock rates exceeding 2.4MHz, provided that the minimum acquisition time t_{ACQ}, is kept above 1.7µs.

Digital Timing

Figure 4 and Tables VI and VII provide detailed timing for the digital interface of the ADS8341.

SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNITS
t_{ACQ}	Acquisition Time	1.5			µs
t_{DS}	DIN Valid Prior to DCLK Rising	100			ns
t_{DH}	DIN Hold After DCLK HIGH	10			ns
t_{DO}	DCLK Falling to DOUT Valid			200	ns
t_{DV}	$\overline{CS}$ Falling to DOUT Enabled			200	ns
t_{TR}	$\overline{CS}$ Rising to DOUT Disabled			200	ns
t_{CSS}	$\overline{CS}$ Falling to First DCLK Rising	100			ns
t_{CSH}	$\overline{CS}$ Rising to DCLK Ignored	0			ns
t_{CH}	DCLK HIGH	200			ns
t_{CL}	DCLK LOW	200			ns
t_{BD}	DCLK Falling to BUSY Rising			200	ns
t_{BDV}	$\overline{CS}$ Falling to BUSY Enabled			200	ns
t_{BTR}	$\overline{CS}$ Rising to BUSY Disabled			200	ns

TABLE VI. Timing Specifications ($+V_{CC}$ = +2.7V to 3.6V, T_A = –40°C to +85°C, C_{LOAD} = 50pF).

SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNITS
t_{ACQ}	Acquisition Time	900			ns
t_{DS}	DIN Valid Prior to DCLK Rising	50			ns
t_{DH}	DIN Hold After DCLK HIGH	10			ns
t_{DO}	DCLK Falling to DOUT Valid			100	ns
t_{DV}	$\overline{CS}$ Falling to DOUT Enabled			70	ns
t_{TR}	$\overline{CS}$ Rising to DOUT Disabled			70	ns
t_{CSS}	$\overline{CS}$ Falling to First DCLK Rising	50			ns
t_{CSH}	$\overline{CS}$ Rising to DCLK Ignored	0			ns
t_{CH}	DCLK HIGH	150			ns
t_{CL}	DCLK LOW	150			ns
t_{BD}	DCLK Falling to BUSY Rising			100	ns
t_{BDV}	$\overline{CS}$ Falling to BUSY Enabled			70	ns
t_{BTR}	$\overline{CS}$ Rising to BUSY Disabled			70	ns

TABLE VII. Timing Specifications ($+V_{CC}$ = +4.75V to +5.25V, T_A = –40°C to +85°C, C_{LOAD} = 50pF).

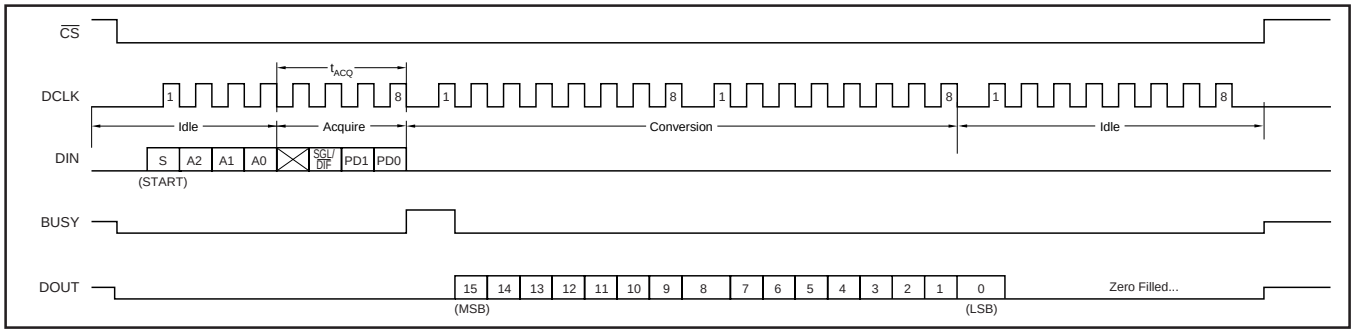


FIGURE 5. External Clock Mode 32 Clocks Per Conversion.

