

16-BIT, 2 MSPS, UNIPOLAR DIFFERENTIAL INPUT, MICROPOWER SAMPLING ANALOG-TO-DIGITAL CONVERTER WITH PARALLEL INTERFACE AND REFERENCE

FEATURES

- 2-MHz Sample Rate
- 16-Bit NMC Ensured Over Temperature
- Zero Latency
- Unipolar Differential Input Range: V_{ref} to $-V_{ref}$
- Onboard Reference
- Onboard Reference Buffer
- High-Speed Parallel Interface
- Power Dissipation: 175 mW at 2 MHz Typ
- Wide Digital Supply
- 8-/16-Bit Bus Transfer
- 48-Pin TQFP Package
- ESD Sensitive - HBM Capability of 500 V, 1000 V at All Input Pins

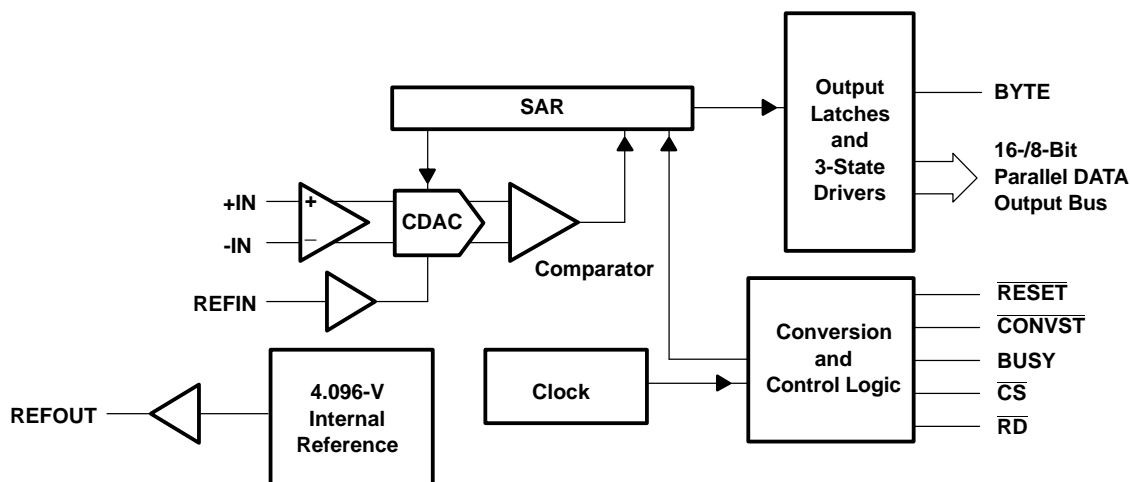
APPLICATIONS

- DWDM
- Instrumentation
- High-Speed, High-Resolution, Zero Latency Data Acquisition Systems
- Transducer Interface
- Medical Instruments
- Communication

DESCRIPTION

The ADS8412 is a 16-bit, 2 MHz A/D converter with an internal 4.096-V reference. The device includes a 16-bit capacitor-based SAR A/D converter with inherent sample and hold. The ADS8412 offers a full 16-bit interface and an 8-bit option where data is read using two 8-bit read cycles.

The ADS8412 has a unipolar differential input. It is available in a 48-lead TQFP package and is characterized over the industrial -40°C to 85°C temperature 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.



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ORDERING INFORMATION⁽¹⁾

| MODEL | MAXIMUM INTEGRAL LINEARITY (LSB) | MAXIMUM DIFFERENTIAL LINEARITY (LSB) | NO MISSING CODES RESOLUTION (BIT) | PACKAGE TYPE | PACKAGE DESIGNATOR | TEMPERATURE RANGE | ORDERING INFORMATION | TRANSPORT MEDIA QUANTITY |
|-----------|----------------------------------|--------------------------------------|-----------------------------------|--------------|--------------------|-------------------|----------------------|--------------------------|
| ADS8412I | -6 ~ 6 | -2~+3 | 15 | 48 Pin TQFP | PFB | -40°C to 85°C | ADS8412IPFBT | Tape and reel 250 |
| | | | | | | | ADS8412IPFBR | Tape and reel 1000 |
| ADS8412IB | -2.5 ~ 2.5 | -1~+2 | 16 | 48 Pin TQFP | PFB | -40°C to 85°C | ADS8412IBPFBT | Tape and reel 250 |
| | | | | | | | ADS8412IBPFBR | Tape and reel 1000 |

(1) For the most current specifications and package information, refer to our website at www.ti.com.

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted⁽¹⁾

| | | UNIT |
|--|-----------------------------------|--|
| Voltage | +IN to AGND | -0.4 V to +VA + 0.1 V |
| | -IN to AGND | -0.4 V to +VA + 0.1 V |
| Voltage range | +VA to AGND | -0.3 V to 7 V |
| | +VBD to BDGND | -0.3 V to 7 V |
| | +VA to +VBD | -0.3 V to 2.55 V |
| Digital input voltage to BDGND | | -0.3 V to +VBD + 0.3 V |
| Digital output voltage to BDGND | | -0.3 V to +VBD + 0.3 V |
| Operating free-air temperature range, T _A | | -40°C to 85°C |
| Storage temperature range, T _{stg} | | -65°C to 150°C |
| Junction temperature (T _J max) | | 150°C |
| TQFP package | Power dissipation | (T _J Max - T _A)/θ _{JA} |
| | θ _{JA} thermal impedance | 86°C/W |
| Lead temperature, soldering | Vapor phase (60 sec) | 215°C |
| | Infrared (15 sec) | 220°C |

(1) Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

SPECIFICATIONS
 $T_A = -40^{\circ}\text{C}$ to 85°C , $+V_A = 5\text{ V}$, $+V_{BD} = 3\text{ V}$ or 5 V , $V_{\text{ref}} = 4.096\text{ V}$, $f_{\text{SAMPLE}} = 2\text{ MHz}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|--|--|----------------------------|--------------------|----------------------------|--------|
| ANALOG INPUT | | | | | | |
| Full-scale input voltage ⁽¹⁾ | | +IN – (–IN) | $-V_{\text{ref}}$ | | V_{ref} | V |
| Absolute input voltage | | +IN | –0.2 | | $V_{\text{ref}} + 0.2$ | V |
| | | –IN | –0.2 | | $V_{\text{ref}} + 0.2$ | |
| Common-mode input range | ADS8412I | | $(V_{\text{ref}}/2) - 0.2$ | $V_{\text{ref}}/2$ | $(V_{\text{ref}}/2) + 0.2$ | V |
| Input capacitance | | | | 25 | | pF |
| Input leakage current | | | | 0.5 | | nA |
| SYSTEM PERFORMANCE | | | | | | |
| Resolution | | | | 16 | | Bits |
| No missing codes | | ADS8412I | 15 | | | Bits |
| | | ADS8412IB | 16 | | | |
| INL | Integral linearity ⁽²⁾⁽³⁾ | ADS8412I | –6 | ±4 | 6 | LSB |
| | | ADS8412IB | –2.5 | ±1.5 | 2.5 | |
| DNL | Differential linearity | ADS8412I | –2 | ±1 | 3 | LSB |
| | | ADS8412IB | –1 | ±0.8 | 2 | |
| E _O | Offset error ⁽⁴⁾ | ADS8412I | –3 | ±1 | 3 | mV |
| | | ADS8412IB | –1.5 | ±0.5 | 1.5 | |
| E _G | Gain error ⁽⁴⁾⁽⁵⁾ | ADS8412I | –0.15 | | 0.15 | %FS |
| | | ADS8412IB | –0.098 | | 0.098 | |
| CMRR | Common-mode rejection ratio | At dc ($\pm 0.2\text{ V}$ around $V_{\text{ref}}/2$) | | 80 | | dB |
| | | +IN – (–IN) = 1 V _{pp} at 1 MHz | | 80 | | |
| Noise | | | | 60 | | μV RMS |
| PSRR | DC Power supply rejection ratio | At 7FFFh output code, $+V_A = 4.75\text{ V}$ to 5.25 V , $V_{\text{ref}} = 4.096\text{ V}$ ⁽⁴⁾ | | 1 | | LSB |
| SAMPLING DYNAMICS | | | | | | |
| Conversion time | | | 340 | | 400 | ns |
| Acquisition time | | | 100 | | | ns |
| Throughput rate | | | | | 2 | MHz |
| Aperture delay | | | | 2 | | ns |
| Aperture jitter | | | | 25 | | ps |
| Step response | | | | 100 | | ns |
| Overvoltage recovery | | | | 100 | | ns |
| DYNAMIC CHARACTERISTICS | | | | | | |
| THD | Total harmonic distortion ⁽⁶⁾ | $V_{\text{IN}} = 8\text{ V}_{\text{pp}}$ at 100 kHz | | –95 | | dB |
| | | $V_{\text{IN}} = 8\text{ V}_{\text{pp}}$ at 500 kHz | | –90 | | |
| SNR | Signal-to-noise ratio | $V_{\text{IN}} = 8\text{ V}_{\text{pp}}$ at 100 kHz | | 90 | | dB |
| SINAD | Signal-to-noise + distortion | $V_{\text{IN}} = 8\text{ V}_{\text{pp}}$ at 100 kHz | | 88 | | |
| SFDR | Spurious free dynamic range | $V_{\text{IN}} = 8\text{ V}_{\text{pp}}$ at 100 kHz | | 95 | | dB |
| | | $V_{\text{IN}} = 8\text{ V}_{\text{pp}}$ at 500 kHz | | 93 | | |
| –3 dB Small signal bandwidth | | | | 5 | | MHz |

(1) Ideal input span, does not include gain or offset error.

(2) LSB means least significant bit

(3) This is endpoint INL, not best fit

(4) Measured relative to an ideal full-scale input [+IN – (–IN)] of 8.192 V

(5) This specification does not include the internal reference voltage error and drift.

(6) Calculated on the first nine harmonics of the input frequency

SPECIFICATIONS (continued)

$T_A = -40^{\circ}\text{C}$ to 85°C , $+VA = 5\text{ V}$, $+VBD = 3\text{ V}$ or 5 V , $V_{\text{ref}} = 4.096\text{ V}$, $f_{\text{SAMPLE}} = 2\text{ MHz}$ (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|------------|-------|------------|-------------------------|
| EXTERNAL VOLTAGE REFERENCE INPUT | | | | | |
| V_{ref} Reference voltage at REFIN | | 3.9 | 4.096 | 4.2 | V |
| Reference resistance ⁽⁷⁾ | | | 500 | | k Ω |
| INTERNAL REFERENCE OUTPUT | | | | | |
| Internal reference start-up time | From 95% (+VA), with 1 μF storage capacity | | | 120 | ms |
| V_{ref} Reference voltage | IOUT = 0 | 4.065 | 4.096 | 4.13 | V |
| Source current | Static load | | | 10 | μA |
| Line regulation | +VA = 4.75 ~ 5.25 V | | 0.6 | | mV |
| Drift | IOUT = 0 | | 36 | | PPM/ $^{\circ}\text{C}$ |
| DIGITAL INPUT/OUTPUT | | | | | |
| Logic family — CMOS | | | | | |
| V_{IH} High level input voltage | $I_{\text{IH}} = 5\ \mu\text{A}$ | +VBD – 1 | | +VBD + 0.3 | V |
| V_{IL} Low level input voltage | $I_{\text{IL}} = 5\ \mu\text{A}$ | –0.3 | | 0.8 | |
| V_{OH} High level output voltage | $I_{\text{OH}} = 2\ \text{TTL loads}$ | +VBD – 0.6 | | +VBD | |
| V_{OL} Low level output voltage | $I_{\text{OL}} = 2\ \text{TTL loads}$ | 0 | | 0.4 | |
| Data format – 2's complement | | | | | |
| POWER SUPPLY REQUIREMENTS | | | | | |
| Power supply voltage | +VBD | 2.7 | 3 | 5.25 | V |
| | +VA | 4.75 | 5 | 5.25 | |
| +VA Supply current ⁽⁸⁾ | $f_s = 2\ \text{MHz}$ | | 35 | 40 | mA |
| P_D Power dissipation ⁽⁸⁾ | $f_s = 2\ \text{MHz}$ | | 175 | 200 | mW |
| TEMPERATURE RANGE | | | | | |
| T_A Operating free-air | | –40 | | 85 | $^{\circ}\text{C}$ |

(7) Can vary $\pm 20\%$

(8) This includes only +VA current. +VBD current is typically 1 mA with 5-pF load capacitance on output pins.

