

2.7V 12-Bit A/D Converter with SPI[®] Serial Interface

FEATURES

- 12-bit resolution
- ± 1 LSB max DNL
- ± 1 LSB max INL (MCP3201-B)
- ± 2 LSB max INL (MCP3201-C)
- On-chip sample and hold
- SPI[®] serial interface (modes 0,0 and 1,1)
- Single supply operation: 2.7V - 5.5V
- 100ksps max. sampling rate at $V_{DD} = 5V$
- 50ksps max. sampling rate at $V_{DD} = 2.7V$
- Low power CMOS technology
 - 500nA typical standby current, 2 μ A max.
 - 400 μ A max. active current at 5V
- Industrial temp range: -40°C to +85°C
- 8-pin PDIP, SOIC and TSSOP packages

APPLICATIONS

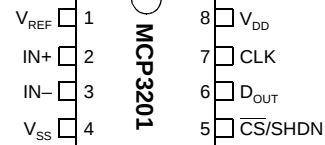
- Sensor Interface
- Process Control
- Data Acquisition
- Battery Operated Systems

DESCRIPTION

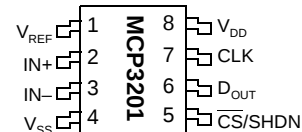
The Microchip Technology Inc. MCP3201 is a successive approximation 12-bit Analog-to-Digital (A/D) Converter with on-board sample and hold circuitry. The device provides a single pseudo-differential input. Differential Nonlinearity (DNL) is specified at ± 1 LSB, and Integral Nonlinearity (INL) is offered in ± 1 LSB (MCP3201-B) and ± 2 LSB (MCP3201-C) versions. Communication with the device is done using a simple serial interface compatible with the SPI protocol. The device is capable of sample rates of up to 100ksps at a clock rate of 1.6MHz. The MCP3201 operates over a broad voltage range (2.7V - 5.5V). Low current design permits operation with typical standby and active currents of only 500nA and 300 μ A, respectively. The device is offered in 8-pin PDIP, TSSOP and 150mil SOIC packages.

PACKAGE TYPES

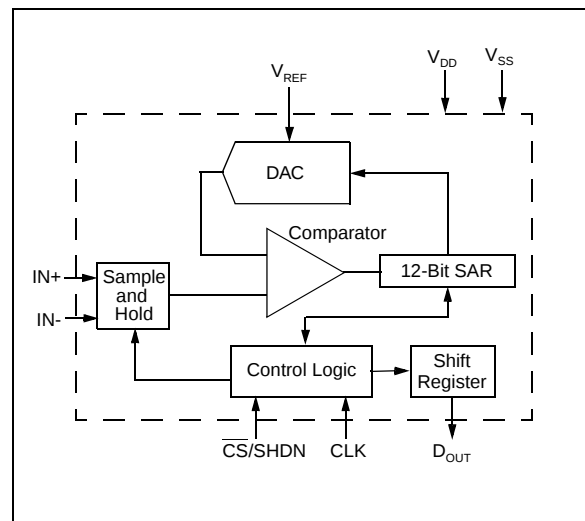
PDIP



SOIC, TSSOP



FUNCTIONAL BLOCK DIAGRAM



1.0 ELECTRICAL CHARACTERISTICS

1.1 Maximum Ratings*

V_{DD} 7.0V
 All inputs and outputs w.r.t. V_{SS} -0.6V to $V_{DD} + 0.6V$
 Storage temperature -65°C to +150°C
 Ambient temp. with power applied -65°C to +125°C
 Soldering temperature of leads (10 seconds) .. +300°C
 ESD protection on all pins > 4kV

*Notice: Stresses above those listed under "Maximum ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

PIN FUNCTION TABLE

NAME	FUNCTION
V_{DD}	+2.7V to 5.5V Power Supply
V_{SS}	Ground
IN+	Positive Analog Input
IN-	Negative Analog Input
CLK	Serial Clock
D_{OUT}	Serial Data Out
CS/SHDN	Chip select/Shutdown Input
V_{REF}	Reference Voltage Input

ELECTRICAL CHARACTERISTICS

All parameters apply at $V_{DD} = 5V$, $V_{SS} = 0V$, $V_{REF} = 5V$, $T_{AMB} = -40^{\circ}C$ to $+85^{\circ}C$, $f_{SAMPLE} = 100ksps$ and $f_{CLK} = 16 * f_{SAMPLE}$ unless otherwise noted.

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNITS	CONDITIONS
Conversion Rate						
Conversion Time	t_{CONV}			12	clock cycles	
Analog Input Sample Time	t_{SAMPLE}		1.5		clock cycles	
Throughput Rate	f_{SAMPLE}			100 50	ksps ksps	$V_{DD} = V_{REF} = 5V$ $V_{DD} = V_{REF} = 2.7V$
DC Accuracy						
Resolution			12		bits	
Integral Nonlinearity	INL		± 0.75 ± 1	± 1 ± 2	LSB LSB	MCP3201-B MCP3201-C
Differential Nonlinearity	DNL		± 0.5	± 1	LSB	No missing codes over temperature
Offset Error			± 1.25	± 3	LSB	
Gain Error			± 1.25	± 5	LSB	
Dynamic Performance						
Total Harmonic Distortion			-82		dB	$V_{IN} = 0.1V$ to $4.9V@1kHz$
Signal to Noise and Distortion (SINAD)			72		dB	$V_{IN} = 0.1V$ to $4.9V@1kHz$
Spurious Free Dynamic Range			86		dB	$V_{IN} = 0.1V$ to $4.9V@1kHz$
Reference Input						
Voltage Range		0.25		V_{DD}	V	Note 2
Current Drain			100 .001	150 3	μA μA	$\overline{CS} = V_{DD} = 5V$
Analog Inputs						
Input Voltage Range (IN+)		IN-		$V_{REF} + IN-$	V	
Input Voltage Range (IN-)		$V_{SS} - 100$		$V_{SS} + 100$	mV	
Leakage Current			0.001	± 1	μA	
Switch Resistance	R_{SS}		1K		Ω	See Figure 4-1
Sample Capacitor	C_{SAMPLE}		20		pF	See Figure 4-1

ELECTRICAL CHARACTERISTICS (CONTINUED)

All parameters apply at $V_{DD} = 5V$, $V_{SS} = 0V$, $V_{REF} = 5V$, $T_{AMB} = -40^{\circ}C$ to $+85^{\circ}C$, $f_{SAMPLE} = 100ksps$ and $f_{CLK} = 16 \cdot f_{SAMPLE}$ unless otherwise noted.

PARAMETER	SYMBOL	MIN.	TYP.	MAX.	UNITS	CONDITIONS
Digital Input/Output						
Data Coding Format		Straight Binary				
High Level Input Voltage	V_{IH}	$0.7 V_{DD}$			V	
Low Level Input Voltage	V_{IL}			$0.3 V_{DD}$	V	
High Level Output Voltage	V_{OH}	4.1			V	$I_{OH} = -1mA$, $V_{DD} = 4.5V$
Low Level Output Voltage	V_{OL}			0.4	V	$I_{OL} = 1mA$, $V_{DD} = 4.5V$
Input Leakage Current	I_{LI}	-10		10	μA	$V_{IN} = V_{SS}$ or V_{DD}
Output Leakage Current	I_{LO}	-10		10	μA	$V_{OUT} = V_{SS}$ or V_{DD}
Pin Capacitance (all inputs/outputs)	C_{IN} , C_{OUT}			10	pF	$V_{DD} = 5.0V$ (Note 1) $T_{AMB} = 25^{\circ}C$, $f = 1 MHz$
Timing Parameters						
Clock Frequency	f_{CLK}			1.6 0.8	MHz MHz	$V_{DD} = 5V$ (Note 3) $V_{DD} = 2.7V$ (Note 3)
Clock High Time	t_{HI}	312			ns	
Clock Low Time	t_{LO}	312			ns	
CS Fall To First Rising CLK Edge	t_{SUCS}	100			ns	
CLK Fall To Output Data Valid	t_{DO}			200	ns	See Test Circuits, Figure 1-2
CLK Fall To Output Enable	t_{EN}			200	ns	See Test Circuits, Figure 1-2
CS Rise To Output Disable	t_{DIS}			100	ns	See Test Circuits, Figure 1-2 (Note 1)
CS Disable Time	t_{CSH}	625			ns	
D_{OUT} Rise Time	t_R			100	ns	See Test Circuits, Figure 1-2 (Note 1)
D_{OUT} Fall Time	t_F			100	ns	See Test Circuits, Figure 1-2 (Note 1)
Power Requirements						
Operating Voltage	V_{DD}	2.7		5.5	V	
Operating Current	I_{DD}		300 210	400	μA μA	$V_{DD} = 5.0V$, D_{OUT} unloaded $V_{DD} = 2.7V$, D_{OUT} unloaded
Standby Current	I_{DDs}		0.5	2	μA	$CS = V_{DD} = 5.0V$

Note 1: This parameter is guaranteed by characterization and not 100% tested.

2: See graph that relates linearity performance to V_{REF} level.

3: Because the sample cap will eventually lose charge, effective clock rates below 10kHz can affect linearity performance, especially at elevated temperatures. See Section 6.2 for more information.

