

TLC5540 8-BIT HIGH-SPEED ANALOG-TO-DIGITAL CONVERTER

SLAS105C – JANUARY 1995 – REVISED MAY 1999

features

- **8-Bit Resolution**
- **Differential Linearity Error**
 - ± 0.3 LSB Typ, ± 1 LSB Max (25°C)
 - ± 1 LSB Max
- **Integral Linearity Error**
 - ± 0.6 LSB, ± 0.75 LSB Max (25°C)
 - ± 1 LSB Max
- **Maximum Conversion Rate of 40 Megasamples Per Second (MSPS) Max**
- **Internal Sample and Hold Function**
- **5-V Single Supply Operation**
- **Low Power Consumption . . . 85 mW Typ**
- **Analog Input Bandwidth . . . ≥ 75 MHz Typ**
- **Internal Reference Voltage Generators**

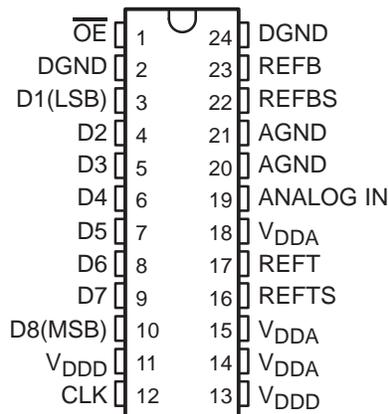
applications

- **Quadrature Amplitude Modulation (QAM) and Quadrature Phase Shift Keying (QPSK) Demodulators**
- **Digital Television**
- **Charge-Coupled Device (CCD) Scanners**
- **Video Conferencing**
- **Digital Set-Top Box**
- **Digital Down Converters**
- **High-Speed Digital Signal Processor Front End**

description

The TLC5540 is a high-speed, 8-bit analog-to-digital converter (ADC) that converts at sampling rates up to 40 megasamples per second (MSPS). Using a semiflash architecture and CMOS process, the TLC5540 is able to convert at high speeds while still maintaining low power consumption and cost. The analog input bandwidth of 75 MHz (typ) makes this device an excellent choice for undersampling applications. Internal resistors are provided to generate 2-V full-scale reference voltages from a 5-V supply, thereby reducing external components. The digital outputs can be placed in a high impedance mode. The TLC5540 requires only a single 5-V supply for operation.

PW OR NS PACKAGE (TOP VIEW)



AVAILABLE OPTIONS

| T _A | PACKAGE | |
|----------------|------------|--------------|
| | TSSOP (PW) | SOP (NS) |
| –0°C to 70°C | TLC5540CPW | TLC5540CNSLE |
| –40°C to 85°C | TLC5540IPW | TLC5540INSLE |



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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

 **TEXAS
INSTRUMENTS**

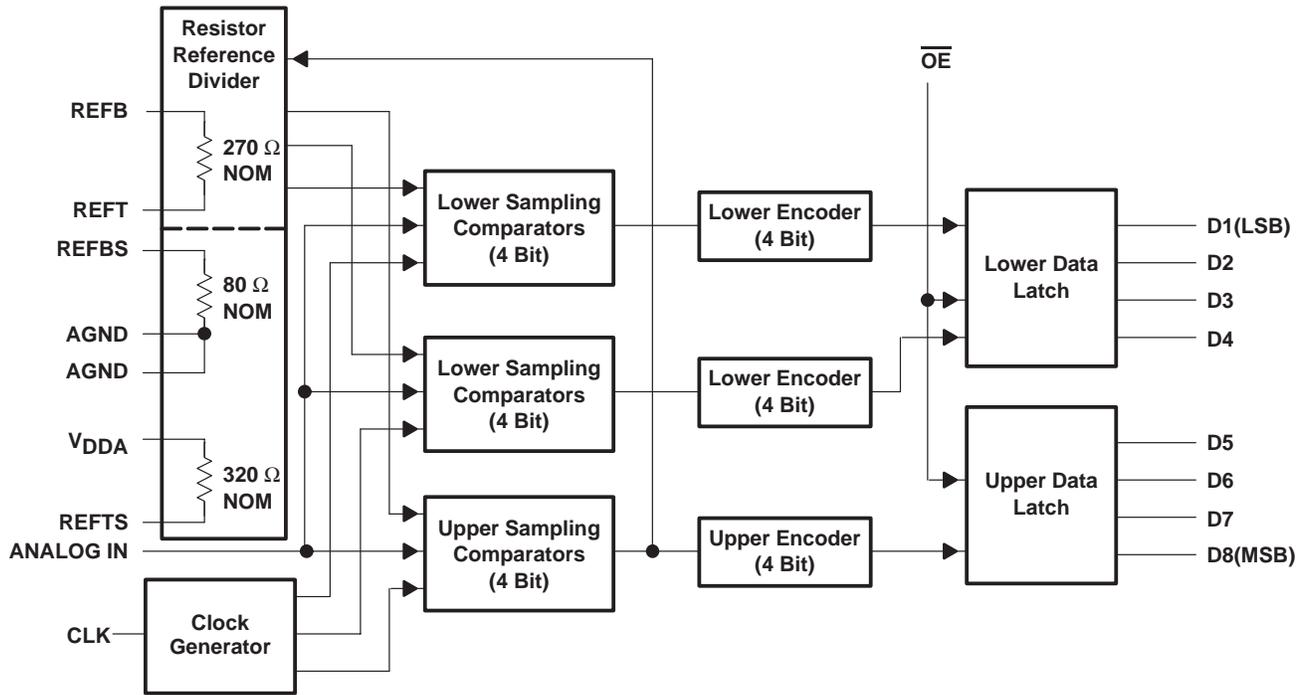
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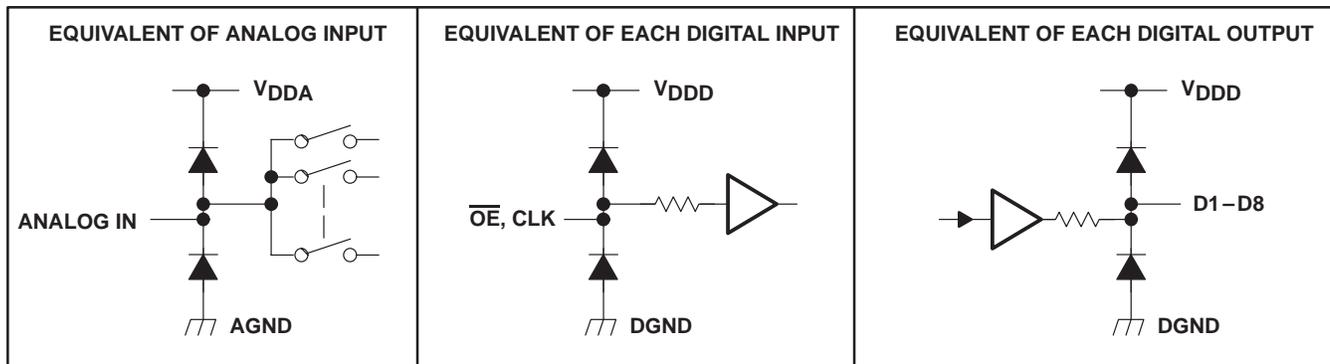
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functional block diagram



