

5-V, LOW POWER, 14-BIT, 200-KSPS SERIAL ANALOG-TO-DIGITAL CONVERTERS WITH AUTO-POWER DOWN

FEATURES

- 200-KSPS Sampling Rate
- Built-In Conversion Clock
- INL: ± 1 LSB Max
DNL: ± 1 LSB Max
- SINAD = 81.5 dB, SFDR = 95 dB
THD = 94 dB at 15 kHz f_{in} , 200 KSPS
- SPI/DSP-Compatible Serial Interfaces With SCLK Input up to 15 MHz
- Single 5-V Supply
- Rail-to-Rail Analog Input With 500 kHz BW
- Two Input Options Available:
 - TLC3541 – Single Channel Input
 - TLC3545 – Single Channel, Pseudo-Differential Input
- (TLC3541) Optimized DSP Interface – Requires FS Input Only
- Low Power With Auto-Power Down
 - Operating Current: 3.5 mA
 - Auto-Powerdown Current: 5 μ A
- Pin Compatible 12-/14-/16-Bit Family in 8-Pin SOIC and MSOP Packages

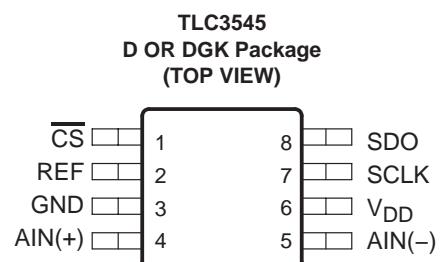
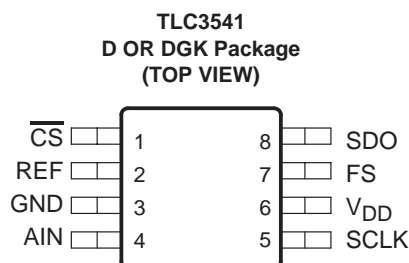
APPLICATIONS

- ATE System
- Industrial Process Control
- Measurement
- Motor Control

DESCRIPTION

The TLC3541 and TLC3545 are a family of high performance, 14-bit, low power, miniature CMOS analog-to-digital converters (ADCs). These devices operate from a single 5-V supply. Devices are available with single, dual, or single pseudo-differential inputs. All of these devices have a chip select (\overline{CS}), serial clock (SCLK), and serial data output (SDO) that provides a direct 3-wire interface to the serial port of most popular host microprocessors (SPI interface). When interfaced with a DSP, a frame sync signal (FS) is used to indicate the start of a serial data frame on either pin 1 (\overline{CS}) or pin 7 (FS) for the TLC3541. The TLC3545 ADC connects to the DSP via pin 1 only (\overline{CS}).

The TLC3541 and TLC3545 are designed to operate with low power consumption. The power saving feature is further enhanced with an auto-power down mode. This product family features a high-speed serial link to modern host processors with an external SCLK up to 15 MHz. Both families use a built-in oscillator as the conversion clock, providing a 2.67 μ s maximum conversion time.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

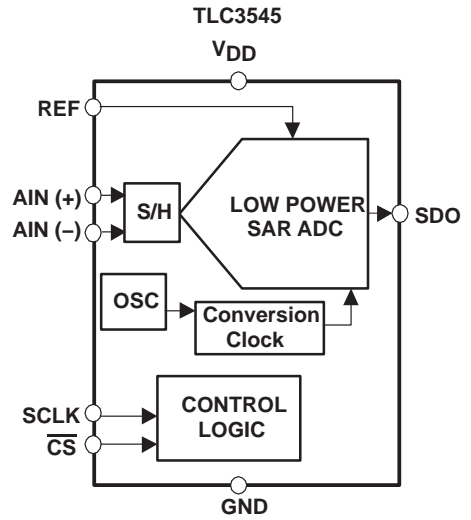
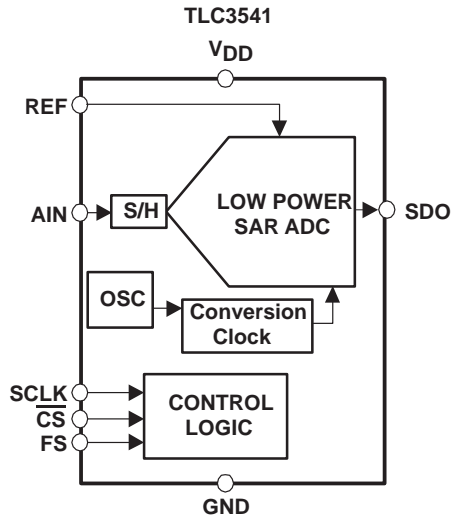
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AVAILABLE OPTIONS

| T _A | PACKAGED DEVICES | |
|----------------|------------------------------|------------|
| | 8-MSOP (DGK) | 8-SOIC (D) |
| -40°C to 85°C | TLC3541IDGK (PKG Code = AMG) | TLC3541ID |
| | TLC3545IDGK (PKG Code = AMM) | TLC3545ID |

functional block diagram



Terminal Functions

TLC3541 single channel unipolar ADCs

| TERMINAL NAME | NO. | I/O | DESCRIPTION |
|------------------------|-----|-----|---|
| AIN | 4 | I | Analog input channel |
| $\overline{\text{CS}}$ | 1 | I | Chip select. A high-to-low transition on the $\overline{\text{CS}}$ input removes SDO from a high-impedance state within a maximum delay time. If the TLC3541 is attached to a dedicated TMS320 DSP serial port using the FS input, $\overline{\text{CS}}$ can be grounded. |
| FS | 7 | I | DSP frame sync input. Indication of a start of a serial data frame. A low-to-high transition removes SDO from the high-impedance state and the MSB is presented. Tie this pin to V_{DD} if not used. |
| GND | 3 | I | Ground return for the internal circuitry. Unless otherwise noted, all voltage measurements are with respect to GND. |
| SDO | 8 | O | The 3-state serial data output for the A/D conversion result. SDO is kept in the high-impedance state when $\overline{\text{CS}}$ is high. The output format is MSB first. Remaining data bits are presented on the rising edge of SCLK. When FS is not active (FS = 1 at the falling edge of $\overline{\text{CS}}$): The MSB is presented on the SDO pin on the falling edge of $\overline{\text{CS}}$ after a maximum delay time. Data is valid on each falling edge of SCLK until all data is read. When FS is active (FS = 0 at the falling edge of $\overline{\text{CS}}$): The MSB is presented to the SDO output on the rising edge of FS. Data is valid on the falling edge SCLK and changes on the rising edge SCLK (this is typically used with an active FS from a DSP). SDO returns to the high-impedance state after the 17th rising edge on SCLK. If a 17th SCLK cycle is not presented, as is the case when using an SPI host, SDO returns to the high-impedance state on the rising edge of $\overline{\text{CS}}$. |
| SCLK | 5 | I | Serial clock. This terminal receives the serial SCLK from the host processor. |
| REF | 2 | I | External voltage reference input |
| V_{DD} | 6 | I | Positive supply voltage |

TLC3545 single channel pseudo-differential ADCs

| TERMINAL NAME | NO. | I/O | DESCRIPTION |
|------------------------|-----|-----|---|
| AIN0 (+) | 4 | I | Positive analog input for the TLC3545. |
| AIN1 (-) | 5 | I | Inverted analog input for the TLC3545. |
| $\overline{\text{CS}}$ | 1 | I | Chip select. A high-to-low transition on $\overline{\text{CS}}$ removes SDO from the high-impedance state within a maximum delay time. The $\overline{\text{CS}}$ input can be connected to a DSP frame sync (FS) output when a dedicated TMS320 DSP serial port is used. |
| GND | 3 | I | Ground return for the internal circuitry. Unless otherwise noted, all voltage measurements are with respect to GND. |
| SDO | 8 | O | The 3-state serial data output for the A/D conversion result. SDO is kept in the high-impedance state when $\overline{\text{CS}}$ is high and presents output data after the $\overline{\text{CS}}$ falling edge until the LSB is presented. The output format is MSB first. The remaining data bits are presented on the rising edge of SCLK. Output data is valid on each falling edge of SCLK until all data is read. SDO returns to the high-impedance state after the 17th rising edge on SCLK. If a 17th SCLK cycle is not presented, as is the case when using an SPI host, SDO returns to the high-impedance state on the rising edge of $\overline{\text{CS}}$. |
| SCLK | 7 | I | Serial clock. This terminal receives the serial SCLK from the host processor. |
| REF | 2 | I | External voltage reference input |
| V_{DD} | 6 | I | Positive supply voltage |

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

| | |
|--|--------------------------|
| Supply voltage, GND to V_{DD} | -0.3 V to 6.5V |
| Analog input voltage range | -0.3 V to $V_{DD}+0.3$ V |
| Reference input voltage | $V_{DD}+0.3$ V |
| Digital input voltage range | -0.3 V to $V_{DD}+0.3$ V |
| Operating virtual junction temperature range, T_J | -40°C to 150°C |
| Operating free-air temperature range: T_A (I suffix) | -40°C to 85°C |
| Storage temperature range, T_{stg} | -65°C to 150°C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260°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.