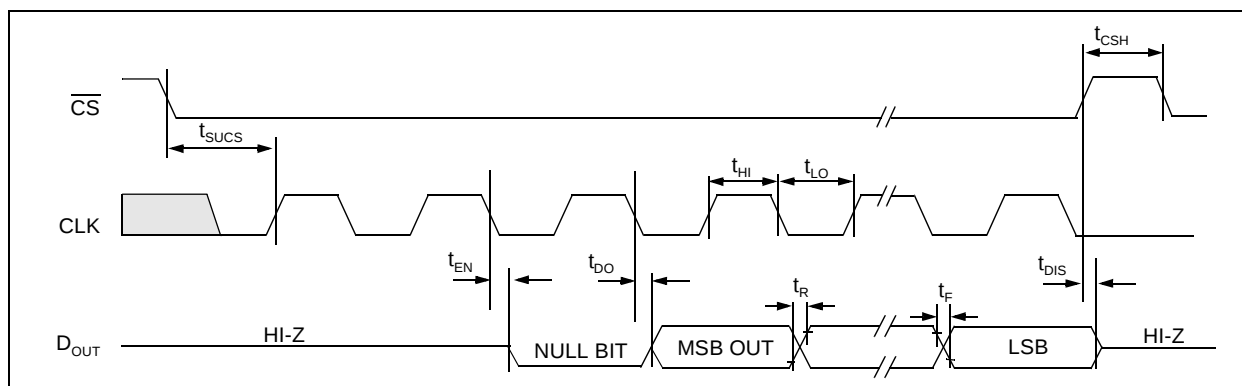


FIGURE 1-1: Serial Timing.

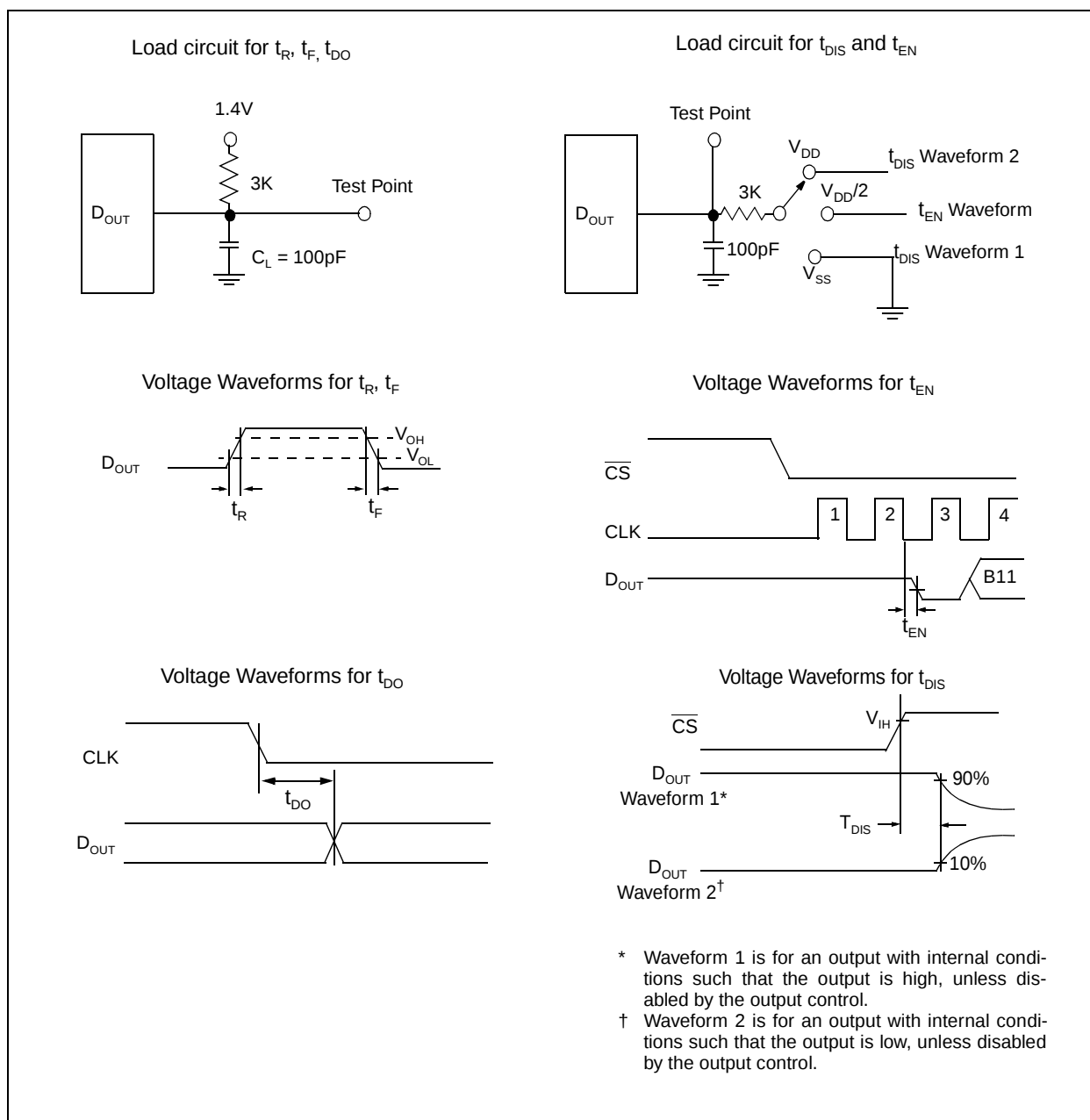


FIGURE 1-2: Test Circuits.

2.0 TYPICAL PERFORMANCE CHARACTERISTICS

Note: Unless otherwise indicated, $V_{DD} = V_{REF} = 5V$, $V_{SS} = 0V$, $f_{SAMPLE} = 100\text{kpsps}$, $f_{CLK} = 16 \cdot f_{SAMPLE}$, $T_A = 25^\circ\text{C}$

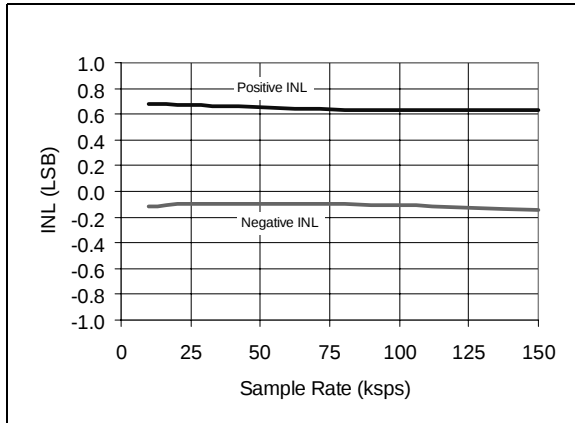


FIGURE 2-1: Integral Nonlinearity (INL) vs. Sample Rate.

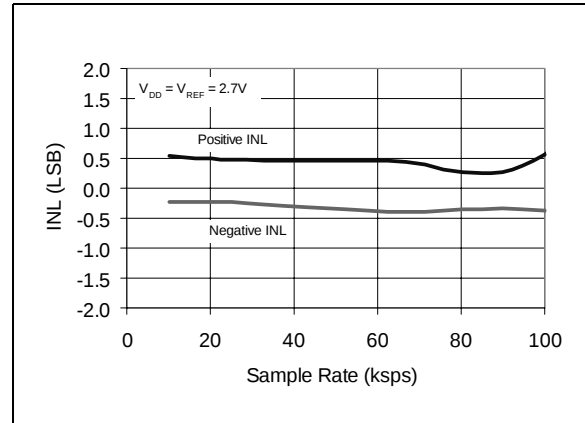


FIGURE 2-4: Integral Nonlinearity (INL) vs. Sample Rate ($V_{DD} = 2.7V$).

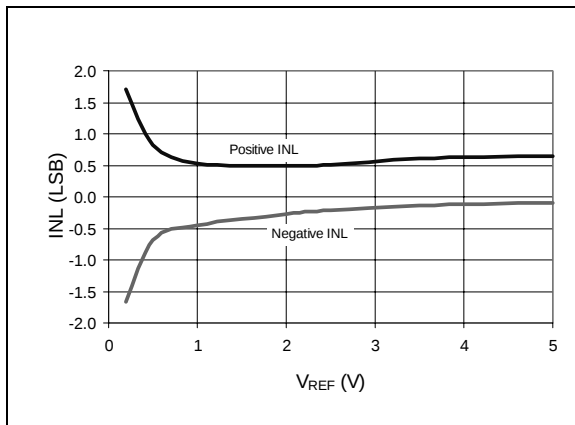


FIGURE 2-2: Integral Nonlinearity (INL) vs. V_{REF} .

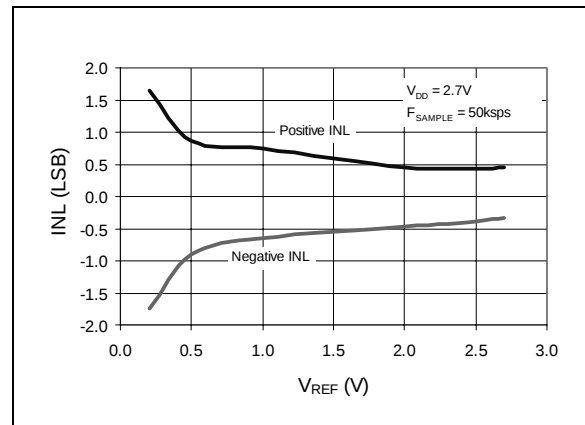


FIGURE 2-5: Integral Nonlinearity (INL) vs. V_{REF} ($V_{DD} = 2.7V$).

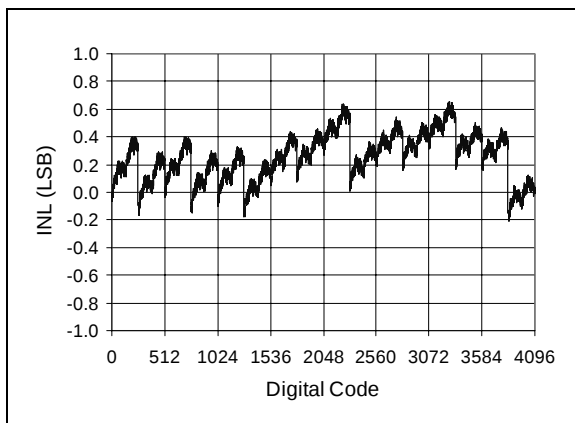


FIGURE 2-3: Integral Nonlinearity (INL) vs. Code (Representative Part).

