



ADS930

**Speed<sup>PLUS</sup>™ 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
- 28-LEAD SSOP PACKAGE

**APPLICATIONS**

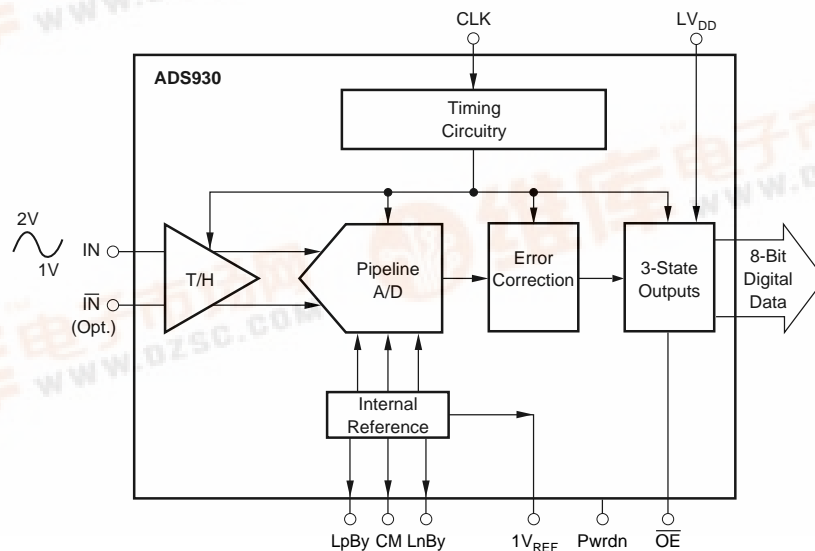
- BATTERY POWERED EQUIPMENT
- CAMCORDERS
- PORTABLE TEST EQUIPMENT
- COMPUTER SCANNERS
- COMMUNICATIONS

**DESCRIPTION**

The ADS930 is a high speed pipelined analog-to-digital converter 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 A/D converter is specified for performance at a 30MHz sampling rate. The ADS930 is available in a 28-lead SSOP package.





## SPECIFICATIONS (CONT)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = +3\text{V}$ , Single-ended Input and Sampling Rate = 30MHz, unless otherwise specified.

PARAMETER	CONDITIONS	TEMP	ADS930E			UNITS
			MIN	TYP	MAX	
<b>ACCURACY</b>						
Gain Error	Referred to Ideal Midscale $\Delta V_S = +10\%$	Full		5.9	10	%FS
Input Offset		Full		$\pm 10$	$\pm 60$	mV
Power Supply Rejection (Gain)		Full	42	56		dB
Power Supply Rejection (Offset)		Full	42	56		dB
Internal Positive Reference Voltage		Full			+1.75	V
Internal Negative Reference Voltage		Full			+1.25	V
<b>POWER SUPPLY REQUIREMENTS</b>						
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, $\theta_{JA}$ 28-Lead SSOP				50		$^\circ\text{C/W}$

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.

### ABSOLUTE MAXIMUM RATINGS

$+V_S$ .....	+6V
Analog Input .....	$+V_S + 0.3\text{V}$
Logic Input .....	$+V_S + 0.3\text{V}$
Case Temperature .....	+100 $^\circ\text{C}$
Junction Temperature .....	+150 $^\circ\text{C}$
Storage Temperature .....	+150 $^\circ\text{C}$



### 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.

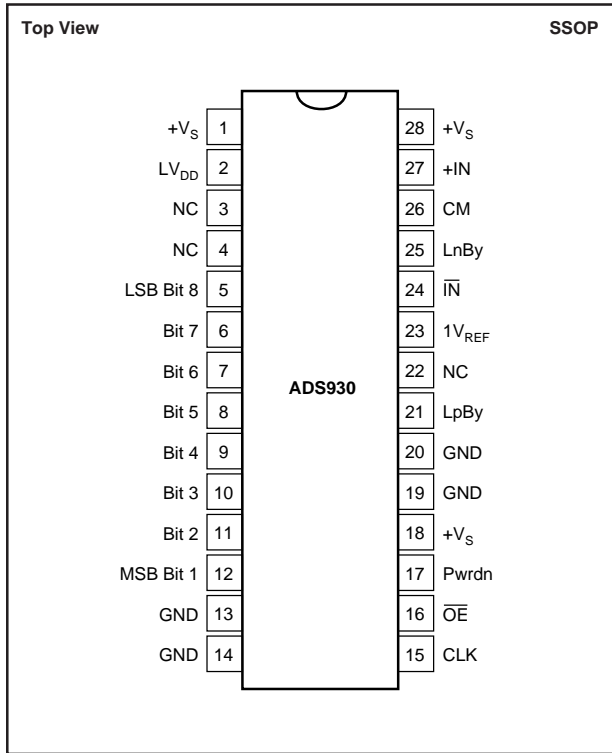
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### PACKAGE/ORDERING INFORMATION

