19-2006; Rev 0; 5/01

MAXIM

# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier



## General Description

The MAX105 is a dual, 6-bit, analog-to-digital converter (ADC) designed to allow fast and precise digitizing of in-phase (I) and quadrature (Q) baseband signals. The MAX105 converts the analog signals of both I and Q components to digital outputs at 800Msps while achieving a signal-to-noise ratio (SNR) of typically 37dB with an input frequency of 200MHz, and an integral nonlinearity (INL) and differential nonlinearity (DNL) of ±0.25 LSB. The MAX105 analog input preamplifiers feature a 400MHz, -0.5dB, and a 1.5GHz, -3dB analog input bandwidth. Matching channel-to-channel performance is typically 0.04dB gain, 0.1LSB offset, and 0.2 degrees phase. Dynamic performance is 36.4dB signal-to-noise plus distortion (SINAD) with a 200MHz analog input signal and a sampling speed of 800MHz. A fully differential comparator design and encoding circuits reduce out-of-sequence errors, and ensure excellent metastable performance of only one error per $10^{16}$ clock cycles.

In addition, the MAX105 provides LVDS digital outputs with an internal 6:12 demultiplexer that reduces the output data rate to one-half the sample clock rate. Data is output in two's complement format. The MAX105 operates from a +5V analog supply and the LVDS output ports operate at +3.3V. The data converter's typical power dissipation is 2.6W. The device is packaged in an 80-pin, TQFP package with exposed paddle, and is specified for the extended (-40°C to +85°C) temperature range. For a lower-speed, 400Msps version of the MAX105, please refer to the MAX107 data sheet.

## Applications

VSAT Receivers

WLANs

Test Instrumentation

Communications Systems

***Pin Configuration appears at end of data sheet.***

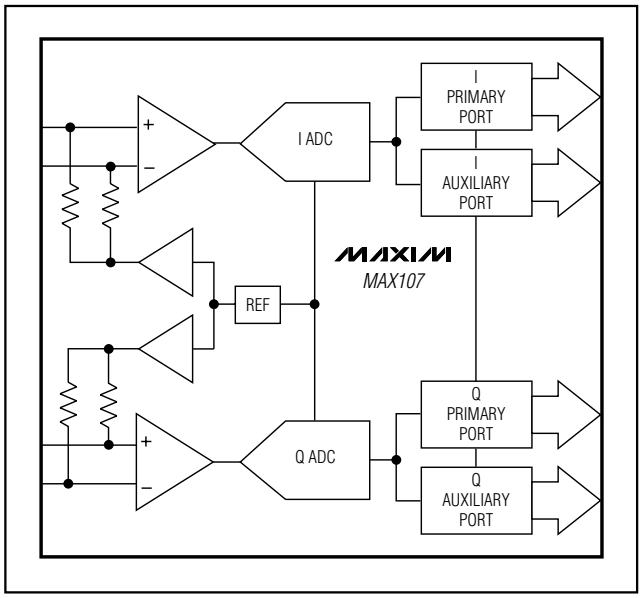
## Features

- **Two Matched 6-Bit, 800Msps ADCs**
- **Excellent Dynamic Performance**
  **36.4dB SINAD at $f_{IN}$ ≈ 200MHz and $f_{CLK}$ ≈ 800MHz**
- **Typical INL and DNL: ±0.25LSB**
- **Channel-to-Channel Phase Matching: ±0.2°**
- **Channel-to-Channel Gain Matching: ±0.04dB**
- **6:12 Demultiplexer reduces the Data Rates to 400MHz**
- **Low Error Rate: $10^{16}$ Metastable States at 800Msps**
- **LVDS Digital Outputs in Two's Complement Format**

## Ordering Information

| PART | TEMP. RANGE | PIN-PACKAGE |
|---|---|---|
| MAX105ECS | -40°C to +85°C | 80-Pin TQFP-EP |

## Block Diagram






***For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.***

# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier

## ABSOLUTE MAXIMUM RATINGS

$AV_{CC}$, $AV_{CC}I$, $AV_{CC}Q$ and $AV_{CC}R$ to AGND.....-0.3V to +6V
$OV_{CC}I$ and $OV_{CC}Q$ to OGND.....-0.3V to +4V
AGND to OGND ..... -0.3V to +0.3V
P0I± to P5I± and A0I± to A5I±
DREADY+, DREADY- to OGNDI.....-0.3V to $OV_{CC}I$+0.3V
P0Q± to P5Q±, A0Q± to A5Q±
DOR+ and DOR- to OGNDQ .....-0.3V to $OV_{CC}Q$+0.3V
REF to AGNDR.....-0.3V to $AV_{CC}R$+0.3V
Differential Voltage Between INI+ and INI- .....-2V, +2V
Differential Voltage Between INQ+ and INQ-.....-2V, +2V
Differential Voltage Between CLK+ and CLK- .....-2V, +2V
Maximum Current Into Any Pin .....50mA
Continuous Power Dissipation ($T_A$ = +70°C)
80-Pin TQFP (derate 44mW/°C above +70°C).....3.5W
Operating Temperature Range
MAX105ECS .....-40°C to +85°C
Junction Temperature.....+150°C
Storage Temperature Range .....-60°C to +150°C
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

($AV_{CC}$ = $AV_{CC}I$ = $AV_{CC}Q$ = $AV_{CC}R$ = +5V, $OV_{CC}I$ = $OV_{CC}Q$ = +3.3V, AGND = AGNDI = AGNDQ = AGNDR = 0, OGNDI = OGNDQ = 0, $f_{CLK}$ = 802.816MHz, $C_L$ = 1µF to AGND at REF, $R_L$ = 100Ω ±1% applied to digital LVDS outputs, $T_A$ = $T_{MIN}$ 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 | | 6 | | | Bits |
| Integral Nonlinearity (Note 1) | INL | | -1 | ±0.2 | 1 | LSB |
| Differential Nonlinearity (Note 1) | DNL | No missing codes guaranteed | -1 | ±0.25 | 1 | LSB |
| Offset Voltage | $V_{OS}$ | (Note 2) | -1 | ±0.25 | 1 | LSB |
| Offset Matching Between ADCs | OM | (Note 2) | -0.5 | ±0.1 | 0.5 | LSB |
| **ANALOG INPUTS (INI+, INI-, INQ+, INQ-)** | | | | | | |
| Input Open-Circuit Voltage | $V_{AOC}$ | | 2.4 | 2.5 | 2.6 | V |
| Input Open-Circuit Voltage Matching | | $(V_{INI+} - V_{IN-}) - (V_{INQ+} - V_{INQ-})$ | | | ±7.5 | mV |
| Common Mode Input Voltage Range (Note 3) | $V_{CM}$ | Signal + Offset w.r.t. AGND | 1.85 | | 3.05 | V |
| Full-Scale Analog Input Voltage Range (Note 4) | $V_{FSR}$ | | 0.76 | 0.8 | 0.84 | $V_{p-p}$ |
| Input Resistance | $R_{IN}$ | | 1.7 | 2 | | kΩ |
| Input Capacitance | $C_{IN}$ | | | 1.5 | | pF |
| Input Resistance Temperature Coefficient | $TCR_{IN}$ | | | 150 | | ppm/°C |
| Full-Power Analog Input BW | $FPBW_{-0.5dB}$ | | | 400 | | MHz |
| **REFERENCE OUTPUT** | | | | | | |
| Reference Output Resistance | $R_{REF}$ | Referenced to AGNDR | | 5 | | Ω |
| Reference Output Voltage | $\sqrt{REF}$ | $I_{SOURCE}$ = 500µA | 2.45 | 2.50 | 2.55 | V |

## ELECTRICAL CHARACTERISTICS (continued)

($AV_{CC}$ = $AV_{CC}I$ = $AV_{CC}Q$ = $AV_{CC}R$ = +5V, $OV_{CC}I$ = $OV_{CC}Q$ = +3.3V, AGND = AGNDI = AGNDQ = AGNDR = 0, OGNDI = OGNDQ = 0, $f_{CLK}$ = 802.816MHz, $C_L$ = 1µF to AGND at REF, $R_L$ = 100Ω ±1% applied to digital LVDS outputs, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| **CLOCK INPUTS (CLK+, CLK-)** | | | | | | | |
| Clock Input Resistance | $R_{CLK}$ | CLK+ and CLK- to AGND | | | 5 | | kΩ |
| Clock Input Resistance Temperature Coefficient | $TCR_{CLK}$ | | | | 150 | | ppm/°C |
| Minimum Clock Input Amplitude | | | | 500 | | | $mV_{p-p}$ |
| **LVDS OUTPUTS (P0I± TO P5I±, P0Q± TO P5Q±, A0I± TO A5I±, A0Q± TO A5Q±, DREADY+, DREADY-, DOR+, DOR-)** | | | | | | | |
| Differential Output Voltage | $\lvert V_{OD} \rvert$ | | | 247 | | 400 | mV |
| Change in Magnitude of $\lvert V_{OD} \rvert$ Between "0" and "1" States | $\Delta\lvert V_{OD} \rvert$ | | | | | ±25 | mV |
| Steady-State Common Mode Output Voltage | $V_{OC(SS)}$ | | | 1.125 | | 1.375 | V |
| Change in Magnitude of $V_{OC}$ Between "0" and "1" States | $\Delta\lvert V_{OC} \rvert$ | | | | | ±25 | mV |
| Differential Output Resistance | | | | 80 | | 160 | Ω |
| Output Current | | Short output together | | | 2.5 | | mA |
| | | Short to OGNDI = OGNDQ | | | 25 | | |
| **DYNAMIC SPECIFICATION** | | | | | | | |
| Effective Number of Bits (Note 8) | ENOB | $f_{IN}$ = 200.018MHz at -0.5dB FS (Note 9) | Differential | 5.4 | 5.8 | | Bits |
| | | | Single-ended | | 5.75 | | |
| | | $f_{IN}$ = 400.134MHz at -0.5dB FS | Differential | | 5.65 | | |
| Signal-to-Noise Ratio (Notes 10, 11) | SNR | $f_{IN}$ = 200.018MHz at -0.5dB FS (Note 9) | Differential | 35 | 37 | | dB |
| | | | Single-ended | | 36.7 | | |
| | | $f_{IN}$ = 400.134MHz at -0.5dB FS | Differential | | 36.5 | | |
| Total Harmonic Distortion (Note 11) | THD | $f_{IN}$ = 200.018MHz at -0.5dB FS (Note 9) | Differential | | -44.5 | -41 | dBc |
| | | | Single-ended | | -44.5 | | |
| | | $f_{IN}$ = 400.134MHz at -0.5dB FS | Differential | | -41 | | |
| Spurious-Free Dynamic Range | SFDR | $f_{IN}$ = 200.018MHz at -0.5dB FS (Note 9) | Differential | 41 | 45 | | dB |
| | | | Single-ended | | 45 | | |
| | | $f_{IN}$ = 400.134MHz at -0.5dB FS | Differential | | 41.5 | | |

# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier

## ELECTRICAL CHARACTERISTICS (continued)

($AV_{CC}$ = $AV_{CC}I$ = $AV_{CC}Q$ = $AV_{CC}R$ = +5V, $OV_{CC}I$ = $OV_{CC}Q$ = +3.3V, AGND = AGNDI = AGNDQ = AGNDR = 0, OGNDI = OGNDQ = 0, $f_{CLK}$ = 802.816MHz, $C_L$ = 1µF to AGND at REF, $R_L$ = 100Ω ±1% applied to digital LVDS outputs, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C)

| PARAMETER | SYMBOL | CONDITIONS | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| Signal-to-Noise Plus Distortion Ratio | SINAD | $f_{IN}$ = 200.018MHz at -0.5dB FS (Note 9) | Differential | 34 | 36.4 | | dB |
| | | | Single-ended | | 36.1 | | |
| | | $f_{IN}$ = 400.134MHz at -0.5dB FS | Differential | | 35.2 | | |
| Two-Tone Intermodulation | TTIMD | $f_{IN1}$ = 124.1660MHz, $f_{IN2}$ = 126.1260MHz at -7dBFS | | | -52 | | dBc |
| Crosstalk Between ADCs | XTLK | $f_{INI}$ = 200.0180MHz, $f_{INQ}$ = 210.0140MHz at -0.5dB FS | | | -70 | | dB |
| Gain Match Between ADCs | GM | (Note 12) | | -0.3 | ±0.04 | +0.3 | dB |
| Phase Match Between ADCs | PM | (Note 12) | | -2 | ±0.2 | +2 | deg |
| Metastable Error Rate | | | | Less than 1 in $10^{16}$ | | | Clock Cycles |
| **POWER REQUIREMENTS** | | | | | | | |
| Analog Supply Voltage | $AV_{CC_}$ | $AV_{CC}$ = $AV_{CC}I$ = $AV_{CC}Q$ = $AV_{CC}R$ | | | 5 ±5% | | V |
| Digital Supply Voltage | $OV_{CC_}$ | $OV_{CC}I$ = $OV_{CC}Q$ | | | 3.3 ±10% | | V |
| Analog Supply Current | $I_{CC}$ | $I_{CC}$ = $AI_{CC}R$ + $AI_{CC}I$ + $AI_{CC}Q$ + $AI_{CC}$ | | | 250 | 320 | mA |
| Output Supply Current | $OI_{CC}$ | $OI_{CC}$ = $OI_{CC}I$ + $OI_{CC}Q$ | | | 400 | 510 | mA |
| Analog Power Dissipation | $P_{DISS}$ | | | | 2.6 | | W |
| Common-Mode Rejection Ratio | CMRR | $V_{IN_+}$ = $V_{IN_-}$ = ±0.1V (Note 6) | | 40 | 60 | | dB |
| Power-Supply Rejection Ratio | PSRR | $AV_{CC}$ = $AV_{CC}I$ = $AV_{CC}Q$ = $AV_{CC}R$ = +4.75V to +5.25V (Note 7) | | 40 | 57 | | dB |
| **TIMING CHARACTERISTICS** | | | | | | | |
| Maximum Sample Rate | $f_{MAX}$ | | | 800 | | | Msps |
| Clock Pulse Width Low | $t_{PWL}$ | | | 0.56 | | | ns |
| Clock Pulse Width High | $t_{PWH}$ | | | 0.56 | | | ns |
| Aperture Delay | $t_{AD}$ | | | | 100 | | ps |
| Aperture Jitter | $t_{AJ}$ | | | | 1.5 | | $ps_{RMS}$ |
| CLK-to-DREADY Propagation Delay | $t_{PD1}$ | (Note 13) | | | 1.5 | | ns |
| DREADY-to-DATA Propagation Delay | $t_{PD2}$ | (Notes 5, 13) | | 0 | 120 | 300 | ps |

## ELECTRICAL CHARACTERISTICS (continued)

($AV_{CC}$ = $AV_{CC}I$ = $AV_{CC}Q$ = $AV_{CC}R$ = +5V, $OV_{CC}I$ = $OV_{CC}Q$ = +3.3V, AGND = AGNDI = AGNDQ = AGNDR = 0, OGNDI = OGNDQ = 0, $f_{CLK}$ = 802.816MHz, $C_L$= 1µF to AGND at REF, $R_L$ = 100Ω ±1% applied to digital LVDS outputs, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| DREADY Duty Cycle | | (Notes 5, 13) | 47 | | 53 | % |
| LVDS Output Rise-Time | $t_{RDATA}$ | 20% to 80% (Notes 5, 13) | 200 | | 500 | ps |
| LVDS Output Fall-Time | $t_{FDATA}$ | 20% to 80% (Notes 5, 13) | 200 | | 500 | ps |
| LVDS Differential Skew | $t_{SKEW1}$ | Any differential pair | | <65 | | ps |
| | | Any two LVDS output signals except DREADY | | <100 | | ps |
| DREADY Rise-Time | $t_{RDREADY}$ | 20% to 80% (Notes 5, 13) | 200 | | 500 | ps |
| DREADY Fall-Time | $t_{FDREADY}$ | 20% to 80% (Notes 5, 13) | 200 | | 500 | ps |
| Primary Port Pipeline Delay | $t_{PDP}$ | | | 5 | | Clock Cycles |
| Auxiliary Port Pipeline Delay | $t_{PDA}$ | | | 6 | | Clock Cycles |

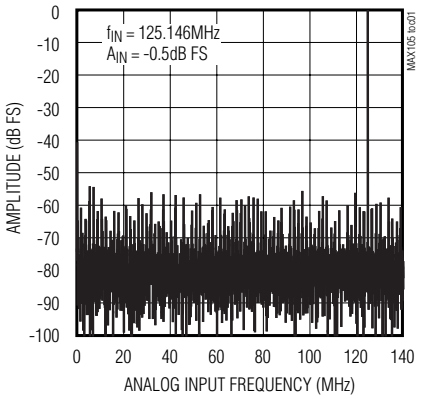
**Note 1:** NL and DNL is measured using a sine-histogram method.
**Note 2:** Input offset is the voltage required to cause a transition between codes 0 and -1.
**Note 3:** Numbers provided are for DC-coupled case. The user has the choice of AC-coupling, in which case, the DC input voltage level does not matter.
**Note 4:** The peak-to-peak input voltage required, causing a full-scale digitized output when using a trigonometric curve-fitting algorithm (e.g. FFT).
**Note 5:** Guaranteed by design and characterization.
**Note 6:** Common-mode rejection ratio is defined as the ratio of the change in the offset voltage to the change in the common-mode voltage expressed in dB.
**Note 7:** Measured with analog power supplies tied to the same potential.
**Note 8:** Effective number of bits (ENOB) is computed from a curve-fit referenced to the theoretical full-scale range.
**Note 9:** The clock and input frequencies are chosen so that there are 2041 cycles in an 8,192-long record.
**Note 10:** Signal-to-noise-ratio (SNR) is measured both with the other channel idling and converting an out-of-phase signal. The worst case number is presented. Harmonic distortion components two through five are excluded from the noise.
**Note 11:** Harmonic distortion components two through five are included in the total harmonic distortion specification.
**Note 12:** Both I and Q inputs are effectively tied together (e.g. driven by power splitter). Signal amplitude is -0.5dB FS at an input frequency of $f_{IN}$ = 200.0180 MHz.
**Note 13:** Measured with a differential probe, 1pF capacitance.

# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier

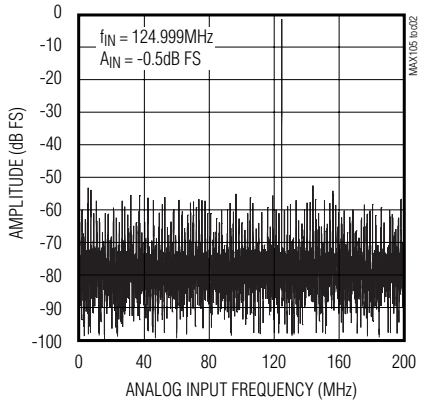
## Typical Operating Characteristics

($AV_{CC}$ = $AV_{CC}I$ = $AV_{CC}Q$ = $AV_{CC}R$ = +5V, $OV_{CC}I$ = $OV_{CC}Q$ = +3.3V, AGND = AGNDI = AGNDQ = AGNDR = 0, OGNDI = OGNDQ = 0, $f_{CLK}$ = 802.816MHz, differential input at -0.5dB FS, $C_L$ = 1µF to AGND at REF, $R_L$ = 100Ω ±1% applied to digital LVDS outputs, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C)