schematics of inputs and outputs



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Terminal Functions

| TERMINAL NAME | NO. | I/O | DESCRIPTION |
|------------------|------------|-----|---|
| AGND | 20, 21 | | Analog ground |
| ANALOG IN | 19 | I | Analog input |
| CLK | 12 | I | Clock input |
| DGND | 2, 24 | | Digital ground |
| D1–D8 | 3–10 | O | Digital data out. D1:LSB, D8:MSB |
| \overline{OE} | 1 | I | Output enable. When $\overline{OE} = L$, data is enabled. When $\overline{OE} = H$, D1–D8 is high impedance. |
| V_{DDA} | 14, 15, 18 | | Analog V_{DD} |
| V_{DDD} | 11, 13 | | Digital V_{DD} |
| REFB | 23 | I | ADC reference voltage in (bottom) |
| REFBS | 22 | | Reference voltage (bottom). When using the internal voltage divider to generate a nominal 2-V reference, the REFBS terminal is shorted to the REFB terminal and the REFTS terminal is shorted to the REFT terminal (see Figure 13 and Figure 14). |
| REFT | 17 | I | Reference voltage in (top) |
| REFTS | 16 | | Reference voltage (top). When using the internal voltage divider to generate a nominal 2-V reference, the REFTS terminal is shorted to the REFT terminal and the REFBS terminal is shorted to the REFB terminal (see Figure 13 and Figure 14). |

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

| | |
|--|-------------------|
| Supply voltage, V_{DDA} , V_{DDD} | 7 V |
| Reference voltage input range, $V_{I(REFT)}$, $V_{I(REFB)}$, $V_{I(REFBS)}$, $V_{I(REFTS)}$ | AGND to V_{DDA} |
| Analog input voltage range, $V_{I(ANLG)}$ | AGND to V_{DDA} |
| Digital input voltage range, $V_{I(DGTL)}$ | DGND to V_{DDD} |
| Digital output voltage range, $V_{O(DGTL)}$ | DGND to V_{DDD} |
| Operating free-air temperature range, T_A : TLC5540C | 0°C to 70°C |
| TLC5540I | –40°C to 85°C |
| Storage temperature range, T_{stg} | –55°C to 150°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 under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

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recommended operating conditions

| | | MIN | NOM | MAX | UNIT |
|---|------------------------|---------------------------|-------------------------|---------------------------|------|
| Supply voltage | V _{DDA} –AGND | 4.75 | 5 | 5.25 | V |
| | V _{DDD} –AGND | 4.75 | 5 | 5.25 | |
| | AGND–DGND | –100 | 0 | 100 | mV |
| Reference input voltage (top), V _{I(REFT)} | | V _{I(REFB)} +1.8 | V _{I(REFB)} +2 | V _{DDA} | V |
| Reference input voltage (bottom), V _{I(REFB)} | | 0 | 0.6 | V _{I(REFT)} –1.8 | V |
| Analog input voltage range, V _{I(ANLG)} (see Note 1) | | V _{I(REFB)} | | V _{I(REFT)} | V |
| Full scale voltage, V _{I(REFT)} – V _{I(REFB)} | | 1.8 | | 5 | V |
| High-level input voltage, V _{IH} | | 4 | | | V |
| Low-level input voltage, V _{IL} | | | | 1 | V |
| Pulse duration, clock high, t _{w(H)} | | 12.5 | | | ns |
| Pulse duration, clock low, t _{w(L)} | | 12.5 | | | ns |
| Operating free-air temperature, T _A | TLC5540C | 0 | | 70 | °C |
| | TLC5540I | –40 | | 85 | °C |

NOTE 1: $1.8\text{ V} \leq V_{I(REFT)} - V_{I(REFB)} < V_{DD}$



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electrical characteristics at $V_{DD} = 5\text{ V}$, $V_{I(REFT)} = 2.6\text{ V}$, $V_{I(REFB)} = 0.6\text{ V}$, $f_s = 40\text{ MSPS}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | | MIN | TYP | MAX | UNIT |
|-------------------|--|--|---|------|-----------|------------|---------------|
| E_L | Linearity error, integral | $f_s = 40\text{ MSPS}$, $V_I = 0.6\text{ V to }2.6\text{ V}$ | $T_A = 25^\circ\text{C}$ | | ± 0.6 | ± 1 | LSB |
| | | | $T_A = \text{MIN to MAX}$ | | | ± 1 | |
| E_D | Linearity error, differential | | $T_A = 25^\circ\text{C}$ | | ± 0.3 | ± 0.75 | |
| | | | $T_A = \text{MIN to MAX}$ | | | ± 1 | |
| | Self bias (1), V_{RB} | Short REFB to REFBS | See Figure 13 | 0.57 | 0.61 | 0.65 | V |
| | Self bias (1), V_{RT} | Short REFT to REFTS | | 2.47 | 2.63 | 2.80 | |
| | Self bias (2), V_{RB} | Short REFB to AGND | See Figure 14 | AGND | | | |
| | Self bias (2), V_{RT} | Short REFT to REFTS | | 2.18 | 2.29 | 2.4 | |
| I_{ref} | Reference-voltage current | $V_{I(REFT)} - V_{I(REFB)} = 2\text{ V}$ | | 5.2 | 7.5 | 12 | mA |
| R_{ref} | Reference-voltage resistor | Between REFT and REFB terminals | | 165 | 270 | 350 | Ω |
| C_i | Analog input capacitance | $V_{I(ANLG)} = 1.5\text{ V} + 0.07\text{ V}_{rms}$ | | | 4 | | pF |
| E_{ZS} | Zero-scale error | $V_{I(REFT)} - V_{I(REFB)} = 2\text{ V}$ | | -18 | -43 | -68 | mV |
| E_{FS} | Full-scale error | | | | -25 | 0 | |
| I_{IH} | High-level input current | $V_{DD} = 5.25\text{ V}$, | $V_{IH} = V_{DD}$ | | | 5 | μA |
| I_{IL} | Low-level input current | $V_{DD} = 5.25\text{ V}$, | $V_{IL} = 0$ | | | 5 | |
| I_{OH} | High-level output current | $\overline{OE} = \text{GND}$, | $V_{DD} = 4.75\text{ V}$, $V_{OH} = V_{DD} - 0.5\text{ V}$ | -1.5 | | | mA |
| I_{OL} | Low-level output current | $\overline{OE} = \text{GND}$, | $V_{DD} = 4.75\text{ V}$, $V_{OL} = 0.4\text{ V}$ | 2.5 | | | |
| $I_{OZH}(I_{kg})$ | High-level high-impedance-state output leakage current | $\overline{OE} = V_{DD}$, | $V_{DD} = 5.25$, $V_{OH} = V_{DD}$ | | | 16 | μA |
| $I_{OZL}(I_{kg})$ | Low-level high-impedance-state output leakage current | $\overline{OE} = V_{DD}$, | $V_{DD} = 4.75$, $V_{OL} = 0$ | | | 16 | |
| I_{DD} | Supply current | $f_s = 40\text{ MSPS}$, $C_L \leq 25\text{ pF}$, | NTSC‡ ramp wave input, See Note 2 | | 17 | 27 | mA |

† Conditions marked MIN or MAX are as stated in recommended operating conditions.

