

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

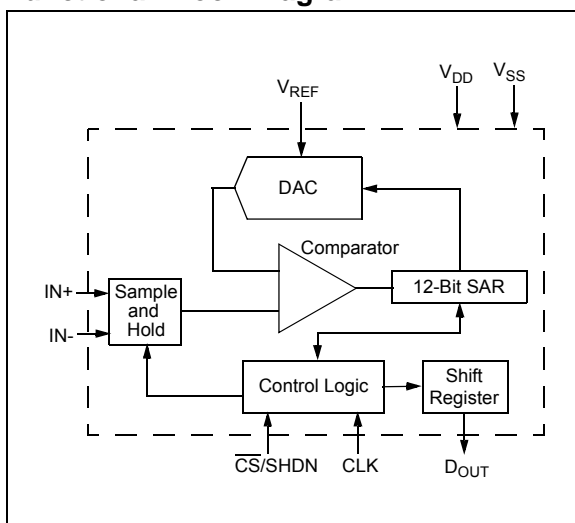
Features

- 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
- 100 ksp/s Maximum Sampling Rate at $V_{DD} = 5V$
- 50 ksp/s Maximum Sampling Rate at $V_{DD} = 2.7V$
- Low-Power CMOS Technology
- 500 nA Typical Standby Current, 2 μA Maximum
- 400 μA Maximum Active Current at 5V
- Industrial Temp Range: $-40^{\circ}C$ to $+85^{\circ}C$
- 8-pin MSOP, PDIP, SOIC and TSSOP Packages

Applications

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

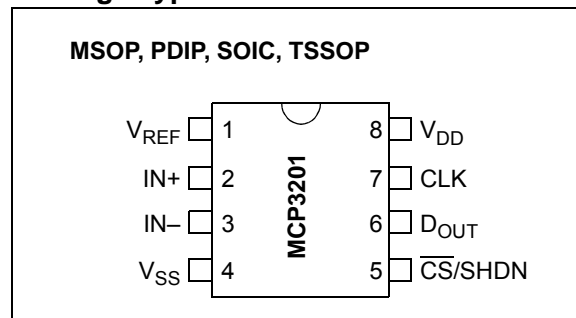
Functional Block Diagram



Description

The Microchip Technology Inc. MCP3201 device 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 100 ksp/s at a clock rate of 1.6 MHz. The MCP3201 device operates over a broad voltage range (2.7V-5.5V). Low-current design permits operation with typical standby and active currents of only 500 nA and 300 μA , respectively. The device is offered in 8-pin MSOP, PDIP, TSSOP and 150 mil SOIC packages.

Package Types



MCP3201

NOTES:

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 |
| ESD protection on all pins (HBM) | > 4 kV |

†**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.

ELECTRICAL CHARACTERISTICS

Electrical Specifications: All parameters apply at $V_{DD} = 5V$, $V_{SS} = 0V$, $V_{REF} = 5V$, $T_A = -40°C$ to $+85°C$, $f_{SAMPLE} = 100$ ksps, and $f_{CLK} = 16 * f_{SAMPLE}$, unless otherwise noted.

| Parameter | Sym | 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 | THD | — | -82 | — | dB | $V_{IN} = 0.1V$ to $4.9V@1$ kHz |
| Signal to Noise and Distortion (SINAD) | SINAD | — | 72 | — | dB | $V_{IN} = 0.1V$ to $4.9V@1$ kHz |
| Spurious Free Dynamic Range | SFDR | — | 86 | — | dB | $V_{IN} = 0.1V$ to $4.9V@1$ kHz |
| Reference Input: | | | | | | |
| Voltage Range | | 0.25 | — | V_{DD} | V | Note 2 |
| Current Drain | | — | 100 .001 | 150 3 | μA μA | $CS = V_{DD} = 5V$ |
| Analog Inputs: | | | | | | |
| Input Voltage Range (IN+) | IN+ | IN- | — | $V_{REF} + IN-$ | V | |
| Input Voltage Range (IN-) | IN- | $V_{SS} - 100$ | | $V_{SS} + 100$ | mV | |
| Leakage Current | | — | 0.001 | ± 1 | μA | |
| Switch Resistance | R_{SS} | — | 1K | — | W | See Figure 4-1 |
| Sample Capacitor | C_{SAMPLE} | — | 20 | — | pF | See Figure 4-1 |
| 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 | |

Note 1: This parameter is established 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 10 kHz can affect linearity performance, especially at elevated temperatures. See [Section 6.2 “Maintaining Minimum Clock Speed”](#) for more information.

MCP3201

ELECTRICAL CHARACTERISTICS (CONTINUED)

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

| Parameter | Sym | Min | Typ | Max | Units | Conditions |
|---|----------------------|-----|------------|------------|--------------------|--|
| High Level Output Voltage | V_{OH} | 4.1 | — | — | V | $I_{OH} = -1$ mA, $V_{DD} = 4.5V$ |
| Low Level Output Voltage | V_{OL} | — | — | 0.4 | V | $I_{OL} = 1$ mA, $V_{DD} = 4.5V$ |
| 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) $T_A = +25^{\circ}C$, $f = 1$ 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 | |
| \overline{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 |
| \overline{CS} Rise To Output Disable | t_{DIS} | — | — | 100 | ns | See Test Circuits, Figure 1-2 (Note 1) |
| \overline{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 | $\overline{CS} = V_{DD} = 5.0V$ |

Note 1: This parameter is established 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 10 kHz can affect linearity performance, especially at elevated temperatures. See [Section 6.2 "Maintaining Minimum Clock Speed"](#) for more information.

TEMPERATURE CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated, $V_{DD} = +2.7V$ to $+5.5V$, $V_{SS} = GND$.

| Parameters | Sym | Min | Typ | Max | Units | Conditions |
|------------------------------------|---------------|-----|-------|------|---------------|------------|
| Temperature Ranges | | | | | | |
| Specified Temperature Range | T_A | -40 | — | +85 | $^{\circ}C$ | |
| Operating Temperature Range | T_A | -40 | — | +85 | $^{\circ}C$ | |
| Storage Temperature Range | T_A | -65 | — | +150 | $^{\circ}C$ | |
| Thermal Package Resistances | | | | | | |
| Thermal Resistance, 8L-MSOP | θ_{JA} | — | 211 | — | $^{\circ}C/W$ | |
| Thermal Resistance, 8L-PDIP | θ_{JA} | — | 89.5 | — | $^{\circ}C/W$ | |
| Thermal Resistance, 8L-SOIC | θ_{JA} | — | 149.5 | — | $^{\circ}C/W$ | |
| Thermal Resistance, 8L-TSSOP | θ_{JA} | — | 139 | — | $^{\circ}C/W$ | |

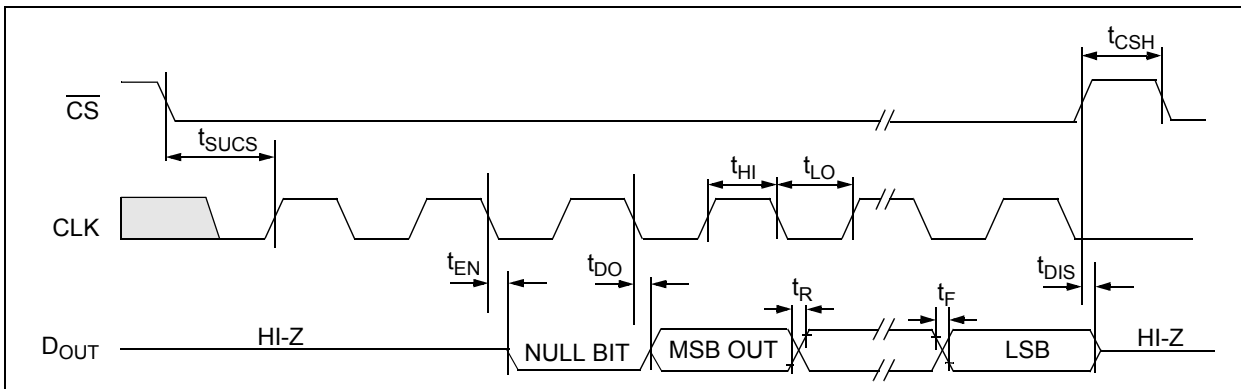


FIGURE 1-1: Serial Timing.

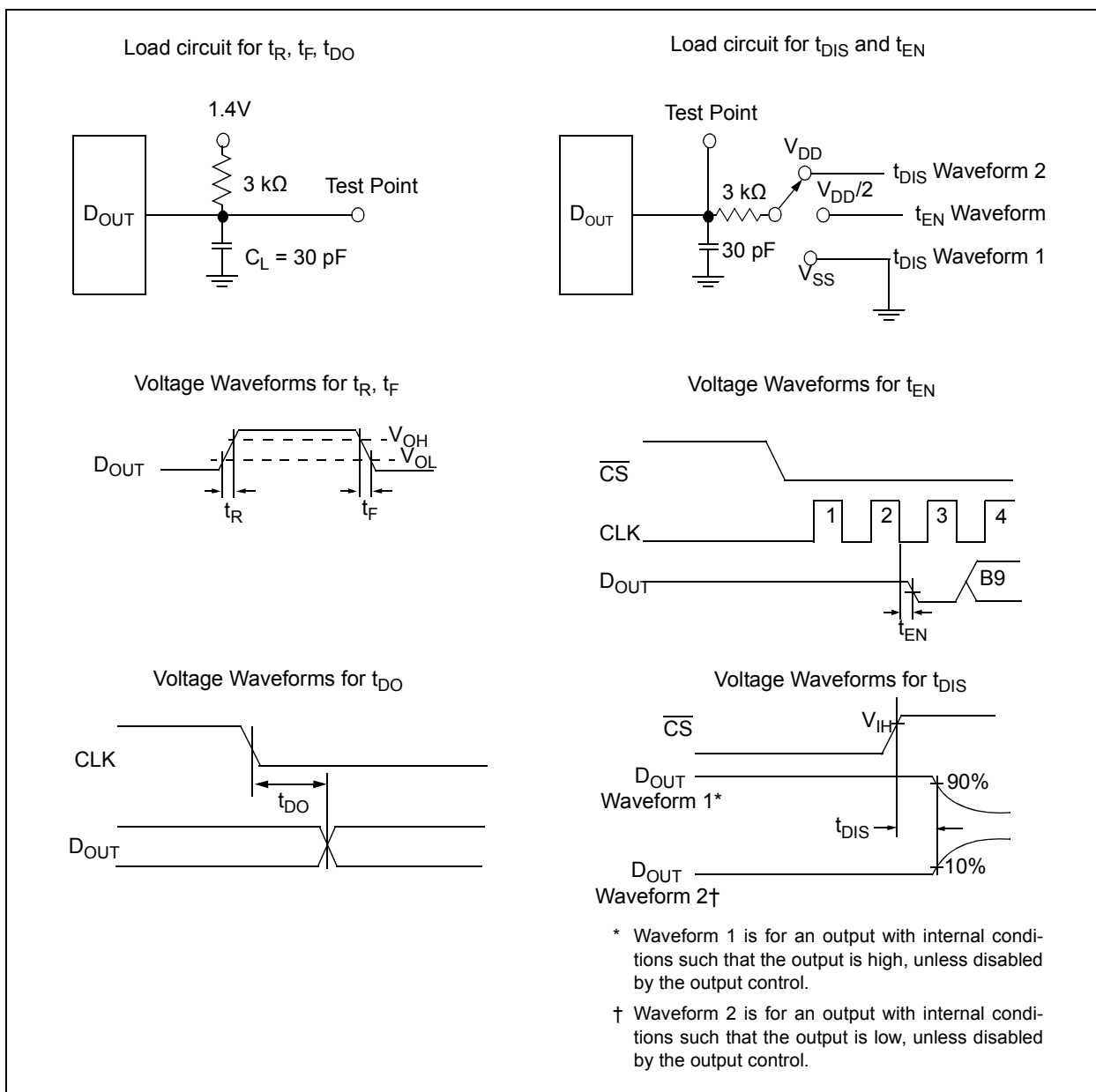


FIGURE 1-2: Test Circuits.