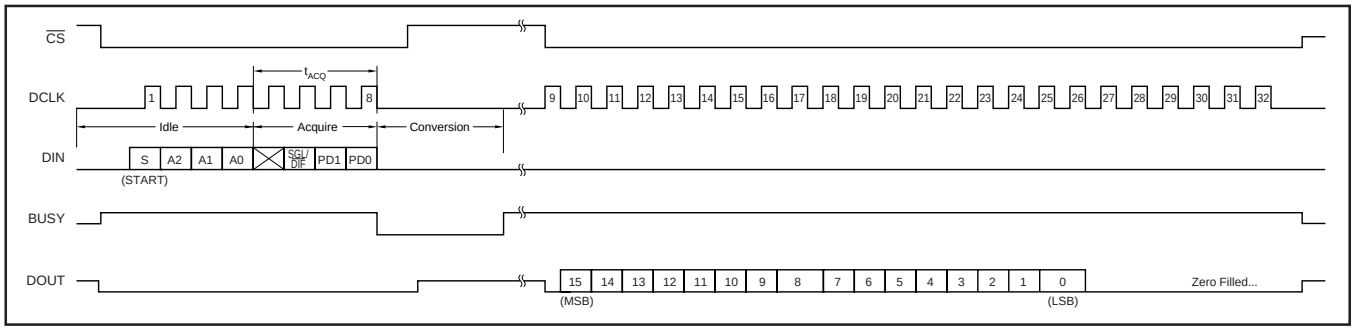


FIGURE 6. Internal Clock Mode Timing.

Data Format

The ADS8341 output data is in straight binary format as shown in Figure 7. This figure shows the ideal output code for the given input voltage and does not include the effects of offset, gain, or noise.

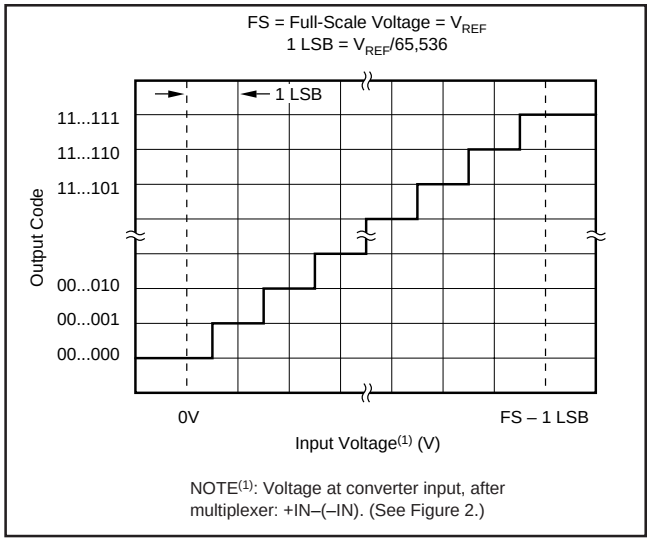


FIGURE 7. Ideal Input Voltages and Output Codes.

POWER DISSIPATION

There are three power modes for the ADS8341: full power (PD1 - PD0 = 11B), auto power-down (PD1 - PD0 = 00B), and shutdown ($\overline{SHDN}$ LOW). The affects of these modes varies depending on how the ADS8341 is being operated. For example, at full conversion rate and 24-clocks per conversion, there is very little difference between full power mode and auto power-down, a shutdown ($\overline{SHDN}$ LOW) will not lower power dissipation

When operating at full-speed and 24-clocks per conversion (as shown in Figure 3), the ADS8341 spends most of its time acquiring or converting. There is little time for auto power-down, assuming that this mode is active. Thus, the difference between full power mode and auto power-down is negligible. If the conversion rate is decreased by simply slowing the frequency of the DCLK input, the two modes remain approximately equal. However, if the DCLK frequency is kept at the maximum rate during a conversion, but conversion are simply done less often, then the difference between the two modes is dramatic. Figure 8 shows the difference between reducing the DCLK frequency ("scaling" DCLK to match the conversion rate) or maintaining DCLK at the highest frequency and reducing the number of conversion per second. In the later case, the converter spends an increasing percentage of its time in power-down mode (assuming the auto power-down mode is active).