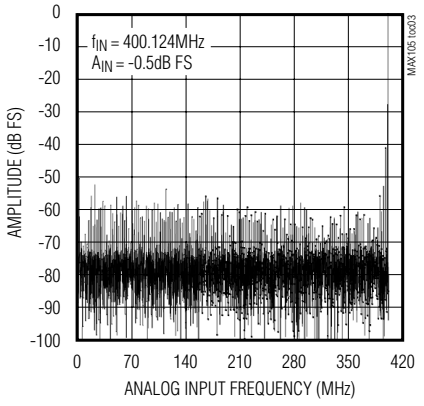
**8192-POINT FFT, DIFFERENTIAL INPUT**



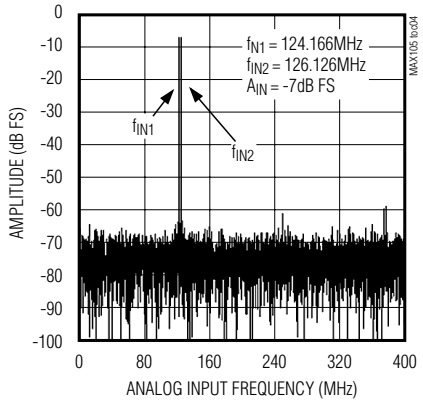

**8192-POINT FFT, DIFFERENTIAL INPUT**



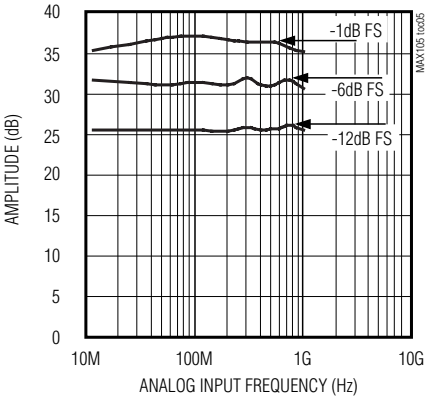

**8192-POINT FFT, DIFFERENTIAL INPUT**



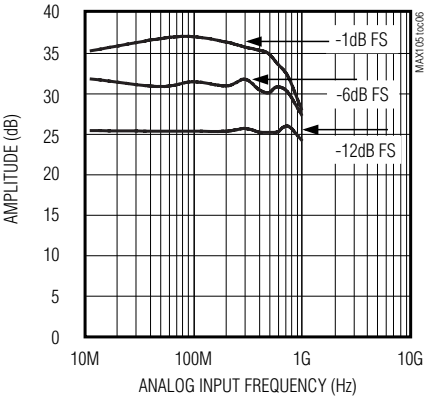

**TWO-TONE IMD (8192-POINT RECORD), DIFFERENTIAL INPUT**



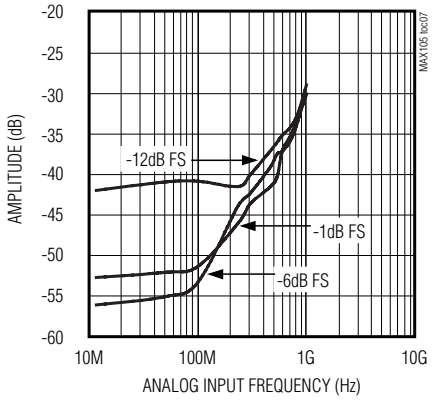

**SNR vs. ANALOG INPUT FREQUENCY, DIFFERENTIAL INPUT**



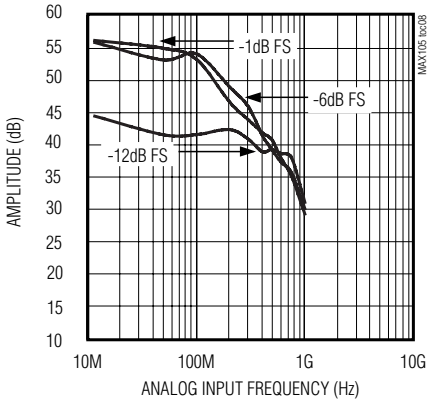

**SINAD vs. ANALOG INPUT FREQUENCY, DIFFERENTIAL INPUT**



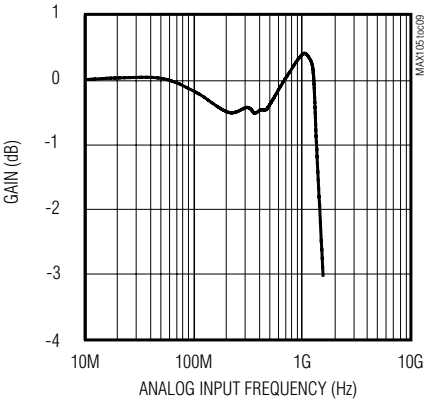

**THD vs. ANALOG INPUT FREQUENCY, DIFFERENTIAL INPUT**




**SFDR vs. ANALOG INPUT FREQUENCY, DIFFERENTIAL INPUT**



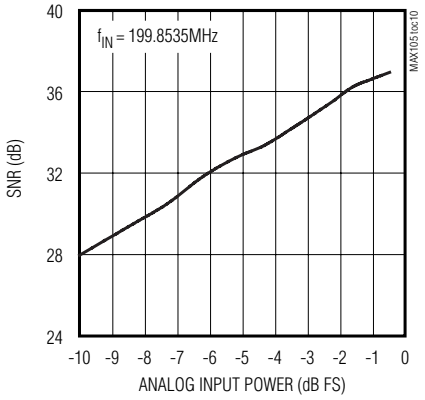

**FULL-POWER INPUT BANDWIDTH SINGLE-ENDED INPUT**



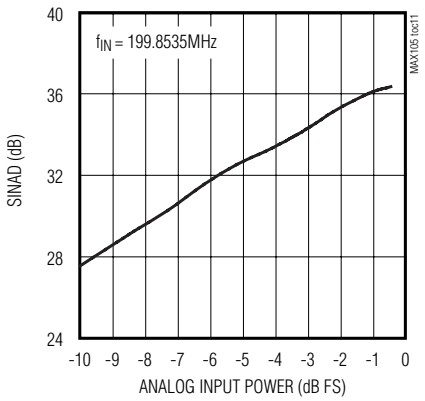
## Typical Operating Characteristics (continued)

($AV_{CC}$ = $AV_{CC}I$ = $AV_{CC}Q$ = $AV_{CC}R$ = +5V, $OV_{CC}I$ = $OV_{CC}Q$ = +3.3V, AGND = AGNDI = AGNDQ = AGNDR = 0, OGNDI = OGNDQ = 0, $f_{CLK}$ = 802.816MHz, differential input at -0.5dB FS, $C_L$ = 1µF to AGND at REF, $R_L$ = 100Ω ±1% applied to digital LVDS outputs, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C)

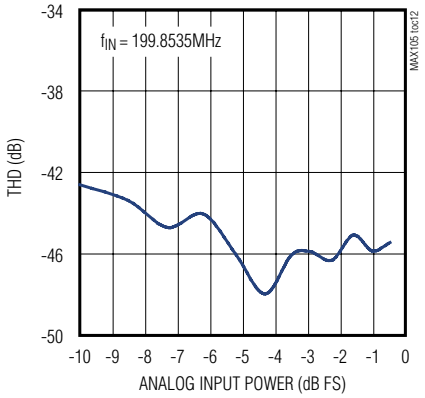
**SNR vs. ANALOG INPUT POWER, DIFFERENTIAL INPUT**



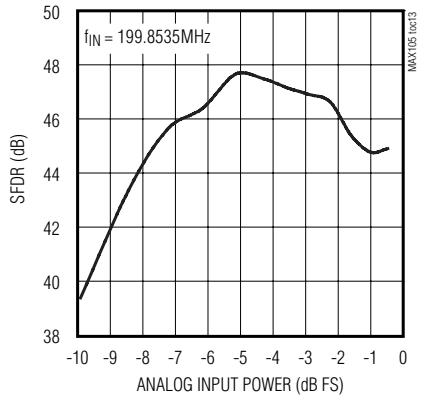

**SINAD vs. ANALOG INPUT POWER, DIFFERENTIAL INPUT**



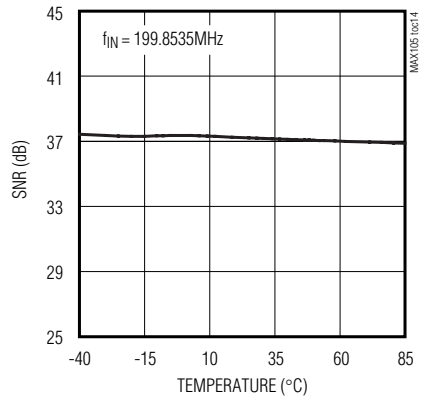

**THD vs. ANALOG INPUT POWER, DIFFERENTIAL INPUT**



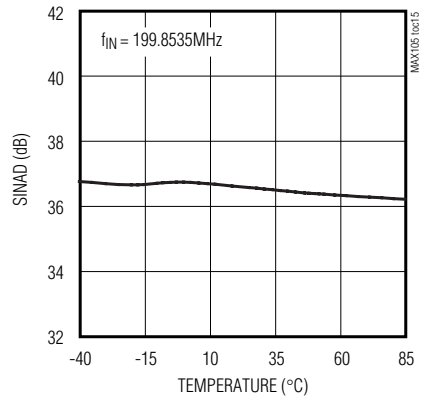

**SFDR vs. ANALOG INPUT POWER, DIFFERENTIAL INPUT**



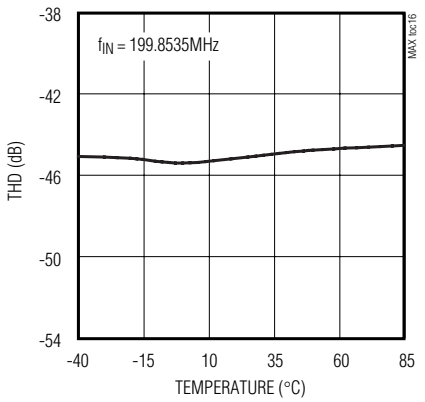

**SNR vs. TEMPERATURE**



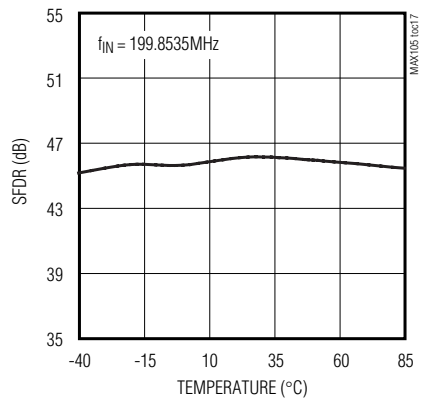

**SINAD vs. TEMPERATURE**



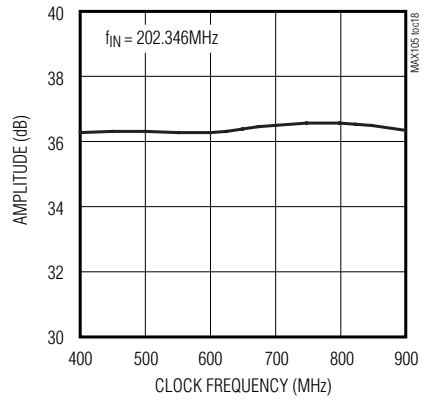

**THD vs. TEMPERATURE**




**SFDR vs. TEMPERATURE**




**SNR vs. CLOCK FREQUENCY, DIFFERENTIAL INPUT (-1dB FS)**

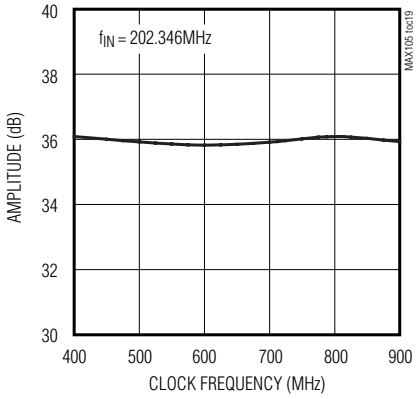


# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier

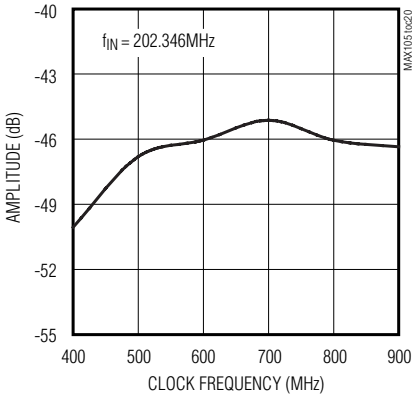
## Typical Operating Characteristics (continued)

($AV_{CC}$ = $AV_{CC}I$ = $AV_{CC}Q$ = $AV_{CC}R$ = +5V, $OV_{CC}I$ = $OV_{CC}Q$ = +3.3V, AGND = AGNDI = AGNDQ = AGNDR = 0, OGNDI = OGNDQ = 0, $f_{CLK}$ = 802.816MHz, differential input at -0.5dB FS, $C_L$ = 1µF to AGND at REF, $R_L$ = 100Ω ±1% applied to digital LVDS outputs, $T_A$ = $T_{MIN}$ to $T_{MAX}$, unless otherwise noted. Typical values are at $T_A$ = +25°C)

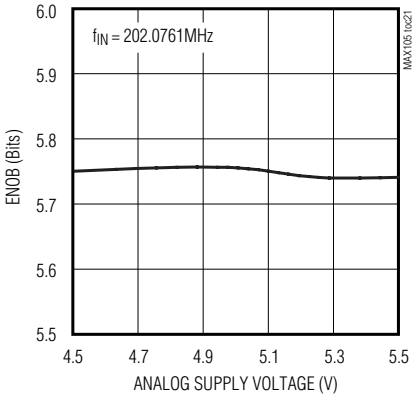
**SINAD vs. CLOCK FREQUENCY, DIFFERENTIAL INPUT (-1dB FS)**