recommended operating conditions

| | | MIN | NOM | MAX | UNIT |
|---|---|------|------|----------|------------|
| Supply voltage, V_{DD} | | 4.5 | 5 | 5.5 | V |
| Frequency, SCLK | $V_{DD} = 4.5$ V to 5.5 V | 100 | | 15000 | kHz |
| Tolerable clock jitter, SCLK | $V_{DD} = 4.5$ V to 5.5 V | | | 97 | ps |
| Aperature jitter | $V_{DD} = 4.5$ V to 5.5 V | | 100 | | ps |
| External reference voltage input, V_{REF} | External reference voltage input, V_{REF} | 4 | | V_{DD} | V |
| V_{REF} input impedance | $V_{DD} = 5$ V, $\overline{CS} = 1$, SCLK = 0 | 100 | | | M Ω |
| | $V_{DD} = 5$ V, $\overline{CS} = 0$, SCLK = 15 MHz | 20 | 25 | | k Ω |
| External reference input current | $V_{DD} = V_{REF} = 4.5$ V, $\overline{CS} = 0$, SCLK = 15 MHz | | 0.02 | 1 | mA |
| Analog input voltage | AIN, AIN(+) | 0 | | V_{DD} | V |
| | AIN(-) | -0.2 | | 0.2 | V |
| High level control input voltage, V_{IH} | | 2.1 | | | V |
| Low level control input voltage, V_{IL} | | | | 0.8 | V |
| Operating free-air temperature, T_A | TLC3541/45I | -40 | | 85 | °C |

electrical characteristics over recommended operating free-air temperature range,
 $V_{DD} = 5\text{ V}$, $V_{REF} = 4.096\text{ V}$, SCLK frequency = 15 MHz (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--------------|---|--|-----|--------|------|---------------|
| V_{OH} | High-level output voltage | $V_{DD} = 4.5\text{ V}$, $I_{OH} = -0.2\text{ mA}$ | 3.9 | | | V |
| V_{OL} | Low-level output voltage | $V_{DD} = 4.5\text{ V}$, $I_{OL} = 0.8\text{ mA}$ | | | 0.4 | V |
| I_{OZ} | Off-state output current (high-impedance-state) | $V_O = V_{DD}$, $\overline{CS} = V_{DD}$ | | 1 | 2.5 | μA |
| | | $V_O = 0$, $\overline{CS} = V_{DD}$ | | -1 | -2.5 | |
| I_{IH} | High-level input current | $V_I = V_{DD}$ | | 0.005 | 2.5 | μA |
| I_{IL} | Low-level input current | $V_I = 0$ | | -0.005 | 2.5 | μA |
| I_{CC} | Operating supply current | \overline{CS} at 0 V, $V_{DD} = 4.5\text{ V}$ to 5.5 V | | | 3.5 | mA |
| $I_{CC(PD)}$ | Power-down supply current | For all digital inputs, $0 \leq V_I \leq 0.3\text{ V}$ or $V_I \geq V_{DD} - 0.3\text{ V}$, SCLK= V_{DD} , $V_{DD} = 4.5\text{ V}$ to 5.5 V | | 3 | 5 | μA |
| | Selected analog input channel leakage current | Selected channel at V_{DD} | | | 1 | μA |
| | | Selected channel at 0 V | | | -1 | |
| C_i | Input capacitance | Analog inputs | | 11 | 14 | pF |
| | | Control Inputs | | 20 | 25 | |
| Z_i | Input resistance | $V_{DD} = 5.5\text{ V}$ | | | 500 | Ω |

ac specifications (TLC3541/45)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-----------|---|-----------------------------------|-----|------|-----|------|
| SINAD | Signal-to-noise ratio +distortion | $f_I = 15\text{ kHz}$ at 200 KSPS | | 81.5 | | dB |
| SNR | Signal-to-noise ratio | $f_I = 15\text{ kHz}$ at 200 KSPS | | 82 | | dB |
| THD | Total harmonic distortion | TLC3541 | | -94 | -87 | dB |
| | | TLC3545 | | -94 | -89 | |
| ENOB | Effective number of bits | $f_I = 15\text{ kHz}$ at 200 KSPS | | 13.2 | | Bits |
| SFDR | Spurious free dynamic range | TLC3541 | | -95 | -87 | dB |
| | | TLC3545 | | -95 | -89 | |
| | Full-power bandwidth, -3 dB, analog input | | | 1 | | MHz |
| | Full-power bandwidth, -1 dB, analog input | | | 500 | | kHz |
| Crosstalk | | 0.25 LSB | | 80 | | dB |

dc specifications (TLC3541/45)

| PARAMETER | | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|-----------|---------------------------------------|-----------------|------|------|-----|------|
| INL | Integral linearity error (see Note 1) | | -1 | | 1 | LSB |
| DNL | Differential linearity error | | -1 | 0.75 | 1 | LSB |
| E_O | Offset error (see Note 2) | TLC3541 | -3.5 | | 3.5 | mV |
| | | TLC3545 | -1 | | 1 | |
| E_G | Gain error (see Note 2) | TLC3541 | -2 | | 2 | mV |
| | | TLC3545 | -1.8 | | 1.8 | |

† All typical values are at $V_{DD} = 5\text{ V}$, $T_A = 25^\circ\text{C}$.

- NOTES: 1. Linear error is the maximum deviation from the best straight line through the A/D transfer characteristics.
 2. Zero error is the difference between 0000h and the converted output for zero input voltage: full-scale error is the difference between ideal full-scale and the converted output for full-scale input voltage.

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timing requirements, $V_{DD} = 5\text{ V}$, $V_{REF} = 4.096\text{ V}$, SCLK frequency = 15 MHz (unless otherwise specified)

| | | MIN | TYP | MAX | UNIT |
|-------------------------|---|------|-----|-------|---------------|
| $t_{cyc}(\text{SCLK})$ | SCLK cycle time, $V_{DD} = 4.5\text{ V}$ to 5.5 V (see Note 3) | 66 | | 10000 | ns |
| t_{w1} | Pulse duration, SCLK low | 27 | | 5000 | ns |
| t_{w2} | Pulse duration, SCLK high | 27 | | 5000 | ns |
| t_{h1} | Hold time, $\overline{\text{CS}}$ high after SCLK falling edge | 3 | | | ns |
| t_{su1} | Setup time, $\overline{\text{CS}}$ falling edge before the first SCLK falling edge | 15 | | | ns |
| t_{h2} | Hold time, $\overline{\text{CS}}$ low after 16th SCLK falling edge | 5 | | | ns |
| t_{w3} | Pulse duration, $\overline{\text{CS}}$ high | 0.5 | | | SCLKs |
| t_{d1} | Delay time, $\overline{\text{CS}}$ falling edge to SDO MSB valid, $V_{DD} = V_{REF} = 4.5\text{ V}$, 20 pF | | 12 | 17 | ns |
| t_{d2} | Delay time, SCLK rising edge to next SDO data bit valid, $V_{DD} = V_{REF} = 4.5\text{ V}$, 20 pF | | | 15 | ns |
| t_{d3} | Delay time, 17 th SCLK rising edge to 3-stated SDO, $V_{DD} = V_{REF} = 4.5\text{ V}$, 20 pF (see Note 4) | | | 20 | ns |
| t_{su3} | Setup time, $\overline{\text{CS}}$ falling edge before FS rising edge (TLC3541 only) | 0.5 | 1 | | SCLKs |
| t_{w4} | Pulse duration, FS high (TLC3541 only) | 0.5 | 1 | | SCLKs |
| t_{su4} | Setup time, FS rising edge before SCLK falling edge (TLC3541 only) | 12.5 | | | ns |
| t_{h4} | Hold time, FS high after SCLK falling edge (TLC3541 only) | 5 | | | ns |
| t_{su5} | Setup time, FS falling edge before 1st SCLK falling edge (TLC3541 only) | 12 | | | ns |
| t_{d4} | Delay time, FS rising edge to SDO MSB valid, ($V_{DD} = V_{REF} = 4.5\text{ V}$, 20 pF TLC3541 only) | | | 15 | ns |
| t_{h6} | Hold time, $\overline{\text{CS}}$ low after 1st SCLK falling edge | 5 | | | ns |
| t_{su6} | Setup time, $\overline{\text{CS}}$ rising edge before 9th (or the last) SCLK falling edge | 5 | | | ns |
| t_{h7} | Hold time, FS low after 1st SCLK falling edge (TLC3541 only) | 5 | | | ns |
| t_{su7} | Setup time, FS rising edge before 9th (or the last) SCLK falling edge | 5 | | | ns |
| $t_{cyc}(\text{reset})$ | Active $\overline{\text{CS}}$ /FS cycle time, SCLK falling edges required to initialize ADC | 1 | | 8 | SCLKs |
| t_{conv} | Conversion time (20 conversion clocks based on 7.5 MHz to 12 MHz OSC) | 1.67 | | 2.67 | μs |
| t_s | Sample time, 20 SCLKs, SCLK up to 15 MHz | 1.33 | | 200 | μs |

NOTES: 3. Timing specifications given for 40/60 to 60/40 duty cycle

4. SDO goes into the high impedance state after detection of the 17th rising SCLK edge or a rising $\overline{\text{CS}}$ edge if a 17th SCLK is not presented.