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER <sup>(1)</sup>	TEMPERATURE RANGE
ADS930E	28-Lead SSOP	324	-40 $^\circ\text{C}$ to +85 $^\circ\text{C}$

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

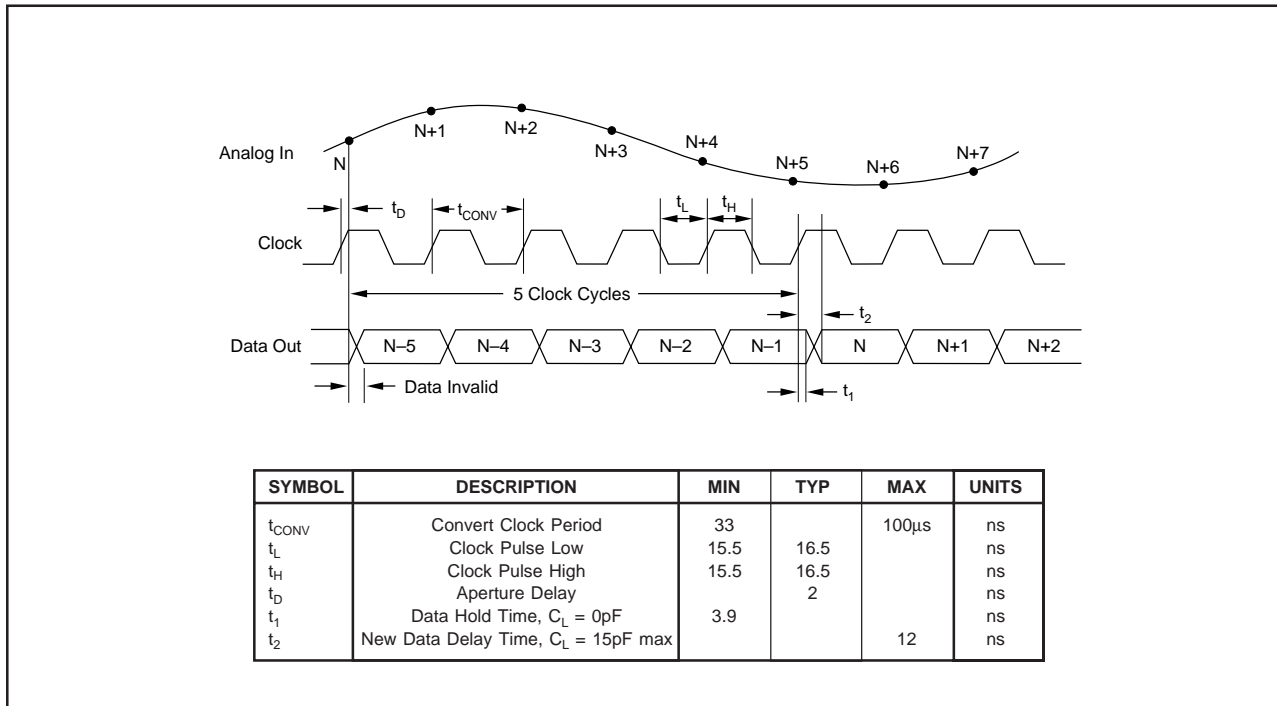
## PIN CONFIGURATION



## PIN DESCRIPTIONS

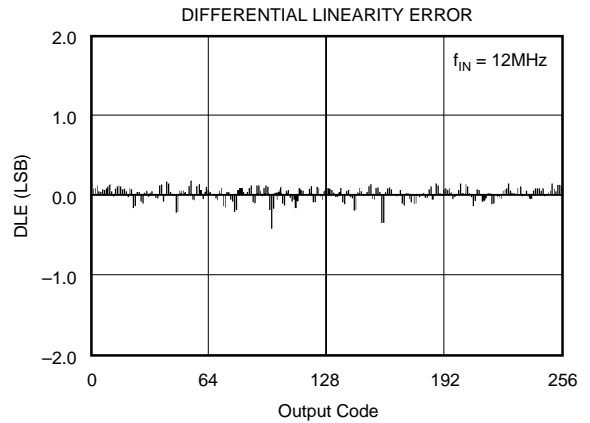
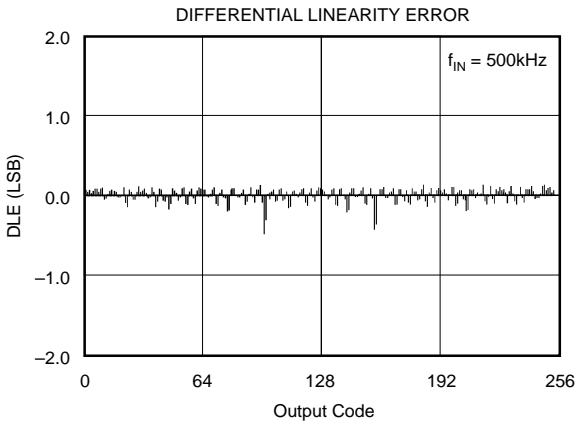
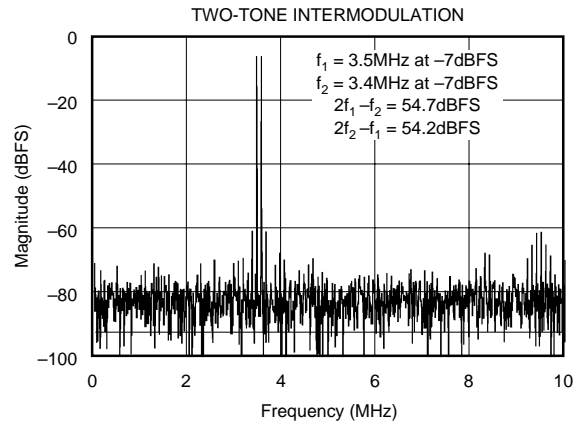
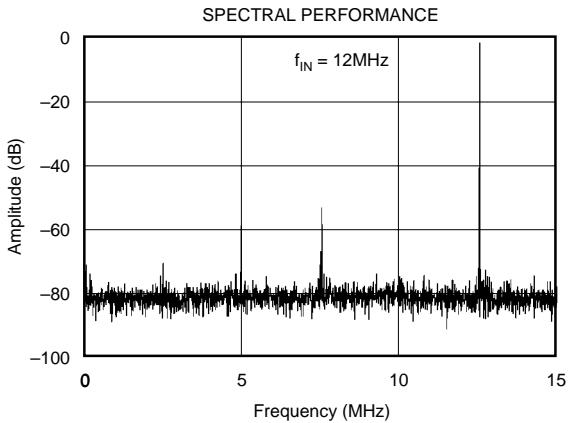
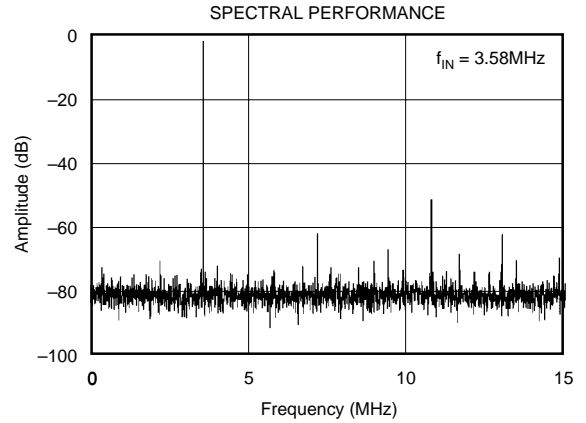
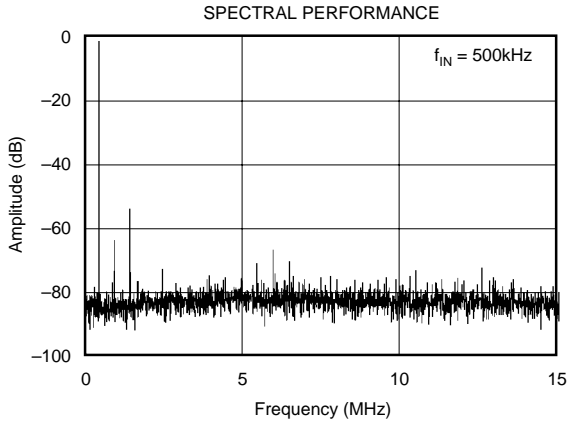
PIN	DESIGNATOR	DESCRIPTION
1	+V <sub>S</sub>	Analog Supply
2	LV <sub>DD</sub>	Output Logic Driver Supply Voltage
3	NC	No Connection
4	NC	No Connection
5	Bit 8 (LSB)	Data Bit 8 (D7)
6	Bit 7	Data Bit 7 (D6)
7	Bit 6	Data Bit 6 (D5)
8	Bit 5	Data Bit 5 (D4)
9	Bit 4	Data Bit 4 (D3)
10	Bit 3	Data Bit 3 (D2)
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	OE	Output Enable, Active Low
17	PwrDn	Power Down Pin
18	+V <sub>S</sub>	Analog Supply
19	GND	Analog Ground
20	GND	Analog Ground
21	LpBy	Positive Ladder Bypass
22	NC	No Connection
23	1V <sub>REF</sub>	1V Reference Output
24	IN	Complementary Input
25	LnBy	Negative Ladder Bypass
26	CM	Common-Mode Voltage Output
27	+IN	Analog Input
28	+V <sub>S</sub>	Analog Supply

