



16-Bit, 135ksps, Single-Supply ADC with 0 to 10V Input Range

MAX1177

General Description

The MAX1177 is a 16-bit, low-power, successive-approximation analog-to-digital converter (ADC) featuring automatic power-down, a factory-trimmed internal clock, and a byte-wide parallel interface. The device operates from a single +4.75V to +5.25V analog supply and features a separate digital supply input for direct interface with +2.7V to +5.25V digital logic.

The MAX1177 accepts an analog input voltage range from 0 to +10V. It consumes no more than 26.5mW at a sampling rate of 135ksps when using an external reference, and 31mW when using the internal +4.096V reference. AutoShutdown™ reduces supply current to 0.4mA at 10ksps.

The MAX1177 is ideal for high-performance, battery-powered, data-acquisition applications. Excellent AC performance (THD = -100dB) and DC accuracy (± 3 LSB INL) make this device ideal for industrial process control, instrumentation, and medical applications.

The MAX1177 is available in a 20-pin TSSOP package and is fully specified over the -40°C to +85°C extended temperature range and the 0°C to +70°C commercial temperature range.

Features

- ◆ Byte-Wide Parallel Interface
- ◆ Analog Input Voltage Range: 0 to +10V
- ◆ Single +4.75V to +5.25V Analog Supply Voltage
- ◆ Interfaces with +2.7V to +5.25V Digital Logic
- ◆ ± 3 LSB INL
- ◆ ± 1 LSB DNL
- ◆ Low Supply Current (max)
 - 2.9mA (External Reference)
 - 3.8mA (Internal Reference)
 - 5μA AutoShutdown Mode
- ◆ Small Footprint
- ◆ 20-Pin TSSOP Package

Ordering Information

| PART | TEMP RANGE | PIN-PACKAGE |
|-------------|----------------|-------------|
| MAX1177ACUP | 0°C to +70°C | 20 TSSOP |
| MAX1177BCUP | 0°C to +70°C | 20 TSSOP |
| MAX1177CCUP | 0°C to +70°C | 20 TSSOP |
| MAX1177AEUP | -40°C to +85°C | 20 TSSOP |
| MAX1177BEUP | -40°C to +85°C | 20 TSSOP |
| MAX1177CEUP | -40°C to +85°C | 20 TSSOP |

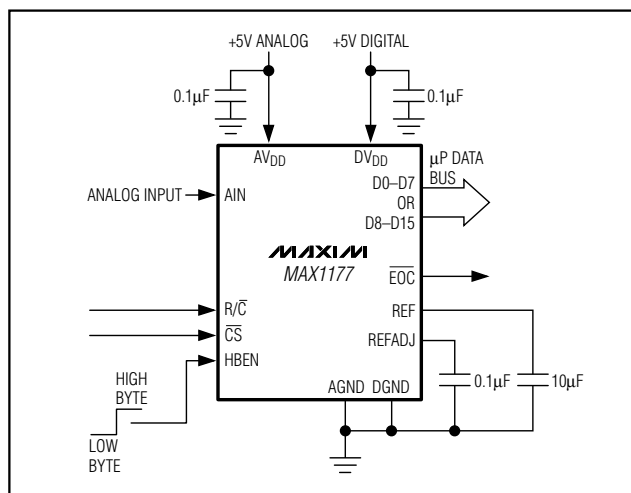
Applications

Temperature Sensing and Monitoring
Industrial Process Control
I/O Modules
Data-Acquisition Systems
Precision Instrumentation

Pin Configuration and Functional Diagram appear at end of data sheet.

AutoShutdown is a trademark of Maxim Integrated Products, Inc.

Typical Operating Circuit



16-Bit, 135ksps, Single-Supply ADC with to 10V Input Range

ABSOLUTE MAXIMUM RATINGS

| | | | |
|---|------------------------------------|---|-----------------|
| AV _{DD} to AGND | -0.3V to +6V | Continuous Power Dissipation (T _A = +70°C) | |
| DV _{DD} to DGND | -0.3V to +6V | TSSOP (derate 10.9mW/°C above +70°C) | 879mW |
| AGND to DGND | -0.3V to +0.3V | Operating Temperature Ranges | |
| AIN to AGND | -16.5V to +16.5V | MAX1177_CUP | 0°C to +70°C |
| REF, REFADJ to AGND | -0.3V to (AV _{DD} + 0.3V) | MAX1177_EUP | -40°C to +85°C |
| CS, R/C, HBEN to DGND | -0.3V to +6V | Storage Temperature Range | -65°C to +150°C |
| D ₋ , EOC to DGND | -0.3V to (DV _{DD} + 0.3V) | Junction Temperature | +150°C |
| Maximum Continuous Current into Any Pin | 50mA | Lead Temperature (soldering, 10s) | +300°C |

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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(AV_{DD} = DV_{DD} = +5V ±5%, external reference = +4.096V, C_{REF} = 10μF, C_{REFADJ} = 0.1μF, V_{REFADJ} = AV_{DD}, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at T_A = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|------------------|-----------------------------------|----------|------|------|--------------------|
| DC ACCURACY | | | | | | |
| Resolution | RES | | 16 | | | Bits |
| Differential Nonlinearity | DNL | No missing codes over temperature | MAX1177A | -1 | +1 | LSB |
| | | | MAX1177B | -1.0 | +1.5 | |
| | | | MAX1177C | -1 | +2 | |
| Integral Nonlinearity | INL | MAX1177A | -3 | | +3 | LSB |
| | | MAX1177B | -3 | | +3 | |
| | | MAX1177C | -4 | | +4 | |
| Transition Noise | | RMS noise, external reference | | 0.6 | | LSB _{RMS} |
| | | Internal reference | | 0.75 | | |
| Offset Error | | | -10 | 0 | +10 | mV |
| Gain Error | | | | 0 | ±0.2 | %FSR |
| Offset Drift | | | | 16 | | μV/°C |
| Gain Drift | | | | ±1 | | ppm/°C |
| AC ACCURACY (f _{IN} = 1kHz, V _{AIN} = full range, 135ksps) | | | | | | |
| Signal-to-Noise Plus Distortion | SINAD | | 85 | 90 | | dB |
| Signal-to-Noise Ratio | SNR | | 86 | 91 | | dB |
| Total Harmonic Distortion | THD | | | -100 | -92 | dB |
| Spurious-Free Dynamic Range | SFDR | | 92 | 103 | | dB |
| ANALOG INPUT | | | | | | |
| Input Range | V _{AIN} | | 0 | | 10 | V |
| Input Resistance | R _{AIN} | Normal operation | 5.3 | 6.9 | 9.2 | kΩ |
| | | Shutdown mode | 5.3 | | | |
| Input Current | I _{AIN} | 0 ≤ V _{AIN} ≤ +10V | -0.1 | | +2.0 | mA |
| Input Capacitance | C _{IN} | | | 10 | | pF |