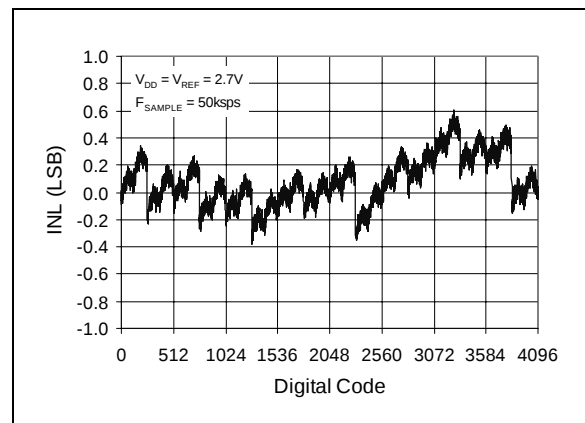


FIGURE 2-6: Integral Nonlinearity (INL) vs. Code (Representative Part, $V_{DD} = 2.7V$).

Note: Unless otherwise indicated, $V_{DD} = V_{REF} = 5V$, $V_{SS} = 0V$, $f_{SAMPLE} = 100\text{kpsps}$, $f_{CLK} = 16 \cdot f_{SAMPLE}$, $T_A = 25^\circ\text{C}$

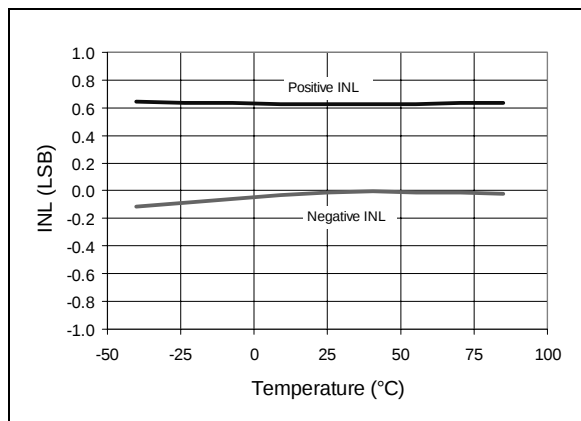


FIGURE 2-7: Integral Nonlinearity (INL) vs. Temperature.

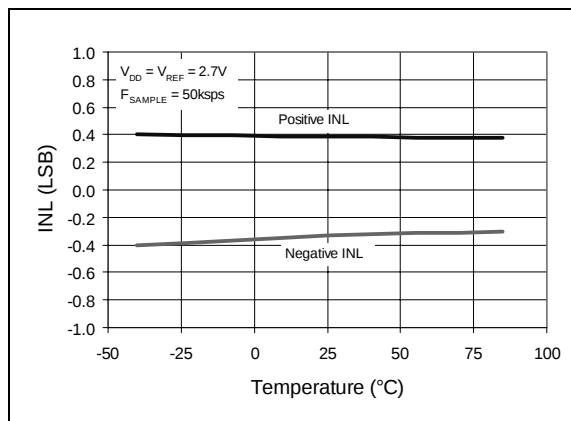


FIGURE 2-10: Integral Nonlinearity (INL) vs. Temperature ($V_{DD} = 2.7V$).

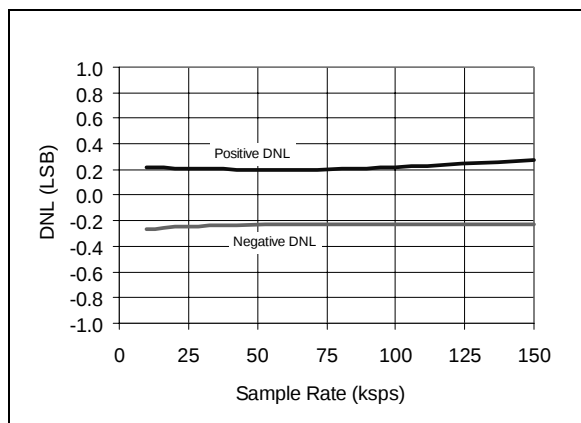


FIGURE 2-8: Differential Nonlinearity (DNL) vs. Sample Rate.

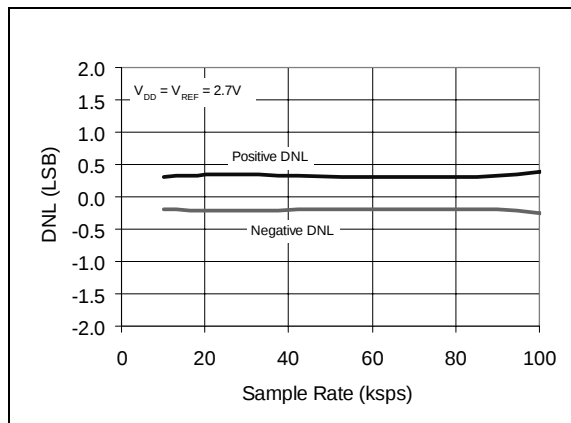


FIGURE 2-11: Differential Nonlinearity (DNL) vs. Sample Rate ($V_{DD} = 2.7V$).

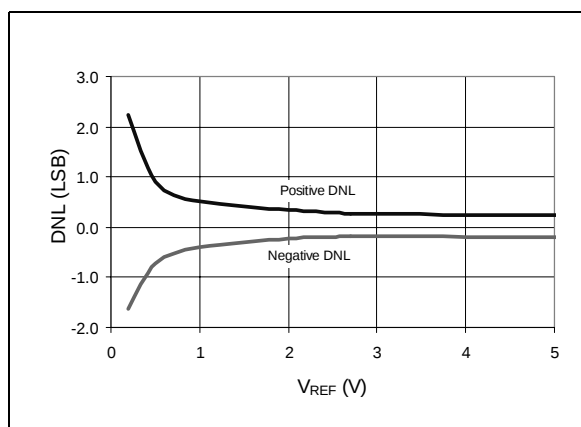


FIGURE 2-9: Differential Nonlinearity (DNL) vs. V_{REF} .

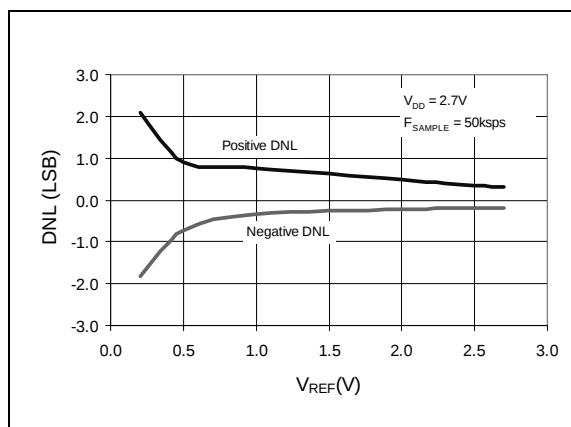


FIGURE 2-12: Differential Nonlinearity (DNL) vs. V_{REF} ($V_{DD} = 2.7V$).

Note: Unless otherwise indicated, $V_{DD} = V_{REF} = 5V$, $V_{SS} = 0V$, $f_{SAMPLE} = 100kps$, $f_{CLK} = 16 \cdot f_{SAMPLE}$, $T_A = 25^\circ C$

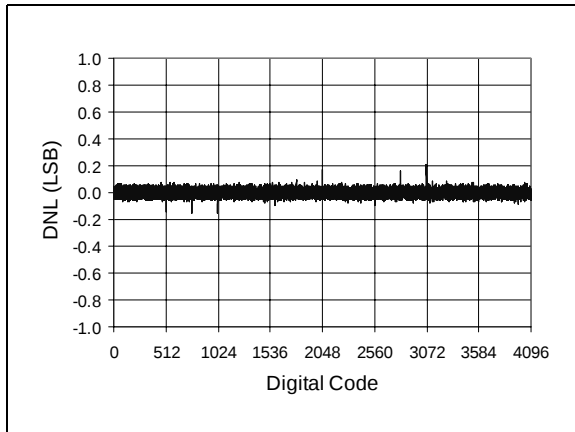


FIGURE 2-13: Differential Nonlinearity (DNL) vs. Code (Representative Part).

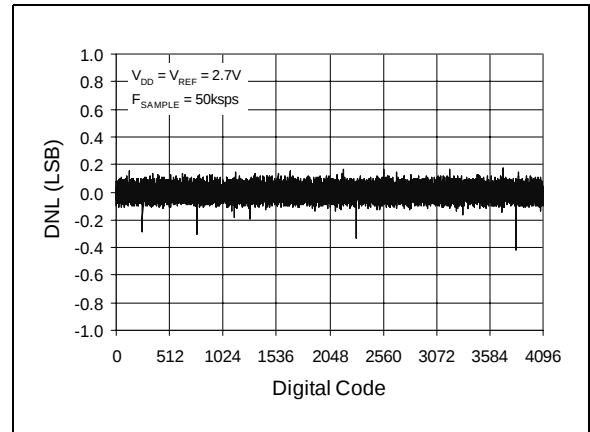


FIGURE 2-16: Differential Nonlinearity (DNL) vs. Code (Representative Part, $V_{DD} = 2.7V$).

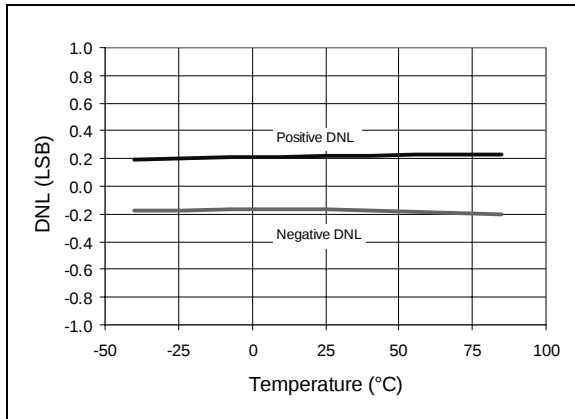


FIGURE 2-14: Differential Nonlinearity (DNL) vs. Temperature.