TIMING CHARACTERISTICS

All specifications typical at -40°C to 85°C , $+VA = +VBD = 5\text{ V}^{(1)(2)(3)}$

| PARAMETER | | MIN | TYP | MAX | UNIT |
|---------------------|---|---|-----|-----|------|
| t_{CONV} | Conversion time | 340 | | 400 | ns |
| t_{ACQ} | Acquisition time | 100 | | | ns |
| t_{pd1} | $\overline{\text{CONVST}}$ low to BUSY high | | 30 | | ns |
| t_{pd2} | Propagation delay time, end of conversion to BUSY low | | 5 | | ns |
| t_{w1} | Pulse duration, $\overline{\text{CONVST}}$ low | 20 | | | ns |
| t_{su1} | Setup time, $\overline{\text{CS}}$ low to $\overline{\text{CONVST}}$ low | 0 | | | ns |
| t_{w2} | Pulse duration, $\overline{\text{CONVST}}$ high | 20 | | | ns |
| | $\overline{\text{CONVST}}$ falling edge jitter | | | 10 | ps |
| t_{w3} | Pulse duration, BUSY signal low | Min(t_{ACQ}) | | | ns |
| t_{w4} | Pulse duration, BUSY signal high | | 370 | | ns |
| t_{h1} | Hold time, first data bus data transition ($\overline{\text{RD}}$ low, or $\overline{\text{CS}}$ low for read cycle, or BYTE input changes) after $\overline{\text{CONVST}}$ low | 40 | | | ns |
| t_{d1} | Delay time, $\overline{\text{CS}}$ low to $\overline{\text{RD}}$ low (or BUSY low to $\overline{\text{RD}}$ low) | 0 | | | ns |
| t_{su2} | Setup time, $\overline{\text{RD}}$ high to $\overline{\text{CS}}$ high | 0 | | | ns |
| t_{w5} | Pulse duration, $\overline{\text{RD}}$ low | 50 | | | ns |
| t_{en} | Enable time, $\overline{\text{RD}}$ low (or $\overline{\text{CS}}$ low for read cycle) to data valid | | | 20 | ns |
| t_{d2} | Delay time, data hold from $\overline{\text{RD}}$ high | 0 | | | ns |
| t_{d3} | Delay time, BYTE rising edge or falling edge to data valid | 2 | | 20 | ns |
| t_{w6} | Pulse duration, $\overline{\text{RD}}$ high | 20 | | | ns |
| t_{w7} | Pulse duration, $\overline{\text{CS}}$ high | 20 | | | ns |
| t_{h2} | Hold time, last $\overline{\text{RD}}$ (or $\overline{\text{CS}}$ for read cycle) rising edge to $\overline{\text{CONVST}}$ falling edge | 50 | | | ns |
| t_{su3} | Setup time, BYTE transition to $\overline{\text{RD}}$ falling edge | 0 | | | ns |
| t_{h3} | Hold time, BYTE transition to $\overline{\text{RD}}$ falling edge | 0 | | | ns |
| t_{dis} | Disable time, $\overline{\text{RD}}$ high ($\overline{\text{CS}}$ high for read cycle) to 3-stated data bus | | | 20 | ns |
| t_{d5} | Delay time, end of conversion to MSB data valid | | | 10 | ns |
| t_{su4} | Byte transition setup time, from BYTE transition to the next BYTE transition | 50 | | | ns |
| t_{d6} | Delay time, $\overline{\text{CS}}$ rising edge to BUSY falling edge | 50 | | | ns |
| t_{d7} | Delay time, BUSY falling edge to $\overline{\text{CS}}$ rising edge | 50 | | | ns |
| $t_{\text{su(AB)}}$ | Setup time, from the falling edge of $\overline{\text{CONVST}}$ (used to start the valid conversion) to the next falling edge of $\overline{\text{CONVST}}$ (when $\overline{\text{CS}} = 0$ and $\overline{\text{CONVST}}$ used to abort) or to the next falling edge of $\overline{\text{CS}}$ (when $\overline{\text{CS}}$ is used to abort) | 60 | | 340 | ns |
| t_{su5} | Setup time, falling edge of $\overline{\text{CONVST}}$ to read valid data (MSB) from current conversion | MAX(t_{CONV}) + MAX(t_{d5}) | | | ns |
| t_{h4} | Hold time, data (MSB) from previous conversion hold valid from falling edge of $\overline{\text{CONVST}}$ | MIN(t_{CONV}) | | | ns |

- (1) All input signals are specified with $t_r = t_f = 5\text{ ns}$ (10% to 90% of +VBD) and timed from a voltage level of $(V_{\text{IL}} + V_{\text{IH}})/2$.
- (2) See timing diagrams.
- (3) All timings are measured with 20 pF equivalent loads on all data bits and BUSY pins.

TIMING CHARACTERISTICS

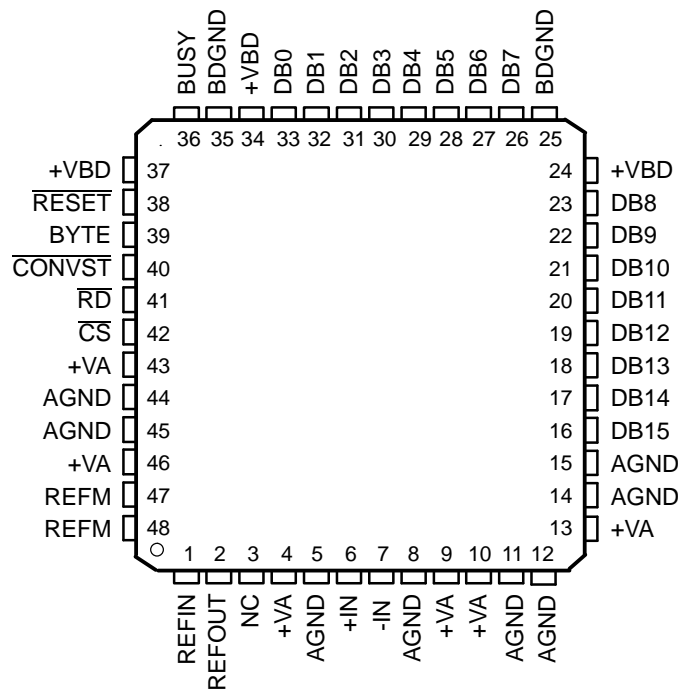
All specifications typical at -40°C to 85°C , $+V_A = 5\text{ V}$, $+V_{BD} = 3\text{ V}$ ⁽¹⁾⁽²⁾⁽³⁾

| PARAMETER | | MIN | TYP | MAX | UNIT |
|---------------------|---|---|--------------------------|-----|------|
| t_{CONV} | Conversion time | 340 | | 400 | ns |
| t_{ACQ} | Acquisition time | 100 | | | ns |
| t_{pd1} | $\overline{\text{CONVST}}$ low to conversion started (BUSY high) | | 40 | | ns |
| t_{pd2} | Propagation delay time, end of conversion to BUSY low | | 10 | | ns |
| t_{w1} | Pulse duration, $\overline{\text{CONVST}}$ low | 20 | | | ns |
| t_{su1} | Setup time, $\overline{\text{CS}}$ low to $\overline{\text{CONVST}}$ low | 0 | | | ns |
| t_{w2} | Pulse duration, $\overline{\text{CONVST}}$ high | 20 | | | ns |
| | $\overline{\text{CONVST}}$ falling edge jitter | | | 10 | ps |
| t_{w3} | Pulse duration, BUSY signal low | Min(t_{ACQ}) | | | ns |
| t_{w4} | Pulse duration, BUSY signal high | | 370 | | ns |
| t_{h1} | Hold time, first data bus transition ($\overline{\text{RD}}$ low, or $\overline{\text{CS}}$ low for read cycle, or BYTE input changes) after $\overline{\text{CONVST}}$ low | 40 | | | ns |
| t_{d1} | Delay time, $\overline{\text{CS}}$ low to $\overline{\text{RD}}$ low (or BUSY low to $\overline{\text{RD}}$ low) | 0 | | | ns |
| t_{su2} | Setup time, $\overline{\text{RD}}$ high to $\overline{\text{CS}}$ high | 0 | | | ns |
| t_{w5} | Pulse duration, $\overline{\text{RD}}$ low | 50 | | | ns |
| t_{en} | Enable time, $\overline{\text{RD}}$ low (or $\overline{\text{CS}}$ low for read cycle) to data valid | | | 30 | ns |
| t_{d2} | Delay time, data hold from $\overline{\text{RD}}$ high | 0 | | | ns |
| t_{d3} | Delay time, BYTE rising edge or falling edge to data valid | 2 | | 30 | ns |
| t_{w6} | Pulse duration, $\overline{\text{RD}}$ high | 20 | | | ns |
| t_{w7} | Pulse duration, $\overline{\text{CS}}$ high | 20 | | | ns |
| t_{h2} | Hold time, last $\overline{\text{RD}}$ (or $\overline{\text{CS}}$ for read cycle) rising edge to $\overline{\text{CONVST}}$ falling edge | 50 | | | ns |
| t_{su3} | Setup time, BYTE transition to $\overline{\text{RD}}$ falling edge | 0 | | | ns |
| t_{h3} | Hold time, BYTE transition to $\overline{\text{RD}}$ falling edge | 0 | | | ns |
| t_{dis} | Disable time, $\overline{\text{RD}}$ high ($\overline{\text{CS}}$ high for read cycle) to 3-stated data bus | | | 30 | ns |
| t_{d5} | Delay time, end of conversion to MSB data valid | | | 20 | ns |
| t_{su4} | Byte transition setup time, from BYTE transition to next BYTE transition | 50 | | | ns |
| t_{d6} | Delay time, $\overline{\text{CS}}$ rising edge to BUSY falling edge | 50 | | | ns |
| t_{d7} | Delay time, BUSY falling edge to $\overline{\text{CS}}$ rising edge | 50 | | | ns |
| $t_{\text{su(AB)}}$ | Setup time, from the falling edge of $\overline{\text{CONVST}}$ (used to start the valid conversion) to the next falling edge of $\overline{\text{CONVST}}$ (when $\overline{\text{CS}} = 0$ and $\overline{\text{CONVST}}$ used to abort) or to the next falling edge of $\overline{\text{CS}}$ (when $\overline{\text{CS}}$ is used to abort) | 70 | | 350 | ns |
| t_{su5} | Setup time, falling edge of $\overline{\text{CONVST}}$ to read valid data (MSB) from current conversion | MAX(t_{CONV}) + MAX(t_{d5}) | | | ns |
| t_{h4} | Hold time, data (MSB) from previous conversion hold valid from falling edge of $\overline{\text{CONVST}}$ | | MIN(t_{CONV}) | | ns |

- (1) All input signals are specified with $t_r = t_f = 5\text{ ns}$ (10% to 90% of $+V_{BD}$) and timed from a voltage level of $(V_{IL} + V_{IH})/2$.
- (2) See timing diagrams.
- (3) All timings are measured with 20 pF equivalent loads on all data bits and BUSY pins.