If DCLK is active and $\overline{CS}$ is LOW while the ADS8341 is in auto power-down mode, the device will continue to dissipate some power in the digital logic. The power can be reduced to a minimum by keeping $\overline{CS}$ HIGH. The differences in supply current for these two cases are shown in Figure 9.

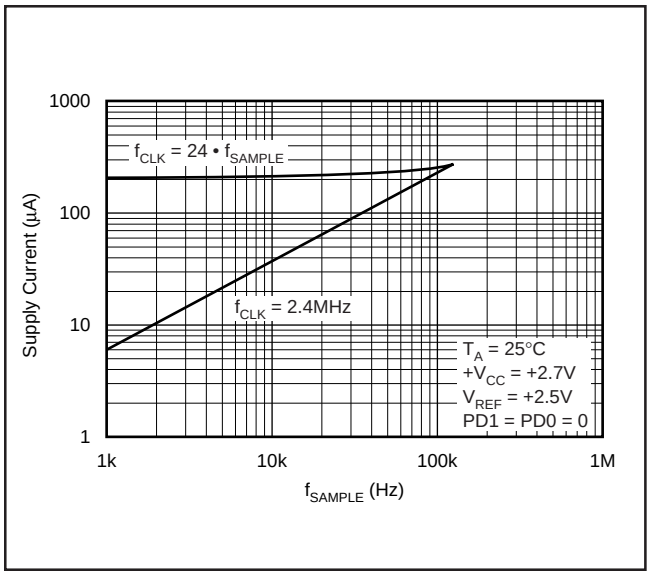


FIGURE 8. Supply Current vs Directly Scaling the Frequency of DCLK with Sample Rate or Keeping DCLK at the Maximum Possible Frequency.

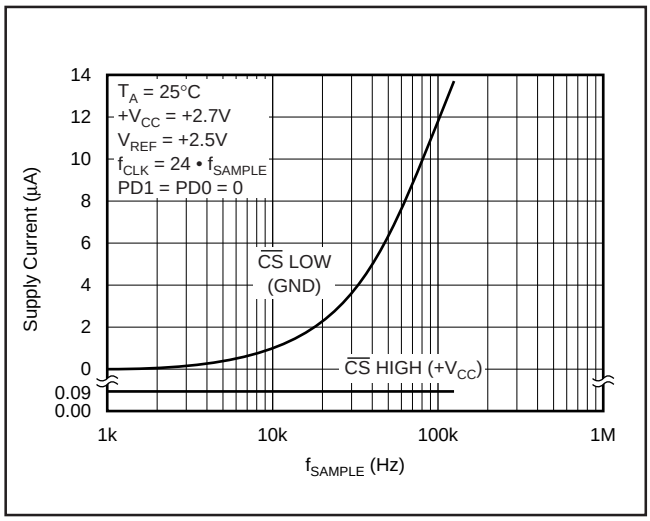


FIGURE 9. Supply Current vs State of $\overline{CS}$.

Operating the ADS8341 in auto power-down mode will result in the lowest power dissipation, and there is no conversion time "penalty" on power-up. The very first conversion will be valid. SHDN can be used to force an immediate power-down.

