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Burr-Brown Products
from Texas Instruments

ADS930

SBAS059A – MARCH 2001

SpeedPLUS™ 8-Bit, 30MHz Sampling ANALOG-TO-DIGITAL CONVERTER

FEATURES

- +3V TO +5V SUPPLY OPERATION
- INTERNAL REFERENCE
- SINGLE-ENDED INPUT RANGE: 1V to 2V
- LOW POWER: 66mW at +3V
- HIGH SNR: 46dB
- LOW DNL: 0.4LSB
- SSOP-28 PACKAGE

APPLICATIONS

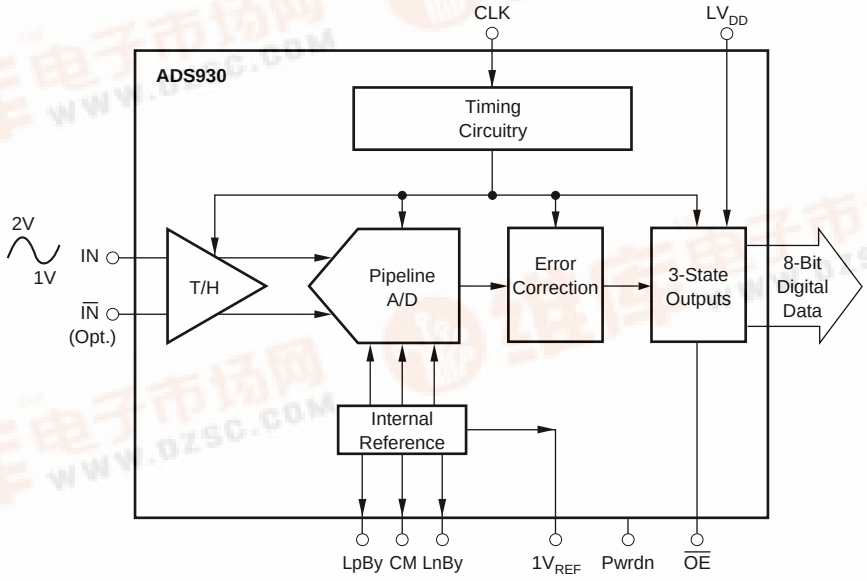
- BATTERY POWERED EQUIPMENT
- CAMCORDERS
- PORTABLE TEST EQUIPMENT
- COMPUTER SCANNERS
- COMMUNICATIONS

DESCRIPTION

The ADS930 is a high speed pipelined Analog-to-Digital Converter (ADC) specified to operate from nominal +3V or +5V power supplies with tolerances of up to 10%. This complete converter includes a high bandwidth track/hold, a 8-bit quantizer and an internal reference.

The ADS930 employs digital error correction techniques to provide excellent differential linearity for demanding imaging applications. Its low distortion and high SNR give the extra margin needed for telecommunications, video and test instrumentation applications.

This high performance ADC is specified for performance at a 30MHz sampling rate. The ADS930 is available in a SSOP-28 package.



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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include

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ABSOLUTE MAXIMUM RATINGS

$+V_S$	+6V
Analog Input	$+V_S$ +0.3V
Logic Input	$+V_S$ +0.3V
Case Temperature	+100°C
Junction Temperature	+150°C
Storage Temperature	+150°C

ELECTROSTATIC DISCHARGE SENSITIVITY

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

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER(1)	TRANSPORT MEDIA
ADS930E	SSOP-28	324	–40°C to +85°C	ADS930E	ADS930E	Rails
"	"	"	"	ADS930E	ADS930E/1K	Tape and Reel

NOTE: (1) Models with a slash (/) are available only in Tape and Reel in the quantities indicated (e.g., /1K indicates 1000 devices per reel). Ordering 1000 pieces of "ADS930E/1K" will get a single 1000-piece Tape and Reel.

ELECTRICAL CHARACTERISTICS

At T_A = +25°C, V_S = +3V, Single-ended Input and Sampling Rate = 30MHz, unless otherwise specified.

PARAMETER	CONDITIONS	TEMP	ADS930E MIN	ADS930E TYP	ADS930E MAX	UNITS
RESOLUTION				8		Bits
Specified Temperature Range	Ambient Air		–40		+85	°C
ANALOG INPUT						
Differential Full Scale Input Range	0.5Vp-p		+1.25		+1.75	V
Single-Ended Full Scale Input Range	1Vp-p		+1.0		+2.0	V
Common-mode Voltage				1.5		V
Analog Input Bias Current				1		µA
Input Impedance				1.25 || 5		MΩ || pF
DIGITAL INPUTS		Full				
Logic Family				TTL/HCT Compatible CMOS		
High Input Voltage, V_{IH}			2.0		V_{DD}	V
Low Input Voltage, V_{IL}					0.8	V
High Input Current, I_{IH}				±10		µA
Low Input Current, I_{IL}				±10		µA
Input Capacitance				5		pF
CONVERSION CHARACTERISTICS						
Start Conversion				Rising Edge of Convert Clock		
Sample Rate		Full	10k		30M	Samples/s
Data Latency				5		Clk Cyc
DYNAMIC CHARACTERISTICS						
Differential Linearity Error						
f = 500kHz	Largest Code Error	Full		±0.4	±1	LSB
f = 12MHz	Largest Code Error	Full		±0.4		LSB
No Missing Codes		Full		Guaranteed		
Integral Nonlinearity Error, f = 500kHz		Full		±1.0	±2.5	LSB
Spurious Free Dynamic Range(1)						
f = 500kHz (–1dBFS input)		Full		51		dBFS(2)
f = 12MHz (–1dB input)		Full	46	50		dBFS
Two-Tone Intermodulation Distortion(3)						
f = 3.4MHz and 3.5MHz (–7dBFS each tone)				54		dBc
Signal-to-Noise Ratio (SNR)						
f = 500kHz (–1dBFS input)		Full		46		dB
f = 12MHz (–1dBFS input)		Full	44	46		dB
Signal-to-(Noise + Distortion) (SINAD)						
f = 500kHz (–1dBFS input)		Full		45		dB
f = 3.58MHz (–1dBFS input)		Full		45		dB
f = 12MHz (–1dBFS input)		Full	42	45		dB

ELECTRICAL CHARACTERISTICS (Cont.)