‡ National Television System Committee

NOTE 2: Supply current specification does not include I_{ref} .

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operating characteristics at $V_{DD} = 5\text{ V}$, $V_{RT} = 2.6\text{ V}$, $V_{RB} = 0.6\text{ V}$, $f_s = 40\text{ MSPS}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | MIN | TYP | MAX | UNIT |
|-----------------------------|-----------------------------------|--|-----------------------|-----|------|---------|
| f_s | Maximum conversion rate | $T_A = \text{MIN to MAX}$ | 40 | | | MSPS |
| f_s | Minimum conversion rate | $T_A = \text{MIN to MAX}$ | | 5 | | MSPS |
| BW | Analog input full-power bandwidth | At -3 dB , $V_{I(\text{ANLG})} = 2\text{ V}_{pp}$ | | 75 | | MHz |
| t_{pd} | Delay time, digital output | $C_L \leq 10\text{ pF}$ (see Note 3) | | 9 | 15 | ns |
| t_{PHZ} | Disable time, output high to Hi-Z | $C_L \leq 15\text{ pF}$, $I_{OH} = -4.5\text{ mA}$ | | | 20 | ns |
| t_{PLZ} | Disable time, output low to Hi-Z | $C_L \leq 15\text{ pF}$, $I_{OL} = 5\text{ mA}$ | | | 20 | ns |
| t_{PZH} | Enable time, Hi-Z to output high | $C_L \leq 15\text{ pF}$, $I_{OH} = -4.5\text{ mA}$ | | | 15 | ns |
| t_{PZL} | Enable time, Hi-Z to output low | $C_L \leq 15\text{ pF}$, $I_{OL} = 5\text{ mA}$ | | | 15 | ns |
| | Differential gain | NTSC 40 IRE‡ modulation wave, | | 1% | | |
| | Differential phase | $f_s = 14.3\text{ MSPS}$ | | 0.7 | | degrees |
| t_{AJ} | Aperture jitter time | | | 30 | | ps |
| $t_{d(s)}$ | Sampling delay time | | | 4 | | ns |
| SNR | Signal-to-noise ratio | $f_s = 20\text{ MSPS}$ | $f_1 = 1\text{ MHz}$ | | 47 | dB |
| | | | $f_1 = 3\text{ MHz}$ | 44 | 47 | |
| | | | $f_1 = 6\text{ MHz}$ | | 46 | |
| | | | $f_1 = 10\text{ MHz}$ | | 45 | |
| | | $f_s = 40\text{ MSPS}$ | $f_1 = 3\text{ MHz}$ | | 45.2 | |
| | | | $f_1 = 6\text{ MHz}$ | 42 | 44 | |
| ENOB | Effective number of bits | $f_s = 20\text{ MSPS}$ | $f_1 = 1\text{ MHz}$ | | 7.64 | Bits |
| | | | $f_1 = 3\text{ MHz}$ | | 7.61 | |
| | | | $f_1 = 6\text{ MHz}$ | | 7.47 | |
| | | | $f_1 = 10\text{ MHz}$ | | 7.16 | |
| | | $f_s = 40\text{ MSPS}$ | $f_1 = 3\text{ MHz}$ | | 7 | |
| | | | $f_1 = 6\text{ MHz}$ | | 6.8 | |
| THD | Total harmonic distortion | $f_s = 20\text{ MSPS}$ | $f_1 = 1\text{ MHz}$ | | 43 | dBc |
| | | | $f_1 = 3\text{ MHz}$ | 35 | 42 | |
| | | | $f_1 = 6\text{ MHz}$ | | 41 | |
| | | | $f_1 = 10\text{ MHz}$ | | 38 | |
| | | $f_s = 40\text{ MSPS}$ | $f_1 = 3\text{ MHz}$ | | 40 | |
| | | | $f_1 = 6\text{ MHz}$ | | 38 | |
| Spurious free dynamic range | | $f_s = 20\text{ MSPS}$ | $f_1 = 3\text{ MHz}$ | 41 | 46 | dBc |
| | | $f_s = 40\text{ MSPS}$ | $f_1 = 3\text{ MHz}$ | | 42 | |

† Conditions marked MIN or MAX are as stated in recommended operating conditions.

‡ Institute of Radio Engineers

NOTE 3: C_L includes probe and jig capacitance.