NOISE

The noise floor of the ADS8341 itself is extremely low, as can be seen from Figures 10 thru 13, and is much lower than competing A/D converters. The ADS8341 was tested at both 5V and 2.7V and in both the internal and external clock modes. A low level DC input was applied to the analog input pins and the converter was put through 5,000 conversions. The digital output of the A/D converter will vary in output code due to the internal noise of the ADS8341. This is true for all 16-bit SAR-type A/D converters. Using a histogram to plot the output codes, the distribution should appear bell-shaped with the peak of the bell curve representing the nominal code for the input value. The $\pm1\sigma$, $\pm2\sigma$, and $\pm3\sigma$ distributions will represent the 68.3%, 95.5%, and 99.7%, respectively, of all codes. The transition noise can be calculated by dividing the number of codes measured by 6 and this will yield the $\pm3\sigma$ distribution or 99.7% of all codes. Statistically, up to 3 codes could fall outside the distribution when executing 1000 conversions. The ADS8341, with < 3 output codes for the $\pm3\sigma$ distribution, will yield a < ±0.5 LSB transition noise at 5V operation. Remember, to achieve this low noise performance, the peak-to-peak noise of the input signal and reference must be < 50µV.

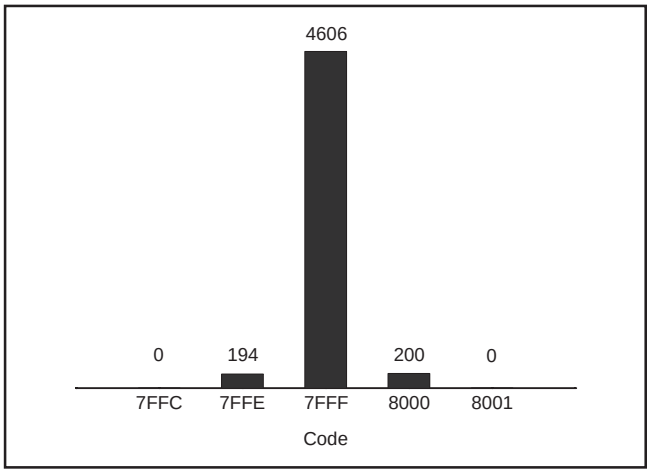


FIGURE 10. Histogram of 5000 Conversions of a DC Input at the Code Transition, 5V operation external clock mode.

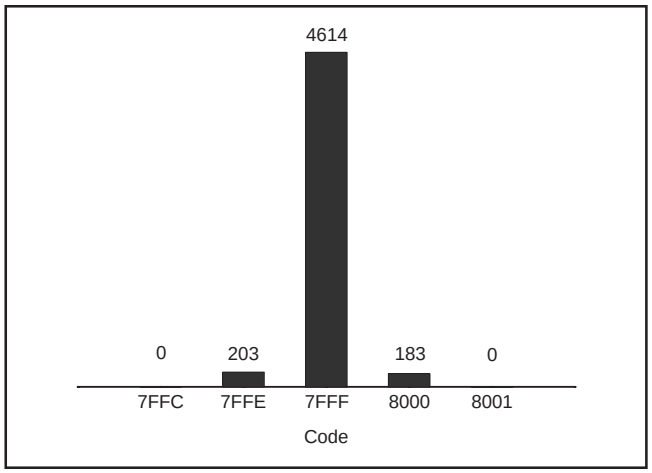


FIGURE 11. Histogram of 5000 Conversions of a DC Input at the Code Center, 5V operation internal clock mode.

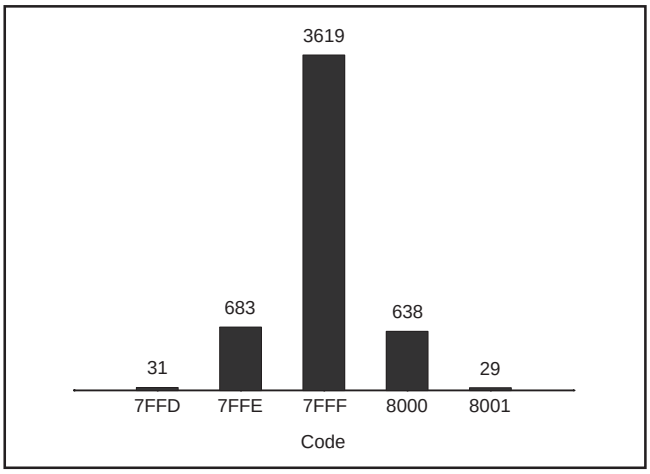


FIGURE 12. Histogram of 5000 Conversions of a DC Input at the Code Transition, 2.7V operation external clock mode.