16-Bit, 135ksps, Single-Supply ADC with 0 to 10V Input Range

ELECTRICAL CHARACTERISTICS (continued)

(AVDD = DVDD = +5V ±5%, external reference = +4.096V, CREF = 10μF, CREFADJ = 0.1μF, VREFADJ = AVDD, TA = TMIN to TMAX, unless otherwise noted. Typical values are at TA = +25°C.)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|------------------------------------|---------|--|------------|-------|------------|--------|
| INTERNAL REFERENCE | | | | | | |
| REF Output Voltage | VREF | | 4.056 | 4.096 | 4.136 | V |
| REF Output Tempco | | | | ±35 | | ppm/°C |
| REF Short-Circuit Current | IREF-SC | | | ±10 | | mA |
| EXTERNAL REFERENCE | | | | | | |
| REF and REFADJ Input-Voltage Range | | | 3.8 | | 4.2 | V |
| REFADJ Buffer-Disable Threshold | | | AVDD - 0.4 | | AVDD - 0.1 | V |
| REF Input Current | IREF | Normal mode, fSAMPLE = 135ksps | | 60 | 100 | μA |
| | | Shutdown mode (Note 1) | | ±0.1 | ±10 | |
| REFADJ Input Current | IREFADJ | REFADJ = AVDD | | 16 | | μA |
| DIGITAL INPUTS/OUTPUTS | | | | | | |
| Output High Voltage | VOH | ISOURCE = 0.5mA, DVDD = +2.7V to +5.25V, AVDD = +5.25V | DVDD - 0.4 | | | V |
| Output Low Voltage | VOL | ISINK = 1.6mA, DVDD = +2.7V to +5.25V, AVDD = +5.25V | | | 0.4 | V |
| Input High Voltage | VIH | | 0.7 × DVDD | | | V |
| Input Low Voltage | VIL | | | | 0.3 × DVDD | V |
| Input Leakage Current | | Digital input = DVDD or 0V | -1 | | +1 | μA |
| Input Hysteresis | VHYST | | | 0.2 | | V |
| Input Capacitance | CIN | | | 15 | | pF |
| Tri-State Output Leakage | IOZ | | | | ±10 | μA |
| Tri-State Output Capacitance | COZ | | | 15 | | pF |
| POWER SUPPLIES | | | | | | |
| Analog Supply Voltage | AVDD | | 4.75 | | 5.25 | V |
| Digital Supply Voltage | DVDD | | 2.70 | | 5.25 | V |
| Analog Supply Current | IAVDD | External reference, 135ksps | | | 2.9 | mA |
| | | Internal reference, 135ksps | | | 3.8 | |
| Shutdown Supply Current | ISHDN | Shutdown mode (Note 1), digital input = DVDD or 0V | | 0.5 | 5 | μA |
| | | Standby mode | | 3.7 | | mA |
| Digital Supply Current | IDVDD | | | | 0.75 | mA |
| Power-Supply Rejection | | AVDD = DVDD = 4.75V to 5.25V | | 3.5 | | LSB |

16-Bit, 135ksps, Single-Supply ADC with to 10V Input Range

TIMING CHARACTERISTICS (Figures 1 and 2)

($AV_{DD} = +4.75V$ to $+5.25V$, $DV_{DD} = +2.7V$ to AV_{DD} , external reference = $+4.096V$, $C_{REF} = 10\mu F$, $C_{REFADJ} = 0.1\mu F$, $V_{REFADJ} = AV_{DD}$, $C_{LOAD} = 20pF$, $T_A = T_{MIN}$ to T_{MAX} .)

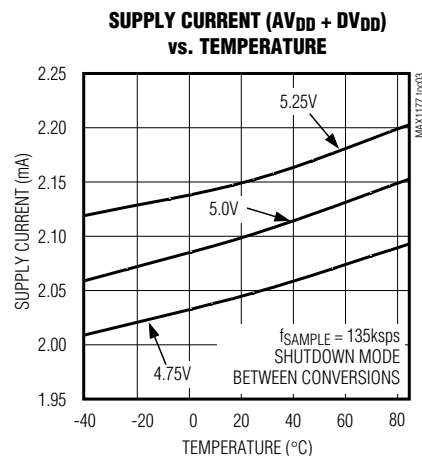
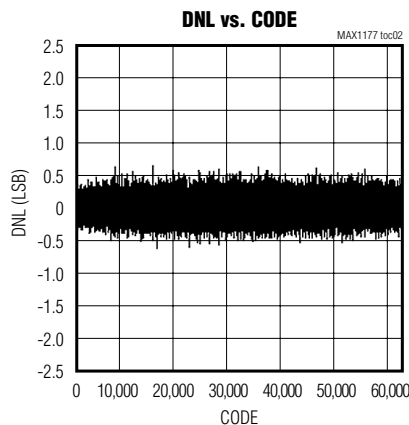
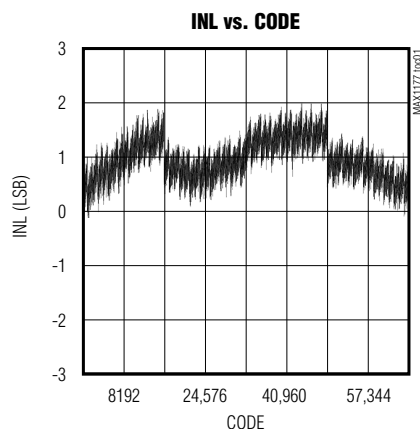
| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|------------------|------------------------------|-----|-----|-----|---------|
| Maximum Sampling Rate | $f_{SAMPLE-MAX}$ | | | | 135 | ksps |
| Acquisition Time | t_{ACQ} | | 2 | | | μs |
| Conversion Time | t_{CONV} | | | | 4.7 | μs |
| \overline{CS} Pulse-Width High | t_{CSH} | (Note 2) | 40 | | | ns |
| \overline{CS} Pulse-Width Low (Note 2) | t_{CSL} | $DV_{DD} = 4.75V$ to $5.25V$ | 40 | | | ns |
| | | $DV_{DD} = 2.7V$ to $5.25V$ | 60 | | | |
| R/C to \overline{CS} Fall Setup Time | t_{DS} | | 0 | | | ns |
| R/C to \overline{CS} Fall Hold Time | t_{DH} | $DV_{DD} = 4.75V$ to $5.25V$ | 40 | | | ns |
| | | $DV_{DD} = 2.7V$ to $5.25V$ | 60 | | | |
| \overline{CS} to Output Data Valid | t_{DO} | $DV_{DD} = 4.75V$ to $5.25V$ | | | 40 | ns |
| | | $DV_{DD} = 2.7V$ to $5.25V$ | | | 80 | |
| \overline{EOC} Fall to \overline{CS} Fall | t_{DV} | | 0 | | | ns |
| \overline{CS} Rise to \overline{EOC} Rise | t_{EOC} | $DV_{DD} = 4.75V$ to $5.25V$ | | | 40 | ns |
| | | $DV_{DD} = 2.7V$ to $5.25V$ | | | 80 | |
| Bus Relinquish Time | t_{BR} | $DV_{DD} = 4.75V$ to $5.25V$ | | | 40 | ns |
| | | $DV_{DD} = 2.7V$ to $5.25V$ | | | 80 | |
| HBEN Transition to Output Data Valid | t_{DO1} | $DV_{DD} = 4.75V$ to $5.25V$ | | | 40 | ns |
| | | $DV_{DD} = 2.7V$ to $5.25V$ | | | 80 | |