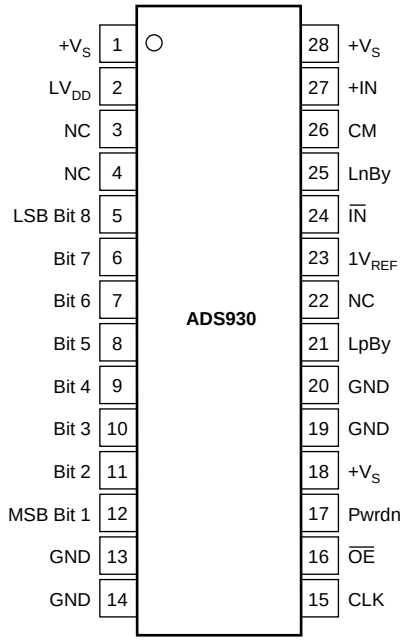
At T_A = +25°C, V_S = +3V, Single-ended Input and Sampling Rate = 30MHz, unless otherwise specified.

PARAMETER	CONDITIONS	TEMP	ADS930E MIN	ADS930E TYP	ADS930E MAX	UNITS
Differential Gain Error	NTSC, PAL			2.3		%
Differential Phase Error	NTSC, PAL			1		degrees
Output Noise	Input Grounded			0.2		LSBs rms
Aperture Delay Time				2		ns
Aperture Jitter				7		ps rms
Analog Input Bandwidth						
Small Signal	–20dBFS Input			350		MHz
Full Power	0dBFS Input			100		MHz
Overvoltage Recovery Time(4)				2		ns
DIGITAL OUTPUTS	C_L = 15pF					
Logic Family				TTL/HCT Compatible CMOS		
Logic Coding				Straight Offset Binary		
High Output Voltage, V_{OH}			+2.4		LV_{DD}	V
Low Output Voltage, V_{OL}					0.4	V
3-State Enable Time	$\overline{OE}$ = L			20	40	ns
3-State Disable Time	$\overline{OE}$ = H			2	10	ns
Internal Pull-Down				50		kΩ
Power-Down Enable Time	PwrDn = L			133		ns
Power-Down Disable Time	PwrDn = H			18		ns
Internal Pull-Down				50		kΩ
ACCURACY	f_S = 2.5MHz					
Gain Error		Full		5.9	10	%FS
Input Offset	Referred to Ideal Midscale	Full		±10	±60	mV
Power Supply Rejection (Gain)	Δ V_S = +10%	Full		56		dB
Power Supply Rejection (Offset)		Full		56		dB
Internal Positive Reference Voltage		Full		+1.75		V
Internal Negative Reference Voltage		Full		+1.25		V
POWER SUPPLY REQUIREMENTS						
Supply Voltage: $+V_S$	Operating	Full	+2.7	+3.0	+5.25	V
Supply Current: $+I_S$	Operating, +3V	Full		22		mA
Power Dissipation	Operating, +3V	Full		66	84	mW
	Operating, +5V	Full		168		mW
Power Dissipation (Power Down)	Operating, +3V	Full		10		mW
	Operating, +5V	Full		15		mW
Thermal Resistance, θ_{JA}						
SSOP-28				89		°C/W

NOTES: (1) Spurious Free Dynamic Range refers to the magnitude of the largest harmonic. (2) dBFS means dB relative to full scale. (3) Two-tone intermodulation distortion is referred to the largest fundamental tone. This number will be 6dB higher if it is referred to the magnitude of the two-tone fundamental envelope. (4) No “Rollover” of bits.

PIN CONFIGURATION

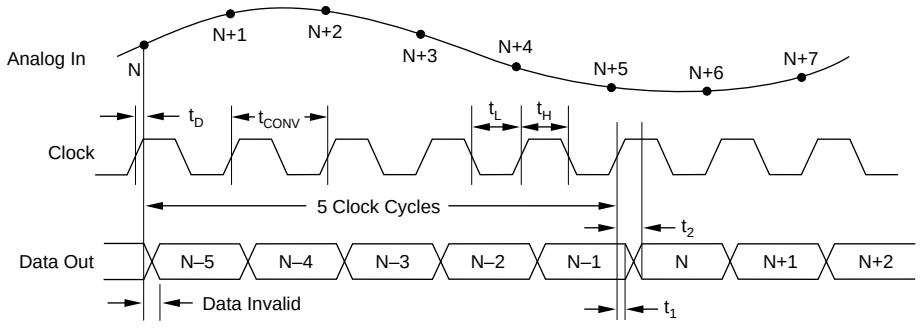
Top View **SSOP**



PIN DESCRIPTIONS

PIN	DESIGNATOR	DESCRIPTION
1	$+V_S$	Analog Supply
2	LV_{DD}	Output Logic Driver Supply Voltage
3	NC	No Connection
4	NC	No Connection
5	Bit 8 (LSB)	Data Bit 8 (D7)
6	Bit 7	Data Bit 7 (D6)
7	Bit 6	Data Bit 6 (D5)
8	Bit 5	Data Bit 5 (D4)
9	Bit 4	Data Bit 4 (D3)
10	Bit 3	Data Bit 3 (D2)
11	Bit 2	Data Bit 2 (D1)
12	Bit 1(MSB)	Data Bit 1 (D0)
13	GND	Analog Ground
14	GND	Analog Ground
15	CLK	Convert Clock Input
16	$\overline{OE}$	Output Enable, Active Low
17	Pwrdn	Power Down Pin
18	$+V_S$	Analog Supply
19	GND	Analog Ground
20	GND	Analog Ground
21	LpBy	Positive Ladder Bypass
22	NC	No Connection
23	$1V_{REF}$	1V Reference Output
24	$\overline{IN}$	Complementary Input
25	LnBy	Negative Ladder Bypass
26	CM	Common-Mode Voltage Output
27	+IN	Analog Input
28	$+V_S$	Analog Supply

TIMING DIAGRAM

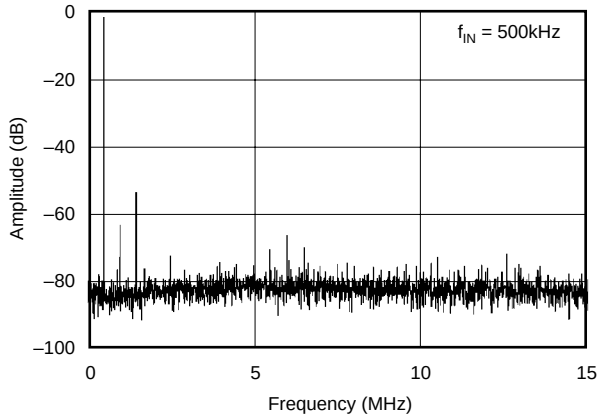


SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNITS
t_{CONV}	Convert Clock Period	33		100µs	ns
t_L	Clock Pulse Low	15.5	16.5		ns
t_H	Clock Pulse High	15.5	16.5		ns
t_D	Aperture Delay		2		ns
t_1	Data Hold Time, C_L = 0pF	3.9			ns
t_2	New Data Delay Time, C_L = 15pF max			12	ns