PIN ASSIGNMENTS

**PFB PACKAGE
(TOP VIEW)**

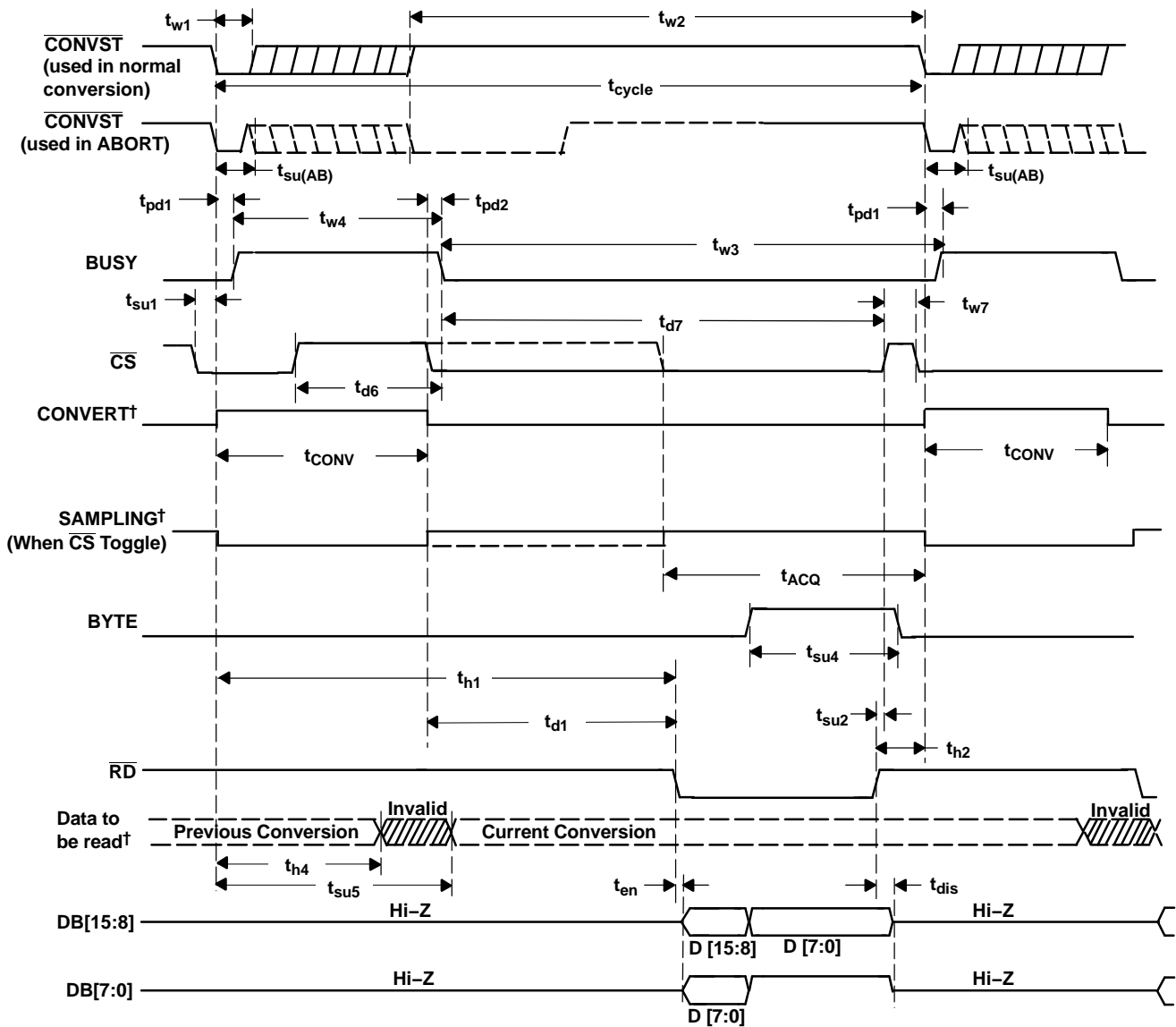


NC - No connection

Terminal Functions

| NAME | NO. | I/O | DESCRIPTION | | |
|----------------------------|------------------------------|-----|---|-----------------|-------------------|
| AGND | 5, 8, 11, 12, 14, 15, 44, 45 | - | Analog ground | | |
| BDGND | 25, 35 | - | Digital ground for bus interface digital supply | | |
| BUSY | 36 | O | Status output. High when a conversion is in progress. | | |
| BYTE | 39 | I | Byte select input. Used for 8-bit bus reading. 0: No fold back 1: Low byte D[7:0] of the 16 most significant bits is folded back to high byte of the 16 most significant pins DB[15:8]. | | |
| $\overline{\text{CONVST}}$ | 40 | I | Convert start. The falling edge of this input ends the acquisition period and starts the hold period. | | |
| $\overline{\text{CS}}$ | 42 | I | Chip select. The falling edge of this input starts the acquisition period. | | |
| Data Bus | | | 8-Bit Bus | | 16-Bit Bus |
| | | | BYTE = 0 | BYTE = 1 | BYTE = 0 |
| DB15 | 16 | O | D15 (MSB) | D7 | D15 (MSB) |
| DB14 | 17 | O | D14 | D6 | D14 |
| DB13 | 18 | O | D13 | D5 | D13 |
| DB12 | 19 | O | D12 | D4 | D12 |
| DB11 | 20 | O | D11 | D3 | D11 |
| DB10 | 21 | O | D10 | D2 | D10 |
| DB9 | 22 | O | D9 | D1 | D9 |
| DB8 | 23 | O | D8 | D0 (LSB) | D8 |
| DB7 | 26 | O | D7 | All ones | D7 |
| DB6 | 27 | O | D6 | All ones | D6 |
| DB5 | 28 | O | D5 | All ones | D5 |
| DB4 | 29 | O | D4 | All ones | D4 |
| DB3 | 30 | O | D3 | All ones | D3 |
| DB2 | 31 | O | D2 | All ones | D2 |
| DB1 | 32 | O | D1 | All ones | D1 |
| DB0 | 33 | O | D0 (LSB) | All ones | D0 (LSB) |
| -IN | 7 | I | Inverting input channel | | |
| +IN | 6 | I | Non inverting input channel | | |
| NC | 3 | - | No connection | | |
| REFIN | 1 | I | Reference input | | |
| REFM | 47, 48 | I | Reference ground | | |
| REFOUT | 2 | O | Reference output. Add 1 μF capacitor between the REFOUT pin and REFM pin when internal reference is used. | | |
| $\overline{\text{RESET}}$ | 38 | I | Current conversion is aborted and output latches are cleared (set to zeros) when this pin is asserted low. $\overline{\text{RESET}}$ works independantly of $\overline{\text{CS}}$. | | |
| $\overline{\text{RD}}$ | 41 | I | Synchronization pulse for the parallel output. When $\overline{\text{CS}}$ is low, this serves as the output enable and puts the previous conversion result on the bus. | | |
| +VA | 4, 9, 10, 13, 43, 46 | - | Analog power supplies, 5-V dc | | |
| +VBD | 24, 34, 37 | - | Digital power supply for bus | | |

TIMING DIAGRAMS



†Signal internal to device

Figure 1. Timing for Conversion and Acquisition Cycles With \overline{CS} and \overline{RD} Toggling