TYPICAL CHARACTERISTICS

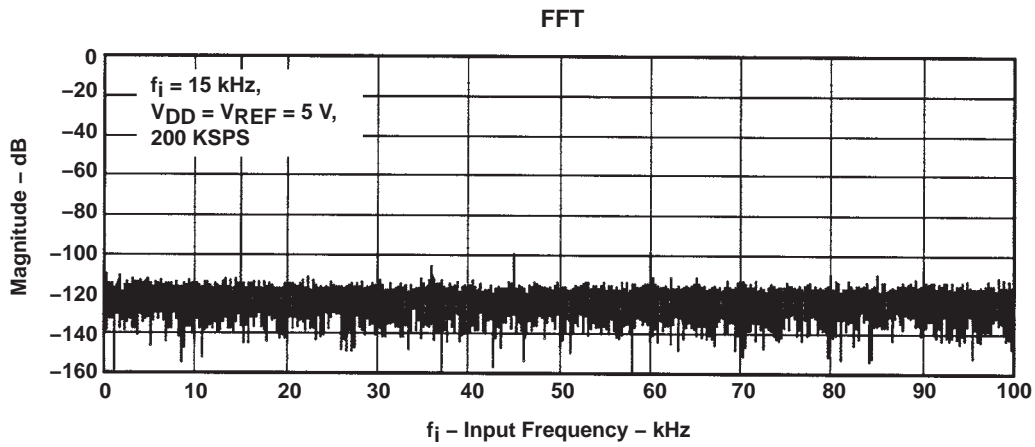


Figure 1

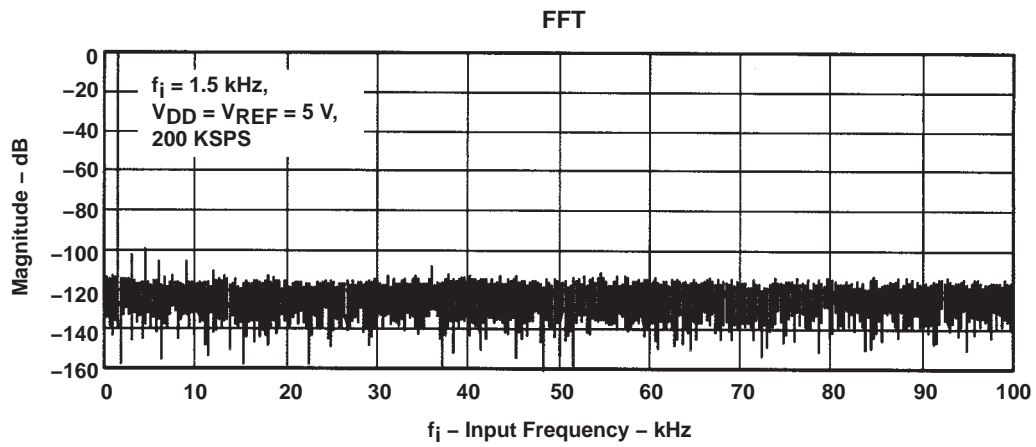


Figure 2

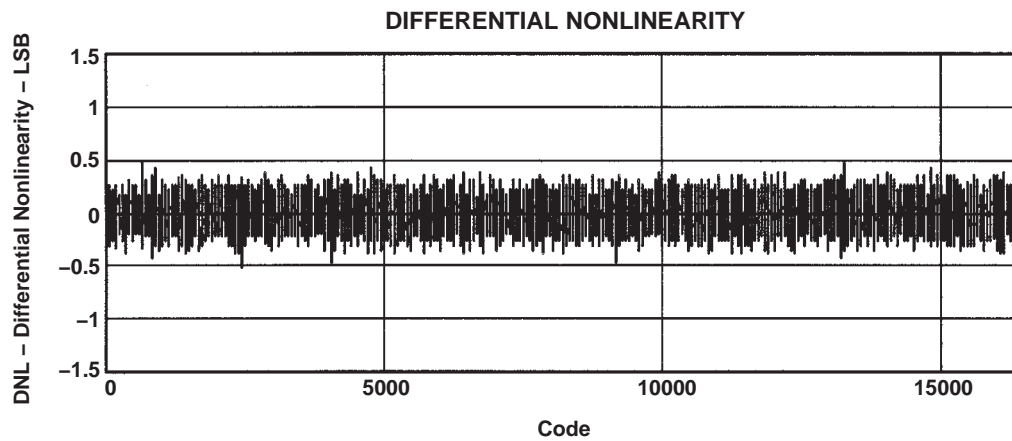


Figure 3

TYPICAL CHARACTERISTICS

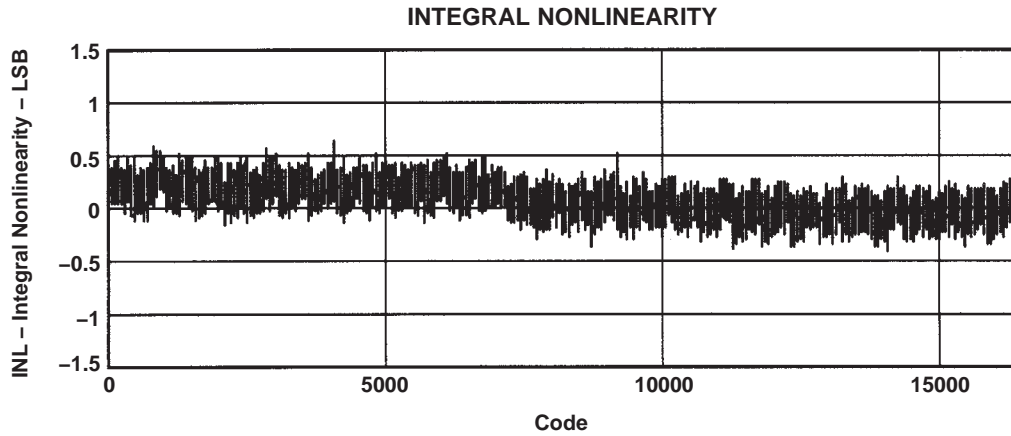


Figure 4

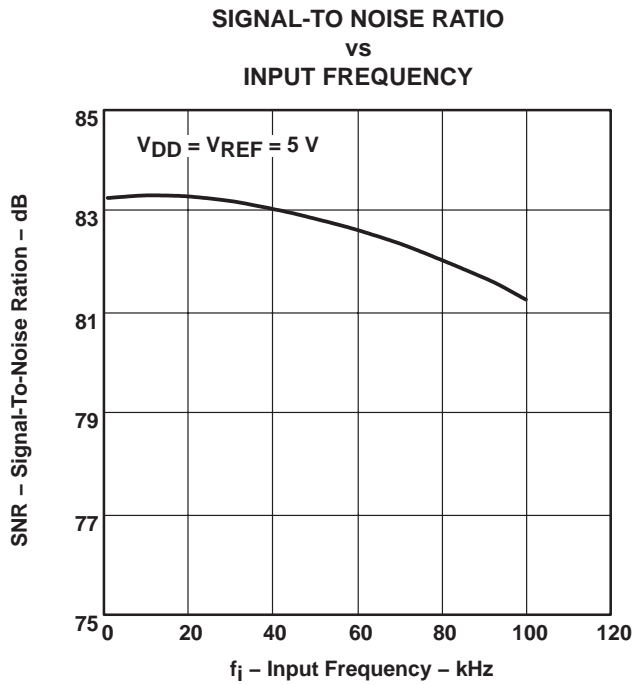


Figure 5

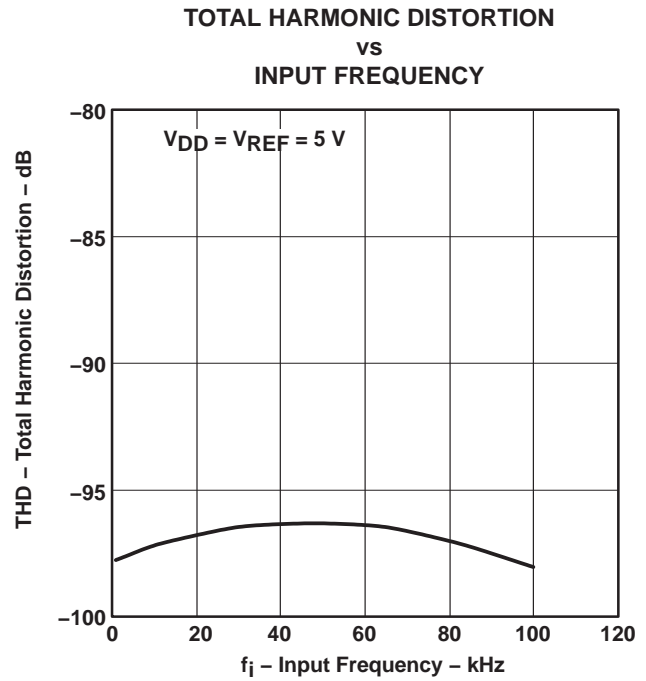


Figure 6

TYPICAL CHARACTERISTICS

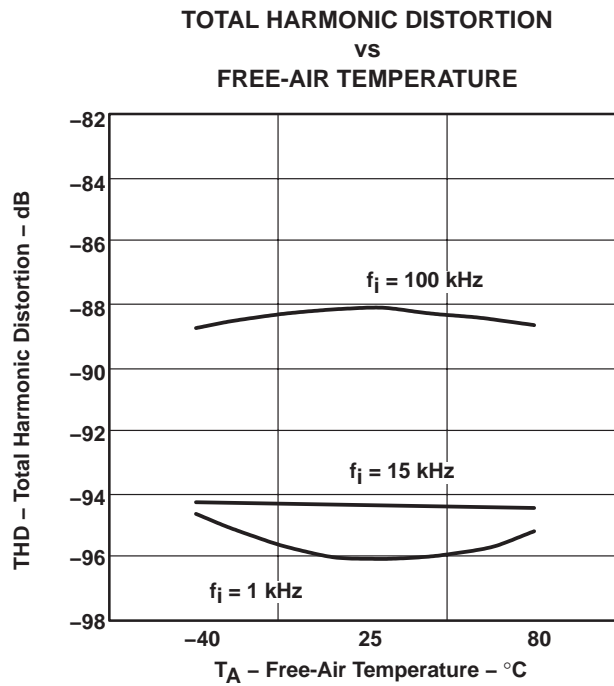


Figure 7

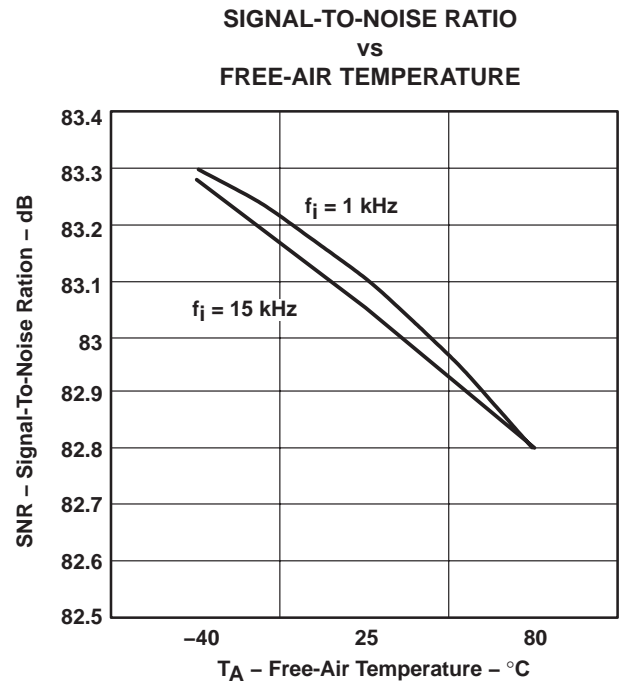


Figure 8

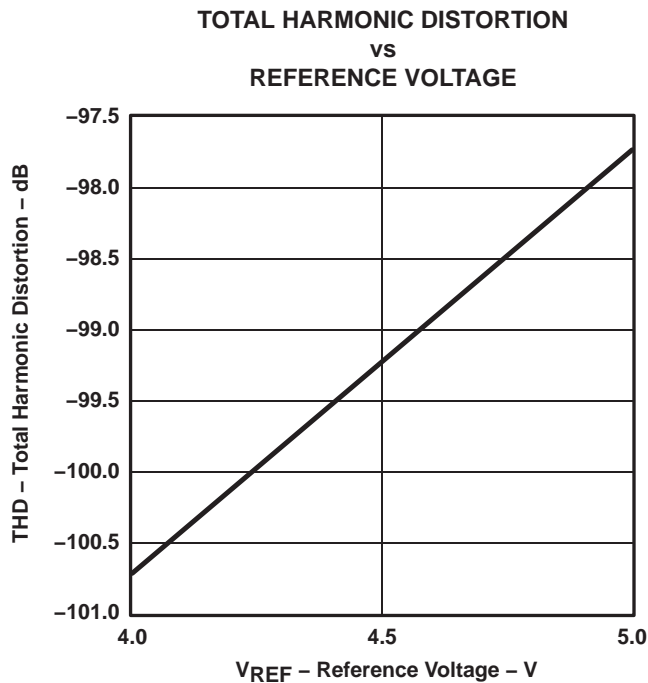


Figure 9

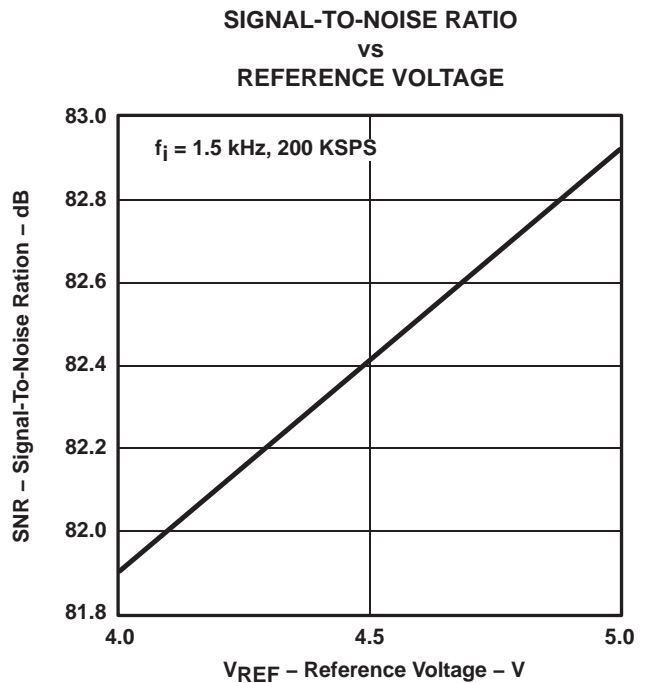


Figure 10

TYPICAL CHARACTERISTICS

MAXIMUM DIFFERENTIAL NONLINEARITY
vs
REFERENCE VOLTAGE

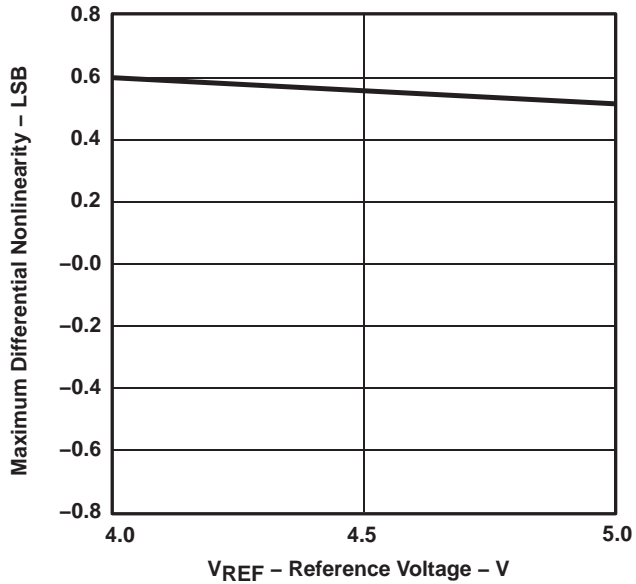


Figure 11

MINIMUM DIFFERENTIAL NONLINEARITY
vs
REFERENCE VOLTAGE

