

## 12-Bit 10 $\mu$ s Sampling CMOS ANALOG-to-DIGITAL CONVERTER

### FEATURES

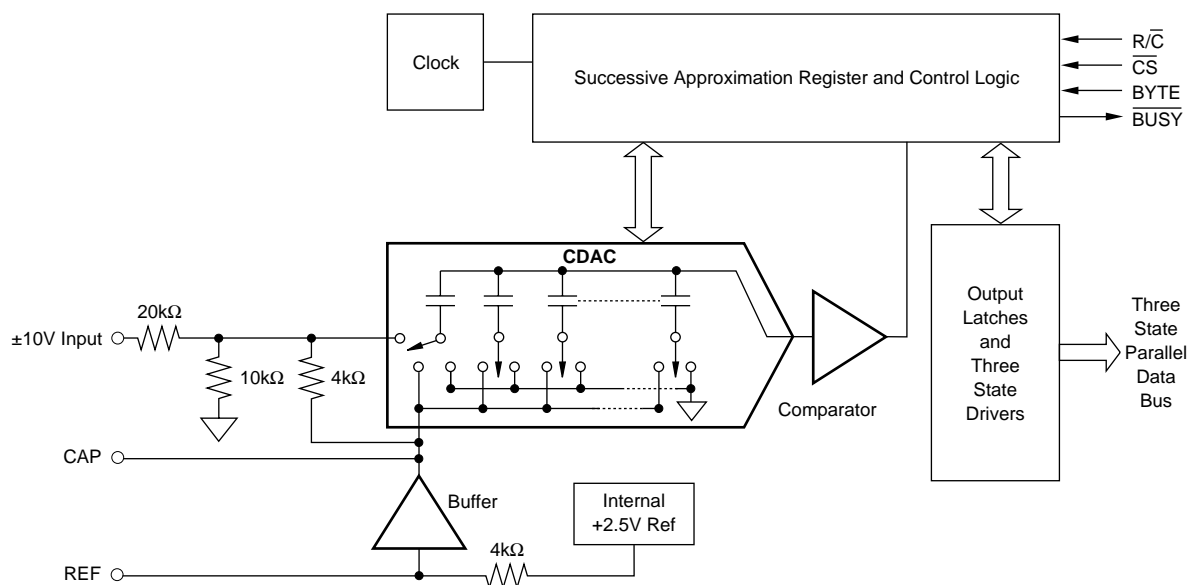
- 100kHz min SAMPLING RATE
- STANDARD  $\pm 10$ V INPUT RANGE
- 72dB min SINAD WITH 45kHz INPUT
- $\pm 0.45$  LSB max INL
- DNL: 12 Bits "No Missing Codes"
- SINGLE +5V SUPPLY OPERATION
- PIN-COMPATIBLE WITH 16-BIT ADS7805
- USES INTERNAL OR EXTERNAL REFERENCE
- COMPLETE WITH S/H, REF, CLOCK, ETC.
- FULL PARALLEL DATA OUTPUT
- 100mW max POWER DISSIPATION
- 28-PIN 0.3" PLASTIC DIP AND SO PACKAGES

### DESCRIPTION

The ADS7804 is a complete 12-bit sampling analog-to-digital (A/D) converter using state-of-the-art CMOS structures. It contains a complete 12-bit, capacitor-based, SAR A/D converter with S/H, reference, clock, interface for microprocessor use, and three-state output drivers.

The ADS7804 is specified at a 100kHz sampling rate, and guaranteed over the full temperature range. Laser-trimmed scaling resistors provide an industry-standard  $\pm 10$ V input range, while the innovative design allows operation from a single +5V supply, with power dissipation under 100mW.

The 28-pin ADS7804 is available in plastic 0.3" DIP and SO packages, both fully specified for operation over the industrial  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  range.



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.

## ABSOLUTE MAXIMUM RATINGS

Analog Inputs: $V_{IN}$ .....	$\pm 25V$
CAP .....	$+V_{ANA} +0.3V$ to AGND2 $-0.3V$
REF .....	Indefinite Short to AGND2
	Momentary Short to $V_{ANA}$
Ground Voltage Differences: DGND, AGND1, AGND2 .....	$\pm 0.3V$
$V_{ANA}$ .....	7V
$V_{DIG}$ to $V_{ANA}$ .....	$+0.3V$
$V_{DIG}$ .....	7V
Digital Inputs .....	$-0.3V$ to $+V_{DIG} +0.3V$
Maximum Junction Temperature .....	$+165^{\circ}C$
Internal Power Dissipation .....	825mW
Lead Temperature (soldering, 10s) .....	$+300^{\circ}C$



## 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	MAXIMUM LINEARITY ERROR (LSB)	MINIMUM SIGNAL-TO-(NOISE+DISTORTION) RATIO (LSB)	PACKAGE-LEAD (DESIGNATOR) <sup>(1)</sup>	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
ADS7804P	$\pm 0.9$	70	DIP-28 (NT)	$-40^{\circ}C$ to $+85^{\circ}C$	ADS7804P	ADS7804P	Tube, 13
ADS7804PB	$\pm 0.45$	72	DIP-28 (NT)	$-40^{\circ}C$ to $+85^{\circ}C$	ADS7804PB	ADS7804PB	Tube, 13
ADS7804U	$\pm 0.9$	70	SO-28 (DW)	$-40^{\circ}C$ to $+85^{\circ}C$	ADS7804U	ADS7804U	Tube, 28
"	"	"	"	"	"	ADS7804U/1K	Tape and Reel, 1000
ADS7804UB	$\pm 0.45$	72	SO-28 (DW)	$-40^{\circ}C$ to $+85^{\circ}C$	ADS7804UB	ADS7804UB	Tube, 28
"	"	"	"	"	"	ADS7804UB/1K	Tape and Reel, 1000

NOTE: (1) For the most current specifications and package information, refer to our web site at [www.ti.com](http://www.ti.com).

## ELECTRICAL CHARACTERISTICS

At  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ ,  $f_S = 100kHz$ , and  $V_{DIG} = V_{ANA} = +5V$ , using internal reference, unless otherwise specified.

PARAMETER	CONDITIONS	ADS7804P, U			ADS7804PB, UB			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
<b>RESOLUTION</b>				12			*	Bits
<b>ANALOG INPUT</b>								
Voltage Ranges			$\pm 10V$			*		V
Impedance			23			*		k $\Omega$
Capacitance			35			*		pF
<b>THROUGHPUT SPEED</b>								
Conversion Time	Acquire and Convert		5.7	8		*	*	$\mu s$
Complete Cycle				10			*	$\mu s$
Throughput Rate		100			*			kHz
<b>DC ACCURACY</b>								
Integral Linearity Error	Ext. 2.5000V Ref Ext. 2.5000V Ref  +4.75V < $V_D$ < +5.25V			$\pm 0.9$			$\pm 0.45$	LSB <sup>(1)</sup>
Differential Linearity Error				$\pm 0.9$			$\pm 0.45$	LSB
No Missing Codes			Ensured			*		Bits
Transition Noise <sup>(2)</sup>			0.1			*		LSB
Full Scale Error <sup>(3,4)</sup>				$\pm 0.5$			$\pm 0.25$	%
Full Scale Error Drift			$\pm 7$			$\pm 5$		ppm/ $^{\circ}C$
Full Scale Error <sup>(3,4)</sup>				$\pm 0.5$			$\pm 0.25$	%
Full Scale Error Drift			$\pm 2$			*		ppm/ $^{\circ}C$
Bipolar Zero Error <sup>(3)</sup>				$\pm 10$			$\pm 10$	mV
Bipolar Zero Error Drift			$\pm 2$			*		ppm/ $^{\circ}C$
Power Supply Sensitivity ( $V_{DIG} = V_{ANA} = V_D$ )				$\pm 0.5$			*	LSB
<b>AC ACCURACY</b>								
Spurious-Free Dynamic Range	$f_{IN} = 45kHz$	80			*			dB <sup>(5)</sup>
Total Harmonic Distortion	$f_{IN} = 45kHz$			-80			*	dB
Signal-to-(Noise+Distortion)	$f_{IN} = 45kHz$	70			72			dB
Signal-to-Noise	$f_{IN} = 45kHz$	70			72			dB
Full-Power Bandwidth <sup>(6)</sup>			250			*		kHz
<b>SAMPLING DYNAMICS</b>								
Aperture Delay	FS Step		40			*		ns
Aperture Jitter			Sufficient to meet AC specs				*	
Transient Response				2			*	$\mu s$
Overvoltage Recovery <sup>(7)</sup>			150			*		ns