MCP3201

NOTES:

2.0 TYPICAL PERFORMANCE CHARACTERISTICS

Note: The graphs provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

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

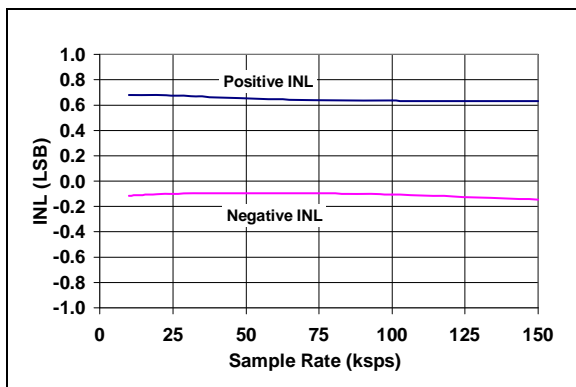


FIGURE 2-1: Integral Nonlinearity (INL) vs. Sample Rate.

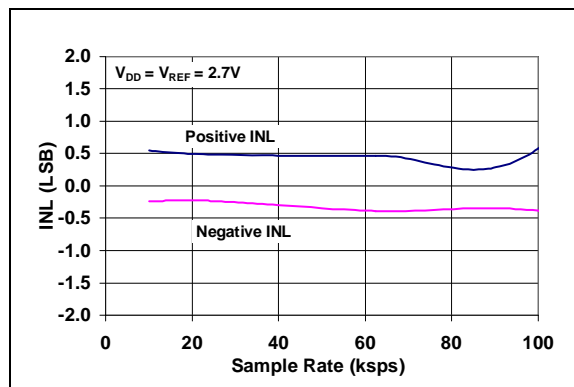


FIGURE 2-4: Integral Nonlinearity (INL) vs. Sample Rate ($V_{DD} = 2.7V$).

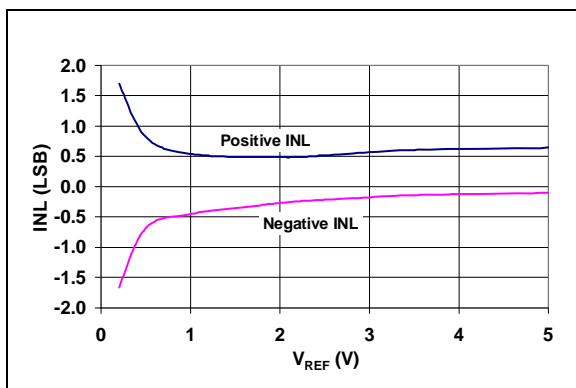


FIGURE 2-2: Integral Nonlinearity (INL) vs. V_{REF} .

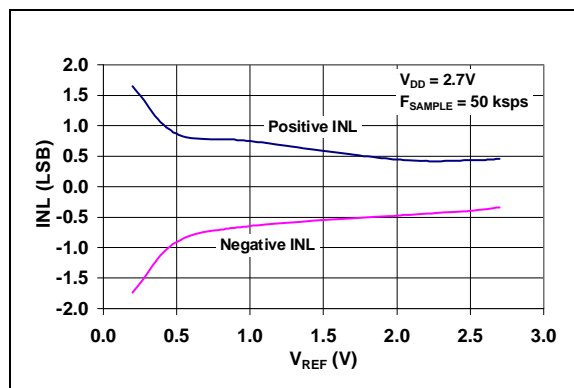


FIGURE 2-5: Integral Nonlinearity (INL) vs. V_{REF} ($V_{DD} = 2.7V$).

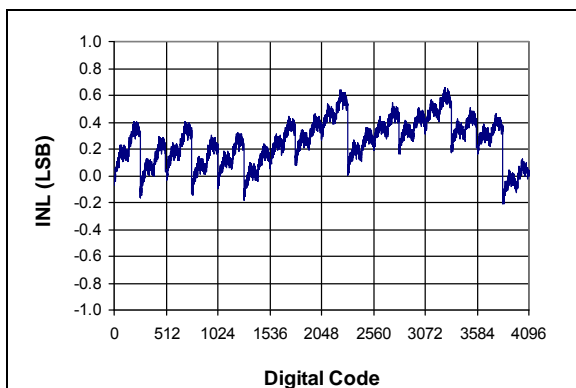


FIGURE 2-3: Integral Nonlinearity (INL) vs. Code (Representative Part).

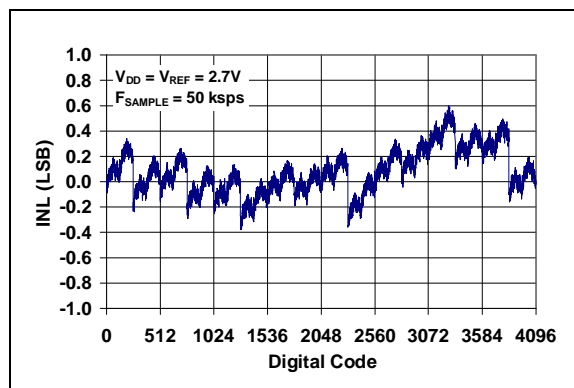


FIGURE 2-6: Integral Nonlinearity (INL) vs. Code (Representative Part, $V_{DD} = 2.7V$).

MCP3201

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

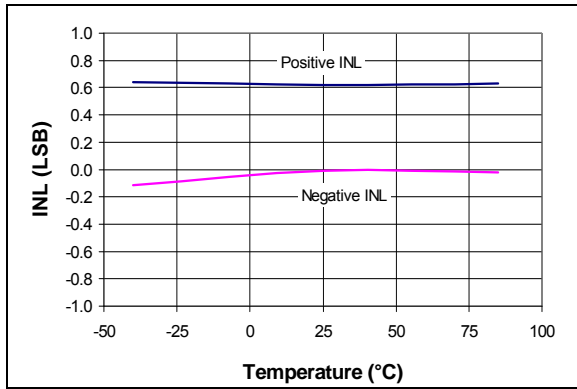


FIGURE 2-7: Integral Nonlinearity (INL) vs. Temperature.

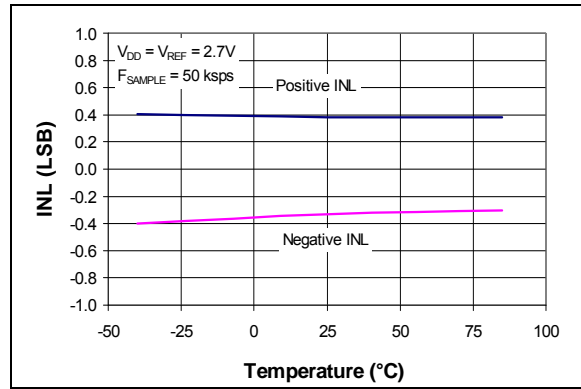


FIGURE 2-10: Integral Nonlinearity (INL) vs. Temperature ($V_{DD} = 2.7V$).

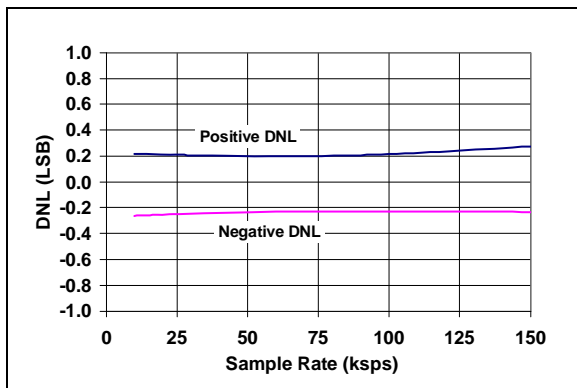


FIGURE 2-8: Differential Nonlinearity (DNL) vs. Sample Rate.

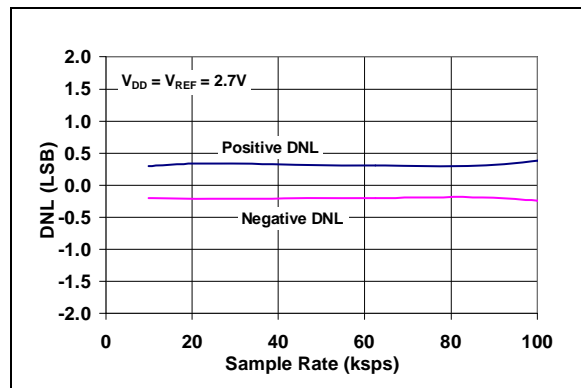


FIGURE 2-11: Differential Nonlinearity (DNL) vs. Sample Rate ($V_{DD} = 2.7V$).

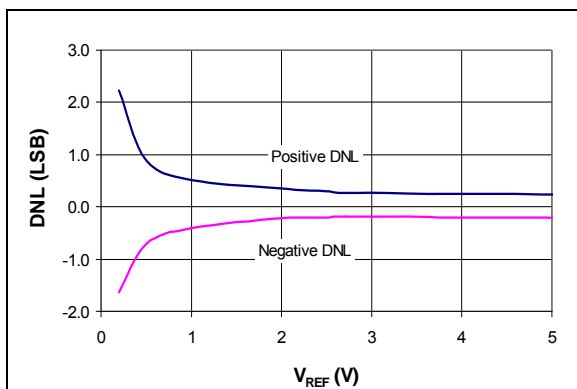


FIGURE 2-9: Differential Nonlinearity (DNL) vs. V_{REF}

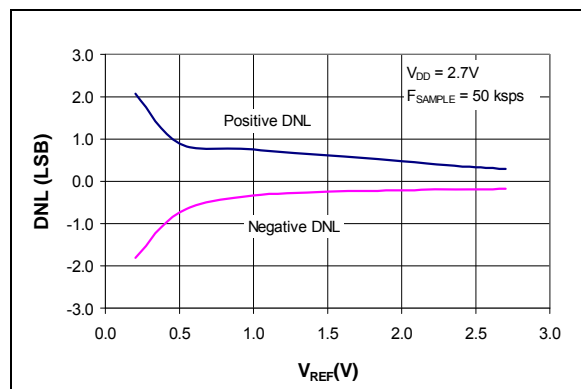


FIGURE 2-12: Differential Nonlinearity (DNL) vs. V_{REF} ($V_{DD} = 2.7V$).