PARAMETER MEASUREMENT INFORMATION

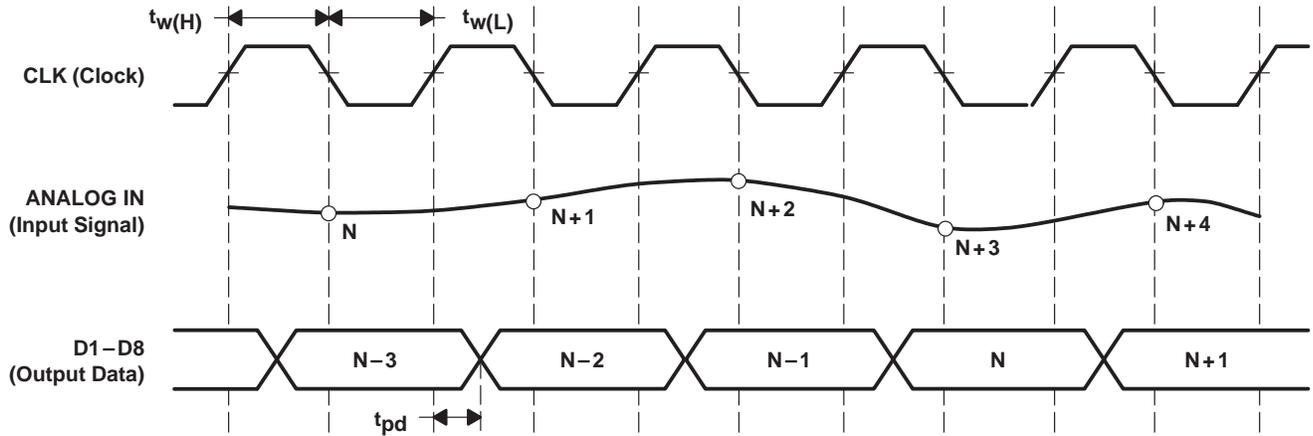


Figure 1. I/O Timing Diagram

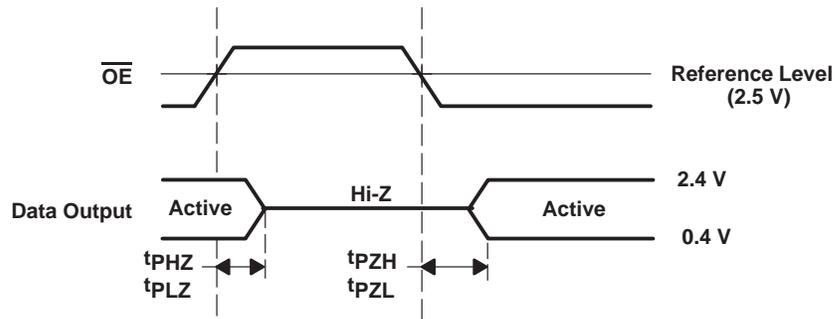


Figure 2. I/O Timing Diagram

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TYPICAL CHARACTERISTICS

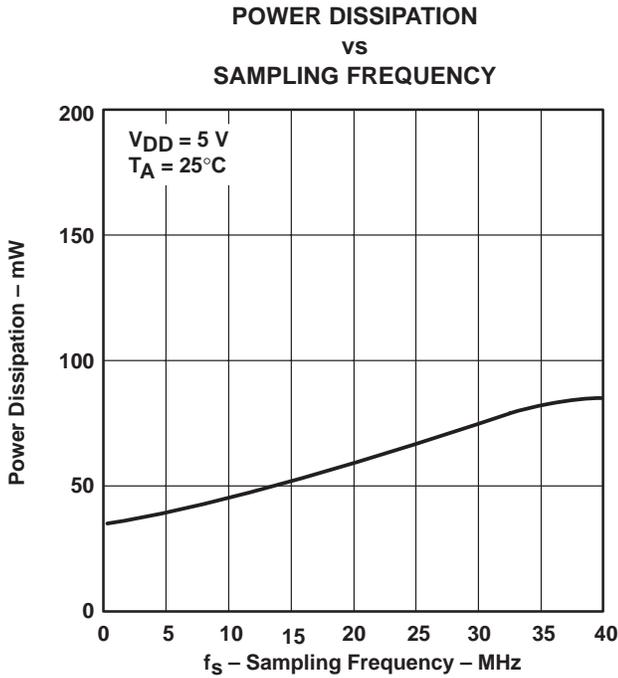


Figure 3

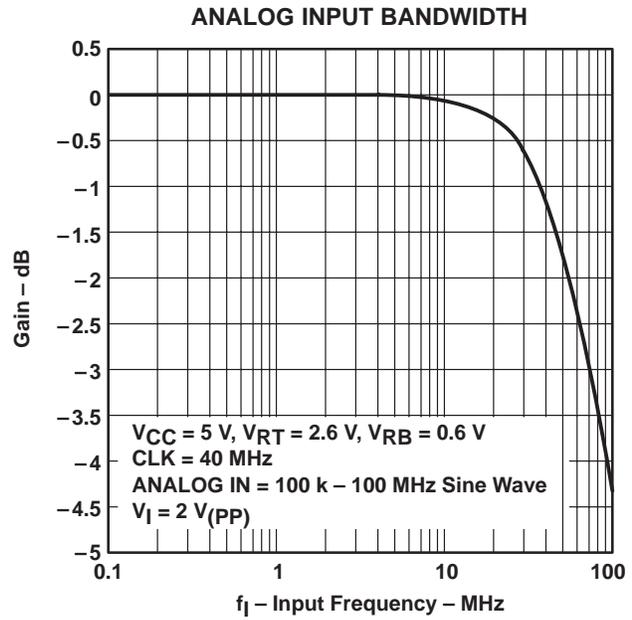


Figure 4

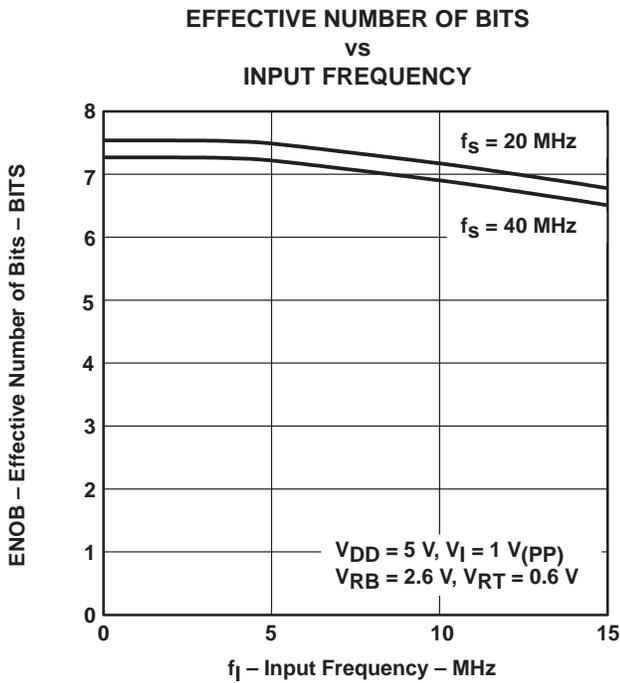


Figure 5

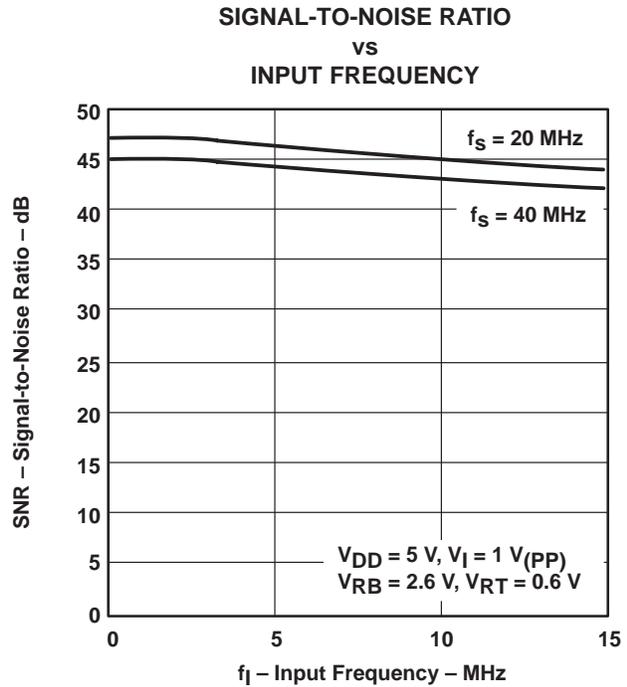


Figure 6

TYPICAL CHARACTERISTICS

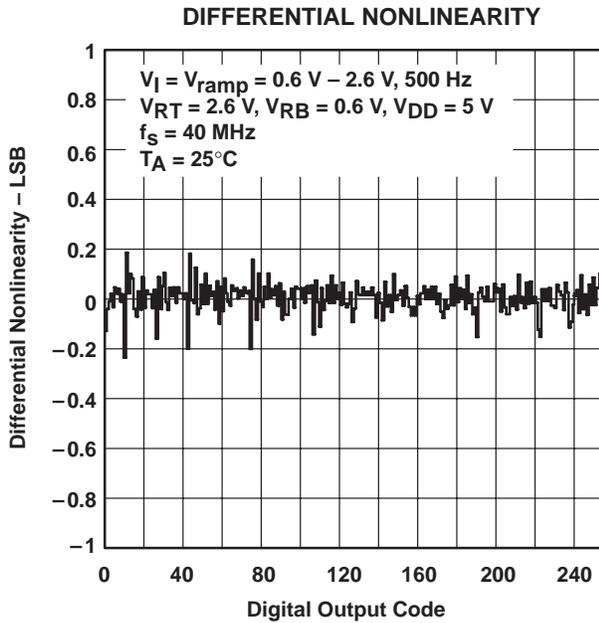


Figure 7

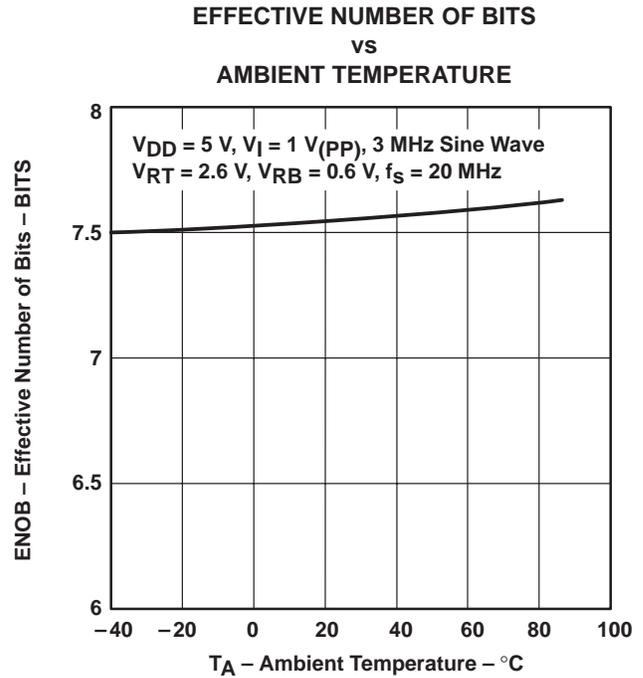


Figure 8

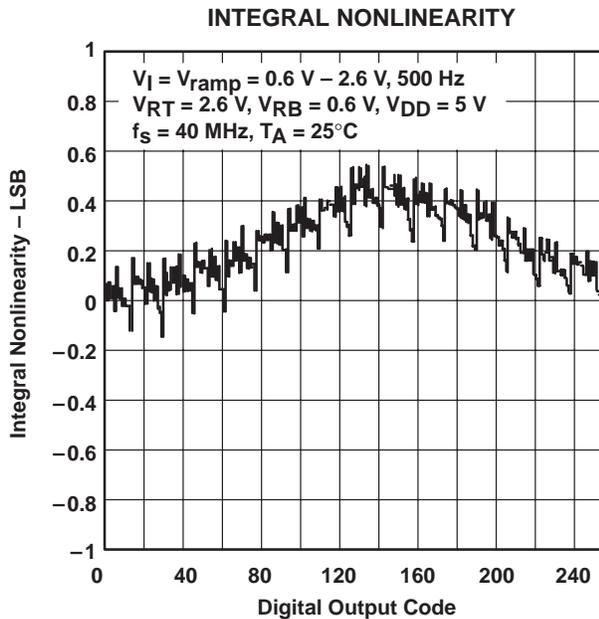


Figure 9

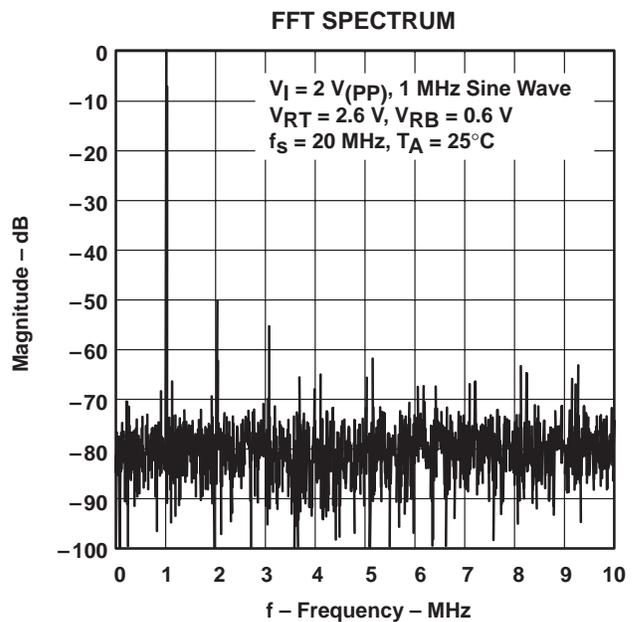


Figure 10

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APPLICATION INFORMATION

grounding and power supply considerations

A signal ground is a low-impedance path for current to return to the source. Inside the TLC5540 A/D converter, the analog ground and digital ground are connected to each other through the substrate, which has a very small resistance ($\sim 30\ \Omega$) to prevent internal latch-up. For this reason, it is strongly recommended that a printed circuit board (PCB) of at least 4 layers be used with the TLC5540 and the converter DGND and AGND pins be connected directly to the analog ground plane to avoid a ground loop. Figure 11 shows the recommended decoupling and grounding scheme for laying out a multilayer PC board with the TLC5540. This scheme ensures that the impedance connection between AGND and DGND is minimized so that their potential difference is negligible and noise source caused by digital switching current is eliminated.