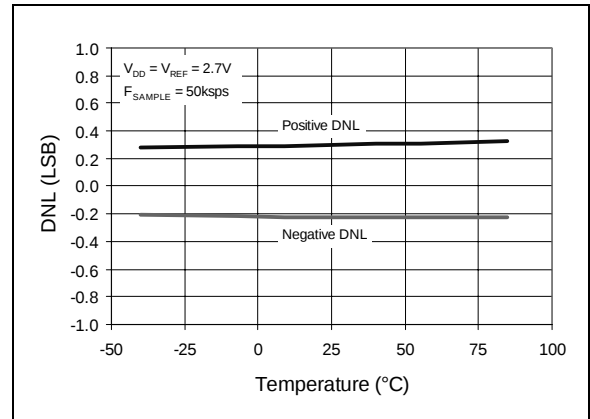


FIGURE 2-17: Differential Nonlinearity (DNL) vs. Temperature ($V_{DD} = 2.7V$).

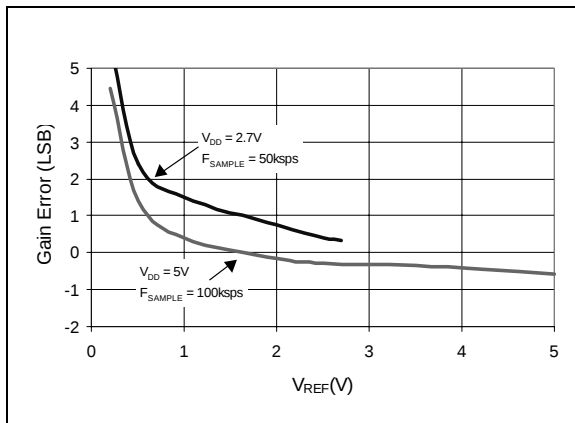


FIGURE 2-15: Gain Error vs. V_{REF} .

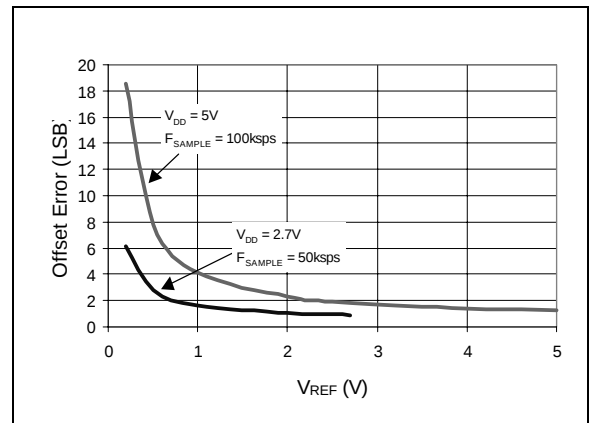


FIGURE 2-18: Offset Error vs. V_{REF} .

Note: Unless otherwise indicated, $V_{DD} = V_{REF} = 5V$, $V_{SS} = 0V$, $f_{SAMPLE} = 100\text{kps}$, $f_{CLK} = 16 \cdot f_{SAMPLE}$, $T_A = 25^\circ\text{C}$

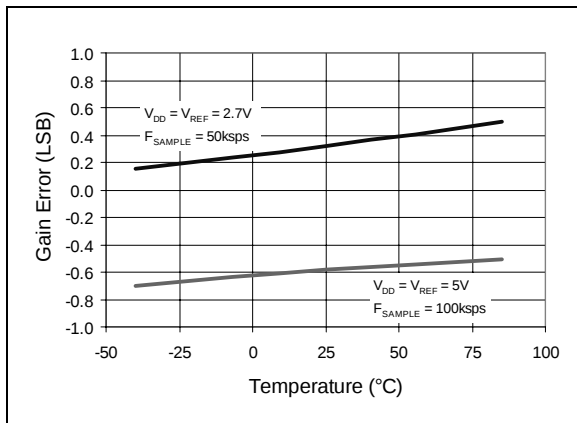


FIGURE 2-19: Gain Error vs. Temperature.

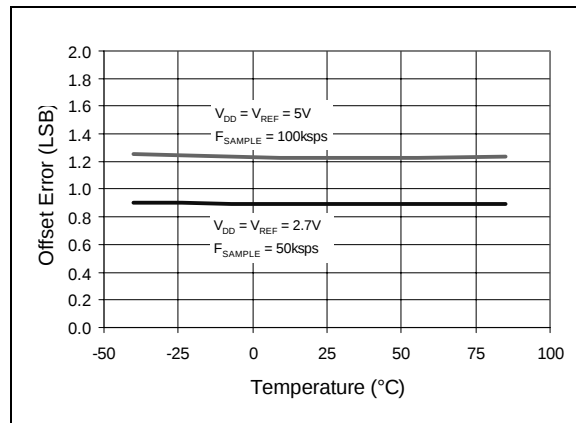


FIGURE 2-22: Offset Error vs. Temperature.

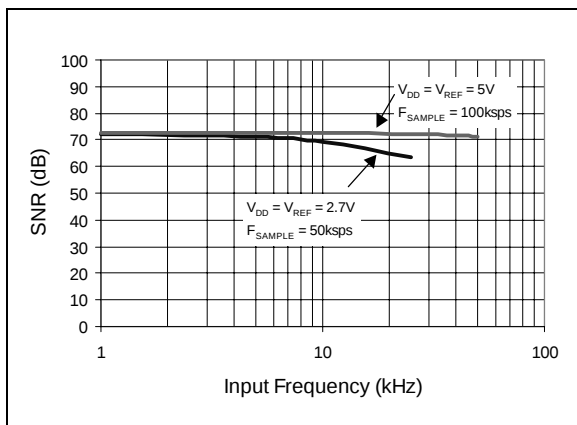


FIGURE 2-20: Signal to Noise Ratio (SNR) vs. Input Frequency.

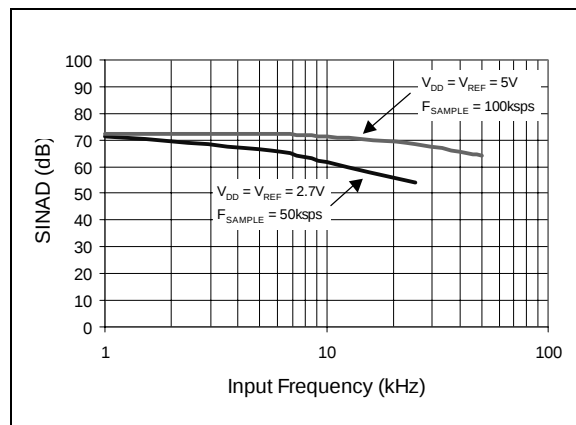


FIGURE 2-23: Signal to Noise and Distortion (SINAD) vs. Input Frequency.

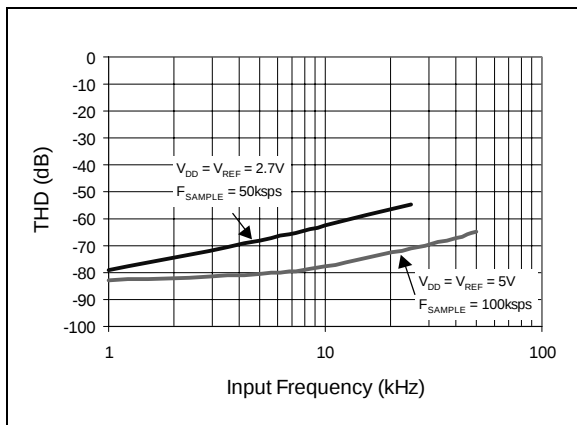


FIGURE 2-21: Total Harmonic Distortion (THD) vs. Input Frequency.

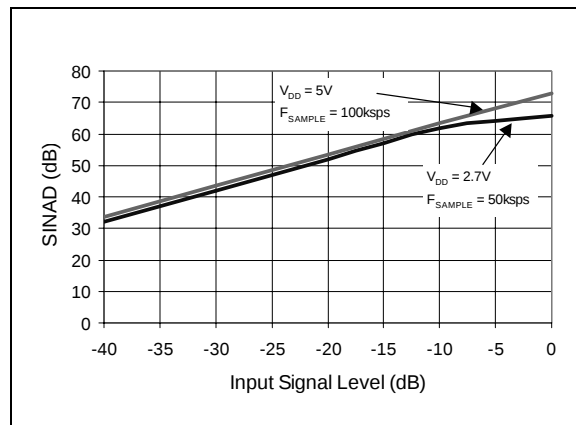


FIGURE 2-24: Signal to Noise and Distortion (SINAD) vs. Input Signal Level.

Note: Unless otherwise indicated, $V_{DD} = V_{REF} = 5V$, $V_{SS} = 0V$, $f_{SAMPLE} = 100kps$, $f_{CLK} = 16 \cdot f_{SAMPLE}$, $T_A = 25^\circ C$

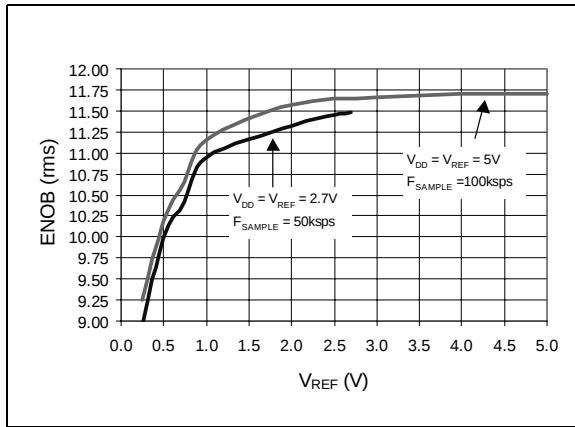


FIGURE 2-25: Effective Number of Bits (ENOB) vs. V_{REF} .