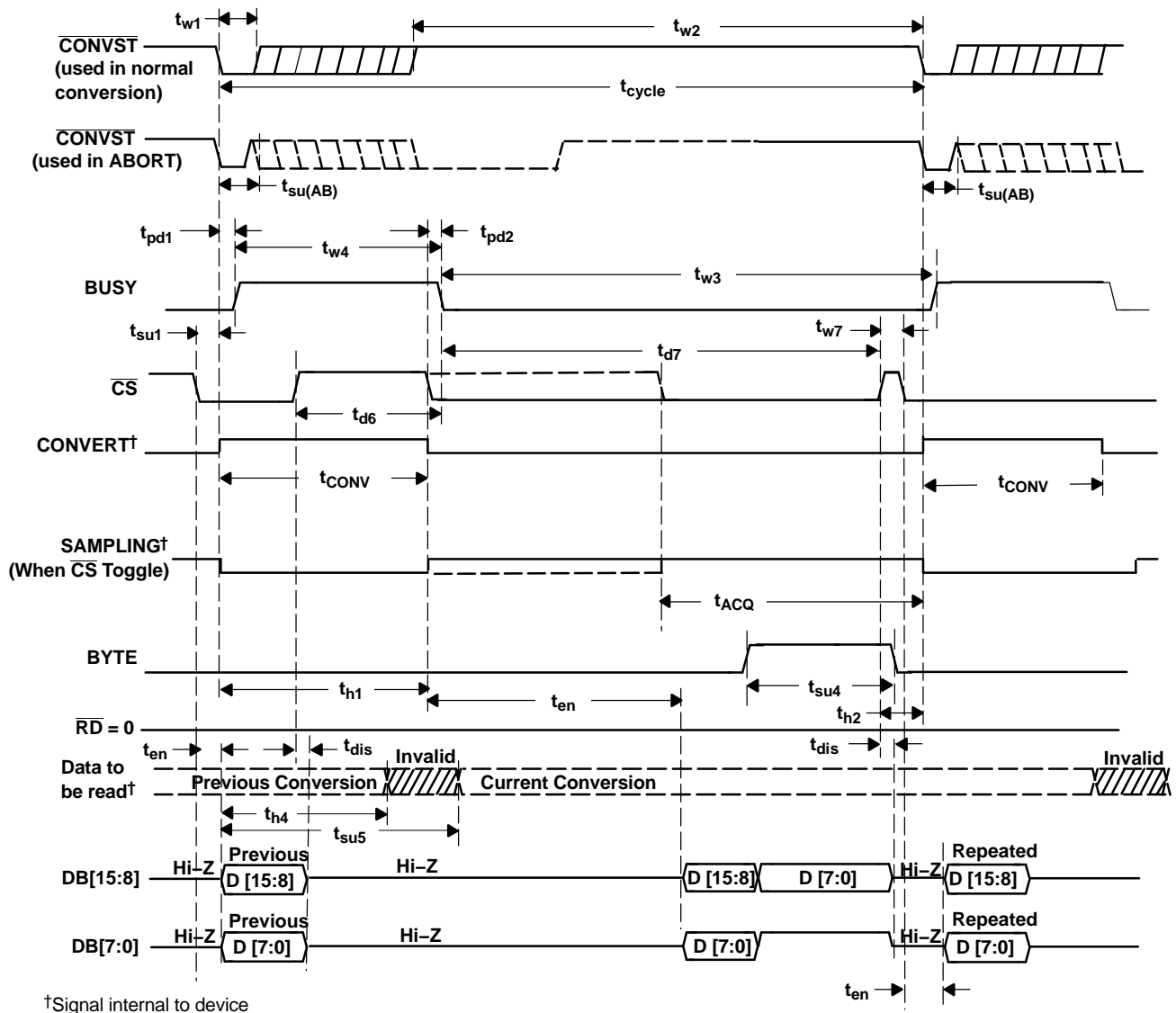
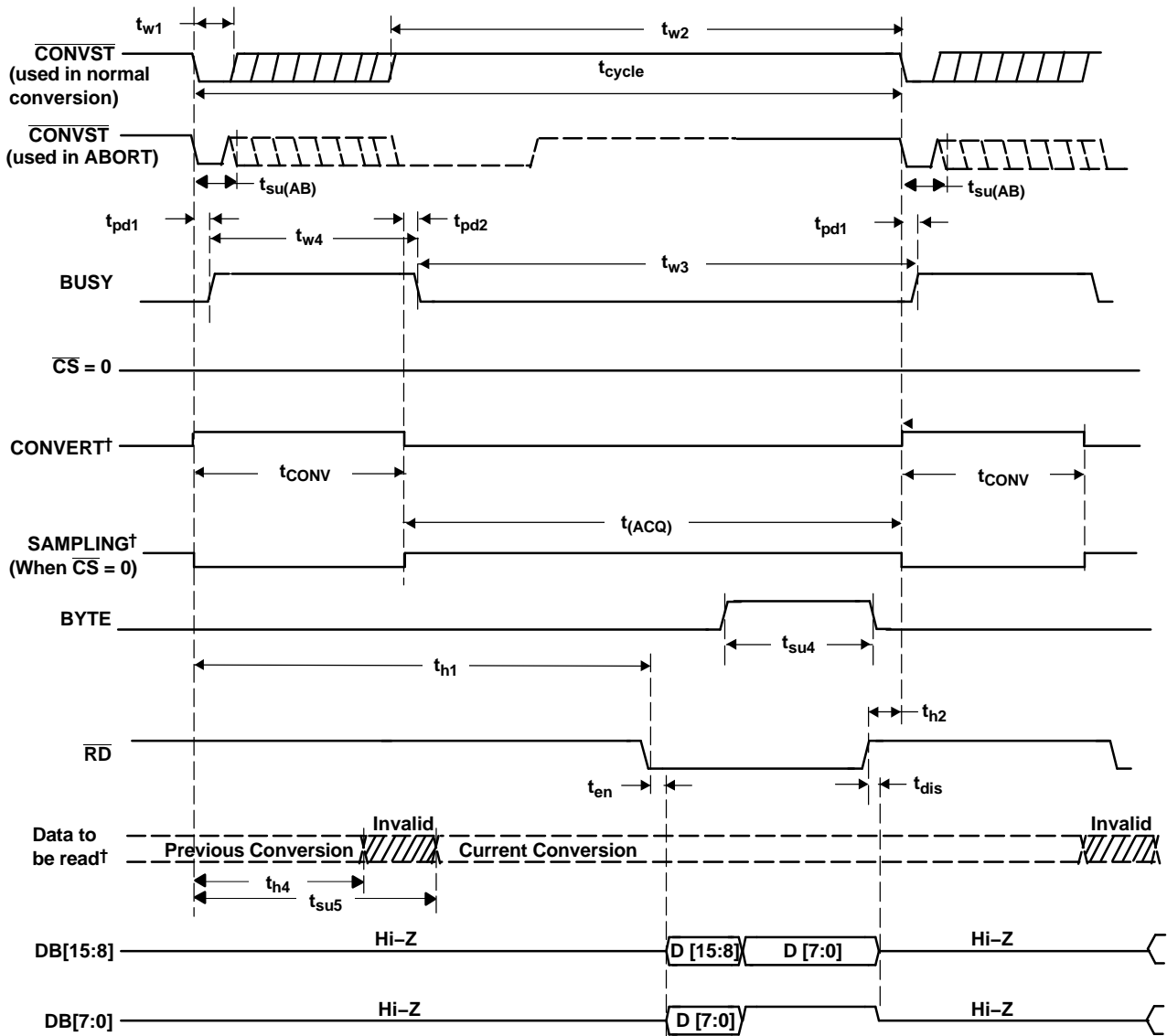
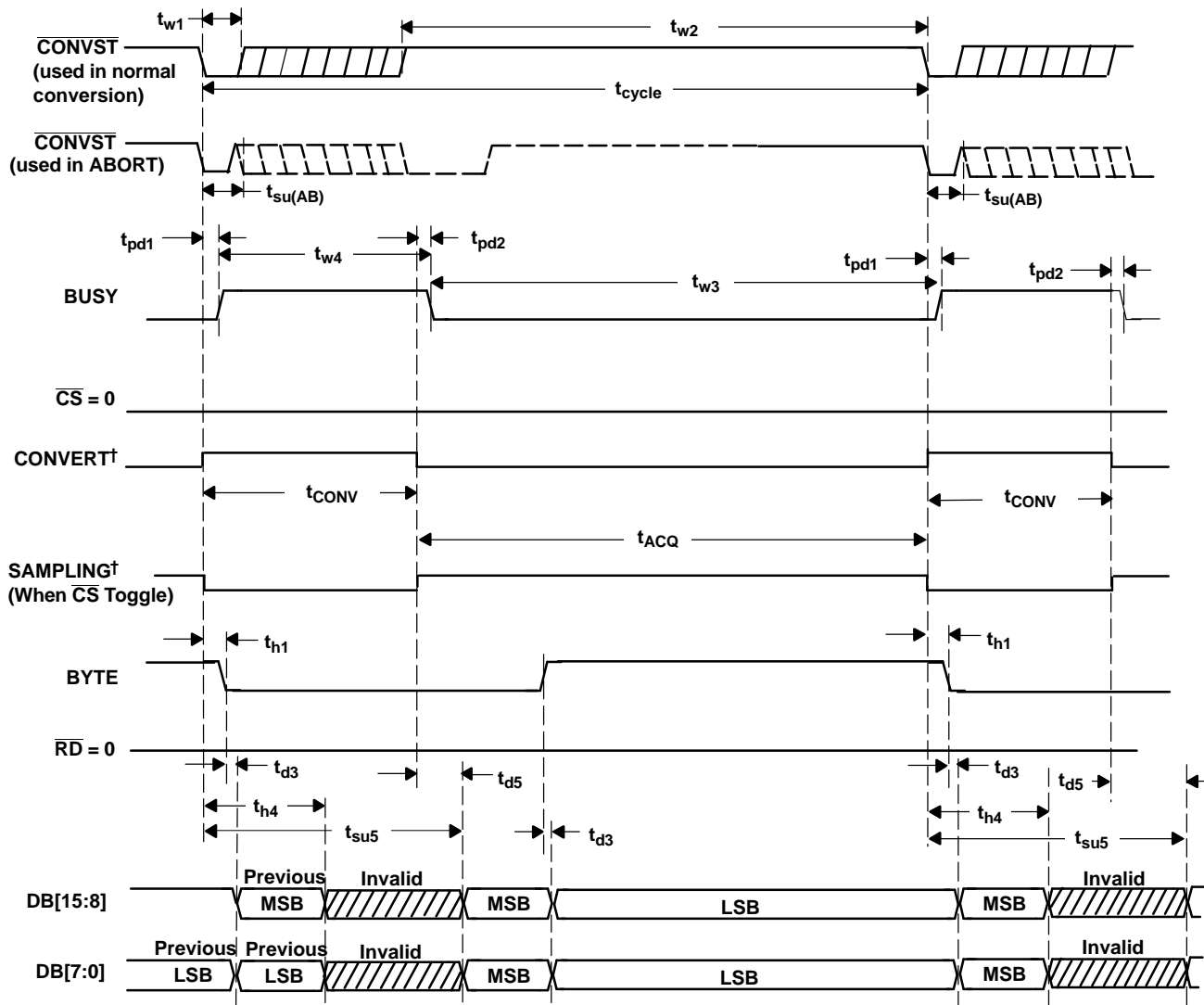


Figure 2. Timing for Conversion and Acquisition Cycles With \overline{CS} Toggling, \overline{RD} Tied to BDGND



†Signal internal to device

Figure 3. Timing for Conversion and Acquisition Cycles With \overline{CS} Tied to BDGND, \overline{RD} Toggling



†Signal internal to device

Figure 4. Timing for Conversion and Acquisition Cycles With \overline{CS} and \overline{RD} Tied to BDGND—Auto Read

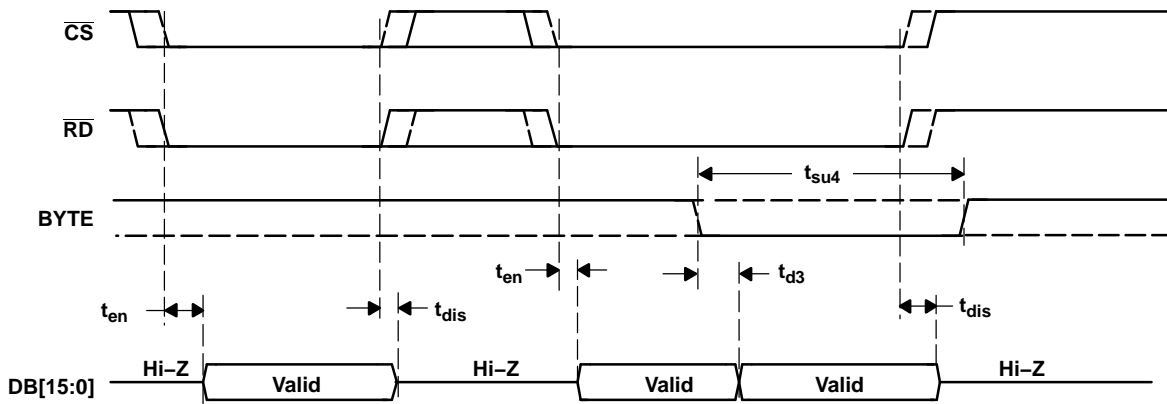


Figure 5. Detailed Timing for Read Cycles

TYPICAL CHARACTERISTICS

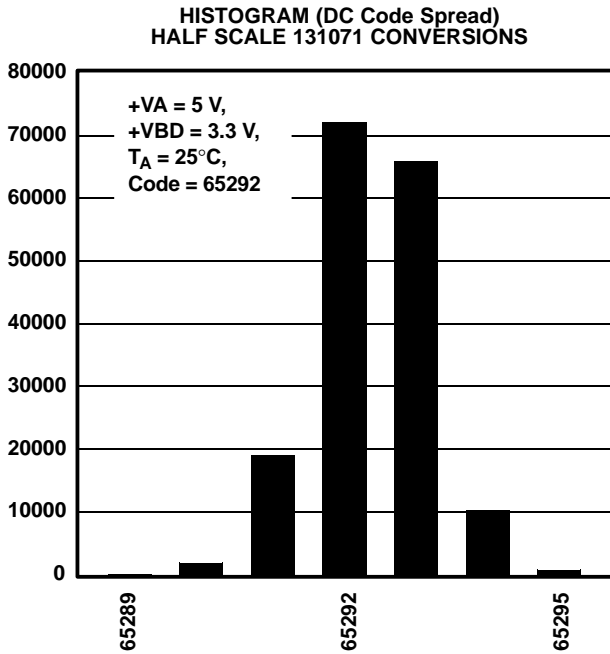


Figure 6.

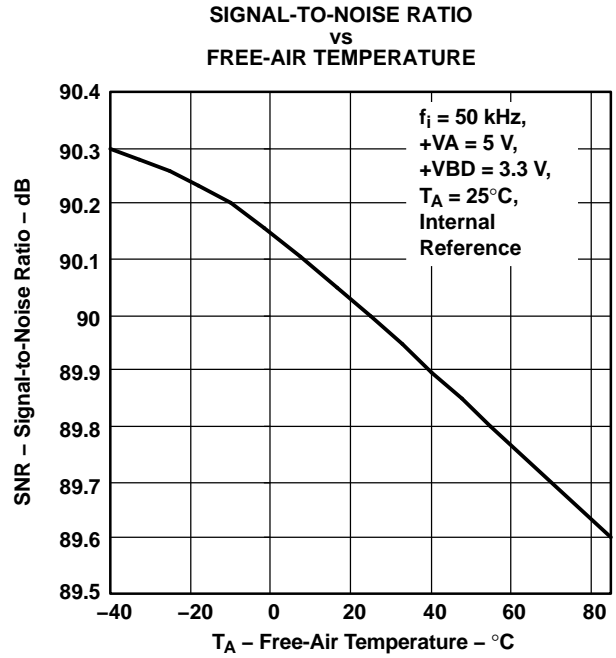


Figure 7.

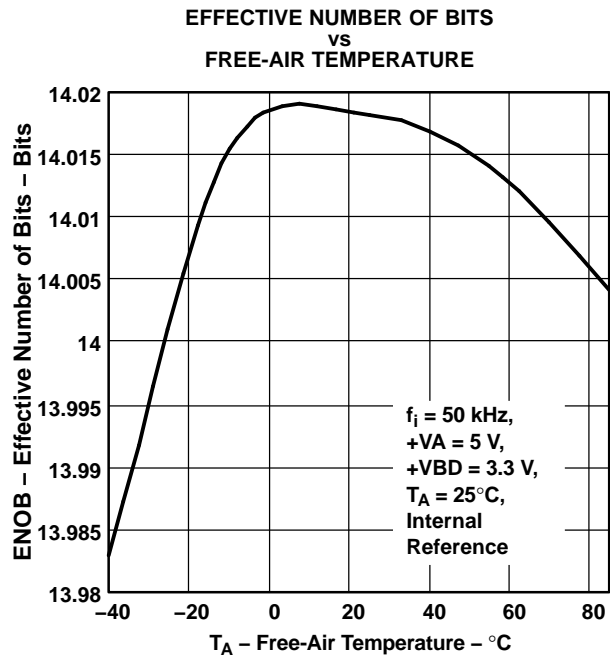


Figure 8.