## TIMING DIAGRAM



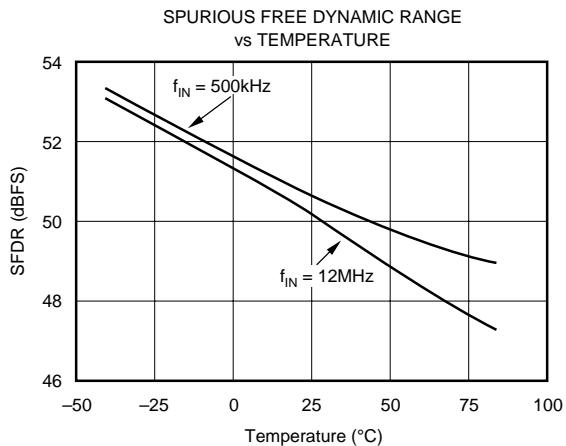
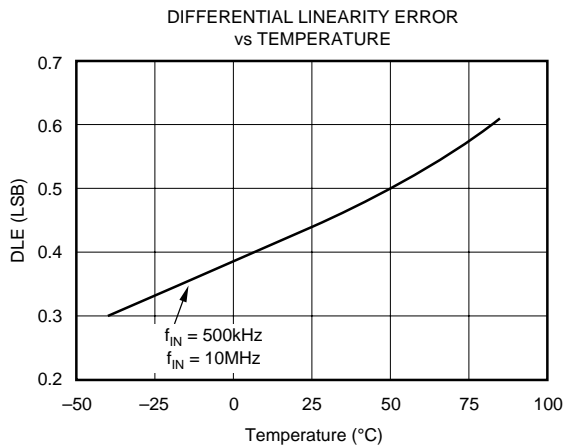
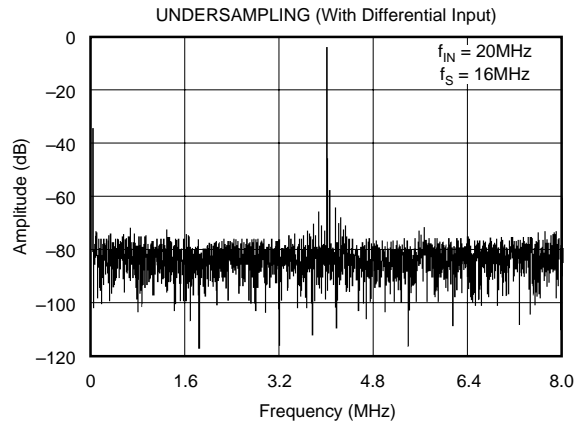
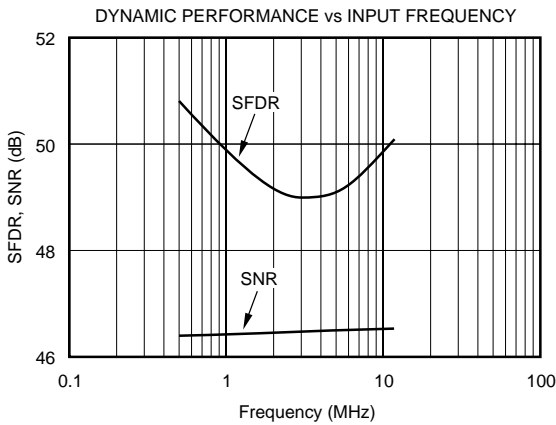
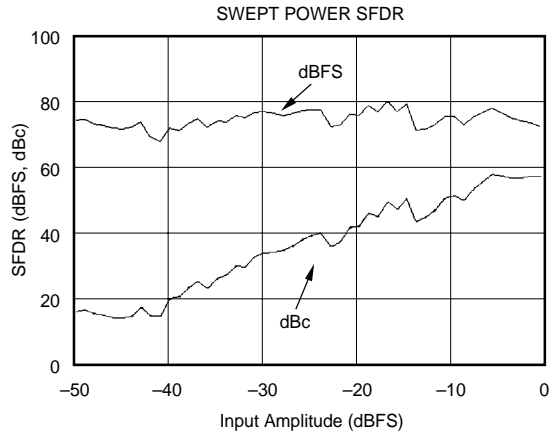
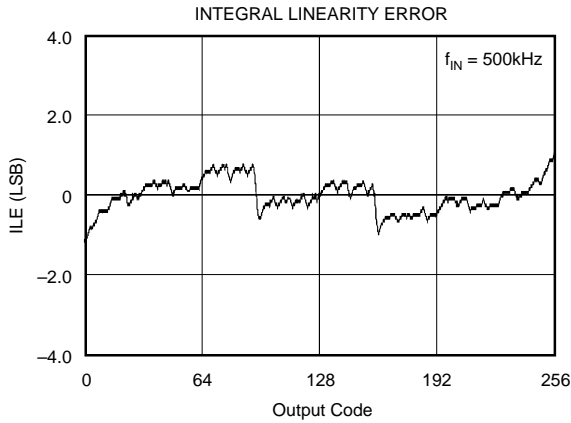
# TYPICAL PERFORMANCE CURVES

At  $T_A = +25^\circ\text{C}$ ,  $V_S = +3\text{V}$ , Single-ended Input and Sampling Rate = 30MHz, unless otherwise specified.