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

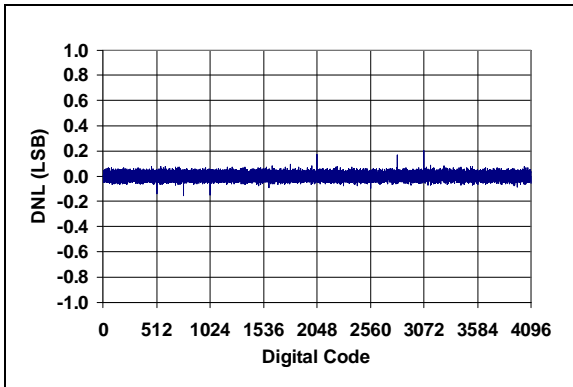


FIGURE 2-13: Differential Nonlinearity (DNL) vs. Code (Representative Part).

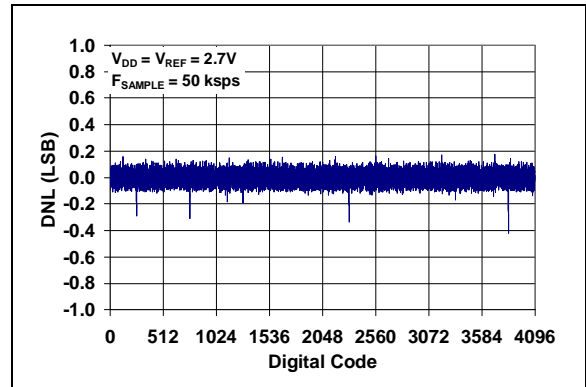


FIGURE 2-16: Differential Nonlinearity (DNL) vs. Code (Representative Part, $V_{DD} = 2.7V$).

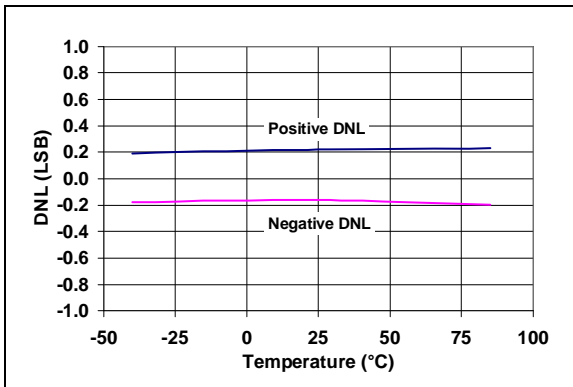


FIGURE 2-14: Differential Nonlinearity (DNL) vs. Temperature.

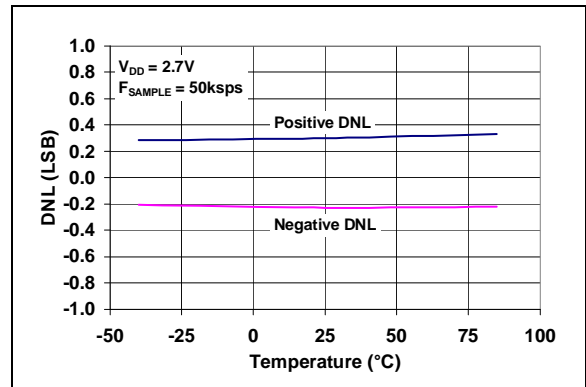


FIGURE 2-17: Differential Nonlinearity (DNL) vs. Temperature ($V_{DD} = 2.7V$).

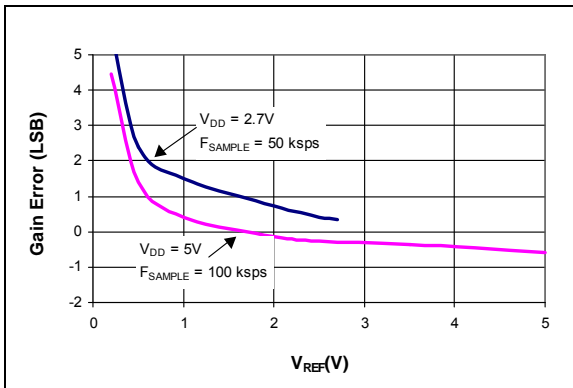


FIGURE 2-15: Gain Error vs. V_{REF}

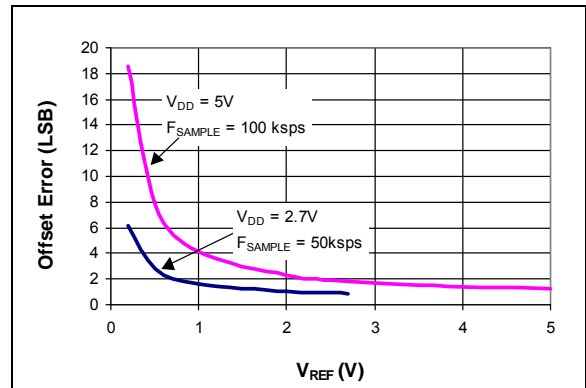


FIGURE 2-18: Offset Error vs. V_{REF}

MCP3201

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

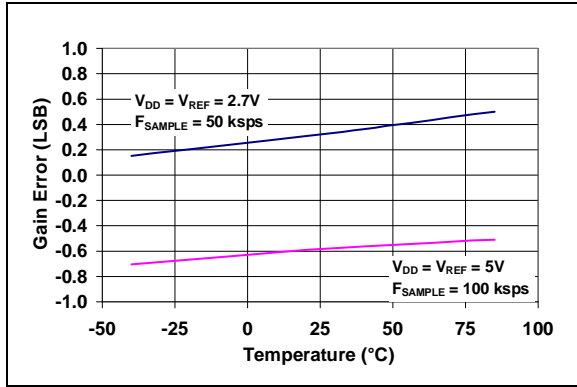


FIGURE 2-19: Gain Error vs. Temperature.

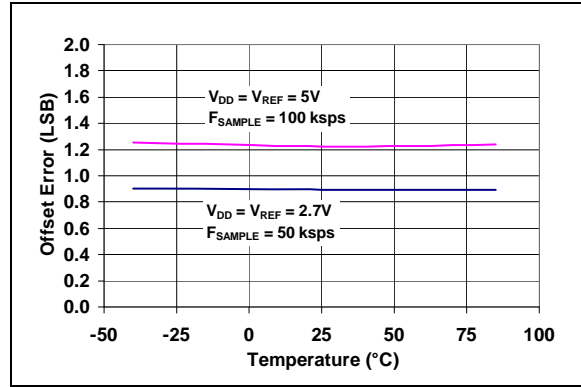


FIGURE 2-22: Offset Error vs. Temperature.

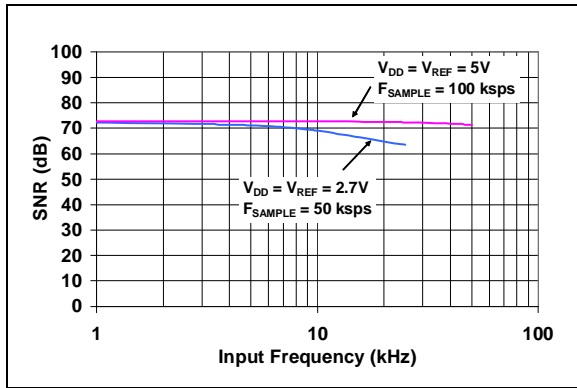


FIGURE 2-20: Signal-to-Noise Ratio (SNR) vs. Input Frequency.

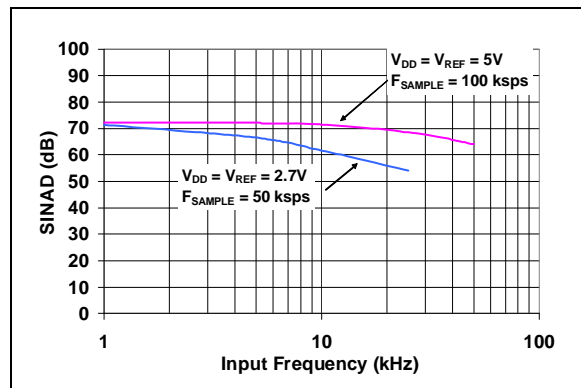


FIGURE 2-23: Signal-to-Noise and Distortion (SINAD) vs. Input Frequency.

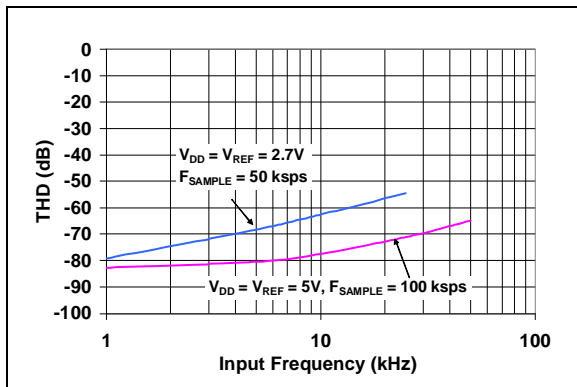


FIGURE 2-21: Total Harmonic Distortion (THD) vs. Input Frequency.

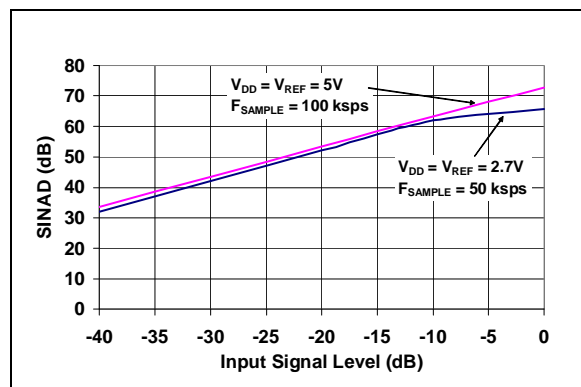


FIGURE 2-24: Signal-to-Noise and Distortion (SINAD) vs. Input Signal Level.

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

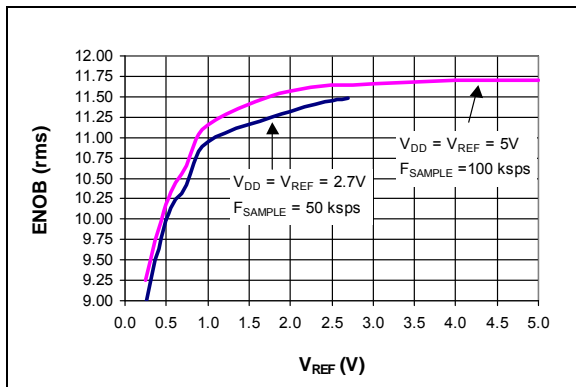


FIGURE 2-25: Effective Number of Bits (ENOB) vs. V_{REF}

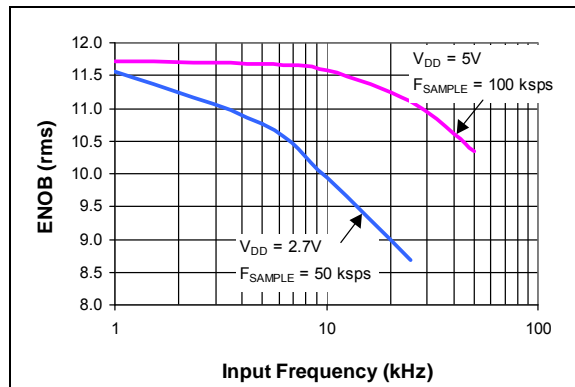


FIGURE 2-28: Effective Number of Bits (ENOB) vs. Input Frequency.

