

## 16-Bit, 2.5MSPS Analog-to-Digital Converter

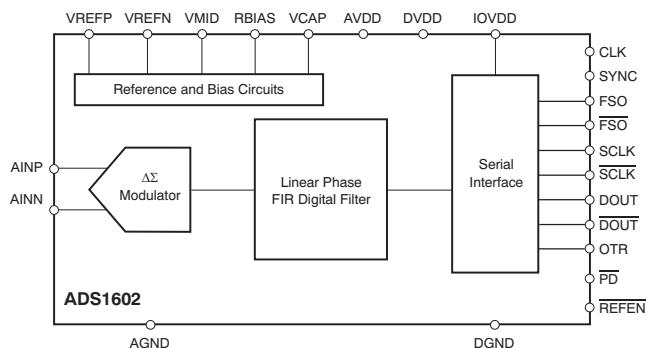
Check for Samples: [ADS1602](#)

### FEATURES

- **High Speed:**
  - **Data Rate:** 2.5MSPS
  - **Bandwidth:** 1.23MHz
- **Outstanding Performance:**
  - **SNR:** 91dB at  $f_{IN} = 100\text{kHz}$ ,  $-1\text{dBFS}$
  - **THD:**  $-101\text{dB}$  at  $f_{IN} = 100\text{kHz}$ ,  $-6\text{dBFS}$
  - **SFDR:** 103dB at  $f_{IN} = 100\text{kHz}$ ,  $-6\text{dBFS}$
- **Ease-of-Use:**
  - **High-Speed 3-Wire Serial Interface**
  - **Directly Connects to TMS320 DSPs**
  - **On-Chip Digital Filter Simplifies Antialias Requirements**
  - **Simple Pin-Driven Control—No On-Chip Registers to Program**
  - **Selectable On-Chip Voltage Reference**
  - **Simultaneous Sampling with Multiple ADS1602s**
- **Low Power:**
  - 530mW at 2.5MSPS
  - **Power-Down Mode**

### APPLICATIONS

- **Sonar**
- **Vibration Analysis**
- **Data Acquisition**



### DESCRIPTION

The ADS1602 is a high-speed, high-precision, delta-sigma ( $\Delta\Sigma$ ) analog-to-digital converter (ADC) manufactured on an advanced CMOS process. The ADS1602 oversampling topology reduces clock jitter sensitivity during the sampling of high-frequency, large amplitude signals by a factor of four over that achieved by Nyquist-rate ADCs. Consequently, signal-to-noise ratio (SNR) is particularly improved. Total harmonic distortion (THD) is  $-101\text{dB}$ , and the spurious-free dynamic range (SFDR) is 103dB.

Optimized for power and performance, the ADS1602 dissipates only 530mW while providing a full-scale differential input range of  $\pm 3\text{V}$ . Having such a wide input range makes out-of-range signals unlikely. The OTR pin indicates if an analog input out-of-range condition does occur. The differential input signal is measured against the differential reference, which can be generated internally or supplied externally on the ADS1602.

The ADS1602 uses an inherently stable advanced modulator with an on-chip decimation filter. The filter stop band extends to 38.6MHz, which greatly simplifies the antialiasing circuitry. The modulator samples the input signal up to 40MSPS, depending on  $f_{CLK}$ , while the 16x decimation filter uses a series of four half-band FIR filter stages to provide 75dB of stop band attenuation and 0.001dB of passband ripple.

Output data is provided over a simple 3-wire serial interface at rates up to 2.5MSPS, with a  $-3\text{dB}$  bandwidth of 1.23MHz. The output data or its complementary format directly connects to DSPs such as TI's [TMS320 family](#), FPGAs, or ASICs. A dedicated synchronization pin enables simultaneous sampling with multiple ADS1602s in multi-channel systems. Power dissipation is set by an external resistor that allows a reduction in dissipation when operating at slower speeds. All of the ADS1602 features are controlled by dedicated I/O pins, which simplify operation by eliminating the need for on-chip registers.

The high performing, easy-to-use ADS1602 is especially suitable for demanding measurement applications in sonar, vibration analysis, and data acquisition. The ADS1602 is offered in a small, 7mm  $\times$  7mm TQFP-48 package and is specified from  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$ .



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

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This integrated circuit can be damaged by ESD. Texas Instruments 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.

## PACKAGE/ORDERING INFORMATION

For the most current package and ordering information, see the Package Option Addendum at the end of this document, or visit the device product folder at [www.ti.com](http://www.ti.com).

### ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

Over operating free-air temperature range, unless otherwise noted.

	ADS1602	UNIT
AVDD to AGND	–0.3 to +6	V
DVDD to DGND	–0.3 to +3.6	V
IOVDD to DGND	–0.3 to +6	V
AGND to DGND	–0.3 to +0.3	V
Input current	100, momentary	mA
Input current	10, continuous	mA
Analog I/O to AGND	–0.3 to AVDD + 0.3	V
Digital I/O to DGND	–0.3 to IOVDD + 0.3	V
Maximum junction temperature	+150	°C
Operating temperature range	–40 to +105	°C
Storage temperature range	–60 to +150	°C

- (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

## ELECTRICAL CHARACTERISTICS

All specifications at  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ ,  $\text{AVDD} = 5\text{V}$ ,  $\text{DVDD} = \text{IOVDD} = 3\text{V}$ ,  $f_{\text{CLK}} = 40\text{MHz}$ , external  $V_{\text{REF}} = +3\text{V}$ ,  $V_{\text{CM}} = +1.45\text{V}$ , and  $R_{\text{BIAS}} = 37\text{k}\Omega$ , unless otherwise noted.

PARAMETER	TEST CONDITIONS	ADS1602			UNIT
		MIN	TYP	MAX	
<b>Analog Input</b>					
Differential input voltage ( $V_{\text{IN}}$ ) (AINP – AINN)	0dBFS		$\pm V_{\text{REF}}$		V
Common-mode input voltage ( $V_{\text{CM}}$ ) (AINP + AINN) / 2			1.45		V
Absolute input voltage (AINP or AINN with respect to AGND)		-0.1	4.6		V
<b>Dynamic Specifications</b>					
Data rate		2.5 $\left( \frac{f_{\text{CLK}}}{40\text{MHz}} \right)$			MSPS
Signal-to-noise ratio (SNR)	$f_{\text{IN}} = 10\text{kHz}, -1\text{dBFS}$	92			dB
	$f_{\text{IN}} = 10\text{kHz}, -3\text{dBFS}$	87	90		dB
	$f_{\text{IN}} = 10\text{kHz}, -6\text{dBFS}$	84	87		dB
	$f_{\text{IN}} = 100\text{kHz}, -1\text{dBFS}$	91			dB
	$f_{\text{IN}} = 100\text{kHz}, -3\text{dBFS}$	87	89		dB
	$f_{\text{IN}} = 100\text{kHz}, -6\text{dBFS}$	84	86		dB
	$f_{\text{IN}} = 800\text{kHz}, -1\text{dBFS}$	91			dB
	$f_{\text{IN}} = 800\text{kHz}, -3\text{dBFS}$	89			dB
	$f_{\text{IN}} = 800\text{kHz}, -6\text{dBFS}$	86			dB
Total harmonic distortion (THD)	$f_{\text{IN}} = 10\text{kHz}, -1\text{dBFS}$	-94			dB
	$f_{\text{IN}} = 10\text{kHz}, -3\text{dBFS}$	-106	-92		dB
	$f_{\text{IN}} = 10\text{kHz}, -6\text{dBFS}$	-108	-93		dB
	$f_{\text{IN}} = 100\text{kHz}, -1\text{dBFS}$	-90			dB
	$f_{\text{IN}} = 100\text{kHz}, -3\text{dBFS}$	-96	-90		dB
	$f_{\text{IN}} = 100\text{kHz}, -6\text{dBFS}$	-101	-92		dB
	$f_{\text{IN}} = 800\text{kHz}, -1\text{dBFS}$	-116			dB
	$f_{\text{IN}} = 800\text{kHz}, -3\text{dBFS}$	-114			dB
	$f_{\text{IN}} = 800\text{kHz}, -6\text{dBFS}$	-110			dB
Signal-to-noise + distortion (SINAD)	$f_{\text{IN}} = 10\text{kHz}, -1\text{dBFS}$	89			dB
	$f_{\text{IN}} = 10\text{kHz}, -3\text{dBFS}$	85	90		dB
	$f_{\text{IN}} = 10\text{kHz}, -6\text{dBFS}$	82	87		dB
	$f_{\text{IN}} = 100\text{kHz}, -1\text{dBFS}$	87			dB
	$f_{\text{IN}} = 100\text{kHz}, -3\text{dBFS}$	85	88		dB
	$f_{\text{IN}} = 100\text{kHz}, -6\text{dBFS}$	82	86		dB
	$f_{\text{IN}} = 800\text{kHz}, -1\text{dBFS}$	91			dB
	$f_{\text{IN}} = 800\text{kHz}, -3\text{dBFS}$	89			dB
	$f_{\text{IN}} = 800\text{kHz}, -6\text{dBFS}$	86			dB
Spurious-free dynamic range (SFDR)	$f_{\text{IN}} = 10\text{kHz}, -1\text{dBFS}$	95			dB
	$f_{\text{IN}} = 10\text{kHz}, -3\text{dBFS}$	90	107		dB
	$f_{\text{IN}} = 10\text{kHz}, -6\text{dBFS}$	93	112		dB
	$f_{\text{IN}} = 100\text{kHz}, -1\text{dBFS}$	91			dB
	$f_{\text{IN}} = 100\text{kHz}, -3\text{dBFS}$	90	96		dB
	$f_{\text{IN}} = 100\text{kHz}, -6\text{dBFS}$	93	103		dB
	$f_{\text{IN}} = 800\text{kHz}, -1\text{dBFS}$	120			dB
	$f_{\text{IN}} = 800\text{kHz}, -3\text{dBFS}$	119			dB
	$f_{\text{IN}} = 800\text{kHz}, -6\text{dBFS}$	114			dB
Intermodulation distortion (IMD)	$f_1 = 995\text{kHz}, -6\text{dBFS}$ $f_2 = 1005\text{kHz}, -6\text{dBFS}$	94			dB
Aperture delay		4			ns

## ELECTRICAL CHARACTERISTICS (continued)

All specifications at  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ ,  $\text{AVDD} = 5\text{V}$ ,  $\text{DVDD} = \text{IOVDD} = 3\text{V}$ ,  $f_{\text{CLK}} = 40\text{MHz}$ , external  $V_{\text{REF}} = +3\text{V}$ ,  $V_{\text{CM}} = +1.45\text{V}$ , and  $R_{\text{BIAS}} = 37\text{k}\Omega$ , unless otherwise noted.

PARAMETER	TEST CONDITIONS	ADS1602			UNIT
		MIN	TYP	MAX	
<b>Digital Filter Characteristics</b>					
Passband		0	$1.1\left(\frac{f_{\text{CLK}}}{40\text{MHz}}\right)$		MHz
Passband ripple				$\pm 0.001$	dB
Passband transition	–0.1dB attenuation		$1.15\left(\frac{f_{\text{CLK}}}{40\text{MHz}}\right)$		MHz
	–3dB attenuation		$1.23\left(\frac{f_{\text{CLK}}}{40\text{MHz}}\right)$		MHz
Stop band		$1.4\left(\frac{f_{\text{CLK}}}{40\text{MHz}}\right)$	$38.6\left(\frac{f_{\text{CLK}}}{40\text{MHz}}\right)$		MHz
Stop band attenuation		75			dB
Group delay			$10.4\left(\frac{40\text{MHz}}{f_{\text{CLK}}}\right)$		μs
Settling time	Complete settling		$20.4\left(\frac{40\text{MHz}}{f_{\text{CLK}}}\right)$		μs
<b>Static Specifications</b>					
Resolution		16			Bits
No missing codes		16			Bits
Input-referred noise		0.5	0.85		LSB, rms
Integral nonlinearity	–1dBFS signal	0.75			LSB
Differential nonlinearity		0.25			LSB
Offset error		–0.1			%FSR
Offset error drift		–0.1			ppmFSR/°C
Gain error		0.25 <sup>(1)</sup>			%
Gain error drift	Excluding reference drift	10			ppm/°C
Common-mode rejection	At dc	75			dB
Power-supply rejection	At dc	65			dB
<b>Internal Voltage Reference</b>	$\text{REFEN} = \text{low}$				
$V_{\text{REF}} = (V_{\text{REFP}} - V_{\text{REFN}})$		2.75	3	3.25	V
$V_{\text{REFP}}$		3.5	4	4.3	V
$V_{\text{REFN}}$		0.5	1	1.3	V
$V_{\text{MID}}$		2.3	2.5	2.7	V
$V_{\text{REF}}$ drift		50			ppm/°C
Startup time		15			ms
<b>External Voltage Reference</b>	$\text{REFEN} = \text{high}$				
$V_{\text{REF}} = (V_{\text{REFP}} - V_{\text{REFN}})$		2	3	3.25	V
$V_{\text{REFP}}$		3.5	4	4.25	V
$V_{\text{REFN}}$		0.5	1	1.5	V
$V_{\text{MID}}$		2.3	2.5	2.6	V

(1) There is a constant gain error of 2.5% in addition to the variable gain error of  $\pm 0.25\%$ . Therefore, the gain error is  $2.5 \pm 0.25\%$ .

## ELECTRICAL CHARACTERISTICS (continued)

All specifications at  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ ,  $\text{AVDD} = 5\text{V}$ ,  $\text{DVDD} = \text{IOVDD} = 3\text{V}$ ,  $f_{\text{CLK}} = 40\text{MHz}$ , external  $V_{\text{REF}} = +3\text{V}$ ,  $V_{\text{CM}} = +1.45\text{V}$ , and  $R_{\text{BIAS}} = 37\text{k}\Omega$ , unless otherwise noted.