Note 1: Maximum specification is limited by automated test equipment.

Note 2: To ensure best performance, finish reading the data and wait t_{BR} before starting a new acquisition.

Typical Operating Characteristics

(Typical Operating Circuit, $AV_{DD} = DV_{DD} = +5V$, external reference = $+4.096V$, $C_{REF} = 10\mu F$, $C_{REFADJ} = 0.1\mu F$, $V_{REFADJ} = AV_{DD}$, $C_{LOAD} = 20pF$. Typical values are at $T_A = +25^\circ C$, unless otherwise noted.)

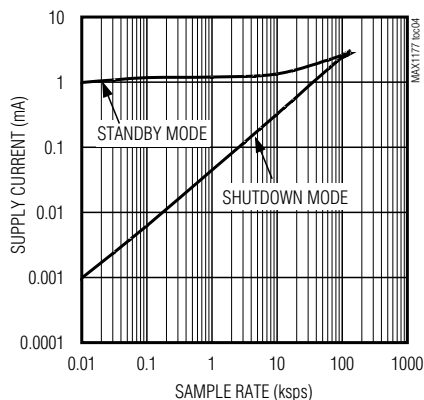


16-Bit, 135ksps, Single-Supply ADC with 0 to 10V Input Range

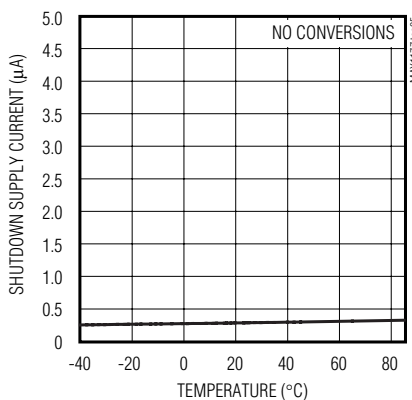
Typical Operating Characteristics (continued)

(Typical Operating Circuit, $AV_{DD} = DV_{DD} = +5V$, external reference = +4.096V, $C_{REF} = 10\mu F$, $C_{REFADJ} = 0.1\mu F$, $V_{REFADJ} = AV_{DD}$, $C_{LOAD} = 20pF$. Typical values are at $T_A = +25^\circ C$, unless otherwise noted.)

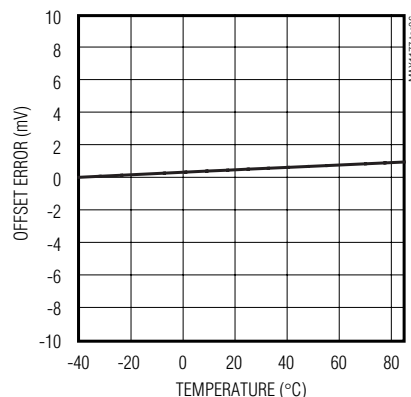
**SUPPLY CURRENT ($AV_{DD} + DV_{DD}$)
vs. SAMPLE RATE**



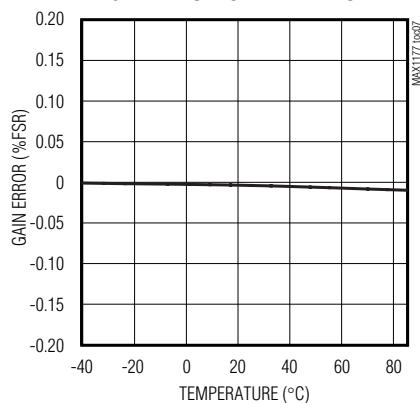
**SHUTDOWN CURRENT ($AV_{DD} + DV_{DD}$)
vs. TEMPERATURE**