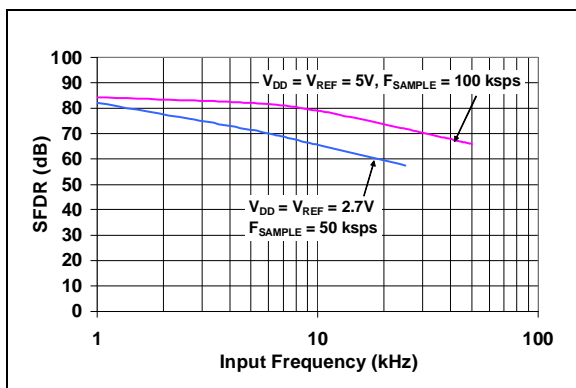


FIGURE 2-26: Spurious Free Dynamic Range (SFDR) vs. Input Frequency.

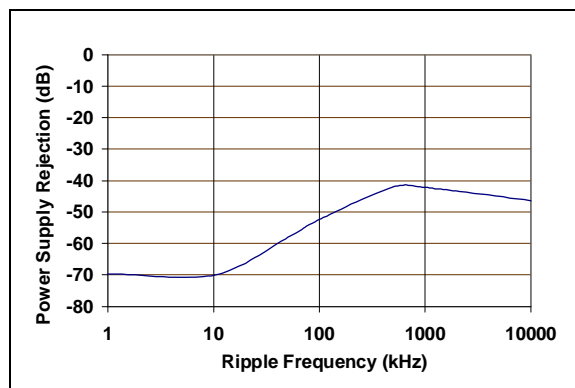


FIGURE 2-29: Power Supply Rejection (PSR) vs. Ripple Frequency.

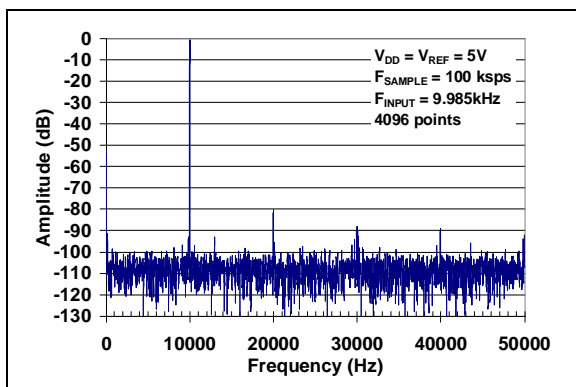


FIGURE 2-27: Frequency Spectrum of 10 kHz input (Representative Part).

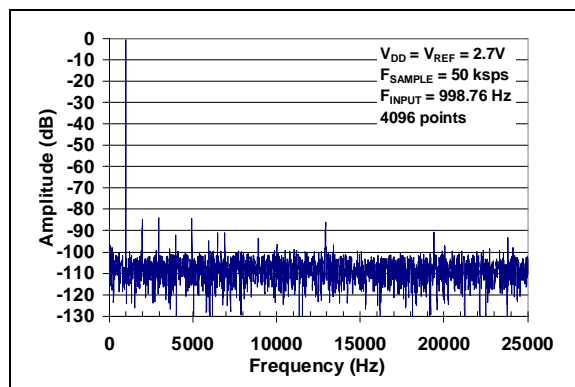


FIGURE 2-30: Frequency Spectrum of 1 kHz input (Representative Part, $V_{DD} = 2.7V$).

MCP3201

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

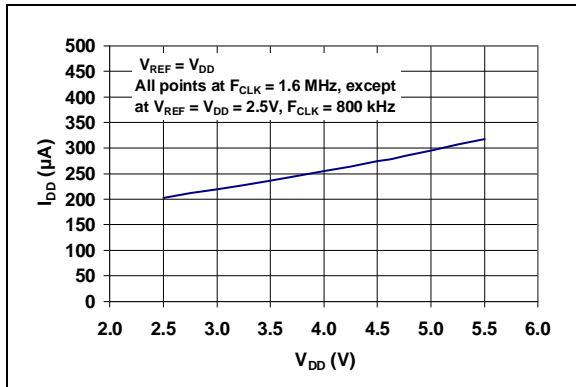


FIGURE 2-31: I_{DD} vs. V_{DD} .

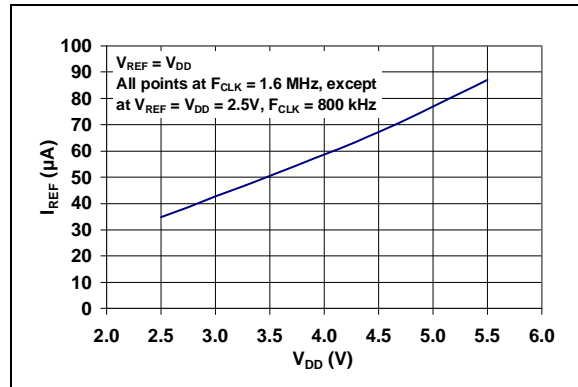


FIGURE 2-34: I_{REF} vs. V_{DD} .

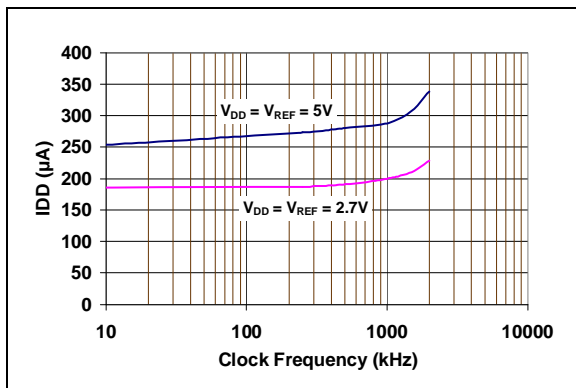


FIGURE 2-32: I_{DD} vs. Clock Frequency.

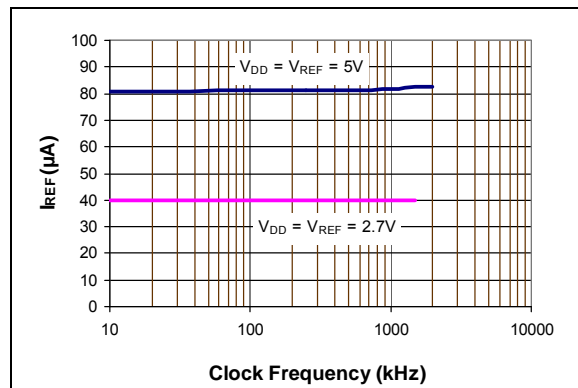


FIGURE 2-35: I_{REF} vs. Clock Frequency.

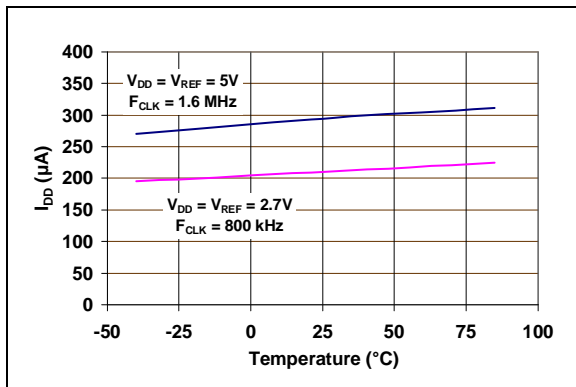


FIGURE 2-33: I_{DD} vs. Temperature.

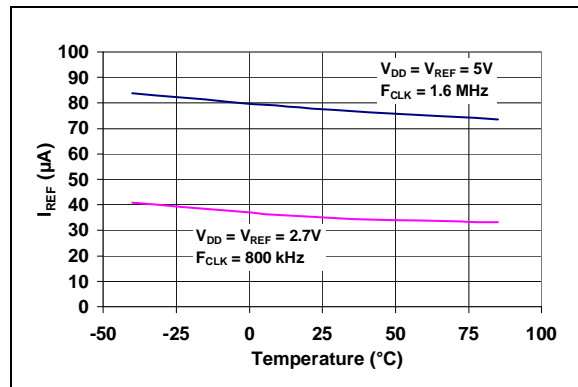


FIGURE 2-36: I_{REF} vs. Temperature.

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

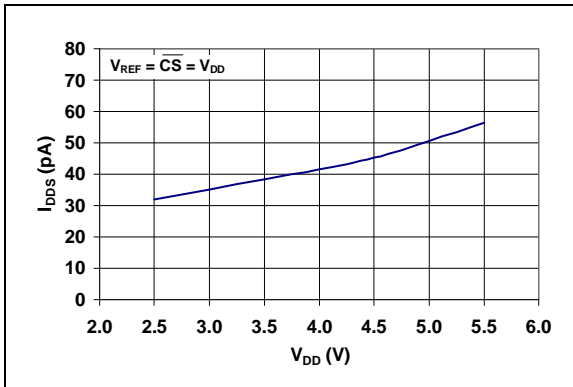


FIGURE 2-37: I_{DDS} vs. V_{DD} .

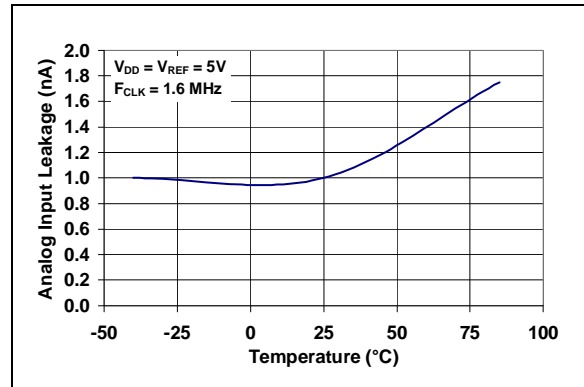


FIGURE 2-39: Analog Input Leakage Current vs. Temperature.

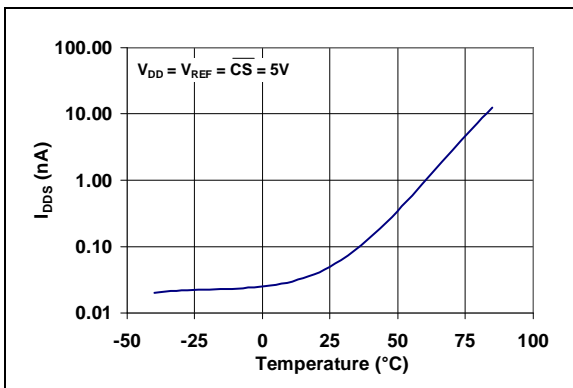


FIGURE 2-38: I_{DDS} vs. Temperature.