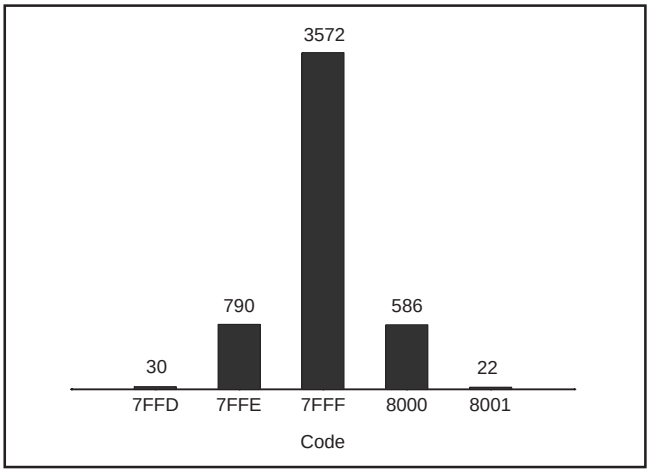


FIGURE 13. Histogram of 5000 Conversions of a DC Input at the Code Center, 2.7V operation internal clock mode.

AVERAGING

The noise of the A/D converter can be compensated by averaging the digital codes. By averaging conversion results, transition noise will be reduced by a factor of $1/\sqrt{n}$, where n is the number of averages. For example, averaging 4 conversion results will reduce the transition noise by 1/2 to ±0.25 LSBs. Averaging should only be used for input signals with frequencies near DC.

For AC signals, a digital filter can be used to low pass filter and decimate the output codes. This works in a similar manner to averaging; for every decimation by 2, the signal-to-noise ratio will improve 3dB.

LAYOUT

For optimum performance, care should be taken with the physical layout of the ADS8341 circuitry. This is particularly true if the reference voltage is low and/or the conversion rate is high.

The basic SAR architecture is sensitive to glitches or sudden changes on the power supply, reference, ground connections, and digital inputs that occur just prior to latching the output of the analog comparator. Thus, during any single conversion for an n-bit SAR converter, there are n "windows" in which large external transient voltages can easily affect the conversion result. Such glitches might originate from switching power supplies, nearby digital logic, and high power devices. The degree of error in the digital output depends on the reference voltage, layout, and the exact timing of the external event. The error can change if the external event changes in time with respect to the DCLK input.

With this in mind, power to the ADS8341 should be clean and well bypassed. A 0.1µF ceramic bypass capacitor should be placed as close to the device as possible. In addition, a 1µF to 10µF capacitor and a 5Ω or 10Ω series resistor may be used to lowpass filter a noisy supply.