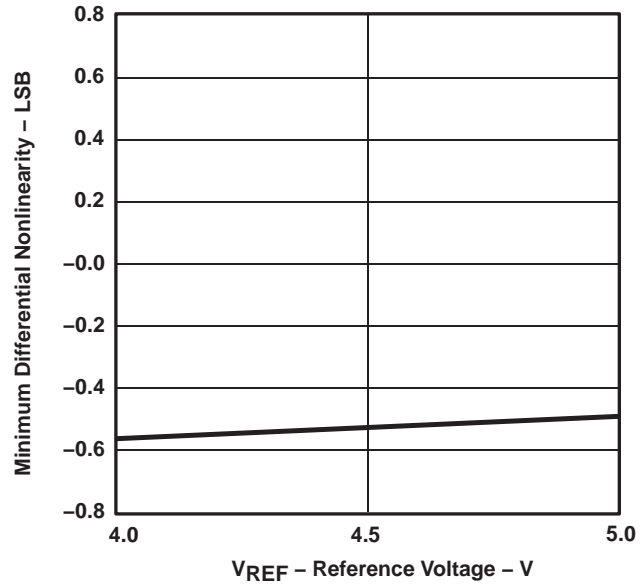


Figure 12

INTEGRAL NONLINEARITY
vs
REFERENCE VOLTAGE

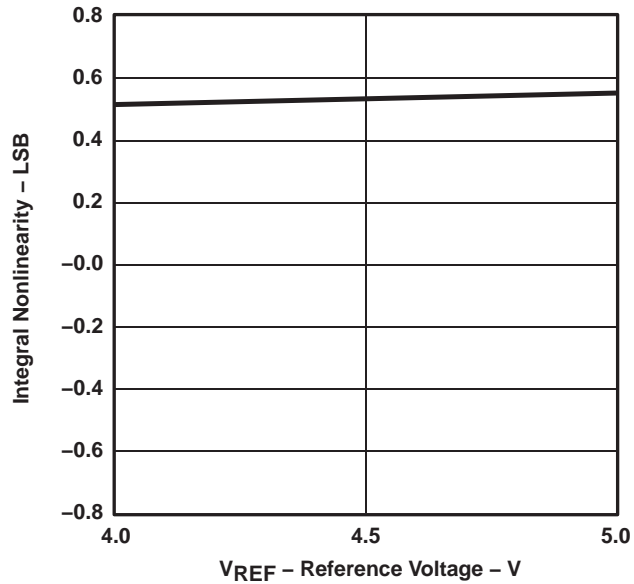


Figure 13

PRINCIPLES OF OPERATION

control and timing

device initialization/RESET cycle

The TLC3541/45 each require one RESET cycle after power-on for initialization in order to operate properly. The RESET cycle is initiated by asserting the \overline{CS} pin (pin 1) low for a minimum duration of at least one SCLK falling edge but no more than 8 SCLK falling edges in length. The RESET cycle is terminated by asserting \overline{CS} high. If a valid RESET cycle is issued, the data presented on the SDO output during the following cycle is 3FC0h. This output code is useful in determining when a valid reset/initialization has occurred.