PARAMETER	TEST CONDITIONS	ADS1602			UNIT
		MIN	TYP	MAX	
<b>Clock Input</b>					
Frequency ( $f_{\text{CLK}}$ )				40	MHz
Duty cycle	$f_{\text{CLK}} = 40\text{MHz}$	45	55		%
<b>Digital Input/Output</b>					
$V_{\text{IH}}$		0.7 $\times$ $\text{IOVDD}$	$\text{IOVDD}$		V
$V_{\text{IL}}$		DGND	0.3 $\times$ $\text{IOVDD}$		V
$V_{\text{OH}}$	$I_{\text{OH}} = 50\mu\text{A}$	$\text{IOVDD} - 0.5$			V
$V_{\text{OL}}$	$I_{\text{OL}} = 50\mu\text{A}$		DGND + 0.5		V
Input leakage	$\text{DGND} < V_{\text{DIGIN}} < \text{IOVDD}$			$\pm 10$	$\mu\text{A}$
<b>Power-Supply Requirements</b>					
$\text{AVDD}$		4.75	5.25		V
$\text{DVDD}$		2.7	3.3		V
$\text{IOVDD}$	$I_{\text{OH}} = 50\mu\text{A}$	2.7	5.25		V
AVDD current ( $I_{\text{AVDD}}$ )	$\overline{\text{REFEN}} = \text{low}$	110	125		mA
	$\overline{\text{REFEN}} = \text{high}$	88	98		mA
$\text{DVDD}$ current ( $I_{\text{DVDD}}$ )	$\text{IOVDD} = 3\text{V}$	25	30		mA
$\text{IOVDD}$ current ( $I_{\text{IOVDD}}$ )	$\text{IOVDD} = 3\text{V}$	8	10		mA
Power dissipation	$\text{AVDD} = 5\text{V}$ , $\text{DVDD} = 3\text{V}$ , $\text{IOVDD} = 3\text{V}$ , $\overline{\text{REFEN}} = \text{high}$	530	610		mW
	$\overline{\text{PD}} = \text{low}$ , CLK disabled	10			mW
<b>Temperature Range</b>					
Specified		-40	+85		$^\circ\text{C}$
Operating		-40	+105		$^\circ\text{C}$
Storage		-60	+150		$^\circ\text{C}$

## DEFINITIONS

### Absolute Input Voltage

Absolute input voltage, given in volts, is the voltage of each analog input (AINN or AINP) with respect to AGND.

### Aperture Delay

Aperture delay is the delay between the rising edge of CLK and the sampling of the input signal.

### Common-Mode Input Voltage

Common-mode input voltage ( $V_{CM}$ ) is the average voltage of the analog inputs:

$$\frac{(AINP + AINN)}{2}$$

### Differential Input Voltage

Differential input voltage ( $V_{IN}$ ) is the voltage difference between the analog inputs ( $AINP - AINN$ ).

### Differential Nonlinearity (DNL)

DNL, given in least-significant bits of the output code (LSB), is the maximum deviation of the output code step sizes from the ideal value of 1LSB.

### Full-Scale Range (FSR)

FSR is the difference between the maximum and minimum measurable input signals ( $FSR = 2V_{REF}$ ).

### Gain Error

Gain error, given in %, is the error of the full-scale input signal with respect to the ideal value.

### Gain Error Drift

Gain error drift, given in ppm/ $^{\circ}$ C, is the drift over temperature of the gain error. The gain error is specified as the larger of the drift from ambient ( $T = +25^{\circ}$ C) to the minimum or maximum operating temperatures.

### Integral Nonlinearity (INL)

INL, given in least-significant bits of the output code (LSB), is the maximum deviation of the output codes from a best fit line.

### Intermodulation Distortion (IMD)

IMD, given in dB, is measured while applying two input signals of the same magnitude, but with slightly different frequencies. It is calculated as the difference between the rms amplitude of the input signal to the rms amplitude of the peak spurious signal.

### Offset Error

Offset Error, given in % of FSR, is the output reading when the differential input is zero.

### Offset Error Drift

Offset error drift, given in ppm of FSR/ $^{\circ}$ C, is the drift over temperature of the offset error. The offset error is specified as the larger of the drift from ambient ( $T = +25^{\circ}$ C) to the minimum or maximum operating temperatures.

### Signal-to-Noise Ratio (SNR)

SNR, given in dB, is the ratio of the rms value of the input signal to the sum of all the frequency components below  $f_{CLK}/2$  (the Nyquist frequency) excluding the first six harmonics of the input signal and the dc component.

### Signal-to-Noise and Distortion (SINAD)

SINAD, given in dB, is the ratio of the rms value of the input signal to the sum of all the frequency components below  $f_{CLK}/2$  (the Nyquist frequency) including the harmonics of the input signal but excluding the dc component.

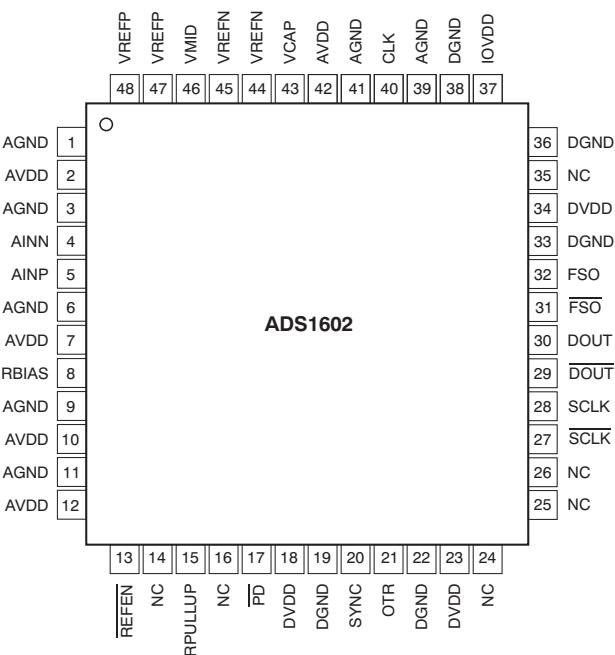
### Spurious-Free Dynamic Range (SFDR)

SFDR, given in dB, is the difference between the rms amplitude of the input signal to the rms amplitude of the peak spurious signal.

### Total Harmonic Distortion (THD)

THD, given in dB, is the ratio of the sum of the rms value of the first six harmonics of the input signal to the rms value of the input signal.

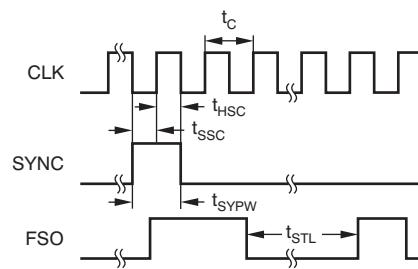
## PIN ASSIGNMENTS

**TQFP PACKAGE  
(TOP VIEW)**


## TERMINAL FUNCTIONS

TERMINAL	FUNCTION	DESCRIPTION
NAME	NO.	
AGND	1, 3, 6, 9, 11, 39, 41	Analog
AVDD	2, 7, 10, 12, 42	Analog
AINN	4	Analog input
AINP	5	Analog input
RBIAS	8	Analog
REFEN	13	Digital input: active low
NC	14, 16, 24–26, 35	Do not connect
RPULLUP	15	Digital input
PD	17	Digital input: active low
DVDD	18, 23, 34	Digital
DGND	19, 22, 33, 36, 38	Digital
SYNC	20	Digital input
OTR	21	Digital output
SCLK	28	Digital output
SCLK	27	Digital output
DOUT	30	Digital output
DOUT	29	Digital output
FSO	32	Digital output
FSO	31	Digital output
IOVDD	37	Digital
CLK	40	Digital input
VCAP	43	Analog
VREFN	44, 45	Analog
VMID	46	Analog
VREFP	47, 48	Analog

## TIMING DIAGRAMS

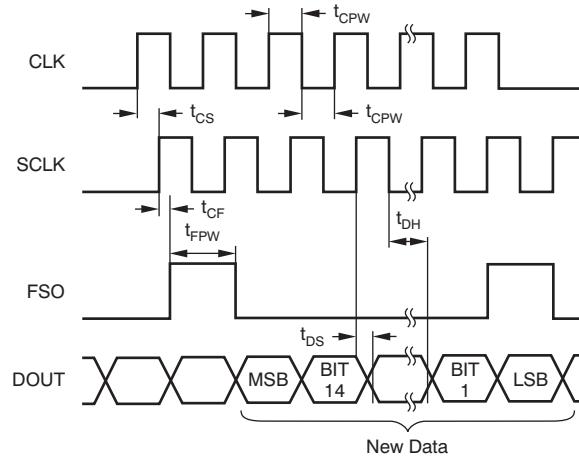


**Figure 1. Initialization Timing**

## TIMING REQUIREMENTS

For  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , DVDD = 2.7V to 3.6V, and IOVDD = 2.7V to 5.25V.

SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNIT
$t_{SYPW}$	SYNC positive pulse width	1			CLK period
$t_c$	Clock period (CLK)	25			ns
$t_{SSC}$	Setup time; SYNC rising edge to CLK rising edge	0.5			CLK period
$t_{HSC}$	Hold time; CLK rising edge to SYNC falling edge	0.5			CLK period
$t_{STL}$	Settling time of the ADS1602; FSO falling edge to next FSO rising edge		833		CLK periods



**Figure 2. Data Retrieval Timing**

## TIMING REQUIREMENTS

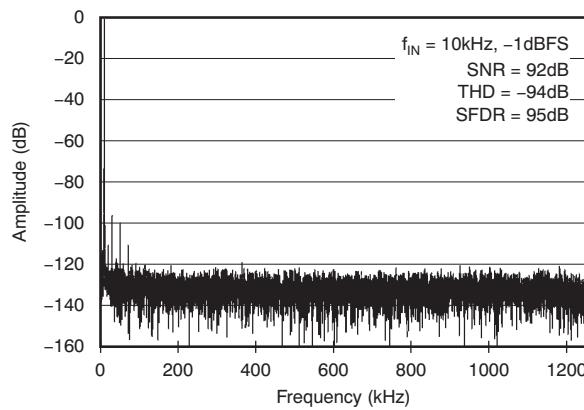
For  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , DVDD = 2.7V to 3.6V, and IOVDD = 2.7V to 5.25V.

SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNIT
$t_{CS}$	Rising edge of CLK to rising edge of SCLK		15		ns
$t_{CF}$	Rising edge of SCLK to rising edge of FSO		5		ns
$t_{CPW}$	CLK positive or negative pulse width	11.25			ns
$t_{FPW}$	Frame sync output high pulse width		1		CLK period
$t_{DS}$	SCLK rising edge to new DOUT valid		5		ns
$t_{DH}$	SCLK falling edge to DOUT invalid	6			ns

## TYPICAL CHARACTERISTICS

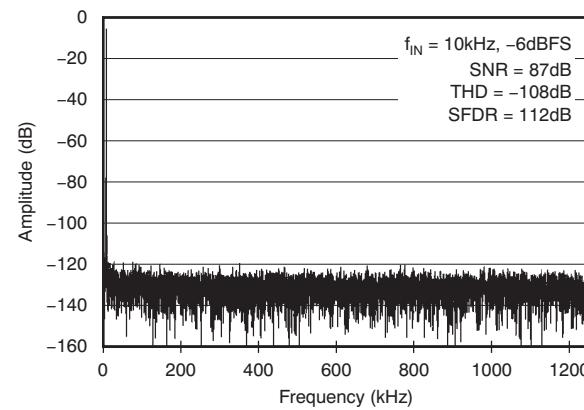
All specifications at  $T_A = +25^\circ\text{C}$ , AVDD = 5V, DVDD = IOVDD = 3V,  $f_{\text{CLK}} = 40\text{MHz}$ , External  $V_{\text{REF}} = +3\text{V}$ ,  $V_{\text{CM}} = +1.45\text{V}$ , and  $R_{\text{BIAS}} = 37\text{k}\Omega$ , unless otherwise noted.