MCP3201

NOTES:

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in [Table 3-1](#). Additional descriptions of the device pins follows.

TABLE 3-1: PIN FUNCTION TABLE

| MCP3201 | Symbol | Description |
|-------------------------|----------------------|----------------------------|
| MSOP, PDIP, SOIC, TSSOP | | |
| 1 | V_{REF} | Reference Voltage Input |
| 2 | IN+ | Positive Analog Input |
| 3 | IN- | Negative Analog Input |
| 4 | V_{SS} | Ground |
| 5 | $\overline{CS}/SHDN$ | Chip Select/Shutdown Input |
| 6 | D_{OUT} | Serial Data Out |
| 7 | CLK | Serial Clock |
| 8 | V_{DD} | +2.7V to 5.5V Power Supply |

3.1 Positive Analog Input (IN+)

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

3.2 Negative Analog Input (IN-)

Negative analog input. This input can vary ± 100 mV from V_{SS} .

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

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 Serial Clock (CLK)

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 “Maintaining Minimum Clock Speed”](#) for constraints on clock speed.

3.5 Serial Data Output (D_{OUT})

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.

MCP3201

NOTES:

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 \overline{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 100 ksp/s are possible on the MCP3201 device. See [Section 6.2 “Maintaining Minimum Clock Speed”](#) 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 device 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 ± 100 mV 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.

EQUATION 4-1:

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

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.

EQUATION 4-2:

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

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.

MCP3201

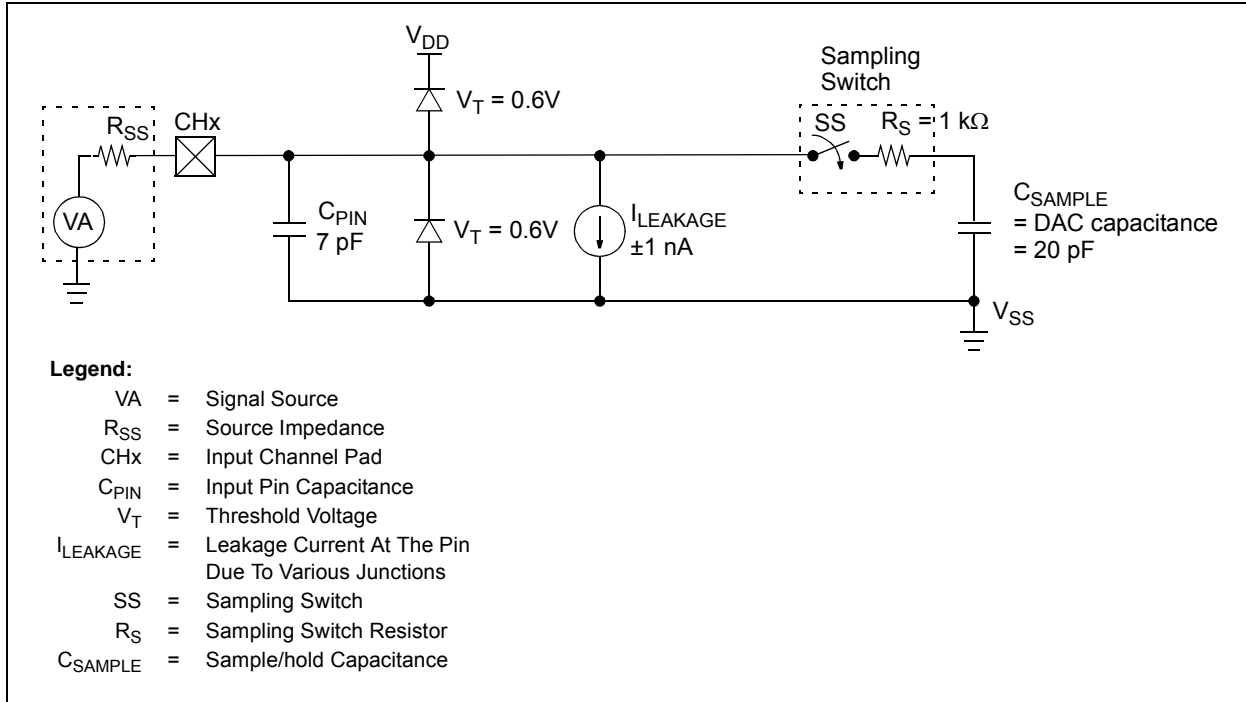


FIGURE 4-1: Analog Input Model.

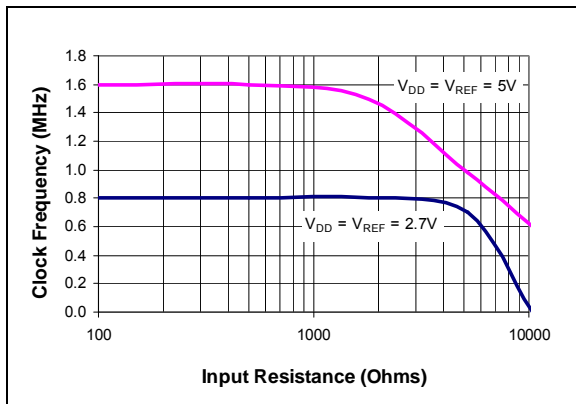


FIGURE 4-2: Maximum Clock Frequency vs. Input Resistance (R_S) to maintain less than a 0.1 LSB deviation in INL from nominal conditions.

5.0 SERIAL COMMUNICATIONS

Communication with the device is done using a standard SPI-compatible serial interface. Initiating communication with the MCP3201 device 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 conversion 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.

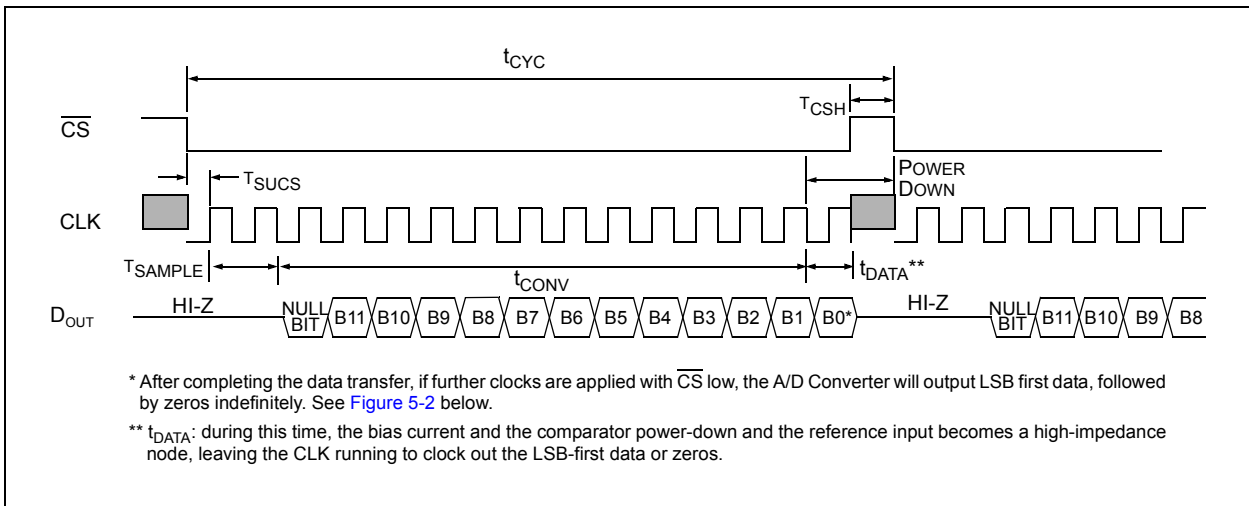


FIGURE 5-1: Communication with MCP3201 device using MSB first Format.

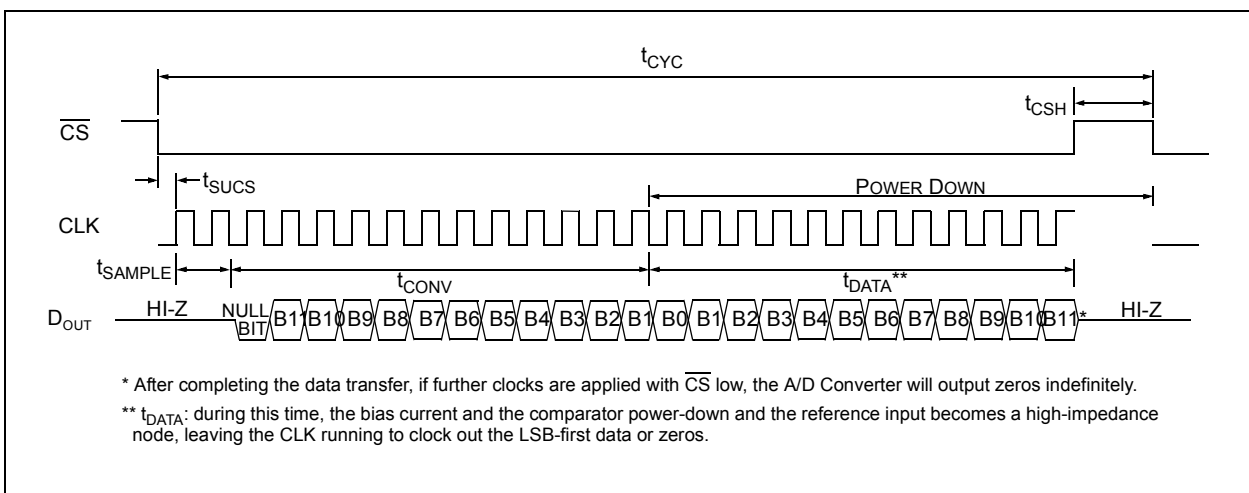


FIGURE 5-2: Communication with MCP3201 device using LSB first Format.

MCP3201

NOTES:

6.0 APPLICATIONS INFORMATION

6.1 Using the MCP3201 Device 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 device 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.

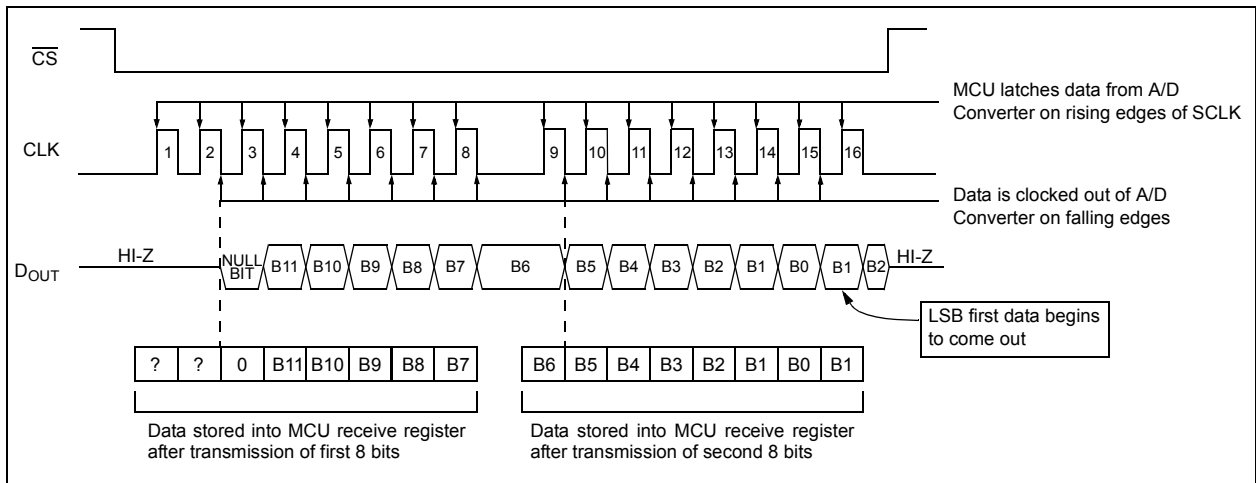


FIGURE 6-1: SPI Communication using 8-bit segments (Mode 0,0: SCLK idles low).