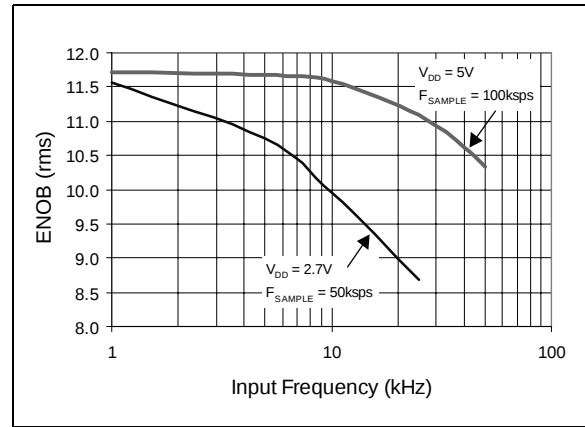


FIGURE 2-28: Effective Number of Bits (ENOB) vs. Input Frequency.

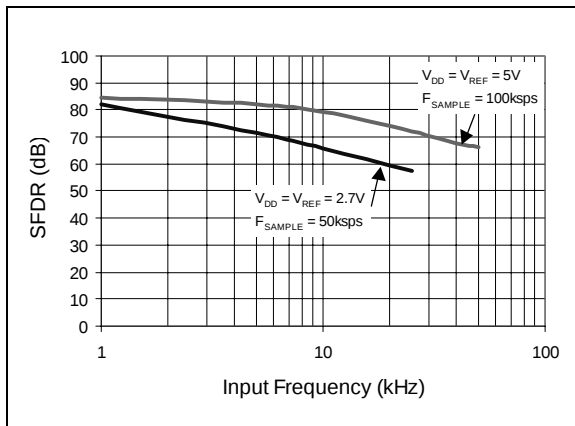


FIGURE 2-26: Spurious Free Dynamic Range (SFDR) vs. Input Frequency.

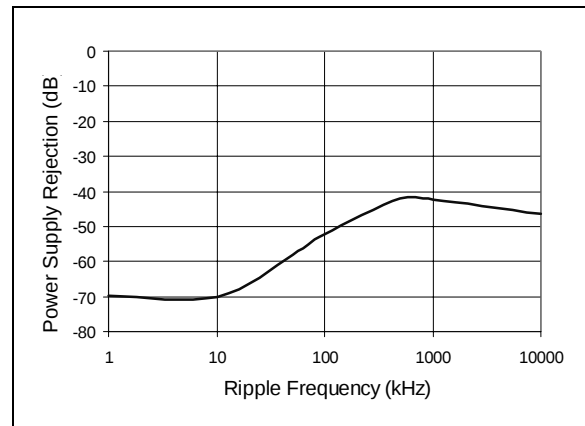


FIGURE 2-29: Power Supply Rejection (PSR) vs. Ripple Frequency.

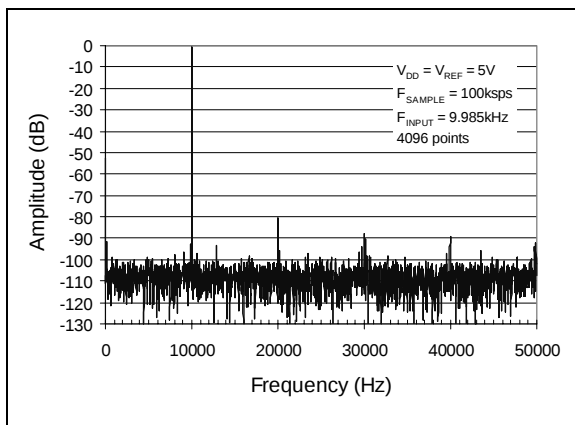


FIGURE 2-27: Frequency Spectrum of 10kHz input (Representative Part).

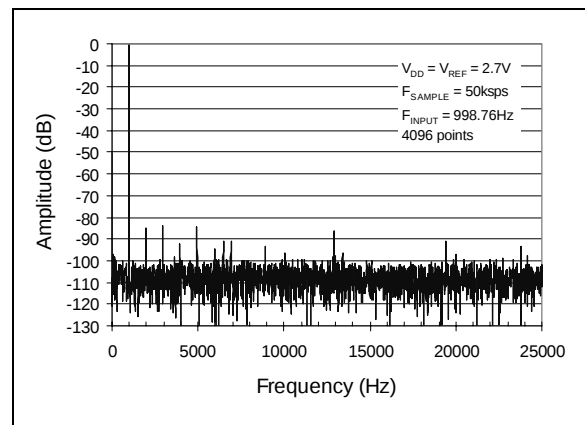


FIGURE 2-30: Frequency Spectrum of 1kHz input (Representative Part, $V_{DD} = 2.7V$).

Note: Unless otherwise indicated, $V_{DD} = V_{REF} = 5V$, $V_{SS} = 0V$, $f_{SAMPLE} = 100ksps$, $f_{CLK} = 16 \cdot f_{SAMPLE}$, $T_A = 25^\circ C$

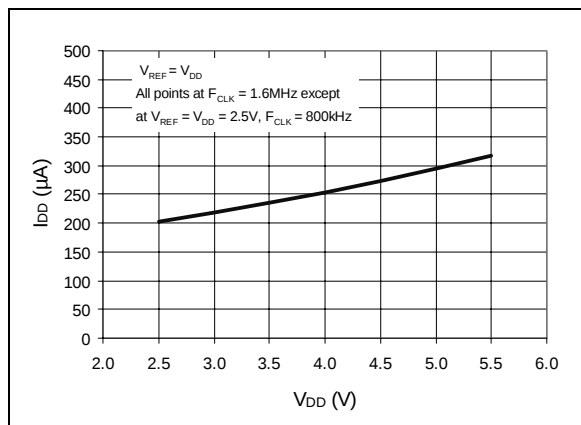


FIGURE 2-31: I_{DD} vs. V_{DD} .

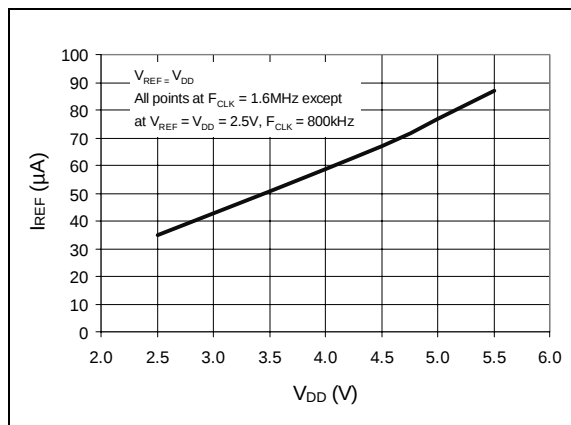


FIGURE 2-34: I_{REF} vs. V_{DD} .

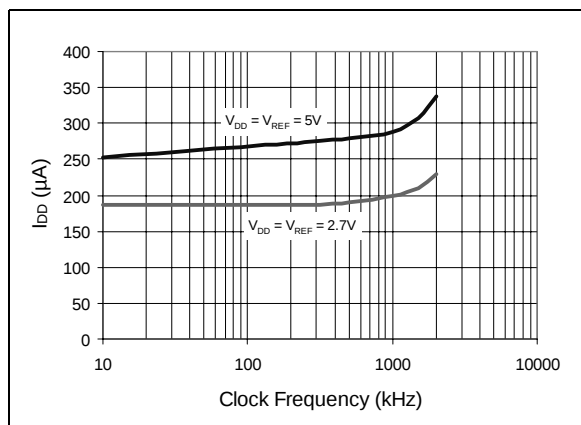


FIGURE 2-32: I_{DD} vs. Clock Frequency.

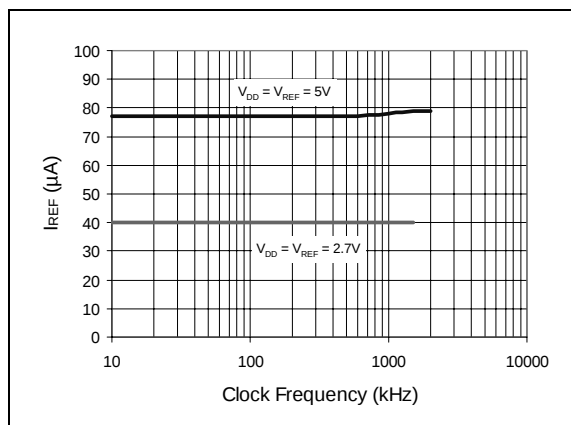


FIGURE 2-35: I_{REF} vs. Clock Frequency.

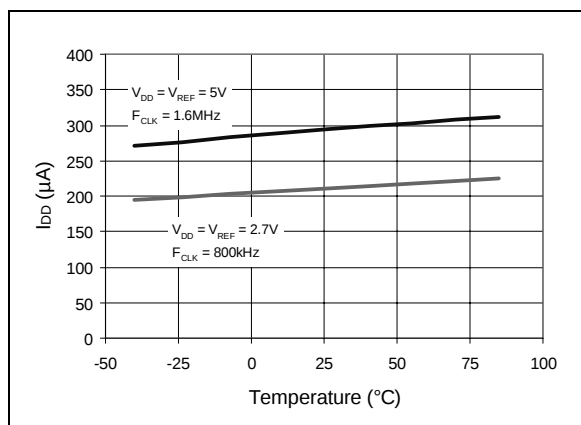


FIGURE 2-33: I_{DD} vs. Temperature.