### SPECTRAL RESPONSE



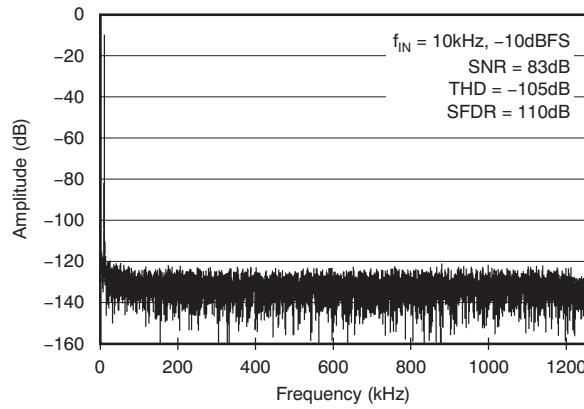
**Figure 3.**

### SPECTRAL RESPONSE



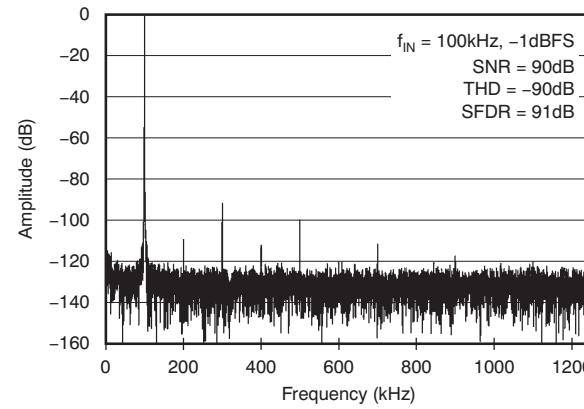
**Figure 4.**

### SPECTRAL RESPONSE



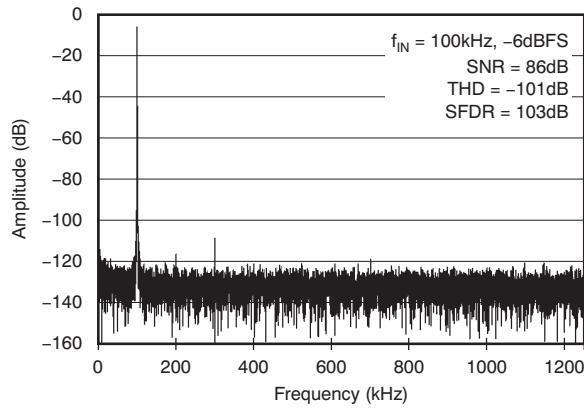
**Figure 5.**

### SPECTRAL RESPONSE



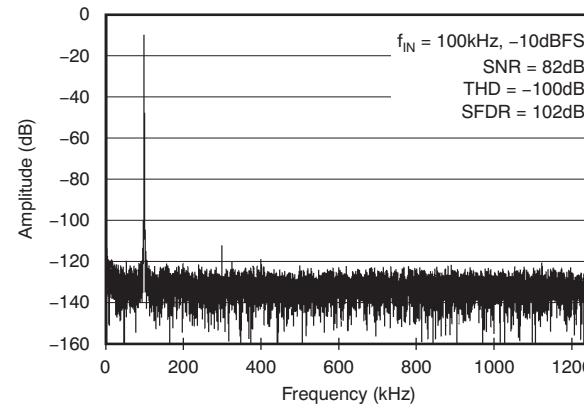
**Figure 6.**

### SPECTRAL RESPONSE



**Figure 7.**

### SPECTRAL RESPONSE



**Figure 8.**

### TYPICAL CHARACTERISTICS (continued)

All specifications at  $T_A = +25^\circ\text{C}$ , AVDD = 5V, DVDD = IOVDD = 3V,  $f_{\text{CLK}} = 40\text{MHz}$ , External  $V_{\text{REF}} = +3\text{V}$ ,  $V_{\text{CM}} = +1.45\text{V}$ , and  $R_{\text{BIAS}} = 37\text{k}\Omega$ , unless otherwise noted.

#### SPECTRAL RESPONSE

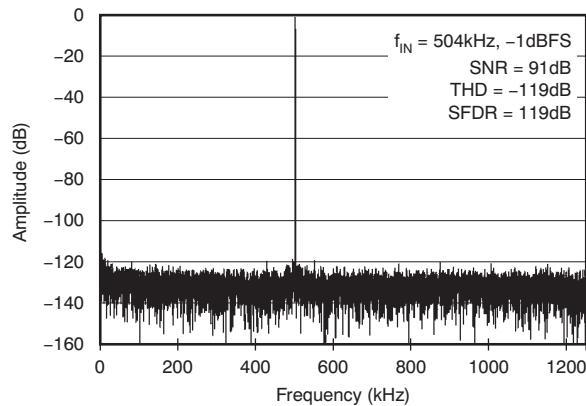


Figure 9.

#### SPECTRAL RESPONSE

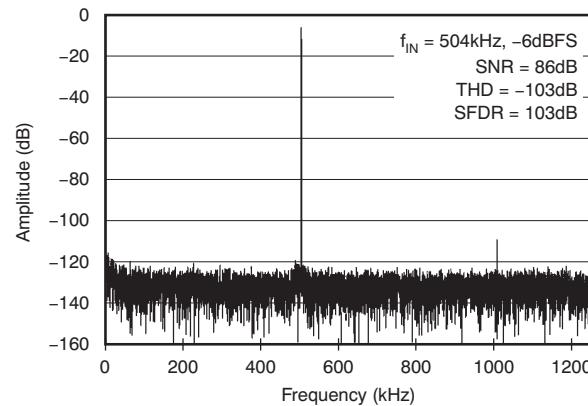


Figure 10.

#### SPECTRAL RESPONSE

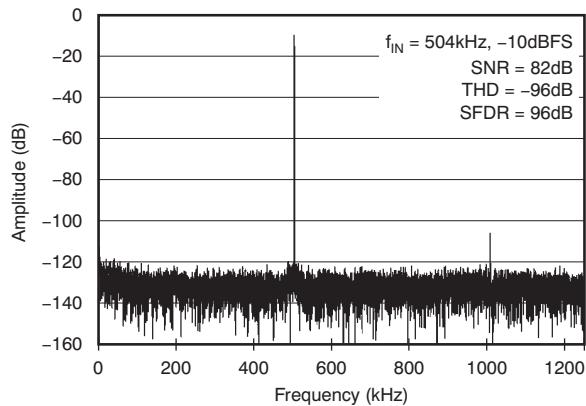


Figure 11.

#### SPECTRAL RESPONSE

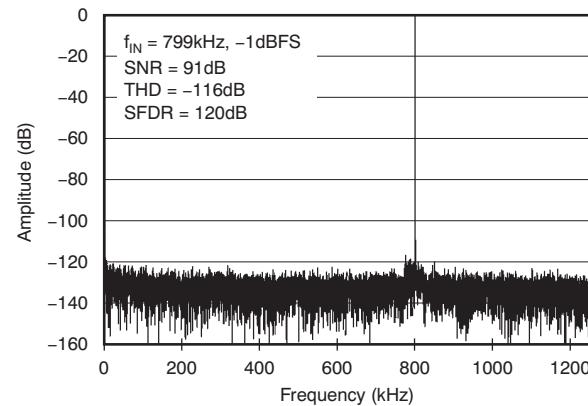


Figure 12.

#### SPECTRAL RESPONSE

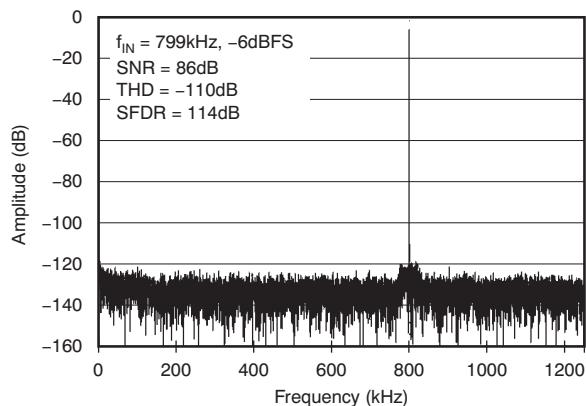


Figure 13.

#### SPECTRAL RESPONSE

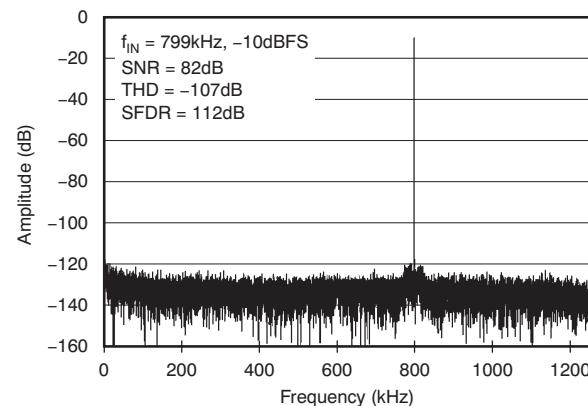


Figure 14.

### TYPICAL CHARACTERISTICS (continued)

All specifications at  $T_A = +25^\circ\text{C}$ ,  $\text{AVDD} = 5\text{V}$ ,  $\text{DVDD} = \text{IOVDD} = 3\text{V}$ ,  $f_{\text{CLK}} = 40\text{MHz}$ , External  $V_{\text{REF}} = +3\text{V}$ ,  $V_{\text{CM}} = +1.45\text{V}$ , and  $R_{\text{BIAS}} = 37\text{k}\Omega$ , unless otherwise noted.

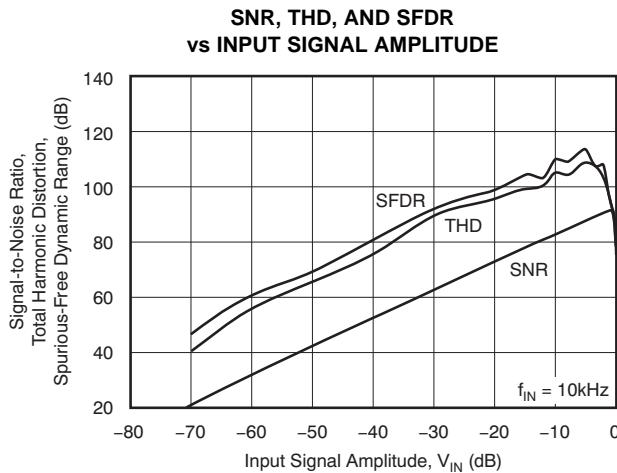


Figure 15.

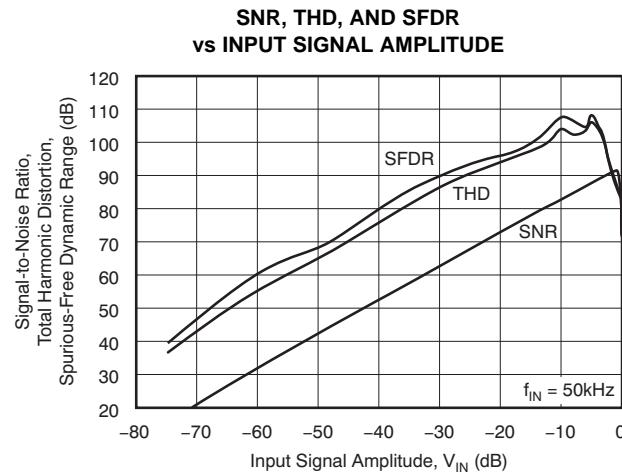


Figure 16.

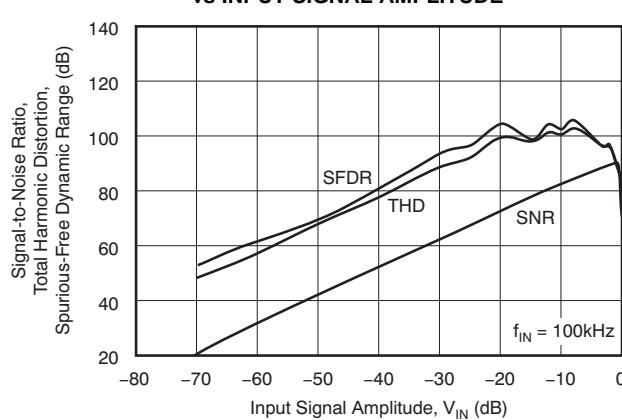


Figure 17.

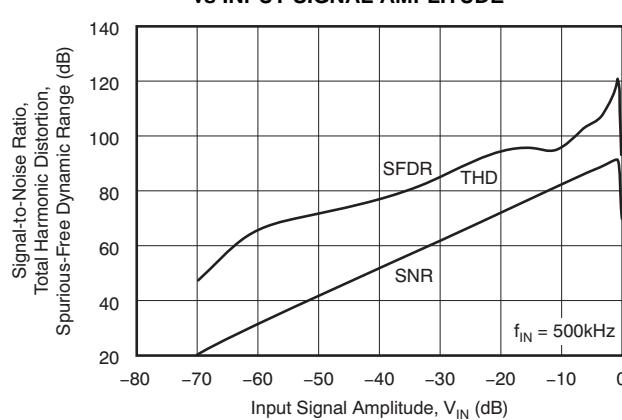


Figure 18.

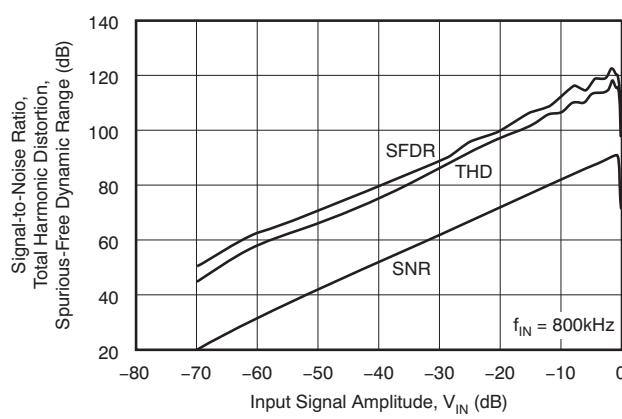


Figure 19.

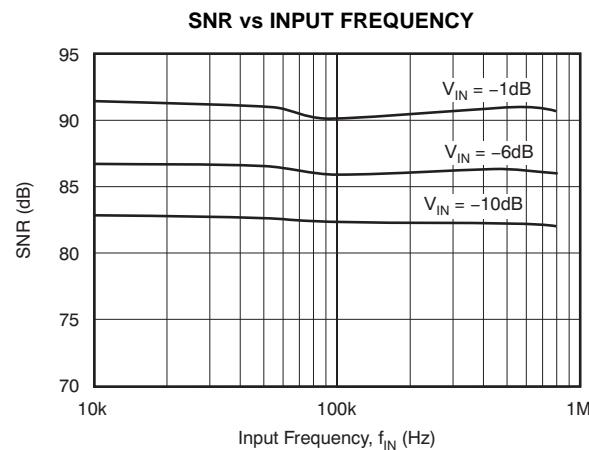


Figure 20.

### TYPICAL CHARACTERISTICS (continued)

All specifications at  $T_A = +25^\circ\text{C}$ ,  $\text{AVDD} = 5\text{V}$ ,  $\text{DVDD} = \text{IOVDD} = 3\text{V}$ ,  $f_{\text{CLK}} = 40\text{MHz}$ , External  $V_{\text{REF}} = +3\text{V}$ ,  $V_{\text{CM}} = +1.45\text{V}$ , and  $R_{\text{BIAS}} = 37\text{k}\Omega$ , unless otherwise noted.