The TLC3541 has separate \overline{CS} and FS pins. In this case, it is also possible to initiate the RESET cycle by asserting FS low if \overline{CS} is already asserted low. The RESET cycle can be terminated by either asserting \overline{CS} high (as shown in the first RESET cycle in Figure 14), or by asserting FS high (as shown in the second RESET cycle in Figure 14), whichever happens first.

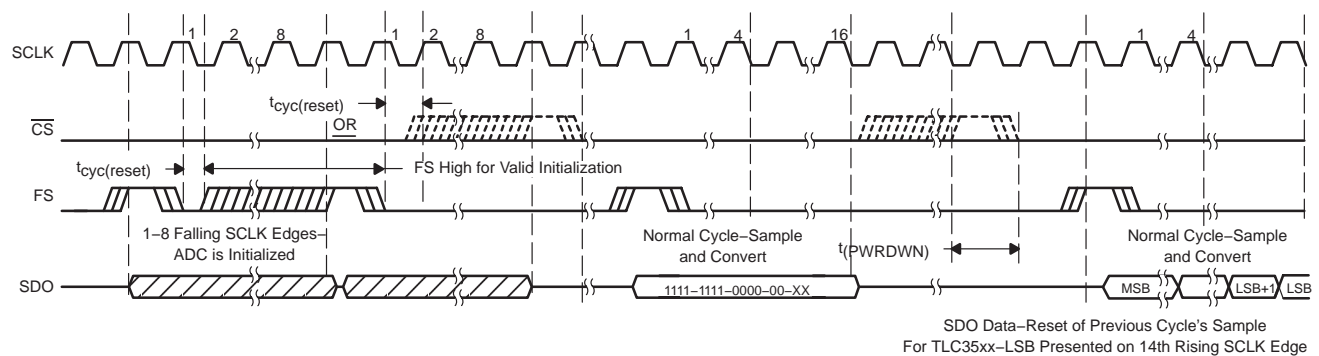


Figure 14. TLC3541/45 Initialization Timing

sampling

The converter sample time is 20 SCLKs in duration, beginning on the 5th SCLK received during an active signal on the \overline{CS} input (or FS input for the TLC3541.)

conversion

Each device completes a conversion in the following manner. The conversion is started after the 24th falling SCLK edge. The \overline{CS} input can be released at this point or at any time during the remainder of the conversion cycle. The conversion takes a maximum of 2.67 μ s to complete. Enough time (for conversion) should be allowed before the next falling edge on the \overline{CS} input (or rising edge on the FS input for the TLC3541) so that no conversion is terminated prematurely. If the conversion cycle is terminated early, the data presented on SDO during the following cycle is 3FC0h. This predefined output code is helpful in determining if the cycle time is not long enough to complete the conversion. The same code is also used to determine if a reset cycle is valid.

For all devices, the SDO data presented during a cycle is the result of the conversion of the sample taken during the previous cycle. The output data format is shown in the following table.

| SERIAL OUTPUT DATA FORMAT | | |
|---------------------------|------------------------------|-------------|
| | MSB [D15:D2] | LSB [D1:D0] |
| TLC3541/45 | Conversion result (OD13–OD0) | Don't care |

PRINCIPLES OF OPERATION

control and timing (continued)

sampling and conversion cycle

TLC3541:

Control via pin 1, \overline{CS} ($FS = 1$ at the falling edge of \overline{CS}) – The falling edge of \overline{CS} is the start of the cycle. Transitions on \overline{CS} can occur when SCLK is high or low. The MSB may be read on the first falling SCLK edge after \overline{CS} is low. Output data changes on the rising edge of SCLK. This control method is typically used for a microcontroller with an SPI interface, although it can also be used for a DSP. The microcontroller SPI interface should be programmed for CPOL = 0 (serial clock inactive low) and CPHA = 1 (data valid on the falling edge of serial clock).

Control via pin 7, FS (\overline{CS} is tied/held low) – The rising edge of FS is the start of the cycle. Transitions on FS can occur when SCLK is high or low. The MSB is presented on SDO after the rising edge of FS. The MSB may be read on the first falling edge of SCLK after the FS falling edge. Output data changes on the rising edge of SCLK. This is the typical configuration when the ADC is the only device on the TMS320 DSP serial port.

Control via pin 1 and pin 7, \overline{CS} and FS – Transitions on \overline{CS} and FS can occur when SCLK is high or low. The MSB is presented after the rising edge of FS. The falling edge of FS is the start of the sampling cycle. The MSB may be read on the first falling edge of SCLK after the FS falling edge. Output data changes on the rising edge of SCLK. This is typically used for multiple devices connected to a single TMS320 DSP serial port.

TLC3545:

All control is provided using the \overline{CS} input (pin 1) on the TLC3545. Transitions on \overline{CS} can occur when SCLK is high or low. The cycle is started on the falling edge transition on the \overline{CS} input. This signal can be provided by either a \overline{CS} signal (when interfacing with an SPI microcontroller) or FS signal (when interfacing with a TMS320 DSP). The MSB is presented to SDO on the falling edge of the signal applied to pin 1 and may be read on the first falling SCLK edge after this input is low. Output data changes on the rising edge of SCLK.

control modes

control via pin 1 (\overline{CS} , SPI interface)

All devices are compatible with this mode of operation. A falling edge on the \overline{CS} input initiates the cycle. (For the TLC3541, the FS input is tied to V_{DD}). The \overline{CS} input remains low for the entire sampling time plus 4 SCLK decoding time (24 falling SCLK edges) and can then be released at any point during the remainder of the conversion. Enough time should be allowed before the next falling \overline{CS} edge so that the conversion cycle is not terminated prematurely. The microcontroller SPI interface should be programmed for CPOL = 0 (serial clock inactive low) and CPHA = 1 (data is valid on the falling edge of serial clock).

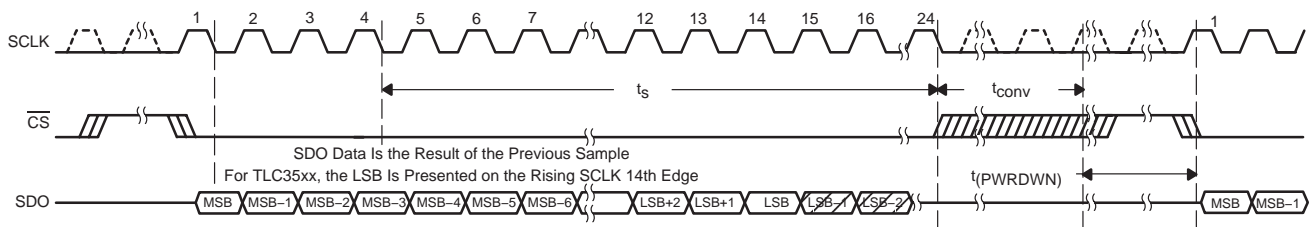


Figure 15. SPI Cycle Timing Using the CS Input ($FS = 1$ for TLC3541)

PRINCIPLES OF OPERATION

control via pin 1 (\overline{CS} , DSP interface)

All devices are compatible with this mode of operation. The FS signal from a DSP is connected directly to the \overline{CS} input of the ADC. A falling edge on the \overline{CS} input while SCLK is high or low initiates the cycle. (For TLC3541 in this configuration, the FS input is tied to V_{DD} .) Enough time should be allowed before the next rising \overline{CS} edge so that the conversion cycle is not terminated prematurely.