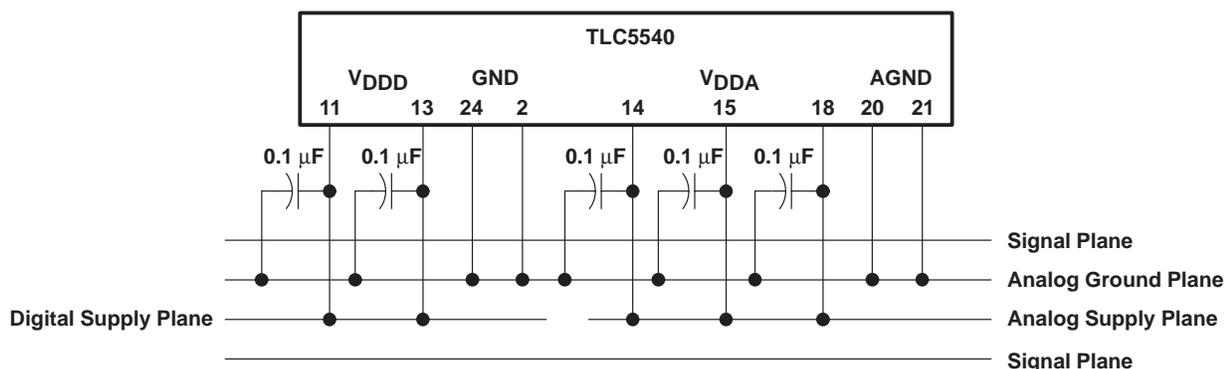


Figure 11. AV_{DD} , DV_{DD} , AGND, and DGND Connections

printed circuit board (PCB) layout considerations

When designing a circuit that includes high-speed digital and precision analog signals such as a high speed ADC, PCB layout is a key component to achieving the desired performance. The following recommendations should be considered during the prototyping and PCB design phase:

- Separate analog and digital circuitry physically to help eliminate capacitive coupling and crosstalk. When separate analog and digital ground planes are used, the digital ground and power planes should be several layers from the analog signals and power plane to avoid capacitive coupling.
- Full ground planes should be used. Do not use individual etches to return analog and digital currents or partial ground planes. For prototyping, breadboards should be constructed with copper clad boards to maximize ground plane.
- The conversion clock, CLK, should be terminated properly to reduce overshoot and ringing. Any jitter on the conversion clock degrades ADC performance. A high-speed CMOS buffer such as a 74ACT04 or 74AC04 positioned close to the CLK terminal can improve performance.
- Minimize all etch runs as much as possible by placing components very close together. It also proves beneficial to place the ADC in a corner of the PCB nearest to the I/O connector analog terminals.
- It is recommended to place the digital output data latch (if used) as close to the TLC5540 as possible to minimize capacitive loading. If D0 through D7 must drive large capacitive loads, internal ADC noise may be experienced.