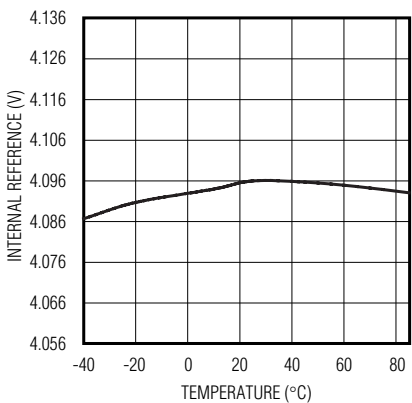
OFFSET ERROR vs. TEMPERATURE



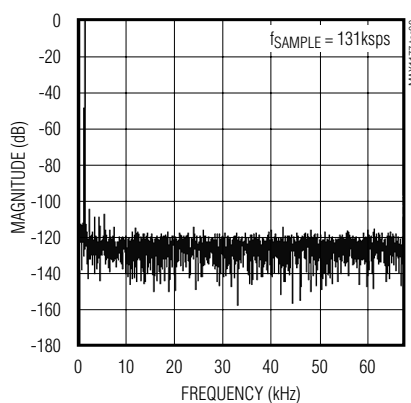
GAIN ERROR vs. TEMPERATURE



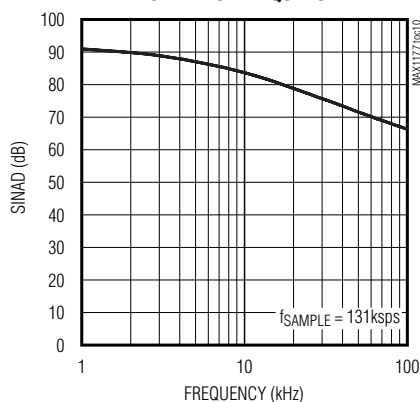
**INTERNAL REFERENCE
vs. TEMPERATURE**



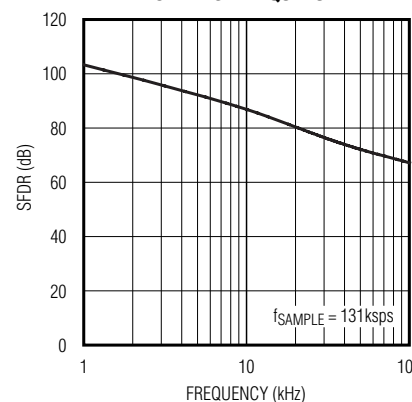
FFT AT 1kHz



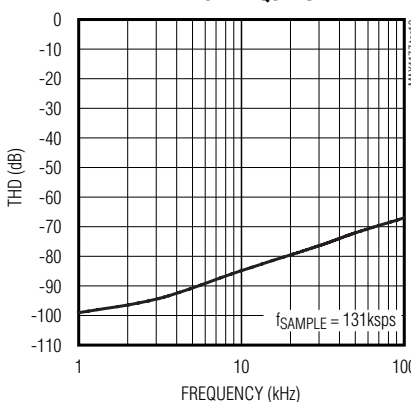
SINAD vs. FREQUENCY



SFDR vs. FREQUENCY



THD vs. FREQUENCY



16-Bit, 135ksps, Single-Supply ADC with to 10V Input Range

Pin Description

| PIN | NAME | FUNCTION |
|-----|-------------------|--|
| 1 | D4/D12 | Tri-State Digital-Data Output |
| 2 | D5/D13 | Tri-State Digital-Data Output |
| 3 | D6/D14 | Tri-State Digital-Data Output |
| 4 | D7/D15 | Tri-State Digital-Data Output. D15 is the MSB. |
| 5 | R/ \overline{C} | Read/Convert Input. Power up and put the device in acquisition mode by holding R/ \overline{C} low during the first falling edge of \overline{CS} . During the second falling edge of \overline{CS} , the level on R/ \overline{C} determines whether the reference and reference buffer power down or remain on after conversion. Set R/ \overline{C} high during the second falling edge of \overline{CS} to power down the reference and buffer, or set R/ \overline{C} low to leave the reference and buffer powered up. Set R/ \overline{C} high during the third falling edge of \overline{CS} to put valid data on the bus. |
| 6 | \overline{EOC} | End of Conversion. \overline{EOC} drives low when conversion is complete. |
| 7 | AV _{DD} | Analog Supply Input. Bypass with a 0.1 μ F capacitor to AGND. |
| 8 | AGND | Analog Ground. Primary analog ground (star ground). |
| 9 | AIN | Analog Input |
| 10 | AGND | Analog Ground. Connect pin 10 to pin 8. |
| 11 | REFADJ | Reference Buffer Output. Bypass REFADJ with a 0.1 μ F capacitor to AGND for internal reference mode. Connect REFADJ to AV _{DD} to select external reference mode. |
| 12 | REF | Reference Input/Output. Bypass REF with a 10 μ F capacitor to AGND for internal reference mode. External reference input when in external reference mode. |
| 13 | HBEN | High-Byte Enable Input. Used to multiplex the 16-bit conversion result. 1: MSB available on the data bus. 0: LSB available on the data bus. |
| 14 | \overline{CS} | Convert Start. The first falling edge of \overline{CS} powers up the device and enables acquire mode when R/ \overline{C} is low. The second falling edge of \overline{CS} starts the conversion. The third falling edge of \overline{CS} loads the result onto the bus when R/ \overline{C} is high. |
| 15 | DGND | Digital Ground |
| 16 | DV _{DD} | Digital Supply Voltage. Bypass with a 0.1 μ F capacitor to DGND. |
| 17 | D0/D8 | Tri-State Digital-Data Output. D0 is the LSB. |
| 18 | D1/D9 | Tri-State Digital-Data Output |
| 19 | D2/D10 | Tri-State Digital-Data Output |
| 20 | D3/D11 | Tri-State Digital-Data Output |

MAX 177

Input Scaler

16-Bit, 135ksps, Single-Supply ADC with to 10V Input Range

Power-Down Modes

Select standby mode or shutdown mode with the R/\overline{C} bit during the second falling edge of \overline{CS} (see the *Selecting Standby or Shutdown Mode* section). The MAX1177 automatically enters either standby mode (reference and buffer on) or shutdown (reference and buffer off) after each conversion, depending on the status of R/\overline{C} during the second falling edge of \overline{CS} .

Internal Clock

The MAX1177 generates an internal conversion clock to free the μP from the burden of running the SAR conversion clock. Total conversion time (t_{CONV}) after entering hold mode (second falling edge of \overline{CS}) to end-of-conversion (EOC) falling is $4.7\mu s$ (max).

Applications Information

Starting a Conversion

\overline{CS} and R/\overline{C} control acquisition and conversion in the MAX1177 (Figure 2). The first falling edge of \overline{CS} powers up the device and puts it in acquire mode if R/\overline{C} is low. The convert start is ignored if R/\overline{C} is high. The device needs at least 12ms for the internal reference to wake up and settle before starting the conversion ($C_{REFADJ} = 0.1\mu F$, $C_{REF} = 10\mu F$), if powering up from shutdown.