THD vs INPUT FREQUENCY

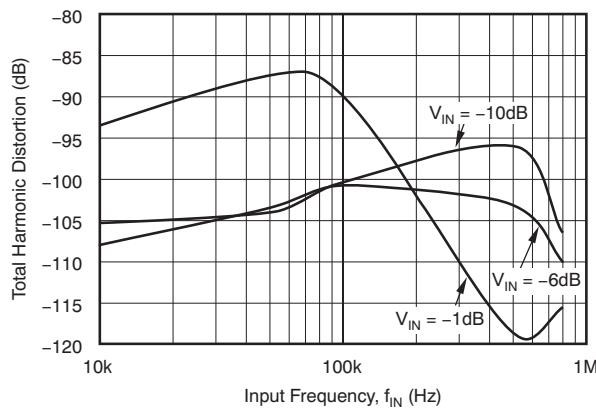


Figure 21.

SFDR vs INPUT FREQUENCY

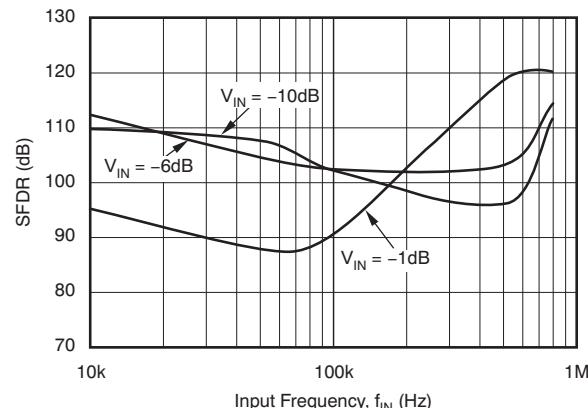


Figure 22.

SNR vs INPUT COMMON-MODE VOLTAGE

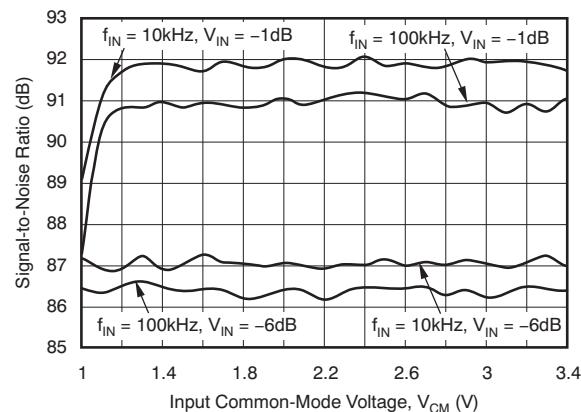


Figure 23.

THD vs INPUT COMMON-MODE VOLTAGE

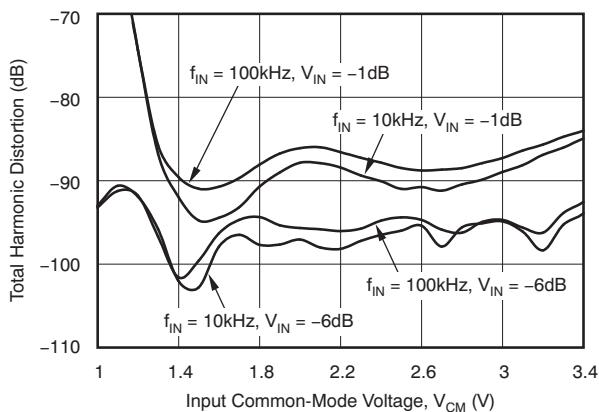


Figure 24.

SFDR vs INPUT COMMON-MODE VOLTAGE

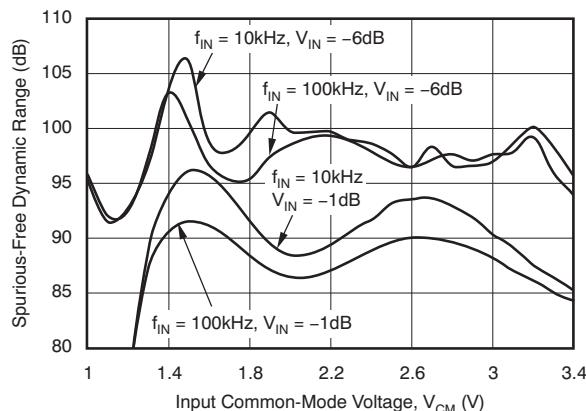


Figure 25.

OFFSET DRIFT OVER TIME

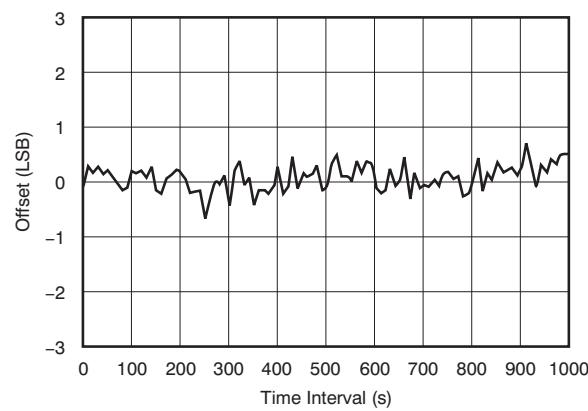
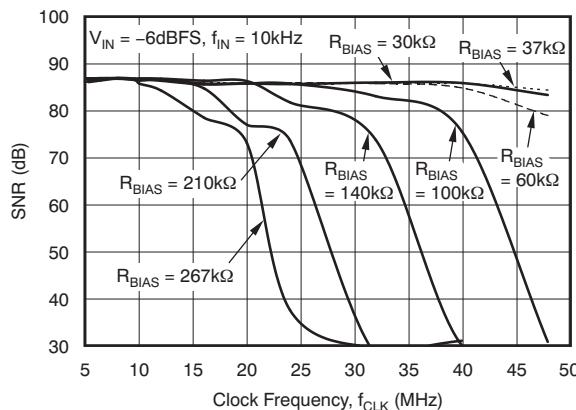


Figure 26.

### TYPICAL CHARACTERISTICS (continued)

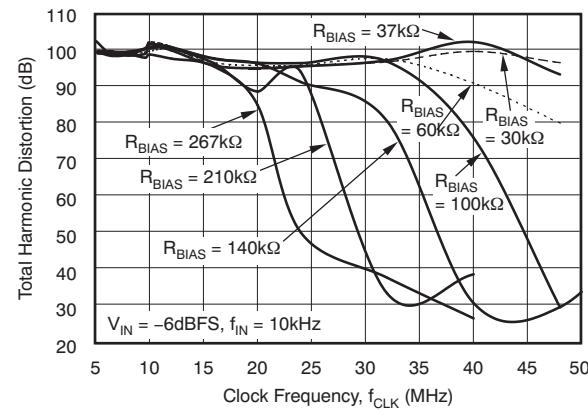
All specifications at  $T_A = +25^\circ\text{C}$ ,  $\text{AVDD} = 5\text{V}$ ,  $\text{DVDD} = \text{IOVDD} = 3\text{V}$ ,  $f_{\text{CLK}} = 40\text{MHz}$ , External  $V_{\text{REF}} = +3\text{V}$ ,  $V_{\text{CM}} = +1.45\text{V}$ , and  $R_{\text{BIAS}} = 37\text{k}\Omega$ , unless otherwise noted.

**SNR vs CLOCK FREQUENCY**



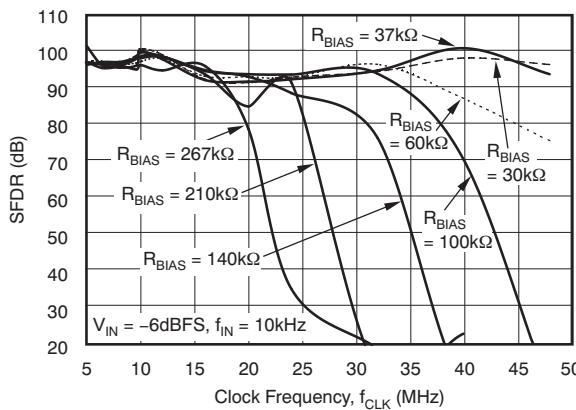
**Figure 27.**

**THD vs CLOCK FREQUENCY**



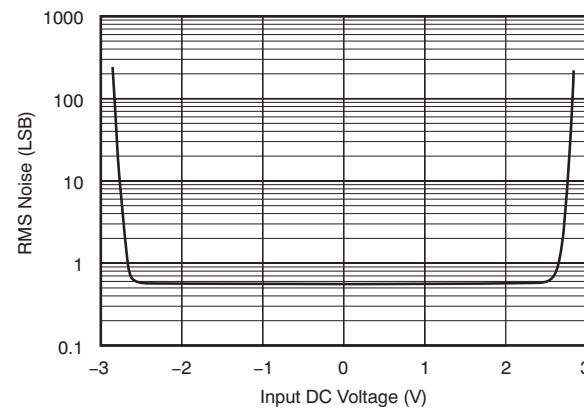
**Figure 28.**

**SFDR vs CLOCK FREQUENCY**



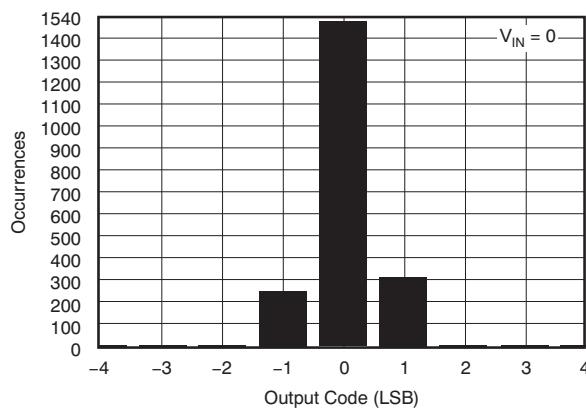
**Figure 29.**

**NOISE vs DC INPUT VOLTAGE**



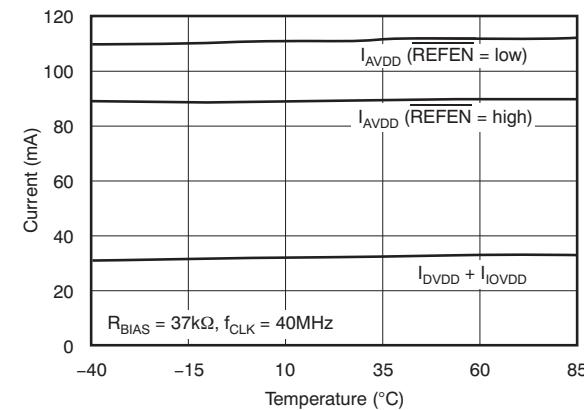
**Figure 30.**

**NOISE HISTOGRAM**



**Figure 31.**

**POWER-SUPPLY CURRENT vs TEMPERATURE**



**Figure 32.**

### TYPICAL CHARACTERISTICS (continued)

All specifications at  $T_A = +25^\circ\text{C}$ ,  $\text{AVDD} = 5\text{V}$ ,  $\text{DVDD} = \text{IOVDD} = 3\text{V}$ ,  $f_{\text{CLK}} = 40\text{MHz}$ , External  $V_{\text{REF}} = +3\text{V}$ ,  $V_{\text{CM}} = +1.45\text{V}$ , and  $R_{\text{BIAS}} = 37\text{k}\Omega$ , unless otherwise noted.

#### SUPPLY CURRENT vs CLOCK FREQUENCY

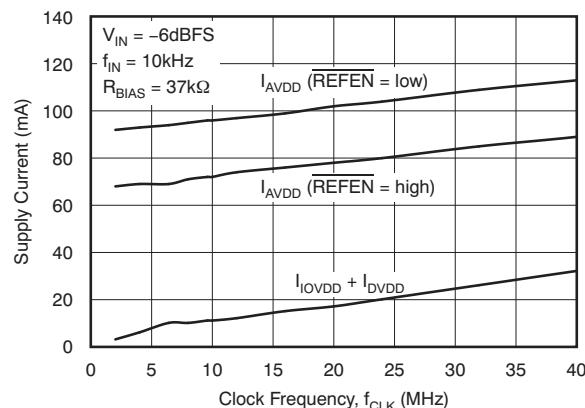


Figure 33.

#### ANALOG SUPPLY CURRENT vs $R_{\text{BIAS}}$

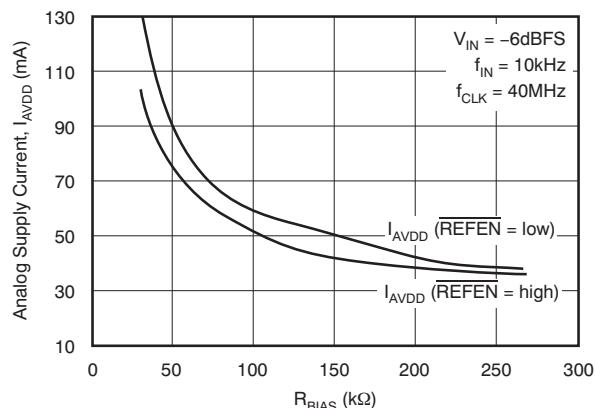


Figure 34.