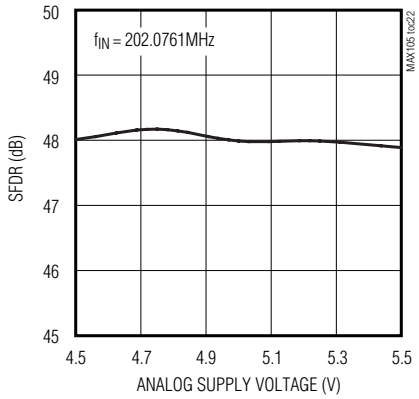

**THD vs. CLOCK FREQUENCY, DIFFERENTIAL INPUT (-1dB FS)**



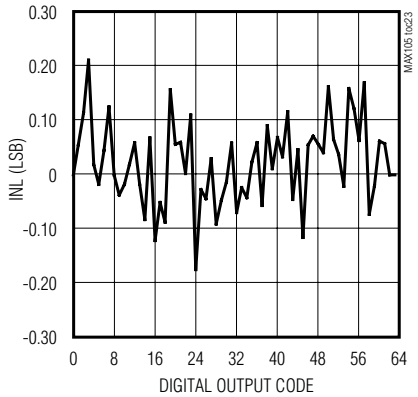

**ENOB vs. ANALOG SUPPLY VOLTAGE, DIFFERENTIAL INPUT (-1dB FS)**



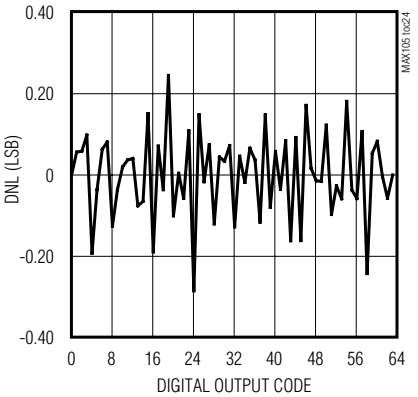

**SFDR vs. ANALOG SUPPLY VOLTAGE, DIFFERENTIAL INPUT (-1dB FS)**



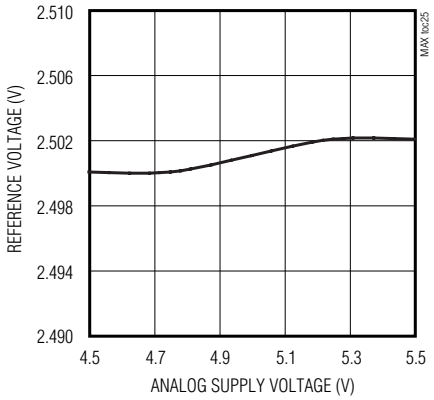

**INL vs. DIGITAL OUTPUT CODE**



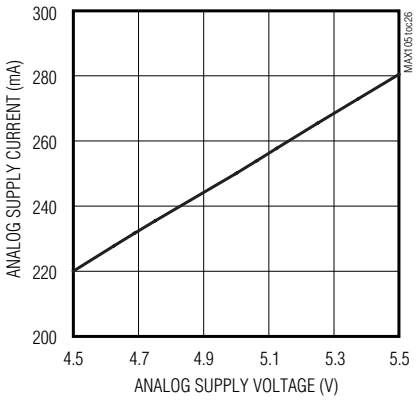

**DNL vs. DIGITAL OUTPUT CODE**



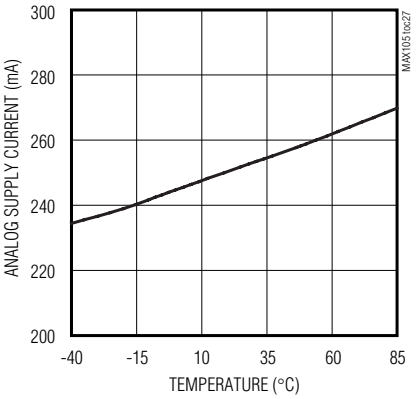

**REFERENCE VOLTAGE vs. ANALOG SUPPLY VOLTAGE**




**ANALOG SUPPLY CURRENT vs. ANALOG SUPPLY VOLTAGE**




**ANALOG SUPPLY CURRENT vs. TEMPERATURE**



## Pin Description

| PIN | NAME | FUNCTION |
|---|---|---|
| 1, 20 | T.P. | Test Point. **Do not connect.** |
| 2 | REF | Reference Output |
| 3 | $AV_{CC}R$ | Analog Reference Supply. Supply voltage for the internal bandgap reference. Bypass to AGNDR with 0.01µF in parallel with 47pF for proper operation. |
| 4 | AGNDR | Reference, Analog Ground. **Connect to AGND for proper operation.** |
| 5, 8 | AGNDI | I-Channel, Analog Ground. **Connect to AGND for proper operation.** |
| 6 | INI- | I-Channel, Differential Input. Negative terminal. |
| 7 | INI+ | I Channel, Differential Input. Positive terminal. |
| 9 | $AV_{CC}I$ | I-Channel, Analog Supply. Supplies I-channel common-mode buffer, pre-amplifier and quantizer. Bypass to AGNDI with 0.01µF in parallel with 47pF for proper operation. |
| 10 | CLK+ | Sampling Clock Input |
| 11 | CLK- | Complementary Sampling Clock Input |
| 12 | $AV_{CC}Q$ | Q-Channel, Analog Supply. Supplies Q-channel common-mode buffer, pre-amplifier and quantizer. Bypass to AGNDQ with 0.01µF in parallel with 47pF for proper operation. |
| 13, 16 | AGNDQ | Q-Channel, Analog Ground. **Connect to AGND for proper operation.** |
| 14 | INQ+ | Q-Channel, Differential Input. Positive terminal. |
| 15 | INQ- | Q-Channel, Differential Input. Negative terminal. |
| 17, 18 | AGND | Analog Ground |
| 19 | $AV_{CC}$ | Analog Supply. Bypass to AGND with 0.01µF in parallel with 47pF for proper operation. |
| 21 | A5Q+ | Auxiliary Output Data Bit 5 (MSB), Q-Channel |
| 22 | A5Q- | Complementary Auxiliary Output Data Bit 5 (MSB), Q-Channel |
| 23 | P5Q+ | Primary Output Data Bit 5 (MSB), Q-Channel |
| 24 | P5Q- | Complementary Primary Output Data Bit 5 (MSB), Q-Channel |
| 25 | A4Q+ | Auxiliary Output Data Bit 4, Q-Channel |
| 26 | A4Q- | Complementary Auxiliary Output Data Bit 4, Q-Channel |
| 27 | P4Q+ | Primary Output Data Bit 4, Q-Channel |
| 28 | P4Q- | Complementary Primary Output Data Bit 4, Q-Channel |
| 29, 35 | $OV_{CC}Q$ | Q-Channel Outputs, Digital Supply. Supplies Q-channel output drivers and DOR logic. Bypass to OGND with 0.01µF in parallel with 47pF for proper operation. |
| 30, 36 | OGNDQ | Q-Channel Outputs, Digital Ground. **Connect to designated digital ground (OGND) on PC board for proper operation.** |

# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier

## Pin Description (continued)

| PIN | NAME | FUNCTION |
|---|---|---|
| 31 | A3Q+ | Auxiliary Output Data Bit 3, Q-Channel |
| 32 | A3Q- | Complementary Auxiliary Output Data Bit 3, Q-Channel |
| 33 | P3Q+ | Primary Output Data Bit 3, Q-Channel |
| 34 | P3Q- | Complementary Primary Output Data Bit 3, Q-Channel |
| 37 | A2Q+ | Auxiliary Output Data Bit 2, Q-Channel |
| 38 | A2Q- | Complementary Auxiliary Output Data Bit 2, Q-Channel |
| 39 | P2Q+ | Primary Output Data Bit 2, Q-Channel |
| 40 | P2Q- | Complementary Primary Output Data Bit 2, Q-Channel |
| 41 | A1Q+ | Auxiliary Output Data Bit 1, Q-Channel |
| 42 | A1Q- | Complementary Auxiliary Output Data Bit 1, Q-Channel |
| 43 | P1Q+ | Primary Output Data Bit 1, Q-Channel |
| 44 | P1Q- | Complementary Primary Output Data Bit 1, Q-Channel |
| 45 | A0Q+ | Auxiliary Output Data Bit 0 (LSB), Q-Channel |
| 46 | A0Q- | Complementary Auxiliary Output Data Bit 0 (LSB), Q-Channel |
| 47 | P0Q+ | Primary Output Data Bit 0 (LSB), Q-Channel |
| 48 | P0Q- | Complementary Primary Output Data Bit 0 (LSB), Q-Channel |
| 49 | DOR+ | Complementary LVDS Out-Of-Range Bit |
| 50 | DOR- | LVDS Out-of-Range Bit |
| 51 | DREADY- | Complementary Data-Ready Clock |
| 52 | DREADY+ | Data Ready Clock |
| 53 | P0I- | Complementary Primary Output Data Bit 0 (LSB), I-Channel |
| 54 | P0I+ | Primary Output Data Bit 0 (LSB), I-Channel |
| 55 | A0I- | Complementary Auxiliary Output Data Bit 0 (LSB), I-Channel |
| 56 | A0I+ | Auxiliary Output Data Bit 0 (LSB), I-Channel |
| 57 | P1I- | Complementary Primary Output Data Bit 1, I-Channel |
| 58 | P1I+ | Primary Output Data Bit 1, I-Channel |
| 59 | A1I- | Complementary Auxiliary Output Data Bit 1, I-Channel |
| 60 | A1I+ | Auxiliary Output Data Bit 1, I-Channel |
| 61 | P2I- | Complementary Primary Output Data Bit 2, I-Channel |

## Pin Description (continued)

| PIN | NAME | FUNCTION |
|---|---|---|
| 62 | P2I+ | Primary Output Data Bit 2, I-Channel |
| 63 | A2I- | Complementary Auxiliary Output Data Bit 2, I-Channel |
| 64 | A2I+ | Auxiliary Output Data Bit 2, I-Channel |
| 65, 72 | $OV_{CC}I$ | I-Channel Outputs, Digital Supply. Supplies I-channel output drivers and DREADY circuit. Bypass to OGND with 0.01µF in parallel with 47pF for proper operation. |
| 66, 71 | OGNDI | I-Channel Outputs, Digital Ground. **Connect to designated digital ground (OGND) on PC board for proper operation.** |
| 67 | P3I- | Complementary Primary Output Data Bit 3, I-Channel |
| 68 | P3I+ | Primary Output Data Bit 3, I-Channel |
| 69 | A3I- | Complementary Auxiliary Output Data Bit 3, I-Channel |
| 70 | A3I+ | Auxiliary Output Data Bit 3, I-Channel |
| 73 | P4I- | Complementary Primary Output Data Bit 4, I-Channel |
| 74 | P4I+ | Primary Output Data Bit 4, I-Channel |
| 75 | A4I- | Complementary Auxiliary Output Data Bit 4, I-Channel |
| 76 | A4I+ | Auxiliary Output Data Bit 4, I-Channel |
| 77 | P5I- | Complementary Primary Output Data Bit 5, I-Channel |
| 78 | P5I+ | Primary Output Data Bit 5, I-Channel |
| 79 | A5I- | Complementary Auxiliary Output Data Bit 5, I-Channel |
| 80 | A5I+ | Auxiliary Output Data Bit 5, I-Channel |

## Detailed Description

The MAX105 is a dual, +5V, 6-bit, 800Msps flash analog-to-digital converter (ADC), designed for high-speed, high-bandwidth I&Q digitizing. Each ADC (Figure 1) employs a fully differential, wide bandwidth input stage, 6-bit quantizers and a unique encoding scheme to limit metastable states to typically one error per $10^{16}$ clock cycles, with no error exceeding a maximum of 1LSB. An integrated 6:12 output demultiplexer simplifies interfacing to the part by reducing the output data rate to one-half the sampling clock rate. The MAX105 outputs data in LVDS two's complement format.

When clocked at 800Msps, the MAX105 provides a typical signal-to-noise plus distortion (SINAD) of 36.4dB with a 200MHz input tone. The analog input of the MAX105 is designed for differential or single-ended use with a ±400mV full-scale input range. In addition, the MAX105 features an on-board +2.5V precision bandgap reference, which is scaled to meet the analog input full-scale range.

### Principle of Operation

The MAX105 employs a flash or parallel architecture. The key to this high-speed flash architecture is the use of an innovative, high-performance comparator design. Each quantizer and downstream logic translates the comparator outputs into 6-bit, parallel codes in two's complement format and passes them on to the internal 6:12 demultiplexer. The demultiplexer enables the ADCs to provide their output data at half the sampling speed on primary and auxiliary ports. LVDS data is available at speeds of up to 400MHz per output port.