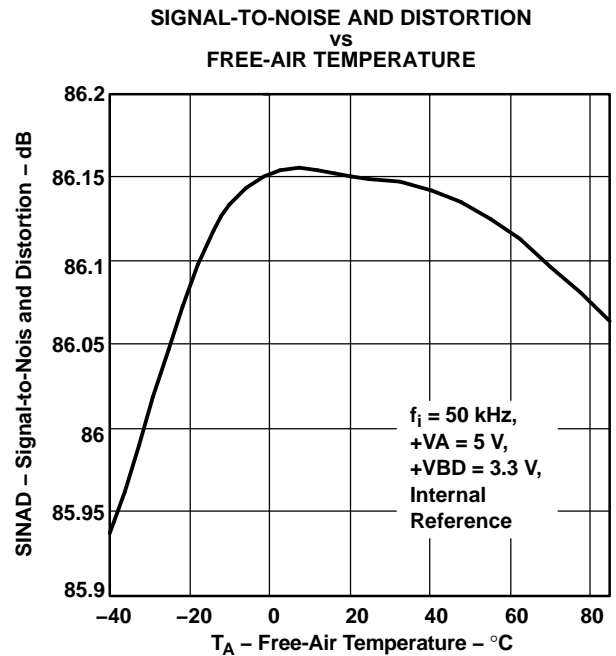


Figure 9.

At -40°C to 85°C, +VA = 5 V, +VBD = 5 V, REFIN = 4.096 V (internal reference used) and f_{sample} = 2 MHz (unless otherwise noted)

TYPICAL CHARACTERISTICS (continued)

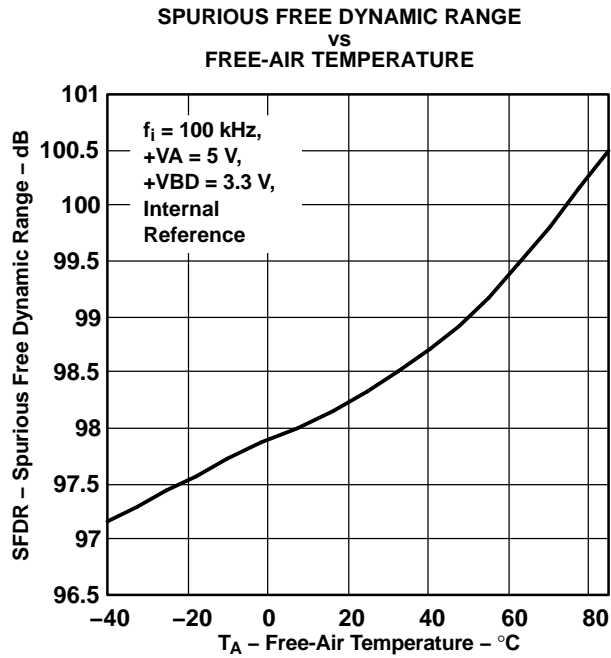


Figure 10.

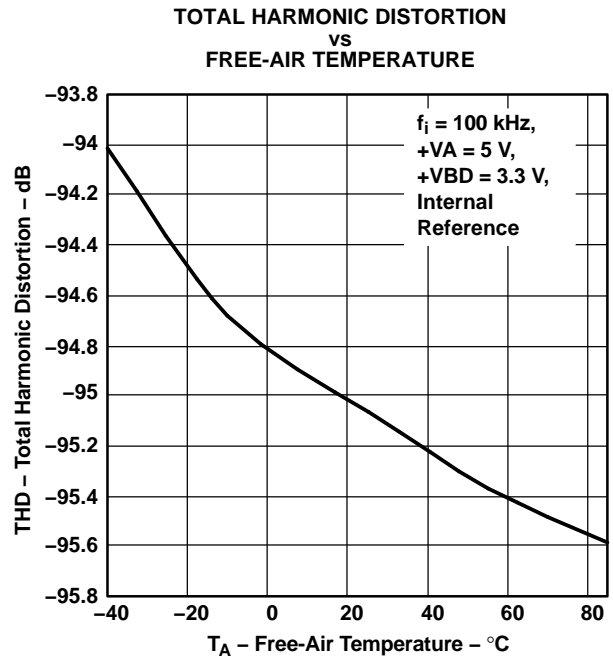


Figure 11.

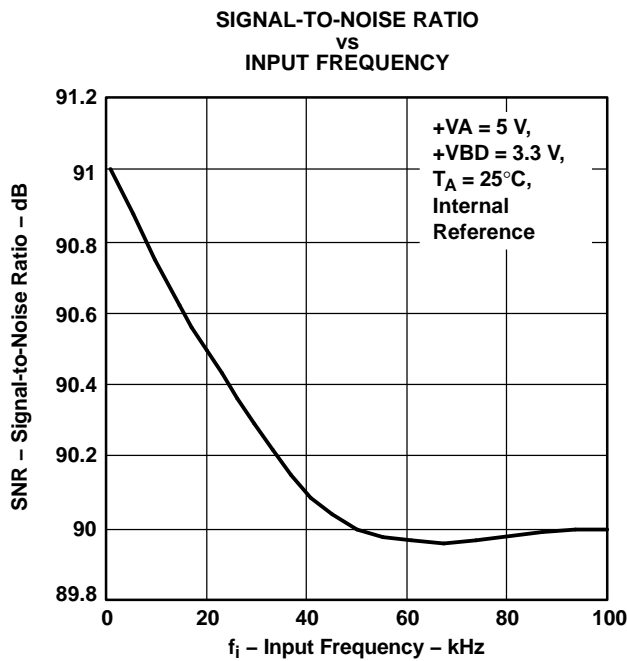


Figure 12.

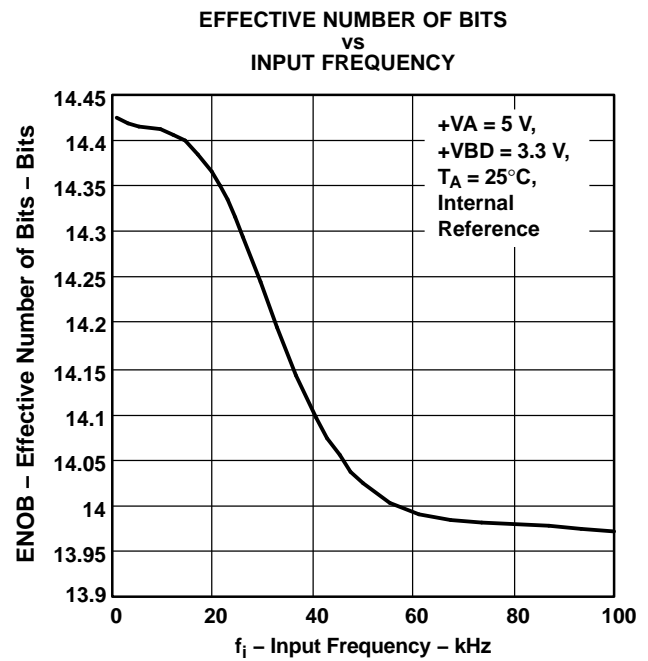
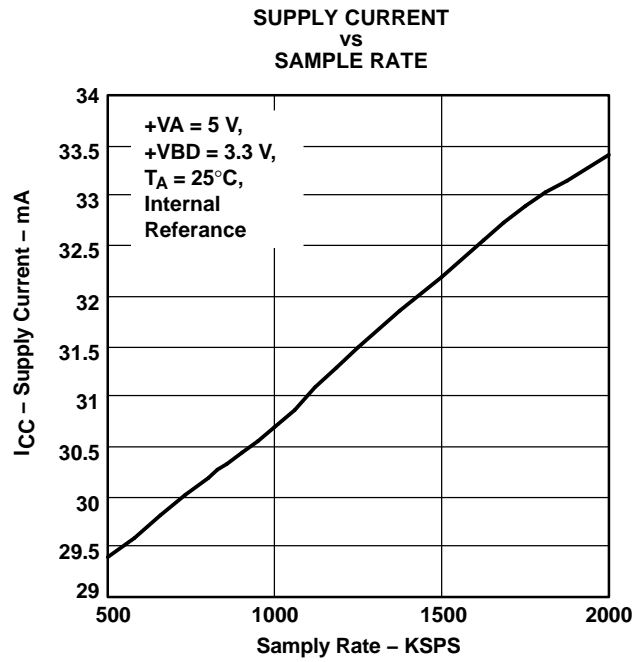
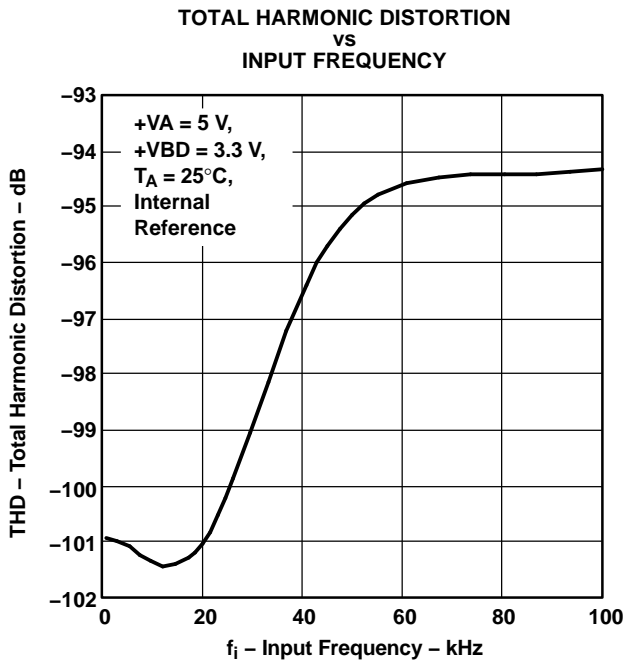
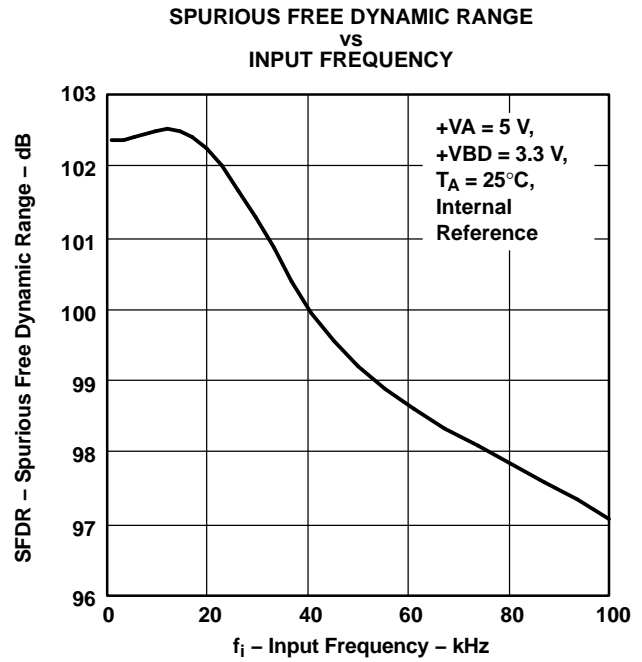
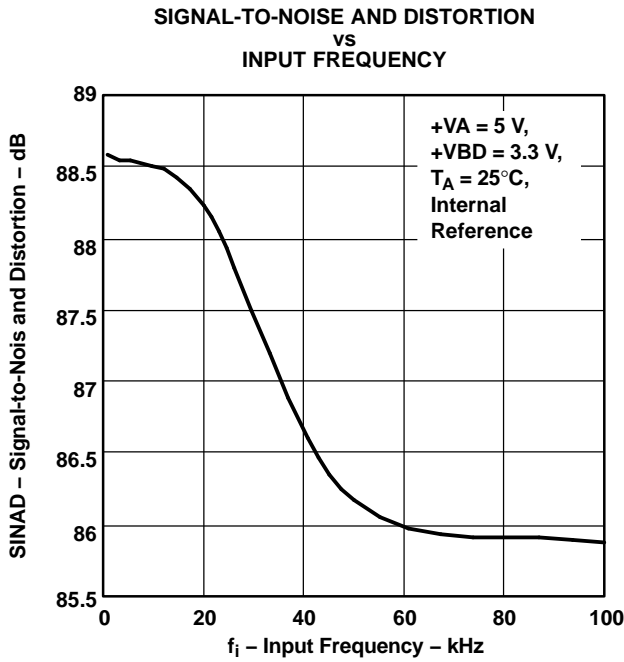
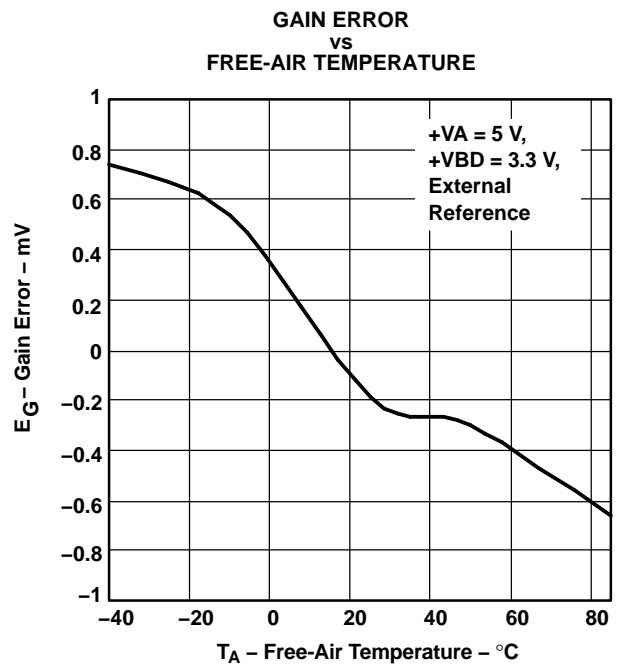
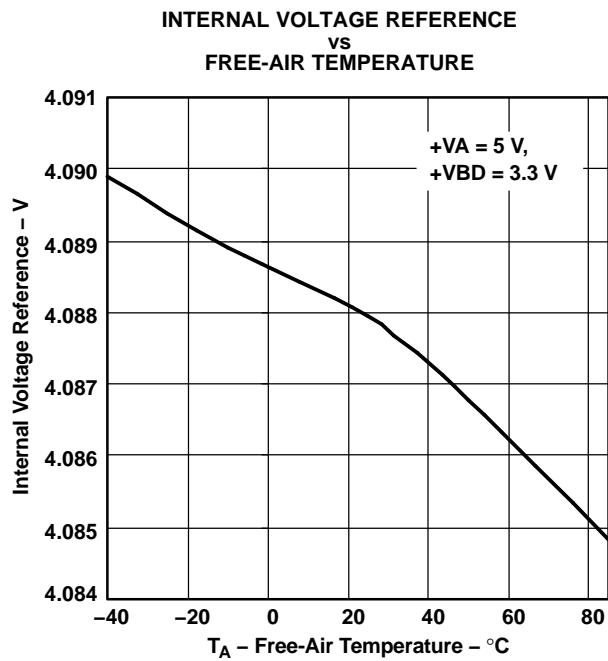
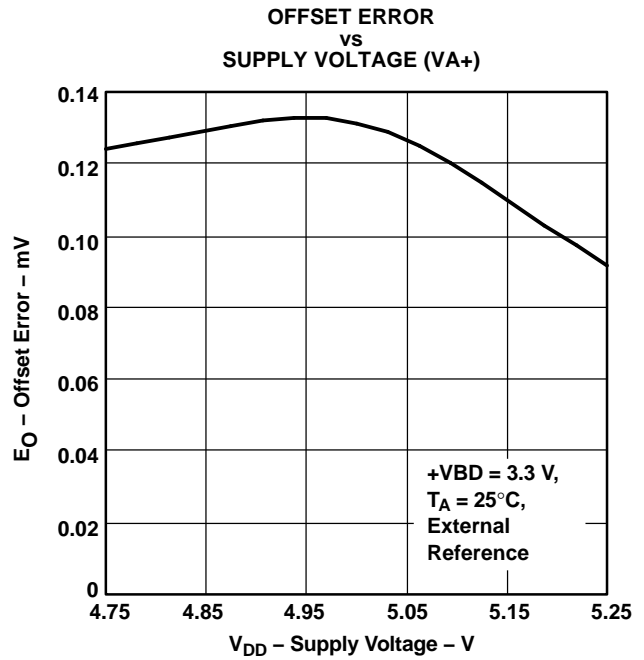
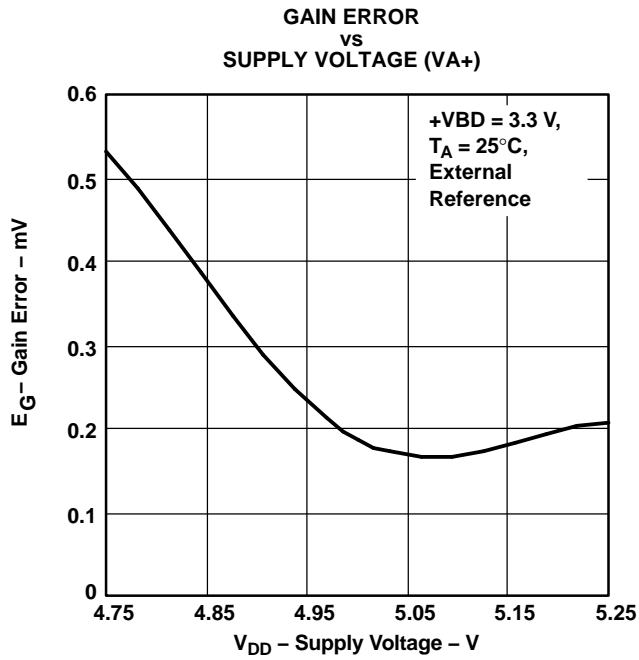