#### SNR vs TEMPERATURE

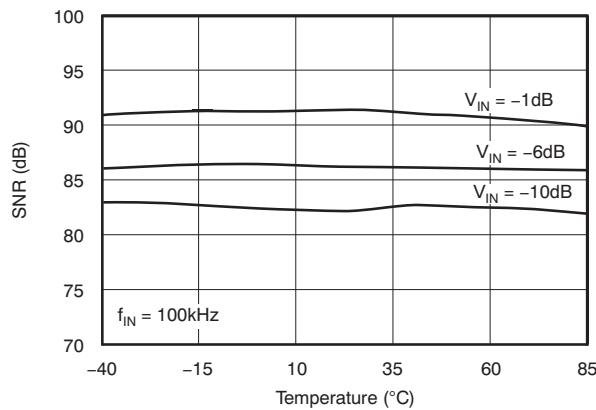


Figure 35.

#### THD vs TEMPERATURE

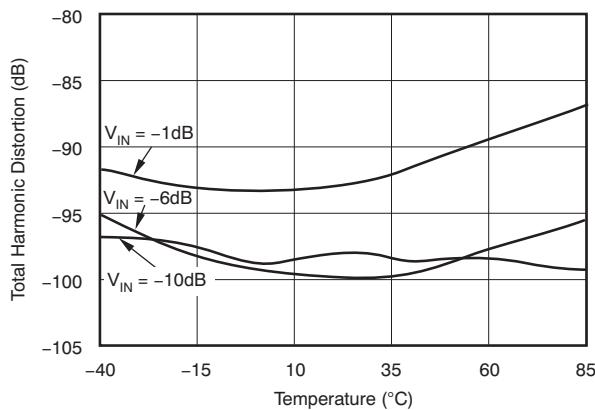


Figure 36.

#### SFDR vs TEMPERATURE

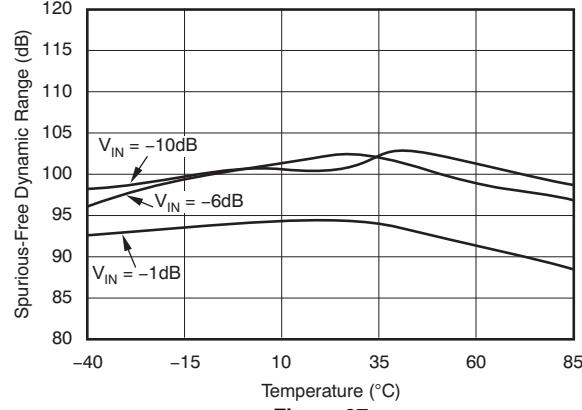


Figure 37.

## OVERVIEW

The ADS1602 is a high-performance delta-sigma ( $\Delta\Sigma$ ) analog-to-digital converter (ADC). The modulator uses an inherently stable 2-1-1 multi-stage architecture incorporating proprietary circuitry that allows for very linear high-speed operation. The modulator samples the input signal at 40MSPS (when  $f_{CLK} = 40MHz$ ). A low-ripple linear phase digital filter decimates the modulator output by 16 to provide high resolution 16-bit output data.

Conceptually, the modulator and digital filter measure the differential input signal,  $V_{IN} = (AINP - AINN)$ , against the scaled differential reference,  $V_{REF} = (VREFP - VREFN)$ , as shown in Figure 38. The voltage reference can either be generated internally or supplied externally. A three-wire serial interface, designed for direct connection to DSPs, outputs the data. A separate power supply for the I/O allows flexibility for interfacing to different logic families. Out-of-range conditions are indicated with a dedicated digital output pin. Analog power dissipation is controlled using an external resistor. This control allows reduced dissipation when operating at slower speeds. When not in use, power consumption can be dramatically reduced by setting the PD pin low to enter Power-Down mode.

### ANALOG INPUTS (AINP, AINN)

The ADS1602 measures the differential signal,  $V_{IN} = (AINP - AINN)$ , against the differential reference,  $V_{REF} = (VREFP - VREFN)$ . The most positive measurable differential input is  $V_{REF}$ , which produces the most positive digital output code of 7FFFh. Likewise, the most negative measurable differential input is  $-V_{REF}$ , which produces the most negative digital output code of 8000h.

The ADS1602 supports a very wide range of input signals. For  $V_{REF} = 3V$ , the full-scale input voltages are  $\pm 3V$ . Having such a wide input range makes out-of-range signals unlikely. However, should an out-of-range signal occur, the digital output OTR goes high.

The analog inputs must be driven with a differential signal to achieve optimum performance. For the input signal:

$$V_{CM} = \frac{AINP + AINN}{2}$$

the recommended common-mode voltage is 1.5V. In addition to the differential and common-mode input voltages, the absolute input voltage is also important. This is the voltage on either input (AINP or AINN) with respect to AGND. The range for this voltage is:

$$-0.1V < (AINN \text{ or } AINP) < 4.6V$$

If either input is taken below  $-0.1V$ , ESD protection diodes on the inputs will turn on. Exceeding 4.6V on either input results in degradation in the linearity performance. ESD protection diodes will also turn on if the inputs are taken above AVDD (+5V).

The recommended absolute input voltage is:

$$-0.1V < (AINN \text{ or } AINP) < 4.2V$$

Keeping the inputs within this range provides for optimum performance.

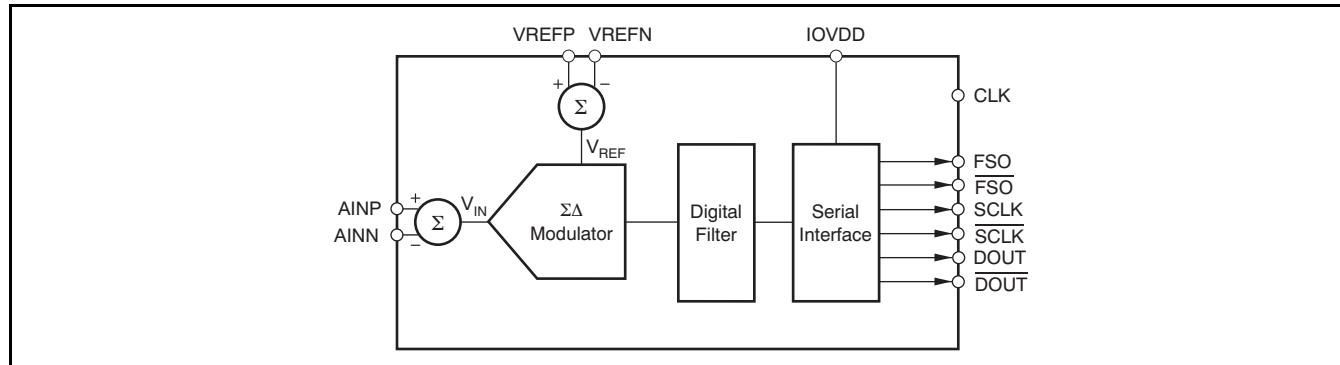


Figure 38. Conceptual Block Diagram

## INPUT CIRCUITRY

The ADS1602 uses switched-capacitor circuitry to measure the input voltage. Internal capacitors are charged by the inputs and then discharged internally with this cycle repeating at the frequency of CLK. Figure 39 shows a conceptual diagram of these circuits. Switches  $S_2$  represent the net effect of the modulator circuitry in discharging the sampling capacitors; the actual implementation is different. The timing for switches  $S_1$  and  $S_2$  is shown in Figure 40.

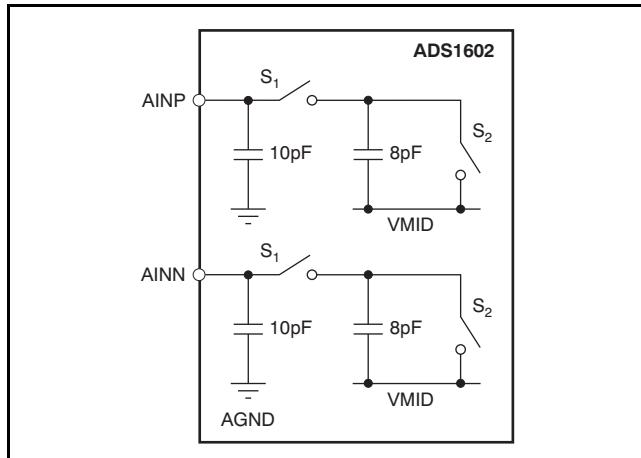


Figure 39. Conceptual Diagram of Internal Circuitry Connected to the Analog Inputs

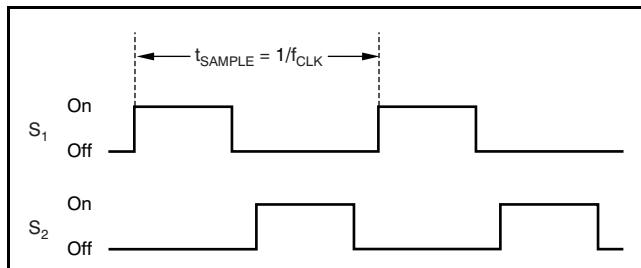


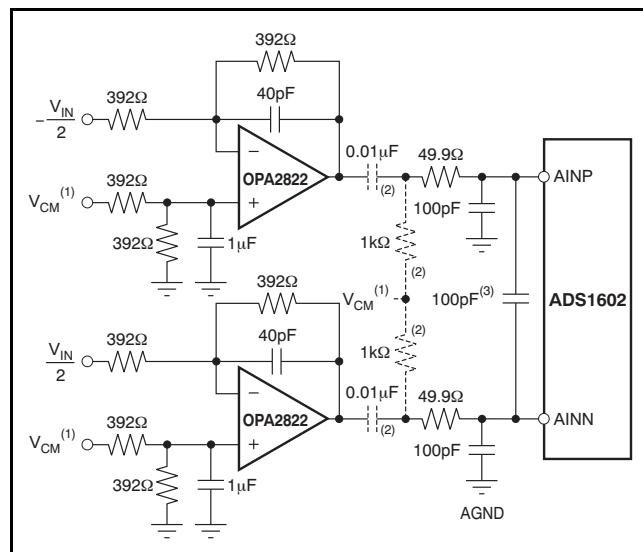
Figure 40. Timing for the Switches in Figure 39

## DRIVING THE INPUTS

The external circuits driving the ADS1602 inputs must be able to handle the load presented by the switching capacitors within the ADS1602. The input switches  $S_1$  in Figure 39 are closed for approximately one-half of the sampling period,  $t_{SAMPLE}$ , allowing only  $\pm 11\text{ns}$  for the internal capacitors to be charged by the inputs when  $f_{CLK} = 40\text{MHz}$ .

Figure 41 and Figure 42 show the recommended circuits when using single-ended or differential op amps, respectively. The analog inputs must be driven differentially to achieve optimum performance. The external capacitors, between the inputs and from each input to AGND, improve linearity and should be placed as close to the pins as possible. Place the

drivers close to the inputs and use good capacitor bypass techniques on the supplies, such as a smaller high-quality ceramic capacitor in parallel with a larger capacitor. Keep the resistances used in the driver circuits low—thermal noise in the driver circuits degrades the overall noise performance. When the signal can be ac-coupled to the ADS1602 inputs, a simple RC filter can set the input common-mode voltage. The ADS1602 is a high-speed, high-performance ADC. Special care must be taken when selecting the test equipment and setup used with this device. Pay particular attention to the signal sources to ensure they do not limit performance when measuring the ADS1602.



- (1) Recommended  $V_{CM} = 1.5\text{V}$ .
- (2) Optional ac-coupling circuit provides common-mode input voltage.
- (3) Increase to 390pF when  $f_{IN} \leq 100\text{kHz}$  for improved SNR and THD.

Figure 41. Recommended Driver Circuit Using the OPA2822

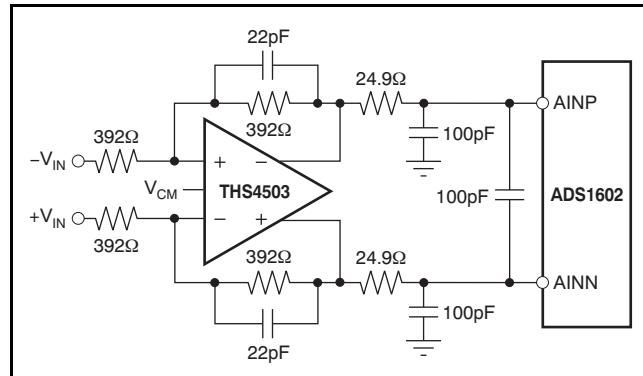


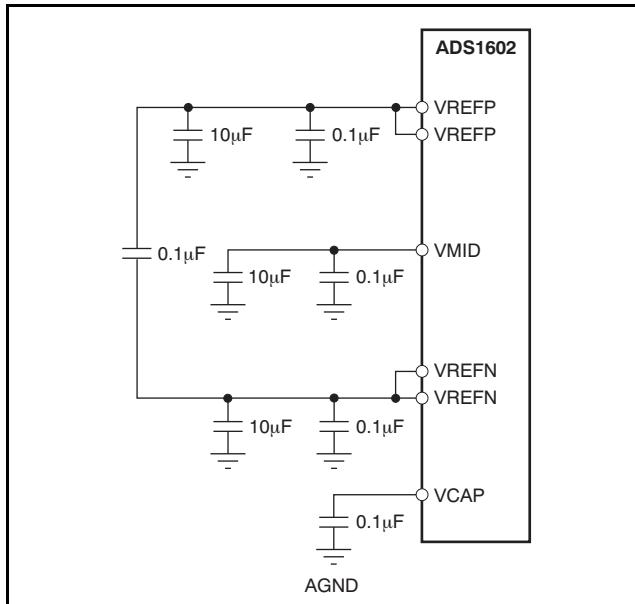
Figure 42. Recommended Driver Circuit Using the THS4503 Differential Amplifier

## REFERENCE INPUTS (VREFN, VREFP, VMID)

The ADS1602 can operate from an internal or external voltage reference. In either case, the reference voltage  $V_{REF}$  is set by the differential voltage between VREFN and VREFP:  $V_{REF} = (VREFP - VREFN)$ . VREFP and VREFN each use two pins, which should be shorted together. VMID equals approximately 2.5V and is used by the modulator. VCAP connects to an internal node and must also be bypassed with an external capacitor.