PRINCIPLES OF OPERATION

functional description

The TLC5540 uses a modified semiflash architecture as shown in the functional block diagram. The four most significant bits (MSBs) of every output conversion result are produced by the upper comparator block CB1. The four least significant bits (LSBs) of each alternate output conversion result are produced by the lower comparator blocks CB-A and CB-B in turn (see Figure 12).

The reference voltage that is applied to the lower comparator resistor string is one sixteenth of the amplitude of the reference applied to the upper comparator resistor string. The sampling comparators of the lower comparator block require more time to sample the lower voltages of the reference and residual input voltage. By applying the residual input voltage to alternate lower comparator blocks, each comparator block has twice as much time to sample and convert as would be the case if only one lower comparator block were used.

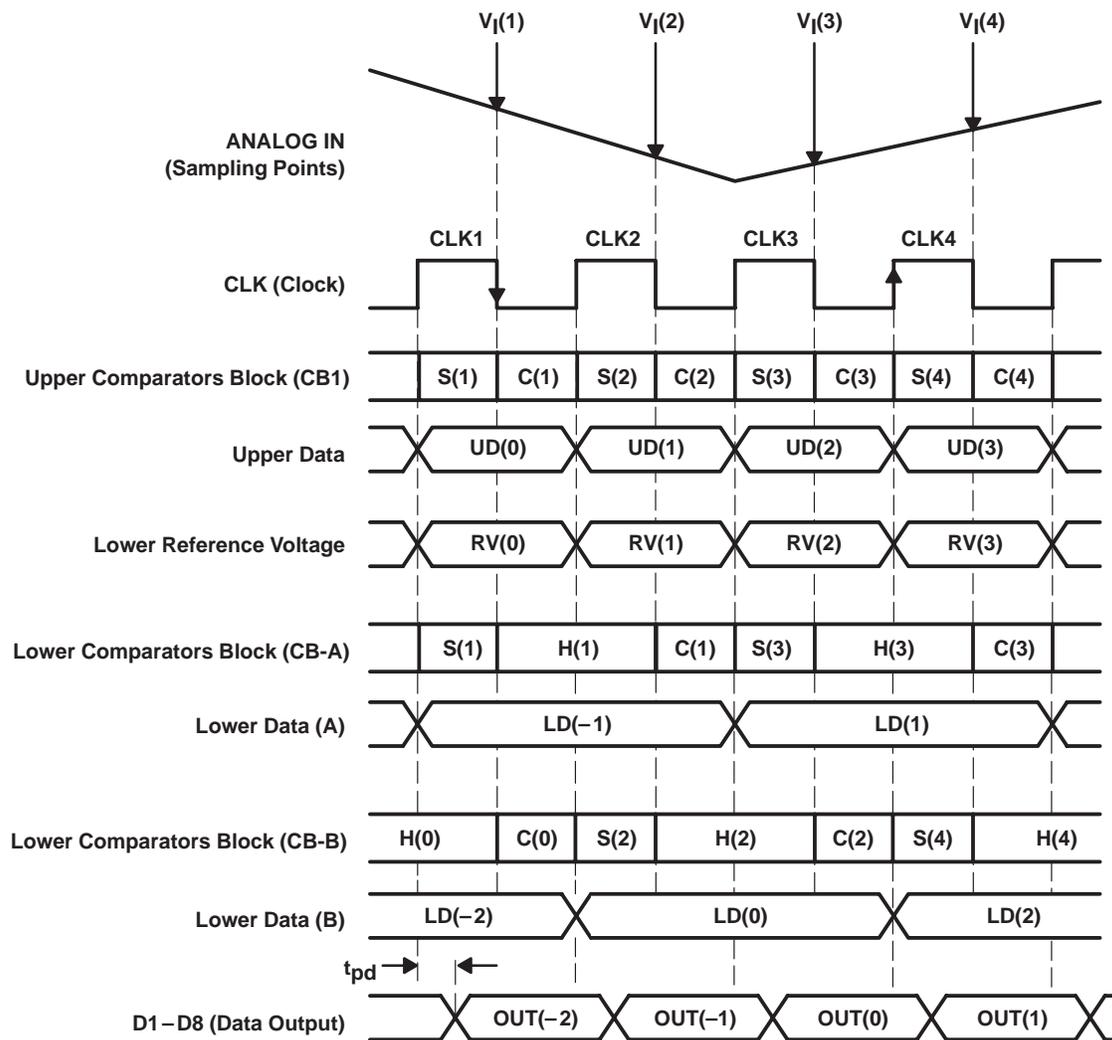


Figure 12. Internal Functional Timing Diagram

This conversion scheme, which reduces the required sampling comparators by 30 percent compared to standard semiflash architectures, achieves significantly higher sample rates than the conventional semiflash conversion method.

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PRINCIPLES OF OPERATION

functional description (continued)

The MSB comparator block converts on the falling edge of each applied clock cycle. The LSB comparator blocks CB-A and CB-B convert on the falling edges of the first and second following clock cycles, respectively. The timing diagram of the conversion algorithm is shown in Figure 12.

analog input operation

The analog input stage to the TLC5540 is a chopper-stabilized comparator and is equivalently shown below:

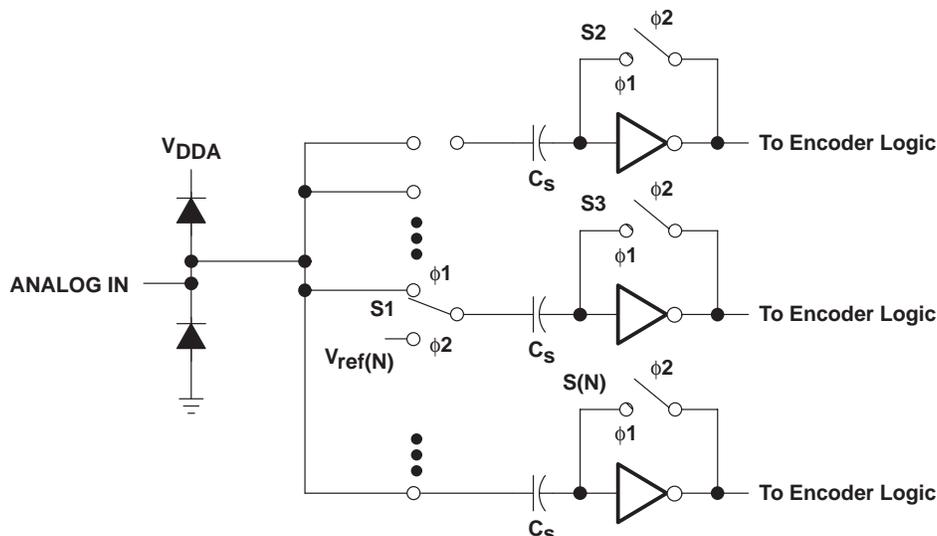


Figure 13. External Connections for Using the Internal Reference Resistor Divider