Selecting Standby or Shutdown Mode

The MAX1177 has a selectable standby or low-power shutdown mode. In standby mode, the ADC's internal reference and reference buffer do not power down between conversions, eliminating the need to wait for the reference to power up before performing the next conversion. Shutdown mode powers down the reference and reference buffer after completing a conversion. The reference and reference buffer require a minimum of 12ms to power up and settle from shutdown ($C_{REFADJ} = 0.1\mu F$, $C_{REF} = 10\mu F$).

The state of R/\overline{C} at the second falling edge of \overline{CS} selects which power-down mode the MAX1177 enters upon conversion completion. Holding R/\overline{C} low causes the device to enter standby mode. The reference and buffer are left on after the conversion completes. R/\overline{C} high causes the MAX1177 to enter shutdown mode and power-down the reference and buffer after conversion (Figures 5 and 6). Set the voltage at R/\overline{C} high during the second falling edge of \overline{CS} to realize the lowest current operation.

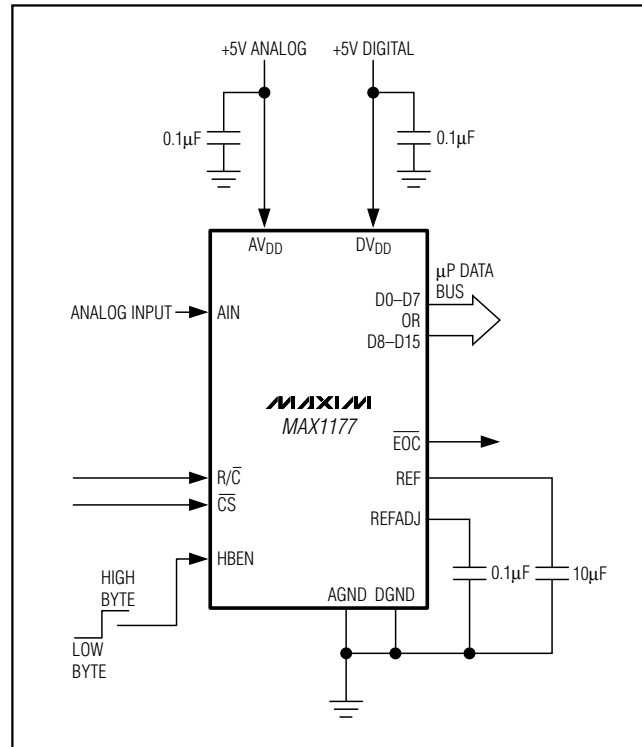


Figure 3. Typical Operating Circuit for the MAX1177

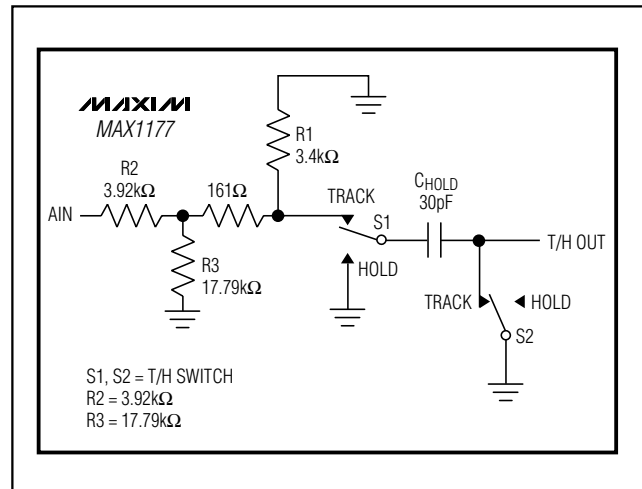


Figure 4. Equivalent Input Circuit

16-Bit, 135ksps, Single-Supply ADC with 0 to 10V Input Range

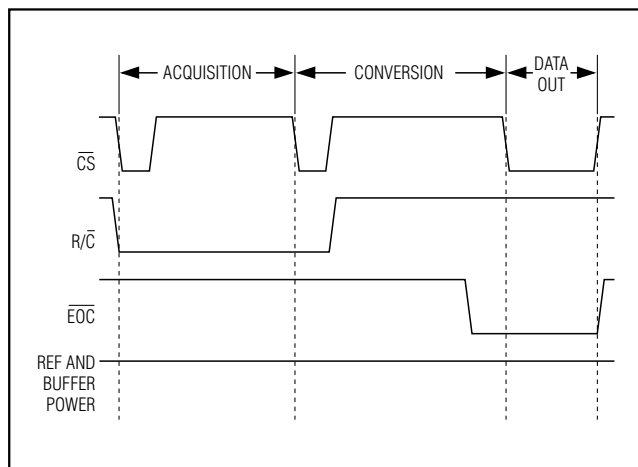


Figure 5. Selecting Standby Mode

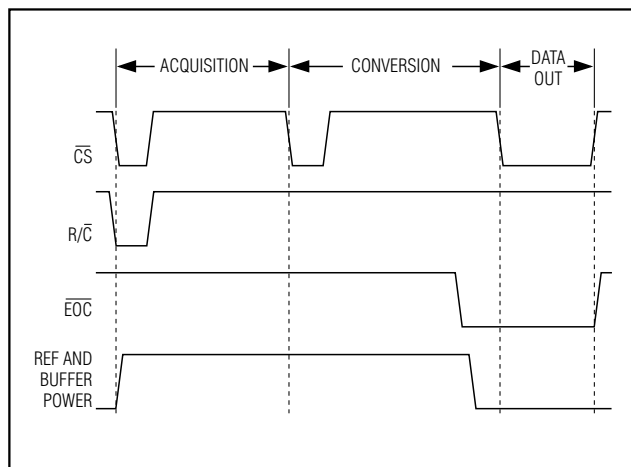


Figure 6. Selecting Shutdown Mode

Standby Mode

While in standby mode, the supply current is less than 3.7mA (typ). The next falling edge of \overline{CS} with R/\overline{C} low causes the MAX1177 to exit standby mode and begin acquisition. The reference and reference buffer remain active to allow quick turn-on time.