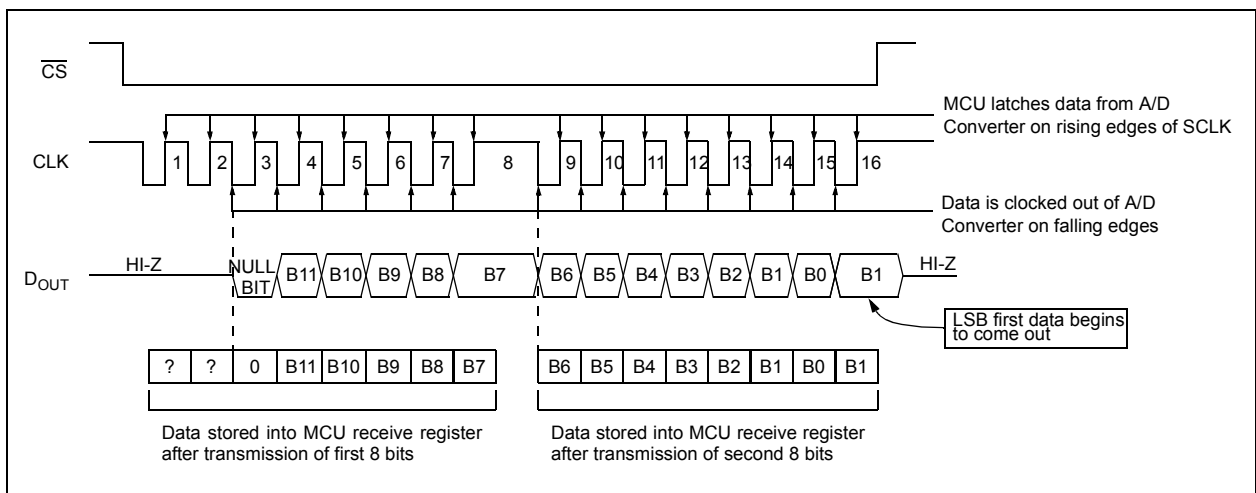


FIGURE 6-2: SPI Communication using 8-bit segments (Mode 1,1: SCLK idles high).

MCP3201

6.2 Maintaining Minimum Clock Speed

When the MCP3201 initiates the sample period, charge is stored on the sample capacitor. When the sample period is complete, the device converts one bit for each clock that is received. It is important for the user to note that a slow clock rate will allow charge to bleed off the sample cap while the conversion is taking place. At 85°C (worst-case condition), the part will maintain proper charge on the sample capacitor for at least 1.2 ms after the sample period has ended. This means that the time between the end of the sample period and the time that all 12 data bits have been clocked out must not exceed 1.2 ms (effective clock frequency of 10 kHz). Failure to meet this criteria may induce linearity errors into the conversion outside the rated specifications. It should be noted that during the entire conversion cycle, the A/D Converter does not require a constant clock speed or duty cycle, as long as all timing specifications are met.

6.3 Buffering/Filtering the Analog Inputs

If the signal source for the A/D Converter is not a low-impedance source, it will have to be buffered or inaccurate conversion results may occur. See Figure 4-2. It is also recommended that a filter be used to eliminate any signals that may be aliased back into the conversion results. This is illustrated in Figure 6-3 where an op amp is used to drive the analog input of the MCP3201 device. This amplifier provides a low-impedance source for the converter input and a low-pass filter, which eliminates unwanted high-frequency noise.

Low-pass (anti-aliasing) filters can be designed using Microchip's interactive FilterLab[®] software. FilterLab will calculate capacitor and resistor values, as well as determine the number of poles that are required for the application. For more information on filtering signals, see application note AN699 "Anti-Aliasing Analog Filters for Data Acquisition Systems."

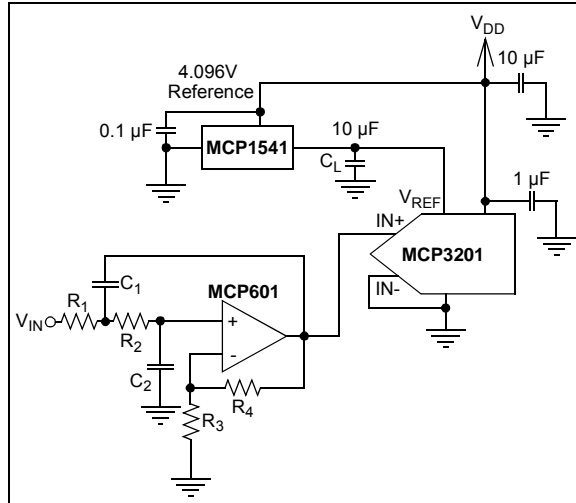


FIGURE 6-3: The MCP601 Operational Amplifier is used to implement a 2nd order anti-aliasing filter for the signal being converted by the MCP3201 device.

6.4 Layout Considerations

When laying out a printed circuit board for use with analog components, care should be taken to reduce noise wherever possible. A bypass capacitor should always be used with this device and should be placed as close as possible to the device pin. A bypass capacitor value of 1 μF is recommended.

Digital and analog traces should be separated as much as possible on the board and no traces should run underneath the device or the bypass capacitor. Extra precautions should be taken to keep traces with high-frequency signals (such as clock lines) as far as possible from analog traces.

Use of an analog ground plane is recommended in order to keep the ground potential the same for all devices on the board. Providing V_{DD} connections to devices in a “star” configuration can also reduce noise by eliminating current return paths and associated errors. See Figure 6-4. For more information on layout tips when using A/D Converter, refer to AN688 “Layout Tips for 12-Bit A/D Converter Applications”.

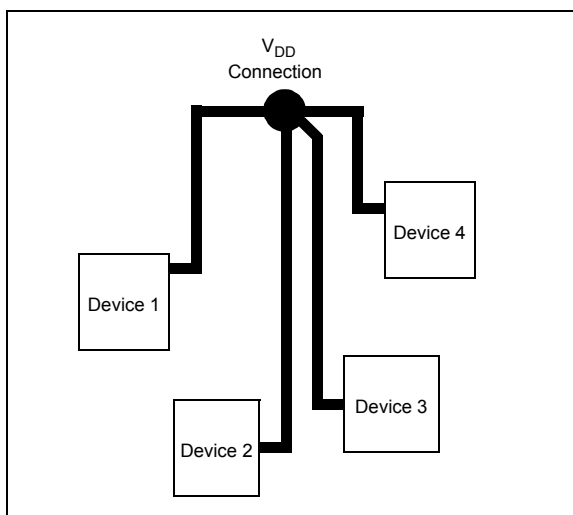


FIGURE 6-4: V_{DD} traces arranged in a ‘Star’ configuration in order to reduce errors caused by current return paths.

MCP3201

NOTES:

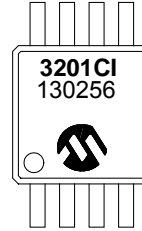
7.0 PACKAGING INFORMATION

7.1 Package Marking Information

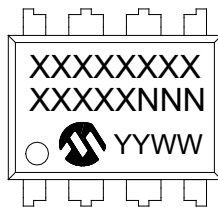
8-Lead MSOP (3x3 mm)



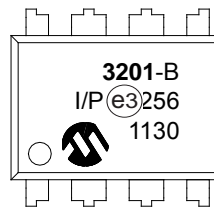
Example



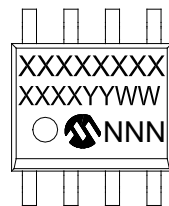
8-Lead PDIP (300 mil)



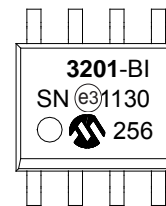
Example



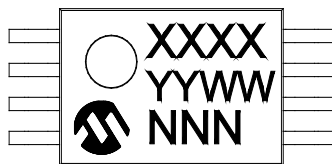
8-Lead SOIC (3.90 mm)



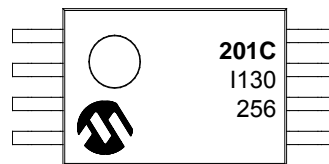
Example



8-Lead TSSOP (4.4 mm)



Example



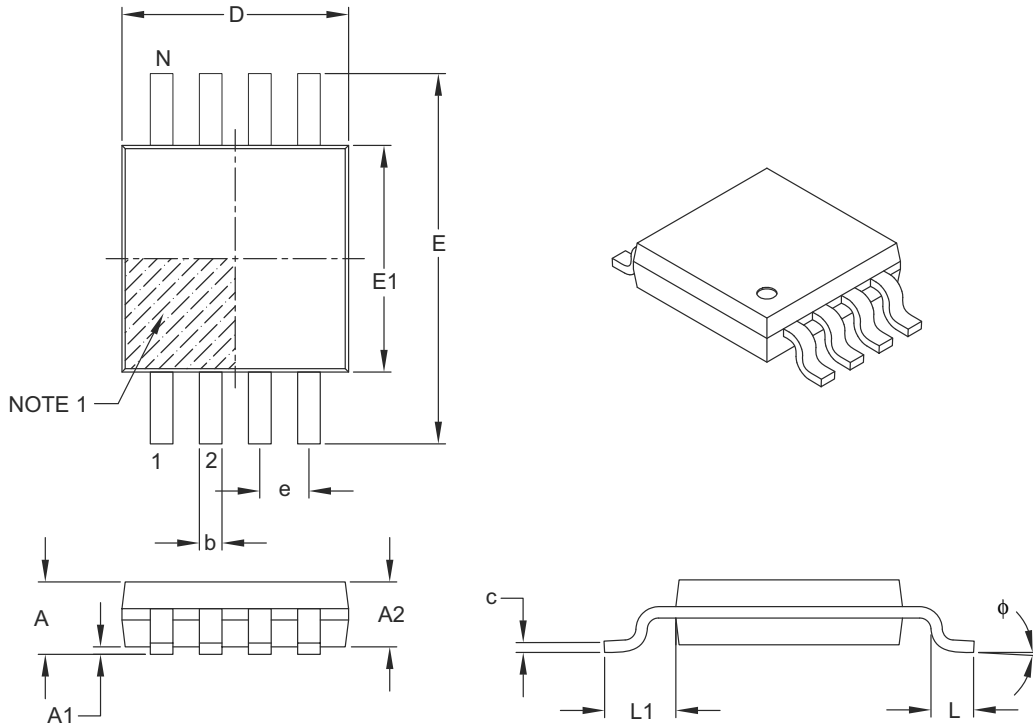
| | | |
|----------------|--------|--|
| Legend: | XX...X | Customer-specific information |
| | Y | Year code (last digit of calendar year) |
| | YY | Year code (last 2 digits of calendar year) |
| | WW | Week code (week of January 1 is week '01') |
| | NNN | Alphanumeric traceability code |
| | (e3) | Pb-free JEDEC designator for Matte Tin (Sn) |
| | * | This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package. |