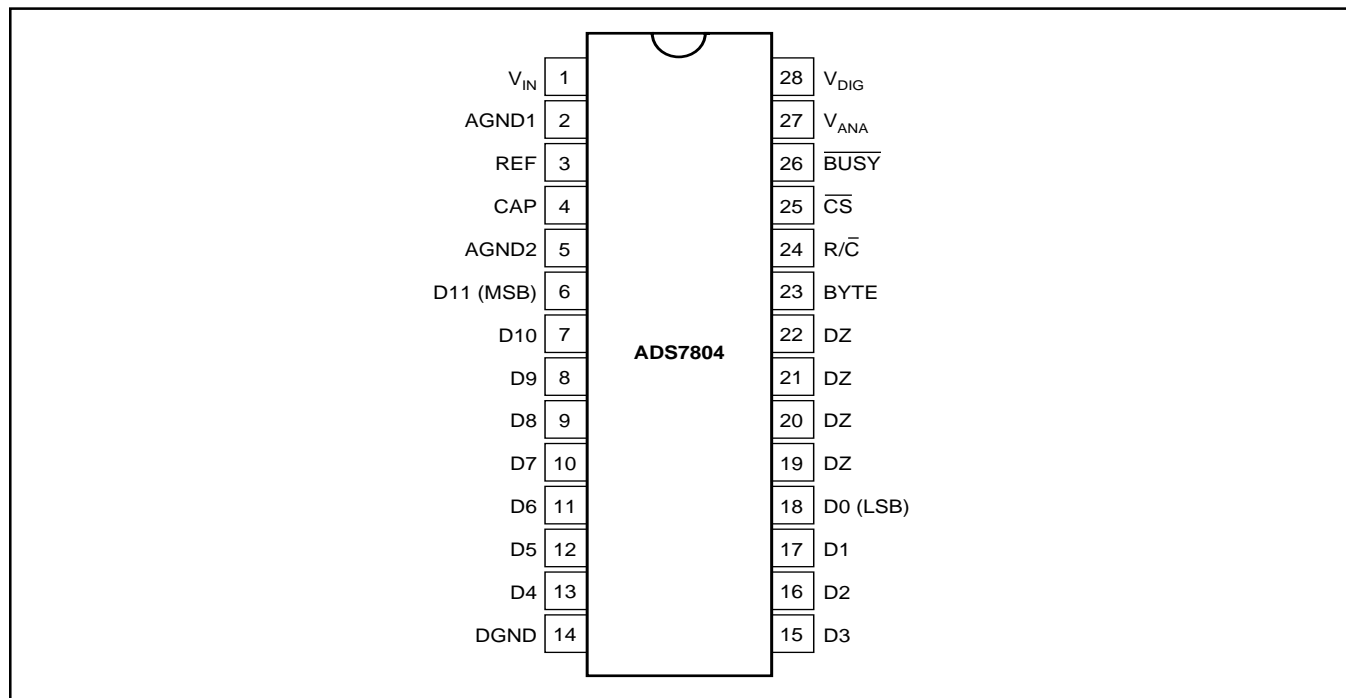
# ELECTRICAL CHARACTERISTICS (Cont.)

At  $T_A = -40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ ,  $f_S = 100\text{kHz}$ , and  $V_{\text{DIG}} = V_{\text{ANA}} = +5\text{V}$ , using internal reference, unless otherwise specified.

PARAMETER	CONDITIONS	ADS7804P, U			ADS7804PB, UB			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
<b>REFERENCE</b>								
Internal Reference Voltage		2.48	2.5	2.52	*	*	*	V
Internal Reference Source Current (Must use external buffer.)			1		*	*	*	$\mu\text{A}$
Internal Reference Drift			8					$\text{ppm}/^{\circ}\text{C}$
External Reference Voltage Range for Specified Linearity		2.3	2.5	2.7	*	*	*	V
External Reference Current Drain	Ext. 2.5000V Ref			100			*	$\mu\text{A}$
<b>DIGITAL INPUTS</b>								
Logic Levels								
$V_{\text{IL}}$		-0.3		+0.8	*		*	V
$V_{\text{IH}}$		+2.0		$V_D + 0.3\text{V}$	*		*	V
$I_{\text{IL}}$				$\pm 10$			*	$\mu\text{A}$
$I_{\text{IH}}$				$\pm 10$			*	$\mu\text{A}$
<b>DIGITAL OUTPUTS</b>								
Data Format								
Data Coding								
$V_{\text{OL}}$				+0.4	*		*	V
$V_{\text{OH}}$				$\pm 5$			*	V
Leakage Current	$I_{\text{SINK}} = 1.6\text{mA}$ $I_{\text{SOURCE}} = 500\mu\text{A}$ High-Z State, $V_{\text{OUT}} = 0\text{V}$ to $V_{\text{DIG}}$ High-Z State	+4		15			15	$\mu\text{A}$
Output Capacitance								pF
<b>DIGITAL TIMING</b>								
Bus Access Time				83			*	ns
Bus Relinquish Time				83			*	ns
<b>POWER SUPPLIES</b>								
Specified Performance								
$V_{\text{DIG}}$		+4.75	+5	+5.25	*	*	*	V
$V_{\text{ANA}}$		+4.75	+5	+5.25	*	*	*	V
$+I_{\text{DIG}}$			0.3			*		mA
$+I_{\text{ANA}}$			16			*		mA
Power Dissipation	$f_S = 100\text{kHz}$			100			*	mW
<b>TEMPERATURE RANGE</b>								
Specified Performance		-40		+85	*		*	$^{\circ}\text{C}$
Derated Performance		-55		+125	*		*	$^{\circ}\text{C}$
Storage		-65		+150	*		*	$^{\circ}\text{C}$
Thermal Resistance ( $\theta_{\text{JA}}$ )								
Plastic DIP			75			*		$^{\circ}\text{C}/\text{W}$
SO			75			*		$^{\circ}\text{C}/\text{W}$

NOTES: (1) LSB means Least Significant Bit. For the 12-bit,  $\pm 10\text{V}$  input ADS7804, one LSB is 4.88mV. (2) Typical rms noise at worst case transitions and temperatures. (3) As measured with fixed resistors shown in Figure 4. Adjustable to zero with external potentiometer. (4) Full scale error is the worst case of -Full Scale or +Full Scale untrimmed deviation from ideal first and last code transitions, divided by the transition voltage (not divided by the full-scale range) and includes the effect of offset error. (5) All specifications in dB are referred to a full-scale  $\pm 10\text{V}$  input. (6) Full-Power Bandwidth defined as Full-Scale input frequency at which Signal-to-(Noise + Distortion) degrades to 60dB, or 10 bits of accuracy. (7) Recovers to specified performance after 2 x FS input overvoltage.