### Input Amplifier Circuits

As with all ADCs, if the input waveform is changing rapidly during conversion, effective number of bits (ENOB), signal-to-noise plus distortion (SINAD), and

# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier

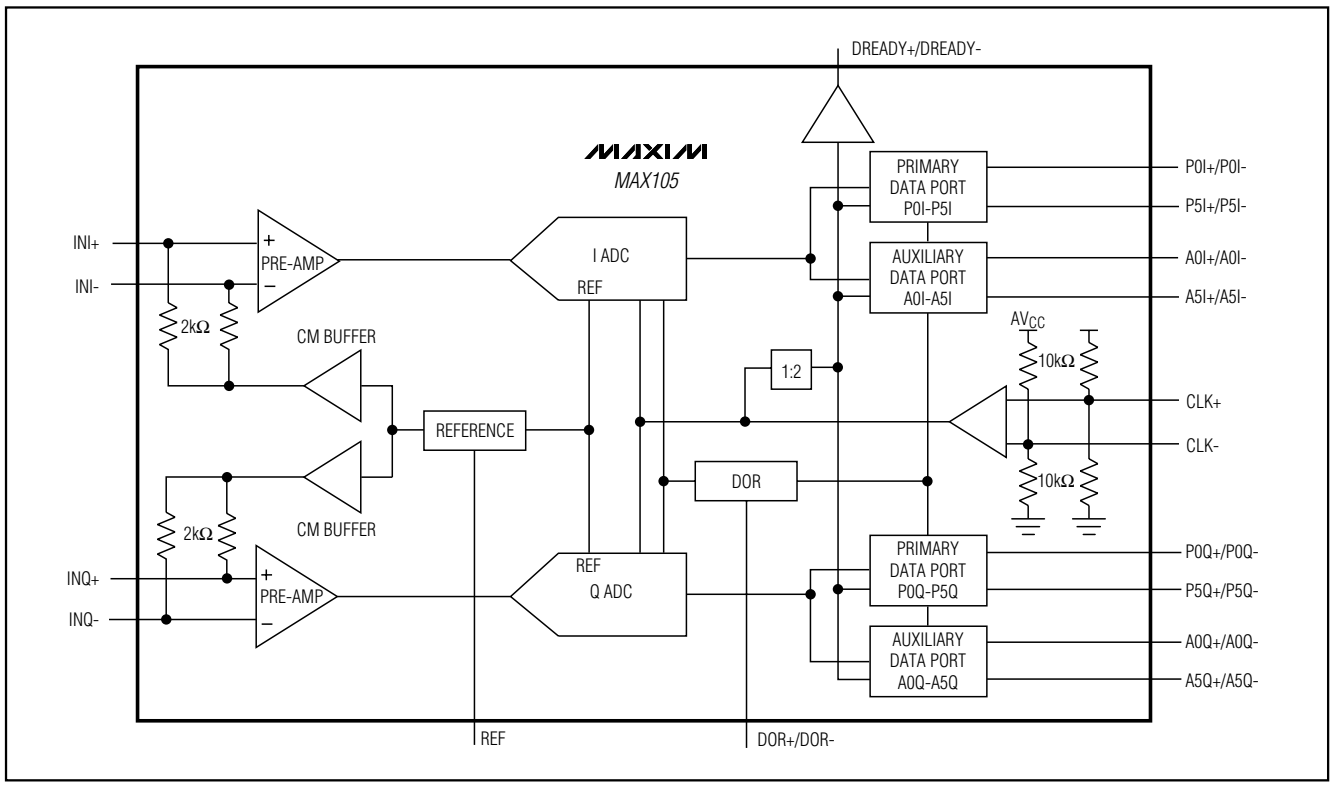



*Figure 1. MAX105 Flash Converter Architecture*

signal-to-noise ratio (SNR) specifications will degrade. The MAX105's on-board, wide-bandwidth input amplifiers (I&Q) reduce this effect significantly, allowing precise digitizing of fast analog data at high conversion rates. The input amplifiers buffer the input signal and allow a full-scale signal input range of ±400mV (800mV$_{p-p}$).

### Internal Reference

The MAX105 features an integrated, buffered +2.5V precision bandgap reference. This reference is internally scaled to match the analog input range specification of ±400mV. The data converter's reference output (REF) can source up to 500µA. REF should be buffered, if used to supply external devices.

### LVDS Digital Outputs

The MAX105 provides data in two's complement format to differential LVDS outputs. A simplified circuit schematic of the LVDS output cells is shown in Figure 2. All LVDS outputs are powered from separate I-channel OV$_{CC}$I and Q-channel OV$_{CC}$Q (Q-channel) power supplies, which may be operated at +3.3V ±10%. The

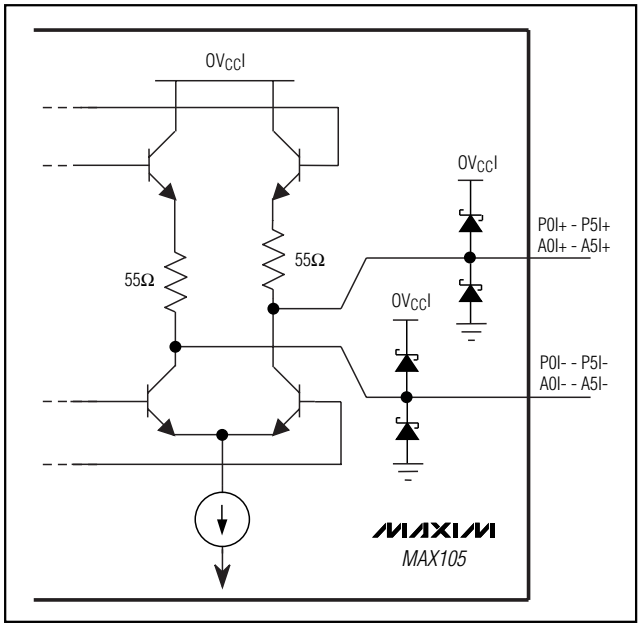



*Figure 2. Simplified LVDS Output Model*

**Table 1. Digital Output Codes Corresponding to a DC-Coupled Single-Ended Analog Input**

| IN-PHASE INPUTS (INI+, INQ+) | INVERTED INPUTS (INI-, INQ-) | OUT-OF-RANGE BIT (DOR+, DOR-) | OUTPUT CODE |
|---|---|---|---|
| > +400mV + $V_{REF}$ | AC – Coupled to AGND_ | 1 | 011111 |
| +400mV - 0.5LSB + $V_{REF}$ | AC – Coupled to AGND_ | 0 | 011111 |
| 0V + $V_{REF}$ | AC – Coupled to AGND_ | 0 | 000000/111111 |
| -400mV + 0.5LSB + $V_{REF}$ | AC – Coupled to AGND_ | 0 | 100000 |
| < -400mV + $V_{REF}$ | AC – Coupled to AGND_ | 1 | 100000 |

**Table 2. Digital Output Codes Corresponding to a DC-Coupled Differential Analog Input**

| IN-PHASE INPUTS (INI+, INQ+) | INVERTED INPUTS (INI-, INQ-) | OUT-OF-RANGE BIT (DOR+, DOR-) | OUTPUT CODE |
|---|---|---|---|
| >+200mV + $V_{REF}$ | <-200mV + $V_{REF}$ | 1 | 011111 |
| +200mV - 0.25LSB + $V_{REF}$ | -200mV + 0.25LSB + $V_{REF}$ | 0 | 011111 |
| 0V + $V_{REF}$ | 0V + $V_{REF}$ | 0 | 000000/111111 |
| -200mV + 0.25LSB + $V_{REF}$ | +200mV - 0.25LSB + $V_{REF}$ | 0 | 100000 |
| <-200mV + $V_{REF}$ | >+200mV + $V_{REF}$ | 1 | 100000 |

MAX105 LVDS-outputs provide a typical ±270mV voltage swing around a common mode voltage of roughly +1.2V, and must be differentially terminated at the far end of each transmission line pair (true and complementary) with 100Ω.

### Out-Of-Range Operation

A single output pair (DOR+, DOR-) is provided to flag an out-of-range condition, if either the I or Q channel is out-of-range, where out-of-range is above +FS or below -FS. It features the same latency as the ADCs output data and is demultiplexed in a similar fashion. With a 800MHz system clock, DOR+ and DOR- are clocked at up to 400MHz.

## Applications Information

### Single-Ended Analog Inputs

The MAX105 is designed to work at full-speed for both single-ended and differential analog inputs without significant degradation in its dynamic performance. Both input channels I (INI+, INI-) and Q (INQ+, INQ-) have 2kΩ impedance and allow for AC- and DC-coupled input signals. In a typical DC-coupled single-ended configuration (Table 1), the analog input signals enter the analog input amplifier stages at the in-phase-input pins INI+/INQ+, while the inverted phase input INI-/INQ- pins are AC-coupled to AGNDI/AGNDQ. Single-ended operation allows for an input amplitude of 800m$V_{p-p}$, centered around $V_{REF}$.

### Differential Analog Inputs

To obtain +FS digital outputs with differential input drive (Table 2), 400mV must be applied between INI+ (INQ+) and INI- (INQ-). Midscale digital output codes occur when there is no voltage difference between INI+ (INQ+) and INI- (INQ-). For a -FS digital output code both in-phase (INI+, INQ+) and inverted input (INI-, INQ-) must see -400mV.

### Single-Ended to Differential Conversion Using a Balun

An RF balun (Figure 3) provides an excellent solution to convert a single-ended signal to a fully differential signal, required by the MAX105 for optimum performance. At higher frequencies, the MAX105 provides better SFDR and THD with fully differential input signals over single-ended input signals. In differential input mode, even-order harmonics are suppressed and each input requires only half the signal-swing compared to single-ended mode.

### Clock Input

The MAX105 features clock inputs designed for either single-ended or differential operation with very flexible input drive requirements. The clock inputs (AC- or DC-coupled) provide a 5kΩ input impedance to $AV_{CC}/2$

# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier

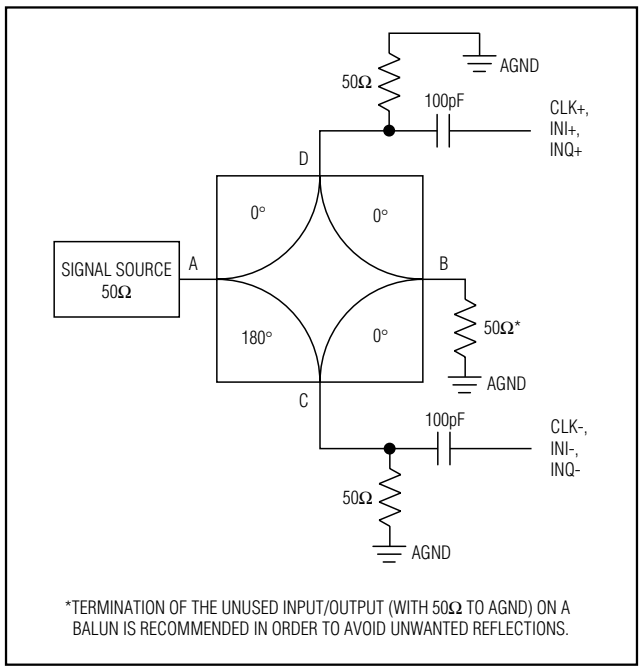



*Figure 3. Single-Ended to Differential Conversion Using a Balun*

and are internally buffered with a preamplifier to ensure proper operation of the converter even with small-amplitude sine-wave sources. The MAX105 was designed for single-ended, low-phase noise sine wave clock signals with as little as 500mV$_{P-P}$ amplitude (-2dBm).