Figure 13 depicts the analog input for the TLC5540. The switches shown are controlled by two internal clocks, $\phi1$ and $\phi2$. These are nonoverlapping clocks that are generated from the CLK input. During the sampling period, $\phi1$, S1 is closed and the input signal is applied to one side of the sampling capacitor, C_s . Also during the sampling period, S2 through S(N) are closed. This sets the comparator input to approximately 2.5 V. The delta voltage is developed across C_s . During the comparison phase, $\phi2$, S1 is switched to the appropriate reference voltage for the bit value N. S2 is opened and $V_{ref(N)} - VC_s$ toggles the comparator output to the appropriate digital 1 or 0. The small resistance values for the switch, S1, and small value of the sampling capacitor combine to produce the wide analog input bandwidth of the TLC5540. The source impedance driving the analog input of the TLC5540 should be less than 100 Ω across the range of input frequency spectrum.

reference inputs – REF B, REFT, REFBS, REFTS

The range of analog inputs that can be converted are determined by REF B and REFT, REFT being the maximum reference voltage and REF B being the minimum reference voltage. The TLC5540 is tested with REFT = 2.6 V and REF B = 0.6 V producing a 2-V full-scale range. The TLC5540 can operate with REFT – REF B = 5 V, but the power dissipation in the reference resistor increases significantly (93 mW nominally). It is recommended that a 0.1 μ F capacitor be attached to REF B and REFT whether using externally or internally generated voltages.

PRINCIPLES OF OPERATION

internal reference voltage conversion

Three internal resistors allow the device to generate an internal reference voltage. These resistors are brought out on terminals V_{DDA} , REFTS, REFT, REFB, REFBS, and AGND. Two different bias voltages are possible without the use of external resistors.

Internal resistors are provided to develop $REFT = 2.6\text{ V}$ and $REFB = 0.6\text{ V}$ (bias option one) with only two external connections. This is developed with a 3-resistor network connected to V_{DDA} . When using this feature, connect REFT to REFTS and connect REFB to REFBS. For applications where the variance associated with V_{DDA} is acceptable, this internal voltage reference saves space and cost (see Figure 14).

A second internal bias option (bias two option) is shown in Figure 15. Using this scheme $REFB = AGND$ and $REFT = 2.28\text{ V}$ nominal. These bias voltage options can be used to provide the values listed in the following table.

Table 1. Bias Voltage Options

| BIAS OPTION | BIAS VOLTAGE | | |
|-------------|--------------|----------|-------------------|
| | V_{RB} | V_{RT} | $V_{RT} - V_{RB}$ |
| 1 | 0.61 | 2.63 | 2.02 |
| 2 | AGND | 2.28 | 2.28 |

To use the internally-generated reference voltage, terminal connections should be made as shown in Figure 14 or Figure 15. The connections in Figure 14 provide the standard video 2-V reference.

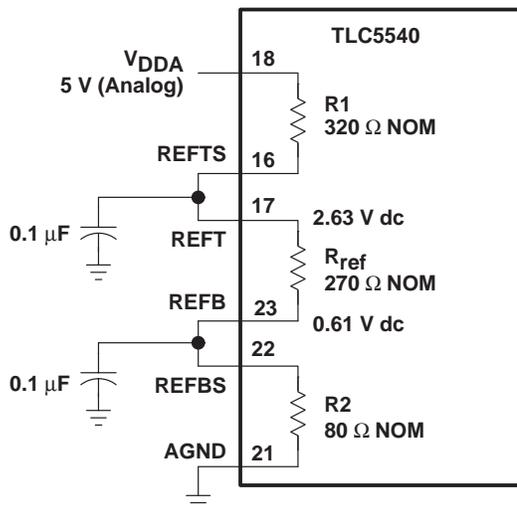


Figure 14. External Connections Using the Internal Bias One Option

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PRINCIPLES OF OPERATION

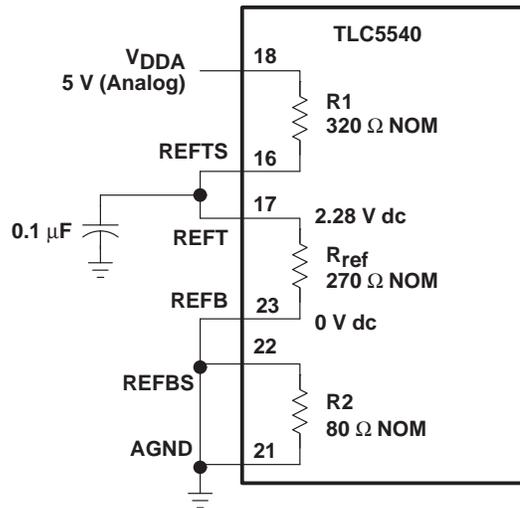


Figure 15. External Connections Using the Internal Bias Two Option

functional operation

Table 2 shows the TLC5540 functions.

Table 2. Functional Operation

| INPUT SIGNAL VOLTAGE | STEP | DIGITAL OUTPUT CODE | | | | | | | |
|----------------------|------|---------------------|---|---|---|---|---|---|---|
| | | MSB | | | | | | | |
| $V_{ref(T)}$ | 255 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| • | • | • | • | • | • | • | • | • | • |
| • | • | • | • | • | • | • | • | • | • |
| • | 128 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| • | 127 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| • | • | • | • | • | • | • | • | • | • |
| • | • | • | • | • | • | • | • | • | • |
| $V_{ref(B)}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