## PIN CONFIGURATION



PIN #	NAME	DIGITAL I/O	DESCRIPTION
1	$V_{IN}$		Analog Input. See Figure 7.
2	AGND1		Analog Ground. Used internally as ground reference point.
3	REF		Reference Input/Output. 2.2 $\mu$ F tantalum capacitor to ground.
4	CAP		Reference Buffer Capacitor. 2.2 $\mu$ F tantalum capacitor to ground.
5	AGND2		Analog Ground.
6	D11 (MSB)	O	Data Bit 11. Most Significant Bit (MSB) of conversion results. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
7	D10	O	Data Bit 10. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
8	D9	O	Data Bit 9. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
9	D8	O	Data Bit 8. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
10	D7	O	Data Bit 7. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
11	D6	O	Data Bit 6. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
12	D5	O	Data Bit 5. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
13	D4	O	Data Bit 4. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
14	DGND		Digital Ground.
15	D3	O	Data Bit 3. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
16	D2	O	Data Bit 2. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
17	D1	O	Data Bit 1. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
18	D0 (LSB)	O	Data Bit 0. Least Significant Bit (LSB) of conversion results. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
19	DZ	O	LOW when $\overline{CS}$ LOW, $R/\overline{C}$ HIGH. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
20	DZ	O	LOW when $\overline{CS}$ LOW, $R/\overline{C}$ HIGH. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
21	DZ	O	LOW when $\overline{CS}$ LOW, $R/\overline{C}$ HIGH. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
22	DZ	O	LOW when $\overline{CS}$ LOW, $R/\overline{C}$ HIGH. Hi-Z state when $\overline{CS}$ is HIGH, or when $R/\overline{C}$ is LOW.
23	BYTE	I	Selects 8 most significant bits (LOW) or 8 least significant bits (HIGH).
24	$R/\overline{C}$	I	With $\overline{CS}$ LOW and $\overline{BUSY}$ HIGH, a Falling Edge on $R/\overline{C}$ Initiates a New Conversion. With $\overline{CS}$ LOW, a rising edge on $R/\overline{C}$ enables the parallel output.
25	$\overline{CS}$	I	Internally OR'd with $R/\overline{C}$ . If $R/\overline{C}$ LOW, a falling edge on $\overline{CS}$ initiates a new conversion.
26	$\overline{BUSY}$	O	At the start of a conversion, $\overline{BUSY}$ goes LOW and stays LOW until the conversion is completed and the digital outputs have been updated.
27	$V_{ANA}$		Analog Supply Input. Nominally +5V. Decouple to ground with 0.1 $\mu$ F ceramic and 10 $\mu$ F tantalum capacitors.
28	$V_{DIG}$		Digital Supply Input. Nominally +5V. Connect directly to pin 27. Must be $\leq V_{ANA}$ .

TABLE I. Pin Assignments.

## BASIC OPERATION

Figure 1 shows a basic circuit to operate the ADS7804 with a full parallel data output. Taking  $\overline{R/C}$  (pin 24) LOW for a minimum of 40ns (6 $\mu$ s max) will initiate a conversion.  $\overline{BUSY}$  (pin 26) will go LOW and stay LOW until the conversion is completed and the output registers are updated. Data will be output in Binary Two's Complement with the MSB on pin 6.  $\overline{BUSY}$  going HIGH can be used to latch the data. All convert commands will be ignored while  $\overline{BUSY}$  is LOW.

The ADS7804 will begin tracking the input signal at the end of the conversion. Allowing 10 $\mu$ s between convert commands assures accurate acquisition of a new signal.

The offset and gain are adjusted internally to allow external trimming with a single supply. The external resistors compensate for this adjustment and can be left out if the offset and gain will be corrected in software (refer to the Calibration section).

## STARTING A CONVERSION

The combination of  $\overline{CS}$  (pin 25) and  $\overline{R/C}$  (pin 24) LOW for a minimum of 40ns immediately puts the sample/hold of the ADS7804 in the hold state and starts conversion 'n'.  $\overline{BUSY}$  (pin 26) will go LOW and stay LOW until conversion 'n' is completed and the internal output register has been updated. All new convert commands during  $\overline{BUSY}$  LOW will be ignored.  $\overline{CS}$  and/or  $\overline{R/C}$  must go HIGH before  $\overline{BUSY}$  goes HIGH or a new conversion will be initiated without sufficient time to acquire a new signal.

The ADS7804 will begin tracking the input signal at the end of the conversion. Allowing 10 $\mu$ s between convert commands assures accurate acquisition of a new signal. Refer to Table II for a summary of  $\overline{CS}$ ,  $\overline{R/C}$ , and  $\overline{BUSY}$  states and Figures 3 through 5 for timing diagrams.

$\overline{CS}$	$\overline{R/C}$	$\overline{BUSY}$	OPERATION
1	X	X	None. Databus is in Hi-Z state.
↓	0	1	Initiates conversion 'n'. Databus remains in Hi-Z state.
0	↓	1	Initiates conversion 'n'. Databus enters Hi-Z state.
0	1	↑	Conversion 'n' completed. Valid data from conversion 'n' on the databus.
↓	1	1	Enables databus with valid data from conversion 'n'.
↓	1	0	Enables databus with valid data from conversion 'n-1'( <sup>1</sup> ). Conversion n in process.
0	↑	0	Enables databus with valid data from conversion 'n-1'( <sup>1</sup> ). Conversion 'n' in process.
0	0	↑	New conversion initiated without acquisition of a new signal. Data will be invalid. $\overline{CS}$ and/or $\overline{R/C}$ must be HIGH when $\overline{BUSY}$ goes HIGH.
X	X	0	New convert commands ignored. Conversion 'n' in process.

NOTE: (1) See Figures 2 and 3 for constraints on data valid from conversion "n-1".

Table II. Control Line Functions for Read and Convert.

$\overline{CS}$  and  $\overline{R/C}$  are internally OR'd and level triggered. There is not a requirement which input goes LOW first when initiating a conversion. If, however, it is critical that  $\overline{CS}$  or  $\overline{R/C}$  initiates conversion 'n', be sure the less critical input is LOW at least 10ns prior to the initiating input.

To reduce the number of control pins,  $\overline{CS}$  can be tied LOW using  $\overline{R/C}$  to control the read and convert modes. This will have no effect when using the internal data clock in the serial output mode. However, the parallel output will become active whenever  $\overline{R/C}$  goes HIGH. Refer to the Reading Data section.

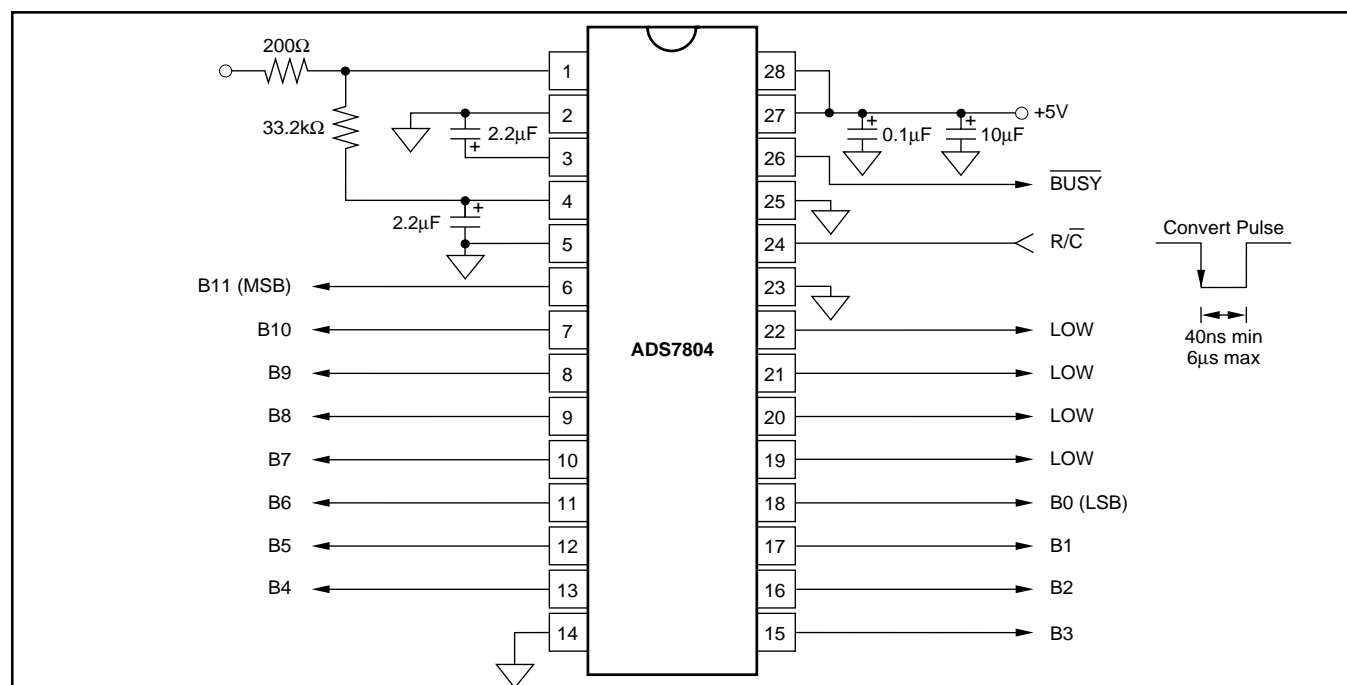


FIGURE 1. Basic Operation.