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

MCP3201

8-Lead Plastic Micro Small Outline Package (MS) [MSOP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Dimension Limits | Units | MILLIMETERS | | |
|--------------------------|--------|-------------|------|------|
| | | MIN | NOM | MAX |
| Number of Pins | N | 8 | | |
| Pitch | e | 0.65 BSC | | |
| Overall Height | A | – | – | 1.10 |
| Molded Package Thickness | A2 | 0.75 | 0.85 | 0.95 |
| Standoff | A1 | 0.00 | – | 0.15 |
| Overall Width | E | 4.90 BSC | | |
| Molded Package Width | E1 | 3.00 BSC | | |
| Overall Length | D | 3.00 BSC | | |
| Foot Length | L | 0.40 | 0.60 | 0.80 |
| Footprint | L1 | 0.95 REF | | |
| Foot Angle | ϕ | 0° | – | 8° |
| Lead Thickness | c | 0.08 | – | 0.23 |
| Lead Width | b | 0.22 | – | 0.40 |

Notes:

- Pin 1 visual index feature may vary, but must be located within the hatched area.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
- Dimensioning and tolerancing per ASME Y14.5M.

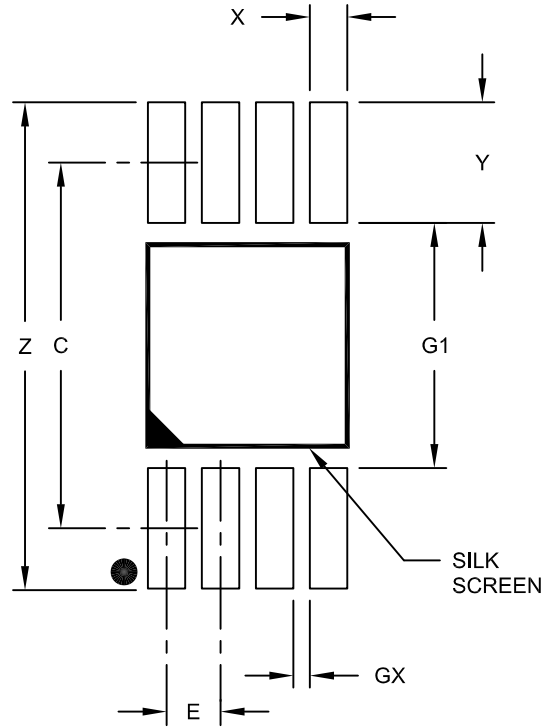
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-111B

8-Lead Plastic Micro Small Outline Package (MS) [MSOP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

| | | MILLIMETERS | | |
|-------------------------|----|-------------|------|------|
| Units | | MIN | NOM | MAX |
| Dimension Limits | | | | |
| Contact Pitch | E | 0.65 BSC | | |
| Contact Pad Spacing | C | | 4.40 | |
| Overall Width | Z | | | 5.85 |
| Contact Pad Width (X8) | X1 | | | 0.45 |
| Contact Pad Length (X8) | Y1 | | | 1.45 |
| Distance Between Pads | G1 | 2.95 | | |
| Distance Between Pads | GX | 0.20 | | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

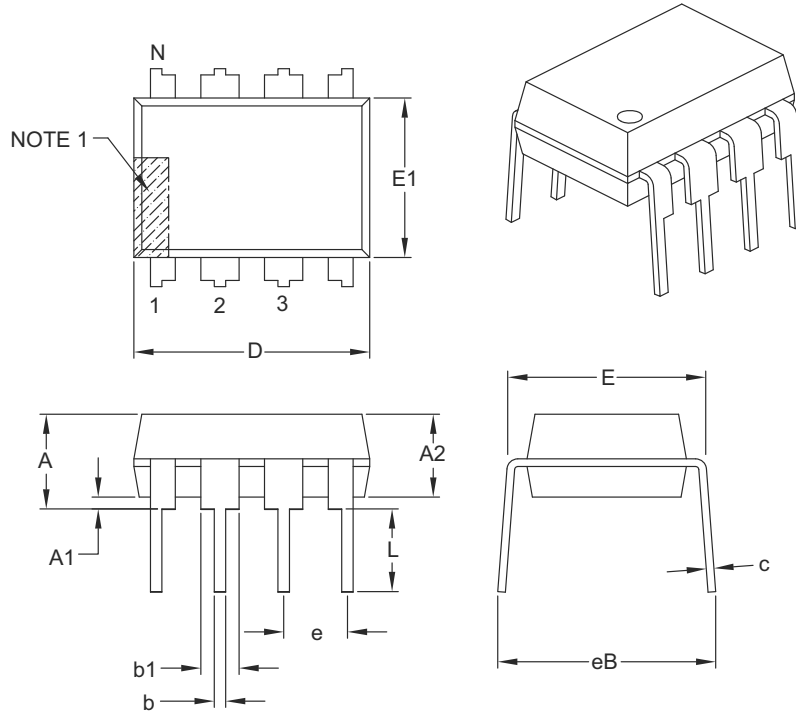
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2111A

MCP3201

8-Lead Plastic Dual In-Line (P) – 300 mil Body [PDIP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Dimension Limits | Units | INCHES | | |
|----------------------------|-------|----------|------|------|
| | | MIN | NOM | MAX |
| Number of Pins | N | 8 | | |
| Pitch | e | .100 BSC | | |
| Top to Seating Plane | A | – | – | .210 |
| Molded Package Thickness | A2 | .115 | .130 | .195 |
| Base to Seating Plane | A1 | .015 | – | – |
| Shoulder to Shoulder Width | E | .290 | .310 | .325 |
| Molded Package Width | E1 | .240 | .250 | .280 |
| Overall Length | D | .348 | .365 | .400 |
| Tip to Seating Plane | L | .115 | .130 | .150 |
| Lead Thickness | c | .008 | .010 | .015 |
| Upper Lead Width | b1 | .040 | .060 | .070 |
| Lower Lead Width | b | .014 | .018 | .022 |
| Overall Row Spacing § | eB | – | – | .430 |

Notes:

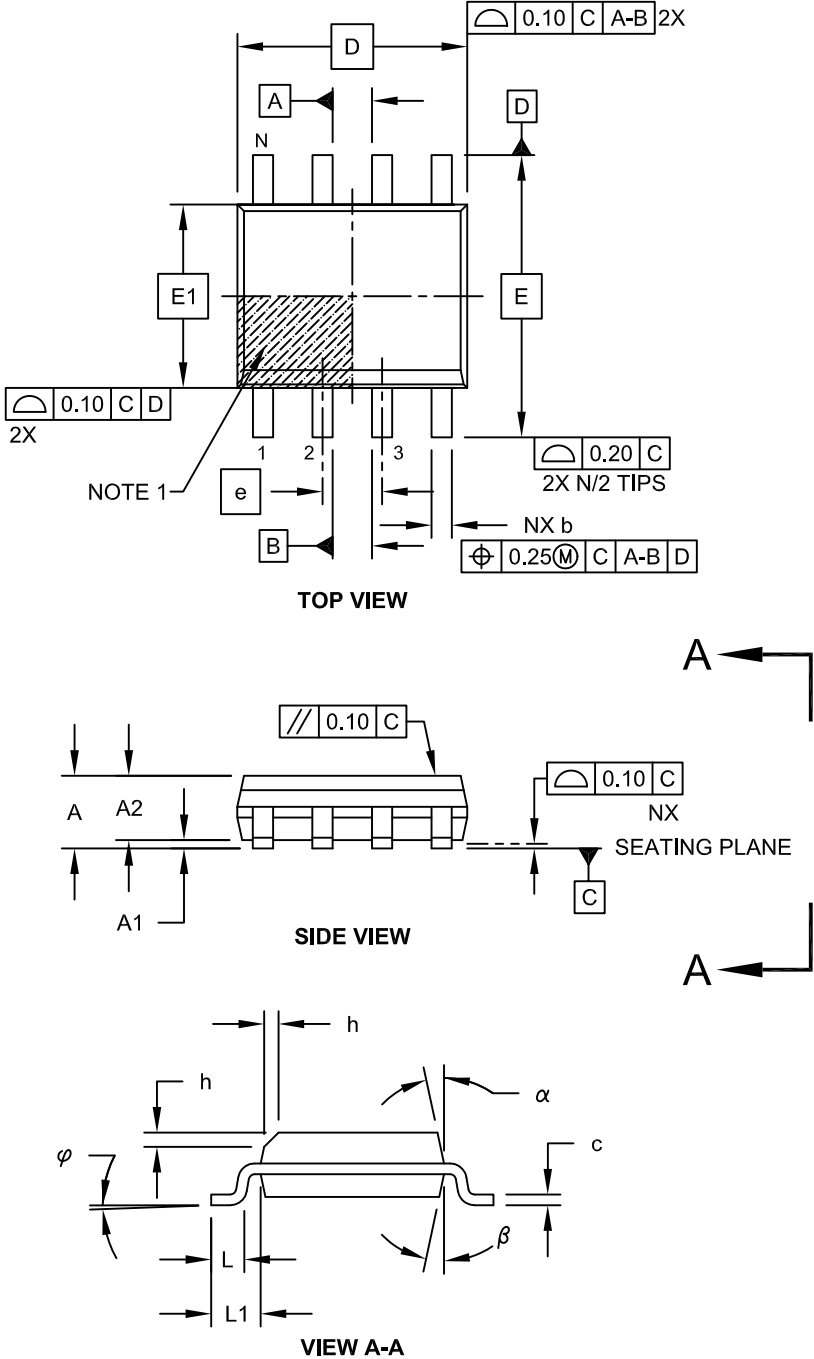
- Pin 1 visual index feature may vary, but must be located with the hatched area.
- § Significant Characteristic.
- Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" per side.
- Dimensioning and tolerancing per ASME Y14.5M.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-018B

8-Lead Plastic Small Outline (SN) - Narrow, 3.90 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>