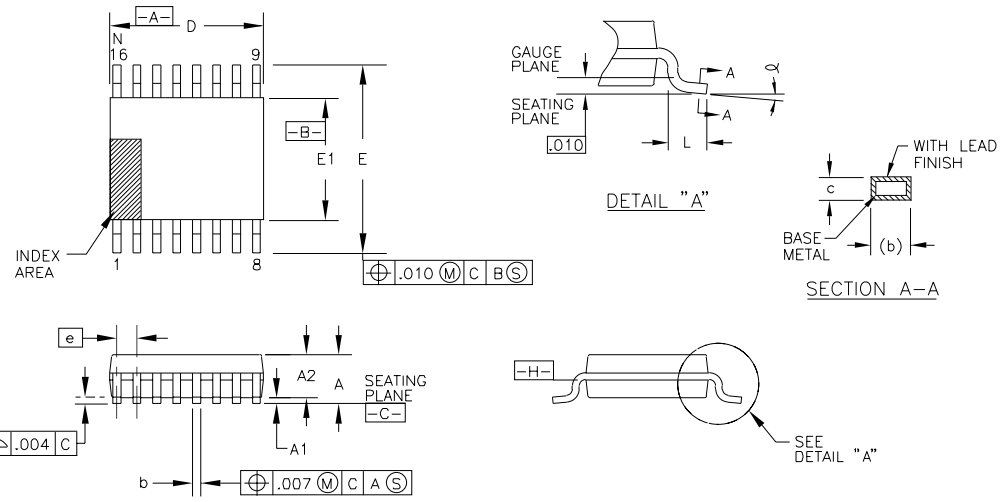
The reference should be similarly bypassed with a 0.1µF capacitor. Again, a series resistor and large capacitor can be used to lowpass filter the reference voltage. If the reference voltage originates from an op amp, make sure that it can drive the bypass capacitor without oscillation (the series resistor can help in this case). The ADS8341 draws very little current from the reference on average, but it does place larger demands on the reference circuitry over short periods of time (on each rising edge of DCLK during a conversion).

The ADS8341 architecture offers no inherent rejection of noise or voltage variation in regards to the reference input. This is of particular concern when the reference input is tied to the power supply. Any noise and ripple from the supply will appear directly in the digital results. While high frequency noise can be filtered out as discussed in the previous paragraph, voltage variation due to line frequency (50Hz or 60Hz) can be difficult to remove.

The GND pin should be connected to a clean ground point. In many cases, this will be the "analog" ground. Avoid connections which are too near the grounding point of a microcontroller or digital signal processor. If needed, run a ground trace directly from the converter to the power supply entry point. The ideal layout will include an analog ground plane dedicated to the converter and associated analog circuitry.

PACKAGE DRAWINGS

Package Number 322 - 16-Lead SSOP, .150 Wide



DIM	INCHES		MILLIMETERS		NOTE
	MIN.	MAX.	MIN.	MAX.	
A	.053	.069	1.35	1.75	
A1	.004	.010	0.10	0.25	
A2	.055	.059	1.40	1.50	
b	.008	.012	0.20	0.30	3,7
c	.007	.010	0.19	0.25	7
D	.188	.197	4.78	5.00	2
E	.228	.244	5.80	6.20	
E1	.149	.157	3.78	4.00	2
e	.025	BASIC	.635	BASIC	
L	.016	.050	0.40	1.27	4
N	16		16		5
α	0°	8°	0°	8°	

DIM	INCHES		MILLIMETERS		NOTE
	MIN.	MAX.	MIN.	MAX.	

NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
2. D AND E1 DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS, BUT DO INCLUDE MOLD MISMATCH AND ARE MEASURED AT DATUM PLANE -H- MOLD PARTING LINE. MOLD FLASH OR PROTRUSION SHALL NOT EXCEED .008 INCH (0.20mm) PER SIDE.
3. DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION/INTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE .005 INCH (0.13mm) TOTAL IN EXCESS OF b DIMENSION AT MAXIMUM MATERIAL CONDITION. DAMBAR INTRUSION SHALL NOT REDUCE DIMENSION b BY MORE THAN .003 INCH (0.07mm) AT LEAST MATERIAL CONDITION.
4. DIMENSION L TO BE DETERMINED AT SEATING PLANE-DATUM "C".
5. "N" IS THE NUMBER OF TERMINAL POSITIONS.
6. A VISUAL INDEX FEATURE MUST BE LOCATED WITHIN THE CROSSHATCHED AREA.
7. DIMENSIONS b AND c APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN .004 AND .010 INCH FROM THE LEAD TIP.

PACKAGE NUMBER: ZZ322	REV.: B
JEDEC NUMBER: MO-137-AB WITH THE EXCEPTION OF DIM. D, E1	