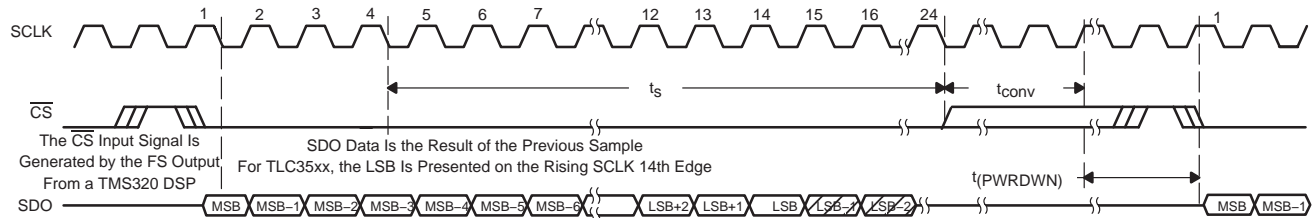


Figure 16. DSP Cycle Timing Using the CS Input (FS = 1 for TLC3541 only)

control via pin 1 and pin 7 (\overline{CS} and FS or FS only, DSP interface)

Only TLC3541 is compatible with this mode of operation. The \overline{CS} input to the ADC can be controlled via a general-purpose I/O pin from the DSP or tied to ground. The FS signal from the DSP is connected directly to the FS input of the ADC. A rising FS edge releases the MSB to the SDO output. The falling edge on the FS input while SCLK is high or low initiates the cycle. The \overline{CS} input should remain low for the entire sampling time plus 4 SCLK decoding time after falling FS (24 falling SCLK edges) and can then be released at any time during the remainder of the conversion cycle. The optimum DSP interface is achieved when tying \overline{CS} to ground and using only the FS input to control the ADC.

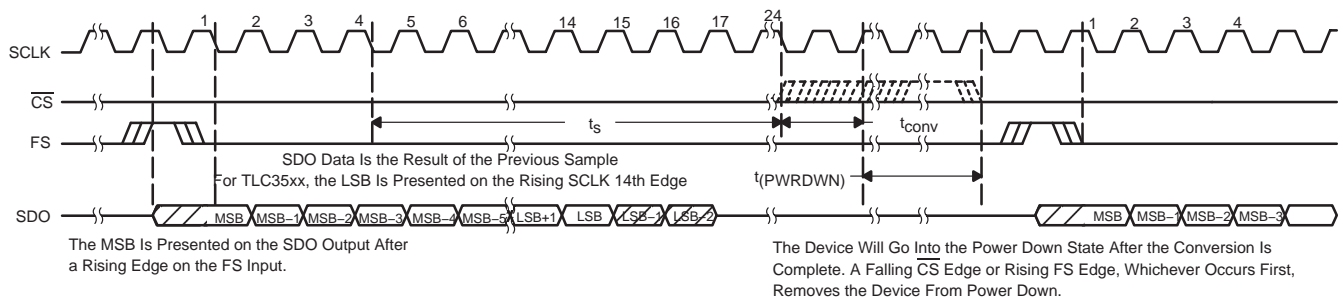


Figure 17. DSP Cycle Timing Using FS Only (or Using Both \overline{CS} and FS for TLC3541)

PRINCIPLES OF OPERATION

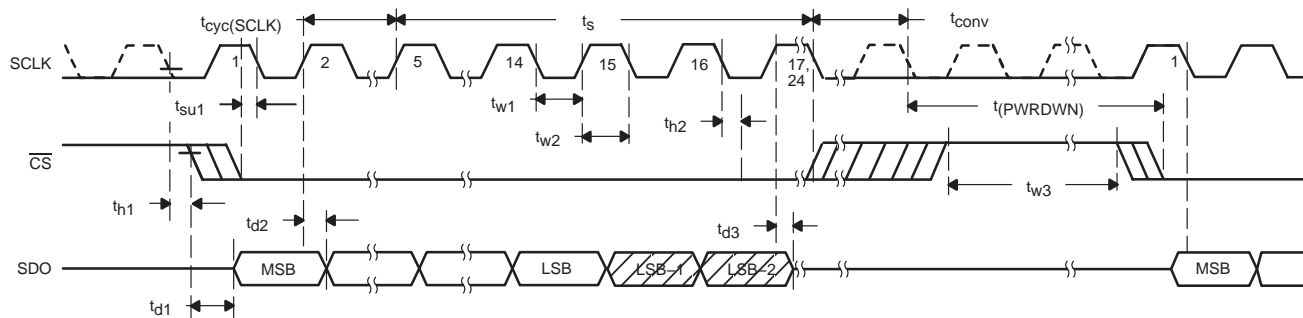


Figure 18. Critical Timing: Control Via CS Input (FS = 1 for TLC3541)

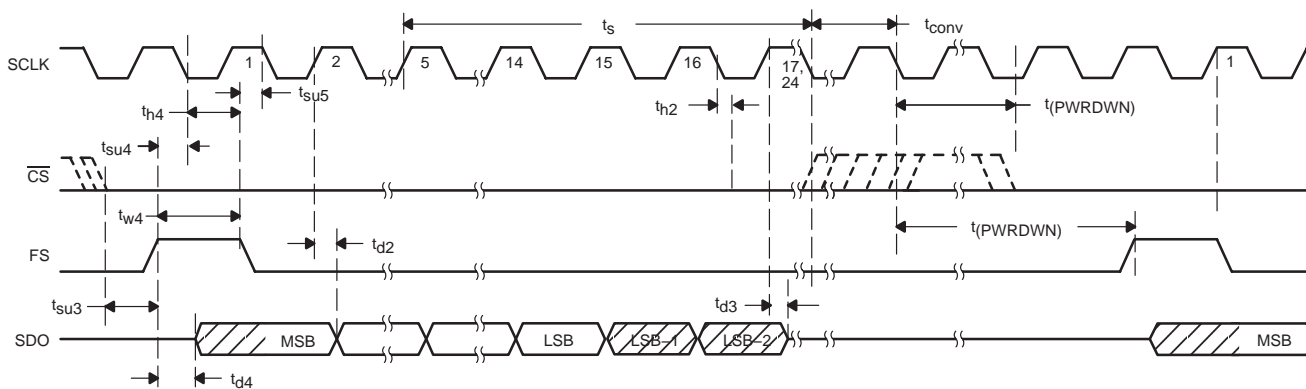


Figure 19. Critical Timing: Control Via CS and FS Inputs (TLC3541 Only)

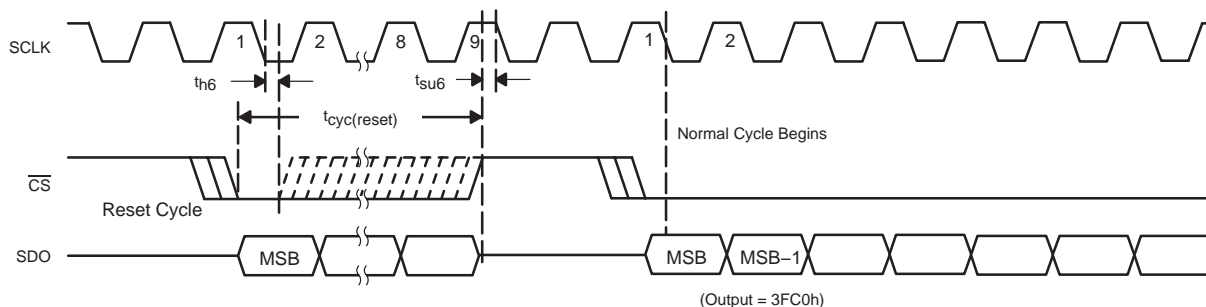


Figure 20. Critical Timing: Reset/Initialization Cycle (FS =1 for TLC3541)

PRINCIPLES OF OPERATION

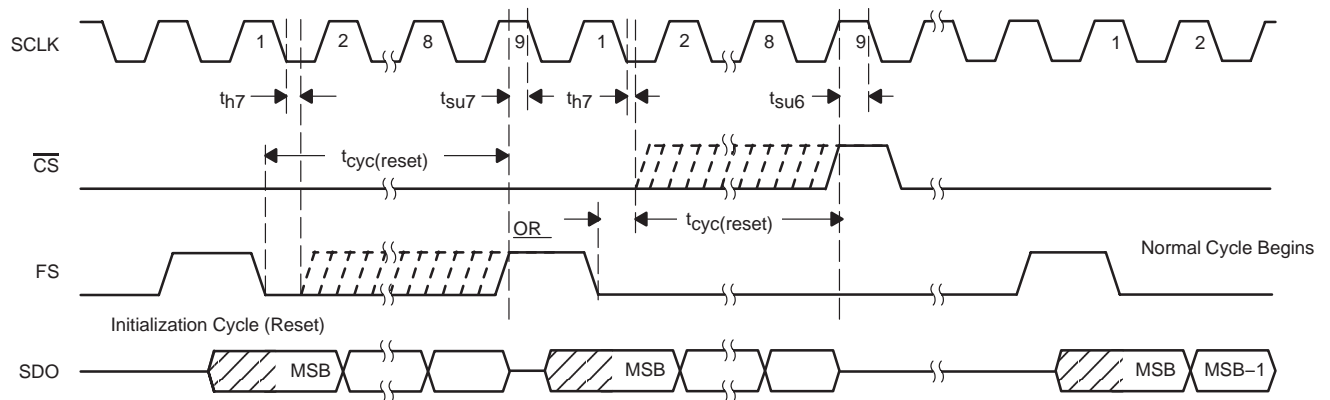


Figure 21. Critical Timing: Initialization Cycle (TLC3541 Only)

detailed description

The TLC3541/5 are successive approximation (SAR) ADCs utilizing a charge-redistribution DAC. Figure 22 shows a simplified version of the ADC. The sampling capacitor acquires the signal on AIN (or the AIN(+) pin for TLC3545) during the sampling period. When the conversion process starts, the SAR control logic and charge redistribution DAC are used to add and subtract fixed amounts of charge from the sampling capacitor to bring the comparator into a balanced condition. When the comparator is balanced, the conversion is complete and the ADC output code is generated.