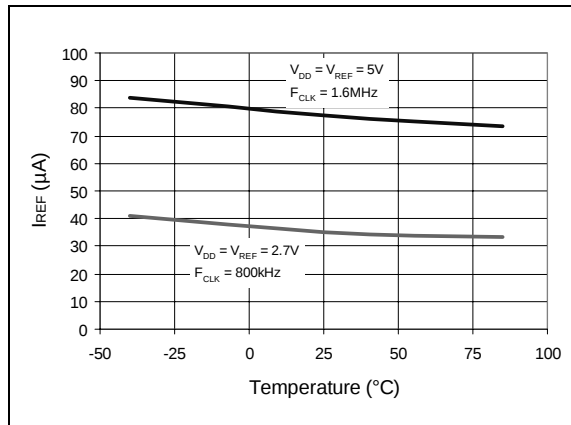


FIGURE 2-36: I_{REF} vs. Temperature.

Note: Unless otherwise indicated, $V_{DD} = V_{REF} = 5V$, $V_{SS} = 0V$, $f_{SAMPLE} = 100kps$, $f_{CLK} = 16*f_{SAMPLE}$, $T_A = 25^{\circ}C$

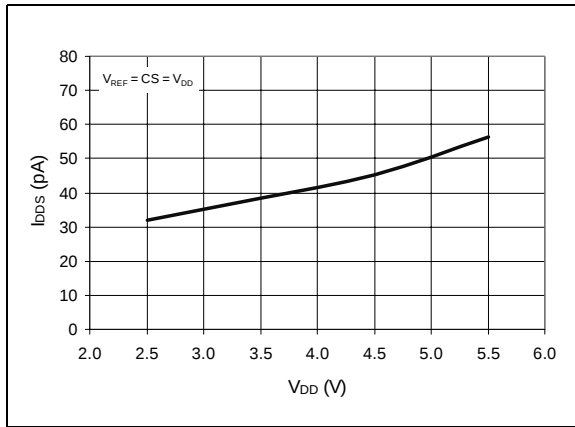


FIGURE 2-37: I_{DDs} vs. V_{DD} .

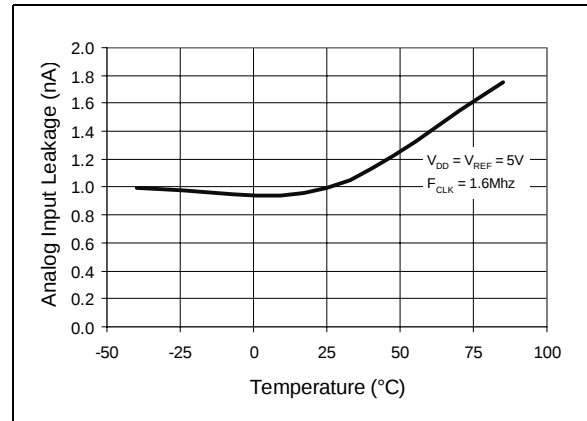


FIGURE 2-39: Analog Input Leakage Current vs. Temperature.

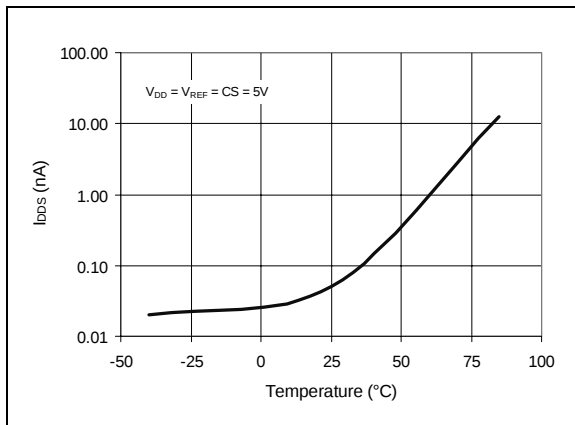


FIGURE 2-38: I_{DDs} vs. Temperature.

3.0 PIN DESCRIPTIONS

3.1 IN+

Positive analog input. This input can vary from $IN-$ to $V_{REF} + IN-$.

3.2 IN-

Negative analog input. This input can vary $\pm 100mV$ from V_{SS} .

3.3 $\overline{CS}/SHDN$ (Chip Select/Shutdown)

The $\overline{CS}/SHDN$ pin is used to initiate communication with the device when pulled low and will end a conversion and put the device in low power standby when pulled high. The $\overline{CS}/SHDN$ pin must be pulled high between conversions.

3.4 CLK (Serial Clock)

The SPI clock pin is used to initiate a conversion and to clock out each bit of the conversion as it takes place. See Section 6.2 for constraints on clock speed.

3.5 DOUT (Serial Data output)

The SPI serial data output pin is used to shift out the results of the A/D conversion. Data will always change on the falling edge of each clock as the conversion takes place.

4.0 DEVICE OPERATION

The MCP3201 A/D Converter employs a conventional SAR architecture. With this architecture, a sample is acquired on an internal sample/hold capacitor for 1.5 clock cycles starting on the first rising edge of the serial clock after CS has been pulled low. Following this sample time, the input switch of the converter opens and the device uses the collected charge on the internal sample and hold capacitor to produce a serial 12-bit digital output code. Conversion rates of 100ksps are possible on the MCP3201. See Section 6.2 for information on minimum clock rates. Communication with the device is done using a 3-wire SPI-compatible interface.

4.1 Analog Inputs

The MCP3201 provides a single pseudo-differential input. The $IN+$ input can range from $IN-$ to V_{REF} ($V_{REF} + IN-$). The $IN-$ input is limited to $\pm 100mV$ from the V_{SS} rail. The $IN-$ input can be used to cancel small signal common-mode noise which is present on both the $IN+$ and $IN-$ inputs.

For the A/D Converter to meet specification, the charge holding capacitor (C_{SAMPLE}) must be given enough time to acquire a 12-bit accurate voltage level during the 1.5 clock cycle sampling period. The analog input model is shown in Figure 4-1.

In this diagram, it is shown that the source impedance (R_S) adds to the internal sampling switch (R_{SS}) impedance, directly affecting the time that is required to charge the capacitor (C_{SAMPLE}). Consequently, a larger source impedance increases the offset, gain, and integral linearity errors of the conversion.

Ideally, the impedance of the signal source should be near zero. This is achievable with an operational amplifier such as the MCP601, which has a closed loop output impedance of tens of ohms. The adverse affects of higher source impedances are shown in Figure 4-2.

If the voltage level of $IN+$ is equal to or less than $IN-$, the resultant code will be 000h. If the voltage at $IN+$ is equal to or greater than $\{[V_{REF} + (IN-)] - 1 \text{ LSB}\}$, then the output code will be FFFh. If the voltage level at $IN-$ is more than 1 LSB below V_{SS} , then the voltage level at the $IN+$ input will have to go below V_{SS} to see the 000h output code. Conversely, if $IN-$ is more than 1 LSB above V_{SS} , then the FFFh code will not be seen unless the $IN+$ input level goes above V_{REF} level.

4.2 Reference Input

The reference input (V_{REF}) determines the analog input voltage range and the LSB size, as shown below.

$$LSB \text{ Size} = \frac{V_{REF}}{4096}$$

As the reference input is reduced, the LSB size is reduced accordingly. The theoretical digital output code produced by the A/D Converter is a function of the analog input signal and the reference input as shown below.

$$Digital \text{ Output Code} = \frac{4096 * V_{IN}}{V_{REF}}$$

where:

$$V_{IN} = \text{analog input voltage} = V(IN+) - V(IN-)$$

$$V_{REF} = \text{reference voltage}$$

When using an external voltage reference device, the system designer should always refer to the manufacturer's recommendations for circuit layout. Any instability in the operation of the reference device will have a direct effect on the operation of the A/D Converter.

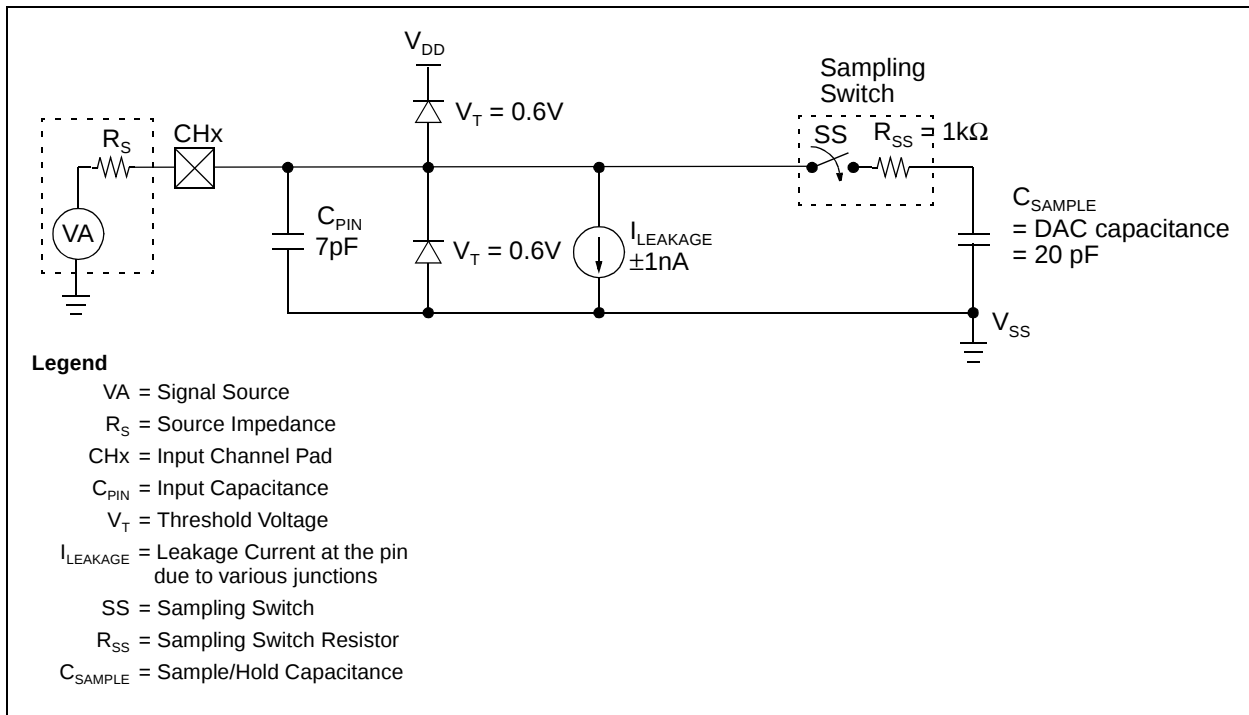


FIGURE 4-1: Analog Input Model.