## INTERNAL REFERENCE (REFEN = LOW)

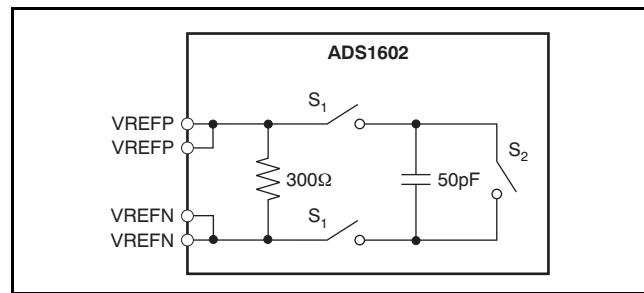
To use the internal reference, set the REFEN pin low. This activates the internal circuitry that generates the reference voltages. The internal reference voltages are applied to the pins. Good bypassing of the reference pins is critical to achieve optimum performance and is done by placing the bypass capacitors as close to the pins as possible. Figure 43 shows the recommended bypass capacitor values. Use high-quality ceramic capacitors for the smaller values. Avoid loading the internal reference with external circuitry. If the ADS1602 internal reference is to be used by other circuitry, buffer the reference voltages to prevent directly loading the reference pins.



**Figure 43. Reference Bypassing When Using the Internal Reference**

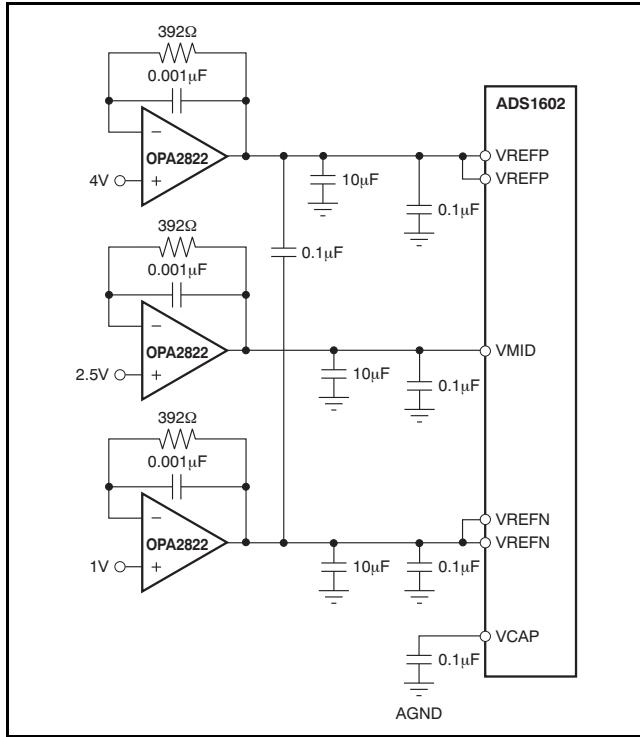
## EXTERNAL REFERENCE (REFEN = HIGH)

To use an external reference, set the REFEN pin high. This deactivates the internal generators for VREFP, VREFN, and VMID, and saves approximately 25mA of current on the analog supply (AVDD). The voltages applied to these pins must be within the values specified in the [Electrical Characteristics](#) table. Typically, VREFP = 4V, VMID = 2.5V, and VREFN = 1V. The external circuitry must be capable of providing both a dc and a transient current. Figure 44 shows a simplified diagram of the internal circuitry of the reference when the internal reference is disabled. As with the input circuitry, switches  $S_1$  and  $S_2$  open and close as shown by the timing in Figure 40.



**Figure 44. Conceptual Internal Circuitry for the Reference When REFEN = High**

Figure 45 shows the recommended circuitry for driving these reference inputs. Keep the resistances used in the buffer circuits low to prevent excessive thermal noise from degrading performance. Layout of these circuits is critical; be sure to follow good high-speed layout practices. Place the buffers, and especially the bypass capacitors, as close to the pins as possible. VCAP is unaffected by the setting on REFEN and must be bypassed when using the internal or an external reference.



**Figure 45. Recommended Buffer Circuit When Using an External Reference**

## CLOCK INPUT (CLK)

The ADS1602 requires an external clock signal to be applied to the CLK input pin. The sampling of the modulator is controlled by this clock signal. As with any high-speed data converter, a high quality clock is essential for optimum performance. Crystal clock oscillators are the recommended CLK source; other sources, such as frequency synthesizers, are usually inadequate. Make sure to avoid excess ringing on the CLK input; keeping the trace as short as possible helps.

Measuring high-frequency, large amplitude signals requires tight control of clock jitter. The uncertainty during sampling of the input from clock jitter limits the maximum achievable SNR. This effect becomes more pronounced with higher frequency and larger magnitude inputs. Fortunately, the ADS1602 oversampling topology reduces clock jitter sensitivity over that of Nyquist rate converters such as pipeline and successive approximation converters by a factor of  $\sqrt{16}$ .

In order to not limit the ADS1602 SNR performance, keep the jitter on the clock source below the values shown in **Table 1**. When measuring lower frequency and lower amplitude inputs, more CLK jitter can be tolerated. In determining the allowable clock source jitter, select the worst-case input (highest frequency, largest amplitude) that will be seen in the application.

**Table 1. Maximum Allowable Clock Source Jitter for Different Input Signal Frequencies and Amplitude**

INPUT SIGNAL	MAXIMUM ALLOWABLE CLOCK SOURCE JITTER	
	MAXIMUM FREQUENCY	MAXIMUM AMPLITUDE
	1MHz	-2dB
	1MHz	-20dB
	500kHz	-2dB
	500kHz	-20dB
	100kHz	-2dB
	100kHz	-20dB
		3.8ps
		28ps
		7.6ps
		57ps
		38ps
		285ps

## DATA FORMAT

The 16-bit output data are in binary two's complement format as shown in **Table 2**. When the input is positive out-of-range, exceeding the positive full-scale value of  $V_{REF}$ , the output clips to all 7FFFh and the OTR output goes high.

Likewise, when the input is negative out-of-range by going below the negative full-scale value of  $-V_{REF}$ , the output clips to 8000h and the OTR output goes high. The OTR remains high while the input signal is out-of-range.

**Table 2. Output Code versus Input Signal**

INPUT SIGNAL (INP – INN)	IDEAL OUTPUT CODE <sup>(1)</sup>	OTR
$\geq +V_{REF} (> 0dB)$	7FFFh	1
$-V_{REF} (0dB)$	7FFFh	0
$\frac{+V_{REF}}{2^{15} - 1}$	0001h	0
0	0000h	0
$\frac{-V_{REF}}{2^{15} - 1}$	FFFFh	0
$-V_{REF} \left( \frac{2^{15}}{2^{15} - 1} \right)$	8000h	0
$-V_{REF} \left( \frac{2^{15}}{2^{15} - 1} \right)$	8000h	1

(1) Excludes effects of noise, INL, offset, and gain errors.

## OUT-OF-RANGE INDICATION (OTR)

If the output code exceeds the positive or negative full-scale, the out-of-range digital output OTR will go high on the falling edge of SCLK. When the output code returns within the full-scale range, OTR returns low on the falling edge of SCLK.

## DATA RETRIEVAL

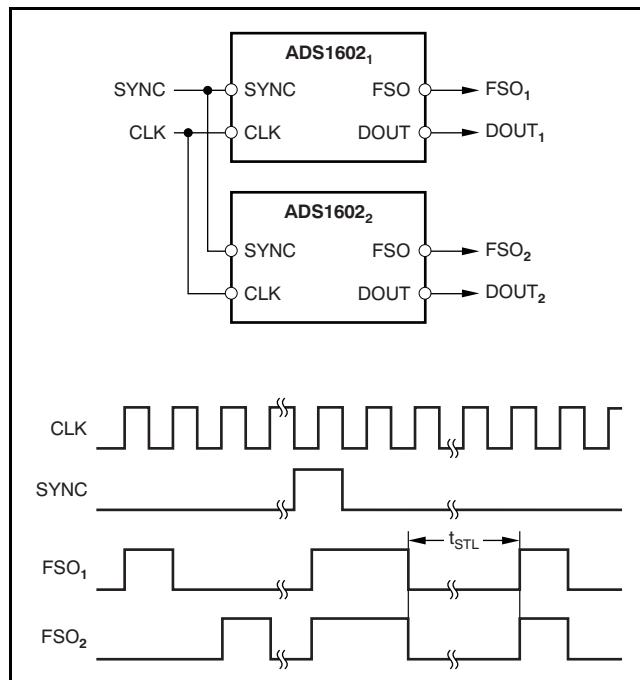
Data retrieval is controlled through a simple serial interface. The interface operates in a master fashion by outputting both a frame sync indicator (FSO) and a serial clock (SCLK). Complementary outputs are provided for the frame sync output (FSO), serial clock (SCLK), and data output (DOUT). When not needed, leave the complementary outputs unconnected.

## INITIALIZING THE ADS1602

After the power supplies have stabilized, you must initialize the ADS1602 by issuing a SYNC pulse as shown in [Figure 1](#). This operation needs only to be done once after power-up and does not need to be performed when exiting the Power-Down mode. Note that the ADS1602 silicon was revised in June 2006. The digital interface timing specifications were modified slightly from the previous revision. This data sheet reflects behavior of the latest revision. Contact the factory for more information on the previous revision.

## SYNCHRONIZING MULTIPLE ADS1602s

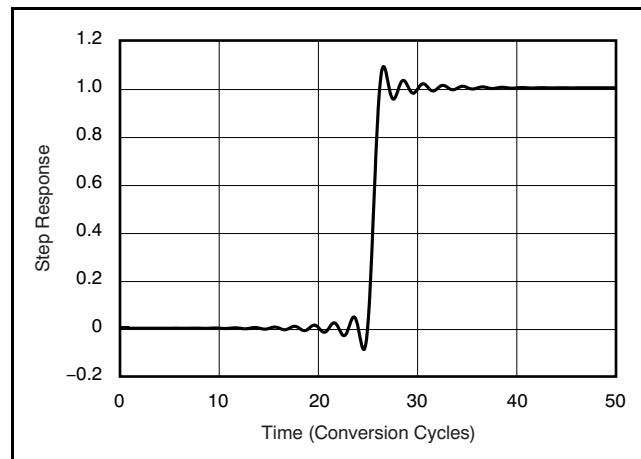
The SYNC input can be used to synchronize multiple ADS1602s to provide simultaneous sampling. All devices to be synchronized must use a common CLK input. With the CLK inputs running, pulse SYNC on the falling edge of CLK, as shown in [Figure 46](#). Afterwards, the converters will be converting synchronously with the FSO outputs updating simultaneously. After synchronization, FSO is held low until the digital filter has fully settled.



**Figure 46. Synchronizing Multiple Converters**

## STEP RESPONSE

[Figure 47](#) plots the normalized step response for an input applied at  $t = 0$ . The x-axis units of time are conversion cycles. It takes 51 cycles to fully settle; for  $f_{CLK} = 40\text{MHz}$ , this corresponds to  $20.4\mu\text{s}$ .

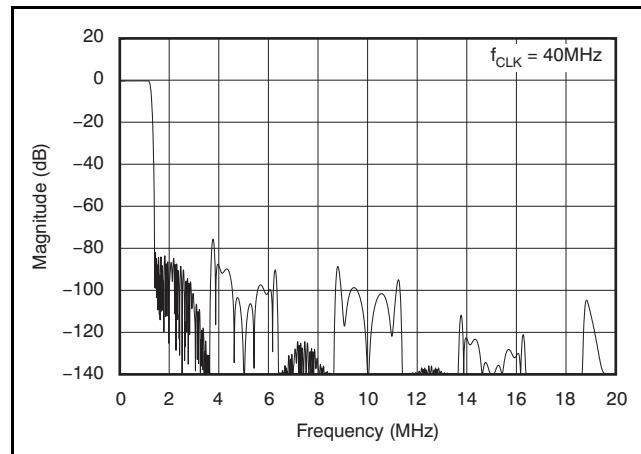


**Figure 47. Step Response**

## FREQUENCY RESPONSE

The linear phase FIR digital filter sets the overall frequency response. [Figure 48](#) shows the frequency response from dc to 20MHz for  $f_{CLK} = 40\text{MHz}$ . The frequency response of the ADS1602 filter scales directly with CLK frequency. For example, if the CLK frequency is decreased by half (to 20MHz), the values on the x-axis in [Figure 48](#) would need to be scaled by half, with the span becoming dc to 10MHz.

[Figure 49](#) shows the passband ripple from dc to 1200kHz ( $f_{CLK} = 40\text{MHz}$ ). [Figure 50](#) shows a closer view of the passband transition by plotting the response from 900kHz to 1300kHz ( $f_{CLK} = 40\text{MHz}$ ).