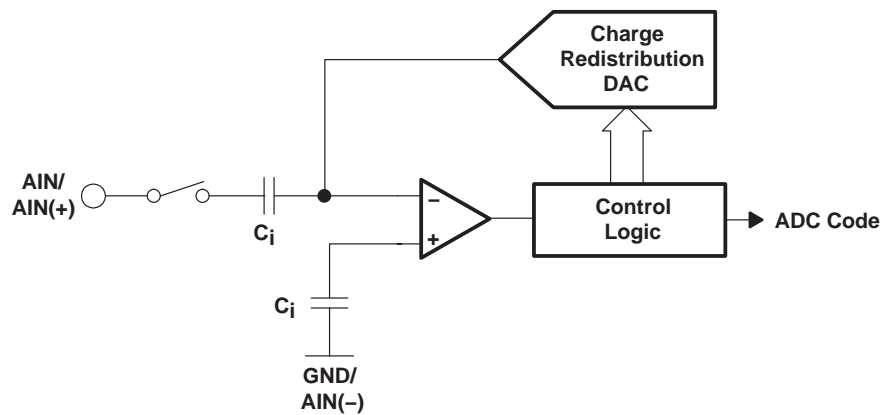


Figure 22. Simplified SAR Circuit

PRINCIPLES OF OPERATION

pseudo-differential inputs

The TLC3545 operates in pseudo-differential mode. The inverted input is available on pin 5. The inverted input can tolerate a maximum input ripple of ± 0.2 V. It is normally used for zero-scale offset cancellation or ground noise rejection.

serial interface

Output data format is binary (unipolar straight binary).

binary

- Zero-Scale Code = 0000h, $V_{AIN} = \text{GND}$
- Full-Scale Code = 3FFFh, $V_{AIN} = V_{REF} - 1 \text{ LSB}$

reference voltage

An external reference must be applied via pin 2, V_{REF} . The voltage level applied to this pin establishes the upper limit of the analog inputs to produce a full-scale reading. The value of V_{REF} , and the analog input should not exceed the positive supply or be less than GND, consistent with the specified absolute maximum ratings. The digital output is at full scale when the input signal is equal to or higher than V_{REF} and at zero when the input signal is equal to or less than GND.

auto-power down and power up

Auto-power down is built into the devices in order to reduce power consumption. The wake-up time is fast enough to provide power down between each conversion cycle. The power-down state is initiated at the end of conversion and wakes up on a falling $\overline{\text{CS}}$ edge (or rising FS edge, whichever occurs first, for TLC3541 only).

APPLICATION INFORMATION

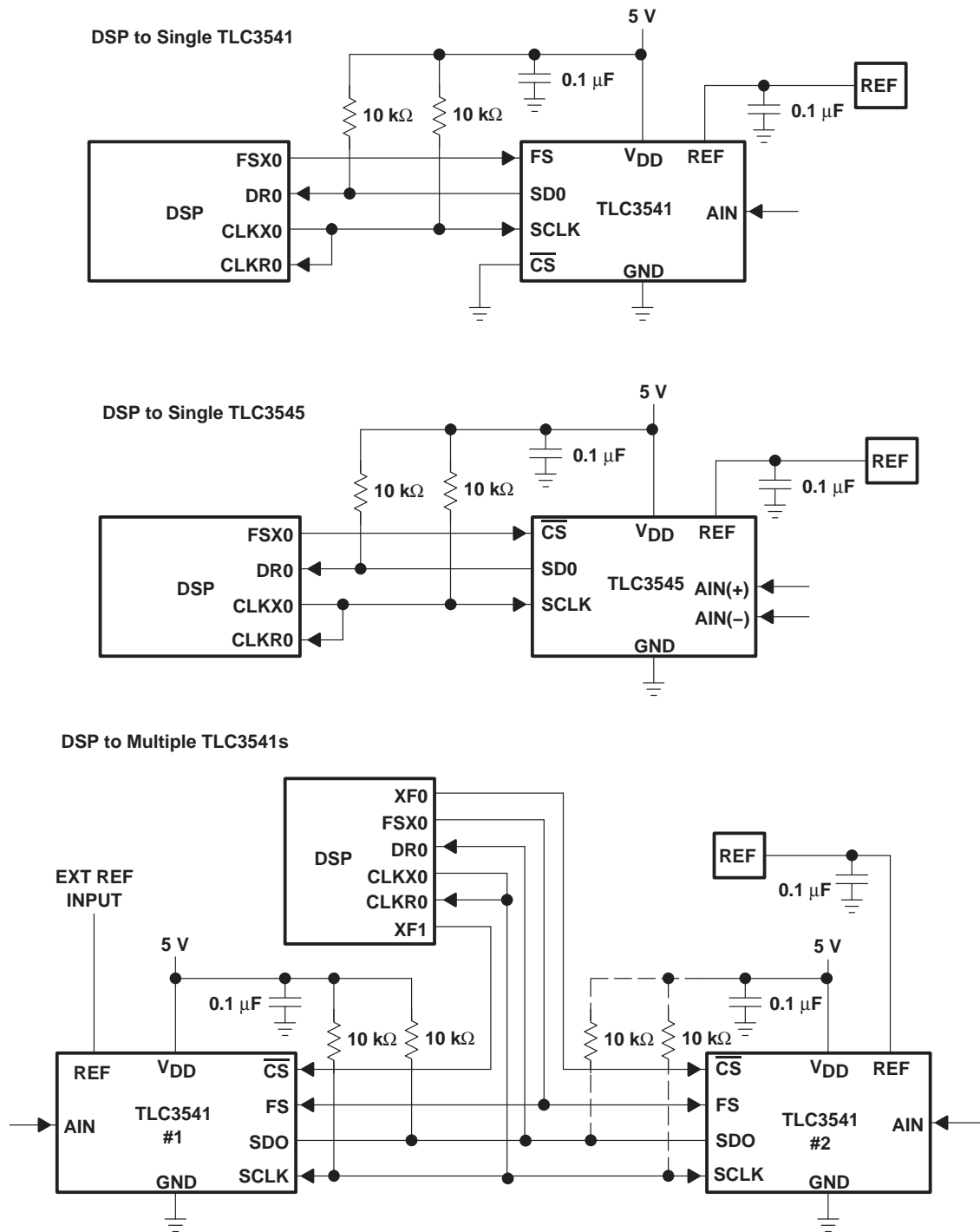


Figure 23. Typical ADC Interface to a TMS320 DSP

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| TLC3541ID | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 3541I | Samples |
| TLC3541IDG4 | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 3541I | Samples |
| TLC3541IDGK | ACTIVE | VSSOP | DGK | 8 | 80 | RoHS & Green | NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | AMG | Samples |
| TLC3541IDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | AMG | Samples |
| TLC3541IDR | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 3541I | Samples |
| TLC3541IDRG4 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 3541I | Samples |
| TLC3545ID | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 3545I | Samples |
| TLC3545IDGK | ACTIVE | VSSOP | DGK | 8 | 80 | RoHS & Green | NIPDAUAG | Level-1-260C-UNLIM | -40 to 85 | AMM | Samples |
| TLC3545IDR | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | 3545I | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSELETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

⁽⁵⁾ Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

⁽⁶⁾ Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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TAPE AND REEL INFORMATION

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

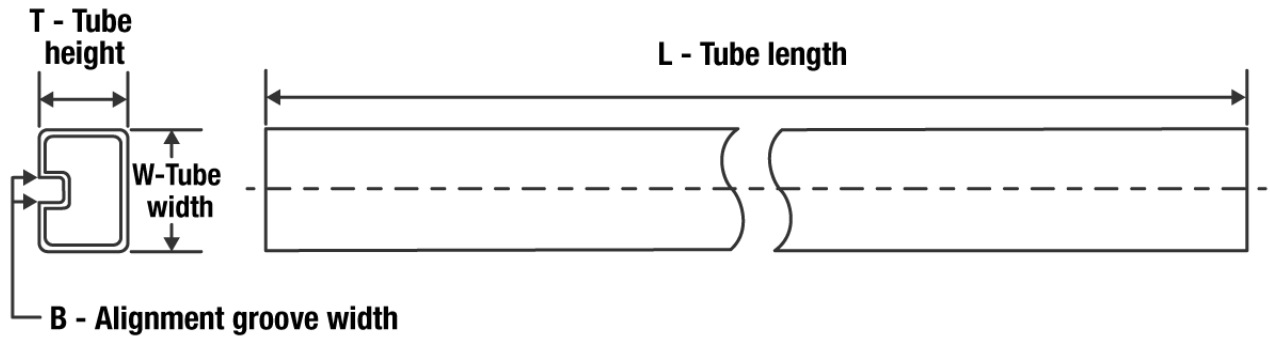

*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TLC3541IDGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| TLC3541IDR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| TLC3545IDR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|--------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TLC3541IDGKR | VSSOP | DGK | 8 | 2500 | 350.0 | 350.0 | 43.0 |
| TLC3541IDR | SOIC | D | 8 | 2500 | 350.0 | 350.0 | 43.0 |
| TLC3545IDR | SOIC | D | 8 | 2500 | 350.0 | 350.0 | 43.0 |