## READING DATA

The ADS7804 outputs full or byte-reading parallel data in Binary Two's Complement data output format. The parallel output will be active when  $\overline{R/\overline{C}}$  (pin 24) is HIGH and  $\overline{CS}$  (pin 25) is LOW. Any other combination of  $\overline{CS}$  and  $\overline{R/\overline{C}}$  will tri-state the parallel output. Valid conversion data can be read in a full parallel, 12-bit word or two 8-bit bytes on pins 6-13 and pins 15-22. BYTE (pin 23) can be toggled to read both bytes within one conversion cycle. Refer to Table III for ideal output codes and Figure 2 for bit locations relative to the state of BYTE.

DESCRIPTION	ANALOG INPUT	DIGITAL OUTPUT BINARY TWO'S COMPLEMENT	
		BINARY CODE	HEX CODE
Full Scale Range	$\pm 10V$		
Least Significant Bit (LSB)	4.88mV		
+Full Scale (10V – 1LSB)	9.99512V	0111 1111 1111	7FF
Midscale	0V	0000 0000 0000	000
One LSB below Midscale	-4.88mV	1111 1111 1111	FFF
-Full Scale	-10V	1000 0000 0000	800

Table III. Ideal Input Voltages and Output Codes.

## PARALLEL OUTPUT (After a Conversion)

After conversion 'n' is completed and the output registers have been updated,  $\overline{BUSY}$  (pin 26) will go HIGH. Valid data from conversion 'n' will be available on D11-D0 (pin 6-13 and 15-18 when BYTE is LOW).  $\overline{BUSY}$  going HIGH can be used to latch the data. Refer to Table IV and Figures 3 and 5 for timing specifications.

## PARALLEL OUTPUT (During a Conversion)

After conversion 'n' has been initiated, valid data from conversion 'n-1' can be read and will be valid up to 16 $\mu$ s after the start of conversion 'n'. Do not attempt to read data from 16 $\mu$ s after the start of conversion 'n' until  $\overline{BUSY}$  (pin 26) goes HIGH; this may result in reading invalid data. Refer to Table IV and Figures 3 and 5 for timing specifications.

**Note!** For the best possible performance, data should not be read during a conversion. The switching noise of the asynchronous data transfer can cause digital feedthrough degrading the converter's performance.

The number of control lines can be reduced by tying  $\overline{CS}$  LOW while using  $\overline{R/\overline{C}}$  to initiate conversions and activate the output mode of the converter. See Figure 3.

SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNITS
$t_1$	Convert Pulse Width	40		6000	ns
$t_2$	Data Valid Delay after $\overline{R/\overline{C}}$ LOW		8		$\mu$ s
$t_3$	$\overline{BUSY}$ Delay from $\overline{R/\overline{C}}$ LOW		65		ns
$t_4$	$\overline{BUSY}$ LOW		8		$\mu$ s
$t_5$	$\overline{BUSY}$ Delay after End of Conversion		220		ns
$t_6$	Aperture Delay		40		ns
$t_7$	Conversion Time		7.6	8	$\mu$ s
$t_8$	Acquisition Time			2	$\mu$ s
$t_9$	Bus Relinquish Time	10	35	83	ns
$t_{10}$	$\overline{BUSY}$ Delay after Data Valid	50	200		ns
$t_{11}$	Previous Data Valid after $\overline{R/\overline{C}}$ LOW		7.4		$\mu$ s
$t_7 + t_6$	Throughput Time		9	10	$\mu$ s
$t_{12}$	$\overline{R/\overline{C}}$ to $\overline{CS}$ Setup Time	10			ns
$t_{13}$	Time Between Conversions	10			$\mu$ s
$t_{14}$	Bus Access Time and BYTE Delay	10		83	ns

TABLE IV. Conversion Timing.

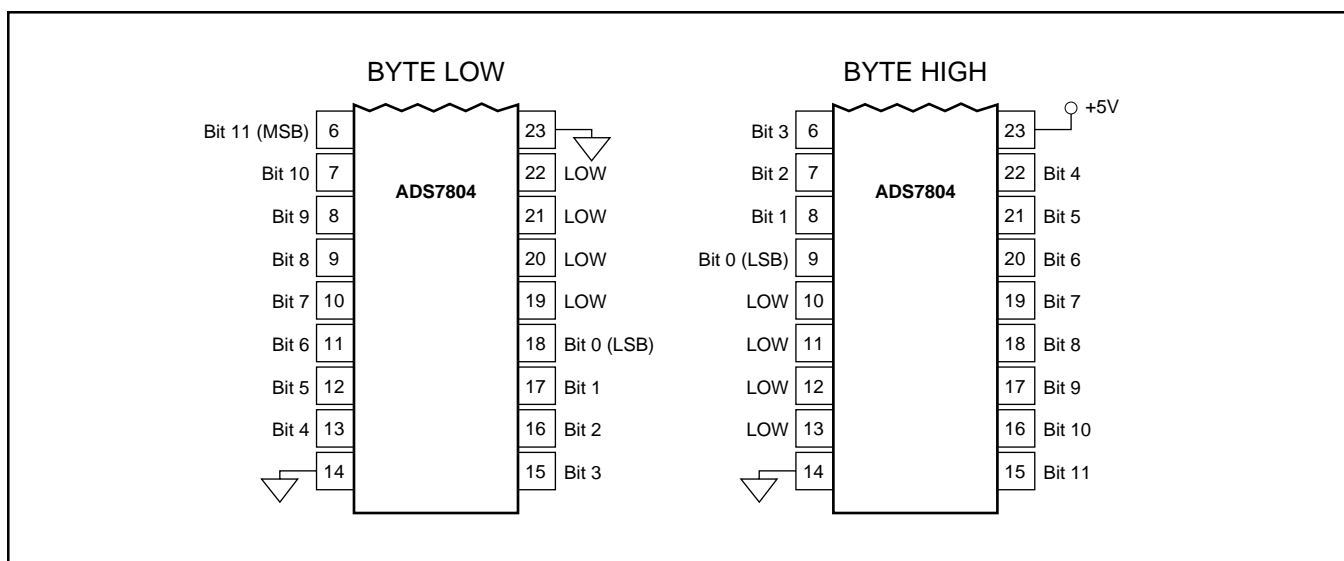


FIGURE 2. Bit Locations Relative to State of BYTE (pin 23).

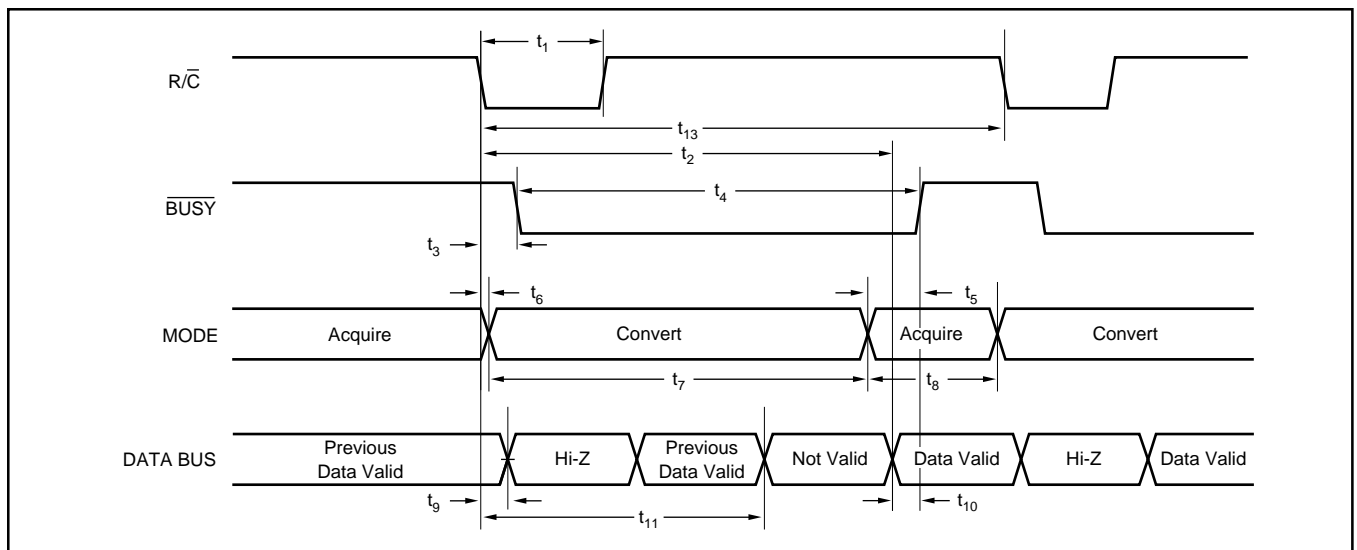


FIGURE 3. Conversion Timing with Outputs Enabled after Conversion ( $\overline{CS}$  Tied LOW.)