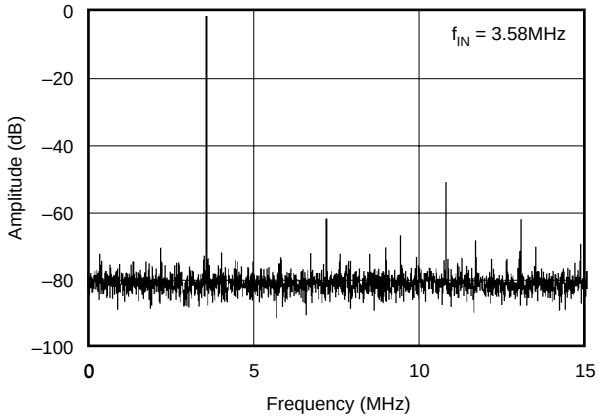
TYPICAL CHARACTERISTICS

At T_A = +25°C, V_S = +3V, Single-ended Input and Sampling Rate = 30MHz, unless otherwise specified.

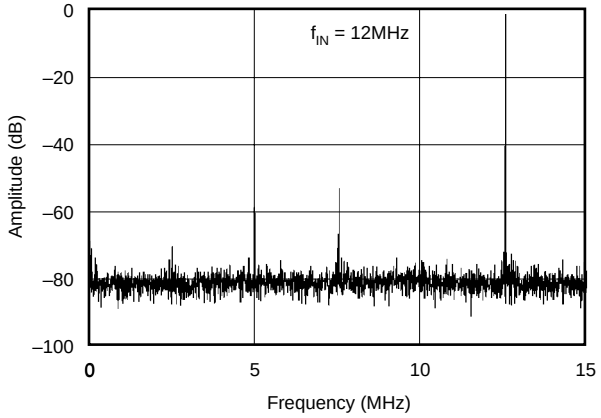
SPECTRAL PERFORMANCE



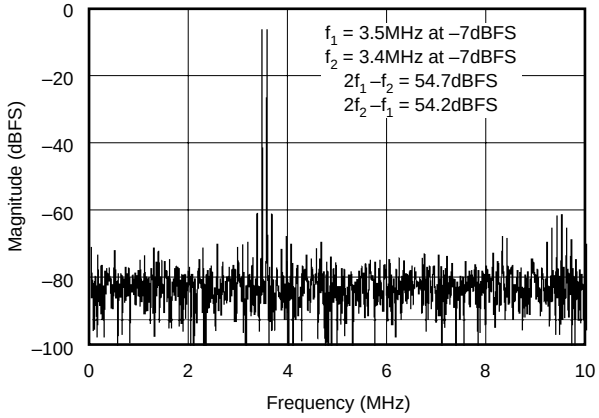
SPECTRAL PERFORMANCE



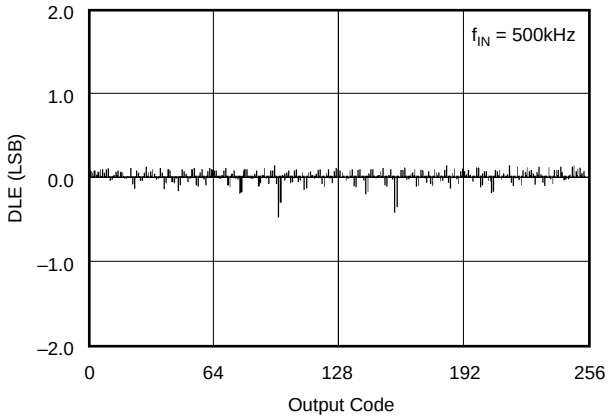
SPECTRAL PERFORMANCE



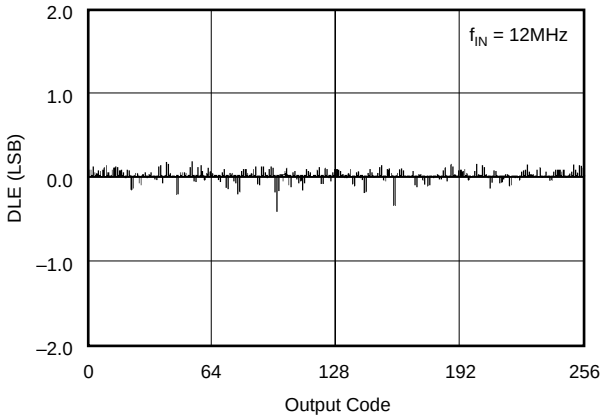
TWO-TONE INTERMODULATION



DIFFERENTIAL LINEARITY ERROR



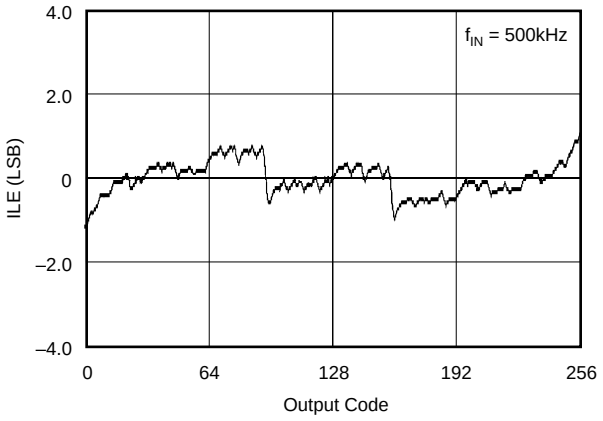
DIFFERENTIAL LINEARITY ERROR



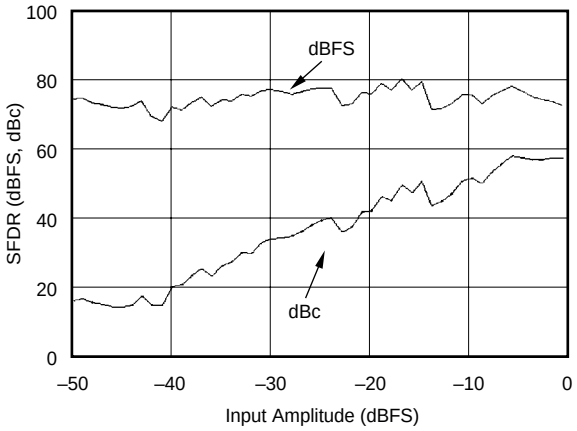
TYPICAL CHARACTERISTICS (Cont.)

At T_A = +25°C, V_S = +3V, Single-ended Input and Sampling Rate = 30MHz, unless otherwise specified.