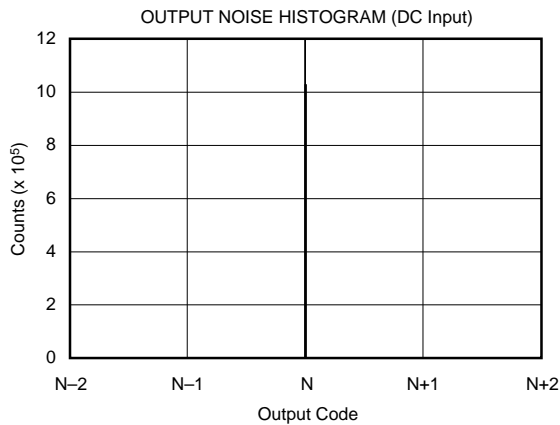
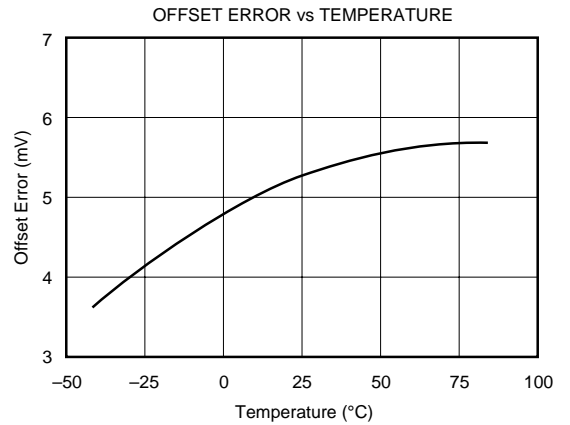
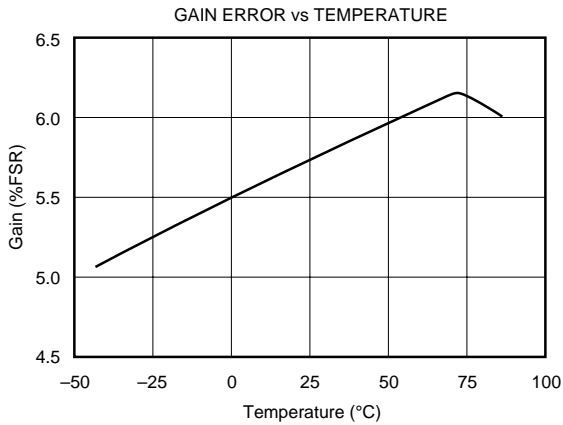
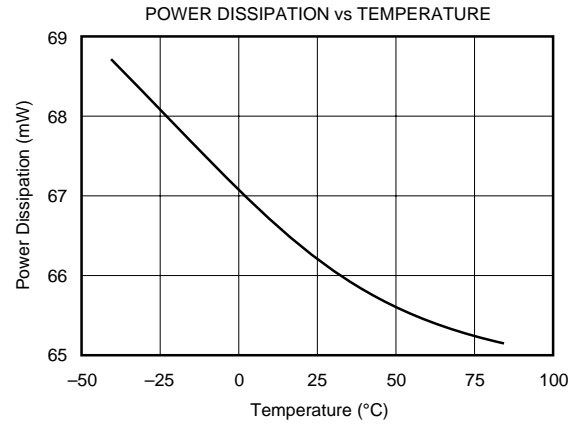
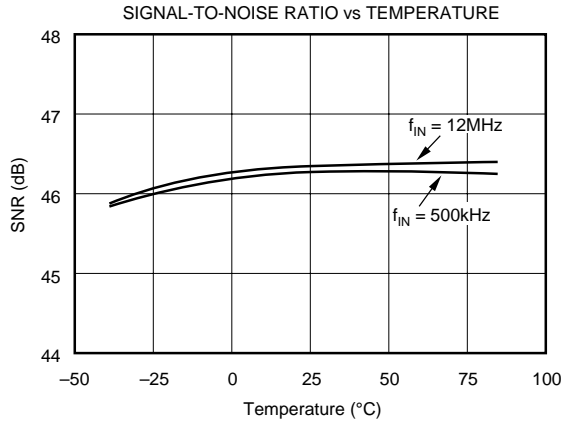
# TYPICAL PERFORMANCE CURVES (CONT)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = +3\text{V}$ , Single-ended Input and Sampling Rate = 30MHz, unless otherwise specified.



# TYPICAL PERFORMANCE CURVES (CONT)

At  $T_A = +25^\circ\text{C}$ ,  $V_S = +3\text{V}$ , Single-ended Input and Sampling Rate = 30MHz, unless otherwise specified.



# THEORY OF OPERATION

The ADS930 is a high speed sampling analog-to-digital converter 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,  $\phi 1$  and  $\phi 2$ . At the sampling time the input signal is sampled on the bottom plates of the input capacitors. In the next clock phase,  $\phi 2$ , 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  $C_1$  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 of 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.