Figure 13.

TYPICAL CHARACTERISTICS (continued)



TYPICAL CHARACTERISTICS (continued)



TYPICAL CHARACTERISTICS (continued)

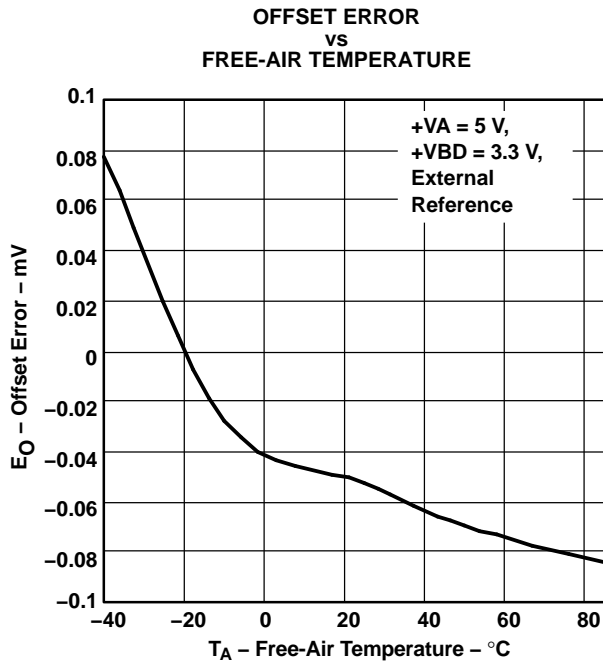


Figure 22.

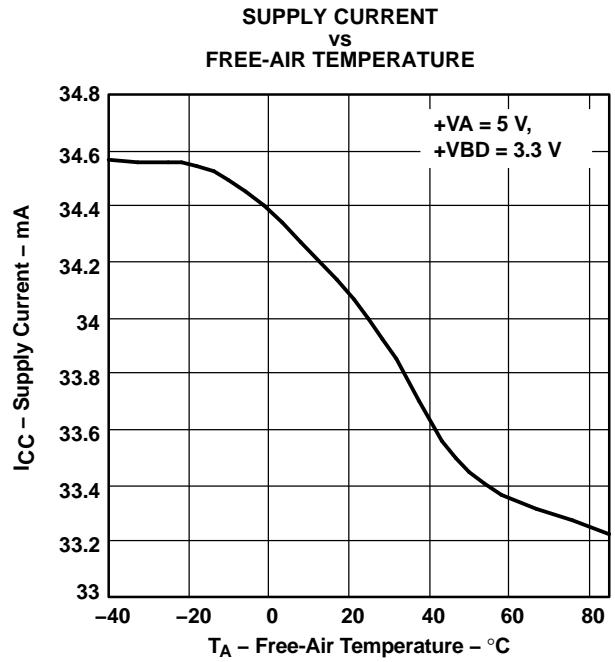


Figure 23.

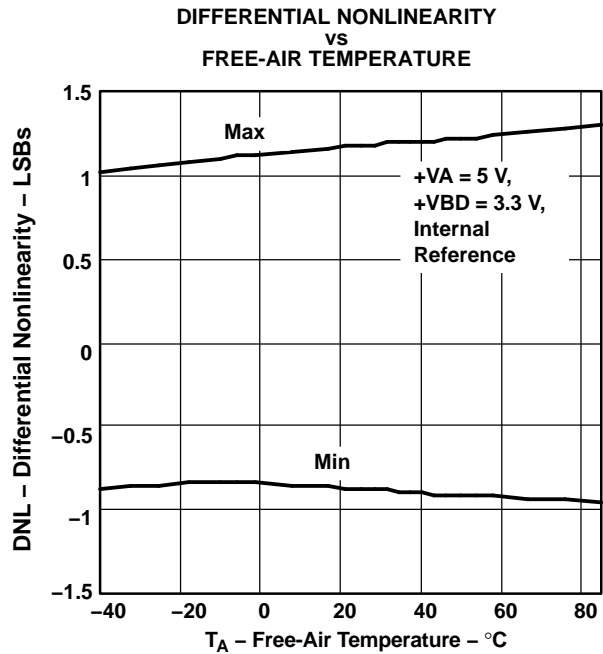


Figure 24.

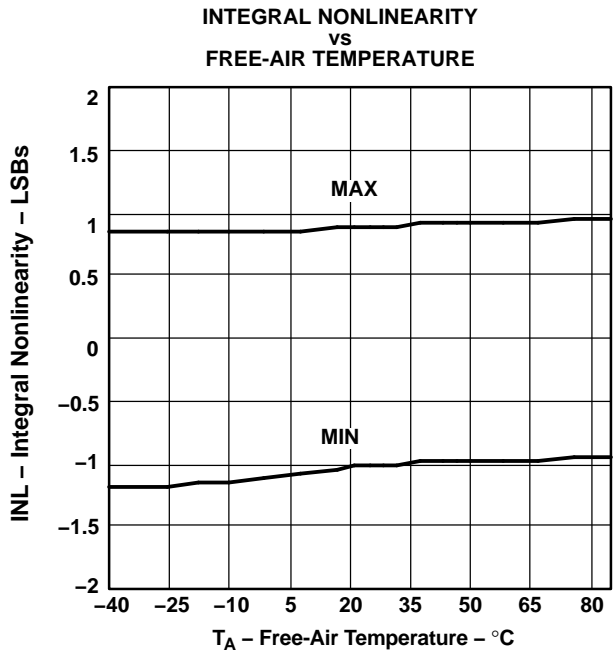


Figure 25.

TYPICAL CHARACTERISTICS (continued)

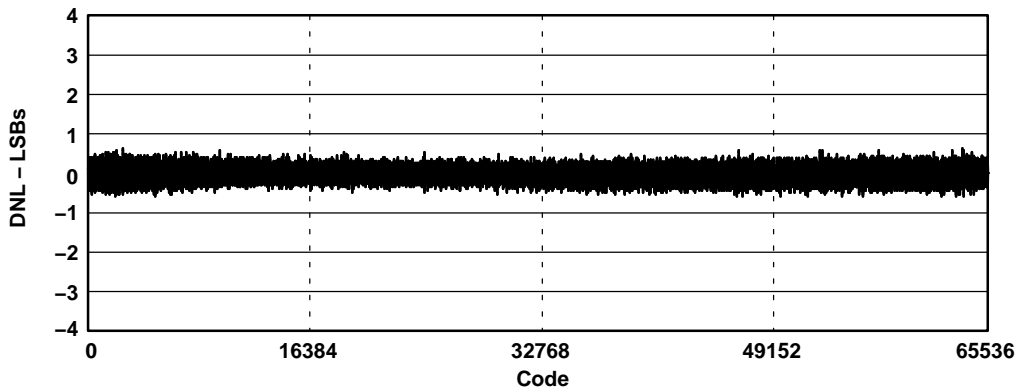


Figure 26.