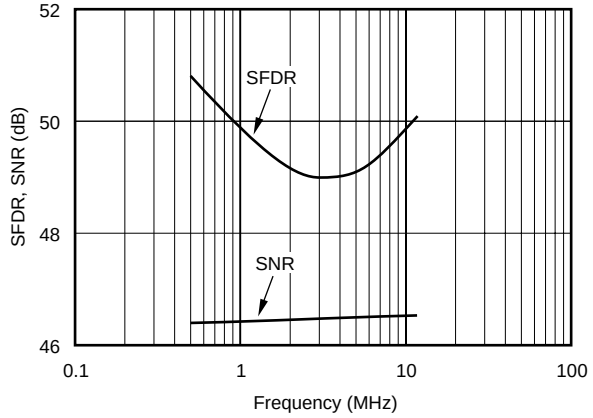
INTEGRAL LINEARITY ERROR



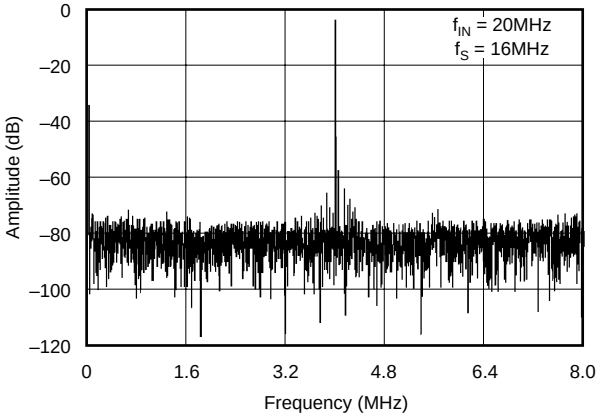
SWEPT POWER SFDR



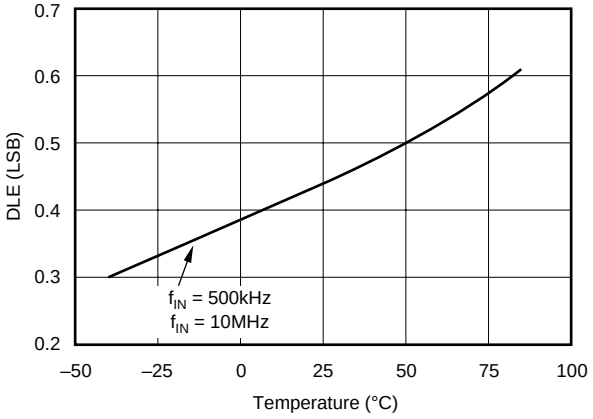
DYNAMIC PERFORMANCE vs INPUT FREQUENCY



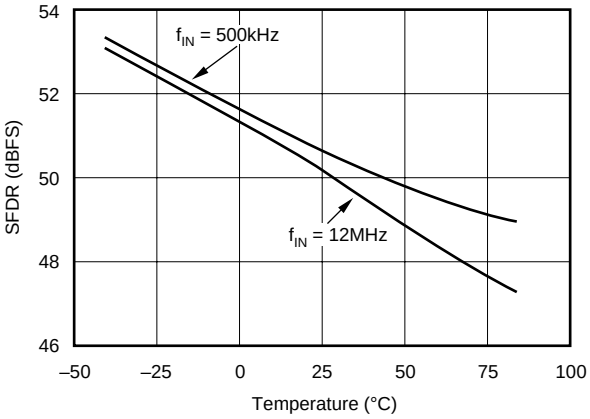
UNDERSAMPLING (With Differential Input)



DIFFERENTIAL LINEARITY ERROR
vs TEMPERATURE



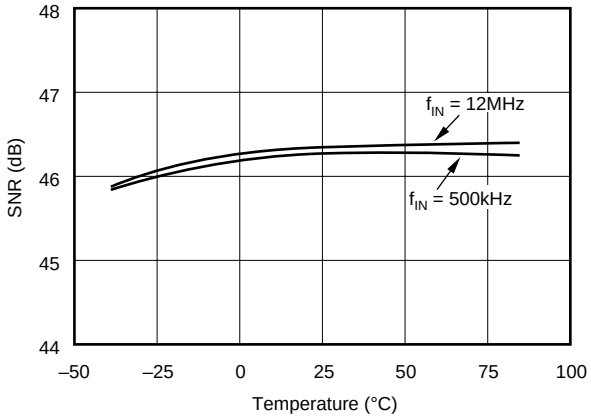
SPURIOUS FREE DYNAMIC RANGE
vs TEMPERATURE



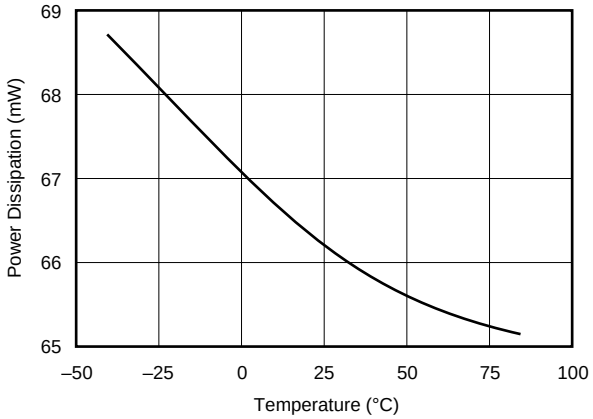
TYPICAL CHARACTERISTICS (Cont.)

At T_A = +25°C, V_S = +3V, Single-ended Input and Sampling Rate = 30MHz, unless otherwise specified.