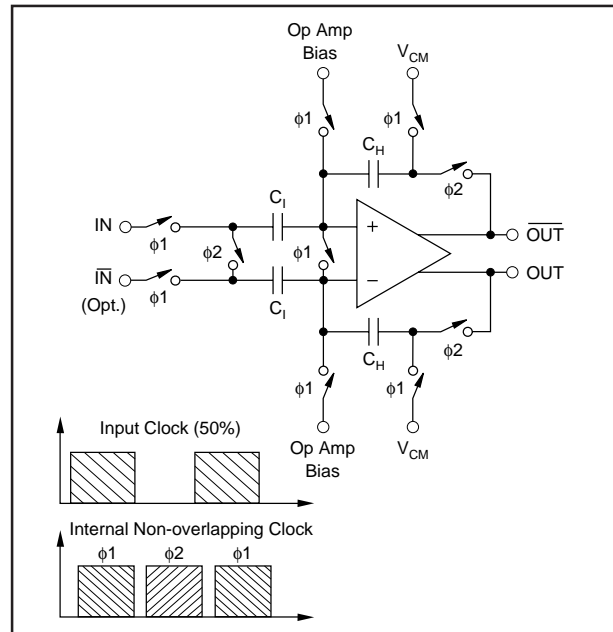


FIGURE 1. Input Track/Hold Configuration with Timing Signals.

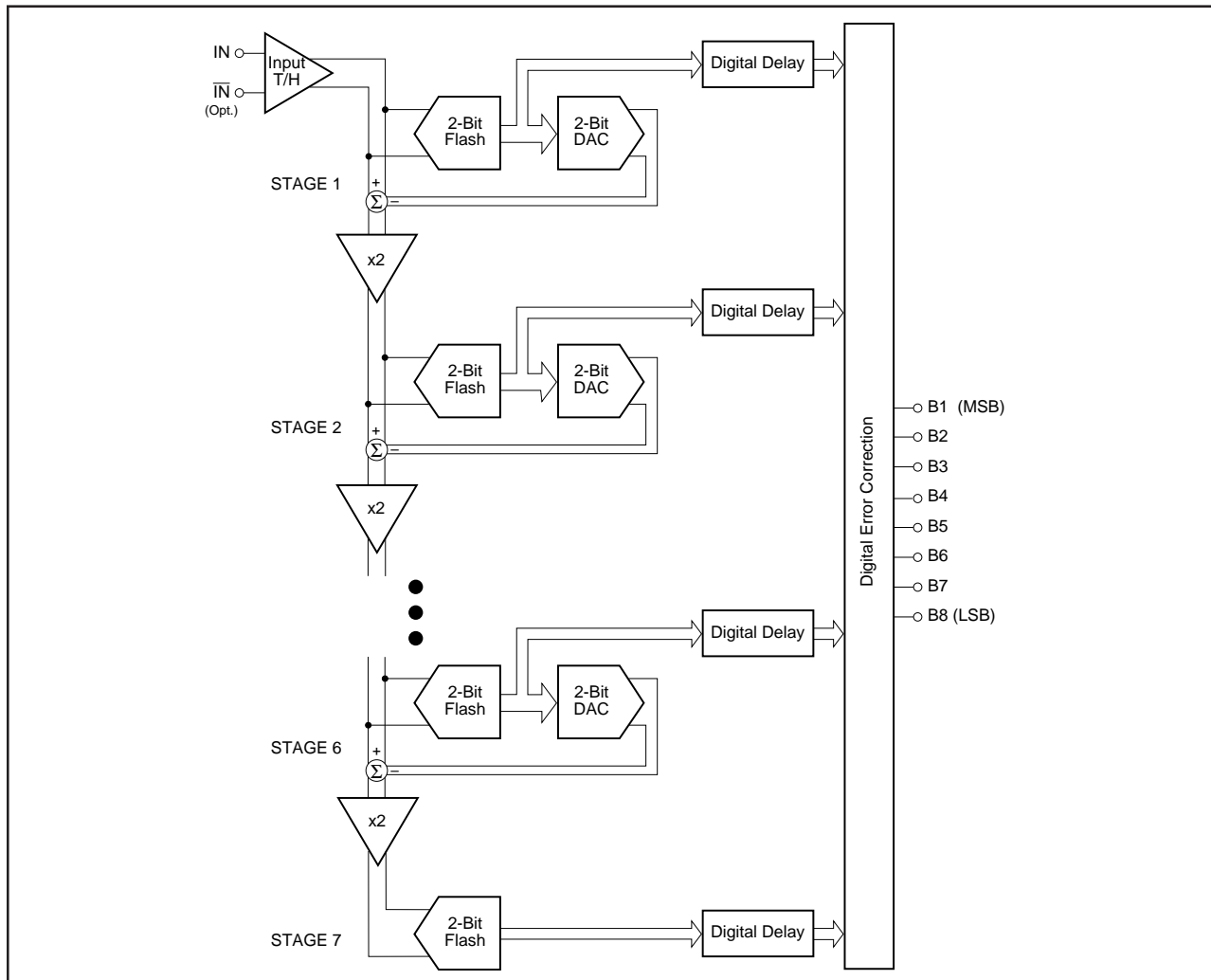


FIGURE 2. Pipeline A/D Architecture.