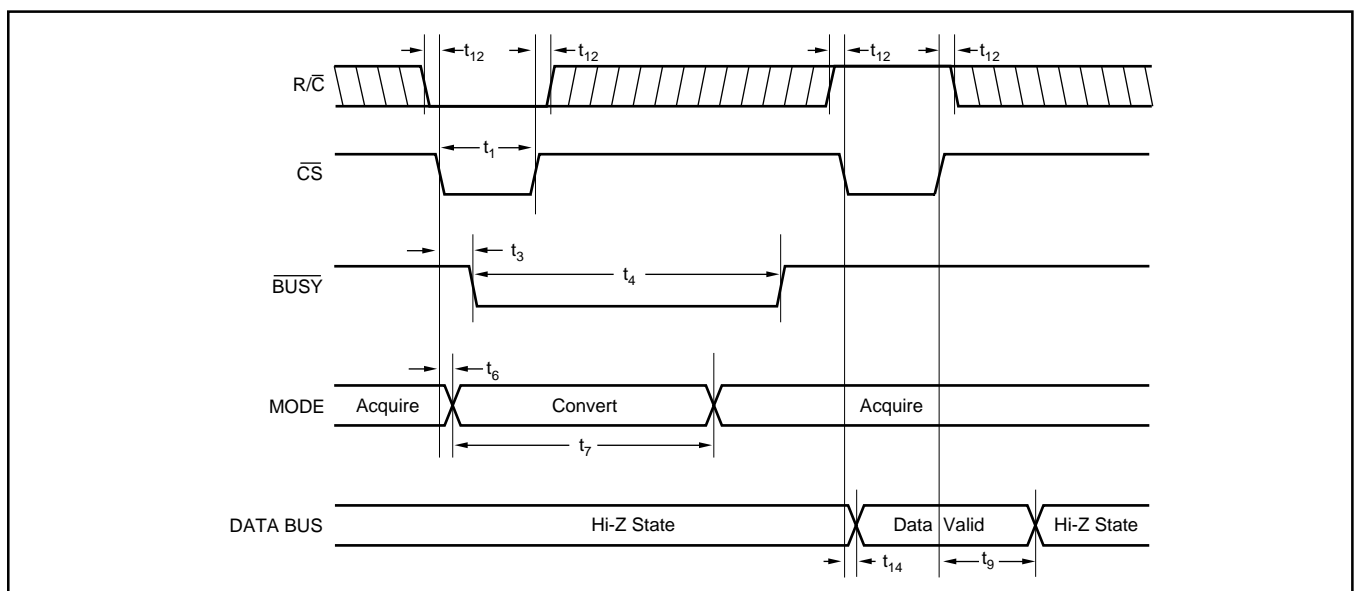


FIGURE 4. Using  $\overline{CS}$  to Control Conversion and Read Timing.

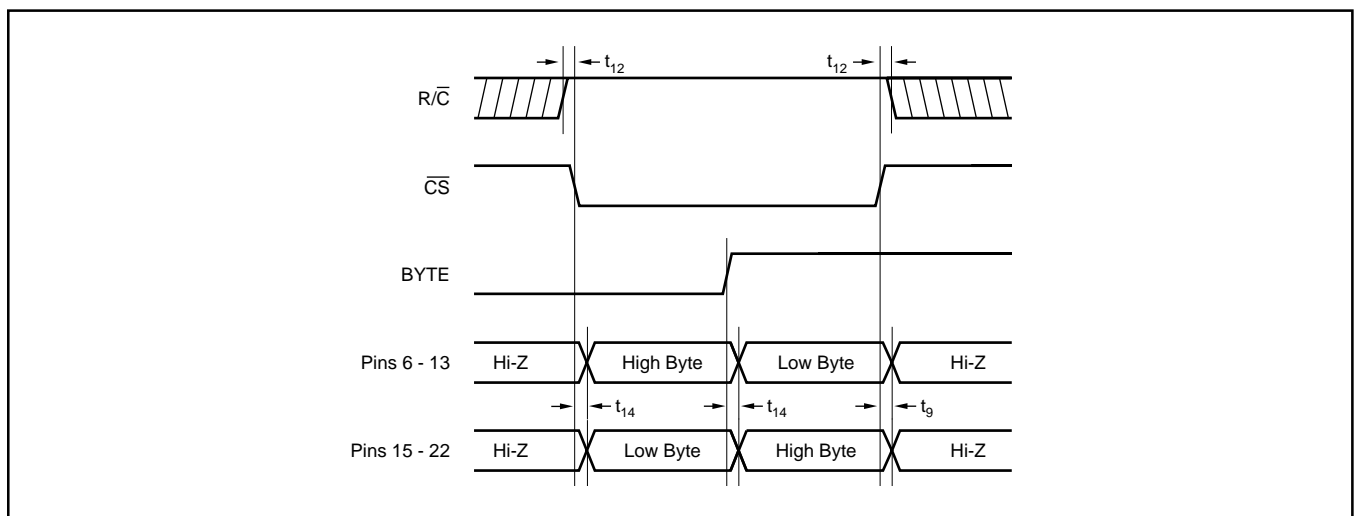


FIGURE 5. Using  $\overline{CS}$  and  $\overline{BYTE}$  to Control Data Bus.

## INPUT RANGES

The ADS7804 offers a standard  $\pm 10\text{V}$  input range. Figure 6 shows the necessary circuit connections for the ADS7804 with and without hardware trim. Offset and full scale error<sup>(1)</sup> specifications are tested and guaranteed with the fixed resistors shown in Figure 6b. Adjustments for offset and gain are described in the Calibration section of this data sheet.

The offset and gain are adjusted internally to allow external trimming with a single supply. The external resistors compensate for this adjustment and can be left out if the offset and gain will be corrected in software (refer to the Calibration section).

The nominal input impedance of  $23\text{k}\Omega$  results from the combination of the internal resistor network shown on the front page of the product data sheet and the external resistors. The input resistor divider network provides inherent overvoltage protection guaranteed to at least  $\pm 25\text{V}$ . The 1% resistors used for the external circuitry do not compromise the accuracy or drift of the converter. They have little influence relative to the internal resistors, and tighter tolerances are not required.

NOTE: (1) Full scale error includes offset and gain errors measured at both +FS and -FS.

## CALIBRATION

The ADS7804 can be trimmed in hardware or software. The offset should be trimmed before the gain since the offset directly affects the gain. To achieve optimum performance, several iterations may be required.

## HARDWARE CALIBRATION

To calibrate the offset and gain of the ADS7804, install the proper resistors and potentiometers as shown in Figure 6a. The calibration range is  $\pm 15\text{mV}$  for the offset and  $\pm 60\text{mV}$  for the gain.

## SOFTWARE CALIBRATION

To calibrate the offset and gain of the ADS7804 in software, no external resistors are required. See the No Calibration section for details on the effects of the external resistors. Refer to Table V for range of offset and gain errors with and without external resistors.

## NO CALIBRATION

See Figure 6b for circuit connections. The external resistors shown in Figure 6b may not be necessary in some applications. These resistors provide compensation for an internal adjustment of the offset and gain which allows calibration with a single supply. The nominal transfer function of the ADS7804 will be bound by the shaded region seen in Figure 7 with a typical offset of  $-30\text{mV}$  and a typical gain error of  $-1.5\%$ . Refer to Table V for range of offset and gain errors with and without external resistors.

	WITH EXTERNAL RESISTORS	WITHOUT EXTERNAL RESISTORS	UNITS
BPZ	$-10 < \text{BPZ} < 10$ $-2 < \text{BPZ} < 2$	$-45 < \text{BPZ} < 5$ $-8 < \text{BPZ} < 1$	mV LSBs
Gain Error	$-0.5 < \text{error} < 0.5$ $-0.25 < \text{error} < 0.25^{(1)}$	$-0.6 < \text{error} < -0.55$ $-0.45 < \text{error} < -0.3^{(1)}$	% of FSR

NOTE: (1) High Grade.