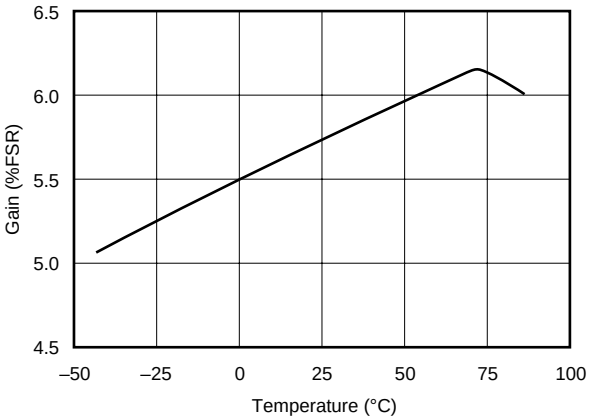
SIGNAL-TO-NOISE RATIO vs TEMPERATURE



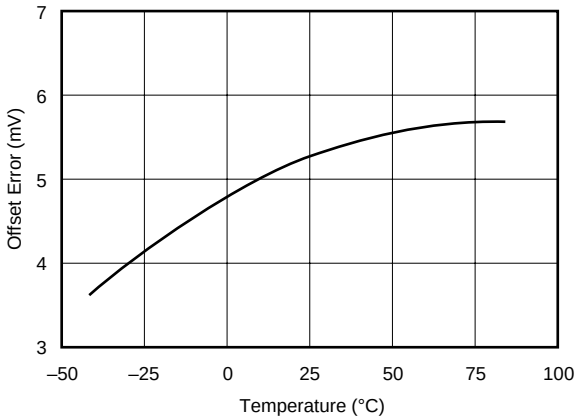
POWER DISSIPATION vs TEMPERATURE



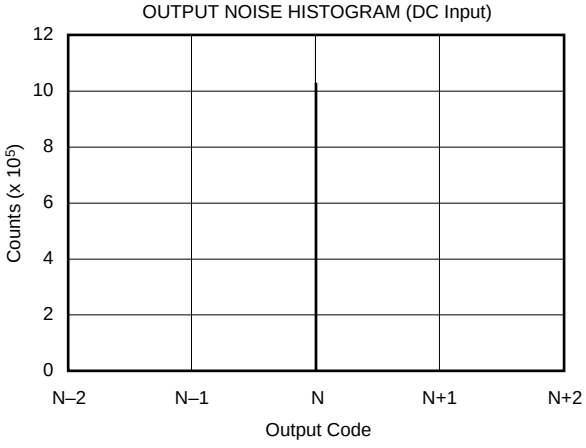
GAIN ERROR vs TEMPERATURE



OFFSET ERROR vs TEMPERATURE



OUTPUT NOISE HISTOGRAM (DC Input)



THEORY OF OPERATION

The ADS930 is a high speed sampling ADC that utilizes a pipeline architecture. The fully differential topology and digital error correction guarantee 8-bit resolution. The track/hold circuit is shown in Figure 1. The switches are controlled by an internal clock which has a non-overlapping two phase signal, ϕ1 and ϕ2. At the sampling time the input signal is sampled on the bottom plates of the input capacitors. In the next clock phase, ϕ2, the bottom plates of the input capacitors are connected together and the feedback capacitors are switched to the op amp output. At this time the charge redistributes between C_I and C_H, completing one track/hold cycle. The differential output is a held DC representation of the analog input at the sample time. In the normal mode of operation, the complementary input is tied to the common-mode voltage. In this case, the track/hold circuit converts a single-ended input signal into a fully differential signal for the quantizer. Consequently, the input signal gets amplified by a gain or two, which improves the signal-to-noise performance. Other parameters such as small-signal and full-power bandwidth, and wideband noise are also defined in this stage.

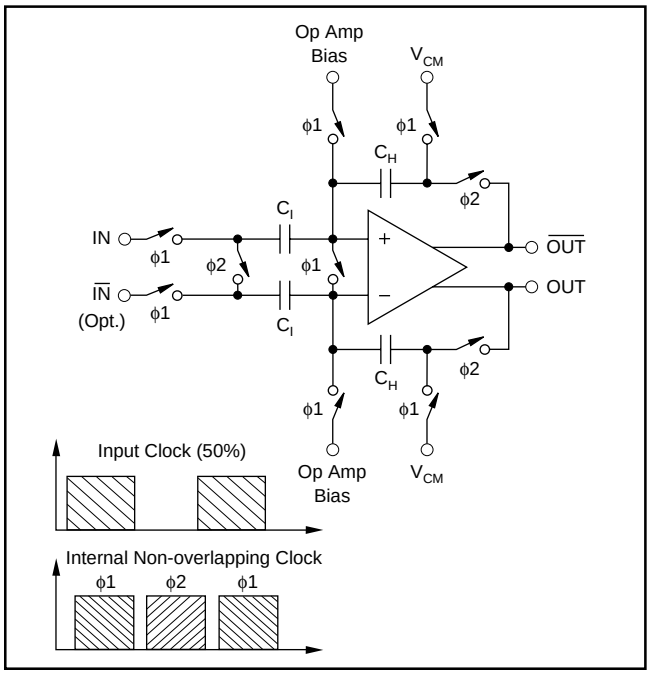


FIGURE 1. Input Track/Hold Configuration with Timing Signals.