**Figure 48. Frequency Response**

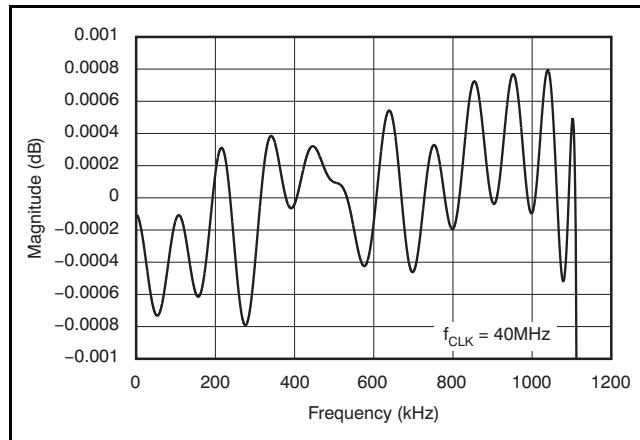


Figure 49. Passband Ripple

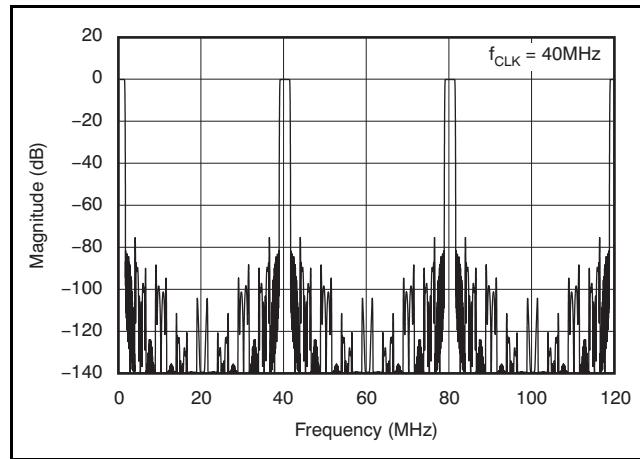


Figure 51. Frequency Response Out to 120MHz

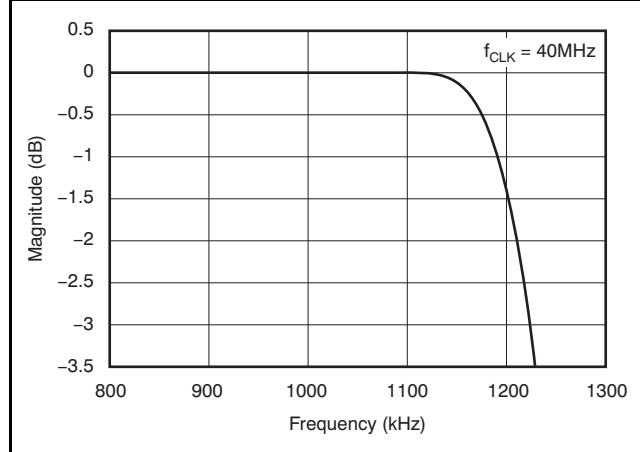


Figure 50. Passband Transition

## ANTIALIAS REQUIREMENTS

Higher frequency, out-of-band signals must be eliminated to prevent aliasing with ADCs. Fortunately, the ADS1602 on-chip digital filter greatly simplifies this filtering requirement. Figure 51 shows the ADS1602 response out to 120MHz ( $f_{CLK} = 40MHz$ ). Since the stop band extends out to 38.6MHz, the antialias filter in front of the ADS1602 only needs to be designed to remove higher frequency signals than this, which can usually be accomplished with a simple RC circuit on the input driver.

## ANALOG POWER DISSIPATION

An external resistor connected between the  $R_{BIAS}$  pin and the analog ground sets the analog current level, as shown in Figure 52. The current is inversely proportional to the resistor value. Table 3 shows the recommended values of  $R_{BIAS}$  for different CLK frequencies. Notice that the analog current can be reduced when using a slower frequency CLK input because the modulator has more time to settle. Avoid adding any capacitance in parallel to  $R_{BIAS}$  because this interferes with the internal circuitry used to set the biasing. Please note that changing the  $R_{BIAS}$  resistor value changes all internally-generated bias voltages, including the internal reference; therefore, the recommendations in Table 3 are only for when using an external reference.

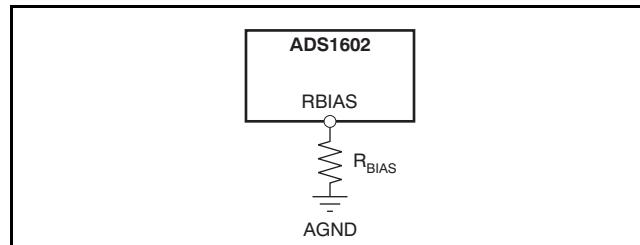


Figure 52. External Resistor Used to Set Analog Power Dissipation

Table 3. Recommended  $R_{BIAS}$  Resistor Values for Different CLK Frequencies

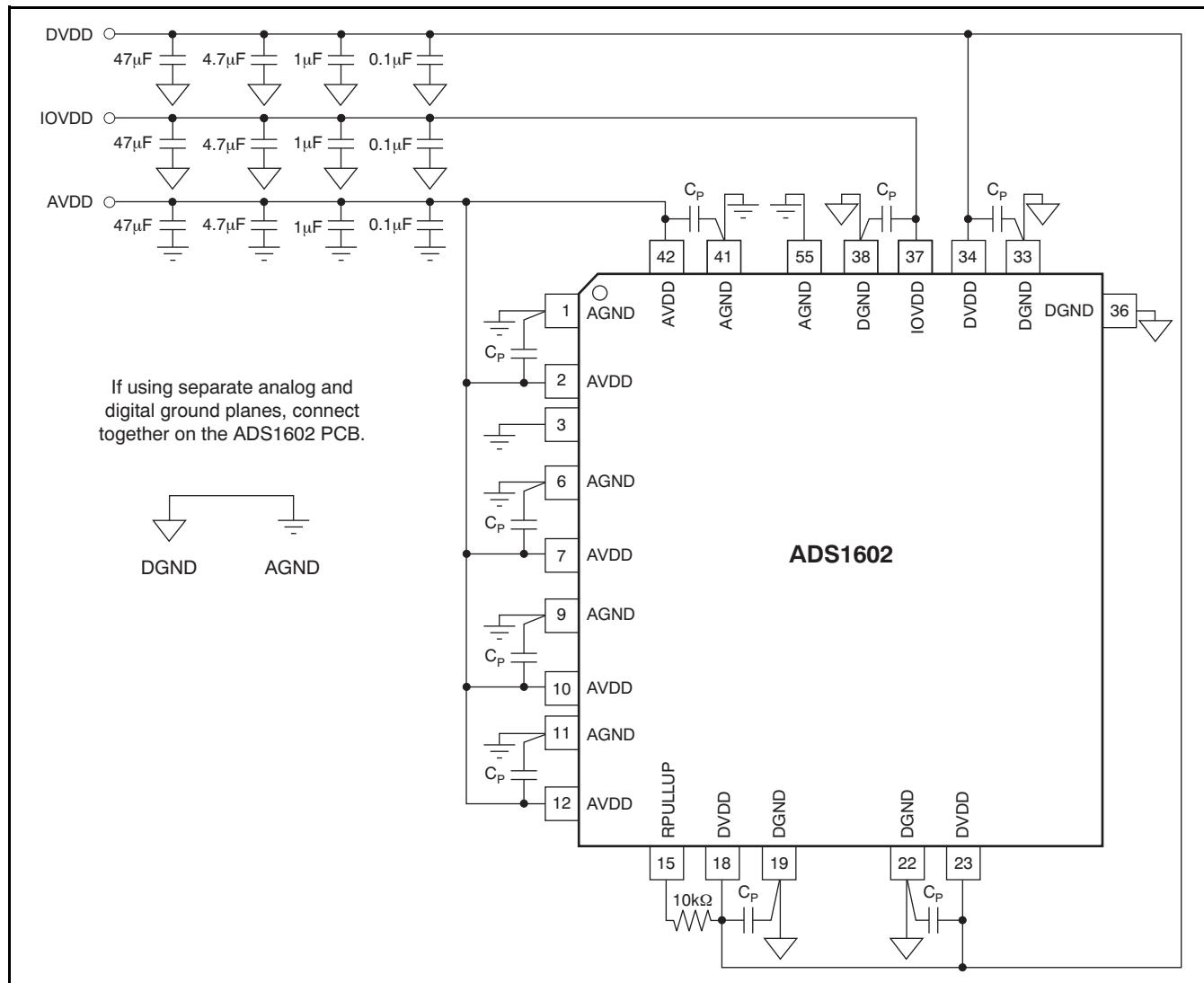
$f_{CLK}$	DATA RATE	$R_{BIAS}$	TYPICAL POWER DISSIPATION WITH REFEN HIGH
16MHz	1MSPS	140k $\Omega$	200mW
24MHz	1.5MSPS	100k $\Omega$	270mW
32MHz	2MSPS	60k $\Omega$	390mW
40MHz	2.5MSPS	37k $\Omega$	530mW

## POWER DOWN (PD)

When not in use, the ADS1602 can be powered down by taking the PD pin low. All circuitry is shut down, including the voltage reference. To minimize the digital current during power down, stop the clock signal supplied to the CLK input. There is an internal pull-up resistor of 170kΩ on the PD pin, but it is recommended that this pin be connected to IOVDD if not used. Make sure to allow time for the reference to start up after exiting power-down mode. The internal reference typically requires 15ms. After the reference has stabilized, allow at least 100 conversions for the modulator and digital filter to settle before retrieving data.

## POWER SUPPLIES

Three supplies are used on the ADS1602: analog (AVDD), digital (DVDD), and digital I/O (IOVDD). Each supply must be suitably bypassed to achieve the best performance. It is recommended that a 1μF and 0.1μF ceramic capacitor be placed as close to each supply pin as possible. Connect each supply-pin bypass capacitor to the associated ground, as shown in Figure 53. Each main supply bus should also be bypassed with a bank of capacitors from 47μF to 0.1μF, as shown. The I/O and digital supplies (IOVDD and DVDD) can be connected together when using the same voltage. In this case, only one bank of 47μF to 0.1μF capacitors is needed on the main supply bus, though each supply pin must still be bypassed with a 1μF and 0.1μF ceramic capacitor.



**Figure 53. Recommended Power-Supply Bypassing**

## LAYOUT ISSUES AND COMPONENT SELECTION

The ADS1602 is a very high-speed, high-resolution data converter. In order to achieve maximum performance, the user must give very careful consideration to both the layout of the printed circuit board (PCB) in addition to the routing of the traces. Capacitors that are critical to achieve the best performance from the device should be placed as close to the pins of the device as possible. These include capacitors related to the analog inputs, the reference, and the power supplies.

For critical capacitors, it is recommended that Class II dielectrics such as Z5U be avoided. These dielectrics have a narrow operating temperature, a large tolerance on the capacitance, and lose up to 20% of the rated capacitance over 10,000 hours. Rather, select capacitors with a Class I dielectric. C0G (also known as NP0), for example, has a tight tolerance less than  $\pm 30\text{ppm}/^\circ\text{C}$  and is very stable over time. Should Class II capacitors be chosen because of the size constraints, select an X7R or X5R dielectric to minimize the variations of the capacitor's critical characteristics.

The resistors used in the circuits to drive the input and reference should be kept as low as possible to prevent excess thermal noise from degrading the system performance.

The digital outputs from the device should always be buffered. This has a number of benefits: it reduces the loading of the internal digital buffers, which decreases noise generated within the device, and it also reduces device power consumption.

## APPLICATIONS INFORMATION

### Interfacing the ADS1602 to the TMS320 DSP family

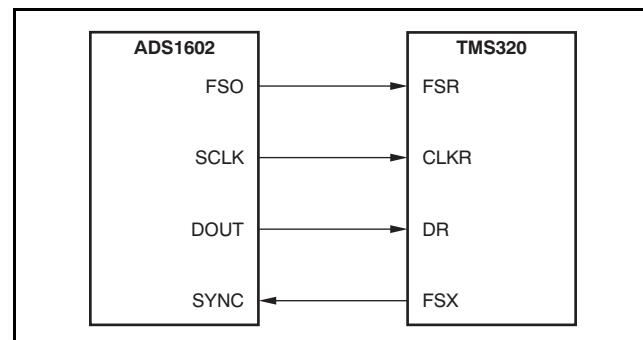
Since the ADS1602 communicates with the host via a serial interface, the most suitable method to connect to any of the TMS320 DSPs is via the multi-channel buffered serial port (McBSP). A typical connection to the TMS320 DSP is shown in [Figure 54](#).

The McBSP provides a host of functions including:

- Full-duplex communication
- Double-buffered data registers
- Independent framing and clocking for reception and transmission of data

The sequence begins with a one-time synchronization of the serial port by the microprocessor. The ADS1602 recognizes the SYNC signal if it is high for at least one CLK period. Transfers are initiated by the ADS1602 after the SYNC signal is de-asserted by the microprocessor.

The FSO signal from the ADS1602 indicates that data is available to be read, and is connected to the frame sync receive (FSR) pin of the DSP. The clock receiver (CLKR) is derived directly from the ADS1602 serial clock output to ensure continued synchronization of data with the clock.



**Figure 54. ADS1602—TMS320 Interface Connection**

An evaluation module (EVM) is available from Texas Instruments. The module consists of the ADS1602 and supporting circuits, allowing users to quickly assess the performance and characteristics of the ADS1602. The EVM easily connects to various microcontrollers and DSP systems. For more details, or to download a copy of the [ADS1602EVM User's Guide](#), visit the Texas Instruments web site at [www.ti.com](http://www.ti.com).

## REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

### Changes from Revision D (November 2010) to Revision E

**Page**

- |  |   |
|--|---|
| • Added footnote to Electrical Characteristics table ..... | 4 |
|--|---|

### Changes from Revision C (September 2010) to Revision D

**Page**

- |   |   |
|---|---|
| • Changed $t_C$ minimum specification in Timing Requirements table for <a href="#">Figure 1</a> .....     | 8 |
| • Changed $t_{CPW}$ minimum specification in Timing Requirements table for <a href="#">Figure 2</a> ..... | 8 |
| • Changed $t_{DH}$ minimum specification in Timing Requirements table for <a href="#">Figure 2</a> .....  | 8 |

**PACKAGING INFORMATION**

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">ADS1602IPFBR</a>	Active	Production	TQFP (PFB)   48	1000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ADS1602I
ADS1602IPFBR.B	Active	Production	TQFP (PFB)   48	1000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ADS1602I
<a href="#">ADS1602IPFBT</a>	Active	Production	TQFP (PFB)   48	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ADS1602I
ADS1602IPFBT.B	Active	Production	TQFP (PFB)   48	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ADS1602I
ADS1602IPFBTG4	Active	Production	TQFP (PFB)   48	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ADS1602I
ADS1602IPFBTG4.B	Active	Production	TQFP (PFB)   48	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ADS1602I

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

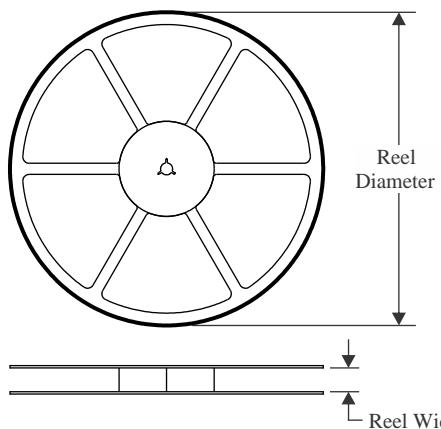
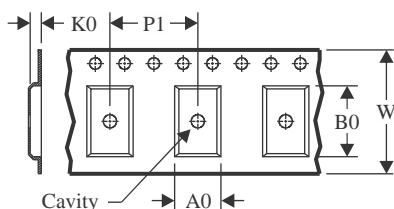
<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

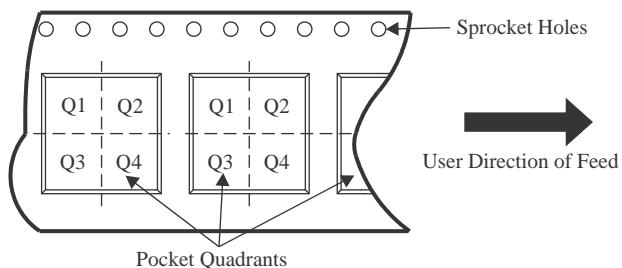
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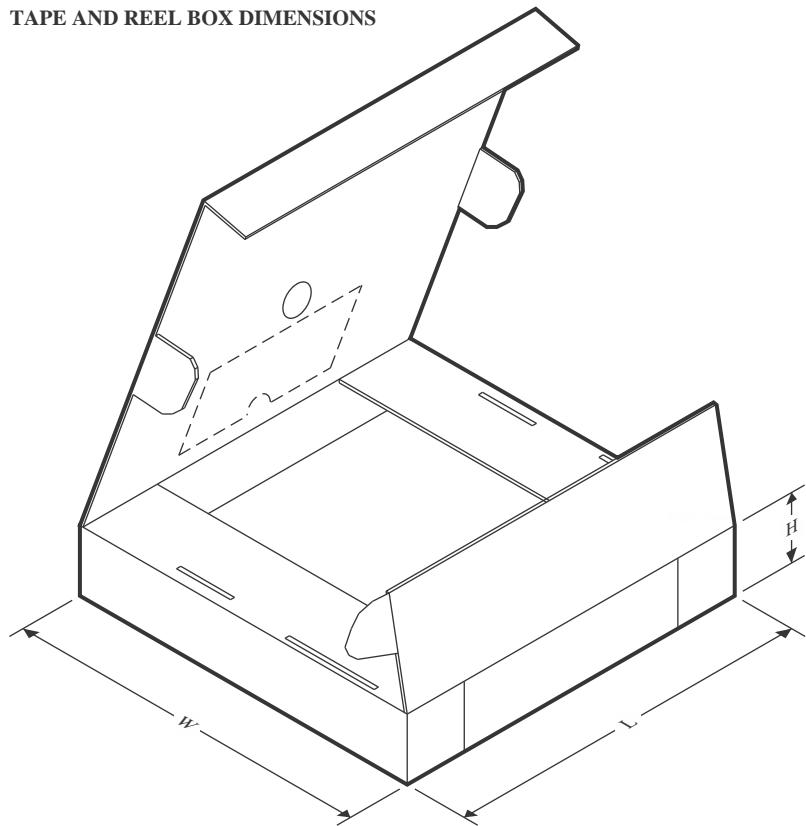
**TAPE AND REEL INFORMATION**
**REEL DIMENSIONS**

**TAPE DIMENSIONS**


A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*All dimensions are nominal

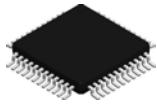
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
ADS1602IPFBR	TQFP	PFB	48	1000	330.0	16.4	9.6	9.6	1.5	12.0	16.0	Q2

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
ADS1602IPFBR	TQFP	PFB	48	1000	350.0	350.0	43.0

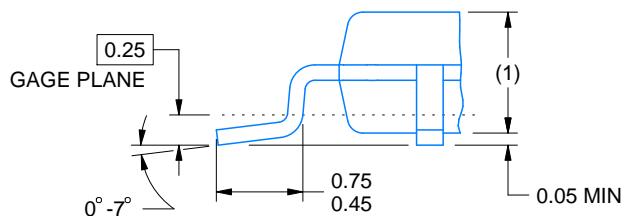
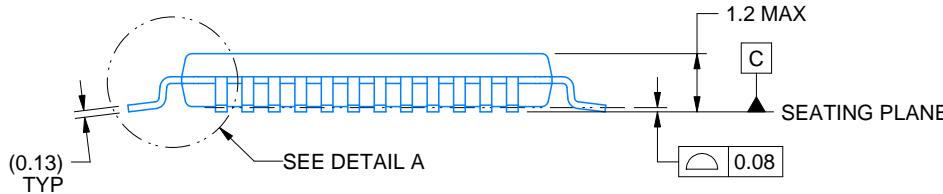
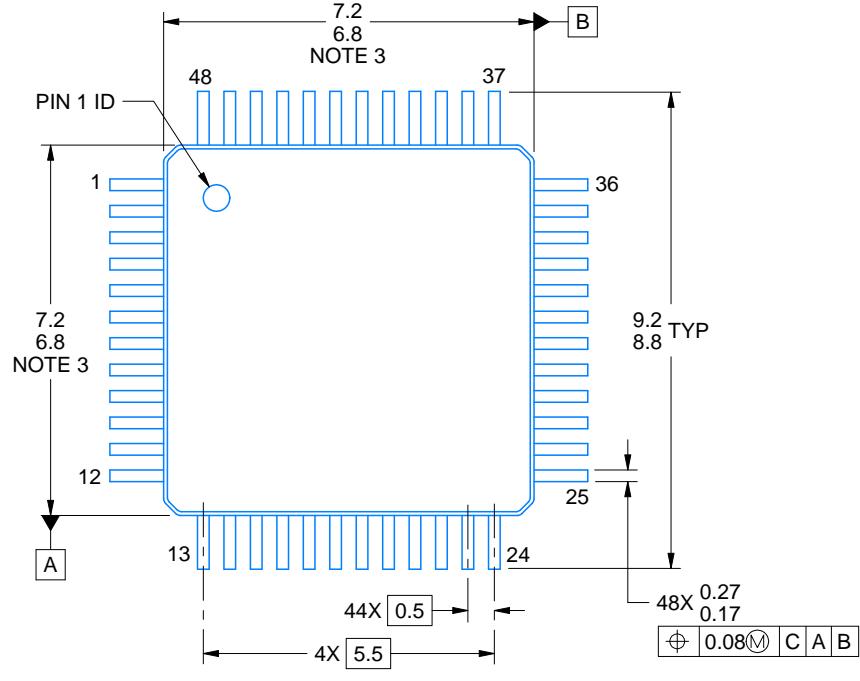
PFB0048A



# PACKAGE OUTLINE

TQFP - 1.2 mm max height

PLASTIC QUAD FLATPACK



DETAIL A  
TYPICAL

4215157/A 03/2024

NOTES:

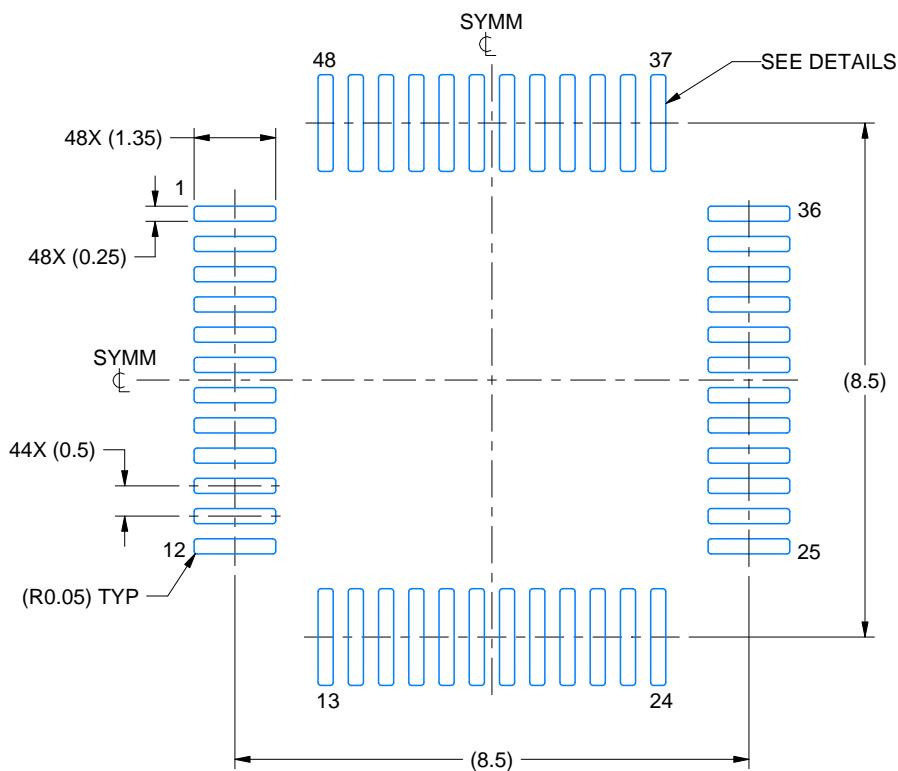
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC registration MS-026.

# EXAMPLE BOARD LAYOUT

PFB0048A

TQFP - 1.2 mm max height

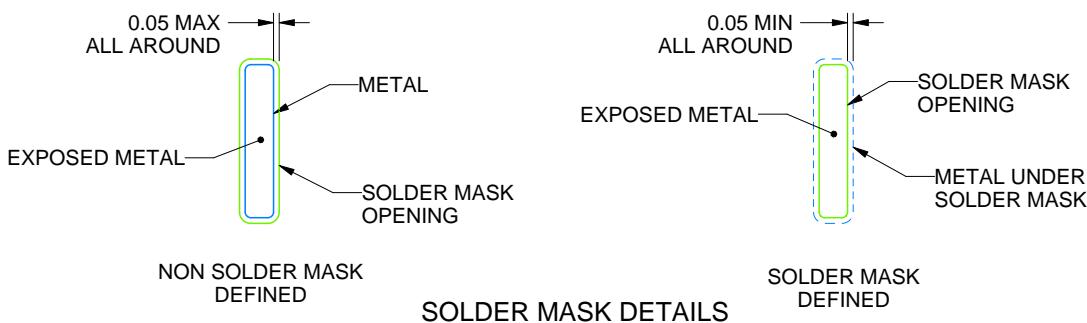
PLASTIC QUAD FLATPACK



## LAND PATTERN EXAMPLE

EXPOSED METAL SHOWN

SCALE:8X



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NOTES: (continued)

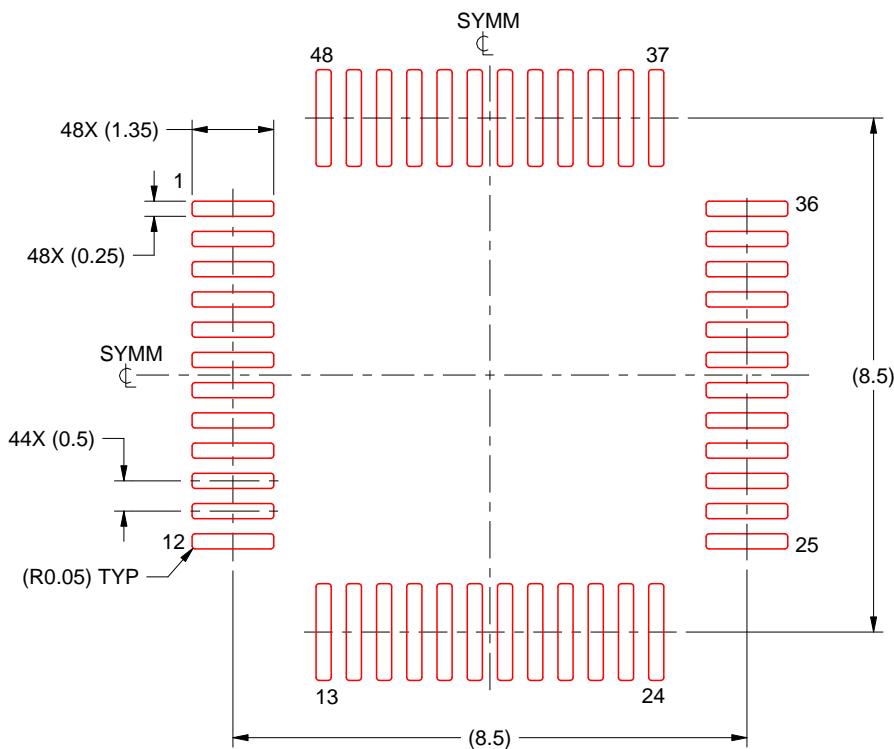
4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

PFB0048A

TQFP - 1.2 mm max height

PLASTIC QUAD FLATPACK



4215157/A 03/2024

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
7. Board assembly site may have different recommendations for stencil design.

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