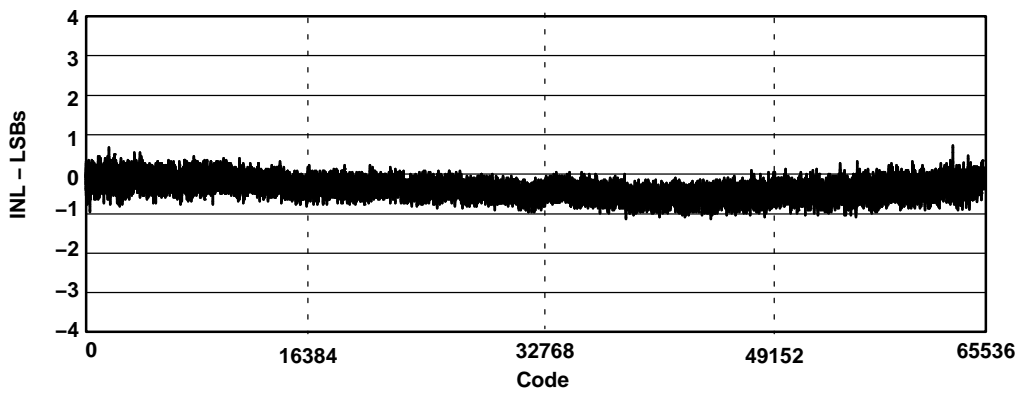


Figure 27.

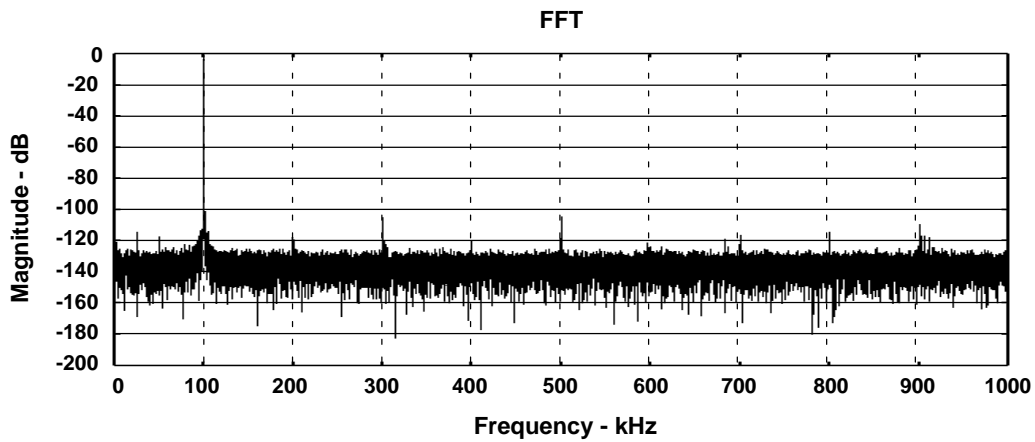


Figure 28.

APPLICATION INFORMATION

MICROCONTROLLER INTERFACING

ADS8412 to 8-Bit Microcontroller Interface

Figure 29 shows a parallel interface between the ADS8412 and a typical microcontroller using the 8-bit data bus. The BUSY signal is used as a falling-edge interrupt to the microcontroller.

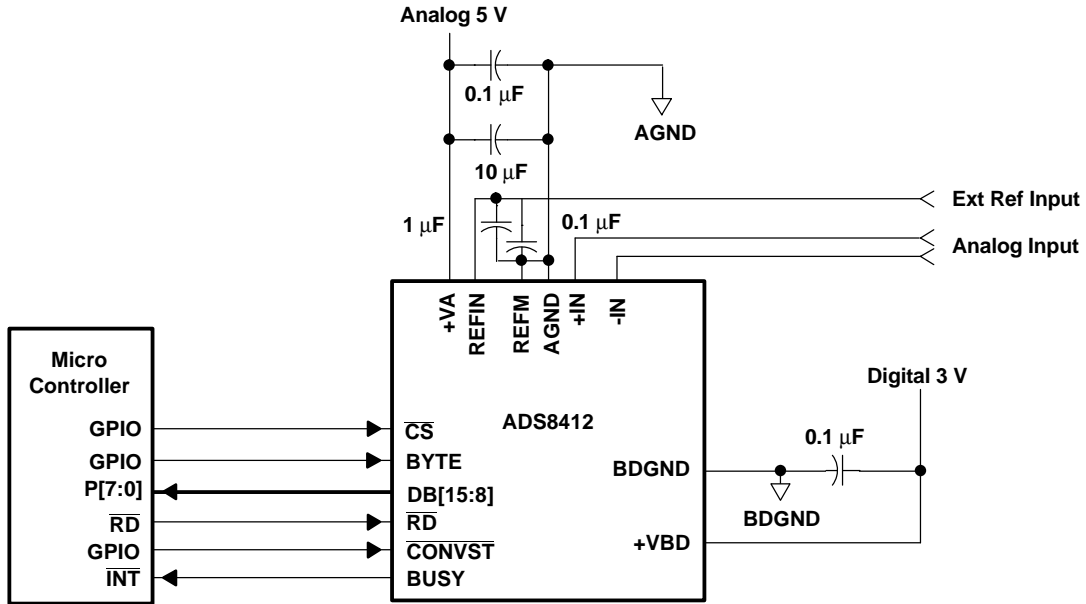


Figure 29. ADS8412 Application Circuitry (using external reference)

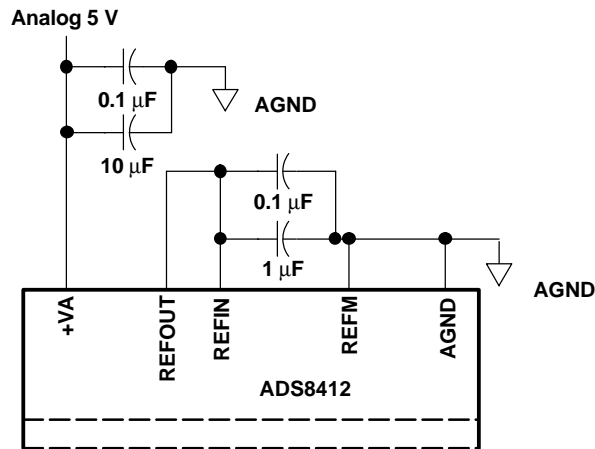


Figure 30. Use Internal Reference

PRINCIPLES OF OPERATION

The ADS8412 is a high-speed successive approximation register (SAR) analog-to-digital converter (ADC). The architecture is based on charge redistribution, which inherently includes a sample/hold function. See Figure 29 for the application circuit for the ADS8412.

The conversion clock is generated internally. The conversion time of 400 ns is capable of sustaining a 2-MHz throughput.

The analog input is provided to two input pins: +IN and –IN. When a conversion is initiated, the differential input on these pins is sampled on the internal capacitor array. While a conversion is in progress, both inputs are disconnected from any internal function.

REFERENCE

The ADS8412 can operate with an external reference with a range from 3.9 V to 4.2 V. A 4.096-V internal reference is included. When internal reference is used, pin 2 (REFOUT) should be connected to pin 1 (REFIN) with an 0.1 μ F decoupling capacitor and 1 μ F storage capacitor between pin 2 (REFOUT) and pins 47 and 48 (REFM) (see Figure 33). The internal reference of the converter is double buffered. If an external reference is used, the second buffer provides isolation between the external reference and the CDAC. This buffer is also used to recharge all of the capacitors of the CDAC during conversion. Pin 2 (REFOUT) can be left unconnected (floating) if external reference is used.

ANALOG INPUT

When the converter enters the hold mode, the voltage difference between the +IN and -IN inputs is captured on the internal capacitor array. Both +IN and -IN input has a range of -0.2 V to $V_{ref} + 0.2$ V. The input span(+IN – (-IN)) is limited to $-V_{ref}$ to V_{ref} .

The input current on the analog inputs depends upon a number of factors: sample rate, input voltage, and source impedance. Essentially, the current into the ADS8412 charges the internal capacitor array during the sample period. After this capacitance has been fully charged, there is no further input current. The source of the analog input voltage must be able to charge the input capacitance (25 pF) to an 16-bit settling level within the acquisition time (100 ns) of the device. When the converter goes into the hold mode, the input impedance is greater than 1 G Ω .

Care must be taken regarding the absolute analog input voltage. To maintain the linearity of the converter, the +IN and –IN inputs and the span (+IN – (-IN)) should be within the limits specified. Outside of these ranges, the converter's linearity may not meet specifications. To minimize noise, low bandwidth input signals with low-pass filters should be used.

Care should be taken to ensure that the output impedance of the sources driving +IN and –IN inputs are matched. If this is not observed, the two inputs could have different settling time. This may result in offset error, gain error and linearity error which varies with temperature and input voltage.

A typical input circuit using TI's THS4503 is shown Figure 31. Input from a single-ended source may be converted into differential signal for ADS8412 as shown in the figure. In case the source itself is differential then THS4503 may be used in differential input and differential output mode.

PRINCIPLES OF OPERATION (continued)

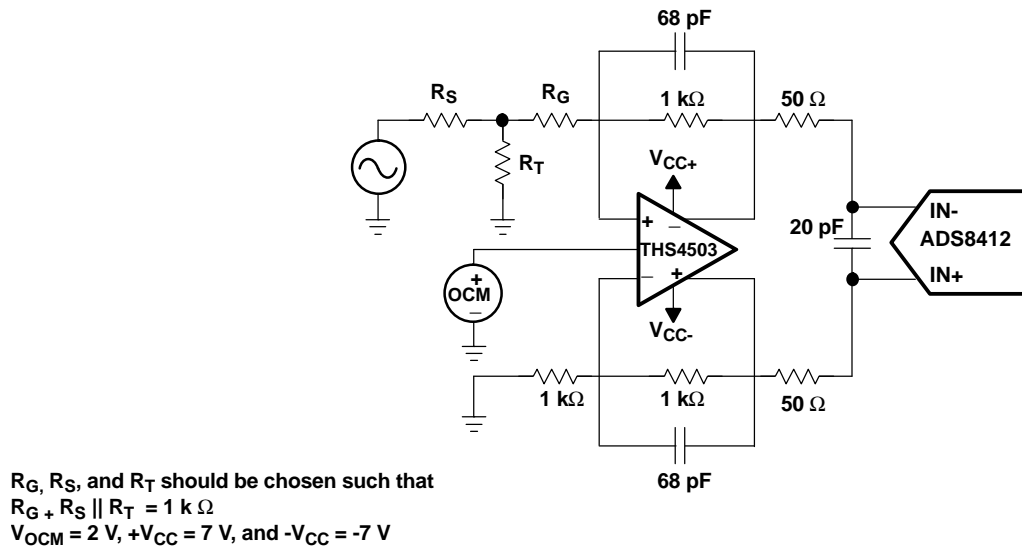


Figure 31. Using THS4503 With ADS8412

DIGITAL INTERFACE

Timing And Control

See the timing diagrams in the specifications section for detailed information on timing signals and their requirements.

The ADS8412 uses an internal oscillator generated clock which controls the conversion rate and in turn the throughput of the converter. No external clock input is required.

Conversions are initiated by bringing the $\overline{\text{CONVST}}$ pin low for a minimum of 20 ns (after the 20 ns minimum requirement has been met, the $\overline{\text{CONVST}}$ pin can be brought high), while $\overline{\text{CS}}$ is low. The ADS8412 switches from the sample to the hold mode on the falling edge of the $\overline{\text{CONVST}}$ command. A clean and low jitter falling edge of this signal is important to the performance of the converter. The BUSY output is brought high after $\overline{\text{CONVST}}$ goes low. BUSY stays high throughout the conversion process and returns low when the conversion has ended.