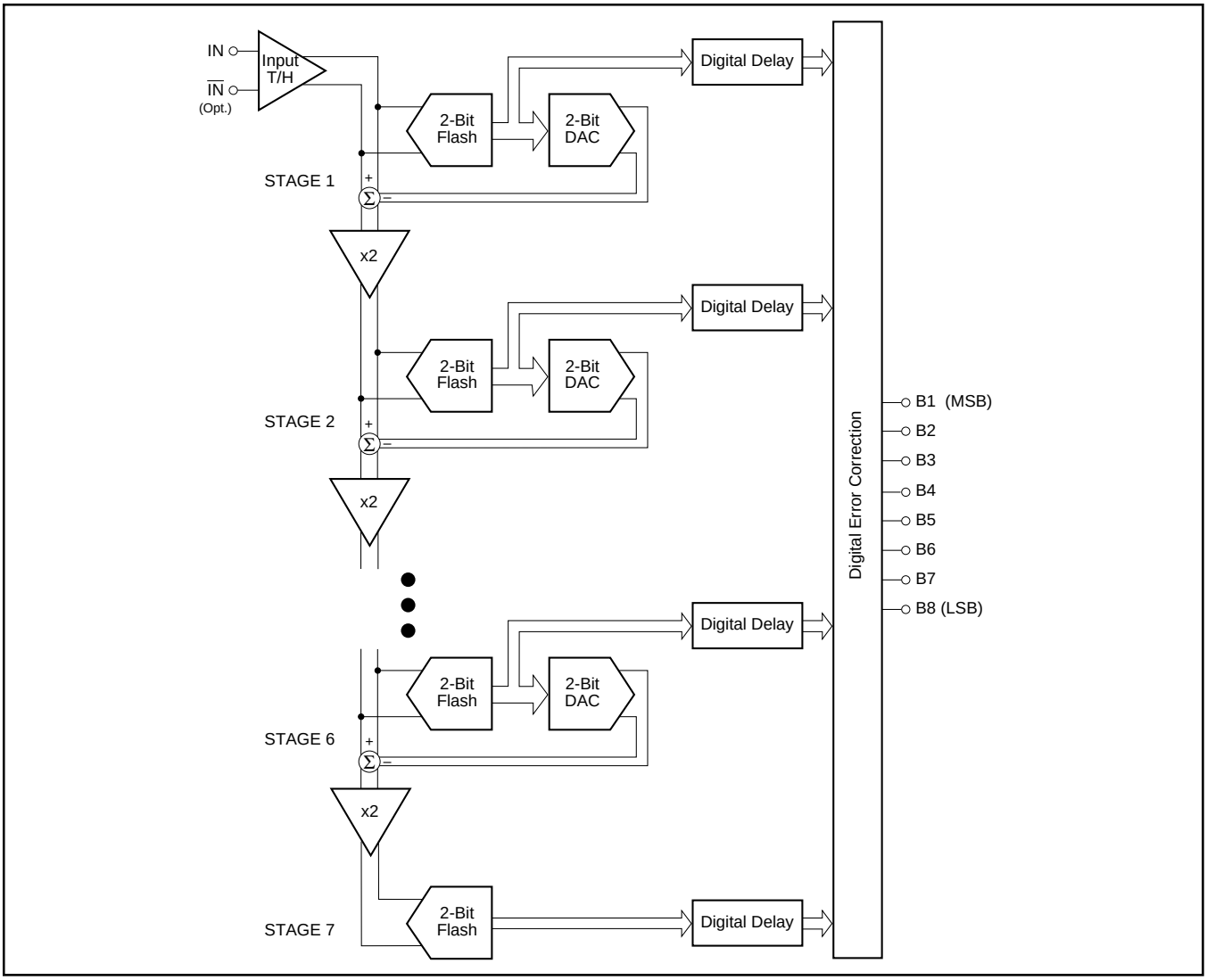


FIGURE 2. Pipeline ADC Architecture.

The pipelined quantizer architecture has 7 stages with each stage containing a two-bit quantizer and a two bit Digital-to-Analog Converter (DAC), as shown in Figure 2. Each two-bit quantizer stage converts on the edge of the sub-clock, which is the same frequency of the externally applied clock. The output of each quantizer is fed into its own delay line to time-align it with the data created from the subsequent quantizer stages. This aligned data is fed into a digital error correction circuit which can adjust the output data based on the information found on the redundant bits. This technique provides the ADS930 with excellent differential linearity and guarantees no missing codes at the 8-bit level.

The ADS930 includes an internal reference circuit that provides the bias voltages for the internal stages (for details see "Internal Reference"). A midpoint voltage is established by the built-in resistor ladder which is made available at pin 26 "CM". This voltage can be used to bias the inputs up to the recommended common-mode voltage or to level shift the input driving circuitry. The ADS930 can be used in both a single-ended or differential input configuration. When operated in single-ended mode, the reference midpoint (pin 26) should be tied to the inverting input, pin 24.

To accommodate a bipolar signal swing, the ADS930 operates with a common-mode voltage (V_{CM}) which is derived from the internal references. Due to the symmetric resistor ladder inside the ADS930, V_{CM} is situated between the top and bottom reference voltage. The following equation can be used for calculating the common-mode voltage level:

$$V_{CM} = (REFT + REFB)/2 \quad (1)$$

APPLICATIONS

DRIVING THE ANALOG INPUTS

Figure 3 shows an example of an ac-coupled, single-ended interface circuit using high-speed op amps which operate on dual supplies (OPA650, OPA658). The mid-point reference voltage, (V_{CM}), biases the bipolar, ground-referenced input signal. The capacitor C_1 and resistor R_1 form a high-pass filter with the –3dB frequency set at

$$f_{-3dB} = 1/(2\ \pi\ R_1\ C_1) \quad (2)$$

The values for C_1 and R_1 are not critical in most applications and can be set freely. The values shown in Figure 3 correspond to a corner frequency of 1.6kHz.

Figure 4 depicts a circuit that can be used in single-supply applications. The mid-reference biases the op amp up to the appropriate common-mode voltage, for example V_{CM} = +1.5V. With the use of capacitor C_G, the DC gain for the non-inverting op amp input is set to +1V/V. As a result, the transfer function is modified to

$$V_{OUT} = V_{IN}\ \{(1 + R_F/R_G) + V_{CM}\} \quad (3)$$

Again, the input coupling capacitor C_1 and resistor R_1 form a high-pass filter. At the same time, the input impedance is defined by R_1. Resistor R_S isolates the op amp's output from the capacitive load to avoid gain peaking or even oscillation. It can also be used to establish a defined bandwidth to reduce the wideband noise. Its value is usually between 10Ω and 100Ω.

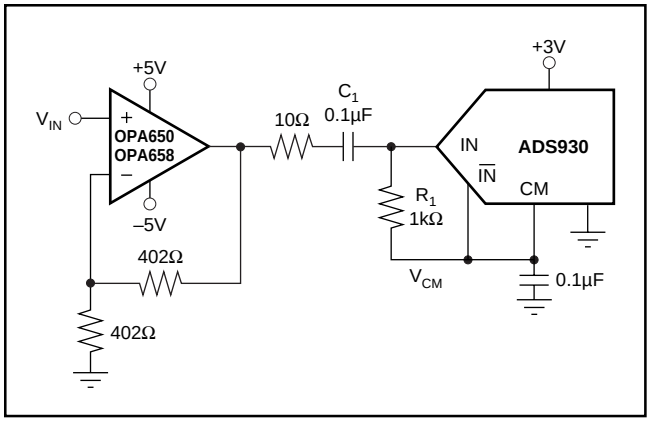


FIGURE 3. AC-Coupled Driver.