Shutdown Mode

In shutdown mode, the reference and reference buffer are shut down between conversions. Shutdown mode reduces supply current to 0.5 μ A (typ) immediately after the conversion. The next falling edge of \overline{CS} with R/\overline{C} low causes the reference and buffer to wake up and enter acquisition mode. To achieve 16-bit accuracy, allow 12ms for the internal reference to wake up ($C_{REFADJ} = 0.1\mu$ F, $C_{REF} = 10\mu$ F).

Internal and External Reference

Internal Reference

The internal reference of the MAX1177 is internally buffered to provide +4.096V output at REF. Bypass REF to AGND and REFADJ to AGND with 10 μ F and 0.1 μ F, respectively. Sink or source current at REFADJ to make fine adjustments to the internal reference. The input impedance of REFADJ is nominally 5k Ω . Use the circuit in Figure 7 to adjust the internal reference to $\pm 1.5\%$.

External Reference

An external reference can be placed at either the input (REFADJ) or the output (REF) of the MAX1177's internal buffer amplifier. Using the buffered REFADJ input

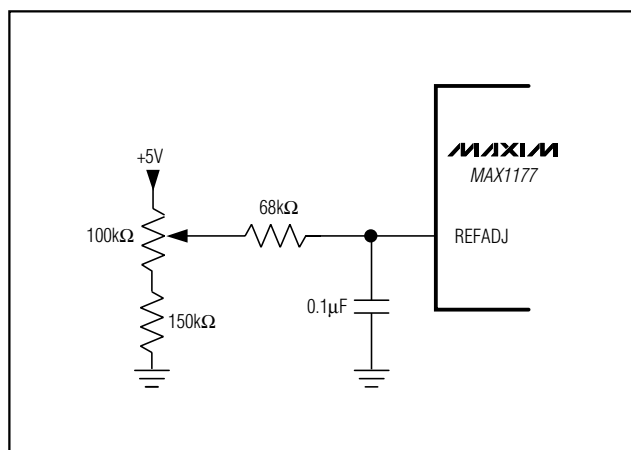


Figure 7. MAX1177 Reference Adjust Circuit

makes buffering the external reference unnecessary. The input impedance of REFADJ is typically 5k Ω . The internal buffer output must be bypassed at REF with a 10 μ F capacitor.

Connect REFADJ to AV_{DD} to disable the internal buffer. Directly drive REF using an external 3.8V to 4.2V reference. During conversion, the external reference must be able to drive 100 μ A of DC load current and have an output impedance of 10 Ω or less.

For optimal performance, buffer the reference through an op amp and bypass REF with a 10 μ F capacitor. Consider the MAX1177's equivalent input noise (0.6 LSB) when choosing a reference.

16-Bit, 135ksps, Single-Supply ADC with to 10V Input Range

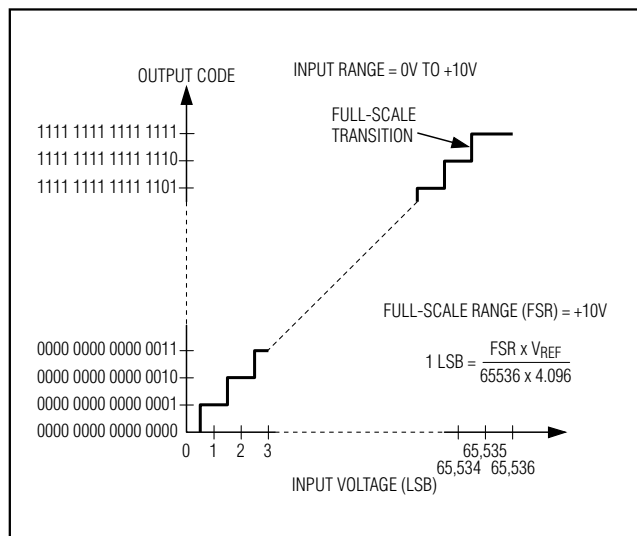


Figure 8. MAX1177 Transfer Function

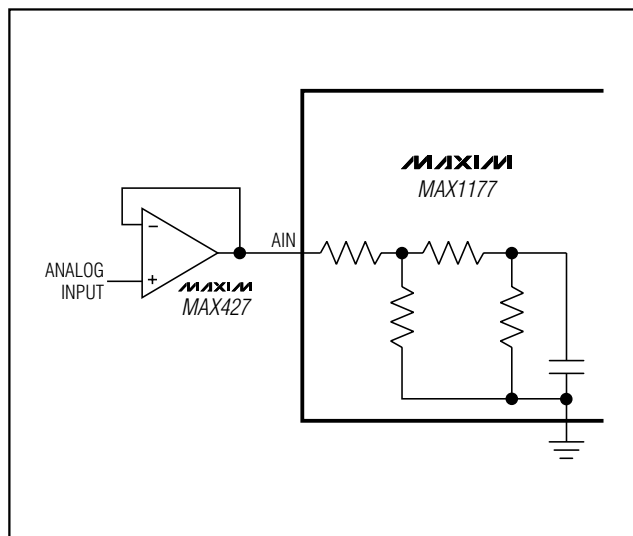


Figure 9. MAX1177 Fast-Settling Input Buffer

Reading the Conversion Result

$\overline{\text{EOC}}$ is provided to flag the μP when a conversion is complete. The falling edge of $\overline{\text{EOC}}$ signals that the data is valid and ready to be output to the bus. D0–D15 are the parallel outputs of the MAX1177. These tri-state outputs allow for direct connection to a microcontroller I/O bus. The outputs remain high impedance during acquisition and conversion. Data is loaded onto the output bus with the third falling edge of $\overline{\text{CS}}$ with R/C high (after t_{DO}). Bringing $\overline{\text{CS}}$ high forces the output bus back to high impedance. The MAX1177 then waits for the next falling edge of $\overline{\text{CS}}$ to start the next conversion cycle (Figure 2).

HBEN toggles the output between the high/low byte. The low byte is loaded onto the output bus when HBEN is low, and the high byte is on the bus when HBEN is high.

Transfer Function

Figure 8 shows the MAX1177 output transfer function. The output is coded in standard binary.