The pipelined quantizer architecture has 7 stages with each stage containing a two-bit quantizer and a two bit digital-to-analog converter, 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. Equation (1) 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  $-3\text{dB}$  frequency set at

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

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  $V_{CM} = +1.5\text{V}$ . With the use of capacitor  $C_G$ , the DC gain for the non-inverting op amp input is set to  $+1\text{V/V}$ . 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  $10\Omega$  and  $100\Omega$ .

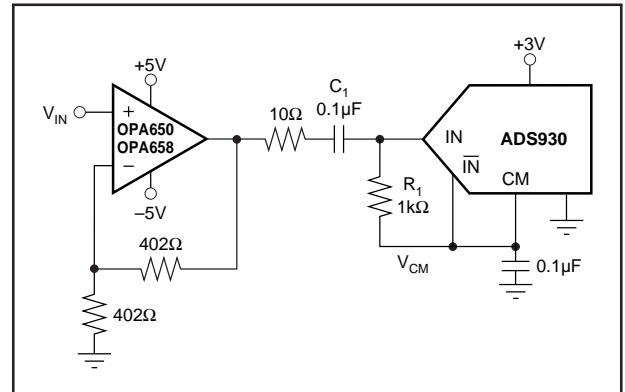


FIGURE 3. AC-Coupled Driver.

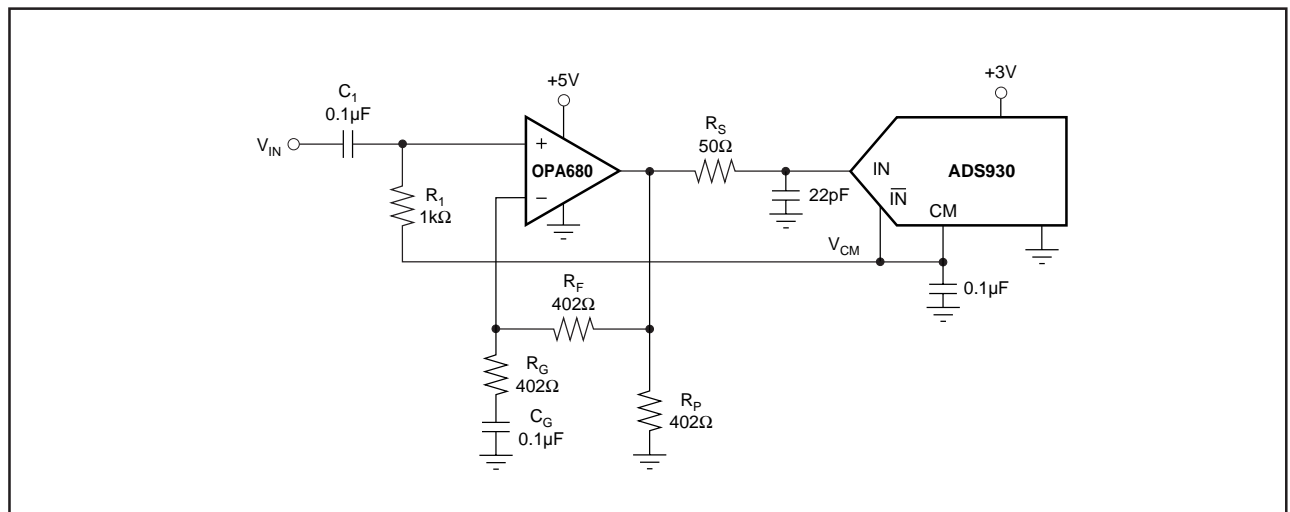


FIGURE 4. Interface Circuit Example Using the Voltage Feedback Amplifier OPA680.

## 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  $5k\Omega$ , drawing only  $250\mu A$  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 A/D converter, 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  $4k\Omega$  ( $\pm 15\%$ ). The two outputs of the buffers are brought out at pin 21 (LpBy) and pin 25 (LnBy), primarily to connect external bypass capacitors, typically  $0.1\mu F$ . 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), are