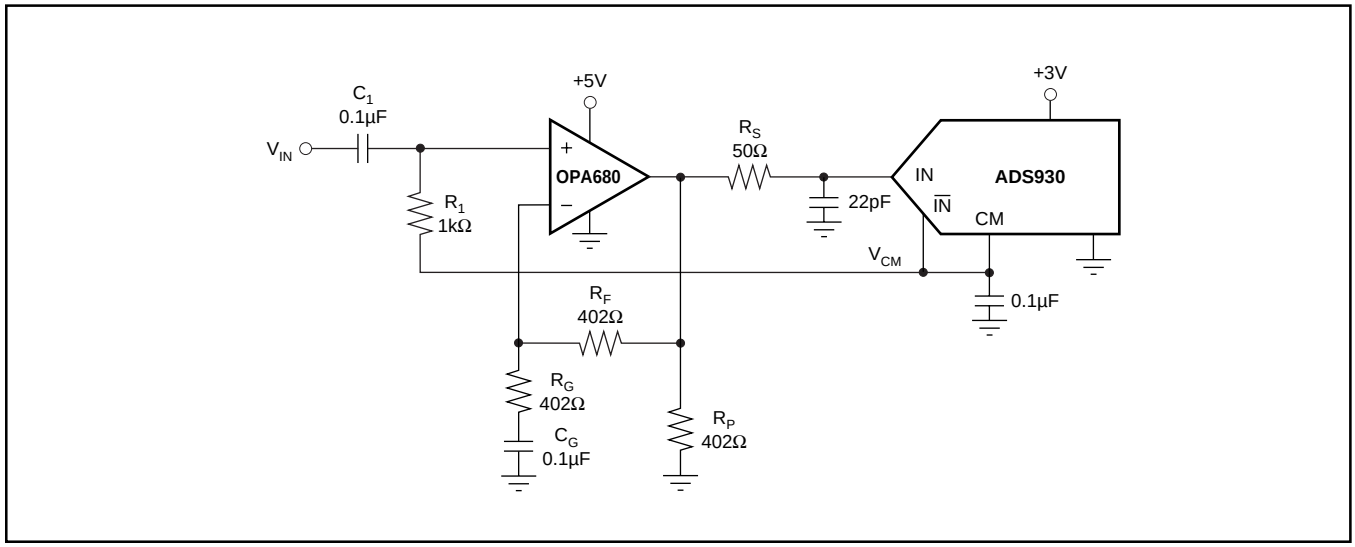


FIGURE 4. Interface Circuit Example Using the Voltage Feedback Amplifier OPA680.

DC-COUPLED INTERFACE CIRCUIT

Figure 5 illustrates an example of a DC-coupled interface circuit using one high-speed op amp to level-shift the ground-referenced input signal. This serves to condition it for the input requirements of the ADS930. With a +3V supply the input signal swings 1Vp-p centered around a typical common-mode voltage of +1.5V. This voltage can be derived from the internal bottom reference (REFB) and then fed back through a resistor divider (R_1, R_2) to level-shift the driving op amp (A_1). A capacitor across R_2 will shunt most of the wideband noise to ground. Depending on the configured gain, the values of resistors R_1 and R_2 must be adjusted since the offsetting voltage (V_{OS}) is amplified by the non-inverting gain, $1 + (R_F/R_{IN})$. This example assumes the sum of R_1 and R_2 to be 5kΩ, drawing only 250µA from the bottom reference. Considerations for the selection of a proper op amp should include its output swing, input common-mode range, and bias current. This circuit can easily be modified for a +5V operation of the ADC, requiring a higher common-mode level (+2.5V).

INTERNAL REFERENCE

The ADS930 features an internal reference that provides fixed reference voltages for the internal stages. As shown in Figure 6, each end of the resistor ladder (REFT and REFB) are driven by a buffer amplifier. The ladder has a nominal resistance of 4kΩ (±15%). The two outputs of the buffers are brought out at pin 21 (LpBy) and pin 25 (LnBy), primarily to connect external bypass capacitors, typically 0.1µF. They will shunt the high frequency switching noise that is fed back into the reference circuit and improve the performance. The buffers can drive limited external loads, for example level-shifting of the converter's interface circuit. However, the current draw should be limited to approximately 1mA.

Derived from the top reference of +1.75V is an additional voltage of +1.0V. Note that this voltage, available on pin 23, is not buffered and care should be taken when external loads are applied. In normal operation, this pin is left unconnected and no bypassing components are required.

CLOCK INPUT

The clock input of the ADS930 is designed to accommodate either +5V or +3V CMOS logic levels. To drive the clock input with a minimum amount of duty cycle variation and support the maximum sampling rate (30MSPS), high speed or advanced CMOS logic should be used (HC/HCT, AC/ACT). When digitizing at high sampling rates, a 50% duty cycle, along with fast rise and fall times (2ns or less),

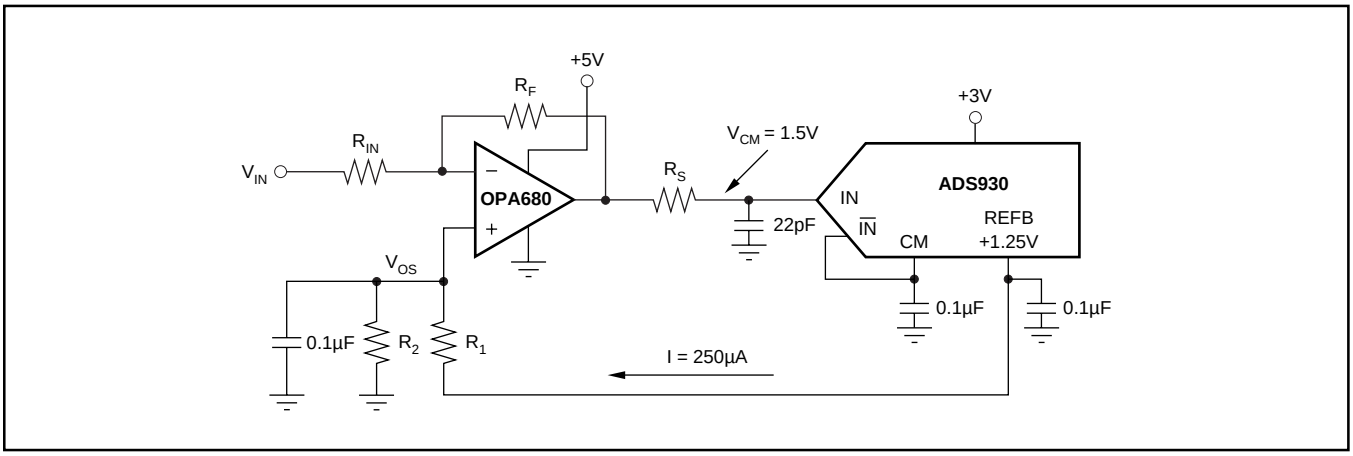


FIGURE 5. Single-supply, DC-coupled Interface Circuit.