TUBE


*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| TLC3541ID | D | SOIC | 8 | 75 | 505.46 | 6.76 | 3810 | 4 |
| TLC3541IDG4 | D | SOIC | 8 | 75 | 505.46 | 6.76 | 3810 | 4 |
| TLC3541IDGK | DGK | VSSOP | 8 | 80 | 331.47 | 6.55 | 3000 | 2.88 |
| TLC3545ID | D | SOIC | 8 | 75 | 505.46 | 6.76 | 3810 | 4 |
| TLC3545IDGK | DGK | VSSOP | 8 | 80 | 331.47 | 6.55 | 3000 | 2.88 |



D0008A

PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed $.006$ [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

EXAMPLE BOARD LAYOUT

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE
 EXPOSED METAL SHOWN
 SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

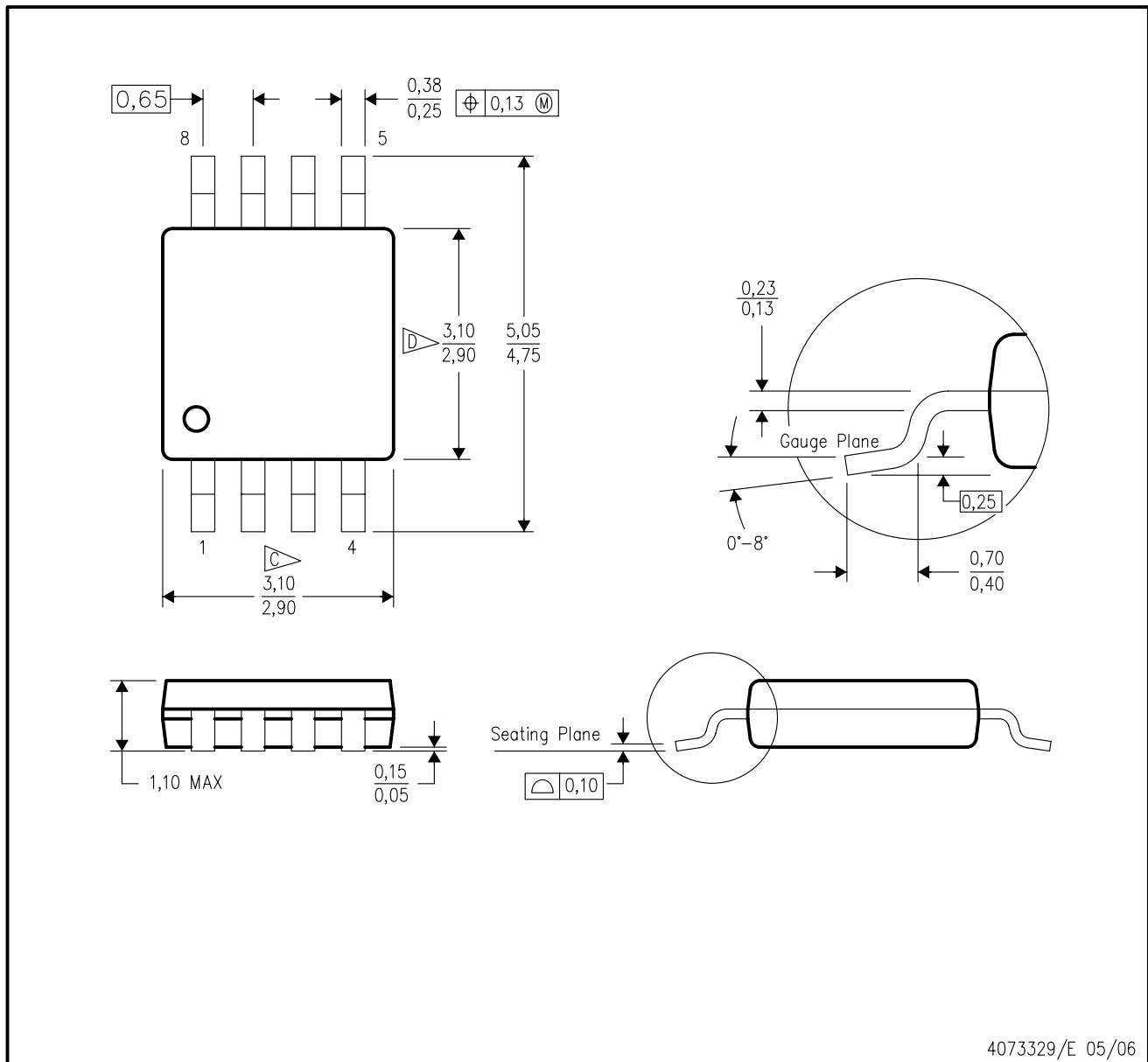
4214825/C 02/2019

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

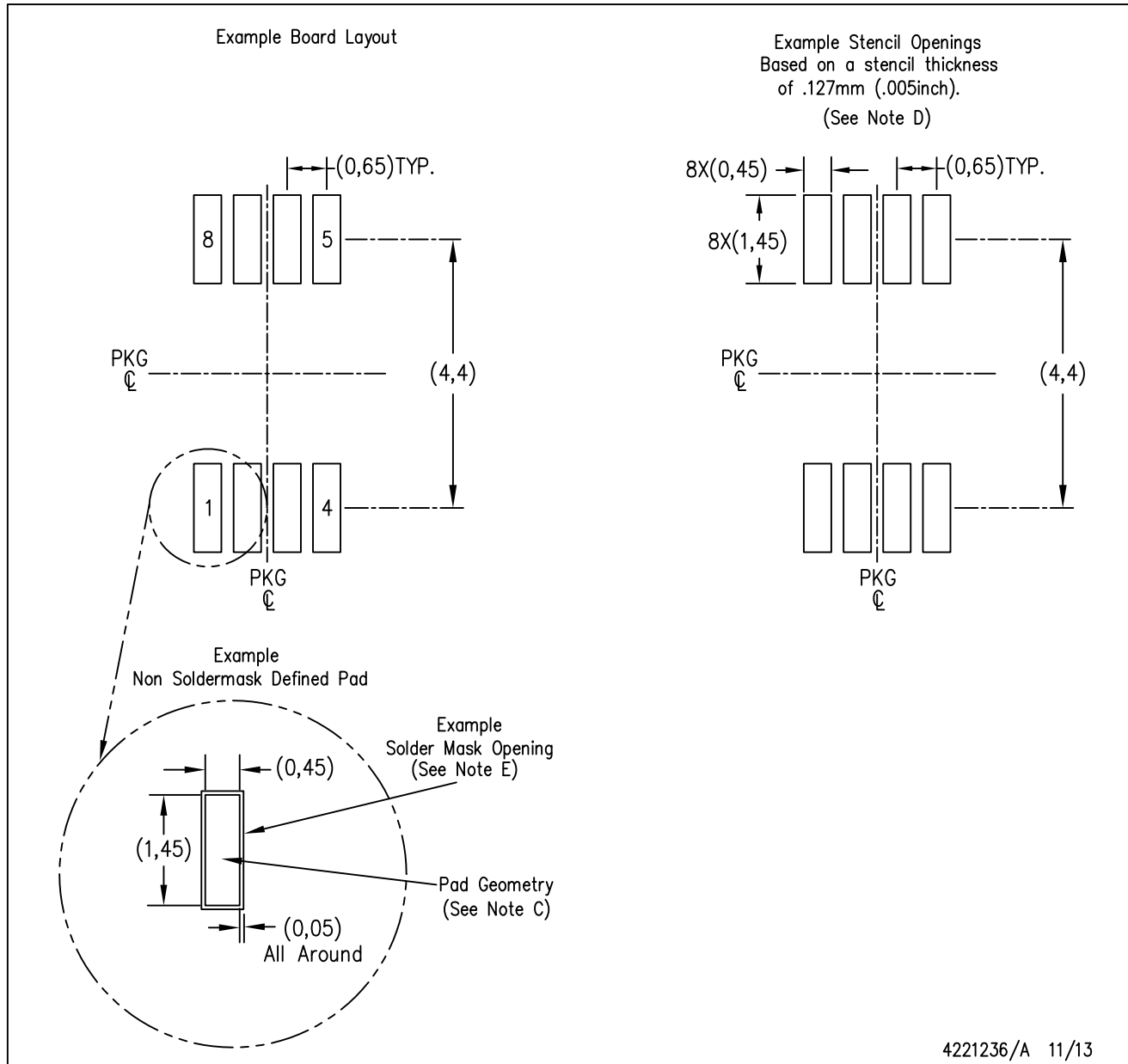
DGK (S-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



4073329/E 05/06

- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
 - E. Falls within JEDEC MO-187 variation AA, except interlead flash.



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
 - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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