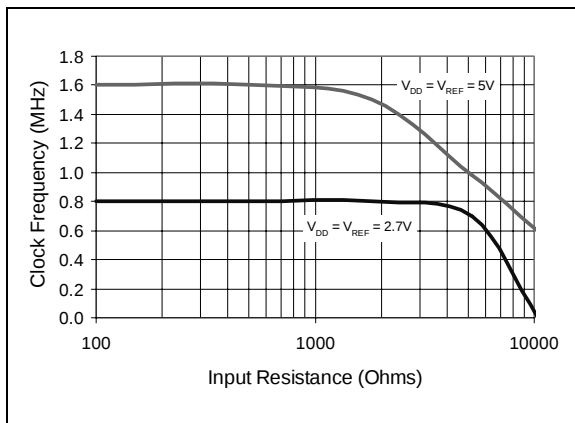


FIGURE 4-2: Maximum Clock Frequency vs. Input Resistance (R_S) to maintain less than a 0.1 LSB deviation in INL from nominal conditions.

5.0 SERIAL COMMUNICATIONS

Communication with the device is done using a standard SPI-compatible serial interface. Initiating communication with the MCP3201 begins with the $\overline{CS}$ going low. If the device was powered up with the $\overline{CS}$ pin low, it must be brought high and back low to initiate communication. The device will begin to sample the analog input on the first rising edge after $\overline{CS}$ goes low. The sample period will end in the falling edge of the second clock, at which time the device will output a low null bit. The next 12 clocks will output the result of the conver-

sion with MSB first, as shown in Figure 5-1. Data is always output from the device on the falling edge of the clock. If all 12 data bits have been transmitted and the device continues to receive clocks while the $\overline{CS}$ is held low, the device will output the conversion result LSB first, as shown in Figure 5-2. If more clocks are provided to the device while $\overline{CS}$ is still low (after the LSB first data has been transmitted), the device will clock out zeros indefinitely.

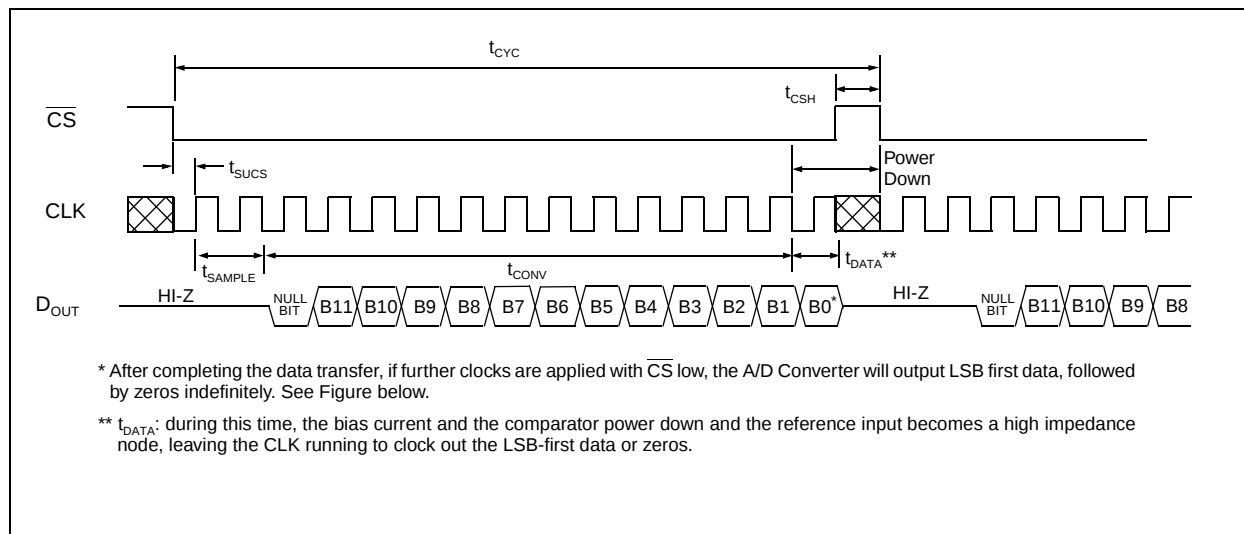


FIGURE 5-1: Communication with MCP3201 using MSB first Format.

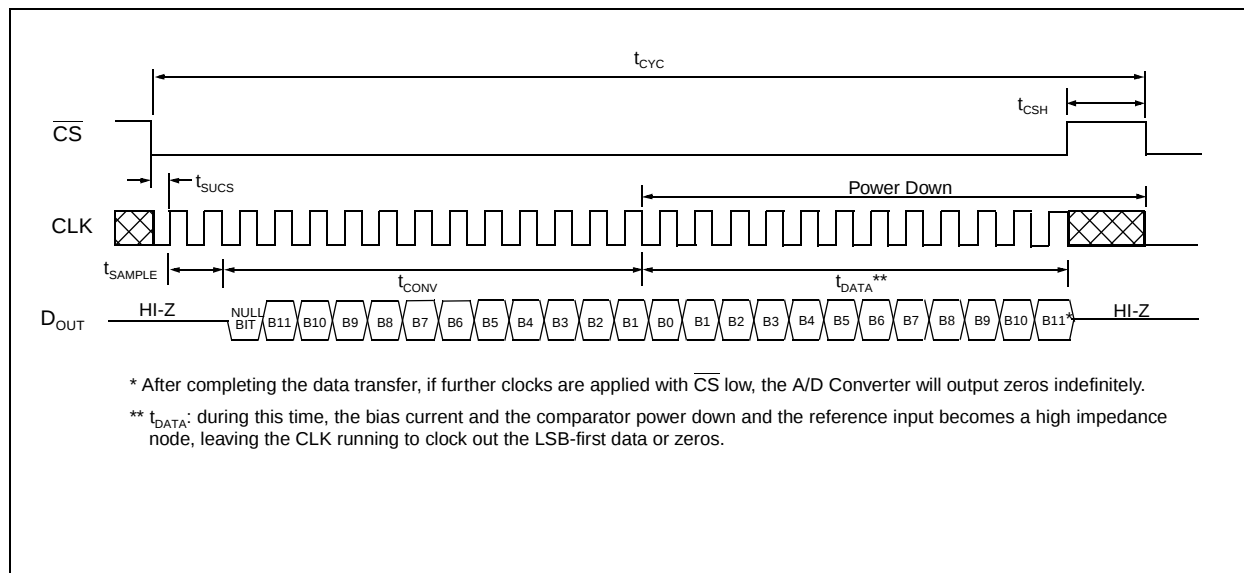


FIGURE 5-2: Communication with MCP3201 using LSB first Format.

6.0 APPLICATIONS INFORMATION

6.1 Using the MCP3201 with Microcontroller SPI Ports

With most microcontroller SPI ports, it is required to clock out eight bits at a time. If this is the case, it will be necessary to provide more clocks than are required for the MCP3201. As an example, Figure 6-1 and Figure 6-2 show how the MCP3201 can be interfaced to a microcontroller with a standard SPI port. Since the MCP3201 always clocks data out on the falling edge of clock, the MCU SPI port must be configured to match this operation. SPI Mode 0,0 (clock idles low) and SPI Mode 1,1 (clock idles high) are both compatible with the MCP3201. Figure 6-1 depicts the operation shown in SPI Mode 0,0, which requires that the CLK from the microcontroller idles in the 'low' state. As shown in the diagram, the MSB is clocked out of the A/D Converter on the falling edge of the third clock pulse. After the first eight clocks have been sent to the device, the microcontroller's receive buffer will contain two unknown bits

(the output is at high impedance for the first two clocks), the null bit and the highest order five bits of the conversion. After the second eight clocks have been sent to the device, the MCU receive register will contain the lowest order seven bits and the B1 bit repeated as the A/D Converter has begun to shift out LSB first data with the extra clock. Typical procedure would then call for the lower order byte of data to be shifted right by one bit to remove the extra B1 bit. The B7 bit is then transferred from the high order byte to the lower order byte, and then the higher order byte is shifted one bit to the right as well. Easier manipulation of the converted data can be obtained by using this method.

Figure 6-2 shows the same thing in SPI Mode 1,1 which requires that the clock idles in the high state. As with mode 0,0, the A/D Converter outputs data on the falling edge of the clock and the MCU latches data from the A/D Converter in on the rising edge of the clock.