TABLE VII. Bipolar Offset and Gain Errors With and Without External Resistors.

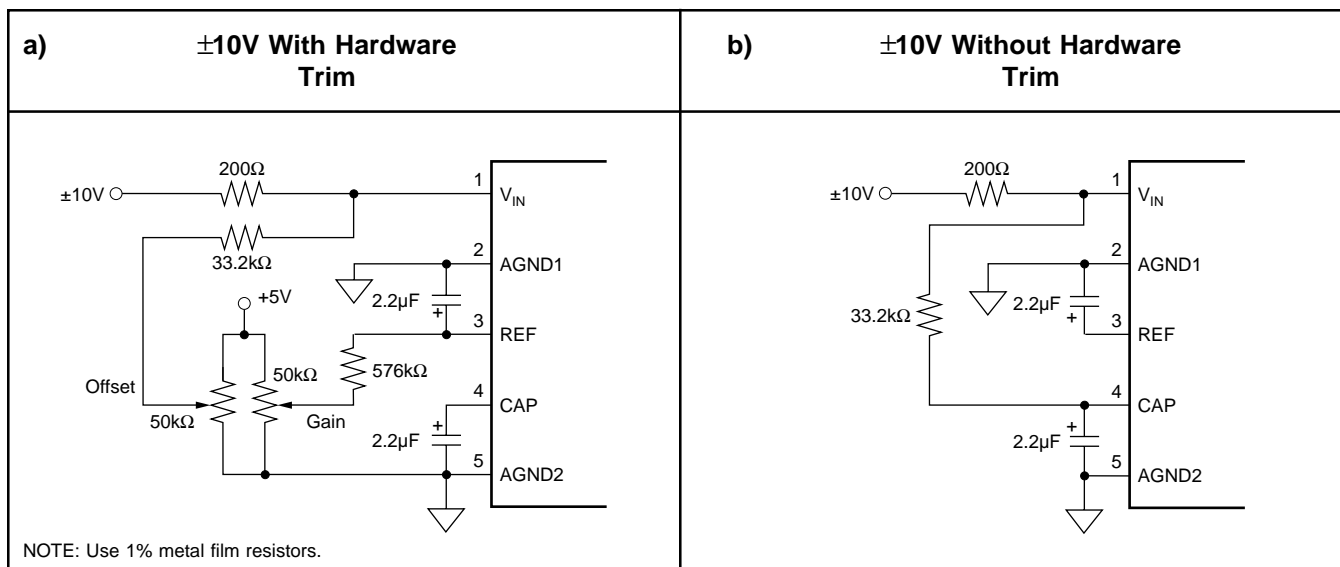


FIGURE 6. Circuit Diagram With and Without External Resistors.



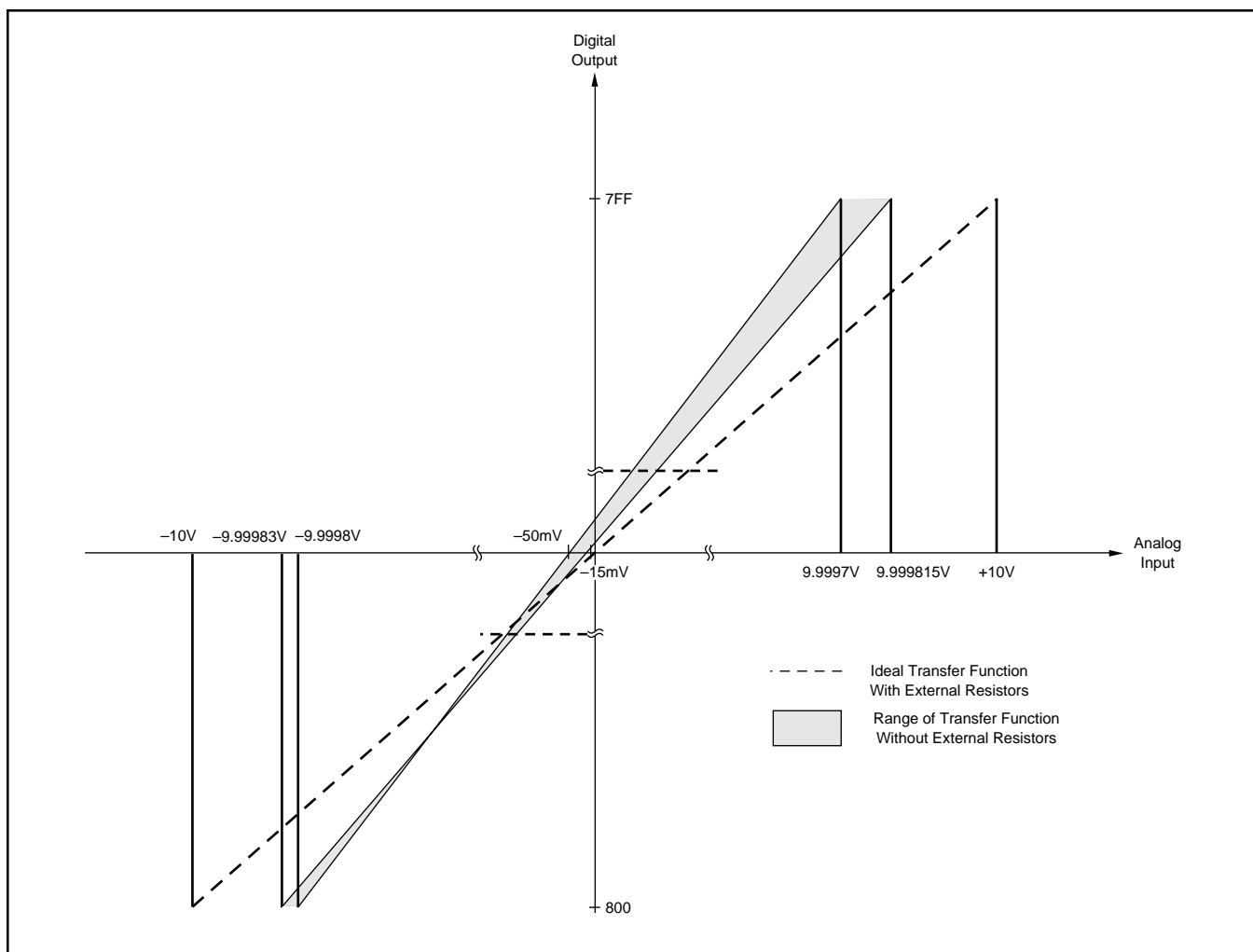


FIGURE 7. Full Scale Transfer Function.

## REFERENCE

The ADS7804 can operate with its internal 2.5V reference or an external reference. By applying an external reference to pin 5, the internal reference can be bypassed. The reference voltage at REF is buffered internally with the output on CAP (pin 4).

The internal reference has an 8 ppm/°C drift (typical) and accounts for approximately 20% of the full scale error (FSE =  $\pm 0.5\%$  for low grade,  $\pm 0.25\%$  for high grade).

### REF

REF (pin 3) is an input for an external reference or the output for the internal 2.5V reference. A 2.2 $\mu$ F capacitor should be connected as close to the REF pin as possible. The capacitor and the output resistance of REF create a low pass filter to bandlimit noise on the reference. Using a smaller value capacitor will introduce more noise to the reference degrading the SNR and SINAD. The REF pin should not be used to drive external AC or DC loads.

The range for the external reference is 2.3V to 2.7V and determines the actual LSB size. Increasing the reference voltage will increase the full scale range and the LSB size of the converter which can improve the SNR.

### CAP

CAP (pin 4) is the output of the internal reference buffer. A 2.2 $\mu$ F capacitor should be placed as close to the CAP pin as possible to provide optimum switching currents for the CDAC throughout the conversion cycle and compensation for the output of the internal buffer. Using a capacitor any smaller than 1 $\mu$ F can cause the output buffer to oscillate and may not have sufficient charge for the CDAC. Capacitor values larger than 2.2 $\mu$ F will have little affect on improving performance.

The output of the buffer is capable of driving up to 2mA of current to a DC load. DC loads requiring more than 2mA of current from the CAP pin will begin to degrade the linearity of the ADS7804. Using an external buffer will allow the internal reference to be used for larger DC loads and AC loads. Do not attempt to directly drive an AC load with the output voltage on CAP. This will cause performance degradation of the converter.