### Single-Ended Clock (Sine-Wave Drive)

Excellent performance is obtained by AC- or DC-coupling a low-phase noise sine-wave source into a single clock input (Figure 4). Essentially, the dynamic performance of the converter is unaffected by clock-drive power levels from -2dBm (500mV$_{p-p}$ clock signal amplitude) to +10dBm (2V$_{P-P}$ clock signal amplitude). The MAX105 dynamic performance specifications are determined by a single-ended clock drive of -2dBm (500mVp-p clock signal amplitude). To avoid saturation of the input amplifier stage, limit the clock power level to a maximum of +10dBm.

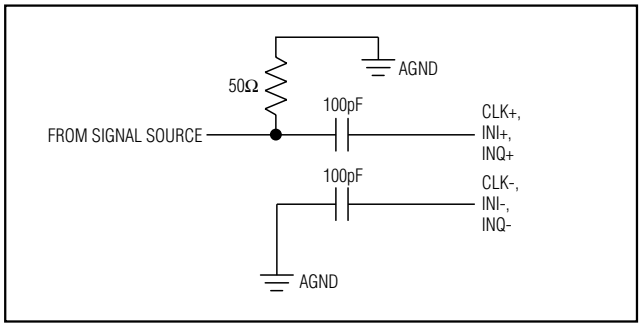



*Figure 4. Single-Ended Clock Input With AC-Coupled Input Drive (CLK, INI, INQ)*

### Differential Clock (Sine-Wave Drive)

The advantages of differential clock drive (Figure 5) can be obtained by using an appropriate balun or transformer to convert single-ended sine-wave sources into differential drives. Refer to *Single-Ended Clock Inputs (Sine-Wave Drive)* for proper input amplitude requirements.

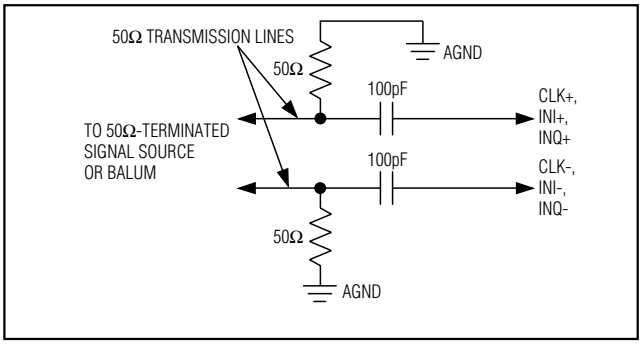



*Figure 5. Differential AC-Coupled Input Drive (CLK, INI, INQ)*

### LVDS, ECL and PECL Clock

The innovative input architecture of the MAX105 clock also allows these inputs to be driven by LVDS-, ECL-, or PECL-compatible input levels, ranging from 500mV$_{p-p}$ to 2V$_{p-p}$ (Figure 6).

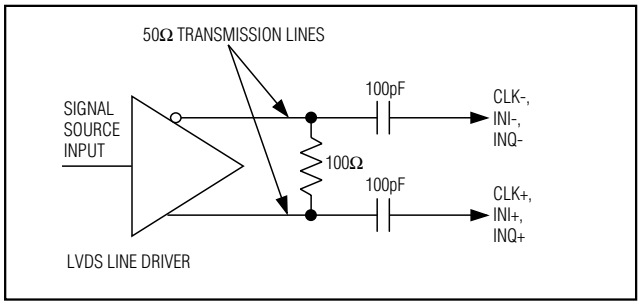



*Figure 6. LVDS Input Drive (CLK, INI, INQ)*

## Timing Requirements

The MAX105 features a 6:12 demultiplexer, which reduces the output data rate (including DREADY and DOR signals) to one-half of the sample clock rate. The

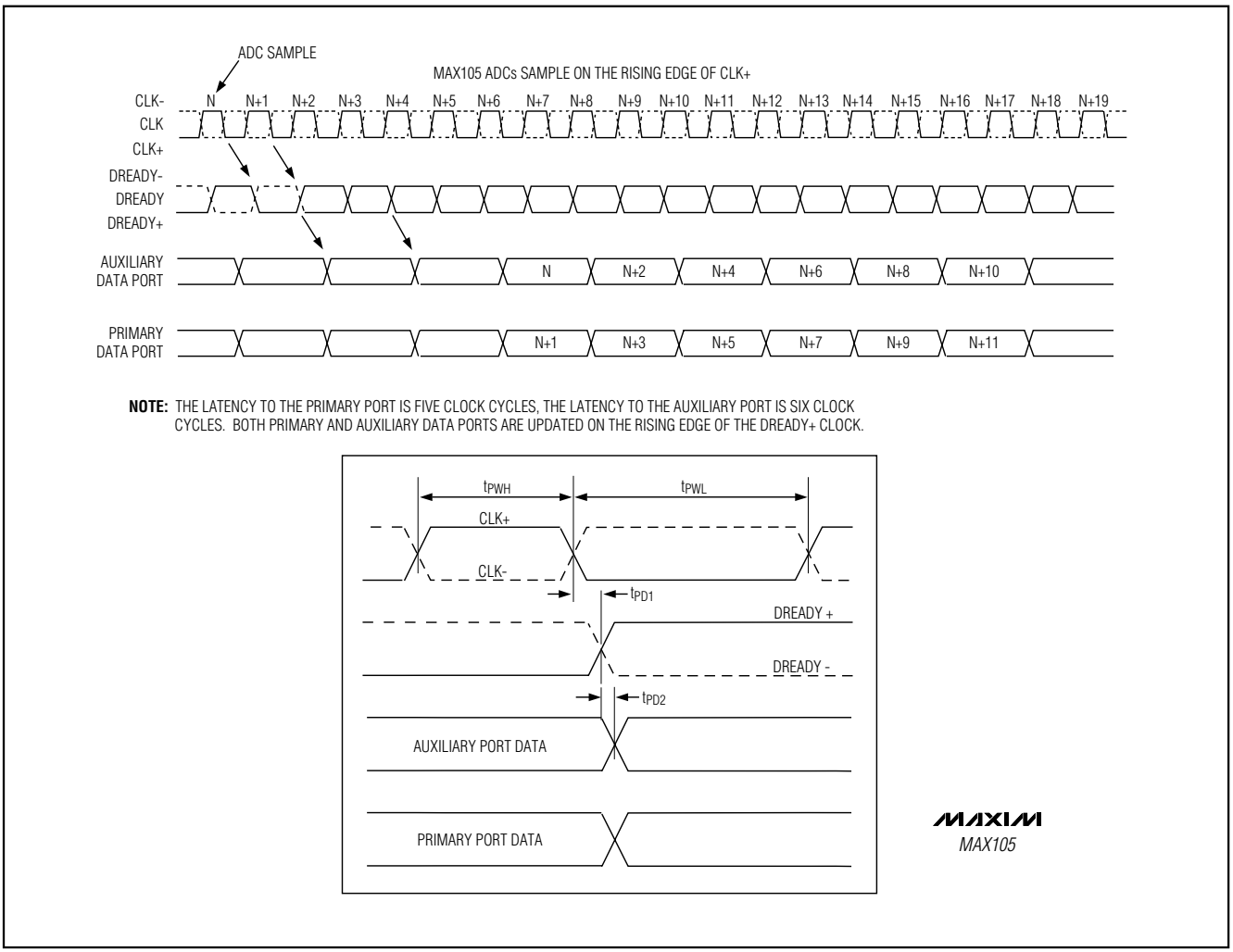



*Figure 7. Output Timing Relationship Between CLK and DREADY Signals and Primary/Auxiliary Output Ports*

demultiplexed outputs are presented in dual 6-bit two's complement format with two consecutive samples in the primary and auxiliary output ports on the rising edge of the data ready clock. The auxiliary data port always contains the older sample. The primary output always contains the most recent data sample, regardless of the DREADY clock phase. Figure 7 shows the timing and data alignment of the auxiliary and primary output ports in relationship with the CLK and DREADY signals. Data in the primary port is delayed by five clock cycles while data in the auxiliary port is delayed by six clock cycles.

### Typical I/Q Application

Quadrature amplitude modulation (QAM) is frequently used in digital communication systems to increase channel capacity. A QAM signal is modulated in both amplitude and phase. With a demodulator, this QAM signal gets downconverted and separated in its in-phase (I) and quadrature (Q) components. Both I&Q channels are digitized by an ADC at the baseband level in order to recover the transmitted information. Figure 8 shows a typical application circuit to directly tune L-band signals to baseband, incorporating a direct conversion tuner (MAX2108) and the MAX105 to digitize I&Q channels with excellent phase- and gain-matching. A front-end L-C filter is required for anti-aliasing purposes.

# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier

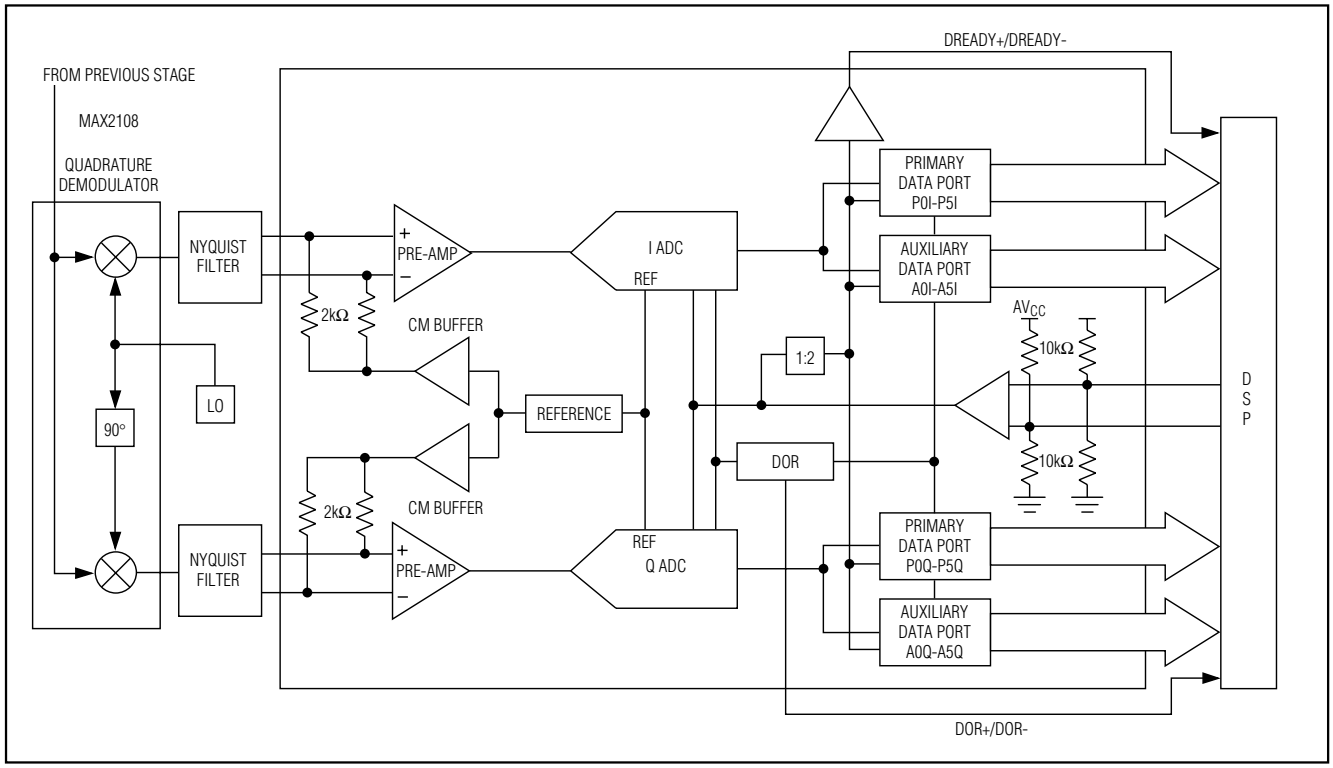



*Figure 8. Typical I/Q Application*

## Grounding, Bypassing, and Board Layout

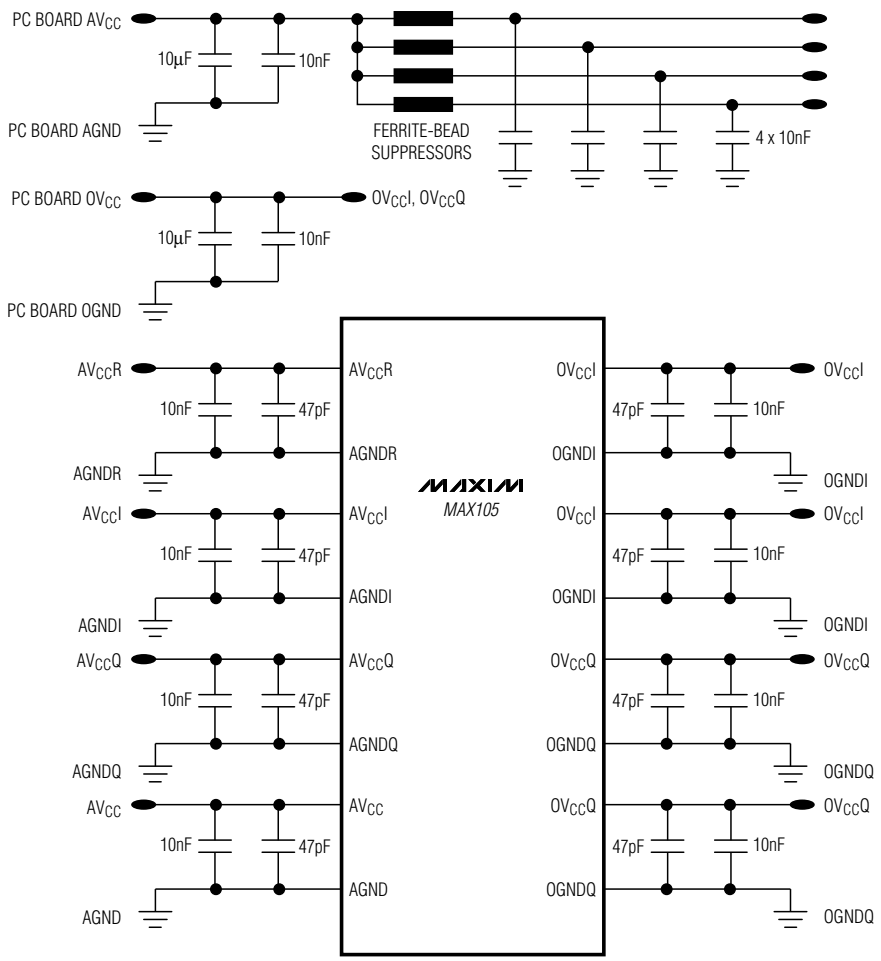
Grounding and power supply decoupling strongly influence the MAX105's performance. At 800MHz clock frequency and 6-bit resolution, unwanted digital crosstalk may couple through the input, reference, power supply, ground connections, and adversely influence the dynamic performance of the ADC. In addition, the I&Q inputs may crosstalk through poorly designed decoupling circuits. Therefore, closely follow the grounding and power-supply decoupling guidelines in Figure 9.

Maxim strongly recommends using a multilayer printed circuit board (PC board) with separate ground and power supply planes. Since the MAX105 has separate analog and digital ground connections (AGND, AGNDI, AGNDQ, AGNDR, OGNDI, and OGNDQ, respectively). The PC board should feature separate sections designated to analog (AGND) and digital (OGND), connected at only one point. Digital signals should run above the digital ground plane and analog signals should run above the analog ground plane. Keep digital signals far away from the sensitive analog inputs, reference inputs, and clock inputs. High-speed signals, including clocks, analog inputs, and digital outputs, should be routed on 50Ω microstrip lines, such as those employed on the MAX105EV kit.

The MAX105 has separate analog and digital power-supply inputs:

- $AV_{CC}$ = +5V ±5%: Power supply for the analog input section of the clock circuit.
- $AV_{CC}I$ = +5V ±5%: Power supply for the I-channel common-mode buffer, pre-amp and quantizer.
- $AV_{CC}Q$ = +5V ±5%: Power supply for the Q-channel common-mode buffer, pre-amp and quantizer.
- $AV_{CC}R$ = +5V ±5%: Power supply for the on-chip bandgap reference.
- $OV_{CC}I$ = +3.3V ±10%: Power supply for the I-channel output drivers and DREADY circuitry.
- $OV_{CC}Q$ = +3.3V ±10%: Power supply for the Q-channel output drivers and DOR circuitry.

All supplies should be decoupled with large tantalum or electrolytic capacitors at the point they enter the PC board. For best performance, bypass all power sup-




**NOTE:**
LOCATE ALL 47pF AND 10nF CAPACITORS, WHICH DECOUPLE $AV_{CC}I$, $AV_{CC}Q$, $AV_{CC}R$, $OV_{CC}I$, AND $OV_{CC}Q$ AS CLOSE AS POSSIBLE TO THE CHIP. IT IS ALSO RECOMMENDED TO CONNECT ALL ANALOG GROUND CONNECTIONS TO A COMMON ANALOG GROUND PLANE AND ALL DIGITAL GROUND CONNECTIONS TO ONE COMMON DIGITAL GROUND PLANE ON THE PC BOARD. A SIMILAR TECHNIQUE CAN BE USED FOR ALL ANALOG AND DIGITAL POWER SUPPLIES.

$AV_{CC} = AV_{CC}I = AV_{CC}Q = AV_{CC}R = +5V \pm 5\%$

$OV_{CC}I = OV_{CC}Q = +3.3V \pm 10\%$

*Figure 9. MAX105 Decoupling, Bypassing and Grounding*

plies to the appropriate ground with a 10µF tantalum capacitor, to filter power supply noise, in parallel with a 0.1µF capacitor. A combination of 0.01µF in parallel with high quality 47pF ceramic chip capacitor located very close to the MAX105 device filters high frequency noise. A properly designed PC board (see MAX105EV Kit data sheet) allows the user to connect all analog supplies and all digital supplies together thereby requiring only two separate power sources. Decoupling $AV_{CC}$, $AV_{CC}I$, $AV_{CC}Q$ and $AV_{CC}R$ with ferrite-bead suppressors prevents further crosstalk between the individual analog supply pins

### Thermal Management

The MAX105 is designed for a thermally enhanced 80-pin TQFP package, providing greater design flexibility, increased thermal efficiency and a low thermal junction-case ($\theta jc$) resistance of ≈1.26°C/W. In this pack-

# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier

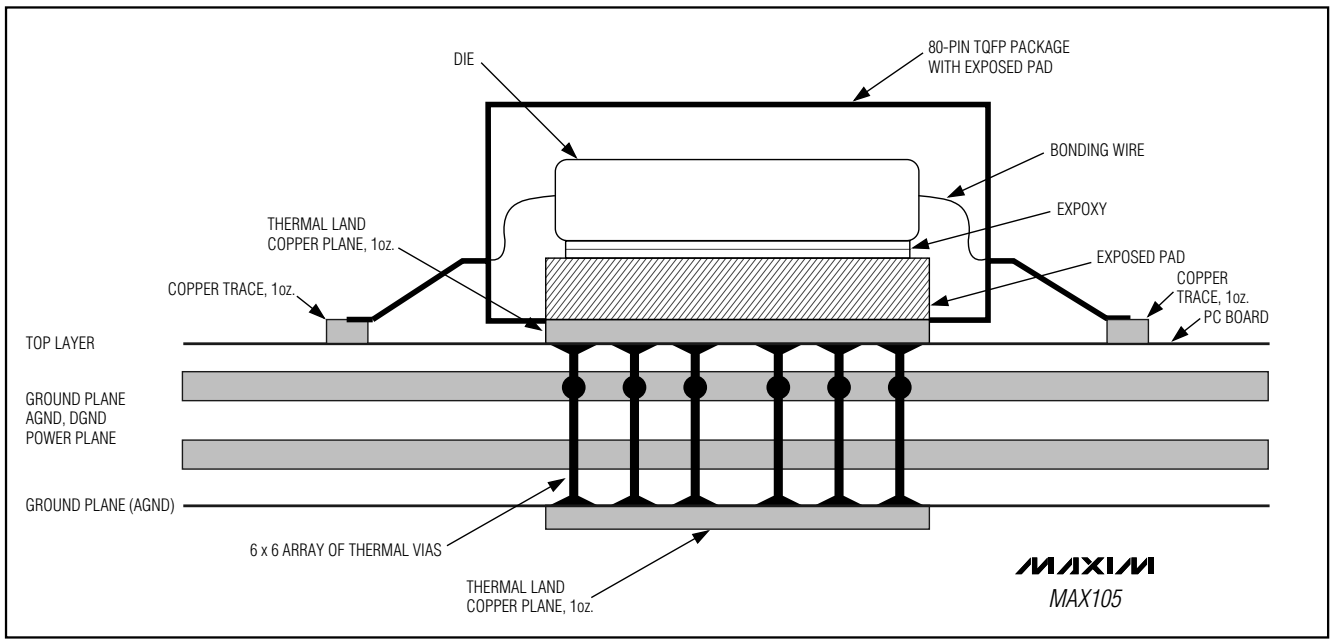



*Figure 10. MAX105 Exposed Pad Package Cross-Section*

age, the data converter die is attached to an exposed pad (EP) leadframe using a thermally conductive epoxy. The package is molded in a way, that this leadframe is exposed at the surface, facing the printed circuit board (PC board) side of the package (Figure 10). This allows the package to be attached to the PC board with standard infrared (IR) flow soldering techniques. A specially created land pattern on the PC board, matching the size of the EP (7.5mm x 7.5mm) does not only guarantee proper attachment of the chip, but can also be used for heat-sinking purposes. Designing thermal vias* into the land area and implementing large ground planes in the PC board design, further enhance the thermal conductivity between board and package. To remove heat from an 80-pin TQFP package efficiently, an array of 6 x 6 vias (≤ 0.3mm diameter per via hole and 1.2mm pitch between via holes) is required.

**Note:** Efficient thermal management for the MAX105 is strongly depending on PC board and circuit design, component placement, and installation. Therefore, exact performance figures cannot be provided. However, the MAX105EV kit exhibits a typical θja of 18°C/W. For more information on proper design techniques and recommendations to enhance the thermal performance of parts such as the MAX105, please refer to Amkor Technology's website at www.amkor.com.

**Connects the land pattern to internal or external copper planes.*

## Static Parameter Definitions

### Integral Nonlinearity (INL)

Integral nonlinearity is the deviation of the values on an actual transfer function from a straight line. This straight line is drawn between the endpoints of the transfer function, once offset and gain errors have been nullified. The static linearity parameters for the MAX105 are measured using the sine-histogram method.