TLC5540 8-BIT HIGH-SPEED ANALOG-TO-DIGITAL CONVERTER

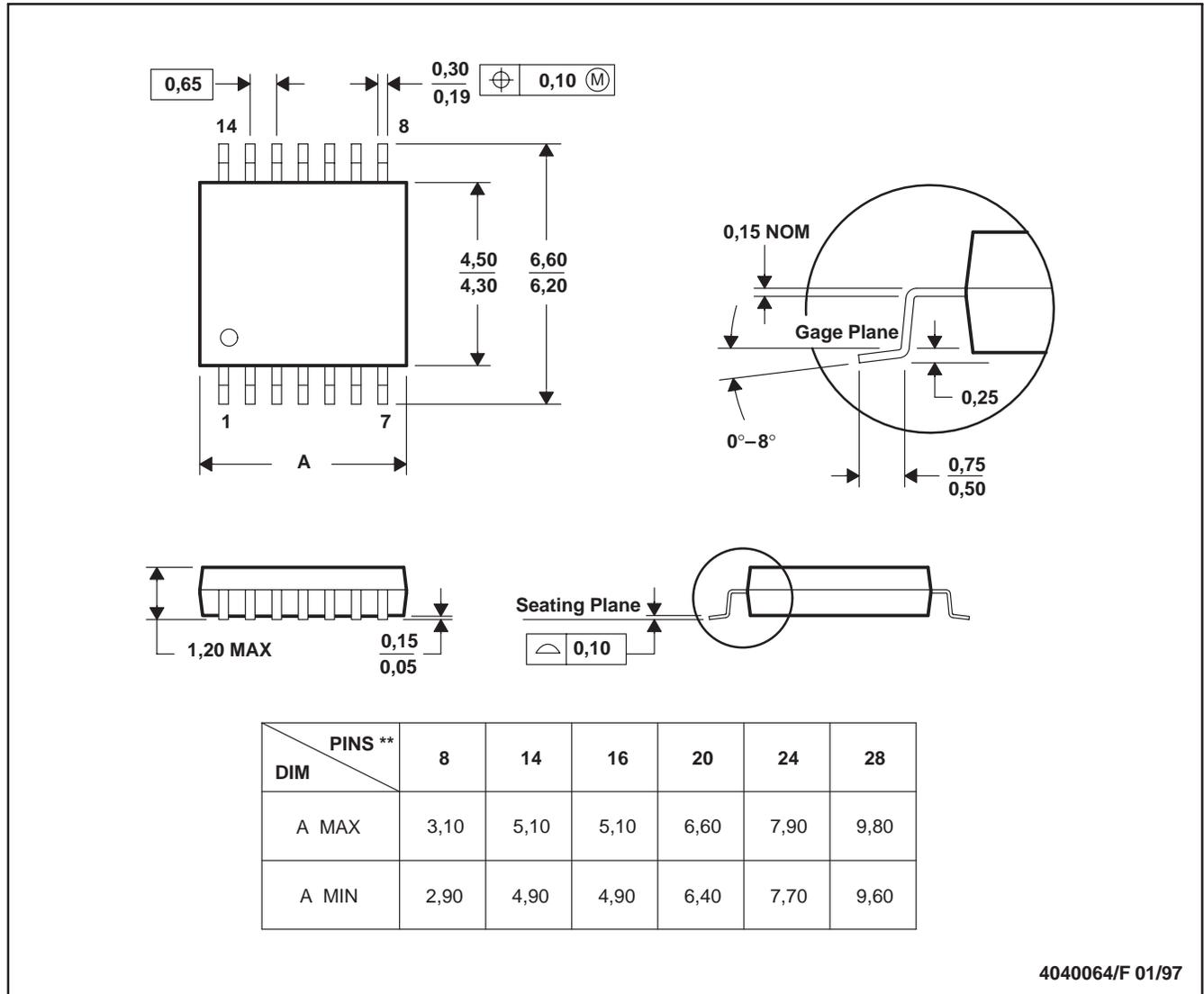
SLAS105C – JANUARY 1995 – REVISED MAY 1999

MECHANICAL DATA

PW (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
 D. Falls within JEDEC MO-153

TLC5540 8-BIT HIGH-SPEED ANALOG-TO-DIGITAL CONVERTER

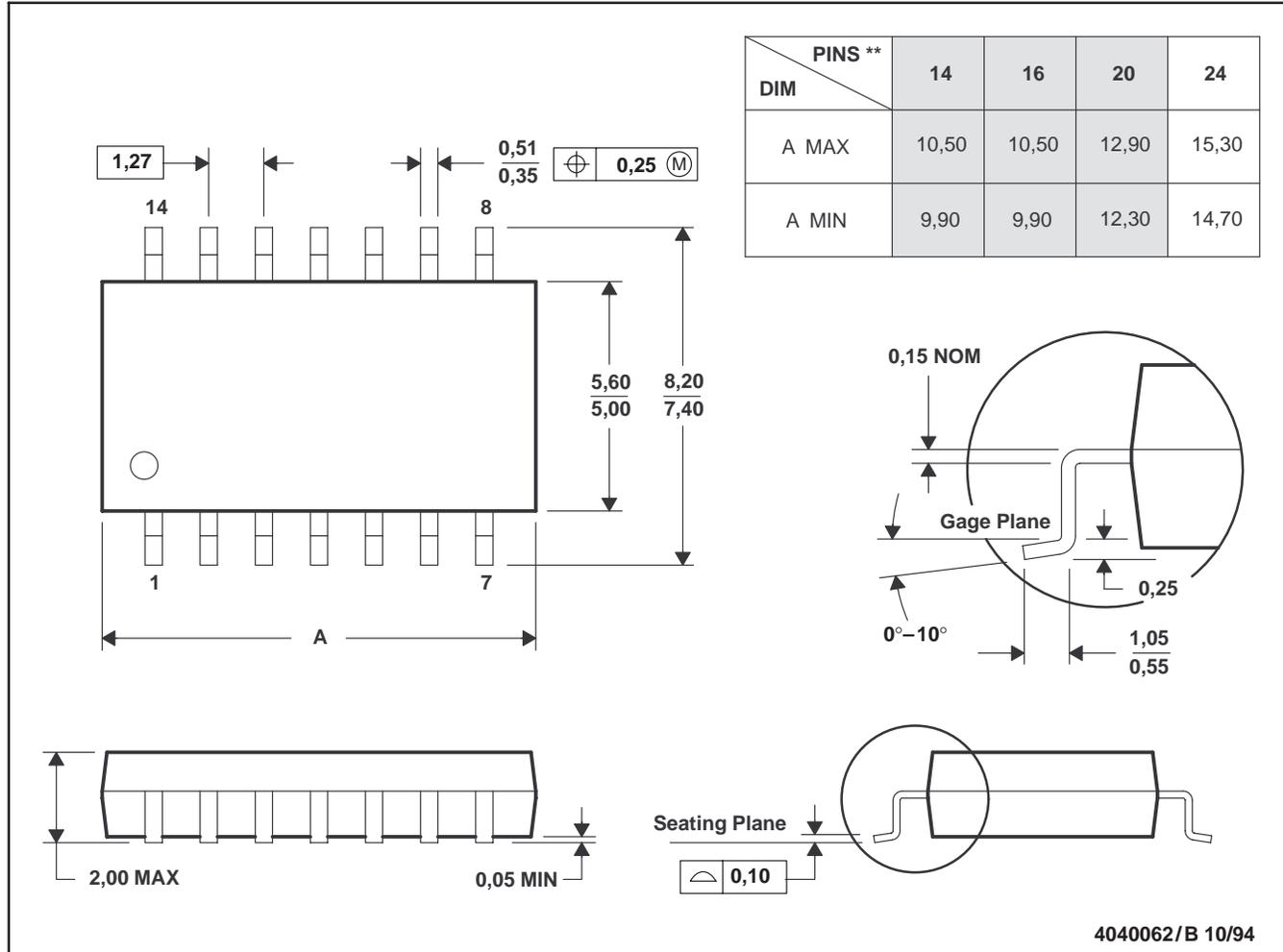
SLAS105C – JANUARY 1995 – REVISED MAY 1999

MECHANICAL DATA

NS (R-PDSO-G**)

PLASTIC SMALL-OUTLINE PACKAGE

14 PIN SHOWN



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

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