# LAYOUT

## POWER

For optimum performance, tie the analog and digital power pins to the same +5V power supply and tie the analog and digital grounds together. As noted in the electrical specifications, the ADS7804 uses 90% of its power for the analog circuitry. The ADS7804 should be considered as an analog component.

The +5V power for the A/D should be separate from the +5V used for the system's digital logic. Connecting  $V_{DIG}$  (pin 28) directly to a digital supply can reduce converter performance due to switching noise from the digital logic. For best performance, the +5V supply can be produced from whatever analog supply is used for the rest of the analog signal conditioning. If +12V or +15V supplies are present, a simple +5V regulator can be used. Although it is not suggested, if the digital supply must be used to power the converter, be sure to properly filter the supply. Either using a filtered digital supply or a regulated analog supply, both  $V_{DIG}$  and  $V_{ANA}$  should be tied to the same +5V source.

## GROUNDING

Three ground pins are present on the ADS7804. DGND is the digital supply ground. AGND2 is the analog supply ground. AGND1 is the ground which all analog signals internal to the A/D are referenced. AGND1 is more susceptible to current induced voltage drops and must have the path of least resistance back to the power supply.

All the ground pins of the A/D should be tied to the analog ground plane, separated from the system's digital logic ground, to achieve optimum performance. Both analog and digital ground planes should be tied to the "system" ground as near to the power supplies as possible. This helps to prevent dynamic digital ground currents from modulating the analog ground through a common impedance to power ground.

## SIGNAL CONDITIONING

The FET switches used for the sample hold on many CMOS A/D converters release a significant amount of charge injection which can cause the driving op amp to oscillate. The FET switch on the ADS7804, compared to the FET switches on other CMOS A/D converters, releases 5%-10% of the charge. There is also a resistive front end which attenuates any charge which is released. The end result is a minimal requirement for the anti-alias filter on the front end. Any op amp sufficient for the signal in an application will be sufficient to drive the ADS7804.

The resistive front end of the ADS7804 also provides a guaranteed  $\pm 25V$  overvoltage protection. In most cases, this eliminates the need for external input protection circuitry.

## INTERMEDIATE LATCHES

The ADS7804 does have tri-state outputs for the parallel port, but intermediate latches should be used if the bus will be active during conversions. If the bus is not active during conversion, the tri-state outputs can be used to isolate the A/D from other peripherals on the same bus. Tri-state outputs can also be used when the A/D is the only peripheral on the data bus.

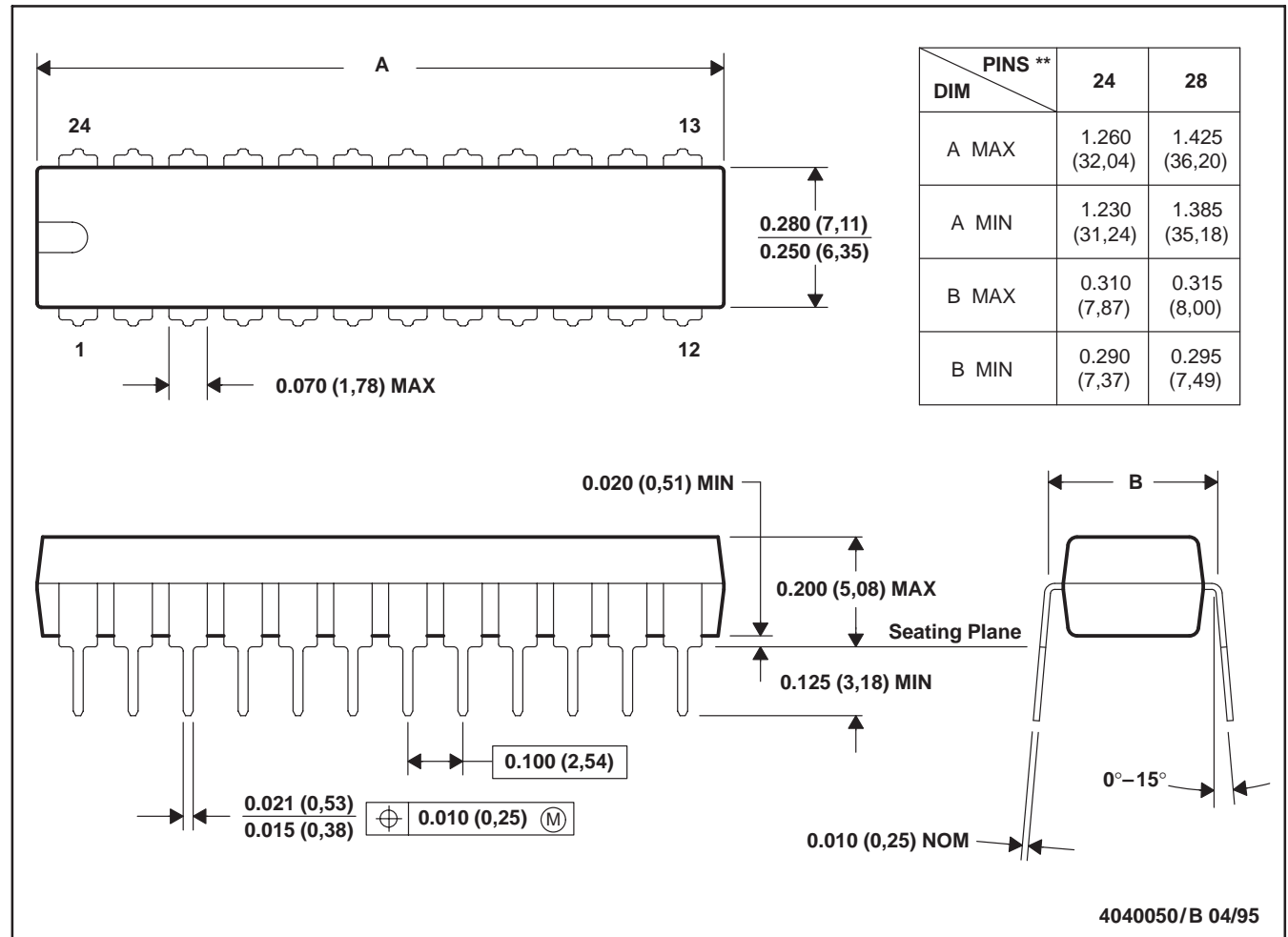
Intermediate latches are beneficial on any monolithic A/D converter. The ADS7804 has an internal LSB size of  $610\mu V$ . Transients from fast switching signals on the parallel port, even when the A/D is tri-stated, can be coupled through the substrate to the analog circuitry causing degradation of converter performance. The effects of this phenomenon will be more obvious when using the pin-compatible ADS7805 or any of the other 16-bit converters in the ADS Family. This is due to the smaller internal LSB size of  $38\mu V$ .

# PACKAGE DRAWINGS

NT (R-PDIP-T\*\*)