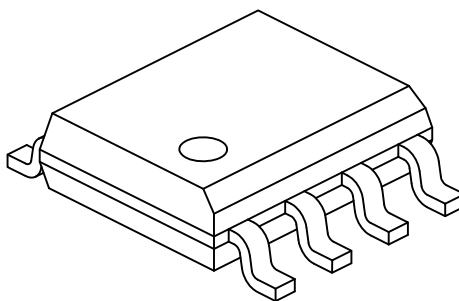


Microchip Technology Drawing No. C04-057C Sheet 1 of 2

MCP3201

8-Lead Plastic Small Outline (SN) - Narrow, 3.90 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Dimension Limits | Units | MILLIMETERS | | |
|--------------------------|-----------|-------------|-----|------|
| | | MIN | NOM | MAX |
| Number of Pins | N | 8 | | |
| Pitch | e | 1.27 BSC | | |
| Overall Height | A | - | - | 1.75 |
| Molded Package Thickness | A2 | 1.25 | - | - |
| Standoff § | A1 | 0.10 | - | 0.25 |
| Overall Width | E | 6.00 BSC | | |
| Molded Package Width | E1 | 3.90 BSC | | |
| Overall Length | D | 4.90 BSC | | |
| Chamfer (Optional) | h | 0.25 | - | 0.50 |
| Foot Length | L | 0.40 | - | 1.27 |
| Footprint | L1 | 1.04 REF | | |
| Foot Angle | φ | 0° | - | 8° |
| Lead Thickness | c | 0.17 | - | 0.25 |
| Lead Width | b | 0.31 | - | 0.51 |
| Mold Draft Angle Top | α | 5° | - | 15° |
| Mold Draft Angle Bottom | β | 5° | - | 15° |

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. § Significant Characteristic
3. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm per side.
4. Dimensioning and tolerancing per ASME Y14.5M

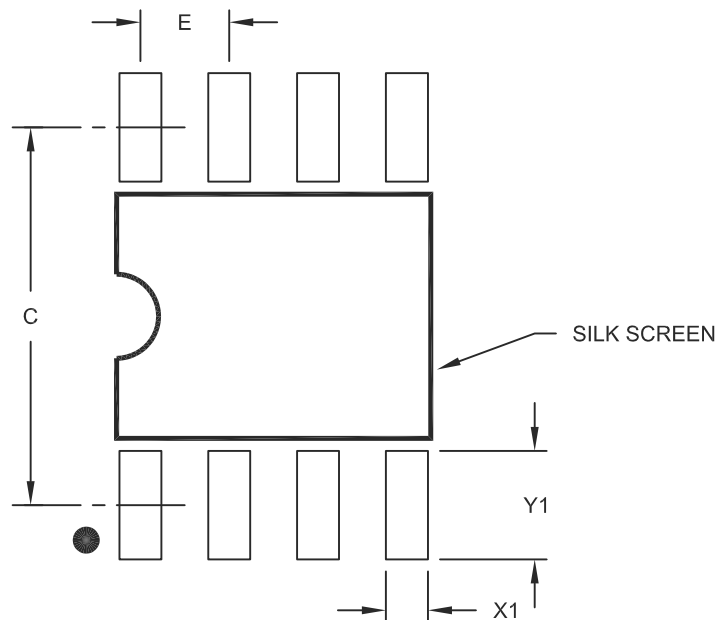
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing No. C04-057C Sheet 2 of 2

8-Lead Plastic Small Outline (SN) – Narrow, 3.90 mm Body [SOIC]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

| Dimension Limits | Units | MILLIMETERS | | |
|-------------------------|-------|-------------|------|------|
| | | MIN | NOM | MAX |
| Contact Pitch | E | 1.27 BSC | | |
| Contact Pad Spacing | C | | 5.40 | |
| Contact Pad Width (X8) | X1 | | | 0.60 |
| Contact Pad Length (X8) | Y1 | | | 1.55 |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

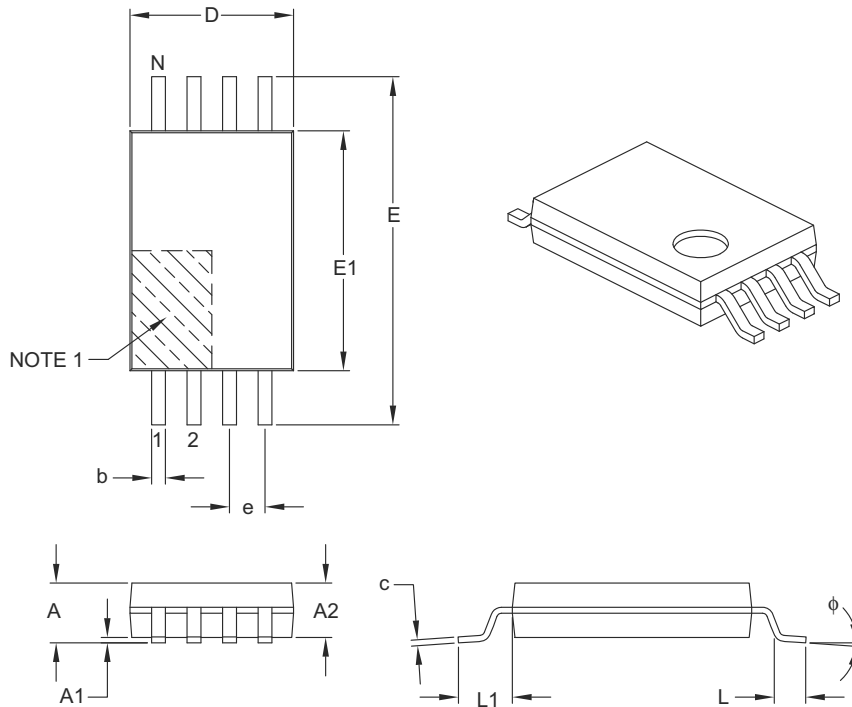
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2057A

MCP3201

8-Lead Plastic Thin Shrink Small Outline (ST) – 4.4 mm Body [TSSOP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



| Dimension Limits | Units | MILLIMETERS | | |
|--------------------------|-------|-------------|------|------|
| | | MIN | NOM | MAX |
| Number of Pins | N | 8 | | |
| Pitch | e | 0.65 BSC | | |
| Overall Height | A | – | – | 1.20 |
| Molded Package Thickness | A2 | 0.80 | 1.00 | 1.05 |
| Standoff | A1 | 0.05 | – | 0.15 |
| Overall Width | E | 6.40 BSC | | |
| Molded Package Width | E1 | 4.30 | 4.40 | 4.50 |
| Molded Package Length | D | 2.90 | 3.00 | 3.10 |
| Foot Length | L | 0.45 | 0.60 | 0.75 |
| Footprint | L1 | 1.00 REF | | |
| Foot Angle | φ | 0° | – | 8° |
| Lead Thickness | c | 0.09 | – | 0.20 |
| Lead Width | b | 0.19 | – | 0.30 |

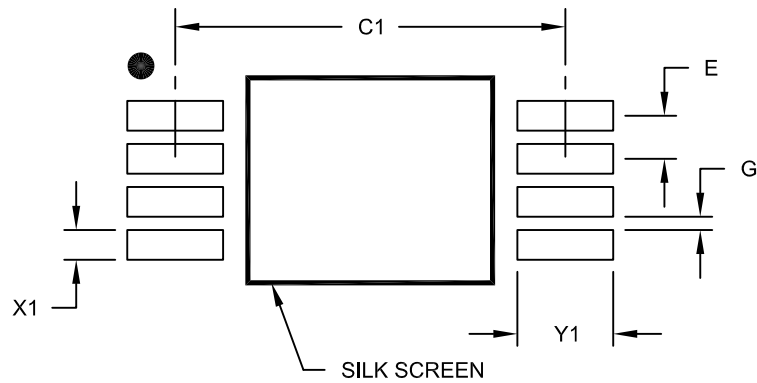
Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15 mm per side.
3. Dimensioning and tolerancing per ASME Y14.5M.
 - BSC: Basic Dimension. Theoretically exact value shown without tolerances.
 - REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-086B

8-Lead Plastic Thin Shrink Small Outline (ST) - 4.4 mm Body [TSSOP]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



RECOMMENDED LAND PATTERN

| Units | | MILLIMETERS | | |
|-------------------------|----|-------------|------|------|
| Dimension Limits | | MIN | NOM | MAX |
| Contact Pitch | E | 0.65 BSC | | |
| Contact Pad Spacing | C1 | | 5.90 | |
| Contact Pad Width (X8) | X1 | | | 0.45 |
| Contact Pad Length (X8) | Y1 | | | 1.45 |
| Distance Between Pads | G | 0.20 | | |

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing No. C04-2086A

MCP3201

NOTES:

APPENDIX A: REVISION HISTORY

Revision F (August 2011)

- Updated **Product Identification System** section.
 - Corrected marking drawings for MSOP packages.
 - Updated PDIP, SOIC, and TSSOP package specification drawings.

Revision E (November 2008)

The following is the list of modifications:

1. Updated **Section 7.0 “Packaging Information”**.
2. Updated **Product Identification System** section.

Revision D (January 2007)

The following is the list of modifications:

1. This revision includes updates to the packaging diagrams.

Revision C (August 2001)

The following is the list of modifications:

1. This revision includes undocumented changes.

Revision B (August 1999)

The following is the list of modifications:

1. This revision includes undocumented changes.

Revision A (September 1998)

- Original release of this document.

MCP3201

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

| <u>PART NO.</u> | <u>X</u> | <u>X</u> | <u>/XX</u> |
|---|--|--|---|
| Device | Grade | Temperature Range | Package |
| Device: MCP3201: 12-Bit A/D Converter w/SPI Interface MCP3201T: 12-Bit A/D Converter w/SPI Interface (Tape and Reel) | Grade: B: = ± LSB max INL (MSOP and TSSOP not available) C: = ± LSB max INL | Temperature Range: I = -40°C to +85°C (Industrial) | Package: MS = Plastic Micro Small Outline (MSOP), 8-lead P = Plastic DIP (300 mil Body), 8-lead SN = Plastic SOIC (150 mil Body), 8-lead ST = Plastic TSSOP (4.4 mm), 8-lead |
| Examples: | | | |
| a) MCP3201-BI/P: | B Grade, | Industrial Temperature, | 8LD PDIP package. |
| b) MCP3201-BI/SN: | B Grade, | Industrial Temperature, | 8LD SOIC package. |
| c) MCP3201-CI/P: | C Grade, | Industrial Temperature, | 8LD PDIP package. |
| d) MCP3201-CI/MS: | C Grade, | Industrial Temperature, | 8LD MSOP package. |
| e) MCP3201-CI/SN: | C Grade, | Industrial Temperature, | 8LD SOIC package. |
| f) MCP3201-CI/ST: | C Grade, | Industrial Temperature, | 8LD TSSOP package. |
| g) MCP3201T-BI/SN: | Tape and Reel, B Grade, | Industrial Temperature, | 8LD SOIC package. |
| h) MCP3201T-CI/MS: | Tape and Reel, C Grade, | Industrial Temperature, | 8LD MSOP package. |
| i) MCP3201T-CI/SN: | Tape and Reel, C Grade, | Industrial Temperature, | 8LD SOIC package. |
| j) MCP3201T-CI/ST: | Tape and Reel, C Grade, | Industrial Temperature, | 8LD TSSOP package. |

MCP3201

NOTES:

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- Microchip products meet the specification contained in their particular Microchip Data Sheet.
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CERTIFIED BY DNV
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Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC[®] MCUs and dsPIC[®] DSCs, KEELOQ[®] code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.



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