Input Buffer

Most applications require an input buffer amplifier to achieve 16-bit accuracy and prevent loading the source. When the input signal is multiplexed, switch the channels immediately after acquisition, rather than near the end of, or after, a conversion. This allows more time for the input buffer amplifier to respond to a large step

change in input signal. The input amplifier must have a high enough slew rate to complete the required output voltage change before the beginning of the acquisition time. Figure 9 shows an example of this circuit using the MAX427.

Layout, Grounding, and Bypassing

For best performance, use printed circuit boards. Do not run analog and digital lines parallel to each other, and do not lay out digital signal paths underneath the ADC package. Use separate analog and digital ground planes with only one point connecting the two ground systems (analog and digital) as close to the device as possible.

Route digital signals far away from sensitive analog and reference inputs. If digital lines must cross analog lines, do so at right angles to minimize coupling digital noise onto the analog lines. If the analog and digital sections share the same supply, isolate the digital and analog supply by connecting them with a low-value (10Ω) resistor or ferrite bead.

The ADC is sensitive to high-frequency noise on the AV_{DD} supply. Bypass AV_{DD} to AGND with a $0.1\mu\text{F}$ capacitor in parallel with a $1\mu\text{F}$ to $10\mu\text{F}$ low-ESR capacitor with the smallest capacitor closest to the device. Keep capacitor leads short to minimize stray inductance.

16-Bit, 135ksps, Single-Supply ADC with 0 to 10V Input Range

Definitions

Integral Nonlinearity

Integral nonlinearity (INL) is the deviation of the values on an actual transfer function from a straight line. This straight line can be either a best-straight-line fit or a line drawn between the end points of the transfer function, once offset and gain errors have been nullified. The static linearity parameters for the MAX1177 are measured using the end-point method.

Differential Nonlinearity

Differential nonlinearity (DNL) is the difference between an actual step width and the ideal value of 1 LSB. A DNL error specification of 1 LSB guarantees no missing codes and a monotonic transfer function.

Signal-to-Noise Ratio

For a waveform perfectly reconstructed from digital samples, signal-to-noise ratio (SNR) is the ratio of the full-scale analog input (RMS value) to the RMS quantization error (residual error). The ideal, theoretical minimum analog-to-digital noise is caused by quantization noise error only and results directly from the ADC's resolution (N bits):

$$\text{SNR} = (6.02 \times N + 1.76)\text{dB}$$

where N = 16 bits.

In reality, there are other noise sources besides quantization noise: thermal noise, reference noise, clock jitter, etc. The SNR is computed by taking the ratio of the RMS signal to the RMS noise, which includes all spectral components minus the fundamental, the first five harmonics, and the DC offset.

Signal-to-Noise Plus Distortion

Signal-to-noise plus distortion (SINAD) is the ratio of the fundamental input frequency's RMS amplitude to the RMS equivalent of all the other ADC output signals:

$$\text{SINAD(dB)} = 20 \times \log \left[\frac{\text{Signal}_{\text{RMS}}}{(\text{Noise} + \text{Distortion})_{\text{RMS}}} \right]$$

Effective Number of Bits

Effective number of bits (ENOB) indicates the global accuracy of an ADC at a specific input frequency and sampling rate. An ideal ADC error consists of quantization noise only. With an input range equal to the full-scale range of the ADC, calculate the ENOB as follows:

$$\text{ENOB} = \frac{\text{SINAD} - 1.76}{6.02}$$

Total Harmonic Distortion

Total harmonic distortion (THD) is the ratio of the RMS sum of the first five harmonics of the input signal to the fundamental itself. This is expressed as:

$$\text{THD} = 20 \times \log \left[\frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + V_5^2}}{V_1} \right]$$

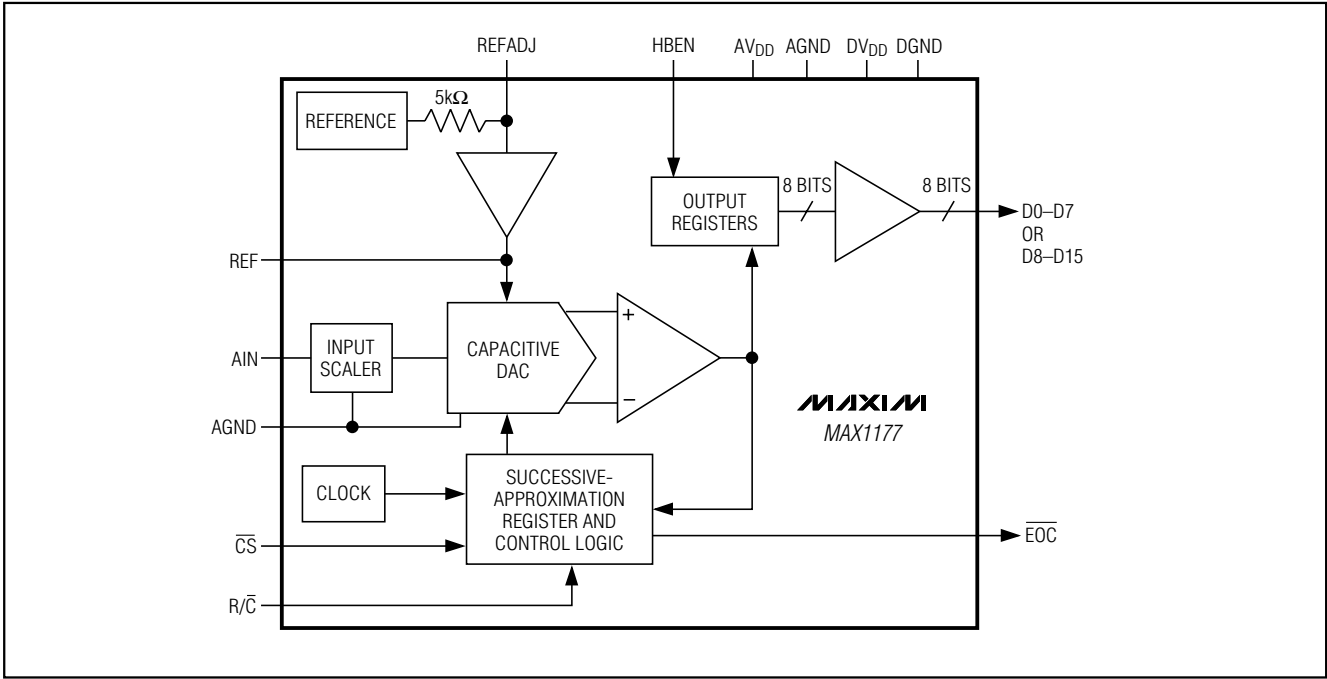
where V_1 is the fundamental amplitude and V_2 through V_5 are the 2nd- through 5th-order harmonics.