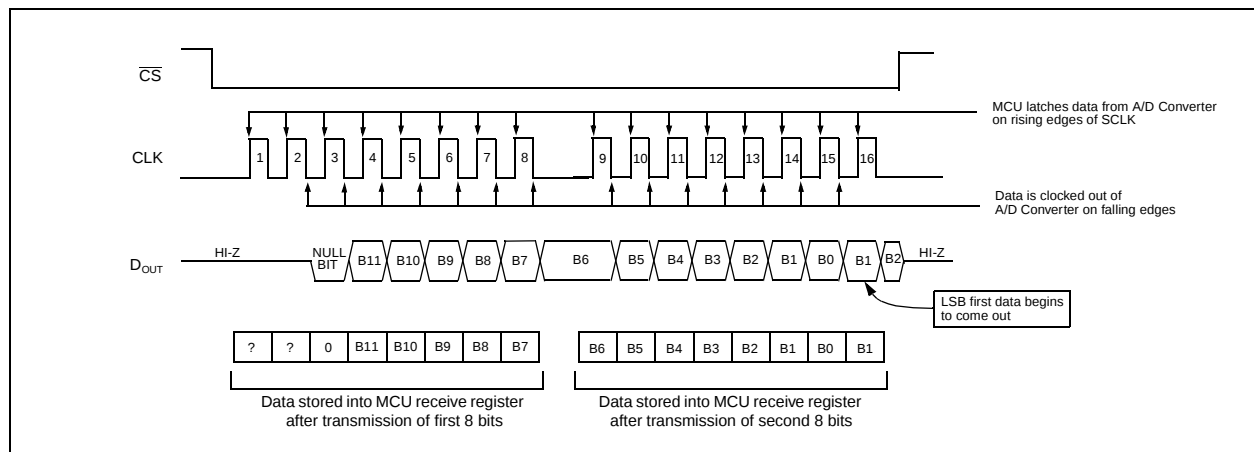


FIGURE 6-1: SPI Communication using 8-bit segments (Mode 0,0: SCLK idles low).

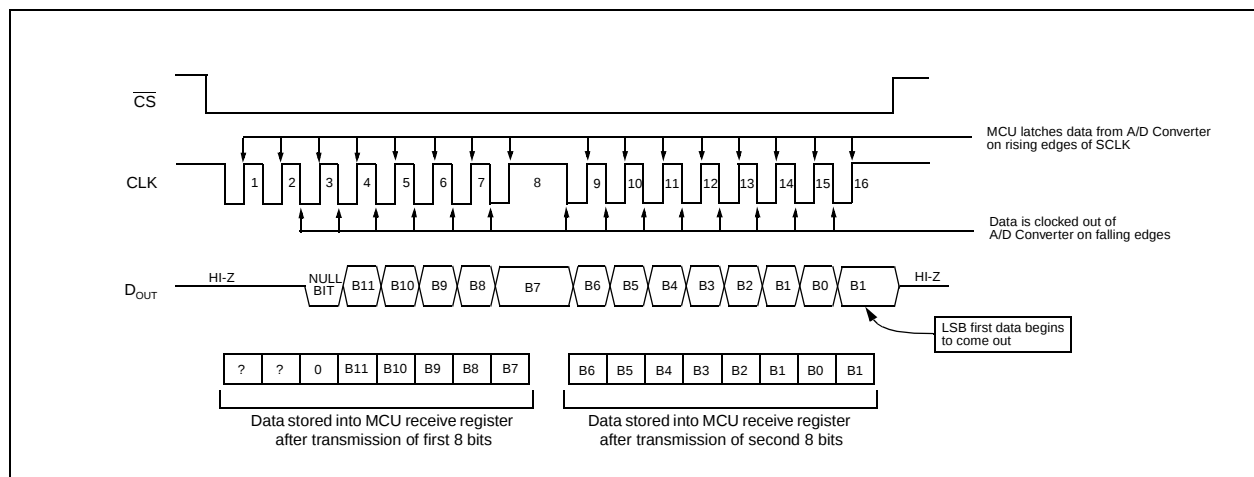
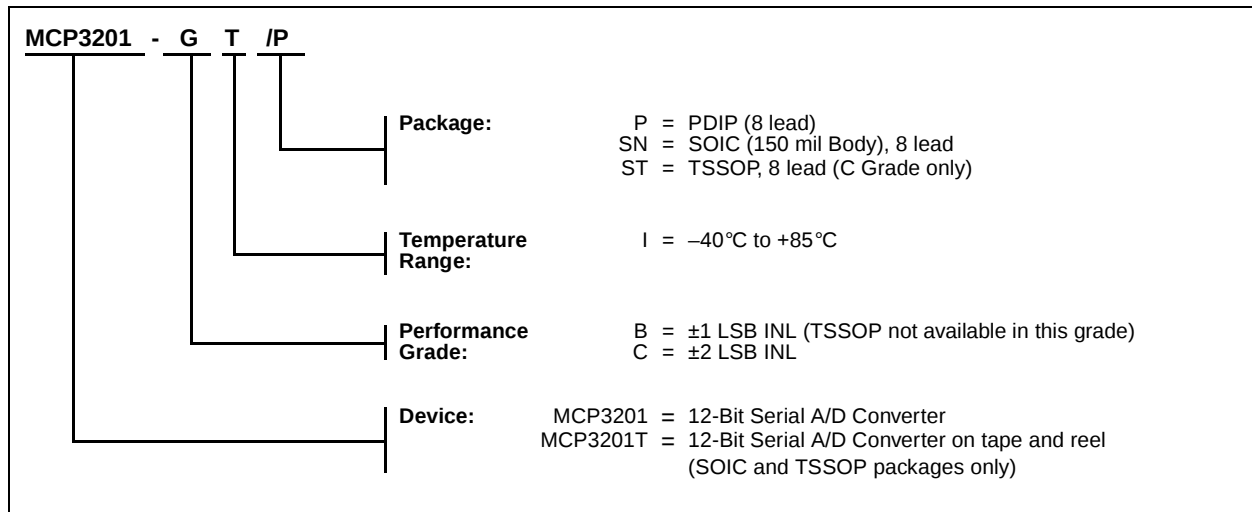


FIGURE 6-2: SPI Communication using 8-bit segments (Mode 1,1: SCLK idles high).

MCP3201 PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.



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Dayton

Microchip Technology Inc.
Two Prestige Place, Suite 150
Miamisburg, OH 45342
Tel: 937-291-1654 Fax: 937-291-9175

Detroit

Microchip Technology Inc.
Tri-Atria Office Building
32255 Northwestern Highway, Suite 190
Farmington Hills, MI 48334
Tel: 248-538-2250 Fax: 248-538-2260

Los Angeles

Microchip Technology Inc.
18201 Von Karman, Suite 1090
Irvine, CA 92612
Tel: 949-263-1888 Fax: 949-263-1338

New York

Microchip Technology Inc.
150 Motor Parkway, Suite 202
Hauppauge, NY 11788
Tel: 631-273-5305 Fax: 631-273-5335

San Jose

Microchip Technology Inc.
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950 Fax: 408-436-7955

AMERICAS (continued)

Toronto

Microchip Technology Inc.
5925 Airport Road, Suite 200
Mississauga, Ontario L4V 1W1, Canada
Tel: 905-405-6279 Fax: 905-405-6253

ASIA/PACIFIC

Hong Kong

Microchip Asia Pacific
Unit 2101, Tower 2
Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2-401-1200 Fax: 852-2-401-3431

Beijing

Microchip Technology, Beijing
Unit 915, 6 Chaoyangmen Bei Dajie
Dong Erhuan Road, Dongcheng District
New China Hong Kong Manhattan Building
Beijing 100027 PRC
Tel: 86-10-85282100 Fax: 86-10-85282104

India

Microchip Technology Inc.
India Liaison Office
No. 6, Legacy, Convent Road
Bangalore 560 025, India
Tel: 91-80-229-0061 Fax: 91-80-229-0062

Japan

Microchip Technology Intl. Inc.
Benex S-1 6F
3-18-20, Shinyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa 222-0033 Japan
Tel: 81-45-471-6166 Fax: 81-45-471-6122

Korea

Microchip Technology Korea
168-1, Youngbo Bldg. 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea
Tel: 82-2-554-7200 Fax: 82-2-558-5934

Shanghai

Microchip Technology
RM 406 Shanghai Golden Bridge Bldg.
2077 Yan'an Road West, Hong Qiao District
Shanghai, PRC 200335
Tel: 86-21-6275-5700 Fax: 86 21-6275-5060

ASIA/PACIFIC (continued)

Singapore

Microchip Technology Singapore Pte Ltd.
200 Middle Road
#07-02 Prime Centre
Singapore 188980
Tel: 65-334-8870 Fax: 65-334-8850

Taiwan, R.O.C

Microchip Technology Taiwan
10F-1C 207
Tung Hua North Road
Taipei, Taiwan, ROC
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

United Kingdom

Arizona Microchip Technology Ltd.
505 Eskdale Road
Wokingham
Berkshire, England RG41 5TU
Tel: 44 118 921 5858 Fax: 44-118 921-5835

Denmark

Microchip Technology Denmark ApS
Regus Business Centre
Lautrup høj 1-3
Ballerup DK-2750 Denmark
Tel: 45 4420 9895 Fax: 45 4420 9910

France

Arizona Microchip Technology SARL
Parc d'Activite du Moulin de Massy
43 Rue du Saule Trapu
Batiment A - 1er Etage
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

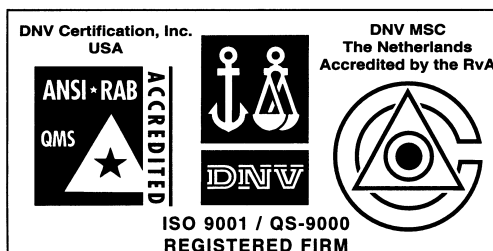
Germany

Arizona Microchip Technology GmbH
Gustav-Heinemann-Ring 125
D-81739 München, Germany
Tel: 49-89-627-144 0 Fax: 49-89-627-144-44

Italy

Arizona Microchip Technology SRL
Centro Direzionale Colleoni
Palazzo Taurus 1 V. Le Colleoni 1
20041 Agrate Brianza
Milan, Italy
Tel: 39-039-65791-1 Fax: 39-039-6899883

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