### Differential Nonlinearity (DNL)

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

## Dynamic Parameter Definitions

### Aperture Jitter and Delay

Aperture uncertainties affect the dynamic performance of high-speed converters. Aperture jitter, in particular, directly influences SNR and limits the maximum slew rate (dV/dt) that can be digitized without significant error. Aperture jitter limits the SNR performance of the ADC, according to the following relationship:

$$SNR_{dB} = 20 \times \log_{10} [1 / (2 \times \pi \times f_{IN} \times t_{AJ[RMS]})],$$

where $f_{IN}$ represents the analog input frequency and $t_{AJ}$ is the RMS aperture jitter. The MAX105's innovative

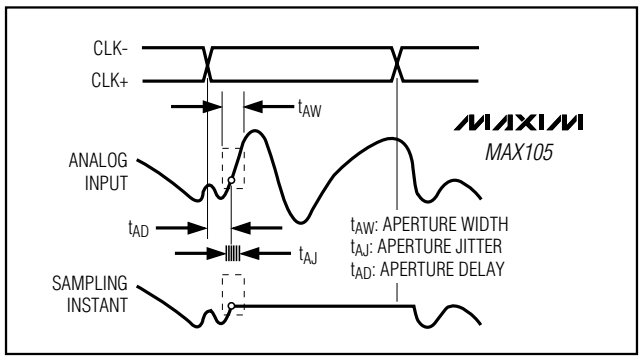



*Figure 11. Aperture Timing*

clock design limits aperture jitter to typically 1.5ps$_{RMS}$. Figure 11 depicts the aperture jitter ($t_{AJ}$), which is the sample-to-sample variation in the aperture delay. Aperture delay ($t_{AD}$) is the time defined between the rising edge of the sampling clock and the instant when an actual sample is taken (Figure 11).

### Signal-to-Noise Ratio (SNR)

For a waveform perfectly reconstructed from digital samples, the theoretical maximum 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 error only and results directly from the ADC's resolution (N-Bits):

$$SNR_{MAX[dB]} = 6.02_{dB} \times N + 1.76_{dB}$$

In reality, there are other noise sources besides quantization noise: thermal noise, reference noise, clock jitter (see *Aperture Uncertainties*). 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 four harmonics, and the DC offset.

### Signal-to-Noise Plus Distortion (SINAD)

SINAD is computed by taking the ratio of the RMS signal to all spectral components minus the fundamental and the DC offset.

### Effective Number of Bits (ENOB)

ENOB specifies the dynamic performance of an ADC at a specific input frequency, amplitude, and sampling rate relative to an ideal ADC's quantization noise. For a full-scale input ENOB is computed from:

$$ENOB = (SINAD - 1.76_{dB}) / 6.02_{dB}$$

### Total Harmonic Distortion (THD)

THD is typically the ratio of the RMS sum of the first four harmonics of the input signal to the fundamental itself. This is expressed as:

$$THD = 20 \times \log\sqrt{(V_2^2 + V_3^2 + V_4^2 + V_5^2)/V_1^2)}$$

where V1 is the fundamental amplitude, and $V_2$ through $V_5$ are the amplitudes of the 2nd- through 5th-order harmonics.

### Spurious-Free Dynamic Range (SFDR)

SFDR is the ratio expressed in decibels of the RMS amplitude of the fundamental to the RMS value of the next largest spurious component, excluding DC offset.

### Two-Tone Intermodulation Distortion (IMD)

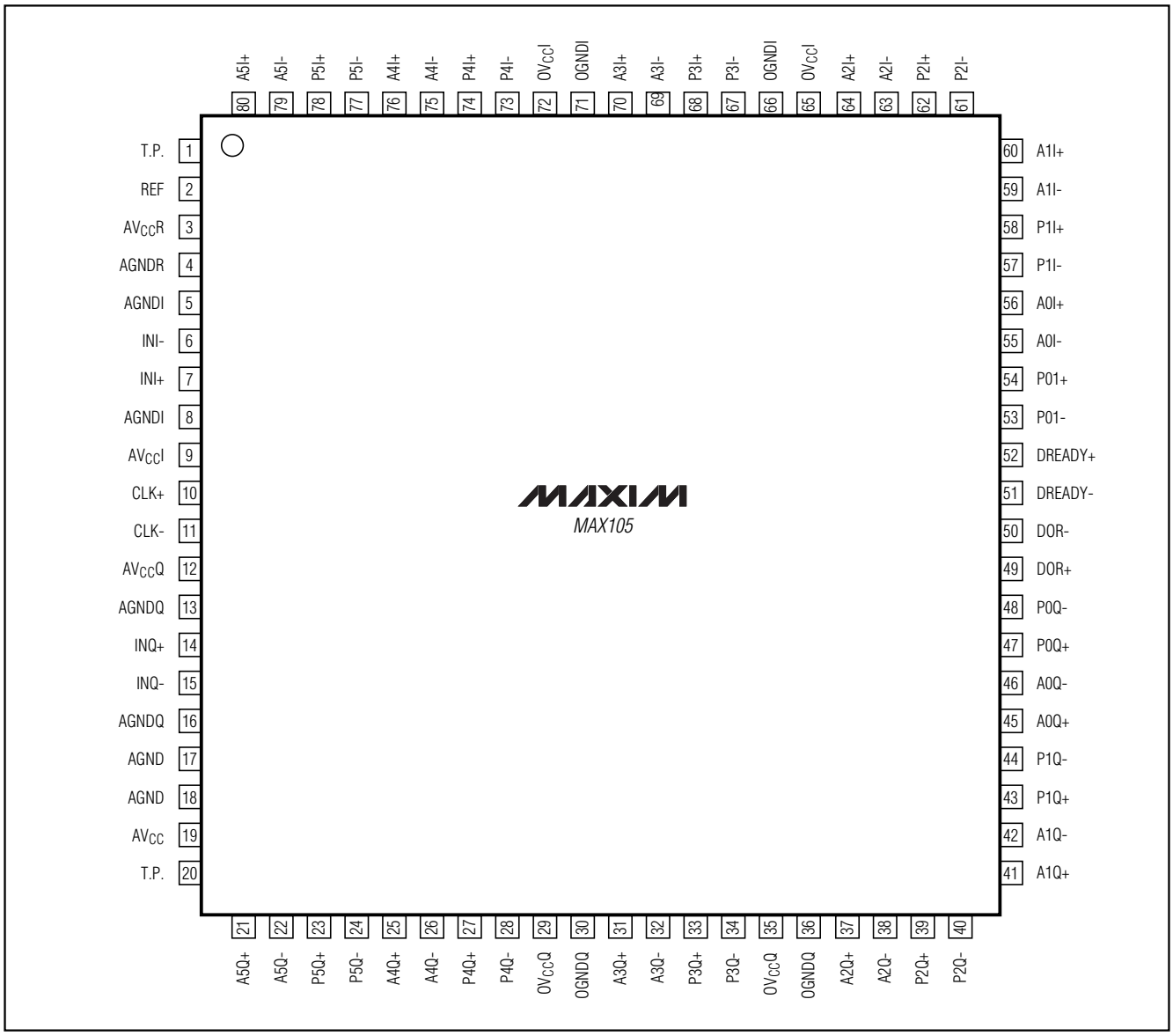
The two-tone IMD is the ratio expressed in decibels of either input tone to the worst 3rd-order (or higher) intermodulation products. The individual input tone levels are at -7dB full-scale and their envelope peaks at -1dB full-scale.

## Chip Information

TRANSISTOR COUNT: 12,286

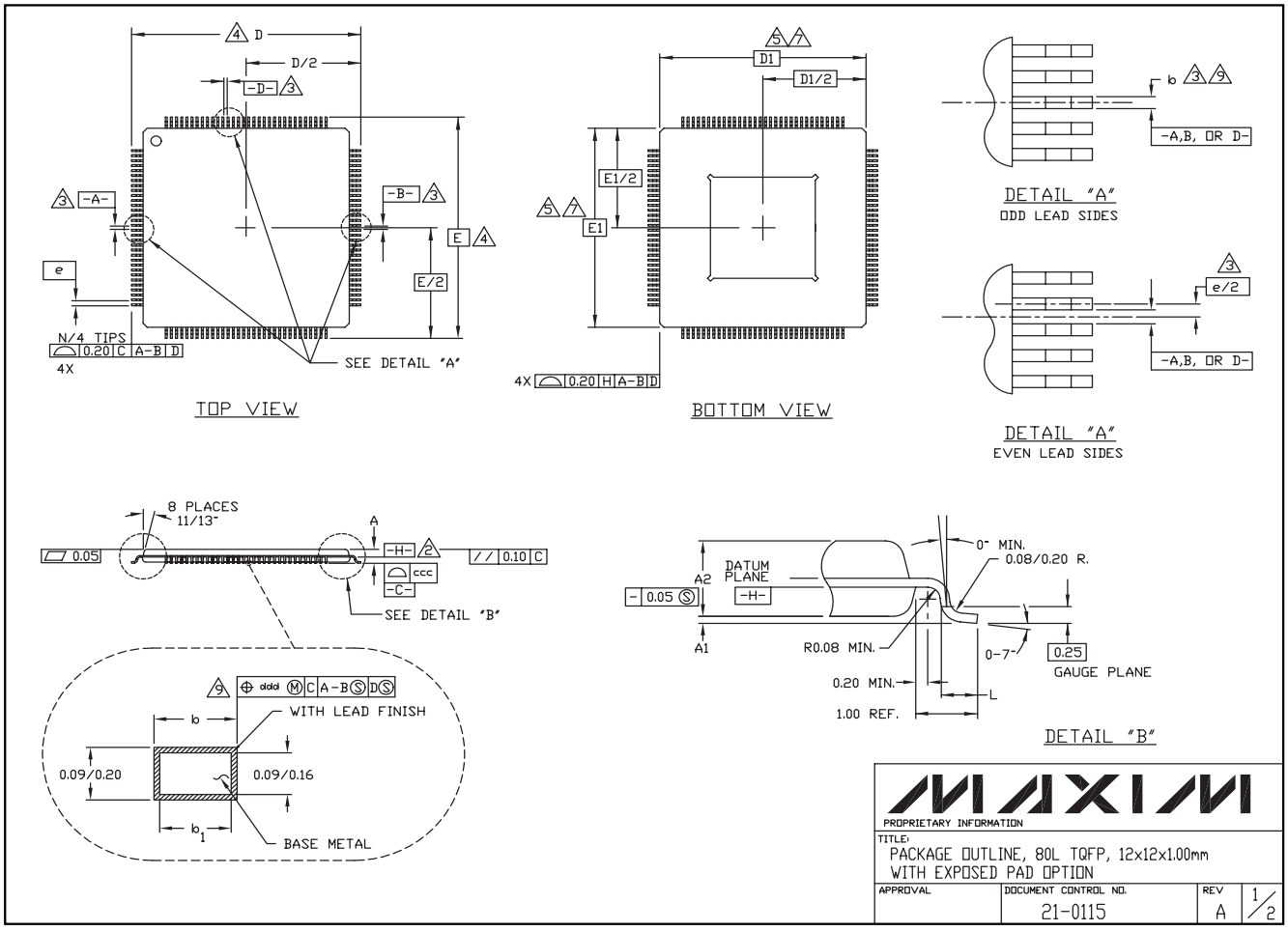
# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier

## Pin Configuration



# Dual, 6-Bit, 800Msps ADC with On-Chip, Wideband Input Amplifier

## Package Information

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