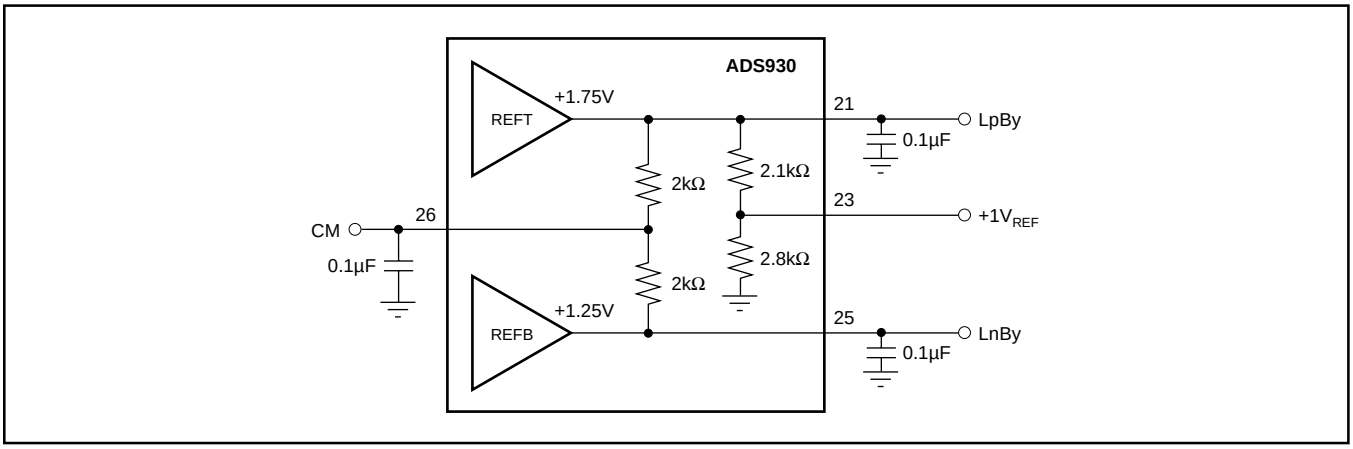


FIGURE 6. Internal Reference Structure and Recommended Reference Bypassing.

are recommended to meet the rated performance specifications. However, the ADS930 performance is tolerant to duty cycle variations of as much as ±10%, which should not affect the performance. For applications operating with input frequencies up to Nyquist ($f_{CLK}/2$) or undersampling applications, special considerations must be made to provide a clock with very low jitter. Clock jitter leads to aperture jitter (t_A) which can be the ultimate limitation in achieving good SNR performance. The following equation shows the relationship between aperture jitter, input frequency and the signal-to-noise ratio:

$$SNR = 20\log10\ [1/(2\ \pi\ f_{IN}\ t_A)] \quad (4)$$

SINGLE-ENDED INPUT ($\overline{IN}$ = 1.5V DC)	STRAIGHT OFFSET BINARY (SOB) PIN 12 FLOATING or LO
+FS (IN = +2V)	11111111
+FS –1LSB	11111111
+FS –2LSB	11111110
+3/4 Full Scale	11100000
+1/2 Full Scale	11000000
+1/4 Full Scale	10100000
+1LSB	10000001
Bipolar Zero (IN +1.5V)	10000000
–1LSB	01111111
–1/4 Full Scale	01100000
–1/2 Full Scale	01000000
–3/4 Full Scale	00100000
–FS +1LSB	00000001
–FS (IN = +1V)	00000000

TABLE I. Coding Table for the ADS930.

DIGITAL OUTPUTS

There is a 5.0 clock cycle data latency from the start convert signal to the valid output data. The standard output coding is Straight Offset Binary where a full scale input signal corresponds to all "1's" at the output. The digital outputs of the ADS930 can be set to a high impedance state by driving the $\overline{OE}$ (pin 16) with a logic "HI". Normal operation is achieved with pin 16 "LO" or Floating due to internal pull-down resistors. This function is provided for testability purposes but is not recommended to be used dynamically.

The digital outputs of the ADS930 are standard CMOS stages and designed to be compatible to both high speed TTL and CMOS logic families. The logic thresholds are for low-voltage CMOS: V_{OL} = 0.4V, V_{OH} = 2.4V, which allows the ADS930 to directly interface to 3V-logic. The digital output driver of the ADS930 uses a dedicated digital supply pin (pin 2, LV_{DD}) see Figure 7. By adjusting the voltage on LV_{DD}, the digital output levels will vary respectively. It is recommended to limit the fan-out to one in order to keep the capacitive loading on the data lines below the specified 15pF. If necessary, external buffers or latches may be used to provide the added benefit of isolating the ADC from any digital activities on the bus coupling back high frequency noise which degrades the performance.

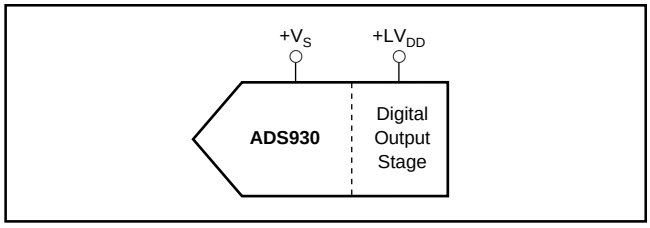


FIGURE 7. Independent Supply Connection for Output Stage.

POWER-DOWN MODE

The ADS930's low power consumption can be reduced even further by initiating a power-down mode. For this, the Power Down Pin (Pin 17) must be tied to a logic "High" reducing the current drawn from the supply by approximately 70%. In normal operation, the power-down mode is disabled by an internal pull-down resistor (50kΩ).

During power-down, the digital outputs are set in 3-state. With the clock applied, the converter does not accurately process the sampled signal. After removing the power-down condition, the output data from the following 5 clock cycles is invalid (data latency).

DECOUPLING AND GROUNDING CONSIDERATIONS

The ADS930 has several supply pins, one of which is dedicated to supply only the output driver (LV_{DD}). The remaining supply pins are not divided into analog and digital supply pins since they are internally connected on the chip. For this reason, it is recommended that the converter be treated as an analog component and to power it from the analog supply only. Digital supply lines often carry high levels of noise which can couple back into the converter and limit performance.

Because of the pipeline architecture, the converter also generates high frequency transients and noise that are fed back into the supply and reference lines. This requires that the supply and reference pins be sufficiently bypassed. Figure 8 shows the recommended decoupling scheme for the analog supplies. In most cases 0.1µF ceramic chip capacitors are adequate to keep the impedance low over a wide frequency range. Their effectiveness largely depends on the proximity to the individual supply pin. Therefore, they should be located as close as possible to the supply pins.

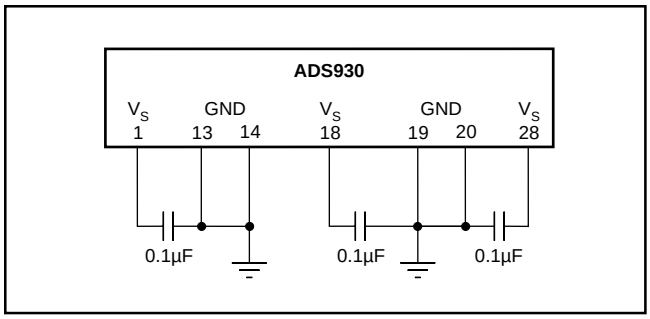


FIGURE 8. Recommended Bypassing for Analog Supply Pins.

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