Spurious-Free Dynamic Range

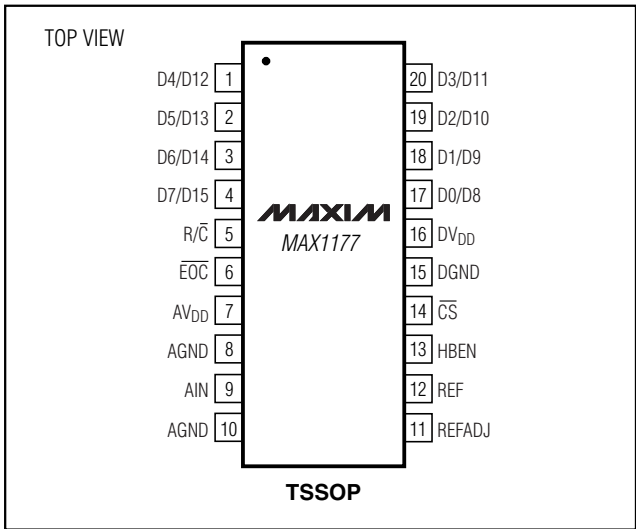
Spurious-free dynamic range (SFDR) is the ratio of the RMS amplitude of the fundamental (maximum signal component) to the RMS value of the next-largest frequency component.

16-Bit, 135ksps, Single-Supply ADC with to 10V Input Range

Functional Diagram



Pin Configuration



Chip Information

TRANSISTOR COUNT: 15,383
PROCESS: BiCMOS

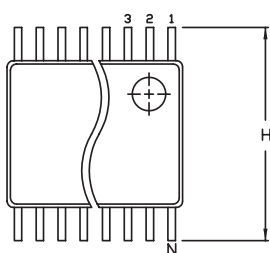
16-Bit, 135ksps, Single-Supply ADC with 0 to 10V Input Range

Package Information

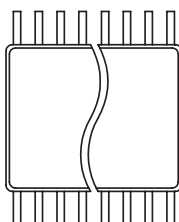
(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to www.maxim-ic.com/packages.)

MAX1177

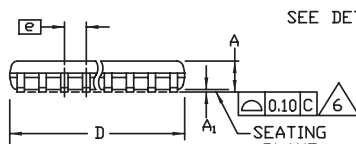
TSSOP4.40mm.EPS



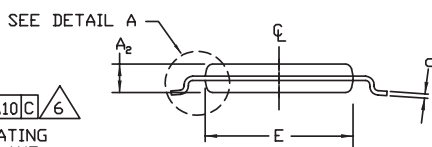
TOP VIEW



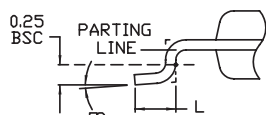
BOTTOM VIEW



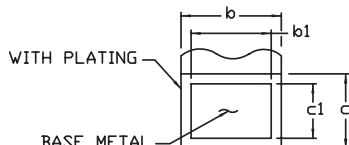
SIDE VIEW



END VIEW



DETAIL A





LEAD TIP DETAIL

NOTES:

1. DIMENSIONS D AND E DO NOT INCLUDE FLASH
 2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED 0.15mm PER SIDE
 3. CONTROLLING DIMENSION: MILLIMETER
 4. MEETS JEDEC OUTLINE MD-153. SEE JEDEC VARIATIONS TABLE
 5. "N" REFERS TO NUMBER OF LEADS
- THE LEAD TIPS MUST LIE WITHIN A SPECIFIED ZONE. THIS TOLERANCE ZONE IS DEFINED BY TWO PARALLEL PLANES. ONE PLANE IS THE SEATING PLANE, DATUM [-C-]; THE OTHER PLANE IS AT THE SPECIFIED DISTANCE FROM [-C-] IN THE DIRECTION INDICATED

| | COMMON DIMENSIONS | | | |
|----------------|-------------------|------|----------------|------|
| | MILLIMETERS | | INCHES | |
| | MIN. | MAX. | MIN. | MAX. |
| A | — | 1.10 | — | .043 |
| A ₁ | 0.05 | 0.15 | .002 | .006 |
| A ₂ | 0.85 | 0.95 | .033 | .037 |
| b | 0.19 | 0.30 | .007 | .012 |
| b ₁ | 0.19 | 0.25 | .007 | .010 |
| c | 0.09 | 0.20 | .004 | .008 |
| c ₁ | 0.09 | 0.14 | .004 | .006 |
| D | SEE VARIATIONS | | SEE VARIATIONS | |
| E | 4.30 | 4.50 | .169 | .177 |
| e | 0.65 BSC | | .026 BSC | |
| H | 6.25 | 6.55 | .246 | .258 |
| L | 0.50 | 0.70 | .020 | .028 |
| N | SEE VARIATIONS | | SEE VARIATIONS | |
| α | 0° | 8° | 0° | 8° |

| JEDEC | | N | VARIATIONS | | | |
|--------|----|---|-------------|------|--------|------|
| | | | MILLIMETERS | | INCHES | |
| | | | MIN. | MAX. | MIN. | MAX. |
| MD-153 | | | | | | |
| AB-1 | 14 | D | 4.90 | 5.10 | .193 | .201 |
| AB | 16 | D | 4.90 | 5.10 | .193 | .201 |
| AC | 20 | D | 6.40 | 6.60 | .252 | .260 |
| AD | 24 | D | 7.70 | 7.90 | .303 | .311 |
| AE | 28 | D | 9.60 | 9.80 | .378 | .386 |

| | | | |
|--|----------------------|---|-----|
|  DALLAS SEMICONDUCTOR | |  | |
| PROPRIETARY INFORMATION | | | |
| TITLE: | | | |
| PACKAGE OUTLINE, TSSOP 4.40mm BODY | | | |
| APPROVAL | DOCUMENT CONTROL NO. | REV. | 1/1 |
| | 21-0066 | F | |

Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600 13