PLASTIC DUAL-IN-LINE PACKAGE

24 PINS SHOWN

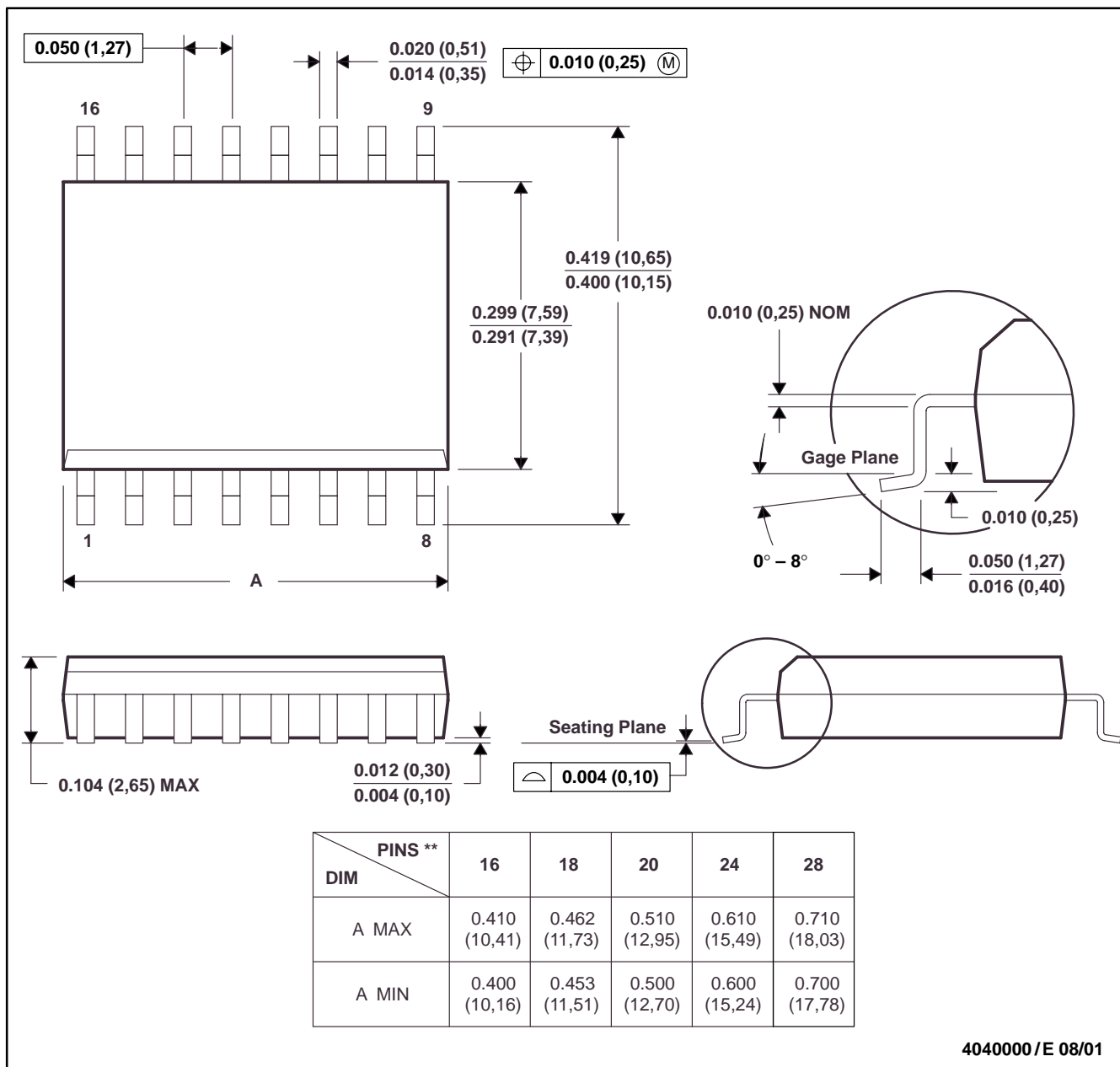


- NOTES: A. All linear dimensions are in inches (millimeters).  
B. This drawing is subject to change without notice.

DW (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

16 PINS SHOWN



- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).  
 D. Falls within JEDEC MS-013

## PACKAGING INFORMATION

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
ADS7804P	ACTIVE	PDIP	NT	28	13	TBD	CU NIPDAU	N / A for Pkg Type
ADS7804PB	ACTIVE	PDIP	NT	28	13	TBD	CU NIPDAU	N / A for Pkg Type
ADS7804U	ACTIVE	SOIC	DW	28	28	Pb-Free (RoHS)	CU NIPDAU	Level-3-260C-168 HR
ADS7804U/1K	ACTIVE	SOIC	DW	28	1000	Pb-Free (RoHS)	CU NIPDAU	Level-3-260C-168 HR
ADS7804U/1KE4	ACTIVE	SOIC	DW	28	1000	Pb-Free (RoHS)	CU NIPDAU	Level-3-260C-168 HR
ADS7804UB	ACTIVE	SOIC	DW	28	28	Pb-Free (RoHS)	CU NIPDAU	Level-3-260C-168 HR
ADS7804UB/1K	ACTIVE	SOIC	DW	28	1000	Pb-Free (RoHS)	CU NIPDAU	Level-3-260C-168 HR
ADS7804UB/1KE4	ACTIVE	SOIC	DW	28	1000	Pb-Free (RoHS)	CU NIPDAU	Level-3-260C-168 HR
ADS7804UBE4	ACTIVE	SOIC	DW	28	28	Pb-Free (RoHS)	CU NIPDAU	Level-3-260C-168 HR
ADS7804UE4	ACTIVE	SOIC	DW	28	28	Pb-Free (RoHS)	CU NIPDAU	Level-3-260C-168 HR

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

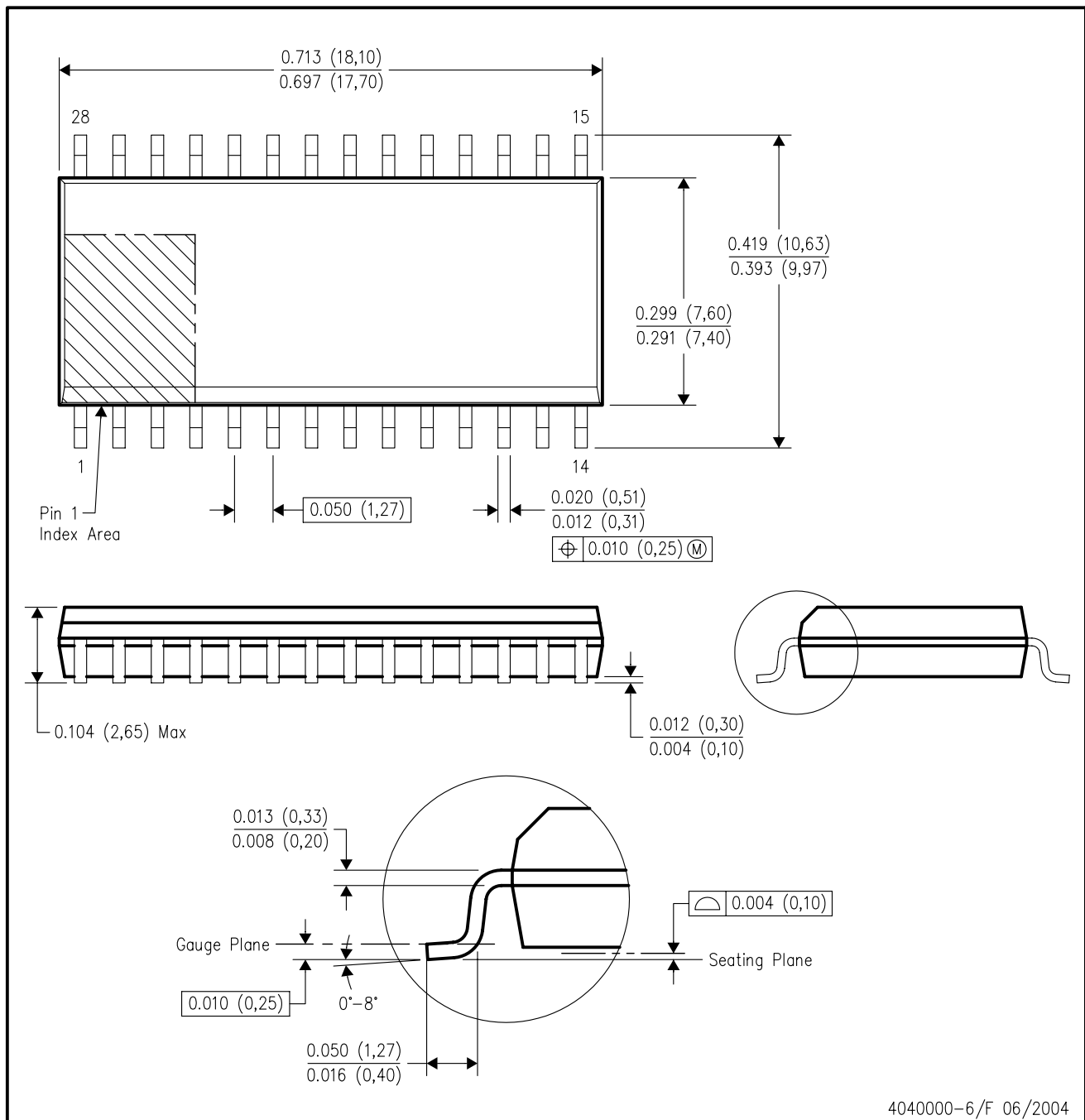
<sup>(3)</sup> MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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DW (R-PDSO-G28)

# PLASTIC SMALL-OUTLINE PACKAGE



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Mailing Address: Texas Instruments  
Post Office Box 655303 Dallas, Texas 75265

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