Sampling starts when $\overline{\text{CS}}$ is tied low or starts with the falling edge of $\overline{\text{CS}}$ when BUSY is low.

Both $\overline{\text{RD}}$ and $\overline{\text{CS}}$ can be high during and before a conversion with one exception ($\overline{\text{CS}}$ must be low when $\overline{\text{CONVST}}$ goes low to initiate a conversion). Both the $\overline{\text{RD}}$ and $\overline{\text{CS}}$ pins are brought low in order to enable the parallel output bus with the conversion.

Reading Data

The ADS8412 outputs full parallel data in two's complement format as shown in Table 1. The parallel output is active when $\overline{\text{CS}}$ and $\overline{\text{RD}}$ are both low. There is a minimal quiet zone requirement around the falling edge of $\overline{\text{CONVST}}$. This is 50 ns prior to the falling edge of $\overline{\text{CONVST}}$ and 40 ns after the falling edge. No data read should be attempted within this zone. Any other combination of $\overline{\text{CS}}$ and $\overline{\text{RD}}$ sets the parallel output to 3-state. BYTE is used for multiword read operations. BYTE is used whenever lower bits of the conversion result are output on the higher byte of the bus. Refer to Table 1 for ideal output codes.

Table 1. Ideal Input Voltages and Output Codes

| DESCRIPTION | ANALOG VALUE | DIGITAL OUTPUT – TWOS COMPLEMENT | |
|-----------------------------|-------------------------------|----------------------------------|----------|
| | | BINARY CODE | HEX CODE |
| Full Scale Range | $2(+V_{ref})$ | | |
| Least significant bit (LSB) | $2(+V_{ref})/65536$ | | |
| +Full scale | $(+V_{ref}) - 1 \text{ LSB}$ | 0111 1111 1111 1111 | 7FFF |
| Midscale | 0 V | 0000 0000 0000 0000 | 0000 |
| Midscale – 1 LSB | $0 \text{ V} - 1 \text{ LSB}$ | 1111 1111 1111 1111 | FFFF |
| –Full scale | $(-V_{ref})$ | 1000 0000 0000 0000 | 8000 |

The output data is a full 16-bit word (D15-D0) on DB15-DB0 pins (MSB-LSB) if BYTE is low.

The result may also be read on an 8-bit bus for convenience. This is done by using only pins DB15-DB8. In this case two reads are necessary: the first as before, leaving BYTE low and reading the 8 most significant bits on pins DB15-DB8, then bringing BYTE high. When BYTE is high, the low bits (D7-D0) appears on pins DB15-DB8.

These multiword read operations can be done with multiple active \overline{RD} (toggling) or with \overline{RD} tied low for simplicity.

Table 2. Conversion Data Readout

| BYTE | DATA READ OUT | |
|------|---------------|--------------|
| | DB15–DB8 Pins | DB7–DB0 Pins |
| High | D7–D0 | All one's |
| Low | D15–D8 | D7–D0 |

RESET

\overline{RESET} is an asynchronous active low input signal (that works independantly of \overline{CS}). Minimum \overline{RESET} low time is 25 ns. Current conversion will be aborted no later than 50 ns after the converter is in the reset mode. In addition, all output latches are cleared (set to zero's) after \overline{RESET} . The converter goes back to normal operation mode no later than 20 ns after \overline{RESET} input is brought high.

The converter starts the first sampling period 20 ns after the rising edge of \overline{RESET} . Any sampling period except for the one immediately after a \overline{RESET} is started with the falling edge of the previous BUSY signal or the falling edge of CS, whichever is later.

Another way to reset the device is through the use of the combination of \overline{CS} and \overline{CONVST} . This is useful when the dedicated \overline{RESET} pin is tied to the system reset but there is a need to abort only the conversion in a specific converter. Since the BUSY signal is held high during the conversion, either one of these conditions triggers an internal self-clear reset to the converter just the same as a reset via the dedicated \overline{RESET} pin. The reset does not have to be cleared as for the dedicated \overline{RESET} pin. A reset can be started with either of the two following steps.

- Issue a \overline{CONVST} when \overline{CS} is low and a conversion is in progress. The falling edge of \overline{CONVST} must satisfy the timing as specified by the timing parameter $t_{su(AB)}$ mentioned in the timing characteristics table to ensure a reset. The falling edge of \overline{CONVST} starts a reset. Timing is the same as a reset using the dedicated \overline{RESET} pin except the instance of the falling edge is replaced by the falling edge of \overline{CONVST} .
- Issue a \overline{CS} while a conversion is in progress. The falling edge of \overline{CS} must satisfy the timing as specified by the timing parameter $t_{su(AB)}$ mentioned in the timing characteristics table to ensure a reset. The falling edge of \overline{CONVST} starts a reset. The falling edge of \overline{CS} causes a reset. Timing is the same as a reset using the dedicated \overline{RESET} pin except the instance of the falling edge is replaced by the falling edge of \overline{CS} .

POWER-ON INITIALIZATION

\overline{RESET} is not required after power on. An internal power-on reset circuit generates the reset. To ensure that all of the registers are cleared, three conversion cycles must be given to the converter after power on.

LAYOUT

For optimum performance, care should be taken with the physical layout of the ADS8412 circuitry.

As the ADS8412 offers single-supply operation, it is often used in close proximity with digital logic, microcontrollers, microprocessors, and digital signal processors. The more digital logic present in the design and the higher the switching speed, the more difficult it is to achieve good performance from the converter.

The basic SAR architecture is sensitive to glitches or sudden changes on the power supply, reference, ground connections and digital inputs that occur just prior to latching the output of the analog comparator. Thus, driving any single conversion for an n-bit SAR converter, there are at least n *windows* in which large external transient voltages can affect the conversion result. Such glitches might originate from switching power supplies, nearby digital logic, or high power devices.

The degree of error in the digital output depends on the reference voltage, layout, and the exact timing of the external event.

On average, the ADS8412 draws very little current from an external reference, as the reference voltage is internally buffered. If the reference voltage is external and originates from an op amp, make sure that it can drive the bypass capacitor or capacitors without oscillation. A 0.1- μ F bypass capacitor and 1- μ F storage capacitor are recommended from pin 1 (REFIN) directly to pin 48 (REFM). REFM and AGND should be shorted on the same ground plane under the device.




The AGND and BDGND pins should be connected to a clean ground point. In all cases, this should be the analog ground. Avoid connections which are close to the grounding point of a microcontroller or digital signal processor. If required, run a ground trace directly from the converter to the power supply entry point. The ideal layout consists of an analog ground plane dedicated to the converter and associated analog circuitry.

As with the AGND connections, +VA should be connected to a 5-V power supply plane or trace that is separate from the connection for digital logic until they are connected at the power entry point. Power to the ADS8412 should be clean and well bypassed. A 0.1- μ F ceramic bypass capacitor should be placed as close to the device as possible. See Table 3 for the placement of the capacitor. In addition, a 1- μ F to 10- μ F capacitor is recommended. In some situations, additional bypassing may be required, such as a 100- μ F electrolytic capacitor or even a Pi filter made up of inductors and capacitors—all designed to essentially low-pass filter the 5-V supply, removing the high frequency noise.

Table 3. Power Supply Decoupling Capacitor Placement

| POWER SUPPLY PLANE SUPPLY PINS | CONVERTER ANALOG SIDE | CONVERTER DIGITAL SIDE |
|---|---|------------------------|
| Pin pairs that require shortest path to decoupling capacitors | (4,5), (8,9), (10,11), (13,15), (43,44), (45,46) | (24,25), (34, 35) |
| Pins that require no decoupling | 12, 14 | 37 |

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|---|
| ADS8412IBPFBR | ACTIVE | TQFP | PFB | 48 | 1000 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 85 | ADS8412I B |  |
| ADS8412IBPFBT | ACTIVE | TQFP | PFB | 48 | 250 | RoHS & Green | Call TI | Level-2-260C-1 YEAR | -40 to 85 | ADS8412I B |  |
| ADS8412IBPFBTG4 | ACTIVE | TQFP | PFB | 48 | 250 | RoHS & Green | Call TI | Level-2-260C-1 YEAR | -40 to 85 | ADS8412I B |  |

(1) 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.

OBSELETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

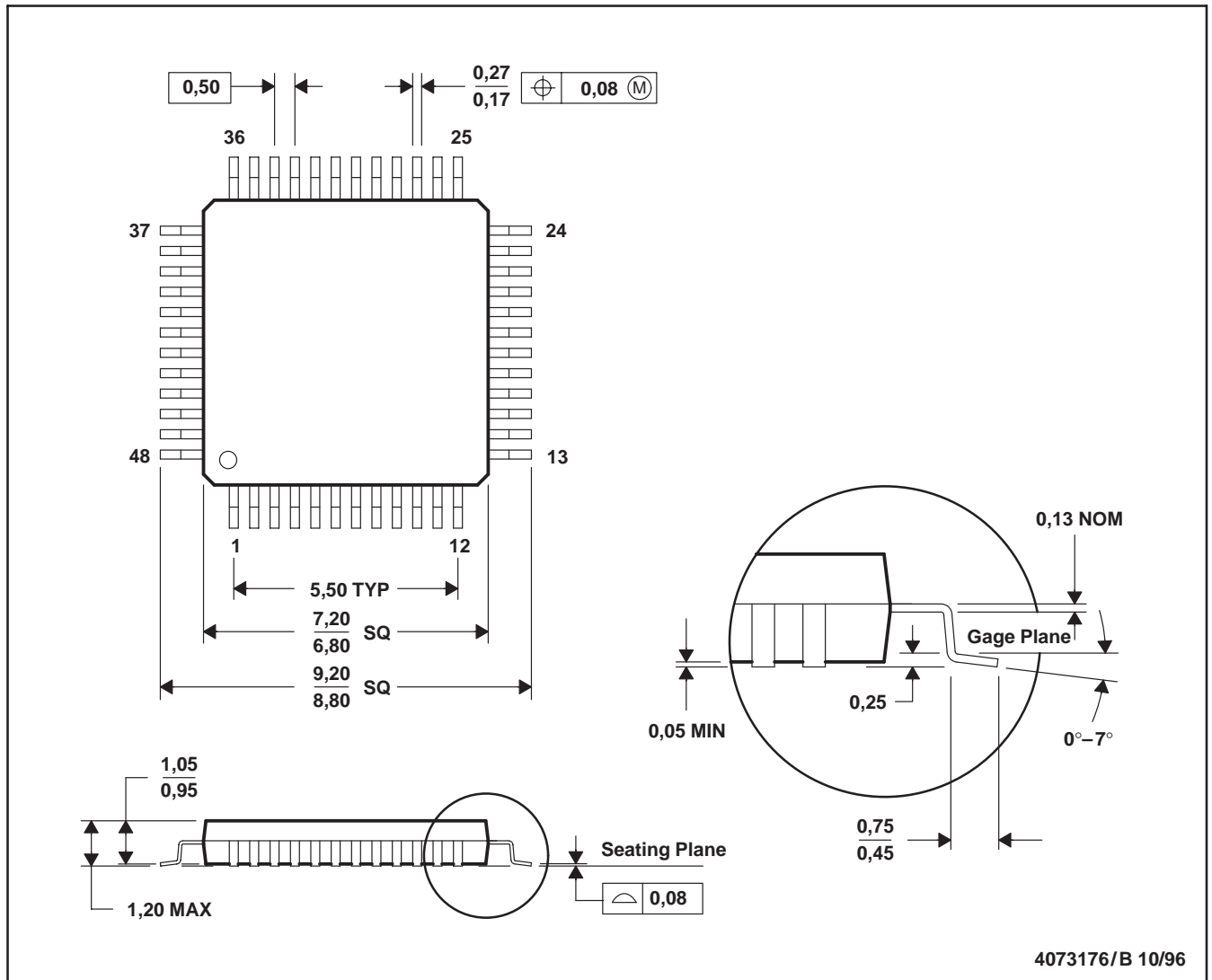
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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PFB (S-PQFP-G48)

PLASTIC QUAD FLATPACK



4073176/B 10/96

- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Falls within JEDEC MS-026

PFB (S-PQFP-G48)



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525.
 - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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