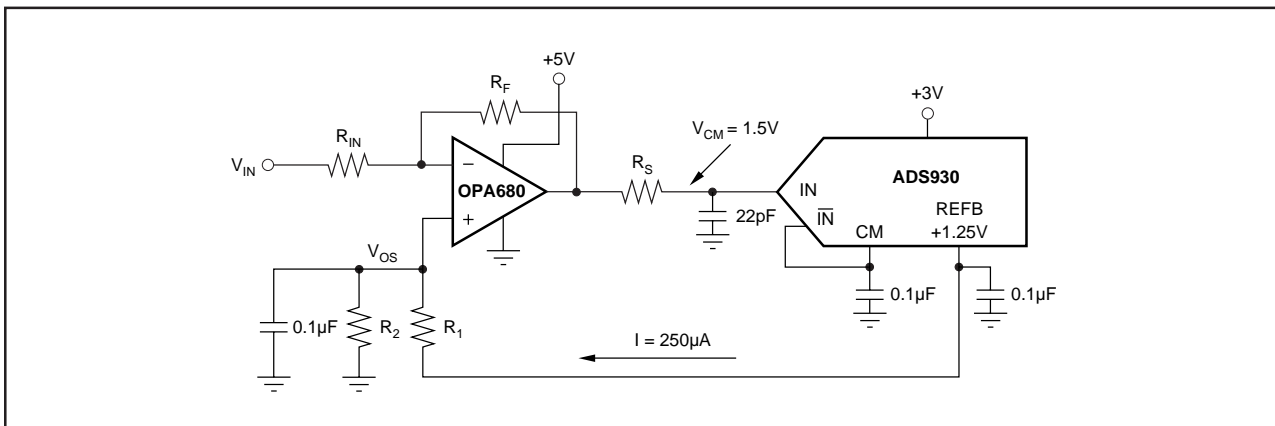


FIGURE 5. Single-supply, DC-coupled Interface Circuit.

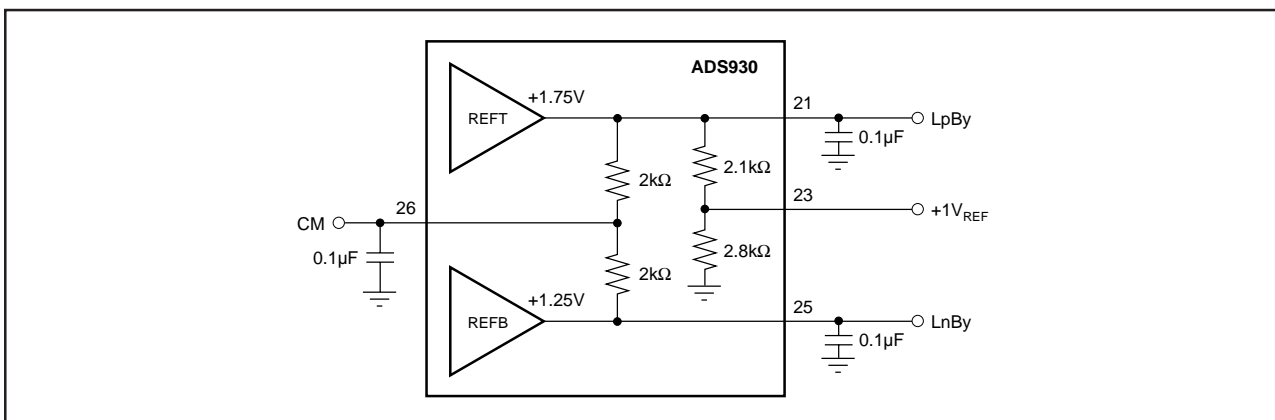


FIGURE 6. Internal Reference Structure and Recommended Reference Bypassing.

recommended to meet the rated performance specifications. However, the ADS930 performance is tolerant to duty cycle variations of as much as  $\pm 10\%$ , 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. Equation (4) shows the relationship between aperture jitter, input frequency and the signal-to-noise ratio:

$$SNR = 20 \log_{10} [1/(2 \pi f_{IN} t_A)] \quad (4)$$

SINGLE-ENDED INPUT ( $I_N = 1.5V$ DC)	STRAIGHT OFFSET BINARY (SOB) PIN 12 FLOATING or LO
+FS ( $I_N = +2V$ )	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 ( $I_N +1.5V$ )	10000000
-1LSB	01111111
-1/4 Full Scale	01100000
-1/2 Full Scale	01000000
-3/4 Full Scale	00100000
-FS +1LSB	00000001
-FS ( $I_N = +1V$ )	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

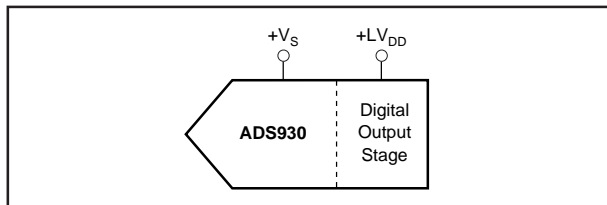


FIGURE 7. Independent Supply Connection for Output Stage.

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 A/D converter from any digital activities on the bus coupling back high frequency noise which degrades the performance.

## 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 (50k $\Omega$ ).

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 0.1 $\mu F$  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.

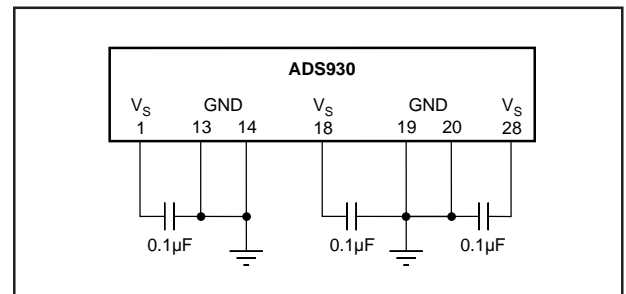


FIGURE 8. Recommended Bypassing for Analog Supply Pins.